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NAVAL ARCTIC OPERATIONS HANDBOOK

PART II. OPERATIONAL NOTES

[redacted]

DEPARTMENT OF THE NAVY

SERIAL NO.

National Oceanic and Atmospheric Administration

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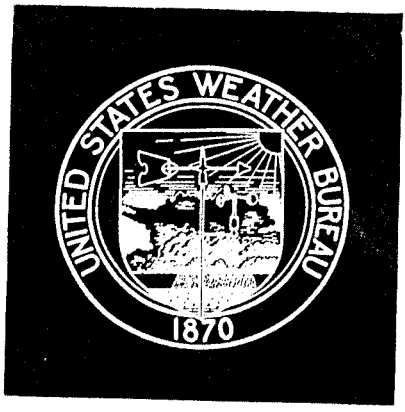
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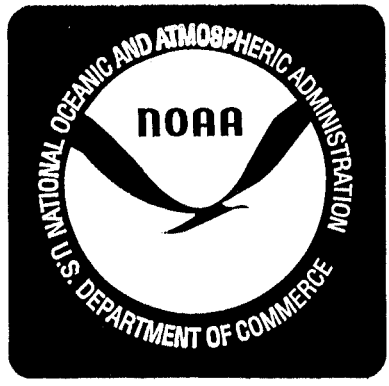
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U.S. Office of Naval Operations. Arctic and Cold Weather Coordinating Committee

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PART II. OPERATIONAL NOTES

Prepared by the Arctic and Cold Weather Coordinating Committee of the Office of the Chief of Naval Operations

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GENERAL NOTE

Naval Arctic Operations Handbook is published for the information and guidance of all concerned. It is presented in two volumes, Part I being a compilation of general information, and Part II lessons learned during the conduct of operations in the polar regions and in areas where the extremes of cold weather have been encountered.

It is desired that commanders of task forces, commanding officers, and others in command of operations in the high latitudes submit data and recommendations for incorporation into subsequent editions of the handbook. Thus naval skill in these operations will develop in a continuing and orderly manner.

In time our arctic and cold weather experiences will become doctrine, to the end that polar naval operations can be planned and conducted routinely. Basic doctrines will be included in the proper USF publications at some future date.

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PREFACE

Part II of the *Naval Arctic Operations Handbook* is concerned with operational notes. An endeavor has been made to write down herein the problems which have arisen and experiences and lessons learned during past operations in polar and cold weather areas. Where reference is made to operations in the Antarctic, it is considered that the material is equally applicable to similar operations in the Arctic.

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GLOSSARY OF TERMS

This selected glossary is limited to definitions helpful for an understanding of this handbook. More extensive glossaries are included in various Hydrographic Office publications. HO Study No. 103, *A Functional Glossary of Ice Terminology*, has been prepared in order to standardize ice terminology and to provide a convenient means for describing ice features and related characteristics. Refer also to Selected Bibliography, chapter 7, part 1, this handbook.

Ablation—Surface removal of ice or snow by evaporation.

Arctic Pack (Polar Pack)—The ice cover of the north polar basin or Arctic Sea (also called Arctic "Ocean").

Barrier—The cliffed edge of shelf ice. (See *Shelf Ice.*)

Bay Ice—Fast, level ice formed in an embayment.

Belt—A relatively narrow band of sea-ice of any variety.

Berg—A large mass of land ice which has broken away from its parent formation on the coast and either floats in the sea or is stranded on a shoal; a berg is tabular if derived from shelf ice, irregular if derived from glacial ice.

Bergybit—A medium-sized piece or cake of glacier ice, heavy floe, or hummocky pack ice washed clear of snow and floating in the sea.

Beset—Situation of a ship or small craft when so closely surrounded by sea-ice that control is lost.

Big Clearing—A large area of open water, other than a lead, encompassed by fields or floes of pack ice; also polynya.

Bit—A single piece of brash or of ice less than two feet in diameter. Note: compare with *Glacon, Cake, Floe* and *Block.*

Blizzard—Snow storm in polar regions in which fine snow drifts so high and thick that it is impossible to tell whether sky is clear or clouded.

Block—A small piece of ice ranging in size from 6 to 30 feet across.

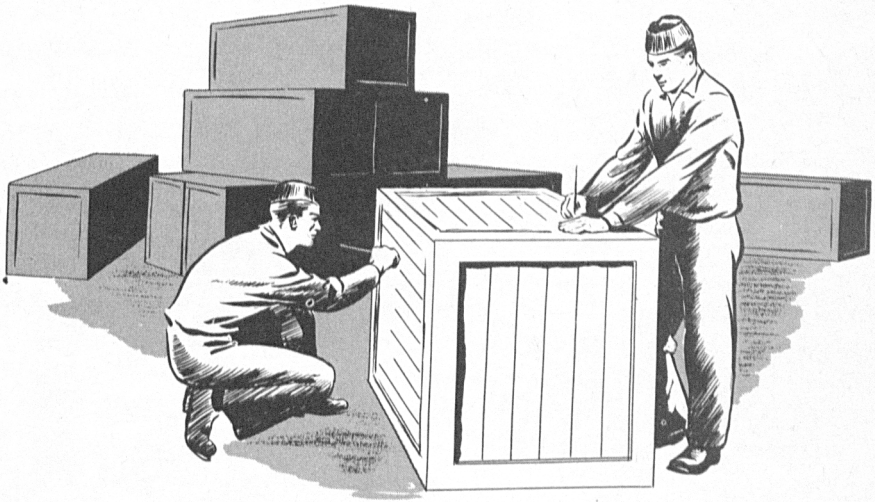
Brash—Small ice fragments less than 6 feet across; the wreckage of other forms of sea-ice.

Broken Ice—Sea-ice consisting of scattered cakes and floes covering five-tenths to seven-tenths of the sea surface.

Cake—A term of general meaning used in reference to individual pieces of pack ice.
Calving—The breaking away of ice from its parent berg, glacier, or shelf ice formation.
Channel—Lead (lane).
Close Ice—Ice so closely packed that it covers seven-tenths to nine-tenths of the sea surface and virtually all sea water openings are obscure.
Close Pack—Close ice or pack composed mostly of cakes in contact.
Coast or Coastal Ice (Fast Ice)—A stretch of ice, broken or unbroken, either stranded in shoal water, attached to the shore, or held fast in position of growth in embayments by glaciers or glacier systems.
Conglomerated Ice—Various forms of floating ice compacted into one mass.
Consolidated Pack—An ice area containing the heaviest forms of sea ice and entirely devoid of water spaces.
Crevasse—A rift or fissure in a glacier, shelf ice, or other land-ice formation.
Cul-de-sac—Blind lead.
Deadman—A large timber buried in the ground, snow, or ice to which a mooring line can be attached for securing a ship. (See HO 551.)
Drift Ice—Loose, very open pack where water predominates over ice; floating ice; any ice that has drifted from its place of origin.
Erosion—Destruction of sea-ice by the action of waves and weather.
Fast Ice—See *Coast Ice.*
Field Ice—The largest connected areas of sea-ice, ranging from several to scores of miles wide; also ice field.
Floe—An area of sea-ice consisting of a single unbroken piece of ice or many large consolidated pieces; small floe, 30 to 600 feet across; medium floe, 600 to 3,000 feet across; giant floe, 3,000 feet to 5 or more miles across.
Floeberg—A mass of thick, heavily hummocked sea-ice usually detached from its parent floe.
Frost Smoke—A mist or thick fog rising from sea surface when the relatively warmer water is exposed to an air temperature much below freezing; steam fog; arctic smoke.
Giant Floe—See *Floe.*

Glacier—A massive body of land-formed ice moving slowly down a mountainside or valley.
Glacial (Glacier) Ice—Ice which originates from glaciers.
Glacon—A piece of sea-ice ranging in size from brash to medium floe (6 to 2,000 feet across).
Grease Ice—Slush ice formed from the congelation of ice crystals in the early stages of freezing.
Growler—A small piece of dense glacier ice usually green in color and barely showing above the water.
Growler Ice—An accumulation of growlers.
Heavy Ice—Any pack ice more than 10 feet thick.
Hummocked Ice—Ice piled haphazardly into the form of a short ridge or hillock.
Ice Barrier—See *Barrier.*
Iceberg—See *Berg.*
Ice Blink—A yellowish-white glare on the underside of extensive cloud areas created by light reflected from ice-covered surfaces.
Ice Cap—An ice sheet of vast extent covering the topographic features of a continental land mass.
Ice Field—See *Field.*
Ice Foot—A wall or belt of fast sea-ice formed along a shore not subject to rise and fall of tides.
Ice Sky—See *Ice Blink.*
Land Sky—Dark streaks, patches, or a grayness on the underside of extensive cloud areas due to the absence of reflected light from bare ground.
Lead (Lane)—A long, narrow but navigable water passage in pack ice.
Medium Floe—See *Floe.*
Nipped—As applied to a ship, caught and held tightly by sea-ice under pressure.
Nunatak—An isolated hill or mountain of bare rock rising above the surrounding ice sheet.
Open Water—Sea areas less than one-tenth covered with floating ice.
Pack Ice (The Pack)—Any large area of floating sea-ice driven closely together. (See *Arctic Pack.*)
Pancake Ice—Piece of newly formed sea-ice about 1 to 6 feet in diameter.
Permafrost—Permanently frozen soil, rock or bedrock.

Polar Ice—The thickest and heaviest form of pack ice more than 1 year old.
Polynya—See *Big Clearing.*
Pool—Polynya; sometimes used to mean a depression on ice floes filled with water as result of summer thaw.
Pressure Ice—A general term for ice displaced vertically by pressure resulting from action of wind, tide, temperature change, etc.
Rafted Ice—A type of pressure ice formed by one cake over-riding another.
Ram—A horizontal extension of floe or berg below its waterline.
Rotten Ice—Old ice in an advanced stage of disintegration as result of melting.
Sastrugi—Wavelike ridges of hard snow formed on a level surface by the action of the wind with axes of the ridges at right angles to the prevailing direction of the wind.
Scattered Ice—Ice that covers less than one-half of the sea surface.
Sea Ice—A general term for all forms of ice encountered on the surface of the sea.
Seracs—Ice pinnacles on a glacier.
Shelf Ice—A thick, glacial ice formation extending from the land but attached thereto.
Shore Ice—Synonym of *Fast* or *Coastal Ice.*
Shore Lead—A lead between floating ice and the shore or between floating ice and fast ice.
Sikussaq—Very old ice trapped in fiords.
Slush—A general term for an accumulation of ice crystals which are either only slightly frozen together or separate.
Small Floe—See *Floe.*
Snow Blink—Similar to ice blink except that glare created by light reflected from snow-covered surfaces is white.
Storis—A regional term applied to large pieces of polar ice moving along the coasts of Greenland from the Arctic Sea.
Sky Map—The mirroring of land, snow, or ice in the clouds.
Tracking—Following the edge of pack ice.
Tundra—Stretch of mucky, treeless land covered with a variety of hardy plants, including grasses, lichens, and shrubs.
Water Sky—Dark stretches or patches of grayness on the underside of extensive cloud areas due to the absence of reflected light from open water areas.
Winter Ice—Sea-ice less than 1 year old.
Young Ice—Newly formed ice in the transitional stage of development from ice crust to winter ice.



CHAPTER 1

PLANNING ARCTIC OPERATIONS

"The success of a polar expedition principally depends upon the preparations which were made before the expedition started out."—Nansen.
"Forethought for every conceivable thing."—Mikkelsen.

In planning arctic operations the same general principles apply as for any routine naval operation, except that it must be done in greater detail. The operation plan with its annexes, the pertinent directives and orders, are governed by the same policy, doctrine, and format as is applicable throughout the Military Services. As pointed out in Part I of this handbook, the arctic regions are unusual in respect to geographic character, climate, accessibility, international agreements, and population trends. These characteristics should be borne in mind throughout the planning and operational phases, and the written operation plan should take these peculiarities into account, as well as the uncertainties of weather and ice conditions, and the hazards to be encountered. The various annexes of a standard arctic operation plan are here discussed in order.

Figure 1–1.—Planning Arctic operations.

CONCEPT OF OPERATIONS

The *Concept of Operations,* as its title implies, is a broad narrative account of the operation, outlining, in sequence, the tasks of accomplishment and operational schedules. It should be written in such a fashion as to enable the novitiate to comprehend the broad objectives of the operation without detailed study of the plan. Such an annex also has been found helpful in past operations for the indoctrination of scientific and non-military observers.

INTELLIGENCE

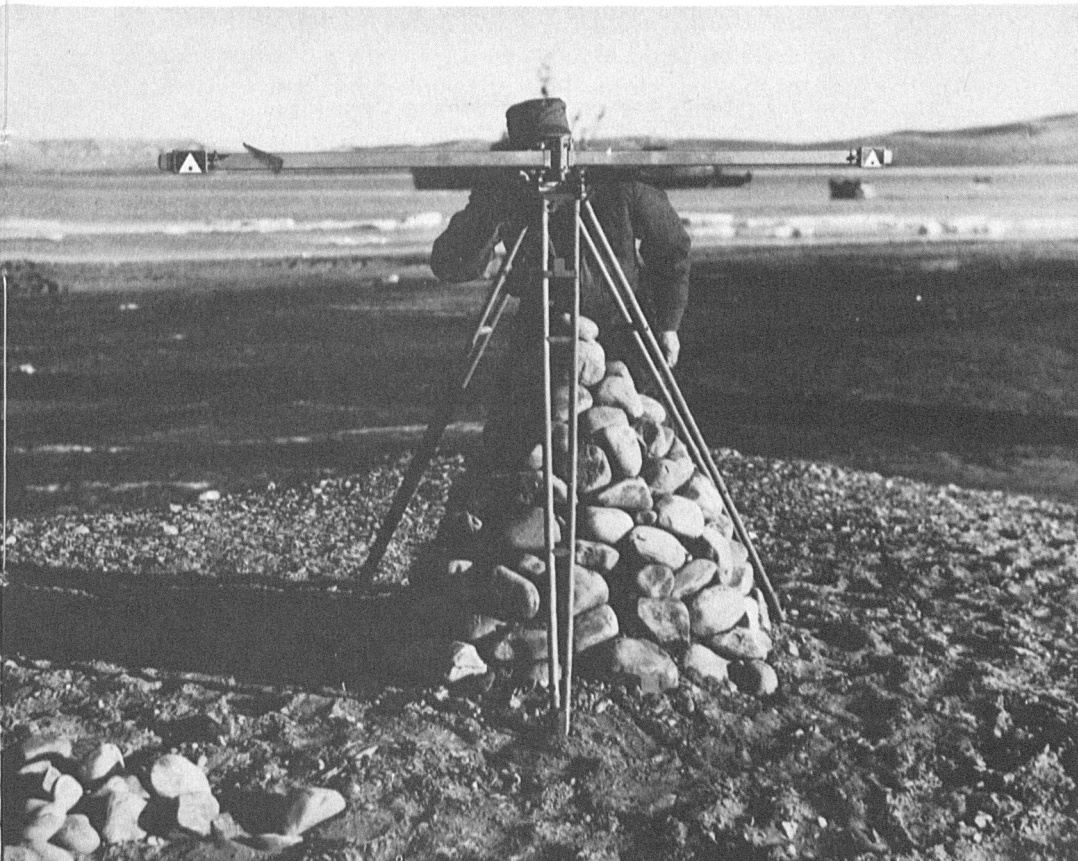
Since sovereignty and jurisdiction in the arctic regions is a complex subject, the *Intelligence Annex* should be factual and complete. In addition, all intelligence should be evaluated and presented in a concise manner that will show the situation as it actually exists in respect to facilities, prominent personnel, and local protocol, as well as international agreements and foreign policy applicable to the area.

NAVIGATION AND AEROLOGY

The *Navigation Annex* should contain a listing of charts, hydrographic publications, and special navigational material required by all units for the safe conduct of the operation. Special navigational data and information gained from previous similar operations and expeditions should also be included, where such data have not been incorporated in standard publications or in this handbook. Provision should be made for special instruction of key personnel in polar navigation prior to commencement of the operation. Pertinent notes on navigation in sea-ice should be outlined, as well as instructions for determining and forecasting ice movements in the area of operations; for reports of ice conditions to be submitted to the Hydrographic Office; for the collection of navigational data as may appear appropriate; and for towing ships beset in the ice, or in event of damage. In the case of submarine operations, it is essential that commanding officers be furnished with digests of information from past operations relating to underice navigation and the use of sonar in ice navigation.

A comprehensive *Aerology Plan* should be formulated to ensure timely collection of meteorological data from every source avail-

Figure 1–2.—Taking hydrographic measurements in the Arctic.

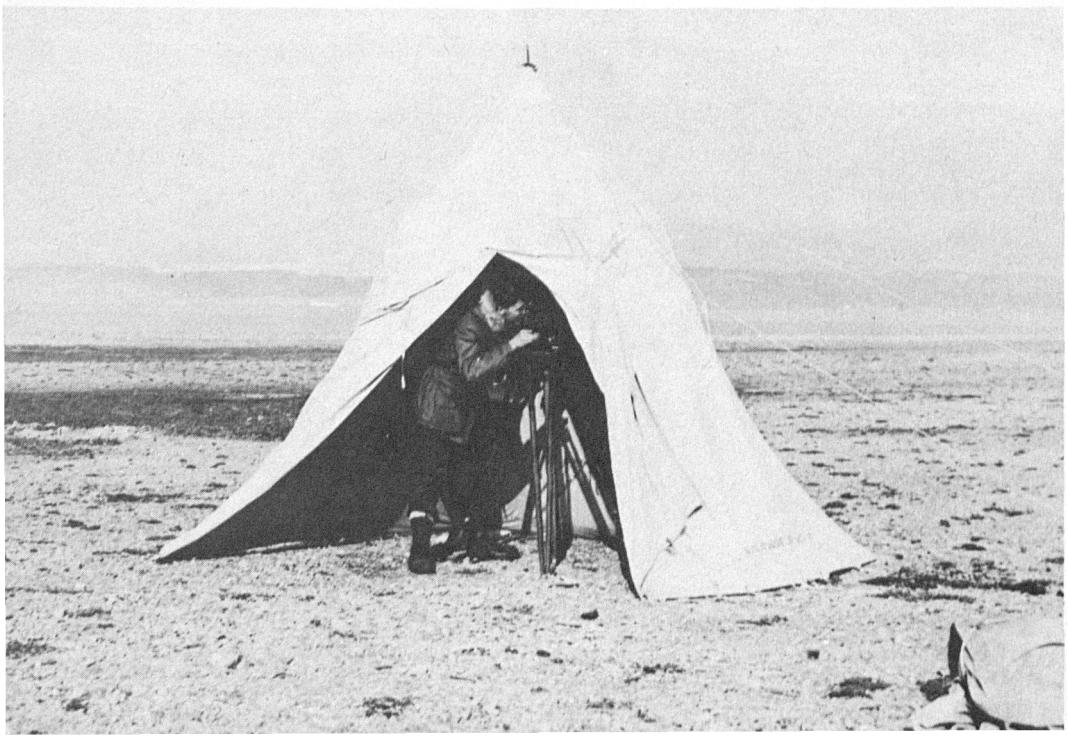


able in the area of operations, to facilitate preparation of forecasts, and to keep the force advised of probable effects of weather upon operations. Full advantage must be taken of *friendly* winds in movements and changes of situations of pack ice. Watch carefully the probable effects of *unfriendly* winds.

LOGISTIC PLAN

Both planning and implementation incident to the service of supply for an arctic operation must be precise since long distances are involved and re-supply points are for the most part non-existent. The *Logistic Plan* must require strict accountability for fuel and consumable supplies in order that the task force may be self-sustaining for the duration of the operation. Additional quantities of critical spares and outfits of special portable equipment, both electronic and navigational, should be prescribed, giving sources of procurement or supply. The procedures of mail service, air lift, and emergency evacuation should be set forth in detail. Since arctic operations usually involve the establishment or re-supply of remote bases, detailed cargo loading and discharge plans, along with possible alternate discharge plans, should be included so that these evolutions may be performed quickly and efficiently without hazarding personnel and materiel. Provision should be made for all special handling equipment such as sleds, cranes, cargo nets, and slings required on board ship and on beachheads.

Figure 1-3.—Taking magnetic measurements on Devon Island.



AIR AND COMMUNICATION PLANS

Flight operations in the Arctic are difficult because of limited directional orientation, uncertain weather, hazardous terrain, and lack of conventional air navigational aids. These factors influence and limit the *Air Plan,* in that suitable safety precautions must be taken and all flights must be conducted with ample safety margins. Facilities and plans for search and rescue are required, and proper rescue procedures must be disseminated throughout the task force and the area of operation. The plan should provide in particular for reconnaissance of pack ice by long-range aircraft and by helicopters, since such reconnaissance is essential to navigation in ice.

From an operational standpoint, efficient communications are of great significance because they are the medium by which command and control of the task force are exercised. Adequate channels and frequencies must be selected and provision made for any additional equipment required by the several units. Distant separation between isolated shore parties, boats, aircraft, ships, and the command center will of necessity exist throughout the operation. The *Communication Plan* must take into account known communication vagaries with respect to the arctic regions, and must be coordinated with all activities involved in the communications net. Provision for alternate frequencies and emergency procedure in the event of communication failure must be made. Periodic situation and position reports must be received from all units operating independently, and safety considerations dictate that these units return to base in the event of communication failure. Provision should also be made for timely reporting, and the exchange of data on meteorological and ice situations. Procedures for transmission of press releases and reception of news should be outlined. Arrangements for maximum utilization of joint facilities should be indicated. If there is need for additional communication personnel, the method of procuring such assistance should likewise be set forth in the Plan.

SCIENTIFIC AND PHOTOGRAPHIC PLANS

The conduct of various research and scientific projects and studies in the polar regions is of real importance to the National Military Establishment and the country. For this reason added emphasis is placed on a coordinated *Scientific Plan* properly cleared well in advance with the other departments of the National Military Establishment and with various interested scientific agencies

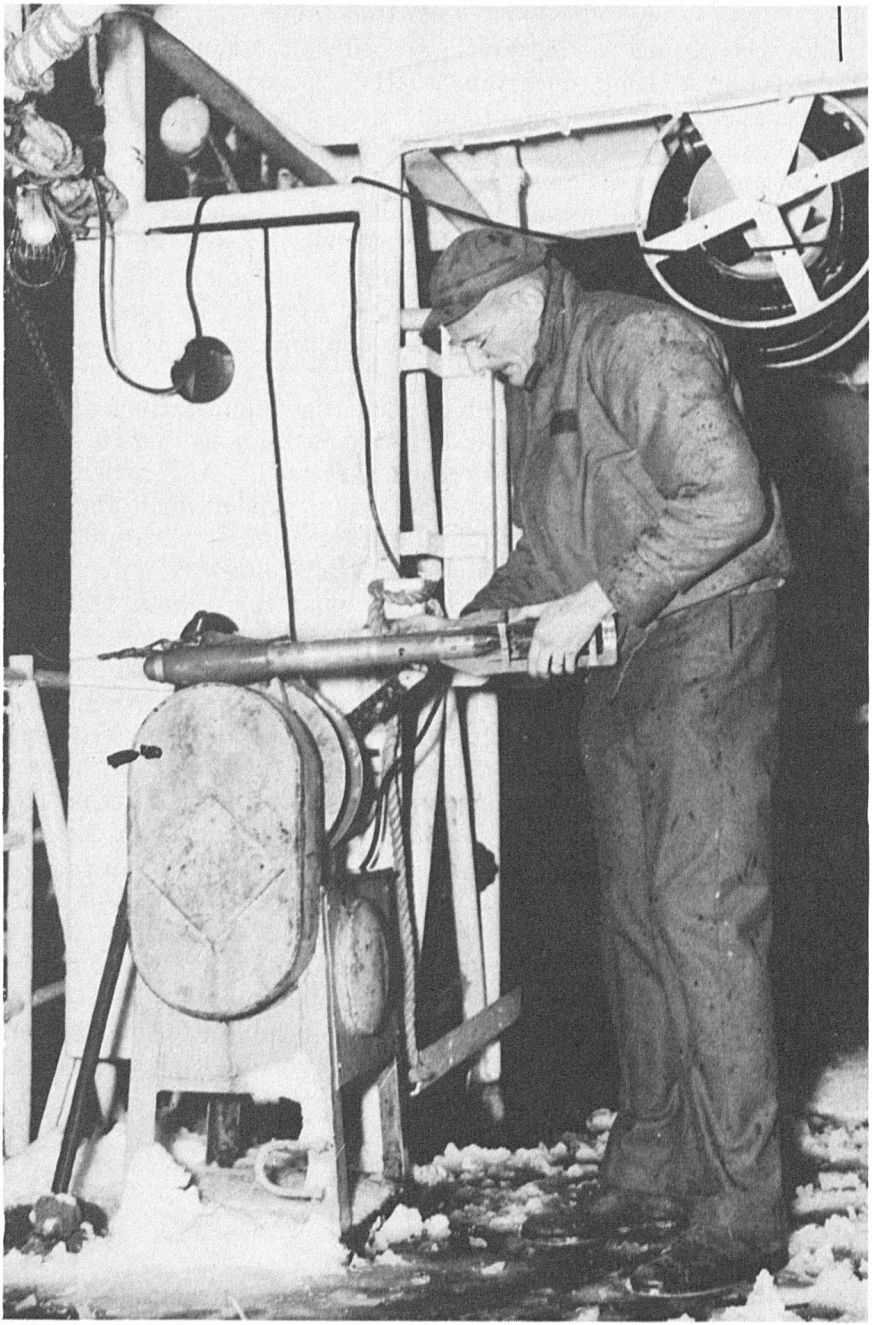


Figure 1–4.—Preparing to launch the bathythermograph.

of the Government. The Plan should provide ample opportunity for special scientific observers to take their measurements and to prosecute their studies, utilizing existing materiel, facilities, and personnel of the task force to the fullest extent. The foregoing applies particularly to oceanographic and ionospheric work. Operational and scientific aspects of an operation or expedition must be carefully integrated, taking into account important operational

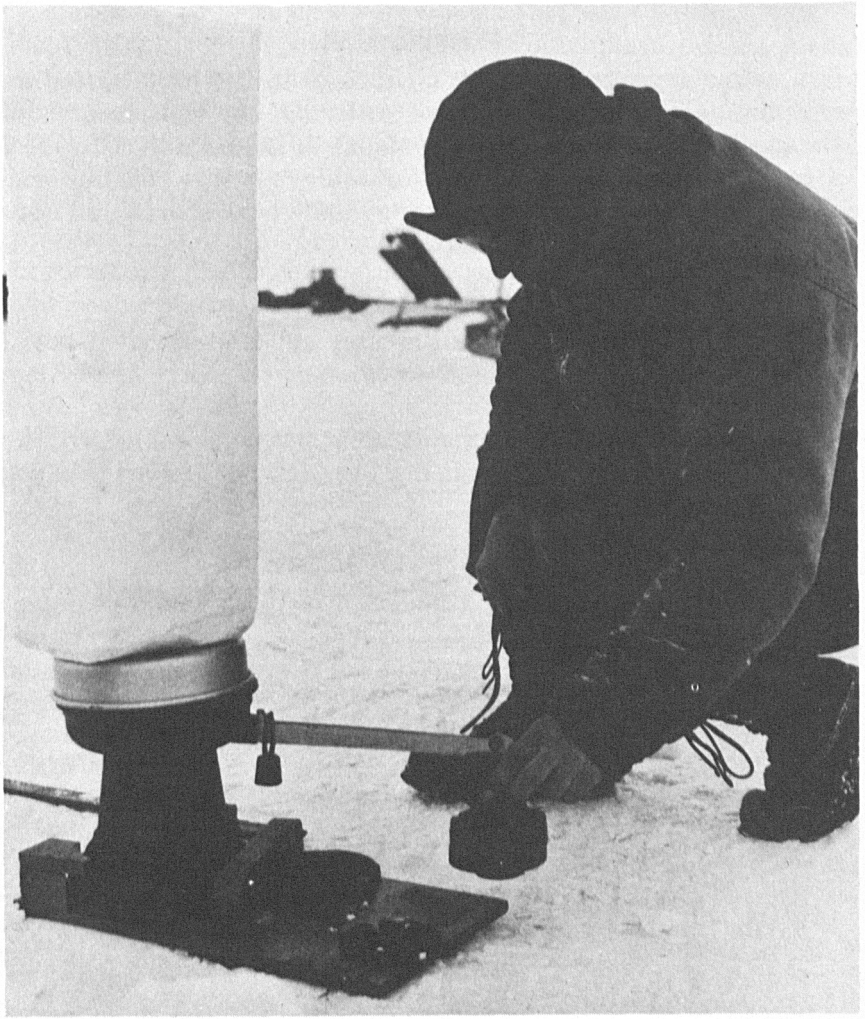


Figure 1–5.—Weighing snow column for density measurement.

missions, safety precautions, and the prime desirability of obtaining as much scientific information as possible. Provision for preparation, format, submission, and distribution of reports on scientific projects should be made in this annex.

A detailed *Photographic Plan,* including provision for supply of materials and personnel, should be included when planned photography is essential to the accomplishment of either the primary or secondary purposes of the operation.

TRAINING PLAN

A secondary purpose of all operations in the high latitudes is training of personnel and test of materials and equipment under the most extreme climatic environment to be encountered. Thus, a comprehensive training plan for achieving this end uniformly and effectively throughout the force should be prepared and issued as an annex of the *Operation Plan.*

HEALTH AND SURVIVAL

Special instructions for health, first aid, and survival not included in standing instructions or in approved Navy Department publications should be set forth in a *Health and Survival* annex. General instructions for abandon ship and subsequent rescue in event of disaster should be included, to the extent deemed necessary by the task force commander.

INSTRUCTIONS FOR OBSERVERS

Consideration must always be given to the accommodations of observers in any operation to the polar regions. Because the Arctic is of strategic and scientific interest, military and civilian personnel, including foreign nationals, will usually accompany the task force. Since these personnel are not always familiar with the customs and rules of the Navy, the annex, *Instructions for Observers,* should set forth the provisions for berthing, messing, finance, mail address, and other personal details which the task force commander desires them to follow. Care must be taken to cover all contingencies despite how simple they appear, in order to avoid possible embarrassments and adverse public relations.

MISCELLANEOUS NOTES

It cannot be emphasized too strongly that early planning will contribute materially to the success of an arctic operation, from both the operational and scientific standpoints. Since careful co-

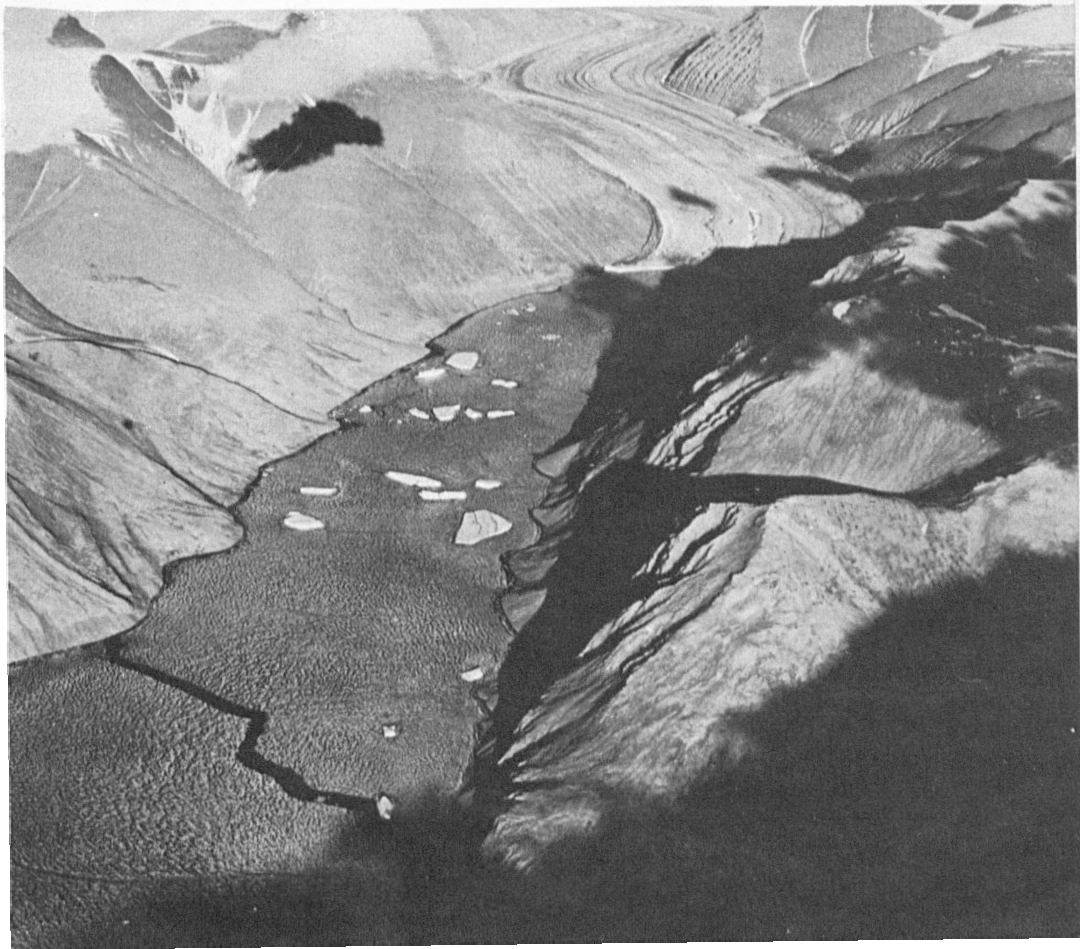
ordination with other services and various interested governmental agencies is always necessary, initial staff studies and planning should be conducted in Washington.

In the operational planning consideration should be given to stopping at one or more liberty ports, particularly if the operation is to be of long duration. Necessarily, operations in the Arctic or Antarctic do not provide opportunity for recreation, and the visiting of a liberty port on the return voyage will contribute substantially to morale.

Directives in respect to the release of public information should be formulated with, and issued as part of, the operation plan. Premature releases, the release of classified information, or undesirable publicity can be avoided by a well defined and executed public relations policy.

Pertinent directives and instructions, including those pertaining to preparation of the operation report, which have not been incorporated in the various other annexes should be included as a final annex of the operation plan.

Figure 1–6.—Navy planes photo terrain within 450 miles of the North Pole.



SUMMARY

The advice of Nansen quoted at the beginning of this chapter is a fitting summary. A polar operation probably will not be successful unless studiously and carefully planned in advance, and unless executed with "forethought for every conceivable thing." Adequate time must be allowed for staff study, formulation of detailed plans, and assembly of the materials, supplies, and special equipment required, while at the same time evaluating the capabilities and limitations of materiel and personnel as they may be expected to function in the area of operations.

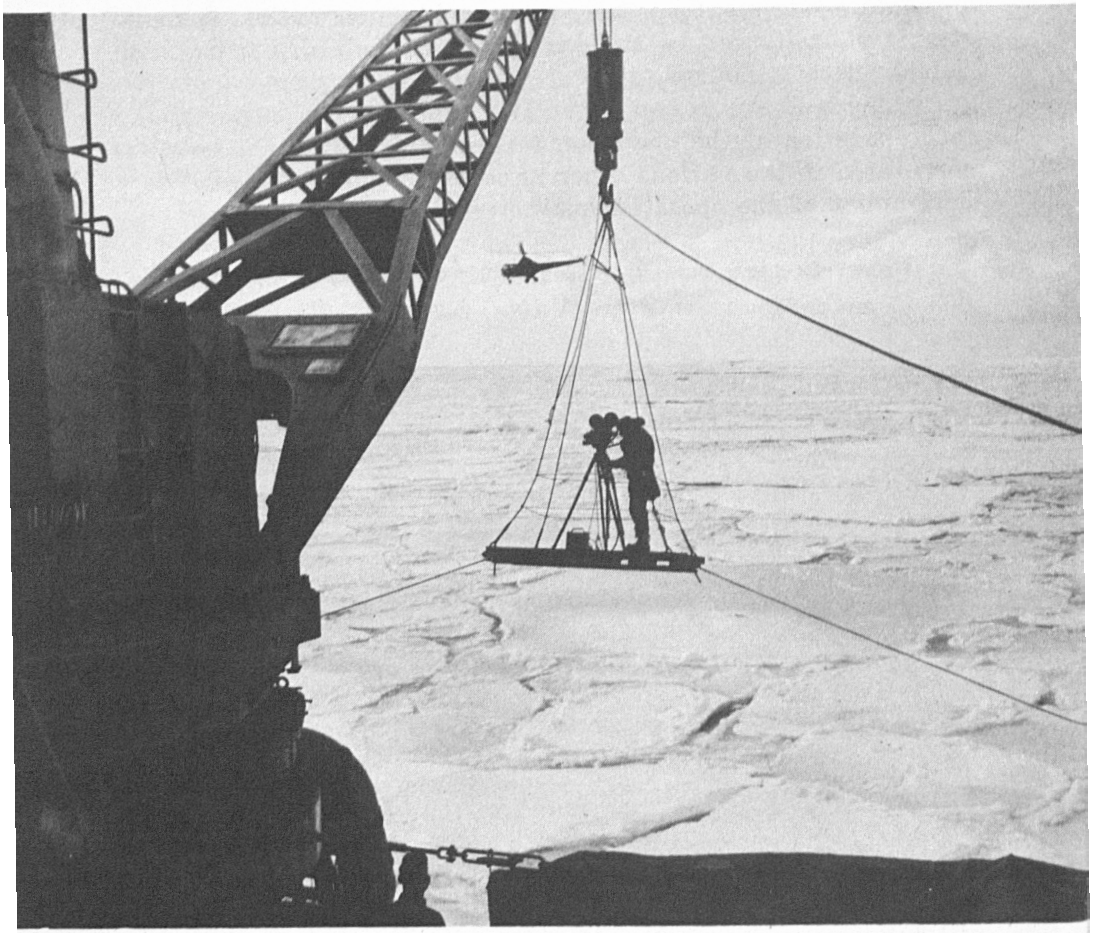
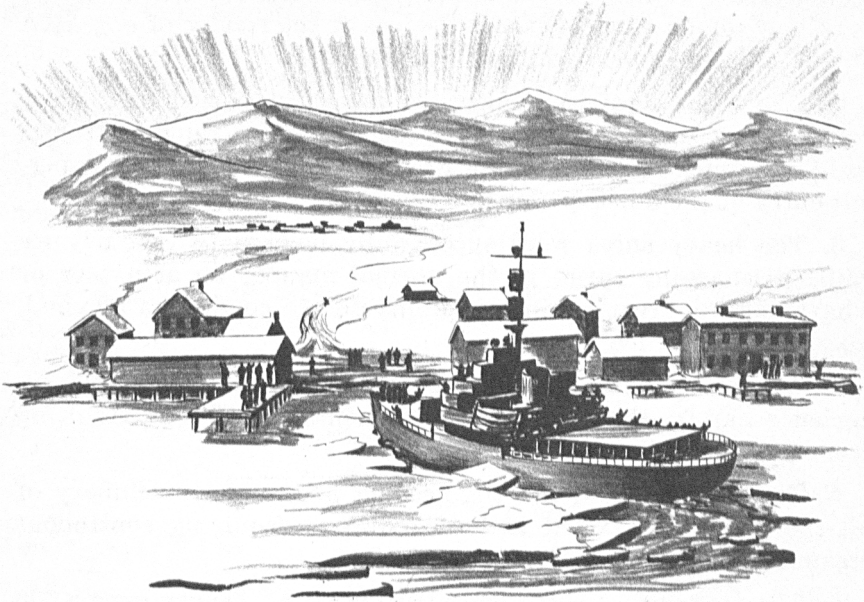


Figure 1–7.—Navy movie cameraman records progress of icebreaker through Antarctic ice pack.



CHAPTER 2

SHIP OPERATIONS

"The arrival of a ship at Nome, Alaska, during the winter months was hailed as the greatest thing to happen since the gold rush."—Gibson.

Ships have played a prominent and dominant role in the history of the arctic and antarctic regions since the earliest times. The accomplishment of major tasks in connection with any type of military operation—land, sea, or air—in the future in the high northern latitudes no doubt will require extensive participation by ships. Such operations might include geographic exploration, establishment of stations and facilities, logistic support of military installations, transportation, establishment and operation of temporary bases, rescue, tests of materiel, scientific observations, training, defense and military security, and offensive operations to the limit of naval weapons—naval aircraft, guided missiles, rockets, and guns.

During *Operation Highjump* in the waters around Antarctica, the significant accomplishments as to ship operations were:

1. Three large unprotected ships (2 AKA, 1 AGC) with the aid of one icebreaker traversed over 600 miles of pack ice varying from a mixture of brash and drift ice to consolidated pack ice.

All designated tasks were accomplished on time, in general, with relatively minor damage except the loss of the rudder of one AKA during a severe storm while still in the pack.

2. One wind class icebreaker, in the short period of 2 days, broke over 2 square miles of hard, dense bay ice ranging from 5 to 15 feet thick and cleared the Bay of Whales sufficiently to permit entry of the 3 heavy ships.

3. The heavy ships were successfully moored to fast bay ice while discharging cargo in the normal manner as at a pier or wharf, despite frequent interruptions due to conditions of wind, sea, and floating ice.

4. A large number of naval personnel gained invaluable experience amidst the unusual environmental conditions resulting from polar weather.

5. The endurance of the engineering plants and machinery of all the ships was tested under conditions requiring continuous steaming for extremely long periods.

6. The force of 13 ships operated without difficulty over 8,000 miles from regularly assigned bases, in unfrequented and unfamiliar waters and geographic areas, without the benefit of outside logistic support for a period of over 6 months.

7. One icebreaker successfully towed an AKA from the limits of the antarctic pack to New Zealand, a distance of over 2,000 miles, across the world's stormiest seas.

SUMMER OPERATIONS

The significant accomplishments during annual summer operations in the Canadian Arctic Archipelago and in the Beaufort Sea around Point Barrow, Alaska, have been:

1. An annual extension of limits of operations of icebreakers to a point at latitude 82°34′ N. in the Lincoln Sea, throughout Jones and Lancaster Sounds, in Prince Regent Inlet through the Fury and Hecla Strait, and in Hudson Bay.

2. The satisfactory development of amphibious techniques under the uncertain and unfavorable conditions prevailing around Point Barrow and in the Beaufort Sea.

3. The collection of valuable scientific data.

WINTER OPERATIONS

During *Operation Frostbite* in Davis Strait it was shown that a

carrier task group could satisfactorily operate up to the limits of the sea ice in northern seas throughout the year. Icebreakers have operated above the Arctic Circle within Davis Strait and the Bering Sea during the winter period. These operations are typical of peacetime naval operations, and possibly may form the pattern for any operations that may be required in the Arctic in time of war.

NAVIGABILITY

The principal limitation upon ship operations in the Arctic, as elsewhere, is navigability in the assigned areas of operations. Navigation amongst ice is uncertain and hazardous at best, and is subject to considerable damage to hulls and fittings of the participating ships.

Figure 2–1.—Observation from helicopters.

The navigability of a given sea area in the Arctic can only be determined by careful study of all available charts, sailing directions. and ice atlases. It also must be remembered that the last named are based on sparse information. Only now are data on the regions becoming systematically collected and interpreted. Appendix A will serve as a guide for ready reference based on average conditions that may be expected to prevail over a period of years. Once in the area, it is quite possible that actual conditions will be different from the average. Thus the appendix can only be depended upon for general information.

Another of the limitations upon naval operations in the high latitudes is the direct effect of extreme cold on personnel and the con-current indirect effect on ship operations.

Table I which follows is a listing of approximate mean and minimum temperatures that likely would be encountered to the limits of navigability during the coldest period of the year, January and February, throughout the arctic regions. This information is essential, since it will form the basis for planning the heating of the ship and for selecting the clothing which the personnel will wear to ensure comfort, and the maintenance of personal efficiency at the highest possible degree.

TABLE I

Navigability—Sea Surface Temperatures, Coldest Month

General area	Latitude, North	Longitude, W. or E.	Average temperature ° F.	Minimum temperature ° F.
Davis Strait	66–30	59 W.	−5	−20
Davis Strait	64	61 W.	−10	−20
Godthaab, Greenland	64–11	57–43 W.	14	−20
Greenland Sea	70	15 W.	15	−15
Greenland Sea	77	0	15	−15
Vardo, Norway	70–22	31–08 E.	22	−9
Barents Sea	70	45 E.	20	
Kola Inlet near Murmansk, U. S. S. R.	68–53	33–01 E.	−22	−39
Grimsey, Iceland	66–33	18–01 W.	28	−23
Belle Island, Newfoundland	51–33	55–22 W.	17	−18
Eastport, Maine			21	−13
Archangel, U. S. S. R.	64–35	40–36 E.	−25	−49
Solovets, U. S. S. R.	65–01	35–45 E.	−7	−22
Sitka, Alaska	57–03	135–20 W.	32	−4
Kodiak, Kodiak Island	57–47	152–24 W.	30	−9
Juneau, Alaska	58–18	134–24 W.	27	−15
Nome, Alaska	64–30	165–24 W.	3	−47
Vladivostok, U. S. S. R.	[1] 42	[1] 132 E.		[1] −15

[1] Approximate.

WINDCHILL

In the language of explorers, polar winds are "bitter," "biting," "keen and bitter as frozen steel," "furious," "an active enemy," "terrific," or "violent and terrible." The intense cold associated with such winds numbs human beings, makes work killing, cuts through the warmest clothing, and slows down everything.

Windchill is the cooling effect of two variables—wind speed and average temperature. A windchill factor of 1450 and higher defines arctic conditions. Since a moving ship creates wind, arctic conditions of windchill usually prevail in northern seas during the winter. Table II below contains a listing of windchill factors under varying conditions of wind and temperature.

TABLE II

Windchill factors

Windchill factor	Body condition	Temperature ° F.	Wind speed statute m. p. h.
50	Hot	88	20
200	Pleasant	81	20
400	Cool	69	20
800	Cold	46	20
1000	Very cold	35	20
1200	Bitterly cold	23	20
1400	Exposed flesh freezes	11	20
1450	Arctic	0	10
1450	do	15	25
1800	do	−12	20

During *Operation Frostbite* near latitude 63° N. in early March of 1946, temperatures as low as 14° F. were experienced. Thus, during flight operations, it can be seen from the above table that arctic windchill conditions prevailed. It was found then that the main problem in carrier operations in cold weather areas is maintenance of efficiency of flight deck crews for the condition of high relative winds and surface air temperatures below freezing.

FORECASTING AND REPORTING SEA-ICE CONDITIONS

Reliable information about the characteristics, distribution, and movements of sea ice, including seasonal variations, is becoming increasingly important for all types of ship operations in the Arctic. In the past, this information has been largely limited to the sparse records obtained from ships which have operated near the edge of the pack ice, from ships frozen in the pack, and from

explorers traveling on foot over the ice. However, all this has contributed very little to our knowledge of seasonal variations of the ice. Increasing arctic operations offer unique opportunities to collect ice data in sea areas heretofore unexplored. These data are essential both during the conduct of an operation and for assembling the data needed for the prediction of ice conditions during the years to come. Each ship operating in a cold-weather area should make systematic observations of sea ice wherever the opportunity affords.

The principal advantage of shipboard reconnaissance of ice is that it affords the opportunity for first-hand, detailed observation of the ice itself, and its changes with time. On the other hand, there are many characteristics of ice that are better observed from the air. During the conduct of an operation over a large area of the sea, long range air reconnaissance, periodic observation from helicopters, and continuous surface observation from the crow's nest are essential to safe ship navigation.

The Hydrographic Office has developed standard ice observer sheets or log forms both for ship and air observers. Certain of the information used in the two systems is interchangeable. In this way shipboard observations and air observations can be easily interpreted and rectified. Each item in the logs is there for a definite reason. Therefore, no item should be skipped because it may appear unimportant. It may be valuable in later analyses.

As occasion permits, radar photographs, ordinary still and movie photographs, sketches, and other means should be employed to obtain permanent records of the observed conditions.

The use of these ice observer log forms is explained in detail in HO Studies 99 and 104.

The task force or task group commander should make provision in his operation plan for the assistance of any available ice pilots familiar with the area of operations, for the tactical control of any air force or naval aircraft that can be made available to him for long range air reconnaissance, and for the preparation of timely ice forecasts for dissemination to all units while in the area.

ICE SEAMANSHIP AND NAVIGATION AMONGST ICE

Admiral Peary has stated that "ice navigation is the key to all polar work."

The Hydrographic Office has issued *A Manual of Ice Seamanship* (HO 551) which is a complete treatise on the subject, representing existing knowledge and the best experience to date. Each line

officer should read and study this publication prior to arrival of his ship in waters where it is expected that sea ice will be encountered.

There are summarized in appendix B some notes on experience during past polar operations relating to preparation for ice navigation, general rules of ice navigation, travel over ice, and safety. They may be applicable only in part in a given area, due to variations in climate and other geographical factors in the two polar regions. This listing is not all inclusive. A check-off list should be prepared and executed in keeping with requirements of the operation.

Navigating officers, officers of the deck, and quartermasters should receive instruction in polar navigation prior to departure from base, including:

1. Instruction in the irregularities of gyrocompasses in high latitudes as well as use of correction tables provided for latitudes above 70°.
2. Magnetic compass variations and corrections in high latitudes.
3. Navigation in fog.
4. Navigation by radar and soundings.
5. Use of bubble sextant. (Each ship should be provided with bubble sextant.)
6. Recognition of land marks or navigational aids in the area.

Remember the regulation of long standing as to the use of a hand lead when on soundings. Remember also the fact that the fathometer is not reliable when the depth is less than 10 fathoms. Take azimuths and plot line of position whenever observations of the sun permit. In the high latitudes a quick swing of the ship sets up a gyro error of considerable magnitude.

OPERATION OF BOATS AND SMALL CRAFT

There are countless tasks and missions to be accomplished by boats and small craft in any naval operation in the polar regions. They must be winterized in accordance with latest instructions of the Bureau of Ships, and placed in first class operating condition prior to arrival in the area of operation. Due to hazards that are liable to be encountered, only skilled and dependable boat crews should be used.

In table 111 and accompanying photographs, figures 2–3a to 2–3j inclusive, are set forth the features, characteristics, and capabili-

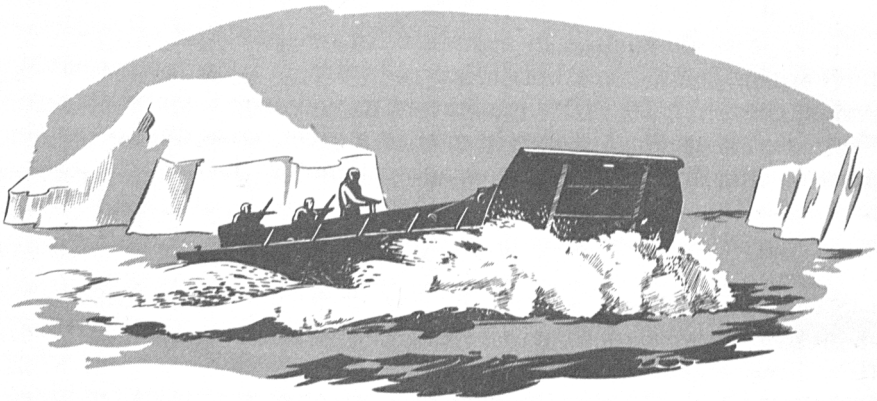


Figure 2–2.—Many tasks can be accomplished by small craft.

ties of various boats and small craft which have been used satisfactorily by the Navy and Coast Guard in the Arctic.

In operating boats in the Arctic, it is mandatory that they be equipped with efficient portable communications equipment and emergency gear. Coxswains should be completely instructed as to procedures to be followed during storms and low visibility. Remember that these boats are not suited for breaking channels through pack ice. LCVP and LCM have a tendency to ride up on the floes. All are subject to holing and damage to rudders and propellers.

The following precautions should be exercised:

1. Use caution when approaching drift ice. Proceed at slow speed. Avoid all ice possible. Avoid areas of slush and brash ice. Keep circulating water inlet free of ice.

2. Coxswains should never leave tillers unattended. Keep boat engines operating as movements of floating ice are unpredictable.

3. When approaching an area of ice for a landing alongside, proceed at dead slow speed and nose gently into it, warping alongside as necessary. Get equipment and personnel on or off the ice as rapidly as possible and back clear.

4. When operating in drift ice areas, station bow lookout to keep coxswain advised of nearby ice and submerged cakes, such as growlers, that will endanger the boat.

5. Keep circulation water to minimum just to prevent overheating of engines. Warm up engines slowly. Never race engines. Keep engine heaters in place when boat is not in use. Drain engine block when boat is hoisted or hauled out of the water for other than a temporary period.

6. Check fuel, lubricating oil, and boat equipment each time before leaving the ship. Keep fuel tanks full at all times to prevent condensation and possible subsequent freezing of the water in the fuel system. Keep storage batteries fully charged. Have portable engine starter available for use to prevent unnecessary discharge of boat batteries in event of hard starting.

7. Keep bilges of boats absolutely clean and dry. Ensure that drain plugs are kept free. Do not let them freeze. Examine carefully before placing boat in water.

8. Keep fire fighting equipment available in boats at all times when in use.

9. Test out boat radio equipment before leaving ship. Keep in communication while away from the ship.

10. First boat ashore should carry adequate survival gear for entire working party to be landed for use in event of emergency —sleeping bags, fire arms, ammunition, fuel, rations, etc.

Figure 2-3a.—LCM-3.

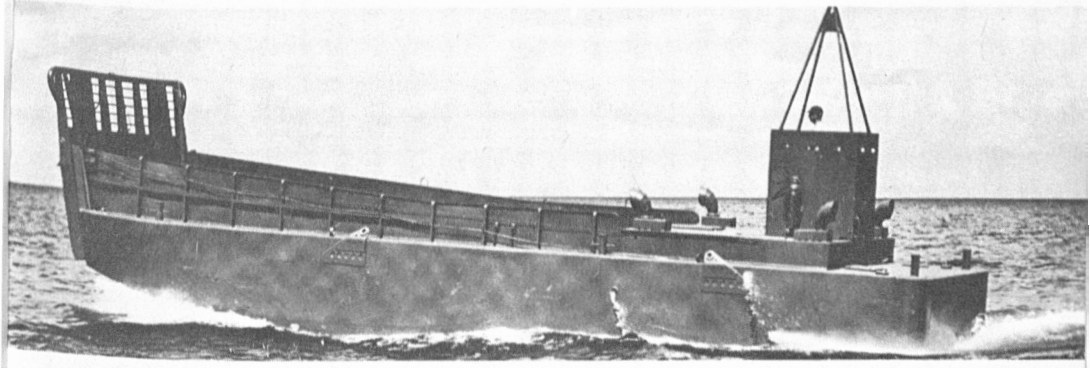


Figure 2-3b.—LCVP.

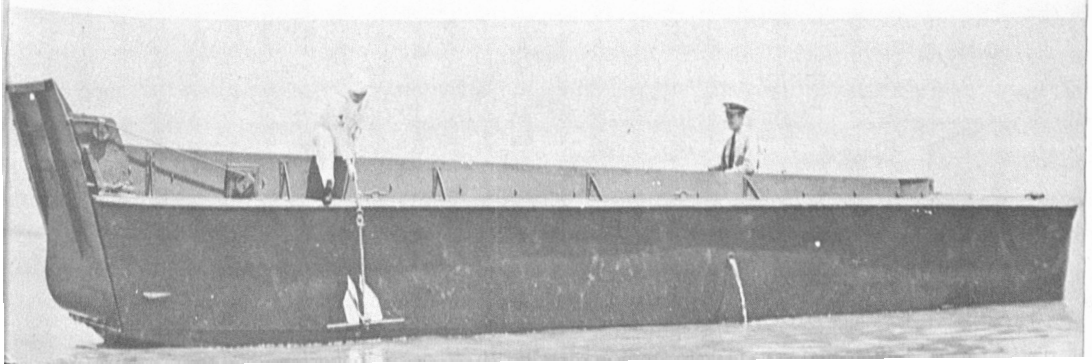
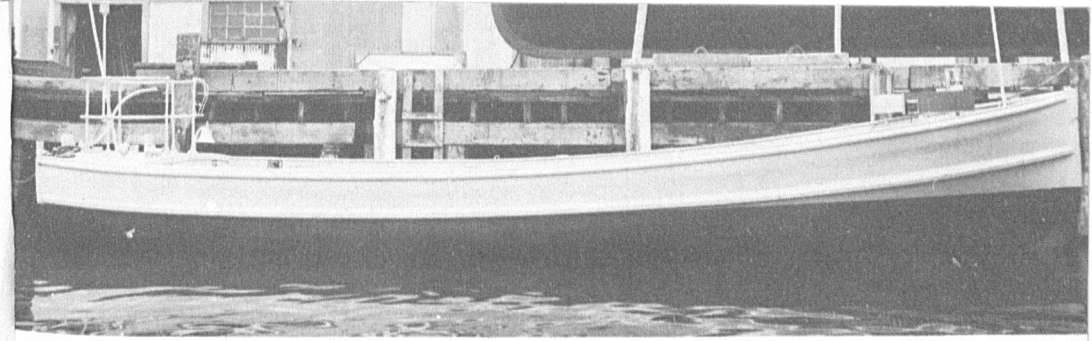


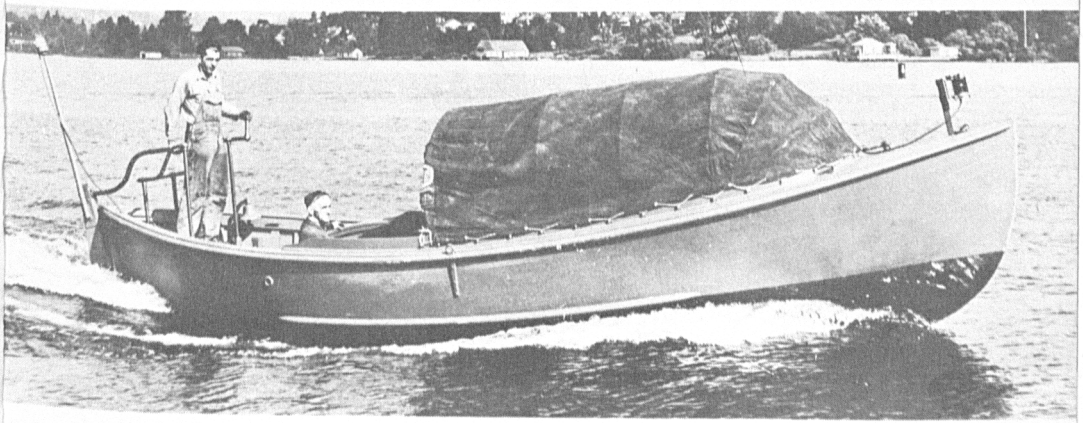
TABLE III

SMALL CRAFT DATA—POLAR OPERATIONS

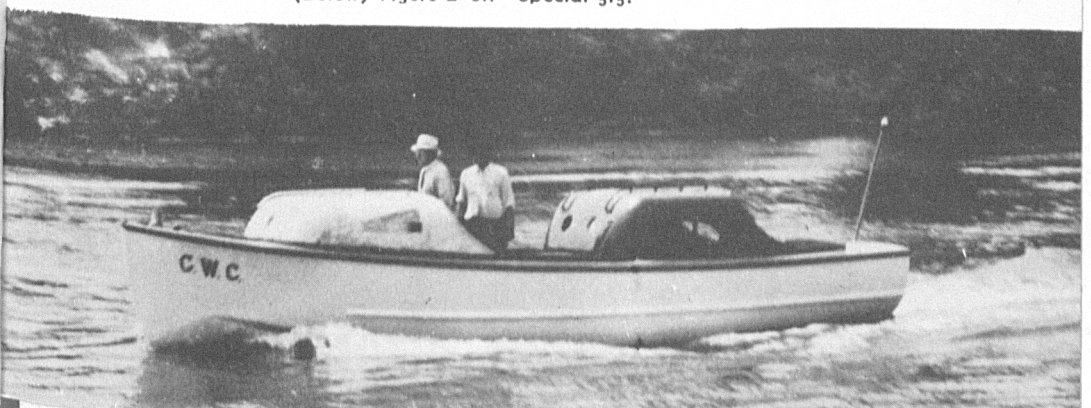
Boat	Length	Beam	Draft	Weight, empty	Usual employment	Capacity	Power plant	Speed	Type hull	Remarks
NAVY										
LCM-3	50′	14′6″	3′6″	52,000 lbs.	Cargo / Passenger	50,000 lbs. / 80 men	Twin diesel, 225 H.P. each	12 m.p.h.	Steel	Fig. 9-1. Dimensions of boat limit capacity to 80 men however *normally* boat capacities assume 10 cubic feet of internal volume per man and a weight of 165 pounds per man.
LCVP	36′	10′6″	3′4″	18,000 lbs.	Cargo / Passenger	8,000 lbs. / 36 men	Diesel, 225 H.P.	10 m.p.h.	....do....	Has carried 10,000 pound T-9 *tractor without difficulty.*
40′ motor launch	40′2″	11′4″	2′4″	16,000 lbs.	Passenger / Cargo	14,850 lbs. / 90 men	Diesel, 50 H.P. DB	9 m.p.h.	Wood	
26′ motor whale boat	25′11″½	7′3″⅜	.....	5,066 lbs.	Passenger / Cargo	(Open) 22 men 3,600 lbs. / (Hood) 20 men 3,300 lbs.	Diesel, Da	.....	....do....	
COAST GUARD										
Motor boat (cabin) "Greenland Cruiser."	36′8″	11′1¼″	3′3″	21,255 lbs.	Passenger	25 men	Diesel 85 H.P. (Buda Lanova)	9 m.p.h.	....do....	Cruising radius 486 miles—300 gallon tank—4 berths—4 heavy chains for lifting—built on 36′ motor surf boat hull.
26′6″ motor launch (Special) GIG.	26′6″	7′10″	2′7″	7,450 lbs.	Passenger	18 men	Diesel, 35 H.P. (Buda)	9 m.p.h.	....do....	*Cruising* radius 95 miles.
Self-bailing motor surf boat.	25′10″	7′4″ (wood fenders) 7′11″ (cork fenders)	2′9″	6,000 lbs.	Rescue / Passenger	16 men	Diesel, 30 H.P.	8 m.p.h.	Wood with Metal Sheathing	High engine hatch with Buda—low engine hatch with Kermath. (Buda has fresh water cooling tank above.) Cruising radius 75 miles.
26′ monomoy surf boat.	26′3″	7′4″	.....	2,100 lbs.	Rescue / Passenger	14 men	Pulling	.....	Wood	Usually equipped with sails.
Ice skiffs	15′6″	3′8″½	.....	510 lbs.	Passenger	4 men	Pulling	.....	....do....	
AMPHIBIOUS										
M29C weasel	10′5″¾	5′1″ (old track) 5′7″¼ (new track)	3′5″1⅛	4,771 lbs.	Passenger	4 men	Gasoline (Studebaker)	Land 32 m.p.h. Water 4 m.p.h.	Steel	Height over all — (top up) 5′10″1⅜ (top down) 4′5″1⅛.
LVT-3	21′6″	9′10″	.....	36,400 lbs.	Cargo / Passenger	9,000 lbs. / 25 men	Twin gasoline (110 H.P. Cadillac)	Land 25 m.p.h. Water 6 m.p.h.	....do....	Height 8′1″½.
DUKW	31′	8′4″	(Loaded) 42″ front wheels 51″ rear wheels	14,880 lbs.	Cargo / Passenger	5,000 lbs. 25 men	Gasoline, 90 H.P.	Land 50 m.p.h. Water 6.5 m.p.h.	....do....	Height 9′2″¼.

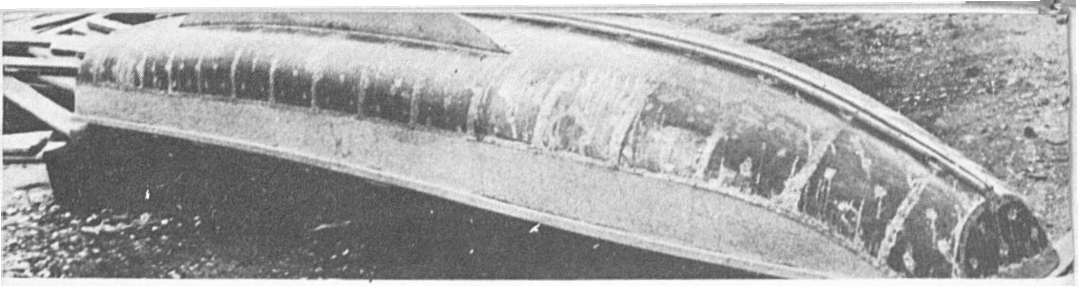


(Above) Figure 2–3c.—Motor launch.
(Below) Figure 2–3d.—Motor whale boat.



(Above) Figure 2–3e.—Greenland cruiser.
(Below) Figure 2–3f.—Special gig.

