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11 JUNE 1976

12 95p.

DEPARTMENT OF THE NAVY
SEA SYSTEMS COMMAND

6 A GUIDE TO POLAR DIVING,

AD A030067

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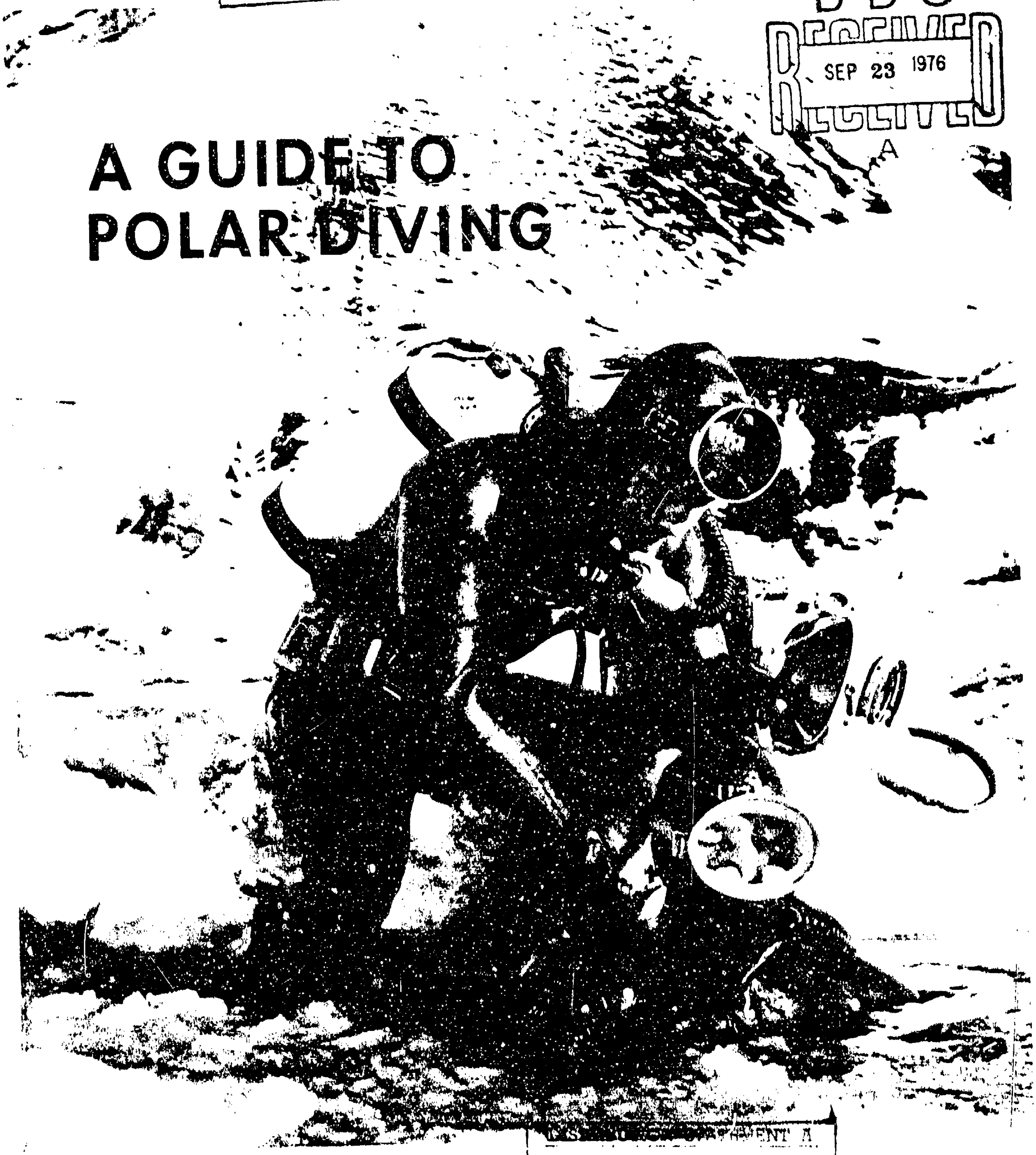
16 RF51-523
17 RF51-523-101

FOR
OFFICE OF NAVAL RESEARCH
ARLINGTON, VIRGINIA 22217

407 296

A GUIDE TO POLAR DIVING



FOREWARD

Diving in Arctic regions has been accomplished with varying degrees of success over the past fifteen years. For diving guidance, the diver, whether he be a Navy diver on an Arctic mission, a civilian accomplishing research in ice-covered waters, or a Coastguardsman repairing or inspecting the hull, propeller, or rudder of an ice breaker, could turn only to his past experience or to published articles that did not cover the diving aspects in an organized fashion.

This report brings together data from many sources covering various techniques and equipments that have been used by divers in polar waters. It also highlights medical and logistical support aspects that may be a part of any such diving operation. It is expected that this document will be of value to the military and civilian diver alike as an Arctic diving operation planning guide. This guide was sponsored by the Office of Naval Research, Ocean Technology Programs Office, under Project RF 51-523-101.

Since this is the initial formal issue of this guide to Arctic diving, the Chief of Naval Research and the U.S. Navy Supervisor of Diving encourages users to provide comments to the author for possible updating as the experience and technology of polar diving increases.

The author wishes to thank the many Arctic-experienced contributors, who, through numerous comments on the preliminary draft, have made this guide a comprehensive coverage of Arctic diving technology.

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INTRODUCTION

SECTION I. PURPOSE AND SCOPE

1-1. General

a. This manual is designed to assist the individual diver and diving supervisor to conduct diving operations, of short or extended duration, in polar regions. The doctrine and techniques in the manual are applicable to any diving area with polar conditions and the accompanying operational problems.

b. The problem of a definitive boundary for polar regions is a complex one. This manual will concentrate on the Arctic where the surface water is at or near 32°F and the salinity approximately 32 ppt. Other criteria such as temperature, vegetation, permafrost, or ionospheric might be of more importance for operations not primarily concerned with diving activity. Most of the operational procedures suggested in this manual can also be applied to diving operations in the Antarctic; however consideration must be made for differences such as terrain, logistic support, and weather conditions. Sections of this manual also apply equally well to diving operations conducted in ice-covered or near-freezing waters in nonpolar regions.

c. The material contained herein emphasizes that polar conditions affect diving operations but do not prevent them. The proper use of authorized diving equipment, support equipment, and protective measures will, to a major degree, overcome any problem encountered as a result of the environment. It is the individual's responsibility to be aware of any procedures and techniques applicable to this environment. It is impossible to work against the elements of the polar world; the success of a diving mission depends upon the ability of each team member to adjust to and work with these elements.

d. The additional time required to conduct diving operations in polar regions cannot be overemphasized and must be included in all planning. In addition to the increased amount of time consumed in actual movement, allowance must be made for other time-consuming tasks that are not present during diving operations in more temperate areas. These (Figure 1-1) include:

1. Clearing the dive site.
2. Preparing the entry hole.
3. Erecting shelters.
4. Providing a supply route.
5. Movement of support equipment and personnel.
6. Maintaining dive site, entry holes, and supply routes.
7. Protecting support equipment from the elements.
8. Providing suitable dressing facilities for divers.

Nearly all the support activities will be performed by men wearing bulky cold weather clothing. Each of these support activities is an integral part of the diving operation, and is discussed in this manual.

1-2. Relation to Other Publications

a. This manual is prepared with the assumption that normal basic diving training has been completed. It should be used in conjunction with the current edition of the U.S. Navy Diving Manual, NAVSHIPS 0994-001-9010. Applicable technical manuals, papers, and publications containing detailed information beyond the treatment given here on the techniques and procedures of polar diving operations are contained in the bibliography.

b. Specific information contained in this manual taken from other publications or sources is referenced. It is intended that proper credit is cited. In general, however, the information contained in this manual was simply assembled from general reading, personal communications, and field experience.

SECTION II. BACKGROUND

1-3. General

a. Traditionally, the Navy has had one of the leading roles in polar explorations and investigations. This has not been by accident; but is a part of the Navy's primary mission; control of the seas.

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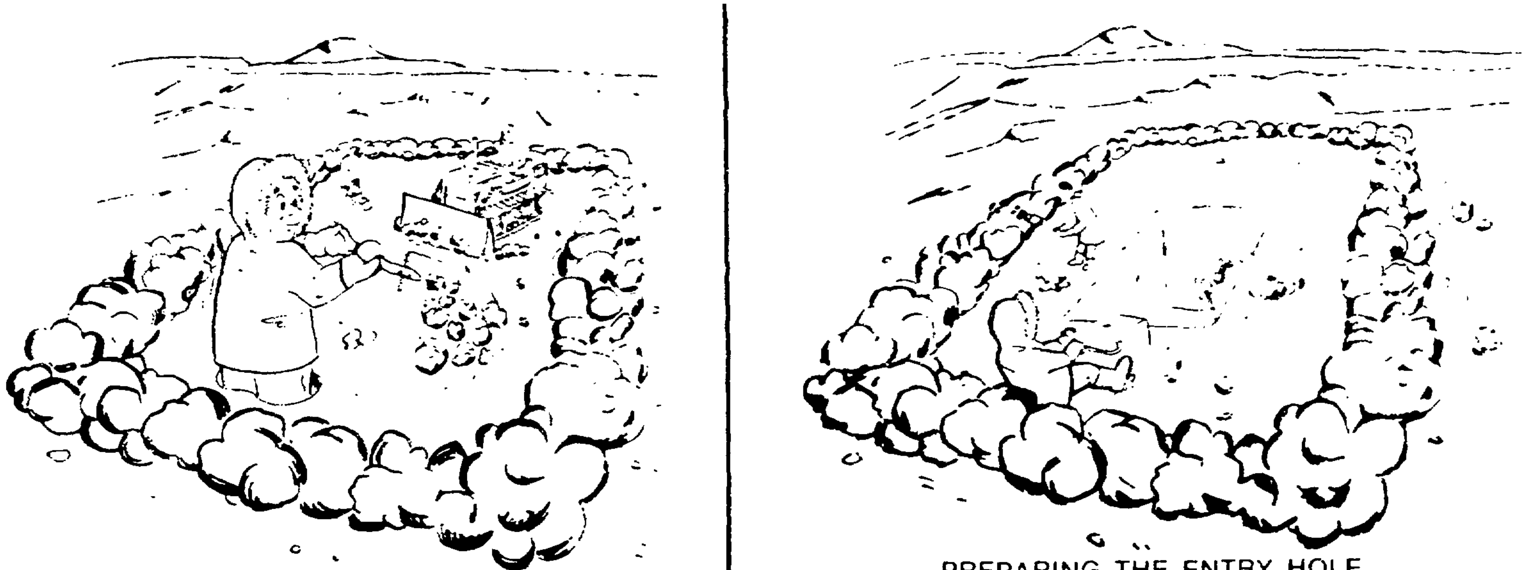
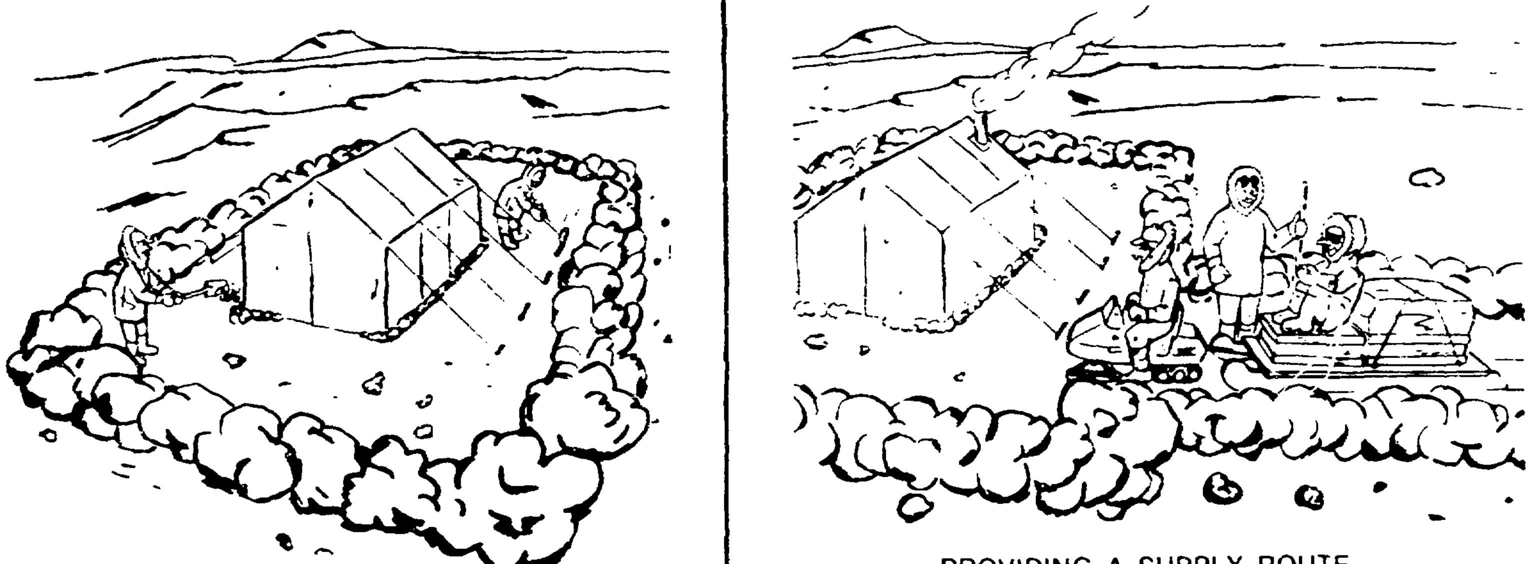


CLEARING THE DIVE SITE

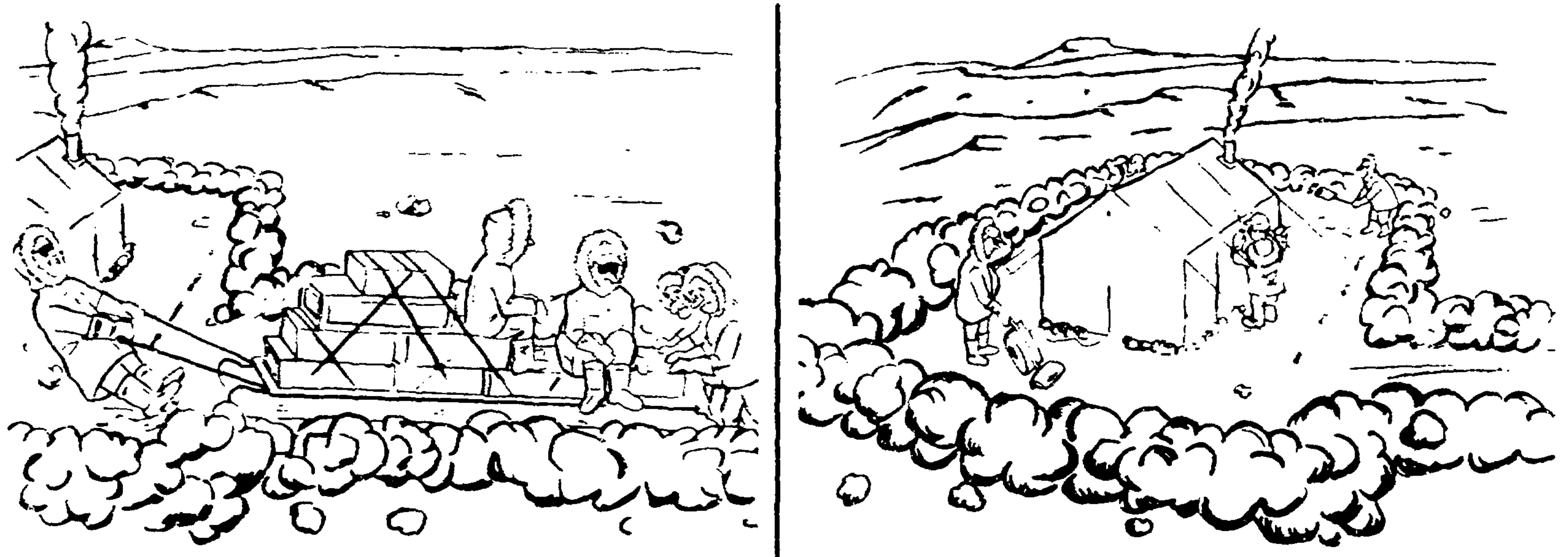
PREPARING THE ENTRY HOLE



ERECTING SHELTERS

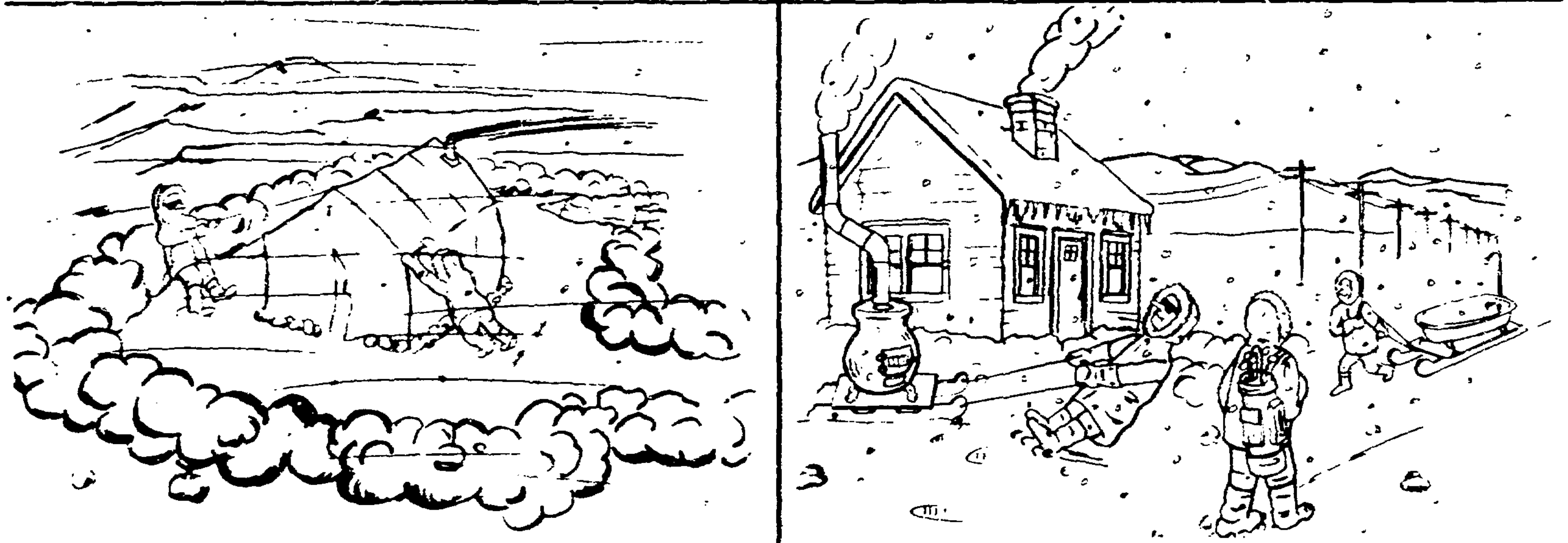
PROVIDING A SUPPLY ROUTE

FIGURE 1-1. EIGHT TIME CONSUMING TASKS



MOVEMENT OF SUPPORT EQUIPMENT AND PERSONNEL

MAINTAINING SITE



PROTECTING SUPPORT EQUIPMENT FROM THE ELEMENTS

PROVIDE SUITABLE DRESSING FACILITIES FOR DIVERS

FIGURE 1-1 (CONTINUED). EIGHT TIME CONSUMING TASKS

b. The first missions of swimmers in the polar regions included blasting ice floes, assisting ships in working free from ice jams, and conducting tests on the capability of swimmers to reconnoiter landing beaches beset by ice. American divers also performed vital tasks in polar waters such as assisting in the DEW line constructions; construction and repair of harbor facilities; hull inspections; changing propellers; recovery of equipment lost through the ice; and the location and recovery of submerged aircraft.

c. Navy UDT teams accompanied the U.S. Navy expedition to the Antarctic in 1946-47. It was thought their usefulness would be limited due to the cold; however, they proved their ability to operate in the extreme cold water (29°F) for extended periods of time, performing many vital tasks.

d. Canadian divers have been actively diving in polar waters for years clearing underwater obstructions, laying pipelines, performing routine salvage, and other assignments. In the summer of 1959, seven divers from the Royal Canadian Navy's (RCN) Operational Diving Unit, Dartmouth, Nova Scotia, logged over 2000 hours of diving time while operating out of some 14 sites in the Canadian Arctic.

e. Nuclear submarines have been operating in the Arctic Ocean since 1958 when the NAUTILUS made the first submerged transit of the Polar Basin. Brief scuba dives, restricted to photographic and visual inspections of the submarine and the under-ice, were made by crewmen when these submarines surfaced in the Arctic Ocean (Figure 1-2).

f. The civilian diving community has been active in polar diving for years. American and Canadian teams have conducted research in oceanography, marine biology, human performance, geology, and other fields. Often conducted on a small scale, these civilian pursuits are impressive in their accomplishments in the hostile polar environment. Many other nations are also active in various aspects of polar diving; however, their activities will not be included in this manual.

g. A great many operations in polar regions, which just a few year ago would have been dismissed as beyond the divers capabilities, are now technically possible and reasonably safe. Nuclear reactors, already serving as power plants in the Antarctic and Greenland, will almost certainly attract more attention and industry in the future. Both military and economic interest in the Arctic will continue to increase, so the requirements for an operational capability in underwater activities will become more important.

SECTION III. THE ENVIRONMENT

1-4. Important Characteristics

a. The climatological history of the operational area should be studied to determine the

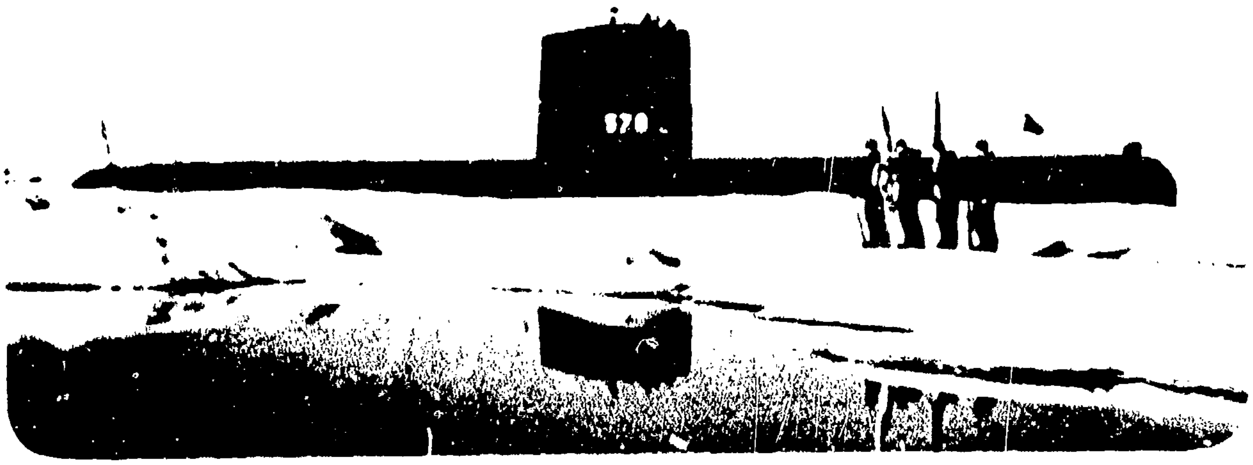


FIGURE 1-2. USS SKATE SSN-578 AT THE NORTH POLE

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[1] Sater, John E (coordinator). *The Arctic Basin*, The Arctic Institute of North America, Washington, D C , 1969

probable frequency and duration of particular weather conditions which will limit or prevent diving operations. Environmental characteristics of polar regions which complicate diving operations include:

1. Extreme and rapid changes in local weather conditions.
2. Wind, snow, and ice storms.
3. Ice cover.
4. Long periods of darkness.
5. Alternate thawing and freezing.
6. Bulky clothing.

1-5. Temperatures.

a. The most common misconception of the Arctic is that the land areas are perennially covered with ice and snow, and that winter is continuous and intensely cold. Actually, a great variety of climatic conditions are encountered in the arctic regions. Areas adjacent to one another are found to have widely differing climatic characteristics determined by latitude, marine influence, and topography. Diving operations will be most concerned with the maritime and coastal temperature conditions and less with continental conditions.

b. The Arctic Ocean region has a flat temperature curve during June, July, and August with small deviations from the freezing point. The winter curve is again flat, but with the temperatures around -29°F.

c. The coastal climate is quite similar to the maritime one. The year consists of a long, cold winter and a short, cool summer. The annual temperature curve has the same winter characteristics as that of the Arctic Ocean but there is a seasonal maximum in July. The mean summer temperature, however, remains below 50°F.

d. The Arctic continental climate is characterized by very low winter temperatures with a pronounced winter minimum and high summer temperatures with a very pronounced summer maximum. Here, the annual range of mean temperature may be as much as 130°F.

1-6. Wind

a. Surface wind velocites are usually not very high over the Arctic Ocean, averaging between 8 and 10 knots. Strong winds are infrequent, being most common in exposed coastal areas; it is in these same locations that storms are most frequent. The seasonal variability of wind speed over the central Arctic Ocean is slight.

b. High surface winds in many arctic areas are often enhanced by local effects. Surface wind data recorded at land stations must not be taken as typical of the wind speed and direction over a large area. Diving operations conducted in the vicinity of islands, fiords, or coastlines may experience peculiar local wind conditions. Wind conditions are of critical importance to a diving operation. What would be considered a mild breeze elsewhere, is capable of blowing the fine arctic snow to the point where visibility is impaired, roads and trails are closed, and equipment is buried (Figure 1-3).

1-7. Precipitation

It is difficult to measure precipitation in the Arctic because it is not always possible to differentiate between snow which has fallen and snow which has blown or drifted into the meassuring device. Other inaccuracies are likely to occur in published figures of arctic precipitation when conversion is made from snow to an equivalent amount of rain. This conversion, which varies from one area to another and upon the type of snow, ranges from 5 inches of snow per inch of water to 20 inches of snow per inch. Over the central Arctic Ocean, the snow cover becomes established in late August, reaches a thickness of 14 to 16 inches by late spring, and has melted by mid-July. The total snowfall varies widely from place to place and is not as important to the progress of a diving operation as is the wind and the resulting blowing snow.

1-8. Visibility

a. Visibility in the Arctic can vary from one extreme to another in any given location. As the arctic atmosphere is fairly uncontaminated by impurities, mountain ranges 60 to 70 miles distant will be clearly seen on one extreme, and people 15 to 20 feet away will be hard to see on the other. These extremes depend on fog, precipitation, or blowing snow. The important thing is, however, that the visibility can go from either extreme to the other in minutes.

b. Melting of the pack ice in summer results in the formation of persistent fog and low clouds. Some Arctic Ocean locations experiience fog more than 100 days per year, most frequently in summer and least in winter. The summer fog is patchy and of short duration, being particularly prevalent from June to September.

c. Wind speeds of about 5 knots will cause dry, powder snow to drift along the surface. At speeds of 10 to 15 knots, the snow is lifted into the air where it is called blowing snow. Some coastal areas along the Arctic Ocean may experience more than 100 days of blowing snow per year, more than half of the days in winter suffer this condition.

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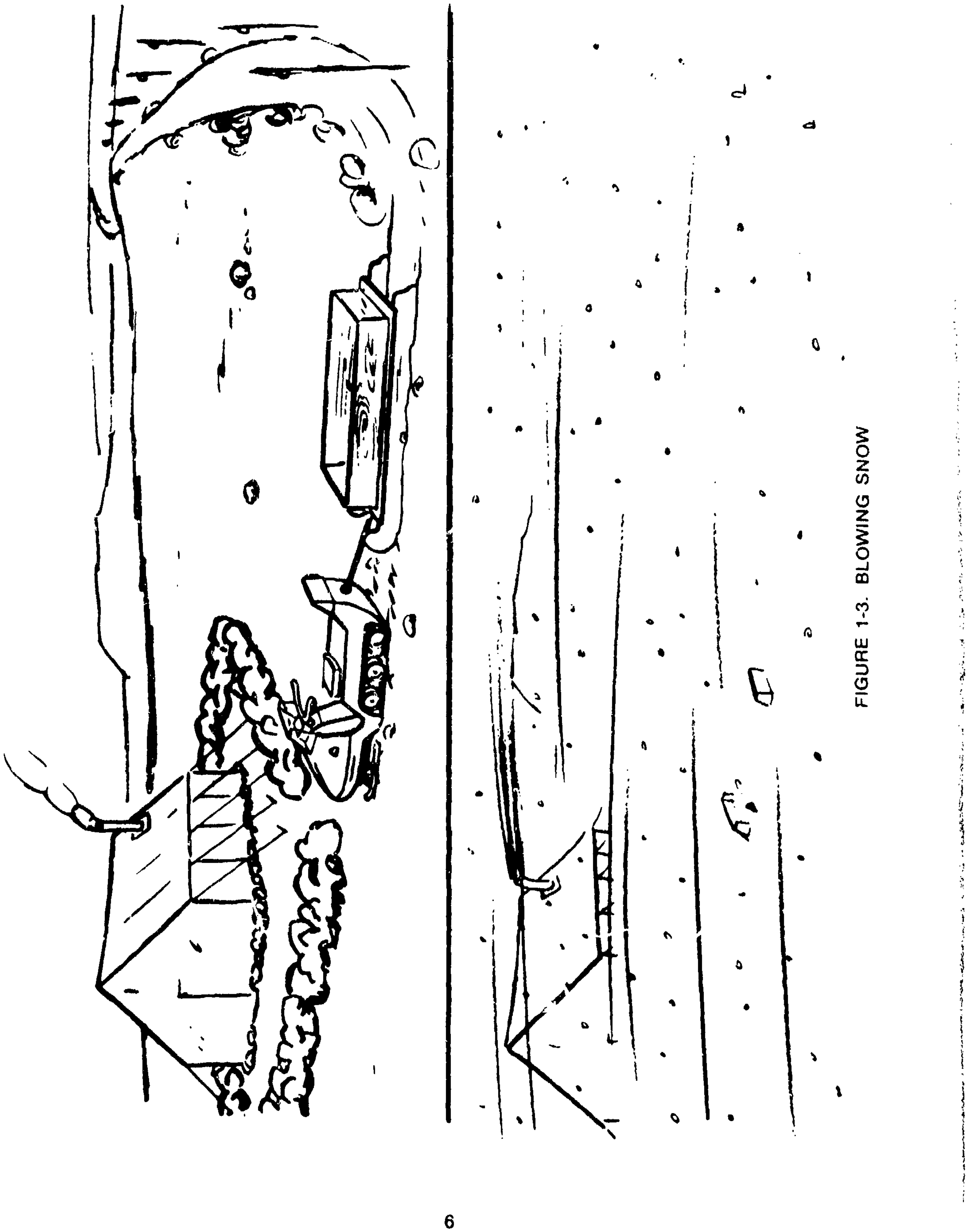

FIGURE 1-3. BLOWING SNOW

d. Whiteout is a simple phenomenon requiring only two conditions to produce: (1) a diffuse shadowless illumination; and (2) a uniformly monotoned white surface. In the Arctic, these conditions occur frequently if the sun is above the horizon. The direct effect of whiteout is the loss of depth perception and inability to discriminate topographic features. In extreme cases, the individual is unable to see his own footsteps, making retracing his steps impossible. Men have walked into snow banks and off embankments under these conditions. Whiteout does not have to be so complete however to greatly hinder the effectiveness of a diving operation. For example, a partial whiteout can make following a trail in a snowmobile nearly impossible, cause excessive eye strain, and make walking through the snow difficult. Partial whiteout conditions will have varying effects depending on the individual's line of sight in reference to the sun.

