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BUREAU OF YARDS AND DOCKS, WASH., D.C. (NAVDOCKS P-17)

COLD-WEATHER ENGINEERING - CHAPTERS I TO V - AND ADDENDUM

1948-1949 117PP PHOTOS, TABLES, DRWGS, MAPS

ARCTIC REGIONS - CONSTRUCTION PROBLEMS
ARCTIC REGIONS - MAINTENANCE PROBLEMS
ARCTIC OPERATIONS - EQUIPMENT
OPERATIONS RESEARCH

MILITARY OPERATIONS (24)
LOGISTICS (5)

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NAVDOCKS P-17

U. S. NAVY
CIVIL ENGINEER CORPS

COLD-WEATHER ENGINEERING

Chapters I to V

BUREAU OF YARDS AND DOCKS
NAVY DEPARTMENT
1948-1949

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CHAPTER I

THE POLAR CHALLENGE TO ENGINEERS

Aleutians in the Headlines.--The only part of North America upon which the enemy established a beachhead in World War II was Alaska. When news of the Japanese landing on three Aleutian Islands came over the wires in the summer of 1942, Americans began to realize for the first time the military importance of our far northern territory.

Although the Aleutians are in the Sub-Arctic rather than the Arctic, the fogs, wind and miserable cold-wet conditions encountered there offered--as no one remembers better than the Seabees--greater resistance in some respects than the enemy. Nevertheless, the Civil Engineer Corps constructed bases in the Aleutians early in the war and later, in 1944, commenced building a base at Point Barrow in the Arctic proper.

The struggle for the Aleutians--which American naval and military power eventually reduced to a side issue in the great war--brings into sharp focus the vital need for greater knowledge of experience in the Arctic and Sub-Arctic. Since part of Alaska is in the Arctic, it is essential, from the standpoint of national security alone, that the Civil Engineer Corps be thoroughly familiar with cold weather engineering.

Over the Top of the World.--But there is an even more compelling reason for these studies in cold weather engineering. Long range airplanes and acceptance of the fact that the shortest commercial air routes between some cities in America and various centers of population in Europe and Asia pass through or near the Arctic circle have broken down the Arctic barrier.

As a result, that vast, frozen and scarcely known area is destined to become the world's busiest crossroads of international air commerce--and possibly our front line in any future war. The Civil Engineer Corps must know how to build bases in support of this line.

For contrast, it is interesting to consider that only 30 years ago magazine and Sunday supplement writers were speculating on the feasibility of trans-polar traffic "some day." It was an intriguing speculation, but most Americans of that time relegated the possibility to the very dim future. "Sure, it makes good sense on a two-foot globe of the world, but the practical difficulties are too many." Not even stunt flights altered this opinion.

Today, however, the immediate fact is that planes are flying over the North Pole as routine duty, and commercial planes may follow tomorrow. The era of speculation is done. The curtain already is rising on air transport problems over the top of the world that from military points of view offer a down-to-earth challenge to engineers.

Building Anchors for Air Bridges Across the Arctic.--More specifically, you, as Civil Engineer Corps officers, might well consider that you may presently be called upon to build Arctic bases to support strategic and tactical operations. Just as ports are required to serve our network of steamship lanes, so bases will be necessary to anchor the air bridges over the polar wastes. The CEC function will be the same; namely, shore support for Sea-Air Power; but climate and geography are bound to present a host of new problems in the design, construction and maintenance of polar bases.

In addition, you will be confronted by a problem in which you will have an abiding personal interest--how to maintain the health and efficiency of yourself and the men under your command when the bottom falls out of the thermometer. And how to survive in emergencies in cold weather. You will find that polar regions require rigid adherence to an entire new set of rules.

The Aim of this Seminar.--The basic problems in Arctic construction, the changes in mode of life required by polar conditions and the rea-

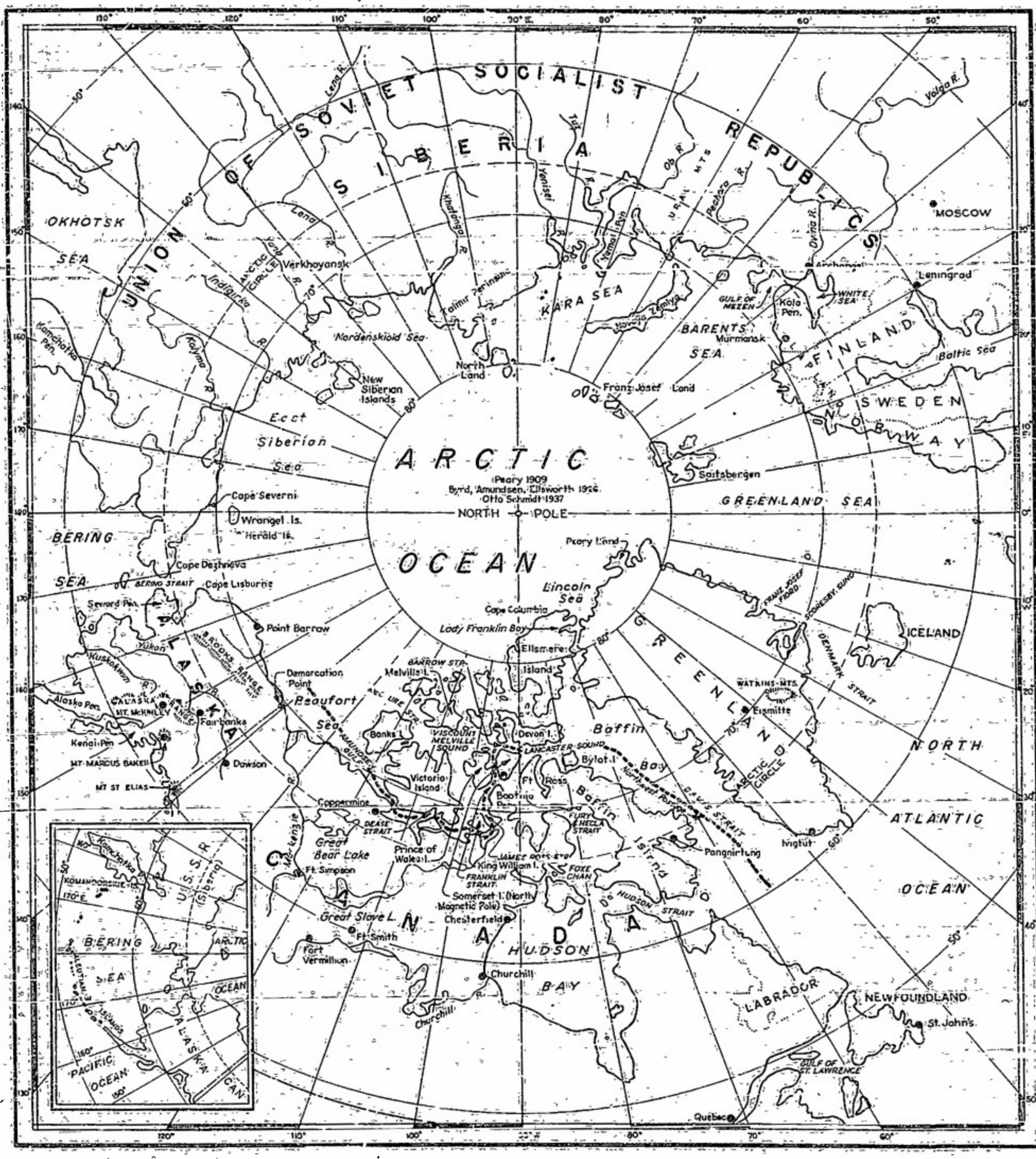

Fig. 1. — Map of Arctic

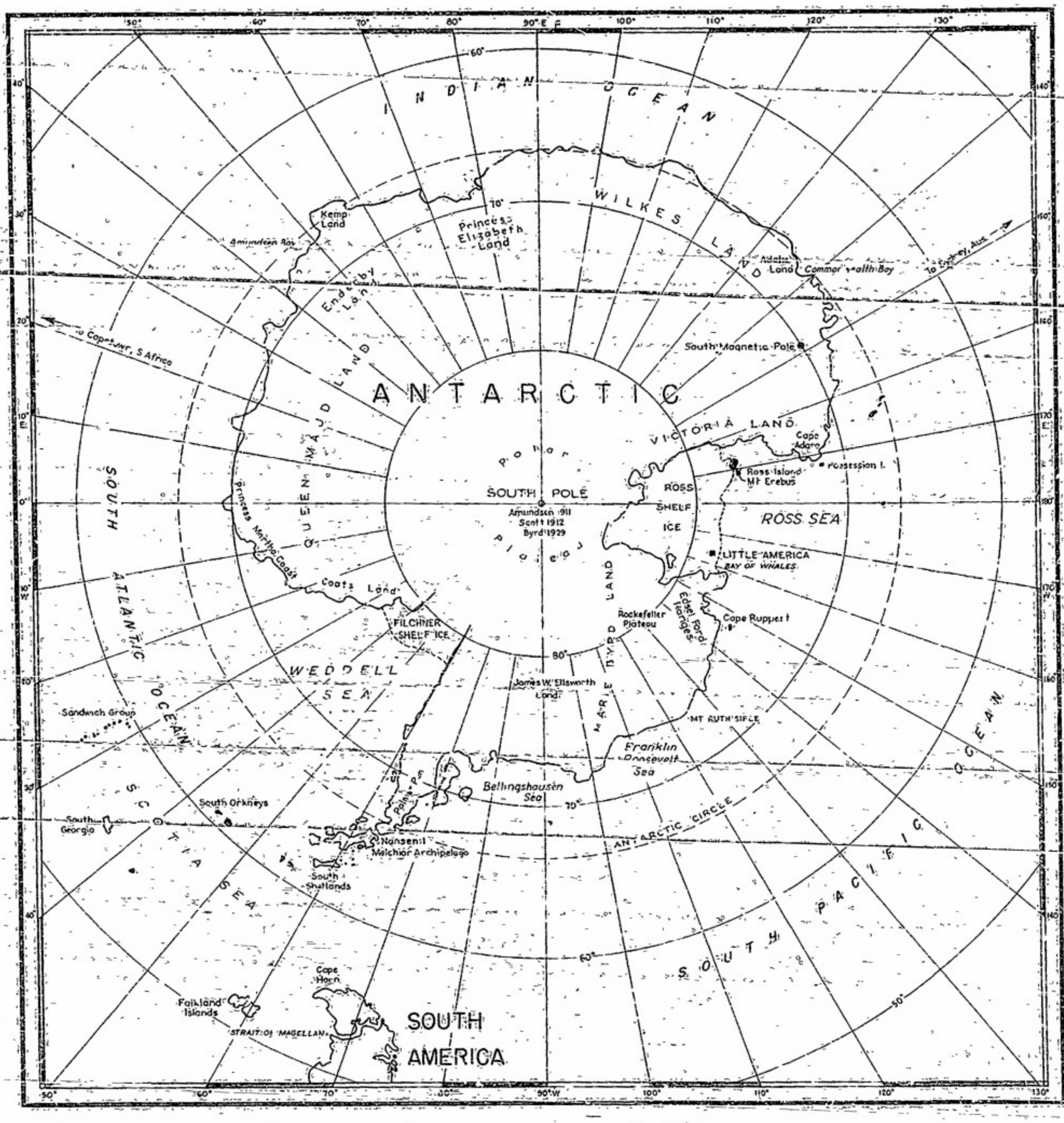

Fig. 2. -- Map of Antarctic

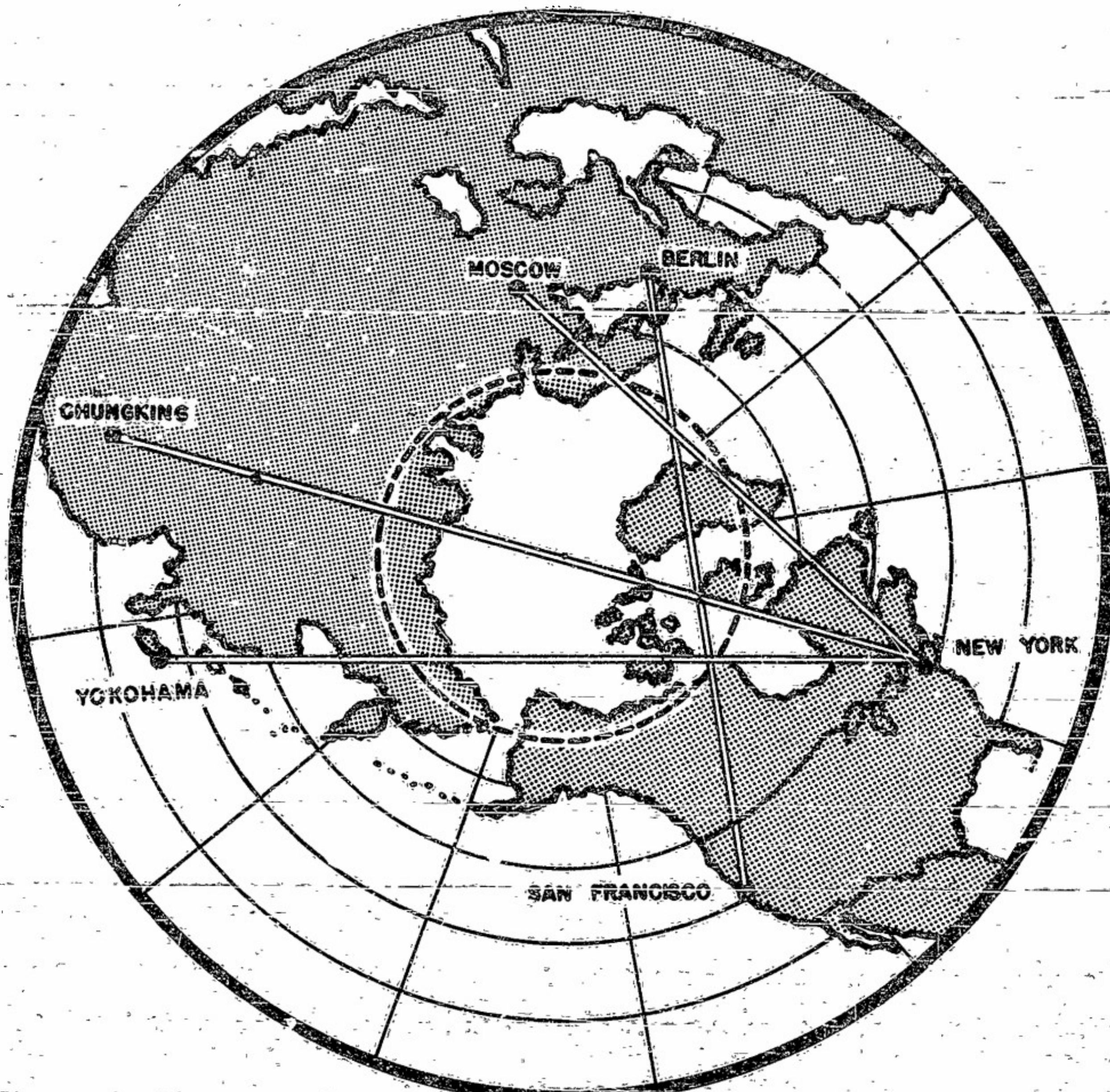

Fig. 3. — Airline Distances

San Francisco to Berlin..............5655 miles
New York to Chungking................7580 miles
New York to Moscow...................4665 miles
New York to Yokohama.................6740 miles

sons for them will be outlined in this course of study. The ten chapters comprising the 1948-1949 seminar review in summary form the best information now available on climate, terrain, engineering, transportation, equipment, living conditions, etc., in the polar regions. It is important to remember the information presented is neither complete nor final. It is only the best that the Navy has at this time. It is based on necessarily limited experience. However, certain principles have already emerged that are unquestionably valid, and many detailed engineering procedures and techniques have already proved successful. These will be described. In addition, a bibliography is offered which will enable you to pursue this study in more detail, if desired.

THE POLAR REGIONS

<u>Practical Guide Posts</u>.--In considering the polar regions, it would be hard to find a field of human knowledge in which the past reveals so many practical guideposts for the present. These result from the stories of hundreds of men--explorers, adventurers, whalers, and more recently scientists--who have from time to time over the centuries reported their findings and experiences. Most of them, however, traveled over limited areas and rarely at the same time, so that it has not always been possible to correlate their findings.

As yet, no truly comprehensive scientific studies of the polar regions have ever been carried out continuously, although there has been a start in that direction.

The first united effort toward scientific study of the Arctic was developed by an international conference in 1879 when ten nations agreed to establish observation stations in the Arctic. The American stations were set up by two U. S. Army lieutenants; Lt. A. W. Greely at Lady Franklin Bay and Lt. P. H. Ray at Point Barrow. Fifty years later, in 1932-33, 44 countries cooperated in establishing stations in the Arctic regions.

In describing the Arctic Research Program of the Office of Naval Research, Dr. M. C. Shelesnyak points out that "there are many empty areas in our scientific knowledge about the conditions of the Arctic. Data have been accumulated with great toil and with heroic effort by small expeditionary forces seeking to explore the North country over the past two hundred years. In the history of exploration of the North country, the United States Navy has played a most significant and exciting role. The names of Admiral Robert E. Peary, Admiral Richard E. Byrd, Commander Donald B. MacMillan, Commander Richard Cruzen, Commander Lincoln Ellsworth and of Dr. Elish Kent Kane, a naval medical officer who led his expedition

Fig. 4. -- Admiral Peary

in search of a lost Sir John Franklin Expedition, immediately make one realize how great has been the role that the United States Navy has played in searching the mysteries of the North.

"We are now at a stage where, realizing our inadequacy of the complete story of the Arctic, we must seek the unknown factors. Many factors affecting man's capacity to survive in the Arctic need study. Some are fundamental and concern the reaction of the body to cold environments and to wind blast; others are related to the proper diets for North country living, and still others are more general in terms of knowing the biological and physical factors which a man may encounter in his sojourn in the North.

"Indirectly related to man's existence in the North is the wealth of data which we must yet find regarding the agricultural possibilities, the geological and natural resources in general, the influence of marine life along the Arctic waters on our own marine life in the east and west coastal waters, the influence of Arctic conditions on radio transmission and reception, the influence of the weather in the Arctic on our local weather, and the general problem of aircraft flight through the Arctic regions.

"The Office of Naval Research is pursuing a program of research to obtain essential data so that the Navy will be in a position to afford those men who are living on or passing through the Arctic regions the best possible protection, and support, and to make life in the North country as truly friendly as it can be when the true North is known. An initial step is to present those facts about the North country as they exist and to make the average person who is unaware of the true North realize that there are many fine features and many friendly aspects of the North country which have been buried in a mass of fable and fiction about the mysteries of the Arctic."

Cooperating in the research program, the Bureau of Yards and Docks has through its activities on Alaska's north coast provided a most practical testing ground for both humans and machines.

Details of oil exploration at Point Barrow will be discussed later, but it is sufficient to say here that experiences of the CEC and BuDocks' contractors' forces on that job are affording an unsurpassed opportunity to develop the "know how" for life and work in the Arctic.

In addition, BuDocks has constructed an Arctic Test Station near Barrow at which our own engineers and Office of Naval Research scientists are conducting tests of a wide variety of materials and machines--ranging from clothing to lubricating oil. And, of course, no better cold weather engineering tests can be run than the actual construction work in progress.

In the Eighth Century, the Norsemen commenced venturing out in Arctic seas in open sailing boats, guided only by the sun, moon, and stars. A legend describes how one party of Vikings headed West with three ravens in their ship. They released one a few days out, and it headed back east. They kept sailing west and released a second raven. It hesitated, then like the first, flew back to the east. Still the Vikings sailed west. Days passed and they released the third raven. It headed west, pointing the way to the Viking's discovery of Iceland. From then on knowledge of that part of the world increased.

Fig. 5. -- Admiral Byrd

EXPLORATION IN THE ARCTIC

First Voyagers to the North.--At about the time Aristotle was meeting with his classes and Alexander the Great was conquering his first world, a Greek named Pytheas sailed out of the Mediterranean and headed into the great unknown. This was a courageous adventure because at that time the Pythagorean school of philosophy had advanced the theory that the earth was spherical with a torrid zone in the middle and two frozen zones to the extreme north and south which were uninhabitable.

He discovered a group of islands where lived the savage Britons who told him of lands farther to the north. They called this Thule (Iceland). We know that Pytheas sailed past Scotland in search for it, but where he landed is uncertain--probably Southern Greenland because he correctly described changes in climate and vegetation. In any event, he got into sludge ice, fog, and endless days in summer and endless nights in winter. He was called a "liar" and his explorations were ignored by the Romans and forgotten for centuries.

The most important of the first explorers were Eric the Red and his son, Leif Ericson. They led the colonization of Greenland where the southern shores offered pasturage for cattle and sheep. Leif went further to a country he called Vineland--probably Newfoundland and possibly New England. Scholars are still debating the subject. But there can be no doubt that the activities of father and son led to the colonization of Greenland. In fact, the colony prospered for three centuries. Towns, churches, and homesteads flourished. Then some unknown catastrophe struck. The colony was wiped out. Nearly two centuries passed, while Greenland drifted into a land of myth and saga.

Commercial Motives for Exploration in the 15th Century.--Exploration of the Arctic was stimulated shortly after Columbus discovered the New World. For it was in the 15th century that the seafaring nations of Europe, principally England, Spain, Holland, Portugal, France, and the Scandinavian countries, commenced a spirited race to find a short sea route to Cathay, the land of spices, silk and gold described by Marco Polo. Columbus went West but other later

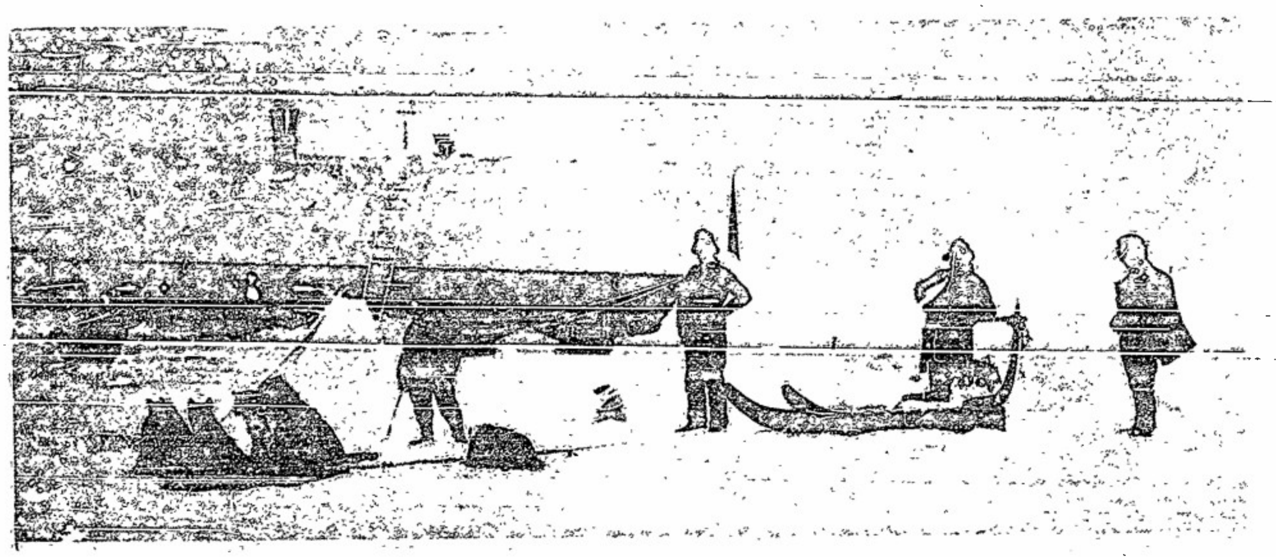

Fig. 6. -- Lt. A. W. Greely and party

voyagers went North seeking a Northwest Passage over the top of North America or a Northeast Passage, skirting the icefields, north of Scandinavia, Russia and Siberia. They did not know that these passages were open only for relatively short periods of the year.

There were other stimulants to Arctic exploration, as well. Whale oil was of tremendous importance to the economy of Europe at the end of the Middle Ages. Not only was it used for light and fuel, but it was the best lubricating oil for the primitive machines of that time. And, of course, the ladies of fashion preferred whale bone to the less pliable steel and wood which they had been using for corsets. And whales were in lamentably short supply, except in Arctic waters. Here they were abundant, but only the most courageous skippers dared to pursue them. This brings up a point worth emphasizing. The whalers were no mere adventurers. They were practical men engaged in a profitable business. Consequently, in their whaling expeditions, they built up a solid knowledge of seamanship in Arctic ice, and also accurately charted areas in the North Atlantic.

In addition to whaling and the search for trade routes, another incentive was the spirit of adventure which poured forth from Europe in the wake of Columbus' discoveries. Explorers who set sail to new lands, claiming them in the names of their sovereigns, were lionized upon their triumphant returns. (It proved in many cases to be a shortcut to becoming an admiral.) Nor were the explorers the only ones to benefit. Wealthy stay-at-homes earned reflected glory by financing expeditions.

The possibility of frozen lands containing natural resources was less a motive of exploration than might have been expected. However, it did play a part. Furs were the principle materials sought, although brief excitement was occasioned when the Martin Frobisher expedition in 1576 brought back some glistening black rock which was first thought to be gold. For this, Queen Elizabet made him both an Admiral and a General. The ore proved worthless, and the approaching Spanish Armada demanded attention nearer home.

One of the most famous expeditions, though ill-fated, was that of Sir John Franklin.

After two voyages to North America in search of the Northwest Passage--during which he had made good progress--this Englishman was put at the head of a major expedition in 1845. His party included 129 men, many of whom were adventurous young sons of leading families in England and, also, the finest officers of the British Navy. Their two ships entered the maze of channels threading the frozen islands to the north of Canada until they reached a point twelve miles north of King William Island where, thanks to a faulty map, they found themselves hopelessly cornered by the pack ice. Three winters held them helpless. Food ran out. The survivors, starving and beridden by scurvy, attempted to march to safety. They never made it.

The search for survivors of the Franklin expedition lasted 11 years and brought to an end, for a time, exploration for commercial ends. Their tradgedy, however, emphasized the need for greater knowledge to enable men to live off the country if necessary, as natives did, in that cold environment.

Discovery of the Northwest Passage.--Other explorers followed, their major concern being to find the Northwest Passage. Stimulating the search were some sizeable rewards offered the first man to find it. One of the promoters ~~in England, for example, was Sir John Barrow,~~ after whom Point Barrow, Alaska, was named. He was instrumental in getting a law passed which would pay 20,000 pounds to the discoverer

Fig. 7. — Lady Franklin Bay

of the passage and another 5,000 to any explorer who could reach 89 degrees N.

The first to discover the passage were two Englishmen whose primary task was to find the missing Franklin expedition. They were Captain Richard Collinson and Captain Robert McClure. They approached from the west and worked east through Melville Sound where their ship was caught in the ice. They took to sled travel and a short time later were rescued by an expedition which had come into the archipelago from the east. The year was 1853.

The first cohesive trip was made more than 50 years later by Roald Amundsen, who earned greater fame for his discovery of the South Pole. Entering Lancaster Sound, he worked his ship down Barrow, Franklin and James Ross Straits to King William Island, thence westward through Dease Strait to Amundsen Gulf.

Northeast Passage Proved More Practical.—Although the Northwest Passage has received the lion's share of romantic interest, the Northeast Passage has infinitely greater practical value. It is navigable during the three summer months, and it is the shortest water route between Soviet ports in Europe and the Far East. It is an important supplement to the trans-Siberian railroad in the shipping of bulk cargoes. And from a military standpoint it has still another significance—in developing and maintaining navigational aids necessary for shipping along this passage, the Russians have gained unequalled experience in Arctic operations.

Modern history of the Northeast Passage dates from the attempt by Sir Hugh Willoughby in 1553 to reach the rich isles of the Indies. He sailed instead into the Arctic winter and his voyage ended at what now is Archangel. From there a lucrative fur trade was established with England. Later attempts were made to push farther to the East, but the frozen Kara Sea proved a major stumbling block for many years.

It was Peter the Great who supplied the impetus for much of the early exploration. He had visited Europe and seen the benefits derived by other countries from whaling and fishing, and he knew, of course, that the opening up of the Northeast Passage would provide an outlet for furs, timber, etc., already being produced in Siberia. Before he died in

1725, he had launched the Great Northern Expedition and placed a Dane, Vitus Bering (after whom Bering Strait is named) in charge. The exploration, begun from the Pacific side, proceeded slowly and carefully, differing from Northwest Passage exploration chiefly in that support and information was available from natives. Bering discovered that Asia and America were separated by water, and he also reached the American continent, although his crew was in such bad shape that he remained there only one day. He died of scurvy before he could get back to civilization.

Others, after years of incredible hardship including battles with hostile tribes, finally mapped the Northeast Passage and gave Russia a true picture of its awe-inspiring coastline.

An explorer-scientist finally accomplished the feat of sailing the Northeast passage. He was A. E. Nordenskiold, a Finn and one of the all-time greats among explorers. Starting from Sweden in 1878 in five boats, he almost made the trip in a single season in the Vega. However, winter caught him 120 miles short of the Pacific, and he had to lay over until the early summer of 1879 to get on through to the Bering Strait.

Discovery of the Polar Current.—A young Navy Lieutenant, George Washington DeLong, set sail from San Francisco in 1879 in the Jeanette. Relying on the Japanese current to carry them up past Wrangel Land, DeLong and his crew planned to go as far toward the pole as possible by ship and then push on by dog team. Winter caught them in the ice and held them there for two years and finally the ice triumphed, crushing the ship. DeLong and his men headed for the nearest shore, Siberia. Half dead they reached the New Siberian Islands, then pushed on to the delta of the Lena river. Here they might have been rescued had it not been for a faulty map which erroneously located a Russian village nearly a hundred miles from its true location. DeLong died, one of the first truly great American explorers. But the broken timbers of the Jeanette sailed on in the ice pack, all the way around the pole and down to the southeast coast of Greenland!

This phenomenon challenged a young Norwegian who was to become one of the most famous of all explorers, Fridtjof Nansen. He was only 23 (and already he had been the first to cross the Greenland ice cap) when he got his revolutionary idea of taking a ship with a specially designed hull into the ice field. His plan was to let the ice freeze around his ship, the Fram, so that eventually it would be forced up on top of the ice. Then, he and his party, supplied for five years, planned to ride the ice cap drift to the North Pole. The daring

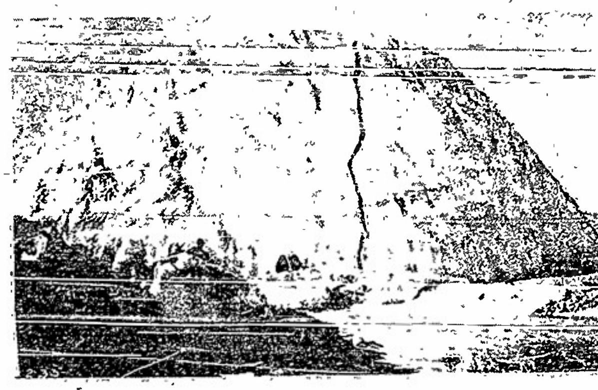

Fig. 8. — Pressure Ice Lady Franklin Bay

of the plan is all the more remarkable when it is realized how scanty was support for the theory of polar ice movement.

It worked. The Fram drifted in a wide circle around the pole and commenced moving south down toward the north Atlantic. When it reached a point about 370 miles north of Franz Josef Land, Nansen and a companion got off on the ice and made a dash for the pole. The drift was too great. At 86 degrees, 13'6" N. they had to turn back. Eventually they reached home as did the Fram and the rest of the crew. And the first intimate study of the drift of the polar pack had been completed

Lessons From History.—It is clear that for centuries men venturing beyond the Arctic and Antarctic circles have come to know, usually the hard way, that survival was essentially a case of man against the elements, and that is exactly what it is today. Yet the lessons which early explorers learned through struggle, starvation and death are the ones which make it possible for modern man to exist and work in the Arctic with complete safety and comparative comfort.

Highlights of early exploration serve perhaps better than any other device to impress upon a student the importance of the rules laid down by frigid climate. That a gallant expedition failed because its members came down with scurvy, that a small party all but died from carbon monoxide poisoning in an air-tight shelter, that brave men died because of an error in deciding whether land or water underlay an ice field—these and many others are the unforgetable lessons which history offers. And while the following sections will hit only the highlights of discovery, a further study which the bibliography makes possible is certainly worth the time and effort.

How Early Explorers added to Knowledge of the Arctic.—Almost a half century before the Pilgrims landed at Plymouth Rock, the voyages made by Martin Frobisher emphasized the need for an improvement in nautical charts and instruments of observation. As a result, the country's best geographers got together with prominent merchants and organized the Northwest Company in 1584. They chose the best navigator they could find, John Davis, for a new expedition. It was a wise choice. Not only did he discover Davis Strait, but he set a fine precedent in his dealing with Eskimos. On his first encounter with them, he ordered his musicians to strike up a tune and his sailors to dance. Thereafter, the Eskimos were his friends--and friends to many a later explorer. He also took time out to list the flora and fauna he observed.

moned enough strength to push open a door.

The story of how survivors of the Barents expedition fought their way in small boats through 1600 miles of ice-filled sea is a stirring adventure, and incidentally, their first act on reaching shore at Lapland offers another tip to modern men; they munched green grass to end their scurvy.

Incidentally, a few years after Barents and others had poked into the Arctic north of Europe, an Englishman named Henry Hudson who earlier, in the ship Half Moon, had discovered the Hudson River and Manhattan Island, was commissioned by a group of Merchant Adventurers

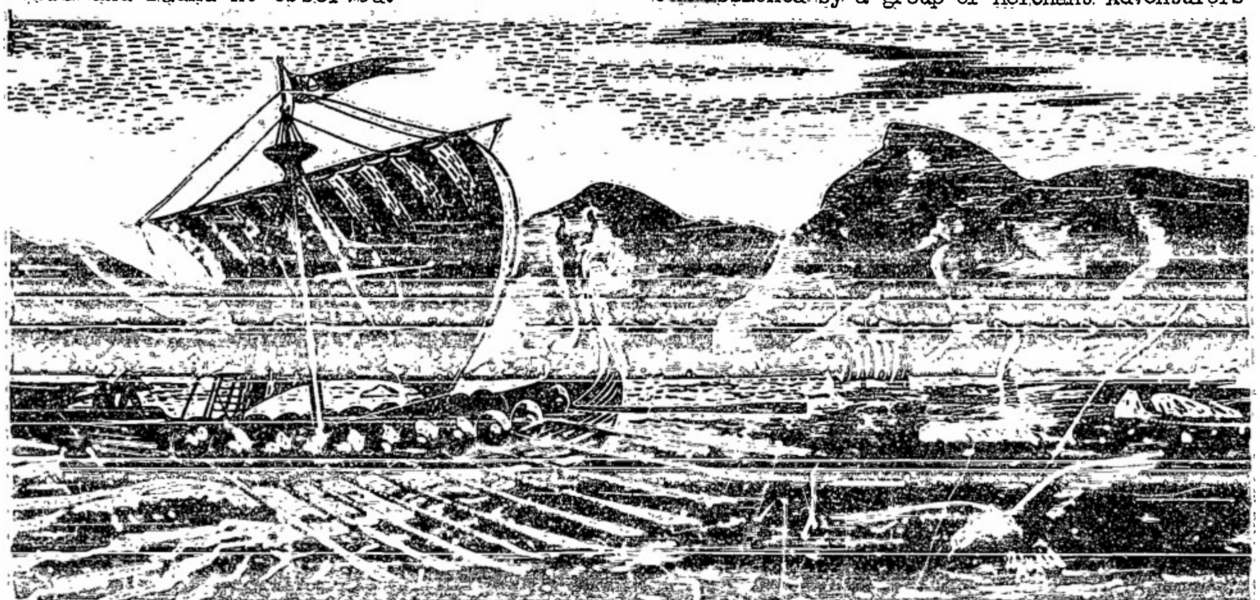

Fig. 9. -- Ancient explorers

But most important, Davis was probably the first of the explorers to appreciate the amount of preparation necessary for a successful invasion of the polar regions. He learned and passed on to his successors the invaluable admonition that patience and caution are imperative to exploration.

Not too long afterwards, in 1596, Willem Barents, the greatest of the Dutch Arctic explorers and discoverer of the Barents Sea north of Scandinavia, contributed another valuable lesson on life in the Arctic. His ship had pushed its way north to the northern tip of Novaya Zemlya when the winter ice closed in, crushing the vessel hopelessly. The men got to shore and built a shelter before the extreme cold set in. They determined to insulate their shelter completely and thereby passed on to posterity one of the most important lessons of cold weather living--the need for ventilation. Carbon monoxide poisoning would have wiped out the entire party had not one of the men sum-

to explore a "furious overfall" which John Davis had reported as emptying into the Davis Strait from the west. Their idea was that if every passageway in North America was explored systematically, sooner or later the Northwest Passage would be found. Hudson sailed up the overfall and entered the bay which bears his name. He never left it. His treacherous crew believing their own chances for survival would be improved by deserting the weak and sick, put them and Hudson adrift in an open boat. An interesting sidelight concerns the ship's carpenter whom the mutineers begged to join them (because of his skill). He declined on grounds that it is better to die than to live among Judases.

Another among the early greats was William Baffin after whom Baffin Bay was named. He was not only a superior seaman but a careful observer and scientist. He was expert also in nautical astronomy and a very practical man. He found that scurvy grass boiled in beer and served with sorrel was a fine antidote for scurvey. It is now recorded what he recommended as an antidote for the antidote.

In evaluating history's lessons, Baffin's significance is that he reinforced the growing conviction that polar exploration needed science more than heroics. And as proof of this point, it was 236 years before any other explorer got as far north in those seas as did Baffin.

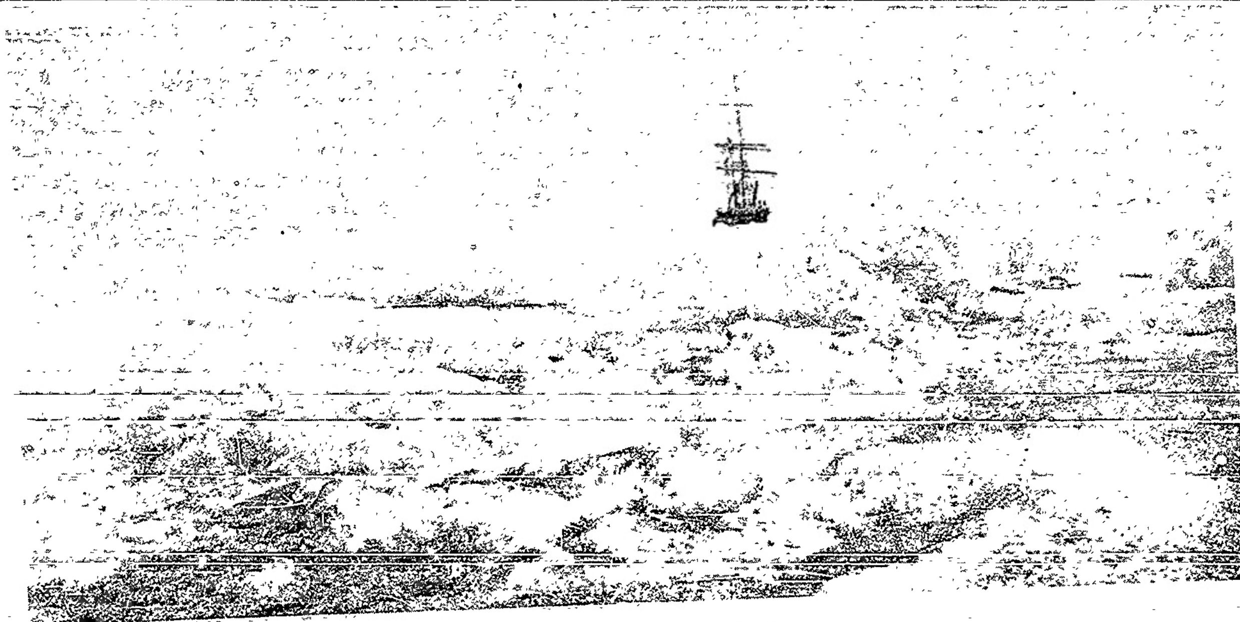

Fig. 10. — Frozen-in for the winter

Attainment of the North Pole.—At the turn of the twentieth century, attainment of the poles became an intriguing sport in which the more adventurous souls in many nations took part.

Unfortunately, since the explorers themselves and the newspaper accounts of their experiences stressed the hardships and dangers of travel in the Arctic and the rigors of life in the far north, a somewhat erroneous picture of life in those regions became fixed in the popular mind and has not yet been entirely corrected.

To illustrate this point consider the following statement taken from the War Department Manual (TM -1-240), Arctic Manual:

"The Arctic region is neither forbidding nor inhospitable. Because of the exaggerated stories of some explorers, it has acquired in minds of many people a wholly undeserved reputation for unlivability. White men settled in the Arctic 500 years before the time of Columbus. And continuously during the last 275 years, resident managers of the Hudson's Bay Company have lived in contentment at permanent posts, many of which are in isolated places. As for the native peoples, scattered evidence suggests that they may have made their first appearance in the North American Arctic as long as 20,000 or 25,000 B. C. At present, the Eskimos are perfectly happy without most of the articles that are considered essential to civilized existence. These people are not an inferior race. Within the limits of their resources they have learned to live in the Arctic more successfully than many so-called civilized peoples in less rigorous climates. Hundreds of white-men-trappers, miners, and missionaries spent their life-times there. They have learned to know the north, to live comfortably in it, and to love it. To be sure, permanent settlement is small, but it has been limited not so much by climate as by lack of natural resources and inadequate communication with the rest of the world.

"These facts should not be interpreted to mean that anyone can live anywhere in the North without forethought, skill and endurance. The Arctic imposes its own natural rules and regulation on its inhabitants, and the secret of success in living there lies in working with rather than against nature."

Admiral Peary and his Contributions.—The later explorers demonstrated a truth which countless tragedies had made increasingly clear—that adequate and scientific preparation achieved results impossible for mere human courage and endurance.

The two, however, were combined in the person of Rear Admiral Robert E. Peary, CEC, USN, who on April 6, 1909 achieved the goal which for centuries had eluded the others---The North Pole.

Fig. 11. — Pressure Ice

In the recent book, "To the Arctic", which Vilhjalmur Stefansson, the famous explorer, described as the best history of northern exploration so far written, Admiral Peary is described as being unique among Arctic explorers. "From his first Arctic trip in 1886 until his eighth in 1908, he labored uninterruptedly toward solving some of the most important Arctic geographical problems. Among Arctic explorers his is a unique nature, a paradoxical combination of forethought and prudence with dash and recklessness, of organizing ability with tremendous physical endurance and patience. Above all, patience, the patience to labor and plan for years, lose everything in a few weeks, and then start in again from the beginning, the richer only for that intangible residue, experience."

Peary's contributions would fill a book-how he learned to adapt himself to the country rather than to fight it, how he profited by befriending the Eskimos and borrowing their techniques, and how he developed to a high point a system of advance supply depots. He also perfected the system of expending the physical strength of his men on an expedition by planned degrees. For example, on his dash for the pole, he used some of his men as early trail-breakers, then when they became exhausted, he sent them back in groups. Thus, he was able to husband the strength of his own last group for the final effort.

While Admiral Peary's success in reaching the pole won him the world's acclaim, his fellow explorers are more impressed by man's patient persistance and courage. Once, he undertook to walk across two miles of rubber ice where an instant's pause was sure death (the man behind him fell through, but Peary didn't pause long enough to look around). Again, on expedition to Northern Greenland, his toes froze, thawed out and left him with raw stumps on both feet, the bones protruding. The Eskimos rescued him. But as soon as his feet healed enough, he was on his way again.

Small wonder the Civil Engineer Corp has made Admiral Peary almost a patron saint!

Modern Exploration of the North Polar Region. The discovery of the pole and the Northeast and Northwest Passages marked the end of the "glamour" era in Arctic exploration. In the last 35 years, emphasis has been on exploring its scientific aspects.

For example in 1906 Vilhjalmur Stefansson, explorer, anthropologist and ethnologist began to study the life of the Eskomos and to learn to live off the land.

From 1926 onward Sir Hubert Wilkins and Carl Eielson contributed much information on polar flying as also, as you will see in a later section did Admiral Richard E. Byrd.

In 1937 a Soviet expedition under the command of Ivan Papanin landed by transport plane at the North Pole with personnel, supplies and equipment and lived on the ice for a period of more than three months. The experience of this expedition, is described in a later chapter.

The various peace-time cold weather operations in the Arctic, as well as research work, which has been carried out by the U. S. Navy serve as other examples but they are related in greater detail in other sections of the course and not therefore summarized here.

Generally speaking, interest has centered on meteorology in view of the fact that the polar regions exercise a dominant influence on weather, particularly in the northern hemisphere. A close second has been the search for natural resources, particularly oil and precious metals. Since the war, of course, uranium has assumed great importance.

Aviation Adds to Polar Knowledge.--The development of aviation has greatly facilitated scientific study of both the Arctic and the Antarctic. Not only were areas inaccessible to ship travel and dog teams opened by planes, but also such phenomena as ice action and currents were observed more easily from the air. In addition, coasts and islands were charted with far greater accuracy.

Aviation, with its power to cover in minutes, regions that previously had required months of foot travel, was not without its adventures. In 1897, Solomon A. Andree, a Swedish aeronaut, and two companions took off from Spitsbergen in a drift balloon. They hoped to guide the balloon by means of heavy guide ropes dragging over the ice. Extreme cold contracted the gas in the balloon, and its occupants were stranded and helpless on the ice field only a short distance from their starting place. It was years before their bodies and last camping site were found. Later, an American, Walter Wellman, built a dirigible which managed to fly 60 miles before being forced down. He was followed by a Russian, Magurskii, who in 1914 managed to fly a hydroplane for a hundred kilometers into the Barents Sea.

After World War I, Lt. Mittelholzer, in 1923, flew several flights over Spitsbergen, and two years later, Lincoln Ellsworth, Lt. Cmdr., USNR, with Roald Amundsen, in two flying boats, reached 88°N. latitude where one of the planes developed engine trouble and both came down in open water. The plane could not be repaired, and ice closed the lead so the other could not take off. Desperately the men worked to flatten out the hummocky surface and, finally, on June 15, they were able to get the plane into the air. When, within sight of Spitsbergen, the controls once more refused to function, they brought the ship down in open water off the coast and were rescued. The following spring, May 1926, Amundsen and Ellsworth, this time accompanied by Umberto Nobile, an Italian aviator, tried again and flew from Spitsbergen to Alaska, in 71 hours, the first to make the trip from east to west over the North Pole, but, not the first to reach the pole. Two days earlier, another member of the U. S. Navy, then Comdr. Richard E. Byrd, had flown from King's Bay, Spitsbergen, to the pole and back, a distance of 700 miles in 16 hours. Ellsworth made another Arctic flight in 1931 as representative of the American Geographical Society on board the Graf Zeppelin. Byrd accompanied MacMillan on his 1925 expedition and then turned his attention to the Antarctic. Nobile, in May 1928, in the dirigible Italia, started once more from Spitsbergen and flew eastward over Franz Josef Land thence north to the pole. On his return, the Italia was wrecked on the Spitsbergen Archipelago but Nobile and most of his crew were saved after being marooned for 6 weeks on the ice. Representatives of 7 nations took part in the search, among them Amundsen, who lost his life in the venture. A Russian amateur wireless operator succeeded in picking up the call for help and a Swedish airman found the party and flew Nobile to safety. On his second flight, the machine was wrecked and the Swedish pilot joined the marooned Italia party. Finally, the entire group was rescued by the Russian ice breaker Krassin.

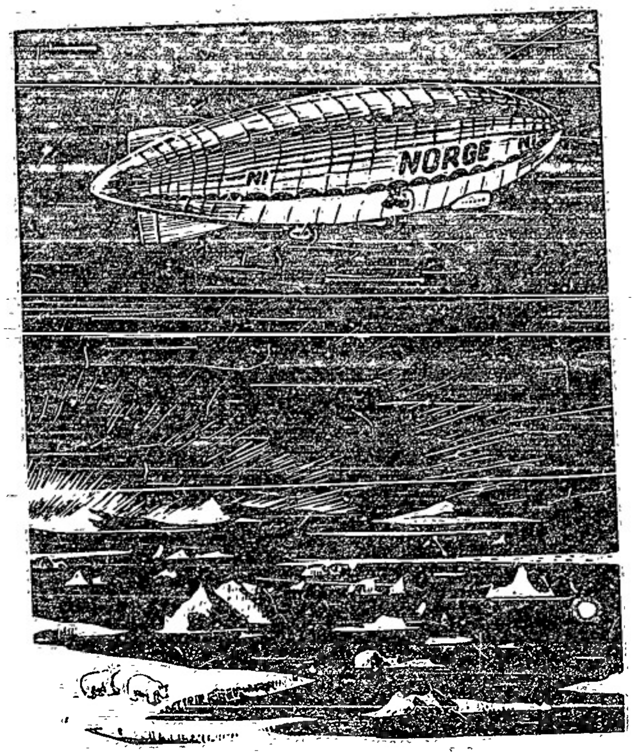

Fig. 12. -- Flight of the Norge

Flying to the North Pole by air has now become somewhat of a commonplace venture. In 1937, the Russians began a series of trips. On 5 May, Golovin flew from Franz Josef Land and returned and on 21 May, aircraft from Franz Josef Land began depositing the Papanin drift party on the ice at the pole. Three other trips were made in May from Franz Josef Land to aid in setting up the Papanin group and in June and July Russian aviators flew from Moscow to the U. S. across the North Pole. In August Levanevski disappeared without a trace between the pole and the U. S. on a flight from Moscow. Thereupon began a search for Levanevski which was carried on into the summer of 1938. On 17 May 1945, V. C. McKinley flew to the pole from Iceland and in the spring of the following year U. S. Army Air Forces made a mass flight from Fairbanks, Alaska. Beginning in March of 1947, the USAAF began regular weather flights to the pole.

THE NATURE OF THE ARCTIC

Modern Definition of the Arctic.--The regions surrounding the North Pole are divided into the Arctic and Sub-Arctic zones. Contrary to popular belief the boundary between these two areas is determined by climate rather than by the Arctic circle which is drawn at 66°30'N. The modern scientific delimitation of the Arctic is that area in which the mean temperature for the warmest summer month is less than 50°

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F., which approximates the tree line or northern limit of the forest. The area in which the mean temperature of the warmest month is higher than 50°F. is considered the Sub-Arctic

Roughly the Arctic embraces in addition to Greenland, Spitsbergen and other polar islands, the northern parts of the mainlands of Siberia, Alaska and Canada, the Canadian Arctic Archipelago, the coasts of Labrador, and the north of Iceland.

The Frozen Sea.--The Arctic Ocean, covering approximately five million square miles, is about one-thirteenth the size of the Pacific Ocean. About two-thirds of this landlocked gulf of the Atlantic Ocean is permanently covered with ice. It is interesting to note that the geographical relationship between the land and sea areas makes it possible to reach the Arctic by overland travel.

The Land Bordering it.--The land bordering the Arctic Ocean is generally flat, marshy, and treeless covered with a variety of plants and grasses known as tundra. The Sub-Arctic on the other hand is heavily forested and quite mountainous in certain sectors.

Most of the tundra and part of the forested Sub-Arctic are permanently frozen a few feet beneath the surface. This condition precludes good drainage in a large part of the Arctic.

The Inhabitants.--While the Arctic is comparatively barren it is not a desolate, uninhabitable wasteland. The abundance of the animal, fish, bird and plant life has supported many tribes of natives for centuries.

The nomadic Lapps, the original people of Northern Europe have thrived for years in the Arctic. The principle source of food is fish, and meat from their reindeer herds. The Samoyedes who follow a similar mode of existence are found further east in Russia and in western Siberia. The chief Arctic people in eastern Siberia are the Chukchee who also herd reindeer as far as the Bering Strait. Available information does not indicate the size of these native populations. However, in the Arctic and Sub-Arctic regions of Canada, Alaska, Greenland, and Labrador it is estimated that there is a total population of 132,000 Indians, Eskimos and Aleutians. This native population is supplemented by numerous white traders, contractors, government officials and missionaries.

The fact that it is possible to live in the Arctic makes the exploitation of the region's natural resources an economic possibility.

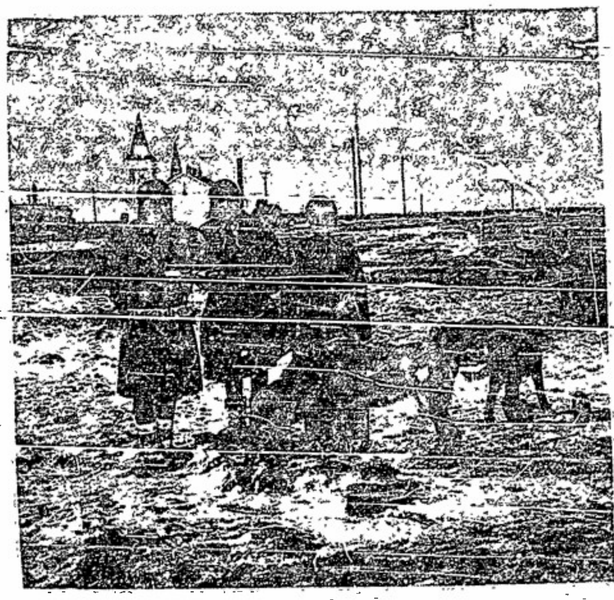


Fig. 13. -- Natives at Barrow

Natural Resources.--Oil has been discovered in many sections of the Arctic and Sub-Arctic. In addition to the U. S. Navy Petroleum Reserve No. 4, private prospectors and large oil companies have staked out oil reserves in Alaska north of the Arctic Circle. The Imperial Oil Company of Canada, a branch of the Standard Oil Company of New Jersey has sunk wells along the Mackenzie River in the Arctic. It is also known that oil exists on Melville Island which is about 500 miles north of the Arctic Circle.

Coal of different degrees of quality has been found throughout the Arctic, and some of excellent quality has been mined for years in Spitsbergen. North of the Arctic Circle, at Cape Lisburne, Alaska, coal was mined before 1885 to fuel the whaling fleets. Today many natives along the north coast of Alaska mine it for their own consumption and for resale to white inhabitants. In addition large coal, apatite, and tin mines are now being operated in the Soviet Arctic.

While there are indications of iron deposits in the Arctic no important ones have been found. On the other hand, copper fields between Great Bear Lake and Victoria Island are quite extensive. Gold, silver, and platinum also are present in the Arctic.

