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INTRODUCTION

The Arctic, that area lying north of the Arctic Circle, is an immense and desolate section of the world, hostile to man, to his equipment, and to his ships. It is an area of relatively little land mass and a great expanse of ocean covered with ice.

The Arctic Ocean, one of the major oceans of the world, covers nearly 5 million square miles of the Arctic. The continental land masses of Europe, Asia, and North America extend well into the Arctic zone; and the northern tip of Greenland is the most northerly land exposure. The broad shallow continental shelves extend outward from Europe and Asia as much as 300 miles, but the North American shelf extends less than 50 miles into the Arctic Ocean. Beyond these continental shelves the Arctic Ocean reaches depths of nearly 15,000 feet.

An area of the Arctic which is of prime interest today is that part of Alaska known as the North Slope. Running east and west across the full width of Alaska north of the Arctic Circle is a very rugged range of mountains, the Brooks Range, with elevations of up to 7,000 feet in the western portion, and Mt. Nicholson rising to 9,239 feet in the east. The North Slope is the flat, low-lying coastal plain from 50 to 150 miles wide between the Brooks Range and the Arctic Ocean. It is an area which in size is comparable to the state of California. There are only a few passes through the Brooks Range for access to the North Slope from the south. The best known of these is the Anaktuvuk Pass with an elevation of 2,200 feet.

The North Slope is liberally sprinkled with small shallow lakes and cut by meandering shallow streams. The largest river in the area is the Colville, which drains most of the center of the Brooks Range to the north and empties into the Arctic Ocean a short distance west of Prudhoe Bay. This is the land of the tundra, the land of the permafrost, and the home of the ice wedge polygons.

What is tundra? Basically, it is a very thin skin of vegetation covering and protecting from erosion the unconsolidated masses of muds, silts, sands, and gravels lying beneath it. Its growth is slow in the extreme; it is easily scarred and slow to heal; and it takes years to recover from damage. An area over-grazed by a herd of caribou will take from 50 to 100 years to recover completely.

What is permafrost? It has been defined as any material the temperature of which remains below 0° centigrade, or 32°F, for over 2 years. In other words, permafrost is a permanently frozen layer of the earth's surface. Permafrost on the North Slope varies from 600 feet in thickness along the coast to as much as 2,000 feet in inland areas. Five miles south of the beach in the Point Barrow area it reaches a depth of 1,250 feet. During the summer months, this mass of frozen material thaws to a depth of from 18 to 30 inches throughout the North Slope area. In some areas south of the Brooks Range it may thaw as much as 16 feet.

What are ice wedge polygons? They are polygons formed by the cracking of the surface of the ground and closely resemble the patterns found in drying mud, as in the bottom of a dry lake bed. They vary in diameter from 30 to 100 feet and constitute the most conspicuous surface feature over thousands of square miles of the North Slope area. The polygons are separated by ice wedges varying in thickness at the surface from a few inches to as much as 10 or 12 feet. These wedge-shaped segments of ice may extend downward as much as 20 feet. Imagine interpreting the results of a series of soil samples along the route of a road in which many of the samples would be 100% ice.

ENVIRONMENT

Holmes & Narver, Inc., for several years has been maintaining and operating facilities and equipment under extremes of cold weather at 3 principal sites: Point Barrow Navy Research Site, Point Barrow, Alaska (truly the Arctic); Amchitka, near the end of the Aleutian Chain (northern sub-Arctic zone); and the Antarctic at the opposite end of the world. Several years ago Holmes & Narver also conducted a 3-year project on the desolate northwest coast of Alaska between Point Hope and Cape Lisburne (also truly Arctic by all the definitions). While conditions vary throughout the Arctic as a whole, they are similar along most of the North Slope. This paper deals principally with facilities and equipment which are being maintained and operated at Point Barrow.

Point Barrow is the northernmost point on the North American continent where people regularly live and work. The environment of northern Alaska is a particularly hostile one. During the winter months, the thermometer may remain in the -20° to -40°F range for weeks, and has been as low as -56°F. The highest recorded temperature is 79°F, but the mean average throughout the year is only 9.8°F. February is the coldest month of the year, with a mean average temperature of -17.9°F; July is the warmest month, with a mean average of 37.7°F. For nearly half the days of the year, the temperature is 0°F or below.