1-9. Cloud Cover

a. Over the Arctic Ocean, the cloud cover is least in winter and spring, and greatest in summer. During winter, the water content of the very cold air is too low for cloud formation. There is a high frequency of stratus and statocumulus clouds in summer due to the continuous cooling of air to the freezing point over the pack ice. These summer clouds are extremely uniform, extending as vast sheets over much wider areas than other clouds.

b. The seasonal variation in cloud cover increases from south to north. The farther north, the greater the cloudiness in summer and the more frequent the low and dense cloud types. In winter, on the other hand, the cloudiness diminishes northward and the frequency of distribution of types is more uniform. The change between summer and winter cloud cover takes place very rapidly during the transition periods in spring (May) and in autumn (October). During any given day, the cloud cover may vary greatly in a very short time.

1-10. Ice Occurrence and Thickness

a. The Arctic Ocean is never totally ice-covered. One estimate, based on infrared temperature measurements, is that even during winter as much as 10 percent of the area of the ocean is either open water or a thin ice cover over refreezing leads. Arctic pack ice is generally not homogenous, especially when considered locally, and consists mostly of ice of varying age. The most common ice encountered is thin, newly frozen leads; first year growth of considerable thickness (winter ice); rafted ice pressure ridges; and ice which may be several years old. Landfast sea ice, found along the coastline of the Arctic Ocean, is mostly a year old and quite uniform in thickness.

TABLE 1-1[*]

MEAN ICE THICKNESS

Location	Mean Maximum Thickness (feet)	Freeze-up	Break-up
Gulf of St. Lawrence (North Shore, Chaleur Bay)	2-1/2	Mid-December	Mid-April
Labrador (Hopedale)	4	Mid-November	Early June
Hudson Bay (Churchill)	6	Mid-October	Late June
Eastern Canadian Arctic (Alert, Resolute, Hall Beach)	7-1/2	Late September	Mid-July
Western Canadian Arctic (Tuktoyaktuk, Coppermine, Cape Parry)	6	Late September	Mid-June to Mid-July
Canadian Archipelago, Pack Ice	7-1/2 to 9	—	—
Arctic Basin, Ice Pack	8 to 12	—	—

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[*] Langleben M P Dr and Pounder E R Dr *The Ice Cover · Occurrence Thickness and Mobility* Symposium Man in Cold Water Department of Industry Trade and Commerce and McGill University Montreal May 1969

b. Sea ice covers a surface area greater than 6 million square miles in the Northern Hemisphere during the winter. The area of the ice cover decreases in the summer when ice melts completely in the subarctic regions and to a slight degree in the Arctic Basin. In these waters, almost all diving operations are vitally influenced by the presence of ice cover.

c. Table 1-1 gives the mean maximum thickness of 1-year ice (winter ice) for a number of sites in the subarctic and arctic, and the approximate dates of freeze-up and break-up. Typical values of the thickness of the polar pack in the Canadian Archipelago and the Arctic Basin are also included.

1-11. Water Clarity

a. The clarity of Arctic waters varies from season to season and from one area to another. The maximum clarity is in the winter and gradually decreases due to marine life attracted to the sunlight of spring (Figure 1-4). Marine life will often become very dense very quickly around a new dive site due to the added sunlight brought about by the removal of surface snow and the cutting of dive holes. Daily fluctuations in the abundance of marine life are the result of natural attrition and tidal changes. The tide can change the clarity of a particular dive site in minutes as it brings in or removes plankton-laden waters. Water clarity will also depend on the proximity to river runoff and surface wave action.

b. The best conditions for diving relative to water clarity are usually when the sun is sufficient to eliminate the need for artificial light underwater, but not sufficient to induce planktonic blooms.

1-12. Atmosphere Sound Transmission

Sound transmission depends upon wind, temperature, and surface conditions. Normally, with an increase in elevation, wind speeds increase and temperatures decrease, resulting in above normal sound intensity downwind. However, since temperature inversions are common occurrences in polar areas, this effect is not always evident. Also, surface conditions can be important because soft snow will absorb sound energy while hard-crusted snow or ice will aid sound transmission. Normal conversation has been carried on at a distance of 1-1/2 miles and shouted words have been heard at 2-1/2 miles. However, under other climatic conditions, the sound of an aircraft engine at full throttle has been inaudible at 1/2 mile.

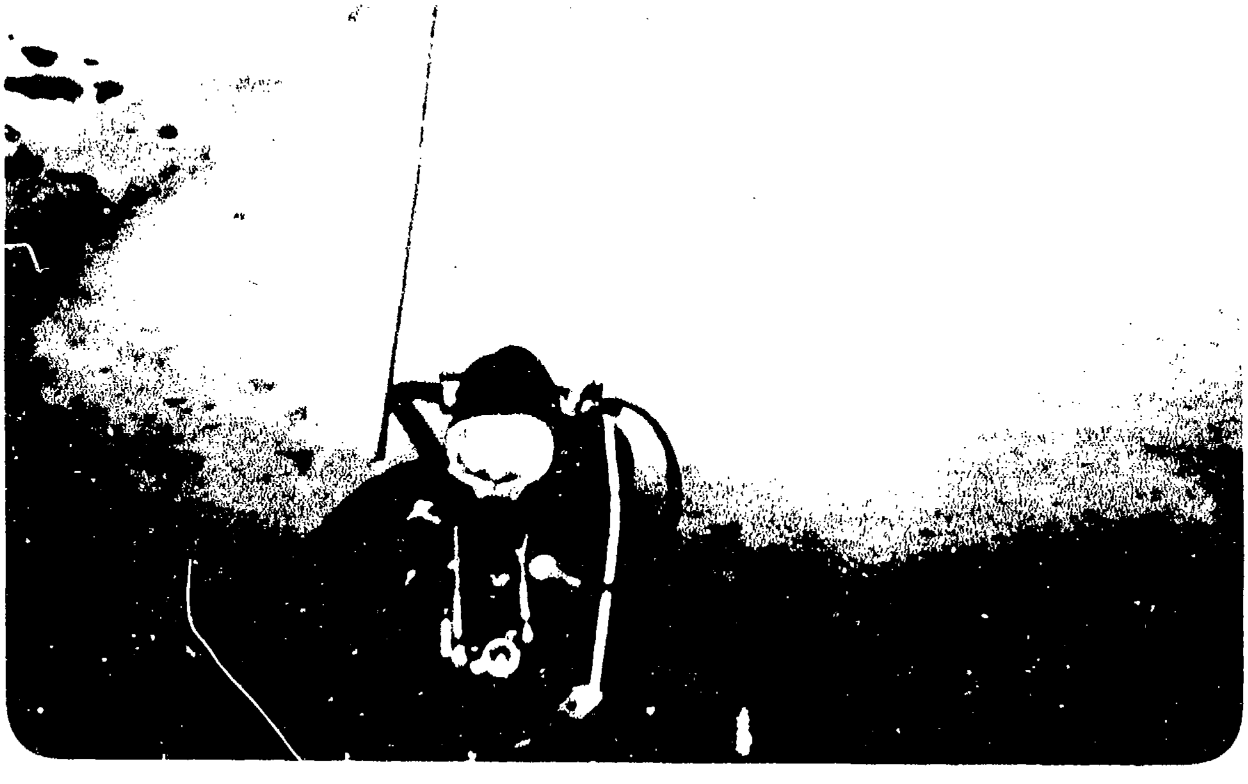

FIGURE 1-4. WINTER DIVING IN CLEAR POLAR WATERS

1-13. Daylight

The long darkness of winter is most extreme at the pole where the sun remains invisible for 24 weeks each year. The season of useful light is much longer than this would indicate due to the long periods of twilight. If daylight is defined as the amount of light sufficient to enable one to read newspaper print out-of-doors under a clear sky, there are 32 weeks of continuous daylight at the pole and over 8 weeks more during which there is at least some twilight all the time. This leaves only about 80 days of real night. While the twilight is sufficient for topside support, the low light level does reduce the efficiency of underwater operations to some extent. The combination of snow and ice cover with twilight surface conditions results in very dark, and for all practical purposes, nighttime diving conditions.

SECTION IV. THERMAL PROTECTION

1-14. Personnel

a. Indoctrination should initially and firmly fix in a person's mind that exposure in the Arctic may at times result in considerable discomfort and a man should modify his physiological response to cold, both mentally and through physical conditioning. The principal and most significant problem for the individual adjusting to the arctic environment under normal conditions is not keeping warm, but rather, by proper use of his clothing and shelter, keeping cool. The human body appears to function best when running "cool" rather than "hot."

b. One of the most certain methods of inviting cold injury is through overdressing, which, when coupled with overexertion, brings on sweating and the resultant increased heat loss because the skin is wet, causing loss of insulation in the clothing when the sweat evaporates or freezes (Figure 1-5). In dressing for cold climates, it is as important to eliminate moisture as it is to protect for warmth, and precautions should be taken to avoid overdressing. Overdressing is one of the major errors in the Arctic of the insufficiently indoctrinated.

c. Adequate clothing properly worn is essential to the welfare and success of topside personnel performance. Arctic clothing is designed to be worn as an assembly for protection of the head, torso, and extremities. Failure to wear the total assembly and improper size of clothing are important factors in cold injury. The assembly depends upon the layering principle to conserve body heat. Loose layers of clothing with air space between and under, and outer wind-and water-resistant garments provide maximum protection. Inner layers may be removed for comfort and efficiency in higher

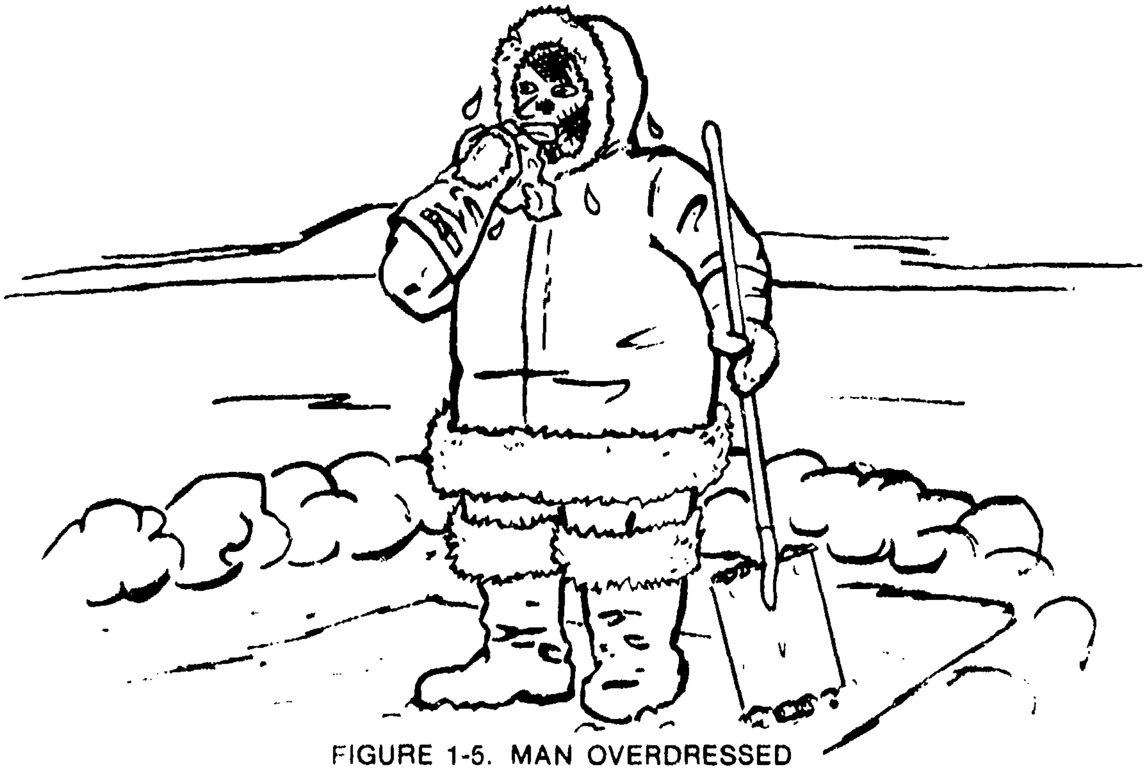

FIGURE 1-5. MAN OVERDRESSED

temperatures or during physical exertion (Figure 1-6). All articles of clothing must be loose enough to avoid constriction and tightness.

d. Excess clothing should be removed when in a warm enclosure. Snow and frost should be dusted off to prevent it melting and wetting the clothing thereby greatly reducing the insulation value. Boots should be dusted off and removed to prevent sweating of the feet. All clothing should be hung up and never laid on the floor where they may get damp from melted snow (Figure 1-7). Individuals should not allow themselves to become overheated while indoors as this makes satisfactory readjustment to the outside cold more difficult.

e. A standard number of layers of clothing cannot be prescribed for universal wear throughout the winter months. Everyone must dress themselves to meet their own needs and flexibility must be provided for local conditions. Certain basic principles are important, including the ventilation of the body during physical activity; the cleanliness and repair of clothing to prevent loss of insulation; and the avoidance of constriction produced by snug-fitting socks, boots, underwear, sweaters, jackets, and trousers.

f. Wind protection for the body is best provided with wind pants and parka. This provides a flexible combination which can be quickly changed. An ideal fabric is one with sufficient density to permit only a minimum of air to pass through it, but at the same time, not absolutely air-tight so it cannot breath and transmit body vapor to the atmosphere.

g. Facial protection from the wind can be provided, unless facing directly into the wind, with a moderately stiff 4-to 5-inch deep tunnel extending in front of the facial aperture of the parka. This should contain a malleable wire at the outer aperture so that the opening may be shaped. A face mask covering the cheeks, nose, and mouth is often worn in severe weather conditions (Figure 1-8). While these do offer additional protection to the facial areas, their constant use will "tenderize" the skin making it especially susceptible to frostbit should the mask be lost or forgotten. Goggles are best to use with these masks because regular sunglasses tend to fog from the exhaled breath. The moisture and ice accumulation from breath condensation must be removed periodically especially when entering a warm area. Adequate facial protection can usually be provided by a one-piece knit cap covering the head and neck and having facial openings for the eyes, nose, and mouth.

h. Adequate hand protection can be provided by a variety of gloves and mittens depending on temperature, dexterity requirements, and individual preference. Any glove or mitten

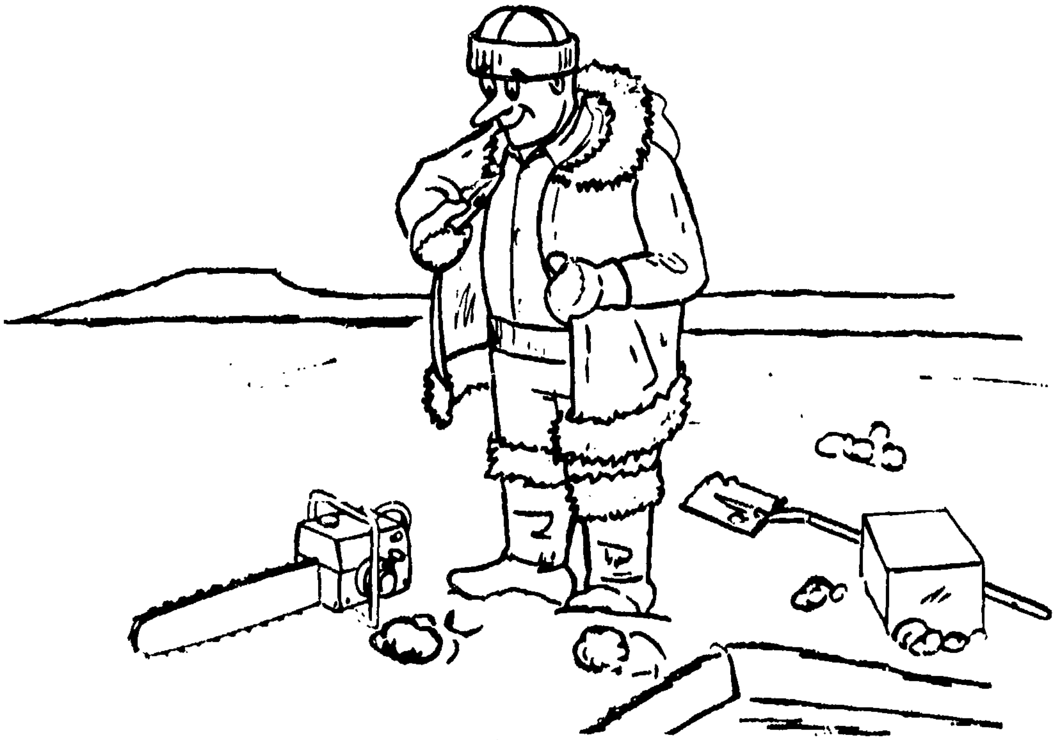

FIGURE 1-6. REMOVE EXCESS CLOTHING

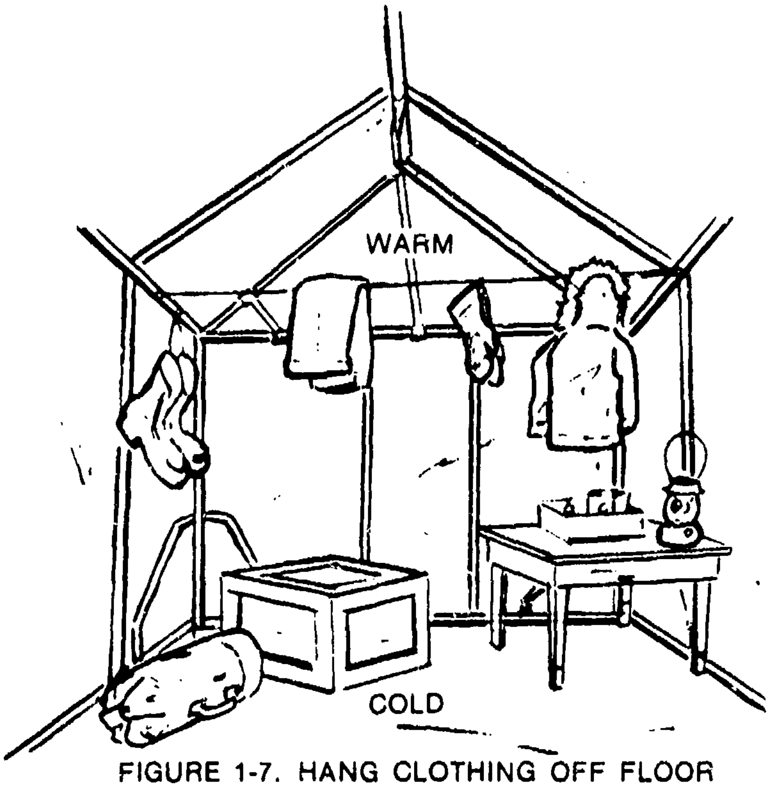

FIGURE 1-7. HANG CLOTHING OFF FLOOR

should allow a level of dexterity so that the wearer is not nearly helpless to perform basic tasks. All gloves and mittens must provide protection against cold injury; however, the hands do not have to be warm to be adequately protected. Light cotton, wool, or nylon gloves worn inside the mittens will allow the wearer to perform short excursions outside the mittens for tasks requiring fine manual dexterity. Any covering will eliminate the danger of touching cold metal with the bare hand.

i. The selection of cold weather clothing is dependent upon the humidity as well as the temperature and wind. Cold, wet conditions occurring when temperatures are near freezing, and variations in day and night temperatures cause alternate freezing and thawing. Freezing and thawing is often accompanied by rain and wet snow causing the ground to become muddy and slushy. In this type of weather, tenders and other topside personnel should wear water-repellent clothing with a wind-resistant outer layer and inner layers with sufficient insulation to provide ample protection from the cold.

j. The bright sunlight of the Arctic can be very deceptive causing personnel to overestimate their capability to perform short jobs with less than adequate clothing. Leaving bulky mittens behind when going to do a quick job requiring dexterity can lead to frostbite. Never underestimate a temperature of -30°F just because it is a bright, sunny day!

k. Footgear must be large enough to permit easy movement of the toes. Flexing and extension of the toes increases circulation and reduces the chance of frostbite, particularly during periods of immobility such as the diving tender. Constriction of the feet will cause a decrease of blood circulation, consequently hastening chilling. Therefore, flying boots or galoshes should not be worn over ordinary shoes, and laced shoes must not be so tight as to reduce free circulation (Figure 1-9). Men entering cold climates should be equipped with boots two or three sizes larger than their regular size; the additional space unoccupied by the feet can be filled with extra socks, insoles, or other thermal footwear.

l. Mesh nylon insoles should be placed between the felt insole and the boot to act as a vapor barrier. Moisture from the foot goes through the felt insole and collects in the mesh insole as frost. When the boots are taken off, the insole should be removed and the frost beaten out. Without such insoles, frost will form at the bottom of the felt insole and eventually freeze the insole to the boot. Removing the insole under this condition will tear it and possibly ruin the insulation. If no mesh pads are available, a piece of newspaper formed so as

FIGURE 1-8. FULL FACE MASK

not to wad will help form a vapor barier. At night, the boots should be thawed inside, dried, and hung from a high place to get away from the colder air on the floor. When entering a warm building, the boots should be loosened or removed to prevent overheating and sweating of the feet.

m. Wind causes low temperatures to seem colder (wind chill), and increases the need for protection of the entire body. If you start to get cold, a little additional exercise is often sufficient to maintain comfort. Basic principles of keeping warm:

1. Keep clothing **C**lean.
2. Avoid **O**verheating.
3. Wear clothing **L**oose and in Layers.
4. Keep clothing **D**ry.
5. Remember C-O-L-D to keep warm in winter.

1-15. Efficiency

a. Mechanical efficiency is reduced by the bulk and clumsiness of the clothing that must be worn in extreme cold areas. Some form of mitten or glove should be worn at all times to reduce heat loss and the discomfort of touching cold metal with the bare skin. If the metal is cold enough and the skin is moist, loss of skin tissue will occur. The loss of the sense of touch reduces the efficiency of personnel. Even the most routine operations, such as handling latches or opening engine enclosures, become exasperating and time-consuming when they must be performed with mittened hands (Figure 1-10). Five-fingered gloves of nylon, silk, or wool are usually worn under the mittens to enable a degree of dexterity upon temporary removal of the mitten; however, the space required for access to controls, adjustable devices, and assemblies is still excessive when bulky, cold weather clothing is worn. As a precautionary measure, a harness or convenient pockets to accommodate mittens temporarily taken off should be used. Do not set mittens on equipment or the ground as they might be blown away or lost, also they tend to gather blowing snow inside which will melt and dampen them. The loss of mittens can be dangerous.

b. The body measurements of personnel with warm weather clothing and cold weather clothing are shown below.

Comparative Body Measurements

	Warm Weather (in.)	Cold Weather (in.)
Hand (width)	4	6
Wrist (circumference)	7-1½	21
Head (circumference)	23	38
Breadth across shoulders	18	32
Foot (width and length)	3-1/2-11	5-14

1-16. Equipment

a. A great handicap associated with polar operations are the problems involved with the use of equipment designed for temperate conditions. Cold weather can cause several ill effects on diving and diving support equipment. Condensation occurs when a piece of equipment is temperature-cycled above and below the freezing point. The condensed moisture can short out resistors and capacitors; or if allowed to freeze, it can damage meter movements, cause connectors to short-circuit, and freeze breathing regulators.

b. Maintenance of equipment in the Arctic is a very important and often a frustrating task. All maintenance for a particular piece of equipment must be accomplished with extreme care; each piece of equipment is valuable and replacements usually do not exist. Spare parts will be scarce if they can be found at all, which will lead to cannibalization of other equipment as well as a lot of ingenuity by the maintenance personnel. Tools are critical items which will be difficult to replace if lost or forgotten. When special tools are required for a particular piece of equipment, extra sets should be taken.

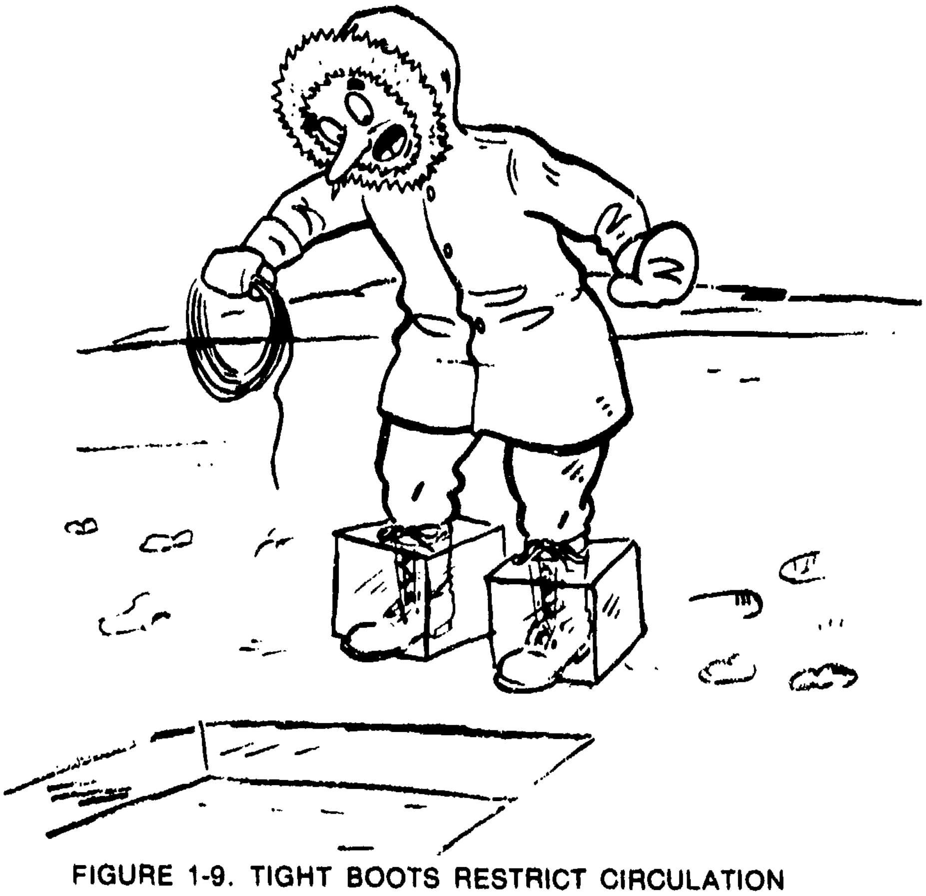

FIGURE 1-9. TIGHT BOOTS RESTRICT CIRCULATION

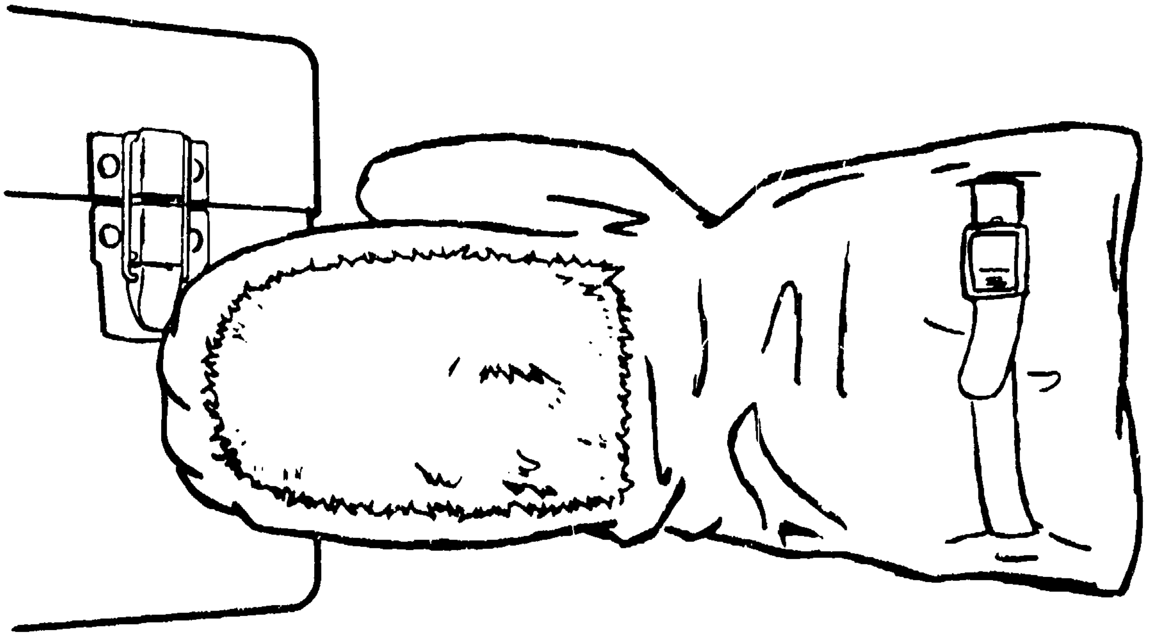

FIGURE 1-10. "SMALL LATCHES ARE DIFFICULT TO OPERATE WEARING MITTENS"

c. Vehicles

1. In the Arctic, vehicles wear approximately 10 times faster then they do in normal operating areas. Only qualified personnel, who are thoroughly familiar with vehicle operations and maintenance for this environment, should be allowed to handle them.

2. Operators must be aware that pedestrians often have a limited field of vision due to their clothing or weather conditions.

3. Beware of brakes; they usually don't work well in the Arctic.

4. Don't engage the emergency brake; it can freeze up.

5. Always carry a shovel in a truck or other wheeled vehicle.

6. Wear gloves when handling latches, gas cap, or other exposed metal.

7. Keep gas tank as full as possible to reduce condensation.

8. Use vehicles only when necessary.

d. Cameras

1. Some companies provide winterizing service for cameras. This is expensive because the entire camera is dismantled, and the oil and grease removed. Certain parts are relubricated with special low temperature lubricants.

2. Unless they have been lubricated with a broad-range lubricant, winterized cameras should be relubricated before use in temperate climates to prevent excessive wear.

3. A precision-built camera with close machine tolerances is more likely to freeze up than a poorly constructed one. A camera that has been used over a long period of time and is well "broken in" will operate better in subzero temperatures than a new camera.

4. Range finder cameras are more satisfactory than single lens reflex cameras because of fewer moving parts, especially the complicated metering and mirror mechanism.

5. Keep cameras covered when not in use to prevent blowing snow from entering the mechanism in winter and blowing dirt in summer. A warm camera taken directly outdoors will melt any snow which touches it. The moisture will then refreeze as the camera cools and interfere with the operation of the camera.

6. The body static electricity generated under the dry, cold Arctic conditions will cause the lens of a camera inside a coat or parka to attract lint from the clothing. Use a lens cap and inspect the lens before use.

7. Do not blow on the lens to remove particles: moisture from the breath will freeze immediately and is difficult to remove in subzero weather.

8. A lens hood will help protect the lens from blowing snow; a lens hood will also improve the quality of photos.

9. Silk or lightweight cotton gloves worn under standard mittens are good for operating fine adjustments and outdoor loading.