The most abundant natural resource in the region is the rich vegetation. Grasses and plants flourish in the region, providing adequate fodder for approximately five million caribou, or reindeer, in Alaska alone. While the exact count is not known, it is estimated the Canadian Arctic and Sub-Arctic are capable of supporting thirty to forty million head of this animal, which is such a valuable source

Fig. 14. — Seabees at Point Barrow

of food and clothing. On that basis the reindeer areas in Asia and Europe are probably capable of feeding twice as many head as the combined Alaskan and Canadian regions. Moose and musk ox, though not as numerous as the caribou, thrive on the natural vegetation in the Arctic and Sub-Arctic.

In addition to this food producing vegetation, another important natural resource in the Sub-Arctic is the coniferous forest that extends north of the Arctic Circle. In some places the trees are over 100 feet high. Some authorities claim that the area would be more valuable without the trees because then it would be covered with grass and plants and provide additional fodder for the caribou herds.

The Importance of the Arctic.--In terms of ship and train travel, we think of China or Siberia as being east or west of the United States. With the advent of long range airplanes, however, we now think of these Asiatic countries as being located to the north. This reversal in thought can be attributed for the most part, to the fact that the shortest air routes to these distant points pass over the Arctic. For example, the shortest shiproute distance between Yokohama, Japan and New York is approximately 11,169 miles, while the air line distance between the two points over the Arctic is only 6,740 miles. Similarly, the plane mileage between Moscow and New York is 4,665 miles. As to time consumed in traveling by ship or plane the difference is obviously much greater.

Flight operations "over the top" were not feasible in the past because of the vast expanses of relatively unexplored territory, the absence of satisfactory landing places, and the rugged weather conditions. Now, with the development of planes with greater cruising range and suitable electronic equipment, the Arctic is no longer an impregnable barrier. In fact, the Arctic is well on the way to becoming one of the busiest air lanes in the world.

In this respect it must be realized that the security we once derived out of our geographical isolation diminishes each day. The vulnerability to attack from the north and the likelihood of the Arctic becoming our first line of defense give cause for serious thought and require appropriate planning and research.

Of equal importance to the geographical position of the Arctic is the mineral potentiality of the region. Its natural resources become increasingly valuable as our stateside deposits and stockpiles dwindle under greater demands.

It is interesting to note that approximately 45% of the area within the Arctic Circle is claimed by Russia. Since shortly after the Bolshevik Revolution of 1917 the Russians have been conducting scientific research in the Arctic in an unprecedented manner. Their efforts were directed towards mastering the Arctic Sea Route from Bering Strait to Barents Sea, developing the Soviet Arctic economically and exploiting the natural resources.

That the Russian ship "Sibiriakov" was the first to conquer the Arctic Sea Route, after sailing from Archangel to Bering Strait 28 July 1932 to 1 Oct. 1932, within one navigating season, was due largely to the network of meteorological stations and navigational aids that had been erected by the Russians. The importance of such stations in determining the influence of weather on both the Arctic and the regions to the south cannot be overstressed. The Russians realized this only too well and, as early as 1935, they had 72 stations engaged in studying and reporting on all phases of the Arctic. There is good indication that the total number of stations maintained there has long since been increased.

DISCOVERIES IN THE ANTARCTIC

"Fit for Neither Man nor Beast."--Because of the remoteness of the Antarctic from the centers of civilization, extensive exploration was delayed until comparatively modern times. Certainly, the earliest explorers contributed little to our knowledge of cold weather living.

The ancient Greek philosophers had predicted cold lands to the far south, but not until Prince Henry the Navigator, in 1418, encouraged his sailors to reach India by sailing around the Cape of Good Hope did Europeans obtain their first verification of the frigid lands in the south. It was 1772 before the Antarctic circle was crossed. This was achieved by Capt. James Cook who proceeded only far enough to convince himself that if land lay farther south it was fit for neither man nor beast. This opinion was shared by the Seabees on "Operation Highjump" 175 years later.

Following Cook's voyage, whalers and sealers poked into the far southern waters, and Fabian von Bellingshausen, an explorer sent out by Russia, managed to cross the Arctic circle at three different places. The English and French, too, reached as far as the ice barrier.

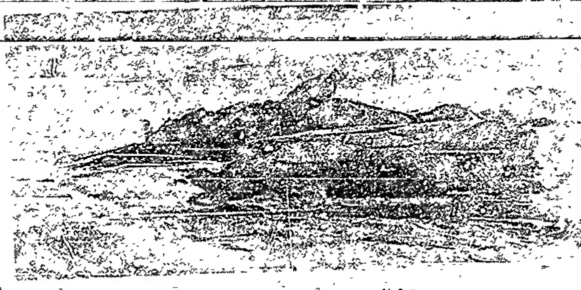


Fig. 15. -- Ice ridge

It remained for a United States Navy officer to discover that a continent lay behind the impenetrable ice. He was Lt. Charles Wilkes who headed an American Antarctic exploration expedition authorized by Congress in 1836. There can be no doubt that Wilkes saw land along the line where Adelie Land, Kemp Land, and Enderby Land are known to exist. On the basis of Wilkes' discovery, the United States would have been able to claim Antarctic. However, we have not yet officially claimed any of the territory nor have we recognized claims of other countries.

Another of the outstanding early Antarctic explorers was Capt. James Clark Ross of the British Royal Navy. He took formal possession of the continent for Queen Victoria by landing on Possession Island in 1841. Not only did he encounter the continental barrier, but he also reached the most southerly latitude attained for 60 years.

There followed expeditions by Norwegians, Belgians, Germans, Scots, Swedish, French and Australians. Among the most tragic of these were the trips made by Capt. R. F. Scott who left England in 1910 with the object of reaching the South Pole. About the same time, Capt. Roald Amundsen departed for Antarctica in the same ship, the "Fram", in which Nansen made his famous North Pole voyage. Amundsen originally had planned to try for the North Pole, but because Adm. Peary already had achieved the feat, Amundsen, secretly, struck out for the South Pole. With four companions on skis and 52 dogs, he reached the pole on 14, December, 1911. Only a matter of days later, on 18 January, 1912, Scott and his party also reached the pole, but died on the return trip to their base.

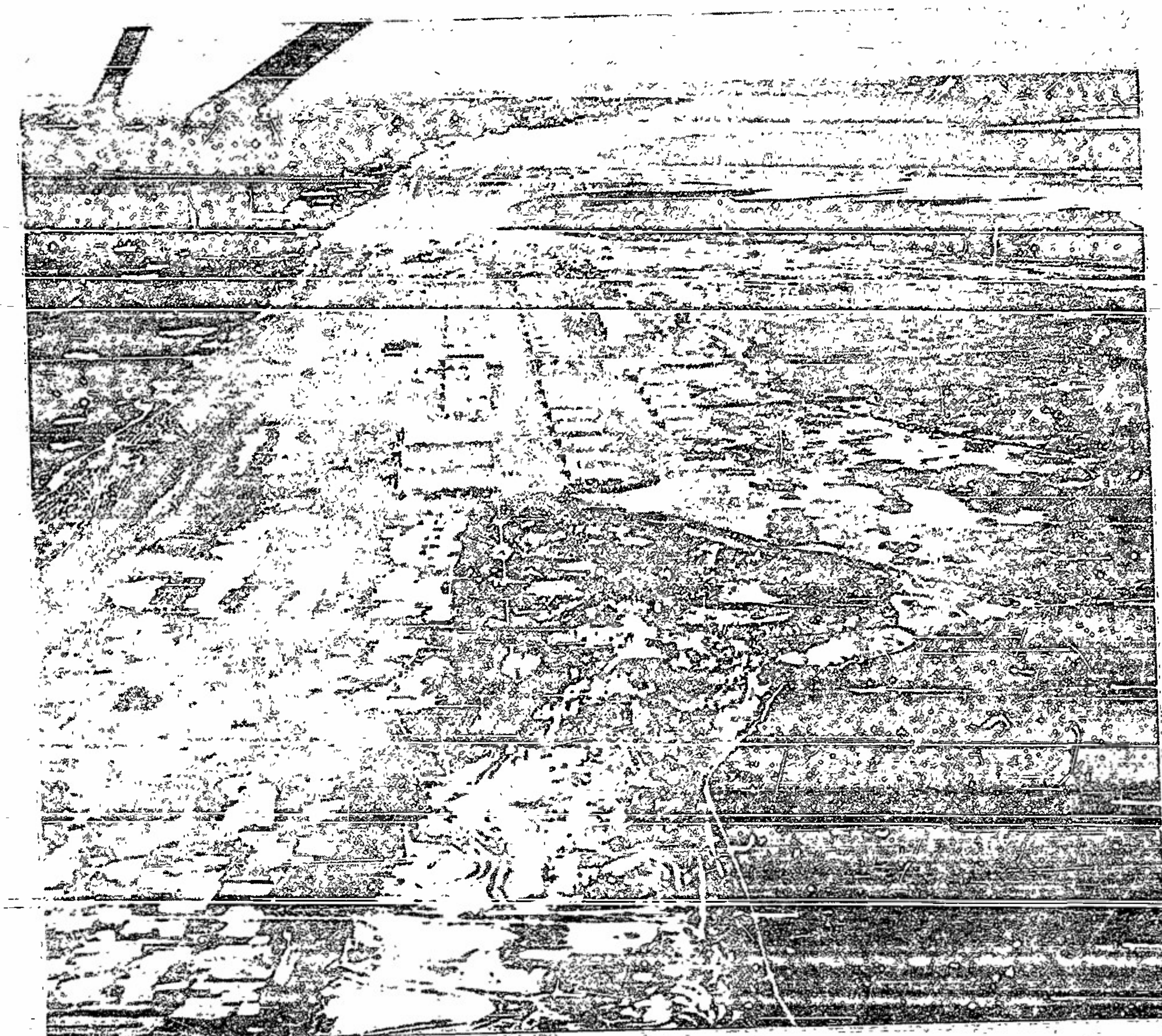


Fig. 16. — Point Barrow

Recent Scientific Expeditions to Antarctica. The Antarctic expeditions led by Rear Admiral Richard E. Byrd, USN, dominate the recent exploration of that continent. His first expedition was begun in 1928 and resulted in the setting up of a base at Little America from which scientific studies were conducted.

Planes left this base on the Ross barrier to explore to the south and east, seeking to map the great mountain ranges which border the Ross Sea. Secondary to the scientific exploration was the first flight over the South Pole. This was achieved by Admiral Byrd, Bernt Balchen, Capt. A. C. McKinley and Harold June in a tri-motored plane on 28 November 1929. A sun compass was used to determine the exact location of the pole, and the flight was completed in slightly under 19 hours.

Admiral Byrd led a second expedition to Little America in 1933-35. He extended his explorations over what he named Marie Byrd Land. The most dramatic accomplishment of this expedition, however, was Byrd's winter-long vigil, alone, at an advance weather base 123 miles south of Little America. This made possible the first meteorological observations in the continent's interior.

Again in 1939-40, the Admiral led another expedition in which extensive geographical explorations were conducted as well as scientific study in the fields of geology, meteorology,

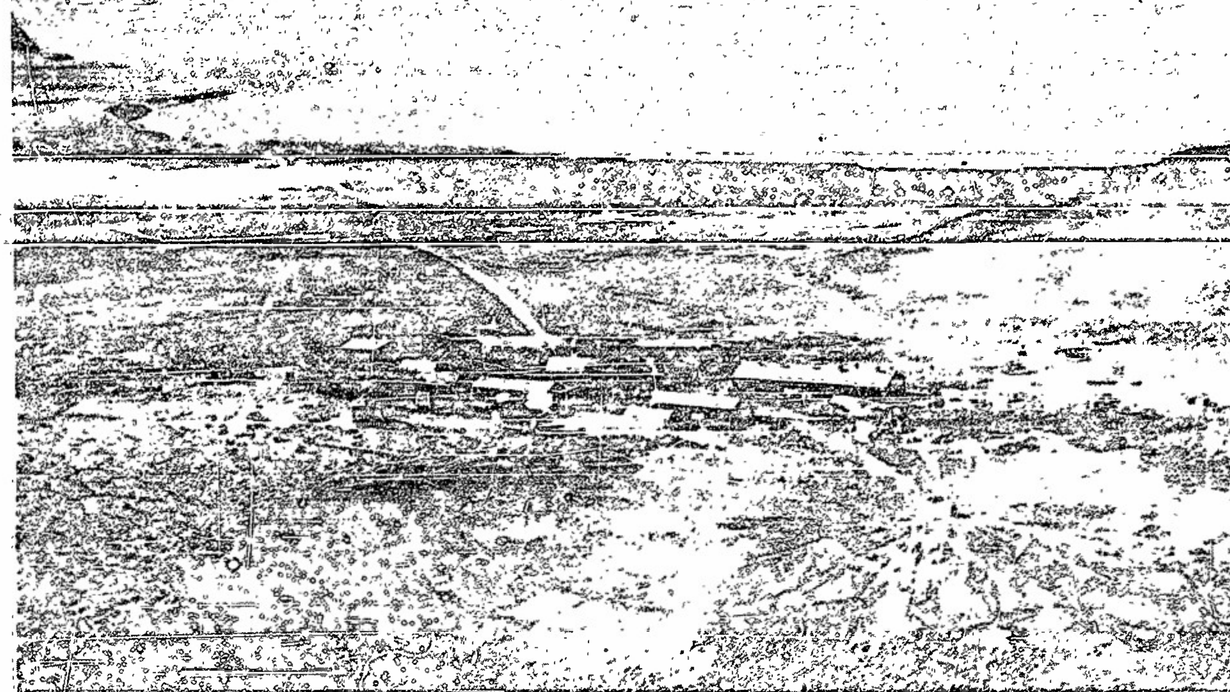


Fig. 17. — Army installation, Greenland

botany, glaciology, terrestrial magnetism and oceanography.

Other nations, too, have been taking a livelier interest in the scientific features and the real estate of Antarctica. For example, since 1943 the British have had year-round stations in the Palmer Peninsula area. Manned by small staffs, they send weather and whaling reports to ships in the area. Semi-permanent stations in the general area have also been set up by the Chileans and Argentines. Argentina has had one in the South Orkneys since 1904, as well as two lighthouses in the Melchior Archipelago. The Chileans put theirs in the South Shetlands.

Political Claims to Antarctica.--Altogether seven countries have laid claim to slices of Antarctica: Great Britain, Australia, New Zealand, Argentina, Chile, Norway and France. Their claims are based on discovery and exploration, and efforts have been made to bolster them by such administrative devices as appointing magistrates and issuing whaling licenses.

The United States, despite the early voyages of Lieutenant Wilkes and the subsequent exploration of such explorers as Admiral Byrd, has made no official claim. On the other hand, we contend that sovereignty requires more than mere discovery, that it must be followed by occupancy and use.

From a practical standpoint, however, Antarctic claims are all pretty much on paper. Real estate down there is likely to continue at the icy bottom of the world market. As one Seabee on the Highjump expedition expressed it: "If this is Little America, all I want is 'Big America'."

THE NATURE OF THE ANTARCTIC

Unlike the Arctic, the Antarctic is determined by geographical boundaries and includes, roughly, that area of the globe encircled by the 60th south parallel.

The Antarctic Continent, comprising some five million square miles, occupies practically all of this area. The remainder is taken up by the continent's coastal waters. It is interesting to observe that the Antarctic continent approximates the size of the Arctic Ocean.

Rather than indicate the areas claimed in Antarctic by the expeditions of ten different nations, it is believed more practical arbitrarily to divide the continent either into quadrants, working clockwise from Greenwich meridian, under the names Enderby, Wilkes, Ross, and Weddell, or into three sectors known as the Atlantic, Pacific and Indian according to the ocean on which each sector borders.

The oceanic moat that isolates the Antarctic from the great continents of the world is over 600 miles in width at its narrowest point. In crossing this natural barrier, some of the world's roughest seas and fiercest winds are encountered. The roaring forties, howling fifties and screaming sixties are choice descriptions of the weather conditions that exist in the respective latitudes surrounding the Antarctic. Sea ice that reaches a thickness of seven feet in winter and immense tabular icebergs over twenty five miles in width increase the hazards of the approach to the South Pole.

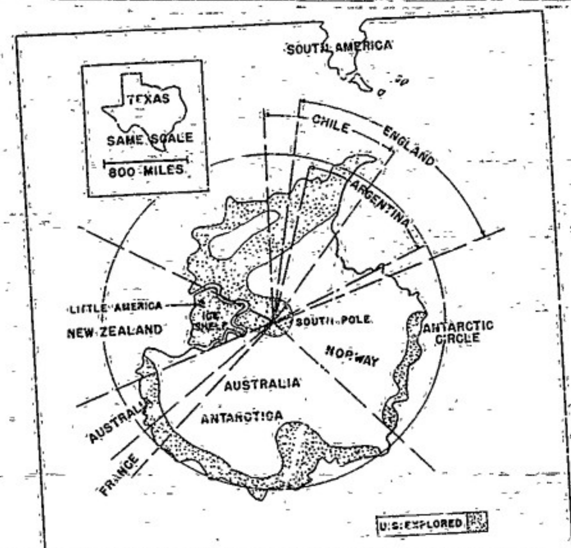


Fig. 18. — International claims, Antarctic

The Antarctic continent is characterized by its icy desolation. The cold climate of the region, where even in summer the mean temperature rarely rises above freezing, is chiefly responsible for the permanent ice cap that covers all but approximately one hundred square miles of the total area. Although the data is incomplete, it is believed that under the permanent ice cap, which is two thousand feet thick in places, the continent is a continuous mountainous plateau with an average height of six thousand feet. The South Pole, which is almost in the center of the continent, is located on a plateau, approximately ten thousand feet in height. It has been estimated that there is enough ice in the Antarctic to cover the entire globe with a one hundred and twenty foot layer.

While there are small quantities of tiny lichens, moss and grass to be found in the Antarctic, that is practically the extent of life. The continent does not have any human inhabitants; trees and brush are non-existent, and the largest land animal is not larger than an

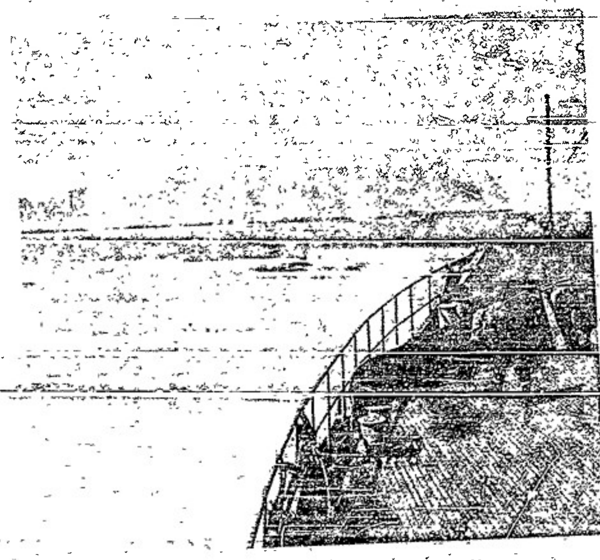


Fig. 19. — Iceberg sighted

insect. Seals, whales and penguins do, however, thrive in the coastal waters.

Deposits of coal are known to exist in the Indian sector and have been found as close as three hundred miles to the South Pole. The rigorous climate, however, opposes the economic exploitation of the ore. Practically the only industry that exists in the Antarctic is whaling which, since 1900, has increased rapidly in importance.

THE IMPORTANCE OF THE ANTARCTIC

The icy fortress of the Antarctic, because it resists colonization so strenuously, is of far less military importance than the

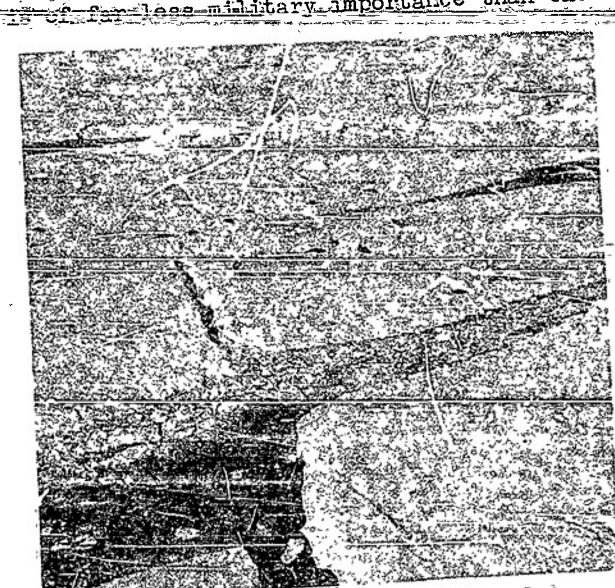


Fig. 20. — Seals on ice

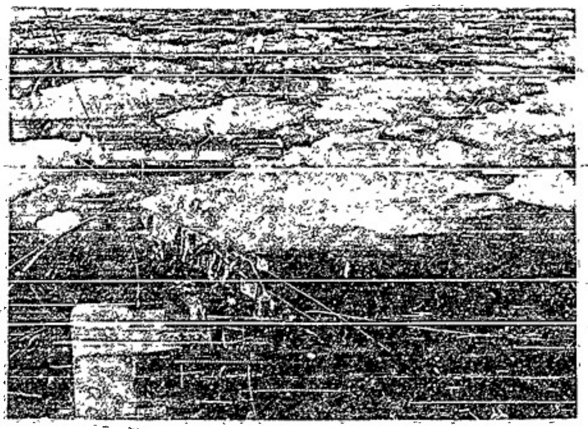


Fig. 21. -- Ice pack encountered

Arctic. At the present time, it is not considered that the air routes over the South Polar region can or will be used to decrease traveling time between the three bordering continents. Neither is it possible to visualize any extensive land or sea maneuvers of a military nature during the short period in which it is physically possible to operate in the Antarctic. For the same reason as has been pointed out, the prospects that the mineral deposits in the region will become economically valuable are somewhat remote.

While the Antarctic conti ent does not, at present, play an important role in our economic or political structure, its coastal waters are a natural refuge for whales and other forms of marine life. The whaling industry in the Antarctic has been a lucrative one since the turn of the century, and to prevent the wanton slaughtering of the species is an international problem.

CEC RESPONSIBILITY IN THE POLAR REGION

In Peace and War.--The responsibility of the Bureau of Yards and Docks and the Civil Engineer Corps in both war and peace is to provide the shore support required by the Fleet in accomplishing its assigned missions. This support calls for the design, construction and maintenance of the shore establishment and the construction of advanced bases.

BuDocks Research Personnel at Point Barrow. Since 1944, the Bureau of Yards and Docks has been actively engaged in making contributions to the Arctic program. On March 21 of that year, on instructions from the Secretary of the Navy, the Bureau sent a reconnaissance party of four officers into Naval Petroleum Reserve No. 4 to investigate problems which would be encountered if a drilling program for oil were to be undertaken. In June, 2 officers and 5 enlisted men were flown to the Reserve headquarters at Point Barrow, Alaska, to make further surveys on which to base the choice of drilling locations. In August, CBD 1058, a petroleum unit consisting of 181 men and 15 officers disembarked at Barrow with 8000 tons of drilling and Arctic equipment. The detachment carried with it sufficient supplies to maintain operation without reinforcement for a 12-month period. Contact with the outside world was maintained by plane and radio. Work was immediately begun on the erection of a camp for shelter, and on the construction of an airstrip for the Naval Air Transport Service which was to serve the operation.

Since that time work has continued steadily. Present plans call for continued exploration for oil through 1950. Point Barrow also

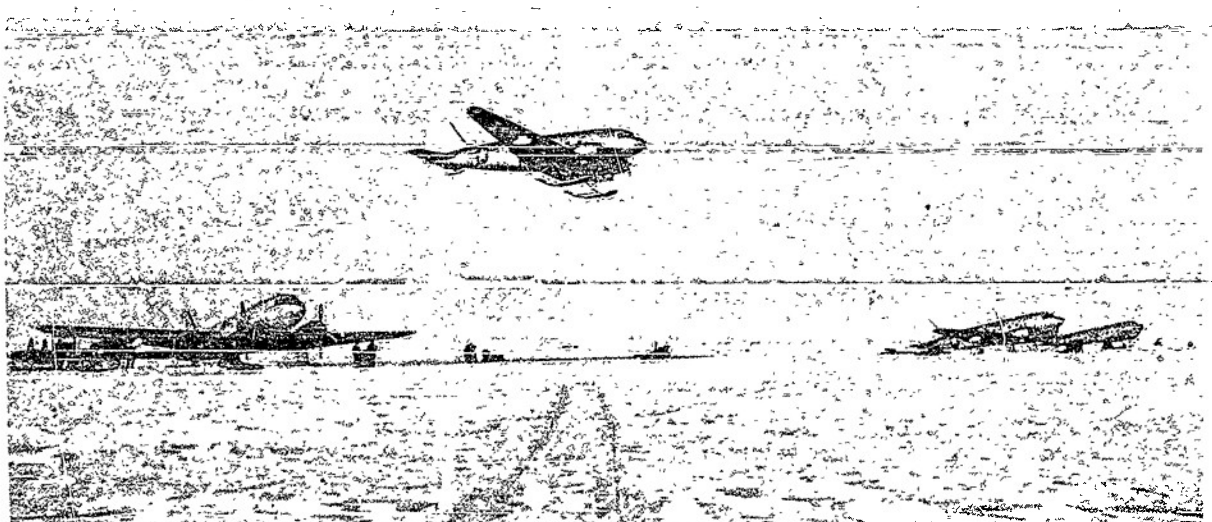


Fig. 22. -- R4D about to land

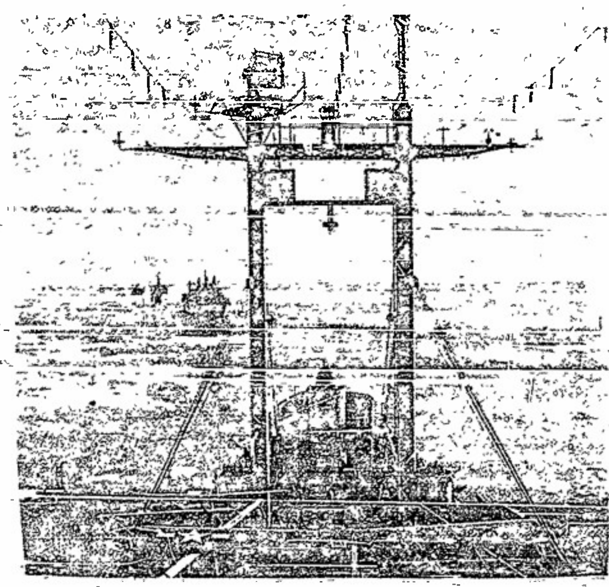


Fig. 23. -- Approaching Antarctica

is being used as a test station for Arctic equipment. Various Arctic practice operations have been carried on since the war. In the winter of 1945, the 4th Canadian Army winter exercises, Operation Musk Ox, had two United States naval observers.

Seabees Participate in Operations-"Frostbite" and "Frigid".--In the spring of '46, the Carrier "Midway", off the east coast of Greenland, tested planes and clothing in Operation "Frostbite." In the summer of '46, a group of 20 Seabees and 3 CEC officers aided in Operation Nanook. It concentrated its operations around Baffin Bay and the adjacent waters. In the winter of '46-'47, Operation Frigid was held in the area of Fairbanks, Alaska, and Operation Williwaw tested equipment in the Aleutians. These last two operations were conducted by the Army, a representative of the Bureau of Yards and Docks being a member of Operation Frigid. BuDocks was not represented on Operation Williwaw.

Seabees take Part in Operation "Highjump".--A Seabee detachment accompanied the Antarctic expedition headed by Rear Admiral Byrd, Task Force 68, known as "Highjump". It formed the nucleus of trained enlisted and officer personnel for unloading, construction and maintenance operations, and for gathering scientific and technical data on such work under conditions of extreme cold.

Liaison was established with CNO through CEC officers who accompanied the expedition, and full engineering and technical assistance was extended by the Bureau in working out logistic and special technical material requirements of the expedition. Numerous special devices and techniques were developed for winterizing on-and-off-the-road equipment, involving heated cabs, extended treads to reduce unit bearing load, and preheaters to make starting of engines possible under sub-zero conditions. Other special devices, fabricated at the Advance Base Depot, Port Hueneme, California, or procured elsewhere included various types of snow compactors for use on the roads and landing strips, bridges for spanning crevasses in the ice, heavy cargo sleds for moving equipment, ice saws, snow melters, and special modifications for living quarters. Sled dogs also were procured. Various testing devices were furnished for checking bearing power of the snow in its original state and under various degrees of compaction. As a result of experimental work, carried out on stabilizing landing strips on snow, much useful technical data was secured.

From their experience, the two ranking Civil Engineer Corps officers on Operation Highjump, Commander Paul D. Davis, CEC, USNR, officer in charge of the Seabees, and Commander Charles O. Reinhardt, CEC, USN, staff liaison officer, concluded that Seabee units engaged in polar work in the future should be "tailored" to the minimum size required for the job and that versatility in the individual members of the unit, rather than the unit as a whole, should be sought. Supply difficulties in a frigid climate very soon bring about "diminishing returns" as the number of men increases, according to their observations.

Not only is the supply situation critical, but opportunities for recreation are so limited that high morale can be maintained only by keeping men busy.

On the Highjump expedition, 166 Seabees participated, including 26 World War II veterans, 20 Seabee fledgings, and 120 general service men. Their assignment was the unloading of equipment and supplies, and the setting up of a temporary naval base, complete with housing (decked tents), a mess hall consisting of

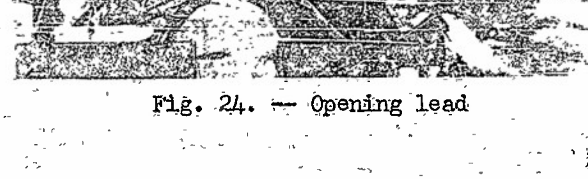


Fig. 24. -- Opening lead

interconnecting tents, and storage facilities. They also built a temporary airstrip and an emergency base including communications.

BuDocks Contribution to Operation "Task Force 68".--In support of two operational moves to Greenland made by Task Force 68, BuDocks at the request of CNO supplied equipment and repair parts for this expedition which furnished logistic support for the United States Weather Bureau and the Strategic Air Command, U. S. Army Air Forces, along the coast of Greenland. Certain critical repair parts required for the unloading operations were sent to Thule, Greenland, by air, and other equipment and supplies were delivered to ships of the Task Force at Boston.

The Mobilization Plan.--The next war will, in all probability strike with less warning and nearer to the heart of our country than did World War II. To repel such an attack and to launch a counter offensive will require almost instantaneous mobilization.

The backbone of the present mobilization plan is the Officer Qualification and Selection Program promulgated by the Bureau of Naval Personnel. This program is based on the premise that as a requirement of effective mobilization and as a need of modern war, officers must be detailed into billets for which they will require no training or for which they will require minimum training.

To accomplish these objectives, officers must be assigned to active Navy billets which are counterparts of the civilian field in which they are most proficient or, at least, to billets within related job families. Getting the right man for the right job will not only reduce training to a minimum, and save time, money, and effort, but it will also increase morale.

The Bureau of Naval Personnel maintains a current record of the qualifications of all Reserve officers through the medium of the Reserve officers annual qualifications questionnaire (form Nav Pers-319). These questionnaires, reviewed annually, reflect any changes in the officers' usefulness to the Navy. Training, advance in age, business experience, education, length of separation from Naval activity, and physical condition are pertinent factors in selecting the proper assignment. While the information collected during World War II provides a firm basis for future utilization of personnel, it becomes less valuable as each year passes. It is important, therefore, that all Reserve officers complete and submit annual questionnaires which will indicate their greatest potential.

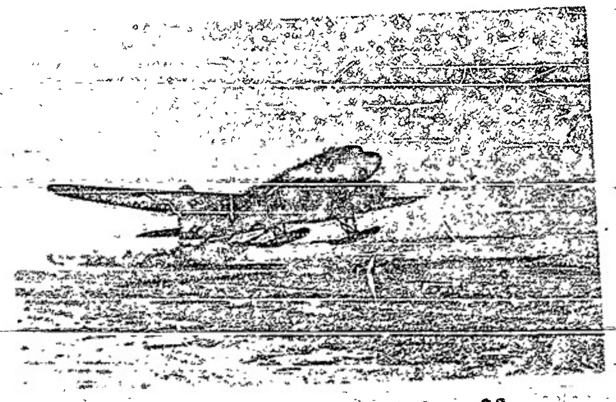


Fig. 25. -- Antarctic take-off

How It Will Work.--Under the present program the task of order writing has been decentralized to spread the work load and to obtain the maximum security in the event of a catastrophe or enemy action. At the present time, Naval Districts have been assigned the responsibility of writing mobilization orders for inactive officers.

Naval Districts have received from the Bureau of Naval Personnel, qualification cards on all officers residing within the District. Based upon the submission of annual questionnaires these qualification cards can be kept up-to-date.

When mobilization becomes imminent the Naval Districts will be advised what qualifications the officers they are to order to various activities must have and the time they are to report on board. This will be accomplished by means of a Mobilization Billet card which will be forwarded by the Bureau of Naval Personnel for each billet to be filled. With these cards on hand the various Naval Districts can, with little difficulty, line up the qualified reserve officers. Electrically operated tabulating machines can rapidly extract any desired pattern of qualifications. It is possible, for example, to select, in a very short time, the cards of all lieutenants who are graduate civil engineers, can speak Chinese, and have had construction experience, under air, in tunnels.

The determination of the Navy's overall requirements in the event of mobilization will be made by the Chief of Naval Operations as the result of inter-Bureau planning. The number of construction battalions required to implement the Fleet in the prosecution of a war will depend on the type and size of the operations and the needs of other bureaus.

At present, the plans of the Bureau of Yards and Docks call for existing Organized Reserve units to be expanded to battalion size. To do this will require utilization of members

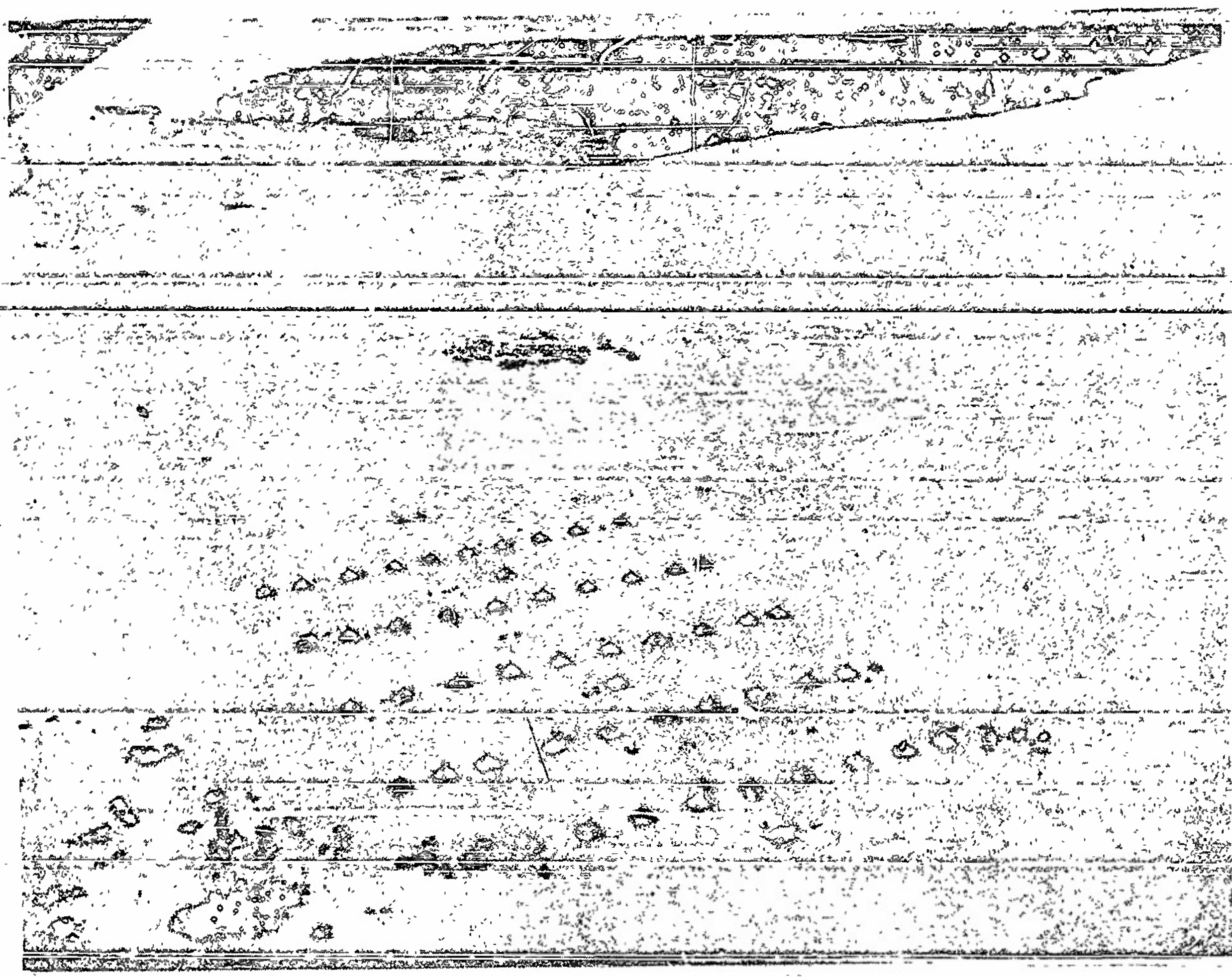
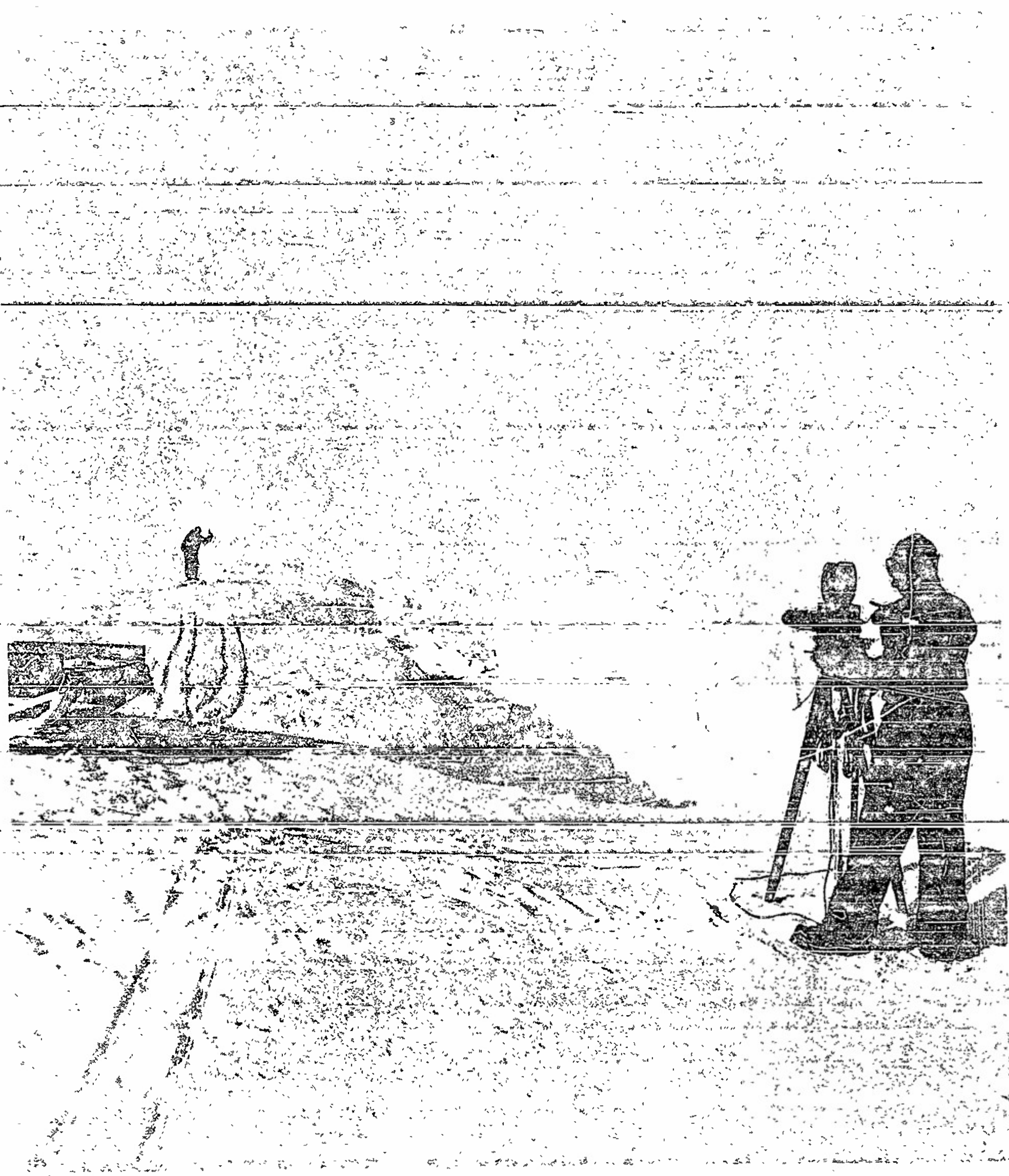


Fig. 26. — "Highjump" tent camp, Bay of Whales

of the Volunteer Reserve. The fact that Reserve units are scattered throughout the country fits into the general pattern of decentralization and thereby lessens the possibility that continuity of the mobilization programs will be disrupted by the destruction of one or more geographical locations.

This is the time of peace but to fulfill the mission of the Navy in protecting the Nation, the admonition of John Paul Jones should be heeded.

"In time of peace it is necessary to prepare and be always prepared for war at sea."



Crevasse in Antarctica

CHAPTER II

CHARACTER OF THE POLAR REGIONS

Starting with the Maps.--The purpose of this chapter is to give you a more detailed view of the geographical features, climate and ocean currents of the polar regions as we know them today. This will provide a fair basis for studying the cold weather engineering principles and applications described in the chapters that follow.

Accompanying maps will remind you that there's more to the Arctic than an ice-pack floating around the North Pole, and little more to the Antarctic, for our immediate purposes at least, than one big ice-covered continent encircled by an ice pack often hundreds of miles wide.

As far as the Arctic is concerned, after a little study, the essentials soon begin to take shape. The jig-saw puzzle of northern islands, straits, and bays, and the ocean currents gets much easier to put together. A much closer study would be more essential, of course, if you were ordered to active duty in the far north, if only to enable you to find your way to safety in an emergency.

PART I — THE ARCTIC

LAND AREAS

Many kinds of country make up the Arctic and Sub-Arctic. Some of it resembles stateside areas, but most of it is vastly different.

Alaska and the Aleutians.--The greater part of Alaska is not Arctic but Sub-Arctic. Actually the Arctic part is more or less confined to a broad zone that includes the coast from the Seward Peninsula, whose tip is only 57 miles from Siberia, to Point Barrow, and eastward to the border of the Yukon Province at Demarcation Point. The Arctic coast of Alaska, like most of the land bordering the Arctic Ocean is low and flat with the exception of a portion of the Seward Peninsula and Cape Lisburne. Harbors are few along this coast and the bottom is gently shelving so that large ships have to stand some distance out from shore. Inland from the coastal plateau is a series of mountain ranges some of which reach altitudes of more than 8000 feet. Both the western and eastern ends of these mountains, known as the Brooks Range approach the coast line, the western end being near Cape Lisburne and eastern end near Demarcation Point. The middle region, however, lies farther inland about 125 miles south of Point Barrow. Although not very well known, the Brooks Range ranks among the greatest mountain ranges of North America.

That portion of Alaska located in the Sub-Arctic which comprises most of the territory, is divided into coastal and interior areas. The former includes territory south of the Seward Peninsula, the Alaska Peninsula, the Aleutian Islands, and the south coast of Alaska.

The region south of the Seward Peninsula contains the broad deltas and alluvial plains of the Yukon and Kuskokwim Rivers and is generally low lying.

The Aleutian Islands together with the Komandorski Islands, form an almost perfect arc stretching across the Northern Pacific Ocean to Kamchatka. Formed of volcanic rock, the islands are generally rugged and mountainous, and probably not fondly remembered by a great many Seabees. Altitudes of 4000 to 5000 feet are common and several mountains are considerably higher. Glaciers radiate from many of the peaks, most of which are volcanic cones. Some volcanoes in the region are still active.

The Alaska Peninsula is a mainland continuation of the Aleutian Islands and is similar to the island arc in general character. Altitudes however, are commonly greater. For example, Iliamna Volcano and some other peaks are more than 10,000 feet high.

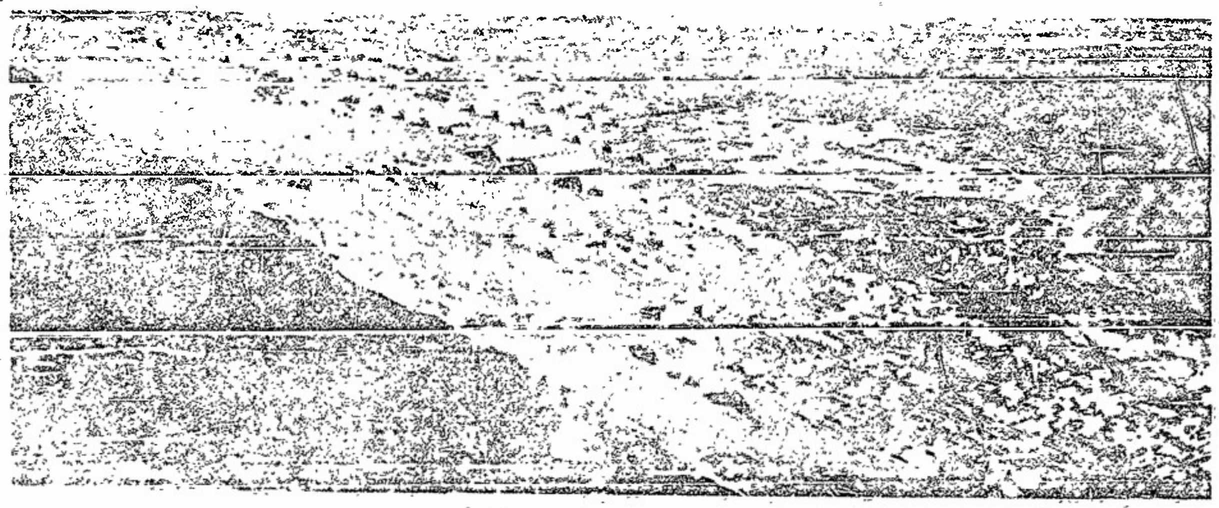


Fig. 1. — Flat Arctic coast at Pt. Barrow

The south coast of Alaska is ever more mountainous than the Aleutian chain. The Kenai Mountains rise to more than 5,000 feet, and Mt. Marcus Baker in the Chugach Mountains farther inland, is 13,250 feet high. Farther southeast, Mt. St. Elias rises to 18,000 feet. This same area also contains large glaciers including the great Malaspina and Hubbard glaciers. One of the major features of the interior region of Sub-Arctic Alaska is the broad valley of the Yukon River.

Over 2000 miles in length the Yukon is one of the major waterways of the world. From early June to late September it is navigable into Yukon Territory by steamboats of the Mississippi type. The valley is fertile in many places and is the center of population. Another major feature is the Alaska Range, the crowning summit of which is Mt. McKinley, the loftiest peak in North America, with an altitude of 20,300 feet.

Canadian Archipelago and Adjacent Mainland in Arctic.—Arctic Canada includes the Canadian Arctic Archipelago and most of the north coast of Canada. It is commonly divided into a western portion and an eastern portion. The boundary between the two is rather indefinite, but is generally placed along the axis of Boothia Peninsula and Somerset Island. Because of the terrain there is almost no travel between the two sections.

Western Arctic Canada comprises the mainland coast from Demarcation Point to Boothia Peninsula and the islands to the north. The largest of these is Victoria Island which is about the size of Oregon. Most of this section of Canada is low lying. Mountains are scarce so there are few glaciers. The mainland in many places is rocky, consisting of granite and gneiss. The islands consist chiefly of sedimentary rocks concealed beneath tundra, mud, and sand.

Boat travel to western Arctic Canada is chiefly carried on via the Mackenzie River, and to much lesser extent along the Arctic coast of Alaska. Commercial flying is conducted along the Mackenzie Valley with a branch route to Coppermine, on Coronation Gulf just south of Victoria Island.

Eastern Arctic Canada includes most of the mainland coast from Boothia Peninsula to Labrador, and the islands to the north. Of these, Baffin Island, which is almost as large as Texas, is the largest island in the Canadian Arctic. Eastern Arctic Canada, in contrast with the western section, is generally high and in places very rugged. The mountains along the eastern coast of Baffin Island rise to 8000 feet, and those in eastern and northern parts of Ellesmere Island to approximately 11000 feet, in altitude. Both islands have numerous valley glaciers and small ice caps. While well developed fiords along the coasts and bare rock surfaces in the mountains are common in most of the islands in the eastern section, there are also large areas of tundra. On the mainland, for example, the entire west coast of Hudson Bay is low, flat and in most places characterized by tundra.

Travel to Eastern Arctic Canada is by rail to Churchill on the west side of Hudson Bay, by boat past the Labrador coast, or by plane. Fort Ross, a Hudson Bay Company post on Bellot Strait, is the western terminus of travel and is the chief point of contact with Western Arctic Canada.

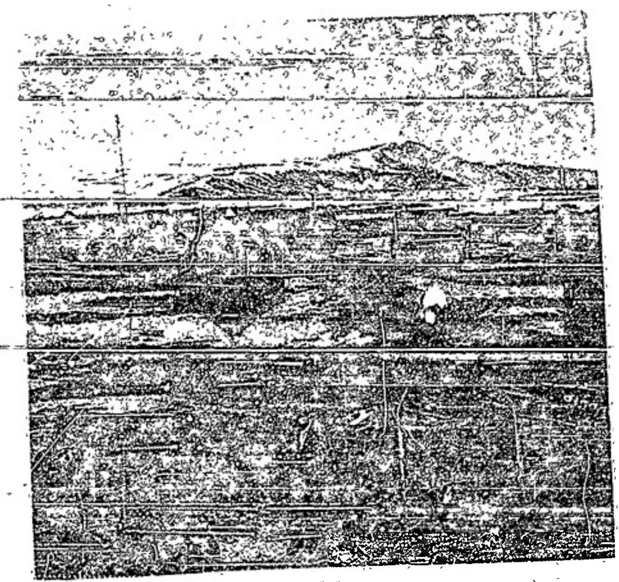


Fig. 2. — Terrain at Umiat, Alaska

Much of Canadian Mainland Sub-Arctic.—Sub-Arctic Canada includes a considerable portion of the mainland, even extending in some places as far as the north coast. The area embraces the Mackenzie Mountains and some other ranges of northwestern Canada which are a continuation of the Rocky Mountains and a broad comparatively flat plain that slopes gently from an altitude of 1400 feet just east of the Mackenzie Valley to sea level around Hudson Bay.

Altitudes of 7000 or 8000 feet in these western mountains are quite common and some of these peaks carry snow the year around. The Mackenzie River like the Yukon is one of the great rivers of the world. From early July to mid-September it is navigable for steamboats from the Arctic Ocean to Fort Smith on the Slave River south of Great Slave Lake, a distance of 1300 miles. In many places the Mackenzie Valley is well forested and fertile. Countless lakes constitute a notable feature of the valley and the plain to the east.

Labrador.—Although Labrador lies entirely south of the Arctic Circle, its northeastern part is truly Arctic. This part of Labrador, like much of Canada's eastern Arctic region, is mountainous particularly in the north where the Torngat Mountains rise to over 5000 feet. Fiords penetrate the coast in many places. While no trees grow in northern Labrador, the southern part is forested and gradually merges with the Sub-Arctic interior of Canada.

Greenland, World's Largest Island.—This island has an area of approximately 827,300 square miles. More than three quarters of this area is occupied by an ice cap that covers all of the interior and leaves only a relatively narrow ice-free strip along the coasts. Next to the Antarctic ice cap, the Greenland ice cap is the largest in the world. It is roughly dome-shaped, reaches a maximum altitude of about 10,000 feet, and the ice is constantly but very slowly flowing outward. It is estimated that in some places the ice cap is 7000 to 8000 feet thick. Near the edge of the ice cap there are numerous crevasses which make travel dangerous and in some places almost impossible. Some crevasses are also found in the interior. Many valleys, extending from the ice cap to the coast, are the outlets through which the slow flowing ice in the form of glaciers is discharged from the ice cap into the sea. Most of the Greenland coast extends out beyond the ice cap, although there are a few stretches, especially in the northwest and northeast, where the ice cap descends directly to the sea.

Much of the coastal zone is mountainous. On the east coast individual peaks rise to altitudes of 10,000 to 12,000 feet. The Watkins, or Gunnbjorns, Mountain with an altitude of 12,139 feet is the highest known, but there may be others not yet measured that are even higher. On the other coasts maximum altitudes

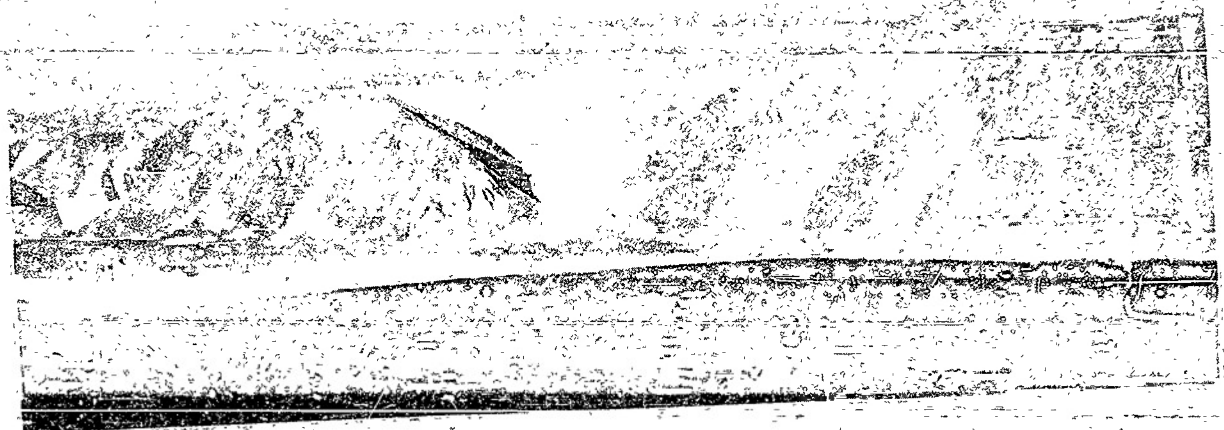


Fig. 3. — Mountainous Ellesmere Island

are generally less than 6000 feet. Fiords cut deeply into the Greenland coast. Many have glaciers at their heads which discharge large icebergs into the sea. The East Greenland fiord system is one of the most imposing in the world. Scoresby Sound, which extends inland more than 150 miles, is the longest fiord in the world and Franz Josef Fiord with its precipitous varied-colored walls equals the splendor of the Grand Canyon.