Winds of from 25 to 45 miles per hour are not infrequent, and winds up to 115 miles per hour have been recorded. However, during an average storm the winds are usually around 17 to 23 miles per hour and seldom last longer than from 2 to 3 days. With freezing temperatures accompanied by wind, care must be taken to protect against the hazard of frozen flesh. A Wind Chill Chart, relating temperature in degrees of Fahrenheit to wind velocity in miles-per-hour, has been developed as a guide for the Arctic and the Antarctic. A temperature reading of -20°F accompanied by a 40-mile-per-hour wind shows on the Chart as the equivalent of -85°F and falls in the area of Chill Index 5, where exposed flesh will freeze in less than one minute.

This is also the land of the midnight sun and of the long dark nights. At Barrow the sun is above the horizon continuously from May 10 to August 2 and is below the horizon continuously from November 18 to January 24. At Christmas time at 10:30 in the morning it is just light enough to see a short distance, and by 2:30 in the afternoon it is again pitch dark.

From the first of June to the first of September the temperature seldom falls below 32°F. It is during this period that the annual thaw takes place. The snow literally melts before your eyes, and the water rushes to the sea as it cannot penetrate the mass of frozen material just beneath the surface. The entire area becomes a soggy mass interspersed with innumerable lakes and small streams. Rapid erosion occurs in areas where the tundra has been damaged. Ruts left by the passage of a single vehicle can become miniature canyons 6 feet wide and 12 feet deep in a matter of 4 hours or less. A 200-yard stretch of road at Barrow has been dry as a bone at 5 p.m. and an hour later covered with 2 feet of rushing water.

After the first of September the freeze begins again, and by the first of October the summer thaw has been refrozen. The first snowfall usually occurs around the first of October and as soon as the tundra is covered cross-country travel is again possible. By mid-December, most of the lakes have developed a sufficient thickness of ice to support even the heaviest tractors. Whenever the wind exceeds a velocity of 8 miles per hour, the snow will move. During the fall months, the wind seldom drops below this figure. The constant movement of the loose snow rounds the frozen particles and the snow packs solidly, so that it is possible to walk anywhere without the aid of skis or snowshoes.

POINT BARROW NAVY RESEARCH SITE

The Naval Arctic Research Laboratory and its supporting camp are located on the shore of the Arctic Ocean, about 4 miles from the Eskimo village of Barrow and the adjacent settlement of Browerville. The Laboratory is operated by the University of Alaska under contract to the Office of Naval Research and is situated on U.S. Naval Petroleum and Oil Shale Reserve Number Four.

The camp, which today is operated in support of the Laboratory, was originally built by the Seabees in 1944, to be used as the base camp from which to explore the petroleum potential of PET 4, as the Navy's petroleum reserve is called. The exploration of PET 4 continued until 1953. The Office of Naval Research began its Arctic research functions at Point Barrow in 1947, using the PET 4 camp as its base; and in 1954 the Air Force took over the operation of the camp as its base of operations for construction of the DEW Line (Distant Early Warning) stations across northern Alaska. The modules which made up the various stations were fabricated at the Barrow camp and, during the winter months, sledded across the tundra to their respective sites. In return for the use of the Navy camp, the Air Force agreed to support the Naval Arctic Research Laboratory which, at that time, had a staff of about 10 people. The Laboratory today has a year-round staff of nearly 100 people, which is increased to about 200 during the summer months.

The camp consists of nearly 100 buildings, most of which are the original Quonsets erected by the Seabees in 1944, (See Figure 1). These buildings are used as dormitories, family quarters, mess hall, shops, warehouses, fire station, boiler plant, power plant, laundry and dry cleaning plant, water distillation and treatment plant, and other service facilities. The new Research Laboratory building, dedicated in 1969, is a modern structure of 45,000 square feet in 3 core units and 7 wings. There are rooms for sleeping 86 people, 41 complete laboratory units, and service and administrative space. The building is the latest word in Arctic construction, resting on 557 piles set 15 feet into the permafrost, with a minimum of 18 inches open airway between the ground and the bottom members of the building. Adjacent to the camp is a 5,000-foot airstrip; 5 miles to the south

Figure 1. Naval Arctic Research Laboratory, summer 1969.

is a small natural gas field with 5 producing wells; and 1 mile to the east of the camp is the DEW Line Station designated as POW-Main.