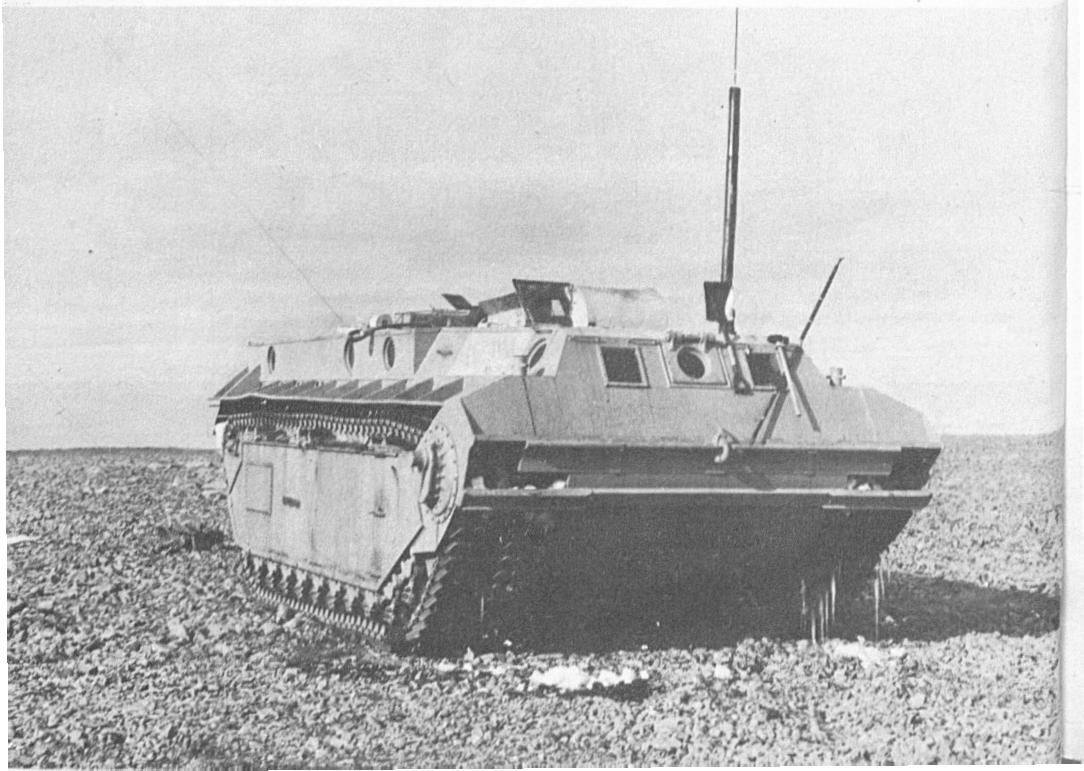




(Top) Figure 2–3g.—Ice skiff

(Above) Figure 2–3h.—M29C weasel.

(Below) Figure 2–3i.—LVT 3.



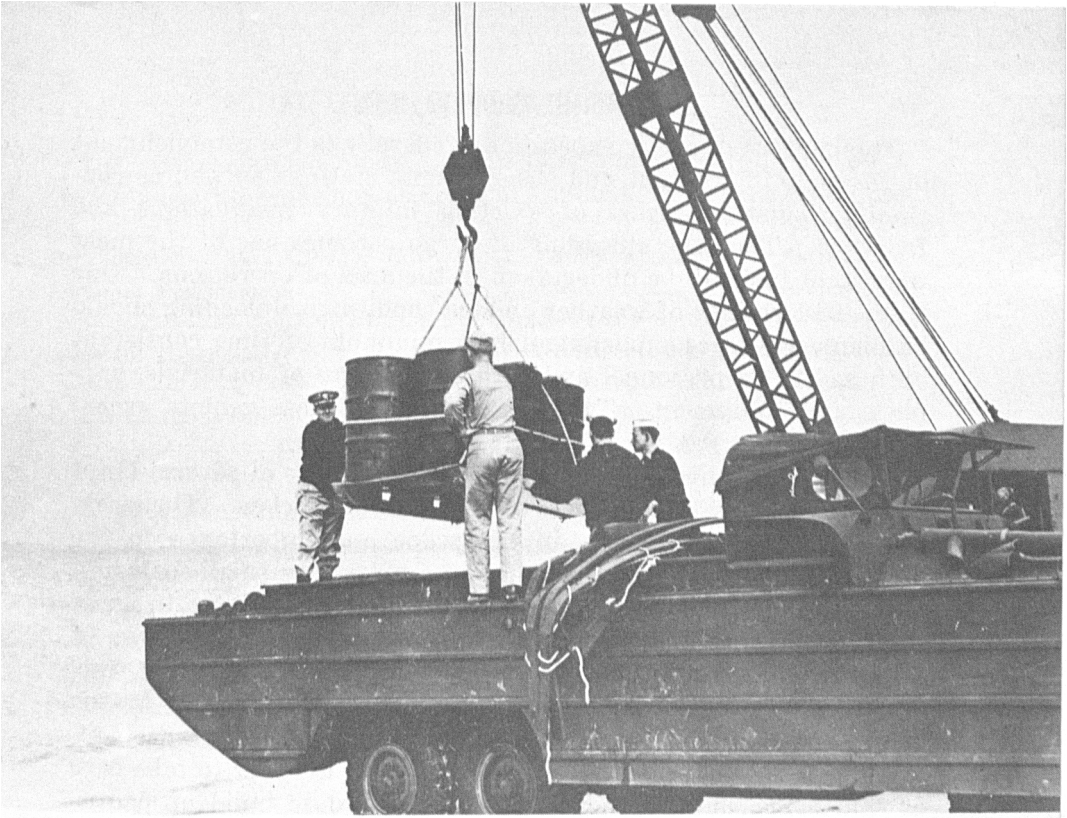


Figure 2-3j.—DUKW.

BEACHHEAD OPERATIONS

The purpose of arctic expeditions generally is the establishment or resupply of weather and other remote stations as well as continuing logistic support of existing military installations and facilities. Thus the unloading of cargo becomes one of the most important tasks to be undertaken in the area of operations. Due to the uncertainty of weather and ice conditions, unloading should be planned for accomplishment in a minimum of time consistent with safety to personnel and careful handling of materials, supplies, and equipment. Take no chances in these remote areas! *Practice safety first!!*

To introduce this subject briefly, the experience of several Point Barrow resupply expeditions will be outlined below. These expeditions have grown steadily in scope and importance to the point that they are now planned and executed as small-scale amphibious exercises. Since such operations are conducted in areas where assistance ashore is limited or not available, the crews of all participating ships must be augmented to ensure that this phase of the expedition is conducted expeditiously and in the manner required to provide the logistic support necessary. Always be prepared to do more than is planned in order to take care of contingencies. Furthermore, it is desired to build up cadres of personnel trained in cold weather exercises. This is another justification for the assignment of additional personnel to ships which participate in such special operations.

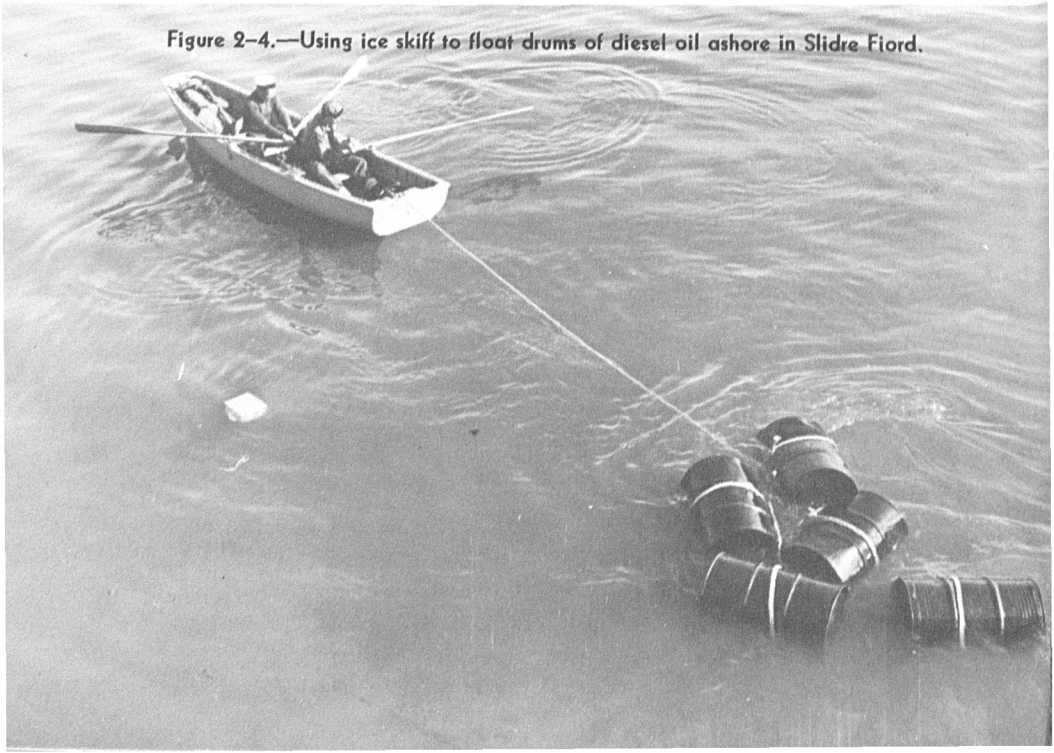


Figure 2–4.—Using ice skiff to float drums of diesel oil ashore in Slidre Fiord.

EXPERIENCE AT POINT BARROW

1. Organize an adequate beachmaster party to function on a watch-and-watch basis consisting of following totals as available:

Beachmaster	CDR or LCDR	Radiomen, Signalmen	As required
Assistant Beachmaster	LT or LT (j. g.)	Seamen	As required
Assistant Beachmaster	ChCarp or ChBosn	Weasel Drivers	2 for each weasel
Communications Officer	LT or LT (j. g.)	Beach Supervisors	2 Bosn's Mates
		Hospitalmen	2
		Motor Machinist Mate	1
		Electronic Technician's Mate	1

2. Provide Jamesway hut, arctic tent, or similar shelter for headquarters for beachmaster party and for shelter of personnel away from ships in emergency. If practicable, subsist party ashore.

3. Organize a Seabee or engineer detachment for operating lighterage, cranes, tractors, and LVT's where quantity of cargo necessitates. This detachment is then divided into a number of units equal to the number of cargo ships with one unit assigned

Figure 2–5.—Three ice skiffs tied together as "barge" for use in shallow water.

to each for the voyage to the area of operations. An officer in charge is designated for the detachment. A unit consists of a chief petty officer and approximately 25 men.

4. The loading activity in the United States is responsible for supplying all ships with additional stevedore gear-straps, slings, and cargo nets required for their own needs on shipboard and on the beaches.

5. For the purpose of keeping cargo segregated, the beach at Point Barrow has been divided in areas as follows:

Area 1.—Lumber, hut materials, building materials, food, and commissary supplies.

Area 2.—General supplies.

Area 3.—Spare parts, heavy automotive equipment, and supplies.

Area 4.—Oil field equipment and supplies.

Area 5.—Fuel and lubricants.

Area 6.—Emergency beach.

6. An area should be selected for safely caching explosives.

7. Drummed gasoline should be segregated, with fire break and fire fighting equipment provided as a precautionary measure.

8. A beach party is organized by the station at Point Barrow

Figure 2–6.—Motor whaleboat taking ice skiff "barge" in tow.

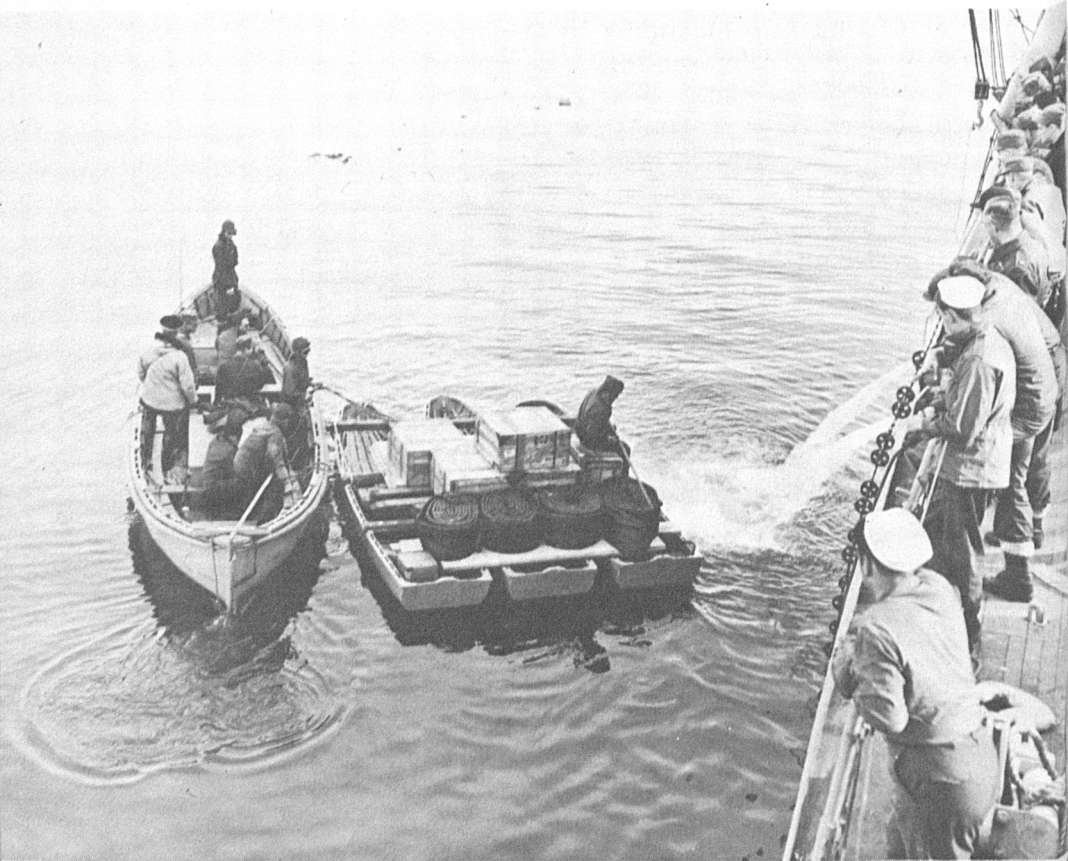


Figure 2–7.—Ice skiff can carry four men comfortably.

to handle cargo after it has reached the beach areas, to maintain weight lifting equipment, and to assist with the maintenance and repair of small craft engaged in the unloading. This party, while maintaining close liaison with the beachmaster unit, moves the cargo from the beach to storage areas. Since weight lifting equipment is available usually in limited quantity, it must be utilized to the highest degree of its capacity and efficiency. Therefore, the unloading operations are planned to avoid any unnecessary moving of special equipment from one beach area to another. Beach areas should be kept clear to avoid congestion and slowing down shipboard and lighterage operations.

9. Unloading should begin within 1 or 2 hours after ships arrive at the anchorage and continue on a 24-hour basis, except for interruptions due to ice or weather. The unloading should be planned for rate of discharge of 45 to 50 tons per hour per ship.

10. Portable communication equipment (SCR 610, TBX, etc.) should be provided in more than adequate quantity for beach party, beachmaster unit, LCM's, LVT's, lighters, and weasels. These sets should be fully winterized and made snow and water tight.

A large scale beach operation in the Arctic can be satisfactory only if the loading was expertly planned with "forethought for every conceivable thing" and taking into account conditions which, from experience, are known to prevail in the area of operations. Do not overlook the contingencies that can be caused by limitations of available weight lifting equipment or by the terrain. Remember that interruptions will occur due to the presence of heavy drift ice or by the pack unexpectedly setting down upon the anchorage.

MARKING AND PACKAGING OF CARGO

The marking and packaging of cargo is extremely important since only periodic resupply is possible. For maximum protection against loss, water damage, rough handling and pilferage, the following requirements should be fulfilled, if possible.

1. Drummed oil products need be marked only for description of contents. Gasoline should be shipped only in *new* drums. The use of reconditioned drums should be limited to lubricating oils and Diesel oil. All drums should be carefully inspected for tightness of plugs, presence of leaks, secure stowage in holds (fig. 2–16). NOTE.—*Load all drums on end with plugged end up.*

2. Cargo other than petroleum supplies should have appropriate beach marking stencilled on each container in black paint. In addition to these target symbols, additional information should be stencilled on each container about as follows:

_____ _____
Shipping Code Year
WT_____ Cube_____
Contents _____
Vendor _____

Figure 2–8.—Using ice skiff to land men on arctic beach.

3. All cargo should be properly export-packed and, insofar as practicable, palletized to facilitate handling in the ships and on the beaches.

4. Palletized materials should be securely strapped with metal strapping using corner plates when the straps are necessary to eliminate damage to material. Loaded pallets ordinarily should not exceed a weight of 4,000 pounds (fig. 2–17).

5. Flour and sugar should be packaged in waterproof containers and boxed; metal containers are preferable, if available.

6. Commissary supplies should be packaged in waterproof containers and securely boxed.

7. Machinery and spare parts should be treated with corrosion resistant materials and preservatives and packaged in export boxing.

8. Drilling mud, sand, cement, and like materials should be packed in metal containers holding 4 sacks each. If metal containers are not available, materials should be placed in waterproof bags and export boxed or sealed in watertight barrels.

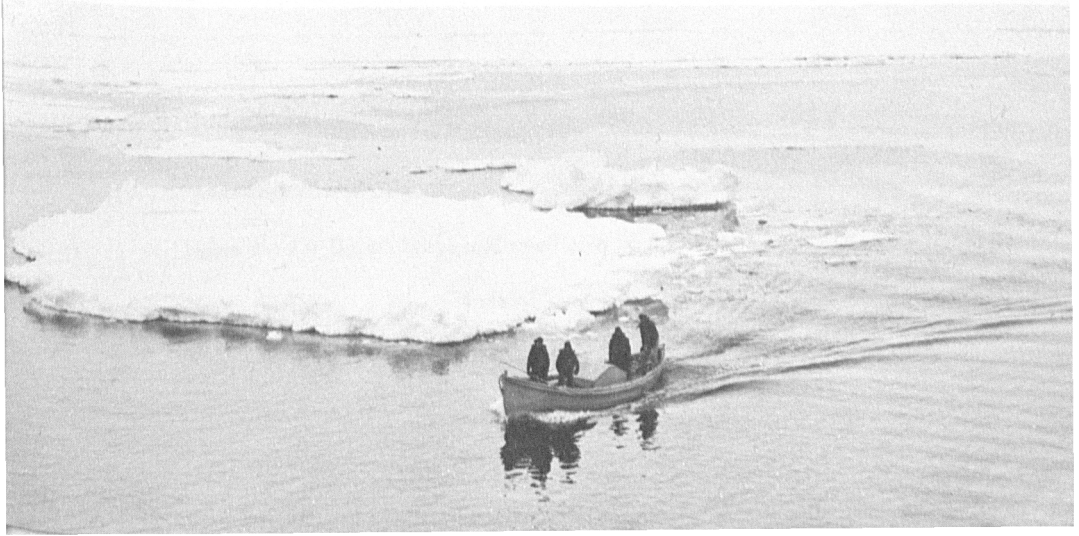
9. Lumber should be metal strapped in sling load lots not to exceed 4,000 pounds. Pieces should be of equal length.

10. Plywood, wallboard, and insulation materials should be waterproof wrapped and well crated with weight not exceeding 1,200 pounds. Figures 2–18 to 2–22 inclusive show beachhead operations in the Antarctic and figures 2–24 to 2–34 inclusive in the Arctic.

DESIGN, CAPABILITIES, AND TACTICAL EMPLOYMENT OF ICEBREAKERS

Up to the year 1939 the design of ice-breaking ships had presented perplexing problems in that very little accurate data was available on ice conditions and on the physical properties of sea

Figure 2–9.—Motor whaleboat underway in a big clearing in the pack.



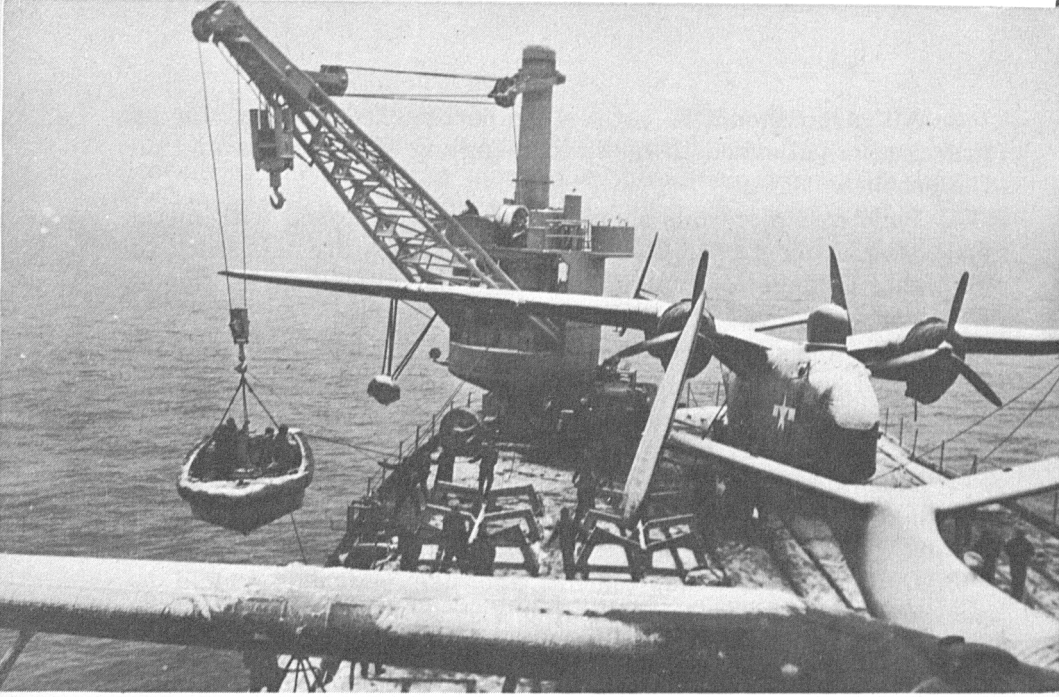


Figure 2–10.—AV lowering retriever boat.

Figure 2–11.—Danish barge and small craft used in West Greenland.

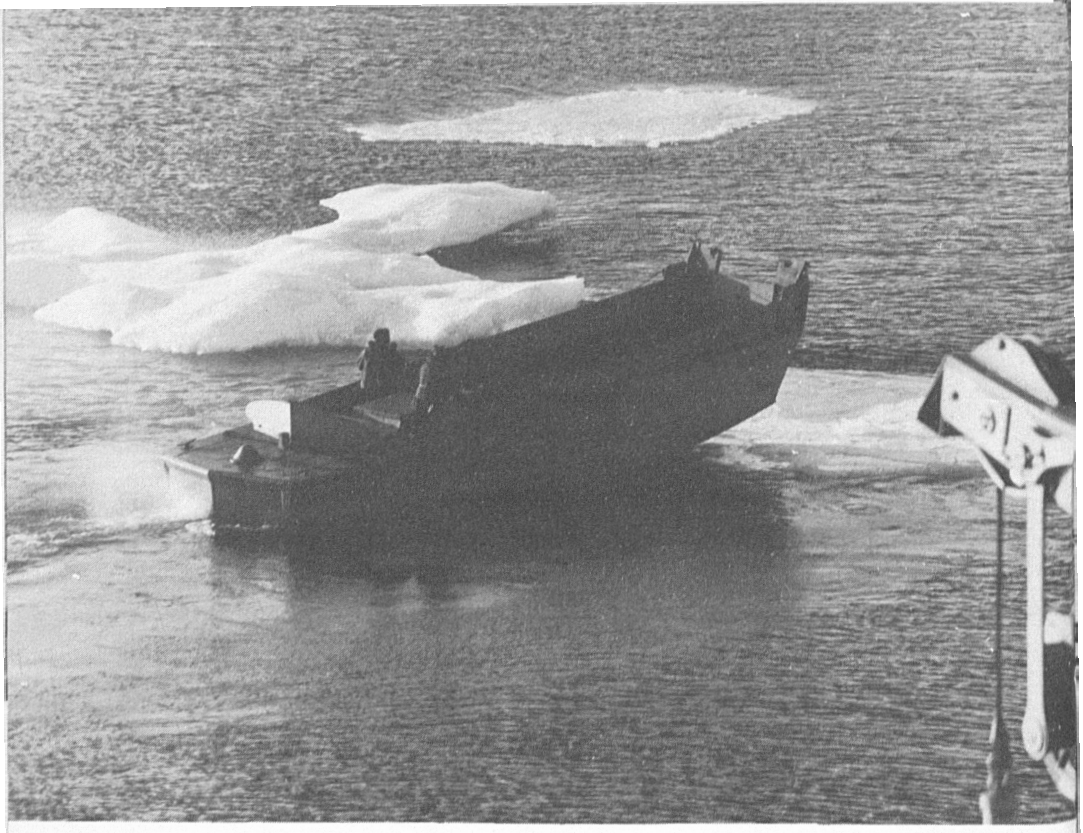
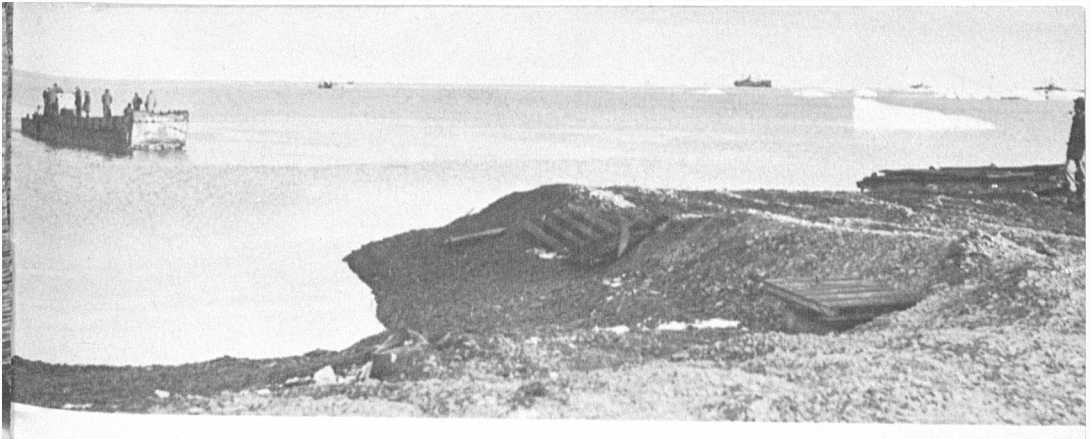
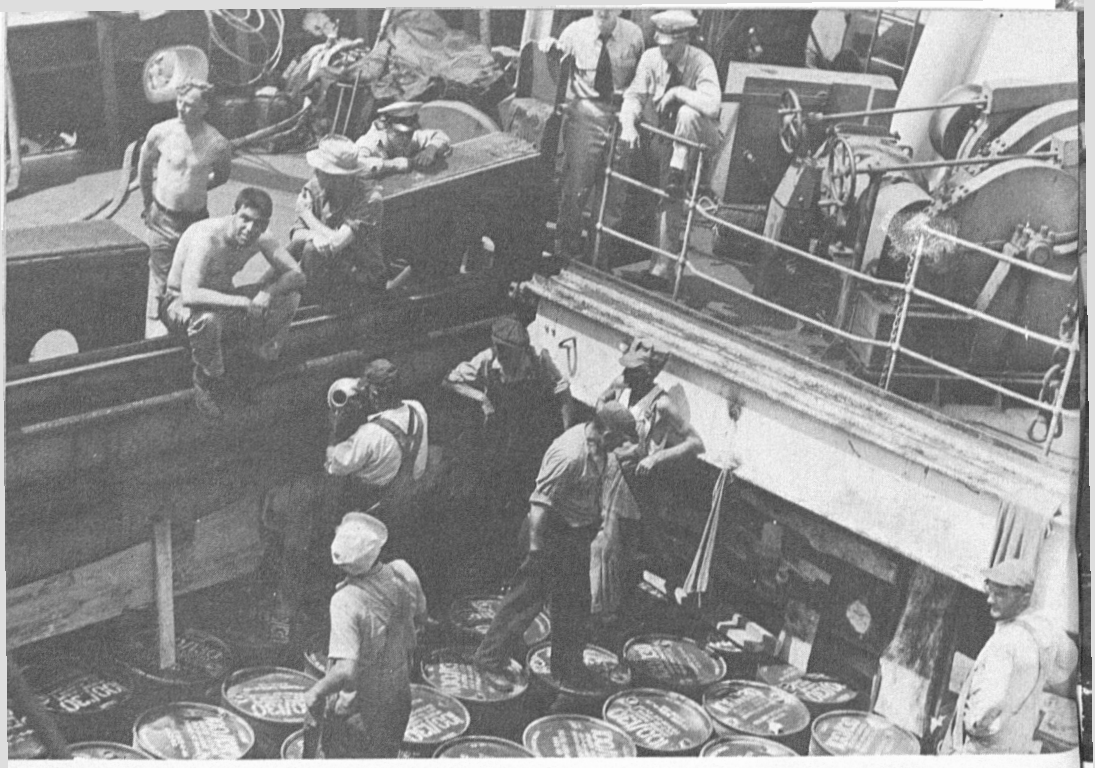


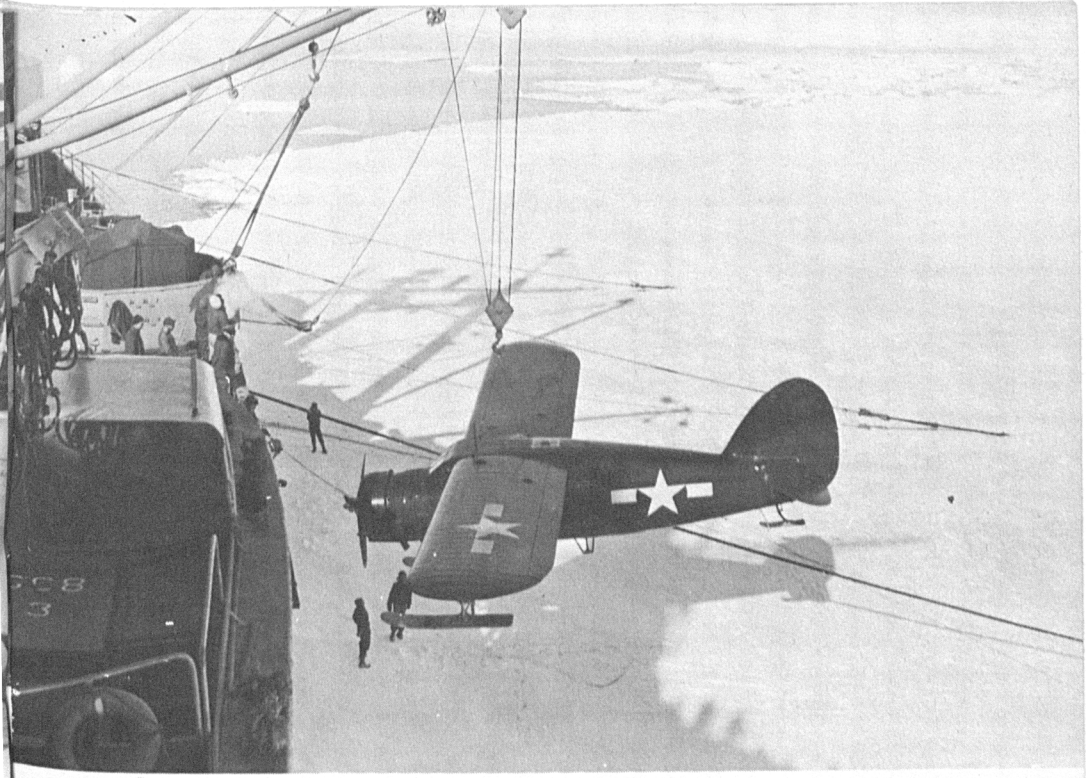
Figure 2–12.—LCVP moving cake of floating ice from side of ship.



(Top) Figure 2–13.—LCM–3 approaching beach at Resolute Bay.
(Above) Figure 2–14.—LVT–3 in Bay of Whales.
(Below) Figure 2–15.—LCVP caching supplies at Bridport Inlet, Melville Island.



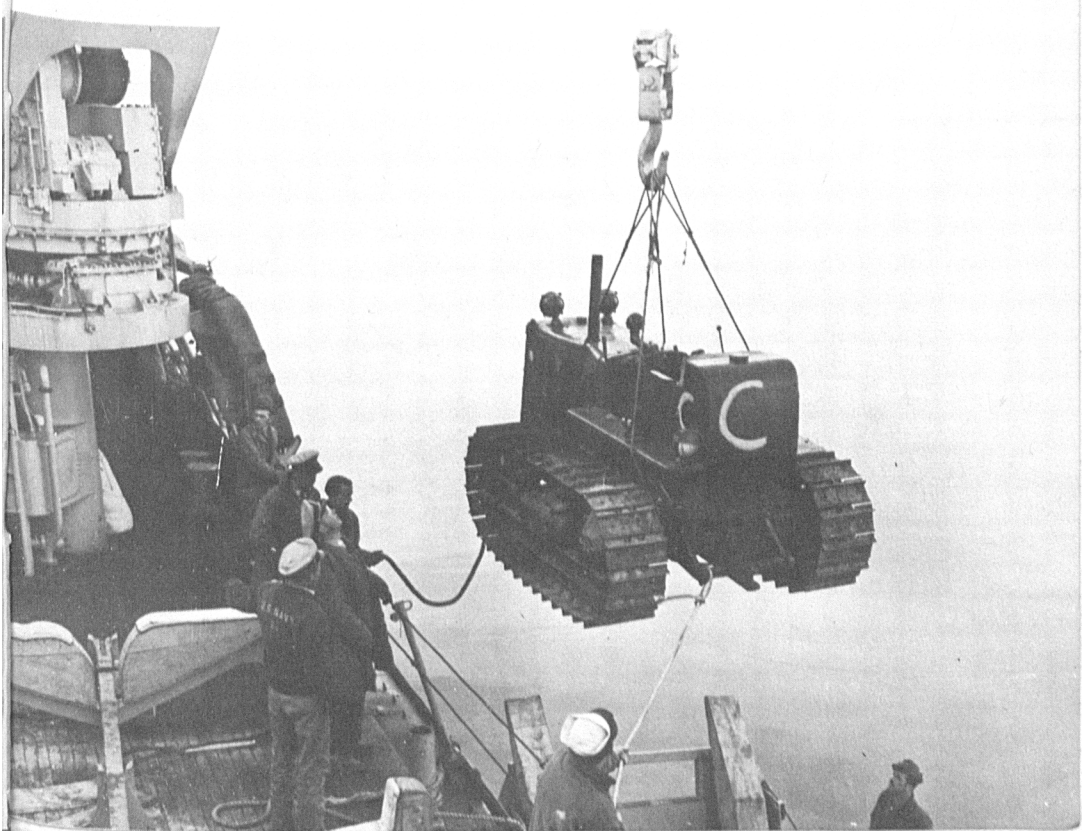
(Above) Figure 2–16.—Loading oil drums in hold of AKA for arctic resupply expedition.
(Below) Figure 2–17.—Palletized cargo should be securely strapped.



(Above) Figure 2–18.—Offloading on the ice.
(Below) Figure 2–19.—Beachhead scene in the Antarctic

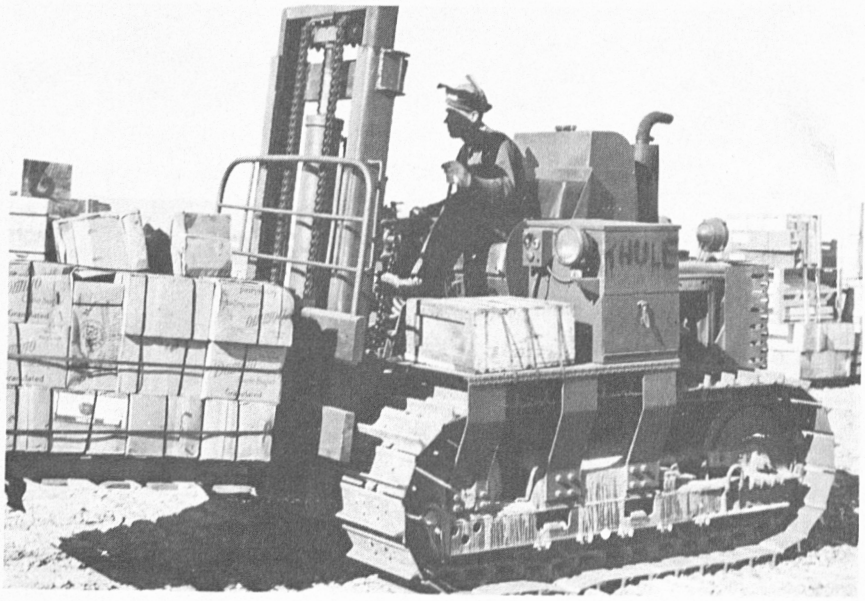
(Above) Figure 2–20.—Leaving the beachhead.
(Below) Figure 2–21.—Increased bearing surface.

(Above) Figure 2–22.—Loading an LCM.
(Below) Figure 2–23.—Tractor away.

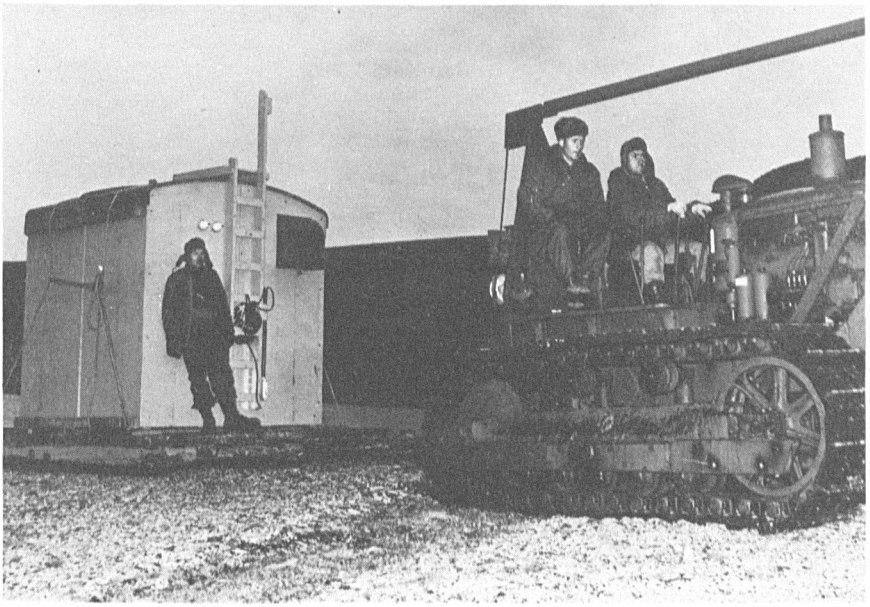


(Above) Figure 2–24.—A cold, wet job.
(Below) Figure 2–25.—Landing aviation gasoline.

(Above) Figure 2–26.—Beachhead scene in the Arctic.
(Below) Figure 2–27.—Transferring cargo to sleds.



(Above) Figure 2–28.—Forklifts are used frequently.
(Below) Figure 2–29.—Spotting a skid.



(Above) Figure 2–30.—Tractors are indispensable.
(Below) Figure 2–31.—General beachhead scene.

(Above) Figure 2–32.—Strong backs are necessary too.
(Below) Figure 2–33.—Sleds are sometimes loaded aboard ship.

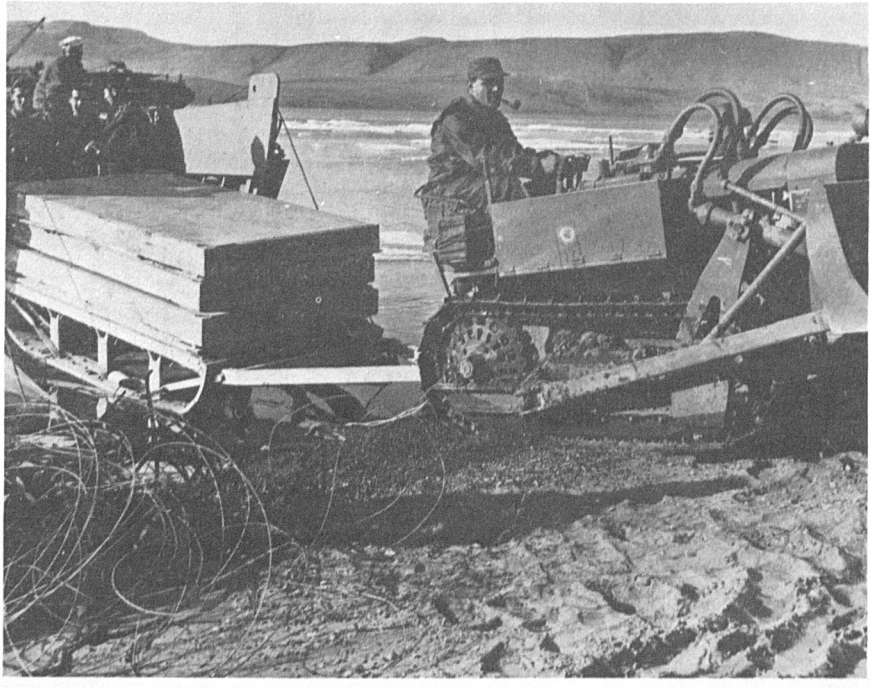


Figure 2-34.—Beachhead scene in the Arctic.

ice. The strength, size, and form of the separate cakes of ice have a definite bearing on the design of a ship required to navigate in ice and to open lanes in frozen waters for commercial or naval ships. The strength of ice appears to vary from a possible compressive strength of 3,000 pounds per square inch and a tensile strength of 250 pounds per square inch for clear, cold solid ice, to nearly zero for slush.

Sea ice found in the waters around Greenland is probably the most heterogeneous of any found in the world. It is made up of glacial ice from the ice cap, winter ice from countless fiords, and storis from the overflow of the Arctic Sea. Glacial ice is usually of such great thickness that it cannot be broken. Similarly grounded ice fields have been reported in waters of 20 fathoms which would be beyond any possibility of breaking. Such fields must be navigated by following open leads or by forcing an opening between individual floes. However, these enormous masses of ice must be considered when they are free to move, and the strength and shape of the icebreaker must be such that the ship can survive or extricate itself if caught in a lead closing under the influence of wind or other effects.

In operating in pack ice it is necessary to take advantage of open leads where they exist along the track or by forming temporary leads by moving floes apart under thrust of a powerful and strongly constructed polar ship. All such leads are necessarily tortuous. Consequently, an icebreaker must be designed with shortest possible length and greatest maneuverability attainable. The beam of the icebreaker must be sufficiently wide to permit

large, unprotected ships to follow in convoy behind it. A machinery plant capable of remote control from conning stations is requisite. Due to remoteness of duty stations and the possibility of wintering over, the plant must be economical in fuel consumption and must have fuel capacity for long periods of full power operation and immobilization. These requirements dictate the choice of Diesel-electric machinery.

The war emergency indicated the possible need for the construction of advance designs of icebreakers capable of operating in any and all the seas of the polar regions. The outstandingly successful Swedish icebreaker *Ymer* served as the prototype for the *Northwind* class developed in the United States. The *Ymer* was reported to be capable of breaking 5-foot solid ice at speed of 5 knots and of opening leads in heavy polar ice over 10 feet thick by backing and ramming while attaining a speed of advance of 1 to 2 knots.

The technique of breaking ice depends upon a personal factor along with design capability. The operations of our Navy and Coast Guard icebreakers of the *Northwind* type have been eminently satisfactory. Our experience has been that naval operations in the high latitudes are being annually extended to sea areas heretofore considered unnavigable by any type of ship.

Remember that these icebreakers, with all their strength and power, can suffer damage to hull, propellers, and rudder like other ships. Therefore the same general principles of safeguarding propellers and rudder apply. In particular, caution must be exercised while working heavy pack in shoal water.

To summarize, the foregoing characteristics along with many special features of ship construction combine to make the *Northwind* class of icebreakers one of the most effective types of icebreaking ships yet developed in any country. The design has been proven during operations around Antarctica, around Greenland, and in the Northwest Passage. In short, these ships can negotiate any broken pack ice with relative ease and can traverse the heaviest type of unbroken ice up to 10 feet thick. It is the general consensus and experience from various operations that the heeling system is not truly effective, due to long heeling cycle (one complete roll). This class of ship rolls heavily in the open sea and this presents a real problem. Equipment must be fixed or lashed securely. Steps must be taken to relieve motion sickness of personnel. During storms in winter months, the topside will ice rapidly.

TABLE IV

Characteristics of Comparable Ice Breakers

Characteristic	Swedish *Ymer*	U. S. S. R. *J. Stalin*	U. S. C. G. C. *Northwind*
Year built	1932	1937	1944.
Place built	Malmo	Leningrad	San Pedro.
Length overall	258	350	269.
Waterline length	246	335	250.
Waterline beam	61	74	62.
Depth, molded to weather deck	33	30	37.6.
Normal draft	21	26	26.
Maximum draft		29.7	29.
Normal displacement (tons)	3,465	9,300	5,300.
Maximum displacement (tons)	4,350	11,000	6,900.
Stem angle to waterline	25°	30°	30°.
Complement	42	142	145.
Speed, knots	15	15	16.
Propelling machinery	Diesel electric	Steam reciprocating.	Diesel electric.
Number shafts	3	3	3.
Number shafts, forward	1		1.
Number shafts, aft	2		2.
SHP after engines, normal	6,000	10,000	6,700–10,000.
RPM normal operation	140	125	105–145.
Thickness ice belt plating	1	1	1⅝.
Frame spacing	24"	21"	16".
Type of steel, hull plating	Medium carbon	Medium carbon	High tensile.
Propellers	Steel	Steel	Steel-built up type.
Cruising radius			30,000 miles at 12 knots.

NOTE.—*Dimensions in Feet Unless Stated Otherwise.*

TACTICAL EMPLOYMENT

Consult HO551 for recommended practice in the tactical employment of icebreakers. Remember the versatility of these ships with the assistance of helicopters and other aircraft serving as eyes of the ship. The following paragraphs have been taken almost verbatim from the *Report of Operation Highjump* and other reports which will serve briefly to introduce the subject of this section.

At all times during the transit of the antarctic pack the escorted ships (2 AKA, 1 AGC) were deployed in column with an icebreaker at the head. When two icebreakers were available and exercised command, one selected the leads and courses while the other attempted to straighten out all the curves and bends in the leader's path. If one of the ships of the convoy got stuck, due to inability to stay in the channel or due to collision with countermingling floes or cakes, the second icebreaker (when available) would im-

mediately proceed to break it out. The remainder of the convoy would proceed at slow speed, following the leading icebreaker, provided the first escorted ship was not the one involved.

It is important to emphasize the necessity for the leading icebreaker to break as straight a path through the ice as possible. If the broken ice channel has devious curves and zigzags in it, the larger ships astern will be unable to follow such a path without a great amount of backing and filling. In time, they will suffer damage by colliding with cakes of solid ice on either side of the relatively narrow channel, cause confusion to the ships astern, and probably cause them to back down hard, thus endangering their propellers and running the risk of ramming the ship ahead. The final result will be that one or more of the ships will become stuck, it will be a hard job for the icebreaker to free them, and invariably there will be a long delay for the convoy.

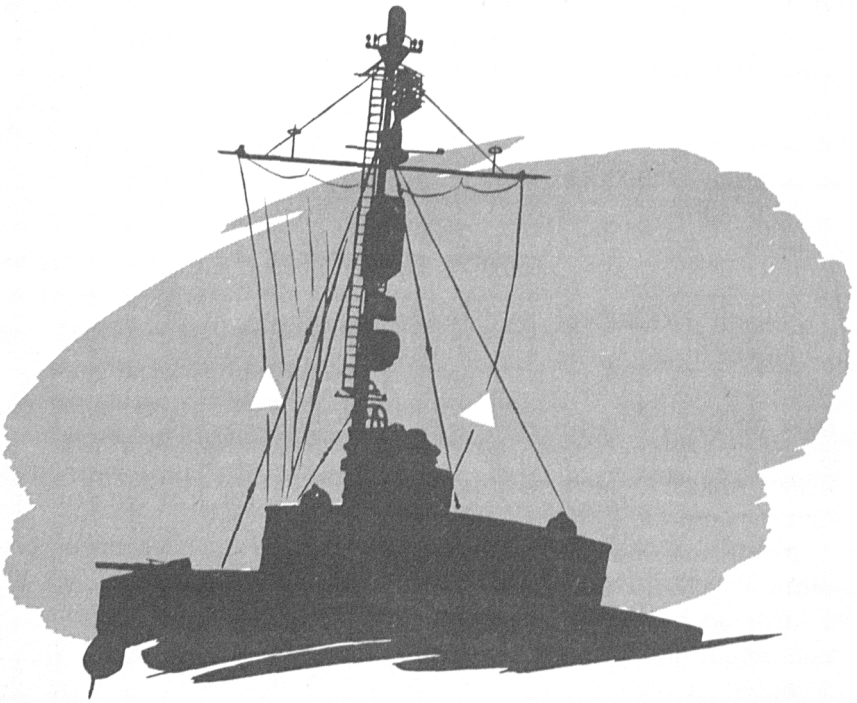


Figure 2–35.—Convoy speeds are normally controlled by speed cones aboard ice breakers.

SPEED THROUGH PACK ICE

Speed through pack ice depends on the character of the ice. It may be from dead slow in close or consolidated pack to 7 or 8 knots in drift ice or scattered rotten pack. On the average, speeds from 3 to 6 knots are employed except for periods of temporary besetment or of the necessarily slow and cautious movement in the heaviest pack. Normally the speed in an ice convoy is controlled by a speed cone from the icebreaker. The cone does not indicate the speed of the latter, but denotes the speed at which it is desired that the ships in the column steam. Speed of the convoy has to be closely controlled by the leading icebreaker, taking into account ice conditions ahead and the ability of the icebreaker to open up leads and maintain a straight—or reasonably straight—channel.

There is constant danger of collision between ships in column, particularly if ice resistance suddenly becomes heavy and following ships overrun, due to excess speed and their inability to kill their way where standard distance is small, as it must necessarily be in most cases. Under certain conditions, particularly in very heavy ice, it is sometimes more practicable for the leading unprotected ship to regulate the speed of the convoy.

It is mandatory that the ships of the convoy keep closed up. Standard distance will vary. Generally 3 or 4 ship lengths or a maximum of 400 yards will be satisfactory. When this distance is not maintained, the convoy will become unwieldy and invariably a stoppage will occur. This is true in areas of pressure ice or in event of cross winds. Remember that channels in pack ice close quickly, causing escorted ships to become scattered or stuck.

The *ice commodore* or officer in tactical command, who should be on the leading icebreaker, must carefully take into account ice conditions along the track. These are judged from reports of observations received from the crow's nest, helicopters, and long range reconnaissance aircraft. He should endeavor to select a generally straight track that will clear all heavy ice fields, hummocky pack, pressure ice, and bergs, floating in the pack. When stretches of heavy ice can not be avoided, he must maneuver the icebreaker so as to maintain course and avert glancing to one side or the other of the track. It is essential that the conner of the icebreaker station himself so that the wake of his ship is constantly in sight. Anticipation and forethought will do much to

allay difficulties. An icebreaker can charge through at high speed glancing from floe to floe without difficulty or damage, but the unprotected ships of the convoy cannot—and must not attempt to do so.

MOVEMENT OF ICE

The final point to consider is movement of the ice itself. Under the influence of wind (especially storms) and current, pack ice often has lateral movement which is most difficult to detect. Often, but not always, it takes the approximate direction of the wind. A course for the convoy should be set parallel to the axis of ice movement or as close thereto as possible. This will minimize the action of the lateral ice movement toward closing up the clear water channel in the wake of the ice breaker. During high winds it can be expected that even a consolidated pack, except in relatively narrow basins or channels, will become a mass of scattered cakes, growlers, bergs, bergy bits all countermingling violently and moving at varying speeds in the general direction toward which the wind blows. The convoy commodore, under these circumstances, must maintain such speed as will permit good maneuverability of all the ships. This may mean a much higher speed over the ground than ordinarily advisable in navigation amongst ice. However, there is no alternative except heaving to.

An icebreaker convoy must work closely as a team and promptly acknowledge and execute all orders received. Visual signalling and the TBS should be used freely to control maneuvering and operations of the group, as well as to keep adjacent ships advised of all changes in speed. Keep 24-inch searchlights ready for station keeping in event fog suddenly sets in.

Upon receiving word that one of the escorted ships is stuck, the convoy immediately stops, as a general rule. The ships not concerned attempt to stay in a maneuverable area, clear of heavy ice, and to maintain relative position in column. This procedure allows the convoy to resume speed quickly when the icebreaker and freed ship return to their positions in column. The ice breaker approaches the stuck ship from well abaft the beam, passing her close aboard. The breaker then backs down on the ship, breaking the ice in front of and to either side of the bow. Sometimes it is unnecessary to back down upon the bows, breaking the ice on one side being sufficient to free the ship. The icebreaker then goes ahead full speed, giving the ship benefit of the propeller wash to

Figure 2–36.—Taking a AKA in tow in pack ice.

clear cakes immediately ahead of it. The stuck ship now comes ahead slowly and generally should be able to follow in the wake of the icebreaker. In this operation of breaking out a ship, both the icebreaker and ship in trouble watch their counters for heavy cakes of ice being drawn under and possibly damaging propellers.

Towing is also used in breaking out ships. It was not too successful in the Antarctic with heavy ships because their bows are too high for towing with the short scope of towing cable that is required. When towing in pack ice, use a bridle; when towing in the open sea use a long scope of cable attached to the anchor chain rather than to a bridle. Figures 2–36 to 2–40, inclusive, illustrate procedure of taking in tow a heavy ship while in pack ice.

Figure 2-37.—Taking an AKA in tow in pack ice.

Figure 2–38.—Taking an AKA in tow in pack ice.

Figure 2–39.—Taking a strain.

Figure 2–40.—Taking an AKA in tow in pack ice.

SCOUTING FOR LEADS

While it is possible to determine to some extent favorable courses and leads by conning from the crow's nest and looking for signs of "water sky," these methods, though still useful, have been outmoded by helicopters and long-range "recco" aircraft. Accurate determination of the character, thickness, and composition of pack ice from the air well along the track is not possible except by use of helicopters. However, the situation at destination and beyond helicopter range can be determined only by long-range aircraft.

Another valuable type of ice reconnaissance is undertaken by the icebreaker. The convoy is left in a big clearing, or in a safe area of pack ice. If left in a clearing, the ships nose into the ice on the windward side of the clearing and keep their propellers turning over slowly. The icebreaker then proceeds in the most likely direction to determine first-hand the character and composition of the ice. When a lead is found, the ice-breaker returns and re-forms the convoy and proceeds in the direction found to be the most promising during its reconnaissance.

SUBMARINE OPERATIONS

In 1931, north of Spitsbergen, Sir Hubert Wilkins, in the *Nautilus*, made the first attempt to dive a submarine under pack ice. The U.S.S. *Atule* (SS403), in July 1946, succeeded in penetrating 1,000 yards under an ice field in Kane Basin, but suffered a collision between submerged pinnacles of ice and the periscope shears. The U.S.S. *Sennet* (SS408) accompanied the task force to Antarctica for *Operation Highjump* and was successful in following the convoy through heavy pack ice for a distance of over 100 miles. Rather than risk the danger of extensive damage, the submarine was escorted out of the pack and continued cold weather operations to the north. During August 1947, the U.S.S. *Boarfish* (SS327) maneuvered under the ice in shallow Chukchi Sea, northwest of Point Barrow, for a total of 10 hours in 3 dives, or a distance of about 30 miles. The U.S.S. *Carp* (SS338) successfully made vertical dives and ascents in big clearings or polynyas of the same sea during September 1948. This ship penetrated over 50 miles of scattered pack ice to the southern limit of the consolidated polar pack at latitude 72°10′ N.

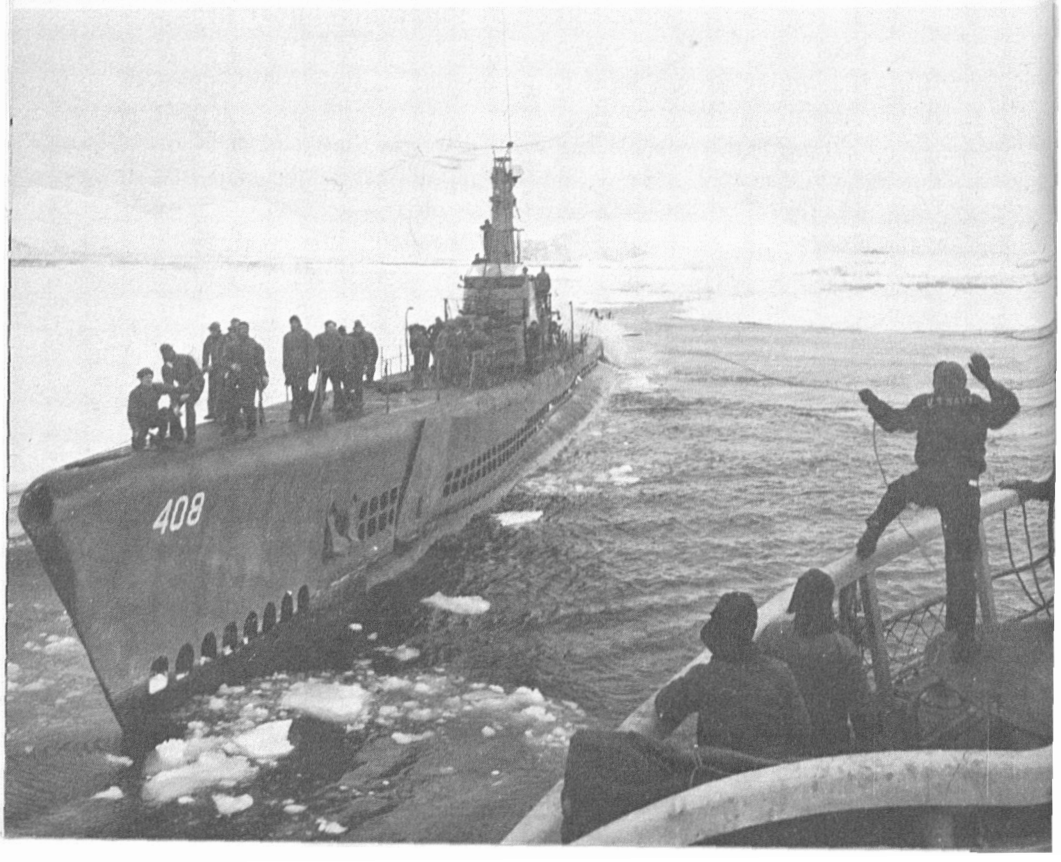
The foregoing are typical of exploratory submarine operations so far conducted in cold weather and arctic areas.

Many of the comments in other places in this handbook apply equally to submarines as to other classes of ships. Briefly set forth below are additional comments applying specifically to undersea operations. This information augments rather than supplants chapter 20 of USF 9—"Cold Weather Operations".

The Fathometer NK 7 and Scanning Sonar QLA-1 have been developed satisfactorily so that when used in conjunction they are capable of supplying information essential for short under-ice excursions and surfacings in scattered ice. The QLA-1 is capable of detecting small cakes of sea-ice from ranges of over 600 yards to its minimum performance range. It requires further improvement for extending its range.

In addition to development of improved sonar, there exist two major problems in operations of submarines in the high latitudes —namely, icing of hull and danger to rudder and propellers from collision with ice. One antidote to the former is periodic submergence to prevent building up of the ice, and to the latter, good seamanship and avoidance of areas of close or heavy pack ice.

Figure 2–41.—The sub Sennet in the Antarctic.



Conclusions that may be drawn from most recent operations of submarines in the high latitudes include:

1. Submarines can be readily adapted for polar operations and can *keep the sea* along the fringe of the polar pack as well as in areas of drift ice and scattered pack ice.
2. Extended under-ice navigation is practical with an efficient fathometer and scanning sonar.
3. Vertical dives and ascents can be made in open areas within pack ice.
4. Development of the trans-arctic submarine remains in the realm of fantasy.

DIVING AND SURFACING

A principal question in the study of under-ice navigation is the buoyancy control. Stationary dives and ascents are prerequisite for successful operations in ice areas. The study of this question was the purpose of the *Carp* patrol. The successful conclusion of the latter admits the practicability of submarine navigation in areas of the Arctic Sea. About 14 vertical dives and ascents were made by the *Carp*. The shiphandling was excellent and the diving procedure was well planned and executed. The water density

Figure 2–42.—Moving with caution.

structure, though complex, was fully recognized, and proper buoyancy changes were anticipated. The amount of sea room was small because of the ice overhead and the shallow bottom (140 feet).

Vertical dives and ascents were made by control of safety tank. Since this tank is centrally located, variations of its buoyancy did not disturb fore-and-aft trim. The venting of this tank produced a bubble screen which blanked out the sound gear. This difficulty can be prevented by inboard vents. The forward-aft trim was always very good, and it was interesting to note that second order shifts in trim were obtained by control of diving planes during ascents (e. g., forward planes thrown to extreme dive or rise to decrease surface normal to direction of motion). The procedure of stationary dives and ascents as concisely described by the commanding officer of the *Carp* is quoted below:

"Normal diving and surface procedure required revision while operating in the arctic ice-field as vertical ascents and descents were almost always mandatory. Diving procedure varied from that normally used, in that negative tank was only partially flooded (12,000 pounds) to prevent an excessive down angle. Submergence rate was controlled by the rate of blowing negative tank to its normal trim level of 6,000 pounds. In the case of the bubble, it was noticed by starting to blow safety slowly at 50 feet, the longitudinal stability was of sufficient force to prevent seesawing and the bubble could be controlled if the fore-and-aft trim was within limits of 1,000 pounds. At times a small bubble in safety tank was required to stop the descent so as to obtain a trim at the ordered depth. For ascending vertically, enough water was blown from safety tank to obtain a positive buoyancy of about 4,000 pounds. Since there was no means for blowing exact amounts from safety tank it was often necessary to reduce the rate of ascent by partially venting safety tank. The bubble was controlled by using the planes to increase or reduce the resistance to ascent on either the bow or the stern, as appropriate. The more rapid the rate of ascent, the more effective was this method of control of the bubble. The point at which safety was vented in order to stop at the desired depth depended upon the rate of ascent and depth of layer present. In ascending into layers of different density than the one in which the hovering trim had been obtained, while on the way up, enough water was pumped from or flooded into auxiliaries to give about 3,000 pounds negative buoyancy at the new depth. As soon as the rate of ascent was checked, this excess water was removed and a hovering trim was attained. The chief disadvantage in using safety tank was the necessary venting which blanked out the sonar gear. The time of venting safety and the time of needing information on the ice disposition nearly always coincided. A large inboard vent on safety tank or a small amidship tank of about 10,000 pounds located at the center of buoyancy which could be blown or vented inboard or in which the amount of water could be varied by a hydraulically operated water displacing piston would eliminate this condition by providing a more flexible means of depth control."

Procedure similar to that employed in mine fields has proven satisfactory for under-ice navigation. The commanding officer should remember the under surface of arctic pack is irregular and pinnacles of floes and ice fields may extend to depths of more than 100 feet.

The following is an almost verbatim report of the commanding officer, U.S.S. *Sennet,* made as a result of his experience in ship handling in the antarctic pack:

"Handling a submarine in an ice pack was an entirely new and different experience for everyone on board. Prior to the patrol, all available printed material on handling a ship in ice was studied. The best source of information seemed to be the translation of the Russian 'Instructions for Handling a Ship in Ice' (refer to Pilot Chart SA March, April, May 1947).

"In the following discussion it will be presupposed that a submarine will be operating in an area of growlers, brash ice, bergy bits, icebergs, and scattered pack ice without the aid of an icebreaker.

"The very first requisite of the embryonic ice pilot is to develop a healthy respect for the tremendous power of the ice. Never allow the peaceful appearance of an ice field to cause you to overestimate the safety and watertight integrity of the boat. On the other hand, do not fear the ice. A great deal of progress into ice can be made by a submarine capably handled.

"First of all, never hit a piece of ice, however small, which can be avoided—regardless of the amount of maneuvering necessary to miss it. It is necessary that well qualified men be stationed in the maneuvering room and at the helm when operating in an area in which more than brash ice and occasional growlers are encountered. The speed at which bells are answered or the rudder put over quite frequently determines whether ice is hit or avoided.

"The trim of the boat is another important consideration when operating in ice. Here the submarine has an advantage over all other types of ships. In pack, with ice extending more than 3 feet below the surface, it is recommended that the stern be trimmed down so that the propeller guards are at least a foot and a half below the surface of the water. This depth is necessary because the pack is indented at the waterline, sometimes as much as 5 feet. The purpose of the flooding down is to protect the propellers from damage by pushing the heavy pack clear of the screws. With the submarine trimmed in this manner, the top blades of the propellers are 10 feet below the surface of the water. It was found during the *Sennet* patrol that, except in close, heavy pack, 200 turns ahead and 133 turns astern could be made without damage to the propellers.