Fig. 5. — Greenland airstrip

Siberia and its Off-Shore Islands.--Arctic Siberia includes the northern portion of the great plain of northern Asia, which slopes slowly into the Arctic Ocean, and all the islands to the north. The coast along the Arctic Ocean varies from Cape Dezhneva, the northeastern extremity of the Asiatic continent, where the mountains rise to 2800 feet, to the Birrango Mountains on the Taimir Peninsula with an altitude of 2000 to 3000 feet. The area between these two is a generally rolling tundra belt that is drained by the Ob, Yenisei, and Lena Rivers. These large rivers are often blocked with ice for months, and flood the surrounding country during the summer thaw. The best known islands in the Arctic Siberian zone are Herald, Wrangel, New Siberian, North Land, Franz Josef Land, Novaya Zemlya, and Spitsbergen. All of these islands with the exception of the last one are claimed by Russia. Spitsbergen was acquired by Norway in 1925 under the Treaty of Paris. Both Norway and Russia operate mines in Spitsbergen. An offer by Russia, early in 1947, to fortify the island jointly with Norway aroused considerable interest throughout the world because of the strategic position of Spitsbergen in the polar air lanes. The proposal was rejected by the Norwegian Parliament when it was realized that the other treaty nations would have to give their consent.

Sub-Arctic Siberia in the east extends from the tree line as far south as the northern boundaries of Manchuria and Mongolia while in the west it includes practically all the northern portion of Russia.

Iceland.--The northern half of this roughly oval-shaped island or approximately half of its total area of 40,437 square miles, has an arctic climate. The island is a plateau or

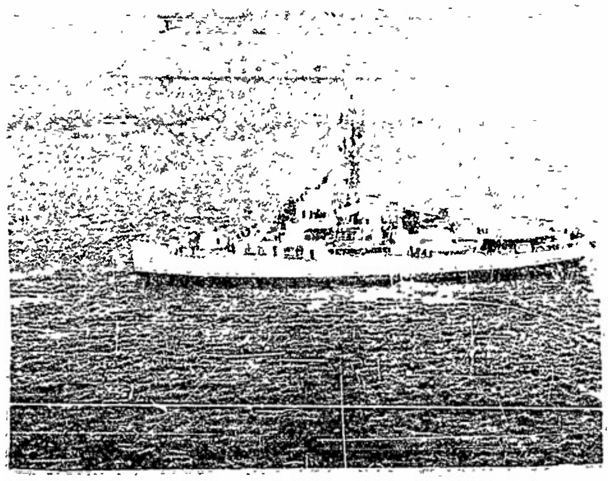


Fig. 4. — Greenland coastline

Fig. 6. — Ice flows off Ellesmere Island

tableland of volcanic rock averaging 2000 feet above sea level. About one-fourth of the area is covered with glaciers and lava field. Valleys and fiords penetrate the great tableland on all sides. The valleys or lowlands which comprise only one-fourteenth of the total area are almost the only parts of the island that are habitable. Over 100 volcanic peaks rise above the surface of the plateau. Many boiling springs and geysers are found on the island. The warm currents of the Gulf Stream help to keep the southern portion of Iceland in the Sub-Arctic category while the ice and cold currents from the Arctic basin imports a great deal of chilliness to the weather of the northern half of the island.

OCEAN AREAS

The Arctic Ocean, a Gulf of the Atlantic.—The Arctic Ocean comprises a comparatively small basin at the North Pole surrounded by a broad continental shelf. The basin is approximately 2000 fathoms in depth while the shelf averages only 100 fathoms. The islands of the Canadian Arctic Archipelago and numerous other islands are on this continental shelf. The continuity of the shelf is also broken by several depressions: in the Western Hemisphere these are identified as Baffin Bay, the Beaufort Sea, and the Greenland Sea, and in the Eastern Hemisphere, as the Barents and Kara Seas. Several other sections of the Arctic Ocean have been identified locally, such as the East Siberian and Nordenskiold Seas, but these do not generally denote any physical distinctions.

Baffin Bay, which has an independent basin more than 6000 feet deep, separates Baffin Island from Greenland. On the north and west, Baffin Bay connects with the Arctic Ocean by means of various channels of the Canadian Arctic Archipelago and on the south it joins the Atlantic Ocean through Davis Strait.

Beaufort Sea is the title given to that land-free section of the Arctic Ocean situated between Alaska and the Canadian Arctic Archipelago.

The Greenland Sea is that body of water bounded roughly by Greenland, Iceland, and Spitsbergen. The basin of the Greenland Sea is separated from the polar basin and the Atlantic Ocean by natural ridges. It does, however, comprise the only broad and comparatively deep means of egress for the Arctic Ocean. The maximum depth of the Greenland Sea that is known today is 16,000 feet.

The Barents Sea lies between the northern coast of Europe and the islands of Spitsbergen, Franz Josef Land, and Novaya Zemlya. The southern part of the Barents Sea, between Kola inlet and Novaya Zemlya, is sometimes known as the Murman Sea. The bottom of the Barents Sea resembles a river-eroded plateau which leads many to believe that at one time it was above sea level.

The Kara Sea is described as that body of water lying between Novaya Zemlya and the Yamal Peninsula. It is comparatively shallow and lies entirely on the continental shelf.

Hudson Bay.—Hudson Bay is not an integral part of the Arctic Ocean but it is one of the important northern seas in the Western Hemisphere. This shallow inland sea reaches the North Atlantic Ocean through Hudson Strait, a lane 500 miles long that separates Baffin Island from Labrador. Foxe Basin, a northern continuation of Hudson Bay, connects through the narrow Fury and Hecla Strait with the channels of the Canadian Arctic Archipelago. In the Hudson Bay depths are generally less than 650 feet. The bottom is gently shelving so that the water is shallow for some distance off shore. As a result, retreating tides uncover extensive mud flats.

ICE CONDITIONS

An outstanding characteristic of northern seas is the vast amount of ice that forms there in winter and much of which remains the year round.

Most of this ice is sea ice, but some of it is in the form of icebergs stemming mostly from the Greenland ice cap. The various types of ice and their physical properties will be discussed in detail in Chapter Three.

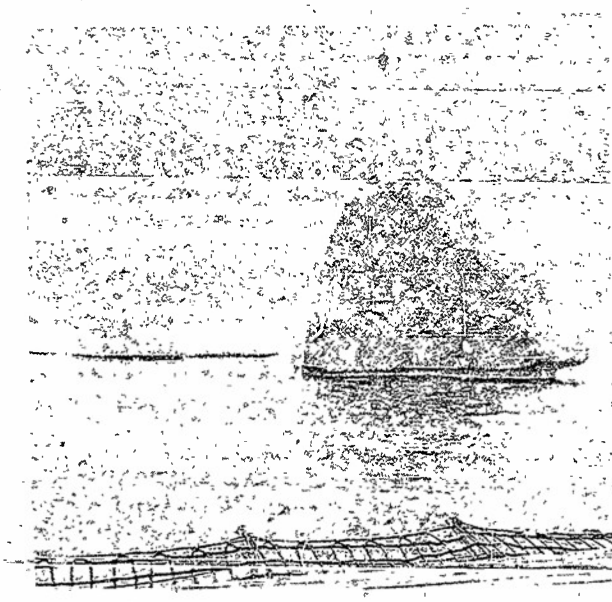


Fig. 7. — Iceberg sighted off Greenland

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TIDES

Small Tides Common in the Arctic.--Tides in the northern seas vary widely from place to place. Tide ranges are always smaller along straight parts of a coast than at the heads of funnel-shaped bays along the same coast. For example, Frobisher Bay, in the southeastern part of Baffin Island, has a funnel-shape and its tide range is 20 to 35 feet. On the other hand, at Clyde Inlet, on an open stretch of the northeast coast of the same island, the tide range is only 2 to 3 feet. In most parts of the Arctic small tides are more common than those of greater range. However, winds are an important influence. On the north coast of Alaska, Canada, and Siberia winds sometimes raise or lower the normal tide by 2 to 3 feet, depending upon their direction.

The normal tide range along the north coast of Alaska is less than 1½ feet. Similarly, the tides are small in the channels leading from the Arctic Ocean into the Canadian Arctic Archipelago. In Coronation Gulf, for example, the normal tide is only about 8 inches. At Winter Harbour, Melville Island, the range varies between 1 foot and 4½ feet.

Baffin Bay has a highly irregular coast with many fiords. As a result its tides vary considerably. At Craig Harbour, in the southeastern part of Ellesmere Island, the tide range is 5 to 6 feet. At Bylot Island off the northeastern coast of Baffin Island, it is 12 to 15 feet, but at Pond Inlet immediately to the south it is only 2 feet.

The tidal range along the European coast of the Barents Sea it considerably large. Along the Murman coast its varies from 11½ feet at Bazarnaya Bay to 18 3/4 feet at Svyatoi Nos. This tidal undulation enters the White Sea where it ranges from 18¼ feet at Cape Gorodetski, and 20¼ feet at Kargovski Point, in the Gulf of Mezen, to 3 feet at Archangel.

In the Kara Sea the range is small, usually not more than 1½ feet to 2½ feet.

OCEAN CURRENTS

Effects on Climate and Navigation.--The climate of various parts of the Arctic is strongly influenced by the ocean currents. An example is the cold Arctic current flowing south past the coast of Labrador, which keeps the Labrador coast cold in comparison with other coastal areas in the same latitude.

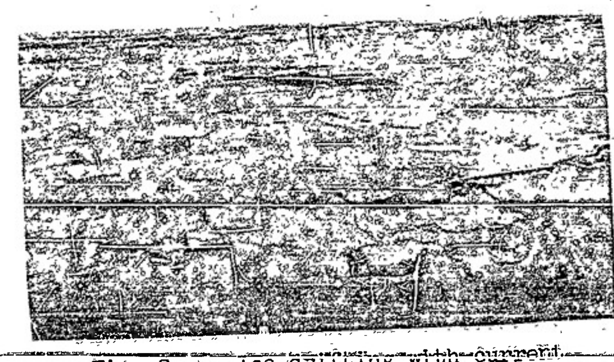


Fig. 8. -- Ice drifting with current off Ellesmere Island

Also currents influence the navigability of certain waters because they control the direction of movement of sea ice. For example, the current that flows south along the east coast of Greenland brings down with it floating ice that in some years blocks that coast.

The action of currents in leaving driftwood along some Arctic shores has saved many lives in the past and will probably save more in the future. However, on some stretches of coast this precious supply has already been used up.

General Drift Across the Arctic.--Most of the surface water in the Arctic Ocean drifts from Alaska and Siberia across the region of the North Pole toward Greenland and Spitsbergen. Some of this water flows eastward through the Canadian Arctic Archipelago. There, joining a small part of the transpolar drift, it flows southward along the western side of Baffin Bay and Davis Strait and eventually feeds the Labrador Current. The bulk of the transpolar drift, however, turns south along the eastern coasts of Greenland and Spitsbergen. As a result, pack ice, brought from the ice-covered Arctic Ocean, slowly drifts past these coasts during a large part of the year. Part of the East Greenland Current turns around the southern tip of Greenland and flows northward along the east side of Davis Strait and Baffin Bay. At the north end of this bay it swings west and south and joins a southward directed current in its progress down the west side of Baffin Bay and Davis Strait.

Clock-wise Drift North of Alaska.--An exception to the general transpolar drift is the current in the Beaufort Sea, which lies west of the Canadian Arctic Archipelago and washes the north coast of Alaska. This current probably flows southward near the western side of the Archipelago and then westward along the Alaskan coast as far as Point Barrow. Here it meets a northeast current. As a result an offshore drift is frequent at this place.

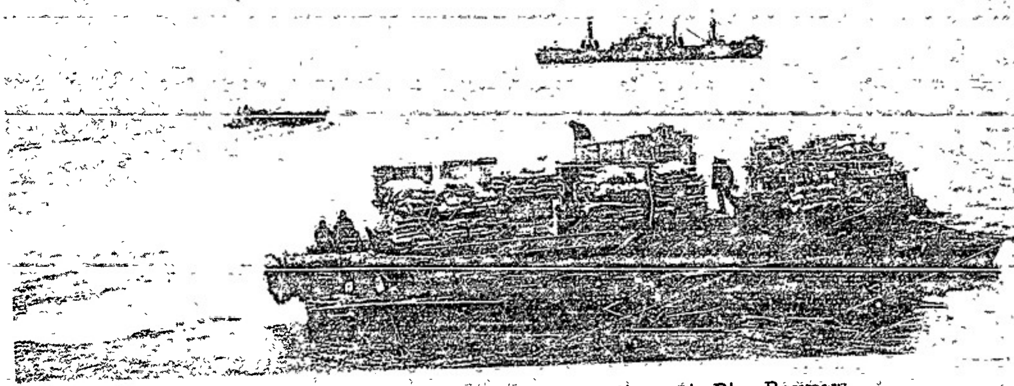


Fig. 9. — Unloading at Pt. Barrow

Gulf Stream warms Scandinavia.—The Gulf Stream which flows along the coast of Norway and eventually through the southern part of the Barents Sea, keeps the latter free from pack ice and also makes it possible for Arctic Norway and the Murman Coast to operate from open harbors. Similarly, another branch of the North Atlantic Drift washes the shores of Spitsbergen and is responsible for keeping its western coast free from ice during most of the year.

Current in the Hudson Bay.—Hudson Bay has a current with a counter-clockwise rotation. Moving southward along the west side of the bay past Chesterfield Inlet and Churchill, it swings eastward near the south end of the bay and then northward along its eastern shore to Hudson Strait. Here it turns eastward and follows the south side of the strait to the ocean, where it joins the Labrador Current.

CLIMATE AND WEATHER

Moving Air Masses are the Star Performers.—As you know, the climate of a locality is the average of its weather over a period of years while weather is simply the current state of the atmosphere and the sea—or what you see and feel from day to day. Weather science is concerned with both phases—current and long range. It is obvious that a sound knowledge of weather science is important to the success of military operations even in the Arctic.

The general circulation of the atmosphere over the earth caused by rotation of the earth and differentials in heat absorption from the sun by masses of air is the primary influence on all the climate and weather we have. Just as the circulation of air within a building obeys strictly physical laws, so does the far greater circulation over the globe. The difficulty in measuring exactly the forces that are exerted upon the atmosphere prevents more accurate and advanced weather predictions.

Great advancements, however, are being made in weather science every day. Perhaps the greatest stimulus to progress in this field was the conclusion reached by Norwegian scientists after World War I that changes in weather are caused by the conflict of sweeping masses of warm and cold air along a polar front.

The United States has played no small part in building up the new knowledge that is rapidly transforming weather science. The Army and the Navy have long been carrying out extensive research in meteorology and allied sciences. Actual observations and measurements in the upper air rather than sheer reasoning about what happens in the higher altitudes have enabled weather scientists to develop practical techniques for forecasting and to make valuable additions to the fundamental theory.

Less Heat in Higher Latitudes.—A major factor in the climate of any locality is the amount of heat the region receives from the sun. This quantity depends on two things—the angle at which the sun's rays strike the earth and the length of the day, both of which vary widely with varying latitude.

The energy delivered by the sun's rays is considerably less at either pole than it is at the equator. This is true because the rays at the pole, striking at an oblique angle, must pass through a thicker layer of atmosphere which absorbs, scatters and reflects them. In addition the angular approach of the rays spread them over a larger area.

The inclination of the earth's axis while the earth is rotating around the sun causes a great variation in the length of day and night at different latitudes. At the North Pole the sun stays above the horizon for 6 months, while at the Arctic Circle it is up all day only on 21 June. In winter there is an equal amount

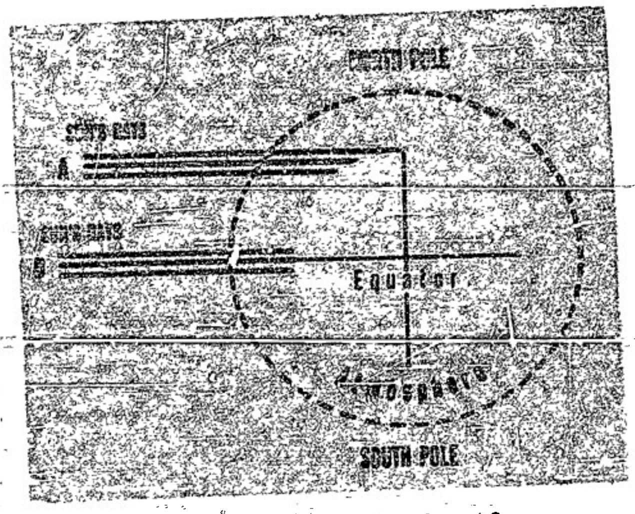


Fig. 10. — Dissipation of sun's energy

of time, latitude for latitude, during which the sun is hidden below the horizon. While these rules are astronomically correct, the sun is often seen when it is actually below the horizon. This is possible because the sun's rays, striking at a low angle, follow a curved path through the dense air near the surface of the earth. Twilight, therefore, is lengthened at high altitudes. Winter is definitely not a period of total darkness. South of latitude 84° N there is some light from the horizon even on 22 December. In addition, the Arctic is favored with particularly long periods of bright moonlight which is an aid in winter travel.

How Topography Affects Arctic Climate.—Another important factor that alters the climate of a region is the topography. The temperature, precipitation pattern, prevailing winds and fog are all modified by the topography.

Normally temperature decreases as altitude increases. Consequently, highlands are cooler than lowlands. An exception to this rule occurs in places where air circulation is restricted. Cold air is heavier than warm air, and therefore, it tends to sink and become trapped if there is poor air circulation. Thus air may be colder on the floor of a valley than on surrounding hills.

Air moving against a highland is forced upward and cooled. Since precipitation results from the cooling of moist air, rain and snow are normally greatest in mountainous areas. The presence of mountains is largely responsible for the many glaciers of Baffin Island, Ellesmere Island, and Greenland. Conversely the absence of mountains explains the lack of glaciers in Canada's western Arctic.

The high Greenland ice cap has a unique effect on winds. Air in contact with the ice becomes cooled and heavy. It settles and flows down the sides of the ice cap, creating gravity winds that gather speed as they approach the edge of the cap. When these winds are further accelerated by a storm, they produce the offshore gales sometimes met along the Greenland coast.

Large bodies of water do not change temperatures very easily and consequently tend to stabilize temperatures in their vicinity. For this reason seacoasts generally have cooler summers and warmer winters than do the interiors of large land masses.

Because of the differences in temperature between large bodies of water and adjoining land masses, coastal areas are the scenes of many fogs. Warm air from the land is chilled as it travels over a cool sea; its moisture condenses, and the result is very likely to be fog. The reverse of this, where warm moist air moves inland from the sea, is also a possible source of fog.

Movement of Air Masses.—Air masses are merely air currents. The more or less continuous conflict between warm, moist currents, usually from the south or west and cold, dry currents from the north or east in the Northern Hemisphere so resembles the battle between two opposing military forces that the name "front" has been applied to the boundary between different air masses. It has been determined that during the movement of air masses over the earth, known as atmospheric circulation, distinctive physical characteristics are developed over various source regions. For example, polar continental air becomes relatively cold and dry through stagnation over the Arctic tundra. By the same token tropical maritime air is warm and moist because its source region is located over warm seas.

Analysis of several air mass migration demonstrates that the dry polar continental air masses pass off the continent with significant gains in moisture, whereas the tropical maritime air masses, whose moisture is derived primarily from oceanic regions, lose considerable amounts of moisture to the land areas during their poleward movement.

In winter a favorite route of polar air masses is from the Arctic Ocean southward along the Mackenzie valley and then eastward over southern Canada and northern United States. In summer an eastward movement takes place farther north so that the air masses tend to pass from the southern islands of the western Canadian Arctic Archipelago toward southeastern Baffin Island.

It is obvious, therefore, that in addition to the permanent influence of latitude and topography, transitory air masses exert a profound effect on climate and weather.

Arctic Seasons.—Seasons represent the weather in any region over a prolonged period and are therefore true expressions of the climate. In the Arctic, summer and winter, with their extremes of temperature, are well defined, but autumn and spring, especially in very high latitudes, are more indefinite.

Spring in the Arctic merges into summer with the general melting of the snow, the break up of ice on rivers and lakes, and the appearance of flowers and numerous birds. After summer begins, sea ice starts to break up along Arctic coasts permitting ships to navigate in many places. By August about three-fourths of all land north of the Arctic Circle has become free from snow. Most of the remaining snow is in the interior of Greenland, parts of Baffin Island, Devon Island, and Ellesmere Island. Contrasted with other seasons, summer is characterized by a profusion of plant and animal life on the land, and by open water in the seas. Continuous daylight during early summer is another notable feature of the Arctic.

Summer merges into autumn when birds start south, when temperatures drop to near freezing at night, and when snow flurries appear. A little later subfreezing temperatures become common, lakes freeze over, then streams, and finally the bays and inlets along the Arctic coasts. By this time the days have become short and there is some snow on the ground. During this freeze-up period when ice is forming on lakes and sea, there is generally little sledge travel.

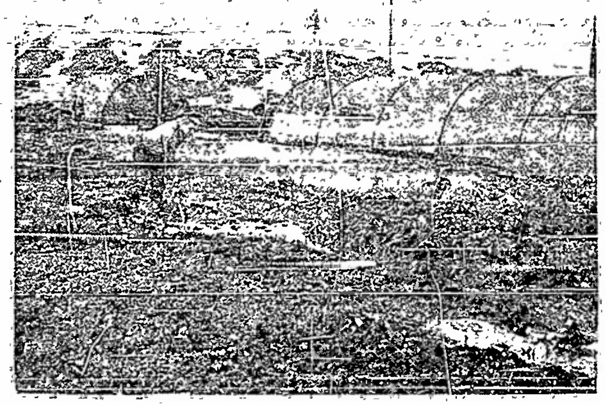


Fig. 11. — Summer season at Umiat, Alaska

Autumn merges into winter when temperatures remain low, snow covers the terrain, and ice thickens over most of the Arctic Ocean. The persistent cold that governs all activities and the long nights are the most prominent characteristics of the winter. Despite the fact that the sun is below the horizon for many weeks in the far north latitudes, the moon, northern lights, and the reflection of light by the snow prevents the area from being in total darkness. Winter travel, except during storms, continues uninterruptedly.

Winter merges into spring as the hours of sunshine increase. Low temperatures are not uncommon and stormy winds may prevail at times, but the weather gradually turns milder and snow starts melting on land. Flowers sprout, at times, through drifts and seals bask in the sun along arctic coasts. The land is freed from snow gradually, rivers break up, lakes open, and finally summer is at hand.

Not the Coldest Place in the World.—The lowest temperature that has been recorded anywhere on the earth was 90°F below zero on 5 and 7 February 1892 at Verkhoyansk, Siberia which strangely enough is on the edge of a great wheat farming belt. This is colder than has been recorded in any section of the Arctic. The next lowest temperature that has been reliably recorded in the Arctic was -78°F at Fort Yukon on 14 January 1934. Comparing these with the lowest temperature of record in the United States, which was -66°F at Riverside Ranger Station, Wyoming in Yellowstone Park on 9 February 1933, the reputation of the Arctic for a chilly climate begins to be seen in better perspective.

There are no authentic records to indicate that temperatures in the Arctic Islands drop below -60°F. It is almost certain that they do not occur. It is believed, therefore, that the temperature at the North Pole, or any other place on the Arctic Ocean, never drops as low as -55°F.

The coldest month of the year in the Arctic is January or February. The mean temperature during that period at various points in the Arctic is as follows:

-60°F	Verkhoyansk, Siberia
-53°F	Eismitte, Greenland Ice Cap
-27°F	Chesterfield Inlet, Hudson Bay
-18°F	Pangnirtung, Baffin Island
+18°F	Ivigtut, Southern Greenland

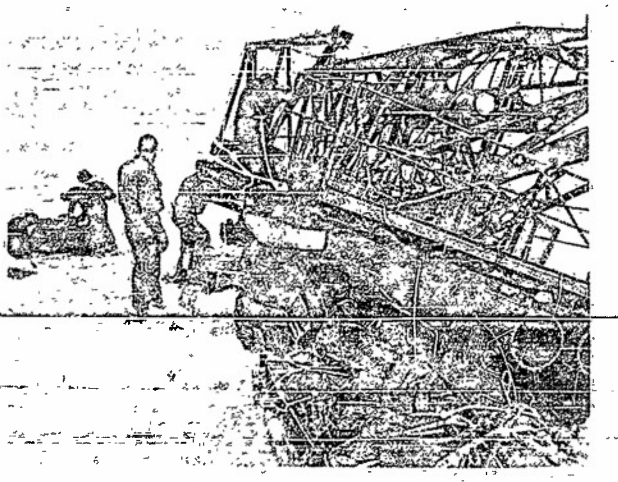


Fig. 12. — Winter operations, Pt. Barrow, Alaska

These are mean temperatures only; the extremes differ from the means by many degrees. For example, the extreme low at Pangnirtung was recorded as -46°F, but the same month has also witnessed a high of +48°F. It is also interesting to note that Ivigtut, which lies a few miles beyond the border of the Greenland ice cap, is only about 3°F colder than Eastport, Maine.

The Sub-Arctic continental winters are sometimes colder than those of a true Arctic climate. At Dawson, Yukon Territory, for instance, the mean January temperature is -22°F, at Fort Simpson, Northwest Territories it is -19°F, at Fort Vermilion, Alberta it is -14°F, ~~and at Tanana, Alaska it is -16°F. Once again,~~ it should be remembered that these are only mean temperatures. The range at Dawson during this same month is -76°F to 30°F. It is obvious, therefore, that during the winter much of the Sub-Arctic is colder than the Arctic. Similarly, the extreme lows of the Sub-Arctic are lower than the extreme lows of most places in the Arctic. While available records do not indicate it, there is good reason to believe that the same conditions exist in interior Siberia.

Throughout the Arctic the warmest month is generally July. Mean temperatures for this month vary in place to place from about 12°F to 50°F. For example, Point Barrow has a July mean of about 41°F. The temperature range, however, varies considerably. At Craig Harbor, Ellesmere Island, the July minimum is 29°F and the maximum is 61°F. At Chesterfield Inlet, Hudson Bay, the highest for July is 84°F.

In Siberia the warmest month is also July when the mean temperature reaches about 54°F at the head of Borkhaya Bay and 37°F near Cape Severni. Westward of the Taimir Peninsula, the mean for July is 43°F on the western coast of Novaya Zemlya and 54°F at Kola. A temperature of 86°F has been recorded in several parts of the Kola Peninsula.

The Sub-Arctic continental summers are sometimes warmer than those of a more southernly temperate climate. But the temperatures are variable, sometimes soaring into the nineties and then sinking below freezing. An illustration of this exists at Dawson where the July extremes are 95°F and 29°F.

Low Annual Precipitation in the Arctic.--Large bodies of water have a definite climatic significance in that they are the ultimate source of all rain and snow. Since a large part of the Arctic Ocean is covered with ice the year around, the winds cannot pick up by evaporation the amount of moisture they could obtain from an ice-free sea. This fact, coupled with low temperatures that prevent the air from holding much moisture, accounts in large part for the low annual rainfall and snowfall of the Arctic.

There are a few exceptions to the generally low annual precipitation. Among these are Ivigtut, Greenland where it averages 44.8 inches, Baffin Island where it is 17 inches, and Labrador with 19.3 inches. The greater portion of the Arctic is relatively arid. Point Barrow has only 5.3 inches, Ellesmere Island only 8.6 inches and 10.9 inches at Coppermine, Northwest Territories. Along the Siberian coast, eastward of the 60th East Meridian, the annual precipitation is less than 8 inches and this entirely in the form of snow from October to ~~May. Probably the only time it is entirely in~~ the form of rain is during the month of June. This proportion of rain to snow varies considerably. At Baffin Island and Hudson Bay about half the precipitation is in the form of rain, but at Ellesmere Island only about one-third of it is rain.

Over most of the Arctic the greatest amount and the greatest probability of precipitation occur in the summer, although in some localities these peaks may come in the spring or autumn. July or August is generally the wettest month of the year. Nevertheless, the average monthly precipitation in most areas is less than 2.5 inches. At Point Barrow and the west coast of Greenland, for example, it is only about 1 inch. Available observations made along the Siberian coast indicate that the greatest precipitation also occurs during the summer and that the average is less than 2 inches per month.

The minimum precipitation commonly occurs during winter or early spring. For instance, the average January precipitation at Point Barrow, Ellesmere Island, Hudson Bay, and the west coast of Greenland is less than 0.6 inches, which is equal to about 6 inches of snow. However, so much snow is raised from the ground and blown around by winter winds that it gives a false impression of the total amount of snowfall.

One of the Least Stormy Regions of the World. Explorers and observers have concluded that the Arctic is, in comparison to other large areas, one of the least stormy regions of the world. Violent gales are unknown, or at least unrecorded, in many parts. In general, the intensity and direction of prevailing winds throughout the Arctic vary greatly with the topography and seasons.

A strong wind from a low shore, not covered with vegetation, blows more strongly near the land than at a distance from it, but a similar wind off a high shore is light in its vicinity, becoming stronger as it moves out to sea. As has been indicated, the strong offshore winds along the coast of Greenland are the result of the mountainous shore line. These winds maintain a constant direction during most of the year. In other parts of the Arctic, however, the direction of the winds is a factor of the season.

Summer winds are mostly light and variable. Northernly and northeasternly winds, gentle in comparison with those of other seasons, prevail on the borders of the polar pack. In general, winds of the polar pack in all seasons are less severe than those of the land. The strongest winds next to the surface of polar pack far from land are seldom more than 50 miles per hour.

Autumn winds are less variable than summer ones, but they are generally much stronger. In the Canadian section of the Arctic, winds are more severe during the autumn and the calms are fewer than at any other time of the year.

Along the Arctic coast of Alaska the winds in winter are strongest from the west or southwest, and the next strongest from the east or northeast. While among the western islands of the Canadian Arctic Archipelago, the prevailing wind appears to be northwest.

When temperatures begin to rise in the spring, storm tracks shift northward and bring to some areas winds stronger than the winter winds.

It is impossible to generalize in determining either the direction or velocity of wind in the Arctic. For example, observations taken on Melville Island in the 1908-1909 seasons indicated that February was the stormiest month. There were seven storms with velocities of over 40 miles per hour; two of these were over 60 miles per hour and one was over 100 miles per hour. At southern and eastern Baffin Island, however, the windiest season occurs during the spring and the strongest winds at points along the Siberian coast during the summer. Information about the area is, however, very scanty.

In the interior of Alaska and Canada, high ground velocities are rare; the maximum, about 50 miles per hour, is seldom attained. But again, at greater altitudes, wind velocities are sometimes 90 to 100 miles per hour.

In the Aleutians, the summer winds are predominantly westerly and northwesterly, but the southeasterly winds are commonly stronger and are often accompanied by rain or mist. On the Alaska Peninsula and along most of the south coast of Alaska, summer winds, although variable, are dominantly southeast and southwest. Gales from these directions are likely to bring rain and thick weather. During winter and spring very strong northwest winds are frequent on most of the south coast and the Alaska Peninsula, where they often reach gale intensity. A peculiar Alaska wind is known as "williwaw". It is comprised of disturbed air currents that sweep down mountain slopes, especially in the lee of islands, with great force and suddenness. Known to reach 100 miles an hour williwaws have caused many planes to crash.

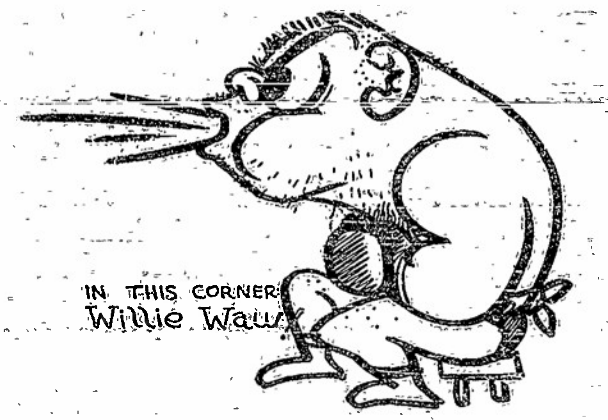


Fig. 13.

Despite these treacherous winds and the gales off the coast of Greenland, the strongest winds on record are not in the Arctic nor Sub-Arctic but on Mount Washington in New Hampshire where gusts of 230 miles per hour have been recorded. However, even very moderate winter winds of 9 to 12 miles an hour will raise snow a few feet off the ground so that it obscures surface objects such as rocks and runway markers. Stronger winds may whisk up the snow to such a height that it appears like a low cloud.

Fog not Restricted to the Aleutians.—In the Arctic and Sub-Arctic as elsewhere in the world certain places are notable for their frequent heavy fogs, whereas other places have almost none. The western part of the Aleutian chain is a particularly foggy area. In the far north fog is especially dependent upon seasons and the variations of temperature and wind that accompany them.

Fogs are most frequent and dense over the Arctic Ocean during the summer, when they occur about 30 percent of the time. But during the winter, from December through March, they are practically absent. In the autumn and spring they are of intermediate frequency.

Coastal fogs, on the other hand, are worse during the spring. It is during that season that the land areas, largely free from snow and heated by the sun, are much warmer than the ice covered sea. In fact the maximum temperature differences between land and sea, and hence the conditions most likely to cause fog, are set up during the spring.

Next to spring, autumn is said to be the worst season for coastal fogs in most places. The reason is that the sea, as long as it remains unfrozen, is considerably warmer than the land, which cools rapidly.

Coastal fogs, like fogs over the Arctic pack, are least frequent during the winter and in general only slightly more common in the summer.

During the summer when the land is warmer than the sea, the winds are likely to produce a fog belt parallel with the shore. Most of these fogs lie lower than the top masts of a ship. While lookouts in crow's nests of neighboring ships can see one another at times, deck personnel can not see beyond their own ship.

Along the coast this fog sets in very rapidly. In the operation order for the 1948 resupply expedition to Point Barrow, Coxswains of all landing craft, that transported the supplies from ship to shore, were instructed to keep all radios manned continuously while in transit. In this manner all small boats could receive storm signals and instructions as to where to seek shelter if they were beset by fog and unable to return to the ship.

In addition to the familiar type of fog there is a "spicule fog" that is characteristic of the Greenland ice cap. Formed of extremely fine ice crystals, spicule fog is a kind of snowfall that results from condensation during cloudless periods of low temperature, high humidity, and calms or light winds. At times it completely obscures the ground and makes flying extremely hazardous. It has been known to extend up as high as 1000 feet above the ground.

PART II — ANTARCTIC

LAND AREAS

Still in the Grip of an Ice Age.—Antarctica, the world's highest continent, equal in size to the areas of the United States and Europe combined, has a coast line of approximately 14,000 miles. In most places the shore reaches the sea in high ice cliffs which only add to the inaccessibility of this land that is still in the grip of an ice age. There are few good harbors or safe anchorages. In most places it is advisable for vessels, which in the open season have broken their way through the belt of floating ice surrounding Antarctic, to moor to ice floes by the use of ice anchors, and be prepared to get under way in the event of unfavorable weather or ice conditions.

The western coast of Palmer Peninsula and the coast of Victoria Land are the most accessible and hence have been more frequently visited. Other parts of the continent have not been investigated in detail and, consequently, our knowledge of those areas is limited.

Extensive mountain ranges, having peaks 13,000 feet high, are situated in various parts of this icy continent. Several volcanoes have been observed in activity, the most impressive of which is Mount Erebus in the southwestern part of the Ross Sea.

ICE CONDITIONS

Another characteristic that is found only in the Antarctic is the floating ice sheets. The inboard sides of these sheets, which are called barriers or shelves, are held fast to the mainland because they are aground and are still attached to the glaciers which act as feeders. The outboard sides of these sheets are afloat in the ocean. One of the largest of these barriers is the Ross Ice Shelf, on which Little America is situated. It is approximately the size of Colorado and Nevada combined and is composed of ice 500 to 1500 feet thick. The precipitous outboard side of the barrier, towering 50 to 150 feet above the ocean, is approximately 400 miles long. This seaward edge undergoes constant change as large portions of it shear off and float to north as icebergs. The inboard side of the shelf is within 300 miles of the South Pole. This, together with the fact that its surface is comparatively smooth makes the shelf an ideal avenue of approach to the South Pole.

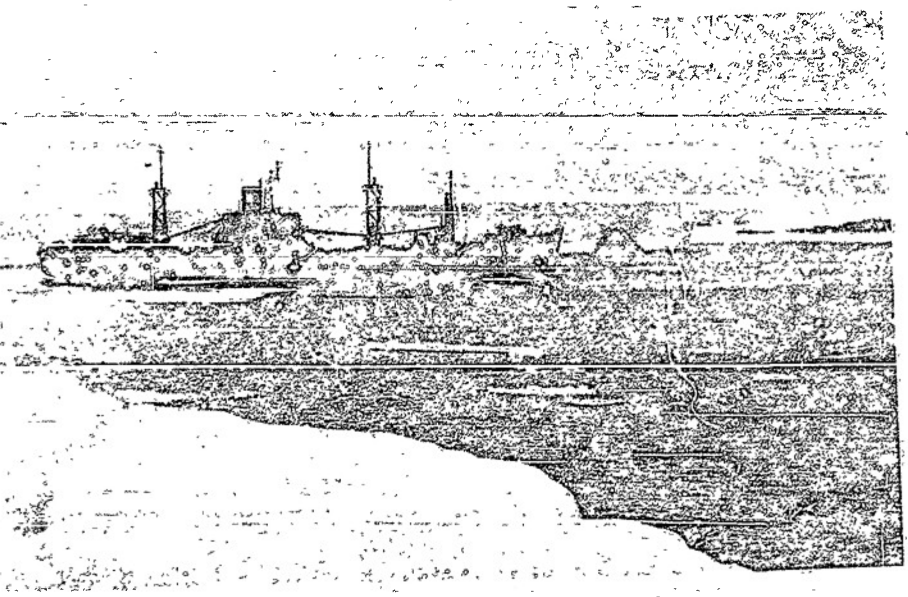


Fig. 14. — Departing, Bay of Whales, Ross Sea

Surveys of the shelf indicate that the entire shelf is moving northward, in some places at the rate of 4 to 12 feet per day.

OCEAN AREAS

Three oceans, the Atlantic, Indian and Pacific border the Antarctic. The conditions existing in these waters differ from those in the Arctic seas. For example, the ice in Antarctic waters drifts centrifugally around a central land mass towards the stormiest seas in the world, while in the Arctic the ice pack is practically landlocked.

The Ice Pack Around the Continent.--The counterclockwise drift of the ice in the Antarctic produces a somewhat consolidated belt of ice through which vessels must pass to reach the shores of the continent.

The northern limit of the ice pack is variable and the location of the extreme edge varies also with the season. During the late winter and spring the edge extends to its most northern limit, lying in much the same position during July, August, September and October. During the summer the edge retreats reaching a southern limit during the autumn months of February and March when it is considerably south of the spring position. There is a wide difference in the range of movement of the pack in different longitudes.

Except on the Pacific Coast and the western portion of the Weddell Sea, it is probable that nearly all parts of the continental coast and the fixed shelf ice are free of pack ice at times in the late summer. For example, in early spring the pack may extend as far northward as 62°S in the Ross Sea. The edge retreats to about 67°S by mid-January, after which disintegration is usually quite rapid near the 180th meridian where easy entrance generally can be made to the Ross Sea through a narrow belt. The sea remains open then until the winter freeze in late March.

Vast Icebergs.--Another hazard found in the waters contiguous to the Antarctic continent is the presence of icebergs in vast numbers. The limit of icebergs varies in the different oceans and with the season. In the Atlantic they generally reach as far north as 40°S. In the Indian Ocean they are rarely seen north of 45°S and in the Pacific the limit is roughly 50°S. The largest iceberg reported was seen by the whale-catcher Odd I on 7 January 1927, off Clarence Island, and was about 130 feet high and about 100 miles both long and wide. Icebergs are most frequently met in November, December and January and most seldom seen in June and July.

Often icebergs are so balanced that melting of the under surface or disintegration may cause a shift in the center of gravity with consequent capsizing and readjustment of the mass to a new state of equilibrium. Vessels, therefore, necessarily keep well clear of icebergs particularly those which give evidence of overturning or breaking up. The ratio of the submerged portion of icebergs to the exposed portion is dependent upon the specific gravity of the ice. Tabular icebergs, the most common type in the Antarctic, float with from one-fifth to one-third of their mass exposed. Some authors give a ratio of depth submerged to height exposed but this is misleading, as measurements below and above water should refer to mass and not to height.

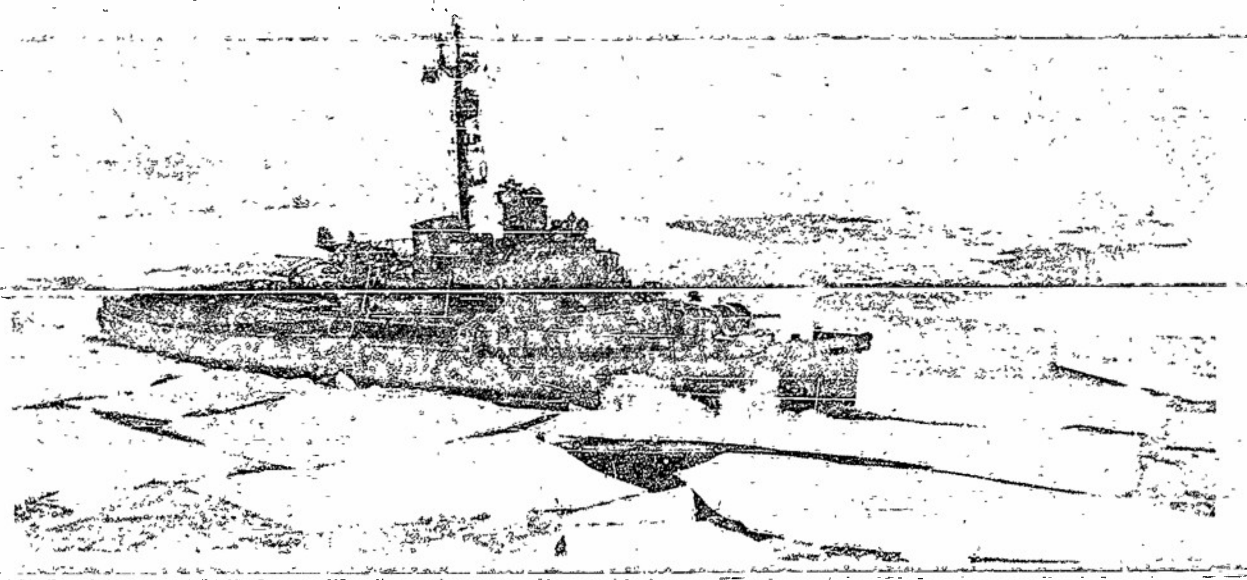


Fig. 15. — Ice breaker off Ross Shelf

The manner in which expeditions attempt a passage through the treacherous water surrounding the Antarctic continent depends largely upon the type of vessels employed, the composition of the pack, the weather, and the proximity and location land relative to the vessels. One thing, however, is certain, the services of a modern ice breaker are invaluable.

TIDES

Tides Irregular.—Although there is a paucity of tidal data it is known that the tides are generally very irregular, there being at times high water for 24 hours together; at other times it flows tide and half tide, and remains high water for only 3 or 4 hours and then ebbs again. Generally, however, there is one flood and one ebb every 24 hours.

Fig. 16. — Iceberg in Bay of Whales, Ross Ice Shelf

The action of tides varies with the location. For example, at Nansen Island they are of a peculiar nature. Instead of a very high tide, succeeded by a very low one, observations record a very low tide, then one not very high, followed by a low tide not falling as low as the previous one; then a higher high tide. The range of the tide at this location is about $4\frac{1}{2}$ feet.

Observations made at other locations indicated the maximum range of tide to be about $5\frac{1}{2}$ feet over a 72 day period. Generally the range is much lower than this.

OCEAN CURRENTS

The prevailing currents in the Antarctic regions correspond with the prevailing winds. Thus near the continent a westerly setting current is found, and in lower latitudes a strong easterly trend. The mixture of these two currents allows polar waters to flow out towards the north.

The cold surface polar water of low salt content has a depth of 300 to 900 feet. Following northward this cold layer converges with and gradually sinks below subtropical waters between 40°S and 50°S. The mixing of these two surface currents produces a warmer type of surface water which aids in the dissolution of the northern edge of the pack.

The prevailing westerly current along the coast of the continent is strictly an encircling one except for diversion into bays and inlets where it sets up a clockwise rotation that produces a subsidiary exchange of water.

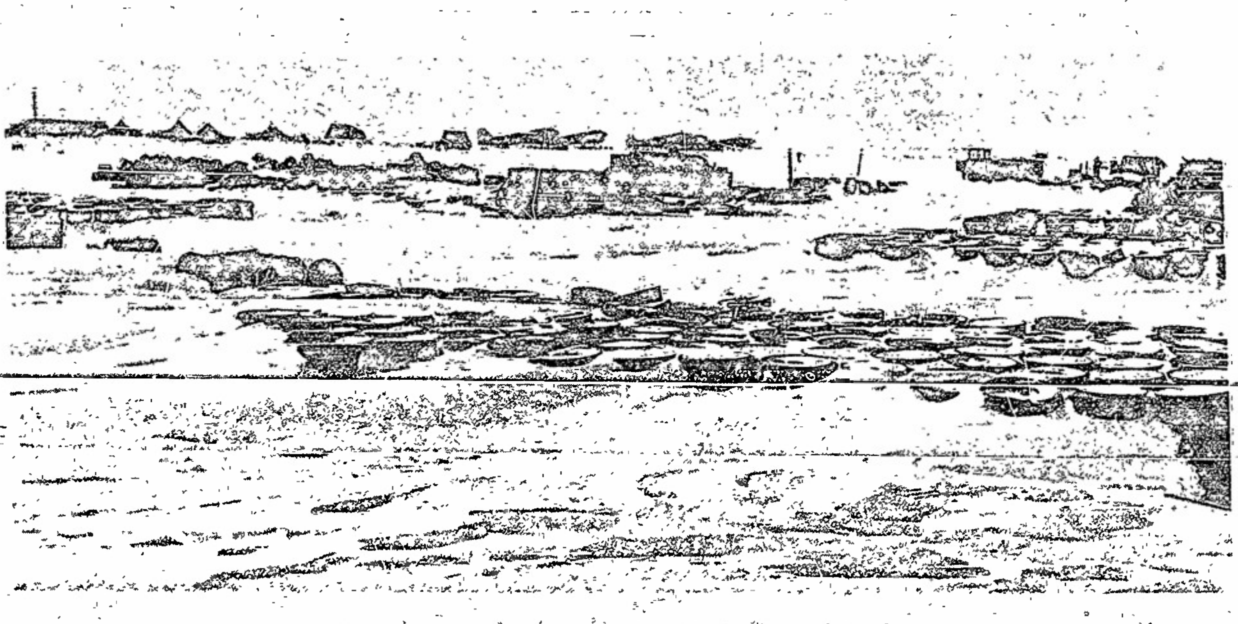


Fig. 17. — Drifted snow, operation Highjump

CLIMATE AND WEATHER

Most of the data collected have been gathered at bases established for relatively short intervals on the coasts or islands, from ships in coastal waters, from brief sledge journeys into the interior and from airplane observation on trips to the South Pole and some other areas, so little is known of the climate of the polar plateau. Until a number of meteorological stations are established along the coasts and in the interior of Antarctica, and observations obtained over a reasonable length of time, the forecasting of south polar weather will remain a matter of deduction and conjecture.

One distinctive characteristic of the Antarctic is the fairly uniform low temperature that exists during the summer. On the western coast of Palmer Peninsula, due to the oceanic influence, average summer temperatures above the freezing point have been recorded. However, the average summer temperature for the greater part of the continent is below freezing.

Fig. 18. — Formal introduction in the Antarctic

Winter temperatures vary in different areas, somewhat dependent upon the frequency of southern blizzards and the presence of open water in the vicinity of the base.

The Bay of Whales region is believed to have the lowest annual temperature (-10°F to -15°F) with minimum temperatures in the minus 70's according to records of four expeditions based in that locality. The minimum temperature recorded there was -75°F on 4 September 1940. A winter sled party, camped on the Ross Ice Shelf near Cape McKay, Ross Island, recorded a low temperature of -77°F on 6 July 1911.

Very little is known of winter temperatures in the interior of the continent, but the moderating effect of the sea on coastal areas is suggested by the winter temperatures recorded by Byrd at a station located 94 miles closer to the pole than the main station at Little America on the Bay Whales. A minimum temperature of -83°F was recorded at the interior station on 21 July, 1934 and the thermometer reached the lower 70's several times during the months of May, July, August, and September. Temperatures were from 10° to 20° lower than those recorded simultaneously at the main base at the Bay of Whales.

On Operation Highjump it was observed that due to the twenty four hours of sunlight very little daily variation existed. However, a

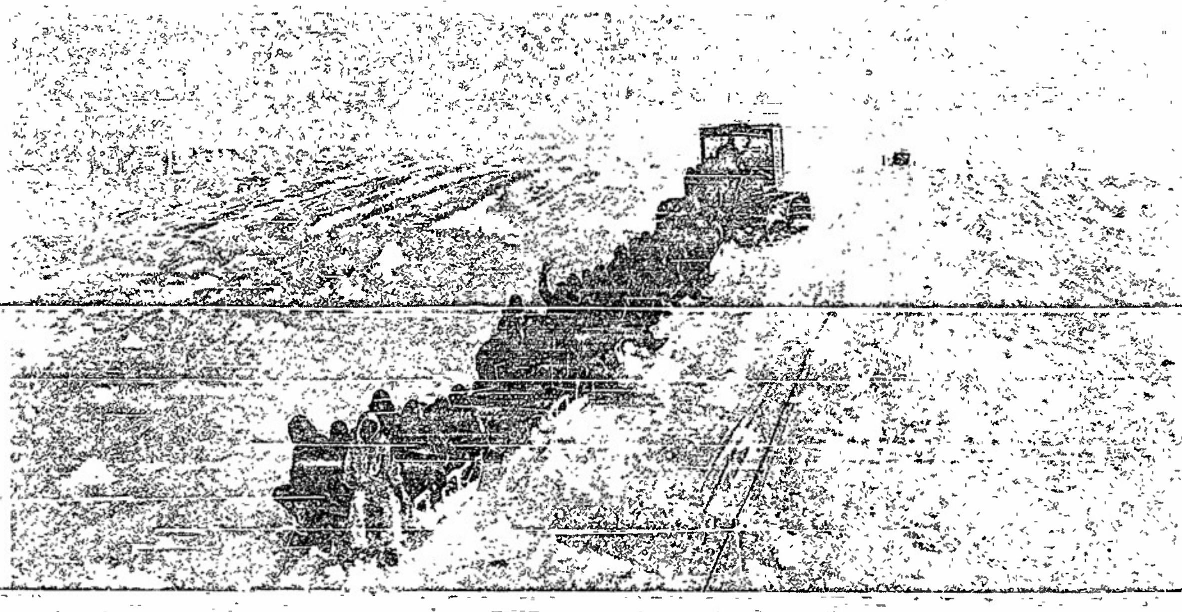


Fig. 19. — Seabees off to work, Antarctica

pronounced day to day variation did exist. The lowest temperatures occurred on days with northerly winds. The temperatures also tended to decrease as fall approached. The minimum temperature observed for the period at Little America was -21.8°F.

Precipitation.—Rain occurs frequently in the northern part and along the west coast of Palmer Peninsula. It is rare in other parts of the continent. During the same Operation High-Jump only frozen precipitation was observed at Little America. Precipitation is invariably in the f[illegible] of snow or hoar frost but the quantity deposited varies in different areas. Measurements have been of little value due to the great amount of drift swept along by the winds. Some authorities have estimated, however, that the net annual precipitation in some areas at sea level would be equivalent to one foot of snow.

Outward blowing winds from the Antarctic continent prevail and since the coast generally slopes east-west, these winds, which are always diverted to the left by the earth's

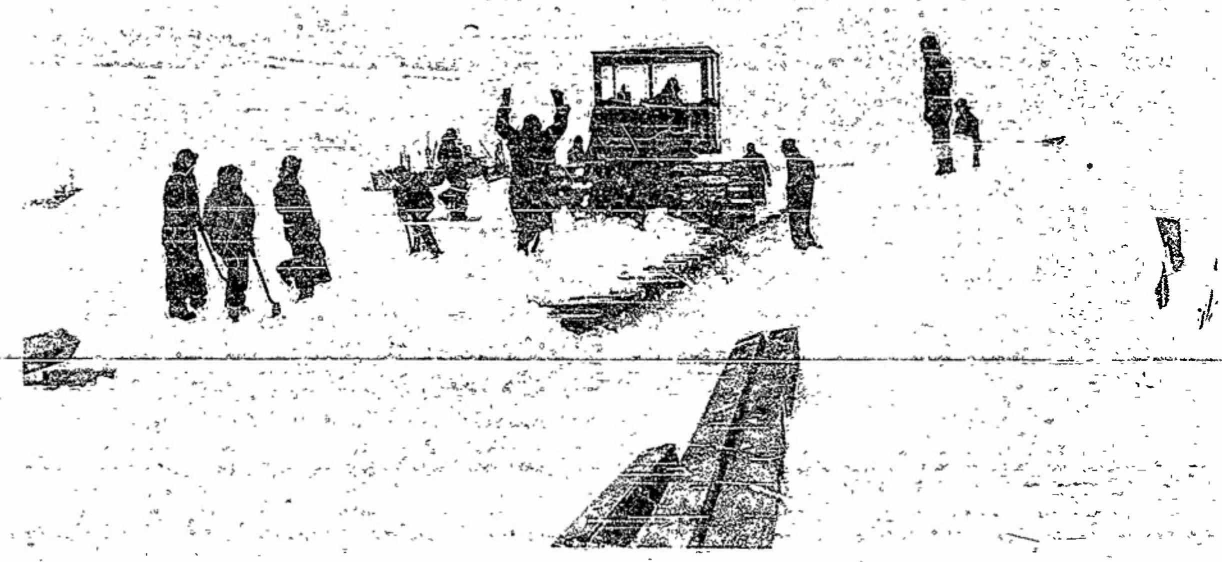


Fig. 20. — Bridging a crevasse, Antarctica.

rotation, generally blow from the southeast- erly quadrant. Where the coast slopes north- south as on the west of the Ross Sea, these winds, for the same reason, blow from the south east. They are often of hurricane intensity and with gust velocities sometimes reaching 150 to 200 miles per hour.