As the Air Force support contractor at Point Barrow, Holmes & Narver maintains and operates most of the facilities. Approximately 40% of the buildings in the camp are assigned to, and are under the control of, the Naval Arctic Research Laboratory, whose personnel do most of the maintenance on these structures. Holmes & Narver is called upon from time to time to execute certain special maintenance and repair projects for the Laboratory and to provide special support to the DEW Line Station, the Federal Aviation Agency, the U. S. Weather Bureau, the U. S. Public Health Service, the Bureau of Indian Affairs, and the Alaska State Police whose representatives are located in Barrow Village.

PREVENTIVE MAINTENANCE AND WORK CONTROL

Holmes & Narver has established an engineered Preventive Maintenance Program at Point Barrow, as at its other operational sites, whereby qualified personnel make periodic scheduled inspections of facilities and equipment and correct minor deficiencies. More extensive repair requirements are reported by the Preventive Maintenance personnel to the Project Engineer for scheduling under the master Work Control Plan.

Because of the rugged climate at Barrow, an inordinate amount of work planning is necessary. Work plans must be flexible so that if adverse weather interferes with certain scheduled work, the crews can be shifted to other productive endeavors. It is the policy to paint one-third of the exterior and interior building surfaces each year. Obviously, exterior painting during the rigorous winter months is practically impossible, so this work is scheduled for the relatively short summer. But even then, schedules can be disrupted by adverse weather, and painting crews must be moved inside.

BUILDINGS AND STRUCTURES

In constructing buildings in the Arctic, especially those which are to be heated, it has been learned by experience that many methods used in the temperate zones are not applicable. Any heated building constructed in a permafrost area, even though built on a gravel pad, must also have adequate air circulation underneath. Otherwise, it will be subjected to differential settling in a very short time. Heat from buildings will melt the ice wedges or the frozen ground for several feet immediately beneath the buildings. As much as 2 feet of settlement has been noted in a 30- by 60-foot heated building within a period of 12 months. To overcome this problem, heated buildings have been placed on piles in order to gain sufficient elevation to permit a natural circulation of air under the building. Usually a 1-1/2- to 3-foot clear air space under the building is adequate and very effective in preventing settlement.

Untreated wooden piles have been found to be more satisfactory and economical than steel piles, as wood does not deteriorate in the Arctic. It is also more satisfactory to auger holes for the piles rather than trying to drive them into the frozen ground. A gravel and water slurry tamped around each pile sets up very rapidly in freezing weather and anchors the pile tightly. The best time to auger and set piles is, of course, during the winter months.

Even unheated buildings and structures should not be set directly on permafrost. A gravel pad from 3 to 4 feet thick should first be laid as protection for the frozen ground.

Other than providing sufficient insulation in heated buildings (walls, roof, and floor) to help offset the 120° to 130°F temperature differential between the inside and the outside of the building, good normal building practices, with only a few minor exceptions, are quite acceptable in the Arctic.

Double- or triple-pane windows should be used, and for most buildings it is good practice to provide a 2-door entranceway similar to the "storm doors" used in the cold areas of "the lower 48," as the original 48 states are called. Other good practices, particularly for living quarters, are to hang the outside doors to open inward, so that drifting snow will not prevent the door from being opened, and to include a vapor barrier within the shell of the building.

ROADS

Much of the construction work in the Arctic must be accomplished 180° out of phase with the time it is done in the lower 48. The winter months, not the spring and summer, are those in which much of the work must be scheduled. It is during the winter that material and equipment can be moved across the snow-covered surface without fear of damaging the tundra, or of getting mired down in mud and/or water. Winter, or the early spring before the thaw, is the time to build roads and pads and building sites, so that work can be continued above the water and mud during the summer months.

The wrong way to build a road across the tundra is to dig borrow ditches along each side of the right of way, berming up the borrow in the middle, as is frequently done in the lower 48. If this method is attempted in the Arctic, and it has been tried with unsatisfactory results, the "road" will end up in the summer as a soggy, impassable quagmire between 2 wide canals. The most practical method of road building in the Arctic is to leave the tundra absolutely unbroken and, during the frozen period, to cover it with a layer of coarse gravel at least 6 inches thicker than the maximum thaw. On top of this gravel, from 12 to 18 inches of fines (sands and clays) are spread and compacted into a good, hard, road surface. The top layer becomes reasonably impervious to surface water, while the bottom layer remains coarse enough to prevent upward capillary action of ground water during the summer and permits the draining off of accumulating moisture during the winter. Furthermore, the frost line at the peak of the thaw will be in the gravel above the original surface, and ice wedges in the tundra will remain frozen the year round. A road built in this manner is normally usable 12 months of the year.