"It is presumed, of course, that a submarine which is to operate in pack ice will have propeller guards, even in wartime. It is also recommended that an additional brace be installed on the propeller guards from the forward outboard corner to a point about 10 feet forward on the hull. This additional brace is deemed necessary, not to give added strength to the present guards, which are considered sufficiently strong, but to streamline them and to prevent ice jams forward of the guards. In the latter case, it is possible that a small cake may duck under the guards and hit the propellers.

"The statement that the present guards are of sufficient strength is made in spite of the fact that the forward horizontal braces of both guards were bent considerably while the *Sennet* was being towed in heavy pack by the ice-breaker. The damage occurred when the boat's stern swung into a heavy floe at a speed that would have been inadvisable under her own power in such a pack. The present guards are considered strong enough to fend the boat off any flow with which she might collide at reasonable speeds. It is desired also to point out at this time that the present guards afforded adequate protection to the propellers while the ship was under its own power. The major damage to the propellers was done when the stern of the boat swung into heavy floes while the boat was being towed. From the above, it is evident that some of our major damage occurred while we were under tow; but, after having been nipped in the ice, it was the opinion of all hands that the most beautiful sight in the world at the time was the rear end of the Coast Guard Cutter *Northwind.*

"The propellers were nicked in several places, and their blades were bent. This damage was due, most probably, to small pieces of ice sliding below the propeller guards and hitting the "soft" bronze blades. To prevent similar damage, it is recommended that submarines designated for operations in pack ice be fitted with steel propellers, where practicable.

"Another reason for trimming the boat down by the stern was to raise the bow as high as possible, giving it more rake from the waterline to the keel. This condition made it possible to ride up on, instead of boring into, floes projecting not more than 3 feet above the water. The amount of punishment from the ice that the bow could absorb without damage was amazing. When the boat had cleared the pack, there was no damage to the bow, as far as could be determined by visual inspection from a rubber boat, from the point 18 inches above the waterline to the keel. Torpedoes were fired later without difficulty from both the forward and after tube nests.

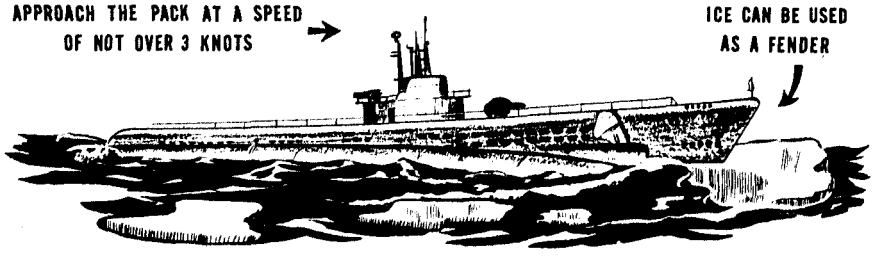


Figure 2–43.—Ice floes can be pushed ahead as a fender.

"A very minor point, but one which would undoubtedly be used to advantage many times in pack ice, is that a collection of small bits of ice around the propeller guards may be cleared very quickly by reversing the propellers.

"Always, when in a narrow lead, and especially when passing through a lead in a pressure ridge, keep way on the boat even at the expense of charging small floes. Once the boat is dead in the water, the ice will close in quickly and, before it is apparent, will nip the boat. It is particularly dangerous for a submarine to be caught in this manner in view of the fact that the ice will ride up over the tank tops, forcing the boat down. Although the *Sennet's* superstructure sustained several small casualties, such as rivets popping out, it is believed that the tanks and hull of a submarine will absorb a great deal of pressure before being damaged.

"When there is a choice of courses while proceeding through leads in relatively close pack ice, choose one as nearly as possible in the direction of the wind. This is recommended because it is believed that ice fields normally move in a direction 20 degrees to the left of the wind in the Antarctic and 20 degrees to the right of the wind in the Arctic. However, because of their small sail area, submarines do not find the problem of crosswinds as serious as do other types of ships.

"The submarine's maneuverability is also an advantage. By twisting, the submarine can easily execute the many turns required to conform to the leads in the pack.

"Should it become necessary to navigate through close pack made up of small floes, with the boat trimmed down by the stern, approach the pack at a speed of not over 3 knots. Use the rudder and engines freely to take the floes just off the stern. Stop engines after the boat has ridden up on a large floe and wait for it to break through. If the ice is too tough to be broken, go ahead slowly, pushing the floe ahead of the ship. Most of the time the floe will slide off to the side, but occasionally it will stay ahead of the ship for a considerable distance, acting as a fender for the entire ship.

"In conclusion, it is believed definitely that a submarine can operate independently without fear of damage in pack ice of less density than close, heavy pack."

MATERIEL—GENERAL NOTE

Torpedo runs in open cold water areas can be expected to be straight, hot, and normal. Gun mounts, if properly maintained, should operate satisfactorily under the extreme conditions that a submarine would encounter. Satisfactory performance of sonar and radar can be expected. In time, further improvements of the devices will enhance safety of navigation amongst scattered pack ice and under consolidated polar pack for short excursions if the tactical situation should require. Probably one of the most difficult materiel problems is control of condensation within the boat. Due to low sea water injection temperatures down to 28° F., it likely will be necessary to restrict flow of water to air conditioning heat exchangers to minimum safe extent.

COLD WEATHER BILL

The commanding officer should prepare a special cold weather bill to cover the general procedure that he desires be followed in accomplishing the mission assigned for operations in the Arctic. The following bill used by the *Carp* is suggested as a guide:

1. Sanitary tanks were blown and vented outboard once each watch.

2. All topside sonar and radar gear was worked out once each hour.

3. The low pressure blower was run at 2-hour intervals. During the blow-up, the main vents were cracked in succession.

4. Periscopes were stowed in a slightly raised position with their bearing surfaces just extending above the tops of the shears.

5. Both air conditioning plants were run continuously.

6. When possible, the main induction system was tested at 2-hour intervals.

7. Engines were drained when it was expected that they would be idle for more than 24 hours.

8. All engines were run for at least 15 minutes out of each 4-hour watch.

9. Before starting an engine, it was rolled for a full 3 minutes (with standby flushing oil).

10. A constant flow of compensating water was maintained at all times.

11. The conning tower hatch was checked and worked out once each hour.

TRAINING

Prior to departure from base for a polar expedition, training essential to successful accomplishment of the mission and the various assigned tasks should be planned and conducted.

The training should ensure smooth, continuous, and controlled rate of discharge of cargo at destination. Dangers inherent in cargo handling on shipboard and on the beaches should be stressed. All hands should be instructed in safety precautions and should be trained not to strive for speed or record breaking. Stress close supervision, precision, and careful handling of all materials and equipment. A rehearsal using dummy cargo should be conducted if time permits.

Personnel should be trained in the operation, winterization and handling of small craft, LVT's, weasels, weight lifting equipment and ship's cargo handling equipment.

A short refresher course in polar navigation for quartermasters and navigating officers should be scheduled during the loading phase or while en route to the area of operations. Officers of the deck, boat coxswains, and others should be instructed in ice seamanship and as many as possible should read and study *Manual of Ice Seamanship*, (HO 551). Boat crews, beachmaster unit, beach party, Seabee, and engineer detachments should be schooled in voice procedure and in the operation and care of portable radio equipments.

Personnel of the force who will be expected to assist with scientific projects or ice observations should be completely briefed as to their duties prior to arrival in the area.

En route to the area, all hands should be briefed on the operation and exercised in damage control, rescue operations, and emergency drills. Conduct flight operations with helicopters at every favorable opportunity.

Commandants of nearby naval districts should be advised well in advance as to available space for assignment of naval reservists desirous of cold weather and arctic training.

In case of submarine operations, the following training while en route to the area is recommended: 3 section dives daily with 1 deep submergence to obtain bathythermograph data; 1 surface and 1 submerged emergency drill daily; casualty and steering drills at unannounced times each watch; school-of-the-boat training program for indoctrination of all personnel in the particular operation. After arrival in the area, several vertical ascents should be conducted and a satisfactory procedure for diving and surfacing in restricted areas evolved. Training of operators in use of QLS sonar in scattered ice areas should be undertaken prior to attempting under-ice navigation.

MISCELLANEOUS AIDS

Mechanical and electronic navigational aids in the arctic regions are sparse. Radar techniques in ice navigation are not sufficiently developed to be absolutely dependable. It must be fully appreciated that older methods in navigation—direct observation of ice conditions, use of hand lead, caution during fog—are still the rule.

Data on work feasibility should be collected for areas of extreme

climate, both ashore and afloat, for guidance and for planning war operations in the high latitudes. From these data, work feasibility charts such as the one shown in chapter 8 of Part II can be prepared. A work feasibility chart is a plot for each month of the year, of data such as daylight hours, average ceiling, visibility, mean and extreme temperatures, average wind speed, and prevailing direction, range of wind chill factors, precipitation, ice situation, transportation, construction, water supply, and other factors that limit or influence the performance of work.

SUMMARY

Ship operations employing all types of naval craft can be conducted in various sea areas in the arctic and subarctic regions throughout the year.

By the use of modern, powerful icebreakers, the navigable season at many places can be extended.

Careful preparation and cautious seamanship are requisite to successful navigation amongst ice. Follow the rule of *safety first!*

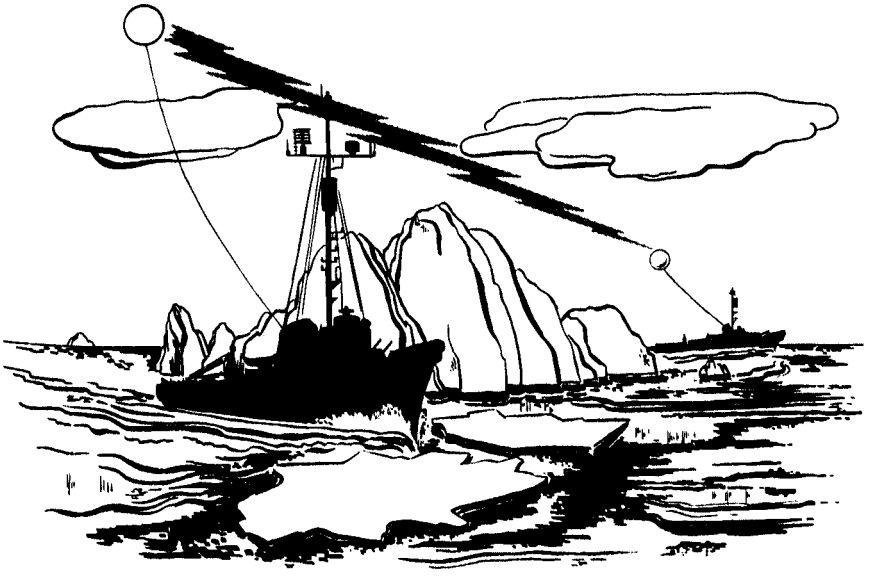
Accurate forecasts of weather are essential to the conduct of special operations in areas where strong winds are required for dispersal of pack ice to permit navigation even by icebreakers.

There are few differences between comparable operations conducted in the Arctic and in more temperate areas. Those that exist must be well known and steps taken to reduce the degree of the limitations imposed by them. The major problems are:

Protection of personnel against windchill.—Clothing must be warm, light, easy to put on and remove. It must permit freedom of movement. An efficient face mask to permit personnel to endure high winds at low temperatures is essential. Foot gear, hand gear and head gear must afford adequate protection to the extremities. An immersion suit which will ensure survival in event of abandon ship awaits development.

Prevention of formation of ice on flight deck, aircraft, ordnance, and other exposed equipment vital to the fighting efficiency.—There are two phases to the problem—retardation of formation and removal. The development of anti-icing and de-icing agents is required. The technique of using ice removal equipments is to be evolved during operations in the high latitudes.

Protection of hulls and fittings of ships against damage from ice as practicable.—"Remember, one has to be tireless to move a ship through ice."—Bartlett.



CHAPTER 3

COMMUNICATIONS

A large amount of the material published on high latitude communications is still controversial. Many anomalies exist and are not yet thoroughly understood. It should be realized, therefore, that the theories and practices outlined in this chapter should be considered only as an effort to acquaint the communication officer with some of the abnormal conditions which he may expect in the Arctic. Also included are some practices which have aided in overcoming these conditions and in maintaining rapid communications in these remote regions.

COMMUNICATION VAGARIES PECULIAR TO ARCTIC REGIONS

Abnormal conditions affecting radio communication in the Arctic likewise are encountered in the Antarctic. In general, the description of those conditions and suggested measures for maintaining reliable communications outlined in this chapter apply also to areas in the high southern latitudes.

Communication plans for operations in the Arctic will normally be the same as those used in temperate regions to cover similar

operations over equivalent distances. In the actual establishment and maintenance of communication circuits in some areas, however, arrangements must be made to provide for prevailing and possible rapid changing wave propagation characteristics not normally experienced in lower latitudes.

Much data on high latitude communication are incomplete and inconclusive. Some observations and conclusions are contradictory. From arctic research projects and past expeditions to the Arctic and Antarctic, it is certain that in some high northern and southern areas absorption of medium and high frequencies exceeding that at lower latitudes is present both day and night. Fadeouts on medium and high frequencies due to ionospheric disturbances are more frequent and remain for longer periods of time. High frequency propagation over long distances, even when normal conditions prevail, is, at times, extremely erratic, and usual practices for selection of optimum working frequencies are not always valid.

The shielding effects of mountains is particularly noticeable on all frequencies, and, in fiords or enclosed harbors, communication may be lost completely.

Transmission following the earth's magnetic field have greater range than those at right angles to it.

For example, in the Baffin Bay area and through the Northwest Passage to Melville Island, where the earth's magnetic field is heavily concentrated around the north magnetic polar area, one expedition found that in transmitting on a frequency of 4 MCS it was possible to work a distance of 1,200 miles while transmitting in the direction of the magnetic field. Using the same equipment and power, it was possible to work a distance of only 300 to 400 miles when the transmission path was at right angles to the field.

THE AURORAL ZONES

The northern auroral zone, so called because auroras are most frequently seen there, is a belt about 10° of latitude in width, located about 1,200 miles radially from a center near Etah, Greenland, at approximately 78°50′ N., 69° W. The belt passes very close to the whole north coast of Europe and Asia, dips down through Iceland and Alaska, and comes farthest south across Canada, through Iceland and Alaska, and comes farthest south across Canada, through Churchill on the Hudson Bay, at latitude 59° N. It should be noted that the auroral zone is about 24° farther north in Siberia than it is in Canada.

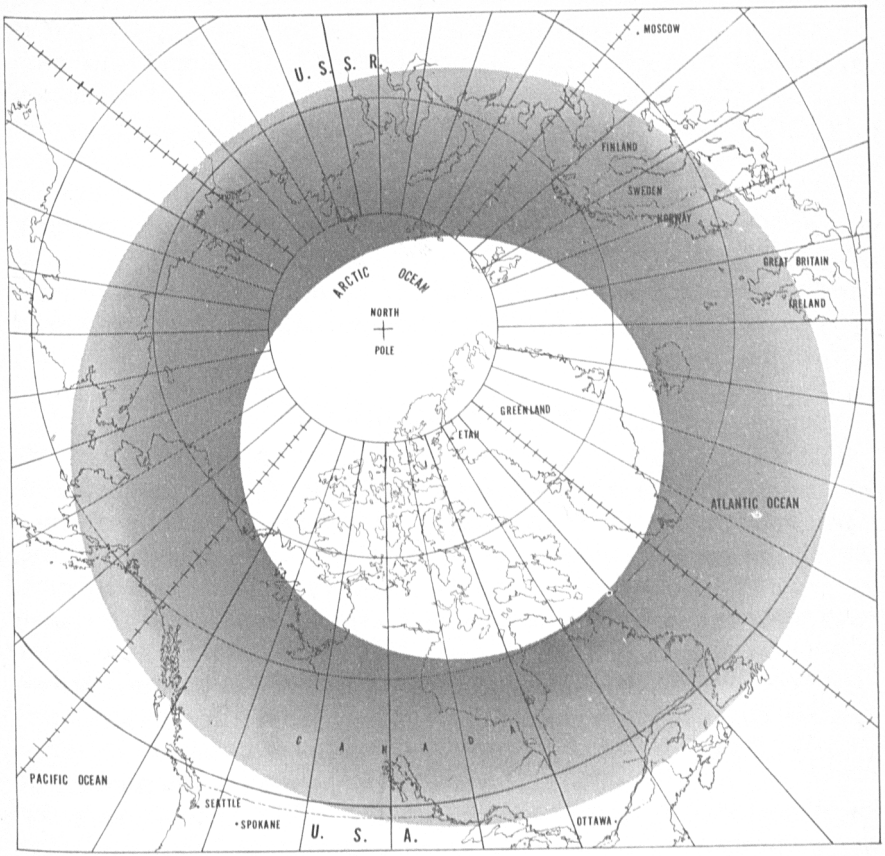


Figure 3–1.—The northern auroral zone.

A similar zone exists in the Antarctic, with its radial center around point 78°30′ S. and 111° E. but it passes south of uninhabited islands, extending farthest north to the south coast of Australia.

The earth's magnetic field, at distances well removed above the surface, is roughly that of a magnet at the earth's center oriented along the axis of the two auroral zones.

These zones are believed to be due to charged particles, possibly electrons, ejected from the sun. These particles, entering the earth's field, are deflected so that they tend to spiral down and around the lines of force, striking the ionosphere both night and day.

The visible effect of the particles striking the ionosphere is the

aurora, called Aurora Borealis in the northern hemisphere and Aurora Australis in the southern, and is seen directly overhead in the auroral zones. The frequency is such that auroras are seen nearly 100 percent of all clear, dark nights, and are maximum across the lower three-quarters of the belts. As one moves from the auroral zones toward either the geo-magnetic pole or toward the equator, auroras are seen less frequently.

During intense magnetic storms the auroras shift to lower latitudes, and with them shift the characteristic magnetic disturbances.

IONOSPHERIC DISTURBANCES

The most striking of anomalous ionospheric phenomena are ionospheric storms that are in no way associated with the meteorological storms of the Troposphere, but derive their names from the similar erratic character of both. They are one aspect of the electro-magnetic disturbance to which the earth is subjected which have been known a long time as *magnetic storms.*

When active solar areas develop into solar storms, there is an extra heavy bombardment of the ionosphere which produces great auroral displays accompanied by extreme instability of the ionospheric layers.

These storms result in disturbances of the earth's magnetic field which last from several hours to several days, during which the magnetic field fluctuates over much wider limits than normally. These fluctuations are not only marked by their magnitude, but also by their irregularity. Many storms begin with a sudden start which is within a few seconds of being simultaneous all over the earth. During the next few hours the horizontal component of the earth's magnetism remains above normal. This is called the *initial* or *positive* phase of the storm. Then the horizontal force drops rapidly to well below a normal value. This is called the *main* or *negative* phase. Recovery continues for the next few days in what is known as the post-perturbation periods. The most violent and erratic changes occur in shifting from the positive to the negative phase. The field changes are such as might be compared roughly to a ring current circling the earth at a distance of several thousand kilometres above the surface, flowing first in one direction (*positive*) and then in the other (*negative*).

While the effects of severe storms on communications are felt in all latitudes, the most erratic changes take place, and last longer, in the auroral zones.

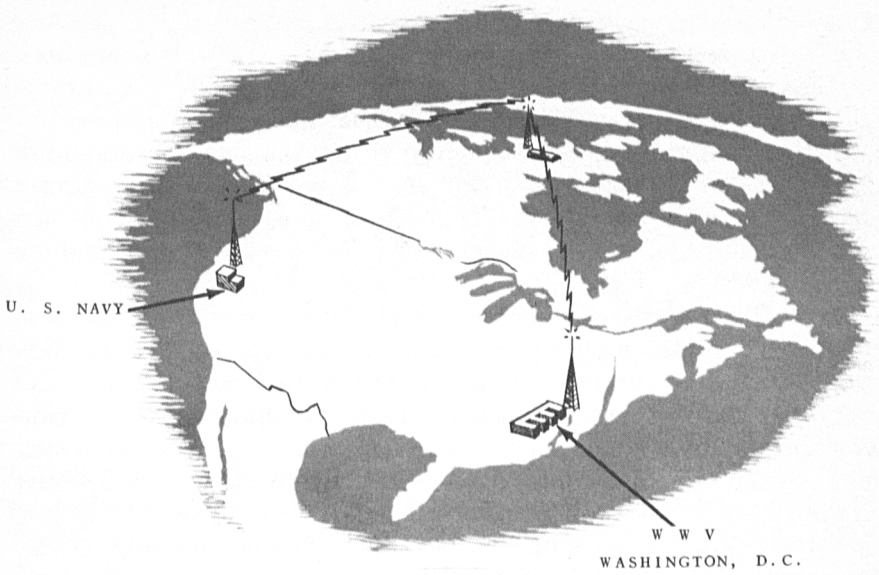


Figure 3–2.—Magnetic storm warnings are broadcast by Station WWV and by major United States Navy radio stations.

The close relationship between magnetic storms and sunspots has been very well established. A tendency of the storms to recur at about 27-day intervals has also been established, as has the fact that magnetic storms occur in about 50 percent of the cases within a day or two of the time when an active sunspot group passes the center meridian of the sun.

These principles furnish the basis for prediction of ionospheric storms, and because during the early phases of some storms communications are not greatly affected, it is sometimes possible to warn radio operators several hours in advance as to when the disturbances are likely to occur, although the intensity and duration of the storms cannot be predicted.

Warnings are broadcast by Station WWV, Bureau of Standards, Washington D. C. in connection with time signal broadcasts and by major U. S. Navy radio stations. Arrangements should be made to copy these broadcasts or receive the information otherwise while operating in the Arctic.

EFFECTS OF IONOSPHERIC DISTURBANCES ON COMMUNICATIONS

The effects of an ionospheric storm on high frequency communication is manifest somewhat as follows:

First, flutter fading becomes extreme and the maximum usable frequency decreases. The turbulence produces erratic propaga-

tion deviation from the normal great circle paths, which may cause wide diversion in direction finder bearings. In a few minutes, as the disturbance penetrates the lower ionospheric levels, absorption increases sharply, blacking out higher and higher frequencies. As the maximum usable frequency drops, the lower useful high frequency rises, with the result that the entire band of useful frequencies may disappear. This condition of black-out may last a few minutes, a day, or several days, and may seriously disturb world communication systems, both wire and radio.

Instances have been recorded in the auroral zone of loss of communication on the higher frequencies for a period of 2 weeks, during which time the only signals heard were local, and low and very low frequency transmissions from Washington, San Francisco, Honolulu, and Halifax. Recovery to normal conditions may be fastest on the lower high frequencies, but black-outs on medium frequencies below 2 MCS may last for several days. At times, however, frequencies much higher than customarily useful may be useful during initial recovery.

Propagation on frequencies below 200 KCS may actually improve during black-outs. This is attributed to the fact that during the auroral storms the density of the lowest ionospheric layer is greatly increased. While this layer acts as an absorbant for the higher frequencies, it becomes a very good reflector for the lower frequencies, so that in effect, a wave guide is formed between the layer and the earth which aids in extending the range of low frequency transmissions.

As an ionospheric storm develops, there is an actual shift of the entire auroral belt toward the equator. Consequently, in a severe storm communications may actually improve over paths on the polar side of the zone while they may be seriously interrupted as much as 20° from the latitude of maximum auroral activity. For this reason, transmission between North America and Europe, which follows great circle paths and is reflected by the ionosphere in high latitudes, is frequently disrupted by electro-magnetic storms. Frequently, communications can be maintained at such times by relaying traffic through low latitude stations which are less subject to disturbances.

MAINTAINING COMMUNICATIONS IN HIGH LATITUDES

Hard and fast rules for maintaining communications cannot be laid down: As in any latitude, thorough preparation, indoctrination, and ingenuity are the important factors. From ex-

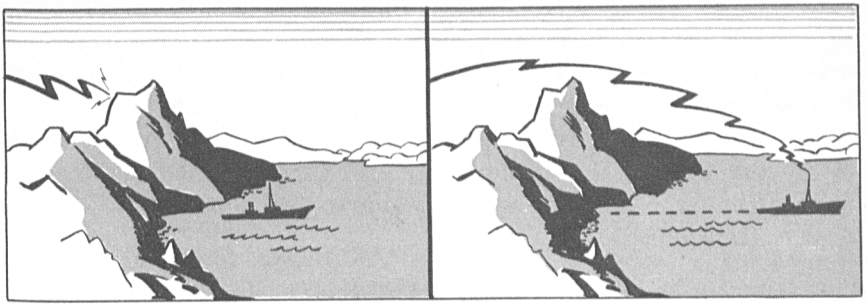


Figure 3–3.—Mountains, fiords, interfere with signal strength.

perience gained on several expeditions some observations, perhaps inconclusive, contained in communication reports herein collated should serve as a guide for assuring optimum continuity of communication.

Communication planning for high latitude operations should be based on consideration of the following known factors:

1. In the auroral zones, absorption of radio waves is normally high at night as well as in day, especially on the lower high frequencies, resulting in high lowest useful frequencies.

2. The zones are characterized by extreme variability, due to the frequency of ionospheric disturbances.

3. Any communication circuit which lies within the zone, or touches it at any point, is affected by the abnormal absorption and is susceptible to disruption during ionospheric storms.

4. During periods of these disturbances high frequency circuits, except for those within a few hundred miles radius, may, with little warning, blackout completely and remain so for periods of from a few minutes to several weeks, or be characterized by extreme instability during such periods.

5. Very low frequency transmissions (10–30 KCS) originating outside auroral zones are not appreciably affected at receiving points across or within the auroral zones.

6. Low frequency transmission on frequencies lower than 200 KCS appear to offer the best means of maintaining communication during black-out periods.

7. Long range high frequency circuits (1,500 to 3,000 miles) to points outside, even in *quiet* periods in the auroral zones, are at times very erratic, due to a rapidly varying effective frequency for the distance and direction involved.

8. The shielding effect of mountain ranges are particularly noticeable, and, in fiords or enclosed harbors, signal strength may decrease to such an extent as to necessitate the ship proceeding to open water in order to reestablish communication.

9. Some evidence exists that VHF/UHF ranges are extended in the auroral zones, both normally and during periods of disturbance, although reports of several naval expeditions do not support that contention.

PREPARATIONS

Before departure for high latitude operations, radio equipment in excess of normal type allowances, if required, should be installed, and all radio equipment thoroughly checked. Spare parts should be carefully inventoried and an additional stock of the most vital items obtained. Communication facilities for high latitude operation should certainly include a transmitter with a high frequency operating range of at least 26 MCS and another that will operate on frequencies as low as 175 or 195 KCS. Both transmitters should have substantial power capabilities.

ROB *Registered Publications* should be carried in sufficient supply to last for the length of possible stay in the Arctic.

Combined crypto systems for communication with friendly foreign governments should be included in the *Registered Publication* allowance on board.

Publications relating to high latitude communications not normally carried aboard United States naval ships should be obtained. (Some recommended publications are listed later in this chapter.)

All transmitters and receivers should be calibrated on the various frequencies which might be used in order to afford the most flexible operation possible.

To capitalize on the advantages of low frequency operation and very low frequency reception during black-out periods, antenna systems in addition to those installed probably will be required.

The standard shipboard low frequency transmitter required for high latitude operations usually covers down to 175 or 195 KCS, depending on the model. At the lower end of the range, the radiated power obtained may be very small, being somewhat in the order of 0.6 percent to 1.5 percent of the rated output power. This is caused by inability to properly load the antenna because of its small physical size. Radiation is further decreased by the necessarily short vertical section of the antenna, upon which radiation depends. Optimum radiation with current shipboard an-

tennas is usually realized at around 500 KCS, and effective radiation decreases as the operating frequency is decreased.

It has been found, too, in operating the low frequency transmitter at frequencies in its lower range at substantial power (1–2 KW), using standard shipboard antennas, that severe arc-overs and large losses in antenna trunks will be experienced.

That these important lower frequencies may be utilized during periods of ionospheric disturbances, procedures should be worked out for installing temporary transmitting antennas of the greatest length and height practicable. The possibility of paralleling or placing existing antennas in series should not be overlooked, nor should provisions for emergency use of a balloon suspension of long wire to obtain more effective antenna.

The Kytoon, which is a helium filled kite-balloon, has been evaluated by the Operational Development Force and recommended as a practical emergency system for suspending sufficient wire to permit greatly improved communications on low frequencies. Communication has been established between ships using the Kytoon, on 195 KCS, over distances across which it was impossible to communicate when using conventional shipboard antennas.

Sound communication planning, therefore, should include procurement of and familiarization with the technique of using Kytoon or comparable suspended antenna systems. Such alterations to antennas, trunks, and coupling devices as approved or recommended by the Bureau of Ships should be effected before sailing. Standard aeronautical balloons have been used for suspending antennas with some success where Kytoons were not available.

Operating personnel should be thoroughly familiarized with any emergency antenna system to be employed, and the capabilities and limitations of the system should be established by experimentation before its use is mandatory.

A list of all fixed radio stations in the general operating area, with their position, call signs, and working frequencies indicated, should be prepared and made available to operating personnel by posting in radio rooms and communication offices. Mobile stations in the area should be similarly listed and kept up to date. In the event of disruption of normal communications, relaying through such stations might provide the only means for clearing traffic.

Several alternate working frequencies with considerable spread in the spectrum should be designated, and definite arrangements made with working stations as soon as communication is established, to shift to various alternates at pre-arranged times, should

communication be lost on one frequency. During magnetic or ionospheric storms, frequent shifting of frequencies will be necessary. Therefore, operators should be thoroughly drilled in rapid tuning of transmitters and receivers, as well as in anticipating shifts by means of stand-by equipment.

In arctic operations, a considerable portion of communications may be with U. S. Air Force, U. S. Army, British, and Canadian stations, including aircraft of these services. Operating personnel should be thoroughly familiar with joint, combined, and commercial operating procedures.

In operations in and around mountainous regions VHF/UHF circuits with aircraft should be paralleled with higher medium frequency circuits, even on local flights.

On long distance circuits the practice of keying two or more transmitters simultaneously on widely divergent frequencies has been found to facilitate communications, and procedures should be worked out in advance for so doing.

Because of erratic propagation, it may be necessary for a flagship to operate two separate circuits to task group commanders, each on a different frequency with separate operators, whereas ordinarily in other regions a single circuit would suffice. This point should be taken into consideration when setting up personnel and equipment allowances.

PUBLICATIONS

In addition to the normal allowance of registered and non-registered publications carried, the publications listed below are considered indispensable for the efficient conduct of communications in high latitudes. They should be included in the library of ships operating in those areas. They are:

1. Berne List (corrected).
2. HO 205—U. S. Hydrographic Office—*Radio Aids to Navigation.*
3. Ionospheric Radio Propagation Circular 462—National Bureau of Standards, Washington, D. C.
4. Basic Radio Propagation—U. S. Navy—DNC 13–1 (—).
5. Equi-distant Chart of the World centered on the U. S. No. ZD-10 with bearing and distance.
6. Nomagram No. ZD10-N—U. S. Coast and Geodetic Survey, Washington, D. C.
7. U. S. Air Force Radio Facility Charts, North Pacific Area.
8. U. S. Air Force Radio Facility Chart, North Atlantic Area.

(These charts are published monthly and may be obtained directly from Commanding Officer, 1917th AACS Squadron, Westover Air Force Base, Mass.)

9. *AACS Communication Planning Chart No. 3, North Pacific Area.

10. *AACS Communication Planning Chart No. 6, North Atlantic Area.

11. *(May be obtained from Commander Military Air Transport Service, Andrews Air Base, Md.)

SUMMARY

High frequency transmissions are often completely blacked out in the polar regions. Very low frequency and low frequency circuits offer the best means of maintaining communication during periods of ionospheric disturbances. By development of a flexible communication plan and by provision of radio equipment covering the usable portions of the frequency spectrum, rapid communications can be maintained with a fair degree of reliability.

Reports of previous expeditions should be carefully studied by personnel charged with the various phases of communications prior to departure for a polar region. Every effort should be made to anticipate operational and material problems that most assuredly will arise.

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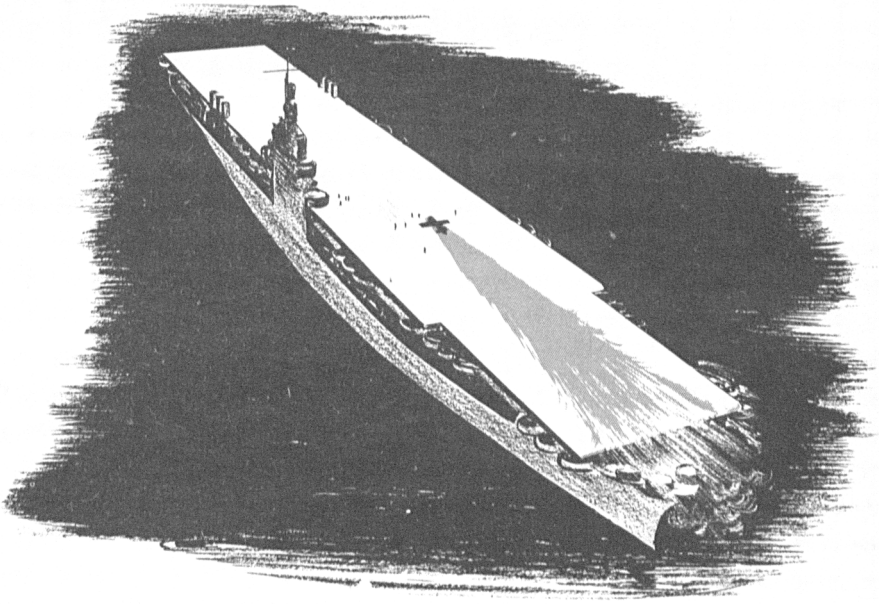

CHAPTER 4

CARE AND OPERATION BUREAU OF SHIPS MATERIAL

"Know every inch of the ship inside and out."—Peary.

Special climatic and other environmental conditions which will affect shipboard material and equipment during arctic and cold-weather operations may be broadly stated as follows:

1. Low surface air temperatures.
2. Sudden changes in air temperature.
3. High winds.
4. Low sea-water injection temperatures.
5. Low humidity.
6. Ice conditions varying from a mixture of slush and drift ice to solid pack.
7. Snow, sleet, or freezing rain.
8. Heavy seas with attendant spray.
9. Abnormal magnetic conditions.

Except that low humidity is a deterrent to corrosion, the general effect of the above conditions on the care and operation of ship-

board material and equipment is adverse. Operations under these conditions require careful planning, preparation, and the institution of suitable precautionary measures prior to and during the time spent in arctic and cold-weather areas.

The necessity for thorough preparation for such operations must be emphasized. Careful attention to all details, complete familiarity with the ship and her equipment, and painstaking inspection to ensure proper material condition prior to departure are essential. For satisfactory performance of the ship and ship's equipage, such material preparation must be coupled with good seamanship and expert ship handling, with due recognition of the limitations of the particular ship or ships involved, with due respect for the conditions of sea, ice, and weather to be encountered, and with the exercise of good judgment and sound engineering and maintenance practices at all times.

SHIPS EQUIPAGE AND MACHINERY

TOPSIDE OR EXPOSED MACHINERY AND EQUIPMENT

Deck machinery and topside or exposed electric motors or motors in unheated compartments along with their driven auxiliaries should be lubricated with suitable low-temperature lubricants in accordance with existing instructions for the particular equipment involved. In general, Navy Department Specification 14G10 grease is suitable for grease lubricated bearings and Universal Gear Lubricant, A2-105, Grade 80 oil should be used in gear casings. For other lubrication, where an oil is required, Navy Symbol (NS) 2135 is suitable for general use.

BuOrd specification 51F21 hydraulic fluid should be used in hydraulic power transmissions (variable delivery pumps and motors). Correct lubrication of the driven auxiliary is of the utmost importance, particularly when electrically driven, for no matter how well the motor itself is lubricated, the motor will be slow in coming up to speed if the driven auxiliary is stiff. The current taken by the motor will be large until the motor comes up to speed. Thus the conductors will be very rapidly heated by the current, which may be detrimental to the motor insulation.

Canvas covers provided for deck winches and similar appliances should be kept securely in place except when the equipment is in use or undergoing inspection, warm-up, or test. Under freezing or icing conditions, covers on essential equipment should be in-

Figure 4–1.—Keep winch covers securely in place.

spected frequently, any accumulated ice removed, and lashings or other securing devices freed-up to ensure that the equipment may be put into operation in the minimum time when needed.

Exposed machinery should be inspected daily, and more frequently under severe icing conditions. Other vital equipment not otherwise protected should be kept freed of accumulated ice insofar as practicable. Care should be taken to avoid damage to the equipment when removing ice. Prior to operation, a check should be made to ensure that there are no lumps of ice which may foul moving parts. When practicable, the equipment should be turned over by hand or jacked prior to operation by power.

It is also necessary to see that any ice formation is removed from certain structural or rigging parts prior to operation of the auxiliary. This applies especially to wire-rope sheaves and guides, trackway rollers and rotating portions of cranes. Steam deck machinery should be operated daily in extremely cold weather and, when conditions necessitate, essential steam capstans and winches may be kept ready for instant use by warming up and turning over at slow speed, taking care that they are not permitted to stop. Steam deck machinery should be given careful attention to prevent clogging with ice, and all condensed water should be drained out immediately after use.

For electric driven apparatus it is not considered advisable to start the motor and run the equipment simply for purposes of warming up or testing. The effect of a warm-up will soon disappear unless the warm-up is continued for a considerable period of time and repeated at frequent intervals. Unnecessary starting of the motor imposes a strain upon the insulation because of the expansion and contraction resulting from heating and cooling. Under emergency conditions, however, electric motors may be warmed-up and kept in operation as necessary and dictated by the circumstances prevailing at the time. A number of motor controllers in exposed locations, such as controllers for unit winches and boat davits, are provided with a heater inside the controller enclosure. Such controllers should be inspected daily to make sure that the heaters are operating.

Where the arrangements permit, space or unit heaters can be used to advantage in warming up hydraulic fluids and lubricants prior to operation. Hydraulic transmissions should be operated with pumps on zero stroke until the hydraulic oil has been at least partially warmed. Should freezing of the hydraulic fluid occur at low temperatures, the equipment will not run and attempts to operate the equipment may seriously damage the electric motor. If the starter button is pushed and the motor does not start to turn over, power should be turned off immediately and the condition of the fluid checked.

Figure 4–2.—Caution will prevent breath freezing telephone transmitters.

Some types of equipment, such as directors and anti-aircraft guns, receive electric power through flexible electric cables which may be exposed to low temperatures. Such equipment should be used to the minimum extent practicable when the temperature is below minus 10° F. When it must be used, every effort should be made to use the equipment in such a way as to twist or flex the cables to the minimum extent practicable.

In using telephones or microphones in exposed locations care should be exercised to prevent the talker's breath from freezing up the transmitter. Certain microphones in shipboard announcing system transmitter stations are or have been converted to the close talking or anti-feed back type. These microphones have smaller holes in the disc than do those not having this feature. If proper operation is prevented by ice formation in these small holes, the disc containing these holes should be removed and the amplifier gain reduced slightly to compensate. In general, the use of portable microphones supplied with the transmitter station in protected spaces is preferred to the use of the microphones in the exposed transmitter station.

Magnetic-minesweeping gear should be kept free of ice. Magnetic-minesweeping cable should be warmed by the best available means before being streamed. Magnetic-minesweeping operations in drift ice areas should be kept to the essential minimum and such care as practicable should be exercised to prevent the ice from cutting the magnetic cable. Motor driven acoustic-minesweeping gear when not in use should be given heated, inside stowage, if available. If such stowage is not available, deck stowage under canvas cover, heated by portable heater, is satisfactory. After streaming, the gear should remain in the water for 2 hours for temperature adjustment prior to operation.

PIPING SYSTEMS, TANKS AND RELATED EQUIPMENT

Main drainage pumps, electric submersible pumps and auxiliary pumps should be maintained in the optimum operating condition and should be tested at least weekly. Hose, and suction hose in particular, should be inspected periodically and maintained in good condition. Bilge well suctions should be inspected as practicable to ensure against clogging, fouling with debris, or freezing. Frequent instruction and drill should be held in the operation of the main drainage system. All overboard drainage and relief valve discharge lines that terminate above the water line should

be inspected daily, and more frequently as practicable and necessary, to insure that they are ice-free.

Fresh-water tanks should not be filled to over 90 percent capacity, to allow for expansion in the event of possible freezing. Potable water should be taken from forward tanks, such as peak tanks, first, due to the greater probability of leaks developing in these tanks from subsequent contacts with ice.

Any occasion for transferring fuel oil from one tank to another should be anticipated by an interval sufficient to permit adequate heating of the oil prior to such transfer. Fuel oil tanks should be kept warmed-up when operating under conditions or circumstances which may require fueling at sea on short notice. Oil filling and fuel oil transfer at sea should follow the standard practice outlined in USF 83. The average temperature requirement will be about 90° F. Steps should be taken to prevent formation of ice in transfer hoses.

FIRE FIGHTING EQUIPMENT

Special and detailed measures to be taken in connection with the firemain system in below-freezing temperatures will depend upon the arrangement of this system, and its relative complexity or simplicity, on the particular ship involved. Such measures as are taken should be carefully studied, and the modified procedures which are thereby required for the emergency use of the system should be rehearsed in fire fighting drills. In general, sections of the firemain which are exposed to the weather or run through unheated compartments should be completely drained and maintained in a dry condition when temperatures are below freezing. For ships on which the arrangements permit and warrant, secure firemain cut-out valves on firemain risers to weather decks and drain plugs at lowest point between riser and plug; leave weather-deck fire plugs in the open position when their risers have been drained and secured from below decks.

For ships having a more complex system, as aircraft carriers, the extent to which the above or other suitable measures can be taken will depend upon the detailed arrangements in any particular case. Fire hose and the locations in which they can be taken and nozzles should be stowed on racks and fittings provided and should be completely dry prior to such stowage. Nozzles should be stowed with shut-off gates in the open position. Cans of foam, proportioners, and P–500 and handy billy pumps should be stowed

in heated compartments with access as close as practicable to weather-deck location of probable use. Oxygen breathing apparatus, together with spare canisters, should likewise be stowed in heated compartments.

Fire hoses and nozzles will perform satisfactorily at freezing temperatures, and below, provided the 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 10° F., 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. Duplex proportioners should be drained after use, dismantled, dried, oiled, and the chamber change-over valves reassembled. Foam, P–500 and handy billy pumps, and oxygen breathing apparatus and spare canisters for same should be returned to below decks stowage as soon as no longer needed.

Portable gasoline engine driven fire pumps should be lubricated with cold weather lubricants, and should be given test runs of approximately one-half hour's duration at least twice weekly. When operating in below-freezing temperatures, a tarpaulin should be thrown over the pump to retain sufficient engine heat to prevent freezing of water in pressure gages and control piping.

RIGGING AND ANCHOR GEAR

The provisions of the *Bureau of Ships Manual,* chapter 17, sections 23 to 27, inclusive, and chapter 18, in regard to booms and rigging, are particularly pertinent in connection with the preparation for and conduct of cold weather operations. Due to the abnormal conditions, rough weather, and possible icing conditions under which rigging, boat-handling gear, and burtoning gear may be required to operate, these items should be placed and maintained in the best possible condition. Mooring lines should be kept dry by stowing below decks or under canvas. Rigging should be protected with a light grease coating and running rigging that can reasonably be covered should be provided with canvas covers. Essential rigging or rigging that may be required for emergency use should be kept as ice-free as practicable at all times with particular care to remove lumps or collection of ice that would foul or damage blocks or sheaves.

Should circumstances indicate a possible need for ground tackle, the anchor detail should be stationed well in advance, with time

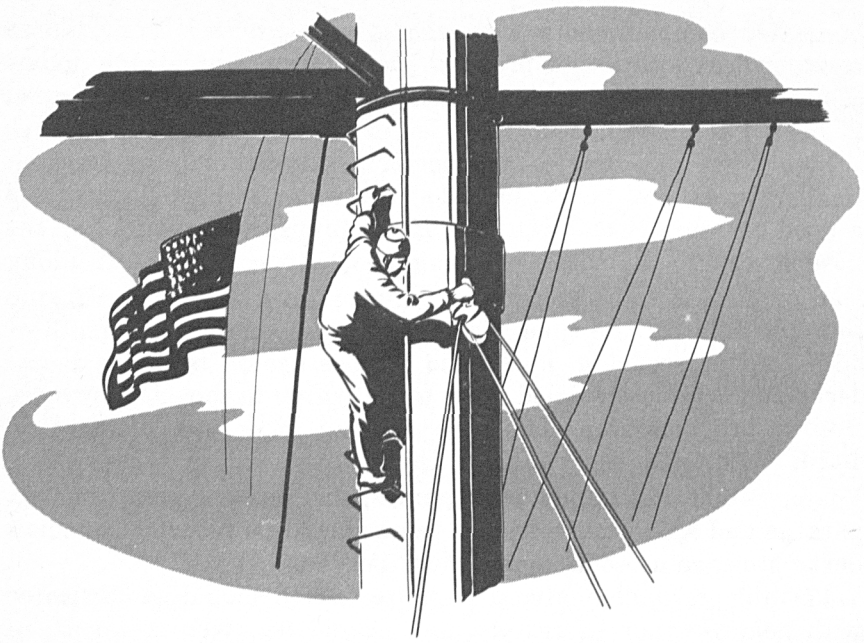

Figure 4–3.—A light grease covering will prevent icing.

to free the chain, stoppers, and wildcats of ice with mallets, scrapers, or other suitable tools. The anchor engine should be warmed up well in advance, and the chain worked back and forth to free the chain and hawse of ice and ensure that the anchor will let go upon release. When on soundings under icing or freezing conditions, a watch should be set and the anchor kept ready for instant use by such of the above measures as may be necessary.

BOATS

Boats should be hauled out and drained when not in use, and boat interiors, particularly bilges and engine compartment, kept as dry as practicable. Boat covers, where available, should be kept in place. Lacking better protection, the engine box should be covered with a small paulin under icing conditions.

Fresh water cooling systems should have antifreeze compound (glycol type, Navy Department Specification 51C39a) added to give protection against the lowest expected temperature. Salt water systems should be checked and, if necessary, petcocks installed at the low points to permit complete drainage of the sys-

tem. If the boat is equipped with a sand strainer, the strainer basket should be removed from one section and water taken through this section when temperatures are freezing or below. For prolonged operations in the Arctic, it may be advisable to remove the entire sandtrap and install as straight a run of pipe as practicable instead.

For ease in starting, artificial means of heating the engine should be used when temperatures fall below 20° F. Glow plugs, flame primers, and associated equipment must be kept in the best condition. Starters and generators should be checked and brushes renewed if worn. Batteries should be kept fully charged and specific gravity raised to 1.280 to increase output (refer *Bureau of Ships Manual,* chapter 62, section II, paragraph 267(4)). Engine and transmission oils in grades specified for arctic service should be used. Care must be taken to avoid grounds in the battery cables when the boat is not in use. If the boat is to be out of service for some time, it is advisable to disconnect the cables at the battery terminals and recharge the battery periodically to maintain it at peak capacity.

MACHINERY PLANT

Regulation of the cooling water temperatures requires special attention during cold weather operations. Since cooling water inlet temperatures may be greatly reduced, special care should be taken to provide cooling water at reduced rates or, if the ship is so equipped, to recirculate the hot discharge water to the inlet chest. Careful observation should be made for any incipient slush formation, and strainers should be cleared as practicable in order to keep the system in operating condition and prevent the cooling water lines from becoming sluggish and clogged with ice. If icing of condenser tube sheets occurs and restricts cooling water to an extent where operation is impaired, the steaming out connection on the inlet scoop should be used. Reducing the flow of inlet water and mixing steam may free the tube sheets of ice. However, caution should be observed against the excessive consumption of fresh water which continuous use of this process may entail.

Prior to starting up, lubricating oil in sump tanks should be heated to the recommended starting temperature or as near thereto as possible. Means are provided for heating this oil by the purifier heater, by steam connections on lubricating oil coolers, and by other means. When lubricating oil system is in operation, the

flow of water through the cooler should be controlled to keep the oil temperature within specified limits.

Normally machinery spaces will be manned and kept above freezing temperatures. If for any reason a space in which machinery or equipment is installed is secured and temperatures allowed to drop below freezing, water coolers and similar equipment should be completely drained or antifreeze solutions used.

VENTILATION AND HEATING

Ventilation heater controls should be adjusted to maintain space temperatures of 66°–69° F. in lieu of 72°–80° F. This will minimize the drying effect in living compartments since the relative humidity of the compartment air will be greater at the lower space temperatures than at the higher. It will also reduce the temperature differential for personnel going to and from topside or exposed locations. To avoid freezing of ventilation heaters, it is essential that condensate lines are kept open and that traps are at all times in proper operating condition. 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. Systems have been designed to give optimum conditions at low speed. Exhaust fans for washrooms and water closets, galleys, sculleries, and similar spaces should be kept running at all times for the proper removal of odors, fumes, and water vapor.

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 a part of each watch. This procedure is particularly recommended for large ships engaged in low temperature operations.

BATTERIES

Dry batteries to be used in equipment subjected to exposure to temperatures below 0° F. should be of the low temperature types designated in Specification JAN–B–18A under battery type numbers 2000 through 2999. Thus ordinary BA–38 batteries should be replaced by BA–2038 batteries. As the low temperature batteries are more expensive and do not have as good shelf life as the ordinary batteries, they should not be used except in the cir-

cumstances specified in the first sentence of this section. Present stocks are not large and orders should be placed through ESO Great Lakes as much in advance of need as possible. The low temperature batteries should be stored in a refrigerated space aboard ship.

Particular care must be exercised to keep all lead-acid storage batteries fully charged when operating under cold weather conditions. Articles 62–262(2), 62–267(4), 62–267(5), 62–269(1), 62–269(2) and 62–269(3) of the *Bureau of Ships Manual* pertain particularly to the handling, storage, and maintenance of storage batteries under cold weather conditions. Although article 62–269 deals specifically with carboys of acid, the pertinent information therein is equally applicable to the acid contained in the storage batteries.

LAUNDRY

In arctic and cold-weather operations, the laundry may handle a considerable amount of woolen and part-woolen clothing, such as underwear. Emphasis is placed on the following important points in laundering woolen. These points are applicable with either low-titerbuilt soap or saltwater soap. Wool should be washed at constant tapwater temperature in 5 minute suds and 3-minute rinses, at high water levels. The wheel must be stopped when draining or filling. A heavy suds should be built up in the wheel before adding the clothes on the first bath. No bleach or additional alkali is needed with woolens.

In no case should live steam be introduced into the wheel. A short formula is necessary to reduce the possibility of shrinkage from too much mechanical action. Woolens are never extracted over 5 minutes. It is customary to allow the extractor to reach top speed, let it run for a minute, then stop it and unload. Too much extraction may damage the fabric. If woolens are to be tumbled dry, they should be separated from any cotton load, and the heat in the tumbler should be reduced by adjusting the dampers. Woolens should be tumbled only for as long as is necessary to dry them. For additional information, see chapter 35 of the *Bureau of Ships Manual.*

GYROCOMPASS EQUIPMENT

When operating in latitudes higher than 70 degrees, special attention should be given to the provisions of the gyrocompass instruction books regarding the manual operation of the speed corrector.

WIND DIRECTION AND INTENSITY EQUIPMENT

In utilizing this equipment allowance should be made for the fact that accuracy will be impaired by ice collecting on the aloft transmitter vanes. Where such equipment is not provided, ships should be provided with hand-held anemometers.

WINDOW WIPERS

The pendulum-type window-wiper mechanisms are designed to operate satisfactorily in cold weather. The following instructions should be followed for optimum results under arctic conditions:

1. To prevent ice formation, saturate felt blade with a solution of 50 percent glycerin and 50 percent alcohol, and fill the reservoir on the back of the blade with the solution (one filling of the reservoir should be satisfactory for several hours operation).
2. Start the wiper as soon as icing conditions are suspected or anticipated—once ice has formed on the glass, the wiper may not be able to remove it.
3. Be sure that the blade is not frozen to the glass before starting the wiper.
4. Ensure that an adequate supply of both rubber and felt blades, which are standard Navy stock, are on hand.

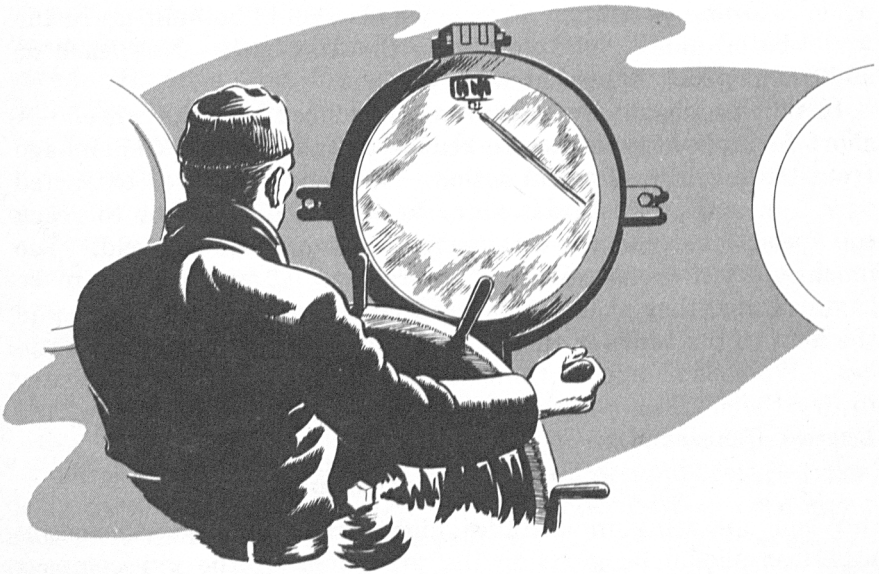

Figure 4–4.—Start window wipers as soon as icing is suspected.

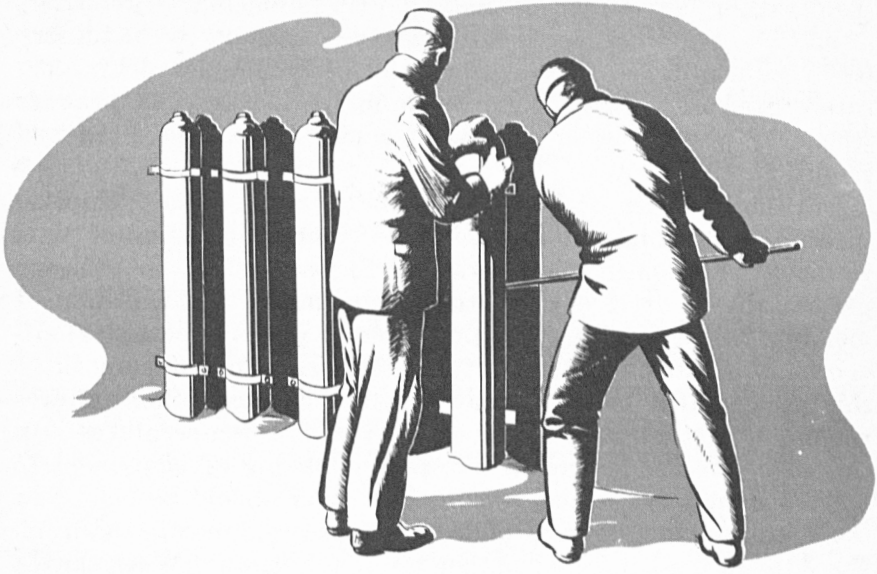

Figure 4–5.—When loosening cylinders do not bear on caps or valves.

COMPRESSED GAS CYLINDERS

Pressure in compressed gas cylinders subjected to cold will drop considerably and may be insufficient for practical use. If such is the case the cylinder may have to be warmed, but extreme caution is necessary if artificial means are used. Care must also be observed in using steam or other heat for de-icing to ensure that cylinders stowed on deck are not overheated (see article 92–273(6), *Bureau of Ships Manual*). When loosening cylinders for use do not allow crowbars or similar tools to bear on cylinder valves or caps (see article 92–280(1), *Bureau of Ships Manual*).

ELECTRONICS

Operation of electronics equipment exposed to the weather conditions encountered in arctic and cold weather areas presents the same general problems encountered in operation of all machinery under similar conditions: such as icing of elements, lubrication problems, breakage due to low temperatures, installation and maintenance difficulties, electrical instability.

Generally speaking, all equipment should be winterized. A check should be made to ensure the installation of all winterization kits available and the execution of applicable winterizing

techniques such as renewal of original grease and oil, use of low temperature lubricants, preheating of equipments. Preheaters should be used wherever possible and are considered mandatory below minus 35° F. Preheating shall be accomplished by separately fired devices. A long warm-up period is good practice whenever possible with equipment under no-load or light-load condition.

In the case of transmitters or radars operating in low temperatures, a preheating period is desirable before application of plate voltages. Equipment not regularly in use should be fired up periodically to drive out moisture from units. Condensation of moisture when bringing equipment from cold temperature outdoors into a warm room will often cause corrosion and many times this accumulated moisture may freeze and cause other failures when the equipment is again exposed to low temperatures. In this case, the use of canvas covers and baking of equipment to drive out moisture is suggested. The cover should be placed on the equipment and zippers pulled while the equipment is still exposed to low temperature and then brought indoors. When canvas covers are not available, it is imperative that equipment be kept dry by wiping off the moisture. It is important to protect all exposed equipment with some sort of shelter.

Much trouble has been encountered in the past due to dry, finely powdered snow sifting into equipment. It is recommended that snowproof covers be provided for all equipment to be used ashore and that a whisk broom be placed in every tool kit. Regarding mobility ashore, skid-mounted equipment is most valuable. Long sleds are also recommended to reduce damage of equipment due to shock and vibration. For outdoor installation and maintenance of equipment, *personnel should always wear gloves to prevent the skin from sticking to metal parts.*

Electronics maintenance in exposed positions will be very difficult at best. However, reasonable comfort can be maintained by providing suitable canopies, where possible, for men to work under and also providing small, safe heaters to heat the space under the canopies.

ELECTRONICS COMPONENTS

Prior to departure from the United States, all ships and units should draw an adequate supply of fresh batteries for all portable equipment. Dry batteries can be stored for long periods at very

low temperatures without appreciable depreciation. Upon removal from stowage at low temperatures, the batteries should be warmed to a temperature of approximately 70° F. very slowly. It is suggested that the cold batteries be placed in a temperature of approximately 5° below freezing temperature for about 1 hour and then moved into a 70° F. temperature for another hour. If cold batteries are exposed to elevated temperatures, frosting will occur and the battery cases may be damaged by ice.

Regarding storage batteries, maximum usable life can be insured by preventing damage due to freezing of the electrolyte. Therefore, the specific gravity should be checked at frequent intervals. Batteries with electrolyte specific gravity of 1.140 will freeze at 10° F. whereas at 1.300 freezing does not occur until minus 90° F. Freezing may cause permanent damage to cells and case. Do not add water to a cold battery, even if fully charged. Always add warm distilled water when the battery is warm and is being charged. To prevent excessive discharge of battery in starting gasoline engines in cold weather, the use of a slave battery is highly recommended.

The use of shelters, and preferably drift-proof shelters, is highly recommended for gasoline engine generators installed in exposed locations. Special cold weather fuels and lubricants should be used whenever possible. It is to be noted that prestone in concentrated form will freeze at 19° F. whereas, by proper dilution, the freezing point may be lowered to approximately minus 65° F.

Microphones fail when left in snow because the snow accumulates, melts, and freezes, or because of breath moisture freezing. This can be prevented by using suitable thin microphone covers of nylon, polyethylene, or vinylite. Supply sufficient spares with each type. Headsets must be kept warm and dry to prevent disabling of diaphragms due to moisture freezing at the edges and to prevent breaking of plastic seats.

All rotating joints, rotary machines, rotating shafts as in switches or potentiometers should be winterized by cleaning with fluids and by replacing existing lubricant with cold weather lubricants or graphite. Also, these units must be kept dry to prevent moisture from freezing and jamming rotating parts.

Ordinarily condensers, resistors, and inductors are not likely to fail at low temperatures. However, their characteristics may change, requiring frequent readjustment of critical circuits. Electrolyte condensers are subject to considerable variation in capacity and in effective series resistance, especially at tempera-

tures lower than 0° F. Capacity decreases with temperature while resistance increases.

The formation of ice on antennas can cause wires to break and may reduce operating range. Check antenna installation frequently. Knock off icicles with a light bamboo pole. Remove all ice from strain insulators to prevent excessive transmission losses.

Ice on connecting points of telescoping or sectional antennas causes damage. As a remedy, a film of light-grade oil is recommended for their protection. Frequent inspection, cleaning, and replacement of the film will be necessary.

Cables and cords should be handled with care to prevent cracking or breaking. Learn the flexing capabilities of the particular cord and handle accordingly. Do not bend at sharp angles. At temperatures approaching minus 40° F., it is necessary that cable be placed in a warm shelter and unreeled in this temperature before attempting installation.

SHORE ELECTRONICS

COMMUNICATIONS EQUIPMENT

Radio interference noise levels may be exceedingly high in standard communications receivers operated on high barrier ice or snow where electrical grounding is impossible and counterpoises become pickup antennas suspended in space. Individual antenna-counterpoise systems are recommended. All transmitters, vehicles, power units, and particularly d.c. generators should be isolated as far as possible from receiving positions.

Nonmobile noise generators should be equipped with filters for isolating noise voltages from radiating power lines and/or bonded to a central connection other than those used for propagation or reception. Additionally, all battery charging near receiving positions should be accomplished with a.c. rectifiers instead of d.c. generators. It is imperative that the number of rotating electrical machines using commutators be held to a minimum. There is no noise trouble with alternating current equipment.

In connection with the above, ice drilling machinery or deep well equipment should be included in all operations involving the installation of radio communication stations on an ice shelf. This machinery could be used to drill through the ice at a number of points on the perimeter of a circle or quadrangle surrounding the buildings housing radio communications equipment. Wires should

Figure 4–6.—Drag wire antennas on snow for good results.

extend from the center radially to the holes drilled and the surface horizontal wires tied together as a counterpoise system. The radius of the counterpoise system should be a minimum of a quarter wave length at the lowest frequency to be employed and the length of the vertical wires down into the ice should be as long as necessary to provide contact with the salt water or ground. Noise elimination and good antenna design cannot be over-emphasized inasmuch as they are prime factors in improving communications.

All MHF portable or vehicular equipment covering long distances should have their whip antennas supplemented by wire dipole antennas, antiprecipitation and corona proof, which can quickly be flung out on the snow one-quarter wave length either side of vehicle when not in motion.

Vehicles, when not too closely accompanied by others, on remote assignments can drag along wire antennas behind them (on thick snow) with excellent results. Whip antennas are especially desirable due to their adaptability to use in igloos or shelters. However, antennas pushed through drift-tight holes in tent roofs that are covered with melting snow are not conducive to optimum operation. (Shunt across antenna.)

RADAR EQUIPMENT

The following comments as applied to early warning radar equipment are applicable to radar navigational aids such as GCA, GCI, IFF or any other equipment similar in construction or in operational features.

Since early warning radars may be either fixed or mobile, they represent two separate and distinct problems in arctic regions. On the one hand, the fixed type is a problem chiefly because of its mass, whereas the mobile type may be difficult to locate. All the usual troubles experienced with motor transport facilities are to be expected and personal comfort may have to be sacrificed to obtain mobility.

The antenna is a very vital part of the radar and must receive special maintenance care. All facilities available to prevent icing must be utilized, such as pedestal space heaters and wave guide stimulated by a warm air blast from below. Only low temperature oils and greases should be used in pedestals. When rotating the antenna after a period of idleness, it should be rotated at slow speed for a short period in one direction only. Sudden changes of speed or changes in direction should not be imposed on the system until it has had a chance to work in. Where high winds prevail the antenna should always be stowed so that its least frontal area will be presented to the prevailing wind direction.

Cable runs from the antenna to the radar should be protected throughout their length, say inside the tower leg if possible, in order to permit whatever servicing required. Stuffing boxes and cable terminals must be well protected. In the case of wave guide runs all points must be regularly inspected to ensure that no moisture is allowed to enter. Well protected drainage holes should be provided at the base of all long wave guide runs and these holes must be constantly checked to assure that they do not become stopped. Condensation and freezing inside a wave guide may cause very considerable power loss and consequent loss of range.

Assuming that the enclosures housing the radar equipment on the ground are kept reasonably comfortable for personnel during periods of operation, it may be that full heat is not maintained during nonoperating periods. Such on-off operation is very hard on the equipment due to condensation, freezing, and strain on mechanical parts incident to extreme temperature changes. About the best means of combating this condition is to keep all tube filaments burning and space heaters on during periods of nonoperation. This will also make the equipment available for oper-

ation almost immediately in emergency, by merely applying the plate voltages.

Secondary power is recommended for all fixed installations. The capacity should be sufficient to supply power for lights, space heaters, low voltage radar filament supplies, etc. This requirement is based on the premise that the radar will be called on to operate only part of each day. Standby power is also highly recommended both for emergency and for use while maintenance is being carried out on the primary radar power supply equipment. The main fuel storage for the motor generators should be located not closer than about 100 feet from any r-f element. As a safety measure all gasoline drums should be adequately grounded when located in the general area of a radar set.