The Commonwealth Bay area is believed to be the windiest region in the world. The average wind velocity for 22 consecutive months during 1911-1914 was found to be 43 miles per hour. In July 1913, a gale of 96 miles per hour was recorded, during which an average velocity of 89 miles per hour was maintained for 12 hours.

Blizzards are very common in the Antarctic but usually do not extend far out to sea. On the other hand fog is not infrequent in the region of icebergs and pack ice, and along coasts.

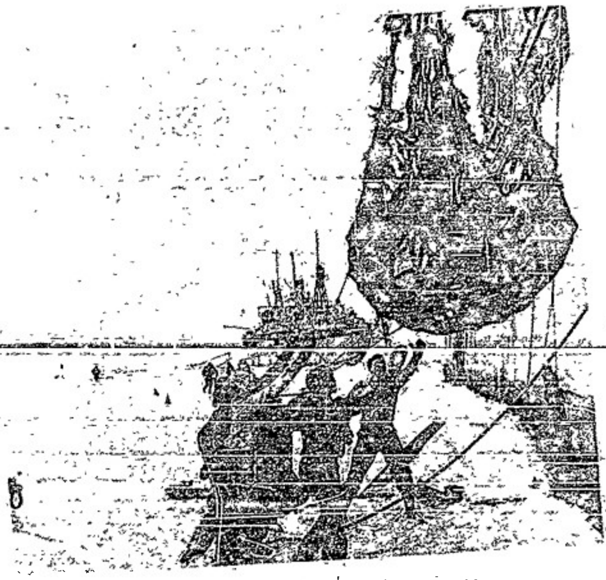
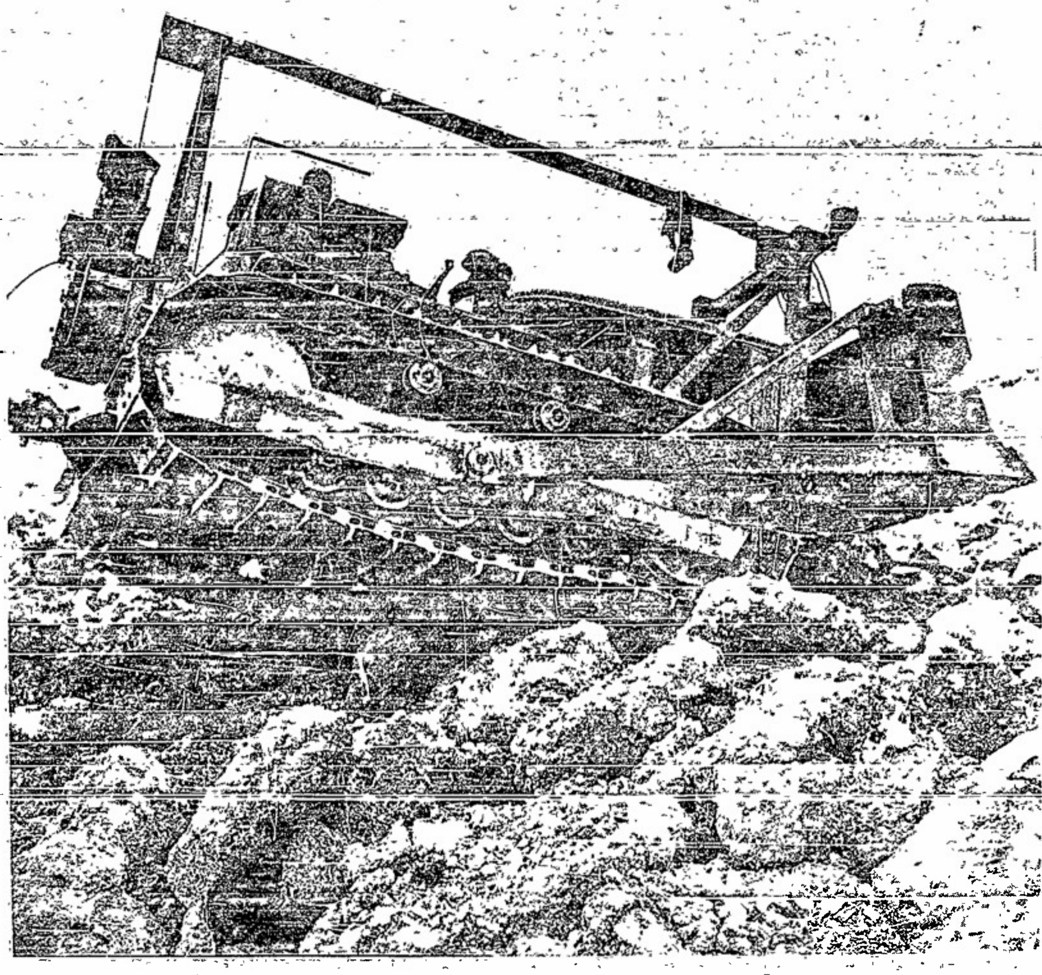


Fig. 21. — Unloading cargo, Bay of Whales

During the months of November, December, and January blizzards are rare, but during the autumn and winter months, they are fre- quent. The duration of a blizzard may be any- thing from a few hours to several days. Lack- ing weather stations, the first indication of an approaching blizzard comes in the form of a darkening sky with thick and low cloud form- ations. Existing winds may steadily increase, or a period of calm suddenly replaced by strong winds of 40 miles per hour. During the bliz- zard the wind holds steadily in direction and carries large quantities of drift. A period of calm generally follows after which the di- rection of the wind changes 180° and continues to blow with great force. This change indi- cates the passing of the storm center.



Rough going in permafrost

CHAPTER III

BASIC ARCTIC ENGINEERING PROBLEMS

PHYSICAL CHARACTERISTICS OF THE ARCTIC

Operations in the Arctic do not vary in principle from those in other regions. There are, however, certain differences in the application of standard engineering principles. The manner in which these principles must be applied depends on the physical character of the Arctic region.

Characteristics peculiar to the Arctic are directly related to the climate. Temperature in the Arctic may range from -53°F in the winter to 50°F. in the summer. The corresponding freezing and thawing that accompanies such extreme temperature changes causes violent reactions in the Arctic terrain.

A thorough knowledge of the physical character of the Arctic during all seasons is therefore essential to the success of any operation in that region.

Surface Conditions.

Snow: The Forest Products Laboratories of Canada has classified snow deposits and types into the following five groups:

1. Dry, soft and fluffy snow which usually occurs at moderately low temperatures.

2. Dry, soft and powdery snow which originates in regions of very low temperatures.

3. Dry, hard and granular snow, sometimes called soft hail or winter hail, which occurs as sleet.

4. Wet, soft and fluffy snow which occur when temperatures approach the freezing point and the air is reasonably still. The flakes are generally large, resulting from collision and cohesion of snow crystals in descent.

5. Slushy snow which occurs when existing snow deposits thaw, when rain falls on snow near freezing or when snow falls upon surfaces having a slightly higher temperature.

Winter snow in the Arctic is fine-grained and becomes packed very solidly (Fig.1), but the summer snow is coarse grained and remains loosely packed with much air between the crystals.

Contrary to popular belief the average snowfall in the Arctic is not exceedingly heavy. It is much less actually than that of Scotland or Illinois. The idea that snow is always falling in the Arctic arises from the fact that the snow there, being light and fine, is easily stirred about by the wind long after it has fallen.

Moderate winds produce drifts, resembling miniature sand dunes, called "sastrugi" which are generally low. Extremely strong winds, however, will normally result in drifts rising four to five feet in height. In addition to producing drifts the swirling snow obscures surface objects and reduces visibility.

DEFINITIONS

Ablation: Surface melting of snow or ice.

Avalanche: A mass of snow or ice detached from its position, and slipping down a slope.

Firn or Neve: Compacted snow in transition from soft snow to glacier ice.

Sastrugi: Snow drift shaped by the wind. A long axis shows the direction of prevailing storm winds, and is a sure guide in travel.

Ice in the Arctic: There are two basic kinds of ice - fresh-water ice, and sea ice. Of the latter, there are two principal types - the kind that is constantly moving (pack ice) (Fig. 2) and a kind that is generally immobile (fast ice), which forms in places along the shore line where currents are not strong, and does not break up until summertime. Both pack ice and fast ice are made from sea water and are therefore salt, although they may in time eventually lose some if not most of their salt-water content. In the sections below, each kind will be explained in greater detail.

The first indication that water is freezing is its greasy or oily appearance, after which small spicules and plates, called frazil ice, become visible. Frazil ice increases until the water is covered with a mush of crystals called slush or sludge. This material forms circular flat masses (pancakes) that, then, join into floes and sheets. In fast-running streams, however, spongy accumulations of frazil ice on the bottom and along the shores usually indicate the first phase in the freeze-up.

Fresh-water ice is found principally in lakes, streams and glaciers. There are tens of thousands of lakes and streams in the Arctic where ice forms in the winter and thaws during the summer. Ice forms faster on lakes than on moving streams and faster on clear-water lakes than on those containing much vegetation.

The ice on many of the lakes and streams in the Arctic grows to a thickness of 6 to 8 feet during a single winter season, and offers emergency landing sites for ski-equipped planes. It can be a source of water supply provided the water is potable and the depth is over 8 feet.

Glaciers, which are comprised almost entirely of fresh-water ice, take form as ice caps and valley glaciers.

Ice caps, as their name implies, cover large areas of land regardless of the nature of its topography. Outstanding examples are the Antarctic and Greenland ice caps, both of which reach an altitude of approximately 10,000 feet and are constantly but very slowly moving seaward.

Valley glaciers are essentially rivers of ice confined to valleys. They may be connected with an ice cap, as a stream is connected with a lake, or they may be independent. Many a valley glacier that extends outward from an ice cap to the coast, is simply the means by which the ice cap discharges its slowly moving masses of ice into the sea. Such glaciers end abruptly at the coast line in great terminal cliffs from which large blocks of ice are constantly breaking off, or calving, to form icebergs. Such icebergs (Fig.3) may be distinguished from sea ice by their greater size and height, and also by the fact that they are always composed of freshwater ice.

Under certain climatic conditions the thickness of ice increases quite rapidly. Table I illustrates the growth of fresh-water ice.

Another method of ascertaining the thickness of fresh-water ice is by use of the curve in (Fig. 4). If exact temperatures are not available, estimates can be made from a general knowledge of the weather conditions in the region. It will be noted, however, that the degree days of frost must be calculated in order to use this method. The number of degree days of frost can be determined from the following formula:

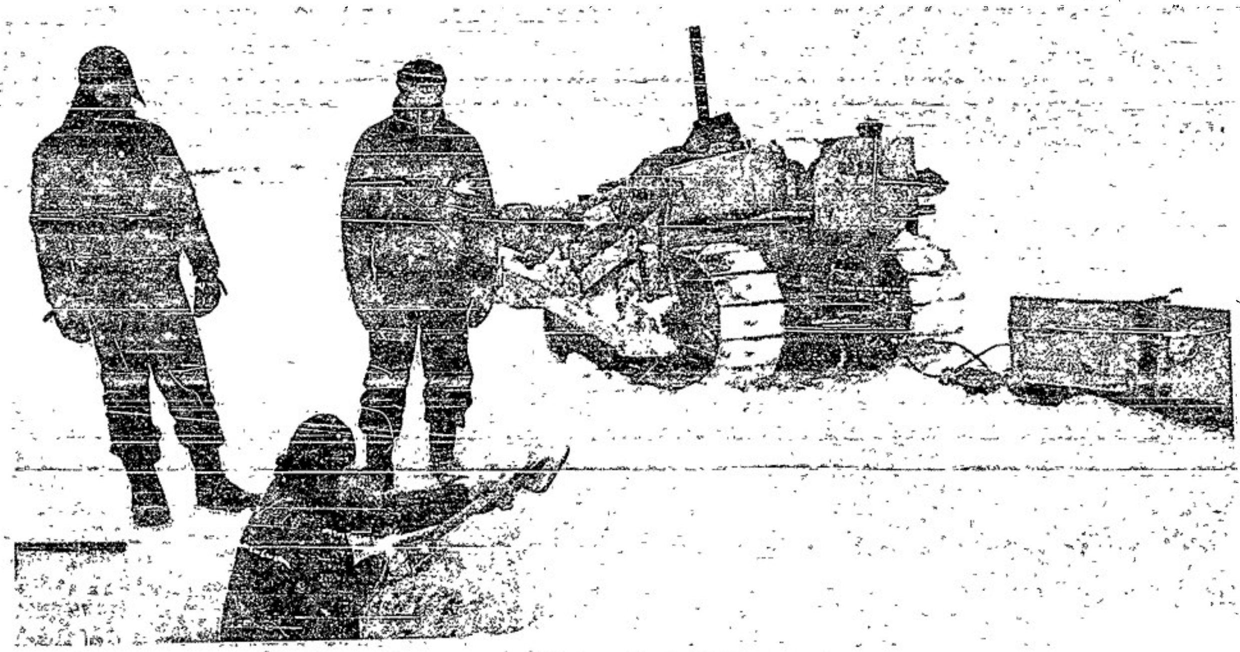


Fig. 1. — Hard packed snow

$$D = \frac{H}{24} \times N\,(32-T)$$

Where D = degree days of frost

H = hours below freezing

N = number of days

T = mean temperature

Example. If a specified day had 8 hours below freezing and the mean temperature for those 8 hours was 25°F, the degree days of frost for the day are:

$$\frac{8\ \text{hr.}}{24\ \text{hr.}} \times (32^\circ - 25^\circ) = 2\ 1/3$$

If the next day had a mean temperature of 20°F. for the entire day the degree days of frost for that day are:

$$24/24 \times (32-20) = 12$$

If the following ten days had approximately a mean temperature of −20°F. during the entire twenty-four hours of each day the degree days of frost for the 10-day period are:

$$24/24 \times 10 \times (32-(-20)) = 520$$

The total degree days of frost for the entire 12-day period would be 534 1/3.

Pack ice may consist of individual pieces of ice from a few feet to a few hundred yards in diameter, called floes, or it may be comprised of great solid ice fields the limits of which extend beyond the horizon.

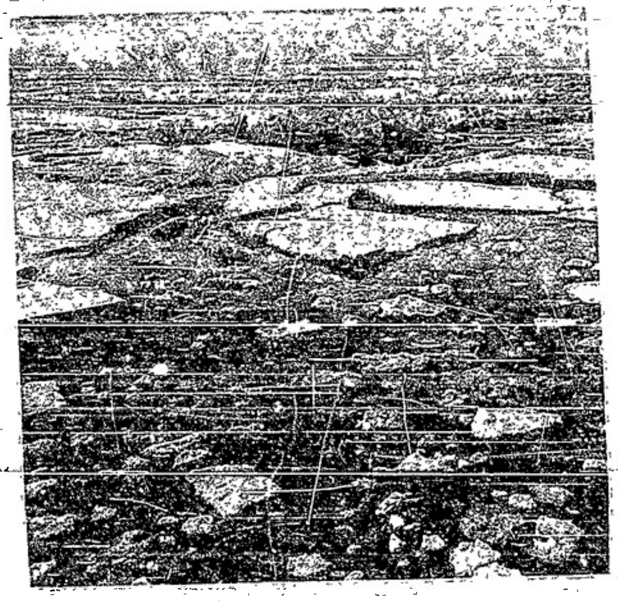


Fig. 2. — Pack ice

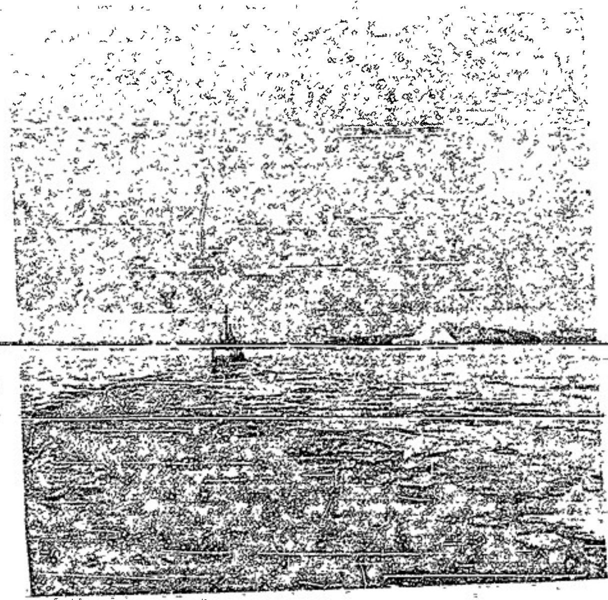


Fig. 3. — Ship working past small iceberg

Pack ice (Fig.5) is always moving under the influence of currents and winds. As a result of continuous movement, the floes and fields crack apart and develop narrows lanes and broad leads of open water. However, leads and lanes forming in winter soon freeze over, making smooth patches of ice.

Pack ice (Fig.6) seldom grows thicker than 5 to 7 feet in the first year but has, in the polar basin where it is perennial, attained a maximum thickness of 12 feet during a four-year period. Thicknesses of 200 feet are not uncommon, but they are almost always the result of the telescoping, or piling up of the floes (Fig.7). This action is known as rafting. At times through actions of the winds and currents, these floes are shoved together and the force is great enough to crush the strongest ship caught between them.

Unlike fresh-water ice, the perennial sea ice in the polar basins may even increase in depth during the summer. This happens when

TABLE I--RATE OF GROWTH OF FRESH-WATER ICE

INCHES	TEMPERATURES			
	−10°C.	−20°C.	−30°C.	−40°C.
1	2.0 hr.	1.0 hr.	41.2 min	30.9 min
6	1.9 day	23.4 hr.	15.6 hr.	11.7 hr.
10	5.1 day	2.6 day	1.7 day	1.2 day
12	7.3 day	3.6 day	2.4 day	1.8 day
24	28.6 day	14.3 day	9.5 day	7.1 day
36	63.6 day	31.8 day	21.2 day	15.9 day

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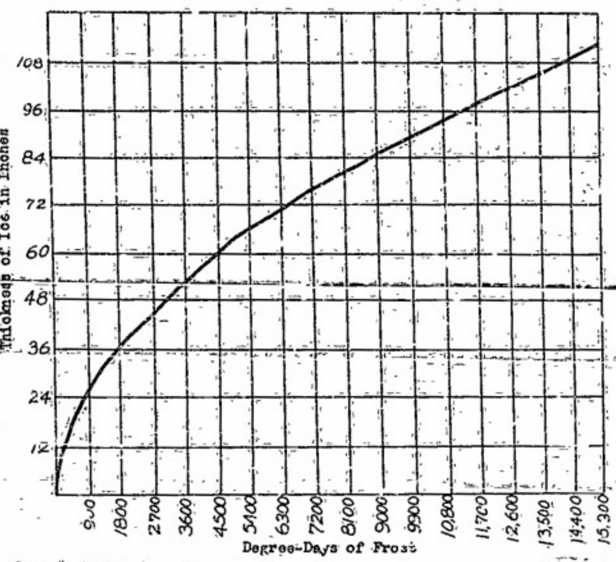


Fig. 4. — Rate of growth of ice

surface snow melts and seeps through to form a layer of fresh water under the ice. Since the underlying salt water is usually colder than the freezing point of fresh water, fresh-water ice is formed on the bottom of the sea ice, thereby increasing the total thickness.

A striking illustration of the slow shifting or movement of the ice pack across the north polar sea in the direction of Greenland is contained in the history of a Soviet expedition to the North Pole. On 21 May 1937 a group of scientists under Ivan Papanin was flown from Rudolf Island in the Arctic basin about 500 miles to the North Pole. After depositing personnel, equipment and supplies, the planes returned to Moscow. The Scientists left on the ice field conducted experiments and lived in temporary shelters on the ice floe for over nine months. On 19 Feb. 1938, after having drifted approximately 1500 miles the party was picked up off the eastern coast of Greenland near the mouth of Scoresby Sound.

Fast ice forms in bays, straits, and other protected inlets, and remains immobile until it breaks up during the summer. Because of its immobility, fast ice affords better sledging routes and emergency landing fields than does pack ice.

Sea water freezes faster than undisturbed-especially if shallow, when diluted by fresh water, or when there is a quantity of old ice present.

Tundra: The Arctic region is characterized by vast stretches of mucky, treeless land covered with a variety of plants, including grasses, lichen and shrubs. This type of country is called tundra. Unlike prairie country which it generally resembles, tundra is, to a large extent, poorly drained and marshy (see Fig. 8).

The earth beneath practically all arctic tundra is permanently frozen a few feet below the surface. During the summer, the ground thaws to a depth of one or two feet but because of the underlying frozen ground, water cannot run off below the thawed layer. Consequently the ground is kept moist and marshy in most places (Fig.9) In addition to being responsible for this poor drainage throughout the Arctic, the underlying permanently frozen ground is partly the cause of the many lakes.

Walking over the marshy tundra in the summer is similar to walking barefooted on a mattress. The alleged thrills of such an experience are rudely interrupted, at times, when the surface fails and you find your leg enmeshed in a foot of mud. Peculiarly enough this marshy condition is not confined to depressions but is also found on the slopes and even the summits of hills.

Considerable time is consumrd in recovering vehicles which have sunk in the marshy tundra (Fig.10).

In places where the summer thaw penetrated the frozen ground to a considerable depth, tractors and other pieces of equipment have been known to sink so low that they almost disappeared from sight.

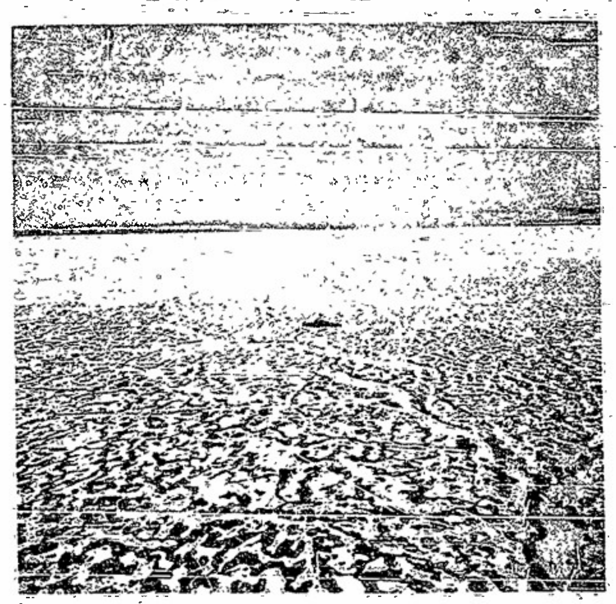


Fig. 5. — Pack ice

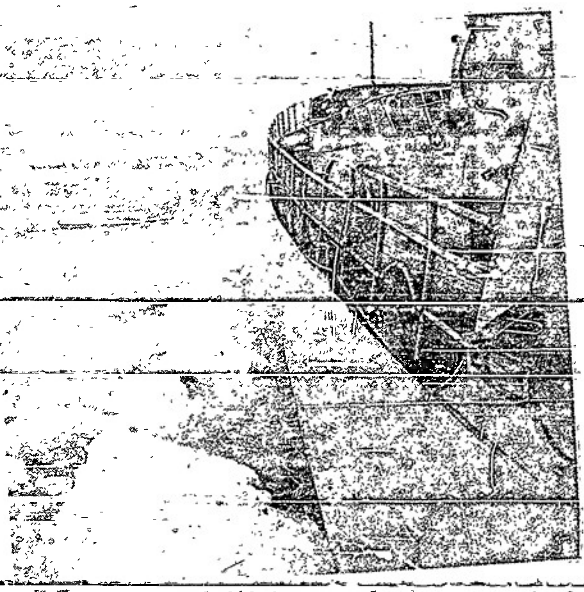


Fig. 6. — Pack ice

DEFINITIONS

Anchor Ice: Ice attached to the bottom.

Bergy Bit : A large piece of glacier ice rising 8 to 16 feet above the surface of the sea.

Beset : When a vessel is out of control in sea ice, it is beset.

Bit : A piece of ice less than 2 feet across.

Blizzard: Snow drifting so thickly that visibility is zero.

Blocky Iceberg: An iceberg having a nearly horizontal surface and steep sides.

Boring : Forcing a vessel steadily through ice by pushing floes apart. Also called slewing.

Bottom Ice: Depth ice that has clung to the bottom.

Brash : Small floating ice fragments, sometimes called slob ice.

Calving: The breaking away of a mass of ice.

Candle Ice: Long crystals formed in ice at right angles to the surface of the water. The length equals the thickness of the ice. Tips are sharp and will cut shoe leather and dogs' feet. Also called needle ice.

Close Ice: Ice so closely packed that it covers most of the sea surface making navigation difficult or impossible.

Confluent Ice: Ice sheets formed by ice tongues, from several glaciers, held together by a land barrier.

Conglomerated Pack: High hummocky floes interspersed with ice bergs. Not navigable.

Consolidated Pack : The heaviest form of pack, containing much pressure ice, and no water spaces.

Crack : A narrow fissure. Travelers speak of a crack if a man can jump over it but of a lead if he cannot do so. Sailors sometimes use the term crack for a lead too narrow for a ship's passage.

Crevasse: A deep fissure in glaciers, shelf ice, or other land-ice.

Debacle : The spring break-up of river ice.

Depth Ice : Small particles of ice formed

Fig. 7. — Rafted ice

Fig. 8. — Marshy tundra

in disturbed sea-water. Some touch bottom and become bottom ice; others freeze together and rise to the surface.

Drift: Wind driven snow. The motion of sea ice or vessels, resulting from ocean currents.

Drift Ice : Very open pack. Vessels usually can pass through it without altering course or speed. Also known as "sailing ice."

Fast Ice : Stretches of unbroken ice attached to the shore. The 12-fathom line is often maximum limit of fast ice. It usually breaks up during the summer.

Field : The largest areas of drift ice. Their limits cannot be seen from a ship's masthead.

Floe : An area of drift ice.

Flower Ice: Salt crystals on top of ice.

Frazil : Fine spicular crystals and ice plates in disturbed water.

Glacier : A field or stream of ice of land origin. It may be either active or stagnant.

Glacier Tongue : Extension of a glacier into the sea. They are generally afloat.

Grounded Ice : Ice so heavily aground that it does not move before a wind or current.

Growler : A small piece of glacier ice, rising 2 to 7 feet above the surface of the sea.

Heavy Ice : Sea ice more than 3 or 4 feet in thickness.

Hummocking: Process by which the young and level sea ice becomes built up into hummocky ridges. The terms "bending", "tenting," and "rafting," describe different phases of the process.

Iceberg : A large mass of floating or stranded glacier ice.

Ice Blink: A mirroring in the sky, usually of snow-covered ice.

Ice Cap : A flat dome-shaped glacier covering a land area.

Ice Fat : Tiny crystals on the surface of the sea that make it seem covered with patches of congealed fat. Ice fat makes the sea look like watered silk (moire).

Ice Jam: A dam formed by seasonal breaking up of river ice.

Ice Limit: The greatest extent of the ice.

Ice Rind : Hard ice formed by the freezing of slush in calm water at low temperatures.

Land Sky: The mirroring of land in clouds. If the land is fully snow covered its cloud appearance is identical with that produced by fully snow-covered ice. If some dead grass sticks out through the snow the land sky is yellowish. If the land is snow-free its sky reflection is nearly black, though seldom the uniform black of water sky.

Lead : A navigable passage through ice. Any crack wider than 3 to 5 feet.

Nipping: Closing of the ice so as to pinch a vessel.

Open Ice: Scattered ice where navigation is possible.

Open Lead: A lead that has not been frozen.

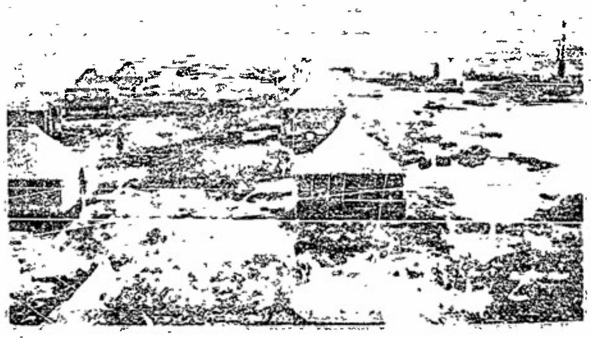


Fig. 9. — Poor drainage in tundra

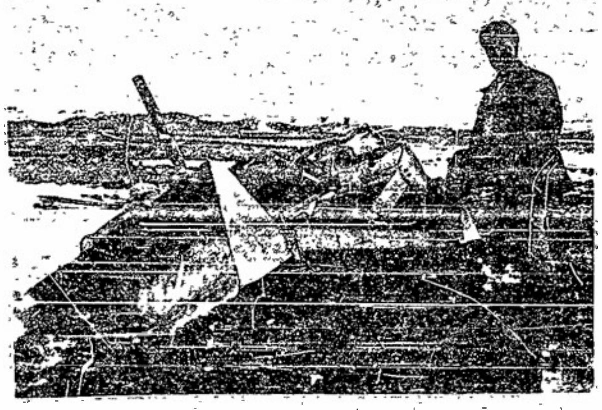


Fig. 10.— Bogged down in tundra

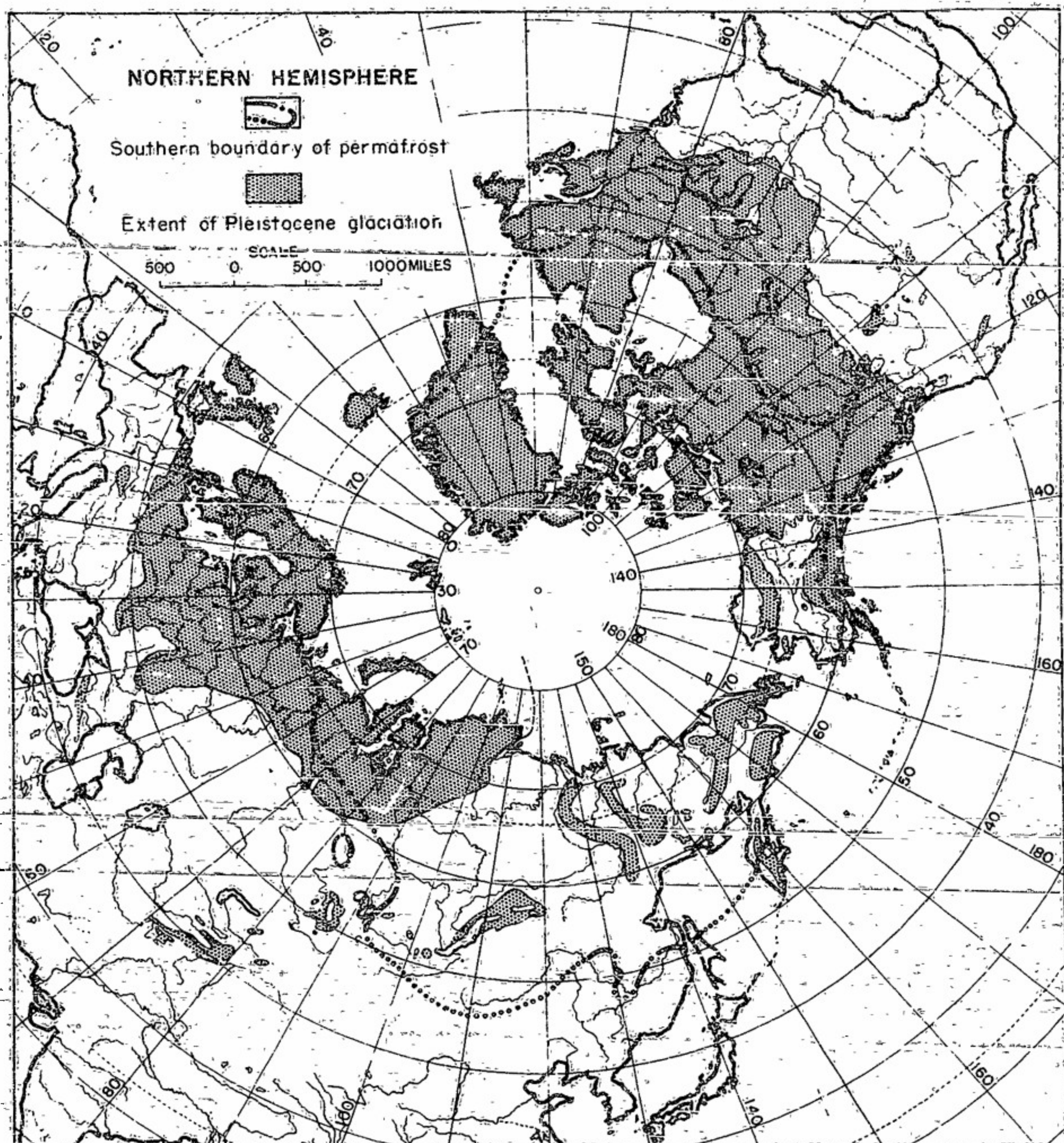


Fig. 11.— Extent of permafrost in Northern Hemisphere

Polynya (Russian term): An unfrozen portion in river ice which remains unfrozen during all or part of the winter owing to a local inflow of warm water either from a subaqueous spring or from a tributary.

Pressure Ice: Crushed ice fragments in heaps or ridges.

Pressure Ridge: Pressure heaps arranged in a long ridge.

Rafted Ice : Several ice layers, formed under pressure.

Shelf Ice : Glacial ice sheet continues out to sea beyond where it rests on the bottom. Best known example is in the Ross Sea in the Antarctic.

Sky Map : The mirroring of land, snow, or ice in the clouds.

Shore Lead: A lead between ice and the shore.

Slush: Accumulation of grey ice crystals not frozen together. Wind ripples disappear in slush.

Snow Concrete: Snow which has been compressed at a low temperature and then had sufficient time to harden, as when the tread of an animal has compressed new-fallen dry snow and a blizzard has swept away the rest of the snow, leaving the tracks standing up on pillars of snow concrete.

Snow Ice: Young ice formed, in part, from drifting snow.

Snow Sky: Reflection in the sky of snow-covered ice or land.

Tide Crack: Crack, usually parallel to a shore, caused by tides.

Water Sky: Dark patches or streaks on the clouds due to the reflection of leads and polynyas, or a uniform black due to an open sea in the vicinity of large areas of ice or snow covered land. Details of the arrangement of the ice can be seen clearly when low stratus clouds are present.

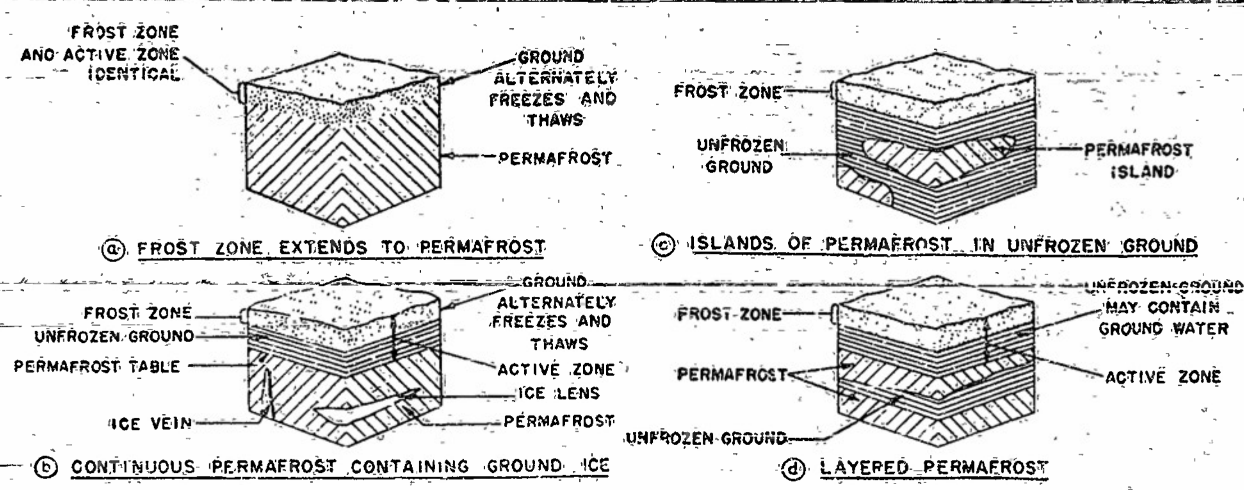


Fig. 12.— Typical sections of ground containing permafrost

Sub-Surface Conditions

Permafrost: Permafrost is a body of soil or other deposit at a variable depth beneath the earth's surface where a temperature below freezing has existed continually for many thousand years.

Permafrost has been in existence since the beginning of the Ice Age, perhaps a million years ago. During subsequent climatic fluctuations corresponding changes must have taken place in the thickness and extent of permafrost. Permafrost is at present forming in areas where the mean annual temperature is below freezing, precipitation is light, and there are long cold winters, short days, and relatively cool summers.

Permanently frozen ground, or permafrost, underlies approximately one fifth of the land area of the world. This condition is most common in the northern hemispheres (Fig.11), where it includes about 80 percent of Alaska, 50 percent of Canada, and practically all of Siberia, but it is also quite extensive in the Antarctic.

The thickness of permafrost ranges from several feet at its southern extremities to more than 900 feet near the Arctic Ocean.

The irregular upper surface of permafrost is known as the permafrost table. All ground above this permafrost table is designated as the Active Zone. The usual thickness of this active zone is inversely proportional to the thickness of the permafrost but it may be affected by the type, moisture content and compaction of the soil, and the insulating cover of vegetation (Fig.12).

The Frost Zone is that portion of the active zone subject to freezing and thawing. Where seasonal freezing penetrates to the permafrost table the frost zone and the active zone are identical. The lower limit of seasonal thawing is called the Frost Table (Fig. 12b).

Nature has established and maintains an equilibrium, called the thermal regime, between the factors in the permafrost province.

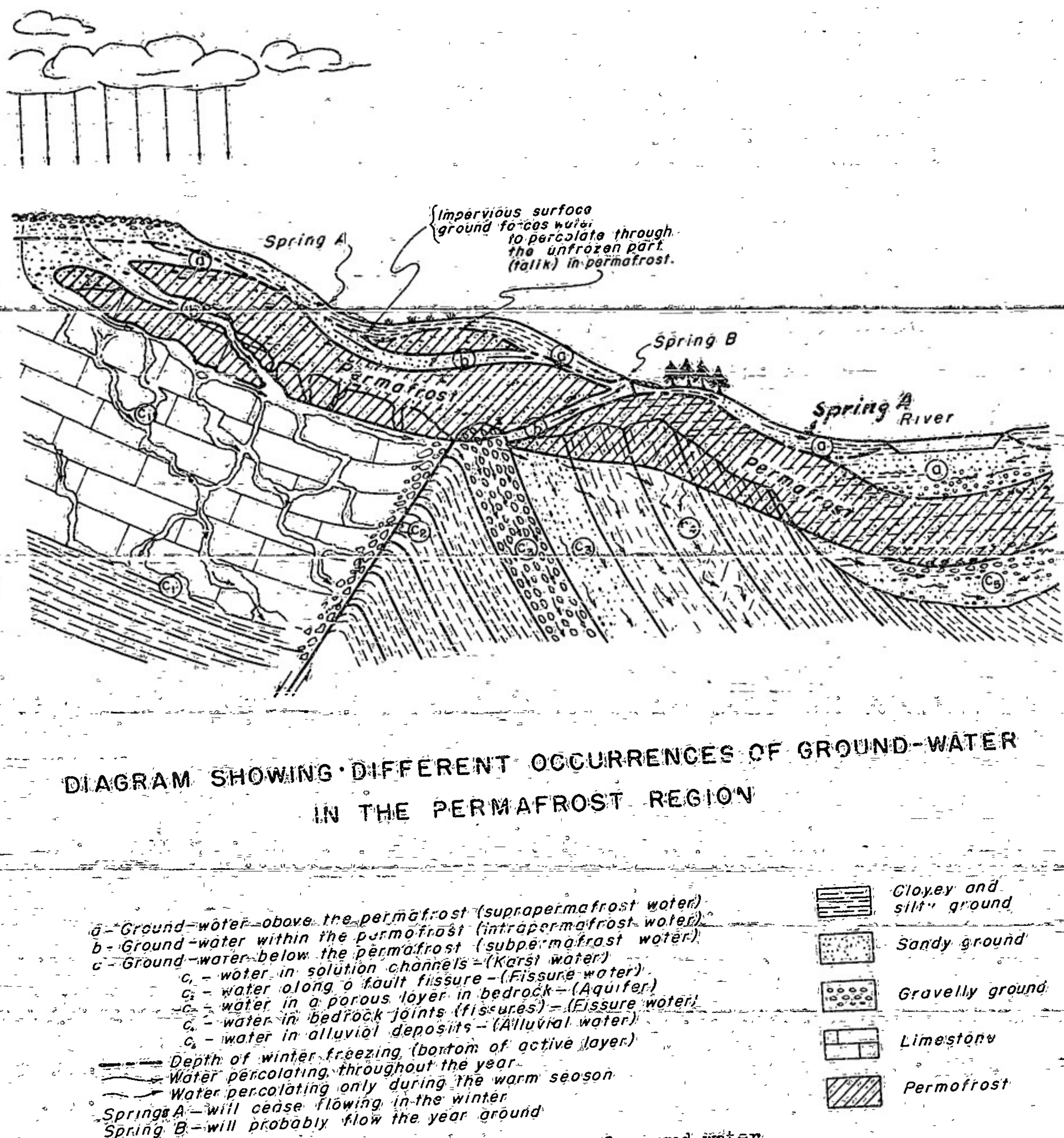
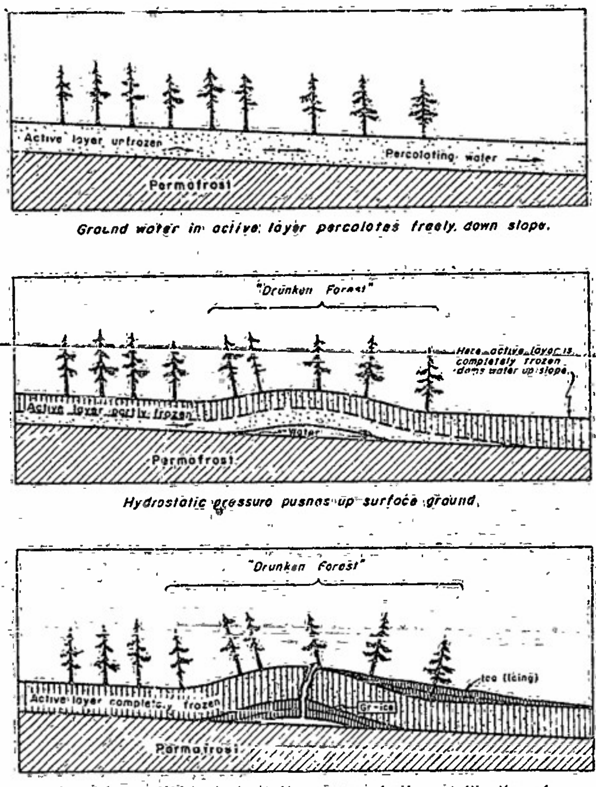


Fig. 13.— Occurrences of ground-water in the permafrost region

Any construction operation which changes or disturbs this thermal regime will be subjected to the forces of nature as they endeavor to reestablish this equilibrium. During this adjustment period a poorly designed structure is most likely to fail. Climatic conditions and geologic changes may also affect the thermal regime and, thereby, result in either the degradation or aggradation of the permafrost.

Since practically all of the destructive effects of freezing and thawing are related to ground water, it is a most important factor. Ground water may be divided into three categories according to its location, above, within, or below the permafrost (Fig.13).



Ground water in active layer percolates freely down slope.

Hydrostatic pressure pushes up surface ground.

Mound is ruptured by hydrostatic pressure (and crystallization of ice?). Water freezes forming icing and ground-ice. Occasionally a hollow space is left in the core of a mound.

Fig. 14.—Frost blister

Ground water above the permafrost is caused by rain, melting snow, and upward seepage from within or below the permafrost. When the frost zone is thawing the behavior of ground water above an impervious surface. However, during seasonal freezing the ground water is constricted in its channel and subjected to hydrostatic pressure. This pressure is proportional to the thickness of the overlying frozen part of the active zone. As a result of this pressure (Fig. 14) the water may be forced to the surface and form sheets of ice, or it may be confined between the frozen and unfrozen layers of the active zone.

Because freezing of the ground water above the permafrost is the main cause of swelling ground, frost-mounds, and icings, it is of vital engineering interest and must be thoroughly investigated before any project is started. Ground water can be discounted as a source of water supply because of its unavailability in the winter and its high degree of pollution in the summer.

Ground water within the permafrost is produced by infiltration from above or beneath, or a combination of both. This water may or may not be under pressure and while it generally exists in considerable volume, it is often strongly mineralized.

The ground water beneath the permafrost is always fluid and, in most cases, under hydrostatic pressure. Except when strongly mineralized or under a layer of permafrost so thick that it would be impracticable to penetrate, it may serve as a good source of water supply.

Plant life in the Arctic is definitely influenced by the presence and extent of permafrost as well as by the duration of seasonal frost. Vegetation may, therefore, give some indication of sub-surface conditions. The presence of pine or fir trees, for example, is good indication that permafrost is either absent, or considerably below the surface, for the prominent top roots of such trees will not thrive where permafrost is present. Another indication of the absence of permafrost and of the presence of ground water, which freezes only for a short time, is the existence of willow groves.

On the other hand, larch and dwarfed birch usually indicate the presence of permafrost close to the surface. Thick moss and hummocky tundra, also, signify a relatively thin water-bearing zone above a high permafrost table. This latter condition is quite common on the flat north Arctic slope.

Also, the topography of an area reflects its sub-surface condition. Where the surface is subdivided into large polygonal soil sections with the appearance of an irregular checkerboard (see Fig. 15), a considerable amount of ground ice will be found. The existence of springs and icings are direct evidence of ground water.

Exposed sand, gravel, and rocks on hillsides usually indicate water in adjoining lowlands. Southerly slopes have lower permafrost tables than northerly slopes with the possibility of large quantities of unconfined ground water. Flood plains near the edges of lakes and rivers ordinarily have large layers of unfrozen ground containing ground water.

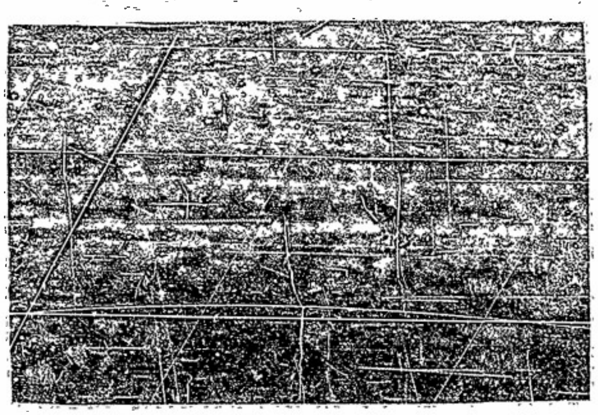


Fig. 15.—Soil polygons

Fig. 16.— Frost mounds

Coarse, permeable soils, clean sand, and gravel usually have a low permafrost table and readily transmit ground water, while fine-grained soils ordinarly have a high perma - frost table and are not conducive to good drainage.

The severe cold and seasonal freezing and thawing cause the surface of the earth in permafrost regions to react in violent and, for the novice, unpredictable ways. One of the most destructive of these reactions is swelling of the ground, commonly called heaving.

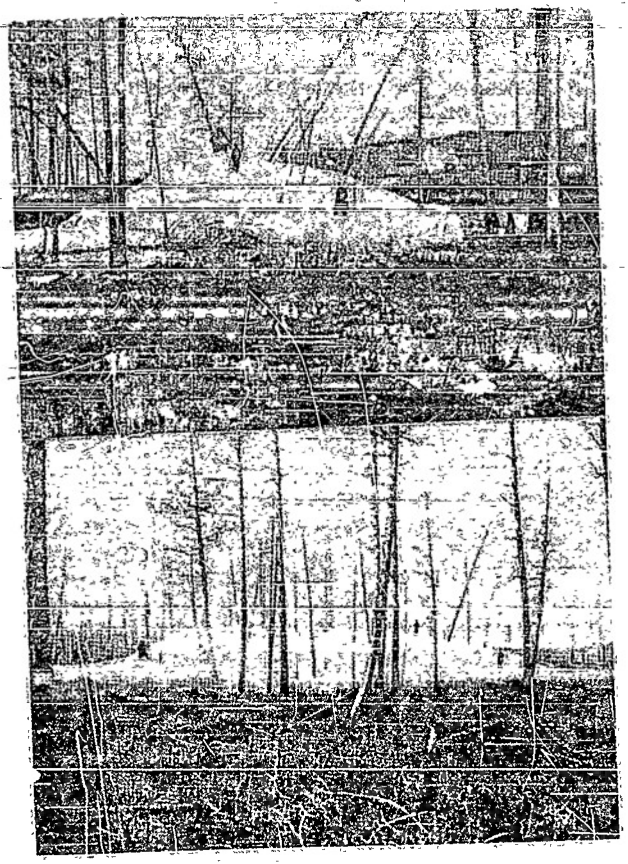


Fig. 17.— Icing mound

The principal causes of heaving are hydrostatic pressure of confined ground water and the volumetric increase resulting from the conversion of this water into ice.

The intensity of heaving will vary according to the composition of the ground, the amount of water present, and the load distribution. The degree of heaving is always potentially greater where the ground is composed of silty, fine, sandy or clayey deposits, or peat, and where the active layer is thick and freezes down through to the permafrost.

Manifestations of heaving are numerous. Known as frost mounds, they vary from small hummocks of peat a few feet in height, to frost blisters (pingo) which have been known to reach a height of 200 feet (see Fig. 16).

Similar to frost mounds are ice mounds, composed almost entirely of ice (Fig. 17). One main distinction between these two is that ice mounds continue for a considerably longer period of time to issue water, which then freezes.

DEFINITIONS

Active Zone: Layer of ground above the permafrost.

Active Permafrost: Active permanently frozen ground. Permafrost which, after having been thawed, due to natural or artificial causes, is able to return to permafrost under the present climate.

Adfreezing: The process by which two objects freeze together.

Adfreezing Strength: Resistance to the force that is required to pull apart two objects which adhere to one another as a result of the binding action of freezing. In Russian reports, this term is frequently used to mean Tangential Adfreezing Strength.

Aggradation of Permafrost: Growth of permafrost under the present climate from natural or artificial causes. Opposite to degradation.

Capillary Water: Water that is retained in the capillary interstices of the ground and is capable of movement through capillary action. It may remain unfrozen at temperatures between -41°C. to -78°C.

Closed System: A condition of freezing of the ground when no additional supply of groundwater is available.

Confined Ground Water: A body of ground water overlain by impervious material.

Critical Moisture Content: Maximum amount of water which, when frozen, will fill all the available pore space of the ground.

Degradation of Permafrost: Disappearance of the permafrost due to natural or artificial causes.

Dilation: A condition where water exists in excess of water of saturation held by swollen ground. Supersaturation.

Dry Frozen Ground: Ground with temperature below 0°C. containing no ice.

Dry Permafrost: Permanently frozen ground with temperatures below 0°C. but containing no ice.

Fine Aggregate Ice: Ice formed by freezing stirred water.

Fixed Ground Water: Water held in saturated material with interstices so small that it is permanently attached to the pore walls, or it moves so slowly that it is not usually used as a source of water for pumping.

Frost Boil: Accumulation of excess water at a place of accelerated spring thawing of ground ice. It usually weakens the surface and may break through, causing a quagmire.

Frost Dam: Artificially induced freezing of ground to intercept sub-surface seepages that cause icings.

Frost Heaving: Upwarp due to the swelling of frozen ground.

Frost Table: A more or less irregular surface that represents the penetration of spring and summer thawing of the seasonal frozen ground not to be confused with permafrost table.

Frozen Ground: Ground that has a temperature 0°C. or lower.

Gravity Water: Vadose water. Water in excess of pellicular water, which can, therefore, be drawn away by the force of gravity.

Ground Ice: Subsoil-ice, underground-ice, fossil-ice, subterranean-ice, stone-ice, bodeneis, ureis, jordbundsis. Term "glacier" used by miners in Alaska. Bodies of more or less clear ice in frozen ground. Excludes ice of glacial origin.

Ice Wedge: A narrow crack or fissure filled with ice which may extend below the permafrost table.

Icing: A mass of surface ice formed during the winter by successive freezing of sheets of water. When the ice is thick and localized, it is called icing-mound, and when it survives the summer it is called "taryn".

Icing Mound: A localized icing of substantial thickness but of limited area. May be formed entirely or in part by the upwarp of a layer of ice (as in a river) by the hydrostatic pressure of water.

Intrapermafrost Water: Ground-water in unfrozen layers, lenses, or veins within the permafrost.

Layered Permafrost: Ground consisting of permanently frozen layers alternating with unfrozen layers, or taliks.

Passive Permafrost: Permafrost that was formed during earlier colder climates, once destroyed, does not form again.

Pellicular Water: Water adhering as films to the surfaces of grains that compose rock. Pellicular water is stored water above the capillary fringe.

Permafrost: That layer of soil beneath the surface of the earth in which a temperature below freezing has existed continuously for a long time.

Permafrost Table: Upper limit of permafrost.

Polygonal Soil: Polygonal pattern of the surface produced by a segregation of constituents of the ground and indicated by a slight relief.

Saturation Water: The total water that can be absorbed by water-bearing materials without increase in volume.

Seepage: The percolation of water through the surface of the earth or through the walls of excavations. Influent seepage is seepage into the ground while effluent seepage is seepage out of the ground.

Soil: The layer or mantle of mixed mineral and organic material penetrated by roots. It includes the surface soil (horizon A), the subsoil (horizon B), and the substratum (horizon C) which is the basal horizon and is limited in depth by root penetration. In engineering practice, under the term, soil, are included practically every type of surficial earthen material, including artificial fill, soft shales, and partly cemented sandstones.

Solifluction: The slow gravitational flowing of masses of superficial materials generally saturated with water.

Sporadic Permafrost: Scattered island of permanently frozen ground occurring in unfrozen areas.

Subpermafrost Water (subwater): Ground water in the unfrozen ground beneath the permafrost.

Suprapermafrost Layer: Thickness of ground above permafrost consisting of active layer.

Surficial Swelling: Small swelling of ground caused by freezing of water at a short depth below the surface.

Swelling Of Ground: Increase in volume due to frost action.