10. A camera that has become very cold should be rewarmed slowly. A cold camera taken directly indoors will get condensation on

the lens and housing which will freeze when taken back outside. It is best to leave the camera in a nonheated, protected area when going indoors for a short time.

11. To help prevent condensation on the camera when it is brought into a warm area, seal it in an airtight bag of polyethylene, rubber, or similar material. Condensation will take place on the bag and the camera will remain dry as it rewarms. For best results, get as much air out of the bag as possible before sealing it.

12. Operation of movie cameras, electronic flash units, and light meters in cold weather requires far more battery power than is necessary at normal temperatures. Light meters operated by a selenium cell rather than a battery are useful in cold weather. This is another reason to keep the camera and light meter covered and protected when not in use.

13. Photographic equipment should be stored near the temperatures at which they will be used to prevent condensation.

14. Flash blubs have a greater tendency to shatter at low temperatures. Use precautionary measures.

e. Film

1. The very high levels of illumination usually found in the polar regions require the use of low speed film for most work. Meter readings should be taken very carefully of the subject being photographed to avoid overexposing film.

2. The speed of film may be lowered slightly by exposure to extreme cold.

3. It is best to load the camera indoors with the film and camera at the same temperature.

4. Load and expose film promptly to prevent it from drying out. Motion picture film which has been in the camera one or two days may break at the loop when the camera is started.

5. Film which retains its proper moisture content, even at subzero temperatures, is more flexible than film which has been allowed to become too dry.

6. The edges of cold, brittle film is sharp and can cut the fingers unless caution is exercised.

7. Film should be advanced and rewound slowly to reduce the chance of tearing brittle film and the buildup of static electricity. Electrostatic discharge from static electricity is most likely to occur on film with a low moisture content; it is not as likely to occur if film is loaded and exposed shortly after the film package is opened. It appears on developed film as marks resembling lightning streaks, nebulous spots, or tree branches.

8. Patience is vital to successful Arctic photography.

f. Miscellaneous

1. Low temperatures change the strength, elasticity, and hardness of metals and generally reduce their impact resistance. Leather, fabrics, and rubber lose their pliability and tensile strength. Plastic, ceramics, and other synthetics are less ductile. Items composed of moving parts and of different materials operate with reduced efficiency.

2. Rubber, in warm weather, is flexible; during extreme cold it becomes stiff, and bending will cause it to break. Rubber, rubber compound seals, and O-rings tend to warp and break.

3. Canvas becomes stiff much the same as does rubber, and is difficult to fold or unfold without damaging it.

4. Glass, being a poor conductor of heat, may crack if it is exposed to any sudden increase in temperature.

1-17. Lubricants, Seals, and Fuels

a. Lubricants not specifically developed for cold weather use will congeal and retard the motion of an engine's moving parts. The low temperature lubricants (oils and greases) developed expressly for the winterizing of equipment have a low rate of viscosity change, a freedom from corrosive action, and low volubility.

b. Cold weather lubricants also must be capable of diffusion over all surfaces requiring lubrication, and permeation of the pores and surface cracks of metal. Cold weather lubricants evaporate at a more rapid rate than do regular lubricants at low temperatures. Their tendency to dry out requires frequent checking of lubricated surfaces and repeated replenishment.

c. In the Arctic, gasoline is often stored for long periods before it is used. Gums settle out and the more volatile components evaporate.

d. Under natural conditions, gasoline does not freeze, but becomes more difficult to vaporize as the temperature is lowered. Since only vapor will burn, combustion of gasoline inside an engine is more difficult, and the unburned gasoline dilutes the oil in the crankcase contributing to the formation of sludge.

e. Oils have a tendency to become thick and, consequently, difficult to pump to places where it is needed for lubrication. Thickened viscous oils, until they become hot, increase the drag on the engine making it more difficult to turn over.

f. Grease, which is a semisolid to begin with, becomes hard and loses a great amount of its lubricating properties.

FIGURE 1-11. FILTERING GASOLINE

g. In dry, cold weather, static electricity can form in the layers of clothing worn by personnel and in liquids being transported. Extreme caution must be exercised when refueling vehicles, stoves, lanterns, etc., because the spontaneous discharge of static electricity may ignite these inflammable fuels. Static electricity should be "drained off" by grounding vehicles or fuel containers prior to starting refueling operations. Personnel should ground themselves by touching a vehicle or container (away from vapor openings) with the hand.

h. Tips for Cold Weather Operations:

1. Lubricate and change oil more often than normal to help reduce abnormal wear and to compensate for contaminated lubricants.
2. Keep oil and gasoline containers sealed tightly to prevent snow and ice moisture from entering.
3. Always make a complete change of engine or gear oil instead of mixing various grades.
4. Standard and Arctic type antifreezes should not be mixed.
5. Allow for expansion when filling radiators.
6. Filter all gasoline through felt (Figure 1-11). Felt will soak up water which will freeze in the material and can be shaken out so that the filter can be reused. If no felt is available use a chamois. Even though it does not soak up water and may increase the danger of static electricity, a chamois is better than nothing.
7. Diesel fuel should be strained to remove paraffin (2 to 2-½ pounds per 55-gallon drum). Use chamois or felt.
8. Kerosene and some stove fuels may be too viscous at extreme low temperatures for a chamois; use felt.
9. Funnels should have a copper screen to help filter out ice particles and foreign debris.
10. If possible, use Diesel Fuel Arctic to reduce debris and water content.
11. Condensation of moisture inside fuel tanks can be minimized by keeping the tank topped up.

12. Add one-half pint of denatured alcohol to each 10 gallons of fuel at the time of filling to improve performance.

13. Approximately one cup of diesel in the transmission and the differential will keep the oil less viscous.

14. If it is too cold for antifreeze, kerosene will work.

15. The use of spray ether will help firing when the spark is weak; use carefully.

16. Appropriate cold-temperature lubricants should be used in prepacked bearings.

17. Usually, the spark ignition engine will be easier to start in extreme cold than the diesel.

18. Only qualified individuals should work on engines and associated equipment.

1-18. Shelters.

a. Most diving operations in the arctic will require some type of surface shelter to protect both personnel and equipment. Depending on the performance and location of the site, this shelter can range from small tents to insulated huts. When selecting a shelter, the problems of transport and assembly should be considered.

b. Large tents such as "Jutland Buildings" can be quickly assembled on site and offer adequate protection in temperatures of -40°F with winds of 40 knots plus. Usually measuring 12 feet by 14 feet with an 8-foot center clearance, these double-layered tents are spread over an easily assembled aluminum tubular frame (Figure 1-12). When the normal canvas decking is replaced by styrofoam pads (styrofoam packing sheets are excellent) and covered with plywood sheets, a satisfactory insulated floor is produced. The tents can be used to protect the diver's entry hole or as a support site (Figure 1-13). Any tent or other structure which must be assembled on the open ice should first be assembled, at least partially, in a heated, protected area as an exercise to familiarize personnel with the procedure.

c. The entry of a tent should have a fastening system, such as Velcro, which can be quickly opened and closed. The use of standard lines to tie the flap shut is too time-consuming and difficult, especially while wearing mittens. Since moisture by condensation or from wet personnel is likely, a "polyester Velcro" should be used instead of the more common "nylon Velcro" because of the better grip retention when wet. Zippers should be avoided as they tend to freeze up. Where zippers are used, long ties that can be grasped while wearing mittens should be used.

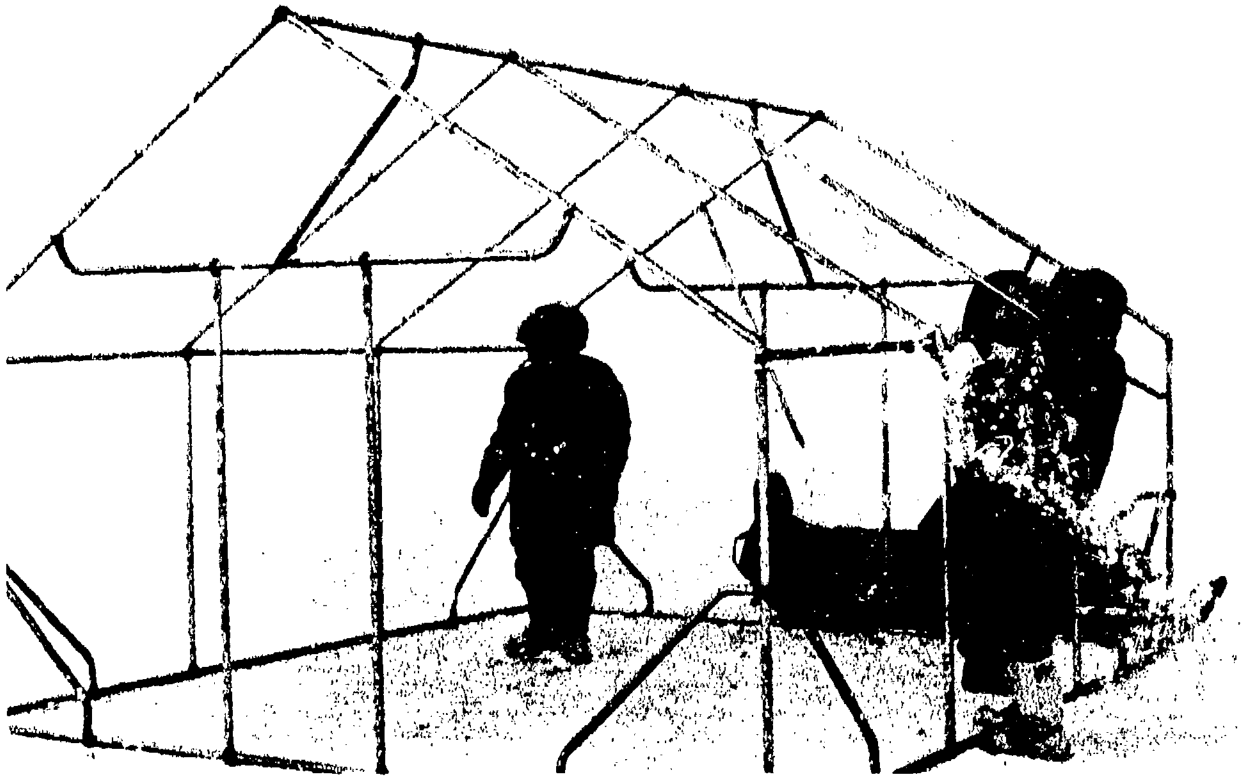

FIGURE 1-12. ASSEMBLING TENT FRAME

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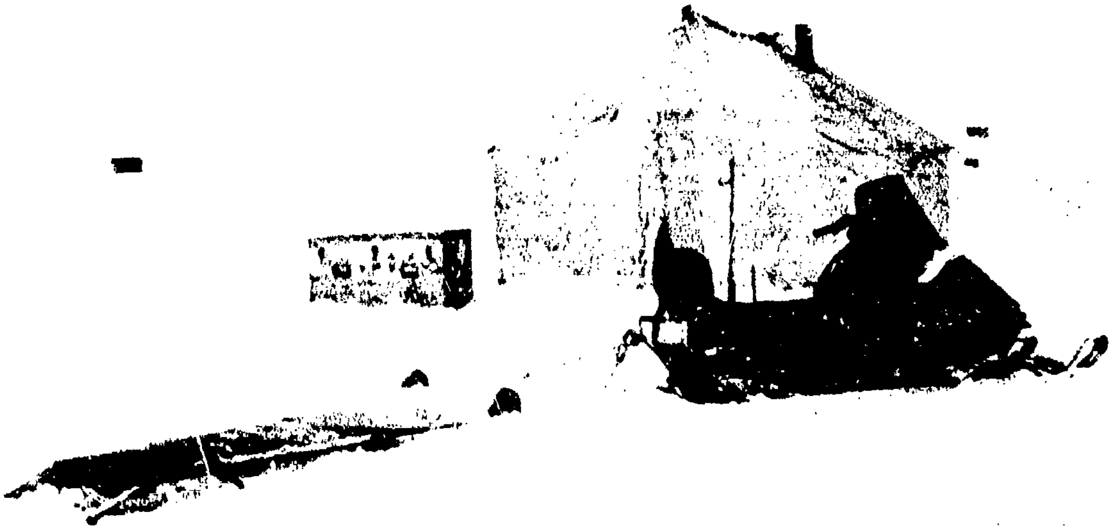

FIGURE 1-13. DIVE SITE

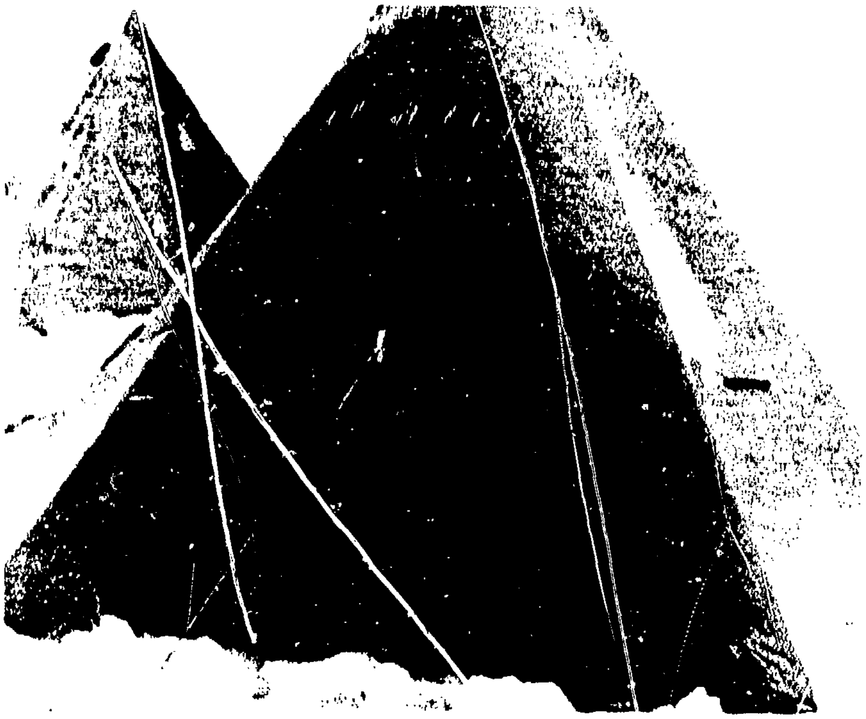

FIGURE 1-14. SMALL BASIC TENT

FIGURE 1-15. SMALL COMPLEX TENT

d. For excursions to distant dive sites, one or more small tents can be used to provide living quarters and dressing areas for divers. These tents should be as simple as possible with a minimum number of pegs, lines, etc. (Figure 1-14). A tent that looks good when planning a mission can turn into a monster when trying to assemble it on the ice (Figure 1-15).

e. Huts can be prebuilt and shipped to the diving site ready for instant usage or in components requiring on-site assembly. Huts are much more comfortable than tents; however, they require more logistic support. The maximum benefit of a hut is realized on a semipermanent site or on surveys where they can be placed on large sleds and double as living quarters. The advantages and disadvantages of huts and tents should be weighed for each individual diving operation.

1-19. Shelter Layout

a. All dive site shelters should have an area where items to be kept dry can be stored. Portable racks which can be kept clear of wet areas and out of the way are required for electronic equipment, cameras, note pads, snacks, mittens, etc. (Figure 1-16).

b. A storage rack should be set up inside the dive site shelter for such items as fins, diving mitts, weight belts, etc. No parkas or other bulky clothing should be stored in the dive tent because of the space requirements.

c. Benches should be provided near the entry hole to provide a resting place off the cold tent floor for topside personnel.

d. Requirements for artificial lighting must be given careful consideration because normal flashlights have short battery life, electric lighting requires major logistic support for generators, and lanterns not only blow out but water condensation in the fuel freezes and blocks the fuel line. Tents require little or no artificial light during daylight periods. Storm lanterns which burn from a wick are simple, require little support, but provide little light. Brighter lanterns requiring mantles, pressurizing, and frequent refueling are a possible source of trouble.

e. A tent heater is required that can be left on "low" overnight if desired. This may be necessary to prevent the entry hole from refreezing as well as protect equipment inside the tent from extreme cold. A fan should be placed near the top of the tent to circulate the warm air.

f. In semi-permanent camps where gasoline or fuel oil stoves are used, the usual 5-gallon gasoline can should be replaced with

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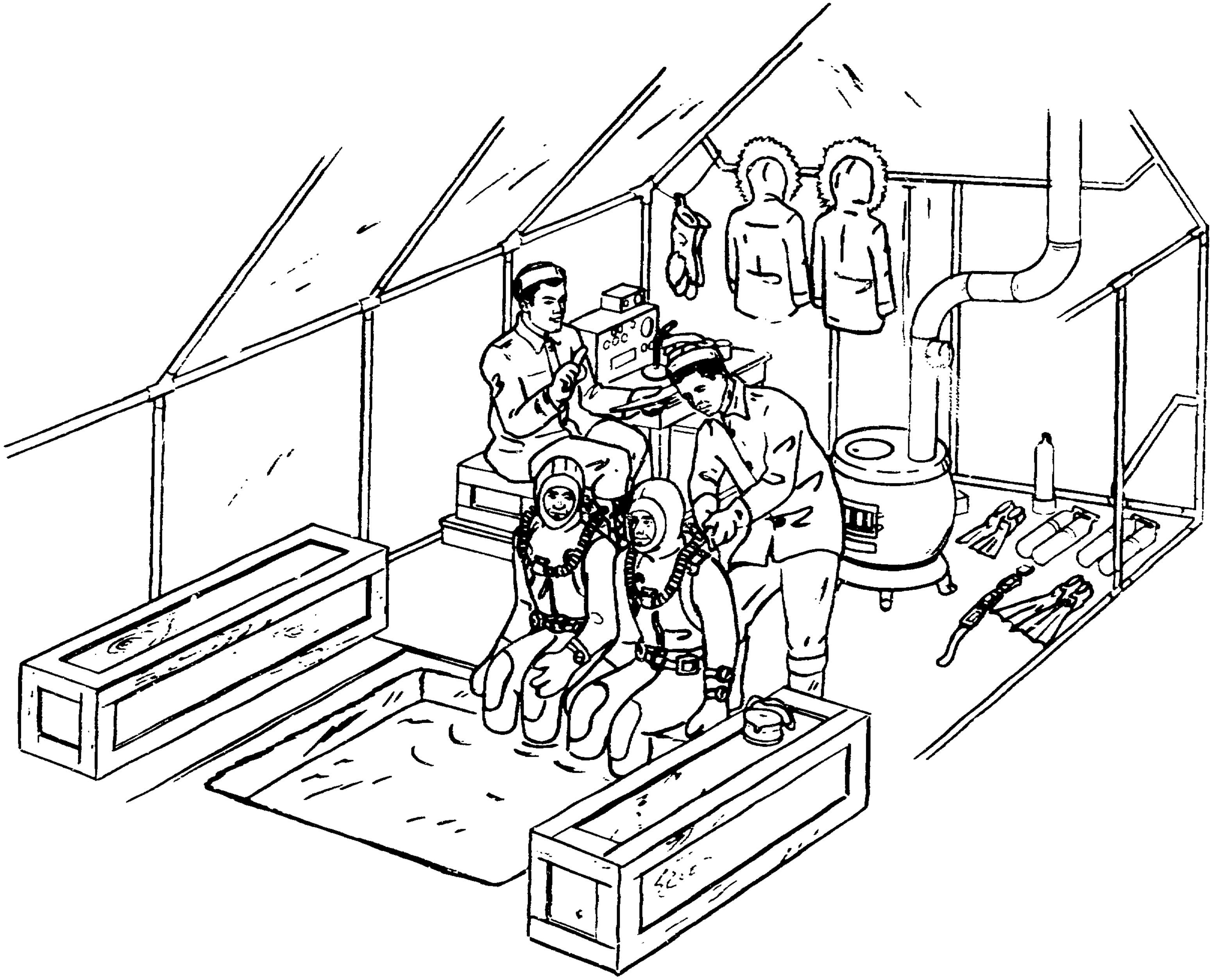

FIGURE 1-16. BASIC LAYOUT OF A TYPICAL DIVING SHELTER

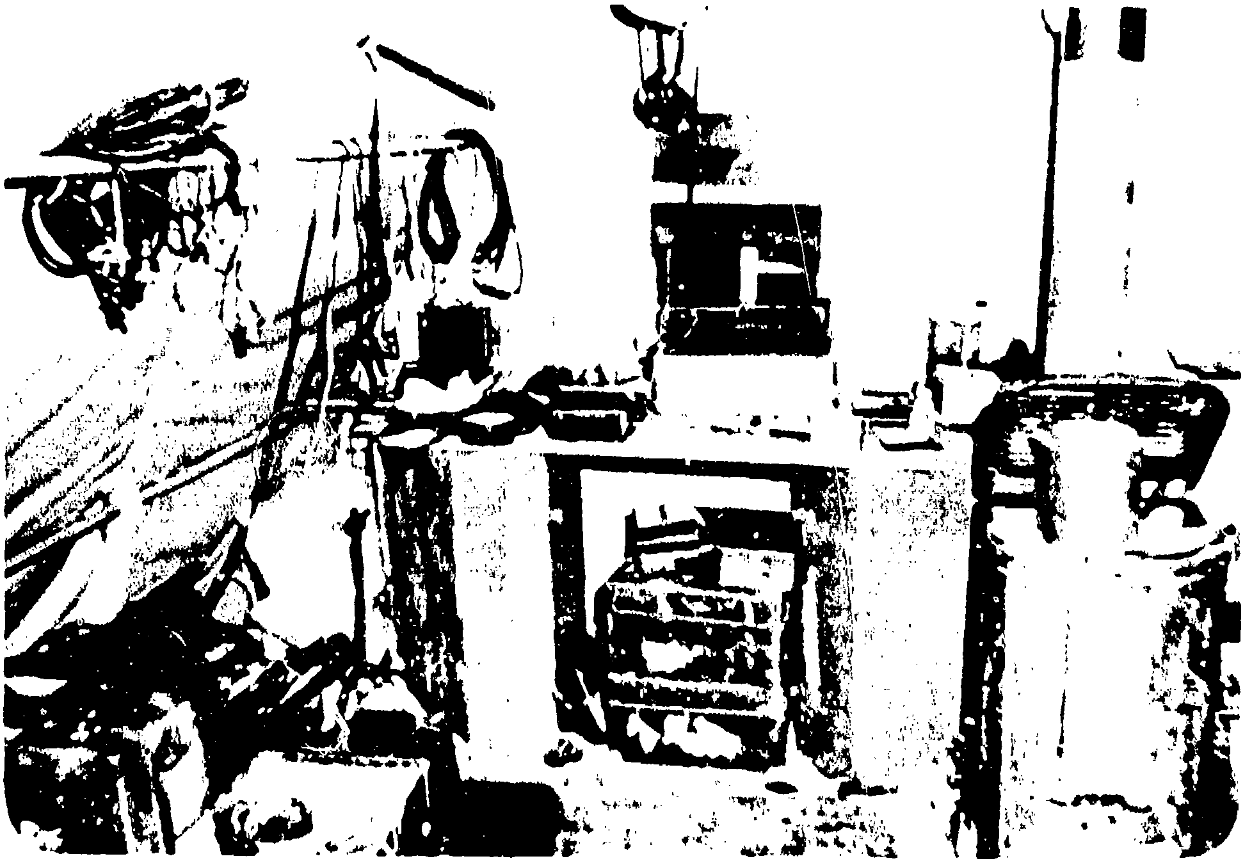

FIGURE 1-17. INSIDE CROWDED DIVE TENT

tanks made from one or more 55-gallon drums set up on stands outside the tent or building with fuel piped to the stove. Frequent inspection for fuel leakage must be made and corrective action taken to eliminate fire hazards. Spilled fuel should not be swept into the dive hole regardless of the amount. It is best to sweep it outside with the snow and water which routinely gets all over the floor.

g. Gasoline and diesel fuel may be stored in flexible containers at low temperature although the containers cannot be moved easily and are subject to damage from handling at temperatures below -30°F. At extremely low temperatures, flexible containers and hoses become brittle and break easily. If the container or hose breaks allowing spillage on an individual, instant frostbite could result.

1-20. Use of Shelter

Shelters for a dive site are usually small and crowded whether they are tents or semi-permanent structures (Figure 1-17). All personnel that are not directly involved in the dive taking place should stay clear of the shelter. This is especially important during the periods of heavy activity immediately prior to and immediately following the dive.

1-21. Fire

The combination of low humidity and the drying effect of continuously heated shelters is conducive to fire. Shifts in wind and the accumulation of frost or soot in the stovepipe can lead to backfiring of flaming fuel in the shelter. Spilling fuel containers and lamps create additional hazards. The stamping of feet to shake off snow or frost can overturn stoves and small heating units that are not equipped with a secure, steady base. A fire extinguisher should always be provided in the tent or shelter. Applicable technical manuals should be consulted prior to operating tent stoves, cooking stoves, or gasoline lanterns.

1-22. Carbon Monoxide Poisoning

a. Whenever a stove, fire, gasoline heater, or internal combustion engine is used indoors, there is danger of carbon monoxide poisoning. A steady supply of fresh air in living and working quarters is vital regardless of the heat loss to incoming cold air. Carbon monoxide is a deadly gas, even in low concentration, and is particularly dangerous because it is odorless. A CO detection kit should be available and periodic checks made in all living and working spaces.

b. Generally, there are no symptoms. With mild poisoning, however, these signs may be present: headache, dizziness, yawning, weariness, nausea, and ringing in the ears. Later on, the heart begins to flutter or throb. However, the effects may strike without any warning whatsoever. A diver tender concentrating on his line may not know anything is wrong until his knees buckle. When this happens, he may not be able to walk or crawl. Unconsciousness follows, then death.

c. In a case of carbon monoxide poisoning, the victim must be moved into fresh air at once and kept warm. This means circulating indoor air that is free from gases because exposure to the outdoor cold might cause collapse. Never exercise the victim, as this will increase his requirements for oxygen. Carbon monoxide poisoning is serious, and a victim who survives it must be kept absolutely quiet and warm for at least a day. If the victim is a diver he should not resume any diving duty until cleared by a medical doctor.

CHAPTER 2

LOGISTICS

SECTION I. GENERAL

2-1. Planning

a. Careful planning and organization are mandatory to transport a diving operation to the polar regions and support it while there. The success or failure of a mission can depend upon the thoroughness with which this logistic support is planned. Nowhere else on earth are expeditions so completely dependent upon their logistics system, not only for the execution of their planned objective, but even for their very existence as a community of human beings. If any single factor could be said to be more important than any other in mounting a polar diving operation, it would be transportation.

b. It is essential to integrate several factors to efficiently and economically provide sufficient appropriate transport to meet the requirements of a diving operation: (1) distance, time, and payload; (2) support capabilities in terms of maintenance and fuel; (3) season and weather; (4) terrain throughout the journey; and (5) reliability and safety.

c. Very few diving operations can depend on one type transportation alone to completely satisfy all logistic requirements. In most instances, a judicious use of a combination of sea, air, and ground transportation will provide the economy, flexibility, and efficiency that the task demands (Figure 2-1).

d. Several factors, some unique to the polar world and some not, which must be considered when planning the logistic support for a polar diving operation are:

1. Environmental factors, including blowing snow, low temperatures, and irregular terrain.
2. The general lack of facilities that can be used for support purposes.
3. The general lack of ground communications system, even near populated areas.
4. The distances over which support must be rendered.

e. Diving operations in polar regions will normally involve small units, but the total effort required will be large because of the difficulties of operating in such areas. It is extremely expensive to simply arrive at the dive site with personnel and equipment. Only those items which are absolutely needed should be taken and, whenever possible, only those that have actually been proven in the Arctic environment. Many items that have performed well in laboratory engineering and user tests, including tests made in cold chambers, have failed to meet specifications when used in polar regions. Diving operations beyond basic scuba will be undertaken at higher operational cost because of the additional support equipment needed.

SECTION II. GROUND TRANSPORTATION

2-3. General

a. The use of ground transportation in polar regions is influenced by the almost complete absence of roads. Those roads that do exist are normally localized around permanent camps and settlements serving local transportation requirements (Figure 2-2). Roads are difficult to keep open due to drifting snow which can block a road in less than an hour. In some areas roads will be subject to the effects of thawing topsoil in the summer months, leading to the problems of mud in place of snow and additional maintenance problems.

b. For relatively short distances from a base camp; setting up, maintaining, and removing a diving station can be handled by a surface vehicle. If the proposed dive site is much more than 20 miles from the base camp however, the use of aircraft should be considered. The final choice will depend on the transportation equipment available, the amount of equipment to be moved, the distance involved, and terrain to be traversed.

2-4. Vehicles

a. The choice of a surface vehicle will depend on the size, bulk, and weight of the equip-

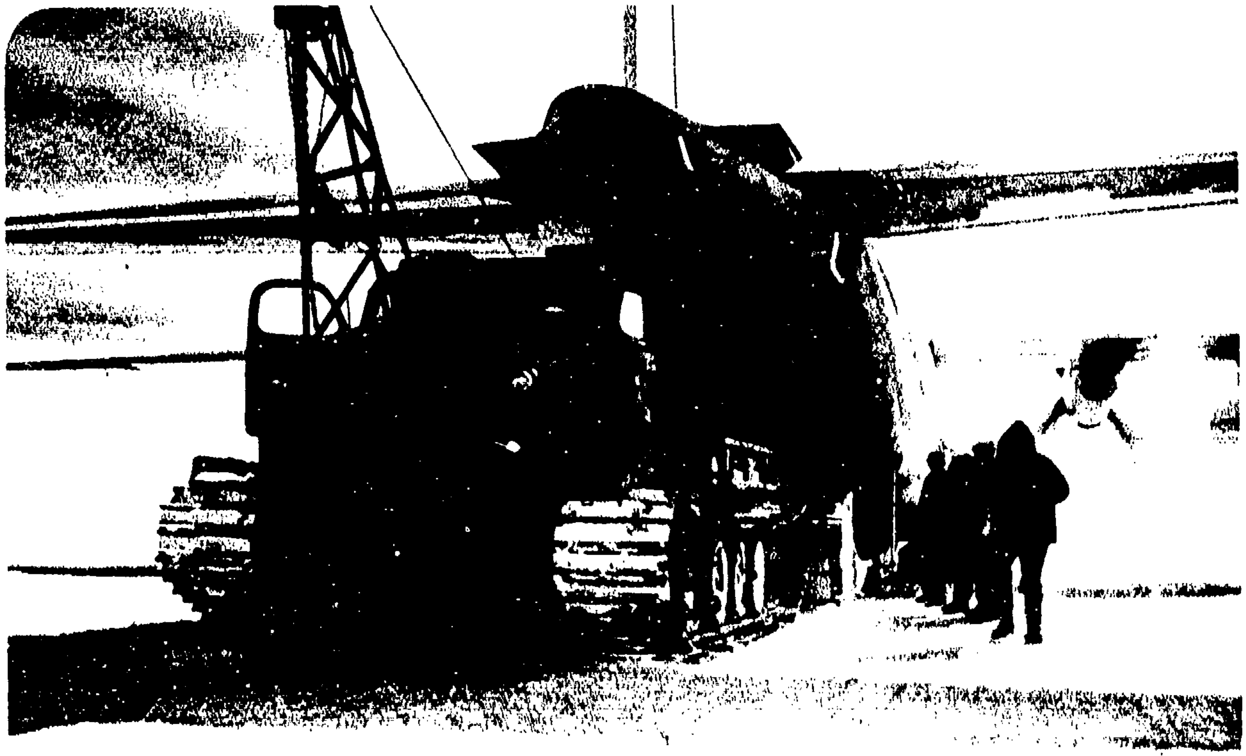

FIGURE 2-1. TRACKED VEHICLE OFFLOADING FROM A HERCULES CARGO AIRCRAFT

ment to be moved and the type terrain to be negotiated. Vehicles which are commonly used range from the small snowmobile to heavy duty specialized tractors and may be wheeled or tracked. The specifications of each should be considered when choosing which vehicle can best support a particular diving operation.