All rotating machinery and gear trains should be checked regularly for proper lubrication. A sufficient quantity of oil or grease is not enough, it must flow or adhere to the moving parts in order to provide satisfactory lubrication. All blower motors should be carefully checked for operation since failure of a blower often is followed by a major breakdown due to overheating in the space served by the blower. Just because it is cold outside it does not follow that the blowers may be dispensed with. Intakes must be kept snow-free and clear. Wick-type bearings are especially susceptible to binding at low temperatures.

As in the case of an automobile the gasoline or Diesel engines which drive the power generators may be expected to start hard in cold weather. Also, it may take as much as 15 minutes before they have reached operating temperature and deliver a constant torque thereby enabling the generator to supply a constant voltage. It is, therefore, recommended that after a period of idleness the radar not be turned on until at least 15 minutes after the generators have been started. This is good tube, transformer, and capacitor insurance.

In cold climates special care must be taken to service adequately the hidden, though vulnerable, portions of the system such as the wet cell batteries and the cooling systems of the engines. The specific gravity of all wet cell batteries should be kept up to prevent freezing and it must be borne in mind that the Navy standard battery has a lower specific gravity than the commercial standard. This means that the former will freeze at a higher temperature than the latter. All water cooled systems must be adequately protected by a suitable antifreeze. Some of the early radar sets

employed circulating distilled water for cooling the plates of the transmitter tubes. Although this is no longer common practice it serves to illustrate how important it is to know your equipment before you try to operate it at subfreezing temperatures.

Mobile early warning radar equipment may be expected to present all the low temperature difficulties experienced with the fixed type of installation plus a few additional ones. As in the case of the fixed installation, the mobile type must also have its antenna located at a high point to obtain an unobstructed view in all directions. This means that the antenna van or trailer, and, most likely, the operations van or trailer, must be driven or hauled into place. It is recommended that at least two trucks in the expedition be provided with high capacity winches for pulling the radar vans into position. Tractors are very desirable for such work. It is also suggested that each van be fitted before the start of the expedition with special skis or steel runners which may be clamped to the wheels. Rubber-tired wheels have virtually no traction on ice or packed snow. Their use should not even be attempted.

Each van, housing operating personnel, must not only be adequately heated, preferably with a gasoline heater, but must also be adequately ventilated with the doors closed. All doors must be tight and vents to the outside must be protected so that powdered snow may not enter.

Since the average van presents a considerable area to the wind and since winds in the Arctic reach a high velocity, it is best to anchor all vans in place by means of suitable guy wires to prevent overturning. If outriggers are furnished as part of the equipment they should be employed instead of guys. If not already

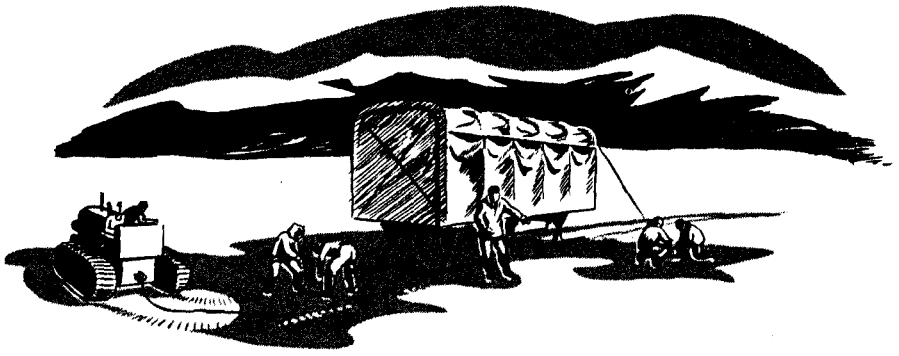

Figure 4–7.—When in place vans are anchored with steel guy wires.

furnished with the equipment, provision should be made for securing the antenna against high winds. Unless absolutely necessary, it is not advisable to drive the antenna in a high wind. Under such conditions the strain on the antenna drive system is great, sudden gusts often reaching higher velocities than economical design may be able to withstand. Also special precautions should be taken to prevent excessive icing on the antenna.

All recommendations concerning the use of low temperature oils and greases and constant maintenance surveillance over all moving parts apply equally well to the mobile installations and to the fixed ones discussed previously. It should also be remembered that there are a greater number of mechanical parts subjected to temperature extremes in the case of mobile installations than in the average fixed installation. The mechanical strains are therefore greater and maintenance must be expanded accordingly.

Comments above concerning early warning radar shall be considered applicable to radar navigational aids.

SHIPBOARD ELECTRONICS

RADIO COMMUNICATIONS EQUIPMENT

LF transmitting equipment is most valuable in arctic and cold weather areas and should be maintained at highest efficiency, particularly if operating with aircraft. Especially large receiving antennas for use on the NSS low-frequency Fox transmissions are recommended for these long distance polar operations. Immense improvement can be effected in the reception of Fox transmissions by rigging from the topmost radar mount a T receiving antenna up to 200 feet long and 90 to 100 feet high. In this connection, it has been found that the *Boston trunk* for bringing LF antennas down to the receiving room proved superior in performance to the solid dielectric flexible coaxial lines.

RADAR EQUIPMENT

Shipboard radar problems are similar to those discussed in section III above for shore radar equipment—in particular, all comments on antenna care, lubrication, icing, and preheating of pedestal, applying.

SONAR EQUIPMENT

For submarine installations, precautions shall be taken to prevent excessive icing of topside sonar transducers and periodic inspections shall be made for any breakage due to the icing. Re-

tractable topside hydrophones shall be in a retracted position when the submarine is surfaced. After submerging, sufficient time shall be allowed for ice to melt before transducer training systems are energized.

In marginal ice areas, retractable domes on surfaced submarines or surface ships should be retracted, tactical situation permitting.

Low temperature lubricants shall be used in cold weather operations and extreme care shall be taken with training systems which present rotating difficulties due to freezing.

NAVIGATIONAL AIDS

The importance of direction finders in polar operations cannot be over-emphasized. All D/F equipment should be calibrated prior to departure for the operational area, and rechecked after arrival therein, where practicable.

Homing beacons are most valuable. Care should be taken to prevent heavy icing of the antenna which will cause failure of the rotating mechanism. The difficulty has been corrected in some installations (of Model YG) by building a radome (shelter) over the antenna pedestal. Despite heavy icing of the radome, operations remained satisfactory.

OTHER SPECIAL ELECTRONICS EQUIPMENT

Regarding the operation of infrared equipment, there is very little special care required other than a check of the lubrication and particular care regarding batteries in portable receivers as stated above. Equipment covers shall be used at all times especially to keep the window of the infrared receiver equipment free from ice. Warm-up period will melt ice from beacons; at least a 10 minute warm-up period will be required in operating the Type Easy (AN/SAC–1) infrared communications equipment.

TOPSIDE DE-ICING AND SNOW REMOVAL ON SHIPS

The most serious effect of topside icing, particularly if ice continues to accumulate, is the increased topside weight. This may result in dangerous loss of stability, reduction in reserve buoyancy, and critical impairment of the ship's ability to withstand damage. Other adverse effects of such icing are: the increased load on decks, masts and other structures; interference with the handling and operation of topside equipment; and the slippery effect on decks and other exposed walking and working areas endangering personnel.

There are several methods of ice removal which have been used with varying degrees of success. These are:

1. *Manual*—Ice broken away and chipped off by use of mallets, clubs, scrapers and similar tools. This method must be used with caution to avoid or minimize damage to metal surfaces, equipment, electric cables, gun mounts, and other machines or mechanisms.

2. *Steam jet.*—This method may be of limited usefulness in small or restricted areas when a steam lance can be employed to undercut layered ice as, for example, in freeing an anchor which has become frozen in the hawse pipe. Disproportionate consumption of steam, with consequent loss of feed water, restricts this method to only very limited application.

3. *Anti-icing and de-icing coatings.*—While not thoroughly tried, this method is applicable to the protection of comparatively small areas or items with grease, usually of special formulation. The grease or anti-icing compound retards the formation of ice and contributes to the ease of removal of any superimposed ice coating or accumulation.

4. *Heated salt water under pressure.*—Sea water at temperature of at least 45° F. (and higher if readily obtainable) is used in high pressure streams to slot, undercut, and break up accumulated ice. No attempt is made to melt the ice directly; but to break it up and weaken it to facilitate mechanical removal.

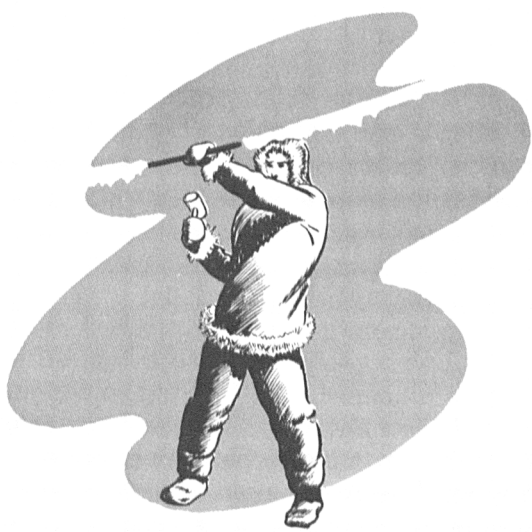

Figure 4–8.—Use mallets and clubs with care.

Figure 4–9.—Undercutting with salt water spray.

In general, a combination of methods (1) and (4) above is considered to be the most effective for any extensive ice removal. Certain ships are equipped with special means for supplying heated salt water through the fire-mains, but at this time these installations are still on an experimental basis. However, ships not so fitted can effectively employ fire and wash deck hoses under most conditions so long as solid streams of water at a pressure exceeding 40 p. s. i. are available. The latter method should be used with caution under conditions of extreme cold. Any tendency of the water to freeze and add to the ice accumulation should be noted and the method discontinued immediately if such conditions occur. It is also essential in using this method that overboard deck drains be kept clear.

When removing ice, care must be exercised not to damage electric cables, including topside degaussing cables installed on some ships. In certain tankers the degaussing cables run over the tank tops only a few inches above the deck and can easily be damaged if an attempt is made to clear the deck of ice by shoving the ice overboard through the space between the deck and the cable.

When conditions of severe topside icing exist and ice continues to accumulate dangerously in spite of all attempts to remove it, it

may be necessary to alter course, lie to, or even head for a warmer area or area of more moderate weather. This may occur when heading into heavy winds or seas with attendant spray under conditions of low air and sea-water temperatures, and is particularly applicable to smaller ships having low freeboard and reserve stability.

The primary consideration in keeping decks clear of snow and ice is to remove the snow before it has an opportunity to form a crust or become trampled and hardened. This may be done by means of rattan hand sweepers, shovels, and similar equipment. On aircraft carrier decks, tractor powered rattan sweepers and rotary brushes have been used with success. Care must be exercised not to damage deck cleats or other deck coverings when using scrapers and rotary brushes. Light snow does not accumulate on steel decks, due to the heat transfer through the deck. In some cases advantage may be taken of high winds to blow the snow clear.

Hand brooms and turning up of aircraft engines are the most effective means of removing snow around closely parked airplanes. Rock salt may be used as a final resort in removing ice and packed snow, but this method should be kept to the minimum due to the corrosive effect of the salt and the hazard to personnel and equipment from the flying salt particles, particularly on carrier flight decks.

HULL DAMAGE

The type of hull damage which may be encountered in sea areas where ice may be encountered is not appreciably different from that which may result in any area of operation. Generally speaking, normal damage control procedures and practices are applicable. However, the possibility of hull damage is considerably increased when operating in close pack ice, and extra preparatory and precautionary measures should be taken. When cargo is loaded it should be distributed to permit access to side plating, bulkheads, and bilge suction drain wells and strainer plates. It should also permit normal drainage in event of hull damage. A full allowance of damage control equipage, including shores, wedges, and plugs, should be on board prior to departure, and should be stowed in various underwater spaces for ready availability in case of damage. As indicated previously the drainage system, portable pumps, and hose should be maintained in the best condition and personnel should be thoroughly instructed and drilled in operation of this equipment. Upon entering ice, con-

dition *Yoke* or *Baker* should be set and an adequate hull repair party kept on watch at all times.

Damage may consist of rupture of shell or distortion and weakening of structure due to ice pressure or contact with ice, or loss or damage to rudder, propellers, shafts, or other appendages. In case of shell rupture, normal damage control procedures are applicable, i. e. contain the flooding, plug, and shore as necessary and feasible, and get the loose water out of the ship. Distorted or weakened structure should be shored as necessary for temporary reinforcement. Voyage repairs for loss of, or serious damage to, underwater appendages are seldom feasible, and such damage may require that the ship be taken in tow. Depending on the nature and extent of the loss or damage, the possibility of a temporary or jury rig should be thoroughly considered, and all possible steps taken to salvage or prevent complete loss of the appendage.

In case any welding is to be done, chapter 92, *Bureau of Ships Manual,* should be consulted, particularly article 92–6(3). As indicated therein, welds made without preheat on very cold metal may not be satisfactory, and may even do further damage.

WINTERIZATION

This section indicates the principal items that should be considered in preparing an ordinary naval ship for operation in the Arctic. The extent to which the various items are applicable will depend upon the type of ship, mission, duration of voyage, and probable area of operations, and upon the time available for preparation.

There are certain items in the nature of temporary modifications or alterations which should be considered. Unless the ship is being readied for extended operations under known severe conditions these changes, in view of their temporary nature, should be accomplished by ship's force with materials at hand and jury rigs insofar as possible. Among them are:

1. Designation or reassignment of certain spaces for drying of heavy weather clothing. On many ships the uptake spaces will be suitable for this purpose. Jack stays or other means of hanging heavy weather clothing should be installed.

2. Rearrangement or designation of certain spaces to provide for stowage of additional heavy weather and bulk clothing to be taken aboard for cold weather operations.

3. Rearrangement or reassignment of certain storerooms, refrigerated spaces, or other spaces to provide for increased capacity of food supplies. In some cases consideration of the temporary topside installation of portable reefer boxes may be warranted.

4. Installation of temporary shelters or wind screens for exposed personnel and topside watch-standers. Locations to be considered are bow station and crow's nest station for ice lookouts and other lookout stations; exposed conning station or pilot house if not enclosed; deck, cargo winch, and crane operators' stations.

5. Suitable lighting for leadsman's platform, particularly for high-latitude winter operations.

6. Installation of special propellers for ice operation, if available, and if docking of the ship is directed prior to departure. Preferable materials for such propellers are stainless steel, copper nickel-silicon (Silicon Monel), or special high strength bronze alloys.

7. Replacement of alcohol-water filled magnetic compasses with oil filled type.

8. Temporary timber bracing of the bow in the forepeak may be advisable, particularly if ship is of light construction, such as LST's. Additional bracing to the forepeak after bulkhead may also be desirable.

9. Installation of thermal insulation on shell or bulkheads behind and above main switchboards if such bulkhead or shell areas have a tendency to show condensation.

10. Replacement of any fluorescent lighting installed in spaces where the ambient temperature may be expected to fall below 50° F. Presently available fluorescent lamps do not operate satisfactorily in spaces below 50° F., and are practically impossible to operate in ambient temperatures below 32° F.

11. Provision of additional insulation for exposed steam and water piping which will not be completely drained at all times except when in use. Lagging should be common to both the steam supply and drain line wherever possible.

12. Provision of a brow which can be easily rigged to shelf ice.

13. Provision, on overboard discharges or drains above the water line, of a temporary heating coil around the piping directly inboard of the shell. Steam supply should be taken from the steam heating system and drainage returned to the heating system drains.

In addition to temporary alterations, provisions, and modifications such as those outlined above, there are certain preparatory measures for installed systems and equipment, and certain tests

and inspections which should be carefully observed as a matter of voyage preparations:

1. Accomplish topside painting maintenance and bring ship to the highest possible standard in this respect to arrest corrosion during a long period of operations in cold climate when routine maintenance can not be accomplished. Little opportunity for further painting may be afforded under cold weather conditions.

2. Clean ventilation and heating systems to ensure that they are in the best operating condition. All heaters, temperature controls, and condensate traps should be checked for installation. Heaters removed in warm climates should be reinstalled and placed in operation.

3. Check towing gear and overhaul or replace items as necessary.

4. Refill water breakers to 75 percent capacity.

5. Check the operating condition of main drainage pumps and portable pumps, inspect and test associated piping and hose, correct all leaks and renew hose as necessary. Clean all bilge well suctions.

6. Overhaul cargo falls. Remove excess grease.

7. Test heating coils for fuel oil tanks.

8. Test main damage control bulkheads and tanks, as practicable, by hydrostatic pressure.

In connection with the stocking and outfitting of the ship, the following items are particularly pertinent:

1. Provide spare batteries for boats, in addition to those installed. Upon request, the Bureau of Ships will approve up to 100 per cent spares in excess of allowance, depending on the nature and expected duration of the operation.

2. Ensure that full allowances of maintenance and repair spare parts are on board. Requisitions should be submitted as far in advance as practicable, and should clearly indicate the special purpose or operation for which required. Particular attention should be given to checking spares for all pumps, both installed and portable, and for electronics equipment, particularly navigation radars.

3. Provide full allowance of damage control and repair materials, such as shores, plates, clamps, wedges, etc.

4. Provide full allowance of mooring gear, and obtain adequate supply of materials needed for any special mooring, such as mooring to shelf ice, if such operations are anticipated.

5. Provide adequate supply of special lubricants, antifreeze solutions, hydraulic fluids.

6. Carry a good supply of wooden mallets, scrapers, and similar tools for ice removal or for working in ice. Provide long ice poles for clearing or fending ice, and special ice fenders (sections of telegraph poles 10 to 15 feet long are suitable for this purpose).

7. Provide supply of special dry batteries as needed for use only below 0° F.

8. Provide extra supply of vacuum-type bottles and jugs for serving hot liquids to watch standers. These are carried as standard stock items:

1-quart size—standard stock No. 63-B-500

1-gallon size—standard stock No. 63-J-600

9. Provide extra space and unit heaters as needed. Requisitions in excess of allowance for these and for item (8) above will be given favorable consideration, depending upon the nature and expected duration of the operation.

10. Provide good supply of window-wiper blades, and glycerin and alcohol for filling. Wiper blades and de-icing liquids are available in standard stock as indicated below.

Blade Length:	*Standard Stock No.*
7 inches	12-B-1616-150
8 inches	12-B-1616-160
9 inches	12-B-1616-170
10 inches	12-B-1616-180

Material and Unit:	*Standard Stock No.*
Denatured alcohol, 5 gallons	51-A-1935
Glycerine, 5 gallons	51-G-356
Ethylene Glycol, 1 gallon	51-C-1554-15

SUMMARY

In general it can be expected that equipment will perform satisfactorily or can readily be adapted to do so. Extreme care and good seamanship must be practiced while operating in pack ice or ice areas to avoid holing and damage to fittings of the ship. In event of holing or other hull damage, "plug the holes, man the pumps, practice damage control, and keep going."

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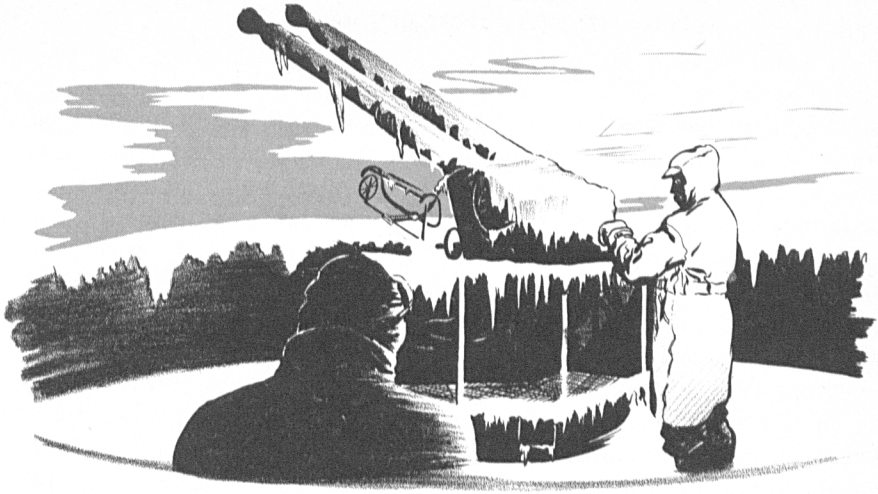

CHAPTER 5

CARE AND OPERATION OF SHIPBOARD ORDNANCE MATERIAL

Ships operating in cold weather areas have, at surface or weather air temperatures below freezing, experienced difficulties with ordnance equipment due principally to the congealing of non-cold-weather lubricants and to the formation of ice on exposed equipment. As a result, equipment may become inoperative, or extremely sluggish and difficult to operate at required speeds.

Low temperatures also have a detrimental effect on most propellants. Propellant grains become brittle at low temperatures and may crack. Gun propellants are satisfactory for firing at propellant temperatures down to 0° F. Rockets should not be fired at rocket motor temperatures below those stencilled on the rocket motors.

According to partially completed tests at the Naval Proving Ground, it is indicated that armor and inert components of ammunition are not affected adversely by low temperatures.

GENERAL PRECAUTIONS

LUBRICATION AND MAINTENANCE

1. Under cold weather conditions certain lubricants, prescribed for normal operating conditions, tend to congeal and cause unsatisfactory operation. In general, the approved lubricants for ordnance service use must meet specification requirements for satisfactory performance down to 0° F. (with the exception of certain lubricants for specific applications). Changes in lubrication required for lower temperatures include dilution of high viscosity oils and heavy greases with low viscosity oils, or by replacing with a suitable cold weather lubricant. Excessive amounts of lubrication must be avoided in all cases. In arriving at these substitutions, consideration has been given to adequate low temperature starting and operation as well as maintenance of satisfactory lubrication at the final operating temperature (which may be nearly as high as under normal temperature conditions). Cold weather relubrication of ordnance equipment should be accomplished prior to entering low temperature areas (0° F. and below). However, if cold weather is encountered before relubrication of the equipment is accomplished, special methods for removing the congealed lubricant must be utilized.

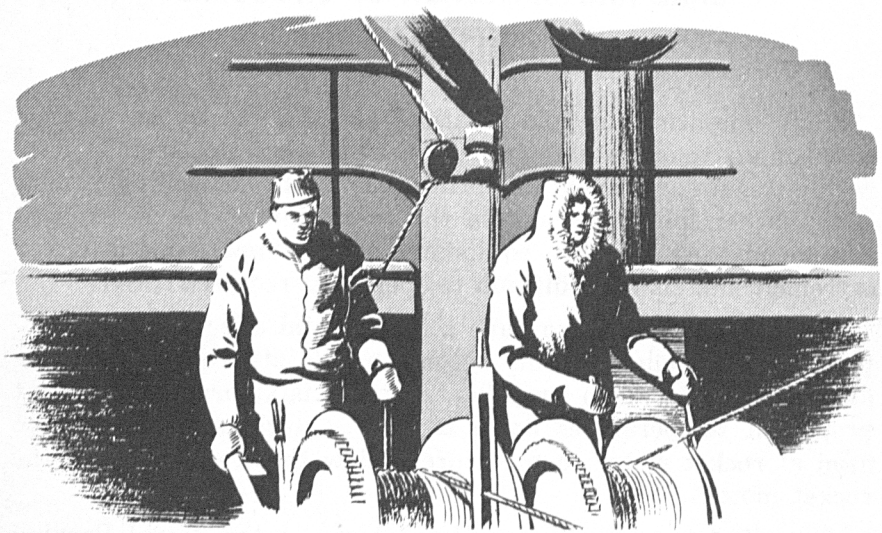

Figure 5–1.—Icing makes equipment difficult to operate at required speeds.

2. Lubrication precautions prior to entering cold weather areas: When relubrication is required, accessible grease lubricated parts should be cleaned prior to applying the cold weather lubricant. Where the parts are not accessible, it is recommended that the units be exercised while lubricating, care being taken to remove any excess grease.

When replacing oil, it may be necessary to raise the temperature of the oil to be removed (to reduce its tenacity) in order to assure as complete a removal as possible. This may require exercising the equipment for a period of time, then draining the oil and refilling with the cold weather lubricant. Oil trapped in pockets should be removed with a hand suction pump. For oil lubricated parts which do not have a pump and are lubricated by direct application, large quantities of the cold weather lubricant should be injected, in order to flush out the original lubricant.

3. Relubrication for cold weather operation under emergency low temperature conditions:

a. *For relubrication of inaccessible parts* during an emergency, such as lack of time to permit cleaning out the lubricant, or where the lubricant has already thickened or congealed under cold weather conditions, a light mineral oil JAN–L–644 (formerly O.S. 1361) (first choice) or VV-O-401 (second choice) should be injected in moderate amounts at intervals, and accompanied by exercising until the equipment operates freely. The use of JAN–L–644 as a diluent is desirable due to its corrosion prevention properties. The proper cold weather lubricant should be applied to the surfaces which have been treated as above.

b. *For relubrication of accessible parts* where the grease has congealed, the cover plates should be removed and the parts wiped off with a kerosene (VV–K–211) soaked cloth and moderately exercised while cleaning whenever possible. Care should be taken to apply the cold weather lubricant immediately after cleaning. If it is apparent that this cleaning procedure does not remove a major portion of the original lubricant, moderate amounts of VV–K–211 should be applied until the parts are freed. Follow up with a generous quantity of JAN–L–644 while exercising the equipment, in order to provide a measure of lubrication until it is possible to relubricate completely for anticipated temperature conditions. When VV–K–211 (kerosene) is used, extreme care must be taken to prevent its running on to adjacent lubricated bearing surfaces or electrical insulation. As kerosene is some-

what volatile, care should also be exercised in its use in areas where an open flame or electric arc may be encountered.

4. Where a lighter oil or diluted lubricant is used as the cold weather lubricant, more frequent applications of the lubricant are required than are prescribed for the normal lubricant.

5. General considerations relating to selection of proper lubricants:

The approved and required lubricants for all ordnance applications appear on the applicable lubrication chart or ordnance publication, or may be contained in other instructions such as NavOrd OD 3000. The lubrication chart drawing numbers are normally found on the assembly sketch list for all mounts, directors, torpedo tubes, and similar equipments, and on the list of drawings for the particular component such as the slide or projectile hoist for all turret equipment. In the case of torpedoes and fire control equipment such as computers, rangekeepers and indicators, lubrication charts are not necessarily issued, and the general lubrication instructions are contained in the applicable ordnance publication which describes the particular equipment.

It is extremely important that the applicable lubrication charts of the latest revision and the latest lubrication instructions issued be used at all times for the lubrication and maintenance of ordnance equipment.

6. The recommended lubricants for normal and cold weather operation for various applications in ordnance equipment are listed in NavOrd OD 3000, section X. Lubrication charts contained in the ordnance pamphlets (other than for torpedoes and fire control equipment) are those of original issue and may have been revised. A cental lubricating chart file and office is being established at the Naval Gun Factory, Washington, D. C., to which application may be made for information concerning specified types of equipment. The lubricants specified on the lubrication charts and in the ordnance pamphlets of current issue are usually adequate to cover operation down to 0° F. In general, cold weather lubricants provide adequate lubrication down to minus 35° F. It will not be necessary to change the lubricants other than normal winter practices in enclosed (heated) locations to cover low temperature limits from 0° to minus 35° F. However, it will be necessary to change to different lubricants or to resort to diluted lubricants for most exposed locations.

NOTE.—*Enclosed locations* are considered to be those in which the equipments involved are inside of a completely enclosed shield

or structure or are in locations normally heated for personnel. *Exposed locations* are those in which the equipments are not shielded and are subjected to weather air temperatures.

GUNS, MOUNTS, AND LAUNCHERS

The following factors influence the firing of guns at low temperatures:

1. Increased tendency of metals to fracture at low temperatures.
2. Propellants.
3. Lubricants.
4. Fluids (recoil, cooling system, and power transmission).

Items, 2, 3 and 4 are discussed in the succeeding paragraphs below. The effect of low temperature on the strength of materials varies with the chemical composition and heat treatment of the material as well as with the presence of sharp corners and cracks under stress in the material.

The safe lowest ambient temperature for firing of shipboard guns is not definitely known. However, the following temperature limits are suggested (refer to appropriate lubrication charts for instructions on lubricants and fluids for low temperature operation):

Gun:	*Lowest ambient temperature for firing*
20 mm	minus 35° F.
40 mm	minus 35° F.
3"/50	minus 35° F.
5"/38	0° F.
6"/47	0° F.
8"/55	0° F.
12"/50	0° F.
16"/50	0° F.

Recoil mechanisms and buffers.—Recoil mechanisms containing glycerine-water mixtures should function satisfactorily in cold weather, except that sluggish action (or perhaps short recoil) may become increasingly apparent at temperatures below the freezing point at which ice crystals begin to form in the mixture, although the solution does not freeze solid until temperatures below the pour point are reached. Heat should be provided if unsatisfactory recoil action is experienced. There is no authorized substitute for either mixture inasmuch as the orifices are designed specifically for each mixture. Freezing points and pour points are given below.

Mixture	Freezing point	Pour point (by test)
OS 1324 (60–40 mixture)	Minus 32° F.	Minus 60° F.
OS 1914 Type A (80–20 mixture)	Minus 5° F.	Minus 55° F.

Buffer fluids under cold weather conditions will slow the action of the buffers as the pour point of the fluid concerned is approached. With the exception of NS (Navy Symbol) oil 2075, having a pour point of approximately minus 10° F., all buffer fluids used in ordnance applications have pour points below minus 35° F. Therefore, no cold weather substitutes are recommended. OS 1362 is the recommended cold weather substitute for NS 2075.

Cooling systems.—In areas where it is certain that freezing temperatures will not be encountered, the normal coolant for gun cooling systems (except .50-caliber machine guns) is fresh water treated with a corrosion inhibitor consisting of 5 grams of neutral (chemically pure) sodium chromate crystals per gallon of fresh water used.

When temperatures below 35° F. are anticipated, a solution of antifreeze compound, 51C39-Type A, and fresh water should be used. Directions for preparing this solution appear on the container or shipping case of the compound and in OD 3000. This compound contains inhibitors to prevent corrosion of metals. It is of extreme importance that the proportions of antifreeze compound and water be maintained at all times.

Hydraulic power transmission systems.—When it is anticipated that the ambient temperature will reach 35° F. or below, 51F23 (Ord) (formerly OS 1113) should be drained from the exposed systems and replaced with 51F21(Ord). It is emphasized that the change should be made well in advance of entering cold weather areas of operation. While changing the fluid, the greatest care must be taken to avoid contamination. Filling should be accomplished by using a Luber-Finer filter, or, if a filter is not available, a filling funnel, BuOrd Dwg. 8–Z–801, pc. 14, or by some other means of straining the fluid through a 200-mesh or finer screen. For power transmission system containing 51F21(Ord) (formerly OS 2943) no replacement of fluid is to be made for cold weather operation. Where very low temperatures are encountered, sluggish operation may be anticipated and frequent exercising of the equipment will be required. The temperature at which the equipment will perform satisfactorily and frequencies of exercising re-

quired are dependent upon the effectiveness of the cold weather lubrication measures taken and the type of hydraulic equipment involved. For instance, hydraulic drives and regulators to operate satisfactorily at minus 10° F. may require exercising 15 minutes per hour.

FIRE CONTROL EQUIPMENT

LUBRICATION AND MAINTENANCE

Hydraulic fluid.—In fire control systems containing hydraulic units, change the fluid from 51F23(Ord) to 51F21(Ord), similar to change described in paragraph (4) above under gun mounts.

Damping devices.—At low air temperatures, handle-bar directors may possibly become difficult to move in train and elevation due to congealing of the damping fluid. In this case, it may be necessary to disconnect the gearing which drives the damping device.

Optics.—Provisions for defrosting and de-icing are described in the applicable ordnance pamphlets and in NavOrd OD 4486.

UNDERWATER ORDNANCE

Steam torpedoes (Mks 13, 14, 15).—Malfunctions, with consequent erratic runs or failures to run, are to be expected in steam torpedoes whenever completely chilled to any temperature below about 30° F., at the instant of starting. Data as to the percentage of erratic runs or failures to run which are to be expected at various temperatures lower than this is lacking, but the percentage can be expected to increase rapidly with decrease of temperature.

Obvious immediate effects of chilling which in turn may lead to erratic runs or failures are:

1. Freezing of the water carried by a steam torpedo (such as Mk 13, 14, and 15).

2. Freezing or frosting of moisture entrained in the high-pressure air charge as pressure is reduced or as air is released from a nozzle or orifice.

3. Thickening of lubricants, causing ineffective lubrication, binding or sluggish controls.

4. In extreme cases, differential contraction of dissimilar metals (such as a steel shaft in a bronze bearing) causing binding, or possibly even causing permanent set or rupture.

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5. Formation of adherent ice upon a chilled torpedo (or, more important, within chambers and passages such as the exploder impeller duct or the tube to the immersion chamber) as it enters the water.

Certain of these effects may be palliated by measures not involving the actual physical preheating of a torpedo. For instance, the water carried by a torpedo may have alcohol added as an antifreeze, in accordance with standard tables, and the pour point of a torpedo lubricant may be reduced by the addition of fluid supplied for the purpose by the bureau. However, since equally simple methods for curing some of the other effects (e. g. 2 and 5 of the preceding paragraph) are not available, the following general precautions are stated:

In destroyers, when the ambient air temperature has been below 30° F. for more than an hour or so, reliance must be placed upon the torpedo tube barrel heaters (steam) to keep torpedoes in tubes ready for action. They require a great deal of care and maintenance in order to prevent breakage, leakage, freezing of condensate in return lines when steam has been turned off, etc. However, in actual experiment, temperatures well above freezing have been maintained in the afterbodies and water compartments of torpedoes in an ambient temperature of 0 ° F., with considerable wind.

Muzzle covers, specially made with weak seams which tear open to permit the exit of torpedoes, are to be used in conjunction with the barrel heaters. These covers decrease heat loss and keep off water which might otherwise freeze solid between the heads of torpedoes and torpedo tube spoons or spoon extensions. During the experiments attendant upon the development of this type of cover, it appeared from high-speed photographs that the weak seams were ruptured by gas pressure rather than by actual contact with torpedoes, and that the covers therefore did not interfere with propellers and rudders of the torpedoes. Nothing in the foregoing should be interpreted to interfere with current instructions for using alcohol as an antifreeze in the water carried in destroyer steam torpedoes (such as Mk 15), or for using pour-point depressants in torpedo lubricants, since the reliability of the torpedo tube steam heaters is not such that they can be operated continuously without breakdown, and freezing of the water in the water compartment of a torpedo (for example) would be expected to damage the torpedo enough to render it unserviceable.

In PT boats the torpedo launching racks customarily installed offer no protection to torpedoes against either chilling or icing. Electrically warmed tarpaulins (although not standard Bureau of Ordnance equipment) can be used where power is available, as from dockside installations, but are beyond the present capacity of the boats themselves to supply with electric power. Lightweight torpedo tubes with air-circulating carbureted gasoline heaters of the commercial *Southwind*-type can be installed, but at a cost of approximately 700 pounds additional weight per torpedo. "Tearable" muzzle covers, similar in principle to those supplied for destroyer torpedo tubes can be supplied. The efficiency of the gasoline-burning heaters for PT boat torpedo tubes has not been established with the same degree of reliability as that of the steam heaters on destroyer tubes, but they are considered effective down to 10° F. or possibly a little lower. As in destroyers, torpedoes in PT boats should receive whatever antifreeze and lubricant-pour-point depressant treatment is prescribed by current instructions.

In submarines temperatures in torpedo rooms less than 30° F. are not expected under ordinary conditions, and no special cold weather procedures are therefore prescribed for steam torpedoes.

In aircraft the water carried by torpedoes Mk 13 should be replaced by alcohol in proportions required to prevent freezing and approved pourpoint depressants should be added to the oil. For aircraft drops when a Mk 13 torpedo will be chilled during flight, provision can be made for heating during its drop by throwing the water trip at the time the torpedo is loaded into the aircraft. This will result in the torpedo starting to run "hot" as soon as it is released from the aircraft (instead of starting to run "cold" at that time and lighting off only when it strikes the water, as when the water trip is operative). This procedure involves the risk of destroying the torpedo by disintegration of the turbine due to overspeeding while in the air (the prevention of which is the function of the water trip mechanism). It is suggested, however, that the acceptance of this risk may, under certain circumstances, be preferable to declining an opportunity to attack. The time required to accelerate a Mk 13 torpedo turbine by a hot run in air to a speed which will cause it to fly apart will vary among individual torpedoes and is not closely predictable, but generally speaking may be taken as 6 to 10 seconds. Dropping heights should be chosen accordingly.

In stowage and transit steam torpedoes are supposed to contain neither water nor high pressure air. Consequently no permanent injury to properly drained steam torpedoes is to be expected from exposure to cold while stored or in transit except by the very remote possibility of mechanical injury of closely associated parts of dissimilar metals due to differential contraction. Although this possibility exists theoretically in various torpedo mechanisms, no actual case of damage definitely due to such cause has as yet been reported.

Electrical torpedoes (Mk 18 and 28).—These torpedoes are used only by submarines and, therefore, are not expected to be exposed, while reliable running is required, to temperatures below about 30° F. The best data now available on effects of various electrolyte and seawater temperatures down to 30° F. upon the range and speed of Mk 18 torpedoes is shown by figure 5–7. Similar data are not yet available for torpedoes Mk 28, but, for an approximation, the following may be applied:

Starting with an assumed average speed of 20.92 knots to 1,000 yards run at an original battery electrolyte temperature of 82° F., reduce average speed by 0.20 knots per each additional 1,000 yards run and also by 0.03 for each degree Fahrenheit which the original electrolyte temperature is less than 82° F. These figures are based upon average sea water temperatures, and take no account of further speed reduction to be expected at lower sea water temperatures, for which data are not yet available. Electrical torpedoes introduce only one factor affecting cold sensitivity which is not also present in the steam torpedoes, previously discussed, i. e., wet-plate storage batteries. These batteries, in torpedoes Mk 18 and 28, are lead-acid types, quite conventional except in minor particulars, and offering no exception (as regards cold weather hazards and treatments) to instructions of the Bureau of Ships for similar types under the cognizance of that bureau.

Electrical dry-cell batteries.—The dry-cell batteries which are used in torpedoes, mines and depth charges generally lose potency, or capacity, at low temperatures. Few will operate at all as low as 0° F. Others will become impotent as high as 30° F., depending apparently upon their "shelf life." Shelf life appears to depend upon other factors than lapse of time alone, notably upon the degree of chemical action allowed to occur before placing the battery in use. Fortunately, chilling of a dry cell to the point of loss of potency (or even to much more extreme temperatures,

e. g., minus 65° F.) does not prevent recovery of potency when the cell is rewarmed, except in the unusual cases where mechanical damage is done by freezing of the electrolyte. Where it is necessary that batteries of this type operate within the range 30° to 0° F., they should be selected from those of shortest shelf life available and from those which have been most continuously stowed under refrigeration (40° F. or lower), since such refrigeration slows chemical action and thereby lengthens shelf life. Unfortunately, no practical, nondestructive test is available from the results of which the remaining power-life of any dry cell at any instant can be predicted.

Mines.—The only known points of vulnerability of mines (as such) to chilling are mechanical impairments due to frosting or icing and loss of potency of dry cells. Since naval mines are not called upon to function in ambient temperatures less than about 30°, since a mine will eventually assume the temperature of the water in which it is laid, and since neither icing nor loss of battery power due to cold are apt to cause *permanent* disablement of a mine, special cold weather procedures applicable to mines are not prescribed. There are still circumstances under which a mine may fail to be properly laid on account of effects of cold. For instance, heavy icing of the flight gear of an aircraft-carried mine could prevent the opening of the parachute. No practical means for preventing such a casualty are provided at this time. On the other hand, no report of the actual occurrence of such a casualty has as yet been received.

Depth charges.—The mechanical or hydraulic features of depth charge arming and firing devices are rendered inoperative by icing, such as may occur either prior to firing from a projector or launching from a release track (by the freezing of rain or spray), or after water entry (due to chilled metal parts). Current instructions as to filling chambers with authorized antifreeze solutions should be followed when cold weather is expected. Depth charges having influence fuzes depend upon electrical dry cell batteries and are subject to the limitations discussed under that heading in subparagraph (3) above.

Torpedo tubes.—Special care required under cold weather conditions includes the following:

In destroyers multi-barrel, deck-mounted, trainable tubes (which covers all in general service use at the present time) are supplied with steam radiators of a "saddle-bag" type for heating torpedoes carried in the torpedo tube barrels. (See under "Steam

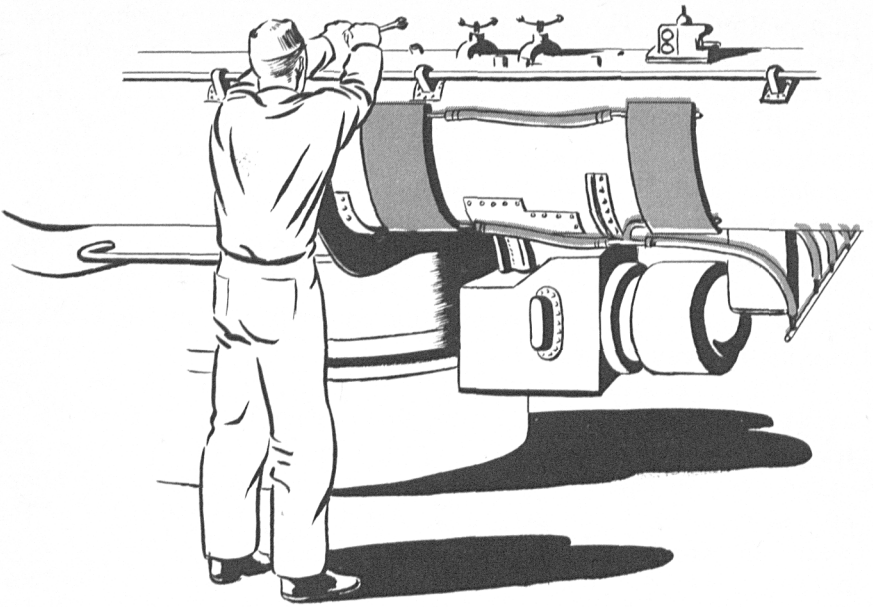


Figure 5–2.—Saddle-bag type heaters are used on torpedo tubes.

Torpedoes.") It is presumed that these heaters also have some small effect upon the temperature of torpedo tube mechanisms which are in immediate contact with torpedo tube barrels (such as tripping latches, gyro and depth setting gear boxes, etc.). However, this effect has not been determined experimentally and must not be counted on to afford protection against icing at any freezing temperature. Also, these same torpedo tube heaters have a single steam coil running around the lower edge of the training circle cover.

The purpose of this coil is to lessen the probability of ice closing the gap between fixed and trainable parts. Although this purpose is undoubtedly served to some degree, again no experimental data exists on the exact extent of protection afforded (although due to the relatively low heat capacity of the single steam coil, and to the low reliability of the present heater as a whole, the extent of such protection must be presumed small). Electric-hydraulic training gear drives on these tubes are powered by an electric motor of nominal 3 horsepower rating which can deliver 6 horsepower at peak load for at least 5 minutes. If current instructions as to use of hydraulic fluid suitable for cold weather operation are followed, 5 minutes operation of this motor (which is direct-

connected to the hydraulic pump or "A" end), before attempting to train the tube, should churn and warm the hydraulic fluid sufficiently so that full training torque can be developed.

If current instructions for replacing ordinary lubricants by cold weather lubricants in the training gear drive have been properly followed, the tube should then train properly at minimum open deck temperatures unless obstructed by solid ice. All shafting between units of gyro and depth-setting mechanisms are protected from the weather by gasketed housings and therefore will not normally be fouled by ice. It should therefore be practicable to set torpedo gyro and depth at minimum open deck temperatures if current lubricating instructions have been properly followed, and the operating handwheels or cranks and the setting spindle extensions are not fouled or obstructed by solid ice. Firing mechanisms on the tubes, and particularly the manual firing gear, are especially susceptible to becoming inoperative from cold weather effects. Impulse chamber doors, firing hammer rods, firing handles, and other exposed mechanical parts must be kept free of ice where it would impede their necessary motions. The manual firing cables, being housed in flexible tubing, will not be interfered with physically by ice, but current instructions for the disassembly and cleaning of these cables, for the flushing of their housing tubes, and for the subsequent filling of these tubes with

Figure 5–3.—Depth charge racks are highly vulnerable to icing.

lubricant suitable for cold weather, *must* be followed if these mechanisms are to remain operative at minimum open deck temperatures.

In addition to the precautions suggested by the foregoing, and to painstaking observance of all current instructions for cold weather lubrication and the use of generally applicable procedures for the removal of ice from deck installations, it is recommended that covers be left in place until the last practicable moment before action. The reason is that ice may usually be loosened more readily from a substance which is inherently pliable than from a rigid object; also because, as a last resort, covers may be forcibly ripped off "ice and all" more readily than ice can be removed from a cold metallic surface.

Make sure that torpedoes can be fired during an expected period of heavy icing, by training the tubes, before heavy icing immobilizes them, to a bearing where they can be safely fired and where the muzzle will be best protected from heavy icing. It is true that when tubes are so trained, torpedo stop tension links may be more apt to break than when the tubes are trained fore-and-aft. But, on the other hand, these links are designed to be at least twice as strong as necessary to withstand the accelerations for normal rolling up to 45° from vertical.

In PT boats torpedo tubes may be either fixed or trainable, depending upon hull arrangements. None of the tube mechanisms are expected to become inoperable from chilling alone. However, these tubes are fired by compressed air, and the impulse tank air pressure should be kept under observation and boosted if it drops below the proper firing pressure due to cold. If trainable, the training gear, due to its lack of housing, exposed location, and features of construction (threaded training nut moving along a threaded training rod) is the most vulnerable to icing of the tube mechanisms.

Other features (common to both trainable and fixed tubes) likely to be rendered inoperative by icing are:

1. The system of levers and connecting rod by which the torpedo starting mechanism is operated from the torpedo stop housing.
2. The local firing handle and the pilot-valve stem extension with which it engages (located at the main firing-valve).
3. The firing valve air vent holes (located in the stop mechanism housing).

Where tubes cannot be fired unless trained out, it is suggested that they be so trained before this is prevented by actual icing,

when action is anticipated under icing conditions. It is obvious that with the tubes trained out caution must be exercised in coming alongside a wharf or another craft. Although the difficulty is realized, it is considered probable that the other features vulnerable to icing (besides the training gear) can be kept operable as long as personnel can safely stay on deck.

In submarines, while at sea, no special cold weather procedures are indicated for torpedo tubes except the observance of current instructions for lubrication. However, if under any conditions a submarine is to be moored upon the surface, with no heat supplied to torpedo rooms during freezing weather, a small appropriate quantity of alcohol should be added to the fresh water which is carried in the firing valves as a hydraulic buffing fluid.

Torpedo launching racks.—It is not considered practicable to keep torpedo launching racks of present design reliably operable under icing conditions.

Torpedo release gear in aircraft.—This material is under the cognizance of the Bureau of Aeronautics.

Mine launching gear.—In submarines, mines are launched from torpedo tubes, the operation of which in cold weather is covered in a preceding paragraph. In surface craft, mine launching gear is under the cognizance of the Bureau of Ships. In aircraft, such gear is under the cognizance of the Bureau of Aeronautics.

Depth charge release tracks.—Depth charge release tracks and associated mechanisms are not apt to be rendered inoperative by chilling alone, but are highly vulnerable to icing, due to exposed location and large surface extent. With present designs and locations, no practicable means exists for keeping them reliably free from ice in freezing weather when they are continuously wetted by rain or spray. Even with wide distribution of electrical spot heating it has been found impractical to keep all parts operably clear of ice without heating other parts to a degree which is dangerous due to the explosive contents of the depth charges themselves. Use of warm sea water as in freeing decks of ice is one possibility.

Depth charge projectors.—This material is classified with gun mounts.

Depth bombs (aircraft).—Depth bombs are classified as ammunition.

AMMUNITION

Ammunition should be kept in protected storage, at temperatures not below the safe values where specified. Gun propellants should be maintained above 0° F. Navy service rocket motors are

subject to the same regulations as smokeless powder as far as storage temperature limits are concerned. Rocket and jato safe firing temperatures are stencilled on the rocket motor or jato unit. These temperatures are the actual temperature of the rocket motor or jato unit, and not necessarily the weather air temperature. If the temperature of the jato unit has been permitted to fall below the safe temperature, it is no longer safe for firing at any temperature. All aircraft gun ammunition is satisfactory for firing at round temperatures down to minus 65° F. (See OP 1480 for instructions on operational use of VT fuzes.)

DEMOLITION EQUIPMENT

The following precautions should be observed in the use of demolition equipment under cold weather conditions:

1. The safety fuse must be handled with care to prevent cracking. If practicable, it should be carried under a coat so that it will be warmed by body heat. It should not be carried uncoiled, since a fuse uncoiled in cold weather cracks readily and becomes unusable.

2. Friction tape loses adhesion in temperatures below 35° F. Taping caps to primacord becomes difficult and could result in misfires. For this reason, detonating cord initiators Mk 2 should be used exclusively during cold weather for securing caps to primacord. Equal quantities of caps and initiators should be carried to avoid the use of tape.

3. Detonating cord, reinforced (primacord) has been found to be deficient in cold weather in that its gummy property is lost and knots cannot be drawn tight. A good tight knot will spring open the instant hand pressure is released. This can be avoided to some extent by substituting the clove hitch for the girth hitch. The former binds on itself and does not depend upon the primacord's cohesion to keep the knot tight. Square knots are not dependable and the clove hitch should be substituted whenever possible.

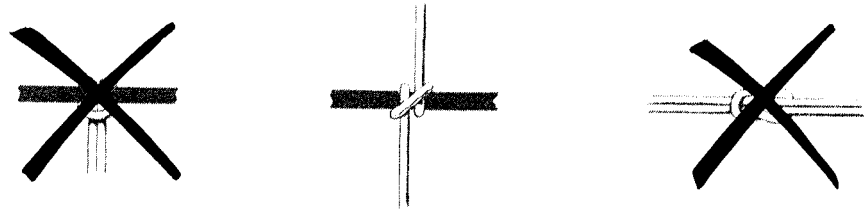


Figure 5–4.—Substitute clove hitch in primacord.

4. Electric firing cable is easily cut by rock fragments and difficult to mend in the cold. In addition, the wire loses some of its flexibility.

5. The galvanometer should be carried under outer clothing since its cell is affected by low temperatures.

6. In the use of the fuselighter, waterproof, M2, care should be taken to avoid failure due to faulty pin pulling. When hands are covered with gloves, there is a tendency not to pull the pin perpendicularly to the fuselighter, thereby breaking off the tip end of the pin leaving the striker locked in position.

7. Tests indicate that the demolition firing device Mk 13 Mod O may tend to fire early when exposed to low temperatures.

8. The Mk 135 Mod O charge composition C–3 loses much of its plasticity at 30° F. after a period of 10 minutes. It can be hand molded at that temperature only after working it for several minutes by bending the Mk 20 charge across the knee. Even after this treatment, the explosive is lumpy and difficult to mold in cracks.

GOING HOME PRECAUTIONS

Lubrication.—Cold weather lubricants or diluted lubricants should be replaced with the specified service lubricant as soon as conditions permit. Where a lubricant classed for extreme emergency cold weather use has been applied (in accordance with section X of NavOrd OD 3000), the emergency lubricant should be removed and relubrication should be accomplished with the specified lubricant immediately after leaving the cold weather area. Substitute lubricants listed for extreme emergency use generally provide less protection against corrosion and are easily removed by water spray or wash and, having lower viscosities, are deficient in desired lubrication properties as normal temperatures are approached.

Cooling systems.—Normal coolants may be substituted for the antifreeze solutions when convenient after returning to normal temperatures.

Hydraulic power transmission systems.—In general, it will not be necessary to replace the power transmission fluid 51F21(Ord) when returning to normal temperature areas. However, if greater leakage is experienced at higher temperatures, 51F23(Ord) may be substituted for the 51F21(Ord) fluid. A flushing is not required when changing unless the fluid to be drained, or the operation of the system indicate that dirt, sludge, or other impurities are

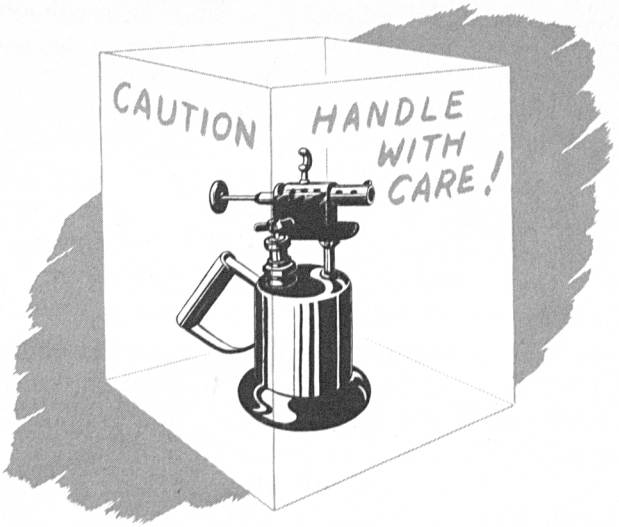


Figure 5–5.—Torches should be used with extreme care.

present. See NavOrd OD 3000 for instructions on power transmission fluids.

DE-ICING AND ANTI-ICING METHODS

1. Instructions for ordnance optical equipment are contained in the applicable ordnance pamphlets.

2. Information on anti-icing for underwater ordnance equipment is included earlier in this chapter.

3. No special methods have been developed to date for de-icing and anti-icing of other ordnance material. For topside equipment, protective covers should remain on the equipment as long as practicable. For removing accumulations of ice from metal shields or from protective covers, when special de-icing and anti-icing means have not been provided, washing with warm water is the preferred method. Chipping or use of torches should be done with considerable care to avoid damage to equipment. Never do this work in the presence of ammunition. Use of unauthorized chemicals to remove or prevent formation of ice on ordnance equipment is prohibited. The quickest way to remove ice is by applying heat. As experience is gained in cold weather operations, means for solving this problem either by adaptation or provision of heaters and improved coverings will be evolved.

SUMMARY

Major sources of difficulty in cold weather operations are due to:

1. Congealing of non-cold-weather lubricants.
2. Formation of ice on exposed equipment. When practicable, accomplish cold weather relubrication prior to entering low temperature areas (0° F. and below, in general).

Avoid an excessive amount of lubrication.—On return to normal temperature, cold weather lubricants or diluted lubricants should be replaced by the specified service lubricant as soon as conditions permit. Where a lubricant classed for extreme emergency cold weather use has been applied, the emergency lubricant should be removed, and relubrication should be accomplished with the specified lubricant immediately after leaving the cold weather area.

Protective covers should remain on exposed equipment as long as practicable. For removing accumulations of ice from equipment or covers, when special de-icing and anti-icing means have not been provided, washing with warm water is the preferred method. Periodic exercising of equipment may be necessary to insure ability to function satisfactorily.

Condensation, which sometimes forms inside of shields, should be wiped off as frequently as practicable, and should not be permitted to drop or seep into electrical equipment.

It may not be found practicable, particularly for some types of present service equipment, to provide automatic means for elimi-

Figure 5–6.—Avoid excessive lubrication.

nating all difficulties arising during cold weather operations. It will be expected that ships' crews will adapt themselves to such conditions and take any steps necessary and practicable to keep ordnance equipment operating satisfactorily.

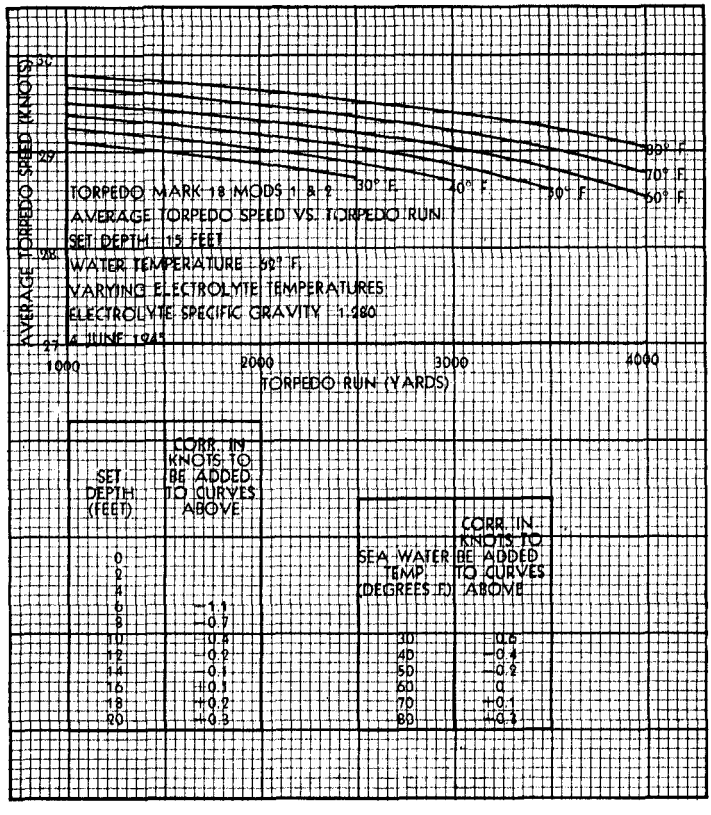
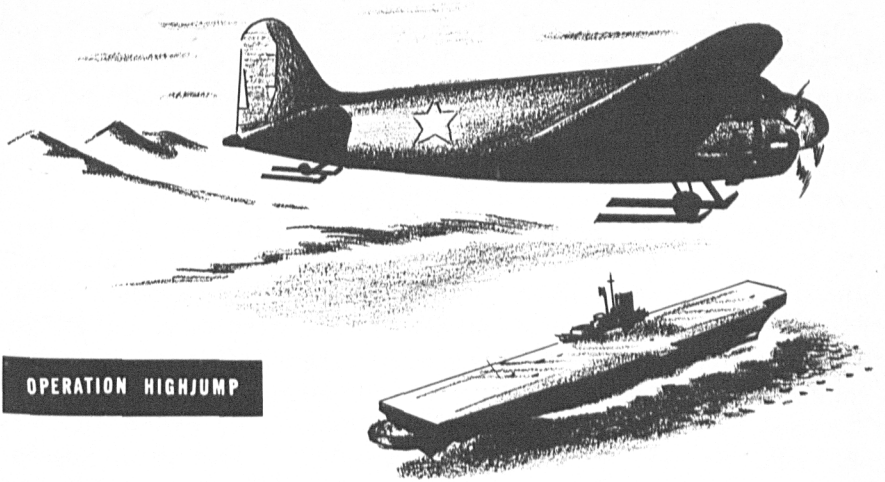


Figure 5-7.—Mark 18 Torpedo Run vs. Average Speed



CHAPTER 6

AIRCRAFT OPERATIONS

"The great circle route from any point in North America to any point in Asia which combines (1) shortest flying time (2) maximum flight over land (3) minimum flight over water is a great circle route through the Arctic."—Owen Lattimore.

The possibility of exploring polar areas by air occurred to aviators as a natural result of their experience with aircraft. The advantages of this most modern mode of travel early became quite apparent to others in polar work. It remained to be seen whether aircraft could be operated under the extreme weather conditions found in polar regions. In 1923, the Bureau of Aeronautics, in official recognition of this fact, requested and received Presidential approval to send the new rigid airship *Shenandoah* to the Arctic. It was planned to base the airship on tenders at Nome, Alaska, and from that point carry out mapping and reconnaissance flights. If it seemed feasible, these flights would be followed by one over the top of the world to Spitsbergen where another tender would be ready to receive the airship. Torn from her mooring mast in a heavy gale at Lakehurst in January 1924, some doubt of the ability of the airship to withstand the arctic storms arose, and, although advance units were already on the way to Alaska, the entire plan was cancelled.

In that same year of 1924, the Bureau of Aeronautics gave Lieutenant Davidson leave to act as aviator for Amundsen, who then was organizing a polar expedition. Because funds could not be raised to finance the exploration, it was cancelled and Davidson, who had already left the bureau, lost his chance to be the first to demonstrate the usefulness of aircraft in polar exploration.

In September of the same year, the U.S.S. *Richmond* took her UO–1's up to Greenland where the pilots made reconnaissance flights in search of suitable landing areas for Army pilots when making an around the world flight. In the next year, one of the *Richmond* pilots, Floyd Bennett, was in the aviation party, under command of the then Lieutenant Commander Richard E. Byrd, attached to the MacMillan expedition bound for exploration of the north Greenland coast. This expedition sailed from Boston on 17 June aboard the *Peary* and was joined by the *Bowdoin* at Wiscasset, Me. After a voyage of 3,000 miles, the expedition on 1 August reached its base at Etah.

The three Loening amphibians (OL–2) were removed from their crates on deck and floated ashore. They were beached without mishap and by the 4th were assembled and ready to fly. Between that date and 20 August, when the end of the arctic summer made it necessary to withdraw from the area, a total of 76 hours of flying time had been logged. Extensive flights over Ellesmere Island and Grinnell Land covered altogether about 30,000 square

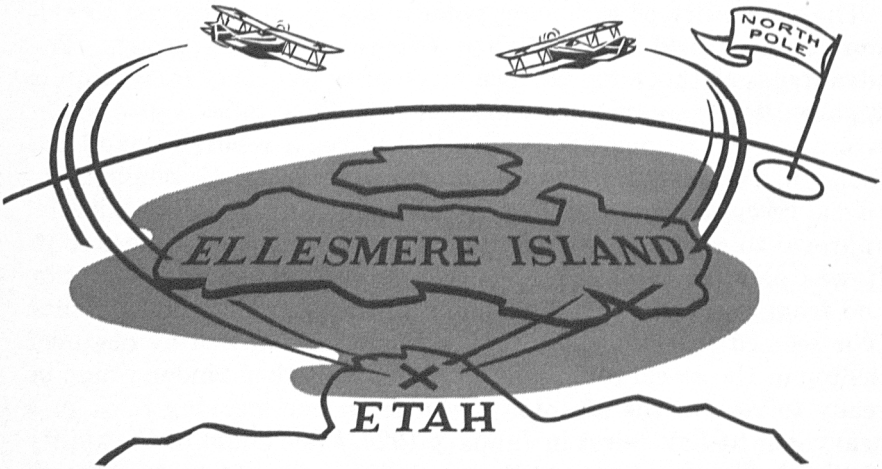


Figure 6–1.—Loening amphibians over Ellesmere Island.

miles of territory, much of which was previously unexplored. During this time only one forced landing occurred and that in open water only a short distance from base.

AIR STRATUM

Several peculiarities of arctic flying were observed. Over the Greenland ice cap a comparatively warm stratum of air was encountered at 7,000 feet and a bitterly cold one at 11,000. As was expected, the navigation problem was different from any before experienced. With the magnetic pole to the south, and the magnetic forces weak, such strange things happened to the magnetic compass that it was practically useless. At times it indicated east for all headings of the plane, and on one occasion Byrd made good a course of 254 true by setting a compass course of 012. The induction compass was found to oscillate slowly after take-off, but a steady course was flown and it soon settled down and gave fairly accurate indications. Byrd was more enthusiastic about the sun compass, devised for the expedition by A. H. Bumstead of the National Geographic Society which, although useful only in clear weather, was extremely accurate.

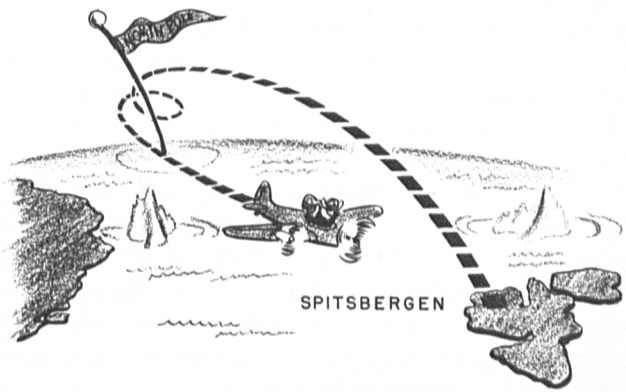


Figure 6–2.—Bennett & Byrd fly over the North Pole.

These experiences proved to Byrd the advantages of aircraft in polar exploration. Not long afterward he and Floyd Bennett, while on leave from the Bureau of Aeronautics, flew the *Josephine Ford,* a three-motored Fokker monoplane, from Spitsbergen to the North Pole. In this historic flight, most of the navigating was

done with the instruments tried out the year before at Etah. On 9 May 1926, they flew over and around the Pole, the first to reach it by air, and on the return flight hit Spitsbergen "on the nose."

In the same month, the Italian aviator Umberto Nobile accomplished what the Bureau of Aeronautics had planned in 1923 when he piloted the airship *Norge* across the Arctic Ocean to Alaska. Amundsen and Lincoln Ellsworth were passengers on this flight. Two years later, Byrd was off on the first of his expeditions to the Antarctic. Here again, he demonstrated the usefulness of aircraft in polar exploration.