Water Table: The upper surface of the body of free water which completely fills all openings in the ground.

Zero Curtain: A layer of ground between active layer and permafrost where zero temperature (0°C.) lasts during the freezing and thawing of overlying ground.

CONSTRUCTION IN THE ARCTIC

Problem Stated.

Construction methods and practices employed in temperate climates must be modified to meet permafrost conditions in the Arctic. Roads, railroads and buildings built in the Arctic have, in the past, sustained serious damage because of the destructive action of permafrost which had been ignored or miscalculated in the original design.

Since stresses that develop in freezing ground may exceed 28,000 pounds per square foot, it is obvious that it is uneconomical and impractical to cope with these forces by using stronger materials or resorting to more rigid design. The successful solution of the problem hinges on recognition of the principle that nature is a prima donna who must be appeased rather than opposed.

A thorough study of permafrost is therefore an important part of the planning of every engineering project. The trend today in Arctic construction is towards a design that minimizes or completely neutralizes the destructive effect of frost action.

Construction Methods

Two methods of construction will maintain thermal equilibrium in permafrost, the Passive Method and the Active Method.

The Passive Method is sub-divided into two general systems. In the first, the vegetation is left intact and additional insulation is added (Fig. 18). In the second, soil and vegetation above the permafrost table are removed and replaced with an insulating blanket of coarse-grained sand and gravel (Fig. 19). Following this system, all frost-action material within the lines of the construction project and to the depth of the frost zone must be removed. The standard design for all buildings should provide for adequate insulation of the floor, and for air circulation between the floor and the new grade.

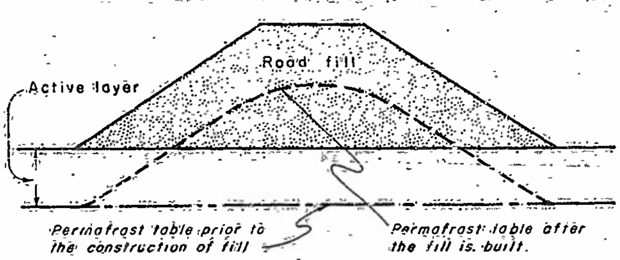


Fig. 18.— Passive method

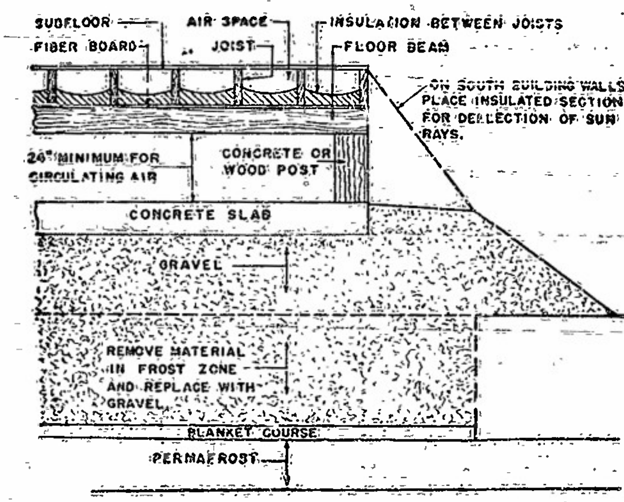


Fig. 19.— Passive method

The second method of construction is known as the Active Method. This method is employed only where the permafrost is thin, and the ground will have a satisfactory compressive strength when thawed. The ground is thawed before construction begins and the design relies on the strength of the thawed ground to support the structure (Fig. 20).

The importance of preliminary investigation of the permafrost conditions at specific locations to determine whether the passive or active method of construction is to be used cannot be overemphasized.

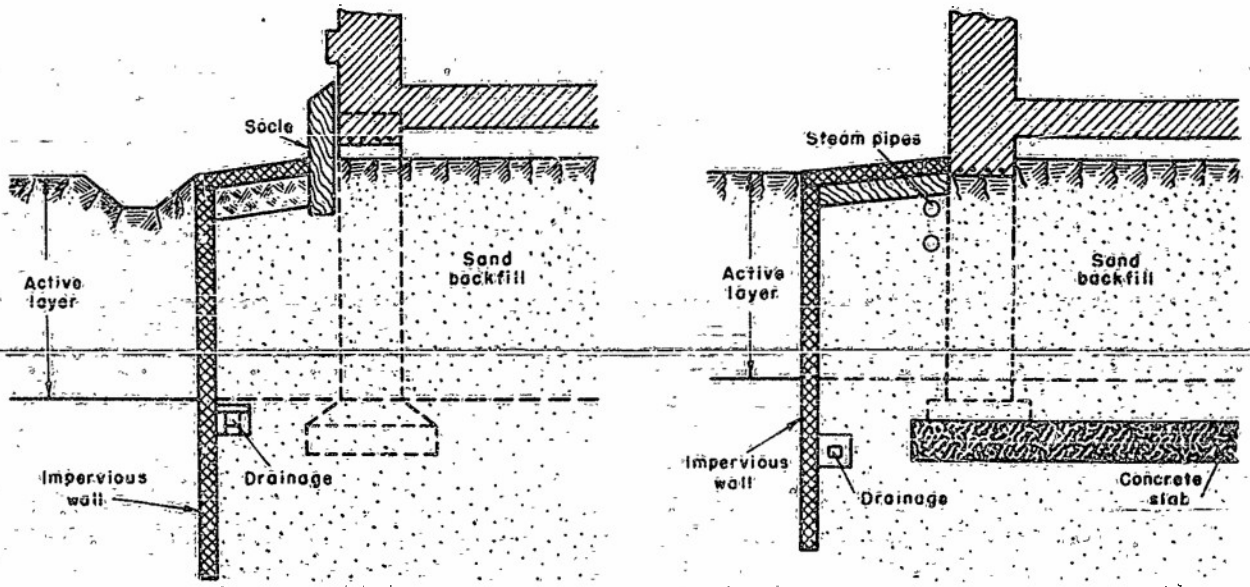


Fig. 20.— Active method

General Comments on Permanent Structures.

When the thermal regime of an area is disturbed by changes affecting the frost or active zone, serious damage to structures may occur. The greatest harm is done when the ground thaws and the permafrost table drops.

Ground will thaw when the vegetation, which is a natural insulation, is removed, or when a poorly insulated structure generates heat downward (Figs. 21 and 22). Even the amount of solar radiation reflected from the south wall of a building causes the ground on that side to thaw to a greater than normal depth while the shaded north side will be affected in just the opposite manner (Fig.23)

It is obvious, therefore, that to insure success in Arctic construction, extreme care must be exercised to avoid disturbing the permafrost table.

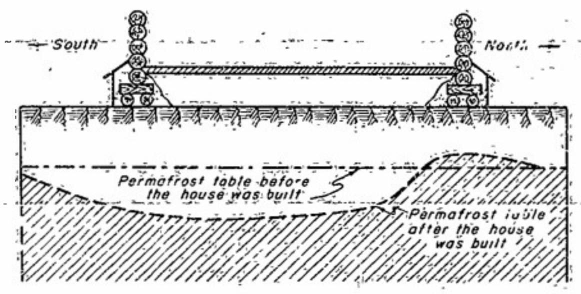
Temporary Shelters

In an emergency many types of temporary shelters and windbreaks can be constructed.

The simplest form of such a shelter is the snow cave (Fig.24). It can be made where the snow blanket is deep and has lain in place long enough to become compact. When possible the cave should slope upward away from the entrance to help keep in the heat. The floor of the cave should be terraced. Only those niches which are above the level of the entrance should be used for sleeping. A vent in the roof of the cave at its highest point will provide ventilation and retard melting. The snow cave, while not the most desirable type of shelter, can mean the difference between life and death in an emergency.

The snow house is another type of temporary shelter. It can be built to accommodate from 2 to 50 men, depending on its size. If the snow is of the lightly packed type, several small snow houses can be built more successfully than one large one. A typical snow house would have an interior diameter of 12 feet 8 inches and a 7-foot ceiling for sheltering 12 men.

Dry, hard snow, from which snow blocks can be cut quickly is best suited for building a snow house. Frozen snow is less suitable; fresh powdery snow is useless. Suitable snow



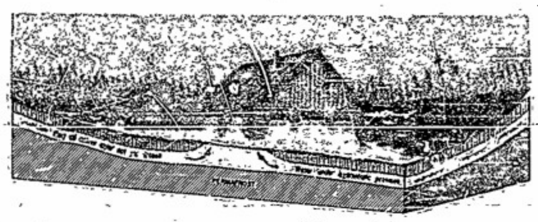


Fig. 21.— Effect of heat from poorly insulated structures   Fig. 22.

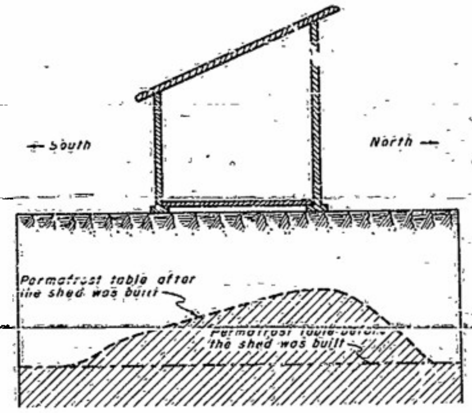


Fig. 23.— Effect of solar radiation on permafrost

should be at least 12 inches thick. The thickness and solidity of the snow can be tested by probing. If the snow is not deep, it is possible to make large snow balls by rolling and then cut them into blocks.

The first step in building a snow house of 16-foot base diameter is to lay out on the snow two concentric circles of 8-foot and 6-foot 4-inch radii. The distance between circles is 20 inches and represents the wall thickness. Snow blocks are then cut out of a pit with vertical walls 12 to 20 inches long. Saws or large knives are used in cutting and trimming the blocks. It is advisable, especially for beginners to use a wooden template of trapezoidal shape (Fig. 25) in order to assure uniformity in the blocks. The long and short parallel sides of the template are placed alternately on the edge of the pit from which the blocks are being cut. The resulting pattern is shown in (Fig. 26).

The first row of blocks is laid and fitted together within the lines of the two circles (Fig. 27). The 13-inch surfaces are set on the circumference of the smaller circle and the 16-inch surfaces on the larger circle. The 20-inch side of the block automatically comprises the wall thickness. By undercutting the underside the block can be made to slant slightly inward. The degree of slant can be determine by shaving off enough snow on the underside of the block to allow the top of the block to lie in a plane formed by stretching a string from the center of the circles to the upper and exterior surface of the block. Blocks should not extend beyond the circumference of the larger circle.

The second tier can be started at any place. The third block in the first tier to the left of the selected starting point is shaved off until approximately the upper quarter is removed; the upper half of the second block is then removed and three quarters of the first block. These three blocks are shaved to a continuous slope (Fig. 28). The first block of the second tier is then placed in the niche in the first tier formed by the last full block and the quarter block on its left. The second tier and successive tiers are built to the left, and the entire snow house is made by adding blocks in a continuous ascending spiral, this work being done by one man standing inside. When the snow house is all but completed, the only space remaining to be filled is the center of the dome overhead, a small irregular space. It is very important that this block be cut to exact size to fit this opening as it will act as a keystone to prevent the other blocks from becoming dislodged. The block is put up through the opening sidewise, then placed at the right angle and lowered into place.

The protruding interior edge of the blocks should be smoothed down, but the exterior is left rough to provide a key for a cover of snow. The crevices between blocks should be chinked with soft snow to make the structure tight.

Approximately two thirds of the floor space can be used for sleeping purposes provided it is covered with insulating materials. Branches of trees, moss, paper, shelter halves, blankets, and similar materials will provide suitable insulation.

In order to provide a space in which snow can be removed from the clothing before entering the snow house, an irregularly shaped access entrance tunnel may be dug.

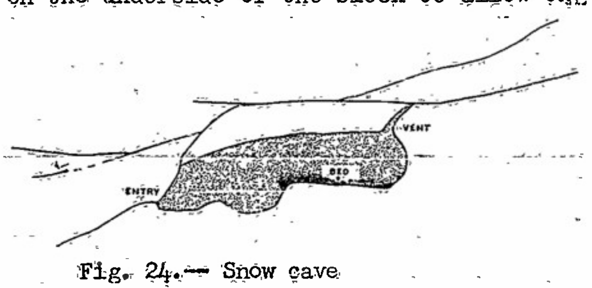


Fig. 24.— Snow cave

Fig. 25.— Cutting snow blocks

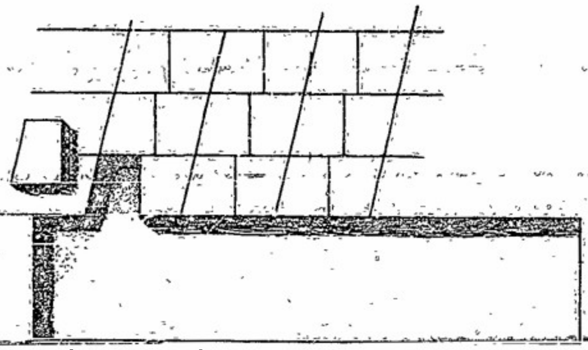


Fig. 26.— Plan view of block pattern

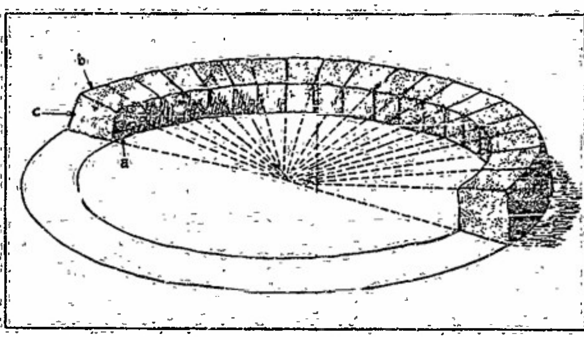


Fig. 27.— Placing of blocks

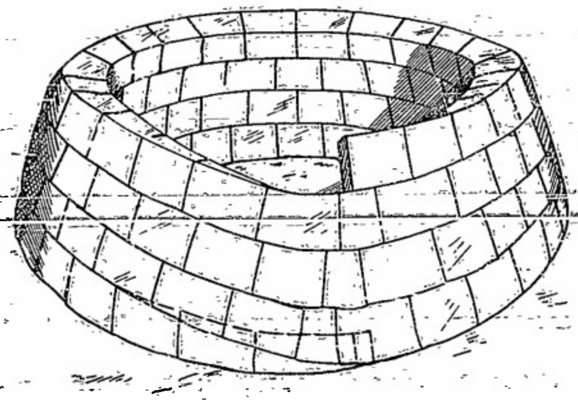


Fig. 28.— Construction of snow house

SOURCES OF WATER SUPPLY

Obtaining sufficient water for cooking and drinking purposes is an important consideration in cold regions. Water from lakes and streams is used whenever available. Glacier water is usually clean enough if the sediment is given a little time to settle. Frequently, however, snow or ice will have to be melted to obtain water.

Ice is preferred because it is denser than snow and consequently yields more water for a given volume. When snow must be used, wet or frozen snow is better than powdered snow.

Water can be obtained from snow by natural or induced thawing.

Natural thawing is based on the principle that dark-colored surfaces absorb heat, while light-colored ones reflect it. Small patches of snow placed in strong sunlight on a background of dark, water-repellent material will melt and can be collected. A shelter half, patches of dark rock, or pavement may be used. Care must be taken not to place too much snow on a dark surface at one time or it will not melt.

Another method that can be used when the temperature is sufficiently high is to dig a conical well in deep snow and collect the water formed in the bottom as the snow melts.

Induced thawing is accomplished simply by placing snow in a vessel that is heated until the snow melts. Care must be taken to add additional snow from time to time to prevent the water from boiling off. This method is used almost exclusively in the Antarctic.

In the absence of drinking water, small quantities of snow may be eaten when personnel are warm, or on the move. It is much better to place the entire piece of snow in the mouth than to suck it; otherwise the lips may become chapped, or cut. Snow should never be consumed in large quantities in this way as it will materially reduce body temperature.

TRANSPORTATION

Travel by Foot.

Prior to the middle of the 19th century it was the general belief that Arctic explorations would necessarily consist of active summers and hibernating winters. It remained for Rear Admiral Robert E. Peary, CEC USN, famed explorer, to demonstrate to the satisfaction of his contemporaries that in the Arctic the summer was a time for preparation and the winter the best time of the year to travel by foot.

Peary pointed out that the marshy tundra resulting from the summer thaw presented a formidable obstacle to travel while the snow and frozen ground characteristic of the winter season provided avenues of approach.

To make the best use of the winter conditions, however, personnel should have proper training and equipment.

In moving personnel by foot over snow-covered ground, various types and formations of snow will be encountered. Of these the hard-packed, dry variety is the most conducive to easy travel.

If melting occurs after a fresh snowfall the resultant sticky surface impedes travel. High temperatures often produce a "pie-crust" surface which appears firm but will not support a man without skis or snow shoes. Such a condition requires the expenditure of considerable energy as the man is forced to extricate himself at each step.

One Seabee said his first experience reminded him of the time he attempted to pull his rubber-boot out of the tropical mud so common in the Pacific.

For normal tactical operations afoot, untrained personnel will be able to adapt them- selves more quickly to snowshoes than to skis. Learning to use snowshoes in marching is not so much a matter of learning a definite technique as conditioning seldom-used muscles. Two weeks' instruction will usually make personnel proficient enough to participate in operations. Training may be given during the course of operations which are already under way.

One period of instruction in the use of snowshoes, followed by several periods of extended order drill and a few cross-country marches will prove adequate. Stiffness and soreness of muscles can be expected at first; for this reason, initial training should not be too severe.

Snowshoes should always be worn when snow is more than 12 inches deep. They should not be worn when it is less than 3 inches deep, for in such shallow snow the webbing of snowshoes will be damaged by rocks, sticks, and clods of earth; besides, snowshoes impede mobility when the snow is not deep.

In soft snow, a long stride is best, while in hard or packed snow, a short stride is more effective. The development of the prop- er stride requires a considerable amount of practice. Generally speaking, the fastest and least fatiguing method of travelling is to use a loose-kneed, rocking gait. In order to conserve the energy of the personnel, vehicles, preferably with mounted snow plows, should always be used as trail breakers.

In spring, before the summer thaw sets in, travel over sea ice is often much more con- travel over sea ice is often much more convenient and rapid than travel over land, because the surface of the ice is generally smooth and free of deep snow. But if pack ice from the previous summer has frozen in along the route of travel, the going can be very rough.

Travel on pack ice is a much more serious matter than travel on fast ice that is anchored to land. On the open pack, the floes, being under the influence of winds and currents, are in constant motion. Lanes and leads are continuously forming and closing between the floes. Small lanes, several yards in width, may be crossed by using small cakes of ice as rafts and paddling across. Sometimes, it is more feasible to travel around the open water or wait until the floes drift together.

Glaciers and ice caps present a special problem in travel because of great, gaping cracks called crevasses, that characterize their brittle surfaces. Crevasses, commonly many tens of feet in depth, are caused by the slow movement of the ice far beneath. Open and obvious crevasses are not dangerous but can be very inconvenient. Many crevasses, however, are covered with snow bridges which make their detection difficult.

A free fall into a crevasse is usually fatal. It is imperative, therefore, that a party travelling in the vicinity of crevasses should be composed of not fewer than three persons, and roped together. When a bridged crevasse is detected, it should be inspected and tested by the leader before the remainder of the party is allowed to approach. The rest of the party must remain alert during the inspection and be prepared to break the fall of the leader should the bridge fail.

Travel by Vehicle

The depth an object will sink in virgin snow does not depend solely on the weight of the object nor the area of pressure surface. Snow will support a gradually increasing load without any appreciable deflection and then, at a certain point, will suddenly fail. This is caused by the destruction of the bond between snow crystals and even the breaking down of the individual snow crystals.

This similarity to the straw breaking the camel's back was vividly illustrated during one of the recent polar operations. A Seabee was busily engaged in jacking up a tractor. The vehicle rose slowly, but suddenly both the jack and the plank supporting it disappeared into the snow. The resounding thud with which the tractor hit the snow startled the Seabee and forcibly impressed upon his mind the indeterminate strength of snow.

On this same polar operation, it was found necessary to increase the width of all tractor or plates by superimposing sets of 3" x 6" x 3' oak extensions and thus distributing the load over a greater surface area. Although these broader treds decreased maneuverability, they enabled the tractors to operate without sinking.

Large-scale freighting operations should not be attempted during the summer as the vehicles will unquestionably become mired in the marshy tundra and mud. Over-land re-supply operations between Point Barrow and the interior are always conducted during the winter because it has been determined that the most favorable traveling conditions exist during this season.

Before attempting to cross a frozen lake or tream, certain safety measures must be taken. The most important of these is to determine the bearing capacity of the ice.

The strength of ice is dependent upon its nature, its thickness, and the level of the underlying water.

Only light, clear ice is a reliable carrier. Rotten ice, which can be detected by its dull color and honey-combed structure, has very little supporting power.

Ice derives a portion of its supporting power from its pressure on the water below it. When the water level falls the bearing capacity of the ice decreases.

In estimating the thickness of ice, the layers of rotten ice found generally on the top and bottom of the clear ice should not be considered. For measuring the thickness, holes are cut at distances of about 10 to 16 feet from the center line of the proposed crossing and spaced from 33 to 65 feet apart. To safeguard large-scale movements, blocks of ice should be cut out and checked for firmness.

Table II, from War Department Basic Field Manual, FM70-15, may be used as a guide to determine the load capacity of ice of varying thicknesses.

The thickness of ice required to support a known load can also be determined by simple proportion. If a certain thickness of ice T_1 will bear a load L_1 then the thickness T_2 needed to carry load L_2 will be as follows:

$$\frac{(T_2)^2}{(T_1)^2} = \frac{L_2}{L_1} \quad \text{or} \quad T_2 = \sqrt{\frac{L_2\,(T_1)^2}{L_1}}$$

When the strength of the ice has been determined to be adequate, an area extending about 20 feet on both sides of the center line of the crossing should be cleared of snow. In this manner the condition of the ice can be observed at all times during the crossing. The path on the crossing to be used by foot troops should be sprinkled with sand and that used by sleds with a thin layer of snow. The carrying capacity of the ice, the distances to be maintained between vehicles and men, and the location of danger areas, should be clearly displayed on markers. Rigid march discipline must be enforced in order to prevent serious accidents.

In some cases, it may be found necessary to increase the bearing capacity of ice by reinforcing it. The simplest way to accomplish this is to place layers of snow and small lumps of ice on the surface and to pour water over the layers to freeze. Each layer should be frozen before the addition of a subsequent layer. Another good method of increasing the strength of ice is by adding, and freezing to it, several layers of boughs or straw, each about 2 inches to 4 inches thick. Boards, planks, and small logs used to form tracks or runways will increase the bearing capacity of ice by distributing the load over a wider area. By this method, the bearing capacity of the ice can be increased from 20% to 50%.

When the snow is covering ice over water and the compaction method is used, the main objection to it is that it obscures all weak spots in the ice. For it must be remembered that snow is an insulator against the chilling effect of the wind. If it is removed, the exposed ice will develop to a greater thickness. In one instance it was found that the ice in an area scraped six days previously was 16 inches thick, while that under an adjacent uncleared area of snow was only 12 inches thick.

On many Canadian airfields, a special method of compacting falling snow is employed successfully. When the snow is two or three inches deep, weighted corrugated steel rollers are operated over the surface, which afterwards is dragged and rolled until five inches of thoroughly compacted snow has been built up. As a result of low temperatures the compacted snow "sets up", to form a "snow concrete" of increased strength. Snow concrete is tough rather than brittle and is not to be confused with slush, which freezes into ice.

The advantages of compacting snow are that its bearing strength is increased and that a surface more even than ice is produced.

TABLE II.— Load Capacity of Ice

Load	Thickness of ice	Minimum interval
	Inches	Feet
Single rifleman on skis or snowshoes	$1\frac{1}{2}$	16
Infantry in single file, 2-pace distance	3	23
Infantry columns, single horses, motorcycles, unloaded sleds or motor toboggans	4	33
Single light artillery piece, $\frac{1}{4}$-ton truck 4 x 4	6	49
Light artillery, passenger cars, medium $1\frac{1}{2}$ ton trucks with total load of $3\frac{1}{2}$ tons	8	65
$2\frac{1}{2}$-ton trucks, light loads	10	82
Closed columns of all arms except armored force and heavy artillery	12	98
Armored scout cars, light tanks	14	115
20-ton vehicles	16	131
45-ton vehicles	24	164

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Hoarfrost on beard

CHAPTER IV

COLD WEATHER LIVING

As has been indicated in the previous chapters, human beings have been living in the Arctic for hundreds of years. True, the number of permanent settlements has been small but people have, within the limits of their resources, learned to live in the Arctic more successfully than many inhabitants in less vigorous climates.

Success in living there is predicated on forethought, skill, and endurance. Military operations in the Arctic, during and after World War II, helped dispel popular fears about the region and verified the importance of living in harmony with Arctic environment.

SHELTER

Adequate shelter is a prime consideration in all military operations in the Arctic.

Cold-weather shelters must provide means of heat, insulation against heat loss, and proper ventilation.

For years, white men tried to protect themselves from the Arctic cold by building airtight shelters. The fact that temperature within a shelter depends largely on insulation and that proper ventilation is essential to good health was completely ignored.

Adequate ventilation by means of a vent near the top of a shelter insures the outflow of enough moist air to minimize condensation. In addition, proper ventilation prevents asphyxiation from the odorless carbon-monoxide gas generated by cooking and heating fuels.

An important factor in securing proper ventilation is site selection. Drifting snow can inundate entire shelters and cut off all ventilation. For this reason an exposed site, even in stormy weather, is preferable to a lee position at the base of a cliff or bank. Also the dryness of the site must be considered. On seacoasts or lake shores therefore a camp should be situated sufficiently inland to avoid damage from this source. During the winter or stormy seasons, ice may be forced inland far above high tide and even over the beach line on inland lakes.

Temporary Shelters

Shelters of a temporary kind may be improvised from materials at hand, or that have been transported. In the preceding chapter, methods of building snow caves and snow houses were outlined. With some ingenuity other available materials, such as brush and tree branches can be utilized to make a lean-to.

If tents are pitched where snow may drift the entrance should be athwart the wind rather than in the lee, to prevent its being blocked by snow. Floors of tents should be properly insulated so that bedding is never in direct contact with cold ground or snow. Moss, tree branches, paper, shelter halves, lumber, or other materials may be used for this purpose. Wooded areas make the best sites because they provide protection from the wind as well as wood for fuel and construction.

Permanent Shelters

The longer the stay in the Arctic, the more protection and comfort will be required. To meet these requirements, permanent camps and bases must be erected. The construction of permanent military installations constructed with materials transported into the Arctic is the subject of a later chapter.

There are, however, other types of permanent shelters built by natives from indigenous materials that are worthy of mention here.

Masonry structures built by laying field stones in mud-mortar provide adequate and comfortable quarters. Moss can be used in chinking the larger cracks between the stones.

If there is a scarcity of stones in the area, sod can be cut into bricks and stacked

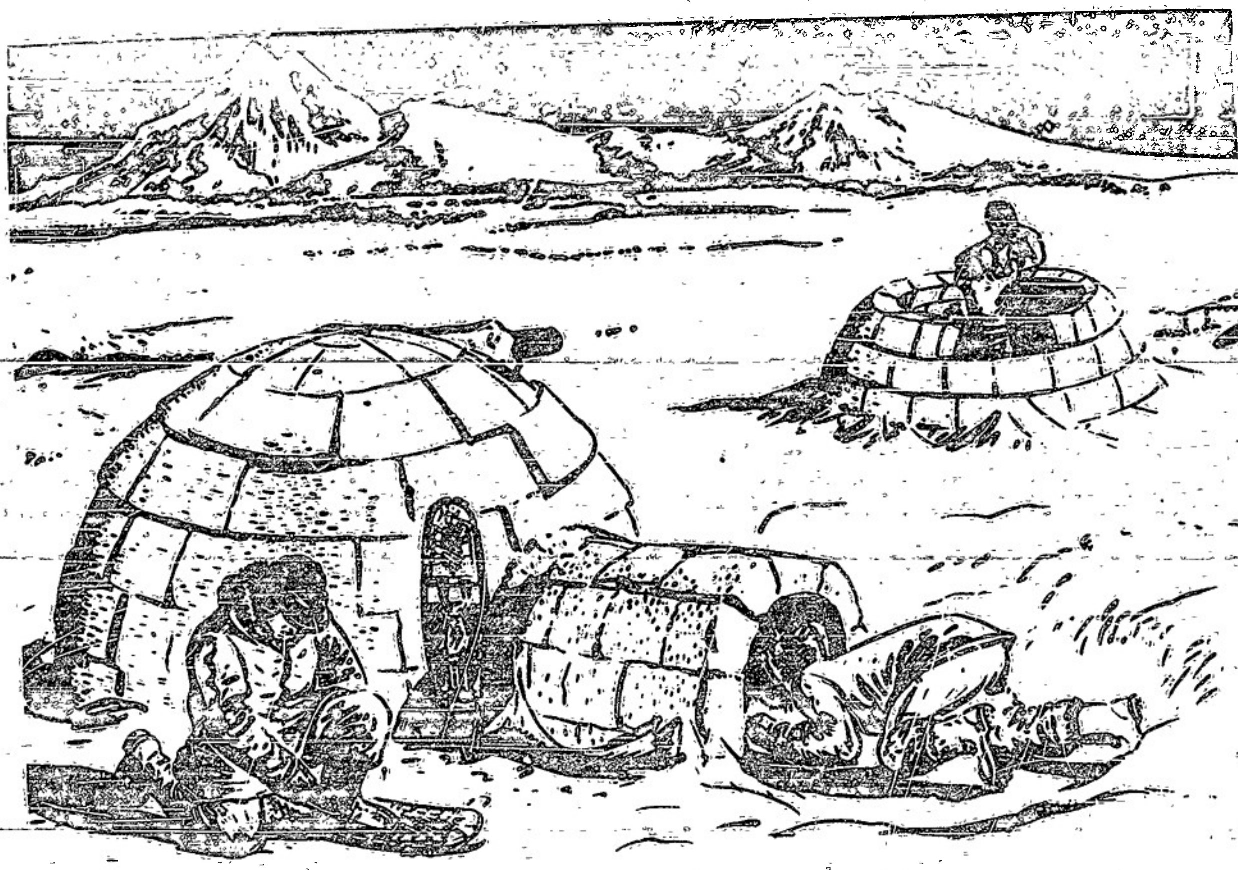

Fig. 1. — Good ventilation is imperative

to form vertical walls, which provide ample protection from cold. The roofs of both masonry and sod structures can consist of well-secured canvas, wood, or a mat of branches supported by beams made from small trees. And, of course, a log cabin makes an excellent shelter.

No matter what type shelter is built, it should have a raised platform or proper insulation to keep feet and sleeping bags off the cold ground.

Heating

The consumption of fuel for heating and cooking in the Arctic must be rigidly supervised. First, because of the scarcity of local fuels and second due to difficulties in transporting fuel from the States.

Local Fuels.--Local fuels in the Arctic consist of coal, wood, animal fats, and shrubs. Outcroppings of coal or lumps of coal washed up on beaches may be found in some places. Such coal is generally of a soft variety producing black smoke and an odor like asphalt. It may be difficult to light without kindling consisting of fats, wood, or shrubs.

Even in the Arctic, clumps of low willows or birch can be found. These can be split into fine pieces and burned green. Birch is quite oily and, if split fine, will burn even if wet. There are also limited sources of dead wood, and occasionally driftwood can be found in the slack waters of river mouths and along the coast even on treeless shores.

A marooned party in danger of running short of food should not use as fuel anything that can be eaten. More heat value is derived from eating, even raw food, than from food burned as a fuel. However, if there is an abundance of food, animal fats may be used as fuel or as kindling to start other fuels. Animal fats placed on pieces of wood will add a considerable amount of heat. Drippings from blubber if added slowly from above to a small flame will produce a hot blaze.

In his book, The Friendly Arctic, Stefanson tells how he and his companions managed after the kerosene gave out. For a few days they burned grizzly bear or caribou hair in an improvised tin stove. They killed seals and used an Eskimo-style seal-oil lamp, improvised from a frying pan. When this proved unsatisfactory for general use, one of the party devised an outdoor "blubber stove" employing a six-gallon cylindrical tank of galvanized iron the sides and bottom of which had been clinched as well as soldered so that it would not come to pieces with the heat. He removed the top and cut a draft hole near the bottom. Six or eight inches up the side he stretched three heavy wires to hold the cooking pot.

In burning seal oil or blubber as in burning tallow. a wick, is needed, so a little piece of rag, not necessarily more than an inch square, soaked in oil, was put on the bottom of the stove. On top of it, he placed a little heap of bones saved from previous meals and on top of the heap several strips of blubber were laid. He then touched a match to the rag, which burned like the wick of a candle. The flame played up between the bones to the blubber, from which the oil dripped down, forming a film around the bones. With sufficient heat, the film flared, and the fire burned with a furious heat as long as a strip of blubber remained. He then placed the cooking pot, filled with meat and water, on the cross wires. The flame struck the bottom of the pot and then spread up all around it, as the diameter of the stove was only slightly larger than that of the pot. Application of heat to the bottom and sides of the pot at one time brings it quickly to a boil.

According to Stefanson, the only disadvantage of this method of cooking is that the smoke of burning seal oil is thick and black and exceedingly sticky.

Methods of heating. -- The basic principle involved in heating any type of temporary or permanent shelter in the Arctic is to provide proper ventilation and draft for the heating unit. This is particularly important when makeshift stoves, constructed out of oil drums, cans, or scrap metal, are used.

On Operation Highjump, the U. S. Navy expedition to the Antarctic in 1946-1947, the standard U. S. Army tent stove, model 1941, proved to be a satisfactory heating unit for the 16-by-16-foot pyramidal tents. This diesel-operated stove, with the carburetor set at from 2/3 to 3/4 full opening, would maintain the central portion of the tent at a comfortable temperature except on extremely cold or windy days.

No serious fires resulted from the operation of these stoves, although center poles of the tents were occasionally charred. In at least two instances the pole collapsed.

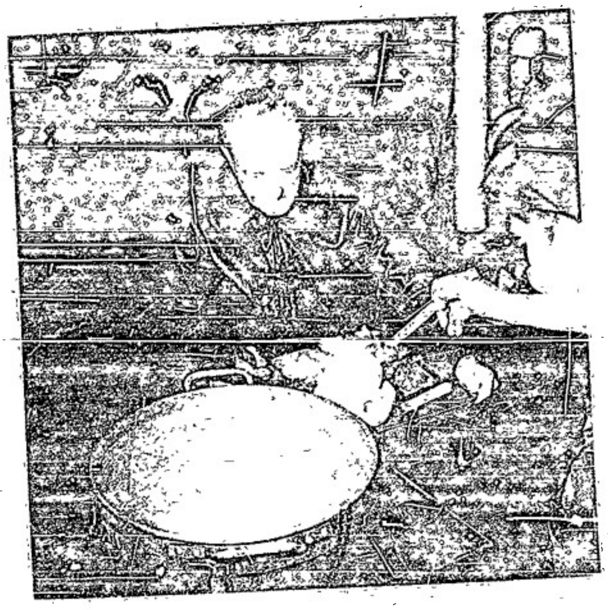

Fig. 2. -- Admiral Byrd hits chow line on "Highjump".

FOOD

Basic Diet Requirements

An adequate diet in the Arctic is essentially the same as that in a temperate climate. The main difference is that a larger quantity of food is required by the body in extremely cold weather.

Food has a threefold function in the body. It provides fuel for heat and energy, material for building and maintaining, and lubricant for operating. The kinds and amount of food needed for building and maintaining and operating are the same in the Arctic as anywhere else, but the amount of food needed for fuel will be greater. The exact additional amount needed will depend upon how much work is done and how much time is spent indoors. Men working outdoors will require more food to offset the loss of body heat and the added burden of heavy Arctic clothing and equipment.

On the 1948 supply expedition to Point Barrow, Alaska, the medical plan prescribed that the standard Navy ration be increased 25% during the period that the expedition was north of the Arctic Circle. The plan indicated, however, that this increase would be sufficient only if the ration was properly prepared and that sufficient portions of each component were eaten. All personnel must be aware of the value of intelligent preparation and intelligent eating habits. Food discipline should never be relaxed.

Selection of Food

The fuel value of food is measured in calories. Each calorie represents the amount of heat required to raise the temperature of about four pounds of water one degree of Fahrenheit.

In temperate climates a vigorously hard-working man expends about 4000 to 4500 calories per day. In the Arctic it has been determined that 5000 to 5500 calories per day is generally addequate, except under extreme conditions of heat loss.

<u>Milk</u>-One pint or more daily. Evaporated or powdered milk is just as good as fresh milk.

<u>Eggs</u>-One or two per day. Dehydrated eggs are as good as fresh eggs.

<u>Meat</u>-One serving per day, preferably with some fat. Liver and fish at least once a week. If meat is scarce eat an equivalent amount of similar foods such as fish, liver, eggs or beans.

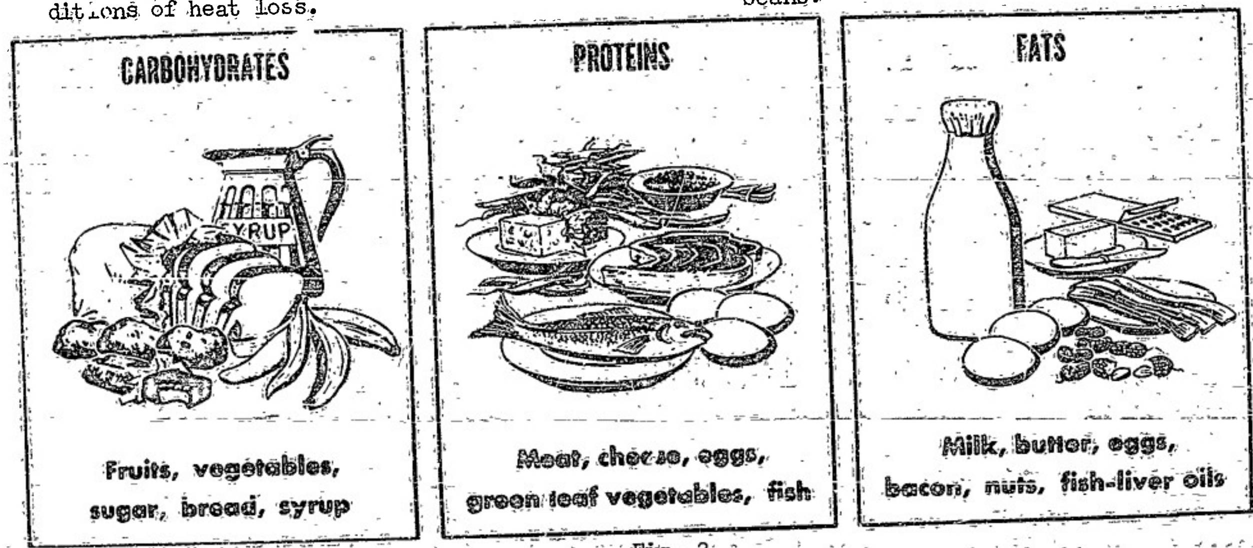

Fig. 3.

Most of the calories in the usual diet are obtained from carbohydrates (sugar, flour, bread, cereals, potatoes) and fats (butter, nuts, cheese, lard).

It must be remembered that while the carbohydrates and fats supply fuel for the human engine they do not help to lubricate or keep it in good repair. Fuel foods will keep you "going" but they do not build muscles, bones, or blood. Neither do they lubricate the body nor act as catalytic agents in the many chemical changes that take place within it.

Material for building, maintaining, and lubricating the human engine is obtained from proteins (meat, fish, milk, eggs) and minerals (green vegetables, whole-grain products, dried fruits, fowl, liver).

Although the principal demand in low temperatures will be for additional fuel foods the diet should be so selected that it will contain components that will sustain as well as heat the body. The following plan, if followed, will assure an adequate diet.

<u>Vegetables</u>-One or more yellow or leafy green vegetables slightly cooked, or raw in salads, at least once a day. Frozen or dehydrated spinach, carrots, peas, and other vegetables are as good as fresh vegetables provided they have been processed to retain most of their vitamin content.

<u>Fruits</u>-One or more servings daily, either raw or cooked citrus fruits and other fruits high in vitamin C, the antiscurvy vitamin (oranges, grapefruit, apples, etc.) are important.

<u>Liquids</u>-Although water has no food value in itself it would be impossible to survive without it. Practically every chemical change in the body depends upon water. The amount of water obtained from solid food is insufficient. The average person requires at least eight cups of liquids a day. This amount, however, includes soups, fruit juices, and other liquids as well as plain water.

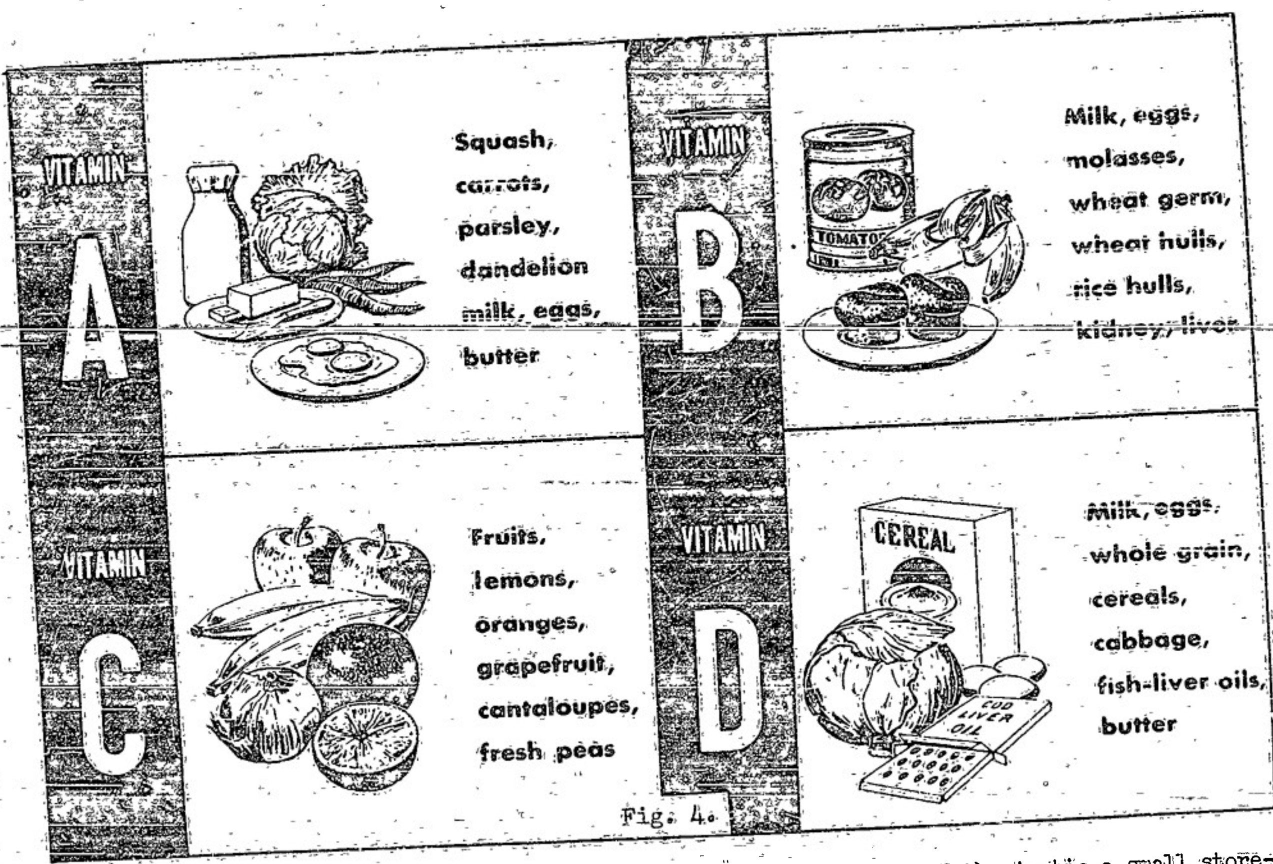

Fig. 4.

Remainder of diet-Having satisfied the foregoing requirements, fill up according to the dictates of appetite on additional energy-yielding foods--potatoes, beans, cereals, bread (preferably made with enriched flour) fats, (preferably butter), and sweets. Do not be surprised at the size of your helpings--you need plenty of calories for hard work at low temperatures. If there is a choice, do not eat the same things day after day or you are likely to loose your appetite. When you do not eat enough, you may lose efficiency. Of course, where there is plenty of outdoor work to do, your appetite will be good and you will eat enough food to take care of your bodily needs.

In some parts of the Arctic a small storehouse can be kept cool by circulating through it the waters of a cold stream. Sea-water will also cool food stored in a drum floating off-shore. Similarly, a pit excavated in perma-frost will provide a natural icebox.

In winter, in places where regular facilities for storing food are lacking, the simplest way to preserve perishable food is to allow it to freeze. Thaw out only enough food for a single meal. Meat frozen and thawed two or three times is tasteless. Fresh fruits, vegetables, and eggs can be kept frozen, and in fairly good condition, all winter, but they will deteriorate if they are allowed to thaw and freeze repeatedly.

Refrigeration of Food

Refrigeration of some sort is required during the summer in the Arctic to keep foods fresh. If artificial refrigeration systems are not available, ice houses should be built and, if the site is near the coast, stocked with sea ice or pieces of icebergs. If located inland, ice should be cut during the winter from rivers or lakes. To provide insulation, the ice house should be buried in the ground or built with double walls.

Most canned foods can be frozen without loss of food value, though the flavor of some products may be affected. Occasionally, a can may burst in freezing. In such cases the contents should not be eaten unless it is certain that they have remained continuously frozen. Rust weakens cans so that if frozen they are more likely to burst. For this reason, cans should not come in contact with salt water or salt spray. Even the salt present in the air at beach sites will cause rusting.

Preparation of Food

The flavor and digestibility of food is almost as important as its contents. Food that does not stimulate the appetite or is difficult to digest hurts morale and places a burden on the body's digestive process.

Water obtained from melted snow is, of course, virtually distilled and free of minerals. Food cooked in such water has its mineral salts dissolved away and is very flat in taste. Adding salt to this water will retard the leaching action on food minerals and improve the taste.

Frozen meat should be thawed out before cooking; partly thawed meat will cook on the outside while the center remains raw. All meats should be heated sufficiently to kill parasites.

Vegetables should be cooked in the least possible amount of water and only until they are tender. Further cooking reduces their vitamin content. Dried fruit should be soaked overnight in cold water and then simmered slowly in the same water until tender.

Living off the Country

The Arctic abounds in many forms of animal, plant and fish life. Consequently, as virtually all species are edible, the danger of starvation, even if supplies from the States are destroyed or exhausted, is rather remote.

Caribou, moose, and musk ox, the largest of the land animals, provide excellent food. They generally travel in herds and can be found on the tundra near lakes and swamps in both winter and summer. They also are found on off shore islands. In hunting these animals, shots should be directed at the shoulder or neck rather than the head; antlers and horns make the head a deceptive target. The animals should be skinned promptly, keeping the fat with the carcass rather than the hide, and frozen. In this state they keep indefinitely.

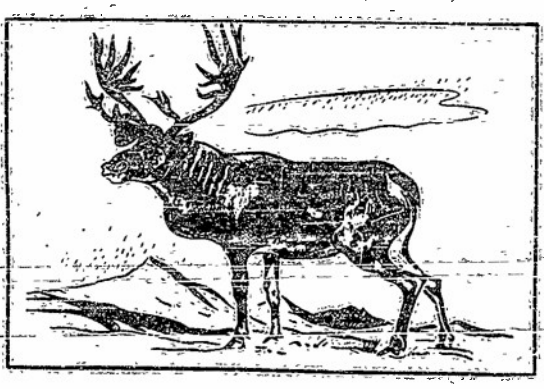

Fig. 5. — Caribou

Fig. 6. — Moose

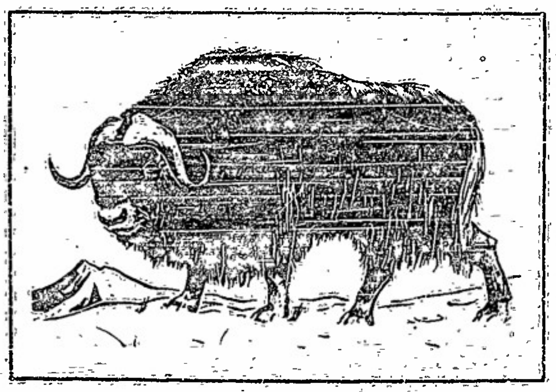

Fig. 7. — Musk ox

Seals are widely distributed and generally common. Their flesh and liver are excellent food, except that the livers of bearded seals are poisonous. Seals come to surface of the water in order to breathe, and as their heads pop up, they make excellent targets. They should be shot in the head, neck, or shoulders because those that are hit in the lungs or stomach usually escape. Another method of catching seals in the summer and autumn is by stretching nets across narrow channels. In the winter the best place to hunt seals is at openings in the pack ice or at their breathing holes in the ice. In the spring, seals lie on the surface of the ice and bask in the sun. It is difficult to approach a basking seal, and unless killed instantly, it slips down the breathing hole and is lost. One method of approach is push a white cloth shield in front of you with a slit for the rifle muzzle. Another method is to creep or crawl along the ice stealithly until within range. The fresh liver, heart, kidney, and flesh of the seal are choice foods, rich in value. Members of Navy polar expeditions have frequently seen Eskimos eat the liver raw, fresh from the body. This may be a little rough on state-side stomachs. Blubber and blood should be removed before the seal meat is stored; otherwise the meat turns rancid and is not fit to eat. The

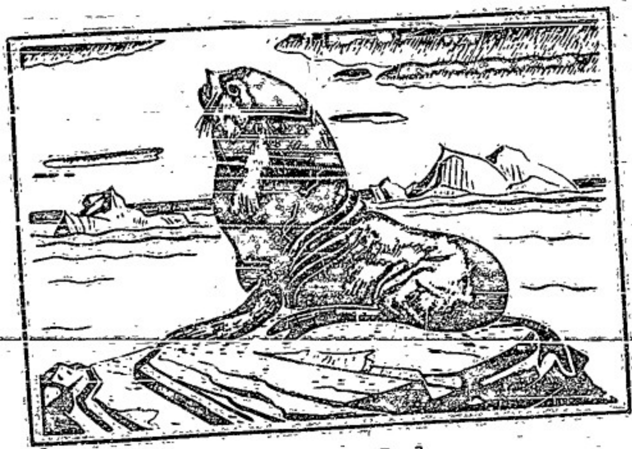

Fig. 8. — Seal

Fig. 10. — Mountain Sheep

most palatable results can be obtained if seal meat is broiled.

The meat and blubber of walruses are edible. However, hunting these beasts can be very dangerous, and it would be well to consult with an experienced walrus hunter before attempting it.

The meat of polar bears, except the liver, is edible. The liver is poisonous. Polar bears and other bears found throughout Canada and Alaska are hard to kill, and a wounded bear is one of the most dangerous of all animals. The neck or just behind the shoulder are the most vulnerable spots to hit. If the bear rears up, a throat or heart shot is preferable.

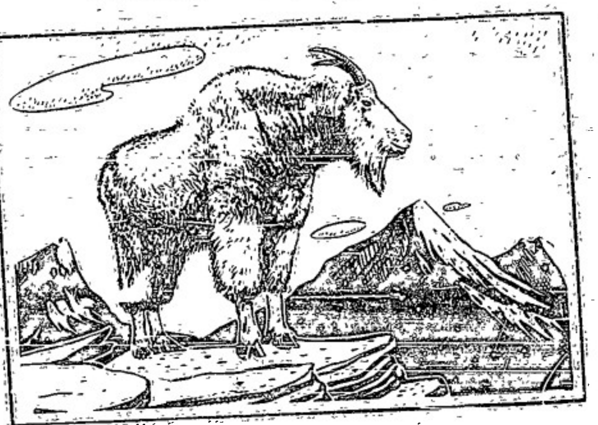

Fig. 11. — Mountain Goat

Wolves and foxes are edible, but are difficult to catch. Steel traps should be used for wolves, traps made of barrels or stones can be used for foxes.

Hares and marmots are smaller edible game that can be shot or caught with snares. Lemming are Arctic mice that can be caught by hand or with snares. Other edible animals, such as porcupine, muskrats, squirrels, beaver, mink, and Canadian lynx are found in the subarctic.

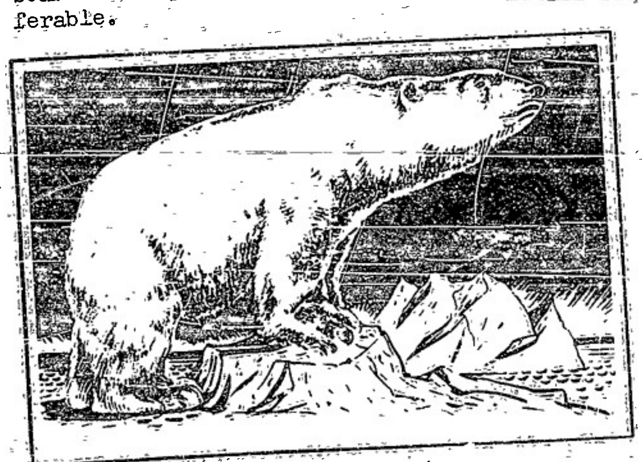

Fig. 9. — Polar Bear

Mountain sheep and goats are found high on the slopes of mountains in Alaska. Hunting these animals usually means stalking and long shots. Retrieving may be hazardous. The goat is not as good to eat as the sheep, but it is meat in an emergency.

Fig. 12. — Marmot

All fish in the Arctic are edible. And all salt-water fish except the shark may be eaten raw. Fresh shark meat is said to be poisonous and should therefore be broiled several times or dried thoroughly before being eaten. Fish are plentiful, wherever found, but many shallow tundra lakes have no fish of any sort. Fish can be caught as in a temperate climate.

Cold northern waters are richer in edible marine animals than any other waters in the world. Clams, mussels, scallops, snails, limpets, chitons, sea urchins, and sea cucumbers are found where there are stretches of open water along the shore. A person can literally pick up a meal with his hands, dig it out of the mud with a stick, or pry it from the rocks with a pocket knife.

All Arctic birds are edible, as are their eggs. To obtain the greatest food value from birds, pluck rather than skin them. If possible, geese and ducks should be plucked while they are still warm.

No plant in the arctic is dangerously poisonous. One, a mushroom with a reddish top, the emetic russula, may cause vomiting but this very characteristic will keep it from being eaten in quantities sufficient to poison fatally.