1. Wheeled Vehicles

Wheeled vehicles such as a crew cab truck, provide an adequate and relatively inexpensive means of transportation when roads or cleared paths across the ice are available. They are not recommended for general use unless equipped with four-wheel drive. A heated enclosure on the back makes them a nice personnel carrier. In deep snow they tend to bog down until stranded on their axles. They must be dug out of such situations and a snow shovel should always be carried. Wheeled vehicles are more limited by local weather conditions and terrain than tracked vehicles, but their low maintenance requirements will usually offset this deficiency (Figure 2-3).

2. Snowmobiles

The snowmobile is excellent for short runs around the base camp and as a personnel and small load carrier between the base camp and nearby dive sites. When coupled with a small sled these vehicles can usually take care of all the daily support requirements for a diving operation which is located where wheeled vehicles cannot go and larger tracked vehicles are not practical (Figure 2-4). Snowmobiles can be easily damaged if not properly maintained and operated. Only qualified personnel should be allowed to drive or perform maintenance on them. Some general points on the snowmobile are.

(a) Avoid elaborate "sports" models. If taking more than one take identical models so parts can be interchanged and the same fuel mix used.

(b) Check them out completely before sending to the Arctic and send plenty of spare parts and any tools required to work on them.

(c) If possible use carbide runners on the skis.

(d) Lift the track off the snow at night to prevent freezing to the ice.

(e) Before moving, turn the machine on its side after the engine is running and slow-

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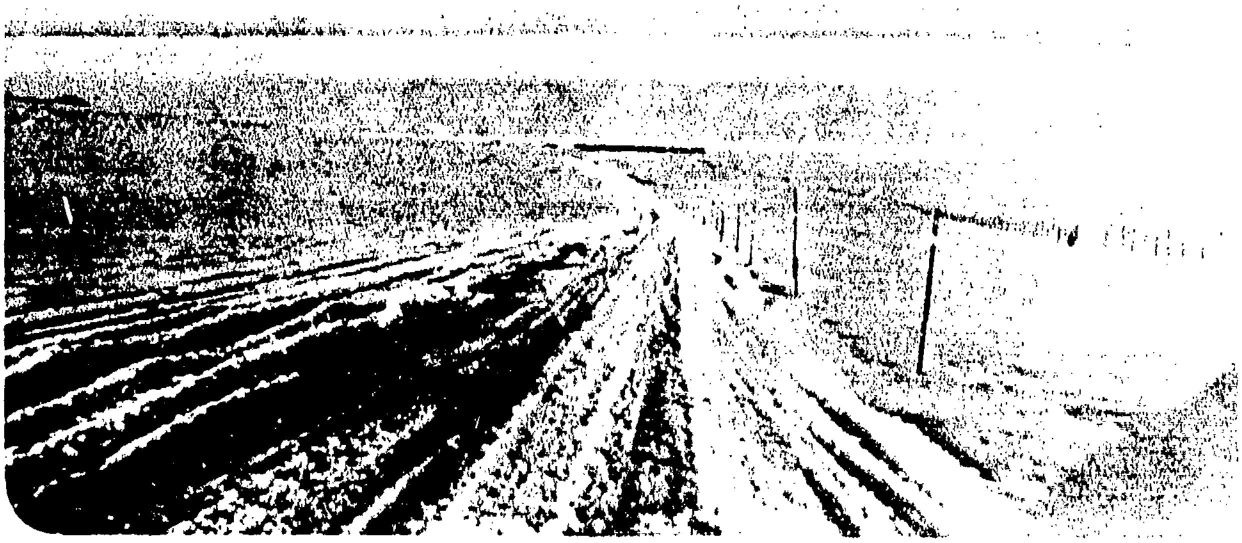

FIGURE 2-2. AN ARCTIC HIGHWAY

FIGURE 2-3. FLOODED AREA AT TIDAL HINGE

FIGURE 2-4. SNOWMOBILE AND SLED

ly engage the throttle until the track turns freely. This can prevent damage to the engine. Beware of sticking throttles.

(f) Fill the gas tank whenever there is any question of fuel remaining to help prevent condensation and never use fuel with the improper gas-oil ratio.

3. Tracked Vehicles

Tracked vehicles larger than the snowmobile range in size from oversized snowmobiles with a cab to 16-ton caterpillars which can pull giant sleds hundreds of miles across the ice (Figure 2-5). These vehicles are generally built and used for specific purposes, and would be of use to the average diving operation only when such a specific need arose. Typical uses include: clearing snow from a new site, opening closed roads or cutting new ones, towing large sleds of equipment to distant sites, and assisting in moving and handling heavy equipment. These machines will normally be used only when absolutely necessary because of their limited availability and high operating cost.

2-5. Sleds

a. Sleds used for polar ground transportation are pulled by everything from snowmobiles to heavy duty caterpillars. They vary from simple, heavily constructed platforms on skids that carry thousands of pounds of equipment at slow speeds (Figure 2-6), to lightweight, small models for use with the snowmobile. Some pointers in the proper selection and use of sleds with snowmobiles include:

1. A solid tow bar rather than a rope will prevent the sled from catching the snowmobile when going downhill, ramming it after a sudden stop or yawing from side to side while traveling.

2. However, when towing across rugged ice a nylon rope is better than a solid bar as the bar may buckle due to the irregular terrain.

3. Any hitch used should be a snap type that can be quickly activated while wearing mittens.

4. Lightweight metal sleds are better than heavy wooden ones.

5. The track of the sled should match the track of the snowmobile skis.

6. Passenger-carrying sleds should physically permit those being towed to get out and help push when the going gets rough; similar to those used on dog teams (Figure 2-7).

7. The Nansen sled is a popular type and has a 1500-pound load carrying capability.

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FIGURE 2-5. TRACTOR PULLING HEAVY DUTY SLED

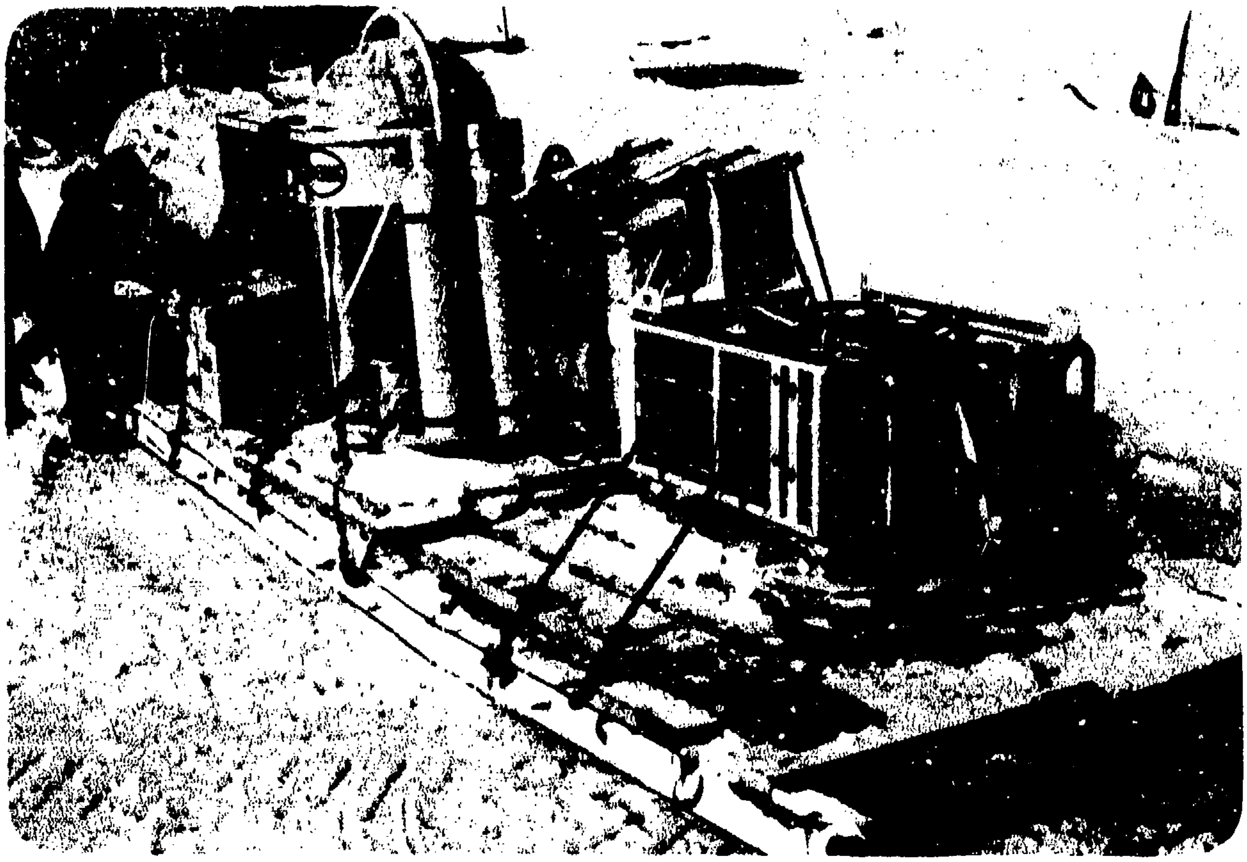

FIGURE 2-6. HEAVY DUTY SLED

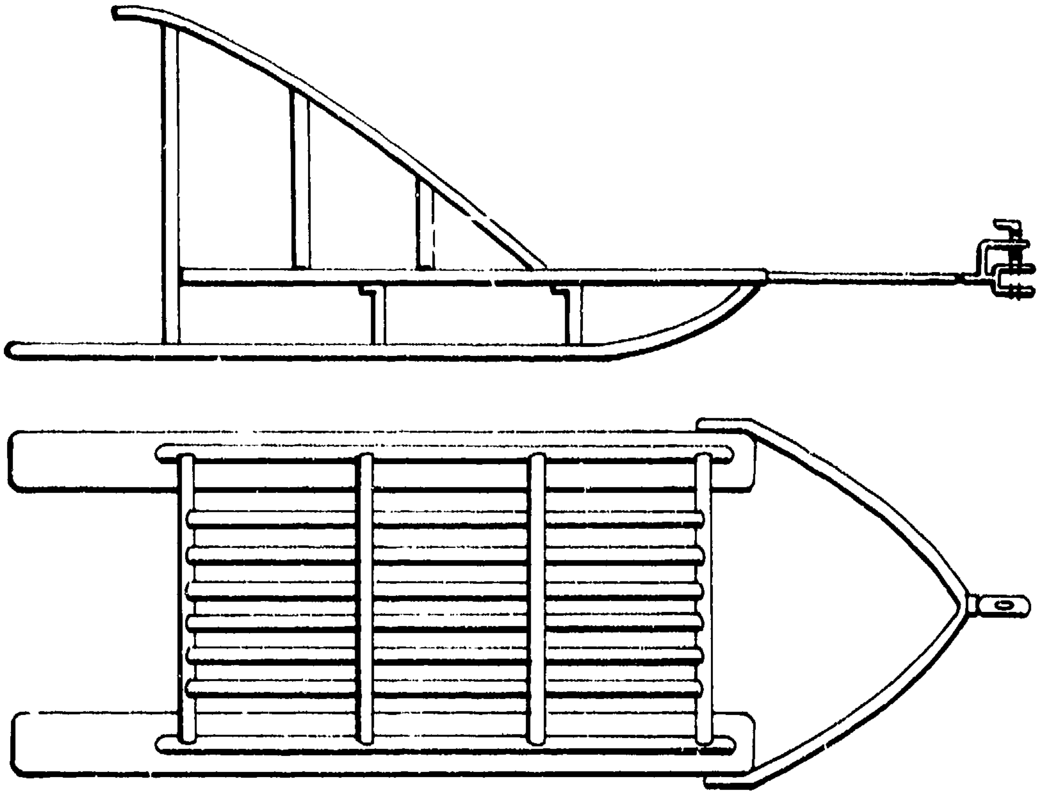

FIGURE 2-7. SNOWMOBILE SLED FOR HEAVY LOADS

2-6. Emergency Survival Equipment

When a vehicle must work away from camp, it should be equipped with some basic survival gear in case of breakdown or inclement weather making movement impossible. Some suggested survival items are:

a. A shelter which is small, compact and easily set up.

b. A shelter heater which can be used for cooking.

c. A cooker pot for melting snow for water.

d. Ground signal devices such as flares, smoke, panels, etc.

e. Radio set with extra batteries.

f. Sleeping bags, rations, medical kit, and extra clothing.

g. Snow knife, saw, and shovel.

h. Mirror, waterproof matches, and extra sun glasses.

SECTION III. AIR TRANSPORTATION

2-7. General

a. Personnel and high-value cargo transportation in the Arctic today is primarily by air. Air transportation is furnished by a variety of aircraft serving remote airstrips many of which are makeshift and accessible only during certain months of the year. Fog, storms, winter darkness, and the many other operational problems of polar flying often prevent the truly free movement of diving teams by air.

b. Ski-equipped aircraft can usually find a suitable landing place on the ice where they can load and offload (Figure 2-8). Aircraft will not normally remain at a remote site for long periods because they are vulnerable to inclement weather which can reduce visibility, damage the aircraft, or destroy the landing strip. There is also the possibility of having to preheat the engines if they have been sitting idle too long. Even during good weather in summer, routine landings may be subject to the amount of ice melt and in some cases a helicopter may be required.

c. The use of helicopters is increasing in polar regions, however they are more limited by weather and have less payload-carrying capacity than conventional aircraft. Their big advantage is that they can sit down in areas where fixed wing aircraft cannot. Helicopters have a limited means of navigation, which, with their small fuel supply restricts flights to relatively short distances of 50 to 75 miles. They have been used to transport diving teams hundreds

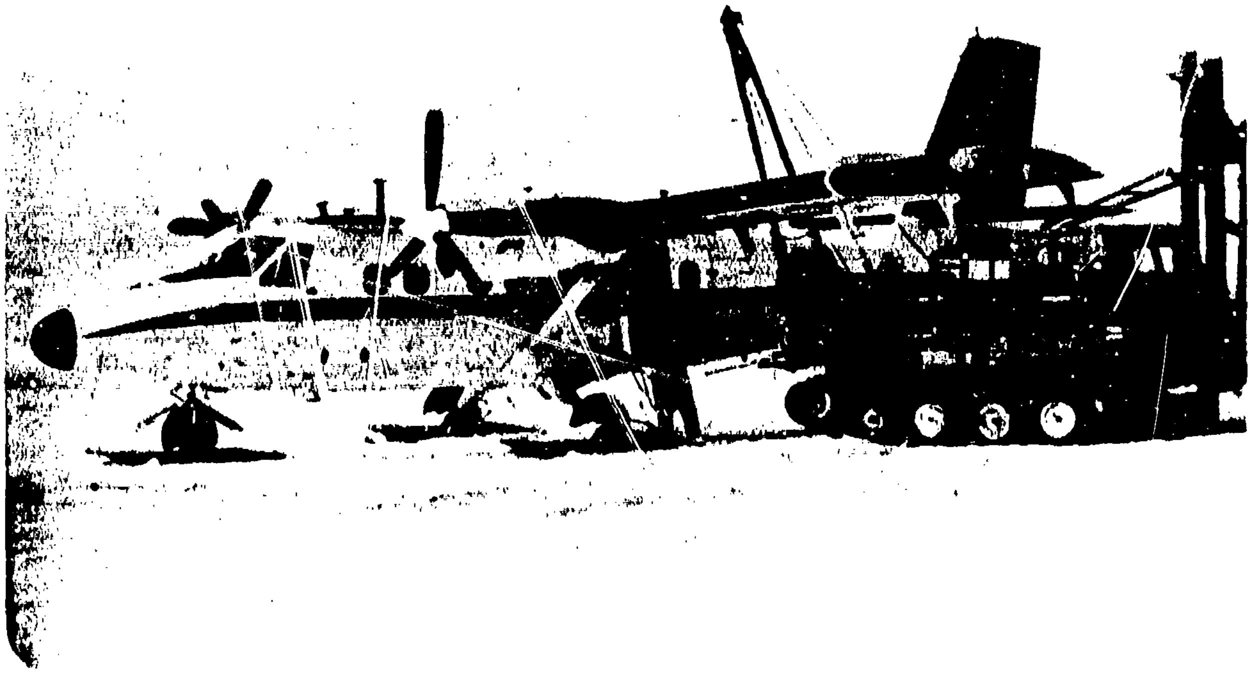

FIGURE 2-8. TWIN OTTER WITH NODWELL TRACKED VEHICLE

of miles across the ice to remote sites but will require the assistance of conventional aircraft for navigation and additional fuel. Additional fuel is airdropped in rubber bladders or conventional drums at designated sites where the helicopter crew can land and refuel. Some helicopters are adapted for air-to-air refueling.

d. Before any diving equipment is flown to polar regions, all appropriate aeronautical rules on shipment of equipment should be checked. When cargo is shipped to the forward area, documentation is important. Under the severe environmental conditions, it is even easier than usual to lose track of cargo and not know where it is just when it is needed. And, once on the ground, most air-lifted cargos still face the ever present deterrents to delivery of cargo from the landing strips to the final point of delivery (Figure 2-9).

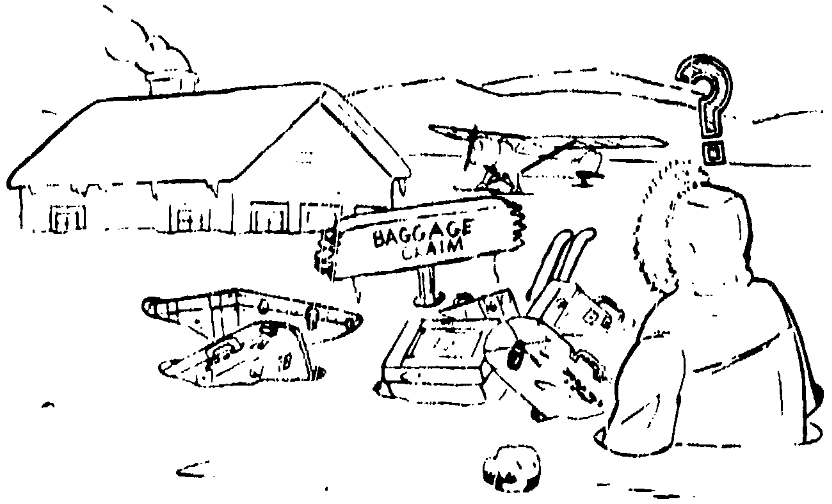

FIGURE 2-9. CARGO COVERED WITH SNOW AT AIR TERMINAL

CHAPTER 3

EQUIPMENT

SECTION I. EXPOSURE SUITS

3-1. Design Considerations

The selection of an exposure suit for polar diving requires careful study and consideration of the mission requirements and the individual suit capabilities. Regardless of the type suit used, it must have some special features to provide the protection required in polar waters. Among these are:

a. The hood should come low over the forehead to protect the frontal sinuses.

b. The bottom of the hood should have a chin cup so that with the mask in place, only a minimum area of the face is exposed to the water.

c. Zippers should be held to a minimum and backed with a gusset.

d. Mittens, boots, and seals should be large enough to prevent restriction of blood circulation.

e. Low density neoprene should be used in suit construction.

f. A neoprene cover, to protect the lower face, provides additional comfort but should be used only after the difficulty of placing and removing the regulator mouthpiece has been considered.

3-2. Dry Suits (Standard)

This type suit was used for most cold water diving prior to the introduction of the foamed neoprene wet suit. Made of two-ply gum rubber worn over layers of dry underwear, its insulation properties depend on the thickness of the air space provided by the undergarments. Unfortunately, this type suit is subject to leaks if the entry is not properly sealed, and a slight tear can result in flooding and loss of thermal insulation. This suit is also uncomfortable at depth due to squeeze; however, this can be compensated for by air introduced into the suit through the face mask seal.

3-3. Wet Suit

a. The foamed neoprene wet diving suit is still occasionally used for diving in polar waters. With a well-tailored, properly fitting 1-1/4 inch suit allowing negligible flushing, dives of 2 hours have been made in 29°F water (Figure 3-1)

b. Unfortunately, the capability of foamed neoprene to protect at depth is greatly reduced because of material compression. Deep dives are limited when this suit is used and the use of thicker suits to compensate for the compression is not practical. Thicker suits such as 3/8-inches are too restrictive to diver movements and require excess weights. They also cause enough extra bouyancy in the leg area to become fatiguing.

c. Other limitations of the wet suit include:

1. Limited thermal protection.
2. Chilling of the diver after leaving the water.
3. Uncomfortable when out of the water, especially between repeat dives.
4. It is difficult to dry, compared to other suits.

d. An advantage of the wet suit, other than its availability and its simplicity, is that there is almost no danger of material failure allowing sudden flooding as there is with all dry suits. For short duration dives of limited depth, the wet suit is satisfactory, even in water temperatures below 32°F.

3-4. Dry Suit (Variable Volume)

a. There are several models of variable volume dry suits on the market today with manufacturers in Sweden, France, Norway, Canada, and the USA. While these suits all work on the same basic principle they differ greatly in design and the quality of construction (Figure 3-2).

b. Typically, a variable volume dry suit is constructed of closed-cell neoprene with a nylon-lined interior and textured rubber or nylon exterior. Built in one piece with attached boots and hood, entry is gained through an access that is sealed with a waterproof zipper.

(Text Continued on Page 32)

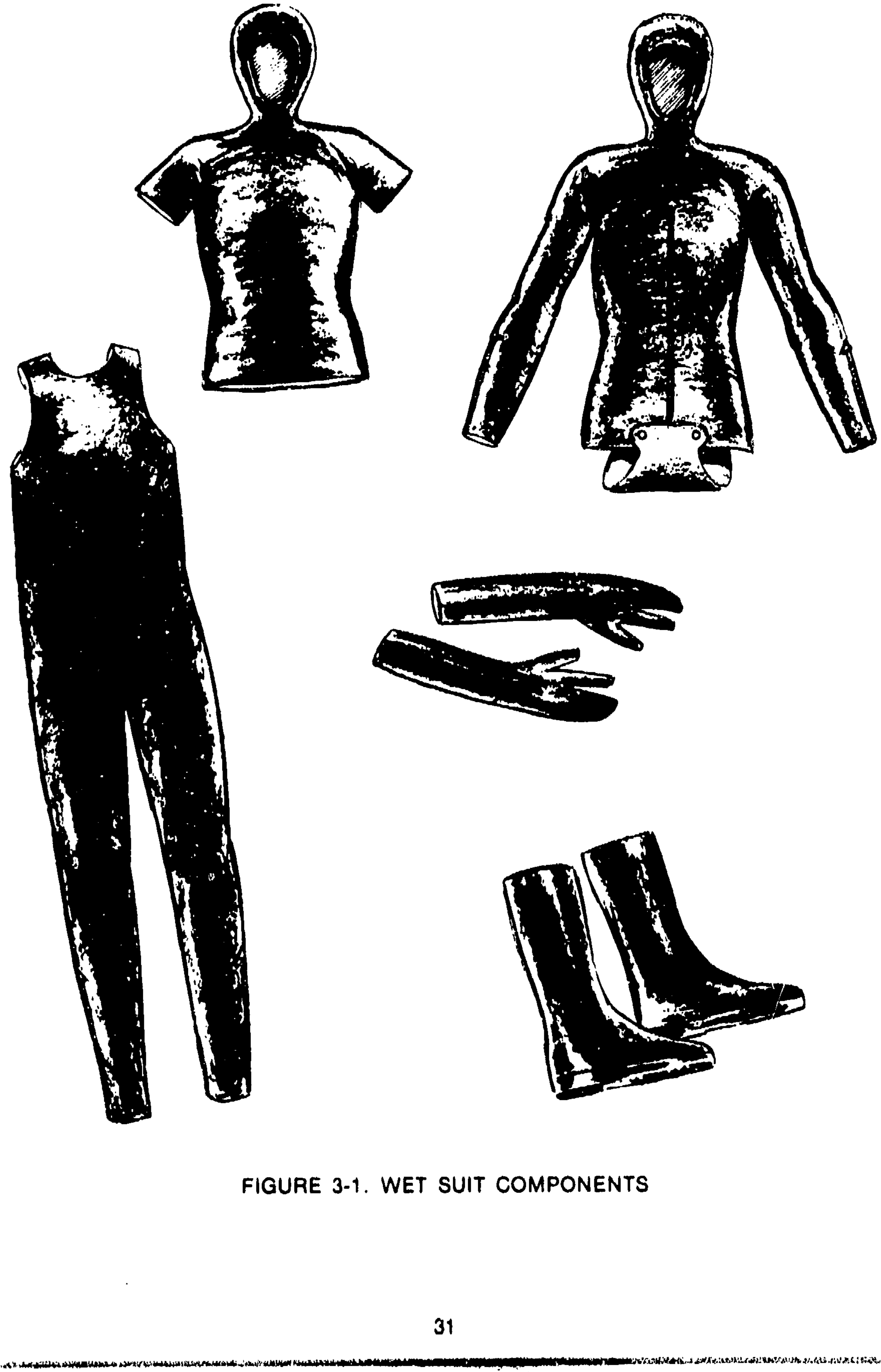

FIGURE 3-1. WET SUIT COMPONENTS

Waterproof seals at the wrist and neck keep the interior dry.

c. The suit can be inflated via an inlet valve which is connected to the diver's air supply at the low pressure fitting on his regulator. Air inside the suit can be exhausted by a second valve and by manipulating these two valves, a properly weighted diver can maintain complete buoyancy control at any depth.

d. This dry suit provides superior thermal protection to the diver while in the water and out of the water. As he is dry and the suit acts as a nearly perfect windbreaker, the diver in this suit is much more comfortable while on the surface than he would be in any other type exposure suit.

e. The variable volume dry suit should not be subjected to ambient outside temperatures below 32°F before a dive. Such exposure can result in super cooling of the inlet and exhaust valves causing icing upon immersion in the seawater. This icing will make the valves inoperable until they have warmed to the ambient seawater temperature and the ice melts. If it is necessary to expose the suit to extreme temperatures prior to diving, do so only after lubricating the valves with silicone. Try to rewarm the valves before entering the water. Icing of the inlet valve in the open position underwater can be caused by using long bursts of expanding air instead of several short bursts to inflate the suit. When the inlet valve freezes in the open position, the diver faces the danger of suit over-inflation and loss of buoyancy control.

f. If over-inflation surpasses the exhaust valve's capability to let air out, the diver can hold up one arm allowing excess air to escape under the suit wrist seal into the mitten. The fist must be tightly balled, grasping the palm of the mitten so that the air from the suit can escape under the mitten wrist seal without pulling the mitten off the hand (Figure 3-3). This is not easy to do; therefore, a little practice with the suit in other, less hostile waters should be performed.

g. The amount and type of long thermal underwear worn with the dry suit will vary with the mission and individual preference. The suit comes with excellent underwear and additional garments, especially socks, are often worn under it. A one-piece wool "union suit" with socks worn under the standard dry suit underwear has proven to be very effective. Two much underwear, however, will be exceedingly bulky and also can cause the diver to overheat before entering the water with the eventual formation of perspiration.

h. The variable volume dry suit is the most satisfactory form of thermal protection available to divers in polar waters. They do, however, have certain limitations. These include:

1. Horizontal swims are fatiguing due to the suit bulk.

2. Air can migrate into the foot area if the diver is horizontal or head down causing over-inflation, loss of fins, and loss of buoyancy control.

3. Inlet and exaust valves can malfunction.

4. A parting seam or zipper could result in sudden and drastic loss of buoyancy as well as thermal shock.

5. Extra lead weights are required to achieve neutral buoyancy.

i. Any diver planning to use a variable volume dry suit in polar waters should be thoroughly familiar with the functioning of the suit and the manufacturer's operational literature. Every diver should have experience using the suit prior to going to the Arctic. In addition to gaining experience using the suit, a thorough checkout should be given in the proper method of donning and doffing, and suit care and maintenance. This should all be done before going north.

j. The following spare parts and repair items are suggested for routine maintenance of the variable volume dry suit:

1. Sharp, heavy duty scissors for cutting neoprene.

2. Needle and thread for seam repairs (15-lb test nylon fishing line works well).

3. Neoprene rubber cement.

4. Extra neoprene material for cuff, face seal, and suit repair.

5. Spare exhaust and inlet valves.

6. Spare low pressure inflator hoses.

7. Large supplies of assorted 'O' rings, silicone spray, and zipper wax.

In addition to the above, extra mittens, underwear, and swim fins should be available.

3-5. Wet Suit (Noncompressible)

a. The noncompressible diving suit is designed to maintain diver comfort in water down to 28°F at any depth without impairing mobility. The suit's basic insulation consists of a layer of hollow glass microspheres suspended in a mineral oil base, sandwiched between two layers of foamed neoprene (Figure 3-4). The thickness of each layer varies with the suit manufacturer, but the total thickness averages less than 1/2-inch.

b. The low compressibility of this insulation, only 3 percent at 1000 feet, allows the suit to retain its surface flexibility and thermal characteristics at depth. Because the material is only negligibly compressed with an increase in

(Text Continued on Page 34)

FIGURE 3-2. DRY EXPOSURE SUIT

FIGURE 3-3. DIVER LEAKING AIR FROM SUIT AT CUFF

depth, the diver will not be burdened with a change in suit buoyancy.

c. The noncompressible suit has been successfully tested under extreme conditions including dives in the Arctic to 130 feet in 29°F water, and in Lake Michigan to 246 feet in 39°F water. Numerous other evaluation dives in cold water have taken place in the field and in Laboratory test tanks.

b. The thermal insulation of the noncompressible suit is far superior at depth to a standard wet suit of the same design and thickness. However, in shallow water where the compression of the standard suit's neoprene material is negligible, the noncompressible suit has no advantage.

e. Disadvantages of the noncompressible suit include:

1. Expensive (still experimental).
2. Difficult to tailor.
3. Easily torn.
4. Heavy (about twice that of comparable standard wet suit).
5. Delay in obtaining from supplier.
6. Less flexible and more difficult to don and doff.

3-6. Heated Suits

The only heated suits in use today require surface support that is unacceptable for normal polar water scuba diving operations. There are numberous reports, manuals, and papers available which describe such heating systems and suits in detail.

SECTION II. REGULATORS

3-7. General

a. The choice between single and two-hose regulators for polar diving is difficult. The single hose has superior breathing characteristics, is easier for "buddy breathing" and is less bulky; it does, however, have a greater tendency to malfunction from freezing than does the two-hose regulator.