All of the foregoing were expeditions intended to reach or explore geographic areas. While much was learned of the aviation requirements, the primary purpose was exploration rather than experimentation. They demonstrated clearly the feasibility of operating aircraft under extreme conditions, and the Navy became interested in a further study of the requirements. For one thing, the aerial mapping of the territory of Alaska was on the agenda and because much of it lies above the Arctic Circle, polar weather conditions would be encountered. For another, aircraft carriers would be more effective if they could operate in any kind of weather, and to increase their effectiveness it was necessary to learn the nature of the special equipment and operating techniques which would be required to meet conditions.

The first carrier to conduct such tests was also the Navy's first carrier, the U.S.S. *Langley* (CV–1). For the first 10 days of December 1931, she operated in the area between Cape Cod and Bar Harbor, encountering temperatures below freezing on 6 of the 10 days. Flight operations with O3U's and F3B's were conducted on 4 days, but tests of flight deck gear operation, engine starting apparatus, and cold weather clothing for pilots and deck hands were made every day. This test brought out clearly how little was known about cold weather requirements and emphasized the need of much preliminary work before another practical test could be made advantageously.

It was not until the winters of 1935 and 1936 that a carrier was again used, this time the *Ranger* (CV–4). Even before she was commissioned, plans were being made but in December 1934 when the shake-down trials revealed the need for additional work on her gasoline tanks, the plans were called off and the *Ranger* went into the yard instead.

This left her air group free to conduct some of the tests ashore which were carried out during January and early February 1935.

Several flights were made from Norfolk to Hartford and Buffalo. During these flights various types of starting equipment were tested under the operating conditions of cross-country flight in temperatures reaching as low as 2° F. and most of the time below the freezing point. In these temperatures it was found that pyralin cockpit enclosures and celluloid computer discs cracked; that enamel tended to crack and peel, while factory finishes and aluminum paint did not; and that radio receivers lost some of their sensitivity. Various types of flight clothing were again tested and recommendations for reducing its bulk and improving its design to meet practical requirements were made. Covers for protecting the aircraft from cold and frost were also tested and improved. Perhaps, the greatest effort went into testing starters and heaters because once the engine was started it was really not much more difficult to fly in low temperatures than in higher ones.

CARRIER TESTS

New information was applied in the laboratory tests which followed and in the preparations which began immediately for another carrier test the next winter. On the basis of meteorological data, Cook Inlet in Alaska was selected as the spot most likely to produce the temperatures and weather required and on 22 January 1936 the *Ranger* arrived in that area with 23 planes aboard. Tests of arresting gear, clothing, and engine starting were to be continued, and in addition the general operating efficiency of the carrier was to be measured.

For over a week the weather was mild and did not drop below freezing until 3 February. From that day until the 12th, the average temperature was 17° F., and the lowest of 10° F. was recorded on the 10th. During that time starting and warm-up operations were conducted daily and 5 test flights were made. The lowest average air strut temperature for these flights was 1.4° F. and the lowest recorded was minus 7.6° F., at 16,000 feet. One blizzard was encountered which lasted 32 hours, and, although there was a 40-knot wind across the deck, the snow covered it in drifts to about 2 feet.

Tests of engine starters showed that much progress had been made. The commanding officer of the *Ranger* reported that this problem could be considered solved down to temperatures of 10° F. Launching and recovery of aircraft was affected only by the condition of the deck. Deck gear worked well under all conditions, but clearing the deck of snow and ice took time. The out-

standing problem encountered was icing and frosting on the wings and the packing of snow and freezing ice over external fittings of the planes. Because planes could not be launched in these conditions, they had to be cleaned and only by taking them back to the heated hangar where they could be dried before being again exposed to cold air, could they be put in condition for safe flight. Once they were in the air following a normal take-off, no unusual cold weather effect was noted.

Tests of carrier operating efficiency were felt inconclusive because a full complement of planes was not aboard. The difficulties of removing ice and frost, although time consuming, were quite simple with only a few planes because there was always space to move them about, but to do this with a full complement of aircraft would be a different matter. Generally this test showed that cold weather in itself was no hazard to flying or to carrier operations. It was apparent that the cold, bad weather experienced in the area along with its snow, ice, and frost, made operations a difficult and serious problem and that additional study of the problem was required.

Before other tests could be made, the Navy became fully occupied with the duties of neutrality patrol. The next time carriers operated in cold weather areas, it was not on an experimental basis but under the conditions approaching war. After completing shakedown trials in 1940, the *Wasp* (CV–7) was assigned to the Atlantic Squadron and became responsible for patrol of coastal waters from Nova Scotia to the Lesser Antilles. During the winter of 1941, this ship operated in the North Atlantic encountering severe weather in which difficulty resulting from the formation of ice crystals in the gasoline system caused delays in refueling planes. The *Long Island* (CVE–1) operated off Argentia during the month of January 1942. Both experienced difficulty with ice and frost on the wings and caked snow and ice on the control surfaces of the aircraft. It could be removed only by sending the planes down to the hangar deck. No difficulty was experienced with the deck and arresting gear.

COLD WEATHER OPERATION

From April through July 1943, the *Ranger* came in for some more cold weather while operating in the Argentia area. In October of that year she appeared on the other side of the Atlantic, launching strikes on German shipping at Bodo, Norway, just above the Arctic Circle.

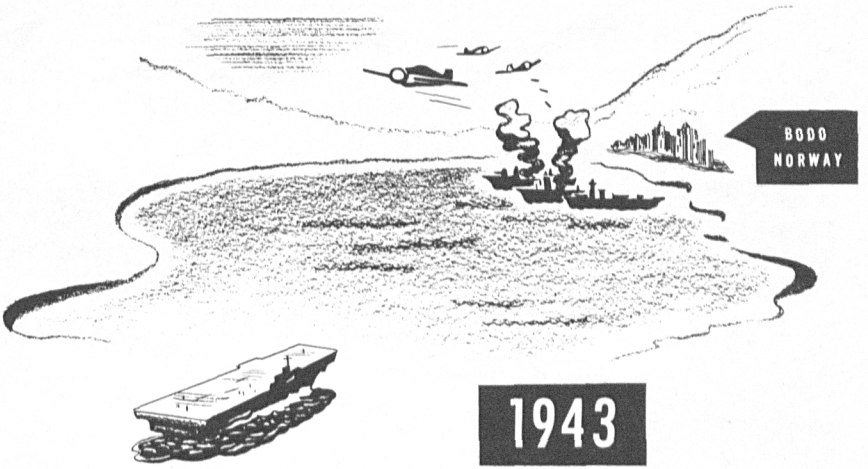


Figure 6–3.—Ranger attacks German shipping—1943.

In May of the same year, the *Nassau* (CVE–16) provided support for the landings on Attu in the Aleutians. This was not cold weather flying, but it was bad weather, perhaps worse than any encountered in the Atlantic. After the initial bombardment, the *Nassau* provided the only air support for the landings and operated as close in as 10 miles from shore to take full advantage of any break in the heavy fogs characteristic of the area. Even then, only 179 sorties were flown and weather was responsible for the loss of 8 planes and 6 pilots.

These were the only instances during the war in which our carriers operated under what can be considered cold weather conditions. Through most of the war period patrol planes operated from bases in the Aleutians, Argentia, Greenland, and Iceland. The war was barely over when the Bureau of Aeronautics issued its technical note on "Instructions for Cold Weather Operations of Naval Aircraft." These instructions informed naval aviators that most of the difficulties of cold weather operations were those encountered on the ground, aboard ship, and on the water before and after each flight. Once the plane was in the air the problems were almost identical to those encountered in warmer climates.

OPERATION FROSTBITE

Early in the next year (1946) carrier tests were resumed during a cold weather cruise designated *Operation Frostbite*. The U. S. S. *Midway* (CVB–41) and three destroyers made up the task group.

Figure 6–4.—Operation Frostbite.

The task group attained highest north at the 63rd parallel in Davis Strait on 9 March. Later the ships hauled to the south to find the low temperatures required and operated at about the fifty-eighth parallel until 21 March. Temperatures between 14° and 41° F were encountered. The lowest mean temperature for a given operating period was 17°. The following planes were aboard the *Midway*: 27 F4U–4, 25 SB2C–5, 2 F6F–5N, 2 F6F–5P, 2 TBM–3, 1 F8F–1, 1 FR–1, and 1 helicopter (HNS–1). Air operations during the period were limited by snow, rain squalls, and high seas. However, flights were conducted whenever weather permitted. As a matter of precaution against delay in rescue, all flights were contact, with aircraft kept within gliding range of the carrier. Training and exercises in rendezvous, glide bombing, break-up, and strafing were carried out.

As a result of the cruise it was concluded that normal carrier operations can be conducted at temperatures above 25° F. with a relatively untrained crew and air group, and that, as training and experience accumulated, operations at lower temperatures would be possible. Snow removal equipment, including tractors equipped with snow plows, was adequate to clear the deck within two hours, only half the time required by the *Ranger* 10 years before. In all respects, the operation showed that much had been learned and

that it was bad weather, rather than cold, that interfered with flight operations. Much was learned of the problems of predicting weather in the higher altitudes and of the effects of nearby sea, land, and ice areas, and cold and warm water currents on the weather in the Davis Strait, in particular.

The importance of the arctic regions in future strategy was becoming more apparent. In cooperation with the Army Air Forces and the Royal Canadian Air Force, other expeditions were outfitted and sent to learn more about meeting the operating requirements of these areas. Toward the end of 1945, a chain of Loran stations was established in northern Canada for experimental purposes and to aid the units participating in *Operation Musk Ox.* This operation covered a series of expeditions during 1945 and 1946 in which Canadian and United States military services participated. Although it was primarily a ground force experiment, naval observers were along to study how naval survival gear stood the test of a long overland trek.

Operation Nanook, a joint United States-Canadian project, took place from July to September 1946 for the purpose of adding to the knowledge of weather and navigational conditions, the collection of scientific data, and to provide training for personnel. In Task Force 68 was included the tender U. S. S. *Norton Sound* (AV–11) with PBM's aboard. These planes were used to spot breaks and leads through the ice and made long reconnaissance flights over Greenland, the Canadian Arctic, and contiguous sea areas. Flying along and beyond the coast of the northernmost land areas, the navigators found the electric gyrocompass a reliable instrument.

Late in the same year, the Navy launched *Operation Highjump,* the largest expedition ever to undertake polar exploration. It was in effect a continuation of *Operation Nanook* and carried the same task designation, Task Force 68. Preliminary planning was done during Nanook by the men in command, many of whom were transferred to the new operation. Objectives for Highjump included: training of personnel and testing equipment, testing the feasibility and developing the techniques for establishing, maintaining, and utilizing air bases in the high latitudes; adding to existing knowledge of the geography of the Antarctic.

Forces finally assigned consisted of 13 ships including the U. S. S. *Philippine Sea* (CV–47), U. S. S. *Currituck* (AV–7) and U. S. S. *Pine Island* (AV–12). Aircraft assigned were: 6 R4D's carried on the deck of the carrier, 6 PBM's aboard the tenders, 2 J2F, 2

SOC, 1 JA, and 2 OY–1, and 6 helicopters, HO3S and HOS. Naval and Marine personnel totalled over 4,700 officers and men, and others included Army and civilian observers and representatives of the press and radio. This force was absent from the country from December 1946 to June 1947. During this time about 1 month, from 19 January to 23 February, was devoted to support and operation of a temporary airbase ashore on the continent of Antarctica at Little America.

Equipped with a combination wheel and ski landing gear, and with jato, the R4D's took off from the carrier deck without difficulty. Once ashore, and with the wheels removed, no serious problem was encountered in operating from atop the Ross Barrier. The planes of the force rolled up a total of 650 hours of flight time much of which was spent in mapping and photo-reconnaissance. With the R4D's concentrating on flights over the continent and the PBM's over the coastline, over 70,000 photographs were taken of 1,500,000 square miles of territory and 5,500 miles of coastline. The area covered was equal to about half that of the United States and the coastline distance almost equal to the combined Atlantic, Pacific, and Gulf coasts of our country.

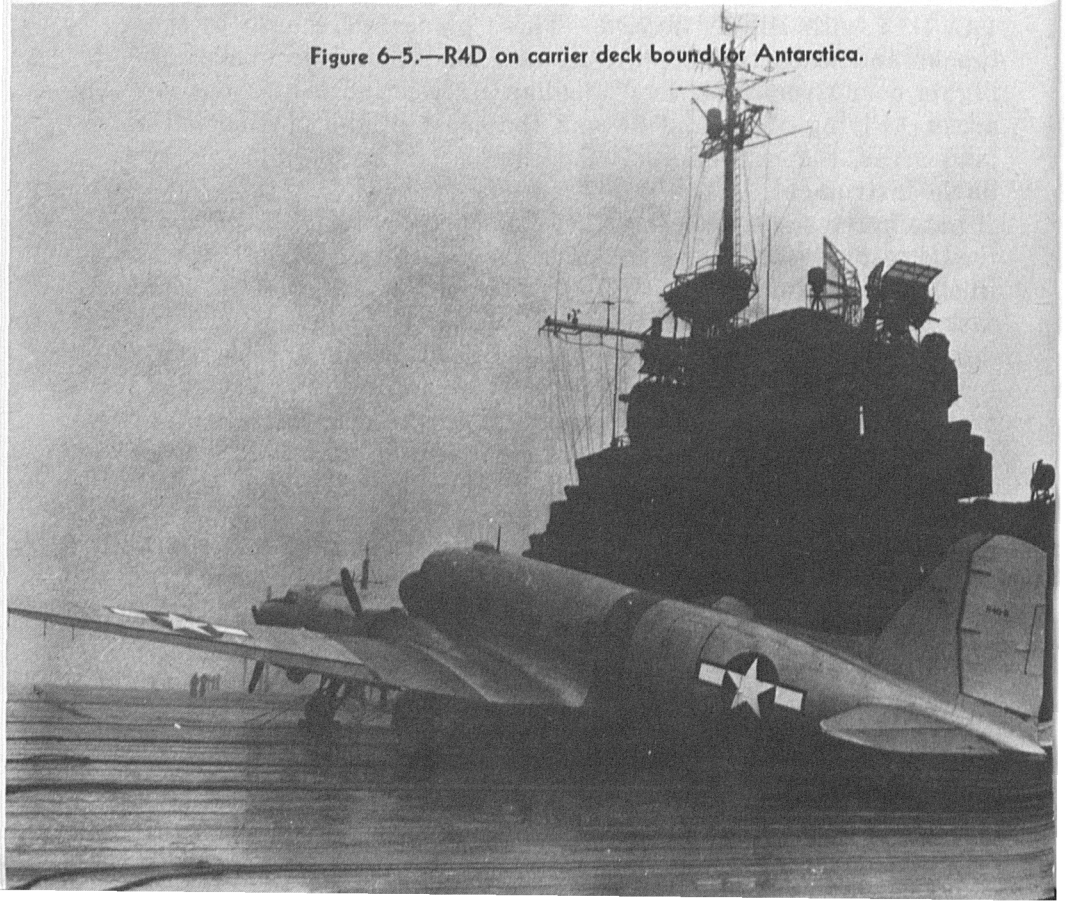


Figure 6–5.—R4D on carrier deck bound for Antarctica.

In an early reconnaissance flight, a PBM was caught in bad weather and crashed, killing three of the nine passengers and crewmen aboard. Two helicopters were lost in water landings without injury to personnel, and one PBM was swept overboard in heavy weather. One R4D had an engine failure and one PBM developed a gas leak requiring feathering of the propeller, both shortly after take-off. In each case normal landings were made. Except for these two minor incidents, there were during the entire period no accidents caused by engine or materiel failures.

These operations provided further proof that polar flying is feasible and possible. Experience once more bore out the fact that the problems of operating aircraft are not basically different from those encountered during the winter months in northern United States, although lack of adequate facilities for service and repair make the problem more difficult. Greatest hazards to flight were low visibility, ice, and frost. Ice was generally present in the clouds particularly at their base. With de-icing equipment only partially effective, the only safe solution was to avoid the clouds. High winds drifted the surface snow and made visibility poor, blending the terrain with the sky and wiping out the horizon so that the general effect was like *flying in a bowl of milk.* The absence of radio aids and lack of well charted landmarks added to the navigators problem, already complicated by weak magnetic forces.

During the same year two much smaller expeditions were sent to the opposite ends of the earth. From July to September 1947, Task Force 68 composed of three small ships operated in the Arctic in cooperation with the United States Weather Bureau, to train personnel, obtain scientific data, and specifically to supply weather stations established in the Canadian Arctic area. Task Force 39, composed of two ice breakers with helicopters aboard, was sent to the Antarctic in December 1947. For about 2 months of the period from December 1947 to March 1948 it operated in and about the antarctic ice pack, gathering scientific data and adding to our knowledge of pack conditions.

The following summer another expedition was sent to the Arctic. From July to September 1948 Task Force 80, composed of the cargo ship *Wyandot* with the icebreakers *Edisto* and *Eastwind,* operated between the islands to the north of Canada. With the cooperation of the Canadian Government and the United States Air Force, this naval task force made further surveys of the area and conducted studies of arctic conditions. The main purpose

of the expedition was to re-supply the jointly operated weather stations in the area and to locate sites for others to be established later. The four helicopters (HTL) operating from the ice breakers logged over 200 hours in reconnaissance and utility flights and the two RB-17G's of the Air Force conducted 25 flights, the longer ones averaging from 8 to 9 hours. As an indication of how much past experience has helped in solving the problem of the Arctic, two of the three ships of this force penetrated beyond the eighty-second parallel, farther north in the Western Hemisphere than any ship up to that time.

Interest in polar areas continues. Experience through the years has resulted in the accumulation of much useful knowledge of the requirements of air operations in cold weather. Through all the tests we find the greatest difficulties being encountered on the ground, although developments of better equipment have done much to simplify them. Cold weather flying cannot even yet be looked upon as a routine matter, but as in all flying, once the dangers and difficulties are known, proper precautions can be taken to overcome them. The continuing program of investigation and testing is directed toward this end.

MATERIAL ASPECTS OF NAVAL AIRCRAFT OPERATIONS

Since its first aviation expedition with 3 Loening amphibians in 1925, the Navy's experience with aircraft operations in polar and other cold weather areas had broadened to include all of the heavier-than-air types—carrier aircraft, seaplanes, land planes, and helicopters. Each type of aircraft has had its peculiar prob-

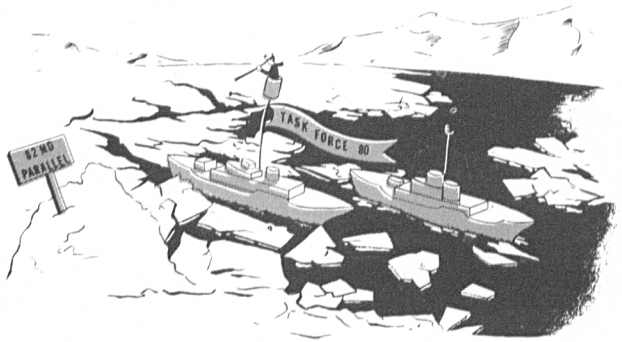


Figure 6–6.—Task Force 80.

lems arising from differences in operating base; yet many problems of flight have been found common to all types. Experience throughout these operations has shown that, while none of the problems was simple, the most serious occurred between flights while the aircraft were on the ground, water, or carrier deck.

Another of the lessons learned, is that the problems encountered on the more recent operations are not essentially different from those met during the earliest ones. The changing character of operations has developed new aspects of old problems. New problems arise only as the field of operations is extended, new techniques are tried, or as new equipment is introduced. Generally, the development of new techniques and improved equipment has changed past problems rather than eliminated them. They remain factors to be considered and guarded against.

Navigation has been outstanding among the problems common to the operation of all types of aircraft. Although enough has been accomplished in this field to make accurate navigation possible, there is still much to be done before it can become as relatively simple as over well charted and marked areas. Polar navigation is still no field for the novice. In the 1925 expedition to Greenland the unreliability of the magnetic compass for aerial navigation was well demonstrated. A compass of the induction type—that is, one which depends on the current generated in a coil revolving in the earth's magnetic field—was found much superior to other types of aircraft compasses, and entirely satisfactory for local flights. For longer flights it was necessary to navigate by the celestial method. Later Byrd found the sun compass accurate and adaptable to the problem. Since this type of navigation required clear weather to take observations, it was necessary to rely on dead reckoning most of the time. The problem had been simplified with the development of the gyrocompass, its adaptation to the peculiarities of the polar regions, and the development of the grid method of plotting courses in the higher latitudes. Radar has been used with success, but is not reliable under certain conditions. Such radio stations and loran networks as have been established have made the air navigator's work easier. There remains a lack of well marked charts. Although this deficiency will be corrected as exploration and air mapping increase knowledge of the various areas, the scarcity of prominent terrain features will make it impossible to provide detailed charts for only the more important and strategic areas.

ADVERSE WEATHER CONDITIONS

Adverse weather restricts flying in any area. In polar areas it is especially necessary to be familiar with conditions which may affect flight operations. Storms are violent and likely to come up with little warning. Icing conditions almost always exist and as long as de-icing equipment remains only partially effective, icing can be overcome best by avoiding those altitudes and areas in which it is most likely to occur. Extensive fogs and low overcast are natural products of polar areas. At times, dry surface snow raised by violently high winds tends to obscure the ground and the horizon, making visibility poor and obliterating all references to surface and sky. Any of these conditions make flying dangerous, but a thorough knowledge of the hazards involved coupled with observance of proper cautions will help to reduce much of the mystery of arctic flying.

Cold weather operations require more careful inspection of aircraft, closer adherence to prescribed procedures, and more frequent servicing than comparable operations under more moderate climate conditions. Closer attention to detail is necessary not only because of the greater strain placed on the aircraft by low temperatures, but also because of the fatal consequences likely to follow mechanical or material failure in flight. Low temperatures increase the difficulty of performing these tasks and also increase the time required to do them. The amount depends largely on the protection afforded personnel and the kind of facilities furnished them.

The use of external power units, engine heating and starting apparatus, wing and engine covers, ice retardents, and other materials and gear used to protect aircraft for flight. For R4D's used in Operation Highjump this time averaged 3 hours per large plane. This factor combined with the rapidity with which weather can change often results in the loss of flight time when the weather clears unexpectedly and in additional work for the ground crews when the weather closes in. Due to short periods when flying weather can be considered good, there is a major problem in maintaining operational readiness of aircraft to quickly take advantage of all such opportunities.

OTHER COLD WEATHER PROBLEMS

Other problems of cold weather operations for all types of aircraft require provisions for the comfort of flight personnel with adequate cabin heat and proper flight clothing, selection of sur-

vival and emergency gear along with instruction in its proper use, and the provision of rescue services.

One of the most difficult and persistent of all the cold weather problems is starting the engine. Discussion of the merits and efficiency of equipment designed to simplify and facilitate engine starting fills the reports of cold weather operations. Practically everything has been tried. More effort has been expended on this one phase of cold weather operations than on any other. As the result of past efforts, equipment has been developed which is considered reliable for use in temperatures as low as 0° F. Below this temperature a real problem exists, particularly in the case of carrier aircraft and helicopters on icebreakers.

Two phases of the engine starting operation are normally required. First, prior to each shut-down of the engine, dilution of the entire lubrication system must be accomplished. This is done by introducing raw gasoline into the system and diluting the oil to the extent required. By reducing the viscosity the oil will not congeal after the engine has been allowed to cool. Then, to simplify and ensure starting, the engine must first be warmed to a temperature where it can be turned over easily. Ordinarily this is done by the application of heat from some external source and by heating the oil either in the crankcase or before it is poured into the engine. With the help of additional power the engine is then turned over and primed to start combustion. Once started, the engine is warmed up slowly under its own power. Although the general types of equipment and methods used have remained the same, the specific items have changed considerably.

HEATING DIFFICULTIES

In tests aboard the U.S.S. *Langley* in 1931, difficulty was encountered with all methods of heating the engine known at that time. Live steam was unsuccessful. The oil immersion heaters then provided required 2½ hours at full heat and 3 hours at half-heat to bring cold lubricating oil up to operating temperature. Inertia starters performed satisfactorily only at temperatures above freezing. Below freezing external types were required although their performance was somewhat deficient. Some of these difficulties came about because much of the equipment was provided without proper fittings and in some cases was incompletely assembled or of poor quality, but others undoubtedly came from lack of previous experience and adequate preparation. Tests

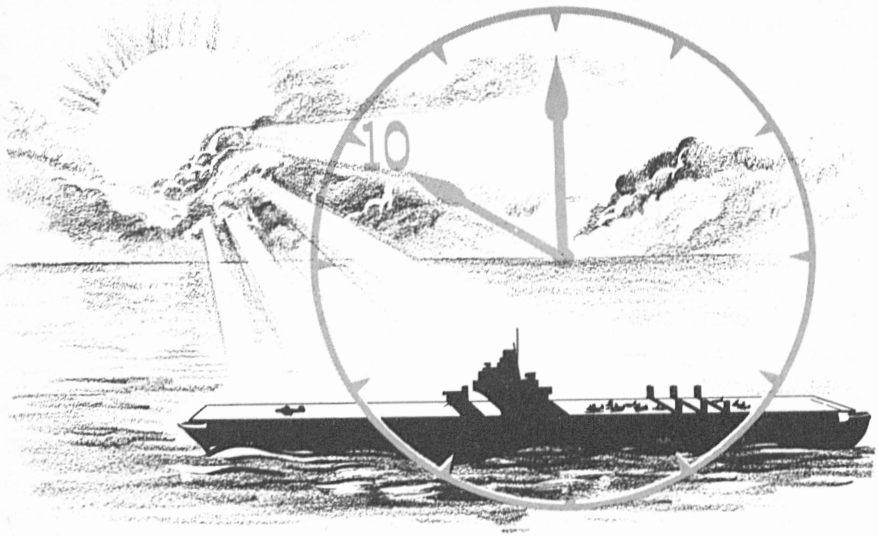


Figure 6–7.—Ranger waits for 1000.

conducted by U. S. S. *Ranger* squadrons ashore in 1935 and aboard ship in 1936 were more promising in this respect and when completed were the most extensive carried out before the war.

In tests ashore and aboard ship, the equipment used seemed reliable for temperatures down to 10° F. Even in the short interval between these tests, however, there was some change and improvement in equipment. In cross country and other tests ashore during cold weather, propane heaters installed in the aircraft were used for preheating. These proved to be unsatisfactory because their location inside the fuselage did not permit adequate air circulation and added what was felt to be unnecessary weight to the aircraft. In the shipboard tests detachable heaters were used with success but some question arose as to the need for preheating in carrier operations.

The use of propane as a primer was discarded in 1936 in favor of a gasoline priming system developed in the cold test room at the Naval Aircraft Factory. This system, using spray nozzle jets to each cylinder, was controlled from the cockpit. It was entirely satisfactory and considered to be one of the most significant developments of the early tests.

Oil immersion heaters were found in both tests to reduce the period of warm-up and a new special oil proved an excellent cold

weather engine lubricant. This was too early to know the results of contemporaneous Army experiments with oil dilution, but it was recommended that further work in the development of cold weather oils be postponed until more about oil dilution was known.

ENGINE COVERS

Engine covers, serving the dual purpose of protecting the engine from the cold and of retaining heat during preheating, were considered unsatisfactory in both tests. They were poorly fitted and, with the electrical heating inserts used aboard ship, were bulky and hard to handle.

Starters of the cartridge and inertia types were used. A large number of mechanical failures made the cartridge type unsatisfactory in the shore tests. However, experience aboard ship was the opposite. Inertia starters lacked power and external units were required to turn over the engine. In both tests it was agreed that external units were essential for cold weather starting.

With this experience, laboratory tests continued the development of equipment and when carriers operated in cold weather areas during the war they were equipped with types quite similar to those in use today. Herman Nelson preheaters were used on board the *Ranger* and the *Wasp* and found superior to the Colvinex electric type. The York nacelle type was under procurement at the time and later this also proved to be reliable. A Waukesha generator powered by a gasoline engine gave satisfactory performance as an auxiliary power unit for engine starting.

Cold weather operating experience was summarized shortly after the war in BuAer Technical Note 84–45. This note contained instructions for handling aircraft aboard ship, aircraft operations, maintenance of aircraft and equipment, and protection of personnel. The following paragraphs summarize briefly its information on engine starting equipment.

EXTERNAL HEATING

The time required to preheat an engine depends on several factors—air temperature, size of engine, output of heater, force of wind over engine, efficiency of engine cover, and amount of oil dilution—but it will usually require ½ to 1 hour's time.

The application of external heat is unnecessary in temperatures down to zero if the engine oil has been properly diluted.

ENGINE HEATERS

The York heater has an electric motor operating a fan which furnishes the air for combustion and circulates the heated air. This unit has an output of about 75,000 B. t. u. per hour. It has an integral fuel tank and can be mounted either on deck, on the ground, or on the engine nacelle.

The Herman Nelson heater has a single cylinder 4-cycle gasoline engine operating the fan and has a rated output of about 250,000 B. t. u. per hour. It is rather large and bulky but is the most satisfactory, completely self-sustained heater in use by the Navy. Because it supplies uncontaminated air it is also suitable for heating spaces occupied by personnel, provided the exhausts have an outside duct.

EXTERNAL AUXILIARY POWER

Some such unit is a "must" for cold weather operations, and should be an auxiliary power plant rather than a battery cart. Suitable types are: Homelite C–10 unit (a combination power plant and battery cart), the Waukesha, Onan, and Homelite (unit without the battery cart).

After the war a series of tests showed the general reliability of Technical Note 84–45 for maintenance and operation of aircraft under cold weather conditions. In March 1946, tests of engine heaters were conducted aboard the U. S. S. *Midway*. They were found unnecessary in the temperatures encountered in that operation—a low of 14° F. The Herman Nelson heater was found reliable but too large for use on a carrier deck. In this respect the York type was more useful but not sufficiently rugged for heavy duty. Three types of auxiliary power units were tested. Of these the Homelite C–10A was considered best for flight deck use because of its ease of handling. The Waukesha and the Hartmann gave satisfactory performance but were too heavy and unwieldy to maneuver easily on the flight deck. Insulated engine covers were heavy, bulky, and hard to handle. This condition was made worse when the covers absorbed the moisture resulting from melting ice and snow. A plywood cover designed to fit over the cowling entrance was equally efficient and much easier to handle. Oil dilution systems proved satisfactory. Inertia starters proved unreliable but direct cranking starters were adequate in all respects.

Experience on Operation Highjump furnished further proof of the above. Herman Nelson heaters operated perfectly under

all conditions ashore and aboard the seaplane tenders. Auxiliary power units of the Lawrence type were satisfactory for use aboard the tenders, but the Homelite failed to provide enough power to start the R4D engines. Engine covers of the insulated type were unsatisfactory because of their bulk, and again plywood covers proved to be a simpler and more useful design. The standard Navy-issue lube oil 1100 series gave good performance under all conditions, and made oil dilution, for the PBM's, unnecessary.

Later operations confirmed the above findings. As more types of aircraft were used certain problems occurred in the operation of one type that did not occur in others. These will be discussed briefly by aircraft types in the following paragraphs.

CARRIER AIRCRAFT

From the first carrier cold weather test with the *Langley* in 1931 through the year 1948, only 3 scheduled carrier tests have been made. Together these covered a total of 35 days but only 15 days on which air operations were conducted. The year 1949 began with carrier tests in each of the first 2 months. In the Atlantic, the U. S. S. *Palau* conducted operations off the coast of Maine, the area used by the *Langley* in 1931. In the Pacific the first test in which more than one carrier participated took place. This was *Operation Micowex*, an amphibious operation in the Aleutians in which carrier aircraft from one CV and two CVE's provided support for the attackers and were opposed by shore-based air from naval and air force bases.

The first tests emphasized the performance of equipment rather than the capabilities of the carrier and its air group. Later tests included the objectives of training pilots, squadrons, and personnel, and the determination of carrier efficiency. No tests were conducted with a full complement of aircraft on board the carriers. Although the wartime operations of two CV's and one CVE in the North Atlantic were carried out with normal complements, experience brought out the fact that the additional demands placed upon handling and servicing personnel made a reduction of aircraft complement desirable if air operations were to be efficient. This was also the conclusion of the British during wartime. There is good reason to believe that it will be some time before cold weather operating techniques will develop to the point where a full aircraft complement can be used under prolonged bad weather conditions coupled with temperatures below 15° F.

Carrier flight operations can be divided into three phases:

1. Preparation of planes for flight.
2. Launching and recovery.
3. The operation of planes in the air.

The effect of cold weather on the first phase depends upon several factors already discussed, but basically it depends upon the severity of the weather conditions. The second phase is affected principally by the condition of the flight deck and the extent to which snow and ice impair operations particularly in the recovery phase. If the problems of the first two phases are adequately met, few difficulties will occur in the third phase.

PREPARATION OF PLANES FOR FLIGHT

The problem of starting engines is the same, whether aboard a carrier or ashore. The outstanding problem initially encountered by the *Ranger* in 1936—the removal of ice, snow, and frost from the wings and control surfaces—was still only partially solved 10 years later. Aboard the ship, no means were found to clear ice from the surface of a plane quickly and effectively or to prevent its formation. Cockpit covers did not keep snow out of the cockpit and away from the interior controls. Wing covers were not used and snow, ice, and frost stuck to the wings and became packed into the fittings. The solution adopted was to send the planes to the comparatively warm hanger deck where they could be thoroughly dried before being again exposed to the cold. Unless planes were absolutely dry, frosting took place when they were returned to the flight deck.

Early war experience confirmed the conclusions of the *Ranger* tests. Freeing the propeller, wings, and control surfaces was particularly difficult with a full complement of aircraft because free use of the hangar deck and easy movement of aircraft was impossible. When the *Ranger* operated in the North Atlantic during the April-July period, take-off was usually delayed until about 1000, by which time the sun's rays had raised the temperature enough to assist in ice and snow removal.

On Operation Frostbite, the first cold weather carrier test after the war, enough difficulty was encountered with wing covers to lead to the conclusion that they were impractical for carrier use. It took 15 men 20 minutes to install a cover on one wing in a relative wind of 30 knots. Covers were dangerous to personnel in high winds and caused some damage to antennae bases and wires during installation. Discarding them was considered de-

sirable because Kilfrost, a standard stock de-icing fluid, applied with a spray gun and wiped off with rags, was found satisfactory for removing light ice.

The increased importance of the hangar deck in cold weather was brought out in these tests. It was also realized that in order to maintain its heat it was necessary to exercise constant care in the use of elevators and in the number of times curtains and doors were opened. On the *Midway* cruise, high seas caused additional difficulty. Water, shipped in during heavy weather, made the hangar deck so slippery that at times plane handling was impossible. More time was spent keeping it in condition than was spent removing ice and snow from the flight deck.

It was also on the *Midway* that the problems resulting from condensation first gave concern. The moisture in the air of the warm hangar deck condensed on the cold metal of planes brought down from the flight deck, froze hard when the planes again returned to the flight deck. Such moisture could be removed from the exterior or exposed parts but on inner parts such as the aircraft machine guns, it could be removed only by complete dismantling. The freezing of this moisture inside the weapon produced many stoppages and when the weapon did function its action was noticeably slow. In view of these difficulties, tests were conducted aboard the *Palau* in January 1949. However, no problems were encountered despite the fact that aircraft were purposely left on deck at all times except for about one-half hour when they were taken to the hangar for condensation purposes.

There were numerous examples of the unexpected troubles which arise in cold weather. Aboard the U.S.S. *Long Island* gasoline tanks, fueled to capacity on the flight deck, overflowed when the planes were sent to the hangar deck—a natural result of the expansion of a fluid in a warmer environment. The U.S.S. *Wasp* was troubled with serious delays resulting from the presence of ice crystals in the ship's gasoline system which blocked the lines during refueling. It was believed that heavy moisture-laden air, drawn into the system during the pumping down process, condensed in the piping and when the fuel was pumped out was carried up to the exposed parts of the system, collecting and freezing in the strainers and meters. On one occasion on the *Ranger* test in 1936, steam from the ship's whistle condensed and froze on the cold metal aircraft wings. On another, spray thrown up by a turn in heavy seas coated the ship's radio insulators causing fail-

ure of the transmitting system and making it impossible to communicate with the aircraft.

All of these increased the time required to prepare the aircraft for flight and caused delays in launching. The extent to which they may be expected to affect air operations is unpredictable. From experience to date it is only possible to state that it will be less on clear, cold days than on days when the cold is combined with inclement weather.

LAUNCHING AND RECOVERY

The safe and efficient operation of aircraft is impossible until the flight deck is skid proof and free of ice and snow. Plane handling is slowed down by an icy deck. Keeping the carrier deck clear and ready for air operations is not particularly difficult but it requires a ready crew, the use of foresight, and a knowledge of climatic conditions combined with accurate weather reporting and forecasting.

Keeping snow off the flight deck is one of the problems. The *Ranger* ran into a blizzard which lasted 32 hours. Although there was a 40-knot wind across the deck, snow covered it in drifts to about 2 feet. Using brooms, shovels, scrapers, and hot blowers and torches, 40 men cleared the deck in 4 hours. Because the time required to clear the deck delayed launching time, and the residue of ice and snow slowed the movement of servicing and handling personnel, it was suggested that the possibility of installing heating units under the flight deck be given some thought.

Experience with delays of this sort was repeated during the early war period in operations in the North Atlantic. It was shown, however, that the extent of delay could be reduced by foresight and particularly by maintaining work parties to keep the deck clear during a storm rather than clearing it after the snow had fallen or ice had formed following its compaction. Rain at temperatures around freezing turned to ice as it hit the cold deck and was much easier to clear before its thickness was built up.

Time required to remove snow from the deck during this period was still more than air operations in wartime could allow. The *Wasp* made use of a plow attached to the tractor to push loose snow over the side but the *Long Island* did it all by hand. Its equipment was 20 each of snow shovels, ice scrapers and heavy bristle brooms, and 12 wooden snow pushers. These, with the help of hot blowers and torches from the shop, were considered sufficient to handle the job.

Figure 6–8.—Cleaning snow off carrier deck.

The validity of the earlier proposal for heating the flight deck was shown on the *Midway* operation in 1946. Although no heating units were installed, the relatively high coefficient of heat transfer of her metal flight deck was of material help in preventing the formation of ice and in melting snow, in temperatures as low as 20° F. The *Midway's* snow removal equipment included rattan and wire rotary brooms and plows attached to tractors, and the usual hand implements. Attaching the rotary brooms to tractors required from 3 to 4 hours. With this equipment, the deck was cleared of 3 inches of snow in 2 hours, using 2 tractor sweepers, 2 tractor plows, and crews for 50 hand brooms and 50 shovels. Wire brooms were more effective than rattan for removing light ice from the deck but were destructive to the skid-proof covering on the flight deck. Rock salt, although satisfactory for removing ice and melting snow, was picked up by propeller blast and blown about over the deck endangering personnel and lodging on aircraft where it caused excessive corrosion. Four hundred pounds scat-

tered on the snow from the barriers aft was enough to keep it soft and slushy for 12 hours in subfreezing temperatures. Grease was superior to Kilfrost or rock salt in removing ice from sunken tie-down pad eyes.

In January 1949, the *Palau* had no difficulty in clearing the decks of 2 inches of snow in 1½ hours using the Hough sweeper and scrapers, shovels, chippers, and brooms. The task was made simple by keeping all unnecessary personnel off the flight deck after a snow because the hard ice which formed in footprints could not be removed by the sweeper and had to be chipped by hand. Excessive wear on the sweeper indicated the advisability of adding a spare to the section "W" allowance for CVE's.

Deck gear has operated well under all conditions. This was true in the *Ranger* tests when flight deck equipment such as wires, sheaves, yielding elements, barriers, and elevators functioned properly and were easily cleared in spite of the fact that ice was intentionally formed on much of the gear by pouring water over it. It was also true during the war period when experience showed that this gear could be kept in operating condition more easily than the flight deck could be kept clear. Catapult tracks were kept covered when not in use. Canvas covers protected the barriers and conventional plate covers the yielding elements when flight operations were not being conducted. Because working units were under the flight deck, arresting gear and barriers functioned satisfactorily even when the exposed parts were heavily iced. Fluid in the unprotected arresting gear units was changed to 70 percent Prestone and 30 percent distilled water. The catapult also operated satisfactorily but it was necessary to increase the opening of the catapult pump regulator orifice valve one-quarter turn to insure automatic action.

Experience aboard the *Midway* was similar. There was no difficulty with the operation of catapults and arresting gear. Canvas covers over the barrier sheaves were satisfactory and metal track covers without rubber gaskets provided adequate protection for the catapult. Steam and salt water from the fire hose cleared the ice from the tracks.

The *Palau* test resulted in similar findings. The amount of ice forming in the catapult tracks offered a problem only when it became so thick that the retraction of the shuttle would not break it up. On this test such ice was cleared by hand or with rock salt, a method which delayed flight operations from 3 to 4 hours.

Yielding elements were kept clear of ice by leaving them in a raised position during nonoperating periods.

Plane handling was slowed down by icy deck conditions and the effect of extreme cold on personnel. Aboard the *Palau* it was found that the comfort of the personnel was helped by proceeding downwind during most of the time the crew was at flight quarters. On another ship it was found advisable to double handling crews when slippery deck conditions combined with high winds to make the task difficult. During the war turnbuckles and sister hooks were found a stronger and faster means of securing planes than the conventional manila lines. This was also considered the best method aboard the *Midway* but the task group commander considered the time required for installation and removal excessive.

On the basis of the *Midway* test it was concluded that normal deck procedures were applicable to cold weather but that more time had to be allowed to carry them out. Time was necessary because pilots needed about 15 minutes to don cold weather clothing, planes took longer to warm up, and plane handling was slower. Condition Thirteen could be maintained satisfactorily in the weather and temperatures encountered. With heat maintenance on the forward half of the deck load, heaters, engine covers, and heater boards could still be removed from the remaining planes in time to launch them on schedule. To maintain Condition Eleven, planes on the catapult required periodic turn-ups, and pilots had to depend on electric boots and gloves for warmth. It was found that spotting two planes on the catapult and the remainder on the hangar deck was the best method. This reduced the number of pilots exposed to the discomfort of sitting in a cold cockpit on the flight deck and planes on the hangar deck would be warm enough for immediate launching when brought up to the flight deck.

OPERATION OF PLANES IN THE AIR

No cold weather effect was noted in air operations conducted from the *Ranger* in 1936 tests nor were any particular difficulties met during wartime operations. Operation Frostbite was the first of the carrier tests in which training was given as a specific objective. With a complement of one bomber and one fighter-bomber squadron, about half the normal complement, flight operations were conducted whenever weather permitted. Although all flights were restricted to within gliding distance of task group units, practice in rendezvous, break-up, glide bombing, rocket attack, and strafing followed normal procedures.

Difficulties in the air were also minor in the tests carried out by the *Palau* in 1949, and in Pacific tests, experience was no different. Strikes in support of the amphibious landings were made on schedule whenever it was possible to take off from the deck. Although there was some difficulty with the functioning of rockets, there were no difficulties with operating aircraft attributable directly to the effects of cold weather.

SEAPLANES

Tests of seaplane operations in cold weather areas have been limited and on each test fewer difficulties were encountered than might be expected. The feasibility of operating from the water was shown on the first naval aviation expedition to the Arctic in 1925. This expedition, equipped with three amphibians, found that landing sites would require an excessive amount of labor to build runways smooth enough to be safe for use. Operations from the water on the other hand required only the location of open spots adjacent to a beach suitable for the erection of temporary maintenance and servicing facilities. Because these were readily found, all operations during this expedition were conducted from the water. When only minor difficulties were encountered, and these mainly a concern over damage likely to occur while the planes were moored at their buoys, the possibilities of the seaplane for operations in the higher altitudes appear to be good.

This promise was not fulfilled, however, by wartime experience. The operations of patrol planes in Iceland during the winter months were hampered by ice. It became necessary to exchange the seaplanes for land types. As a result of this experience it was standard practice during the remainder of the war to assign either land planes or amphibians to all patrol squadrons sent to high northern latitudes.

The first test of the seaplane in cold weather after the war was with PBM's aboard the tender *Norton Sound* in Operation Nanook in the summer of 1946. It was entirely successful and proved the feasibility of operating from the water in northern areas during the summer months, but the most extensive test took place on Operation Highjump during the antarctic summer 1946–47. This was more than a test of engineering equipment. It was a test of the operating capabilities of the aircraft and the ability of the tender to support them during extensive photographic reconnaissance. Heavy seas and bad weather hampered flight operations, but in 20 of the 68 days on which conditions permitted flights, the

6 PBM's aboard the two tenders demonstrated the value of seaplanes for exploration by completing a photographic survey of almost the entire coastline of Antarctica.

All operations were conducted in the open sea, and as might be expected it was this factor that accounted for most of the problems. This was particularly true of hoisting operations and handling the plane alongside during fueling. The design of the PBM allows a weight not exceeding 46,000 pounds on the hoisting sling limiting the gasoline load to about 700 gallons. Since an additional 2,700 gallons was required on each mission, this amount had to be loaded aboard after the plane was waterborne. Load factor had to be considered during the hoisting-in process, and it was often necessary to defuel. This was done either by bowser boat or by jettisoning. For fueling, the plane was hoisted over the side with the gasoline hose messenger attached to the hull and the plane was held in position with the aid of three rearming boats, one secured to each side of the hull at the bow and the third holding lines to the stern. In calm weather, only the stern boat and bow and wing lines from the tender were required. That caution was necessary in bringing the bow boats alongside while the hoisting sling was attached, was shown on one occasion when the roll of the ship lifted the plane from the water while the boats were still secured to the hull, resulting in minor damage to the plane and to the boats. It was standard practice aboard the *Currituck* to release the hoisting hook before the boats came alongside.

Take-offs and landings were made parallel to the swell with a cross wind of less than 15 knots. Little trouble developed from the ice freezing on the windshield during the run. Although a boat swept the landing and take-off area clear of ice, some adroit maneuvering was necessary to avoid the growlers. Visibility was generally good enough so that only once did a plane strike ice on a take-off or landing, and that resulted in only minor damage. At the end of the operating period when the temperature fell to 14° F., some ice was picked up on the plane during the take-off and occasionally ice froze over the static openings of the pressure instruments at times rendering them useless for as long as 3 hours.

Landings, normal in all respects, were made into the wind, full stall. For glassy surfaces a standard power landing was made using the radio altimeter for leveling off, and on some occasions the pilot was talked down from the ship. No instrument landings were made, but let downs through the overcast followed the instrument pattern and were always controlled to give practice to

the pilots and crew. In this procedure the plane was controlled by SK radar until within 5 miles of the ship after which SG radar took over. Controlled landings required care in selecting a safe orbit and let down path particularly in areas where icebergs were present.

Ice picked up on take-off was not particularly troublesome but frost on the windshield formed soon after the plane cleared the water and continued throughout the flight. It was cleared by opening the windows—to the discomfort of the crew. Heated flight suits were adequate to the situation, but being inadequate in case of a forced landing and therefore impractical for operations over barren areas, the need for an efficient defroster was apparent. Cabin and fuselage heat was inadequate. The Selas system was a continuous fire hazard and the Stewart Warner did not give a good distribution of heat.

Maintenance aboard the tenders was normal, although deck space was at a premium and required careful spotting of aircraft. No special techniques were required by cold weather but the need for having planes ready immediately after the weather cleared for flight made it necessary at times to work maintenance crews around the clock. Engine checks were made at frequent intervals; inspection of fuel and oil systems to prevent accumulation of water and ice was made daily, and paralketone was sprayed over the engines to prevent moisture getting into them and their accessories. One adjustment of control cable tension after arrival in the area was sufficient for the entire period. One engine change was accomplished in 75 hours. The outer wing panels were assembled on one PBM and major damage to wing tips, de-icers, boats, and ailerons were repaired with only minor difficulty.

To date, no other tests of seaplanes in cold weather operations have been made. The conclusions from Operation Highjump indicate that a good training program and detailed planning will ensure satisfactory solution of the maintenance and repair problems that are likely to arise in operations around Antarctica. Thus, they should also be applicable to operations in any cold weather area in the Northern Hemisphere where open water exists.

LANDPLANES

The first extensive test of operations on land was carried out in 1935 by carrier aircraft and was primarily a means of determining the value of cold weather equipment designed for use aboard a carrier. Aside from difficulties accompanying starting

the engines as previously discussed, pilots found that low temperatures introduced few new problems for the operation of aircraft in flight. This conclusion was reached in spite of the fact that one flight encountered a low temperature of minus 22° F., which was lower than any encountered on the carrier tests and only 1 degree higher than the lowest encountered at Little America in February 1947 during Operation Highjump.

Planes normally used by the Navy for operations from shore bases are multiengine patrol planes and transports. Except for experiences during the war, only three tests of such plane types have been made. All of these were conducted on an operational basis with emphasis on the effectiveness with which the aircraft could carry out an assigned mission rather than on how well certain types of equipment functioned in cold weather.

The first such test came in Operation Highjump with R4D's. Transported to the Antarctic on the deck of the U.S.S. *Philippine Sea*, take-off from the carrier was the first of many problems. It was solved by equipping the aircraft with a combination wheel and ski landing gear designed so that the wheels protruded through the skis and carried the plane on hard surfaces such as the carrier deck. On softer surfaces such as snow the skis would carry the weight. Jet assisted take-offs from the carrier and landings on the snow were normal in every respect, but for operations at Little America, the wheels were removed to reduce the excessive drag which they created in flight and in take-offs.

LANDING ON SNOW

At first skis gave the pilots some trouble because of the different handling characteristics on the ground. With skis, a landplane handled on the snow much like a seaplane on the water. Having no brakes the plane was difficult to control particularly during landing, but by landing in the sastrugi alongside the runway, enough resistance was provided to slow the plane and at the same time allow better control. Taxiing was something of a problem because of the tendency for the skis to freeze to the snow whenever the speed was slow or any brief stop was made such as for a turn.

With the aid of four jato bottles, the R4D's could take off from the soft and drifted snow with a gross weight up to 33,000 pounds; however, the preparation of a smooth hard snow runway was necessary to avoid delays. Three flight strips were constructed by using a snow drag to level the sastrugi, compacting it with tractors, and giving it a final smoothing with a flat bottom drag

constructed of pontoons. After completion, the strips were kept in operable condition with drags and bulldozers to level the snow and remove the drifts.

Planes equipped with skis and weighing up to 32,000 pounds did not break through the surface. Take-offs were made regularly with two jato bottles and several flights took off without assistance. An R4D on wheels weighing about 23,000 pounds was taxied on the runway but broke through in the spots not properly compacted. Although the method of construction provided a runway satisfactory for this operation, certain climatic conditions and greater density of traffic would be expected to require a stronger surface, perhaps a superimposed one which would distribute the load over a larger area and reduce wear.

TEST STRIPS

Test strips of this type were constructed with pierced planks. In some sections of these strips, the plank was placed directly on the snow, in others over burlap, and in still others over compacted snow. There was a tendency for snow cylinders to build up through the holes as the planks settled, more apparent on undisturbed than on compacted snow, but it did not appear at all through the burlap. Load tests which included taxiing an R4D with wheels over the various sections, gave varying results but led to the general conclusion that a satisfactory surface was possible only when the supporting power of the snow was increased by compaction or by the action of melted water in hardening the surface.

Several problems appeared in servicing and maintenance. Planes were parked on plank platforms to prevent freezing to the

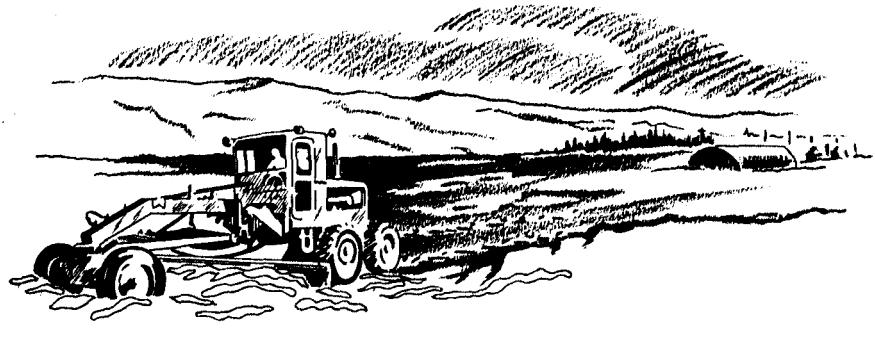


Figure 6–9.—Dragging flight strips.

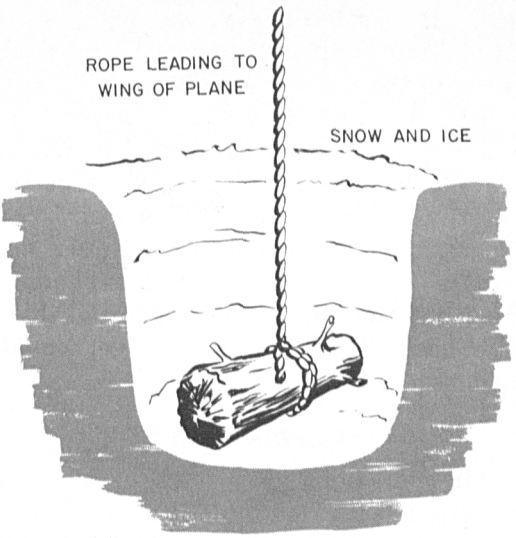


Figure 6–10.—"Deadmen".

snow. The possibility of strong winds made it necessary to keep them tied down at all times. This was done by securing the wing and tail lines to "deadmen" (see Glossary) buried in the snow and anchored by pouring water over them. Fueling a plane with a 1,600-gallon capacity from an 800-gallon truck proved too slow. By installing auxiliary pumps on the forward end of two go-devil sleds, each loaded with 24 drums of gasoline, the process was speeded up. To make use of the separators on the truck, fuel was transferred from the drums to the truck while it was pumping its fuel into the aircraft. The use of two sleds made it possible for one to refill while the other was pumping, thus keeping a continuous supply flowing into the truck. The method of dispensing oil was also changed. The heating system installed on the 500-gallon truck was too slow and the capacity of the truck more than was required. Five-gallon cans with a flexible spout were used instead and proved quite satisfactory.

Maintenance presented no unusual problems principally because the R4D lived up to its reputation for being an easy plane to maintain. It was noted, however, that with low temperature and exposure more men were required to complete a job than would be required in more temperate zones. The progress of work was also noticeably slower. The large wood shelter for working on engines

could not be used. It was too heavy, was equipped with wheels rather than skis making it difficult to move, and it presented too large a frontal area to the wind. A light weight fabric hood was improvised and used instead. It was so constructed that it covered the engine and nacelle being supported in front by the propeller blades, leading back over the trailing edge of the wings, and the lower portion tying to the landing gear strut. After it was erected in place, the duct of a Herman Nelson heater was led inside at the bottom and the heat kept it expanded and warm. This proved a good solution but it was suggested that further improvement, particularly for an engine change, would be possible by the use of a folding framework.

AIR OPERATIONS

Difficulties in air operations were few, the most important occurring in connection with landings. Surface winds over 17 knots picked up the dry snow and made it difficult to judge altitude when coming in for a landing. A GPN unit (ground pulse navigation) was set up and proved a good substitute for GCA. It worked well within 25 miles of the base, but pilots had to use their radio altimeter in a power stall approach for landings. Glare incidence was very high and even when the sun was obscured it was necessary to wear dark glasses or goggles to prevent snow blindness. On good flight days visibility was generally excellent, high mountains sometimes being visible for 150 miles. A most unusual condition, in that it has been noted only in the Antarctic, but a dangerous one, occurred on the so-called "white days" on which snow and clouds blended into one, obliterating all horizontal references and all shadows.

A second test of landplanes was made during an aerial photographic survey of Alaska, but it can hardly be called a cold weather test. It was conducted during the summer of 1948 and covered the southeast portion of Alaska where the temperatures compare favorably with those in the northwest section of the United States. One feature of this operation, was the use of seaplanes tenders to support a shore-based squadron. Although not unique, because it was also used in that area during the war, it was sufficiently effective for it to be repeated in an exercise during 1949.

That was *Operation Micowex* (minor cold weather exercise), an amphibious exercise in which 2,000 Marines were landed in the Kodiak area under cover of carrier aircraft against the opposition of Navy and Air Force land-based planes. Navy aircraft—P2V

and PB4Y—operated from the airstrip at Yakutat and were supported by the tender *Salisbury Sound.*

The tender arrived in the area on 30 January with a deck load of assorted automotive and snow removal equipment and two helicopters. The dock was under about 4 feet of hard packed snow and it took almost nine hours to clear it enough for the ship to moor alongside. Because the "snow-go" had not arrived at Seattle before the departure of the *Salisbury Sound,* only D–6 bulldozers were available for use in clearing the runway for the arrival of the aircraft. When these arrived on 3 February a taxiway from the hangar to the runway with revetments for the aircraft had been cleared of 7 feet of snow but progress had been slow until the arrival of the snow-go on the 2nd. A small rotary snow plow belonging to the CAA had been used to improve the runway and it was noted that this machine required 4 hours to make one trip down the runway.

EMERGENCY LANDING

First aircraft to arrive practiced an emergency GCA landing procedure worked out by the CIC team aboard the tender. The dock at which the ship was moored was nearly in line with the runway at a distance of about 3½ miles. The aircraft were vectored into a long final approach by means of air search radar and when they reached a point approximately 4 miles from the ship, fire control radar was used to make the final corrections in course. Magnetic heading and time to the runway was given to the pilot as the plane passed over the ship. Although the aircraft disappeared from the screen after passing over, the procedure worked well enough to show its possibilities for use in an emergency.

Operations began on 5 February with seven planes flying search sectors. Contact with the attacking force was made on the initial search and in spite of opposition from carrier aircraft, which was reported as being only minor, the surface force was tracked and under constant surveillance for the remainder of that day and the next when the operation was concluded.

An average temperature for the 2 days of 22° F. introduced no difficulty in engine starting and in some cases no preheat or oil dilution was used. Flights were carried out on schedule. Fueling time averaged 2 hours per plane. The support of the tender for operations ashore was entirely satisfactory and the possibilities for using this method for supporting future operations from advanced bases was indicated.

HELICOPTERS

The use of this type of aircraft by the Navy is of fairly recent origin, but few cold weather tests since the war have been conducted without their use. Helicopters have participated in every test since Operation Frostbite. In each they have demonstrated their usefulness. As a mean of close reconnaissance of ice fields they are extremely effective and because of their adaptability to small take-off and landing areas they are without equal for operations from small ships such as icebreakers. In short, they are indispensable for arctic operations.

The helicopter (HNS–1) taken on Operation Frostbite was a U. S. Coast Guard plane intended primarily for use in air-sea rescue. Its operations were satisfactory but several minor difficulties arose which led to the conclusion that this type was too light for carrier use. Its power after engine warm up was not enough to engage the rotor blades on deck when it was exposed to winds of any velocity. This was overcome by placing the plane on the elevator at the hangar deck level and after the rotors were engaged bringing it up to the flight deck. Because the rotor blades were of the nonfolding type it required more stowage space than an SB2C. In addition radio equipment was inadequate.

Seven helicopters of the HO3S, HOS and HNS types were taken along on Operation Highjump. They were used for ice recon-

Figure 6–11.—Helicopter operations.

naissance from the ice breakers and for auxiliary purposes and air-sea rescue from the seaplane tenders and the carrier. Those aboard the seaplane tenders were stowed in the hangar and used very little. None were considered to have proper instruments or radio equipment for antarctic use. Only one, the HNS, was equipped with floats. Personnel assigned had little experience in the care of the aircraft or its engines, and the HO3S's were new and relatively untried. The weight and balance of this type was critical and may have contributed to the loss of the one assigned to the *Philippine Sea.*

Navigation equipment in the helicopters was meager consisting only of a magnetic compass and airspeed meter. Instrument flight was therefore impossible and the weather had to be watched closely. To make this possible radio equipment was installed in all of the craft. An ARC–1 VHF was installed in three of the larger types, an ARR–2 navigational radio was installed in the nose of one, and an ABK-type IFF set was placed in the baggage compartment of another. HOS and HNS types were equipped with SCR 274N radio.

In addition to limited equipment, other drawbacks included the limited range of the craft, which on this operation was 50 miles. Lack of rotor anti-icing equipment was another. Icing of the rotor blades made it impossible for an HO3S to reach the flight deck of the *Pine Island* and it crashed into the water near the ship. Cabin heat was also inadequate and on occasion ice formed on the nose.

Except for these difficulties the aircraft gave satisfactory performance. Starting was accomplished without incident with the aid of the York heater and oil immersion heaters. Maintenance was normal. Constant possibility of carburetor ice was a danger on all flights but careful use of carburetor heat was the answer.

HELICOPTERS ABOARD

Helicopters aboard the ice breakers were parked in position with the brakes locked and were secured to the deck by 3 or 4 turns of 1½-inch manila line or steel tie down cables run from the main landing gear to a deck cleat about 3 feet aft of the wheels. The nose wheel was secured in the same manner, but a small amount of slack was left in the line to permit the wheel to give with the motion of the ship. Under normal wind conditions, rotors were left on with brakes locked and tie down boots over

the tips. When winds of over 25 knots were expected, both main and tail rotors were removed. Aboard the *Currituck* a wind screen was erected which protected the helicopters from damage in winds of over 70 knots.

Four men were enough to handle the planes on deck. With the ship lying to, the direction of the wind was unimportant, but with the ship underway, the big helicopters needed a 10 knot wind within about 30° of the bow to provide a reasonable safety factor. The same wind was best for landing with the ship under way, but sliding in over the deck from a course parallel to the ship was not good practice because of the loss of cushion during the slide. The best procedure was to fly over the deck as fast as possible, then hover for the final approach and landing.

Helicopters were also used by Task Force 68 in the Arctic during the summer of 1947 and by Task Force 39 in the Antarctic during the winter of 1947–48. During the summer of 1948, Task Force 80 took over the task of supplying the weather stations in the Arctic and its experience with helicopters are the most recent on which information is available.

The four aircraft (HTL) operating from two icebreakers, logged 229 flights totalling 213.2 hours. No particular difficulty was encountered until the end of the cruise when the temperatures dropped from a range of 28° to 38° F., to 16° to 24° F. with the dew point consistently within 1 degree of the temperature. These low temperatures were accompanied by fog and high moisture content in the air. Under these conditions ice formed on the canopy, sometimes thick enough to impair visibility. It also formed on the rotor blades but because planes were not kept in the air for long periods under these conditions, no change in flight characteristics was noted. Only one case of carburetor icing was noted, and although it required several adjustments of carburetor heat, it was corrected.

Unless planes on deck were to be launched in a short time, the canopy, engine, and main and tail rotors were kept covered to keep rain and snow from freezing on the parts. When ice formed on the rotor blades, a gust from the Herman Nelson heater, slipped over the blades, melted it immediately and moisture was cleared by wiping the blade with an oiled rag.

ENGINE STARTING

Engine starting was no problem. Auxiliary power units were used occasionally for starting, but generally battery power alone

was enough. From a cold start an engine could be brought to operating temperature in from 6 to 10 minutes.

Navigation was all contact and the planes seldom operated out of sight of the ships. On the few occasions when fog moved in between the planes and the ship, contact was maintained by radio and the plane directed either to the nearest land or back to the ship, being tracked by ship's radar.

Take-off and landing procedure followed normal practice. Helicopters were launched from either side of the deck but the length of the rotor blades permitted only one aircraft to warm up at a time. After being airborne and clear of the ship the aircraft swung into the wind until speed was gained. Landing approaches were made into the wind until over the flight deck at which point the helicopter turned and landed along the fore-and-aft line of the ship. Landing spots ashore were almost always covered with rock and sharp edge shale. On this rough surface the floats gave excellent service. Although several punctures resulted, loss of air did not endanger the landings.

One difficulty with handling trucks was overcome by a substitution of equipment. The trucks were the type used for handling VO-VS aircraft modified to fit into the space between the floats. Screw jacks on the truck, used to raise the floats from the deck, were the seat of all the difficulty. The two jacks on each bar had to be raised or lowered at exactly the same rate or one of them would freeze. When this happened it was extremely difficult to release them and bring them into proper alinement. On one occasion 2 hours was required to mount and secure two helicopters.

The solution was simple. The support bars on the trucks were left in a raised position and four hydraulic jacks of the automotive type were used to raise the helicopter enough to permit the truck to be moved into position. Adjustments of holding clamps and the substitution of wing nuts increased the speed with which the aircraft could be secured and released.

NOTES ON PREFLIGHT PRECAUTIONS

This section deals with the general problems of maintenance and preflight preparation. It does not endeavor to explain in detail the maintenance procedures for each type of airplane. That information is found in technical notes and elsewhere. The effort is made here, however, to briefly list some of the ideas, rules, and precautions which have been found to apply over a period of years.

1. *The airplane.*—At temperatures of minus 15° F. and lower, elevator trim tabs may not operate for as long as 5 minutes after take-off because of the freezing of the drive shaft. Moreover, the trim tabs may not be at zero when the indicator is at zero, and at the high speeds of jet flights, they may cause the pilot to over control. Preheating is therefore essential—the engine, canopy, cockpit, oil system, and elevator trim tabs, in particular.