In the sub-arctic, however, there are a few plants that are dangerously poisonous if eaten. All of them grow in the forests and not in the open tundra. They are plentiful, and it is important they be recognized. Water hemlock is one. It belongs to the parsnip, or carrot, family, as the leathery, toothed leaves and small flowers arranged in clusters suggest. The leaves are streaked with purple and when crushed emit a disagreeable odor. Another is the baneberry which can be detected by the cylindrical cluster of red or white berries borne at the tip of the stem. The berries may turn blue as they get older. The most common is the death-cup amanita. This toadstool is usually white, but the cap may have tints of olive, purple, or brown. When fully grown the cap is 4 to 6 inches wide. The surface is sticky when moist. Beneath, and attached to the cap, are white gills. The stalk is white and brittle and has a spherical base, buried beneath the ground, which rests in a soft white cup. The last of the group is the fly agaric. These attractive toadstools have a yellow orange or red mottled cap, whitish or yellowish scales, and white gills. When young, they are sometimes mistaken for puff balls.

Once the poisonous plants are recognized, all others can be eaten without fear. However, some of the plants have greater food value than others.

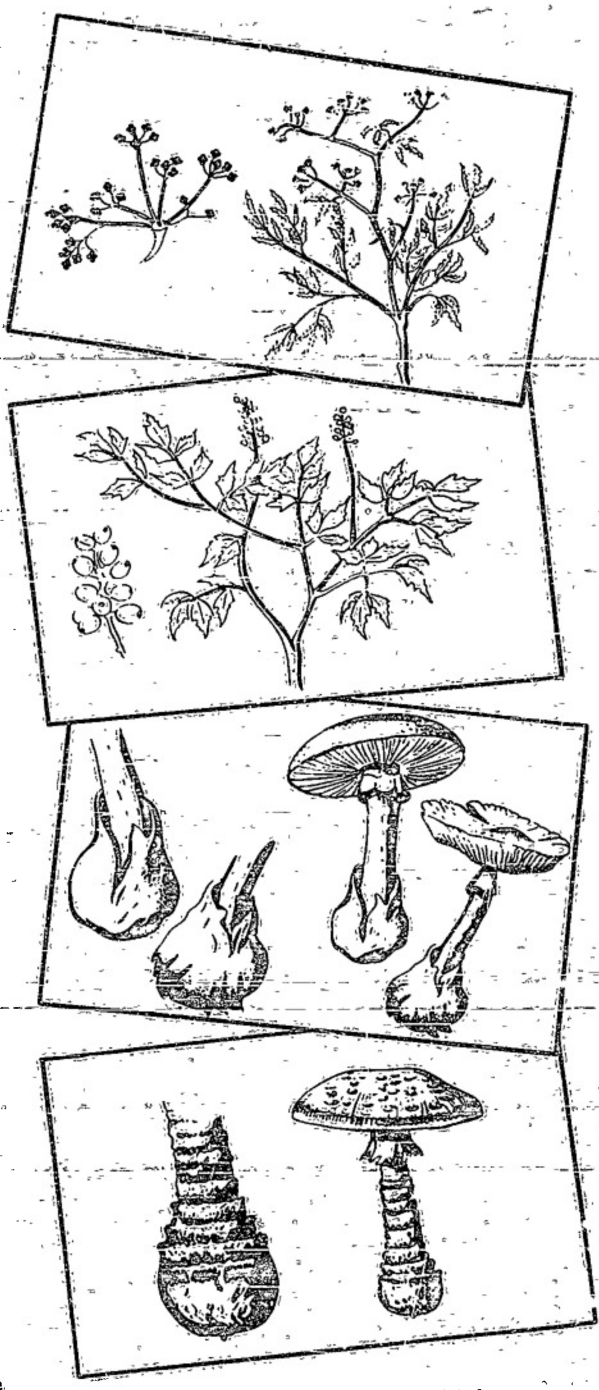

Fig. 13. — Water hemlock
Baneberry
Death-cup amanita
Fly agaric

Lichens have possibly the greatest food value of all Arctic plants. Caribou live almost entirely on lichens for months at a time. Lichens if eaten raw should be soaked overnight. Despite their gelatinous appearance, lichens taste better after being boiled. The jelly can be used to thicken soups and stews.

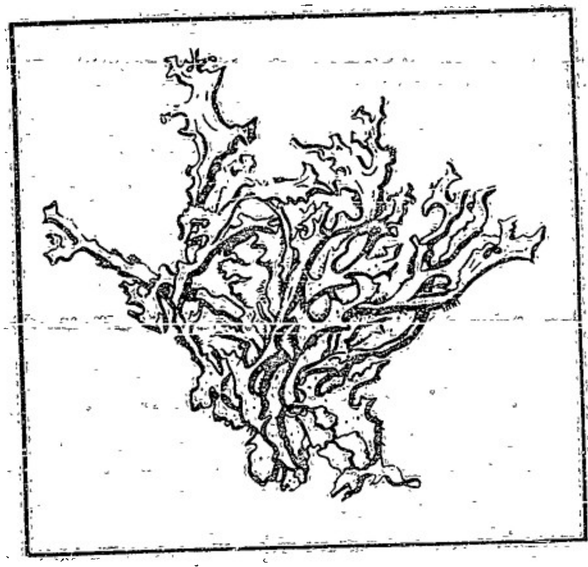

Fig. 14. — Lichen

Rock tripe is a black, brown, or greenish lichen consisting of thin, leathery, irregularly shaped disks, one to several inches across. The disks are attached to rocks by short stalks. They are soft when wet, hard and brittle, when dry. Iceland lichen is a dark brown, bushy, coral-like plant with individual straplike "branches" that have hair edges. It grows in dense colonies on sandy soil. Reindeer lichen is a grayish many-branched, coral-like plant that prefers hollows or slopes with winter snow cover.

All Arctic berries are edible. They may be preserved in seal oil or a vegetable oil or by freezing.

Several Arctic plants have roots that store energy-giving starches. The most common is northern sweetvetch (licorice root) which grows in clumps on sandy soil near lakes and streams. It has pink flowers similar to pea or clover flowers, and the leaves resembles those of locust trees or the famous "loco weed" of our western States. The cooked root tastes like young carrots but is even more nourishing. Another valuable root is that of the woolly lousewort, which grows in dry tundra. Flowers of this plant are rose colored, resembling those of licorice root in shape but arranged in denser clusters. The sulphur-yellow root is large and sweet and is edible raw or cooked. Bistort, or knotweed, also common in dry tundra, has small white or pink flowers that form slender spikes. The root, about the size of a pecan, should be soaked in water for several hours and then roasted. The kamchatka lily grows in meadows and among low shrubs along the Pacific coast of Alaska and on the Aleutian Islands. Its flowers are shaped like other lily flowers. The bulbs or roots of this plant, rich in carbohydrates, serve as potatoes for the natives. The bulbs should be roasted or boiled.

Scurvy has taken its toll of men in the Arctic. This dread disease results from vitamin-C deficiency and may be brought on by a prolonged diet of canned or lean meat and no vegetables. Most plants yield some vitamin-C, but several are notably rich in it, including scurvy grass, which occurs along sea beaches. It has white flowers and globular fruit; the lower leaves, borne on short stalks, are kidney shaped. The leaves, stems, and fruit, eaten raw, are valuable anti-scurvy food.

The buds, needles, and stems of black and white spruce, when chewed raw, will help to counteract scurvy. Similarly, the fresh green leaves and inner bark of the dwarf Arctic birch are high in vitamin C.

Several Arctic plants are fairly good substitutes for the leafy vegetables of stateside diet. Among the more important is wild rhubarb (alpine fleeceflower), which grows on open river banks and recent landslides. The stems are reddish and, like cultivated rhubarb have pointed leaves with wrinkled edges. When cooked, they resemble rhubarb in flavor. Another green is sourgrass (mountain sorrel) that is found on moist shady sloped and in ravines. Its fleshy, kidney-shaped leaves are borne on long slender stalks, and its red or green flowers are arranged in plumelike branching clusters. When cooked, the leaves and stems resemble spinach in both flavor and appearances. Another leafy plant that, when cooked, resembles spinach, is the willowweed (fireweed). This plant, which grows on sandy or gravelly soil along rivers and on beaches, has purple flowers and long, thick leaves. Dandelions are a potential lifesaver to anyone stranded in the Arctic. The young leaves

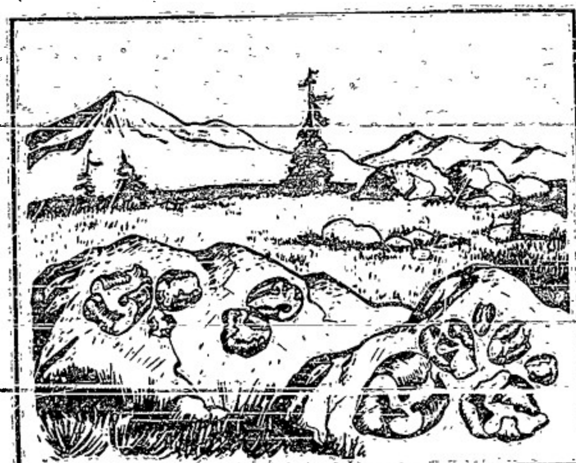

Fig. 15. — Rock Tripe

Mussel. Clam. Scallop. Limpet. Abalone.

Fig. 16.

make fine greens despite their bitter taste. The leaves and stems of the marsh marigold, which is found in swamps and along streams, are delicious when boiled. Cow parsnip is abundant on the coast of Alaska and on the Aleutian Islands. Its large and characteristic flower cluster make it conspicuous. The flower clusters resemble those of the poisonous water hemlock, but the leaves are entirely different. The young shoots and leaf stalks of the cow parsnip are edible either cooked or raw.

Seaweeds contain valuable vitamins and give bulk to any diet. They are particularly useful when much fish is being eaten. The gelatinous consistency of cooked seaweed may offend the senses of sight and taste, but it is just what is needed to round out the diet and prevent constipation. Alaskan Indians, Filipinos, Hawaiians, Chinese, and many other people have eaten seaweed for centuries.

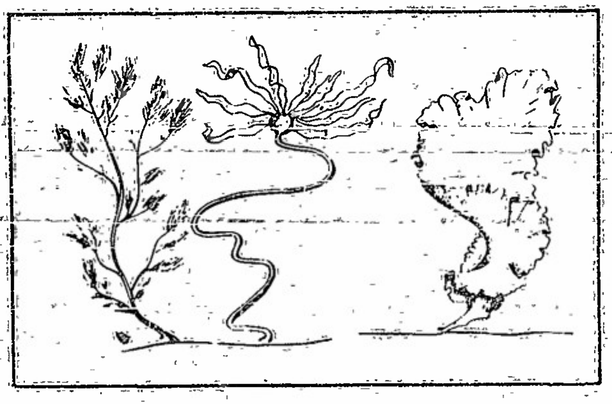

Fig. 18. — Seaweed

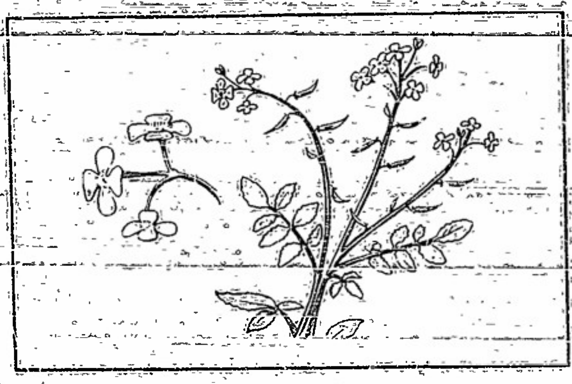

Fig. 17. — Scurvy grass

CLOTHING AND ACCESSORIES

Many types of cold-weather clothing have been tested and approved for issue by various government agencies. The types are too numerous and too frequently modified by research and experience to be discussed here. A few general principles, however, are constant.

Function

In the Arctic the primary function of clothing is to keep the body warm. Heat is transferred from a warmer object to a colder one until theoretically the temperature of the two becomes the same. Clothing prevents, or slows down, the transfer of heat from the body to the outside air.

Triton. Periwinkle. Chiton. Sea Urchin Sea Cucumber.

Fig. 19.

Design

Cold-weather clothing holds a considerable amount of air, which acts as an insulator and retards the transfer of heat through it. A soft, spongy material that holds thousand of little air cells between its fibers is better than a tightly compressed material that holds very little air. On the other hand, loose, air-holding material is not of much use if the air is allowed to blow through it. For this reason, an outer shell of tightly woven cotton cloth is necessary to keep the cold air out and warm air in.

Most newcomers to the Arctic are inclined to overdress. There is no standard that establishes the specific amount of clothing to be worn at any one time. The amount of clothing that keeps one man comfortable might be too much or too little for another man. The quantity of clothing for comfort must be determined by each individual.

The main thing to remember is that clothes should fit loosely. When they are tight, they contain little air and do not insulate. Several thin layers are better than one thick one, because additional insulation will be provided by the dead air trapped between the layers. Another advantage of the layer principle is that clothing can be removed or added with ease to maintain the body at a comfortable temperature.

Although clothing should fit loosely, it also should be air tight. The places at which there is greatest danger of body heat escaping are the neck, wrists, and ankles or shoe tops. At the neck, a woolen scarf and tightened parka drawstrings will stop leakage; at the wrist, a knitted wristlet under the sleeve and glove will help; at the ankles, tying socks and pant legs together will do the job.

The basic items of clothing required in the Arctic are the same as those in any cold section of the United States. Two-piece long underwear, woolen socks, heavy woolen trousers and shirts are effective means of keeping the body warm. A woolen vest, worn over the shirt, is regarded by many as preferable to a sweater. Sweaters are tight and are hard to put on and take off.

Footwear is the most important single item of clothing. Except for the face, the feet are the parts of the body most likely to freeze. This is because shoes form a tight casing that does not allow perspiration to evaporate. For this reason, shoes with felt or fleece linings that cannot be removed for airing or washing should not be worn.

Many types of Arctic footwear have been used with success. Leather boots should be two or three sizes larger in both width and length than those ordinarily worn. They should be large enough to accommodate a quarter-inch insole and two or three pairs of heavy woolen socks, without binding the feet. Shoepacs are laced boots with rubber feet and leather uppers. They are serviceable in wet snow but not

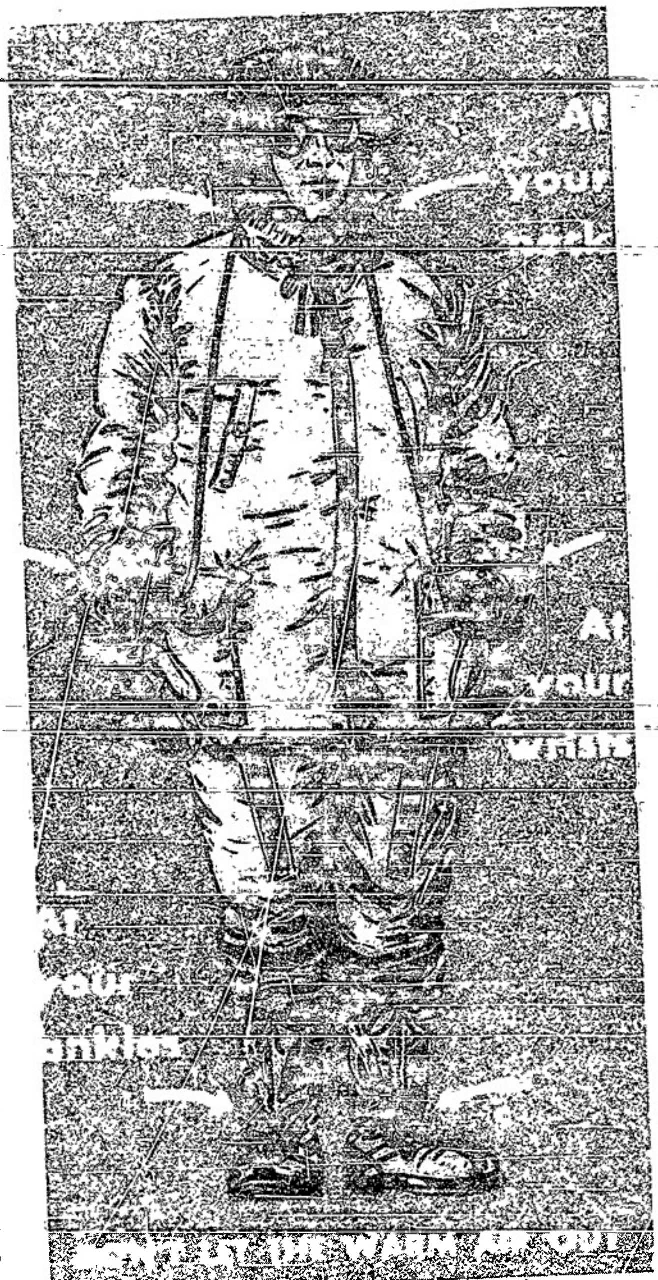

Fig. 20.

in temperatures below $0^{\circ}F$. Leather boots are not however, suitable for temperatures below $20^{\circ}F$.

Mukluk boots, that are copied from the Eskimo kamik, have a dry tanned leather or rubber sole and canvas uppers extending just below the knees. Not being waterproof, they are not adapted for use in wet and slushy snow but they are excellent in extreme cold.

Eskimo mukluks made out of caribou skin are the best boot for sedentary occupations at extremely low temperatures.

All Arctic footwear should be worn with insoles made of felt, burlap, or fur. In an emergency, dry grass can be substituted. Insoles absorb moisture from the feet and provide additional insulation.

Fig. 21. — Mukluk

Gloves present a real problem in the Arctic. In addition to keeping the hands warm, they must allow the wearer enough freedom to work with tools and equipment. At present, the best available type for mechanics is the leather five-finger glove with a woolen insert. At extremely low temperatures, woolen mittens can be drawn over the gloves for quick warming when the hands get cold.

No Arctic wardrobe is complete without a parka. This classic garment, made of wool, woolpile, or fur, comes in either pullover or overcoat style and comes down to the hips or even lower. The hood is generally trimmed with fur. Drawstrings at neck, wrists, and waist enable the wearer to keep the parka fairly

Fig. 22. — Short parka

air-tight. A knitted woolen helmet, similar in design to a flying helmet, is the best covering for the head. Unless it is intended to be worn continuously under the parka hood, it must have a covering of windproof cloth.

Windproofs are made of smooth, lightly woven cotton cloth. They are water repellent but are never waterproof, because they must allow moisture from the body to pass off into the air in the form of vapor. They must be large enough to fit over the maximum amount of clothing that will be worn. The trousers have drawstrings at waist and ankles, and the upper garment is of the parka type with drawstrings at the hood and bottom.

Care of Clothing

The main precaution that must be taken in the care of clothing is to keep it dry.

Water conducts heat faster than does air; wet clothing is cold clothing.

Perhaps the greatest cause of wet clothing is perspiration. Regardless of outside temperature, the body gives off, through the skin, about a pint of moisture a day. This is called "insensible" perspiration. This degree of perspiration must be considered as well as the visible perspiration caused by exertion or overwarm clothing.

Low temperatures condense the perspiration and form hoarfrost on or in clothing. If a man is dressed lightly enough, the frost will either form in the air around him and drift away as fog or it will form on his outer clothing. When it forms on clothing, it should be brushed off. If a man is clad too heavily, the frost will form somewhere within the layers of his clothing. This frost, in the warmth of a camp, will melt, and when exposed to subsequent cold it will freeze. It is important, therefore, that perspiration be controlled. The simplest method is to wear the smallest amount of clothing necessary to keep comfortably cool and adjust it to allow for ventilation.

Men engaged in physical labor such as is required of Seabees can utilize many little tricks to keep perspiration at a minimum. Removing gloves or wearing only the leather shell may be enough to keep the right body temperature. Pulling back the sleeves from the wrists unbuttoning the shirt, or pulling the parka hood down are other practices that help.

If hoarfrost does form in clothing, it should not be allowed to melt, but should be beaten and brushed out of the clothing in its frozen state before entering a warm shelter.

Footwear requires special precautions. As it is impossible to prevent feet from perspiring, one should at least make sure that his footwear does not fit tightly. Socks and insoles should be changed daily. Insoles must be removed as soon as the boot is taken off; otherwise, it will freeze into the boot. A small stiff-bristle brush should be used to remove frost from inside of the boot. Socks as well as other clothing should be hung near the top of the tent to dry. Leather boots should not be greased in cold weather, because grease reduces insulation and will make the boots colder. Greased boots will freeze stiff during the night.

In addition, there is the matter of cleanliness. In the Arctic it not only is "next to Godliness," it can be the difference between life and death.

Clothes should always be kept clean. Oil from the body fills up the tiny air cells in underwear and reduces its insulating quality. Each man must have sufficient replacements of each item of apparel so that it may be changed, washed, and dried frequently.

Summer Clothing

Summer temperatures in ice-free regions of the Arctic are sufficiently high to make the wearing of winter clothing decidedly uncomfortable. This is generally not true along the coasts, where the summers are fairly cool. However, even with high temperatures the body must be kept completely covered to protect it against the hordes of mosquitoes and biting flies.

Since most summer travel is over marshy ground the best footwear is the shoepac. A light rain-jacket or water-repellent jacket and a sweater are additional protection against fog, rain, and a sudden drop in the temperature. In the coastal areas, where fog and rain are frequent during the summer, rain suits are highly desirable.

Accessories

The sleeping bags now being made for military use are part down and part feathers in a water-repellent outer covering. All sleeping bags should have a hood and scarf attachment so that mouth and nose are out of the bag, and so that moisture from the breath will not ice up the interior. Only a minimum amount of clothes should be worn in the bag, and these should be thoroughly dry to prevent hoarfrost from forming.

Perspiration cannot be entirely eliminated, so the bag should be completely aired out immediately after arising. Pumping air in and out of the bag, like a bellows, will help to remove the moist air and reduce the temperature inside the bag. The bag should never be placed directly on snow or any other cold surface. If a mat is not available, spruce or fir boughs or grass will serve as an adequate insulator.

SPECIAL PRECAUTIONS AND FIRST AID

Insects

In the Arctic the word "flies" has a special meaning. It refers not to house flies and other such relatively inoffensive creatures, but to insect-pests that come after a man in hordes, usually two or three kinds at once, intent on eating him alive. Flies include mosquitoes, black flies, deer flies, and midges. These are the curse of the Arctic summer. It is estimated that over at least two-thirds of the tundra there are ten times as many mosquitoes per square mile as over any equivalent area in the tropics. They are abundant because the numerous swamps and lakes and the long, sunny days, with slight variation in heat from night to day, provide ideal conditions for insect incubation.

Mosquitoes resemble their tropical relatives in appearance but prefer day to night for attack. Although they seem to prefer dark places and will settle on dark clothing in preference to light, they do not seem to mind the direct sunlight. Mosquitoes do not bother on cold days and become discouraged by a strong wind. The worst days are the warm quiet ones with a gentle land breeze. Then, for hours at a stretch, the unrelenting attack continues, especially in the afternoon. It is small compensation that both malaria and yellow fever, transmitted by mosquitoes in the tropics, are unknown in the Arctic.

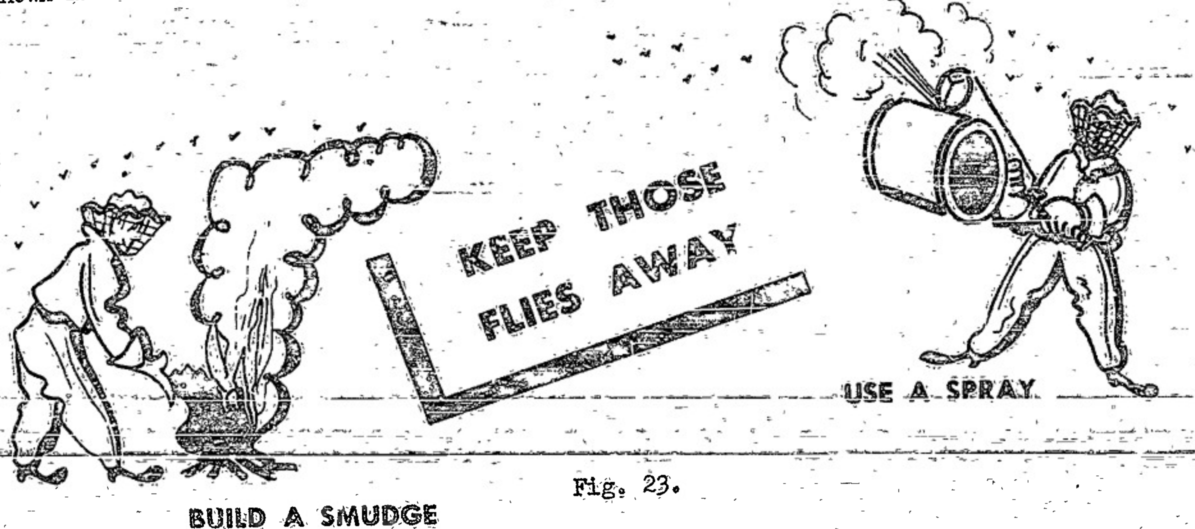

Fig. 23.

Black flies are small, black, stout-bodied and humpbacked insects, sometimes called buffalo gnats, that breed in swiftly moving streams. They are usually active only in daylight and are most numerous during June and July. They hover about the eyes, ears, and nostrils, making little noise but promptly alighting and sucking blood wherever the skin is exposed. Their bites are not especially painful when made, but they soon swell and itch considerably. Black flies can be particularly annoying if they are able to get inside the clothing.

Midges are extremely small, blood-sucking insects, also known as "punkies," "no-see-ums", and "creeping fire," that breed in decaying leaves, along streams, and in holes in trees. They are most abundant in middle and later summer. Their bite is accompanied by a sharp burning pain. They bite chiefly on cloudy days, in the evening, and early in the morning. They are more troublesome because of their small size. They easily penetrate the finest mosquito netting and are only excluded by 60-mesh silk bolting cloth. Spraying the inside of tents or shelters with an oily insecticide is helpful.

Deerflies, mooseflies, and horseflies are the larger types of Arctic insects and are sometimes called "bulldogs." Mooseflies have a thick body with a wing spread of nearly an inch. Deerflies, which are slightly larger than houseflies, have prominently banded wings. Horseflies are usually intermediate in size between deerflies and mooseflies and are rather like houseflies in shape. All these "bulldogs" frequent marshes and bogs on hot bright days. Strong winds do not keep them down, but cool weather sends them to cover. They are extremely annoying because of their continual circling and buzzing and their vicious bites. Nets and gloves give the best protection.

It is one thing to slap a mosquito now and then on a warm summer evening in Ohio, but quite another thing to run from a cloud of Arctic mosquitoes and black flies so thick a man can scarcely see through them. No one is tough enough to get along without the proper type of protective clothing for the entire body.

Arctic summer clothing should be so closely woven that insects cannot penetrate it. Zippered or pull-over shirts are preferable to open fronts. Clothing must be secured at the ankles, wrists, and neck to eliminate any means of access to insects. Gloves or mittens are necessary and must be long enough to close the wrist opening. Mittens can be made of windproof cloth if it is thick enough to prevent bites through the cloth. Gloves should be treated with cresol soap to disguise the skin odor which attracts insects. Head nets should be worn so that the netting will be held away from the face. The netting should be dark, to provide better vision, and equipped with a drawstring by which it can be drawn around the collar to inclose the neck.

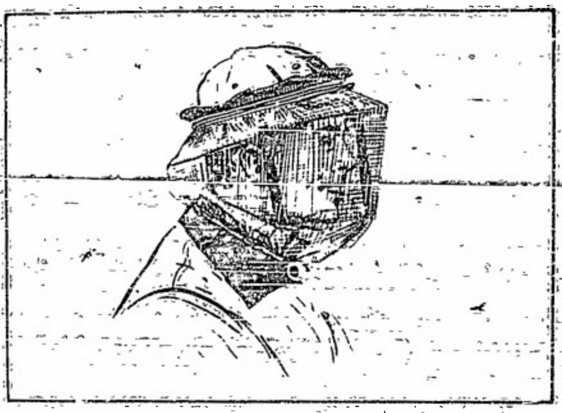

Fig. 24. — Head net

The most satisfactory insect screen for permanent use in shelters is wire cloth no coarser than 18 meshes to the inch. Copper, monel metal, or galvanized steel can be used. Black-painted or japanned steel wire is easier to see through than these, but it rusts.

Bed nets of fine mesh bobbinet are essential to restful sleep. As in the tropics the net must be held away from the face and body of the sleeping person. A net covering the whole bed or sleeping bag is more satisfactory than one covering the head only.

Some substances are particularly effective as insect repellents. Dimethyl-phthlate, now being used by the Army, has proven to be most effective. It gives good protection for a little less than two hours after application even if the person perspires liberally. Many home preparations can be used if a regular repellent is not available. Oil of tar and oil of lavender repel blackflies; citronella discourages mosquitoes; and creosote, spirits of camphor, and oil of cedar keep off midges.

Smudges if properly made, will furnish relief for a short period. For a good smudge, build a fire and let it burn until a bed of coals is formed. Place dry wood on the coals and allow it to burn brightly, then cover the whole fire with green ferns, damp leaves, and rotten wood. The dense smoke that now arises will banish the black flies instantly and repel most of the mosquitoes. Unfortunately, it is unsafe to rely on smudges alone as they are frequently more irritating than insects.

Pyrethrum, kerosene, and some of the commercial fly sprays are useful in the interior of shelters. They should not, however, be used near open flames as some of the sprays are inflammable. The most convenient spray for use indoors is the new aerosol insecticide dispenser. Operation for a few seconds is sufficient to kill all mosquitoes in a pyramidal tent, and one dispenser will suffice for 200,000 cubic feet. This spray is non-inflammable and nontoxic.

Soaking in water is the easiest and best all-round treatment of fly bites. Cold wet compresses, made with weak ammonia, 1-percent alcoholic solution of menthol, zonite, or hydrogen peroxide, may be used. Avoid scratching of bites as there is a real danger of infection.

Frostbite

Frostbite is the freezing of some part of the body. It is a constant hazard in sub-zero operations, especially when the wind is strong. Frostbitten skin becomes stiff. As a rule, frostbite causes numbness rather than pain. The parts that are most easily affected are the cheeks, nose, ears, chin, forehead, wrists, hands, and feet. Prevention is a matter of taking proper precautions. If frostbitten, however, frozen parts should be thawed promptly. Neglected frostbite ultimately causes gangrene. With superficial frostbite, the gangrenous part may slough off, leaving good tissue beneath; when gangrene is deeper, however, amputation is necessary. Only a medical officer should decide to amputate.

Frostbite is caused by exposure to severe cold, particularly in the wind. Contributing factors are loss of body heat and poor blood circulation, the latter condition occurring naturally or caused by over-light clothing. Wet clothing is especially to be avoided. Further important factors are extreme fatigue, improper diet, and excessive carbon monoxide.

The sooner treatment of a frostbitten part is begun the better. The frozen part should be warmed gradually. Legs and arms should be thawed in cool, dry air (60° to 70° F). Elevating frozen limbs slightly also helps. Minor frostbites of the face can be thawed by holding a warm, bare hand against them. To thaw a frozen wrist, grasp it with a warm hand. Thaw frozen hands against chest, under the armpits, or between the legs at the groin. It may be necessary to warm cold hands in a similar manner before they can be used to thaw a frostbitten wrist, ear, or face. For frozen feet, change to warm, dry footgear when possible; otherwise, remove cold shoes and socks and wrap the feet with skins or a sleeping bag. Holding bare feet against a companion's belly or between his thighs also is effective. Do not try to thaw by running; badly frozen toes may be stubbed and broken. Moreover, running is exhausting and causes perspiration.

Never rub frostbite. This breaks skin tissue, causing open wounds, and in subzero temperatures, wounds heal very slowly. Bending frozen arms, legs, or ears also breaks skin tissues. Never apply snow or ice; freezing is increased by doing this. For the same reason, never soak frozen limbs in kerosene or oil as these liquids may be so cold that they will increase the frostbite. On the other hand, a frostbitten person should not get too near a hot stove or other source of heat or use hot water for thawing. Too rapid thawing increases pain and damages skin tissues.

When frostbite is accompanied by breaks in the skin and there is a danger of infection, sulfadiazine should be administered internally.

A burning sensation like that of sunburn follows the thawing of a frozen part, and the treatment following the thawing is the same as that for sunburn. The thawing of serious frostbite may be very painful. Do not break the blisters that sometimes develop; a medical officer should open them. If they happen to break, trim off the dead skin with scissors and treat them like an open wound or cut. Any degree of frostbite should be reported at sick bay. Proper clothing and the proper wearing of it are the surest means of preventing frostbite. Wet clothing should be changed promptly.

Fig. 25.

Cold metal should never be touched with bare hands; the skin will freeze instantly to the metal. If this should happen, a man should not pull away, or he will be likely to part with a piece of skin. The point of contact should be warmed with urine, if necessary.

In cold weather a beard is a liability. Moisture from the breath, collecting on it, will convert it into a veritable ice mask which makes thawing of frostbite on the face very difficult. Clipping facial hair is better than shaving. When a man shaves, he should do it before going to bed, rather than in the morning, to avoid chapping. A piece of thin windproof cloth, pinned to the parka hood just below eye level and hanging loosely, is a good protection against a headwind. A man should make grimaces from time to time and touch his face to test for stiffness. He should also watch his companions faces for tell-tale spots. To maintain good circulation in the ears, they should be pressed forward now and then. Lips should never be brought in contact with cold metal cups or containers; the lips will freeze to them and will have to be thawed loose.

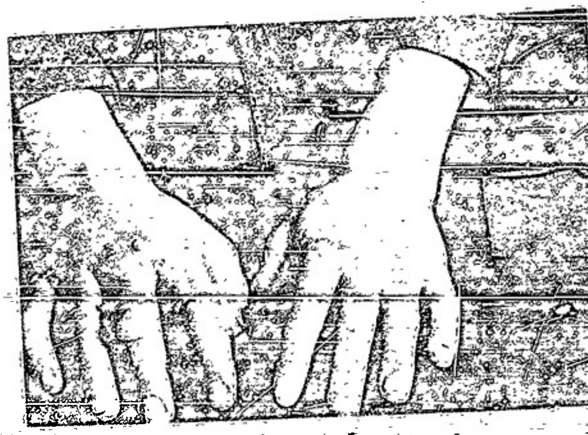

Fig. 26. — Frostbitten hands

Keeping in tiptop physical shape through adequate rest and proper diet is a major frostbite preventive. Alcohol increases the risk of frostbite because it seriously disturbs the body's normal production of heat and the control of body temperature. Alcohol should never be drunk before going out in the cold.

Another danger of frostbite, and one that is quite often overlooked by the novice, occurs during the elimination of human excretion when there is no heated head available. The danger becomes greater because cold climate increases the frequency of the process; it is generally necessary after each meal. In order to reduce the bodily exposure time, preliminary clothing adjustments should be made in advance. When the process is completed all body parts should be thoroughly dried. Snow that may have blown into clothing should be completely removed. If the hands have become numb and stiff during the exposure, assistance in readjusting clothing should be sought. Timing and speed is of the essence. The eskimo has found it expedient to loosen the belt on the knee-length parka so that it will serve as a tent when he assumes position.

Immersion Foot

Immersion foot is the term applied to the condition resulting from prolonged immersion of the feet in water; it is aggravated if the feet are allowed to hang down and remain immobile or if there is constriction by shoes or clothing. The condition can also affect other parts of the body such as hands, knees, and buttocks. Ordinarily, swelling follows immersion of the feet in very cold sea water, but it also may occur in subtropical waters and is essentially different from frostbite. The condition is similar to "trench foot".

Shipwreck and forced landings of planes on the sea are the most frequent conditions leading to immersion foot. Or prolonged wetting and chilling of the feet for more than a few hours will cause them to get numb, swollen, and blistered. As in frostbite, there is a danger of infection and gangrene.

The treatment is similar to that of frostbite. After rescue the patient should be put in a bunk and the body warmed externally by covering with blankets and hot water-bottles if available. Hot soup, coffee, or tea should be taken to help warm the body internally. In this case, a drink of whiskey or brandy may be of real help. While the body is being warmed it is absolutely essential to keep the extremities that have been injured by exposure, cool. This can be done by keeping the room temperature down to 60° to 70°F and directing a blast of cool air from a blower or fan over the feet. Rapid warming should be avoided.

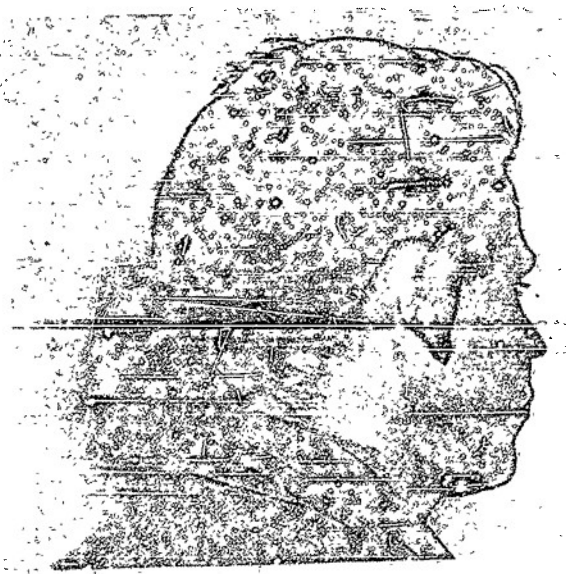

Fig. 27. — Frostbitten ear

Legs should be kept slightly elevated and free from any pressure, either by complete exposure or by means of a cradle. By supporting the back of the legs down to the ankles on a pillow the pressure on the heel will be removed and the danger of pressure sores will be minimized.

Men forced to abandon ship should take their waterproof and loose fitting boots and several extra pairs of woolen socks. If there

Fig. 28. — Warming feet on companion's belly

is room on the boat or raft, the feet should not hang down and certainly not continuously. The feet should be kept dry by changing socks. Nothing tight should be worn around the legs as this will reduce circulation. Circulation may be increased by moving the feet or exercising the toes. If the feet become so swollen that boots get tight, it is best to take them off and wrap the feet in any piece of blanket or cloth that is handy. Whiskey or other alcoholic drinks should never be drunk during exposure.

Hypothermia

Hypothermia is defined as the subnormal temperature of the body. The temperature of the body can drop below normal when the entire body is immersed in cold water as in the case of a man going overboard in extremely low temperatures. Sub-normal body temperature may occur on land in many ways. For example, if a tractor breaks down in an insolated area during cold weather, the operator, who had elected to depend on the heated cab for warmth, may discover he does not have adequate clothing. It is probable that the body temperature of the operator in this situation would drop well below normal even before actual freezing of the body set in.

The treatment of hypothermia now being used is as follows: * "Air Sea Rescue Bulletin," April, NAV Og 128, Vol 11, No.4, p.22-23.

"Rapid rewarming of chilled survivors has long been considered dangerous. It is now believed, however, that in the view of the results of the experiences incident to World War II and the comments on them by outstanding American authorities, the treatment of survivors after exposure to low temperatures may be formulated as follows:

"If unconscious, but breathing (this situation is likely to occur if rectal temperature is below 80.6°F) the individual rescued from cold water shall be immediately undressed and placed in a bath from 115° to 120° (F) for 10 minutes, then dried with a towel and placed in warm blankets. If the temperature does not rise at a rate of at least 2° (F) every 10 minutes, immersion in warm water should be repeated until the rectal temperature reaches 92° (F). There is considerable rise in temperature after removal from the warm water, and there is no advantage to be gained from rapid heating once this safe level has been regained. If a warm bath is not available, warm water should be poured into the sleeves, trousers, legs, over the clothing and body, or the survivor should be carefully held under a warm shower. In any event, no time should be lost in applying treatment after rescue.

"If conscious, the survivor should be immersed in water from 105° to 110° (F) for 10 minutes, after which time treatment may be carried out as for the unconscious person. Water heated to 115° (F) is painful to a conscious patient and may cause some scalding in chilled persons with rectal temperature above 91° or 92° (F). It appears likely that survivors who are conscious when rescued from cold water will often survive without the aid of the warm bath if they are merely dried and placed in light cradles or electric heating bags.

"Survivors exposed to dangerously low temperatures for long periods should be rapidly rewarmed, preferably by a warm bath, until the rectal temperature begins to rise. More gradual rewarming is indicated as soon as the immediate danger from extremely low temperature has passed.

"Massaging is to be avoided under all circumstances. Drugs, such as digitalis, metrozel, lobeline, coramine, and alcohol are of no value. In fact the results of experiences considered reliable show them to be harmful.

"Administration of 100 percent oxygen at atmospheric pressure should be advantageous by supplying dissolved oxygen not dependent upon hemoglobin dissociation.

"The temperature should be taken, immediately after rescue while the warm bath is being prepared.

"The temperature of the sea water at the site of rescue shall be determined and recorded in the survivor report."

Snow Blindness

Snow blindness is both painful and wasteful of time but with proper care can be prevented. Every effort should be made to avoid the first attack because it makes a man susceptible to subsequent attack, and recurrent attacks may permanently impair vision. A snow-blinded person is a liability. A slight attack means a lay-over for at least a day; severe attack means a longer halt. The victim's usefulness, moreover, is reduced even when he is able to resume travel.

The cause of snow blindness is an overabundance of light, produced by reflection or glare from snow. Actually, the eyes are sunburned. Overcast days as well as sunny ones are snowblinding days; so also are days of light fog. It must be kept in mind that snow-blindness may result from very short periods of exposure to glare.

The altitude of the sun above the horizon has long been considered a most important factor in snow blindness. Competent authorities consider that once the sun is below 20° from the horizon, the amount of ultra-violet radiation, which contributes to snow blindness is zero. This would mean that at the Arctic Circle only the period from 1 April to 1 October would be dangerous, and at the Antarctic Circle only the period from 1 October to 1 April; it would be progressively shorter below or above the respective circles. The Royal Mounted Police at North Devon Island consider late March and early April when the sun is a little more than 20 degrees above the horizon, the most dangerous period for snowblindness.

Time of day is also important, for the sun is twenty degrees above the horizon during only part of the day.

If the eyes feel sandy, burn, grow red, fail to focus properly, and become increasingly sensitive to light, a man should stop using his eyes. For these are the first symptoms of snowblindness. The final stage is intense pain.

The victim of snowblindness should be kept in a dark place or his eyes should be bound with a dark bandage, and he should rest until he has recovered. If traveling, the victim will have to be blindfolded and led. A cold compress (where there is no danger of freezing) will soothe the eyes. A mild bland ointment, such as boric acid, yellow mercurous oxide, or sulfathiazole ointment, is prescribed, with oral codeine and acetylsalicylic acid, or even morphine, to control pain. The local use of

Wear colored glasses constantly — Glycerin will partly prevent clouding — Blacken the face around the nose

Fig. 29.

Altitude likewise is important, for at 10,000 feet at the equator there is only 73% of the atmospheric screen to protect the eyes and at 18,000 feet only 50%. Similar conditions probably exist in the Arctic and Antarctic.

The incidence of snowblindness is difficult to determine. The Eskimo has from time immemorial taken elaborate precautions in the form of slit goggles of wood or bone to protect himself. All Arctic or Antarctic explorers have either taken complete precautions or have suffered cruelly at times. Almost every exploring group from 1900 on has had an occasional case of snowblindness; Stefanson, Scott, Shackleton, and Admiral Byrd have had members of their parties suffer from it. There appears to be no natural or acquired immunity.

cocaine and powerful astringents, such as zinc sulfate, are condemned. The softening effect of cocaine on the cornea will only serve to increase the severity of the lesion. Some proprietary mixture, such as butyn and metaphen, might be used, but it is felt that pain should be controlled by other methods than the use of local anesthesia.

At first, convalescent victims are fit only for tasks that do not require precise vision. Normal focus returns only with full recovery.

Colored glasses are the surest means of preventing snow-blindness. For blizzard conditions a leather-lined plastic or metal slit-goggle is useful. Eskimo goggles, as previously mentioned, made by burning or cutting out slits in pieces of wood have the special virtue of not frosting over but they do limit the field of vision. The slits can be straight lines large enough to admit half-dollars or they can be T-shaped.

Colored glasses or their equivalent should be worn constantly for daytime operations in snow or ice-covered regions. Spares should always be carried in case of breakage. When glasses cloud or frost over, resist the impulse to remove them or to peer around the rims. A thin coat of glycerine on the lenses will partly prevent clouding. When glasses must be removed to be cleaned, a handkerchief should be kept handy so that the operation can be performed with dispatch.

Soot placed across the nose and around the eyes, as well as looking at dark objects while traveling, helps somewhat to reduce the glare. These, however, are merely extra precautions and are not substitutes for dark glasses.

Sunburn

Sunburn is a major source of discomfort in summer operations where there is much snow or ice. It is caused both by the direct rays of the sun and by reflection of light from snow or ice. Lips and nostrils are especially susceptible. Sun-blistered lips that become infected can produce serious results. Lanolin cream helps to soothe the sting of sunburn. The best preventive however, is the application of a mild opaque ointment, such as petroleum jelly, along the red line of the lips and at the corners of the nostrils. The temptation to strip to the waist on a very sunny day should be resisted; at least a light garment should be worn at all times.

Carbon-Monoxide Poisoning

As pointed out previously in this chapter, carbon monoxide is an odorless, deadly gas that is a constant danger wherever a stove, fire, or heater is used indoors. The only preventive of carbon-monoxide poisoning is ventilation. Generally, there are no symptoms. With mild poisoning, however, a man may experience a headache, dizziness, yawning, weariness, nausea, and ringing in the ears. Later the heart begins to flutter or throb. The dangerous part, however, is that the gas may hit one without any warning whatever. A man 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. A man may be asphyxiated as he sleeps.

In case of carbon-monoxide poisoning, the victim should be rushed into fresh air at once, but should be kept warm. In an Arctic winter, fresh air means merely circulating air that is free from gas. Exposure to outdoor cold might

Fig. 30. — Homemade sun glasses

cause collapse. If the only fresh air is outdoors, the patient should be put in a sleeping bag for warmth. A carbon-monoxide victim, at no time, should be allowed to exercise. This further reduces the precious supply of oxygen in his blood and increases his demand for it. If a gassed person stops breathing or breathes only in gasps, artificial respiration should be started immediately, and the movements must be synchronized with his gasps. Pure oxygen and a mask should be used if available. Inhaling pure oxygen removes carbon monoxide from the blood faster than does breathing air.

MORALE AND HEALTH

Personnel considered physically fit by present Navy standards are considered physically qualified for duty in the Arctic. However, men do not react to low temperatures in exactly the same manner.

In general, the efficiency of all personnel will decrease 2% for each degree of temperature below 0°F. The amount of clothing and food required for health and efficiency in exhausting cold will vary with the individual's age, size, physical condition, and mental attitude. Men over forty and youths under seventeen appear to be less resistant to the general effects of cold than those of intermediate ages. Racial hypersusceptibility to cold has not definitely been established, but individuals accustomed to a warm environment apparently do not have the same defenses as those who have been accustomed to colder climates.

It is not to be construed that survival in the Arctic requires a type of a superman, because experience has shown that any individual who is physically and mentally capable of adjusting to military life anywhere overseas is also able to adjust to life in the Arctic. The adjustment, however, requires indoctrination and motivation.

Motivation or the will to work, as was demonstrated in the Seabee units during World War II, is not peculiar to any age or physical condition. Older men with physical defects who possessed motivation quite frequently produced considerably more than youths who were given to "gold bricking".

Depending on the individual's idea of fun, he should walk, read, shoot the breeze with the boys, or engage in some sport when he has time off.

Some men will find the Arctic regions so interesting that they will want to explore the

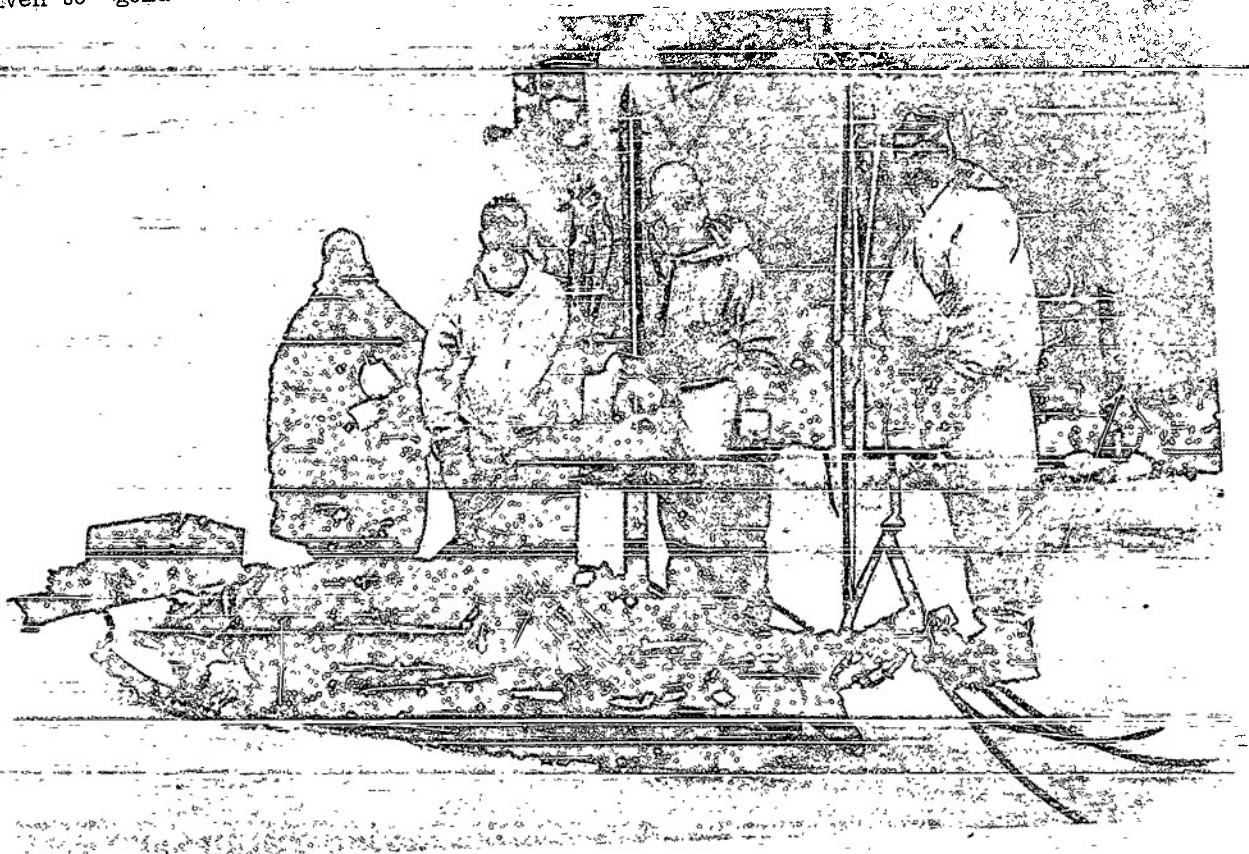

Fig. 31. — Successful seal hunt

areas within easy walking distance. The walk will do wonders for their dispositions and they will come back feeling a lot better.

While motivation is innate, it can be developed by intelligent supervision and administration. Perhaps the most effective method of maintaining high morale is to prevent monotony. One of the most difficult things to get used to is a dull existence. This is true in the Arctic just as well as in the United States or the South Pacific.

Men who have lived successfully in isolated posts are always systematic in their habits because they have found that when they become careless in their personal habits, they become equally careless in their work, and they gradually get depressed. If regular routines are set up and followed, the men will feel better both mentally and physically, and work will progress more efficiently.

If there is enough snow at the post, skiing might be worth trying. The men should start first with cross-country stuff and gentle slopes until they get accustomed to it.

Dog-driving is another great sport. If there are dogs at the base, the men will miss the opportunity for a real thrill if they don't try sledging. The official dog-driver should be asked for lessons in how to harness the animals and give the proper commands.

The men should also take advantage of a tour in the Arctic to get in some hunting, fishing, and an occasional camping trip. An understanding of living in the Arctic is not only fun to acquire, but it may actually pull them out of a jam some day, for one can never tell when he may have to get along on his own in an emergency.

If there are enough interested persons, the men can participate in familiar state-side sports, such as football, baseball, hockey, and sometimes even swimming--depending on the season and location, of course.

These are just a few suggestions for a program of leisure. Participation is up to the individual, but boredom is a kind of disease that may eventually wear men down. Arctic experience can either be an agreeable one or the dullest stretch of duty ever put in. The way a man uses his leisure time and adapts himself to Arctic conditions can make it one or the other.

IN THE ANTARCTIC

When it is realized that probably less than 100 square miles of the total Antarctic continent is free from a permanent covering of ice, it can be understood that there is no attraction there for man or beast or plant. In the Antarctic there is not a single permanent human inhabitant, nor a single land animal larger than an insect. Trees do not exist, and there are very few plants. Whales, seals, and penguins comprise the principal forms of aquatic animal life.

It is obvious, therefore, that living off the country in the Antarctic is impossible. Men have survived for a year, but only because of the food and supplies that were transported from other continents. Similarly, the problem of local fuel is quite different from the Arctic. There are coal deposits but they are virtually inaccessible.

The other main difference between the two polar regions is that there is no insect problem nor any need for summer clothing in the Antarctic.

However, all the other basic rules and regulations about cold-weather living in the Arctic as set forth previously in this chapter apply to the Antarctic.

Fig. 32. — Chow line in Antarctica

CHAPTER V

OPERATION AND MAINTENANCE OF TRANSPORTATION AND CONSTRUCTION EQUIPMENT IN POLAR REGIONS

PART I — THE TRACTOR TRAIN

One of the principle obstacles to construction progress in the polar regions is the lack of transportation. Ships delivering supplies cannot penetrate the ice bound waters in many sections for more than two months during the year. Once the supplies are unloaded on the beach there still remains the problem of transporting them cross country to isolated job sites. For the most part there are no roads and the material and equipment must be hauled over rugged snow covered terrain.

The most effective and dependable means of accomplishing this is the tractor train, consisting of a number of go-devils and sleds towed in tandem by a tractor, equivalent in size and power to a D-8. There should be one tractor for every three trailer units or approximately fifty tons of load.

Each train should have at least three wanigans, a galley, a shop and quarters. The galley and quarters wanigans should be sled mounted for smoother riding while the shop may be mounted on a go-devil. All gear in the galley and tools and equipment in the shop should be adequately secured to counteract the rocking motion of the train.

Of course the need for a shop is dependent upon the scope of the operation. If the route of the train will be within hailing distance of a main repair base, the shop may be dispensed with. However, on long hauls through isolated regions you will need a shop equipped to make all types of repairs and replacements to tractors and sleds.