3-8. Regulator Malfunctions (Freeze-Up)

a. It has been determined that freeze-up may occur in one or two ways, each of which may rapidly cause regulator failure: adiabatic

FIGURE 3-4. NON-COMPRESSIBLE WET SUIT

expansion of high pressure gas, and breathing "wet" air from the regulator. Freeze-up from wet air is not dependent upon whether the regulator is one-hose or two-hose, but upon the dew point of the air delivered to the regulator.

b. Freeze-up of the first stage stems from the adiabatic expansion of the high pressure gas. The resultant subfreezing temperature causes ice to form around the first stage housing (Figure 3-5). The water surrounding the pressure-reducing spring also freezes. As ice forms about the spring, friction and jamming of the spring occurs, jamming the valve open and resulting in an increased intermediate gas pressure. When the intermediate pressure increases, the second stage valve pin lifts off its seat and a free-flow results. As this freeze-up is caused by gas expansion and cooling, the first stage will freeze open sooner at higher gas supply pressures than at lower pressures.

c. The free-flowing gas causes further freezing of the first stage, plus freezing of the demand mechanism in the second stage to a point where the only gas available for the diver to breathe is that which is free-flowing past his mouth. Exhaling into this stream of gas becomes steadily more difficult (to the point of causing dizziness). Freeze-up of water around the first stage spring can be eliminated by covering the ambient chamber surrounding the spring with a flexible rubber cap filled with an antifreeze liquid such as glycol or 100 proof alcohol. Antifreeze itself deteriorates rubber and if oil is used it must be miscible with water or droplets of water will form and freeze. This liquid is subject to ambient pressure as it is only separated from the surrounding water by the cap. The antifreeze liquid should be checked after each dive for leaks and replaced as required.

d. Even with the first stage modification described, if the second stage is purged or allowed to free-flow, the demand mechanism will freeze without prior first stage freeze-up. In this situation, freezing of the second stage is caused by moisture from the diver's exhaled breath, plus water in the chamber which forms ice around the demand lever.

e. The diver must also take care that moisture does not get into the second stage of the single-hose regulator and freeze the demand mechanism before he enters the water or between dives. Special care must be taken to completely dry all residual moisture after post-dive rinsing. This type freeze-up results in no air getting to the diver, but it can be remedied by pouring warm water over the unit to free it of

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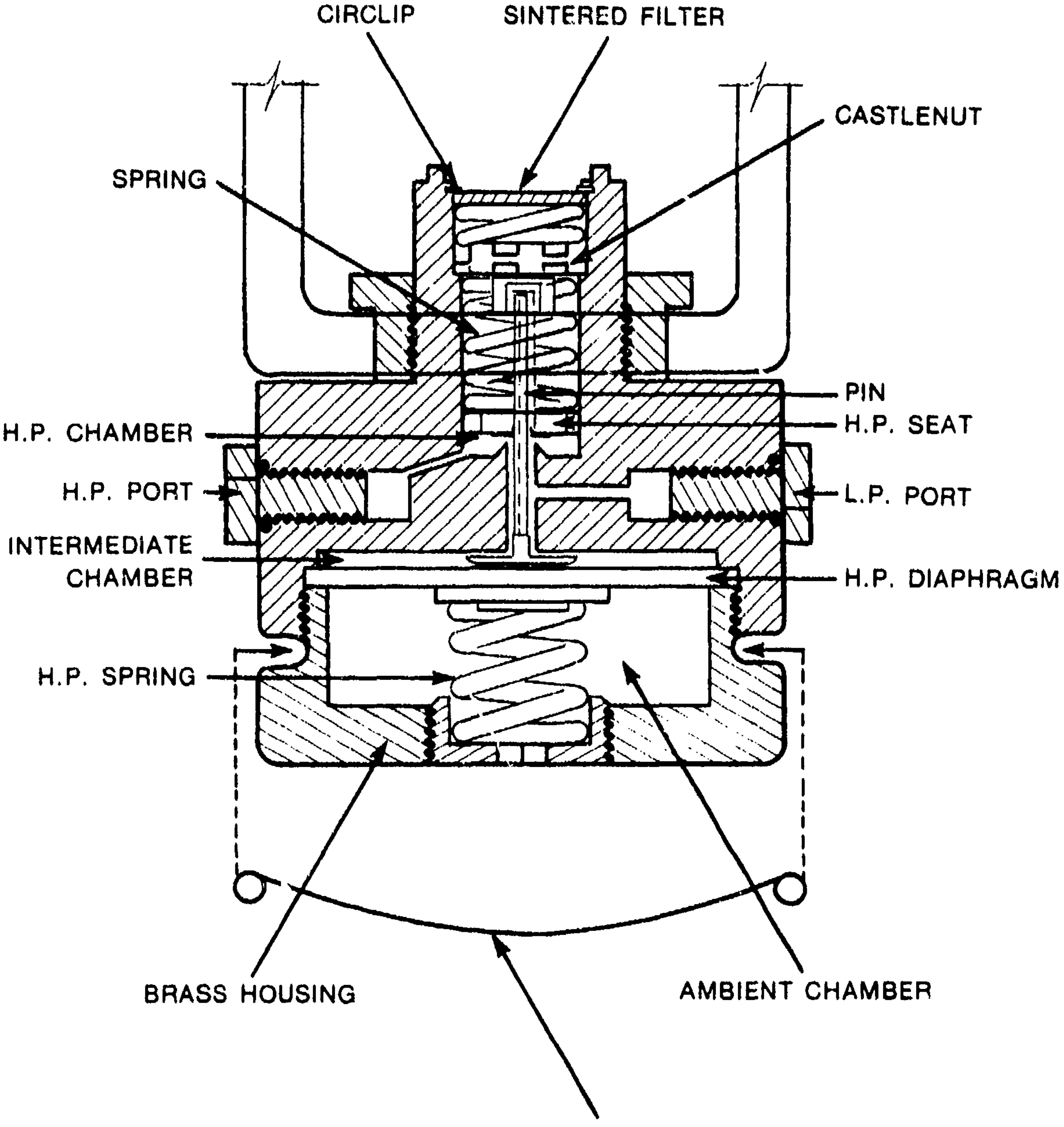

FIGURE 3-5. SCHEMATIC OF SINGLE HOSE REGULATOR

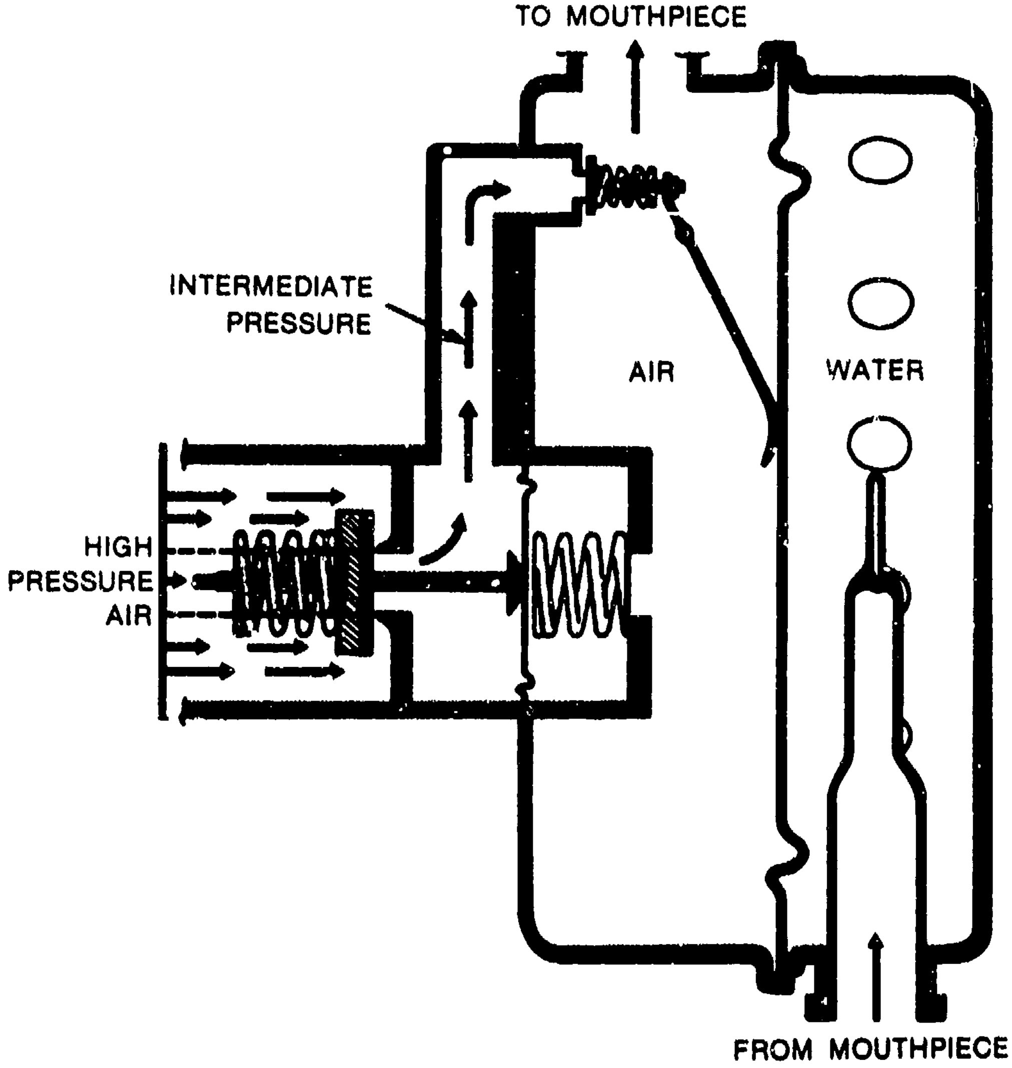

FIGURE 3-6. SCHEMATIC OF DOUBLE HOSE REGULATOR

the ice.

f. It has been shown that breathing from a single-hose regulator in 32°F water will not cause freeze-up, but that free-flowing or purging for longer that 5 seconds will cause cooling in the second stage which may result in freezing. A test of this situation[3] with a full free-flow through the second stage, caused a 5.4°F temperature drop in the second stage. This Δt occurred within 30 seconds and then remained constant. Therefore, we can estimate that in temperatures below 37.4°F (32 + 5.4), freezing of the second stage can occur in fresh water. The salt water equivalent would be 34.2°F (28.8 + 5.4). Hence, a conservative estimate of minimum ambient water temperature at which freeze-up would not occur is 38°F. This would cover operations in both fresh and salt water with a minimum safety factor.

3-9. Precautionary Procedures

a. Due to the serious nature of the freeze-up problems in single-hose regulators, considerable caution should be exercised when they are used in water temperatures below 38°F. A reliable source of dry air should be used to eliminate any trouble from breathing wet air. The regulator should be broken down and all parts sprayed with a nontoxic silicone to help minimize free flow. Any excess should be cleaned

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[3] Fullerton, D J , *Evaluation of Single Hose Regulators*. Defense and Civil Institute of Environmental Medicine, Downsview, Ontario, Canada, January 1973

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FIGURE 3-7. DIVER WITH TWIN TANK ASSEMBLY

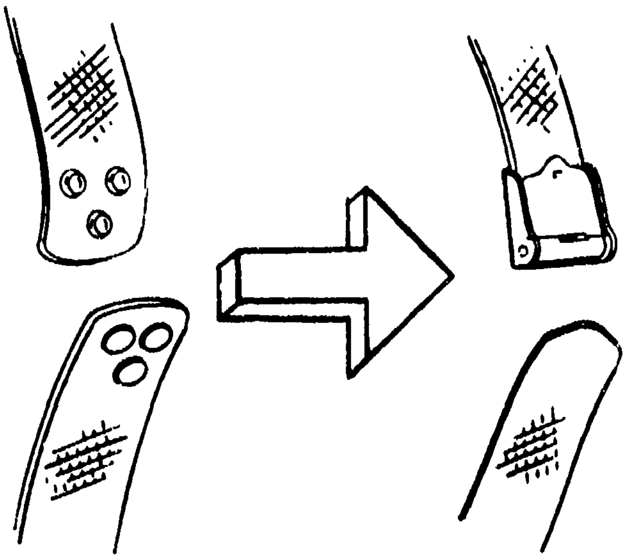

FIGURE 3-8. REPLACE SNAP FITTINGS ON SHOULDER HARNESS WITH BUCKLE

off before reassembly. A quicker but less thorough method of silicone lubrication is accomplished by removing the dust cap from the first stage air inlet and spraying silicone into the filter screen. Drawing air through the first stage mouthpiece will work the silicone into all parts of the regulator. It will draw hard, but this usually needs to be done only once and the regulator will be properly lubricated for the duration of the operation.

b. Single-hose regulators are suitable for cold water use only if an antifreeze bath surrounds the first stage adjusting spring, and purging or free-flowing of the second stage is limited by the diver to less than 5 seconds.

3-10. Two-Hose Regulators

a. The high pressure reduction mechanism of the two-hose regulator is protected from contact with water by the metal body so ice cannot form around the pressure reducing spring (Figure 3-6). Two-hose regulators can and do malfunction when used in polar waters however, and all normal safety precautions must be taken. Moisture from the diver's breath can freeze on the regulator housing and, if it becomes thick enough, can prevent the diaphragm from operating properly. Extremely cold air can also stiffen the diaphragm somewhat which will reduce the regulator efficiency. A loose retainer nut on the regulator will allow moisture inside the housing where it can freeze and cut air off completely. This nut can be inadvertently loosened if the regulator is positioned on the tank valve after the air has been turned on.

b. Other common sources of moisture which can cause the two-hose regulator to malfunction are snow inside the dust cap or on the tank valve, using air tanks that have been used for inflating objects underwater from a bare valve and bled till empty, careless rinsing under a tap allowing water to seep past the one-way valve in the mouthpiece, oversized breathing hoses which prevent adequate sealing, and allowing the regulator to free-flow under water.

c. In general two-hose regulators are satisfactory for use in polar waters and will be more reliable than the single-hose. There are, however, other considerations which should be considered before final selection such as general maintenance, replacement parts, number of pressure ports, and durability.

SECTION III. DIVER SUPPORT

3-11.

In polar waters, the diver requires a wide variety of support equipment. This equipment must be carefully evaluated as to need and suitability for each particular polar diving operation.

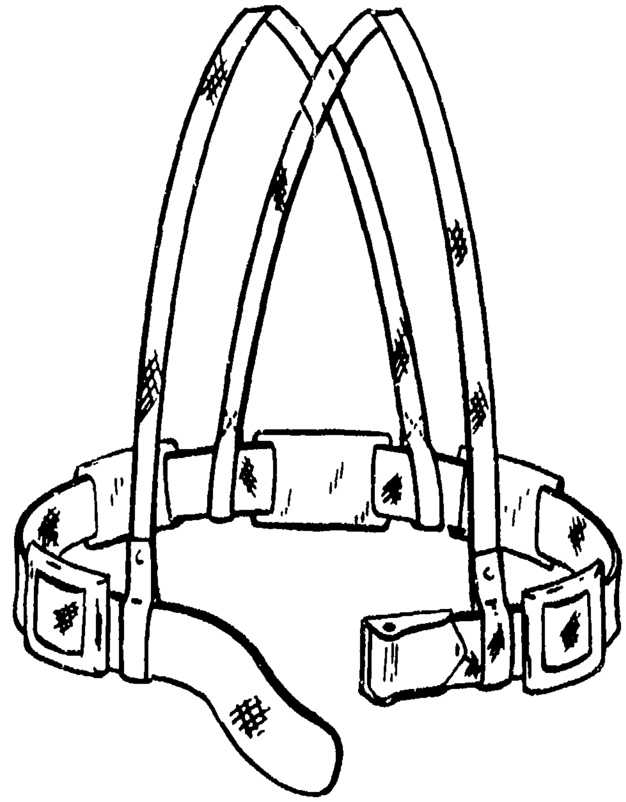

FIGURE 3-9. WEIGHT BELT WITH
SHOULDER SUPPORT STRAPS ATTACHED

3-12. Breathing Apparatus (Self-Contained)

The most frequently used breathing supply system for polar diving is the standard air bottle. Two separate bottles, mounted side-by-side in a back pack with two regulators, offer a very satisfactory and safe system (Figure 3-7). Usually the more dependable two-hose regulator is used as the primary regulator and the single-hose is used as a backup and for purging the dry suit. If a reserve is used, it should be fitted with a pull rod having a large enough ring to accommodate a gloved thumb. The ring on the bottom of the pull rod should be closed to reduce the chance of it snagging on lines while underwater. The backup regulator should be worn so it is readily available to the diver and so it does not drag on the bottom while not in use.

3-13. Back Packs

Contour packs that flare at the waist should be avoided as they are bulky, break easily, interfere with the required bulky weight belt, and are difficult to transport and stack. The smaller, low-profile packs work better even though they may be a little more cumbersome to adjust and put on. For long term diving programs, all snaps in the left shoulder harness should be removed and replaced with a buckle arrangement. Only rugged heavy duty buckles should be used (Figure 3-8).

3-14. Face Masks (Standard)

Individual diver preference and mission requirements are the only guide to the type face mask used.

3-15. Full Face Masks

These masks provide better thermal protection to the face as well as a superior mount for communication equipment. The danger of regulator malfunctions, less buddy-breathing capability, and loss of air supply with mask flooding somewhat offset their advantages. Use of a full face mask will depend on mission requirements and diver preference.

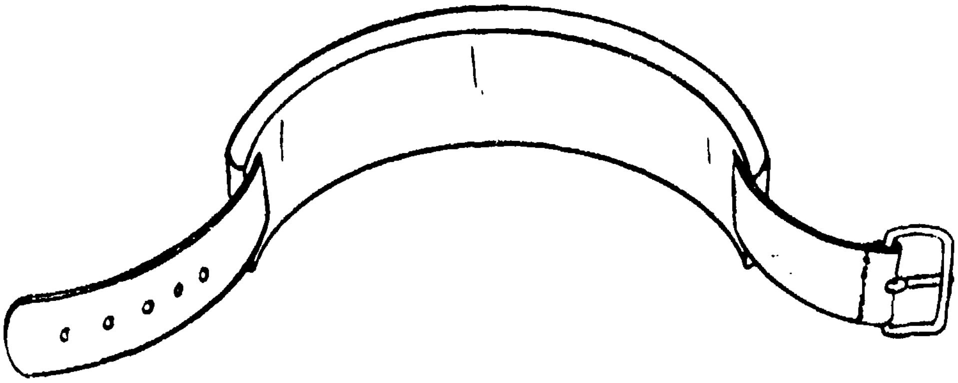

FIGURE 3-10. ANKLE WEIGHTS

3-16. Weight Belt

Arctic diving will require more weight than normal to compensate for the exposure suits, either dry or wet. When the surface is covered by thick ice which the diver cannot break, the weight belt should be secure with no possibility of accidentally coming loose, resulting in a diver being buoyed up against the ceiling of ice. Weight belts will normally be secured and removed by topside support personnel. The larger "hip hugger" weights are best. A quick release is required to allow emergency release in case of a flooded dry suit or as an aid to surface personnel in removing an injured diver from the entry hole. A shoulder harness similar to firemen's suspenders is the best method of preventing the heavy belt from slipping down during a dive (Figure 3-9). This makes for a more comfortable dive and since the straps use Velcro fasteners which can be quickly released, they present no additional hazard. Elastic or stretchable belts are often helpful in compensating for the contraction of the exposure suit on deep dives. Weight vests can easily be constructed with Velcro flapped covers over open-bottom pockets. This enables easy ditching of weights and is not very bulky. Small ankle weights can be strapped on above the fins to assist in overcoming the positive buoyancy of the lower legs (Figure 3-10).

3-17. Ladder

If a ladder is necessary, it should consist of a center bar with steps protruding from either side. This will enable the divers to climb it with large fins on. Frequently, the diver will be using the ladder with numb hands and feet, making it especially difficult for him to get out of the water, often requiring him to pull himself up by his forearms. The ladder should be so placed in the entry hole that it is held away from the side 10 to 12 inches. This will allow enough room for the diver's finned foot, plus prevent the ladder from freezing into the wall of the hole and becoming useless.

3-18. Steps

Usually, a ladder will not be worth the room it takes in the entry hole. A diver can normally get himself out of the water with a little assistance from the tenders; this can be accomplished easier with the help of two small ledges cut into the front and back of the hole (Figure 3-11). The front ledge should be 6 inches wide and 1-1/2 feet below the water line to provide a kneeling platform for the diver which will place him out of the water from the waist up. While in this position his equipment can easily be removed after which he can get all the way out of the water. The second ledge should be a small toe hold on the back side of the hole located about 2 feet deep and cut into the ice some 2 to 3 inches. Most divers will be able to come completely out of the water with all their equipment on by a combination of using the ledges and pulling on the surface tender. The final system used is up to each diver. Never drag a diver out of the water; this will destroy equipment, especially the valves on variable volume dry suits.

3-19. Stage

For some missions requiring the use of support equipment such as cameras, tools, or lights, a small stage or "container" hanging below the surface at the entrance will be helpful. With this, tools, etc., can be set aside by the divers until needed again without sending them

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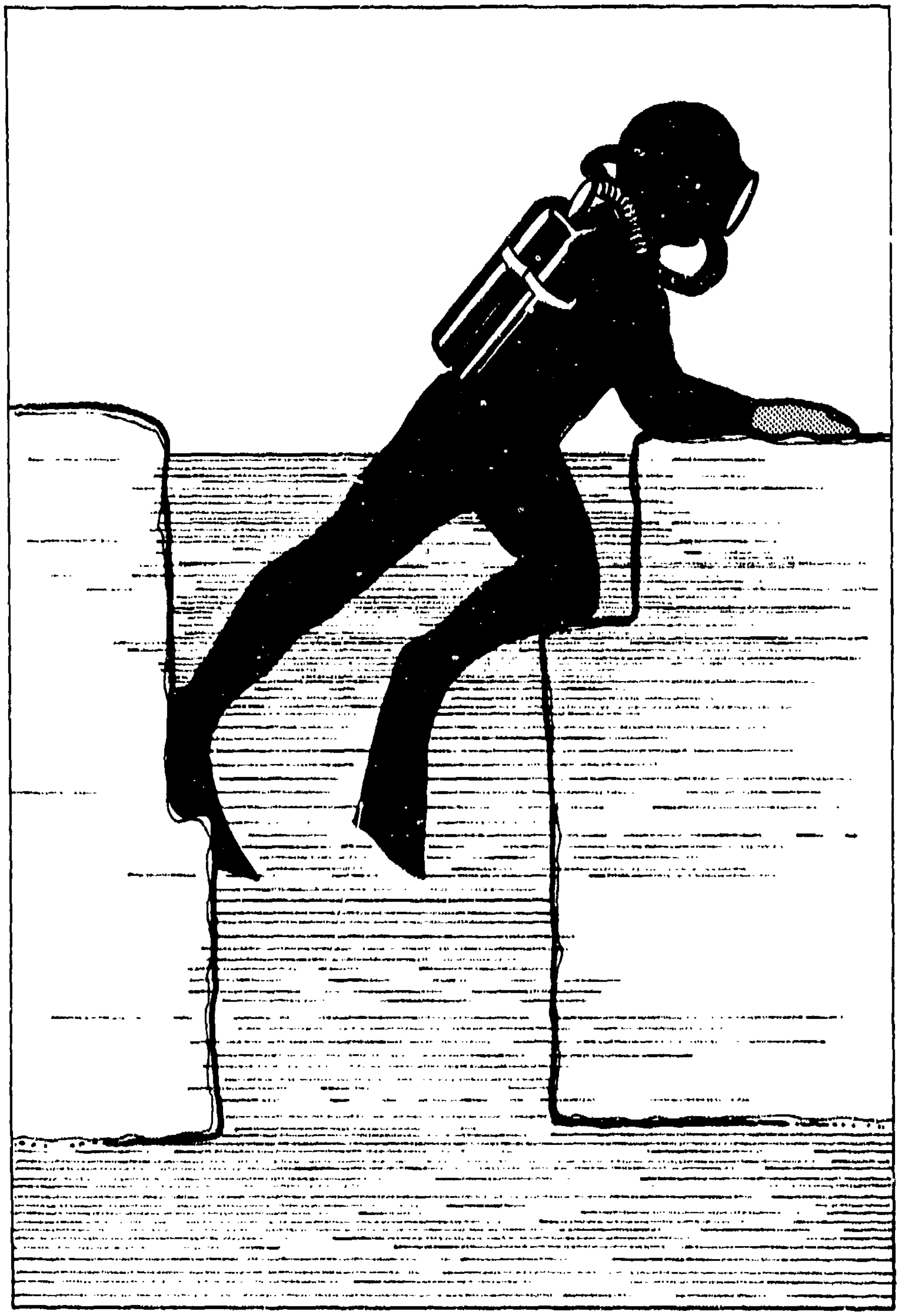

FIGURE 3-11. LEDGES CUT INTO SIDES OF ACCESS HOLE

up to the surface. This reduces the problems such as temperature change, possible damage or loss, and the extra effort encountered when equipment is transferred into and out of the water. The stage configuration can vary, but some possibilities include hanging a negatively buoyant stage well below the diver's entry hole; having a seperate hole near the diver's entry hole for the stage; or having a positively buoyant stage placed under the ice near the entry hole. The approach can vary with the mission and the diving team's ingenuity.

3-20. Cables

Small buoys can be tied off at intervals on power cables to make them neutrally buoyant. These buoys must be tied to the cable in such a way that snagging on the ice cover is avoided. Buoys tied off on short lines will often snag on the under ice surface as the diver pulls the cable behind him. Never pull a cable along the bottom because it snags equipment and obstacles, stirs up mud, and rapidly fatigues the diver.

3-21. Tending Line

A tending line or tether to the diver is often required for under ice diving. A neutrally buoyant, yellow, orange, or white polypropylene line serves well. Mountaineering line (3/8") makes an excellent tending line being strong, yet light and easy to handle. The diver's end should be tied to the diver, NOT to his equipment. The tender's end of the line should be tied to some solid object behind the tender. The tending line serves as a means of communication between diver and surface, a guide back to the entry hole for the diver, and as a means of recovering an injured or unconscious diver.

3-22. Fins

Fins, like face masks, are pretty much an individual diver preference. There are, however, certain additional considerations for polar operations which must be given special attention. Because of the bulk of the exposure suit boots, especially the dry suits, fins will by necessity have to be very large shoe size. For best results, the diver should have a pair of fins which fit snugly enough to eliminate the danger of accidental loss, yet not so snugly as to constrict circulation; this causes rapid chilling of the feet. Loose fins can be held on by restrainers; however, care must be taken that the restrainers do not restrict circulation of the feet. Two straps on each fin, with one end of each buckled at the fin, crossed behind the ankle and snapped together in front, make a secure and comfortable fin restainer.

3-23. Safety Vest

The use of a safety vest is not recommended for diving under the ice. The diver has no need to do a buoyant ascent when ice is overhead. Accidental inflation of a vest could hold a diver up against the ice where he might have difficulty moving to the entrance hole. It is much easier to haul a distressed diver up from the bottom than along horizontally under bumpy ice. These vests should only be used when the surface is free from ice, or covered with slush or thin ice which can be broken by the diver.

3-24. Buoyancy Compensator

A buoyancy compensator may be desired to assist in the performance of certain underwater projects. There are, no doubt, tasks that the polar diver will be called on to perform where such a device would be of assistance. It should be remembered, however, that they are a bulky, cumbersome addition to the already overburdened diver. They were not designed to use with mittened hands nor in waters where any valve releasing air is subject to freezing. They are definitely not recommended for use while wearing the variable volume dry suit as they interfere with the safe operation of the suit valves. The variable volume suit can often serve the same purpose as such a compensator. For dives with a wet suit, a buoyancy compensator is a good system to maintain neutral buoyancy.

3-25. Underwater Loudspeaker

a. A portable underwater communication set with a speaker hanging in the water works well for diver instruction and recall. Divers can hear topside instructions clearly, which reduces the time wasted returning to the surface for communicating. A speaker can be lowered directly into the water at the dive site and suspended at a depth of 8 to 10 feet. With this, the diving supervisor has the capability of speaking directly to his divers to:

1. Give verbal instructions.
2. Provide them with status reports on time in water, changes in plans, new divers, etc.
3. Inform divers of any emergency situations.
4. Recall divers to the surface.

3-26. Underwater Tools

a. Divers have used handtools for years with fairly good results; however, experience with powered tools, especially in cold weather, is limited. Some of the problems to be considered in the use of pneumatic and hydraulic tool systems in the polar environment are:

1. A sheltered surface support platform must be provided for equipment and working area.
2. Fresh water must be provided to clean pneumatic tools after use. Most hydraulic tools can usually be sprayed with WD-40 or equivalent and won't require daily fresh water flushing.
3. Dry air must be available for pneumatic tools to minimize freeze-up. A diving air compressor or an industrial compressor with a water coalescer can be used. The coalescer must be protected to prevent the water it collects from freezing.
4. A large supply of spare O-rings for hydraulic line quick disconnect couplings will be used.
5. An oil immersion heater may be required to reduce hydraulic fluid viscosity. As a last resort, hydraulic oil can be thinned with up to about 15 percent kerosene.
6. Special oils, greases, and lubricants will probably be required. These should be ordered as soon as possible because of the long delivery time. Adequate supplies should be procured in case of extra requirements once on the dive site.
7. All appropriate manuals should be available with the tools and only adequately trained personnel allowed to operate the equipment.

b. Many problems can be expected with powered tools in polar diving operations. With proper planning and operational techniques, these problems should be minimized.

3-27. Air Compressor

a. Compressed air for the diving bottles requires the use of a large capacity compressor, preferably electric using base power. These compressors should be placed in a dry, heated shelter with the intake line extended to the outside atmosphere. All compressers used in polar diving operations should have the standard aluminum and activated charcoal filters, plus a very efficient oil moisture separator. Extra filters or moisture separator can be added if deemed necessary. This dry, cold air supply reduces the possibility of water accumulation through condensation and the resultant freezing at the regulator's high pressure stage during diving operations. Whenever possible, the compressor should be purged with dry nitrogen before use. A carbon monoxide monitor should be available and periodic readings made in any compressor area.

b. When it is necessary to operate a compressor outside, a number of precautions should be taken:

1. Wind direction must be monitored and the air intake tube maintained in an upwind position.
2. Clean, well filtered fuel should be used to prevent fuel line freeze-up.
3. Only cold weather oil should be used.
4. Protect the air intake from any blowing snow or other source of moisture.
5. A simple wind break can be constructed of snow blocks or wood.
6. A wooden box, possibly the compressor crate itself, can be positioned over the compressor so that the exhaust gases are captured and maintained in the compressor vicinity reducing the effect of the cold temperature. This system was used for outdoor operation in temperatures down to minus 40°F with winds up to 40 knots.

3-28. Underwater Lights

a. Diving operations in the polar environment will often require some source of artificial light. Divers carry hand lights for underwater observations and as an aid in locating and signaling other divers. Depending on the mission and operational area, these lights can range from a simple hand-carried, self-contained unit to large lamps requiring a topside power source and cables. For normal operations, small, self-contained units, either hand-carried or mounted on the wrist with the battery power supply mounted on the diver or his diving tanks, will be sufficient. This latter method frees his hands for other work and does not require him to grip the light, which causes undue cooling in the hand. Mounting lights on a board with a handle can make them easier to handle and maneuver as well as reduce the cold effect on the hand.

b. All self-contained lights should have rechargeable batteries and be maintained in a charged and relatively warm state prior to diving. When working up against the ice, hand-carried lights should be buoyed so as to be slightly positive. This not only reduces the chance of losing them if released, but also enables the diver to "rest" the light against the ice overhead, thereby freeing his hands for additional work. The lights sould be slightly negative if working on the bottom so they can be positioned where desired and will not float away. The moderately heavy, cable-powered lights can be modified to slightly positive buoyancy in several different ways. The method will depend on individual preference. When directing a light at another diver, NEVER aim it for his face as this will temporarily ruin his dark adaptation. By directing the light at his chest area, disturbance to diver's visual acuity and dark adaptation will be minimized.