2. *The engine.*—Cold weather starting is a major problem. Experiments are being conducted with special fuels and high pressure priming to ensure ease of starting. At the present preheating by the application of external heat or by stowage in a warm hangar is necessary. If the proper oil dilution procedure was used at shut-down, apply external heat when outside air temperature is below 0° F. If oil dilution was not used, preheating will be required at temperatures lower than freezing. The use of insulated engine covers or engine closures will facilitate preheating. If the whole engine cannot be heated, concentrate first on the rear accessory section and next on the nose gearing and propeller hub. Jet power plants do not require preheating. Preheating is considered satisfactory only after fluid oil will flow from the Y drain and the propellers can be pulled through with comparative ease. Always use an external source for starting and for running the engine and operating electrical equipment of the airplane on the ground.

3. *Snow, ice and frost.*—Never take off 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 a treacherous stalling characteristic. Sweep hoarfrost and snow from surfaces with a stiff broom. Remove all accumulations of snow in the wings and fuselage. To remove ice, apply sufficient heat to loosen the ice particles and remove them with a brush. It is best not to melt the ice completely as water is likely to get into control surface bearings and freeze. Landing gear, bomb-bay doors, flap operating gear must be freed of ice and snow. Remove snow packed in carburetor intake. Clean off antennas using a light bamboo pole before take-off. Operate all ailerons, elevators, rudders, and trim tabs through several complete cycles. If resistance is excessive, a careful investigation must be made.

4. *Tires.*—If tires become frozen to the ground or flight deck, free them by the use of external heat from ground heaters. In an emergency, they can be freed by over-inflation up to 1½ of normal

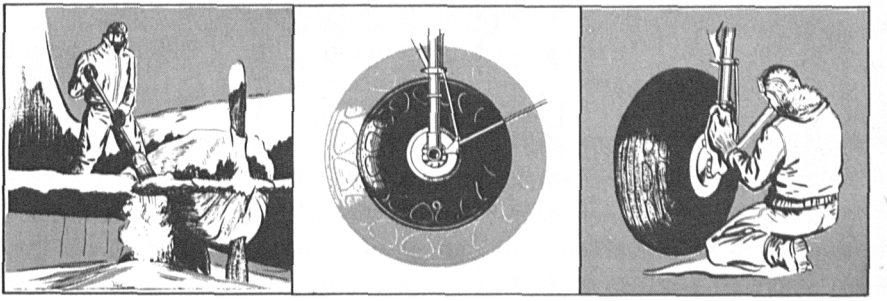


Figure 6–12.—A—Sweeping snow from plane with stiff broom. B—Freeing frozen tires by overinflation. C—Cleaning shock struts.

pressure. Take adequate precautions not to burst tires or endanger personnel.

5. *Shock struts.*—Wipe the shock strut piston tubes clear of all snow, ice, or dirt with a rag soaked in the fluid used in the strut oleo. Use kerosene to clean if necessary. Follow by lubrication with hydraulic fluid. Repeat this procedure on landing. Clean piston rods of actuating cylinders in same manner. Examine shock struts carefully 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.

6. *Drains and vents.*—Check the Y drain and oil tank sump for fluid oil immediately before starting the engines. Do not attempt to start without free oil flow. Take steps to prevent condensation and subsequent formation of ice in the sump.

7. *Engine starting.*—Remove engine covers, ground heaters, and immersion heaters. Pull the propeller through 4 or 5 complete turns before engaging the heater. If this cannot be done with ease, more preheating will be required. Prime the engine in accordance with existing instructions. Be cautious when priming as overpriming will result in fires and engine failures. Start in the usual manner. Use auxiliary power starting. After engine starts, watch the oil pressure. If there is no oil pressure after 30 seconds of operation, shut down immediately and investigate. Keep the carburetor heat control in full cold position while starting in order to avoid heater valve damage due to backfire. Use carburetor heat as soon as the engine is firing regularly to increase the full air ratio and improve vaporization and combustion. After the engine oil temperature and pressure are up to normal, operate the propeller control for full pitch control. When this is observed, allow the rpm to return to normal. Repeat the procedure three times.

8. *Preflight planning.*—Before take-off, get a briefing on the geographical and aerological information relating to the particular area of operations. Learn the distress, bail-out, ditching, and crash landing procedures that have been prescribed. Be sure you know, do not guess. Carefully plan and schedule preflight ground activities. Arrange the periods of preheating so that all equipment will be inspected, warmed, ready, and operating at the time of starting engines or take-off. While preheating is taking place, ice and snow should be removed, inspections and operational checks made, electronic equipment warmed up, and other necessary activities conducted. In short, maintenance crews must know the over-all time required for preparing the airplane for flight at various low temperatures.

9. *Personal care.*—Be sure proper clothing is made available to keep pilots and air crew warm in the air and on the water or ground in event of crash landing. Load in survival equipment and food dictated by the nature of the flight. Dress for the worst possible conditions, not the best. Remember the effect of cold metal on the skin. Wear gloves. Keep out of prop wash. The blast can cause severe frostbite.

10. *Weather.*—Obtain latest weather information. Know limits of airplane and instruments in weather conditions.

11. *Warm-up.*—Warm up engines thoroughly. Do not turn on electrically heated suits or other electrical equipment not absolutely needed until generator shows output.

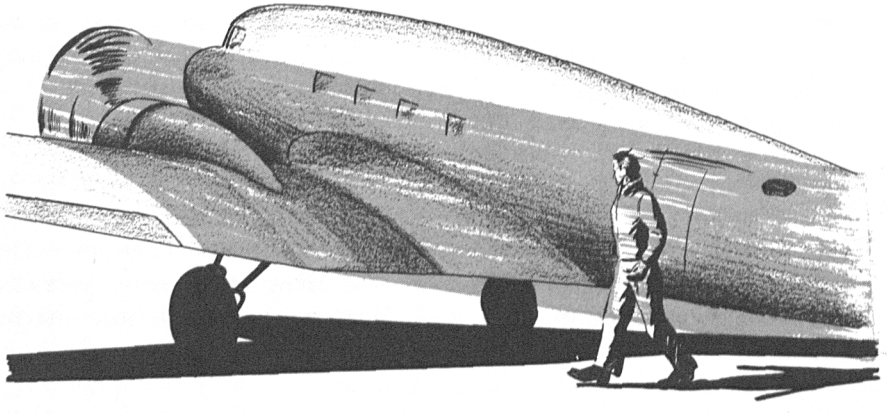


Figure 6–13.—Prop wash can cause severe frostbite.

Present specifications require equipment capable of performing satisfactorily at temperatures ranging from 130° to minus 65° F. Also prescribed are conditions of high humidity, dust, fungus, actual precipitation, and spray. In most cases special precautions must be taken to ensure satisfactory operation at temperatures lower than minus 10° F. Special lubricants must be used on rotating equipment. Storage batteries are affected seriously by cold weather as capacity is reduced by 50 percent at temperature of minus 15° F. Condensation inside the airplane will require more frequent inspection and cleaning of electrical devices.

ELECTRICAL EQUIPMENT

Condensation is a problem in cold weather operations. Watch for corrosion of electrical equipment caused by condensation—particularly relay contacts and switches. Spark plugs, magnetos, ignition harnesses, and electrical leads are all susceptible to the ill-effects of condensation. Interiors of aircraft and exterior surfaces of electrical equipment should be wiped periodically to reduce presence of moisture as interior temperature of the airplane changes.

The capacity of storage batteries falls off rapidly with drop in temperature. The standard-type AN 3150 battery has capacity of 54 amperes for 26 minutes at a temperature of 102° F., while at minus 20° F. the same current can be supplied for only 5 minutes. A cold battery cannot be charged as rapidly as one at normal ambient temperature. The charging rate at minus 20° F. is one-sixth that under ordinary conditions. For these reasons battery power must be conserved. Auxiliary power units are essential for cold weather engine starting and preflight line checks. Do not operate electrically heated flying suits, turrets, or other electrical devices unless a suitable generator is kept in operation.

Late model aircraft are equipped with quick disconnects to facilitate removal and reinstallation of storage batteries. These disconnects should be installed locally on aircraft not so equipped when required for polar operations. When feasible, it might be desirable to remove batteries from aircraft to warmed spaces to prevent freezing and loss of capacity. A battery with specific gravity of 1.100 will freeze at 19° F.; one of 1.200 at minus 16° F.; and one in fully charged condition with specific gravity of 1.250 at minus 62° F. A frozen battery is likely to burst. The evapora-

tion of the electrolyte within the battery is greatly accelerated at low temperatures and may result under some circumstances in sufficient loss in only a few hours to cause complete battery failure.

Battery maintenance is important. Check the battery at least weekly. Use portable generator at every opportunity to build it up. Remove it and recharge if the specific gravity falls below 1.240. Keep the battery in charged condition.

Rotating electrical equipment, motors, dynamotors, inverters, and generators will require special maintenance and low temperature lubricants under conditions of extreme cold. Even then slow starting and heavy loads on equipment may be expected. Electrical radiating heaters or hot air blasts from a hand heater should be used where practicable for preheating prior to operation.

ELECTRONIC EQUIPMENT

Airborne electronic equipment has been designed to operate in most cases at temperatures below minus 40° F. However, failure to operate may result from a variety of reasons. Dry cell batteries and electrolytic condensers will not work at the very low temperatures, but will probably resume normal operation when warmed. Condensation here again is a problem at it always occurs when cold equipment is brought into a warm enclosure. A higher degree of maintenance will be required to prevent corrosion of parts resulting from moisture formed by rapid changes of temperature of equipment. Wipe off visible moisture carefully from exterior surfaces and use warm air to dry out the interior. Changes in electrical characteristics of components may be so great as to necessitate frequent readjustment of critical circuits. On the AN/ART 13 transmitter, for example, the power amplifier output circuit becomes detuned with a temperature drop of 10° below 0° F.

When temperature falls below 0° F., apply heat to electronic equipment if it must be ready for immediate use. Batteries and electrolytic condensers in particular may require the application of heat to operate normally. Long warm-up periods by tube filament heating is good practice because it helps to bring equipment up to proper operating temperatures before application of plate voltage. Follow handbooks of maintenance for instructions on warm-up time. Increase warm-up time for extreme low temperature.

The operation of slow-moving mechanical parts such as shafts and bearing surfaces will operate more satisfactorily if surfaces

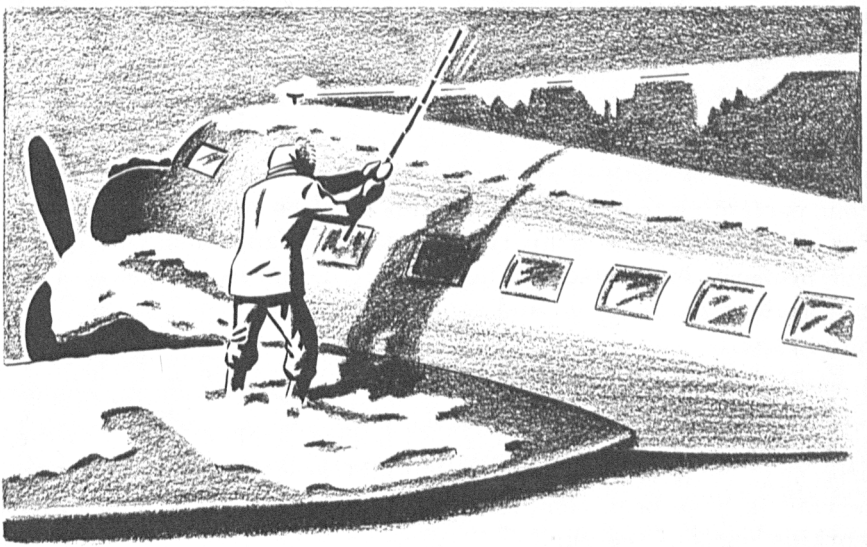


Figure 6–14.—Knock icicles off antenna.

are buffed and polished. Do not lubricate at all unless required and then lubricate sparingly.

Ice formation will be a hazard on all types of external antennas due either to excessive stress causing breakage or to changing antenna characteristics thus reducing the operating range. Knock off icicles with a thin bamboo pole. Remove ice and snow from strain insulators to prevent excessive transmission losses. Keep the antennas a little loose as a slight whip will break the ice.

Rubber-covered flexible cables become stiff at temperatures lower than minus 10° F. Insulation becomes brittle when cold and is liable to crack and shatter rather than bend. Therefore, avoid sharp bends in cables.

To avoid difficulties in selecting channels on push-button type equipment, it is good practice to set it on the desired channel before starting on the mission.

As stated above, electrical and electronic equipments provided in aircraft have undergone operational tests at temperatures as low as minus 65° F. To ensure operational readiness and to operate for long periods at low temperature, more frequent preventive maintenance and adherence to the special precautions outlined herein and in technical maintenance notes will be necessary.

Refer also to chapter 11 of *Polar Guide* (AFTRC 50-0-23), or BuAer Technical Note 84-45.

To ensure satisfactory gun operation at low temperatures and under all weather conditions proper maintenance cannot be overstressed. Preventive maintenance instructions and the safety precautions set forth in applicable technical manuals and publications pertaining to specific equipments must be strictly adhered to. For satisfactory low temperature operation guns must be clean and properly lubricated. When firing in subzero temperatures, gun heaters are required and should always be turned on just before takeoff.

Prior to firing, guns should be completely disassembled, cleaned, inspected for defects that may cause malfunction and parts breakage, and lubricated. When the gun is disassembled and is in the process of being cleaned, ensure that all traces of hard drying preservatives have been removed from the bolt assembly and other working parts of the gun.

It is very important that driving springs and all other springs are within the allowable limits of free length specified in the applicable technical manual. When preparing the gun for firing, refer to current ordnance modification instructions. All applicable and authorized ordnance modifications should be incorporated as soon as possible.

Dry cleaning solvent Specification P–S–661 is recommended for cleaning the gun mechanism. For removal of corrosive primer salts from the bore, bolt and receiver, use rifle bore cleaner Specification JAN–C–372. This solvent contains water and all traces must be removed with a dry cloth. Incomplete removal of the bore cleaning solvent may result in malfunctioning of the gun at low temperatures. Immediately after cleaning apply lubricating oil if guns are being readied for firing, or, if being temporarily stored, apply a preservative. Lubricating oil is required for operation at all temperatures. Oil Specification OS–1361 is the best gun lubricant presently available.

Apply the oil sparingly. This oil *shall not* be diluted with kerosene. Cold temperature tests have proven that gun operation at extremely low temperatures is not improved by lubrication with mixtures of kerosene and oil. At temperatures above minus 20° F. this mixture is not a satisfactory lubricant. For additional information concerning lubrication, cleaning, and preservation of ordnance equipment it is recommended that reference be made to ordnance publication OD–3000.

Guns are subject to rapid rusting from condensation following exposure to low temperatures and introduction into a warm building or space. After the guns have reached room temperature disassemble, wipe the parts dry, thoroughly clean, and reoil immediately. This procedure must be repeated each time the guns are brought from a cold temperature to a warm temperature.

After guns have been installed in aircraft and prior to flight a careful preflight inspection is recommended. When making this inspection bear in mind the following points:

1. Prior to working on the guns remove the feed mechanism and the ammunition belt from the feed way, making sure no live rounds are in the chamber or in the gun mechanism.

2. Do not operate charging mechanism or perform any work on hydraulic system while the feed mechanism and ammunition belt are connected to the gun. After these components have been removed examine chamber to ensure that gun is not loaded.

3. Do not operate gun switches or make gun electrical tests without first removing the feed mechanism and the ammunition belt from the gun and inspecting the chamber to ensure that the gun is not loaded.

4. Prior to arming the plane check the following:

a. Operation of gun heaters.

b. Bore and gun mechanism free of ice, snow, and dirt and freshly lubricated.

c. Bolt assembly free to operate in the receiver body.

d. Gun solenoids and gun chargers operating properly and all connections secure.

e. On aircraft having the 20-mm. M3 gun, check the gas cylinder for freedom of movement.

f. Link and ammunition ejection chutes clear and not bent or damaged.

5. Before loading ammunition ensure that the master armament and individual gun switches are *off* and the gun charger is on safe.

6. When handling ammunition exercise care to keep the rounds in calibration with the links. Lightly lubricate 20-mm. ammunition and links as prescribed in TM 9–229 to prevent extraction malfunctions.

7. When loading the 20-mm. feed mechanism AN–M2 follow the instructions outlined in TM 9–229; however, wind the main drive shaft until the drive spring slips. This may require as much as 35 foot pounds of torque applied to the winding nut. Overwinding will not damage the mechanism.

GUN SIGHTS AND AIRCRAFT FIRE CONTROL EQUIPMENT

All gun sights and aircraft fire control systems are capable of being operated in temperatures as low as minus 55° F. provided lubricants prescribed in the applicable ordnance pamphlets are used.

BOMBSIGHTS AND BOMB DIRECTORS

The bomb director Mark 3 Mod 3 and the Gyro Mark 18 are capable of being operated at minus 65° F., when using prescribed lubricants. Bombsight Mark 15 and stabilizer Mark 15 and SBAE Mark 2 Mod 1 (C-1 Auto-pilot), when covered with a heating blanket and preheated, will operate under conditions minus 55° F. The bombsight Mark 23 is not capable of being operated below minus 40° F. However, lower temperatures will not damage the equipment.

AMMUNITION AND MISCELLANEOUS ORDNANCE

Refer to chapter 5, Part II for information on ammunition, torpedoes, mines and miscellaneous ordnance items.

HEATING

Heating of aircraft is primarily for personnel comfort. It may be used for preheating equipment or for defogging windshields. There are two types of heaters in use—combustion heaters and exhaust gas heat exchangers.

Combustion heater type heating—A cumbustion heater is a complete source of heat in itself although it is dependent upon other aircraft components for fuel, air, and electrical power. The fuel is usually supplied by the engine fuel pump. However, in some installations a special pump is used for the heater alone. The separate pump is small, compact, and light in weight and can pump as much as 25 to 30 gallons of fuel per hour. The fuel is introduced to the heater combustion chamber by either a fuel nozzle or a wick-type evaporating surface. The nozzle is the most common application being used on the majority of heaters. Ram air caused by the forward motion of the airplane is picked up by a scoop and ducted to the heater. Usually two scoops are used, one for combustion air and one for ventilating air. The combustion air is introduced into the combustion chamber of the heater in such a manner that it produces a turbulence, thus mixing

with the fuel and producing a fuel-air mixture that is satisfactory for combustion.

To ignite this mixture use one or the other of these systems:

1. A glow plug or hot wire ignitor similar to the bread toaster principle.

2. A spark plug similar to that used in the aircraft engine.

Of these two systems the spark plug type is the most positive and fastest and will also ignite the mixture at higher altitude than the glow plug type ignitor. The electrical potential for the ignition system is basically supplied by the aircraft power system. Thus, after the fuel-air mixture is ignited, the flame and gases travel through the passages of the combustion side of the heater and exhaust overboard. The heat of the flame and gases is transferred to the combustion chamber during this passing where it is absorbed by the ventilating air passing by on the opposite side of the wall. The ventilating air is scooped from the outside of the aircraft as previously stated and is therefore fresh air. It is directed to the desired locations throughout the airplane by ducts. This type unit has been thoroughly tested for defects in the original design and is perfectly safe in regard to personnel and the aircraft.

Exhaust gas exchanger type heating.—The exhaust gas heat exchanger requires nothing from the airplane other than that the aircraft engines be operated and the airplane be in motion. A single scoop is used to pick up the ram air which is directed to a muff around the exhaust stacks of the engine where it absorbs the heat of the gases in a manner similar to that of the combustion type heater. The warmed air is then directed to the required positions throughout the aircraft.

ANTI-ICING

The formation of ice on the wings, tails surfaces, and propellers of aircraft creates a dangerous situation because of the added weight and change in the shape of the airfoil section which alter the lift or thrust characteristic. Anti-icing equipment is used to prevent the formation of ice on these critical surfaces. This may be accomplished either thermally or chemically.

Thermal anti-icing.—Thermal anti-icing prevents the formation of ice on the critical surfaces of the aircraft by passing hot gases through the leading edges of the desired surfaces and raising the temperature sufficiently to preclude the formation of ice. This is accomplished by the use of exhaust heat exchangers or

combustion heaters that raise the temperature of the gas approximately 350° F. This hot gas may be air or a mixture of air and exhaust gases.

For small items of equipment such as pitot tubes and radio masts, electrically heated pads or blankets are used. Large surfaces are not heated electrically because of the great load imposed on the electrical power system.

Anti-icing compounds.—There have been a few compounds developed to delay or prevent icing of the airplane surfaces. To date these compounds have not proven to be too successful because the surfaces of the aircraft must be resprayed or repainted after a few flights and in some instances after each flight. The problem of recovering the surfaces is impractical for large aircraft, but seems fairly reasonable for some fighter, attack, and utility types which are low to the ground and easily accessible. In general, however, this method must be considered experimental—possibly impracticable—for the present.

DE-ICING

De-icing equipment is for use after ice has formed on the critical surfaces of the aircraft.

Thermal de-icing.—Thermal de-icing is primarily the same as thermal anti-icing except that units producing more heat in B. t. u. per hour are used. Here again either of the heating systems noted previously may be used.

Boot de-icing.—De-icing boots are prepared of rubber or a rubber-type material and installed upon the leading edges of the critical aircraft surfaces. Air pockets or cells in the boot along the logitudinal plane of the surface are inflated and deflated, alternately producing a flexing condition. Thus, the ice is broken from the surface leading edge. Air is supplied to the pockets at approximately 7 pounds per square inch pressure during inflation although the pressure might fluctuate during this period.

Chemical de-icing.—Chemical de-icing methods depend on the use of materials which are soluble in water and which lower the temperature at which the ice melts. A familiar example of this is the use of rock salt to remove ice. Salt, however, may not be used extensively on aircraft surfaces as it may cause serious corrosion difficulties. In some instances such materials have been used in lacquers to provide a thin film of liquid adjacent to the surface. Mechanical action such as the forces exerted by rotating

propellers will throw the ice from the surfaces until the soluble material is exhausted. Those materials are not useful for extensive de-icing of surfaces such as wings, and fuselage, as mechanical forces are required to rupture the ice film.

General de-icing may be performed by concentrated water solutions of salt. It is necessary, however, to provide corrosion inhibition even in thin films. The most effective material used which does not have adverse effects on metal surfaces, paints, and dopes, is a concentrated solution of sodium nitrate, to which molasses and alcohol have been added to provide a slightly thicker film and to provide wetting properties. This material will function at temperatures above 10° F., but becomes relatively ineffective below that temperature. Alcohols, glycols, and glycerine are effective at slightly lower temperatures, but may have serious corrosive and other adverse effects on aircraft materials.

In general, icing conditions occur within a range of 32° F. and 20° F. At lower temperatures the ice is usually not adherent and may be removed mechanically. In some instances the use of de-icing fluids at temperatures below 0° F. may cause adherent ice to form which would not have occurred if the fluid had not been used. This is an inherent difficulty which will occur in any material which depends on the lowering of the melting point of ice to provide removal.

GROUND OPERATION

Ground operation of thermal anti-icing or de-icing equipment is accomplished by blower fans within the conventional installation. This is also applicable to the heating system. The fans supply air for the heating and combustion units. Auxiliary power units supply the electrical power required to drive the blowers.

PRE-FLIGHT PLANNING

In order to navigate a flight in the polar regions, detailed preflight planning is mandatory because of the large amount of work which is necessary during the flight. There are few navigational aids and landmarks. The pilotage charts available are generally inaccurate. In addition to this, the nature of the terrain renders pilotage difficult, to say the least. In summer it is characterized by numerous lakes, islands, and rivers, extremely hard to identify or differentiate; in winter it is covered with ice and snow which obscures the demarcation between the water and land, making identification almost impossible. The variation of seasons further

complicates the situation by limiting the aids offered by celestial navigation.

In summer, continuous months of constant daylight restrict observation of celestial bodies to sights of the sun and periodically, the moon, and then only when they are not obscured by clouds or haze. In spring and fall long twilight periods may prevent any observation at all. The proximity of the north magnetic polar area to the geographic pole prevents the use of the magnetic compass for determining directions in a large part of the Western Arctic and adds to the difficulties and hazards of polar flying. Because of the number of navigational uncertainties, it is recommended that the following pre-flight procedure be followed:

TIME

Because of the difficulties introduced by the seasonal variations and the twilight period, the time schedule for a flight must be planned in advance and as closely adhered to in flight as possible. It is necessary to know:

1. At what time important celestial shots are to be taken.
2. At what time changes in course will occur.
3. At what time gyro precession is to be determined.
4. At what point in the flight the twilight period will occur.
5. What celestial bodies will be available during the flight.

The master watch should be set with a time tick and then carried in an inside pocket because most precision watches are unreliable at low temperatures. This watch should only be used to check the hack wrist watch which should give no difficulty as long as it is worn. The master watch should never be worn on outside clothing or attached to a sextant for more than 15 minutes.

CHARTS

A large variety of maps and charts have been used in an attempt to determine which are most suitable for arctic flying. On these the lack of physical features is evident and in many instances the location of these physical features are inaccurate or conflicting. The following is a list of charts which have been selected for reference and plotting:

U. S. Aeronautical Charts 1:1,000,000.	Map Reading.
National Topographic Series, Aeronautical Edition, 8 mile to 1 in.—Department of Mines and Resources, Canada.	Map Reading.
USAF Aeronautical Planning Charts.	Map Reading.

USAF Long Range Navigation Charts.	Reference.
Emergency reproduction of British Admiralty charts for North Coast of Canada and Arctic Archipelago—original engraving, January 20, 1855, Amended to 1939.	Reference.
Northwest Territories and Yukon 1:5,068,800—Department of Mines and Resources, Canada.	Reference.
Modified Lambert Conformal Projection of Canadian Arctic Regions—Department of Mines and Resources, Canada.	Plotting.
VP Plotting Sheets 1:1,000,000—U. S. Navy Hydrographic Office.	Plotting.

PLOTTING AND DEAD RECKONING

In areas around the magnetic poles, dead reckoning is the foundation of navigation as it is in other areas. The task of maintaining a continuous track is very involved and requires coordination of all navigational procedures to determine ground speed, drift, and position. Keep DR navigation accurate by continual use of radar and celestial observations, where possible.

The standard computers, plotters, dividers, and log forms are used as in lower latitudes. Several revisions to log forms have been suggested to facilitate checking gyro precession rate and heading, but as yet these forms are only suggestions from operational navigators and have not been standardized. It is anticipated that a revised log form for use in polar areas will be adopted within the not too distant future.

The B–3 driftmeter has been winterized to operate in temperatures as low as 65° F. The power and functioning should be checked, and the lenses cleaned before uncaging it. The gyro should warm up 30 minutes after starting before uncaging it. It is impossible to turn the rheostats on these driftmeters at very low temperatures, so the reticle light should be adjusted to the proper intensity before the airplane is exposed to low temperatures.

The most valuable aid for dead reckoning information in these regions is radar. In spite of undercasts the ground can be "seen" and the scope information used in a manner similar to the use of a pilotage chart. Wind runs, drift determination, and fixes from landmarks are obtained in this way similar to the procedure used when the ground is observed. There are some few radar beacons available and their locations are listed on the standard Racon List.

CELESTIAL

Celestial navigation is the most important method of fixing position in polar regions. The procedure is similar to procedures used elsewhere but refractions and coriolis corrections must be applied. Computed altitudes and azimuth can be determined by use of tables in H. O. 249, H. O. 214,—volumes VIII and X, and H. O. 230. The tables in H. O. 249 are the easiest to use, but this volume includes only certain stars and a similar volume is needed for the sun, moon, and planets. Another valuable aid is the Weems Star Altitude Curves, but again these are restricted to the selection of particular stars. By use of these tables it is advisable to plan which stars are to be used and prepare in advance the altitudes and azimuths. In addition meridional altitude shots should be precomputed to save time and effort in flight.

The astrocompass is used for checking gyro precession and heading. This instrument should be properly alined before take-off.

The Mark V sextant will give excellent results, providing it is handled with care. The flashlight batteries should be kept warm by carrying them inside the flying suit because low temperatures affect their generating power. Breathing directly on the index prism of the sextant will cause ice or frost to form and should be avoided. In the event ice does form, the surface should be warmed with the hand until the ice melts and then the prism should be cleaned carefully with a soft clean cloth or lens tissue.

LORAN

Loran stations are gradually being installed in the Arctic. The low frequency loran stations are in the test stage and are not considered to be reliable aids as yet. Three such stations have been established near Point Barrow, on Victoria Island, and at the mouth of the Mackenzie River. Except along the base line extension, they have a fairly reliable coverage up to 1,000 miles of the more distant station of the pair being received. There is a chain of standard-frequency stations centered about the Aleutians with a range of about 700 miles in the day time and 1,400 miles at night. More stations will be installed as time goes on. Information should be obtained from loran charts issued by Hydrographic Office and the Aeronautical Chart Service.

GRID NAVIGATION

Measuring courses in midlatitudes is fairly simple, but in high latitudes the convergence of the meridians at the geographical pole causes the course to change rapidly. To simplify determining course and direction, the grid system is used. This system substitutes a grid for meridians and parallels of the aeronautical chart and grid direction for geographic direction. On any chart, the grid is made by drawing a line parallel to the 0 to one-hundred and eightieth meridian. The direction away from the North Pole along the one-hundred and eightieth meridian is "grid" north. Then, in north polar regions: True Direction plus W. Long equals Grid Direction, and True Direction minus E. Long equals Grid Direction. A series of lines parallel to this grid north-south line are considered as grid meridians and a series of lines perpendicular to these lines are grid parallels. With this new system of coordinates the heading and wind direction remain constant and the determination of the course is greatly simplified.

IN-FLIGHT PROCEDURE

After detailed pre-flight planning, the in-flight procedure is a detailed job. No new principles of navigation are necessary, but constant checking and employing of a combination of all procedures is necessary.

The directional gyro is the instrument used to maintain heading. It is not affected by magnetism and with corrections for precession will maintain a true line in space. The most important procedure with reference to the gyro compass, therefore, is correction for precession. A constant checking of the gyro information by astro-compass is necessary. This information must be logged accurately to determine the precession rate. As previously stated the log form for recording gyro precession and astro-compass information has not been standardized, but the procedure now employed by operational navigators provides a record of gyro precession with enough reliability to use the instrument if an overcast prevents astro-compass checks of heading.

Radar is the chief source of dead reckoning information in the polar regions. The procedure for using radar in pilotage, wind runs, and fixes is the same as the procedure used with a pilotage chart. However, pilotage is not too reliable either visually or from the scope because maps are constructed from sketchy data, and the terrain features are hard to distinguish as discussed above.

Celestial navigation in arctic regions is like celestial anywhere else. The availability of celestial bodies for observation is somewhat limited, however, depending upon the season of the year. Corrections are about the same as anywhere else but refraction and coriolis force corrections are quantitatively larger and they must be applied correctly. During the periods of continuous twilight, celestial navigation is practically impossible, since stars are not visible. An instrument for determining direction by the use of polarized light (the Pfund Sky compass) is being flight tested to prove its value.

Polar navigation is still an arduous task requiring the full time of several well-qualified men. Celestial is the primary method for maintaining direction and determining position, with constant logging of all available information. All phases of the trip must be carefully planned because the success of the undertaking depends entirely upon the accuracy of the navigation.

SEARCH AND RESCUE OPERATIONS

Successful search and rescue—and rescue operations—in the Arctic will require a well organized plan, executed by personnel having an understanding of the problems involved, utilizing efficient communications.

For initial indoctrination; personnel should study the *Air Sea Rescue Manual,* JANP–300, from which much of the following material has been taken.

The primary mission of search and rescue is to render emergency assistance to aircraft and ships in distress and to rescue survivors. It includes assistance and rescue operations, distress communication procedures and distress flight control, survival methods and equipment, and the indoctrination of personnel in these matters.

COLD WEATHER CONDITIONS

The problems connected with search and rescue under cold weather conditions are complex and deviate from those problems occurring in more temperate zones because of the following factors:

1. Cold air temperatures.
2. Low water temperatures.
3. High winds.
4. Vast expanse of waste lands.
5. Low ceilings and icing conditions in clouds.

6. Unreliable communications.

7. Absence of navigational aids and unreliability of magnetic compasses.

Search and rescue for the distressed can be considered to be divided into two operational phases—the first is the search, and the second is the rescue of survivors.

Those concerned with search and rescue in the Arctic should be familiar with all of the various types of special clothing which is available and should be certain that adequate outfits are in their possession before embarking on any mission. The problem of maintaining adequate warmth inside the airplane should be considered. All devices in use, such as cabin heaters, should be checked to ensure that they are in good operating condition. Information concerning survival after an accident has occurred is available. It must be read and understood. Pilots, air crews, and passengers should be appropriately briefed in the various aspects of survival. It should be especially borne in mind that immersion in cold water will cause death in a matter of minutes unless the victim wears an appropriate immersion suit.

The high winds encountered frequently in arctic regions are a concern to those engaged in search as well as the downed personnel. When engaged in the search, the air crew should make every effort to determine the force and direction of the wind and to maintain a constant check thereon. The air crew should obtain all the local aerological and geographical data that has been compiled in the past in order to get a general idea of what may be ahead. The survivor is also concerned with this problem since adequate shelter must be devised to protect him against the wind as well as the cold.

It must be borne in mind that it is difficult to live off the land in the major part of the arctic wasteland. Provision must be made for adequate survival by carrying clothing, food, and other supplies in the airplane. The survivor should also keep firmly in mind that he can hasten his rescue by the accepted use of smoke signals and other signalling devices. Therefore, he must understand their use before take-off.

Low ceilings and icing conditions often hamper search and rescue operations. Here again, a knowledge of local weather conditions can be of the utmost importance to a search plane. At times it may be comparatively safe to fly when there is a 300- or 400-foot ceiling in certain areas. The survivor should understand the obstacles which must be overcome when poor flying conditions prevail.

ERRATIC COMMUNICATIONS

Communications in the Arctic generally will be erratic and unreliable. On some occasions phenomenal ranges and clarity of signals are obtained. At other times results are extremely poor. Hope for the best, but prepare for the worst. The air crew must be alert to these conditions and know how to cope with them, for instance by changing the frequency. It is absolutely essential that all communications equipment be kept in a state of readiness. The network of search and rescue facilities which may be available in local areas by the various government agencies should be known to all those operating in the Arctic. The means of alerting these activities should be understood. The joint frequencies available for communications should be studied.

It is, of course, well known that the magnetic compass becomes unreliable in the high latitudes. For those who conduct extensive flights in the Arctic, the grid system of navigation should be understood and used. Navigational aids, such as radio ranges, beacons, and loran, are meager. However, the location of navigational aids as well as their peculiarities must be understood. If the plane is to be ditched every effort should be made to broadcast its position by use of an urgent message with the proper emergency heading. Prompt action can save the lives of all.

In a search and rescue organization there must be certain key personnel who are trained and designated for operations duty. Rescue operations in the Arctic require even closer understanding and cooperation in operating procedure among separate commands and agencies. Efficient rescue requires the use of all available facilities, prompt delivery of information, competent evaluation of that information and positive immediate action.

RESCUE OPERATIONS

Rescue operational plans and facilities must be consistent with their relative importance to normal or tactical operations. Efficient coordination of such facilities depends upon a well-conceived search and rescue plan for each area. Each such plan should clearly define responsibility of each participant and should provide for precise communications and operations procedure for all parties to the plan.

Basic principles of successful rescue operations require planned methods for:

1. Anticipating distress incidents when operations permit.

2. Promptly reporting and relaying distress information.
3. Promptly dispatching adequate assistance.
4. Following through rescue operations to completion.

When distress reports are received at the operating base, the duty officer or officer in charge of rescue operations must obtain all information available on the situation as rapidly as possible in order to determine the course of action to be followed. If a search is indicated, the following factors will influence search plannings:

1. Best known, or most probable, position of the accident.
2. Whether personnel parachuted or ditched.
3. Time elapsed since parachuting or ditching.
4. Whether personnel are in life rafts.
5. Force and direction of wind.
6. Force and direction of ocean current.
7. Whether personnel (if in rafts) are sailing or drifting.
8. General weather conditions.

When a search aircraft is dispatched on an emergency rescue mission, it should immediately establish and maintain communication with Rescue Operations Center.

During the search all possible observation points for lookouts should be manned by aircrew members. The lookout who makes a sighting should report immediately to the pilot on the interphone, giving the relative bearing.

RESCUE REPORT

The plane or ship effecting rescue should report the following information to rescue operations center as promptly as possible:

1. Total number of personnel rescued.
2. Total number of personnel injured. (If seriously ill or injured give name, condition, treatment administered, and effect.)
3. Total number of personnel dead or missing. (Give names if available.)
4. Destination to which proceeding and ETA.

In combat areas and remote frontiers such as most arctic areas, special directives will be necessary in connection with the various rescue organization systems and procedures. In many cases facilities will differ and methods will vary, but the principles will remain the same. All persons connected directly or indirectly with rescue operations must be familiar with command directives and local orders on the subject.

No airplane available today has been designed especially for rescue purposes, and no existing airplane possesses all the necessary requirements. However, several types of military aircraft are being used for rescue operations, and these are satisfactory if their limitations are borne in mind by operating personnel.

The helicopter is in use in certain areas for limited operations. Difficulties experienced in present operational models are being overcome as rapidly as possible. Improved models are in design, and at such time as they are placed in large scale production, will figure prominently in rescue operations.

Types and quantities of equipment required will vary with different operating localities. With every airplane, weight is a major consideration and discretion must be used to prevent overloading, particularly when aircraft are carrying a regular operational load as well as rescue equipment.

SURVIVAL EQUIPMENT

The air plan should prescribe the essential survival equipment to be carried by the several types of aircraft engaged in the operation. Operational experience indicates the following as a guide:

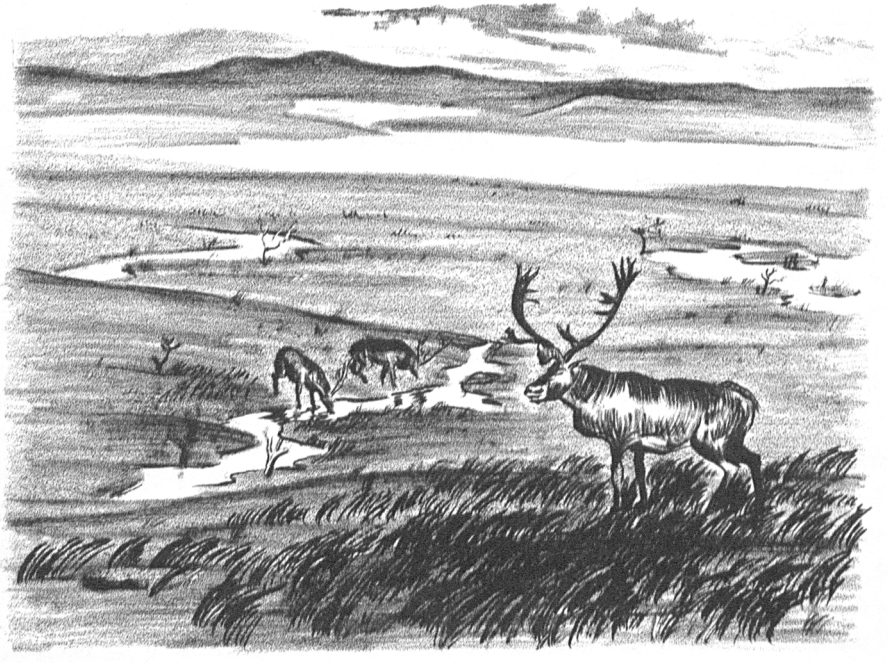


Figure 6–15.—The continental Arctic above the treeline.

Food for 10 men for 60 days:

1 Case of butter.
1 Sack of Navy beans.
1 Case powdered sugar (easier carried in this form).
1 Case raisins.
3 Six-pound cans dehydrated pea soup.
1 Case powdered eggs.
1 Case dehydrated cabbage.
4 Three and one-half pound boxes dehydrated sweet potatoes.
1 Case dehydrated carrots.
2 Cases canned chicken.
12 Cans of canned ham.
10 Pounds tea.
10 Pounds bouillon cubes.
10 Bottles vitamins.
4 Five-pound cans cocoa.
9 Five-pound cans powdered whole milk.
1 Case chocolate bars (Hershey).
360 Life raft rations.
6 42-pound cases of pemmican.
10 2-pound cans of bacon.
10 2-pound cans peanut butter.
10 6½-pound cans of biscuits.
10 2-pound cans oatmeal.
300 ½-ounce pkgs. of salt.
150 4-ounce pkgs. of cheese.
Cigarettes (carried by each man).

NOTE.—The above will provide approximately 3,600 calories per day per man for 60 days.

The following equipment has been carried by various units. Some of it is nonessential. Items not having a quantity should be provided on a basis of one for each expected crew member and passenger.

Sleeping bags (arctic type and pads).
Two-man tents (at least 6).
2 Five-gallon gas cans of safety type.
1 Arctic type two-man sled and harness.
1 Set of sails.

Figure 6–16.—Emergency shelter.

Life rafts with capacity for all intended personnel.
1 Gibson girl.
2 Ice picks.
1 Shovel (Trench type).
1 Machete.
1 Snow saw.
Parachutes and harnesses.
Life jackets.
1 Set cooking equipment.
1 Set plates and eating equipment.
1 Gallon orange paint and brush.
1 Box matches.
Skis and poles.
Crampons.
Snowshoes.
Immersion suits (quick donning).
Byrd cloth wind-proof ski units or equipment.
1 Stocker stretcher.
Flares, smoke, orange, hand held.
2 Stoves, Coleman, single.
1 Set splints.
8 Blankets.
4 First aid kits.

If loading plan will permit, extra gloves, mukluks, parkas, face masks, and other items of outer clothing should be carried in case torn or damaged clothing is caused by the emergency. Each pilot should carry a standard aviator's medicine kit.

The following items should be carried by regular crew members and passengers on extended hops:

1 Tube lip chap.
1 Water proof flashlight with lanyard for securing around the neck.
1 Boy Scout knife.
1 Extra pair sun goggles (preferably N2 type).
1 Small waterproof match container with matches.
Several safety pins.

VA TYPE

The equipment will be greatly reduced over that for VR–VP type; and should include as much of the following as possible:

Food for 5 men for 12 days or 1 man for 60 days:

30 8-ounce pkgs. pemmican.
32 Bags tea.
7½ Pounds powdered milk.
2 Pounds bacon.
2 Pounds peanut butter.
6½ Pounds biscuits.
1 Pound cocoa.
4 Lbs. butter.
2 Lbs. oatmeal.
30 ½-ounce pkgs. salt.
30 20 oz. pkgs. cereal blocks.
30 1½ oz. pkgs. chocolate blocks.
2 Bottles vitamins.
36 Life raft rations.
30 2-ounce cocoa blocks.
60 2¾ oz. sugar blocks.
2 Lbs. sugar.
15 4 oz. pkgs. cheese.
30 Pkgs. breakfast "C" rations if available.
30 Pkgs. dinner "C" rations if available.
30 Pkgs. supper "C" rations if available.
Cigarettes, toilet paper, and wooden spoons packed as necessary.

Figure 6-17.—Raft and wind break.

Due to space limitations the following equipment may not all be carried but should be given consideration over other items:

1 Two-men tent.
1 Ice pick.
1 Shovel (trench type).
1 Snow saw (any large tooth hand saw).
1 Single Coleman stove.
1 Gallon fuel for stove.
2 Immersion suits (constant wear).
2 Blankets.
2 Sleeping bags and pads.
1 Gibson girl.
Flares, orange, smoke, hand.
Snowshoes (if room permits).
2 Byrd cloth windproof ski suits.
1 Box matches.
Life raft.
Life jackets.
Parachutes and harness.

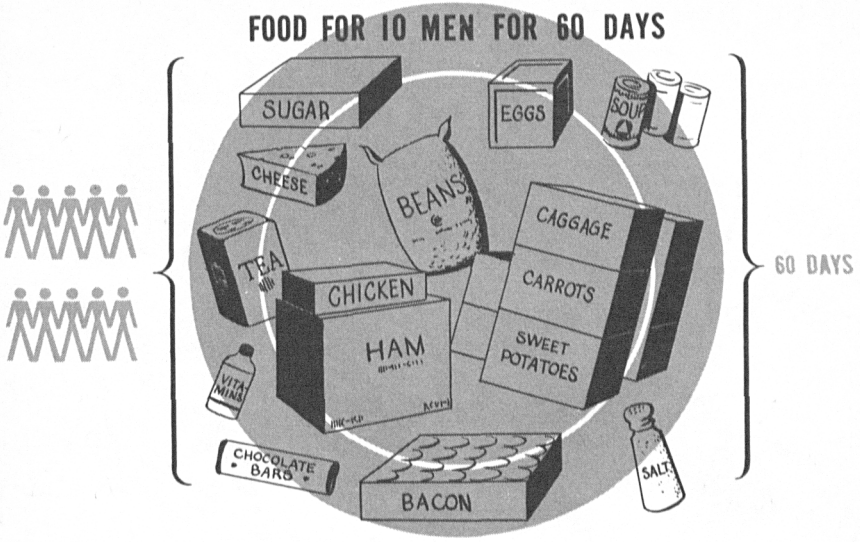


Figure 6–18.—Food for 10 men for 60 days.

VF TYPE

Survival equipment carried in this type of aircraft must be selected with order of precedence. The pilot must be more completely briefed than pilots of other types of aircraft since he will have less equipment on which to depend for survival following a forced landing. The VA type food allowance listed above should be carried, but space and weight should not be taken by food at the expense of the following items:

1 Sleeping bag and pad.
  Flares, orange, smoke hand.
1 Tent (the difference in weight of one man and two is insignificant and should use the two-man).
1 Shovel (trench type).
1 Snow saw.
1 Immersion suit.
  Life raft.
  Life jacket.
  Parachute and harness.
1 Gibson girl.
1 First aid kit.
1 Pair snowshoes (if space permits).
1 Byrd cloth windproof ski suit.

Figure 6–19.—Survivor.

DISTRESS SIGNALS

Visual signalling devices such as signalling paulins, smoke signals, Mark 13, and mirrors are effective for great distances under CAVU conditions in the North. Proper use of the signalling paulin can effect transfer of intelligence to search aircraft when the grounded party has been sighted. Messages may be spelled out with sticks, rocks, or in the snow with dye or lamp black, if available.

SURVIVAL PRECAUTIONS

Survival in the polar regions will always be a struggle against time. Time is of the essence. Select proper fitting clothing and understand the proper use of the immersion suit. Insure that survival equipment and supplies are properly packaged and placed in the airplane before take-off. Rehearse ditching procedure and the plan to be followed in event of forced landing. Do not bail out unless absolutely necessary either over land or water. If a forced landing is made on the water, remain with life raft. Even

if wet, put on immersion suit and cover the hands. Use the same procedure in life raft as in tropical waters. Flex the muscles and try to rig a wind break of some sort. If canned heat is available, try to make a hot drink even if it is dirty water (not sea water, of course). It will help, in event of forced landing, to stay in the vicinity of the aircraft and *keep it visible.*

To facilitate search, a detailed flight plan should always be filed before take-off and adhered to in flight as closely as possible. All changes in flight plan should be reported.

Be prepared for cross-country travelling. Therefore, knowledge of skis, snowshoes, and crampons is important. The cross country ski is the best type for emergency use as it is lighter and is better suited for flat or rolling country.

Refer also to chapters 5 and 6 (part I) and to *Polar Guide* (AFTRC 50-0-23).

SUMMARY

Successful aircraft operations in the Arctic depend on many things—excellent maintenance and preflight preparation, careful and detailed flight planning, mastery of all-weather flying, understanding of polar air navigation, knowledge of survival equipment and techniques, and good communications. Above all else, good judgment is required.

This chapter of the handbook is merely an introduction to the nature of past operations and to the problems and techniques of flying the Arctic with military aircraft. It is based on past experiences under arctic and antarctic conditions and should prove useful to nonflying personnel, as well as flyers.

Naval operations in the polar regions require considerably more preparation than operations anywhere else in the world. This applies particularly to aircraft and airborne equipment. Most cold weather operating difficulties in the case of aircraft will occur on the ground or flight deck. What is done before take-off determines to a large extent whether the mission will be a success or a failure. Failures in the Arctic are likely to be fatal. Check methodically for every source of trouble before take-off.

Since this chapter can touch only the highlights, the attention of the reader is directed to the following publications dealing specifically with the subject of this chapter:

Aircraft Carrier Bulletin No. 1, Aer–E–342–TJW, CV/A4, serial 163080, 23 October 1943. Restricted.

Bureau of Aeronautics Technical Note No. 84-45, instructions for cold weather operations of naval aircraft, Aer–E–43–JED, F24–5(1), 10 September 1945. Restricted.

USAF Polar Guide (AFTRC 50–0–23 of 15 June 1948).

Report on U.S.S. Midway Cold Weather Cruise, 15 June 1946. Restricted. (This is the report of Bureau of Aeronautics' observers to the Chief of the Bureau.)

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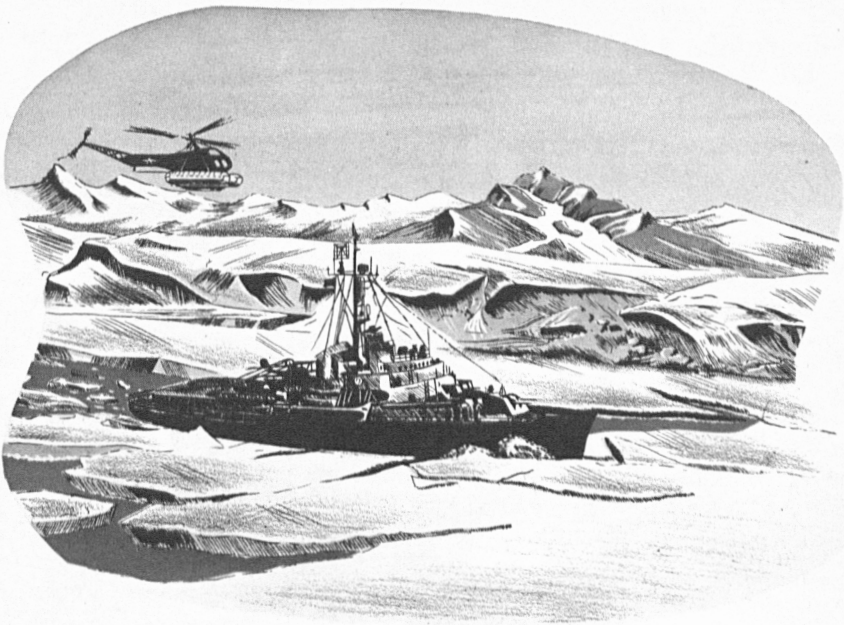

CHAPTER 7

AMPHIBIOUS OPERATIONS

In analyzing the global aspects of modern warfare, particularly with reference to warfare among the major powers of the Northern Hemisphere, the arctic regions raise problems of primary military importance by virtue of their possible strategic location and because of the limited number of previous military operations conducted there. In the vast areas included within these regions, no fully continuous or systematic scientific studies as to geographical and environmental conditions have been conducted nor has there been the necessary accumulation of knowledge adequate for planning military campaigns. Since it may become necessary to seize advance bases for the prosecution of a naval campaign or to destroy enemy bases that may have been established within the arctic and subarctic regions, it is of primary importance that the adaptation of established doctrine and techniques to the characteristics peculiar to these regions be investigated and promulgated within the limitations of the existing data.

Figure 7–1.—Troops about to land at Attu, Aleutian Islands.

The mode of warfare in any theater is characterized by the geographical nature of the theater and by the distribution, frequency, intensity, and duration of environmental factors. In perhaps no other possible military theater of the world do these factors result in such pronounced extremes. The factors of the arctic environment have combined in such a way as to limit the economic development of the area and to influence effectively the sociological characteristics of the inhabitants. Thorough understanding of these factors as they apply to a specific objective area is required in the successful planning and execution of any military operation conducted there, regardless of its size or nature.

The vast regions included within the Arctic are composed of many kinds of country under many combinations of environmental conditions. The difficulties imposed by these conditions, particularly as to limitations upon transportation and communications, have, to a large extent, resulted in curtailment of activity except in areas accessible by water. This general characteristic dictates that amphibious operations will be a major military factor in the control of these regions.

The amphibious planner must determine the arctic characteristics of the target area, and then estimate the effect of these characteristics upon operational planning and execution of the assault phase. The effect of these conditions on subsequent operations ashore, construction and engineering, and the establishment of a base is found in other chapters of this handbook.

EFFECTS OF ARCTIC OCEANOGRAPHIC CONDITIONS

SEA ICE

Within the Arctic, major ocean currents prevent the formation of sea ice within a considerable area in which amphibious operations may be required. Because of this ice-free condition, these areas have progressed economically to a greater degree than the remaining areas of the Arctic and are thus of greater military significance. Within ice-free areas, no departure from standard techniques of amphibious operations is required except as those operations may be influenced by climatic conditions, and operating conditions ashore.

Sea ice is the greatest single factor affecting amphibious techniques in their adaptation to arctic requirements. In any amphibious operation within sea-ice areas, the attack force commander should be given great latitude in determining whether or not he will attack, and the manner of attack, including time and location of the landing, since these factors are influenced by ice conditions.

There always will exist an element of danger to any task force of amphibious ships that must enter an area of pack ice. The force must be accompanied by ice breakers, and even with these, progress will be slow. Probably little evasive action can be undertaken. Positive air protection must be provided against any possible enemy air action. Amphibious operations wherein amphibious ships are required to enter a pack may well be beyond the level of a calculated risk.

UNNAVIGABLE ICE AREAS

Unnavigable ice consists of pack ice on land fast ice fields that are either impenetrable, or penetrable only by the largest and most powerful ice breakers. Should it become necessary to effect a landing against an area protected by unnavigable ice fields, the helicopter appears to afford the best method for the ship-to-shore movement. The manner in which the operation will be conducted

will, therefore, be limited both tactically and logistically in accordance with the limitations of the helicopter. It must be noted that a full investigation of the capabilities and limitations of the helicopter has not yet been completed.

In the event that helicopters cannot be used and amphibious operations must be conducted by surface craft against the edge of an unnavigable pack for subsequent movement against an objective, the operation must be limited in nature. Operations of this type will normally be conducted against undefended or lightly held enemy positions, such as weather stations, for the purpose of destruction, followed by withdrawal from the area. Only small, lightly armed, swiftly moving, highly trained units can be employed. Should flying conditions permit, the unit may be logistically supported by aircraft. Aircraft may also be used, particularly during the withdrawal, to drop trail markers in order to simplify the problem of land navigation. Evacuation of the wounded will constitute a serious problem.

MARGINAL ICE AREAS

Marginal ice areas include those areas that are negotiable by light ice breakers or specially reinforced ships, and areas free of pack ice but subject to drift ice and scattered ice flows. Pack ice within the marginal areas is continuously moving under the influence of winds and currents.

If at all possible, amphibious landings should be undertaken, because of the unpredictable nature of the pack, below the pack area and the units should move overland against the objective. If the landing must be made within the pack area the attack force commander must determine when to attack basing his decision on local ice conditions. Once the attack is initiated, speed in landing troops and conducting logistical support is of critical importance.

Within marginal ice areas, there is always the possibility that land-fast ice may exist on the shore line even though the sea surface may be clear for several miles. When this condition exists, it will impose considerable difficulties upon the landing of heavy equipment and the operation of amphibious craft over the "beachline." Extensive quantities of explosives may be required and considerable time involved in clearing the landing area. This condition may dictate the use primarily of infantry organizations unsupported by heavier weapons or equipment.

The landing in and movement over the solidly frozen pack in marginal ice areas is considered inadvisable by rapidly moving units for more than relatively short distances. Because of the unpredictable nature of the pack even the movement of small, light, and swiftly moving elements will be hazardous.

Within marginal areas, including those subject to small floes, the logistic support of the operations is far more hazardous than the tactical venture. Frequent changes of wind or the current may fill relatively wide open areas with pack ice of such density as to require suspension of operations and the movement of the supporting ships. It is mandatory that an adequate supply be built up ashore as rapidly as possible.

The logistic plan for an operation either within a pack or a marginal floe area should provide for an alternate method of emergency supply. Flying conditions permitting, consideration should be given to the use of aircraft in providing emergency drops. The overland distance to the objective, and the conditions of trafficability may determine the location of dropping areas and the logistic support organization required. In order to facilitate ship-to-shore communications, the shore party may be given full responsibility for logistic support and provided with adequate units and local communication facilities to operate inland dropping areas. In this event, the shore party should be provided with additional communication facilities to communicate directly with the carriers or bases providing the emergency support aircraft.

Marginal ice may restrict the movement of naval gunfire ships, thus limiting the effectiveness of this type support.

The use of helicopters in marginal ice areas may obviate the difficulties involved in the ship-to-shore movement by conventional surface craft.

MARGINAL ICE OPERATIONS

As a general rule, the following points bear consideration in the conduct of amphibious operations in marginal ice areas.

1. A beach assault, within marginal ice areas, may well be beyond the level of a calculated risk. Landings should be made below the marginal ice area if at all practicable, or beyond the limits of enemy interference, and the movement conducted overland to the objective.

2. The attack force commander must be given wide latitude in the conduct of amphibious operations within marginal ice areas

since the success of operations depends to a great degree upon local ice conditions.

3. The operations frequently will be in the nature of a raid of short duration, and with a limited number of troops participating.

4. Speed of landing troops and of the conduct of logistic support is mandatory.

5. The logistic support plan should include provisions for emergency support.

6. If practicable, the operation should be conducted by helicopter and supporting ships should not enter the pack.

7. Submarine reconnaissance will be extremely hazardous or may be entirely precluded. Operation of amphibious reconnaissance units, if not entirely impracticable will be restricted and retarded.

8. Within marginal ice areas, reconnaissance reports of sea-ice conditions are not of long standing value, since conditions may frequently and rapidly change.

TIDES AND CURRENTS

In general, tidal ranges in the Arctic are slight, particularly in areas of straight coastline. In bays, deeply indented coastlines and other restricted areas, the tidal range may be considerable, in some regions varying as much as 20 feet. Tidal conditions in the Arctic have not been completely and progressively studied. Furthermore, since wind and ice conditions exercise such a pronounced influence, predictions are not as reliable as they are in other regions of the world.

As a general rule, the slight tidal changes permit more latitude in the selection of the time of landing than do such changes permit in other areas. However, in areas where the tidal range is great, more caution must be exercised than is required in other regions where regularity exists. Local wind or ice conditions may result in unpredictable tides.

In areas of tidal variation, the beach may be covered with ice floes left as a result of a preceding tide. This condition should normally be expected in any ice area.

In marginal ice areas, it is highly desirable that data on currents be collected so that the movement of ice may be evaluated. The confluence of warm and cold currents gives rise to a vapor condition. The effect of this on amphibious operations is presented later.

SEA, SURF AND SWELL

The sea temperatures normally encountered in cold weather areas are such as to require that troops be landed dry. Immersion for a prolonged period is usually fatal. Both aboard ship and ashore with the shore party, provisions must be provided for the treatment of immersion cases.

Operations of the shore party will be restricted by the temperature of the water. Drying stations must be established wherein clothing may be exchanged and personnel warmed. The efficiency of shore party personnel will be considerably reduced since prolonged individual operations are impossible. To every degree possible, personnel must be protected by adequate replacement clothing. Warm stimulants and food must be available early in the operation and may be expected to be consumed at a high rate.

In shore-to-ship evacuation, casualties must be protected from sea water.

Operations of amphibious reconnaissance units and UDT's will be restricted by low water temperatures. Special individual swim clothing and equipment will be required.

Surf and swell are negligible in marginal and unnavigable ice areas since ice exerts a quieting influence upon the sea. As a consequence, amphibious operations will not normally be affected by surf and swell to any significant degree within ice areas. In ice free areas, surf and swell will require the same consideration as in other areas of the world.

EFFECTS OF TERRAIN UPON AMPHIBIOUS ASSAULT

The Arctic contains coastal land forms varying from extensive coastal plains to rugged mountains, cut by long, deep fjords. The advance and retreat of the great ice shields have left the marks of glaciation. Existing glaciers usually enter or approach very near to the sea.

FROZEN GROUND

Frozen ground is a phenomenon common to the Arctic as a whole. The term frozen ground as used in this chapter includes permafrost, the active layer of permafrost, dry frozen ground, and other variations. Frozen ground is influenced not only by constant factors including geographic position and temperature but also by variable factors including such features as snow cover, vegetation, hydrology, and ground heat conductivity. As a result of the wide variations of local conditions within the Arc-

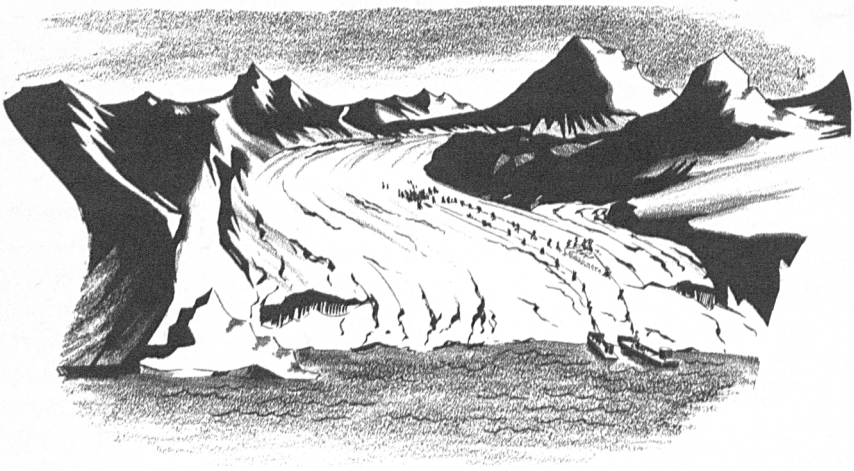

Figure 7–2.—Glaciers make good approaches to inland objectives.

tic that influence the active layer of permafrost, no detailed discussion as to the effects of frozen ground on the amphibious operation is possible.

Permafrost, and particularly the fluctuations of the active layer, will seriously influence the amphibious operation in regions where these conditions exist. The problems of trafficability, field fortifications, effects of projectiles, excavation, including that necessary for road and airfield construction and for the burial of the dead, water supply, and innumerable other activities must be viewed under conditions entirely different from those normal to the temperate and equatorial areas. Analysis of these problems can only be accomplished through understanding of the phenomenon of frozen ground in specific objective areas.

GLACIERS

Glaciers which approach the sea may in some instances provide the best approaches to inland objectives. For this reason the landing force may have to operate over glaciers. However, such operations will very probably be in the form of small raids.

In over-glacier operations, units should be lightly equipped so as to allow maximum mobility. Infantry should be provided with special foot gear. Sledges and tracked vehicles should be used exclusively. Thorough and continuous route reconnaissance must be made in advance of the main body, regardless of the proximity of the enemy. Alternate plans for supply and evacuation by air should be laid.

In many flat coastal plains and more poorly drained areas, innumerable lakes and ponds have been left as a result of glacial action. In summer, when not frozen, they will constitute a serious obstacle to movement inland and will hinder maintenance of direction and control. In winter, the lakes will be frozen so that the landing force may use the ice surfaces as ready-made airstrips ashore.

The recession of the ice shields may have led to emergence of coastal areas from the sea in some parts of the Arctic. At any rate a phenomenon known as the "raised beach" exists. Raised beaches may be characterized by series of beach ridges some of which have water or ice filled marshes behind them. These beaches may extend several hundred yards inland, increasing the requirements for beach matting during periods when the surface is unfrozen.

Glacial action has left many coastal areas with large numbers of rocks and boulders on the beach and hinterland surface. These will constitute a minor obstacle, and may result in difficulties in crossing the beach with land or amphibian vehicles.

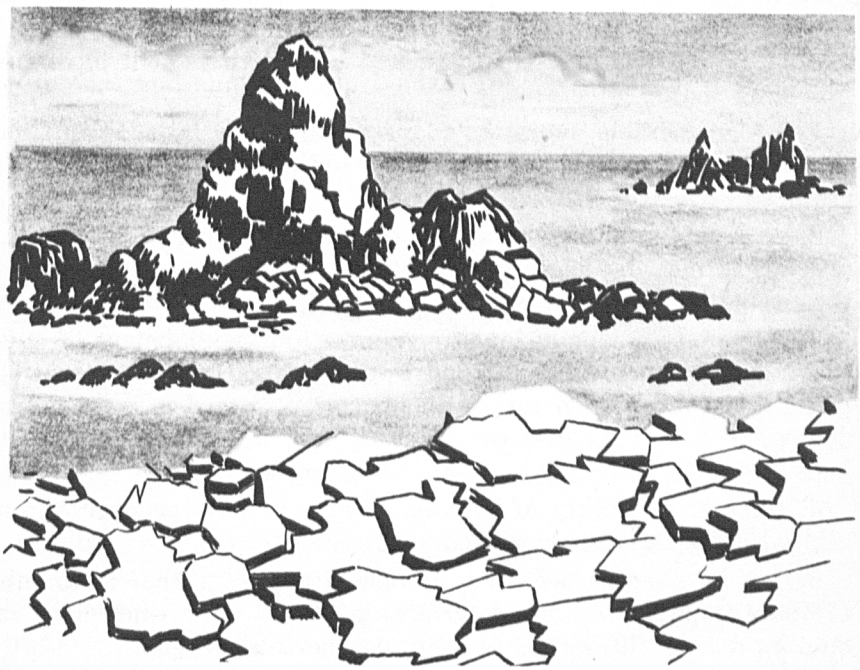

Figure 7–3.—Beach strewn with ice hinders landing operations.