At times, it is advisable to include a utility wanigan in the train. These small, light, combination galley-and-quarters, for trail breaking parties may be mounted on a go-devil.

Selecting the Route.--This is the most important phase of advance planning for tractor train operation, as careless or hasty selection can result in delays and even loss of equipment and man.

If available, aerial reconnaissance, maps, and aerial photographs should be employed for laying out the route. During this stage of the planning the route should be traversed, if at all possible and experienced guides consulted.

A straight line route is desirable, but of course not always practical. In fact, the course of a river often provides the easiest and safest trail. Hills and mountains should be avoided. If mountains have to be crossed, the route should follow a valley to a low pass or saddle.

Grades exceeding 10% are negotiable only with difficulty. Keep in mind that zig-zagging up slopes causes tipping and shifting of loads.

Frozen lakes and streams should be crossed only after the ice has been thoroughly tested and, if weak, only after ice bridges are constructed.

Remember that daily detours from the selected over-all route are often necessary because of shifting snow conditions. Advance parties in a weasel, or small plane, should make daily reconnaissance trips and furnish the trail breaking crew with appropriate directions.

Leading.--Experience and a knowledge of the route to be travelled is of great help in determining the maximum allowable height and weight of loads.

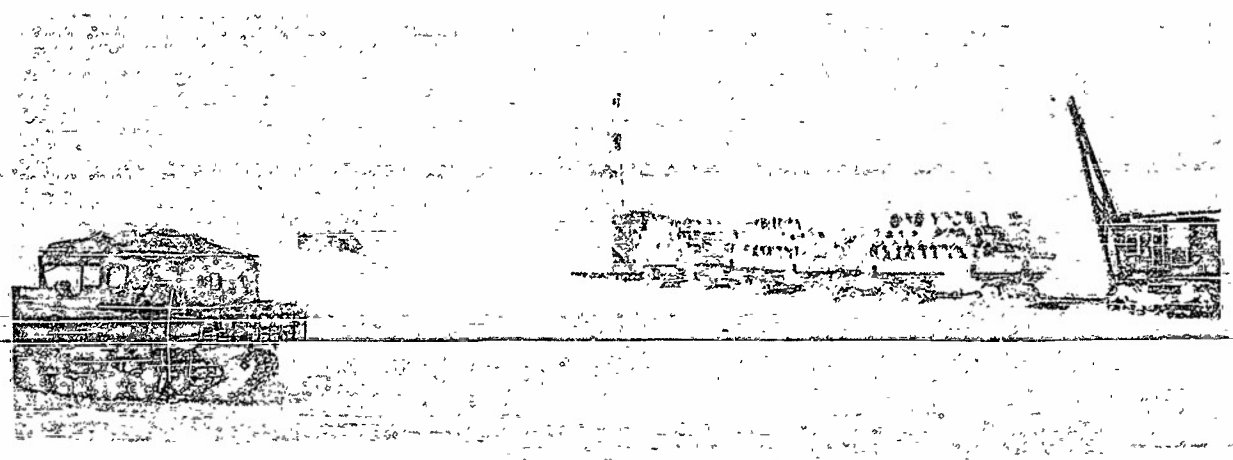

Fig. 1. — Tractor Train, Point Barrow

Most manufacturers mark the load capacity on the sled. Allowance for age and condition of sleds should be made. Since sled platforms are generally constructed in the field and vary in length according to the distance between the front and rear sets of runners the load they will carry will depend on the maximum allowable unit stress in the longitudinal members.

Four 8 x 8 inch timbers or equivalent logs, used as longitudinal member with runner sets 20 to 24 feet apart will provide a platform with a bearing capacity greater than that of the runners. An adequate safety factor can be then maintained by not allowing the load to exceed the manufacturers sled capacity.

The height of the load is generally governed by its tipping tendency rather than its weight. For any but old, smooth trails, the height from the ground to the top of the load should not exceed the width. This last measurement should be kept under 10 feet because of obstructions along twisting routes. Wide loads require breaking a trail wider than the dozer blade which causes excessive work and delay.

Loads should be secured before the train starts. A shifting load not only wastes precious traveling time on the trail but it distracts the operator when he should be concentrating on running the tractor. Loose loads should be boxed in with flat lumber at the sides and open loads such as wire on spools, or a landing mat, should be spiked to the platform and secured by stakes driven through the openings. At each stop along the route every sled should be checked for load shifting.

Assembling the Train.--For greatest efficiency in operation, sleds should be assembled in units of three. The width between runners should be the same on all sleds in the unit. For greater towing ease, the most heavily loaded sleds should be forward of the others. Wanigans and go-devils should always follow loaded sleds. If sleds stand in the open for any length of time the runners will freeze to the snow or ice. If they are not broken free by using a mallet or sledge hammer, the sudden starting strain of the tractor might cause them to fail.

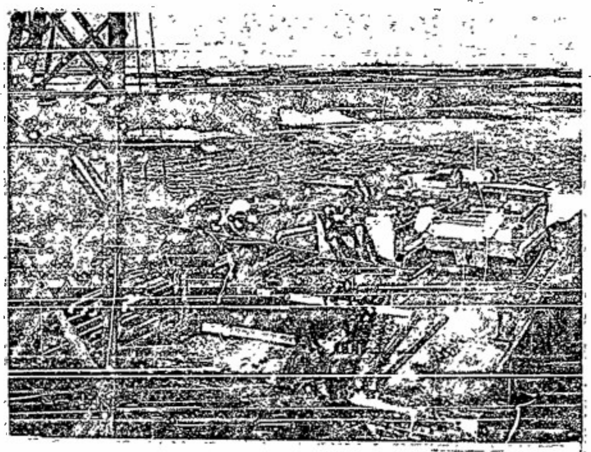

Fig. 2. — Ship to Shore

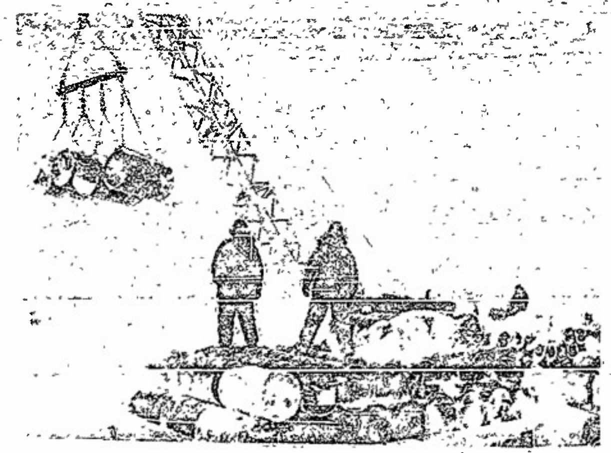

Fig. 3. — Loading Tractor Train

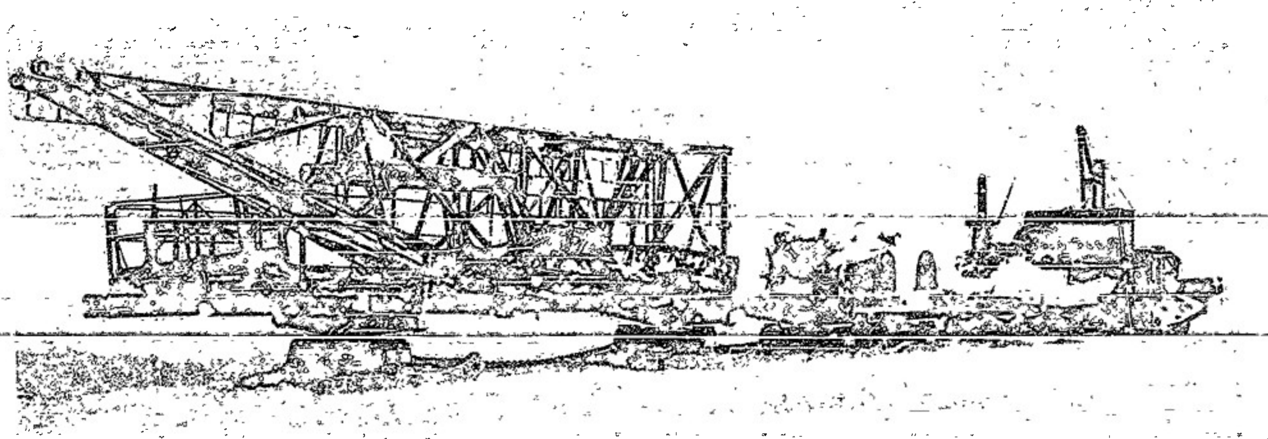

Fig. 4. -- Sled Platform made out of pipe

Breaking Trail.--Except in open country, it is advisable to break trail only in daylight. The usual outfit for trail breaking consists of two tractors and a utility wanigan, with a small supply of fuel. This unit should be operating about a day in advance of the train.

Trail breaking in deep snow or grass, simply requires that the tractor move along the selected route with the dozer blade raised, compacting the snow, and leaving a smooth surface for the train. Where the surface is uneven, the trail must be cleared and left sufficiently level to enable the train to travel without stopping, or tipping the loads dangerously.

Because trees in the Sub-Arctic are generally not deep rooted, they can be bulldozed easily out of the way. Willows give the most trouble because they bend and allow the blade to ride over them and spring up behind the tractor. Willow groves should be avoided as much as possible.

When fills are required they should be made of compacted snow and brush because the extreme hardness of frozen ground makes it difficult to work.

The Operation of the Tractor Train.--To permit greater distances to be covered and avoid restarting cold engines, 24-hour operation is advisable, particularly in low temperatures.

During Arctic winters, the limited daylight results in poor visibility. At night only the sled immediately following the tractor can be seen by the driver. Only the more experienced men should drive at night and they should exercise great care in traveling around curves and across pitches and narrow fills. An extra gasoline lantern for each tractor, an ample supply of flashlights and batteries (kept in a heated cab or wanigan) should be considered required items for night emergencies. Kerosene bombs, similar to those used on highway construction, should also be carried for marking the rear sled or those left behind along the route. Also fire extinguishers must be carried at all times.

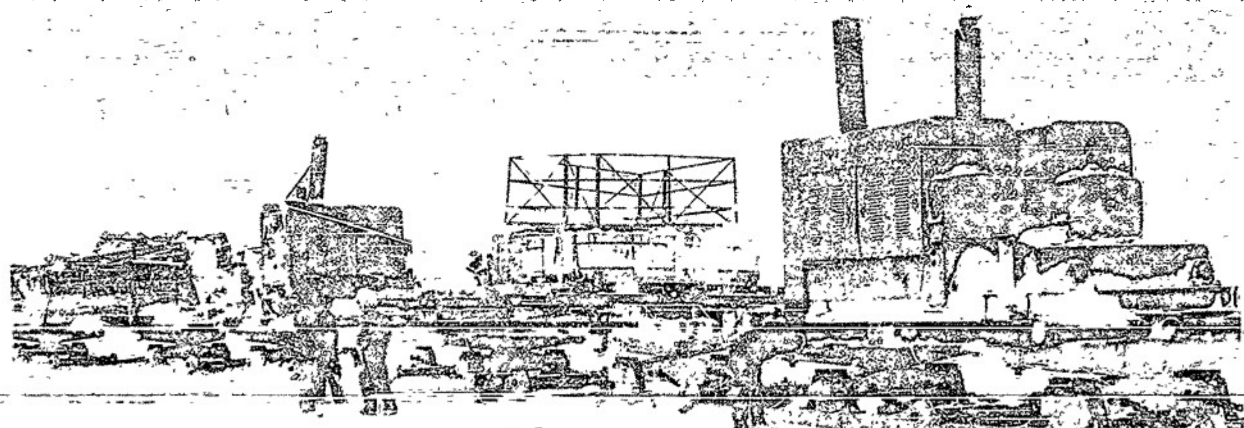

Fig. 5. -- Checking for shifting loads

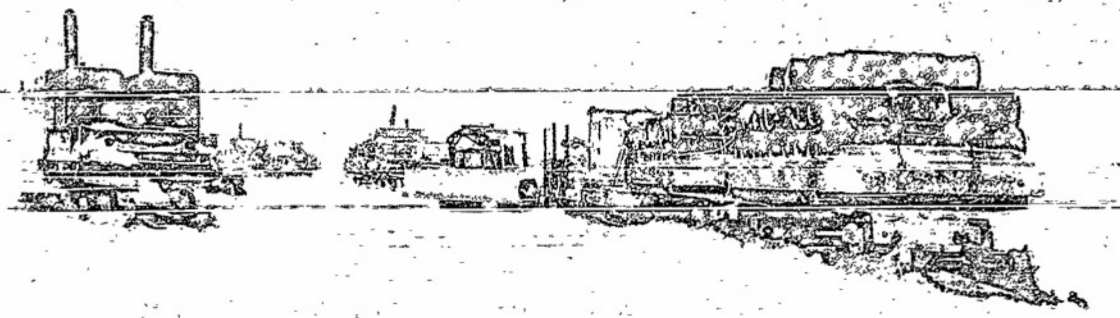

Fig. 6. -- Assembling Train

Breakdowns usually result from broken couplings, cross chains or cables, runners, sled platforms, sheared king pins, loose rollers, overturned sleds and tractor failures. When a breakdown occurs, the shop wanigan and crew remain behind, make the repairs, and then rejoin the main train. If major breakdowns threaten to delay the entire train, all hands should turn to and expedite repairs.

On long hauls, fuel supply is a great problem. In every 15 hours running time, a D-8 tractor consumes 53 gallons of fuel, weighing about 500 pounds. Obviously then, fuel takes up a considerable portion of the starting load. One method of overcoming this is to establish fueling points in advance along the route. But this is not always possible. However, if a route is constantly used, employ special fuel trains to build up stockpiles at strategic points along the route. For runs of less than 100 miles, it is more practical to carry the entir fuel supply with the train.

To insure the success of a tractor train operation, select skilled operators and mechanics who are acquainted with cold weather conditions and who are capable of making even major repairs along the route.

In general, operating in low temperatures, most equipment is about 70% as efficient as it is in temperate or tropical climates. However, results of operations compare favorably with those attained in warmer regions because of the periods of longer daylight and the twenty four hour working schedule.

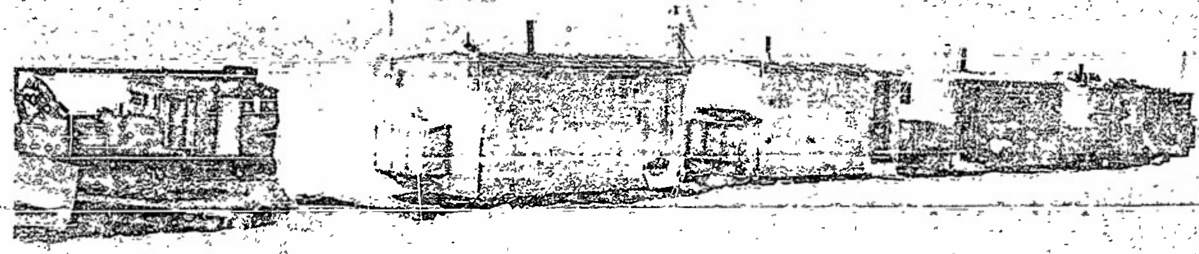

Fig. 7. -- Wanigan Unit

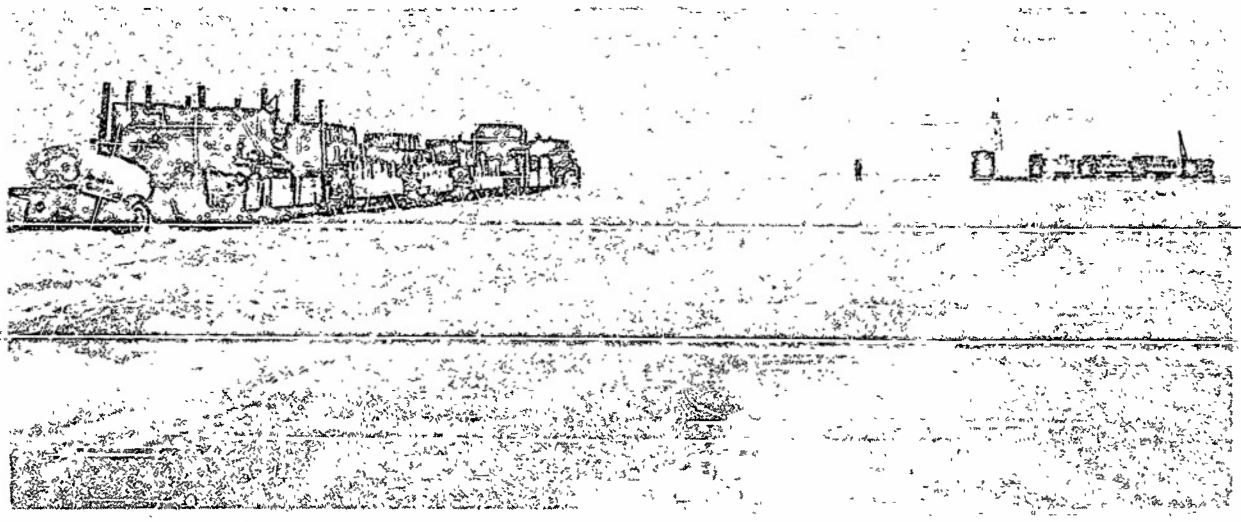

Fig. 8. -- Point Barrow to Umiat Train

PART II -- OPERATION, MAINTENANCE AND MODIFICATION OF EQUIPMENT

Influencing Factors.--Fortunately much construction equipment designed for temperate climates can, with some modifications and adjustments, be used successfully in the polar regions.

The factors that make these adaptations necessary are numerous. Frigid climate, permanently frozen ground, seasonal freezing and thawing of the surface, dearth of transportation facilities -- these are the principle ones.

While the urgencies of war respect neither time or place, they can not alter the fact that certain conditions are less favorable for quick easy construction than others. Cold weather building, even in the states, is a costly and time consuming operation, especially at temperatures below 0°F. How many times in your own experience have you had to suspend a job, knock off the crew and start up the salamanders when the temperature dropped to a point where there was danger of the mortar freezing?

Within the limitations of military necessity every effort should be made to design the construction program to harmonize with the seasons of the year. Construction should be confined to the most sympathetic season of the year. Outdoor work will not ordinarily be attempted at temperatures below -25°F or -30°F, but emergencies may demand it. Remember that low temperatures reduce the efficiency of men and materials and cause damage to equipment. In addition low temperature periods, at least in the Arctic, are generally short-lived. Accordingly, the best season for building construction and earth moving is the summer, while outdoor work in the winter is generally confined to freighting. War time conditions will naturally, require a deviation from this schedule.

General Requirements.--Construction equipment for use in the polar regions must be powerful and rugged to withstand rough useage over ice, snow and frozen ground and still be light enough to operate on marshy tundra during the warm season.

Diesel-powered equipment is preferred because it is more dependable and consumes only two-thirds as much fuel as gasoline engines. The latter feature represents a considerable savings in shipping space and cargo handling.

Wheeled vehicles are of little use until such time as graded roads are built. Tracked vehicles are indispensable.

Various types and sizes of construction equipment and the necessary attachments required in the polar region are described individually in the following paragraphs. The listing is not final or all inclusive. There will be additions to and modifications in the list as experience and research are bound to introduce many improvements and perhaps several new types of cold weather construction equipment.

Tractors.--The crawler type tractor similar to a Caterpillar D-7 or D-8 is as necessary in the Arctic and Sub-Arctic as it was in the Pacific. However, certain adjustments on this Seabee workhorse will have to be made.

The use of standard, or improvised, winter tracks increases towing capacity about 50%. If the standard winter tracks are not available, the summer ones can be altered to serve

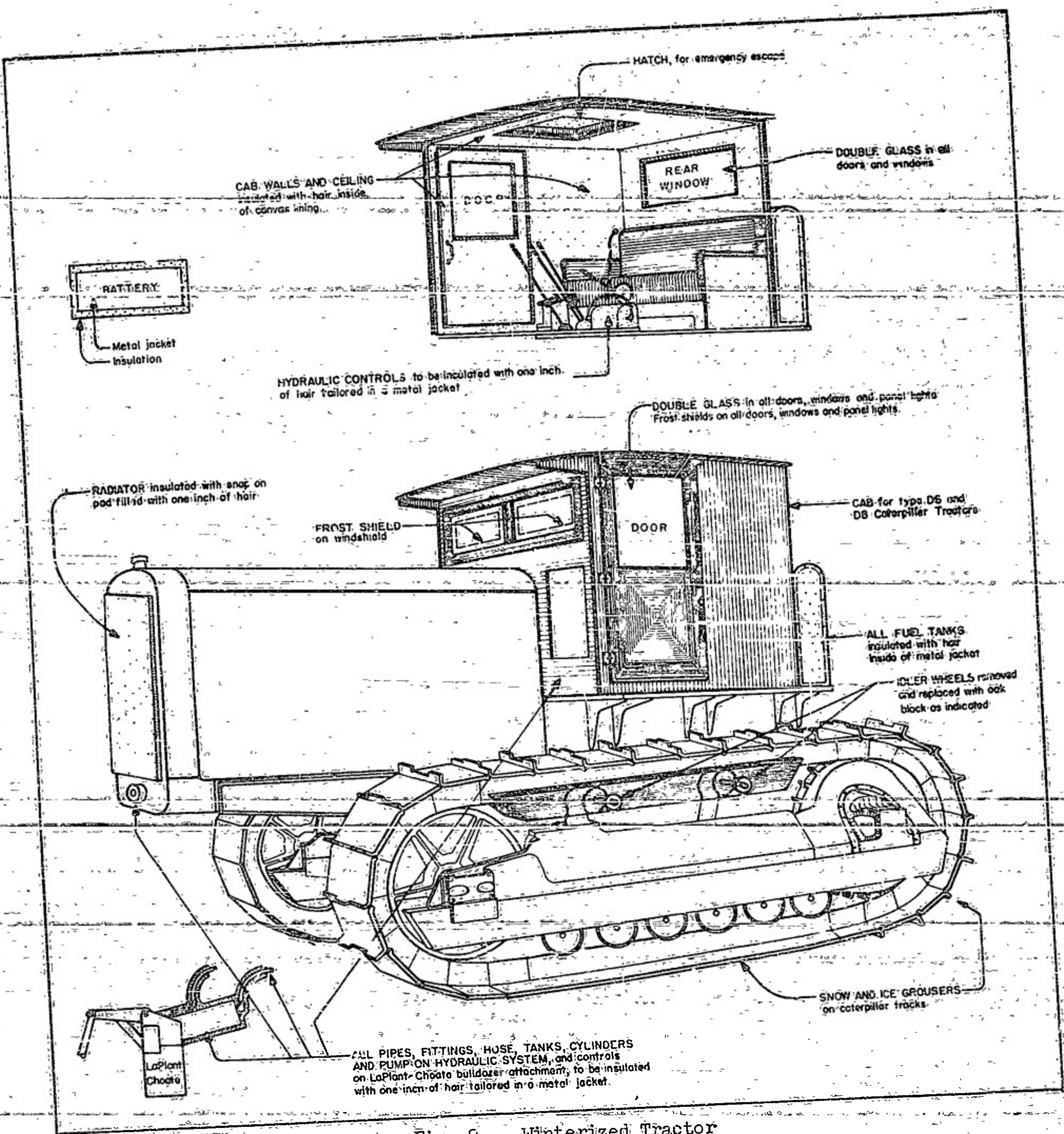

Fig. 9 — Winterized Tractor

the purpose. This is accomplished by cutting 3-inch square holes in each track plate over the line of the drive sprocket. This allows snow to clear from the sprocket instead of becoming packed inside, causing excessive tension. The 3-inch squares that have been cut-out of the tractor plate are cut in half and welded in a staggered pattern to the existing cleats. These cleat extensions, called skeleton snow and ice grousers, assure proper traction. These grousers are also effective for operations in mud and marshy tundra.

As top track carrier rollers become clogged by snow and fail to revolve, they should be replaced with a hard wood block shaped to carry the tracks.

Heavy steel plate roller guards should be installed on both sides of the roller frames to keep out snow, ice or gravel.

The operator of a vehicle must be protected from the weather by a cab. To insure proper vision, cab windows should either be double or have defrosting equipment. In the summer, ventilating fans are needed to keep out insects. All cabs must be equipped with an escape hatch to provide the operator with a secondary and ready means of egress should the vehicle crash through the ice. Air from the engine compartment entering the cab through louvers will provide ample heat for the operator. Ventilation controls should be provided so that the operator will not become overheated.

To prevent snow from drifting into the engine compartment and in order to maintain the proper operating temperatures, the base should be sealed with a full length crankcase guard plate. The hood should have solid side doors and hand operated shutters or a curtain should be installed on the radiator.

Engine intake air should be drawn from inside the cab or some other sheltered part to prevent snow from being sucked into the compartment.

Tractors tend to pitch and twist when operating over rutted and irregular frozen ground. This condition calls for extra heavy duty equalizer springs and protection for the operator from projections in the cab.

Since operators have to wear heavy bulky clothing in winter, the controls should be designed to facilitate their movements under these conditions.

Another precaution that must be taken is to direct the engine exhaust away from the operator's line of vision. The steam formed by this in cold weather is a hazard to safe and efficient operation.

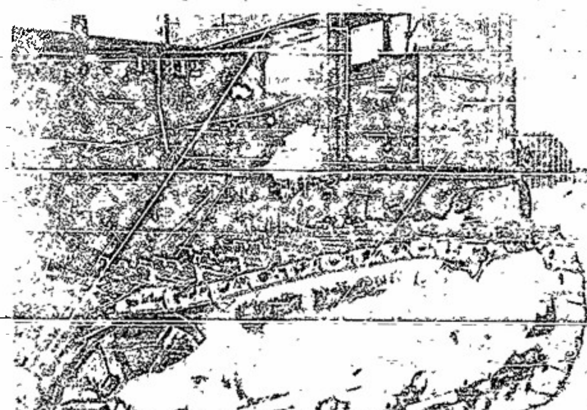

Fig. 10. -- Special snow and ice grousers on track

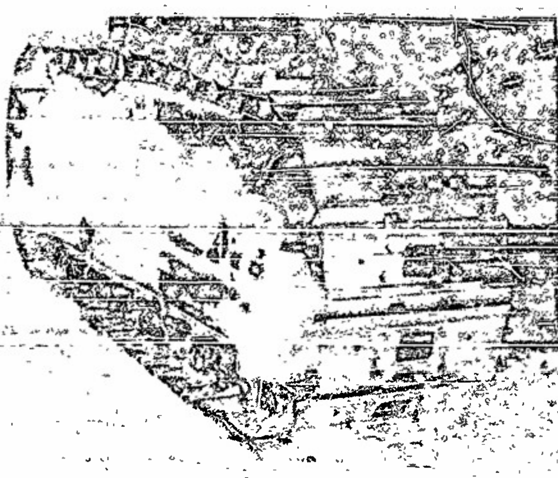

Fig. 11. -- Holes cut in track plate to prevent snow packing inside

A large percentage of the tractors should be equipped with a bulldozer. In addition to its primary purpose of earth moving, the "dozer" is used to break trail, protect the radiator and engine when traveling through timber, and to provide necessary weight forward to overcome the sudden rises or pitches. Hydraulically operated dozers are preferred at Point Barrow principally because they provide downward blade pressure which is so essential in working frozen ground and secondly because they do not develop the destructive vibration found in a cable operated blade. In addition fine snow generally clogs the cable sheaves to such an extent that they can't be operated. Hydraulic systems should be thoroughly insulated.

Winches and front pull hooks for towing and salvage operations should be required items for all tractors.

During the dark winter days, an engine-driven generator is required for lighting. At the present time, a storage battery is not required because the engine is usually left idling when the tractor is stopped for short periods. However, when new lubricants that will resist low temperature are developed and engine shut downs become common practice, batteries will be required.

Smaller size tractors similar to the caterpillar D-6 have been used successfully for summer operations over soft ground. Their low unit pressure, however, provides poor traction, and they are not, generally, used in winter. An exception to this exists in the Antarctic where on Operation Highjump a D-6 tractor with oak track extensions, previously described, operated efficiently on the soft surface snow of the Ross Ice Shelf. Track extensions should not, however, be considered

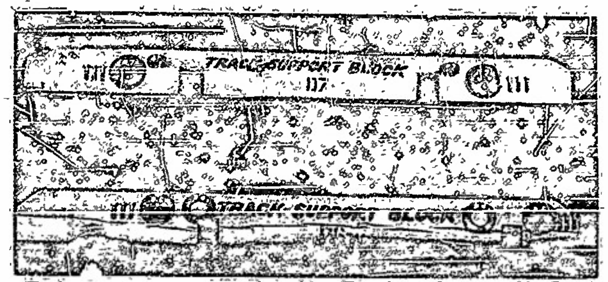

Fig. 12. — Track support block

a "cure all" since they reduce the maneuverability of the tractor.

Scrapers, Graders and Rooters.--Scrapers under 16 cubic yard capacity have been used successfully in the Arctic. They should, however, be equipped with offset frost blades with protruding chisel-bit teeth. The center section of the blade should be slightly lower than the sides for very rough or frozen ground.

Motorized patrol graders with 12-foot blades have proven more effective than the towed type. Here again, the operator should be protected by a heated cab.

The standard 3-tooth rooter or scarifier has been used with some success when only one or two of the teeth were utilized.

Cranes and Power Shovels.--As in all motorized equipment the operators of cranes and power shovels must be protected from the weather with an insulated enclosure. Truck mounted cranes are more mobile, but quite frequently bog down in the marshy tundra.

Fork Lifts.--Crawler mounted fork lifts with winterized cabs are very efficient on snow, ice or marshy tundra. Use of the wheeled model, however, is generally confined to the interior of warehouses.

Personnel and Cargo Carriers.--There is a definite need for personnel and cargo carriers that will withstand all climatic fluctuations. The desirable vehicle should be tracked and capable of accommodating 4 to 8 men in a completely enclosed cab. It should have a capacity of at least 2100 pounds and a speed of 25 miles per hour over snow. The ground pressure of the tracks should be from 1 to $1\frac{1}{2}$ pounds per square inch. The vehicle should be amphibious and able to climb a forty degree slope and descend a sixty degree slope. It should also be light and compact enough to be flown in a cargo plane.

The Weasel (M29c), a standard Army issue, is the most satisfactory vehicle developed so far. It possesses many of the desired features. This Weasel has a capacity of 1000 pounds, can climb a forty degree slope and travel 40 miles per hour on level ground. In spite of its light construction, short-lived tracks, weak transmission and small, high-speed engine, it has proved of great practical value. At Point Barrow it was found that replacing the original tracks with Studebaker tracts improved the efficiency. To a large extent, however, the life of the vehicle depends upon the judgment and experience of the operator.

There is also a need for a heavier carrier with a 3000 to 4000 pound capacity and a ground pressure between 4 and 6 pounds per square inch. At the present time no suitable vehicle of this type has been developed. The nearest approach is the LVT-(3) which is a tracked amphibious landing vehicle. On Operation Highjump a standard unit showed great possibility. Loads in excess of 5 tons were towed over soft snow. Certain modifications, however are being made. The tracks of the LVT-(3) are being widened to reduce the surface bearing pressure and modified to prevent the packing in and building up of snow and ice. The suspension system is being provided with protection from the same snow and ice conditions. The engine cooling system is being modified to protect the operator from the cold blasts of intake air and a removable cowling or roof is being installed.

Another type of vehicle that is satisfactory for short range trips over ice and snow is the M-7 tractor (half track). This two-man personnel carrier will go anywhere a dog team can travel. When fitted with metal skis forward, it is easily operated and will tow a lightly loaded sled.

The usefulness of jeeps and trucks is generally limited to improved roads and camp areas and, to some extent, ice or hard-packed snow.

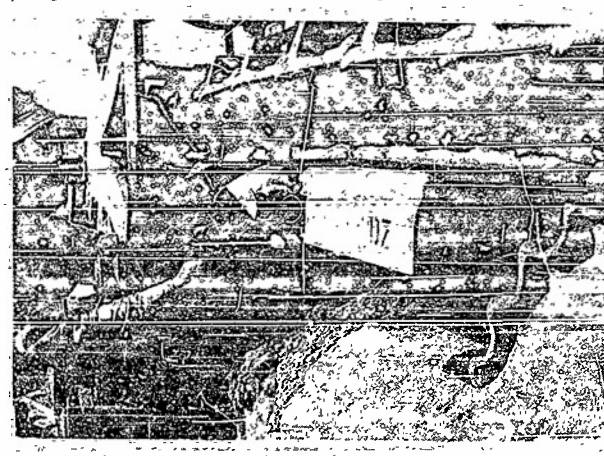

Fig. 13. — Block replacing top track carrier rollers

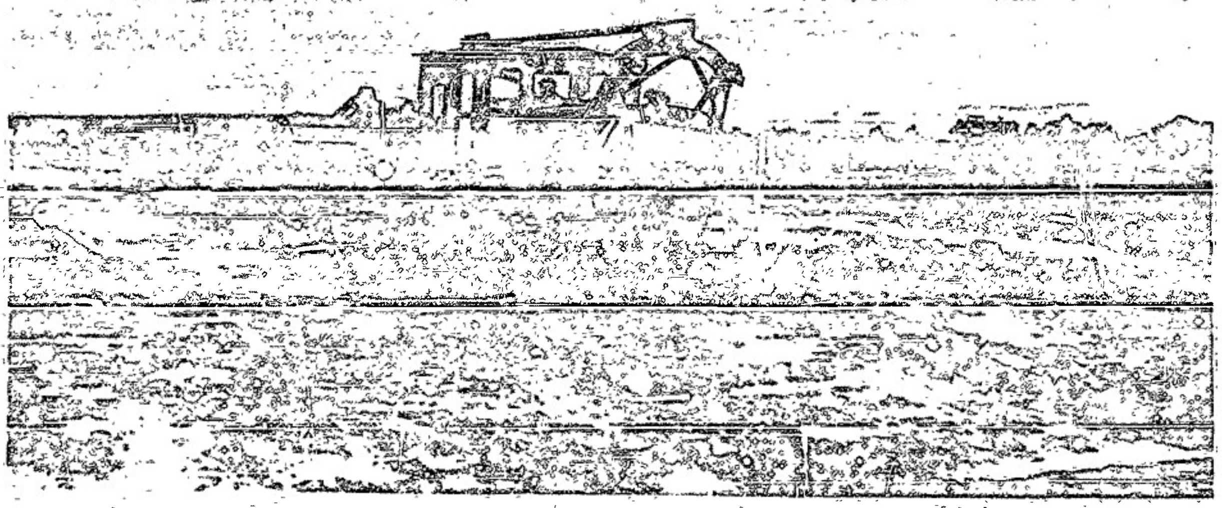

Fig. 14. -- Scraper at Umiat

The standard Army Winterization Kit for one quarter ton jeep on Task Force Frigid included the following items:

- Primer pump
- Side Curtains
- Superfex engine heater
- Fuel tanks
- Hood Curtains
- Radiator cover
- Engine blanket
- Cab heater
- Hose, connections and thermostat
- Slave kit connector

Athey Wagons.--These non-motorized vehicles are tracked cargo carriers with 15 and 25 ton capacity. They give excellent service at low speeds but will not stand up well at towing speeds exceeding 15 miles per hour.

Go-Devils.--These sleds are the simplest and most easily constructed type of trailer unit used. They consist essentially of a pair of runners with a low platform. They may be built by a team of blacksmiths and carpenters in 50 to 150 man-hours. The center of gravity is low, eliminating tipping and the load capacity is limited by bulk rather than weight. The load should not be higher than the width of the sled and no longer than 24 feet to assure satisfactory handling on the trail. The bed of a go-devil drags over a greater area of snow than do the runners of a bob-sled, hence

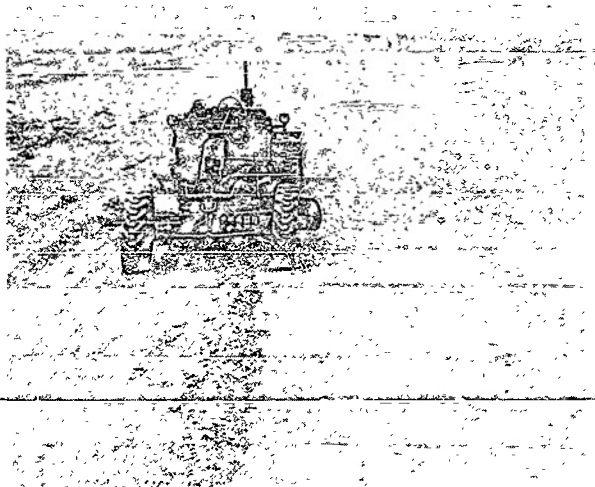

Fig. 15. -- Grader without winterized cab

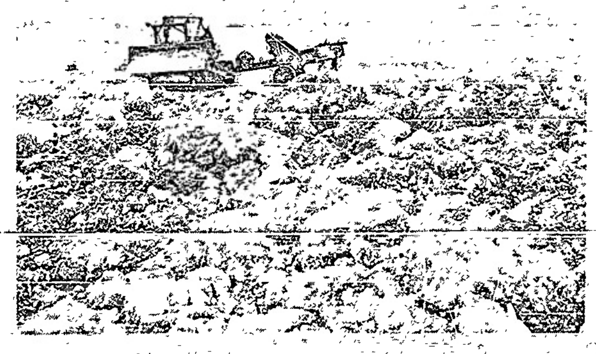

Fig. 16. -- Rooter in permafrost

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more power is required to tow a go-devil than a bob-sled.

Bob-sleds.--These sleds are of various sizes and design. Essentially they consist of two sets of runners joined by cross chains which make the rear set track with those in front when traversing a curve. Each set of runners is connected by a low or stationary bunker. An upper or movable bunker pivots on the stationary bunker, about a king pin. In this manner the runners can swing without interfering with the load. The bob-sled is attached to the tractor by a tongue. All parts are extremely rugged and reinforced with steel. Depending on the size, bob-sleds have a capacity of 10 to 75 tons.

Wanigans.--Wanigans are small buildings for use on the trail or in temporary camps. They can be mounted on sleds or go-devils. They provide quarters, messing and shop facilities. Wanigans are usually constructed of 5/8" plywood or sheet metal on a heavily braced frame to withstand the strains imposed by tractor train operations. The roof is curved in a flat arch and is of the same material as the walls with a sub-layer of roofing paper. Windows require heavy protective screens to prevent damage by branches. The interior is insulated with celotex or similar material. The height should be a minimum of seven feet, the width about eight feet, but no greater than the width of the dozer blade and the length variable. Longer wanigans ride more smoothly on sleds than shorter ones.

Steam Boilers.--Skid-mounted steam boilers are very essential pieces of equipment in the Arctic. Steam is required to thaw holes in the permafrost for piling and explosive charges. It is also used to thaw ice filled culverts and to remove ice and frozen mud from equipment and tools. For small operations a 15 H.P.

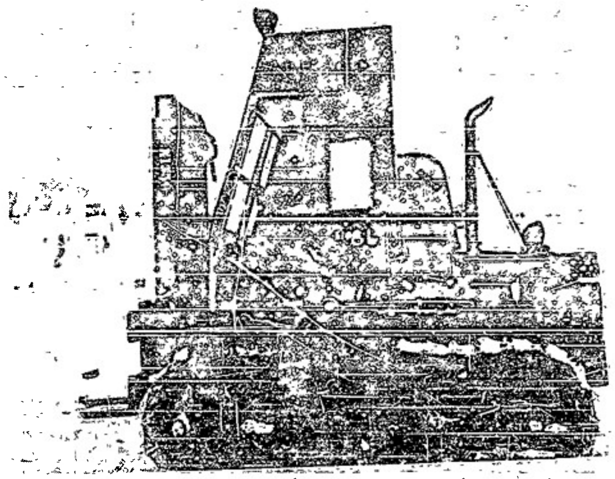

Fig. 17. -- Winterized Fork Lift

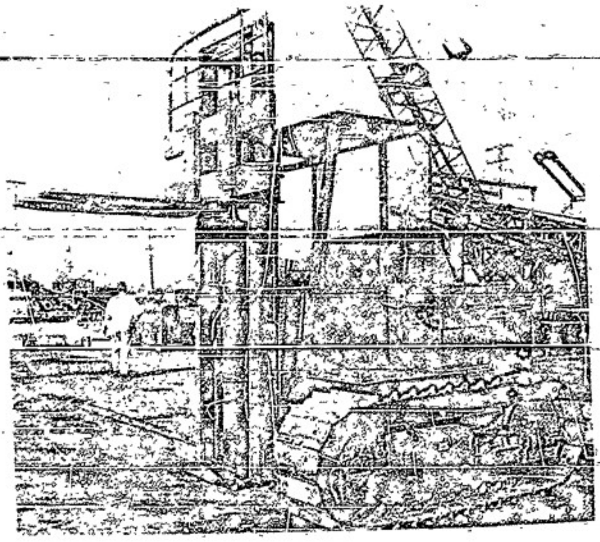

Fig. 18. -- Fork Lift Cab with plexiglass windows

boiler will suffice but for larger jobs a 45 H.P. to 60 H.P. size will be necessary. Pipes of various sizes and lengths for headers, steam hose and steam jet pipes should be included as required accessories.

Batteries and Ignition.--On all equipment using batteries, trouble will arise if the battery becomes cold. A fully charged storage battery at 70°F. will only give half its output at zero and 10% at -60°F. This effect is temporary and the full charge will be available when the battery is heated. It should also be remembered that a battery, three quarters discharged will freeze and burst at 10°F. All batteries should be incased in an insulated frame or metal jacket.

In general the ignition and electrical systems perform satisfactorily down to temperatures of -30°F. Below these temperatures, cracking of the insulation on ignition wires, excessive burning of distributor points, fail-

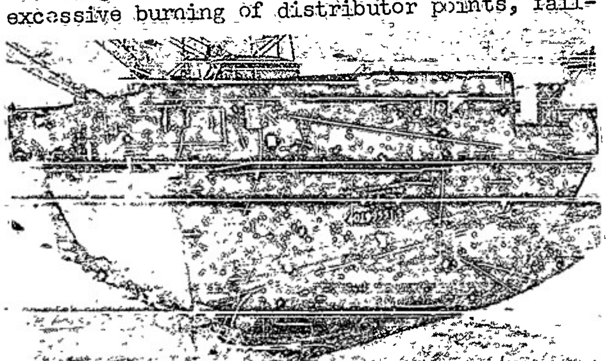

Fig. 19. -- Weasel (M29c) prior to installation of cabin

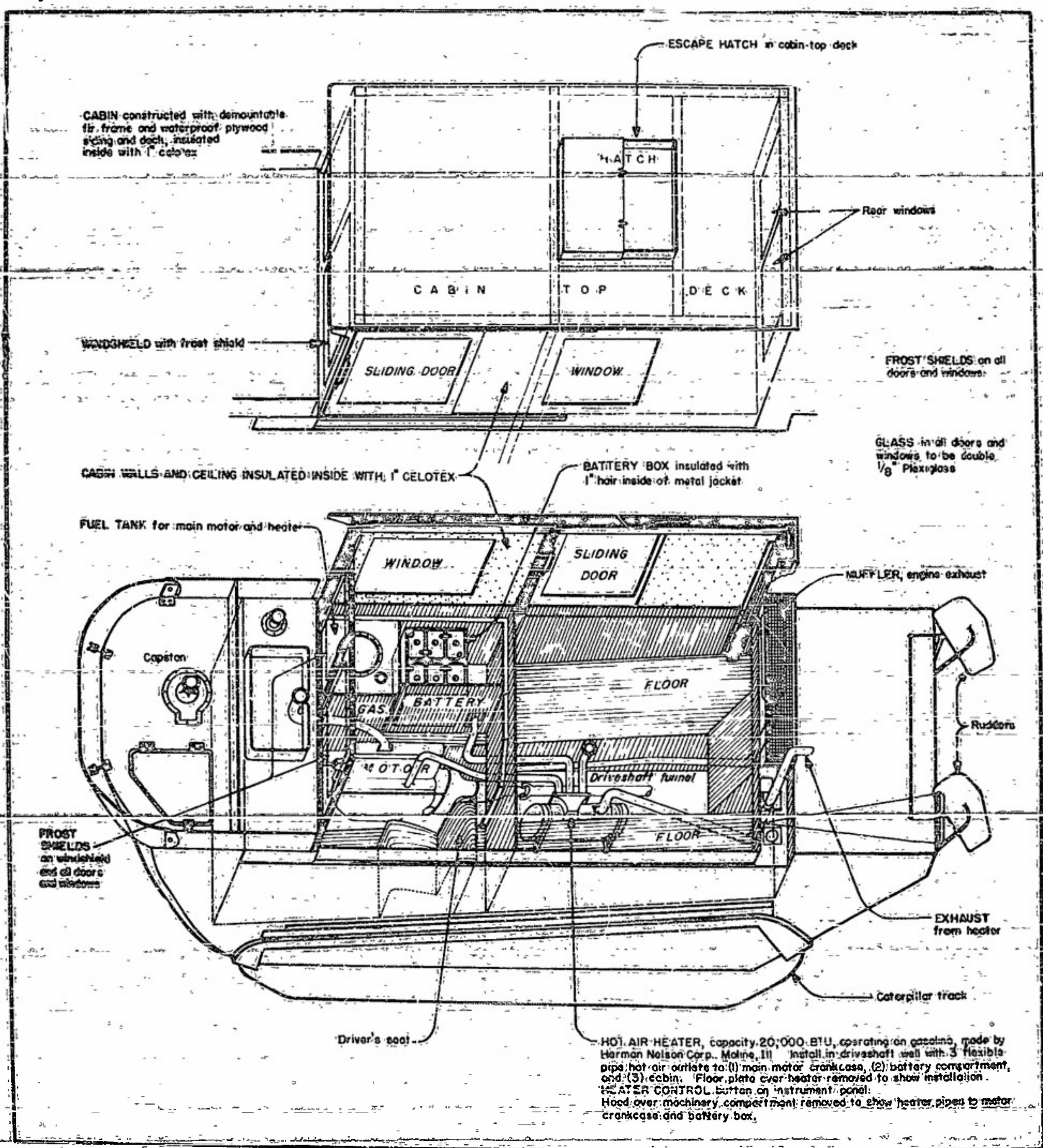

Fig. 20. — Completely winterized weasel

ure of distributor condensers and rotors and fouling of spark plugs is a common occurence. In addition considerable difficulty is sometimes encountered with the mal-functioning of voltage regulators.

Sub-Zero Effect on Materials.—An understanding of the effect of extreme cold on the elasticity, durability, strength and other physical characteristics of materials is important.

A study of the mechanics of various materials at Point Barrow indicated the following:

Rubber—New rubber resists cold rather well while synthetic and old rubber are not reliable. In any case rubber should be handled carefully in low temperatures.

Neoprene—Unsatisfactory at temperatures below -20°F.

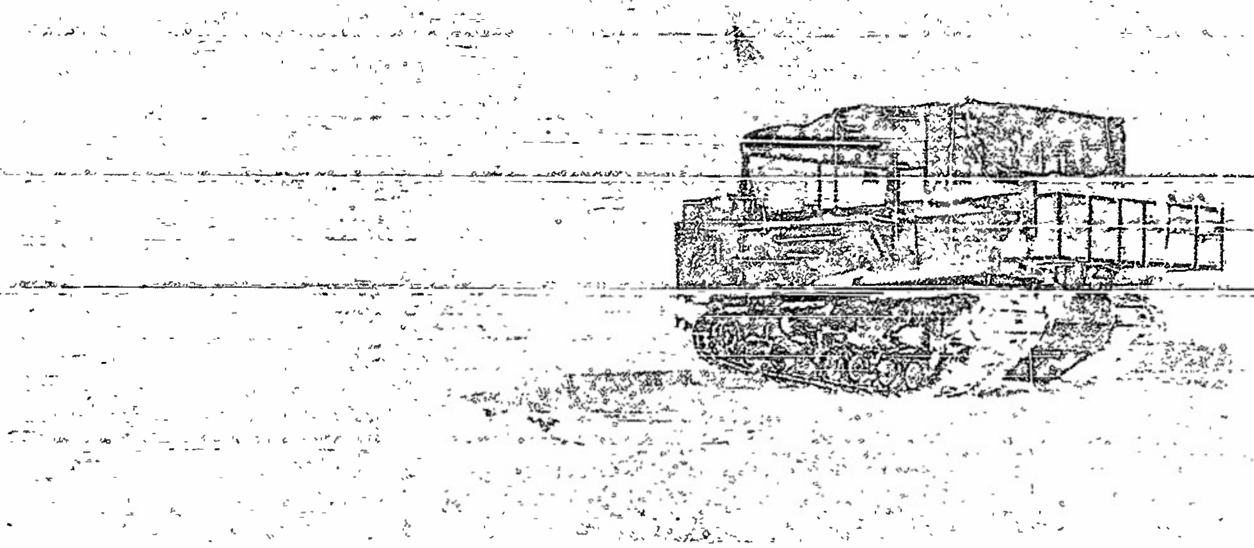

Fig. 21. — Weasel in snow

Fabrics--Untreated and water repellent fabrics give no trouble down to -40°F.

Nylon--Extreme cold, below -40°F has no apparent effect on Nylon. This material does not crack and remains soft and pliable at that temperature.

Canvas--Freezes and loses its pliability, this is sometimes mistaken for shrinkage.

Leather--Becomes stiff and tears easily. Wet leather is usually ruined if frozen. Protective coating of good shoe oil on rough side will increase life.

Glass--Glass is susceptible to sudden change in temperature. A warm blast of air on a thin pane or lens of frozen glass may cause it to shatter.

Ceramics--Glazed ceramics are not effected unless subjected to sudden changes of temperatures.

Copper Wiring--Wiring becomes very brittle - failing under tension.

Steel--Contracts and becomes brittle. Care should be taken to avoid rough handling.

While it is true that the physical properties of many materials undergo a change in extremely low temperatures, particularly an increase in brittleness, it is also true that failure, as in the case of iron or steel, might also be caused by a jolting contact with permanently frozen ground. It is important, that a preventive maintenance program be constantly employed.

Fuels.--Fuels for cold-weather do not present much of a problem. Diesel fuel, U. S. Spec. 2-103, Grade X gives satisfactory service in extremely low temperatures and gasoline, U. S. Spec. 2-103b, performed almost equally as well.

In the selection of fuels and lubricants for cold weather operation it is very important to obtain products which when mixed or combined with the corrosive products of combustion, produce solutions, mixtures or emulsions that will minimize corrosion. In low temperatures corrosion blow-by gases tend to condense in the crank-case and combine or mix with the lubricating oil. In this connection it was noted at Point Barrow that the copper-lead bearings in trucks that used U. S. Spec. OE-10 (Navy Symbol 9110). Federal Spec. 14-0-13-A, lubricating oil failed due to corrosion at less than 1,000 miles. The gasoline used in the trucks at the time was 80 Octane, (approximately 3 cc/gal. lead). In addition all fuel tanks should be well insulated.

On Operation Task Force the fuel lines on gasoline engines frequently clogged and froze at temperatures below -30°F. However much of this could be attributed to the grade of fuel originally issued and carelessness on the part of some operators in not adhering to instruction regarding the use of additives.

Lubricants.--Adequate and effective lubrication of motors and friction creating moving parts of equipment has always been a pressing problem in the polar regions. Frozen lubricants are the root of the problem of starting a cold engine, and inefficient ones cause a large percentage of engine and power-train failures.

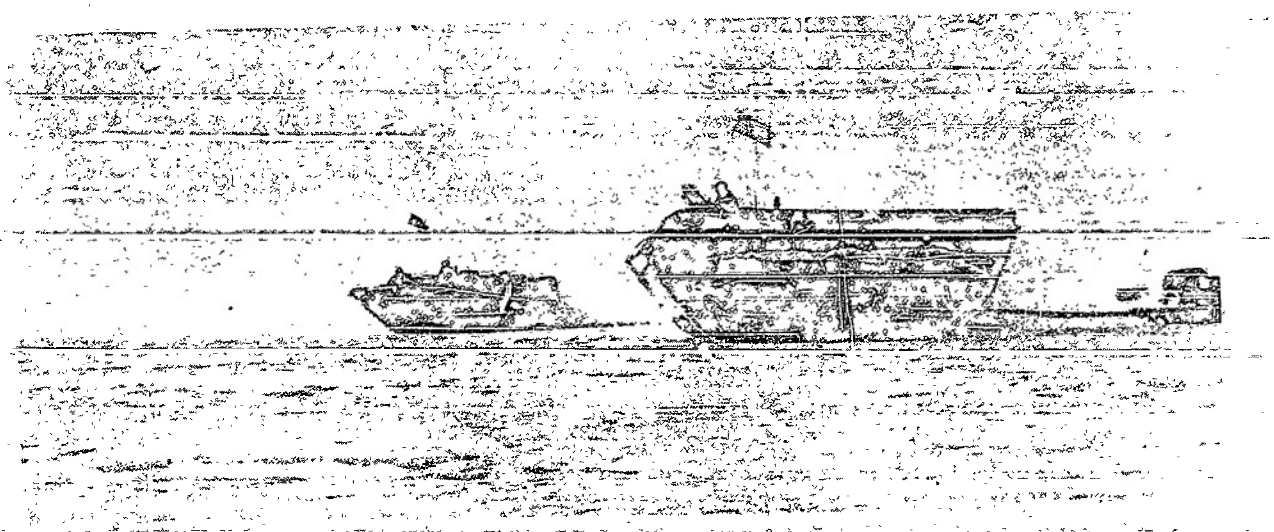

Fig. 22. — LVT (3) and LVT (4) operating in Antarctic

At certain temperatures, oil in a shut down engine will become so stiff that even a fully charged battery cannot turn it over. This situation becomes further aggravated when at lower temperatures batteries lose much of their available energy.

On Task Force Frigid, 13 transmission and 13 clutch failures occurred among 96 vehicles, mainly as a result of the strain produced by stiff lubricants.

While the use of lighter lubricants or the dilution of the specified lubricant will aid starting, these practices are not advocated.

The use of a light lubricant results in an oil that is too thin to do the job after the engine has warmed up. Construction equipment of a type like the D-8 tractor, requires a heavy lubricant to withstand the tremendous work load.

When lubricants are diluted the diluent, theoretically, should burn off when the engine reaches normal operating temperatures. Actually, this does not always happen, with the result that the diluent, (generally gasoline) remains in the oil and impairs its viscosity. Another disadvantage of a dilution is that it is not effective at extremely low temperatures. For example, engine oil OE-10 has a pour point of -10°F., while OE-30 has a pour point of 0°F. but even with maximum dilution both of these oils solidify at -60°F.