3-29. Mixed Gas Scuba

a. When mixed gas breathing apparatus is to be used in polar waters, the reduction in CO absorbent efficiency must be considered. Estimates of reduced efficiency range up to a 90 percent reduction from that obtained in 70°F water. Test results conducted on soda lime and Baralyme at 70°F and 35°F are shown in Table 3-1.

3-30. Batteries

a. General. The output of storage batteries decreases as the temperature decreases. If they freeze, the expanded solution will crack the battery cases; therefore, they should be operated and stored in an insulated cover and should be warm before taken outdoors to use in subzero temperatures. A battery with a low charge should be exceptionally well protected from the cold because the acid content of the electrolyte is lower and the solutions freeze at a higher temperature. Batteries used at low temperatures should be maintained at full charge and should never have water added when dilution of the battery solution will lower its charge. Use of a concentrated electrolyte is recommended, but if it is not available, the addition of ethylene glycol antifreeze solution in the amount of at least one-half of the liquid capacity of the battery will help to prevent freezing.

b. Performance. The following list is a brief summation of various battery types and their cold weather characteristics.

Table 3-1[1]

RELATIVE ABSORBENT CAPABILITIES

Absorbent	Temperature (°F)	Expected Relative Life On a Volume Basis
Baralyme	35	1.0
	70	2.06
Sodasorb	35	1.83
	70	2.36

b. From this table it can be seen that a volume of Baralyme will last more than twice as long at 70°F as it will at 35°F. In addition, an equivalent volume of sodasorb will last nearly twice as long at 35°F as Baralyme (1.83 to 1.0). The improvement of sodasorb at 70°F is not relatively as great as the improvement of Baralyme: however, sodasorb appears to be a superior absorbent at all temperatures and the best absorbent for use in polar diving operations.

NOTE: With mixed-gas scuba apparatus, the numbing of the lips can cause leakage of water past the mouthpiece and into the breathing bag. This water can get into the CO canister causing a further reduction in the efficiency of the absorbent.

1. Dry cell batteries used for cold weather operation should be of a high energy type. As the temperature of a battery falls, its amperage output is reduced. At -40°F, a good flashlight battery is inoperative.
2. Lightweight, high energy, wet cells operate well at -20°F to -30°F and can be clustered to supply necessary operating power to cameras and flash guns.
3. Wet cell (storage) batteries are dependable for cold weather operation when they are specially serviced and protected. However, they are too heavy to use for providing power or light for a free diver, but can be used as a topside power supply to hand-carried lights.
4. At -10°F, the carbon-zinc battery is usually inoperative unless special low temperature electrolytes are used. Since a battery does not reach ambient temperature immediately, insulation is helpful.
5. Alkaline-manganese primary batteries are good at low temperatures.
6. Nickel-cadmium cells experience a relatively small change of output capacity over

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[1] Smith, J G , Dr *Comparison of Sodasorb and Baralyme Performance for The Experimental Diving Unit* U S Navy July 15, 1974

a wide range of operating temperature.

7. In general, Mercury batteries have not performed well at low temperatures; however, recent developments have produced several popular cell sizes which operate well at low temperatures.

8. There are wet cells designed to operate at -100°F, such as the Yardney battery.

c. Power Cable. Most conventional power cables are unsuitable for use in temperatures below -20°F because of the extreme brittleness of the synthetic rubber insulation. A low voltage, natural rubber insulated cable especially manufactured for low temperature use should be substituted for any standard cables.

3-31. Miscellaneous Accessories

Some of the support equipment used by divers will not be affected by the polar water environment; therefore, no special precautions are required for their use. Watches, knives, depth gauges, and other similar items can be selected on the basis of individual preference.

CHAPTER 4

OPERATIONAL

SECTION I. DIVE PLAN

4-1. Purpose of Plan

Planning is vital for the success of any diving operation whether in tropical or polar waters. The diver must be provided every advantage to enable him to perform his mission efficiently. Diving in polar waters involves several critical aspects which must be considered in the overall dive plan. Many of these apply equally to diving operations in other areas while some are applicable solely to the polar regions.

a. Diving Supervisor. The dive plan is prepared by the diving supervisor who coordinates all activity. His primary responsibility is to inform the divers of their mission assignments, see that a log is kept, record work progress as received from the divers, and note any difficulties the divers may have. He will usually have one or more assistants he can use during periods of peak activity.

b. Pre-Deployment Briefing. Prior to deployment of a diving operation to polar regions, a detailed overall briefing should be given to all personnel. This will prevent unnecessary misconception about job scope, duration, and possible hazards.

c. Pre-Dive Briefing. A short briefing should be given immediately before each dive to explain the work planned; how the task will be accomplished; tools required; dive duration; alternate task, if any; and the lead diver.

d. Dive Plan Review. The overall dive plan should be reviewed following each day's diving activities. This helps to resolve problem areas and plan the next day's schedule.

e. Number of Divers. More than four divers scheduled for a dive at one time produces an unweidly situation. Usually, the surface stations are not roomy enough to support a larger group, and the number of surface support personnel will be limited. Dressing a large number of divers in a small space, helping them into the water, tending them, then recovering and helping them with their equipment requires space and support personnel (Figure 4-1). To avoid a lot of confusion and trouble, no more than four divers should operate from a single dive station. One team of divers can be suiting up while another is in the water to obtain the maximum number of man/dives with minimum congestion.

f. Safety Diver. Keeping a standby diver dressed and warm presents problems and tires an additional man. The diving supervisor may decide that the task being performed is such that the difficulties or supporting a standby diver is worth the effort. Considerable experience in Arctic diving operations has shown that the surface tender and buddy diver combination are adequate and a safety diver is usually not required.

g. Dressing Divers. The dressing area for divers should provide protection from the weather and adequate room for at least two people to use at one time. Facilities should be provided for hanging outside clothing (parka, boots, etc.) off the floor and also for hanging exposure suits and accessories between dives. If a permanent structure is used for the dressing area, it should have head facilities, a source of fresh water, a telephone, heating, and flooring which can be routinely soaked without damage.

h. Transporting Divers. Occasionally one site will double as both the dressing area and the diving area, eliminating any requirements for diver transport. Such is the case for ship-supported and remote site operations. Usually, however, it will be required to transport the divers from the dressing area to the diving site. How this is done will depend on distance, weather, site accessibility, and vehicle availability. The primary objective is to get the divers back and forth as quickly as possible with a minimum of exposure. Divers working from small craft should wear a large parka or windbreaker over their exposure suit while being transported or waiting to dive. Often the mittens of the dry suits will offer adequate protection while being transported back to the dressing area, but if dry mitts are worn, excess water should be squeezed out of the suit arms

FIGURE 4-1. TENDER ASSISTING DIVER INSIDE TENT

first or it will drain into the mittens and soak them.

i. Time Limits and Decompression. A maximum time limit should be established for any underwater mission to prevent excessive discomfort from exposure. This limit will vary on the mission and type suits worn, but, in general, exposure times much in excess of 1 hour prove to be uncomfortable, not only to the diver, but to the tender as well. There will be many missions when the limits will be set not by exposure but rather by depth and decompression limits. Decompression dives should be scheduled on an emergency basis only. Any suit or regulator failure can force the diver to abort the dive regardless of decompression requirements and treatment chambers are scarce in the Arctic.

j. Temperature. When planning for a dive, it must be remembered that diver performance on nearly all underwater tasks will decrease as water temperature decreases, often without the diver being aware of it. Cold water is a major limiting factor on diver performance, comfort, safety, and motivation. Considerable thought should be given to the temperature in which the divers will be operating, the thermal protection required, and the complexity of the tasks to be accomplished before sending divers on their missions.

The stress and fatigue from cold is a major cause of physiological depletion. Regardless of the original dive plan, the diver should immediately surface and terminate his dive when:

1. He feels chilled.
2. He is recalled by surface personnel.
3. Any of his equipment malfunctions.
4. His buddy diver surfaces.
5. He feels overly fatigued, sluggish, or detects cramps.
6. He suffers any injury, no matter how minor it may seem to him.
7. He notes any unexpected change in local dive conditions such as increasing current or decreasing visibility.

k. Suit Flushing. Underwater, the diver should avoid flushing; i.e., the movement of water between his exposure suit and skin. Immobility, the only way to completely prevent flushing, accelerates chilling while movement produces body heat but can cause flushing. Therefore, the diver must seek the proper balance between immobility and excessive movement to achieve maximum efficiency. Flushing is not only a major consideration when wearing a wet suit, but can severely affect the hands while wearing the dry suit.

4-2. General Rules

a. The diver should have a protected area for dressing and undressing and should avoid excessive exposure while out of the water.

b. Divers who are suited-up should not delay too long before entering the water. The combination of a heated hut, warm exposure suit, and exertion can cause the diver to perspire before entering the water which will greatly reduce the thermal protection of the garment. While waiting, the divers should attempt to keep their feet off the ice or the cold floor of the hut; even with insulation, the temperature at the hut floor level will be close to freezing.

c. Time on the surface in cold temperatures should be minimized to prevent cooling with subsequent icing of metal, such as suit valves and breathing regulators, upon entering the water.

d. A chilled diver should never go in the water.

e. Fins and fin guards must be loose enough to avoid restricting circulation causing rapid cooling and cramps.

f. Mitts must be large enough to provide protection (a too-small mitt restricts circulation causing rapid cooling of the hand), yet small enough to allow some dexterity. A major weakness of all exposure suits today is inadequate hand protection.

g. Never remain in the water after shivering has commenced.

h. Upon surfacing, the diver's mitts should not be removed until his hands can be dried and dry gloves put on. Be careful that water does not drain off the suit down the arms and into the dry gloves. A poncho or parka over the diver's exposure suit will help protect him from chilling after the dive.

i. The diver should be completely rewarmed before he is either sent back in the water or undertakes any topside support activity.

4-3. Diver Rewarming

a. Arctic diving operations will often require a man to dive more than once a day. To begin a second dive without proper rewarming from the previous dive means the diver will become cold more quickly and lose his efficiency sooner. It is difficult to tell when rewarming is complete as people are poor judges of their own thermal state. A person feels comfortable long before his rectal and skin temperatures have returned to normal; however, once a diver gets cold, complete rewarming is vital before he dives again.

b. Methods of rewarming include a hot drink (be careful of numb lips and shaky hands with hot drinks), which will certainly make the diver feel better; a warm shower or bath (preferably), or possibly mild exercise in a heated area. Breathing the warmer air in a heated structure will increase the speed of rewarming, especially if exercise is included. Warm water can be poured under a wet suit to decrease the chill and warm water poured on the hands is extremely satisfying upon initial surfacing. The water should be about 80 to 98°F and never over 108°F.

c. Warming the diver must be done with care and will depend upon his thermal discomfort. In some cases, too much rewarming can be harmful as it might cause excessive drop in core temperature. The local medical representative will have to determine this on an individual case basis (see 5-4.e.).

4-4. Tenders

a. The tender's responsibility will vary from one dive site to another. However, it is basically the same. There should be one tender for each diver during the dressing and undressing

FIGURE 4-2. TENDERS ASSISTING DIVER ON OPEN ICE

phases. They will set up the diver's equipment, help him with his exposure suit, assist him with difficult dressing steps such as the heavy weight belt, and help him during entry and exit at the entry hole (Figure 4-2). When the diver is under, the tender will remain at the site monitoring a tether, clearing equipment, etc., until the diver returns. The polar diver relies heavily on the support of surface personnel.

b. The tender must be attentive not only to the diver, but also to surface conditions (deteriorating weather or moving ice) which could jeopardize the diver.

c. Tender support efficiency is reduced by the bulk and clumsiness of the clothing worn in cold areas. Since it is dangerous to handle extremely cold metal with a bare wet hand, some form of mitten or glove must often be worn by tenders. The resulting loss of the sense of touch further reduces the efficiency of personnel. Even the most routine operations such as turning on a diver's air or assisting him in adjusting his equipment, becomes exasperating and time-consuming when they must be performed with mittened hands.

d. The tender should avoid immobilization in the cold. If the situation permits, he should walk about and exercise periodically to generate and maintain body heat. If unable to walk about, he should shift position frequently, moving especially his toes, feet, legs, fingers, hands, and arms. Isometric exercises increase heat production. When possible, the tender should stand on some insulated material such as wood, cardboard, burlap bags, or other poor conductors rather than wet ground or snow. Sitting while tending is not only a poor practice under any conditions, but particularly so in the Arctic where it can reduce circulation in the feet and accelerate cooling. Tenders that are forced to stand idly in the open rapidly become chilled and lose much of their efficiency (Figure 4-3).

e. Surface tenders should be fully briefed on the tasks of the diver in order to understand his movements and to enable quick reaction in an emergency. If a tether line is used, it must be closely monitored by the surface tender with the end securely tied off to some stationery object.

FIGURE 4-3. TENDING DIVERS

4-5. Dive Platforms

Diving operations in the Arctic may be conducted from a variety of support platforms including: (1) open beach, (2) small craft, (3) ships, (4) ice floes, (5) ice islands, (6) lockout submersible, and (7) solid ice cover such as fast or pack ice. Operations can sometimes be conducted in open water or through natural leads and openings requiring no special construction of an entry hole. Often, however, it will be necessary to construct a suitable entry hole not only for divers, but for large support equipment as well.

4-6. Entry Hole Preparation

a. When the general location for the entry hole has been chosen, a small test hole should be drilled through the ice with a hand or powered auger (Figure 4-4). The ice thickness and the water depth can be determined using the test hole.

b. After the site is selected for the entry hole, all the snow covering the ice in the immediate vicinity should be cleared away. The cleared area should extend at least 3 to 4 feet beyond the intended hole perimeter to reduce the amount of slush formed around the perimeter. The entry hole should not be cut near the test hole which will refreeze slowly and can prematurely flood the main entry hole if accidentally tapped.

4-7. Tidal Effects

a. When diving through the ice near shore, the tidal range must be considered. In many cases, there is a daily flooding over large surface areas of the ice with the incoming tide. When the water is much warmer than the air, thick patches of fog (sea smoke) are produced. The dive site should not be subject to such daily flooding and the route from the beach to the site should be subject to the minimum flooding possible.

b. Tidal fluctuations can also cause movement of the ice hinges near the beach creating openings which can stall vehicles and present a potential hazard to personnel on foot. (See Figure 2-3).

4-8. Size

The size of the entry hole will depend on several things including what is to be lowered

(Text Continued on Page 53)

FIGURE 4-4. DRILLING A TEST HOLE WITH HAND AUGER

FIGURE 4-5. ICE BLOCKS AROUND ACCESS HOLE

through it other than divers, the difficulty of digging it, whether it is to be in the open or covered by a shelter, the time of year, and the length of time it is to be used. A minimum size would allow three fully dressed divers to be accommodated at one time yet not dominate the space inside a shelter; approximately 3 by 5 feet. Holes for winter diving or for use over a long period should be a little larger initially to compensate for the ice buildup around their perimeter. All holes cut for divers should have vertical walls and, if possible, a step.

4-9. Maintenance

Usually, the entry hole will require some routine chipping to remove new ice forming on the surface and around the perimeter. The amount of chipping and maintenance required will depend on the air temperature as well as how often the hole is used. In very cold conditions, a protective heated cover (tent or hut) will normally be placed over the hole but even this will not stop the formation of ice around the hole perimeter nor the overnight formation of surface ice. Long term diving projects should set up a system to keep the holes as free as possible of ice buildup. Such systems can consist of heating ducts, bubble arrays, or adequate heating and circulation. Brash ice, which accumulates on the surface and reduces the topside support personnel's ability to observe the underwater operation, is best removed with a strong hand net or screen. In exposed holes or in very cold conditions, it can form faster than it can be removed.

4-10. Support Equipment

Where a large amount of support equipment such as cables and lines are required, a second hole should be provided solely for their use. Lines and cables lowered into the diver's entry hole are a source of entanglement. A descending line or ladder, however, should be available beneath the hole for the divers to hang onto while adjusting equipment or waiting.

(Text Continued on Page 55)

FIGURE 4-6. ICE HANDSAW

FIGURE 4-7. POWERED ICE AUGER

4-11. Ice Disposal

The ice removed from the entry hole should be placed in an area where it will not get in the way of surface support operations. Removal to a final dumping site should be performed as soon as possible to prevent the ice from freezing in place on the surface where it is not wanted. Some of the removed ice blocks can be used for wind breaks but this will enhance the buildup of snowdrifts and is usually not worth the trouble. Ice should not be placed in areas where any potential road or snowmobile trail may be needed (Figure 4-5). Large blocks of ice can be removed easily with heavy-duty ice tongs and pulled by either a snowmobile or larger vehicles.

4-12. Cutting the Hole

The method of cutting a hole through the ice will vary from one diving operation to another, the choice depending on several factors including ice thickness and the availability of equipment. Normally, two or more of the tools described will be used for maximum results.

a. Hand Ice Clippers

1. Chipping an entrance hole should be reserved for thin ice or if no other alternative is available. This is not only time-consuming, but very fatiguing. Whether chipping an entire hole or the final perimeter, care should be taken to ensure that the breakthrough to the water is delayed until the last moment; once the breakthrough occurs, the hole fills nearly to the brim and the remaining chipping is made even more difficult. When the hole has filled with water, it is more difficult to guide the chipper; it tends to bind more, less force can be exerted, and the water that gets on the handle will freeze causing extra discomfort.

2. Chippers are handy for periodic clearing new ice formation from an entrance hole. Chippers should have handles of sufficient length so that the personnel using them do not have to stoop over the hole. Wooden handles will not be as cold to hold; however, metal handles will be stronger.

3. Lightweight chippers should be used for hole maintenance only. For heavy duty chipping, they are inefficient requiring the user to physically drive them into the ice causing rapid wrist fatigue. Heavyweight chippers require

FIGURE 4-8. CUTTING OUT MATRIX OF AUGERED HOLES WITH CHAIN SAW

little more than guidance on the downstroke with the physical effort of the user expended lifting them back up; this is less fatiguing over a long period. A triangular, 5 to 10 pound "needle bar" should be used periodically to shatter the ice during chipping. Always remove the wrist watch before commencing to chip ice.

b. Ice Handsaw. A standard ice saw, such as used for years to cut ice cakes commercially on freshwater lakes, can be used if the surface temperature is not too low or the ice not too thick (Figure 4-6). Usually, the ice saw is used to cut the final perimeter of the plug, removing any tiny protrusions missed by the chippers which will hold the plug fast. Care must be taken that the cut of the ice is kept vertical and that the ice does not freeze up again behind the blade. The teeth of the saw must be set so as to produce a wide cut to reduce the chance of any such refreezing.

c. Ice Auger. One of the most commonly used methods for preparing an entrance hole through the ice is the ice auger which can drill a hole through several feet of ice in minutes (Figure 4-7). Bit sizes vary from small, 1 to 2 inches, to over 9 inches. With the use of extensions, they have drilled through 12 feet of ice for "test holes" or placing explosive charges. The auger is normally used in combination with hand chippers and chain saws. Some general rules for operation are:

1. Be certain you have a firm footing before operating the auger.
2. Do not carry the auger or leave it unattended while the enginer is running.
3. Allow sufficient time for engine warm-up.
4. Engage throttle slowly until cutter has entered the hole completely, then the throttle may be opened to maximum.
5. The drill operators should use appropriate footwear and caution to protect themselves from the slush and water pumped up out of the hole.

(Text Continued on Page 58

FIGURE 4-9. CHAIN SAW AND LARGE CHIPPER IN USE

FIGURE 4-10. HOLE BEING CUT IN STEPS

6. Never operate an auger in an enclosed hut or tent; adequate ventilation must always be provided to prevent carbon monoxide poisoning.

7. To eliminate water splash, release the throttle when the hole is cut and raise the drill slowly from the hole. Do not turn the engine off.

8. Protect the auger from ambient temperatures before and after use.

9. Wear ear protection from noise.

10. Guide the auger; do not bear down on it.

11. Two men on the auger will reduce fatigue, make holes more vertical, and reduce the chance of losing control.

12. If ice is thicker than 12 inches, raise drill to clear chips as often as required. This is necessary only if the drill is not equipped with a spiral auger.

13. When drilling thick ice (6 to 20 feet), the throttle should be held on full, especially when approaching the ice-seawater interface. Seepage of seawater through the ice or slush conditions near the interface may promote very rapid freezing of the ice when exposed to low air temperatures. When approaching this interface, the drill may literally "screw" itself into the slush with a sudden rapid downward motion of the drill shaft. At this point, if the throttle is released by the operators (thinking the hole is drilled completely through), rapid freezing may occur with subsequent loss of equipment.

14. For cutting small holes (3 feet by 4 feet), it is sufficient to cut the perimeter with the auger, leaving about 1 inch between holes. After the holes have been cut, the matrix of ice can be chipped away and the center plug removed from the hole or shoved under the surrounding ice.

15. For cutting large holes, a grid pattern of augered holes should be made but none should go all the way through. These holes should be spaced approximately 1 inch apart, which will enable personnel to walk over the pattern. After the last hole has been drilled, the matrix can be removed with chain saws, chippers, and shovels (Figure 4-8). The remaining block can now be removed by chipping around the perimeter until it is cut free. Once free and floating on the surface, the block can be broken up and removed from the hole.

d. Chain Saw. Chain saws are used to make entry holes by cutting the ice into blocks after which they are broken free with a heavy-duty chipper and removed with ice tongs (Figure 4-9). The ice should be cut out and removed in step fashion which provides maximum access with the saw to the lower courses and aids in their removal (Figure 4-10). When properly used, the chain saw is one of the best methods of cutting an access hole through the ice. There are several points in their operation which are noteworthy including:

1. Don't use the saw when exhausted; relieve operator at frequent intervals.
2. Never leave the finger near the trigger when repositioning the saw.
3. Be careful of footing when cutting blocks.
4. Wear ear protectors.
5. Be careful of fumes accumulating in hole.
6. Use good insulated glove with trigger finger. Don't try to use bulky mitts.
7. A large chain saw will require a heavy-duty engine.
8. Don't cut blocks too big as they will be unmanageable.
9. Oil-soak chain at least 24 hours before use.
10. Have several spare blades, tool kit, and spare parts.
11. Never operate saw without oil.
12. Remember the saw will require more oil than if cutting wood as the ice water washes it away. Visually check oily ice/snow for oil coming out.
13. Be careful on final course that the blade does not break through and flood the hole.
14. Cut a shallow crisscross pattern on the top of the plug to help break it up when it floats to the surface.

e. Thermal Ice Cutter. This system uses thermal energy in the form of warm water, delivered to the ice in a controlled manner to cut a groove of the desired shape. A delivery manifold of the desired "cookie cutter" shape delivers the water uniformly along the manifold through a series of loosely spaced, small diameter, downward directed orifices. A suction manifold is mounted directly above the cutting manifold to pick up the mixed melt and deliver water for preheating at the heat source. When penetration is completed, seawater floods the groove and the core is left floating free.

Disposal of the core by pushing it downward through the ice until it tips over and comes to rest on the ice underside is a very efficient technique. A 200-pound man can "push down" (e.g., climb a ladder-like pole placed on top of the plug) a 10-foot thick plug with a cross-sectional area 3 feet. Pushing the plug through the hole bottom requires about one-eighth of the maximum force and one-quarter the energy involved in lifting.

Holes of 28 inches in diameter can be cut at 5 feet an hour with a system delivering 80,000 Btu per hour to the ice. Holes have been cut through 15-foot thick ice at these rates. The practicality of a thermal ice cutter for most diving operations is questionable. The heavy logistic requirement of moving the cutter and support equipment is often more than a small diving operation can manage, especially if they are using snowmobiles for support. There are conditions however where this type cutter will be of value; therefore, personnel should be familiar with its capabilities and characteristics.

f. Blasting. The use of explosives requires caution and training under the most ideal conditions. With the added difficulties of handling explosives and explosive devices in the Arctic, even more caution than normal will be required. **Under no circumstances should one that is not trained in the use of explosives attempt to use them.**

Cutting holes through very thick sea ice is a common problem. If a single charge is set beneath the ice, the resultant crater contains more debris than it is feasible to clean out by hand. A simple alternative is to use delayed deck charges. The top charge, which is used to define the breakout zone, can be designed from cratering data.

Holes for an underside charge may be made with either an ice auger or blasted with a shaped charge. The M2A3-shaped charge (commonly called the 15-pound shaped charge) will penetrate at least 26 feet of ice. Handmade shaped charges can also be used in blowing holes in ice. Commercial dynamite can be used with success against ice with medium strength being preferable to other grades. Dynamite should not be allowed to freeze as it becomes very dangerous.

Great care must be exercised when handling electrical firing devices under winter conditions. Because of improper grounding of an individual caused by the snow and ice covering on the ground, the static electricity that builds up might possibly detonate the device. Personnel should make sure that they are properly grounded prior to handling any type of electrical firing devices. Before a charge is detonated, everyone should retreat to sections of ice that are not likely to crack from the explosion and out of range of flying debris. Loose snow may be shovelled over the charge to partially act as a projectile barrier blanket.

4-13. Open Vessel

When operating from an open craft, the divers should put on their exposure suits before leaving the ship or beach: Heavy parkas should be

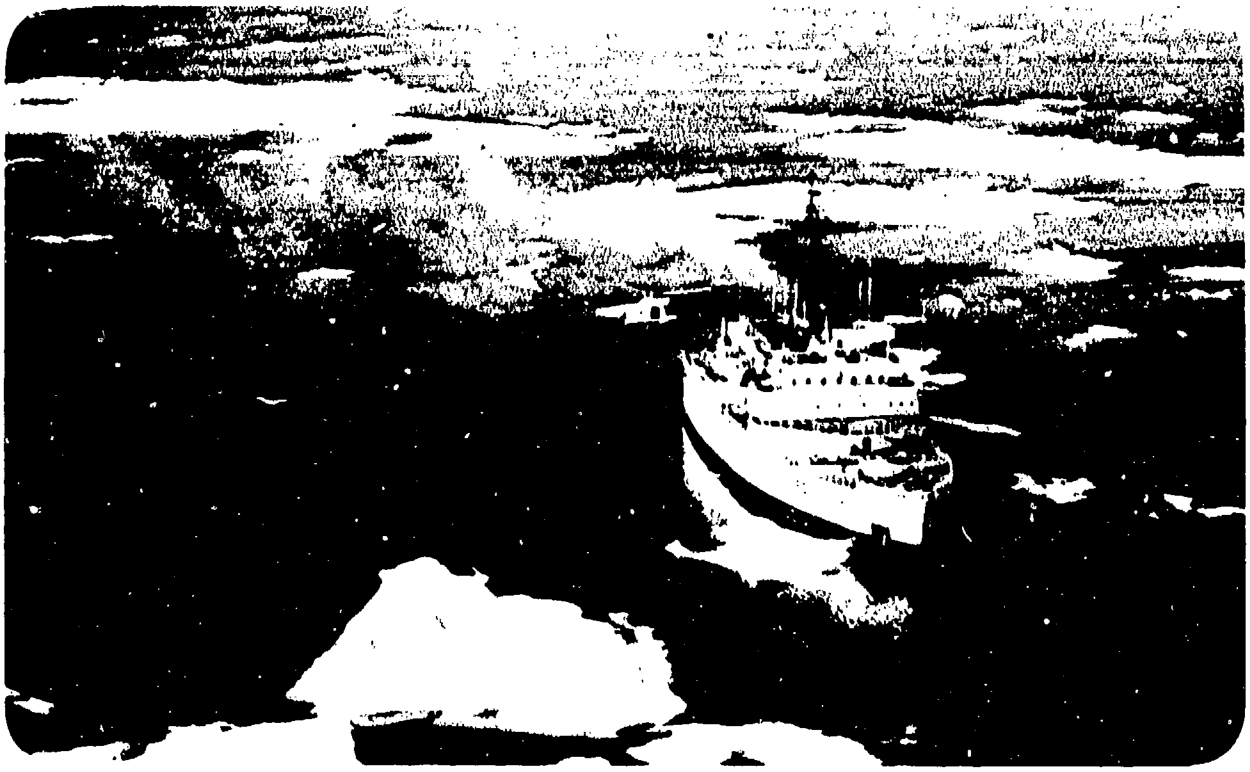

FIGURE 4-11. U.S. COAST GUARD CUTTER GLACIER (WAGB-4)

worn over the suits while the diver is exposed to the weather. Dry mittens can be worn until the diver is ready to go in the water, at which time he can put on his diving suit mittens. When space is available, a warm area on the vessel should be prepared where divers and their equipment can be protected from the weather while waiting to enter the water and upon emerging from the water.

Before diving operations begin some means to control the relative motion of the ship and ice must be devised to ensure the divers a safe entry-exit hole. Wind can keep a "stationary" vessel moving, causing fouling of tending lines and support cables in the ice. Cakes of ice next to the vessel used for temporary diving platforms will tend to drift away and are not easily restrained. The constant shifting of ice can restrict the diver's access to the surface. One possible method of providing clear access for the divers is with a 4 foot by 5 foot frame bolted together from a 4 inch by 4 inch dunnage. Serving as an entry floating on the surface, this will reduce the chance of ice jam-up. Remember, winds pick up fast in the Arctic and ice cover can change in minutes.

When diving from an open vessel near ice floes, the direction and approximate distance to any opening on the floe should be noted. Any sorties that require going under the ice should be tethered, or short-ranged. A descent line lowered beneath the diving boat makes a good reference from which sorties under a floe can be made. The line hanging below the boat serves as a marker, enabling the diver to locate the boat's position. Caution must be exercised when any visual homing device is used. Unlimited visibility can be drastically and suddenly reduced by the stirring of sediments or the shimmer effect which is occasionally experienced at thermoclines.

4-14. Icebreakers

These are very useful for diving platforms in those areas having relatively light ice concentrations (Figure 4-11). Even the most modern icebreaker cannot move at will in the pack ice. The penetrations farthest north by icebreakers have been about 76 degrees north latitude, north of the Chukchi Sea, and about 83 degrees north latitude, north of Franz Josef Land. These far northings were during optimal ice conditions, so that under the prevailing climatic conditions it seems unlikely that icebreakers will be able to improve diving operation capability to any extent in the central Arctic.