VEGETATION AND CULTURE

Characteristic of the Arctic is a general lack of vegetation and man-made culture. Vegetation is low, for the most part, and provides no appreciable concealment. Man-made culture exists in isolated localities, but in the greater portion of the Arctic there are few roads, airfields, or port facilities which are of any significance.

The lack of significant vegetation and culture will require:

1. Increased emphasis upon camouflage discipline and utilization of minor terrain features for cover.

2. Increase in quantity of camouflage material carried by the landing force.

3. Provision by the landing force of all buildings, facilites, and materials required for operations ashore.

EFFECTS OF CLIMATE AND WEATHER

The wide variations in temperature ranges, wind force and direction, type and amount of precipitation, and climatic factors affecting visibility which occur throughout the Arctic, and the sudden unpredictable changes of these factors in many areas, will exert certain major effects on the conduct of the amphibious assault. Their nature, vagaries, and complexities will have the following major effects:

1. Broad, flexible operation plans which allow latitude in time of landing and selection of specific landing areas often will be required.

2. A greater number of alternate plans for operations in certain areas may be necessary, particularly in those areas where the weather factor is subject to sudden and severe change.

3. Alternate means of logistic support and employment of supporting arms should be included in administrative and operation plans and rehearsed prior to an operation in order to precisely determine the time-distance factors and difficulties involved, mainly due to low visibility and heavy snow.

4. Greater flexibility of organization, primarily because of the necessity for the above, will be required.

5. It will often be necessary to delegate more authority to subordinate commanders in determining actual time and place of landing due to differences in local weather conditions.

6. In many areas, due to precipitation in various forms and

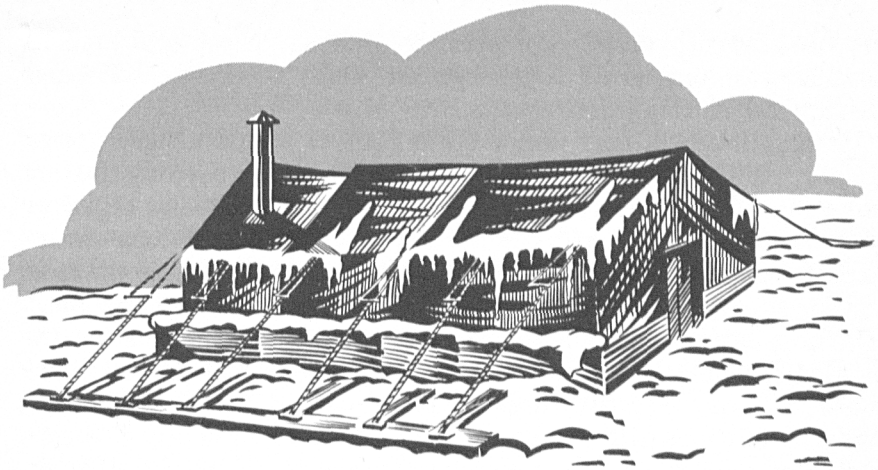

Figure 7–4.—Shelter.

combinations, there will be an increased dependence on manhandling and manhauling of landing in severe cold.

8. Weather alone, particularly low temperatures, will require inclusion of a far greater proportion of special clothing, equipment, rations, fuels and lubricants, and other special items.

9. Amphibious forces operating in the Arctic over a period which includes more than one season will be required to include equipment and supplies appropriate for each season.

TEMPERATURE AND WIND

The severe cold of arctic winters will affect both the materiel and personnel of the amphibious force. Extreme low temperatures in themselves have a very strong effect on such materials as glass, rubber, copper wiring, steel, and explosives. They also effect the functioning of such elements of equipment as motors and storage batteries. The effects of extreme low temperature on personnel, in itself is severe, but when combined with wind, oftimes produces situations that are humanly unbearable. The combination of these factors is known as windchill. Windchill alone may be the factor that prevents successful completion of a landing operation.

Shelter is one of the important factors in successful arctic operations, especially during the winter months. Adequate shelter must be provided the landing force, and it is likewise desirable that the landing force destroy enemy shelter. Winter conditions may require a considerable increase in number of troops needed because of the frequent reliefs required. Likewise, it may

be necessary to reduce the number of boat spaces allocated as standard in temperate zones because more room is needed per person for clothing and equipment.

The chill which may result from getting wet is an even more important factor in the winter and must be guarded against at all costs. This may require enclosed landing craft and certainly will require special arctic suits for use by amphibious reconnaissance units and underwater demolitions teams. The extreme cold may require special storage facilities for explosive ordnance. Naval gunfire support ships should not, however, encounter the same problems in using VT fuze projectiles as will field artillery units ashore. Temperatures of freezing and below along with other conditions will tend to cause duds and premature bursts.

Water supply by conventional means ashore will be difficult. It will be impossible, for example, to utilize the standard 5-gallon can as a means of water supply and resupply. Obtaining water ashore from natural sources will be difficult in view of the fact that the vast majority of the sources will be completely frozen. Water may have to be obtained from ships and carried ashore in heated containers. Recoil of artillery will be slow under conditions of extreme cold. This will reduce the rate of fire of the larger artillery pieces and may indicate increased need for naval gunfire support and an increased use of the smaller weapons which do not require a lengthy period to return to battery. The reduced performance of aircraft and aviation ordnance may restrict operations of air support units and may require a considerable increase in the number of aircraft allotted to the landing force because of the slowing down effects of the extreme cold combined with the wind. The time involved in any operation may be increased considerably.

PRECIPITATION

Precipitation in the form of snow will cause difficulties which may effectively reduce the ability of the landing force to operate ashore. Movement over snow covered areas which are not tightly packed, and through areas of heavy drift, may be restricted to foot troops and special over-snow vehicles. Even the movement of foot troops will often be slowed down considerably. The usual time factors utilized in movement of supplies, troops, and vehicles may have to be increased considerably. Air and naval gunfire support may be presented with difficulties in spotting and target designation. The snow will cover landmarks ordinarily visible

and will so change the surface feature of any particular area as to make it very difficult to operate from a map.

Likewise, the presence of snow on beaches and coastal terrain may make it hard to conduct suitable aerial photographic surveys and to provide the landing force with aerial photographic interpretation in sufficient detail. The difficulties of map-reading and orientation from maps in snow covered areas may be so extreme that the landing force will have to operate entirely from information obtained after landing in the area and relayed to higher echelons and supporting arms. Cold rains and sudden freezes may require that the shore party and other units establish drying stations or shelters in which wet clothing may be exchanged for dry.

VISIBILITY

Intense low lying coastal fogs, heavy low cloud cover in coastal areas, intense rainfall, snow driven by high winds, and periods of long winter darkness, all of which occur in various areas of the Arctic, may restrict observation to the extent that landing operations, particularly those involving combined arms, may have to be postponed or executed with great difficulty. Utilization of support aviation, naval gunfire, and artillery will be extremely limited in such situations. Air and ground reconnaissance, control and coordination of the ship-to-shore movement, and direction of the landing force ashore may be seriously affected. Conversely, periods in which decreased visibility prevails may often provide the landing force with much needed concealment for grouping and movement. In general, the operations of large units employing combined arms and vehicular equipment will be severely restricted by decreased visibility while the operations of small, lightly equipped landing forces may be facilitated by the same factor.

OTHER SPECIAL CONSIDERATIONS

DAYLIGHT AND DARKNESS

The characteristic long summer day and the long winter night of the Arctic will provide difficulties for the landing force. In the summer, daylight lasts 24 hours, and although the sun may not necessarily be above the horizon, it is present sufficiently to provide continuous illumination. The lack of darkness in the summer will make it difficult for individuals to adjust themselves to a schedule normally followed in the temperate areas.

Tactical movements involving regroupment of forces and movement of supporting units to positions in readiness for attack cannot be accomplished under cover of darkness. This again may require extensive use of smoke. Obviously the need for illuminating shells by naval gunfire and artillery will be reduced to a very minimum in summer operations. In the winter, however, when there is little light it may be necessary to increase the quantity of illuminating shells tremendously. It should be borne in mind, however, that except where reflection is poor, the arctic night is not totally dark; for example, when half the moon is visible, it is possible to see a mountain as far away as it can be seen in full daylight. Operation of supporting arms, such as naval gunfire support ships, and air support will be hampered during the winter by darkness. Considerable reliance may have to be placed on radar beacons for directing gunfire support. The arctic night, despite the hindrance it imposes upon operations in general, will provide ideal conditions in which to conduct small raids which are dependent almost entirely upon surprise for success.

Morale of troops may be adversely affected by the continuous darkness during the winter. Conversely, in the summer, as a result of lack of darkness, morale may be considerably higher as long as enforced rest is carried out. During arctic winter operations, some consideration should be given to providing artificial lighting for operations conducted behind the lines, particularly those involving the shore party operations and cargo unloading.

Figure 7–5.—Moonlight in the Arctic.

MAGNETISM

Terrestrial magnetism, particularly that in the vicinity of the north magnetic pole, will provide difficulties in the use of the compass. The hand compass, however, in most areas in the Arctic can be relied upon for local beachhead operations.

SUMMARY

The very nature of winter warfare, especially in arctic regions, is so complex as to require the highest caliber of planning, training, and logistic support. However, the strategic situation may force upon us the need to conduct these difficult operations in order to counter operations or prospective operations by enemy forces in such areas.

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CHAPTER 8

BASE OPERATIONS

"Can it be done? Is it worth while? What will it cost?"—Peary.

Advanced base construction in the Arctic resolves itself into the fundamentals of A B C, "Achievement Bespeaks Commonsense."

Sir Hubert Wilkins, noted arctic explorer, once said, "A misadventure in the Arctic is due to one of three reasons: Ignorance, incompetency, or inexperience." This is another way of saying that operations such as the establishment and maintenance of advanced bases in the arctic and sub-arctic regions can be successfully accomplished when a full understanding of the conditions to be met are known. Realizing the conditions of terrain and climate, and working in accordance with the limitations imposed by them, personnel can successfully complete an assigned task provided they are properly equipped and provided they follow the established techniques. The Bureau of Yards and Docks along

with other units of the Navy has been conducting successful operations above the Arctic Circle since 1944. A brief review of material from Part I will facilitate understanding of this chapter and is therefore included.

The arctic region in the Western Hemisphere includes the northern coasts of Alaska and Canada, the Canadian Arctic Archipelago, much of Labrador, and the greater portion of Greenland. The sub-arctic region, a belt of variable width south of the arctic region, includes Newfoundland, southwestern Labrador, most of Alaska, and most of interior Canada. In the Arctic and the subarctic areas there is a great contrast in climate between the coast and the interior. For this reason the coastal and interior areas of the Subarctic are usually considered separately. The greater part is, with the exception of a few spots here and there, heavily forested.

The arctic region, on the other hand, has no forests whatever. Aside from the shrub willows which are more or less common there, it is characterized chiefly by vast stretches of mucky, treeless land covered with a variety of hardy plants, including grasses, lichens, and shrubs. This type of country is called tundra. Unlike prairie country which it generally resembles, tundra is, to a

Figure 8–1.—Arctic station at Point Barrow, Alaska.

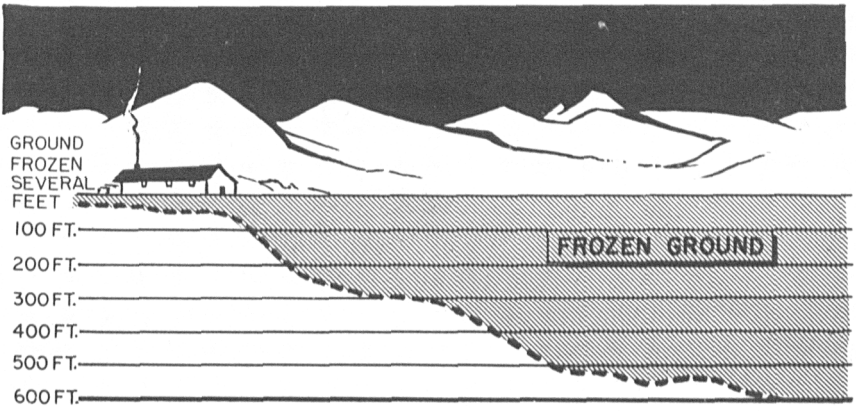


Figure 8–2.—Permanently frozen ground varies from several feet to 600 ft.

large extent, poorly drained and marshy. Hummocks of vegetation abound in the marshy areas, but the soil is poor.

Most of the tundra and parts of the forested subarctic region are permanently frozen a few feet below the surface. The thickness of this permanently frozen ground varies from several feet in the southern fringes of the subarctic area to depths reaching reportedly as great as 600 feet in the coastal plains of Alaska and East Siberia. During the summer the ground thaws to a depth of two feet or more, but, because of the underlying frozen ground, water can neither sink below the thawed layer nor run off. This results in the marshy character of the tundra and the notoriously poor drainage of large parts of the Far North. It is also partly responsible for the many lakes scattered over the region (fig. 8-1).

Temperatures vary considerably throughout these areas. In general, the subarctic interior area has the coldest winters and warmest summers. The arctic coastal area has warmer winters and cooler summers because the large bodies of contiguous water tend to stabilize the temperatures.

LIGHT, FINE SNOW

It is a popular fallacy that there is a great deal of snowfall in these regions. The idea arises from the fact that the snow, being light and fine, is easily stirred about by the wind after it has fallen. So, as long as the wind blows, it appears to be snowing.

Although it is true that many places are windy, at most places the winds are moderate. Winds are usually stronger on or near

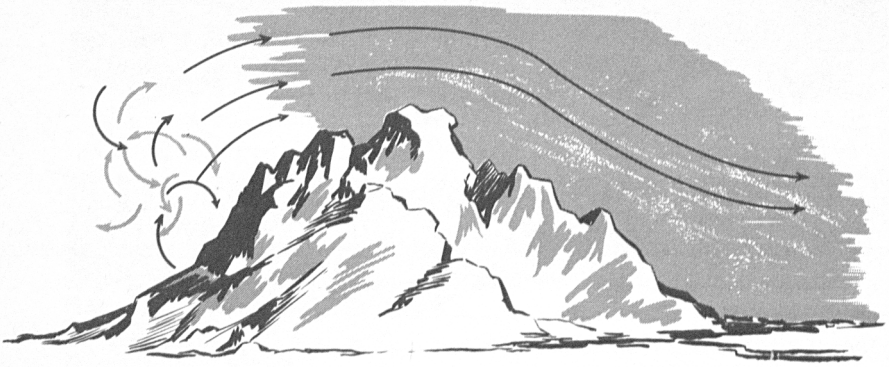


Figure 8–3.—The williwaw.

land than out at sea. The most intense storms occur on high land facing the sea. An outstanding example of a windy region is western Greenland. Gusts of over 100 m. p. h. have been measured frequently in southwestern Greenland.

A peculiar Alaskan wind is the williwaw. It is caused by winds piling up on the windward side of a mountain and boiling over on the leeward side. The turbulence is similar to a thunderstorm and is nearly as violent. These types of winds are common to the Aleutian chain of Alaska.

One of the peculiar effects of cold temperatures (minus 30° F. to minus 60° F.) in the sub-arctic interior regions is to dry the air, because colder air loses its ability to hold moisture. This inability to hold moisture causes condensation of the exhaust of engines, resulting in an ice or steam fog sometimes great enough to suspend operations. Such a situation often arises in the areas of still wind and extreme cold of the interior regions of the Subarctic.

Factors such as the above—tundra, muskeg, lakes, snow, ice, wind, extreme cold—must be taken into account in any construction project in the Arctic.

WORK FEASIBILTY

Temperature, wind, visibility, amount of daylight, rain and snow greatly influence construction operations. Figure 8–4, Work Feasibility Chart, graphically illustrates the recommended times in which to conduct various operations with reasonable effective-

ness in a given area such as around Point Barrow or Fairbanks in northern Alaska. To meet these climatic conditions, as well as to cope with permanently frozen ground and remoteness, construction methods and techniques must be adapted accordingly.

The movement of equipment, personnel and supplies and the establishment of bases in the Arctic may be likened to the techniques of an amphibious operation. All supplies for use in arctic regions except sand, gravel, and water must be brought in either by ship or aircraft and then delivered to the construction site by tractor or bush plane. Native workers may sometimes be utilized to a limited degree, but skilled personnel must be moved to the site and properly trained to resist the rigors of the environment.

Although the mission or function of a base in an arctic or subarctic area is an important factor in the lay-out and plot plan of an installation, due consideration when selecting a site must be given to the features of terrain and minimizing permafrost problems, providing adequate water supply, and insuring adequate waste and sewage disposal.

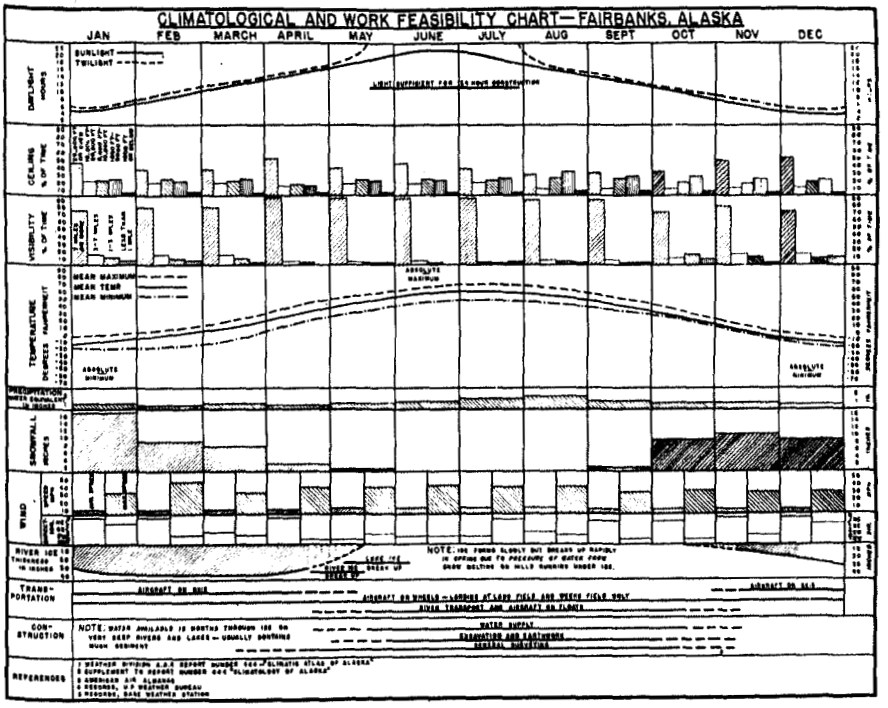


Figure 8-4.—Work Feasibility Chart.

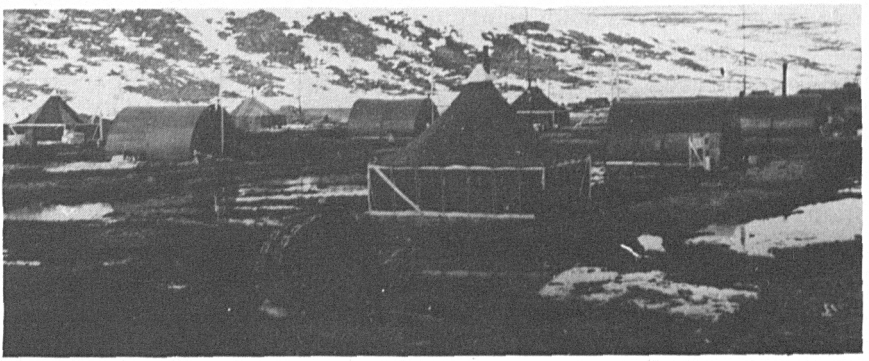


Figure 8–5.—Drainage problem in a permafrost area.

On the arctic plain and plateau regions, ridges and old river terraces located inland, and former beaches along the coast are likely sites for facilities. The site should be in an area that is well drained in order to permit the most efficient construction with the least possibility of permafrost problems. Areas having natural drainage and composed of soil made up of coarse, well-drained material are the most suitable. Figure 8–5 is an illustration of the drainage problem in a permafrost area.

Lay-outs should consider the effects of drifting snow, and buildings should be located with their long axes parallel to the direction of the prevailing winter winds.

FIRE PREVENTION

Due to the presence of many gasoline heaters, fire is an ever present menace. The difficulties of combating fires at extremely low temperatures and in high winds require that established fire

Figure 8–6.—Buildings should be located with long axis parallel to prevailing winterwind.

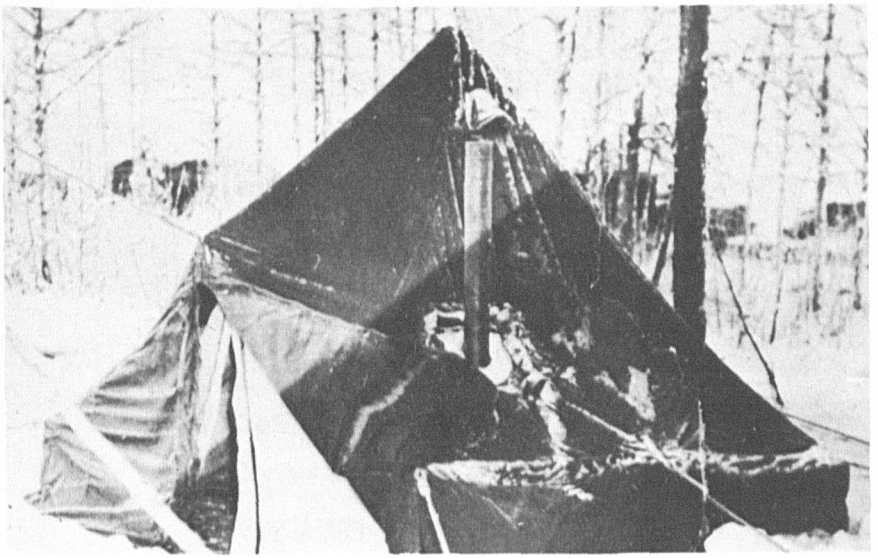


Figure 8–7.—5-man pyramidal tent, with inner liner.

prevention discipline be rigidly observed. Precautionary measures are the best fire-fighters in the Arctic, as elsewhere. For this reason, buildings should not be grouped or interconnected unless fire resistant and fire prevention techniques are used. Caches of fuel, gasoline, and explosives should be located remote from any buildings.

SHELTERS AND BUILDINGS

Since presently designed arctic clothing does not provide adequate insulation for extended periods of time in extremely low temperatures and wind, shelter is essential for the survival of personnel as well as for the maintenance of equipment. The types of shelters and structures that may be used are varied, but all must be capable of providing adequate heating and insulation, ventilation, maximum usable space, and ease of erection. Temporary shelters may include double-walled nylon tents (fig. 8–7), wanigans, Jamesway huts, improvised shelters made from tarpaulins, or snow houses with heaters or stoves. The 16 by 16 or 16 by 24 Jamesway hut and the 20 by 48 Arctic hut (fig. 8–8) may be utilized for temporary bases while the northern-type, insulated 20 by 48 quonset hut (fig. 8–9) is satisfactory when climatic conditions are not too severe to prevent erection. The Navy arctic hut can be erected at minus 65° F. by 12 men in less than 4 hours.

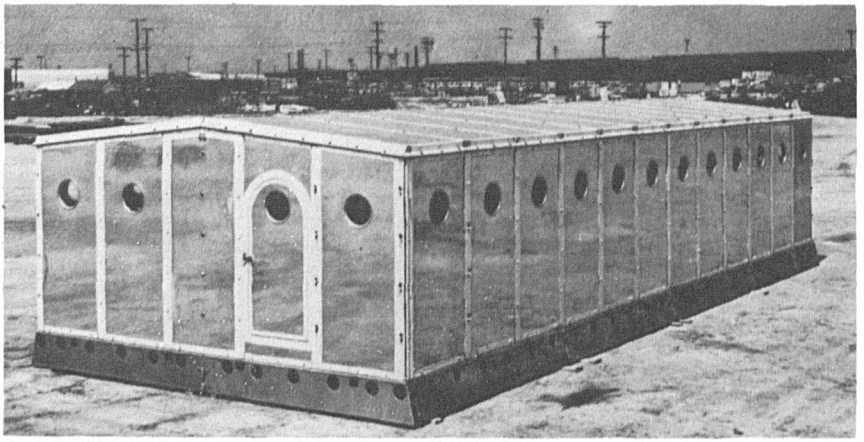


Figure 8–8.—Navy arctic hut.

CONSTRUCTION IN PERMAFROST

Construction in permafrost areas again emphasizes the importance of site selection and the proper scheduling of the various phases of construction in relation to terrain and seasons of the year.

In connection with operations, the selection of a suitable site for a facility is of prime importance. It should be in an area that will permit the most efficient construction with the least possibility of permafrost problems. Areas of natural drainage are most suitable. If natural drainage is not available, the area should be capable of being easily drained by artificial means. Carefully located ditches provide artificial drainage when natural drainage is inadequate. In permafrost areas, ditches should be lined with gravel to prevent erosion and to provide adequate insulation against the possibility of lowering the permafrost table, with resulting sluffing and possible damage to any road or facility.

Most earth work is accomplished during the period from mid-June to the first of September. During this time all types of gravel, sand or silt can be moved with conventional earth-moving equipment. During the winter season, river bed gravel may be obtained through the ice. All coarse sands and gravel located above the water table may be loosened by blasting or shocking with a dozer grader. Permafrost may be moved during the winter by blasting, or a limited amount of frozen earth may be thawed by steam produced by a small Alaska protectors-type low pressure boiler. Such earth moving is slow and not very efficient, and is feasible only in emergency.

The characteristics of the active layer on the permanently frozen ground makes foundation construction a serious problem. A structure of subgrade built on the active layer may change the frost table. After a thaw, settling may occur; and after a freeze, if moisture has been trapped, heaving is probable. To take care of such a possibility, heavy foundations are placed on piles which extend well down into permafrost. Prevention of the lowering of the permafrost table or the maintenance of thermal equilibrium is maintained by wide spacing of piles, and, in case of buildings, by providing adequate ventilation between the floor and ground and by insulating the floor. The heavy force of the active layer is counteracted by the ad-freezing force of permafrost to the piling. In some cases the silt and organic material of the active layer is removed and replaced by coarse or drained material. Figure 8–10 is a typical view of permafrost terrain in the Arctic.

ROAD CONSTRUCTION

Road construction is usually limited to camp areas and immediate surroundings. The active layer is removed if it contains moisture-holding material such as silt, fine sand, or organic material. Such material is replaced by coarse gravel, or material suitable for good drainage is provided. Air strips have been similarly constructed except for final surfacing.

The Point Barrow strip has a gravel foundation and a pierced-plank surface. The runway has been able to take care of large two and four engine aircraft. The only maintenance involves the replacement of pieces of mat. The Umiat strip is on an old river

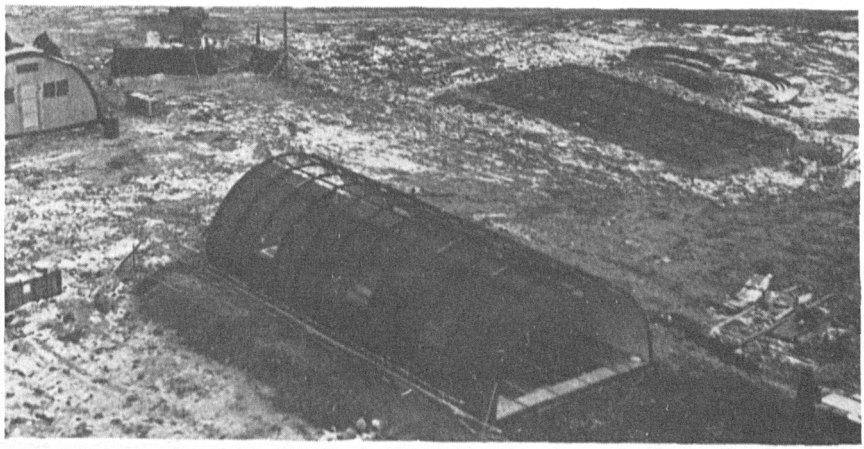


Figure 8–9.—Northern type quonset hut.

terrace. Coarse silt and gravel replace the silt and organic material in the active layer, and ditches have been provided to effect a fast run-off of water. The Barter Island runway was constructed on a gravel bar in a river delta, and in this case the active layer consisted of well-drained gravel and silt. This material was sufficiently coarse so that only grading was necessary.

Various types of buildings have been constructed, most being of the temporary advanced base type. The 40 by 100 quonset hut is usually erected on piling extending into permafrost, or in areas of coarse, well-drained materials. Sills are placed on short wooden blocks. For heavier foundations where piles are not desired, flat footings or slabs placed well within the permafrost and fastened to the base of a concrete or timber pillar may be used.

Old river terraces and gravel beach bars provide the most suitable landing areas. The use of frozen fresh water lakes for airstrips for planes on wheels has been successfully used from November to early June. Landings can be made on frozen terrains on skis.

Snow runways have been successfully used by R4Ds equipped with skis (fig. 8–11). To compact the snow, a pontoon drag is used in conjunction with bolted wooden track extensions to the tractor's track-plates, utilizing the weight and vibration of the machine.

An important property of snow which must be considered in compaction is that it automatically continues to harden if left undisturbed after having been compacted by mechanical means. This curing interval must be recognized because attempting to work hard, dry snow continuously without allowing this interval will only result in churning the snow mass with no increase in compaction.

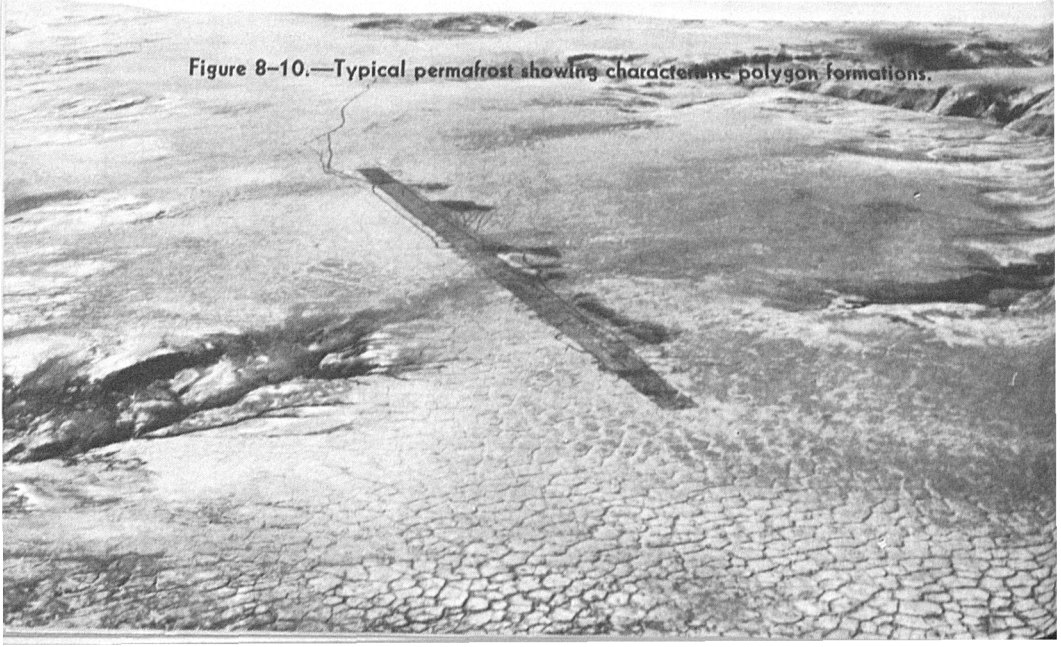


Figure 8–10.—Typical permafrost showing characteristic polygon formations.

Figure 8–11.—Runway in an arctic area.

UTILITIES

For temporary and mobile bases, a source of water can usually be obtained from lakes or rivers which have not frozen to the bottom, or from the melting of snow or fresh water ice. All water used for drinking or cooking should be given primary treatment, such as chlorination. Heated latrines are essential since answering "nature's call" is rather inconvenient, to say the least, unless a heated shelter is provided. Waste material may be collected in oil drums lined with burlap, allowed to freeze, and then periodically burned. In some cases, it may be dumped on ocean ice, should the location be so situated. For temporary bases, electrical distribution can be handled in the conventional manner. Permanent installations should provide heated "utilidors" for carrying of utility lines as well as fire lines.

FOOD AND DIET

The problem of food and diet in base operations in the Arctic resolves itself into the careful preparation of tasty and highly nutritious food. The morale of personnel can be considerably increased by the provision of the widest and most divergent diet possible. However, there is no essential difference between nutrition in the Arctic and nutrition in other parts of the world. Base

operations will require personnel to be exposed to cold weather for extended periods of time, warranting increased rations and the improved level of preparation made necessary by the climatic conditions and the environment.

The amount of food required by individuals will vary, with average requirements approximating 4,500 calories per day. Under some circumstances as many as 6,000 calories may be required. A greater than normal amount of body heat energy must be generated to balance the loss of heat due to the extreme low temperatures and inadequacies of clothing.

Special precaution must be taken in the packaging and shipping of food to prevent the freezing of liquids and the possible breakage of glass containers.

Advantage can be taken of natural refrigeration by utilizing underground storage in permanently frozen ground. This can be accomplished by sinking a shaft into the permafrost and widening the bottom horizontally for storage area. This practice has been followed by the Eskimo for centuries.

TRAINING OF CONSTRUCTION PERSONNEL

The tendency of travelers in relating their experiences in the Arctic, or for that matter, in other parts of the world, is to recount those that are most vivid in their minds. It is only human nature to remember the most startling or severe experiences encountered.

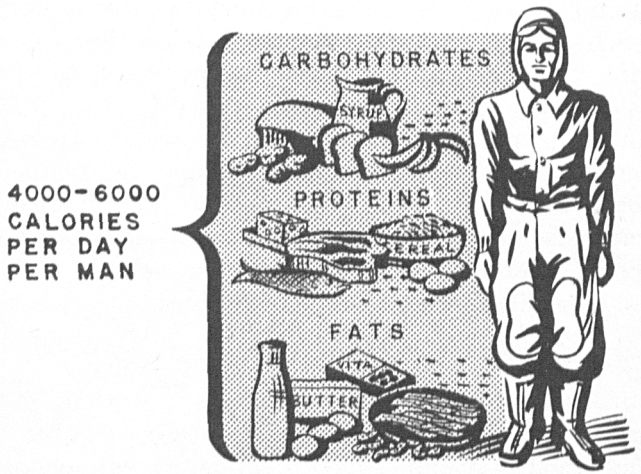


Figure 8–12.—4500–6000 calories per day, per man.

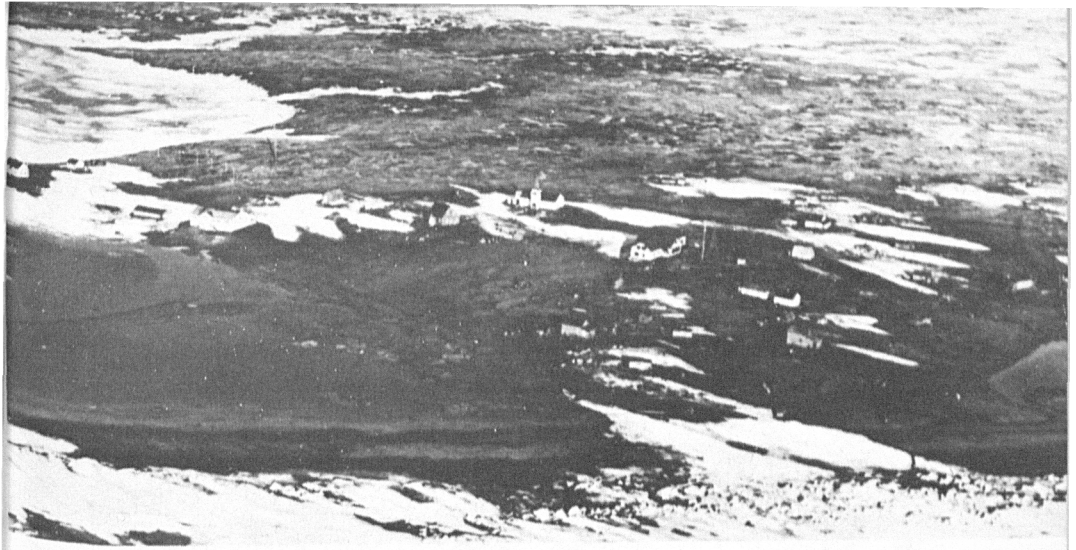


Figure 8–13.—Typical arctic terrain in Point Barrow, Alaska, area.

As a result, the tales of people who have been in the Arctic will gloss over the many normal conditions of life there and stress only the most severe and exciting conditions. This breeds in their hearers a psychological fear of the cold.

Experience has proven that this psychological fear can best be overcome by natural exposure to the arctic environment, rather than by lectures and movies. The techniques of survival will be based on the experiences of the men moving into the uninhabited area to establish an advance base. It is essential that these people have special training to enable them to adapt themselves to the rigors of the North and how to best use their personal equipment. The fact should also be emphasized that, as the temperature drops, personal efficiency will also be lowered. Obviously then, personnel for arctic duty should be carefully selected and highly trained.

TRAFFICABILITY

Due to the terrain features of the Arctic (fig. 8–13) and the absence of roads, wheeled vehicles are unsatisfactory except in an immediate camp area where a few roads may have been constructed. Track-type equipment has been most successful. The presence of many streams and lakes during the summer season requires that personnel and light utility vehicles be amphibious in order to provide year-round service.

At the present time, the M29C cargo carrier or weasel (fig. 8–14), with proper modification and winterization is the most

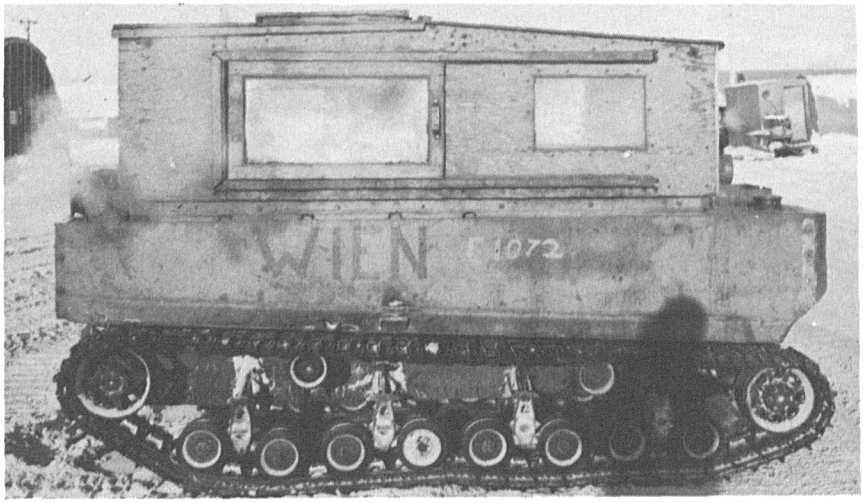


Figure 8–14.—Winterized weasel with permanent type cab.

satisfactory vehicle yet developed for small personnel carriers. The basic weaknesses in the weasel are general fragile construction, weak track suspension assemblies, weak transmission and a very high-speed motor. These limitations must be taken into account in the use of the equipment.

Advantage is taken of the frozen terrain to transport heavy equipment during the winter months. It has been the practice of Seabees engaged in construction work in northern Alaska to move their large quantities of supplies and equipment over the ice and frozen terrain by means of tractor trains between January and June. The trains are made up of five D–8 tractors, cook house wanigan, one 8-bunk sleeping wanigan, one emergency shop, and 12 to 16 sleds or go-devils. The lead tractor is provided with a V-type plow or dozer blade for breaking trail. The trail is scouted by a single-engined aircraft which drops weighted trail flags. This trail is then reconnoitered by a weasel scout vehicle which checks ice and route conditions.

OPERATION AND MAINTENANCE OF CONSTRUCTION EQUIPMENT

In general, most of the construction equipment designed for temperate climates can, with some modifications, be successfully used in construction projects in the arctic regions. However, this equipment must be fortified to meet the conditions of severe cold by the use of proper winterization kits, proper lubricants, coolants,

and cold starting aid kits. The general points of consideration in winterizing equipment will consist in protection for personnel, insulation of the engine compartment, insulation of hydraulic sytsems, heat of the batteries, and in some cases, modification of the track system.

Construction equipment used in the Arctic must be powerful and rugged to withstand the rough usage over the frozen terrain. However, it must be realized that during the summer season the trafficability of heavy construction equipment is limited, due to the marshy tundra.

Diesel power equipment is preferred because it has proven more dependable than other types and is usually more rugged. Wheeled vehicles are of little use until such time as graded roads are built.

PRIME MOVERS

The D–8 caterpillar tractor, equipped with a hydraulic bulldozer and a single drum winch equipped with ice grousers for winter and standard grousers for summer, has proven to be the most satisfactory of the prime movers. The D–6 tractor has proven satisfactory for operations during the summer months over the tundra and for pulling loads up to 5 tons.

Due to the many possibilities of failure on equipment operating at the low temperatures and over the rough terrain, all mechanical equipment used must be kept in the best condition possible. Equipment scheduled for arrival in the Arctic during the winter months should be completely overhauled and winterized prior to shipment. If equipment arrives during the warm season, schedules of operation must provide for winterization overhaul prior to the beginning of the cold weather.

Only first echelon maintenance can be accomplished in exposed areas at extremely low temperatures. Mechanics cannot handle tools while wearing heavy mittens. Exposure of bare hands will cause almost immediate freezing, and handling of cold metal can be very uncomfortable. In fact, bare hands stick all too easily to cold metal surfaces. It is therefore necessary to provide a greater area of heated shop space in any camp layout than would normally be provided in temperate climates.

LUBRICATION

Lubrication is, by and large, one of the most serious problems encountered in the operation of internal combustion engines. The effect of cold on greases and oils is one of the principal causes of

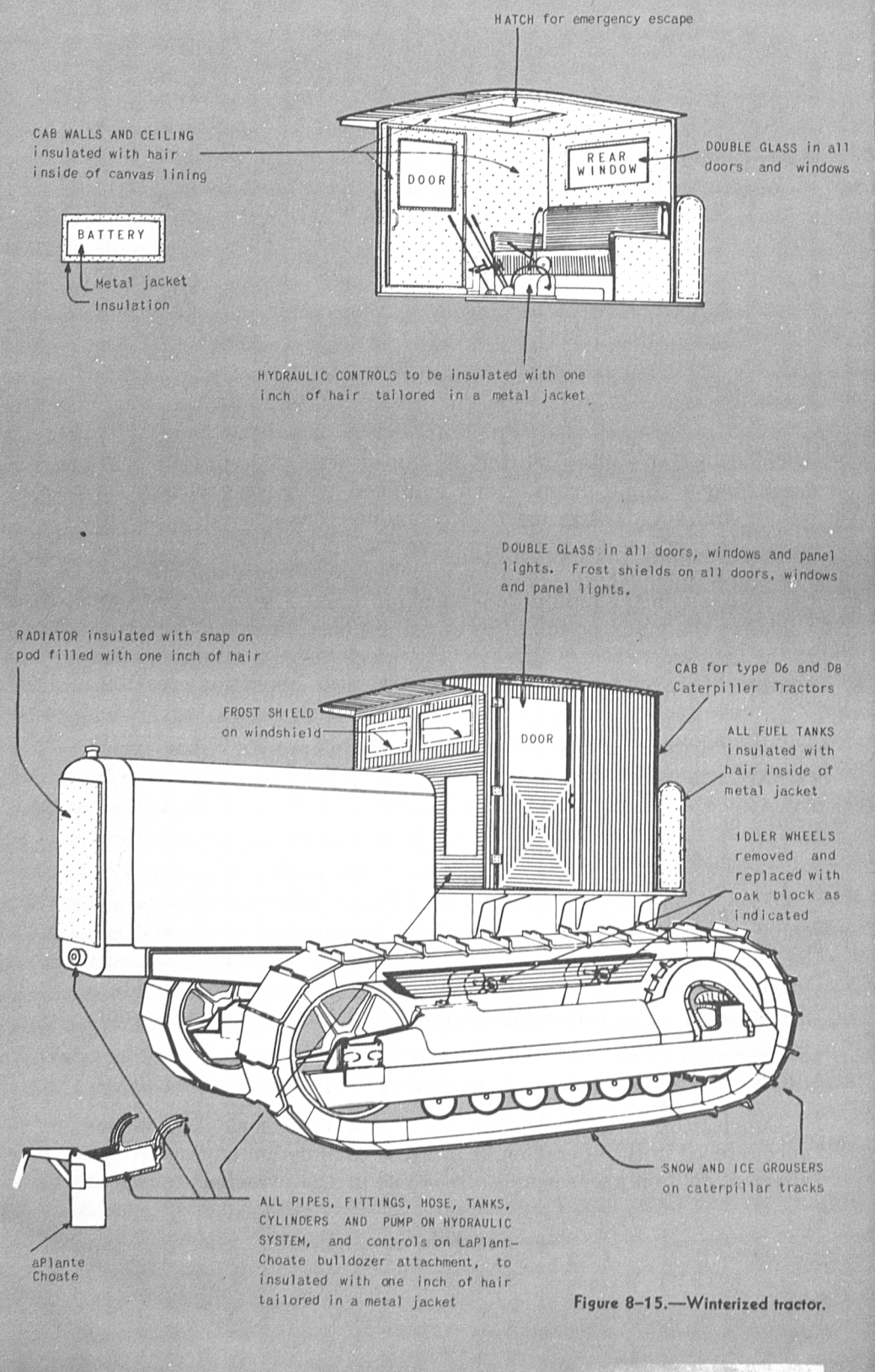


Figure 8-15.—Winterized tractor.

engine starting trouble. Lubrication ties in very closely with the problem of cold engine starting. Ten-weight engine oil in an engine cold-soaked for more than 3 or 4 hours can become so stiff that a fully charged battery with a specific gravity of 1.3 cannot turn over the engine. The problem of cold weather starting is further aggravated by the tendency for lead-acid storage batteries to lose much of their available capacity at lower temperatures. At 0° F. a storage battery can be expected to produce about 50 percent of its rated capacity, while at minus 30° F. its output is only 20 percent of its rated capacity.

While dilution aids starting by lowering the pour point of lubricants, it may also contribute to failures due to lack of lubrication. Engine oil OE–10 has a pour point of minus 10° F., while OE–30 has a pour point of 0° F., but with maximum dilution both of these oils are solid at minus 60° F. As a result, preheat is essential below minus 35° F. At minus 40° F., it may require about 2 hours of operation of a 250,000 B. t. u./hr. heater to start a gasoline engine, and about twice that time, or about 4 hours, to start a cold-soaked Diesel engine. Theoretically, the diluent should burn off at normal operating temperatures leaving the original grade lubricant, but often normal operating temperature is not reached and the diluent remains in the oil unless precautions are taken to check the operating temperature of the engine.

It is essential to analyze the type of operation to be undertaken when considering methods of cold engine starting. Military requirements will call for shutdown periods and quick start periods depending upon the tactical situation or the availability of fuel supply. In this situation, a light or low pour point lubricant, dilution, or reliable sources of preheat are required. On the other hand, construction in the limited time available will often require continuous operation of equipment, eliminating for the most part the problem of cold engine starting.

Heavy duty operation of construction equipment entails long hours of continuous operation, requiring a heavy-bodied oil despite the ambient temperature, so that when the engine has warmed up we will have an oil that is heavy enough to provide the necessary lubrication. For heavy equipment, such as a D-8 tractor, a heavy lubricant must be used to withstand the workload, and present methods make preheat almost mandatory for starting when the equipment has been cold-soaked.

STARTING THE ENGINE

Starting a gasoline engine at extremely low temperatures requires an engine that is free to rotate, a source of power to turn the engine, a fuel that will vaporize and burn at these temperatures, and ignition systems which will provide the necessary spark under these conditions. Free rotation may be prevented by the solidification of oil and the stiffness of fan belts and other accessories which turn with the engine. At minus 50° F., fan belts may become so stiff that they shatter like glass when twisted. Rubber tires may freeze solid and often develop frozen flat spots when left standing for a short period. Congealed or frozen gear lubricants may result in wheels skidding on ice-covered terrain and from starting. It is necessary therefore to start vehicles by heating each individual vehicle with such preheaters as the slave kit or 250,000 B. t. u. Herman Nelson heater.

Two methods of applying preheat are commonly used. First, by stand-by heaters which are run continuously during the shutdown period of the engine, and then by quick heaters which are operated just prior to attempting to start the engine. To date, the most dependable of the stand-by heaters is the Superfex 460 coolant-type heater. The best of the quick heaters is the Herman Nelson 250,000 B. t. u./hr. gasoline heater. The biggest objection to the Herman Nelson is its high rate of fuel consumption. Until low pour point lubricants have been developed, we shall have to depend on external heat for starting at temperatures as low as minus 40° F.

SCRAPERS, GRADERS AND ROOTERS

Scrapers under 16-cubic yard capacity have been used successfully in the Arctic. They should, however, be equipped with offset frost blades with protruding chisel-bit teeth. The center section of the blade should be slightly lower than the sides for very rough or frozen ground.

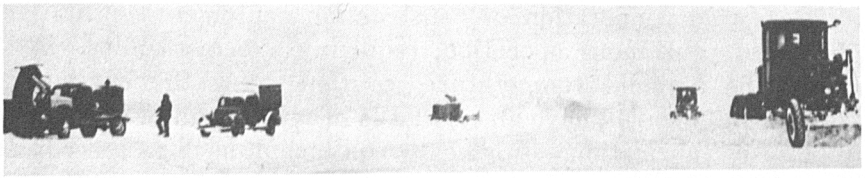


Figure 8–16.—View of motorized graders clearing snow off runway.

Motorized patrol graders with 12-foot blades have proven more effective than the towed type. It is essential that the grader operator be protected by a heated cab.

The standard 3-tooth rooter or scarifier has been used with some success when only 1 or 2 of the teeth were utilized.

CRANES AND POWER SHOVELS

As in all motorized equipment, the operators of cranes and power shovels must be protected from the weather with an insulated enclosure. Truck-mounted cranes are more mobile, but frequently bog down in the marshy tundra.

FORK LIFTS

Crawler mounted fork lifts with winterized cabs are very efficient on snow, ice, or marshy tundra. Use of the wheeled model, however, is generally confined to the interior of warehouses (fig. 8–17).

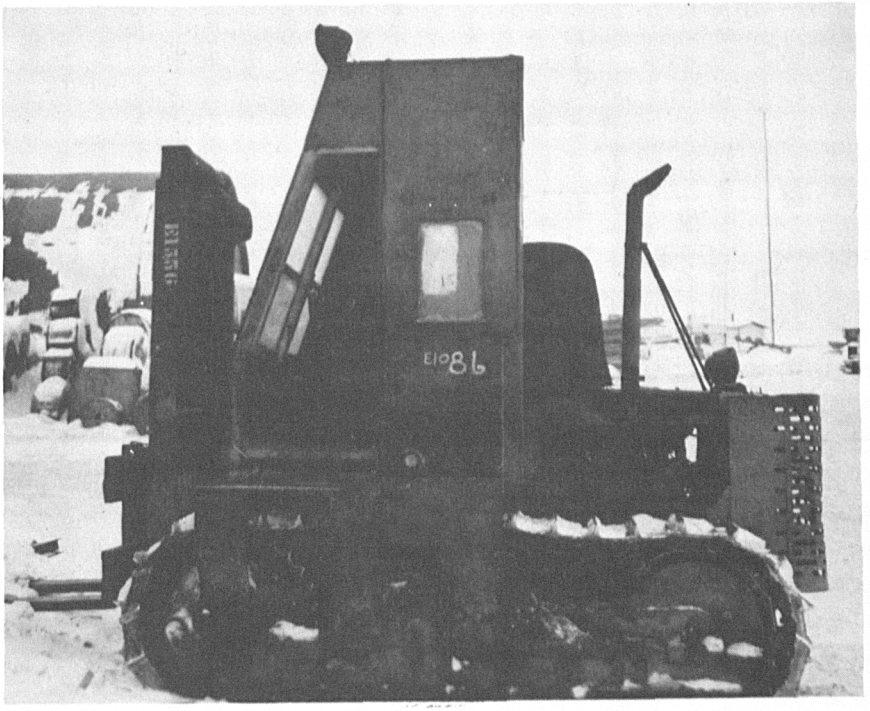
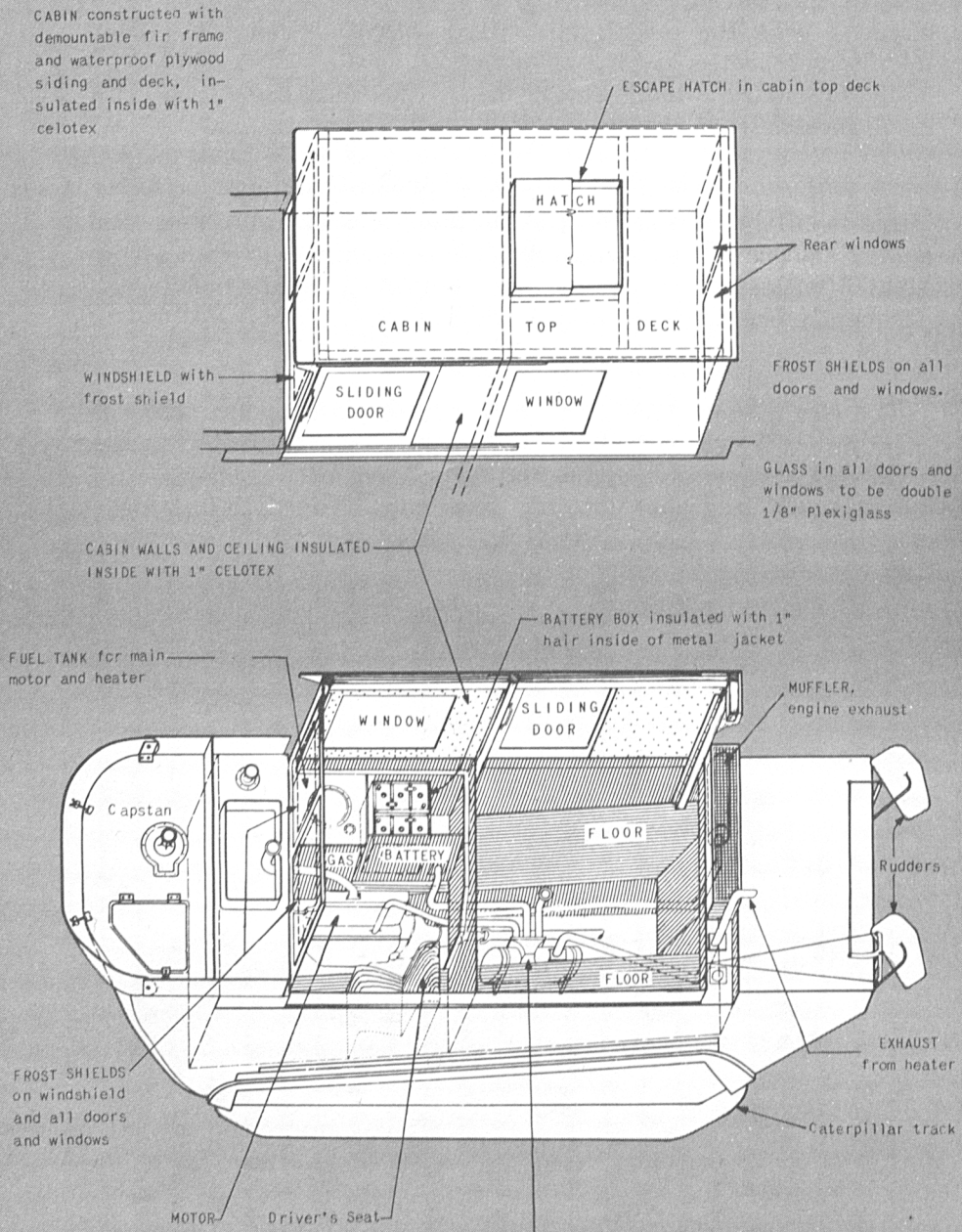


Figure 8–17.—Winterized fork lift crawler tractor.



HOT AIR HEATER, capacity 20,000 BTU, operating on gasoline, made by Herman Nelson Corp., Moline, Ill. Install in driveshaft well with 3 flexible pipe hot air outlets to (1) main motor crankcase, (2) battery compartment, and (3) cabin. Floor plate over heater removed to show installation.
HEATER CONTROL button on instrument panel. Hood over machinery compartment removed to show heater pipes to motor crankcase and battery box.

Figure 8-18.—Winterized weasel.

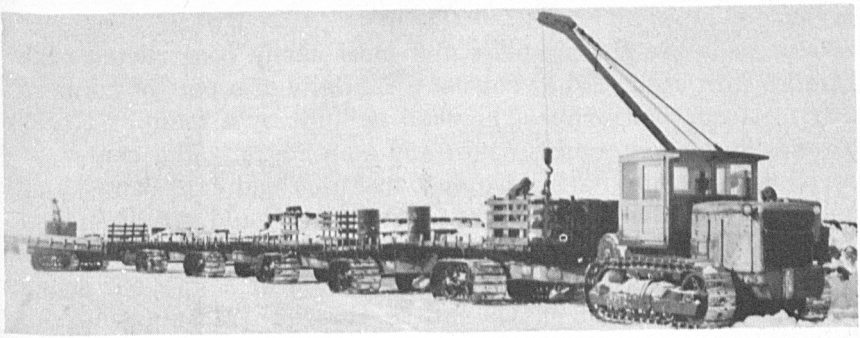


Figure 8–19.—A train of athey wagons.

PERSONNEL AND CARGO CARRIERS

The usefulness of jeeps and trucks is generally limited to improved roads and camp areas and, to some extent, to surfaces of ice or hard packed snow (fig. 8–14, winterized weasel).

The standard Army winterization kit for ¼-ton jeep on Task Force Frigid included the following items:

Primer pump.
Side curtains.
Superfex engine heater.
Fuel tanks.
Hood curtains.
Radiator cover.
Engine blanket.
Cab heater.
Hose, connections, and thermostat.
Slave kit connector.

ATHEY WAGONS

These nonmotorized vehicles are tracked cargo carriers of 15 and 25-ton capacity, used as a cargo carrying trailer. They give excellent service at low speeds but will not stand up well at towing speeds exceeding 15 miles per hour.

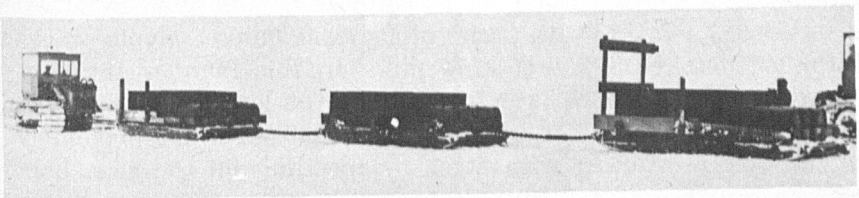


Figure 8–20.—View of go-devil sleds.

GO-DEVIL SLEDS

These sleds are the simplest and most easily constructed type of trailer unit used. They consist essentially of a pair of runners carrying a low platform. They can be built by a team of blacksmiths and carpenters in 50- to 150-man-hours. The center of gravity is low, eliminating tipping, and the load capacity is limited by bulk rather than weight. The load should not be higher than the width of the sled and no longer than 24 feet to assure satisfactory handling on the trail. The bed of a go-devil drags over a greater area of snow than do the runners of a bob-sled, hence more power is required to tow a go-devil than a bob-sled (fig. 8–20, view of go-devil type sled).

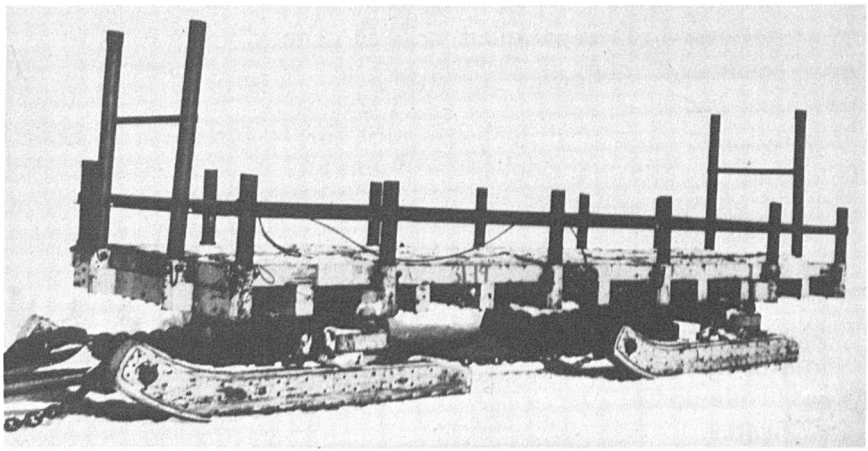


Figure 8–21a.—View of bob-sleds.

BOB-SLEDS

These sleds (fig. 8–21a) are of various sizes and design. Essentially, they consist of two sets of runners joined by cross-chains which make the rear set of runners track with those in front when negotiating a curve. Each set of runners is connected by a low or stationary bunker. An upper or movable bunker pivots on the stationary bunker, about a king pin. In this manner the runners can swing without interfering with the load. The bob-sled is attached to the tractor by a tongue. All parts are extremely rugged and reinforced with steel. Depending on the size, bob-sleds have a capacity of 10 to 75 tons.

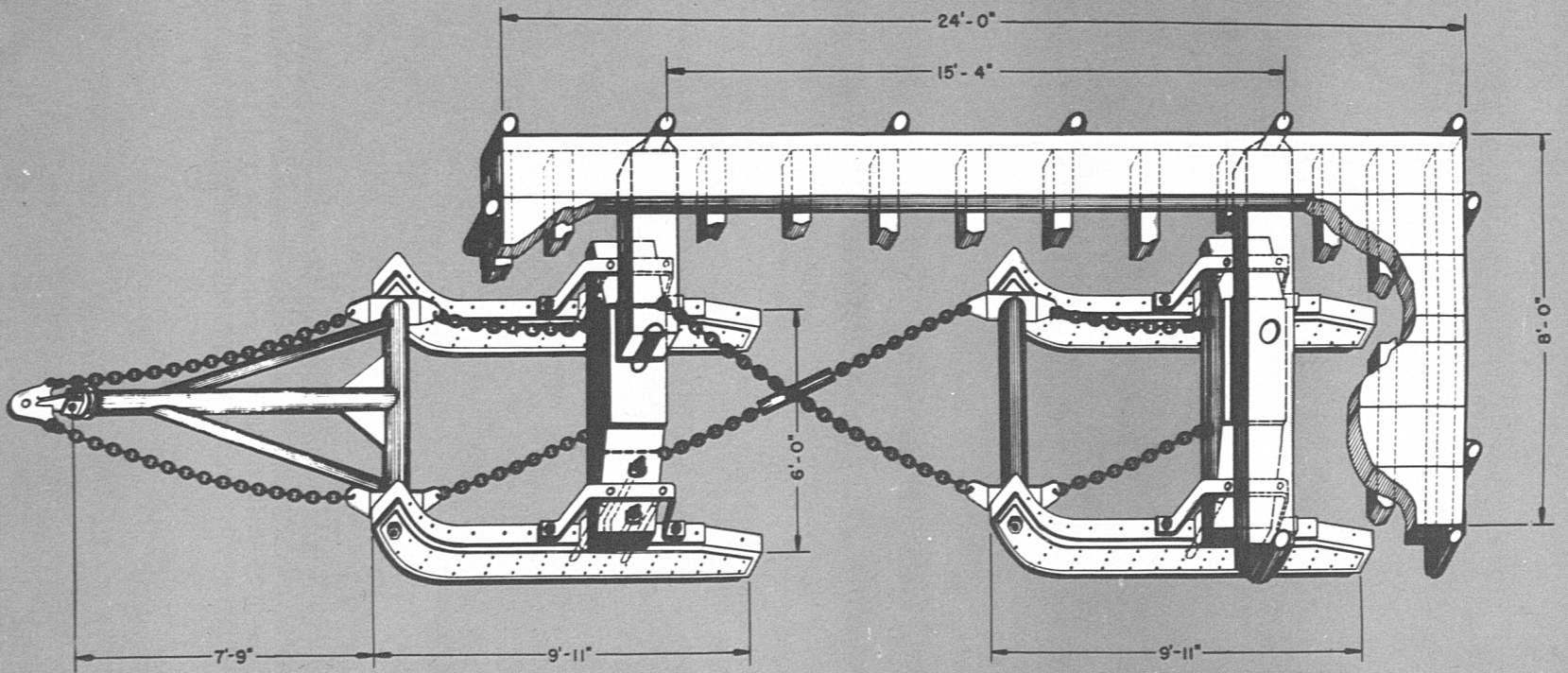


Figure 8–21b.—Drawing of Modified Micheler No. 9 sled.