While dilution is not recommended, occasions may arise when there is no alternative. In that event, for temperatures between -10°F and -60°F SAE 10 oil diluted with 1% to 16% gasoline can be used in the crankcase of a diesel engine. If kerosene is used as the diluent, the percentage would be approximately 10% to 40% depending upon the temperature. For heavier oils, the percentage increases proportionately. The gasoline or other diluent may be poured into the crankcase through the oil filter after the engine is shut down. When adding gasoline to a hot engine, guard against fire.

Much research is being devoted at present to develop lubricants that will not stiffen at extremely low temperatures. Until such discoveries are made, existing lubricants will have to used. The best method of overcoming stiffness in present day lubricants is the external application of heat to both gasoline and diesel engines.

This practice, while it is the most satisfactory one at the present time is not the final answer. It introduces many problems and has many disadvantages. No doubt engines of the future will have some means of internal heating incorporated in the design of the oil and battery systems.

But the problem doesn't end with engine lubricants. Frozen gear lubricants make it impossible to shift gears. When using GO-75 at -50°F on Task Force Frigid it was necessary to leave vehicles in the gear that would be used next if they were to stand for any length of time. It often was impossible to shift from neutral until the transmission had been heated. Steering also became very difficult at -40°F and impossible at -60°F in some vehicles.

Dilution in this case is permissable. As much as 25% to 50% diesel oil has been used with some success as the diluent.

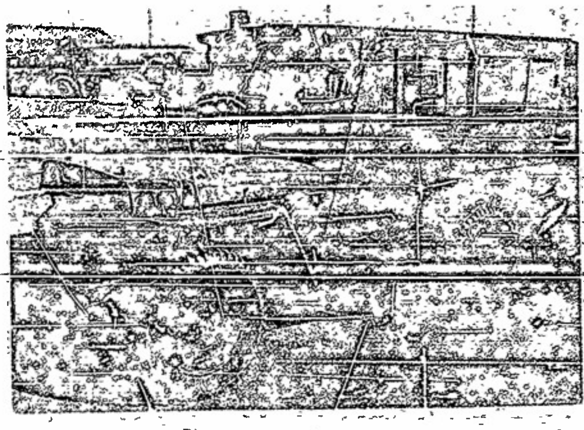

Fig. 23. -- Winterized jeep

In some instances it has been found expedient to idle engines twenty four hours a day or at least that portion of the day when they were not performing a job. It is obvious, however, that such a practice will increase fuel consumption and shorten the life of the engines.

Lubrication Charts.--During the 1946 operations at Point Barrow in temperatures, ranging from +80°F. to -50°F., equipment lubricated in accordance with the following specifications gave the most satisfactory service--

Weasels, small engines exposed to low temperatures and used intermittently and tractor starting engines---SAE 10 or similar selected base stock.

Gasoline engines with copper-lead bearing, exposed to low temperatures and used regularly---SAE 20 or similar selected base stock.

Lighting plants pumps, battery chargers with gasoline engines and used indoors---SAE 30 or similar selected base stock.

Diesel engines---SAE 20 or similar selected base stock.

Tractor transmissions, final drives, rollers and chassis fillings at low temperatures---SAE 90 transmission lubricant.

Tractor and vehicle chassis fillings at moderate temperatures--00 Army all purpose chassis lubricant.

Tractor rollers at moderate temperatures---C. G. No. 0 Army.

Coolants.--An anti-freeze mixture containing 60% Prestone (Ethylene Glycol) and 40% water should give protection down to -64°F. Pure water or pure anti-freeze should never be added directly to the radiator. Only a thoroughly mixed solution should be added. At extremely low temperatures fan belts sometimes crack and fail.

Preheaters.--At the present time, the cold weather starting of all motorized equipment is accomplished by preheating. There are three main types of preheaters.

The most satisfactory of these units is the Herman Nelson Heater that generates 250,000 BTU per hour. It is a self-powered unit designed to produce a steady flow of hot air. It consists of a vaporizing type gasoline burner, a combustion chamber, a pressure-type propeller fan, a blower fan, a gasoline engine, and a system of ducts. The heater was originally designed for use in heating large spaces

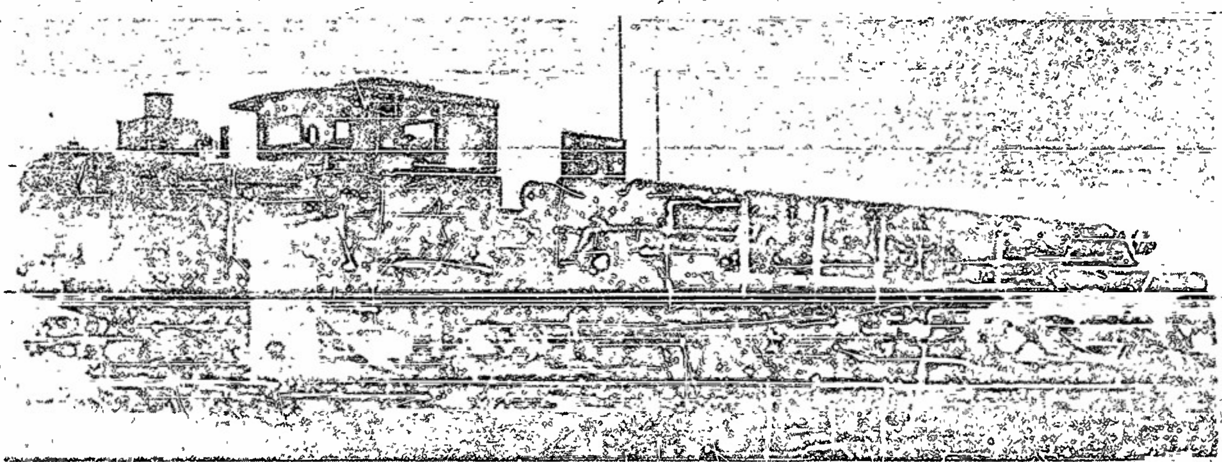

Fig. 24. -- Athey wagon being towed by tractor

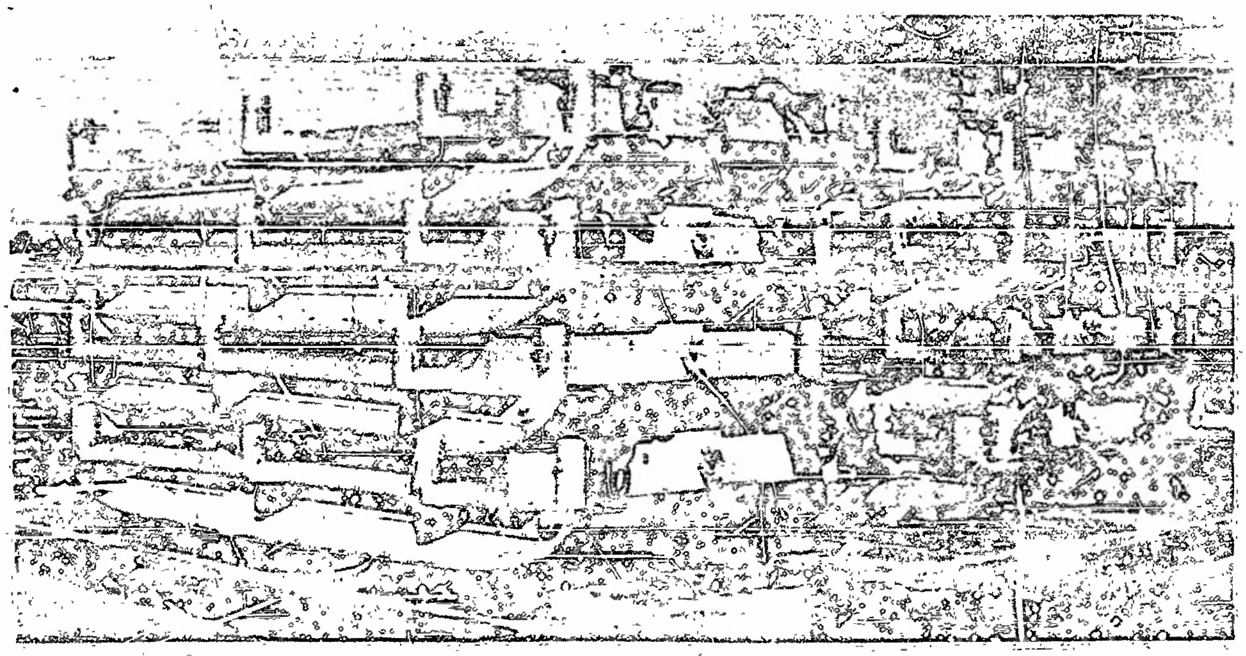

Fig. 25. — Stacked Go-devil sleds

such as portable hangars and garages. However, it is used by both Army and Navy in heating vehicle engines and battery compartments and planes. One difficulty with it is that its gasoline engine generally has to be preheated at temperatures below -10°F. If a source of power is available, the Herman Nelson heater can be converted to an electric motor drive which would eliminate its own cold weather starting problems. Anyway, its efficiency is greatly reduced at temperatures below -35°F. It has a high rate of fuel consumption, averaging about 4 gallons of gasoline per hour; but at present it is considered indispensable in cold weather starting of all equipment. The heat is applied to intake manifold, crank case, oil pan and carburetor.

Another type of heater is known as the Stewart Warner Self-Powered Heater. This portable unit, weighing 200 pounds, is designed to produce a steady flow of hot air through a system of collapsible ducts. The heat output is 100,000 BTU per hour with a gas consumption of $1\frac{1}{2}$ gallons per hour. Like the Herman Nelson heater its efficiency is greatly reduced at temperatures below -35°F.

A smaller type of preheating unit is the Stewart Warner Hand Crank Model 796-A Heater. This small portable unit weighing only five and a half pounds is capable of delivering 40,000 BTU at 120 RPM through a flexible metal hot air duct. This unit is satisfactory for heating small engines such as the one on the Herman Nelson heater. It is unsatisfactory at temperatures below -30°F.

Plumbers-type firepots and ordinary blow torches have been found acceptable for limited use. However, due to the fire hazard, they are not recommended.

Another typo of portable heater is the superfex Heater Model 460 which is a component part of the Army's vehicle winterization kit. It is a forced draft heater and is used as a stand-by heater to maintain starting temperatures in both gasoline, and diesel engines. At -30°F the unit will supply sufficient heat to start engines after 30 or 40 minutes. It has also worked at -62°F.

Getting the engine started is only the first step.

Parts Replacement Plan.—The effect of extreme cold on equipment and the transportation difficulties encountered emphasize the need for economy, preservation, and careful handling of supplies and equipment.

The types of repair parts required for equipment operating in polar regions are in general the same that would be needed in any other part of the world, but the quantity is greater.

This amount will vary with the location. One civilian contractor in the Sub-Arctic estimated that the number of pieces of equipment should be 20% greater than that needed for a similar job in the states, implying that repairs to the equipment were not readily or quickly made. Still another allowed that 20% of his original investment in equipment was for repair parts.

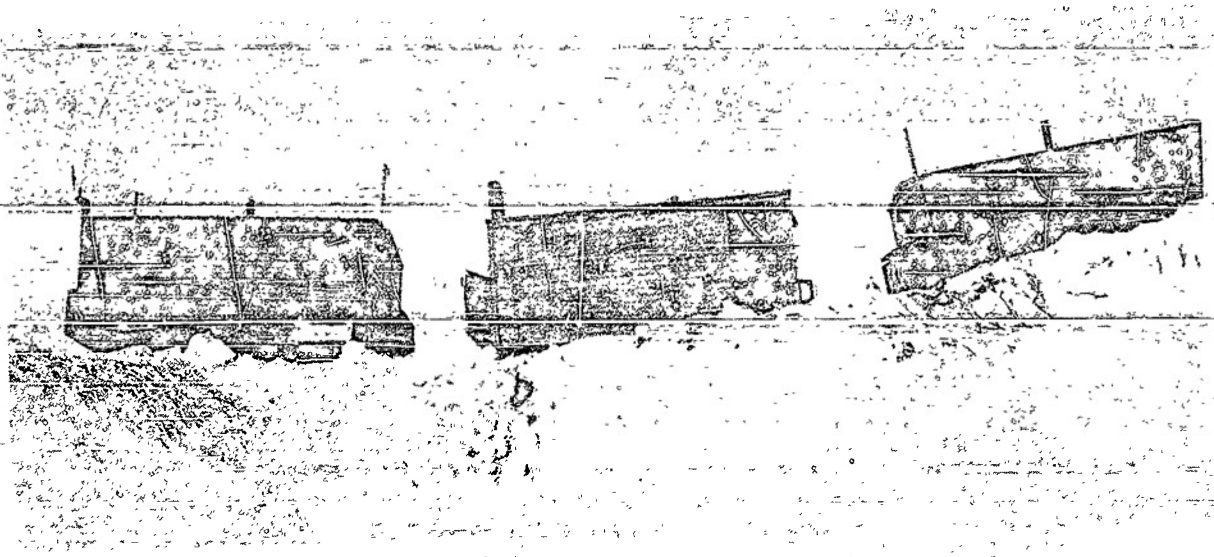

Fig. 26. — Wanigan on a rough trail

The Navy installation at Point Barrow is only resupplied by water once a year because the Arctic Ocean is only free of ice during a short period in the summer. Other parts of the Arctic are equally if not more remote. It is obvious, therefore, that advance planning on the number of repair parts must be given prime consideration.

Another important reason why a shortage cannot be tolerated is that the construction season is so short. Lack of replacements may cause enough delay to require carrying a project over until next season.

Another step in assuring an adequate supply of parts is to strive for standardization of equipment. For example, all tractors if possible, should be of the same make to permit interchange of parts.

Every effort should be made to preserve the existing reservoir of repair parts. All personnel must be acquainted with the problems peculiar to cold weather operation and maintenance of equipment. Proper indoctrination of officer and enlisted personnel is mandatory.

PART III — COLD WEATHER STARTING PROCEDURE FOR MOTORIZED EQUIPMENT

The following procedure promulgated by Task Force Frigid, best summarizes the important actions to be taken. It also provides evidence of the careful attention to detail which cold weather operations constantly require, as far as equipment is concerned.

<u>Preparation.</u>—Service the radiator with a 60% solution of Prestone (Ethylene Glycol) Antifreeze. This should give protection down to -64°F. Check with a hydrometer to insure proper protection. <u>Never</u> add pure water or pure antifreeze; always add a thoroughly mixed 60% solution.

Check the battery with a hydrometer to insure that the battery is fully charged to a reading 1.275 and 1.300. A battery with a hydrometer reading of only 1.125 will freeze and burst at 0°F.

Check the generator and cranking motor to see that the commutator is clean, and that the brushes are making good contact. Check all wiring and connections. Be sure that the voltage regulator is functioning correctly.

Remove and clean fuel sediment bowl, clean strainers, and replace bowl with new gasket, if available. If the sediment bowl is excessively dirty or contains a great amount of water, drain the fuel tank and blow out the fuel lines. <u>CAUTION — DO NOT</u> blow high pressure air through the fuel pump.

Check, clean and tighten all wiring connections; especially battery and starter terminals. Check for breaks and shorts in high tension ignition wiring.

Clean distributor thoroughly, and clean, or replace breaker points. Slightly pitted points will cause failure to start at low temperatures.

Clean or replace spark plugs. Insure that the porcelain is free of dirt, paint, chips or cracks. If continued starting trouble occurs, decrease the plug gap 0.005" (five thousandths of an inch) below that normally used.

Check timing carefully; and insure that the automatic spark advance and vacuum advance are in good working order.

Inspect cranking motor throw-out unit (Bendix Gear) to see that it is <u>not</u> coated with heavy grease.

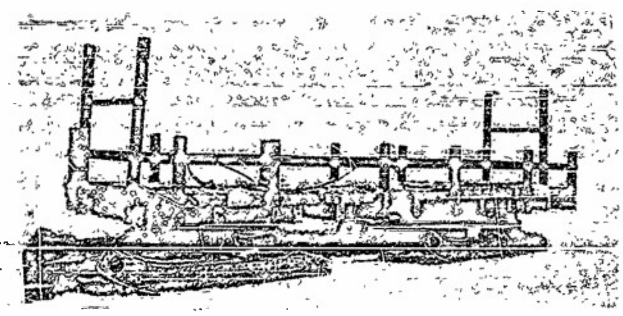

Fig. 27. — Heavy duty Arctic bob-sled

Air cleaners should be empty, or contain only a slight amount of oil at temperatures below 0°F.

Drain and fill the engine crank case with OE-10 engine oil.

Daily Service.--Service the fuel tank daily. Do not allow the vehicle to stand over night with a partly filled tank as moisture condensation on the inside of the tank will introduce water into the fuel. Clean away all snow and ice before opening the filler cap. Check to see that the dispensing hose and nozzle are clean and free of snow, ice, or water.

Add one-half pint of grade three denatured alcohol (POISON) to each tank of fuel, or one-half pint per 20 gallons of fuel. If the vehicle is to be left standing immediately after servicing, the alcohol should be added to the vehicle tank before the gas is poured into the vehicle. This will insure mixing with the fuel. DO NOT ADD alcohol to fuel in drums or cans, as it will dissolve ice and water in the container and carry it into the gas tank. The first time alcohol is added, the engine should be run long enough to clean all non-treated fuel out of the lines and the carburetor, and the sediment bowl should be cleaned.

Fig. 28 — Insulated battery jacket

Check oil frequently. Heavy choking and priming and extreme cold weather operation cause a noticeable increase in engine oil consumption on most vehicles. Use only OE-10 unless otherwise directed. Do not dilute engine oil on wheeled vehicles unless the temperature is below -40°F.

Preliminary Inspection.--Check oil, fuel, antifreeze, and tires. Perform normal pre-start inspection.

Clean drift snow and frost away from spark plugs, ignition wiring and distributor cover. Snow and frost are insulators, but as the engine warms up, they melt and become water, one of the best conductors.

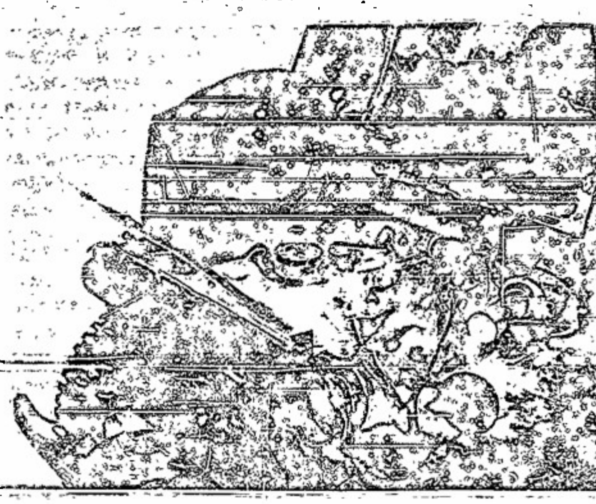

Fig. 29. — Snow can foul up motors

Remove the distributor cover and see that the breaker point arm is free on its pivot shaft. (Necessary in extreme cold only).

Make sure that the carburetor choke valve closes fully.

If the vehicle has been standing 24 hours or longer, operate the fuel pump hand lever to insure that the carburetor float bowl is full of fuel. (Note: Not all vehicles have hand lever fuel pumps.)

Turn the engine over at least ten times with the hand crank. This is important! The starting motor will not have enough power to break the oil film at low temperature, and the battery will be run down very quickly, unless the oil film is broken by hand cranking.

Starting the Engine.--Pull the choke control all the way out (adjust later as the engine starts. Depress and release the accelerator

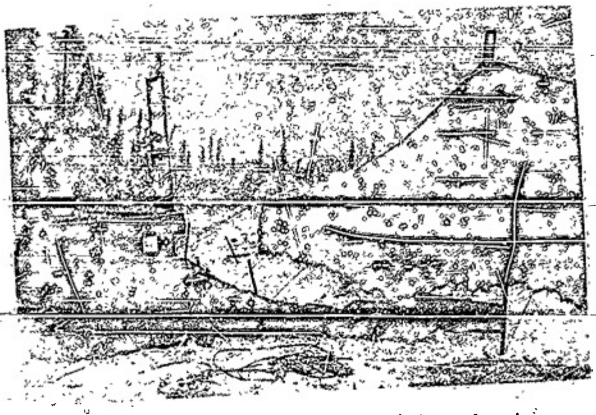

Fig. 30. -- Herman Nelson Pre-heater

pedal all the way several times. Pull out hand throttle one inch. Turn ignition to ON position. Depress clutch pedal, and hold in the disengaged position until engine starts.

Step on starter switch. Release when engine starts. NOTE: Starter should not be operated more than 15 seconds at one time. If engine does not start, release the starter switch and wait one minute for starter motor to cool off.

When engine starts, adjust the choke and throttle to give a fast idle speed (about 800 RPM) but do not race engine. Do not pump the foot throttle continuously after the engine is running, and refrain from rapid acceleration until the engine is completely warmed up.

Stop the engine immediately if no oil pressure is indicated on the gauge in one minute, and notify the maintenance.

When engine is running smoothly, engage the clutch to warm up the transmission.

Check engine and instruments to see that the oil pressure is up, generator is charging, and that engine is warming up without overheating. Overheating immediately is an indication that the engine cooling system is frozen up.

Additional Procedures with Winterization Kits. The primer pump (Round Black Knob located on instrument panel) is to assist in choking the vehicle. This pump sprays gasoline into the manifold to assist in getting vaporized fuel into the cylinders. To operate the pump, pull out slowly on the handle, and push in sharply to force the fuel into the manifold. Operate the pump one or two full strokes before beginning to turn the engine over, continue to prime the engine steadily while cranking with the starter, and use the pump sparingly, if needed, after the engine starts. The actual number of strokes needed will vary with the conditions, and can be determined only by experience. Excessive use of the primer will cause flooding, and is to be avoided. Use the choke as needed, in addition to the primer pump.

The radiator cover is provided to protect the engine heat during periods of operation. The cover may be operated so as to cover either the top or the bottom of the radiator. Covering the lower part of the radiator materially assists in reducing the number of frozen gas lines. Particular attention should be paid to the temperature gauge, and the amount of radiator area covered governed accordingly. If the engine is running cold, close up the cover; if running hot, open the cover.

Superfex Battery and Water Heater Unit.--This is a STAND BY unit intended to keep the engine warm and always ready during periods of inactivity. The heater is most useful when the temperature is below $-10^{\circ}F$. This unit opera on the principle of the thermo-syphon, i.e., hot water rises, cold water descends. The heater consists of a gasoline burning fire pot with suitable control elements, a hot water coil coil, and an exhaust stack. The hot water coil is connected to the radiator, engine block, battery heater pad, and the cab heater. This hot water coil is the lowest point in the system, so that water heated in the coil tends to rise through the other units. The cold water is then displaced and descends into the coil to be heated, thus continuing the cycle. The unit, if started immediately after the engine stops, is capable of maintaining engine heat at stand by temperatures. If the unit is fired on a cold engine, six to eight hours of operation are required to bring the engine up to stand by temperatures.

Operation of Stand By Heater.--To light the heater, extend the flue stack by opening the hood cover, raise the flue, and turn to right to lock in position. Then open fuel valve at heater and open caps on bottom of the heater. Remove lighter from inside of cover and hang in lighting hole. When asbestos wick is wet with gasoline, remove, light with match, and return to lighter hole until the heater is burning.

Remove lighter, close cover of lighting hole only, and put out the lighter wick. Leave the burner caps open. When unit is equipped with electric ignition, follow instructions on the instrument panel plate.

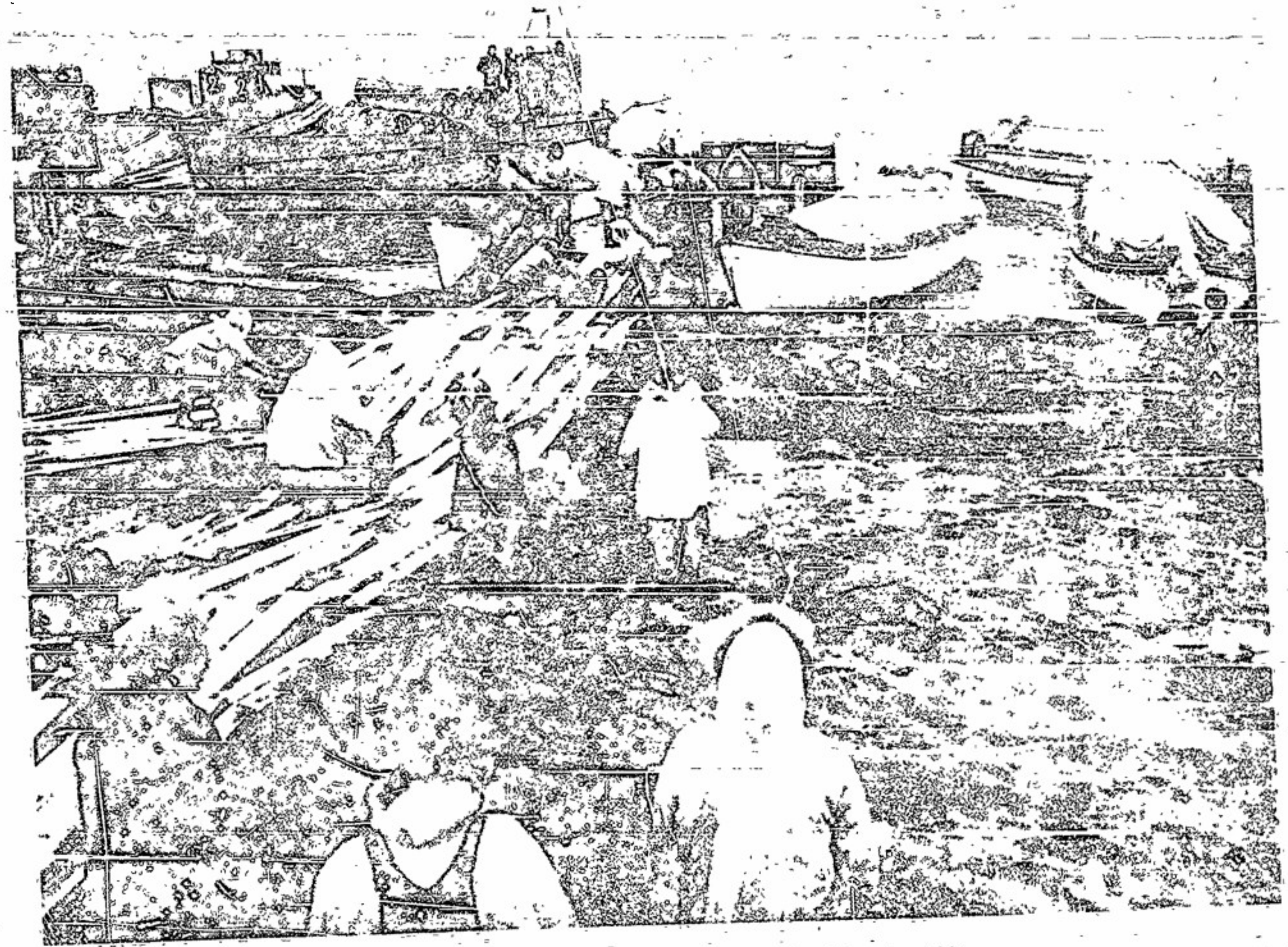

Fig. 31. — Supplies are important in the Arctic

The screw for adjusting the flame projects just below the small tube when the cover caps are open. The lowest position of the screw gives the highest flame and should be used only for extreme cold (below zero). Turning the screw upward reduces the fire. If the heater smokes, turn the screw upward until the smoking stops. The screw adjusted to position near the indicator no. 2 gives normal operation.

To extinguish the fire close caps on the bottom of the heater. Close valve in fuel line and turn telescopic flue stack to left and lower. CAUTION: Stack may be hot! Then close flue stack cover in hood and start engine.

When engine is warmed up, thoroughly, regulate radiator cover.

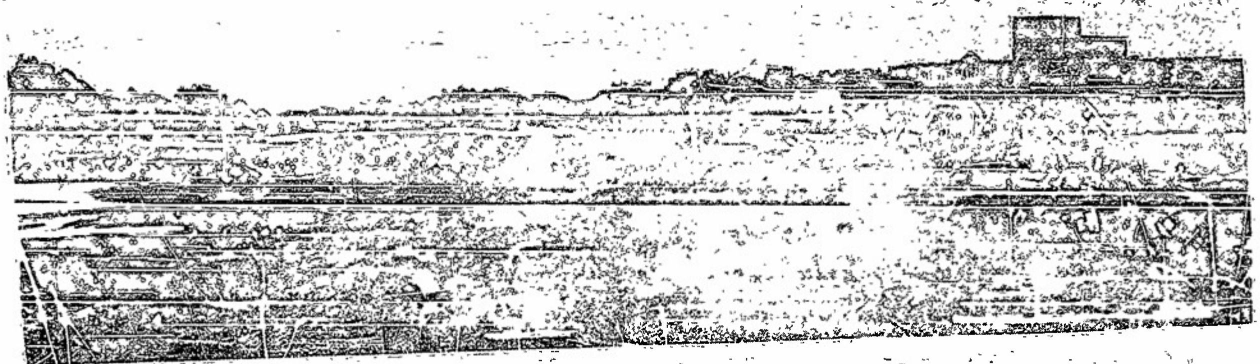

Fig. 32. — Fuel and lubricants stored at Pt. Barrow

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U S GOVERNMENT PRINTING OFFICE O- 1948

THIS COULD HAPPEN

HYPOTHETICAL CAMPAIGN BASED ON CHAPTERS I TO V

NAVDOCKS P-17

Navy Department
Bureau of Yards and Docks
Washington, D. C.

B-1717

THIS COULD HAPPEN

HYPOTHETICAL CAMPAIGN BASED ON CHAPTERS I TO V

Except for scientists, scholars, and a few professors, nobody does any mental sweating unless he has to.

It's easier to "pick up a pretty good general idea" of a subject than to know it thoroughly. And why not? You can always comfort yourself with the alibi that you've grasped the principles without cluttering your mind with a lot of detail. Besides, it makes for better relaxation. You get the same comfortable sense of accomplishment as you do from an interesting conversation with a friend, with a couple of tall, cold ones for lubrication.

But you don't learn much.

The ideal background for the study of these lessons would be a cold, uncomfortable, and dangerous one. It would help, too, if you hadn't had anything to eat for 30 hours and a bunch of cold hungry Seabees were looking to you for a quick answer to their plight. And it would help even more if, on top of all your other woes, you had a construction deadline to meet or there'd be hell to pay. Under such circumstances, you'd want more than a pretty good general idea" of what to do. You'd give your eye-teeth for some detailed know-how.

The idea behind the hypothetical "Arctic campaign" which follows is to help you to retain details of engineering and living in polar regions.

Admittedly it's a trick device, but with your help it will work. All you've got to do is to forget that you are comfortable and safe. You've got to imagine.....

CHAPTER I

That the telephone has just rung. That you've picked up the receiver to hear the excited voice of your wife telling you to get to a radio as fast as you can. The Country's been attacked --- Detroit, Seattle, Chicago, New York, Washington, Pittsburgh. Tremendous explosions. Simultaneously.

You've been afraid for a long time that trouble was coming from Hadesia. but as you listen to the frantic radio announcers, you are stunned by the suddenness of the attack. Then you get mad clear through. The enemy might have given some warning. But he didn't --- and we might have known he wouldn't.

So what do you do?

Specifically, as a Civil Engineer Corps Reserve officer what is the first thing you should do? (Question No.1)

While you're waiting for orders, plenty is happening. The newspapers have been trying to piece together a cohesive account of the attack, but the front page is pretty much a jumble of bulletins, intermingled with small editor's-note paragraphs stating that ground communications have been cut off from San Francisco and New Orleans, and that radio accounts of the situation there are not detailed. In fact, not until the third "EXTRA" hits the streets do you find any encouraging news. The Secretary of Defense has issued a communique from unidentified headquarters stating that Navy fleet units have been ordered into action and that the Air Force has sent out squadrons to deliver retaliatory attacks. You're glad that we aren't entirely helpless --- some of the taxes you've paid for defense are producing results. But the fact remains -- thanks to our country's ethics -- that Hadesia has won the first round by almost a knockout.

You've had only time for a few quick and moist farewells with your friends, and the inevitable question will be asked: "Where do you figure you're going to be sent?" You don't know yourself, but you've got a hunch it might be to build a base in the far north --- that's the direction from which all the fireworks are coming. So you mention this possibility and your wife immediately demands to know if your insurance is all paid up. Of course, it won't be, so you'll have to sit down and explain that the Arctic isn't the death trap she thinks it is.

"Men have been going into the Arctic for years," you say, patting her on the shoulder.

"What on earth for?" she will ask.

What would your answer be? There are at least seven reasons why white men have explored the Arctic and Antarctic. What are they? (Question No. 2)

This historical review won't, of course, impress your wife worth a damn. Chances are she'll point out that most explorers never made a nickel out of their explorations and that most of them either froze or starved to death, or both.

"But their experiences have taught us a lot," you'll say.

Can you back up this statement with illustrations? Can you mention specific contributions to Arctic knowledge made by Admiral Peary? William Barents? John Davis? Fridtjof Nansen? (Question No. 3)

This will be about all the time you can spare to give your wife a history lesson. It'd be simpler to pay up your insurance.

Your orders haven't arrived, but you suspect that you'll be assigned duty with the Seabees - possibly with the Reserve Company in your own city. You know that the plan is for this company to be expanded into a full battalion. This brings up several tough questions: (1) In view of the fact that speed is paramount, do you think it would be better to pool all the Reserve companies and form several battalions from them? Or do you think each company should serve as the nucleus of a new battalion? What about the danger of filling the battalion's complement with men drawn from the same locale? What would happen to the civilian morale in that vicinity if the battalion should be wiped out by enemy action? In brief, what would you recommend? And why? (Question No. 4)

Your personal affairs are in order, and all you need now are your orders from the Bureau of Naval Personnel in Washington. A letter arrives in the next morning's mail — it's from your district commandant. At least, you think it is, although you've read that enemy fifth columnists have been sending out spurious orders to create confusion. So you begin to suspect that maybe the letter is a phoney. Why didn't it come from BuPers in Washington? (Question No. 5)

Satisfied as to the authenticity of your orders, you nevertheless are puzzled that the Navy apparently is ignoring the fact that you have gained a special knowledge of electronics in the past four years. You shrug your shoulders and express a dim view of the Navy's officer-procurement system. Possibly the Navy's mistake is really your own. How could this be? Specifically, how should you, as a civilian, have cooperated with the Navy's officering procedures? (Question No. 6)

Meanwhile, war news continues to be bad. Hadesian planes have dropped fire bombs on a dozen small towns in the midwest as a means of adding to national confusion — the idea being to frighten citizens into demanding a large share of armament production for local defense. This the country can't afford if we are to wage a successful offensive against the enemy. At the same time, you know that local communities need protection. What do you think of the idea of CEC Reserve officers, pending their call to active duty, assisting in the engineering aspects of civilian defense? Is there any organization set up for this purpose? If so, what steps should an officer take to volunteer for disaster-control work? (Question No. 7)

Your orders call for you to report to Davisville, R. I. and you remember that it was quite a place in World War II. At the same time, you are aware that the Hadesian air attacks have chosen big installations as their prime targets. You begin to wonder if a 55,000 man camp wouldn't be something of a jack-pot for the enemy. So, you start wondering if Seabees might not be trained adequately in smaller groups. There are both advantages and disadvantages. What is your own opinion? And while you're thinking about it, what recommendations would you make for the selection of new training-camp sites, keeping in mind, of course, that your outfit will serve in the Arctic. What would an ideal site require? (Question No. 8)

You've arrived at your training camp now, and you find out that you're no longer a boy. Your peacetime fat comes off the hard way. In fact, if the Hadesians weren't still bombing hell out of the country, you'd be inclined to forgive and forget and go back home. At this point you happen to overhear an argument between two of your fellow officers about whether Fairbanks, Alaska, is in the Arctic or the Sub-Arctic. One of them points out that it's below the Arctic Circle. The other says the warmest month averages 60 degrees. How would you settle the argument? (Question No. 9)

The officer who lost the argument quickly changes the subject. He leans back in his chair and says, "What the hell difference does it make, it's all cold --- Arctic or Antarctic. Six of one and half a dozen of the other."

Of course, the other guy challenges him, and starts to point out the differences between the two --- only can't quite remember specifically what they are. Can you help him out on the following points of difference: (1) human habitation, (2) political ownership, including claims, (3) plant and animal life, (4) climate, (5) land and ocean characteristics? (Question No. 10)

Eventually, your own reconditioning has been completed, and you receive your assignment as Officer-in-Charge of a Seabee battalion. You get your first look at the experience records of the enlisted men, and what you see doesn't make you any happier. You find that too few are Seabee veterans, that maybe 20 per cent served with the Army in World War II and that the rest are kids who have just learned which end of a razor to use.

You wish you had more time to whip the outfit into shape, but the situation has become so desparate there's no time for really adequate training. The Hadesians are poised for a full-scale attack on the Aleutians, and their planes are staging raids over the polar regions from Franz Josef Land and Spitsbergen. Obviously, they want bases in northern Greenland, Ellesmere Island, and Victoria Island. And that would be only the first step --- bases farther to the south in Canada would permit more frequent attacks with heavier bomb loads.

Thus, with time at a premium, you would try to develop an in-training program for your own outfit. Your veterans and your more skilled workmen would have to pass on their information to the younger and more inexperienced men. How would you set up such a program? How would you counter the morale problem of having lower-rated men with previous Seabee experience give instruction to higher-rated men without that experience? (Question No. 11)

It is now October, and you and your outfit arrive at a camp in the state of Washington preparatory to being shipped to Iceburg X. The men have not been told their ultimate destination, but it's common knowledge that it will be in the polar region. What worries you is that some vicious scuttlebutt has been started to the effect that not one man out of twenty has a chance of coming out of the Arctic alive. The scuttlebutt goes on to describe what happened to inexperienced prospectors during the famous Gold Rush. So you decide it would be a good idea to give the men a short talk to spike the rumors.

Could you list half a dozen good reasons why life and travel in the Arctic is comparatively safe today? What fundamental rule would you advise your men to follow? (Question No. 12)

CHAPTER II

You and your battalion are keyed for action and are waiting to ship out on the next move to the North. You've been able to allow the men brief embarkation leave, but due to a million and one last-minute details, the best you can do is a 12-hour jaunt to Portland to inspect that city's alcoholic beverage distribution system. You are happy to discover that enemy bombing has not rendered it inoperative.

Then, when you get back to camp, you run into an age-old Navy tradition --- that of waiting and waiting and waiting. You can't understand whyinell your orders haven't come through. But you've been in the Navy before, so you shrug your shoulders and search for a way to spend the time to advantage. You decide to give your men a course of background instruction on the Arctic.

You call in a couple of pretty resourceful young officers and discuss how the course could best be presented. One of them recommends that any such training is a waste of time --- that enlisted men don't need to know anything about the Arctic except how to live and work there. The other counters this argument by saying that the more understanding a man has of the region into which he's sent, the more willingly will he accept its discomforts and dangers. Which officer would you support and why? (Question No. 1)

Let's suppose you've decided to give the men a brief, background course of instruction. You decide the only way they can get a clear conception of the topography of the northland is to make a rough-scale model, showing mountains, river valleys, and coastal contours. You also would want to show alternate routes to Alaska and northern Canada in case the Hadesians are able to block us at Bering Strait. What are these routes and during which months can they be traveled best? (Question No. 2)

In conducting the course, you are particularly irritated by Ensign Hoopenloofer who can't let any statement go by without adding his two-bits worth. Usually, he asks questions, and while you suspect he's doing it just to demonstrate how interested in the subject he is, his questions nevertheless put you on the spot. For example, he asks you whether it's better to try to land supplies on the open coast of northern Alaska or to take advantage of the shelter of fiords there. What would your answer be? (Question No. 3)

Your reply ought to squelch him for a while, but it doesn't. A few minutes later he interrupts your discussion of the route to the north via Davis Strait to ask why it wouldn't be easier to go up the West Coast of Greenland. How would you reply to this one? (Question No. 4)

So, you start to resume your talk, but Hoopenloofer is raising his hand again. Before he can ask his question you get smart and shoot one at him first. "If it were possible," you say, "to put you and your questions on an ice cake north of Bering Strait, where do you think you would eventually wash ashore? Where would he? (Question No. 5)

While he's pondering, you could be discussing what the political situation in the Arctic was before Hadesia launched its attack. Your men know only that we bought Alaska from the Russians and that the islands to the east belong to Canada. Most believe that Greenland belongs to Denmark, but they're not sure whether Iceland is independent. They can only guess as to the ownership of Spitsbergen, Herald, Wrangel and the New Siberian islands, Novaya Zemlya, and Franz Josef Land. Can you put them straight? (Question No. 6)

Following this discussion, you get on the subject of tides. You realize that there's no sense in trying to get your men to remember too many details so you try to get across a few general principles about tides which will stick with them. What could you say relative to the variation of tide range in the Arctic generally and the types of coast where minimum and maximum ranges could be expected? (Question No. 7)

While you're explaining, Ensign Hoopenloofer finally figures out where the polar currents would carry him on his ice block, and he's ready for another question. He wants to know how the tides would be affected by winds along the northern coast of Alaska. What would your answer be? (Question No. 8)

Then, when you've pointed out that on the open beaches of northern Alaska, care must be exercized in unloading supplies to allow for both tide and wind, one of the men volunteers the suggestion unloading must be a pretty rough job when it's pitch black night during the six winter months. You ask, "Why six months of night?" He replies that the coast lies north of the Arctic circle. Can you straighten him out on this? Is there any 24-hour period during the winter at Point Barrow when there is no light on the horizon? Why? Remember, it's north of the Arctic circle. (Question No. 9)

Because you've got a hunch your battalion might be ordered to the northernmost islands of the North American continent to build guided missile launching facilities, you are anxious to correct the general impression that the farther north you go the colder it gets. Could you explain to the men the reason minimum temperatures are higher along the coast than in the interior? Could you support this statement with examples? (Question No. 10)

About this time, Ensign Hoopenloofer adds another two-bits worth -- he volunteers the information that during the month of July in Alaska the climate is almost identical with that of Missouri or Illinois -- you have to stop and correct him. In what respect is he correct and in what, incorrect? (Question No. 11)

Your mention of the difference in rainfall fails to impress the Ensign. He immediately replies that in the Aleutians, there is even more rain than in the middle west. So you remind him that the Aleutians are in Sub-Arctic and that in the true Arctic there are two good reasons why, despite the great areas of ocean, rain and snowfall are so light. What are the two reasons? (Question No. 12) Are there any exceptions to this rule in the North American Arctic? (Question No. 13)

In order to prevent further interruptions from Hoopenloofer, you shoot another question at him that will worry him for a while. So you ask: "If you were erecting a hut on the North coast of Alaska for the winter season and you wanted to protect the entrance from prevailing winds, which way would you face it?"

Resuming your lecture, you discuss fogs, pointing out that they are not confined to the Aleutians and that they are encountered on the northern coast of Alaska particularly during spring. Meteorologically speaking, what is the cause of this? (Question No. 14) Incidentally, what is "spicule fog?" About this time, your discussion gets out of hand; everybody starts describing the worst fogs they ever encountered.

So you change the subject to icebergs. And you ask if it's true that you can tell the underwater depth of a berg by the heighth of the berg above water. Hoopenloofer, still quick with the answers, replies the ratio is about one-to-seven below water. Do you let him get by with it? (Question No. 15)

He defends his ignorance by asking another question: "What, sir, is the difference between icebergs in the Arctic and in the Antarctic?" You have to qualify his question, but there is a difference generally speaking. What is it? (Question No 16) And incidentally, why is it a good idea not to bring a ship too close to a berg, barring the obvious reasons?

So far, you've managed to answer the questions thrown at you with some degree of success. In fact, you're just about to congratulate yourself that you've squeaked through, when the lieutenant who got his degree from M.I.T. asks you this question.

"In what major climatic respects does Antarctica differ from the Arctic?"

CHAPTER III

Shortly after the accelerated indoctrination course is completed and your men are, you hope, thoroughly familiar with the topographical and climatic mysteries of the polar regions the orders arrive.

They seem almost an anticlimax after the months of anxiety. Your fingers are crossed that this isn't just another dry run. The whole battalion is on edge after the interminable waiting. That daily close order drill on the black top hasn't sweetened their dispositions.

With the hope that the orders will not be changed, you read them to your officers. The news is received with mixed emotions of relief and doubt.

After the excitement simmers down you analyze the orders. They direct that the battalion report, combat loaded, to Bremerton on or before 10 July for ship transportation to Point Barrow, Alaska.

The next few days are hectic. Clothing, equipment, and supplies are checked and double checked. Replacements for those men in sick bay and the hospital are obtained. Pay accounts, health records, and jackets are securely crated.

On 10 July the unit boards an APA which gets under way the same day.

The trip to Point Barrow is made without incident except for some rough weather off the Alaska Peninsula.

Upon arriving at Point Barrow around the middle of August, you are directed to remain on the alert. Your unit is scheduled to take part in an operation headed for an undisclosed location in the Canadian Archipelago. Your units specific assignment will be to construct an airstrip and a weather station.

While standing by for the main operation, you are requested on 25 August to furnish a detachment to erect a 200-man camp at Beechey Point on the Beaufort Sea approximately 240 miles to the east.

It is known that the terrain between the two points is generally flat and devoid of all shrubbery except hummocky tundra. During the preceding two months no snow has fallen and the mean temperature in the area was 30°F. You are also able to learn that the average thaw in the area is 8 to 10 inches and that the mean temperature during the previous winter was -25°F.

You are advised that there is no water transportation available and therefore the men, equipment, and supplies must be transported by land at the earliest practicable date. What climatic factors will determine the date on which the movement to Beechey Point can be started? (Question No. 1)

After gathering all the information possible you start to evaluate it. From what you know now about the area, what is your estimate of the relative position of the permafrost table? (Question No. 2)

Having decided approximately where the permafrost table will be found, with no measureable assistance from Ensign Hoopenloofer, you have to decide whether you should employ the passive or active method of construction. Explain your decision! (Question No. 3)

You have also been advised that there is a permanent Eskimo settlement at Beechey Point indicating that there is a source of water supply. What is the first step you would take in establishing your own supply? Where is it most likely to be found? (Question No. 4)

Now you start worrying about the shelters you will have to erect. Right away you get back to this permafrost joker. How is it going to react when you disturb it in preparing the building sites? How will the buildings affect it? (Question No. 5)

Thinking of shelters reminds you that although your detachment will be amply equipped for the trip to Beechey Point, there is a possibility that they might lose all or a large portion of the equipment and supplies as a result of enemy bombing while enroute. They must be prepared to build temporary shelters for their own survival. Explain briefly how a snow house is constructed? (Question No. 6)

Just as your detachment is set to shove off the orders are cancelled. You begin to feel its the same old merry-go-round. In Feb-

-uary, the main operation is still being planned, and you are again ordered to send a detachment to Beechey Point on the original assignment. This time you decide to take charge of the small unit yourself and leave your exec to handle the remainder of the battalion at Point Barrow. You feel you may regret your decision but at least you will be acquiring additional experience that will be invaluable.

Reconnaissance reveals that the route to Beechey Point is now covered with 14 inches of snow. In what way does this snow differ from the summer snow? (Question No. 7)

You also know that a fresh-water lake, three miles in width, must be traversed. During the previous 30 days an average temperature of -30°F has prevailed. Deciding once again to teach our ensign friend a lesson, you ask him how many degree days of frost were there during the last 7 days of the preceding month. Do you know the answer? (Question No. 8)

Assuming you receive the correct answer, or know it yourself, how would you use the information in determining the thickness of the ice on the lake that has to be crossed? What other method could you use to find out the thickness of the ice before you actually reached the lake? (Question No. 9)

Do your calculations indicate that the ice will support a 10-ton load? (Question No. 10)

In the event that the ice does not have enough bearing capacity what method would you use to increase its strength? (Question No. 11)

CHAPTER IV

During the second night of the move to Beechey Point the detachment is caught in a blizzard and forced to halt for the night. To the left of the trail at this point is a small ridge and to the right is a wide stretch of flat tundra. What features of the terrain should be considered in selecting a temporary tent-camp site? What instructions would you issue regarding the proper method of preparing the tent floors for sleeping? What precautions should be taken to insure proper ventilation in the tents? (Question No. 1)

The morning of the third day your radio operator picks up word that Point Barrow is being subjected to heavy bombardment and that there is very little possibility that additional supplies can be brought up to you immediately. Your own food supply is only good for ten days. The intensity of the storm makes it look as though you will be marooned at this spot for some time.

You realize that in order to survive, you will probably have to live off the country for awhile. How would you organize foraging parties and what types of animal and plant life should they seek? How would you counteract the threat of scurvy? Of course you will order them to lay down trail markers so that they can find their way back to camp. How would you preserve the food that is brought in by the parties? (Question No. 2)

The first party returns with a fairly good haul. But you notice that quite a few of the men appear overheated from the strenuous work. What is the danger of this condition and what immediate steps should be taken to care for the clothing of these men? How can overheating be avoided? (Question No. 3)

The next day the wind velocity decreases slightly but the thermometer begins to fall. Your fuel supply is being rapidly depleted and there is no shrubbery in the region that can be used as a substitute. What instructions would you give your hunting parties in order to replenish your fuel supply? (Question No. 4)

It is now the fifth day and things are definitely not looking any brighter. You are still in the dark as to the extent of the damage that has been sustained at Point Barrow. Finally, you pick up word that Umiat, farther inland than Point Barrow, has escaped and that it is planned to fly emergency supplies from there directly to Beechey Point. You are ordered to continue to advance to the original destination as soon as the weather permits. As you figure it the fresh-water lake that was sighted in the early reconnaissance is only about three miles due east.

You decide to send out an advance party of three men, including your corpsman, to investigate the thickness and strength of the ice on the lake. During the course of the inspection, the corpsman and one of the other men crash through a weak section of ice. They are immersed in the water for about three minutes before they are rescued by the third man and rushed back to camp. On arrival the two men are unconscious. What treatment should be administered immediately? (Question No. 5)

Shortly after you have made the two men fairly comfortable one of the hunting parties returns and reports two cases of frostbitten hands and one case of snowblindness. How would you treat these injuries? (Question No. 6)

Your troubles are not over yet. That evening one group of exhausted men neglected to see that their tent was properly ventilated. One of the men before succumbing to carbon monoxide poisoning is able to summon help. What type of treatment should be administered to the victims? (Question No. 7)

Three days later the general situation appears to be improving. The storm subsides, the injured are recovering rapidly, and it looks as though you can resume travelling.

The temperature is 15° below 0°F as you start the last leg of the journey to Beechey Point. In general, what effect will this temperature have on the efficiency of your men? (Question No. 8)

Speaking of efficiency, the morale problem you would encounter during a long Arctic night would be something for the book. What recommendations would you like to see put into effect relative to rotating battalions, detachments, etc.? (Question No. 9)

Another interesting problem directly affecting morale concerns the selection of men for particularly grueling and isolated jobs in which they would be forced to live in close confinement with each other for long periods of time. What personality traits and experience backgrounds would you consider most desirable in selecting candidates for such assignments? (Question No. 10) What special qualifications would you like to have for the officer in charge of such group? Which quality would you consider more important, leadership or engineering ability? (Question No. 11)

CHAPTER V

Upon arriving at Beechey Point you learn that the project there is to be abandoned and that you and your detachment are to be flown back to Umiat as soon as the weather permits. Your orders also state that all material and equipment is to be stored at Beechey Point by the small station force at that location, pending further disposition. This will enable your detachment to be flown as light as possible.

The trip to Umiat is uneventful. But immediately upon reporting, you learn that Point Barrow is in pretty bad shape and that food, equipment, fuel, and building material are needed. Emergency rations have been parachuted in and will suffice until much greater quantities are transported overland.

You are selected to lead a tractor-train expedition to carry the necessary supplies and are provided with a light plane to lay out a route. What general geographical features must be taken into consideration in order to select the most practical route? (Question No. 1)

It is estimated that 600 tons of load will have to be transported. Ignoring the bulk of the load, how many tractors will be required for towing? (Question No. 2)

Other than two large generators the remainder of the load can be stacked in fairly compact units. What will determine the width and the height of the load? (Question No. 3)

When the train has been completely loaded, what precautions should be taken before it actually starts out on the trail? (Question No. 4)

Reconnaissance reveals that the general route is flat but rough in many sections. Would you choose sleds or go-devils to carry the load? (Question No. 5)

The route you have selected is approximately 305 miles in length. Should you attempt to establish refueling points along the route? (Question No. 6)

In assembling the various units of the train, where will the heavier loads be placed and in what position should the wanigan unit be spotted? (Question No. 7)

The tractors that have been furnished have winterized cabs and grousers installed on the tracks. What other modifications should be made before the trip is started? (Question No. 8)

The advance party is to be provided with a weasel (M29c) and will be based on the trail-breaking crew for quarters, food, and supplies. What modifications should be made to the weasel in order that it will operate efficiently on the trip? (Question No. 9)

The urgency of your mission makes a 24-hour operation mandatory. Do you think, however, that preheaters should be included as essential accessories? Standard cold-weather fuel is available. Is there any reason to anticipate trouble from this source? (Question No. 10)

Finally, the train is loaded and assembled and all modifications have been made to the motorized equipment. The advance reconnaissance party and the trail-breaking crew have a day's start. The train starts on its long trek. Everything moves along smoothly until the third day when the wood block that was substituted for the top track carrier rollers on the lead tractor fails. The repairs are estimated to take about 30 minutes. Would you halt the entire train for that length of time or place one of the spare tractors into service and leave the damaged tractor behind to catch up later? (Question No. 11)

During the second week on the trail, with the thermometer at $-35^{\circ}F$, the fuel line on the tractor towing the wanigan unit becomes clogged. Would you hold up the entire train to make this type of repair? (Question No. 12)

While making the repairs, it is discovered that a gasket has blown. Would you replace it with neoprene or new rubber if both were available? (Question No. 13)

After 45 minutes the tractor is repaired and ready to resume travelling. Will there be any difficulty in starting the motor? If there is, would you dilute the lubricant or utilize a preheater? If you do decide to use a preheater, where would you apply the heat? (Question No. 14)

Things move along smoothly for the next two weeks, when suddenly the weasel being used by your advance reconnaissance party has a major breakdown. Would you put a jeep that is part of the cargo into service or would you assign the additional duty to the trail-breaking crew? (Question No. 15)

The remainder of the trip into Point Barrow is made without any mishaps.

Based upon your experience on this tractor-train operation, what are some of the significant rules pertaining to repair parts that should be observed in polar regions? (Question No. 16)