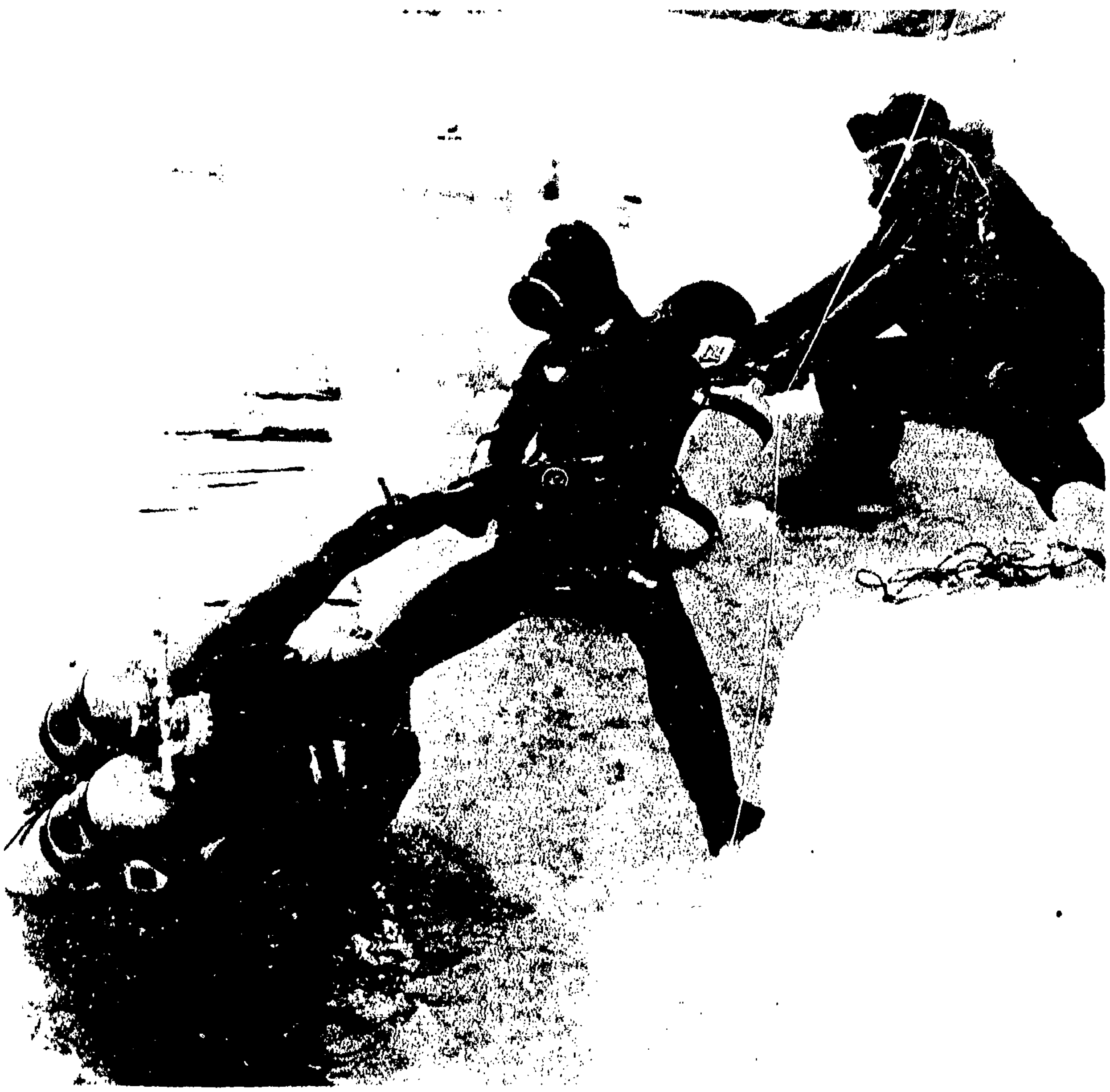

FIGURE 4-12. ASSISTING DIVER OUT OF WATER

4-15. Ice Floe

Diving from an ice floe is the most dangerous type of polar diving. It is best to have two holes, natural or man-made, for escape. When diving in moving ice, a large vessel or cutter is almost mandatory. The surface may be covered with free-floating ice ranging in size from bergy bits (about 30 feet across) to brash ice (small fragments up to 6 feet across). Some advantages of this type ice are that the larger pieces can provide temporary stable diving platforms and the total ice mass tends to diminish wave action, improving underwater visibility. Disadvantages in diving in this type of ice are that it is difficult for the diver to get in an out of the water (Figure 4-12), currents and tides can cause the ice to move so that entrapment at the surface or against the sea floor is possible, and the diver can become separated from his surface dive station or boat and have difficulty making his way back.

Only shallow dives are safe in the leads of free-floating ice because they can close rapidly. The surface crew must have the experience to anticipate these closures and return the diver to

FIGURE 4-13. ONE TYPE SUBMERSIBLE OPERATING IN PANCAKE ICE BUILT BY PERRY OCEANOGRAPHICS, INC.

the surface before they occur.

Wind and current, acting on free-floating ice, expose the diver to additional hazards. Icebergs, large or small, can become unstable and roll over, and ice floes and bergs can be pushed against each other, crushing an unwary diver. Currents can be deceptive with little or none close to the surface, while a few feet down (and away from the friction of the ice), the current may be 1 or 2 knots. A diver should not operate in these conditions without a tether.

It is important to recognize that relative movement of ice and water must be considered while diving beneath free-floating ice. If the wind and current combine to move the ice in a direction opposite to the current, then the diver may be quickly separated from his entry-exit hole. If the wind and current are in the same direction, the diver may be able to work better by being in an apparent null-current situation.

4-16. Lockout Submersible

Submersibles capable of providing lockout facilities for divers have operated in the Arctic, at times with almost 10/10ths sea ice coverage (Figure 4-13). To date, all launching and recovering have been through small but stable polynyas; however, openings for these submersibles could be blasted in most cases.

Lockout submersibles will normally work with a mother ship with a heated enclosure for storage and maintenance. The mother ship most suited for working in heavy ice fields would be an icebreaker; however, for easily navigable waters, this is not necessary. A heated enclosure will prevent the possibility of ice formation on the submersible if it is cooled below the freezing point and then launched into seas which are at the freezing point.

Submersibles will normally be fitted with a scanning sonar which can home in on a sonar "pinger" located at the support ship or polynya. A backup system consisting of neutrally buoyant polypropylene line attached to the submersible will allow navigation back to the polynya by following the line visually. The amount of ice coverage will dictate the navigation systems desired for any given mission.

Dressing inside a lockout submersible can be difficult and fatiguing. The distortion of the exposure suit from compression and the cramped conditions inside the submersible can cause overheating from the exertion of dressing. The resultant perspiration from this overheating can cause the diver to become chilled, thereby reducing his tolerance to the cold water. His tolerance will be further reduced when a mixture of helium and oxygen is used as the breathing medium. With nonheated exposure suits, dives made from a lockout submersible in polar waters will be of relative short duration.

4-17. Shore

Diving operations conducted from the Arctic shoreline require planning for some unusual conditions. Among these are drifting ice near the beach and patches of ice on the beach, making entry and exit difficult (Figure 4-14). Dives that require moving offshore for a considerable distance must have a support boat. Without some type of support boat, excursions from the beach should not take the diver so far from shore that he could not return with a flooded exposure suit. Most diving operations conducted from shore will be around piers and in harbors, and as such, will not require much horizontal movement away from shore support.

Thick patches of brash ice often gather along the shoreline, sometimes extending for a considerable distance offshore. This "slush" presents a barrier to the diver reducing underwater visibility to the point where navigation is possible only by swimming on the surface. Brash ice will instantly fill a removed mouthpiece and it cannot be cleared out by any conventional means; the diver must surface and physically knock the material from the mouthpiece. If the air temperature is low enough, the slush will freeze in the mouthpiece forcing the diver to abort. A small boat should be used to transport divers through large areas of brash ice.

4-18. Hole Plug

When small items such as transducers, hydrophones, lights, etc., are lowered beneath the ice through small holes, they become trapped below when the hole refreezes. For short periods, water can be excluded from the hole by the inflation of a cloth-reinforced neoprene rubber balloon, similar to a "plumber's plug." The balloon can be removed easily after deflation if it is greased. Unfortunately, the water beneath the ice is near the freezing point so that, in very cold weather, convection currents of cold air within the balloon permit a cup of ice to form over the bottom of the balloon. This ice can be broken away after the balloon is deflated, provided it is not left in place more than a week or so.

SECTION II. NAVIGATION

4-19. General Problems

a. Establishing and maintaining orientation under water is essential for any diving operation. Navigation under water is difficult at best, but in polar waters there are several additional problems that must be taken into consideration. These include:

1. The proximity of the magnetic pole makes the ordinary compass nearly useless.
2. Cold water shortens the life of batteries used on homing beacons and strobes.
3. Permissible error is negligible; the one and only acceptable goal is often the small entry hole in the ice cover.
4. Surface light, if available at all, is diffused to such an extent by the ice cover that it is nearly impossible to determine its source.
5. Direct ascent to the surface is impossible when under ice, and a rapid means of determining direction is often critical.
6. In shallow waters, detours are often required to circumvent bottoming pressure ridges.
7. With an ice cover, there are no waves, therefore, no ripple patterns on the bottom to use for general orientation.

4-20. Navigation Techniques

Several techniques have been used for under-ice navigation with varying degrees of success. These include:

a. Tether. The safest and only acceptable method of navigating for most under-ice diving operations is a tether attached to the diver and leading back to the entry hole and the surface tender. The tether eliminates any fear the diver may have of becoming disoriented or lost, and provides a basic means of communications with the use of standard diving signals. The length of the tether will depend on the mission; however, it should not be so great that the diver cannot be safely hauled back in an emergency situation even at the maximum extent of the tether.

b. Compass. Navigation in polar waters cannot be performed with an acceptable percentage of error using a compass. The extremely small target; i.e., the entrance hole through the ice, and the proximity to the magnetic pole renders a compass nearly useless.

c. Strobe Light. A flashing strobe hanging under an extrance hole can be seen for a considerable distance by the diver. The combination of the bright flashes, overhead ice, and clear water tend to cause confusion as to the

FIGURE 4-14. BEACH ENTRY THROUGH SLUSH ICE

exact direction of the light source. Because of this confusion, a strobe should be used as a backup, homing beacon only.

d. Light (Steady). A steady light with a 360-degree circle of illumination hanging under the entrance hole is one of the best homing beacons available. Such lights should be arranged in clusters in case one burns out; and the power source should have a battery back up in case of general power failure on the surface. If a directional light is used, the divers must be careful to stay within the cone of illumination as the clear, particle-free water often encountered will offer very little backscattering effect. A properly aligned directional light will offer a great range for the diver; they have been detected under the ice at a measured distance of 425 feet.

e. Acrylic Sphere. An acrylic sphere makes an excellent beacon during periods of ambient light by reflecting the surface glow from the sun. Such a sphere is highly visible in turbid or poorly illuminated water long after all nonreflective objects have disappeared. In very clear water with a high ambient light level, light reflected from the sphere will usually be visible as a greater distance than an artificial light.

f. Homing Pingers. The adverse effect of cold water on pingers and pinger receivers limit their usefulness. Eventually, systems which are completely reliable may be developed, but the short amount of time available to a diver with a flooded suit or malfunctioning regulator reduces the requirement for long-range navigation where pingers would be of benefit.

g. Surface Lights and Flares. Where the ice layer is thin enough, a system of surface lights or flares can be used to guide the diver back to the entrance hole. This system has limited application but could be used.

h. Surface (Trails). Under certain conditions of light and ice thickness, snow-cleared areas on the ice are very easily detected by the diver. By using these areas for reference points and trails, such as a cleared roadway to the dive site, the diver has a very useful navigational aid for short excursions. Great care must be used in this type navigation as the irregular snow cover on the ice will present light and dark patches to the diver which he might confuse with cleared and noncleared areas.

i. Multiholes. When the diving operation requires working in widely separated sites, a second hole is often desirable at the second site to serve both as a navigation aid and as an emergency exit. When multiholes are used, a system of monitoring them must be available to give assistance when a diver surfaces.

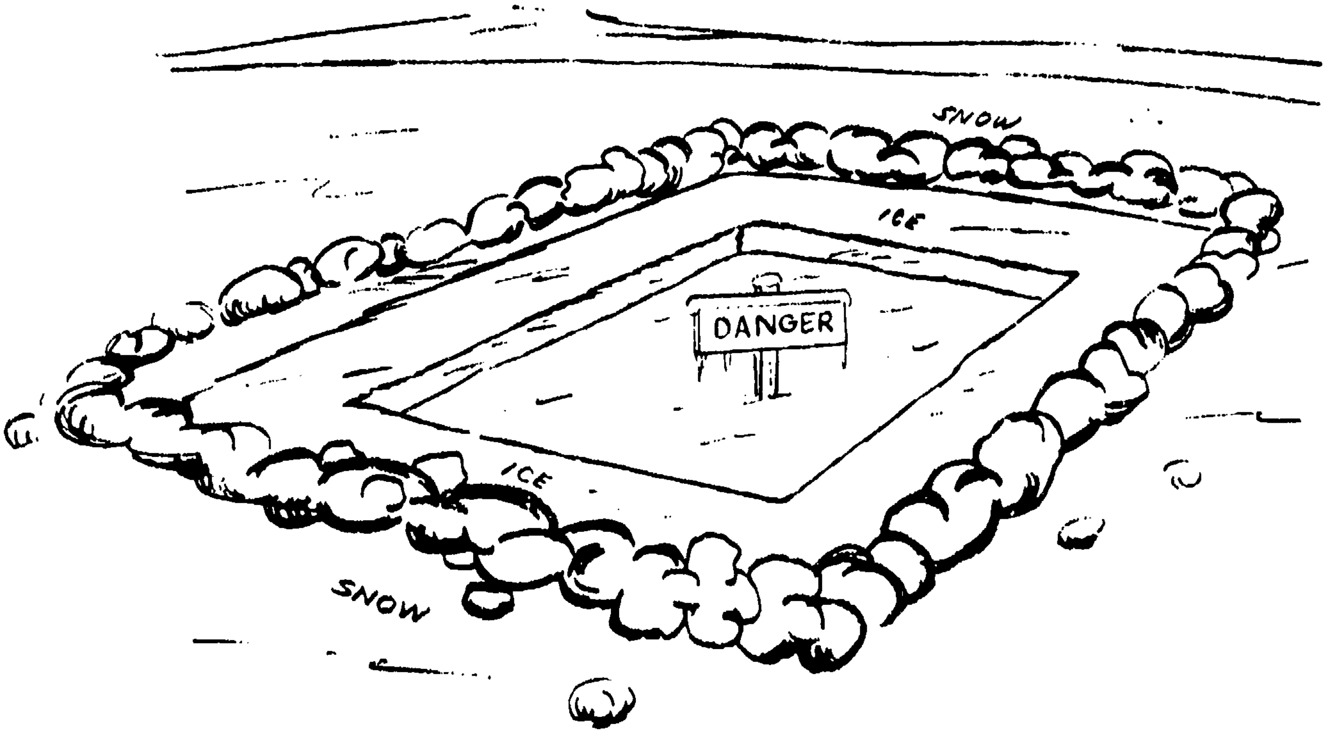

FIGURE 4-15. DANGEROUS ENTRY HOLE

SECTION III. EMERGENCY PROCEDURES

4-21. Falling Overboard

a. It may be assumed that the water temperature in the polar regions with ice will be 28°F to 29°F. A man who falls into this water, depending on the amount and type of clothing worn, will lose his breath. There is initial shivering and then the voluntary control of the muscles is lost. Consciousness lasts 5 to 7 minutes, and death occurs in 10 to 20 minutes.

b. In a few instances, men have saved themselves by violent exertion as soon as they hit the water, were able to swim a short distance, and pull themselves out on the ice or up a ladder. Without help, many have died because of the muscle spasm. The man must be very quick in removing himself from the water because the ungloved hand will cramp, lose all sensation, and be useless in just over 1 minute.

c. Personnel should stay clear of entry holes when they are not required to assist a diver. Often, the water splashed over the hole edge freezes into a layer of slick ice around the perimeter, sometimes as much as 2 or more feet back from the edge. Crampons might be useful in bad cases of ice buildup around the hole. Topside personnel should never work in the vicinity of an entry hole alone. A fully clothed individual without any flotation device will have a difficult time pulling himself out of the entry hole unaided (Figure 4-15).

4-22. Stricken Diver

In the event of a stricken diver, his partner should get him to the surface as quickly as possible. If the partner feels that assistance is needed and that he can attract another diver's attention without lost time, he should do so. However, the time lost attracting the attention of another diver is often not worth the extra support they can provide. As soon as the topside supervisor is aware of a problem he should prepare to receive the stricken diver on the surface and provide assistance.

4-23. Breathing System Failure

In the event of breathing system failure, the diver should:

a. Switch to his backup system, if available.
b. Notify his partner.
c. Exit to the surface with partner.
d. Exit to the surface without partner if

necessary and have him recalled by surface personnel.

NOTE: Buddy-breathing in polar waters is difficult and may result in a loss of valuable time. Individual circumstances will dictate when it is best to head directly for the surface without buddy breathing on the way, or when buddy breathing would be better. In any case, all divers should take the time to practice buddy breathing in these waters before they make any excursions away from the entry hole.

4-24. Suit Failure

a. In the event of a tear or flooding of the exposure suit, the diver should surface immediately.

b. The time available to a diver with a flooded exposure suit will vary with the extent of flooding. Regardless of the degree of flooding, the extreme chilling effect of polar water will cause thermal shock in the diver within minutes.

4-25. Uncontrolled Ascent

In the event of a suit blow-up or lost weight belt, both resulting in rapid ascent, the diver should:

a. Exhale continuously during ascent.
b. Relax against the ice.
c. If suit blow-up, relieve the excess pressure with exhaust valve.
d. Either pull air intake out or cut supply hose if air is still entering the suit. This may allow a slight amount of water to enter the suit.
e. Signal the tender to haul in, if on tether.
f. Make way to entry hole if possible.
g. Wait for assistance from buddy diver.

4-26. Lost Diver

In the event a diver becomes lost under the ice, he should:

a. Ascend to the overhead ice cover immediately.
b. Relax as much as possible to conserve air.
c. Wait for assistance.

NOTE: Under certain conditions of ice thickness and daylight, the release of a large volume of dye would be an effective way to indicate to topside personnel the location of a lost diver relative to the entrace hole.

4-27. Emergency Procedure Reminder

a. The procedures to be followed in an emergency will vary somewhat with the different diving operations conducted in polar waters. Regardless of what the procedures are, they should be made known to all personnel involved, both diving and nondiving. The procedures should be specified for each type emergency situation which might be encountered.

b. Polar diving requires careful planning and the use of common sense. Those who try to succeed with the use of brute force and prove that they can outlast, outperform, and outdive other divers will get into trouble and are a threat not only to themselves, but to the entire mission. Dares are neither offered nor taken. Necessary risks are bad enough. Success depends on hard work; not heroics.

CHAPTER 5

BIOMEDICAL*

SECTION I. PHYSIOLOGICAL STRESS

5-1. Effects on Performance

a. Cold stress limits the capability of a diver to perform both mentally and physically. Sensory and mental functions are disturbed; thinking itself is disrupted, being most evident when sustained attention and memory are involved. The effects of peripheral cooling are a substantial decrease in touch sensitivity of the finger ends and in the grip strength of the hands. Manipulative actions involving arm motions and finger dexterity decrease rapidly in cold water.

b. In many cases, discomfort will be felt in the hands because they are the most difficult area of the body to protect. The diver is still able to perform certain tasks even with "cold" hands; however, individual judgment should prevail for deciding when the dive should be terminated. The diver is not likely to suffer any permanent injury from long exposure of his hands to uncomfortably low temperatures; however, when he begins to lose dexterity, tactile discrimination, and kinesthetic sensation, he is not only useless as a working diver, but is a hazard to himself and his fellow divers. The diving operations medical doctor should be available to closely monitor problems of this nature.

c. When shivering and the muscular activity of increased respiratory rate occur, the diver should immediately ascend and terminate his dive before severe cold stress sets in. In polar waters, the time a diver may have to get out of the water safely can be very short once he has begun shivering. Shivering as a defense mechanism against cold is inefficient, for increased blood flow accompanies the muscular activity of shivering, which markedly decreases tissue insulation.

5-2. Effect on Physical Disorders

It can generally be expected that exposure to climatic extremes will increase the effects of any physical disorder. Men with heart diseases often become quick casualities due to the requirement for increased physical exertion. The individual with arthritis suffers from damp and cold, plus abnormal physical exertion.

5-3. Individual Difference

Heavily built divers seem to tolerate cold better than the wiry types as their extra subcutaneous fat provides more insulation. Repeated exposure to cold water increases a man's tolerance to cold; however, this acquired acclimation disappears rather quickly when cold exposures are discontinued. The extreme cold of polar waters requires a high level of skill, physical stamina, and motivation.

One fact should be well recognized: diving operations in polar regions cannot be performed in warmth and comfort. The diver must learn quickly and carefully how cold he can become while still working safely and not be a hazard. When this limit is ignored cold injury can result.

SECTION II. TYPES OF COLD INJURY

5-4. Primary Types

There are five primary types of cold injury: chilblains, frostbite, freezing, immersion foot, and general hypothermia. The type of injury produced depends upon the degree of cold to which the body is exposed, the duration of exposure, and the environmental factors of moisture and wind.

a. Chilblains. This mildest of dry cold injury occurs with repeated prolonged exposure of bare skin at temperatures from about 60°F down to freezing. Severity is proportional to temperature, humidity, wind, and frequency of exposure. In acute cases, the skin gets red, swollen, hot, more or less tender, and usually itches. Between periods of reactivation, the skin is red, rough, and cool. Normal vascular response to cold is said not to be lost and there is no loss of tissue in untreated cases. Treatment consists of dressing adequately to prevent further exposure and any bland, soothing ointment can be applied for relieving discomfort.

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*Much of the information in this chapter was obtained from communications with Dr E E Hedblom CAPT , MC, USN (RET).

FIGURE 5-1. BLANCHING OF FACE "FROSTBITE"

b. Frostbite. This is the most common condition encountered in acute exposure to extreme dry cold. The parts of the body most likely to be frostbitten are the cheeks, nose, chin, ears, forehead, wrists, hands, ano feet. It depends directly on the wind chill factor, duration of exposure, and adequacy of protection.

The onset of frostbite is signaled by a sudden blanching of the skin, which may be accompained by a momentary tingling sensation. The skin changes from a pink color to white or greyish-yellow. Initial pain quickly subsides and the extremity will feel numb. In extreme cold, when your feet or hands quit hurting, they should be investigated at once for possible frostbite. The buddy system in which men watch each other's faces for the telltale yellow-white spots minimizes tissue damage by early detection (Figure 5-1). Generally, the victim is not aware of frostbite.

Overall physical well-being, good clothing, and intelligent operations in the field are the best insurance against frostbite. Hands, face or feet should not be washed too thoroughly or too frequently. Tough, weatherbeaten face and hands, kept reasonably clean, resist frostbite. Shaving of the face should be done carefully so none of the protective skin is scraped away; this provides an excellent site for frostbite. Shaving every two to three days allows the face to remain tough and resistant. Beards will offer some protection from the cold; however, if they become to shaggy, they will collect the powderlike snow which melts and forms ice, which can cause extreme facial cold injury (Figure 5-2).

1. Frostbite should be treated immediately whenever encountered, for it always precedes a freezing injury. The quick thaw of injured tissue in a water bath of 104°F to 109°F has a specific benefit on ultimate tissue recovery; however, such treatment is rarely possible in the field.

2. In the field, frostbite of the face can be thawed by placing a warm hand over the spot until it hurts again. Frostbite of the fingers is best treated by wearing a parka with sufficiently large armholes that the hand may be warmed under the opposite armpit. Frostbite of the feet can be thawed with warm hands; warm the heels and the toes will warm more quickly. The victim should be taken to a heated area as soon as possible and the frostbitten part placed in warm water or gently wrapped in blankets, electric if possible. Do not rub or massage the affected area before, during, or after rewarming as it can damage tissues; let circulation return naturally. Encourage the victim to exercise the affected joints when they have rewarmed.

3. Frostbite results from crystallization of tissue fluids in the skin or immediate subcutaneous tissues and, depending upon the ambient temperature or wind chill, the time of exposure varies from a few seconds to several hours. At very low temperatures, severe injury may be almost instantaneous, especially to exposed areas such as fingers, ears, and nose. A previous episode of frostbite may increase the individuals risk of subsequent cold injury.

c. Freezing. Freezing is the formation of ice crystals in tissues deep in the skin and the immediate subcutaneous tissues. It occurs most commonly in the feet and occasionally in the hands and ears, and is always preceded by frostbite. Untreated, it is painless and the tissues have a pallid, yellowish color and appear waxy. Freezing is serious and even with proper treatment, loss of tissue can take place with loss of all or part of the extremity. Even if there is no tissue loss, reduced sensation, general tingling, and sensitivity to cold may occur in the recovered extremity.

A frozen part should never be exposed to an open fire, really hot water, or any other intense form of heat. Excessive use of dry heat in rewarming appears to produce almost certain

FIGURE 5-2. ICE FROST IN A FULL BEARD

additional injury and possible gangrene; the injured part has lost most or all feeling and will not be able to tell the degree of heat being applied.

d. Immersion Foot. While not common in the Arctic, immersion foot can result from long periods of wet feet, from 68°F down to freezing, whether from sweat or from external moisture. Immobility speeds development of immersion foot. Proper foot gear and dry socks will prevent this, and it is not seen as a serious problem for diving operations. A previous episode of immersion foot invariably increases the individual's risk of subsequent cold injury.

e. General Hypothermia. At environmental temperatures less than 68°F to 70°F, survival depends upon insulation (body fat, clothing), ratio of body surface to volume, the body fire (basic metabolic rate), and the will to survive. When the core temperature goes below 95°F, hypothermia produces diminished BMR, heart rate, blood pressure, and uncontrollable shivering. Hallucinations, apathy, and narcosis occur at core temperatures of 86°F to 80°F, and death from ventribular fibrillation, or cardiac arrest occurs between 80°F to 75°F.

Those who have come close to dying from hypothermia describe the symptoms as extreme fatigue (only the fatigued sleep through the violent shivering), weak muscles, joint stiffness, and ultimately a feeling of warmth, comfort, and an overpowering sleepiness.

Mild cases will recover if the patient is wrapped in blankets (electric, if possible) or a sleeping bag and allowed to rewarm from his own metabolic heat production. Severe cases will die unless they are rewarmed actively; this should be performed under the supervision of a medical doctor if possible. Improper rewarming can lead to a further reduction of the core temperature "after drop" with possible fatal results. The preferred treatment is immersion in a tub of water at 105°F to 110°F or hot shower until all shivering has ceased. In practice, even severe hypothermia of limited duration seldom causes lasting ill effects of any kind in healthy people.

5-5. Miscellaneous Injuries

a. Cold Fluids. Injuries resulting from contact with volatile fluids tend to be superficial and, as a rule, not very serious, UNLESS THE FLUID COMES IN CONTACT WITH THE EYES. If the eye tissues are frozen, permanent impairment of vision may result. When working with gasoline or other volatile liquids in extreme cold, the individual must be particularly careful to protect the eyes. If a volatile liquid does come in contact with the eyes, get medical help at once. Until medical help arrives, flush eyes with copious amounts of water warmed to 70°F to 80°F and make sure that the victim does not rub them. Drops of mineral oil or olive oil may be put in the eyes for additional relief.

Serious injury to the eyes can also result from the carbon dioxide absorbents Baralyme and sodasorb. Caution must be exercised to prevent any absorbent dust from getting into eyes while filling breathing apparatus canisters. Copious flushing of the eyes with water and administration of weak acidic eye drops is recommended.

b. Snow Blindness. Snow blindness occurs when the sun is shining on an expanse of snow or ice, and is due to the reflection of ultraviolet rays. It is most likely to occur when the rays of the sun are obscured by high overcast. (This produces the deadly "whiteout" when all shadows disappear.) Symptoms of snowblindness are a sensation of grit in the eyes with pain in and over the eyes made worse by eyeball movement, watering, redness, headache, and increased pain on exposure to light. First aid measures consist of blindfolding and rest. The condition heals within a few days once unprotected exposure to sunlight is stopped, but the eyes will have increased susceptibility for periods of up to 5 years.

Prevention of snowblindness depends on the wearing of proper glasses which optically reduce ultraviolet exposure and which, physically, sufficiently cover the field of vision. For clear vision and continued use, plastic lenses are never as desirable as ground glass. Even on short trips, it is advisable to carry a second pair of glasses for safety against breakage or loss.

c. Frostbite of Lungs. During hyperventilation following strenuous exercise at temperatures below -25°F, an individual may cough up blood from the tracheobronchial tree. This is particularly a problem at high altitude and will not be of much concern for most polar diving operations except for possible travel across the high, mountainous areas. This is not "frostbite" since there is no freezing of tissue. Concurrently, or as an aftermath, an asthmatic type of breathing may occur for periods of hours to a day or two, depending on the sensitivity. Parka hoods, face masks, and mufflers can prevent this condition to some extent by enhancing some rebreathing of warmed, humidified expired air.

SECTION III. PREVENTION OF COLD INJURY

5-6. Warning Signs

The lack of warning symptoms emphasize the insidious nature of cold injury which, unfortunately, is casually overlooked by many personnel temporarily subjected to cold climatic conditions. The only warning symptoms may be the cessation of pain; when cold pain stops, investigate immediately. The skin briefly becomes pale or waxy white. At this stage, the affected part may feel "like a block of wood." If freezing has occurred, the tissue appears "dead white," is hard and "woody" with complete lack of sensation and movement. Low temperatures and moist skin favor frostbite.

5-7. Wind Chill

Temperature is not the final determinant of "cold;" it must be remembered that in cold climates the combination of temperatures and wind produces the greatest heat loss and discomfort. With a wind speed of 20 miles an hour, a temperature of 5°F is just as effective in chilling the body as a temperature of -40°F with a very slight wind of less than 2 miles per hour. It should be noted that the wind chill concept applies principally to bare skin, and its effect is particularly dependent upon the type and style of cold weather clothing worn. Nevertheless, wind speed must always be checked before leaving a heated shelter.

5-8. Basic Precautions

a. Personnel scheduled to go to the Arctic should be instructed in cold weather physiology and the prevention of cold injuries. The best treatment for cold injury is the prevention. An excellent source of information is the "Polar Manual" written by Dr. E.E. Hedblom, CAPT., MC, USN (Ret).

b. Individuals should wear warm, dry clothing, preferably several layers, with a wind-resistant outer garment. Wet clothing, socks and shoes should be removed as soon as possible and replaced with dry ones. Extra socks, mittens, and insoles should be carried when in cold or ice areas. Cramped positions, constricting clothing, and prolonged dependency on the feet are to be avoided. Exercising arms, legs, fingers, and toes to maintain circulation is essential. It is important to avoid becoming wet or damp, and to keep sheltered from the wind. Smoking is discouraged when the danger of frostbite is present.

c. If a person is unable to walk or exercise vigorously, the hands and feet can be kept warm by moving the fingers and toes. Fingers may be warmed quickly in the armpit under the parka. Moving the lips from side to side and up and down increases blood circulation throughout the face and helps prevent cold injury to facial tissues. Remember to keep warm, keep moving, and keep dry. (Don't sweat!)

d. Cold injury tends to occur in individuals who display little muscular activity and are prone to pay less attention to rules and procedures. The health of each diver and confidence in his ability to meet the rigors of Arctic diving is related directly to his physical condition. The effect of physical fitness on morale cannot be overemphasized.

e. Fatigue is a contributory factor to cold injury in that personnel may become so exhausted that they fail to carry out simple preventive measures. Weariness can cause apathy leading to neglect of acts vital to a safe diving operation. Even the simple act of walking in heavy Arctic clothing and through the rugged terrain must be paced to prevent fatigue. Predive fatigue will reduce the efficiency of the diver and could jeopardize the individual if extreme enough. All work and movement should be performed at a nonfatiguing pace if possible.