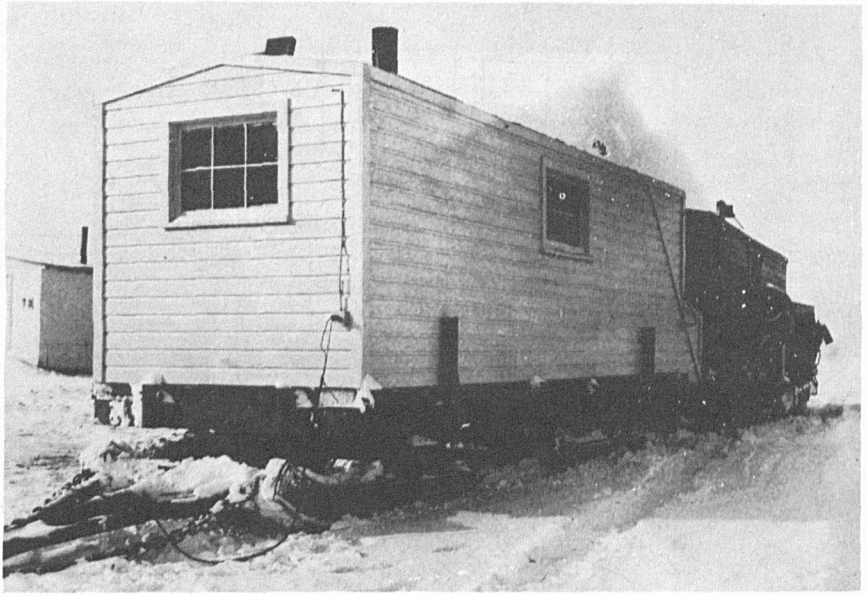


Figure 8–22.—A typical wanigan.

WANIGANS

Wanigans (fig. 8–22) are small buildings for use on the trail or in temporary camps. They can be mounted on sleds or go-devils. They provide quarters, messing, and shop facilities. Wanigans are usually constructed of 5/8" plywood or sheet metal on a heavily braced frame to withstand the strains imposed by tractor train operations. The roof is curved in a flat arch and is of the same material as the walls with a sub-layer of roofing paper. Windows require heavy protective screens to prevent damage by branches. The interior is insulated with celotex or similar material. The height should be a minimum of 7 feet, the width about 8 feet, but no greater than the width of the dozer blade and the length variable. Longer wanigans ride more smoothly on sleds than shorter ones.

STEAM BOILERS

Skid-mounted steam boilers (fig. 8–23) are very essential pieces of equipment in the Arctic. Steam is required to thaw holes in the permafrost for piling and explosive charges. It is also used to thaw ice-filled culverts and to remove ice and frozen mud from equipment and tools. For small operations, a 15-h.p. boiler

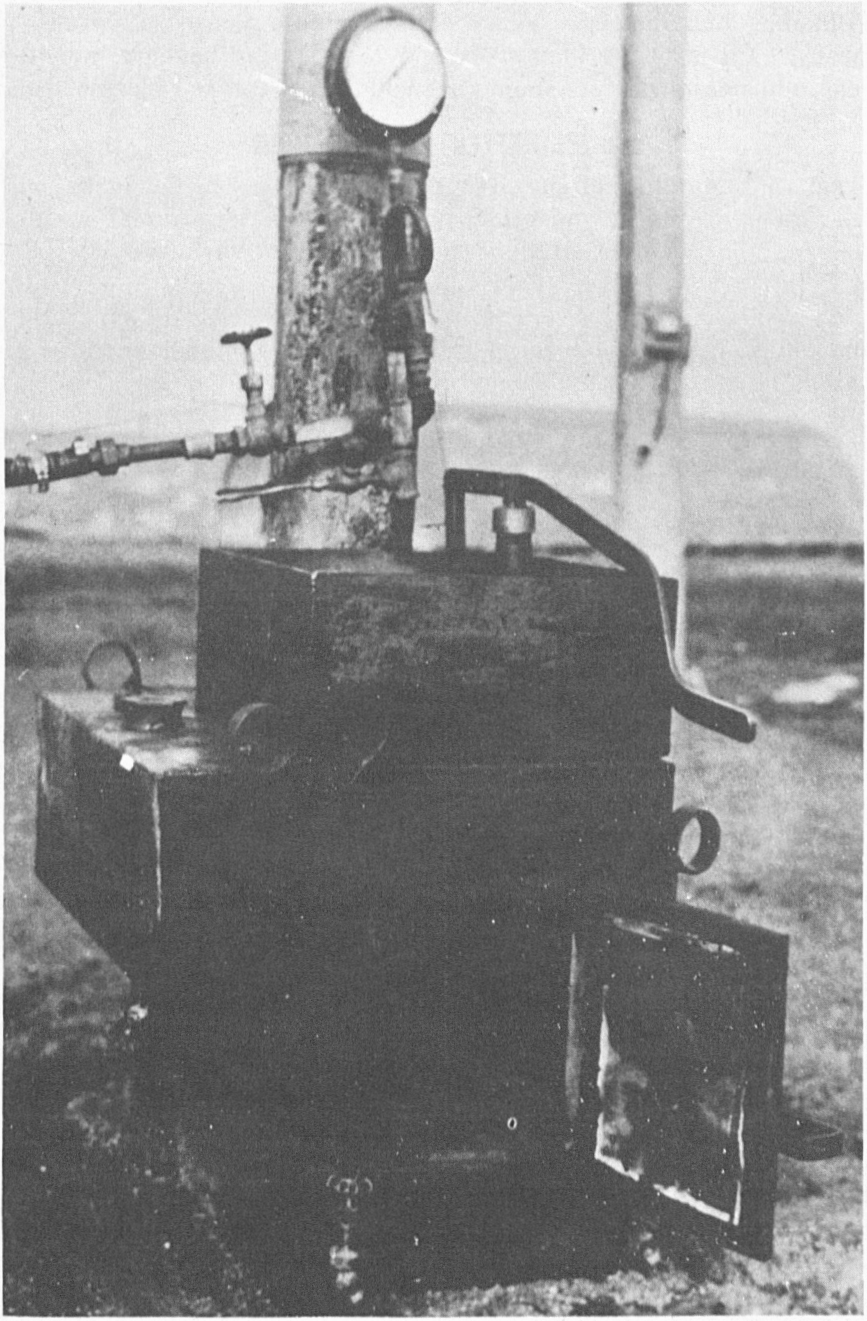


Figure 8–23.—A low pressure miners steam boiler for thawing frozen ground.

will suffice but for larger jobs a 45-h.p. to 60-h.p. size will be necessary. Pipes of various sizes and lengths for headers, steam hose, and steam jet pipes should be included as required accessories.

SUB-ZERO EFFECT ON MATERIALS

An understanding of the effect of extreme cold on the elasticity, durability, strength, and other physical characteristics of materials is important. A study of the mechanics of various materials at Point Barrow indicated the following:

Rubber.—New rubber resists cold rather well while synthetic and old rubber are not reliable. In any case, rubber should be handled carefully in low temperatures.

Neoprene.—Unsatisfactory at temperatures below minus 20° F.

Fabrics.—Untreated and water-repellent fabrics give no trouble down to minus 40° F.

Nylon.—Extreme cold, below minus 40° F. has no apparent effect on nylon. This material does not crack and remains soft and pliable at that temperature.

Canvas.—Freezes and loses its pliability; this is sometimes mistaken for shrinkage.

Leather.—Becomes stiff and tears easily. Wet leather is usually ruined if frozen. Protective coating of good shoe oil on rough side will increase life.

Glass.—Glass is susceptible to sudden change in temperature. A warm blast of air on a thin pane or lens of frozen glass may cause it to shatter.

Ceramics.—Glazed ceramics are not affected unless subjected to sudden changes of temperature.

Copper Wiring.—Wiring becomes very brittle—failing under tension.

Steel.—Contracts and becomes brittle. Care should be taken to avoid rough handling.

While it is true that the physical properties of many materials undergo a change in extremely low temperatures, particularly an increase in brittleness, it is also true that failure, as in the case of iron or steel, might also be caused by a jolting contact with permanently frozen ground. It is important that a preventive maintenance program be constantly employed.

COOLANTS

An antifreeze mixture containing 60 percent Prestone (ethylene glycol) and 40 percent water should give protcetion down to minus 64° F. Pure water or pure antifreeze should never be

Figure 8–24.—A Herman Nelson heater in operation.

added directly to the radiator. Only a thoroughly mixed solution should be added.

PREHEATERS

At the present time, the cold weather starting of all motorized equipment is accomplished by preheating. There are three main types of preheaters.

The most satisfactory of these units is the Herman Nelson heater (fig. 8–24) that generates 250,000 B. t. u./hr. It is a self-powered unit designed to produce a steady flow of hot air. It consists of a vaporizing-type gasoline burner, a combustion chamber, a pressure-type propeller fan, a blower fan, a gasoline engine, and a system of ducts. The heater was originally designed for use in heating large spaces, such as portable hangars and garages. However, it is used by both the Army and the Navy in heating vehicle engines and battery compartments and planes. One difficulty with it is that its gasoline engine generally has to be preheated at temperatures below minus 10° F. If a source of power is available, the Herman Nelson heater can be converted to an electric motor drive which would eliminate its own cold

weather starting problem. Anyway, its efficiency is greatly reduced at temperatures below minus 35° F. It has a high rate of fuel consumption, averaging about 4 gallons of gasoline per hour; but at present it is considered indispensable in cold weather starting of all equipment. The heat is applied to intake manifold, crankcase, oil pan, and carburetor.

Another type of heater is known as the Stewart Warner self-powered heater. This portable unit, weighing 200 pounds, is designed to produce a steady flow of hot air through a system of collapsible ducts. The heat output is 100,000 B. t. u./hr. with a gas consumption of 1½ gallons per hour. Like the Herman Nelson heater, its efficiency is greatly reduced at temperatures below minus 35° F.

A smaller type of preheating unit is the Stewart Warner hand crank model 796–A heater. This small portable unit, weighing only 5½ pounds, is capable of delivering 40,000 B. t. u. at 120 r. p. m. through a flexible metal hot air duct. This unit is satisfactory for heating small engines such as the one on the Herman Nelson heater. It is unsatisfactory at temperatures below minus 30° F.

Plumbers-type firepots and ordinary blow torches have been found acceptable for limited use. However, due to the fire hazard, they are not recommended.

Another type of portable heater is the Superflex heater model 460 which is a component part of the Army's vehicle winterization kit. It is a forced draft heater and is used as a stand-by heater to maintain starting temperatures in both gasoline and Diesel engines. At minus 30° F. the unit will supply sufficient heat to start engines after 30 or 40 minutes. It has also worked at minus 62° F.

INSECT PESTS

Swarms of mosquitos and other insects are prevalent in the Arctic following a spring thaw. Among these are the horse fly, bot fly, and blue fly, which are a nuisance and troublesome but present no serious problem. However, the arrival of mosquitos coincides with the mildest weather and the season of greatest human activity. To eliminate this nuisance, control measures may be required in the vicinity of bases and permanent camps. An effective control program which has been used in the arctic region of Alaska consists of 5 percent and 10 percent solutions

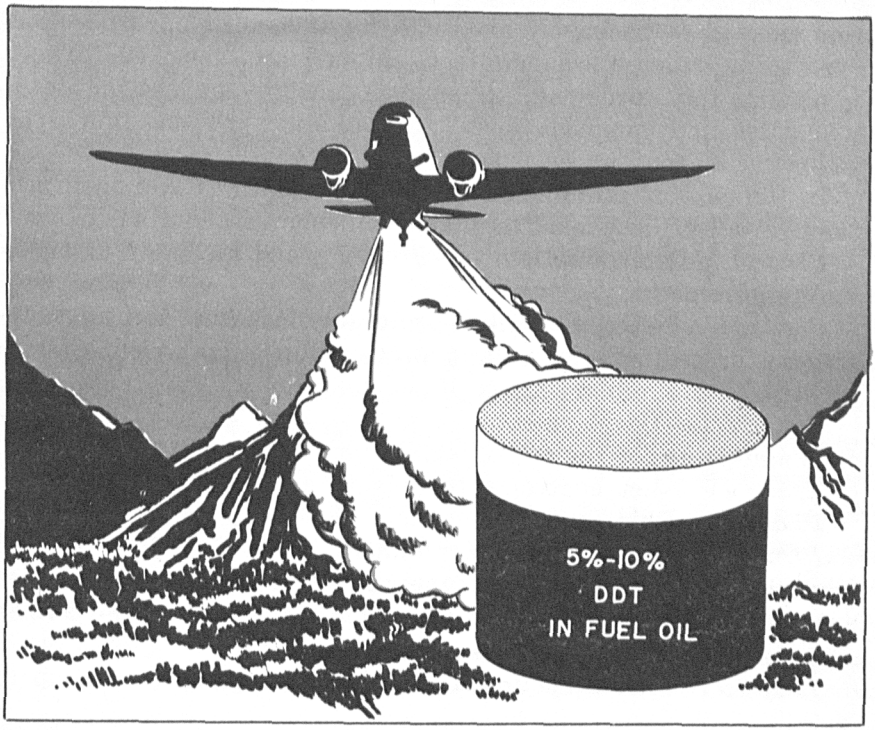


Figure 8–25.—Spraying with DDT.

of DDT in fuel oil applied aerially in dosage of 0.2 to 0.4 pounds of DDT per acre, sprayed at approximately 5-day intervals. Personnel in the field should be provided with repellents, head nets, and aerosol bombs.

SUMMARY

Only the highlights of problems encountered in the establishment of stations and in construction projects in the Arctic are described herein. For greater detail the following publications should be consulted:

NavDocks P–17, *Cold Weather Engineering.*

NavDocks, P–19, *Report on Equipment and Structures in the Arctic.*

NavDocks P–13, *Report on Arctic Clothing Experience.*

In arctic operations, time is precious. Advanced, detailed planning for a construction project is essential to success. All materials and equipment must be delivered to site in good condi-

tion, in secure packages, and with an inventory ensuring that everything ordered was, in fact, shipped and received. There is no time for reordering. Shortages can prevent meeting deadline dates and can well delay completion of the task until the following season.

In the case of establishment of special stations and facilities, the over-all project must be planned in phases about as follows:

Phase I.—Determination, procurement, and assembly of material requirements.

Phase II.—Selection of site—preferably by actual sighting during the preceding season—and preparation of a lay-out of site along with preliminary study of soil conditions.

Phase III.—Development of complete, detailed working drawings and plans for the entire installation.

Phase IV.—Let contracts to private contractors if required.

Phase V.—Shipment of materials and equipment to site.

Phase VI.—Selection of personnel. Important factors are: high skill, dependability, willingness to see project through, ability to adjust to a harsh and uncomfortable environment, and ability to get along well with others.

Phase VII.—Construction and installation plan worked up in detail.

Phase VIII.—Plan for evacuation of personnel, as required.

Figure 8-26.—Head nets.

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APPENDIX A

NAVIGABILITY IN ARCTIC AND NORTHERN SEAS

Area	Navigable season	Remarks
Eurasiatic Sector of Arctic Sea from Wrangel Island to Spitsbergen.	Not navigable, but penetrable by specially constructed polar ship or icebreaker.	In the autumn of 1893, Nansen in the *Fram* deliberately entered one of the leads in the arctic pack to the northward of the New Siberian Islands and became beset. The *Fram* remained closely beset for three winters and was finally liberated from the pack north of Spitsbergen. The drift was to the north of all the islands on the continental shelf.
American Sector Arctic Sea from Greenland to Bering Straight.	Not navigable; generally impenetrable.	The ice is impenetrable with the exception of the arctic coast of Alaska and occasionally the southern part of the Lincoln Sea and the west side of Banks Island. For a short period most years, the ice recedes 20 or 30 miles from the Alaskan coast permitting limited navigation of small ships from Point Barrow to the Delta of the Mackenzie River. There is little level ice in the sector. The Pole of Relative Inaccessibility of the Arctic Sea lies north of Alaska near 84° N., 160° W.
Barents Sea; Novaya Zemlya.	Navigable generally during all seasons in southernmost part to entrance of White Sea; southeastern part from White Sea to Kara Strait icebound from November to June.	Access to the bays and gulfs along the Murman coast of the Kola Peninsula is possible all year. Occasionally Kola Inlet and the harbor at Murmansk are covered with ice for a short period in winter.
Franz Josef Archipelago	July and August with icebreaker assistance.	Some years navigation is possible in late June.
White Sea	Navigation possible throughout the year in a considerable part of this sea from its entrance to Archangel.	The normal season is May to December. It is possible that powerful icebreakers can keep Archangel and other ports open during the period from December through April when heavy ice in inlets and along the shores exists. The central part of sea is usually open to navigation. Due to its shallowness and narrowness the entrance is frequently clogged with ice during the winter period.
Kara Sea	August to October with icebreaker assistance. This is a main link in the Soviet Northern Sea Route — Northeast Passage.	Navigation in southern part is generally favorable, while in northern part it is usually uncertain due to intrusion of heavy polar ices breaking away from the arctic pack. Matochkin Shar and Kara Strait are usually open latter part of July.
Laptev Sea, East Siberian Sea, Chukchi Sea.	August to September with icebreaker assistance.	Considerable floebergs, tabular bergs, and grounded ice are encountered in these waters. Navigation is generally uncertain, difficult, and hazardous.

Davis Strait, Godthaab to Cape Farewell.	June to December. Some places could probably be reached all year with icebreakers.	At Cape Farewell, southernmost point of Greenland, storis usually arrives in January extending sometimes 150 miles seaward. By April this belt averages 70 miles and by August 30 miles wide on an average. The bay at Julianehaab may have drift ice all year and is usually closed during February. At Arsuk Fiord, storis appears in March rendering access difficult or impossible up to June. There is little ice along the coast and in the fiords from June to December.
Davis Strait, Godthaab to Disko Bay.	June to December. This period can be extended by use of icebreakers. Icebreakers probably can operate in winter up to arctic circle.	"West ice," or Baffin Bay polar ice, appears along the coast to latitude 66° N. in January. Winter ice forms far out to sea during period February to April, and west ice from the North appears in the districts of Sukkertoppen and Holsteinsborg. In May, coast is usually free of ice; often west ice is not far off. In June and July coast is clear of ice with the west ice appearing 70 to 80 miles off the coast. From August to November there is little ice. In December ice appears in the vicinity of Egedesmunde.
Baffin Bay, Disko Bay to Upernivik.	June to November; period may be extended with ice-breakers.	In November west ice begins to appear and winter ice to form. In December the two ices freeze together. In June the ice begins to break up. Coasts are generally clear of ice from July to December. There are many bergs calved during the latter period.
Baffin Bay, Melville Bay. Upernivik to Cape York.	July to October; icebreaker assistance required.	Due to grounding of bergs in the shallow waters of Melville Bay, ice forms in thick, consolidated sheets during the winter months. There is usually a congestion of ice until late in the navigation season.
Cape York to Smith Sound.	July to September; icebreaker assistance desirable.	Waters and coasts are generally clear of ice except for bergs and drift ice during this period.
Smith Sound to Lincoln Sea; Hall Basin, Kane Basin, and Robeson Channel.	August to September; icebreaker assistance required.	Navigation is uncertain due to narrowness of channels and fact that this is an overflow of heavy polar pack from Lincoln Sea.
Davis Strait, West Side	July to October	Entrance to Frobisher Bay generally closed from October to July. Cumberland Sound is navigable from July to September.
Hudson Strait, Hudson Bay.	July to November; period can be extended with icebreaker assistance.	Ice forms in late November and breaks up in late June. However, neither the bay or strait is entirely frozen over in winter. Fury and Hecla Strait and Prince Regent Inlet leading into Lancaster Sound possibly may be navigable by icebreakers during some summers.
Lancaster Sound, Barrow Strait, Viscount Melville Sound, Prince of Wales Strait, Amundsen Gulf.	August to September for icebreakers or icebreaking type ships only.	This is the Northwest Passage from Baffin Bay to the Bering Sea. Ice conditions vary considerably from year to year. Heavy amphibious ships cannot operate safely west of Cornwallis Island (95° to 97° W.).

Area	Navigable season	Remarks
Southwest Spitsbergen	Probably most of the year except March to May—with assistance of icebreakers.	April and May are worst months for ice. In late summer the pack has receded northward leaving little ice along west coast of the archipelago. Late May to November is normal period of navigation for Advent Bay.
Spitsbergen, North and East Coasts.	August; icebreaker assistance required.	Navigation is uncertain except along north coast which is usually open for a short period during August.
Iceland	All year	Drift ice reaches north coast occasionally.
Baltic Sea	All year except Gulfs of Bothnia and Finland.	There is ice in Gulf of Bothnia and gulfs in eastern part of the Baltic Sea during period January through March. The Gulf of Finland to Leningrad can be navigated in winter with assistance of icebreakers.
Black Sea	All year	This sea is a cold weather area with shore ice forming along north coast in winter and with drift ice in harbors and over northern part of the Sea.
Bering Sea, South of Pribilof Islands.	All year	Drift ice seldom appears south of the latitude of the Pribilof Islands except along east coast of the Kamchatka Peninsula.
Bering Sea, North; Beaufort Sea, Chukchi Sea to Wrangel Island.	July to September with icebreaker assistance; powerful icebreakers of wind class can possibly reach Bering Strait all year and under favorable circumstances might even reach Point Barrow in winter.	By July, Bering Strait and southern part of Chukchi Sea to latitude of 70° N. are usually free of ice. Ships should be able to reach Icy Cape without the assistance of icebreakers. In August the southern limit of arctic pack lies near the 72nd parallel and in some places may recede as far as 73° N. Ships are seldom able to reach Point Barrow prior to 1 August. Beyond Icy Cape navigation is uncertain and extremely hazardous. The arctic pack starts its annual southward motion toward Alaskan coast around the middle of September. It is safest to be clear of the Beaufort and Chukchi Seas by the middle of September at the latest. Let it be remembered that north winds will drive the arctic pack to the coast of Alaska from Point Barrow to Barter Island at anytime during the navigable period. Wrangel Island can be reached by icebreakers during the season. Bering Strait is usually covered with polar ice by the end of October. Submarines have reached latitude of 72° 10′ N. in the Chukchi Sea during navigable period. Western side is probably more favorable than eastern side of Bering Sea for navigation during winter months.

APPENDIX B

NOTES ON ICE SEAMANSHIP AND NAVIGATION AMONGST ICE

Thorough preparation and painstaking inspection of the ship before departing for operations in polar seas are essential to success. The following "arctic measures," written from the point of view of a large amphibious ship, should be taken in full or in part, as appropriate:

1. Inspect ship in most painstaking manner.
2. Check the operating condition of main drainage pumps, electric submersible pumps, and auxiliary pumps such as gasoline *handy-billies* and P–500 pumps. Check spare parts and ensure that there is on board a full allowance of parts for these pumps. Inspect suction hose and discharge hose to see that both are in good condition. All pumps should be in as near perfect operating condition as possible. After departure, tests pumps regularly—at least twice weekly—for operability.
3. Thoroughly clean out bilge well suctions in holds, wash down with fresh water, and take suction on each for an over-all operating test. While loading cargo, station men in holds to prevent debris from fouling bilge wells. Do not permit use of sand, sawdust, or like materials used frequently by stevedores for traction for *fork lifts* while loading a ship.
4. Enroute to area of operations instruct personnel as to operation of main drainage system and all types of portable pumps.
5. Provide some form of jury rudder rig for emergency use.
6. If available and authorized, fit steel propellers to shaft(s); carry spare propeller(s) if operation is remote from bases. Ensure that prints of docking plans are on board ship in event docking in commercial dockyard might be required to repair rudder or propeller following damage in ice.
7. Draw good supply of hull damage repair materials—shores, timbers, sand, cement, steel hull plate, angle iron, and channels. Distribute throughout the ship in vital spaces for ready use for strengthening bent frames and backing up sections of the ship's side that might become dented by collisions with ice floes.

8. Distribute plugs, mattresses, shores, etc. in various underwater spaces to have them handy in event of holing. Instruct personnel in the repair of underwater damage resulting from holing.

9. Pay close attention to loading of cargo. Ensure that it is properly shored and distributed in such manner as will permit access to side plating, bulkheads, and bilge suction drain wells and strainer plates. If possible, load for a drag of 3 to 4 feet. Ensure that cargo stowage plans are accurate and that all cargo is adequately marked for ease of identification. Cargo must also be inspected for packaging and packing to ensure that damage from water, rough handling, and pilferage will not be possible.

10. If required, install "ice beams" or heavy timbers extending from one side of the ship to the other at loaded waterline in forward part of the ship. This would not apply in the case of ships whose hulls have been strengthened for navigation in ice.

11. *Rig towing bridle forward for immediate use in event of damage to rudder or propeller and for being towed in traversing areas of consolidated pack. Ensure that bridle is made up to permit ease of connection to towing cable of icebreaker. Consult ice breaker on this point before departure. In pack ice it is best to use bridle, while for ocean towing in the open sea, it is preferable to connect towing cable to anchor chain of towed ship. Conduct of towing exercise while en route to area of operations is desirable when time and conditions permit.*

12. Break out towing cable after arrival in the area of operations and secure in position so that it will be ready for emergency use in event of receipt of orders to tow another ship.

13. Safeguard exposed fresh and salt water piping by appropriate means. Deck risers for fire mains freeze at 15° F. or lower temperature. To keep operative, it may be necessary to keep a trickle of water running through the lines.

14. Install air or preferably steam blow lines on salt water injection piping in order to prevent choking of strainer plates by slush ice.

15. Draw additional quantities of electronic spares as may be required to service radar and radio equipments during the operation. Check over TBS, other radio equipments permanently installed, and all portable equipment received for use in boats, LVT's, and weasels. Ensure that radars are in perfect operating condition.

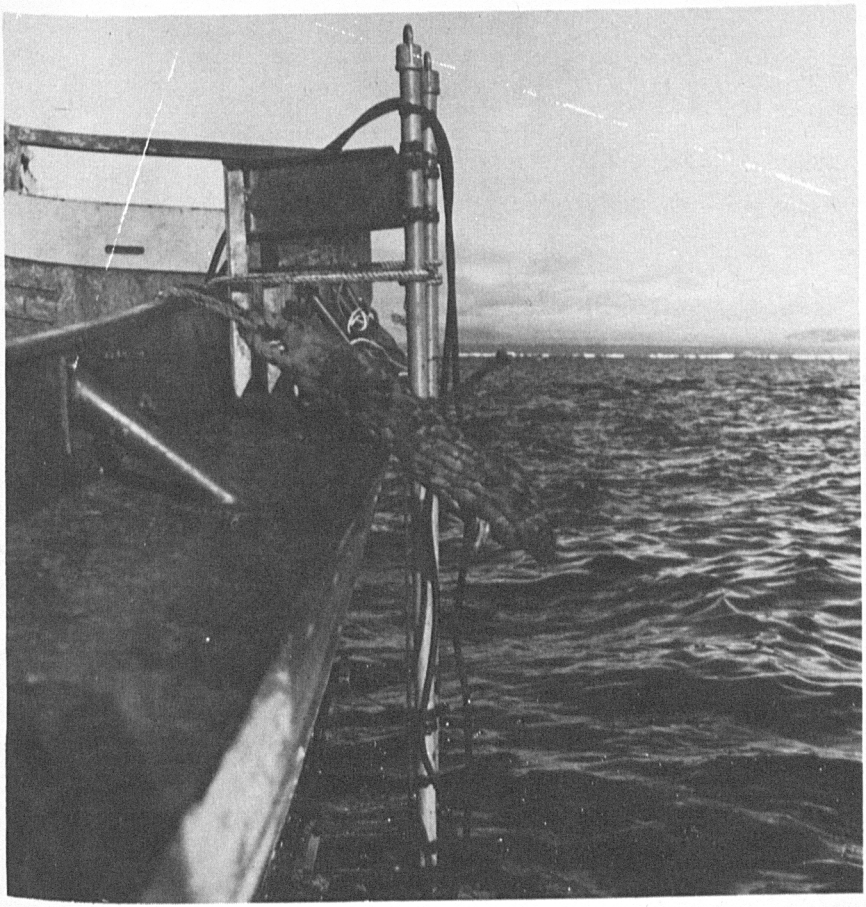


Figure B–1.—LCVP equipped with portable fathometer.

16. Rig up shelter on open deck over pilot house for conning detail.

17. Winterize forward crow's nest. Fit it out as an emergency conning station, if practicable.

18. Build shelter in eyes of the ship for ice lookouts.

19. Winterize pilot house and bridge deck as practicable.

20. Overhaul falls for all booms. Remove excess grease.

21. Winterize all deck machinery. Keep covered with tarpaulins or canvas covers when not in use.

22. Equip one boat with portable fathometer for use in sounding ahead of the ship when entering poorly charted or doubtful harbors (fig. B–1).

Figure B–2.—Stern line attached to "dead man" buried in fast bay ice.

23. Do not fill fresh water tanks in excess of 90 percent of capacity while in cold climates.

24. Winterize searchlights, both signalling and 24″, and place in best operating condition.

25. Refill waterbreakers to 75 percent of capacity to prevent breakage in event of freezing.

26. Carry good supply of antifreeze materials (Prestone) for cooling systems of boat engines, emergency Diesel pump engines, transportation equipment.

27. Where mooring to shelf ice will be required, provide good supply of pickaxes, shovels, crowbars, 7/8″ wire straps, 8″ manila straps, "deadmen," commanders, etc. for use in mooring (fig. B–2).

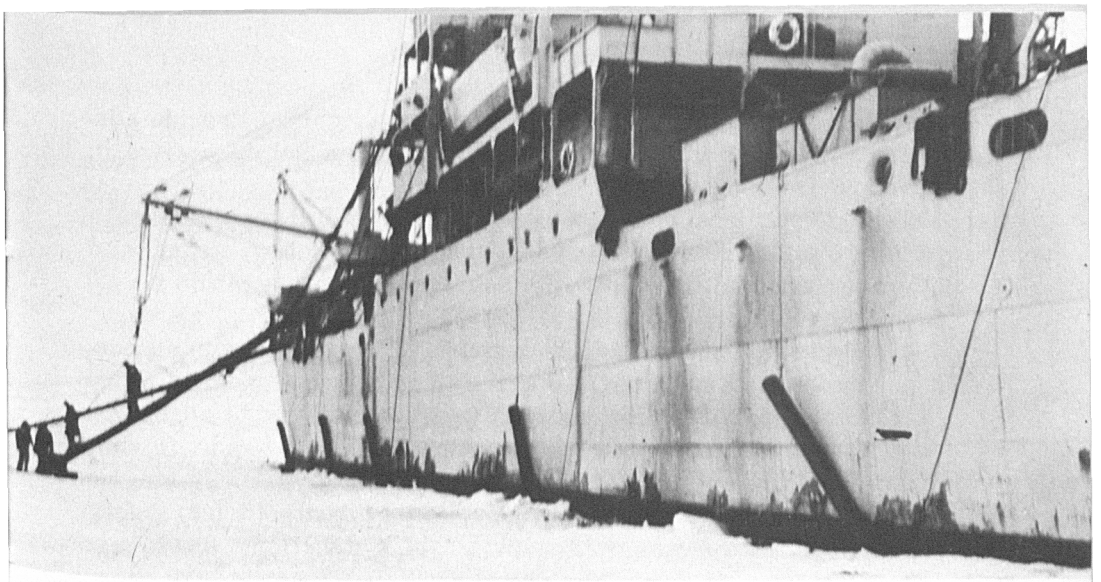


Figure B–3.—Ice fenders.

28. Provide supply of wooden mallets, shovels, heavy wire or rattan brooms and scrapers for removing ice and snow from exposed decks.

29. Provide supply of ice fenders (sections of telegraph poles 10 to 15 feet long) for use when mooring to ice. Lay out ball and cylindrical cone fenders about main deck for handy use while navigating in ice. Provide a number of long ice poles for fending ice from around counter (fig. B–3).

30. Provide several pairs of wading boots for use in event of holing—also immersion or constant wear exposure suits, if available. Provide equipment using the principle of the boom and basket method of survivor recovery.

31. Provide supply of latest abandon ship equipment suitable for cold water.

32. If no anemometer is installed, draw two portable or hand-held ones.

33. Rig canvas screens for windbreaks at stations for control of boom winches.

34. Carry breeches buoy rig and parbuckling gear for transfer of personnel and supplies while under way.

35. Prior to departure from base test out heating coils for fuel tanks.

36. Clean and overhaul ventilation and heating systems to ensure that they are in best operating condition.

37. Have leadsman's platform fitted with lights. Provide adequate number of hand leads. Train leadsmen before arrival in the area.

38. Carry at least two movie projectors with full supply of spare parts. Provide additional books, magazines, hobby crafts, and other recreational supplies. Set aside space for recreation rooms for the crew.

39. Have medical and dental examinations conducted on all personnel prior to departure from base. Transfer bad medical risks.

40. Exercise care in fitting cold weather clothing to all hands.

41. Enroute to the area of operations brief all hands on subjects: handling and stowage of cargo, geography and climate, ice seamanship, polar navigation, operation of boats in ice, safety precautions, over-ice or over-snow travel instructions.

GENERAL RULES OF ICE NAVIGATION

Admiral Peary on ice navigation.—"The chief work of a polar ship is to push and pry and wedge its way in and out among cakes and floes ranging from three to twenty or fifty and even up to one hundred and twenty feet thick."

Captain Bob Barlett on ice navigation.—"The man in the crow's nest has to look out for the best lead ahead. To be a good conner, one must not let his mind stray from the job in hand. He must always look for the best leads and high up as he is and often with a heavy ship, deeply laden with supplies, he has to look out for corners of ice. He also has to watch her stern for the swinging of the quarter onto a hard point of ice. A tongue (ram) underneath the water may carry away propeller blade, shaft, and propeller. Then, if she is deeply laden, she may carom from the corner of a heavy piece of ice to a hard opposite corner, hitting her on the turn of the bow, which is liable to cripple her. In going astern the rudder should always be amidships. One has to exercise great caution in going astern (and in backing). The officers on the bridge must be trained and skilled to watch every movement. One has to be tireless to move a ship through ice. The ice movements themselves may be very quick and a few minutes lost may put one a long way astern. Patience, again, is a great virtue. The first thing is to keep your ship free. When she is free, you can go where the breaks occur; if caught in the ice you are powerless and have to go where the ice brings you, but free you can take the first favorable opportunity or leads that open in the direction you want to go."—(Not an exact quotation.)

42. The rule of precaution, caution, and good seamanship applies. Allow only officers fully qualified in ship handling to conn the ship in pack ice (fig. B–4).

43. On approach to drift ice or iceberg waters reduce speed, set radar watch, station ice lookouts aloft and in the eyes of the ship.

44. On entry into pack ice station stern lookouts to keep the conning station advised of ice conditions around the propeller. The forecastle ice lookouts keep the conner advised as to dangerous floes or cakes ahead which can be missed. *Water sky* helps in choosing a general direction in which ice conditions may be favorable. *Ice blink* indicates areas to avoid.

45. Avoid the weather edge of pack ice; avoid areas of pack ice having the appearance of pressuring and churning; avoid grounded and hummocky ice in the pack.

46. Before entering pack ice make a complete reconnaissance by all means available—radar, aloft lookouts, helicopter observations, ice breaker scouting, long range aircraft observations and photographic records. Always enter pack ice at the most favorable point and proceed in general toward weakest areas of the pack (fig. B–5).

47. Avoid the leeward shore on which ice is usually dense and hummocky. Favor the windward shore where there should be a free channel. Remember that strong currents set out from inlets,

Figure B–4.—The rule of precaution, caution, and good seamanship applies.

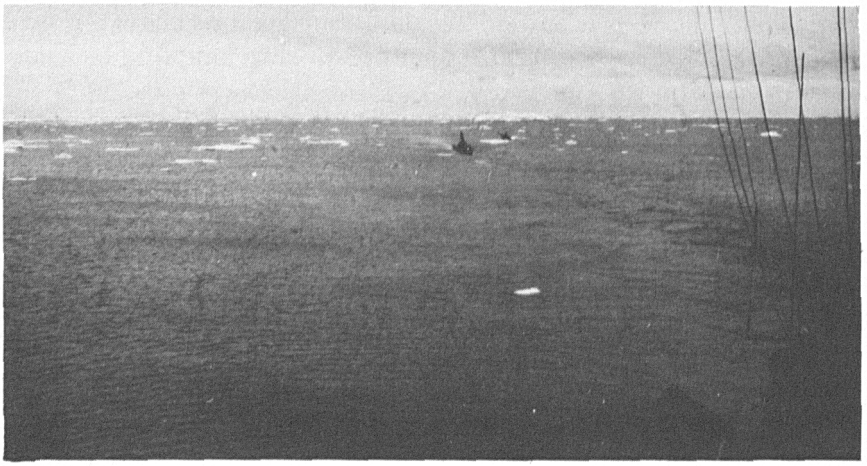


Figure B–5.—Enter the pack at the most favorable point.

fiords, and bays into channels and basins. Therefore, do not operate so closely to points of land that a combination of heavy ice and strong, unknown currents can drive a ship aground.

48. Give all icebergs—in the open sea and in the pack—as wide a berth as possible.

49. Follow the general rule of avoiding all ice possible—no matter how small or rotten. If necessary to collide with floes or cakes, try to take them on the stem with the ship decelerating rapidly by backing full speed. Do not collide with growlers in drift ice areas. *Watch your propellers!*

50. Go around large accumulations of ice on the windward side.

51. Avoid dead spaces where currents or wind have little effect on the condition of the ice.

52. Do not navigate in pack ice during dark nights, dense fogs, or at the time of heavy compression of the ice.

53. Avoid dropping anchor in a place where there is considerable floating ice or the liability of the pack setting down upon the ship and driving the ship aground (fig. B–6).

54. Keep accurate dead reckoning since celestial observations are rare and unreliable, especially in summer.

55. Ice breakers should break the ice from ships which they are clearing on the windward side.

56. Remember cardinal principles of working in pack ice are (a) keep moving (b) work with—not against—the ice (c) do not rush the work—be patient.

57. Keep closed up; standard distance 3 to 4 ship lengths.

58. First ship after icebreaker is convoy guide and regulates the speed of advance depending on ability of the leading icebreaker to keep moving. Icebreaker displays speed cone to indicate desired speed of guide or first ship in column of escorted ships.

59. Be alert to prevent collision with ship ahead in event of temporary besetment. In case the ship ahead stops engines, becomes jammed against a floe in the channel or is forced out of the lead, all ships in column astern should immediately back engines to kill headway and avoid piling up. In cases of this kind each ship should endeavor to maintain relative position in column.

60. Each ship of the convoy should use its TBS or signal searchlights for keeping ship immediately astern advised of all engine changes.

61. Convoy commodore in the icebreaker selects a generally straight track, if possible, that will clear heavy ice, pressurized ice, hummocks, bergs, and grounded ice (fig. B–7).

62. Avoid groups of bergs and shelf ice or areas of consolidated pack; 2 to 4 knots in close pack; 5 to 7 knots in drift ice and open pack.

63. Speed—dead slow in close, heavy or consolidated pack; 2 to 4 knots in close pack; 5 to 7 knots in drift ice and open pack.

Figure B–6.—Pack ice setting down upon AKA in Resolute Bay.

Figure B–7.—Select a track that will clear heavy ice, hummocks, and bergs.

OPERATIONAL EXPERIENCE—NOTES

OPERATION HIGHJUMP

Operate helicopters only in contact weather (fig. B–8). Be prepared to tow seaplanes (PBM).

Keep planes warmed up to take early advantage of good weather when it comes.

Keep fuel tanks warmed in order to be able to fuel other ships on short notice.

Use adequate number of ice lookouts. In no case accept radar as 100 percent perfect. Be prepared for periods when radar is not available at all. Visual lookouts should be primary means for detecting and reporting sea ice.

Keep a hull repair party on watch while in pack ice. Keep living spaces, heads, and washrooms well heated and comfortable.

Provide storeroom for stowage of special clothing when not in use.

Provide recreation rooms for enlisted men.

Be prepared to serve 4 meals daily as workday is 24 hours.

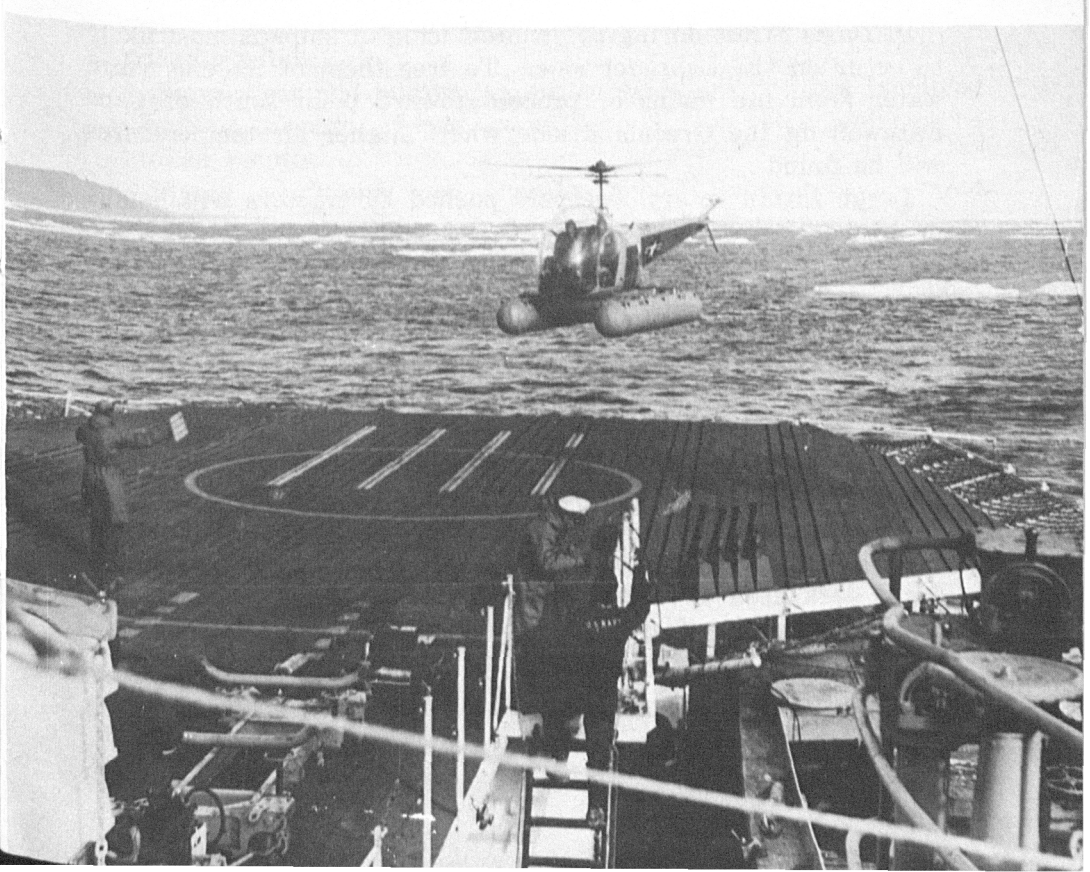
Ice forms rapidly on ships under conditions of injection temperature 34° F. or lower, continuous spray, and surface air temperature 25° F. or lower. It has been estimated that 1 inch of

ice forming on topside (main deck and upper works) of a large destroyer will weigh 80 tons approximately. A building up of such an ice cover would soon place the ship in a critical and unsafe condition. Warm water from fire main is most effective combatant of topside ice.

In flying large seaplanes in polar seas remember that:

1. Wind over 17 knots is hazardous due to wind getting under the wings while hoisting.
2. Swell causes the tender to roll and pitch with the natural tendency of the plane to swing while hoisting.
3. Chop or wind swell puts a heavy strain on the hoisting sling and makes boating alongside planes hazardous.
4. Bad combinations of swell and low wind make take-offs hazardous for a heavily loaded plane.
5. Brash, drift ice, growlers in the line of take-off and landing are a constant danger.
6. Heavy wind, low ceiling, undercast, and other unfavorable weather phenomena are limiting factors in polar flying.
7. Icebergs do not provide much of a lee for seaplane operations.
8. Straight off-pack winds give best weather and calmest sea conditions.

Figure B–8.—Operate helicopters only in contact weather.



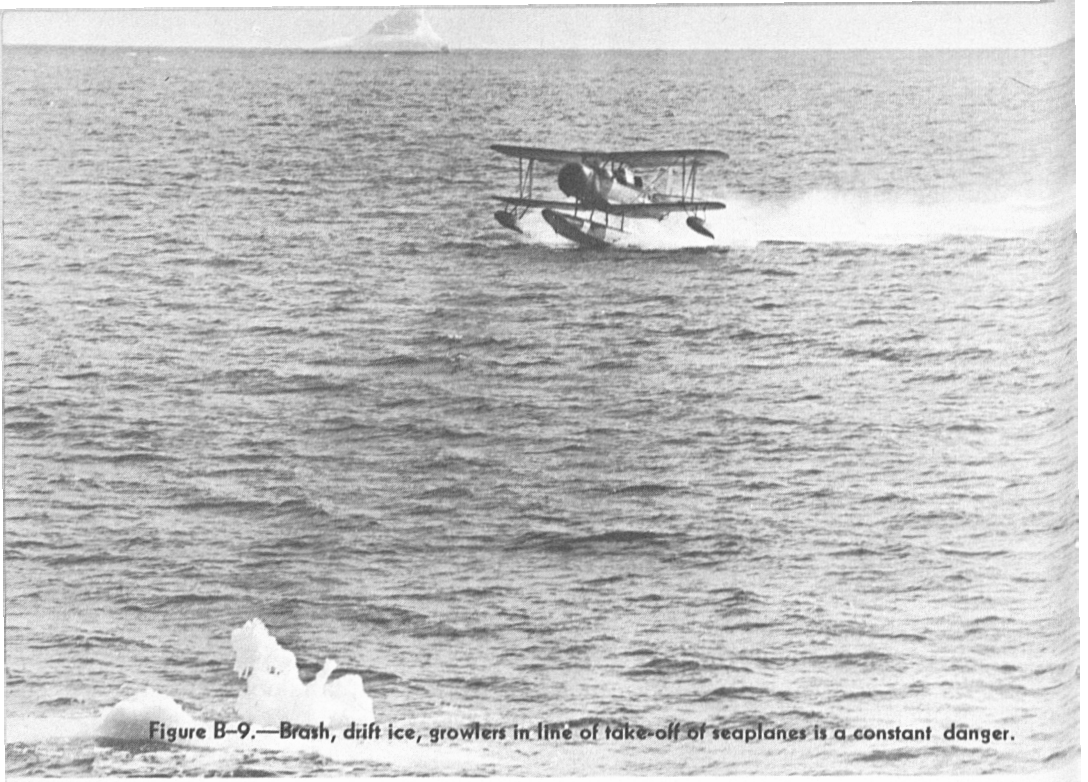


Figure B–9.—Brash, drift ice, growlers in line of take-off of seaplanes is a constant danger.

OPERATION FROSTBITE

In Davis Strait during the winter, icing of ships is most likely to occur on the Labrador side. To free them of ice use warm water from fire mains or proceed toward point south of Cape Farewell on the Greenland side where higher air temperatures will be found.

Large rattan rotary sweepers pushed by tractors will handle up to 6 inches of snow on flight deck. Do not tramp down the snow as it will freeze and be harder to remove. Use rattan or wire hand brooms, large or street size, in the areas around parked planes. Clear windward side of flight deck first. To free catwalks of snow and ice use warm water from the fire main.

Rotary wire sweepers will remove up to ½ inch of ice on flight deck. Use rock salt only as last resort.

Use canvas covers over barrier sheaves of arresting gear to keep out snow and ice.

Use metal cover over catapult tracks to keep out snow and ice.

Winterize all mobile machinery and handling equipment for flight deck use. Stow below at night for ease of starting during early morning flight operations following day.

The installation of covers over wings and tails of aircraft is hazardous; use of killfrost and other chemicals is preferable when such can be obtained.

Planes must be secured with heavy weather tie-downs due to prevalence of storms (winds over 70 knots) and rough seas in the North Atlantic. Take extra precaution to prevent loss of personnel over side due to combination of slippery decks and rough seas.

Familiarize all personnel with cold weather operating procedures prior to arrival in the area.

Safety first! Make no effort to attain small or average launching and landing intervals, at the expense of safety.

During air operations all rescue facilities shall be completely manned and alerted.

Provision should be made to rotate exposed personnel at hourly intervals for hot drinks and warming.

Flight deck personnel should wear face masks when wind velocity is in excess of 30 m. p. h. over flight deck.

ICEBREAKER OPERATIONS BERING SEA IN WINTER

A wind-class ice breaker can penetrate north of Bering Strait and might even reach Point Barrow if advantage taken of *friendly* winds.

Snow cover and hummocks on ice fields are limiting factor of breaking through. Level ice is 2 to 3 feet thick and can be broken readily.

Flying conditions are generally good. Helicopters operated satisfactorily at minus 10° F. Principal limitation was controls becoming sluggish or inoperative.

M29C cargo carrier or weasel performed satisfactorily without special winterization down to minus 20° F.

Heavy swell was encountered in open pack during storms.

During the early part of a 5-day storm when the temperature was below freezing, a hard ice cover built up over the ship to a thickness of almost 2 inches.

An arctic adapted cargo ship could follow an icebreaker to Nome and discharge cargo over the shelf ice without difficulty.

Star sights were possible. Loran was satisfactory up to the latitude of St. Lawrence Island. Radar was valuable north of that island.

Snow squalls and blizzards spring up suddenly. Thus helicopters should stay within 20 or 30 miles of the icebreaker.

The western side of Bering Sea was found to be more open than the eastern side.

SAFETY PRECAUTIONS

Below is set forth a listing of safety precautions applicable to naval personnel working away from their ships in the polar regions.

TRAVEL

1. Remain in vicinity of your ship or your temporary camp unless accompanied by other members of your party.

2. When away from camp be equipped with safety lines, emergency rations, and sufficient wearing apparel to protect yourself in event of a sudden blizzard. *Never take chances!*

3. While traversing an unknown area of sea or land ice, walk in single file, lead man continously testing the surface of the ice. If possible, stay on marked trail or on solid surface unless soundings and tests are made to determine the condition of the surface of the ice. Use trail markers freely.

4. Do not take the risk of falling into an unmarked crevasse. Give a wide berth to areas where cracks, disturbed or pressure ice, and crevasses are found.

5. Stay away from the edges of bay ice, shelf ice, icefoots, shore ice.

6. In event of a sudden or unexpected blizzard while away from camp or ship, dig in for shelter. Do not wander aimlessly about and get lost.

7. Do not molest wild life in the area. In the Arctic there are laws against it. Walruses, seals, penguins, and skuas can be vicious. Do not hunt animals unless a license has been granted and unless accompanied by experienced Arctic huntsman. Do not kill an animal unless necessary in self-defense.

8. Do not eat snow except in an emergency and then very slowly. Try to melt it first. Always carry a canister of water.

OPERATION OF SHIP'S MECHANIZED EQUIPMENT ASHORE

1. If preheating of engines is necessary for starting, be sure not to play the flames of heating torches directly onto cast-iron pipes.

2. Keep fuel tanks as full as possible by frequent refueling to reduce condensation in the tank. Ice in fuel and carburetors is a considerable hazard.

3. Do not pump fuel drums completely dry as to do so increases the chances of picking up water which has developed due to condensation. Before removing the plug of a fuel drum, brush all snow, ice, or water from off the top of the drum. Keep plugs of all drums tight. Caches of gasoline should be kept distant from other supplies with fire guard stationed around the cache as a precautionary measure.

4. When possible, filter all fuel before filling fuel tanks.

5. Do not start a tracked vehicle in motion too quickly. Rock it back and forth for a short period to loosen up track bands.

6. Do not permit men to ride on tracked vehicles, weight handling equipment and other vehicles used on beach heads, except where their duties so require.

7. By careful inspection ensure that all mechanized equipment to be used away from the ship is properly winterized prior to departure from base.

8. While working with hand tools around equipment, men should tie light lashings to them keeping other end secured to their wrists to prevent loss of tools when dropped.

9. When off-loading cargo directly from ship to shelf ice for sledging to caches, restrict amount placed on ice to small quantities to reduce loss to minimum in event of calving or breaking away of a section of the shelf ice. It is preferable to load cargo directly on sleds and to haul them away by a tractor as soon as sleds are loaded (figs. B–11 and B–12).

GENERAL

1. Keep constant watch for evidences of frostbite on the persons of your shipmates or companions. Skin becomes milk-white when frozen. Do not rub or apply snow to frozen flesh. *Thaw by warmth!*

2. Mark the locations of temporary caches of food, clothing, and supplies with trail markers as drifting snow will cover everything once a storm sets in. Never remove trail markers from a trail unless placed there by yourself. A suitable trail marker can be made by attaching a square of red or blue bunting, 1½- to 2-feet on a side, to a bamboo pole 5 or 6 feet in length.

3. When a ship is moored to shelf ice, use trail markers freely in marking cracks or areas of the ice which are likely to break away suddenly. Place cautionary signs nearby.

4. When finished using skis and skipoles, stand them upright in the snow to prevent loss (fig. B–10).

5. Do not set up a cache or place any large object in such position that snow drifting from the object will cover nearby articles of equipment.

6. When cooking or sleeping in an arctic tent ensure that there is adequate ventilation to permit escape of fumes and to protect the occupants against carbon monoxide poisoning.

7. Remain active when outside the shelter.

8. Remove snow from clothing before entering camp shelter or quarters on board ship.

9. For defecations use heads on board ship or in camp area. Carry supply of toilet paper in your pockets. You may urinate off trails or beaten tracks.

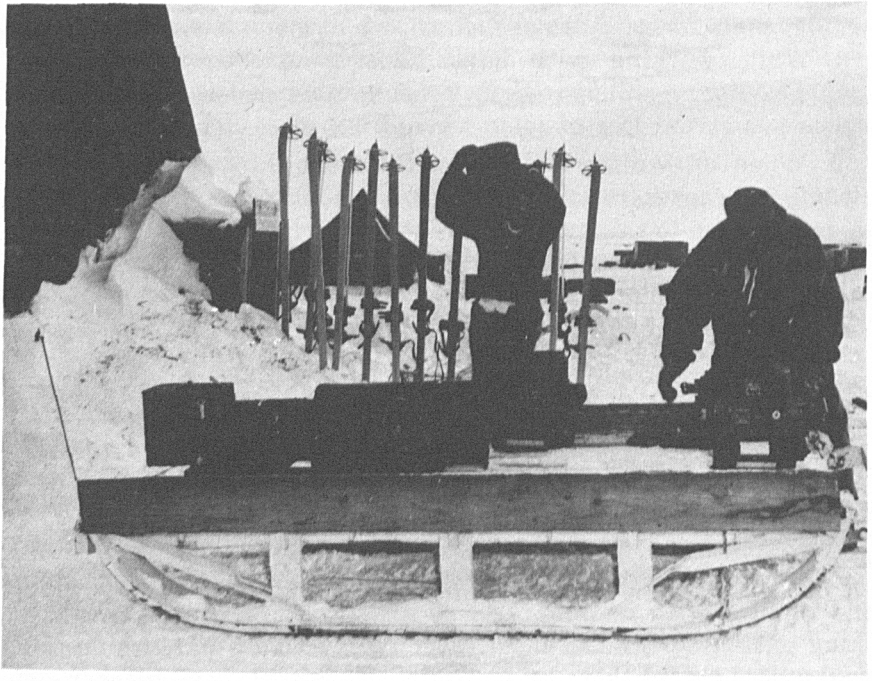


Figure B–10 —When finished with skiis and ski poles, stand them upright in the snow to prevent loss.

APPENDIX C

DESIGN CRITERIA FOR U. S. NAVAL MATERIEL FOR USE IN ARCTIC AND COLD WEATHER AREAS

	Unnavigable ice areas and ashore	Marginal ice areas
Minimum *sustained* temperature/knots*	Minus 65° F./10	Minus 20° F./40.
Maximum *sustained* temperature/knots*	80° F./100	80° F./100.
Mean minimum temperature (coldest month)	Minus 25° F.	10° F.
Mean maximum temperature (warmest month)	40° F.	50° F.
Minimum sea water temperature	28° F.	28° F.
Maximum solar radiation temperature	160° F.	160° F.

*Maximum wind speed to be expected at the temperature indicated.

FOOTNOTES

NOTE 1.—Ambient air temperatures specified, in degrees Fahrenheit.

NOTE 2.—Maximum wind velocity for any area is considered as 100 knots from any quadrant, and may reverse itself in direction in a few minutes.

NOTE 3.—Relative humidity may vary from 10 to 100 percent, and can change 50 percent in 4 hours or 80 percent in 7 hours.

NOTE 4.—Temperatures may change as much as 50° F. in 1 hour.

NOTE 5.—Wind velocities may increase from a dead calm to 70 knots within a few minutes and subside to calm just as rapidly.

NOTE 6.—Heavy ice may accumulate on board ships due to wind and temperature combination in otherwise ice-free area.

NOTE 7.—By "sustained" is meant "for period of 24 hours or longer."

APPENDIX D

TRACK CHARTS OF OPERATIONS IN WESTERN ARCTIC, SUMMER OF 1948, AND WINTER 1948-1949

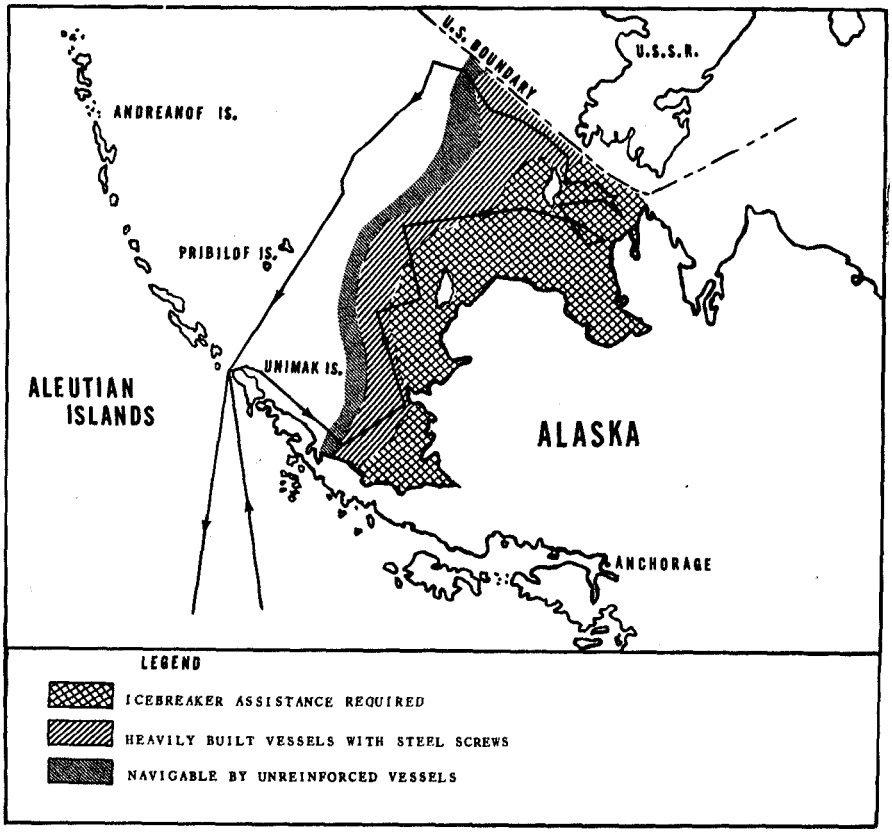


Figure D–1.—Track chart—Icebreaker operations—Winter 1948–49.

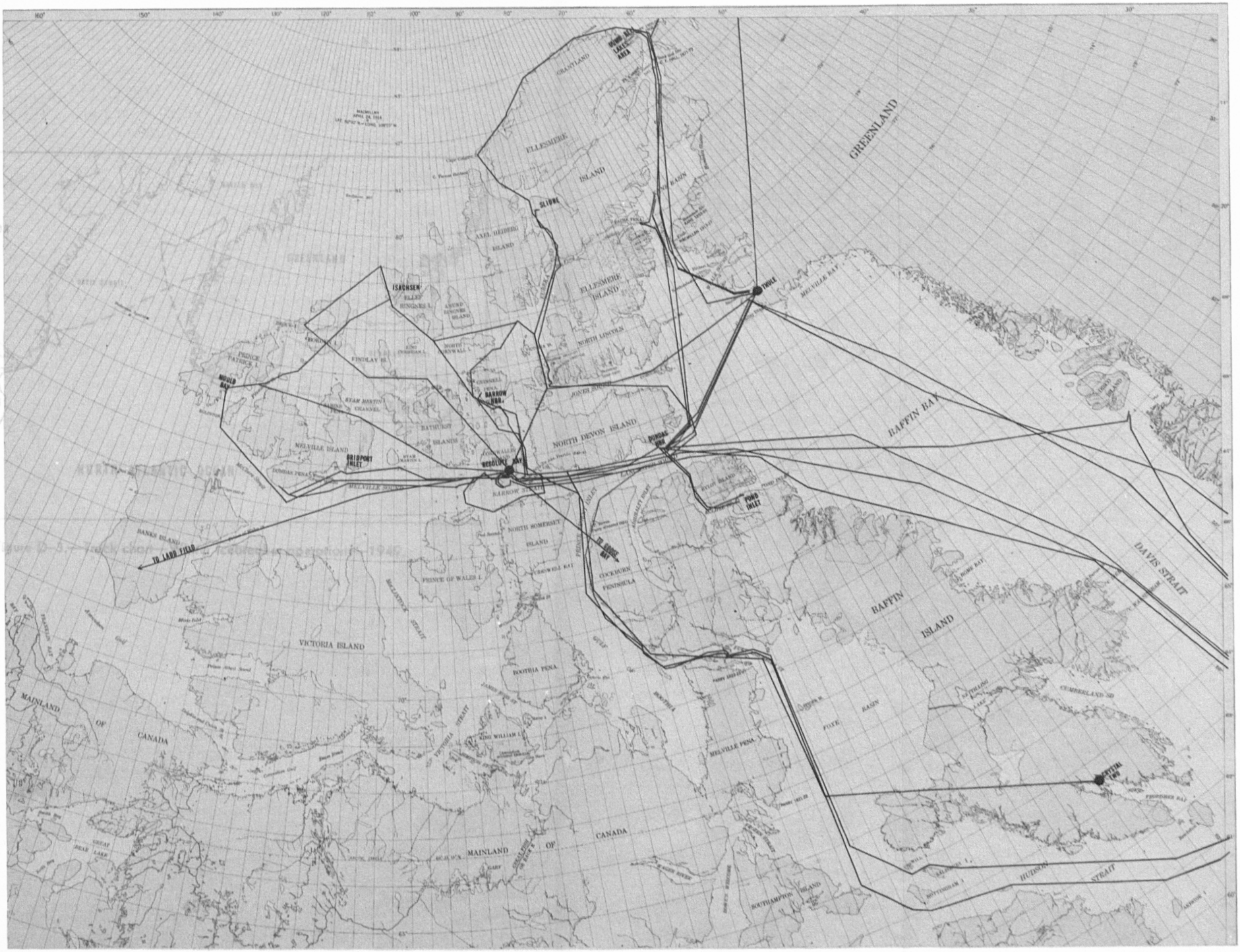


Figure D–2.—Air and Surface Track chart—Task Force 80—1948.

Part II (Face p. 484)

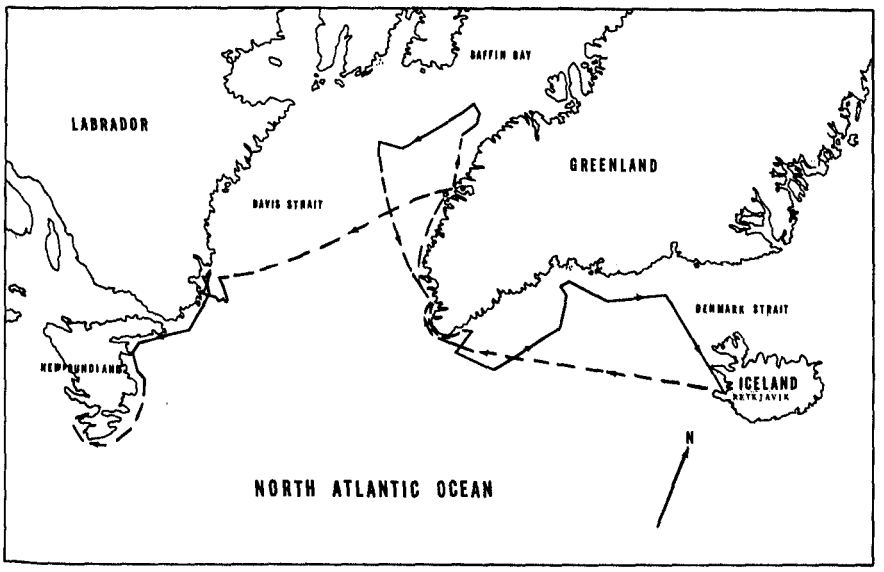


Figure D–3.—Track chart—Winter icebreaker operations—1949.

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