5-9. Diet

a. There is no better investment in the well-being, safety, and efficiency of a diving expedition than plenty of good, well prepared food. Providing this and at the same time ensuring a well balanced diet in the Arctic environment will require careful planning in amounts, types, storage, preparation, and distribution of foods.

b. Given free choice of unlimited amounts of foods of all types, the normal individual working in extreme cold continues to consume proteins, carbohydrates, and fats in approximately the same ratio as in temperate climates. Carbohydrates are quick energy producing foods. An ounce of beef fat contains 80 percent more calories than the same weight of sugar or lean beef. A greatly increased intake of lean meat or carbohydrates cannot be tolerated by the normal individual unless accompanied by a corresponding increase in fat. Arctic diving operations on a sustained basis will require greater amounts of food due to the increased physical demands being made on the body.

c. Because outdoor activity in extreme cold results in body dehydration, abnormal amounts of thirst-provoking foods should be avoided, both for comfort and logistical reasons. Every individual should drink one to two glasses of water or juice at each meal to keep up water balance. Hot drinks and soups serve not only to quench the thirst and correct fluid deficiency, but also to physically transfer heat to the body.

d. The energy intake of personnel stationed in Alaska has been found to range from 3100 to

3400 calories a day with a slight (200 calories) increase during the winter months. This increase may be partially attributed to the weight of Arctic clothing during movement outdoors. These figures are not significantly different from the figures from dietary studies of U.S. troops stationed in temperate or tropical regions, nor is the ratio of intake by food source; i.e., protein, fat, carbohydrates. Under conditions of continuous outdoor exertion at low temperatures, man acclimates and the daily caloric requirement will increase to as much as 5500, and the men will be hungry for fats.

e. It is easy to overeat in the Arctic and quickly put on excess weight. Personnel should eat the full daily ration, including all vitamins recommended, but they should not stuff themselves with candy or other sweets between meals. If they must snack, figs, prunes, and raisins make an excellent substitute for candy and they are a recommended part of the diet for the Arctic environment.

5-10. Health

a. Injuries. An example of what might be expected on polar diving operations as to type and rates of injuries can be seen from a record of the first 5 years of Operation Deepfreeze (Antarctic).* There was a 50 percent higher admission rate for injuries (fractures, abrasions, contusions, amputations, burns, and multiple extreme injuries) than for the Navy at large. These injuries were mostly due to clumsiness from heavy clothing, poor traction of foot gear, increased contact with machines (not automobiles), multiple sources of heat, and increased logistic use of aircraft.

b. Disease. Figures from Deepfreeze admissions for the above period showed the Antarctic crews over two times healthier that the rest of the Navy suffering less respiratory infections, gastrointestinal disturbances, skin disease (with many fewer baths), infections, and fewer neuropsychiatric difficulties.

c. A large portion of the minor maladies that confront personnel in U.S. Arctic installations can, in all probability, be traced to one of the following:

1. Dehydration.
2. Overheated quarters and living space (the optimum temperature is 60°F to 66°F).
3. Overeating.
4. Lack of fresh air.
5. Lack of vigorous exercise (this is probably the prime malfactor) and leads in part to both 3 and 4.
6. Overcrowding in quarters.

d. Long periods of total darkness at polar installations, as well as separation from family, may cause minor mental depression and insomnia.

5-11. Sanitation

a. Sewage and garbage disposal should be well away from the diving station and in areas where the water supply cannot be contaminated. Since there are few sources of fresh water available in the Arctic isolated from inhabited areas, all water must be considered polluted and must be purified before drinking. Chlorination or boiling of all water should be mandatory at all stations.

b. The Arctic has many infectious diseases which are potential hazards to personnel. Pulmonary tuberculosis has been widespread in the native populations and is a potential hazard to anyone exposed to native personnel. If sanitation is defective, intestinal infections are hazards. All local animal life should be avoided due to the prevalence of parasitic diseases and rabies. There is a danger of bacterial contamination of food and water. Insect-carried communicable diseases are unknown in the Arctic but the mosquitoes, deer flies, and no-see-ums in the subarctic will require protection for personnel to operate in the summer months.

5-12. Body Parasites

a. Body parasites occur in the natives populating cold regions because of the crowded living conditions, and shortage of bathing and cleaning facilities. When occupying shelters which have been used by natives, individuals should routinely inspect clothing and body for parasites.

b. If clothing becomes infested with lice, the following methods of removing them are recommended:

1. While extreme cold does not kill lice, it paralyzes them. The garments should be hung in the cold, then beaten and brushed. This will help rid the garments of lice, but not of louse eggs.
2. An appropriate insecticide powder can be used to free the body and clothing of body parasites.

SECTION IV. SELECTION OF PERSONNEL

5-13. Prior Conditioning

a. One of the major problems confronting units designated to participate in polar diving operations is the lack of personnel with ade-

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*Dr. E E Hedblorn. Personal Communications.

quate training in cold weather operation and maintenance.

b. Experiments have shown that a period of 1 to 2 years is required to give proper and complete training to a person totally unfamiliar with the Arctic environment. However, the general physiological changes resulting from acclimation are small compared with the importance of such factors as exercise, training, and fitness.

c. An individual thoroughly conditioned physically (as all who plan polar dives should be) can be transported from tropical areas into the Arctic and immediately begin diving without deleterious effects.However they will differ in how well-suited they are for cold weather operations. For long term operations the selection of a special cold weather group may be warranted. It is much better if at least half of the diving team has had previous experience in polar diving operations and is well-qualified to train the newcomers.

5-14. General Considerations

When selecting personnel for a polar diving operation, it should be remembered that often those individuals with the most favorable and unrealistic expectations toward polar service might be the most easily disappointed in the experience. While there are no standard guidelines upon which to base personnel selection, some factors worth noting include:

a. Age. Within the usual age range of divers, age is not a significant factor to cold injury, but it is probable that persons below the age of 17 and above 40 are more susceptible.

b. Sex. Women have already shown their ability to dive in the Arctic and will no doubt continue to do so. They may be excluded from some diving expeditions however because of the extra logistic support required to provide suitable living conditions for a mixed team.

c. Race. It appears that some racial groups, particularly the Nordic types, have been more successful in the physiological and psychological adjustment to the environment than have other groups. This is due, in part, to accepting the natural conditions and adjusting and adapting actions to fit these conditions. The Negro, with all environmental conditions equal, is approximately six times more vulnerable to cold injury than Caucasins, and his injury is usually more severe.

d. Geographic Origin. The geographic origin of the individual seems to be a significant factor among Caucasian personnel in the incidence of cold injury. Those coming from warmer climates; i.e., where the mean minimum January temperature is above 20°F, seem to be more susceptible to cold injury.

e. Physical Defects. In addition to the standard physical requirements for divers, special attention should be made to ensure that those operating in the Arctic are free from the following physical defects or limitations:

1. Circulatory diseases affecting the extremities.
2. Skin grafts on the face, hands, or feet.
3. Inner ear difficulties.
4. Previous history of wet cold injury.

SECTION V. PSYCHOLOGICAL STRESS

5-15. Individual Indoctrination and Performance

a. Only well-trained personnel should be used for polar diving operations and care should be taken to avoid creating any psychological obstacle to them.[1] A short indoctrination on what to expect presented by personnel with previous experience in polar diving and a chance to familiarze themselves with equipment they will be using will be of invaluable help when the actual diving operation begins. For reasons of morale, logistics, and training, it is not desirable to maintain divers in polar areas for long periods.

b. The isolation of the area, the long periods of darkness and light, and the immobilizing effect of the weather can all affect mental stamina. The "cabin fever" stories of the trapper and the prospector, and the talk of "moon sickness" of the Indian and Eskimo are not just myths. The effect will vary with the individual and varies from nervous tension in some to loss of mental equilibrium in others.

c. There are three important aspects of how well an individual and a group functions and operates at polar stations: group compatibility, motivation, and group accomplishment. A diving operation will normally rate very high in all three areas, and by its very nature, suffer little from problems of psychological nature. However, the polar diver is exposed to a complex series of above-water stresses and hazards which will require a large portion of his time and energy for self-preservation. This, naturally, reduces the efficiency of personnel in the operation of a complex diving mission.

d. A psychological problem peculiar to the modern period of Arctic mobility is often labeled "carelessness," as when pilots and drivers of vehicles with heated cabs leave on a mission without proper and complete cold weather equipment. Familiarity often breeds contempt. Even a minor repair job can prove fatal without

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[1] Hedblom, E E., CAPT MC, USN, *Disturbances Due to Cold. Current Thearpy*, W B Saunders Company, Philadelphia and London, 1967, pp 758-674

adequate protection from the cold. The attitudes that result in this type of carelessness vary considerably but always include a lack of personal commitment to the objective of the organization to which the individual belongs. Obtaining a team member's commitment to a mission is probably the major task of cold weather indoctrination. They must be true volunteers and not those trying to escape from personal or family problems, nor those seeking some type of aggrandizement.

e. Emergencies come even to the initiated and acclimated polar worker. The sympathetic nervous system is already taxed with a hostile environment and any sudden extra emergency might turn normal apprehension into stark fear or its more destructive end product, PANIC. Only by being well-trained to prepare for the worst, can the individual produce automatic constructive action rather than destructive.

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GLOSSARY

A

Acicular Ice — (Also called fibrous ice, satin ice). Fresh water ice consisting of numberous long crystals and hollow tubes having variable form, layered arrangement, and a content of air bubbles. This ice often forms at the bottom of an ice layer near its contact with water.

Adfreezing — The process by which one object becomes adhered to another by the binding action of ice.

Anchor Ice — (Also called bottom ice, depth ice, ground ice, lappered ice, underwater ice). Ice found attached or anchored to the bottom irrespective of its nature of formation.

Antarctic Ocean — The name commonly applied to those portions of the Atlantic, Pacific, and Indian Oceans which reach the Antarctic Continent on the south and are bounded on the north by the Subtropical Convergence. This feature is not a recognized ocean body.

Apron — A sloping underwater extension of an iceberg, or an outspread deposit of ice or rock material in front of a glacier.

Arched Iceberg — An iceberg with a large opening at the water line, extending through the iceberg forming an arch.

Arctic Pack — 1. (Sometimes called many-year ice). Sea ice more than two years old. This nearly salt-free ice has a smoothly undulating surface due to the smoothing of pressure ice by weathering. It also has a thickness of more than 2.5 meters (8.2 feet), and often is colored in different tints of blue.
2. (Sometimes called polar ice). The drifting ice floes of the Arctic Basin; specifically, the thick, heavily hummocked polar ice of the central Arctic Ocean.

Arctic Sea Smoke — Same as steam fog; but often specifically applied to steam fog rising from small areas of open water within sea ice.

Autumn Ice — 1. Sea ice in early stage of formation. It is comparatively brackish, and crystalline in appearance. Like young ice, it is not yet affected by lateral pressure.
2. A Russian term defining a specific form of one-year ice (70 to 200 centimeters thick). At the end of the growth season in spring the thickest one-year ice is also called autumn ice since it formed earliest the previous autumn. Thus, it has been defined as 150 to 200 centimeters or more thick. Autumn ice usually does not completely disappear during the summer.

Average Limit of Ice — Average seaward extent of ice during a normal winter.

B

Ball Ice — Sea ice consisting of a large number of soft, spongy spheres 1 to 2 inches in diameter. This is a rare form of ice.

Bare Ice — Ice without snow cover.

Barrier — 1. In polar terminology, an early term for ice shelf; first used by Sir James Clark Ross for the face of the Antarctic ice shelf named for him, "Ross Barrier."
2. Barrier is being replaced by ice shelf and ice front in publications and maps.

Bay Ice — 1. Level ice of more than one winter's growth which has remained free of hummocks and is nourished by surface layers of snow.
2. A Labrador term for one-year ice formed in bays or inlets.
3. In the Antarctic, sometimes applied to heavy floes recently broken away from an ice shelf.
4. Young flat sea ice sufficiently thick to impede navigation.

Bergy Bit — A medium-sized piece of ice, generally less than 5 meters (16.4 feet) high and about the size of a small cottage. A bergy bit mainly originates from glacier ice but occasionally from a massive piece of sea ice or hummocked ice. When it is known to be sea ice, the term floeberg may be used.

Bergy Seltzer — Sizzling sound comparable to that of Seltzer water which icebergs emit when they melt. It is caused by the release of air bubbles that were retained in the berg at high pressure.

Beset — Surrounded so closely by sea ice that steering control is lost. The term does not imply pressure. If the ship is incapable of proceeding, it is icebound. If pressure is involved, the ship is said to be nipped.

Biennial Ice — Sea ice between one and two years old.

Black and White Iceberg — An iceberg having a dark, opaque portion containing sand and stones, and separated from the white portion by a definite line of demarcation.

Black Ice — Thin, new ice on fresh or salt water, appearing dark in color because of its transparency.

Blocky Iceberg — An iceberg with steep, precipitous sides, and with an essentially horizontal upper surface.

Blue Ice — The oldest and hardest form of glacier ice. It is distinguished by a slightly bluish or greenish color.

Brash Ice — A fragment of sea ice or river ice less than 2 meters (6.6 feet) in diameter.

Breakup — In general, the spring melting of snow, ice, and frozen ground. Specifically, the destruction of the ice cover on rivers and seas during the spring thaw; or applied to the time when the solid sheet of ice breaks into pieces that move with the current.

Breakup connotes the end of winter to a resident of the north.

Brine Slush — A mixture of ice crystals and salt water, which retards or prevents complete freezing, often found between young sea ice and a cover of newly fallen snow.

Broad Ice Field — A Russian term for an ice field of more than 10 kilometers (5.4 nmi) in width. It corresponds to the current WMO definition of vast ice floe.

Broken Belt — The transition zone between open water and consolidated ice.

Broken Ice — (Also called loose ice, loose pack ice, open ice, open pack ice, slack ice). Ice that covers from 5-tenths to 8-tenths of the sea surface.

Note: This term is being superseded by the term open pack ice by WMO.

Bummock — From the point of view of the submariner, a downward projection from the underside of the ice canopy; the submerged counterpart of a hummock.

C

Cake Ice — An ice pack composed of fragments of flat sea ice.

Calf — A piece of floating ice which has broken away from a larger piece of sea ice or land ice. Specifically, a piece of ice which rises to the surface after breaking away from the submerged portion of its parent formation.

Calving — The breaking off of a mass of ice from its parent glacier, iceberg, or ice shelf.

Candle Ice — (Or candled ice, penknife ice, needle ice, frost columns of ice). A form of rotten ice; disintegrating sea ice (or lake ice) consisting of ice prisms or cylinders oriented perpendicular to the original ice surface; these "ice fingers" may be equal in length to the thickness of the original ice before its disintegration.

Close Pack Ice — (Or close drift ice). Sea ice consisting of ice floes that are generally in contact. Their concentration ranges between 7-tenths and 9-tenths (6-eighths to 7-eights).

Concussion Crack — (Also called shock crack). A fracture in sea ice produced by the impact of one ice cake upon another.

Conglomerated Ice — (Or compact ice). All types of floating ice compacted into one mass; term refers to the contents of an ice mass, not the concentration.

Consolidated Ice — (Also called consolidated pack). An area of the sea covered by ice of various origins compacted by wind and currents into a firm mass. In sea ice reporting, consolidated ice is a term used to describe an area completely devoid of open water with a concentration of 10-tenths. It usually includes some of the heavier forms of ice.

D

Dried Ice — The ice surface from which the water has disappeared after the formation of cracks and holes. During the period of drying, the surface becomes increasingly white.

Drift Ice — (Or floating ice). Any sea ice that has drifted from its place of origin. The term is used in a wide sense to include any area of sea ice, other than fast ice, no matter what form it takes or how disposed.

Drift Station — A scientific station established on the ice of the Arctic Ocean. Most drift stations are based on ice floes, although two American stations (T-3 and ARLIS II) have been on ice islands.

USSR Stations are numbered consecutively from NP-1 (NP for North Pole) and are sometimes referred to as "SP" for the Russian "Severnyy Polyus" (North Pole).

F

Fast Ice — 1. Sea ice that generally remains in the position where originally formed and may attain a considerable thickness. It is formed along coasts where it is attached to the shore or over shoals where it may be held in position by islands, grounded icebergs, or grounded polar ice. (Preferred definition).
2. (Also called landfast ice). Any type of sea ice attached to the shore (ice foot, ice shelf, beached, (shore ice), stranded in shallow water, or frozen to the bottom of shallow waters (anchor ice).

Field Ice — 1. A general term used for all types of sea ice except newly-formed ice.

Flaw — A lead between fractured offshore ice and landfast ice.

Floeberg — A mass of thick, heavily hummocked sea ice resembling an iceberg or bergy bit. Floebergs have been reported to be as high as 50 feet and are considered to be the result of extreme pressure ice formation.

G

Glacier Berg — A mass of glacier ice that has broken away from its parent formation on the coast, and either floats, generally at least 5 meters (16.4 feet) above sea level, or is stranded on a shoal.

Glacon — A fragment of sea ice ranging in size from brash ice to a medium ice floe.

Granular Ice — Ice composed of many tiny, opaque, white or milky pellets or grains frozen together and presenting a rough surface. This is the type of ice deposited as rime and compacted as neve.

Grease Ice — (Also called ice fat, lard ice). A sludge of ice crystals in the sea that gives the sea surface a greasy appearance.

Growler — A piece of ice smaller than a bergy bit, which often appears greenish in color and barely shows above water. It may originate from sea ice and glacier ice.

H

Hinge Crack — (Or weight crack). A crack in sea ice running parallel and adjacent to a pressure ridge. Hinge cracks are believed to be caused by the weight of the pressure ridge.

Hummocked Ice — Pressure ice, characterized by haphazardly arranged mounds or hillocks (hummocks). This has less definite form, and shows the effects of greater pressure than either rafted ice or tented ice, but in fact may develop from either of those. When hummocked ice has been weathered and snow-covered it resembles similarly metamorphosed rafted ice, the term "hummocked ice" is then applied to both formations.

I

Iceberg — (Or berg). A large mass of detached land ice floating in the sea or stranded in shallow water. Irregular icebergs generally calve from glaciers, whereas tabular icebergs and ice islands are usually formed from shelf ice. Icebergs are the largest form of floating glacier ice, bergy bits and growlers being generally the fragments of broken icebergs.

An iceberg is usually defined as being the size of a ship or larger, although any piece of glacier ice greater than 15 feet in height is often called an iceberg. The WMO code defines an iceberg as any piece of glacier ice more than 5 meters (16.4 feet) above sea level.

Ice Blink — A relatively bright, usually yellowish-white glare on the underside of a low cloud layer, produced by light reflected from a distant ice-covered surface such as pack ice. This term is used in pola[illegible]ions with reference to the sky map; [illegible]nk is not as bright as snow blink, but [illegible] brighter than water sky or land sky.

Ice Cake — (Or cake, block). An ice floe smaller than 10 meters (32.8 feet) across.

Ice Canopy — Pack ice and its enclosed water areas from the point of view of the submariner.

Ice Cap — A perennial cover of ice and snow over an extensive portion of the earth's land surface. The most important of the existing ice caps are those on Antarctica and Greenland (the latter often called inland ice).

Ice Field — (Or field of ice). 1. Any area of sea ice of any size and of such extent that its limit cannot be seen from the crow's nest. 2. An area of sea ice more than 5 nmi across; the largest areal subdivision of sea ice.

Ice Floe — (Or floe). A single piece of sea ice, other than fast ice, large or small, described if possible as "light" or "heavy" according to thickness.

Vast — over 10 kilometers (5.4 nmi) across.

Big — 1 to 10 kilometers (3,281 feet to 5.4 nmi) across.

Medium — 200 to 1,000 meters (656 to 3,281 feet) across.

Small — 10 to 200 meters (32.8 to 656 feet) across.

Ice Fog — A type of fog, composed of suspended particles of ice, partly ice crystals 20 to 100 microns in diameter but chiefly, especially when dense, droxtals (crystals) 12 to 20 microns in diameter. It occurs at very low temperatures, and usually in clear, calm weather in high latitudes. The sun is usually visible and may cause halo phenomena.

Ice fog is rare at temperatures warmer than -30°C or -20°F, and increases in frequency with decreasing temperature until it is almost always present at air temperatures of -45°C or -50°F in the vicinity of a source of water vapor. Such sources are the open water of fast-flowing streams or of the sea, herds of animals, volcanoes, and especially products of combustion from heating or propulsion. At temperatures warmer than -20°F, these sources can cause steam fog of liquid water droplets, which may turn into ice fog when cooled.

Ice Island — 1. A large tabular fragment of shelf ice found in the Arctic Ocean. Nearly six hundred have been identified since the first one was discovered on aircraft radar in 1946. All have level, slightly undulating surfaces 10 to 25 feet above water, and most appear to have calved from the Ward Hunt Ice shelf off the northern coast of Ellesmere Island. Ice islands are smaller than the largest tabular icebergs of the Antarctic the largest one known being about 300 square miles in area. They are up to 175 feet thick and unlike the surrounding pack ice, they are influenced more by currents than by wind. Several ice islands have been occupied as drift stations.

2. Any tabular iceberg. Rare.

3. A giant floe. Rare.

4. An island completely covered by ice and snow. Rare.

Ice Rafting — The transportation of sediments and rock fragments of all sizes by floating ice. Such material is widely distributed in marine sediments along the paths of melting icebergs and is identified by glacial abrasion marks, composition, angularity (in contrast to rounded, water-worn alluvial-marine sediments), and size too large for any but ice-rafting method of transportation.

Ice Shelf — (Also called shelf ice; formerly barrier ice).

1. A thick ice formation with a fairly level surface, formed along a polar coast and in shallow bays and inlets, where it is fastened to the shore and often reaches bottom. It may grow hundreds of miles out to sea. It is usually an extension of land ice, and the seaward edge floats freely in deep water.

The calving of an ice shelf forms tabular icebergs and ice islands.

2. More specifically, a level ice formation over 2 meters (6.6 feet) above the sea surface which originates from annual accumulations of firn snow layers on bay ice or on the seaward extension of a glacier.

Ice Skylight — From the point of view of the submariner, thin places of the ice canopy, usually less than 1 meter thick and appearing from below as relatively light translucent patches in dark surroundings. The undersurface of an ice skylight is normally flat. Ice skylights are called large if big enough for a submarine to attempt to surface through them (120 meters or 393.7 feet) or small if not.

L

Lead — (Or channel, lane). A navigable passage through pack ice. A lead may be covered by young ice. From the point of view of the submariner it becomes an ice skylight.

Level Ice — Ice with a flat surface, which has never been hummocked; typical with regard to bays, gulfs, straits, archipelagoes, and shallow waters, where the ice formation occurs in undisturbed conditions.

Light Floe — In sea ice reporting, an ice floe generally less than 2 feet thick.

Light Ice — Sea ice less than 2 feet thick.

M

Medium Ice Field — (Or medium field of ice). An ice field 15 to 20 kilometers (8.1 to 10.8 nautical miles) across.

Medium Ice Floe — An ice floe of sea ice 600 to 3,000 feet across.

O

Open Ice Edge — Unsteady and not sharply defined ice edge limiting an area of open ice, usually located to the leeward.

Open Lead — A lead that is not covered with ice.

Open Pack Ice — (Or open drift ice). Ice floes of sea ice that are seldom in contact with each other; generally covering between 4 and 6 tenths (or 3 to 5 eights) of the sea surface.

P

Pack Ice — (Also called drift ice, ice pack, pack). 1. The term used to denote any area of sea ice other than fast ice, no matter what form it takes or how disposed.
2. A large area of floating ice which has been driven together. The concentration can generally vary between 1 and 10 tenths. Other terms that can be applied to pack ice include: broken, loose, consolidated, and unbroken. The terms pack ice and ice pack have been used indiscriminately for both the sea area containing floating ice and ice itself.

Paleocrystic Ice — Old sea ice, generally considered to be at least 10 years old; it is nearly always a form of pressure ice, and often is found in floebergs and in the pack ice of the central Arctic Ocean.

Pancake Ice — (Also called lily-pad ice, plate ice). 1. Pieces of newly-formed ice, usually approximately circular, about 30 centimeters (12 inches) to 3 meters (10 feet) across, and with raised rims caused by the striking together of the pieces as a result of wind and swell.
2. One or more pieces of newly-formed floating ice, usually between 1 and 6 feet in diameter, with raised rims and circular outline caused by rotation and collision with other ice fragments.

Perennial Ice — Sea ice more than 2 years old.

Permafrost — 1. A layer of soil or bedrock at a variable depth beneath the surface of the earth in which the temperature has been below freezing continuously from a few to several thousands of years. Permafrost exists where the summer heating fails to descend to the base of the layer of frozen ground. A continuous stratum of permafrost is found where the annual mean temperature is below about 23°F.
2. As limited in application by P.F. Svetsov: soil which is known to have been frozen for at least a century.

Polar Ice — (Or polar-cap ice). 1. Sea ice that is more than 1 year old (in contrast to winter ice). It is usually the thickest form of sea ice, occasionally exceeding a thickness of 10 feet.
2. A Russian term for any sea ice more than 2 years old.

Polyna — (Or clearing, ice clearing). 1. A water area enclosed in ice, generally fast; this water area remains constant and usually has an oblong shape; sometimes limited to one side by the coast.
2. Any enclosed sea water area in pack ice other than a lead, not large enough to be called open water. If a polynya is found in the same region every year, for example, off the mouths of big rivers, it is called a recurring polynya. A temporary small clearing in pack ice which consists of small ice floes and brash ice in continuous local movement is called an unstable polynya; an opening which is flanked by large floes and therefore appears to be relatively stable is called a stable polynya. When frozen over, a polynya becomes an ice skylight from the point of view of the submariner.

Pressure Ridge — A ridge or wall of hummocks where one ice floe has been pressed against another.
Ridges may be several miles long and have sails up to 100 feet high. The underside of the ridge is called the keel.

Puddle — (Also called pool, snow puddle on the ice). A small body of water, usually fresh melt water, in a depression or hollow on ice.

R

Rafted Ice — (Also called telescoped ice). Pressure ice in which one ice floe overrides another.

Ram — 1. (Also called spur or apron). An underwater ice projection from an iceberg or a hummocked ice floe. Its formation is usually due to a more intensive melting of the unsubmerged part of the floe.
2. In ice navigation, to charge obstructing ice with a ship.

Ramp — (Also called drift ice foot). An accumulation of snow that forms an inclined plane between land or land ice elements and sea ice or shelf ice.

Ridged Ice — Pressure ice in linear formation.

Rotten Ice — (Also called spring sludge). Ice that has become honeycombed in the course of melting and is in an advanced state of disintegration.

Rotten ice may appear transparent (and thus dark) when saturated with sea water, and thus may easily be confused with newly forming black ice.

S

Shell Ice — (Also called cat ice). Ice, on a body of water, that remains as an unbroken surface when the water level drops so that a cavity is formed between the water surface and the ice.

Shore Ice — 1. The basic form of fast ice. It is a compact ice cover that is attached to the shore and, in shallow water, also grounded.
2. (Or grounded ice). Sea ice that has been beached by wind, tides, currents, or ice pressure. It is a type of fast ice and may sometimes be rafted ice.

Shore Lead — A lead between pack ice and a narrow fringe of fast ice, or between pack ice and the shore.

It may be closed by wind or currents so that only a tide crack remains.

Slob Ice — An accumulation of sludge, so dense as to make the passage of small craft impossible.

Sludge — 1. Spongy whitish ice lumps a few centimeters across. They consist of slush, snow slush, and sometimes of spongy ice lumps formed on the bottom of a shallow sea and emerging at the surface.
2. (Also called slush, cream ice). An accumulation of ice crystals which remain separate or only slightly frozen together. It forms a thin layer and gives the sea surface a grayish or leaden-tinted color. With light winds no ripples appear on the surface.

Snow Blink — (Also called snow sky). A bright, white glare on the underside of clouds, produced by the reflection of light from a snow covered surface. This term is used in polar regions with reference to the sky map; snow blink is lighter than ice blink, and much lighter than land sky or water sky.

T

Tabular Iceberg — (Or barrier iceberg, table iceberg). A flat-topped iceberg showing horizontal firn-snow layers, usually calved from an ice-shelf formation.

Newly formed tabular icebergs have nearly vertical sides and flat tops. In the Antarctic where they are most numerous, tabular icebergs may be tens of miles wide, up to 100 miles long, and as much as 1,000 feet thick with about 100 feet exposed above the sea surface. In the Arctic, the large icebergs of this type are called ice islands, but they are considerably smaller than the largest of the antarctic variety.

Tented Ice — Pressure ice in which two ice floes have been pushed into the air, leaving an air space underneath.

T-3 — (Also called Fletcher's ice island, Drift Station Bravo). A drifting ice island of the Arctic Ocean, probably formed by the calving of shelf ice from Ward Hunt Island in the Canadian Archipelago. T-3 is short for Target 3, so named because it was first observed by radar from aircraft in July 1950. (T-1, originally called Target-X, was first seen on radar in August 1946). T-3 has been occupied intermittently as a scientific drift station since 1952, first by the U.S. Air Force, and since February 1962 by the Naval Arctic Research Laboratory of Point Barrow, Alaska. During the IGY, it was known as Drift Station Bravo. It is also known as Fletcher's ice island after Colonel Joseph O. Fletcher, its first station leader.

U

Unbroken Ice — Sea ice which has not been disturbed since its formation. It is usually fast ice, although a single smooth ice floe could be said to be unbroken ice.

Unconformity Iceberg — An iceberg consisting of more than one kind of ice, such as blue water-formed ice and neve. Such an iceberg often contains many crevasses and silt bands.

Undermelting — The melting from below of any floating ice.

V

Vein — A narrow lead or lane in pack ice.

Very Close Pack Ice — Sea ice whose concentration is practically 10-tenths (8-eights) with little if any open water.

Very Open Pack Ice — Sea ice whose concentration ranges between 1 and 3 tenths (1 to 2 eights).

W

Weathered Ice — Hummocked polar ice subjected to weathering which has given the hummocks and pressure ridges a rounded form. If the weathering continues, the surface may become more or less level.

Whiteout — (Also called milky weather). An atmospheric optical phenomenon of the polar regions in which the observer appears to be engulfed in a uniformly white glow. Neither shadows, horizon, nor clouds are discernible; sense of depth and orientation is lost; only very dark objects can be seen.

Wind Chill — That part of the total cooling of a body caused by air motion.

Winter Fast Ice — 1. Fast ice in fiords, gulfs, and straits, mainly formed by growth from the shore, but also by cementing of pack ice. Winter fast ice rises and falls according to the tide.
2. Fast ice made up of winter ice.

Y

Young Polar Ice — (Also called 2-year ice). Polar ice that has survived its first summer of melting and has passed on to its second year of growth. At the end of its second winter, young polar ice may become thicker than 2 meters (6.5 feet). It differs from 1 year ice in that a greater portion shows above the water surface and any hummocks present show more weathering.

POLAR DIVING OPERATIONS

COMMENT SHEET

This publication will be periodically updated to provide the latest information available on polar diving techniques. Your personal experiences, comments, ideas, and suggestions will assist in this effort.

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