The same precepts hold true for camp sites, drilling sites, runways, or any other sites on which it is desired to move about throughout the year. Gravel pads thick enough to keep the frost line above the original surface must be built up above the surface of the original ground.

In the maintenance of roads at Point Barrow, Holmes & Narver has made it a practice to scrape off the snow before the spring thaw so as to eliminate as much moisture as possible from the road before the heavy runoff. In anticipation of road repairs, gravel from the nearby lake shore is hauled and stockpiled before the ground has thawed. The timing is mandatory, as it is necessary to cross the tundra to reach the gravel pit, and it would be impossible to do any hauling over thawed ground. During past years, there has been considerable trouble in the maintenance of the road from the camp to Barrow Village. This past winter, the road was further elevated thereby accomplishing 2 things: avoidance of snow drifts, and considerably decreased road repairs in the spring.

AIRFIELD

The airfield at Point Barrow consists of a 5,000-foot runway, runway lights, terminal building, a warehouse, 2 hangars (1 constructed this year), and POL dispensing units. This field is used by the 7 aircraft operated by the Naval Arctic Research Laboratory and by military aircraft carrying official visitors and resupply cargo. There is another airstrip at Barrow Village, operated by the state of Alaska, which is normally used by commercial aircraft; but often weather prevents the use of this field, and the commercial aircraft then use the Point Barrow airstrip, unless it also is closed.

The runway at Point Barrow was surfaced with nonpierced steel planking for 80% of its length 2 years ago and completed for its full length in the summer of 1969. Because of the smoothness of the planking, aircraft landings were somewhat hazardous, particularly in a crosswind. For this reason, in the summer of 1970 the steel planking was coated with "Durapox," an epoxy nonskid surfacing compound. Because of temperature limitations, it was necessary to apply this material before freezing weather in order to obtain proper adherence to the steel plate. Snow removal from the runway does not present much of a problem, as the runway configuration and elevation do not induce large drifts. By using a grader to scrape the snow into windrows and then blowing it off the runway with a snowblower, the runway can usually be cleared in about 2 hours after a severe storm.

POWER GENERATION AND DISTRIBUTION

Power generation in the Arctic is basically no different from anywhere else in the world. Diesel-driven units perform quite adequately. Naturally, all units must be appropriately housed, and care must be taken to assure that the cooling systems of reciprocal engines are not exposed to the elements and that the flow of air around the radiators can be controlled and kept from becoming unduly chilled. Turbine-driven generators are coming into use more and more, not only in the temperate areas but also in the Arctic. These units are not so efficient as a diesel engine unless the exhaust heat is utilized; if it is, they are more efficient.

The main power plant at Point Barrow has 4 Cleveland diesel engines, each driving a 350 kw generator. These units were originally designed for World War II submarines. The plant was built in 1949, at which time 3 units were placed on the line. In 1955 these units were converted to dual fuel (diesel/gas) prime movers in order to burn natural gas, which is readily available from the nearby gas field, and thus reduce the demand for diesel fuel, which must be shipped in by barge once a year. The fourth diesel unit was converted to gas operation and put on the line in February of this year. In January 1969, a 750 kw generator, powered by a gasdriven SOLAR turbine, was placed on the line and relieved the shortage of electric power. The peak power demand at Point Barrow has been over 1200 kw, with the average for the winter months slightly under 1000 kw, and in the summer around 600 kw. Much of the time during the summer months enough power could be generated with only the turbine unit but, since this ia temporary installation and as yet no use is made of the exhaust heat, at least 1 of Cleveland units must be in operation at all times in order to keep the powerhouse and the engine coolant sufficiently warm. There is another small power plant in the natural gas field some 5 miles from camp. This plant has a gas-fueled generator and a diesel-driven standby unit which provide power for the gas field only.

Electrical distribution lines consist of approximately 42,000 feet of primary overhead and 24,000 feet of primary underground at 2400 volts. Secondary distribution lines carrying 220/110 volts total about 8,700 feet of overhead. No particular maintenance problems have been experienced with these lines, except for the difficulty of working outside on a pole during the winter.

WATER SUPPLY

At first thought, it may seem surprising that one of the major problems in the Arctic is the development and maintenance of an adequate supply of potable water. Wells are, of course, out of the question in deep permafrost. The Eskimo method of cutting and storing blocks of ice from a fresh water lake, or from the top of a relatively salt-free layer of ocean ice, is also out of the question if a substantial quantity of water is required.

The best source of fresh water in the Arctic is a fresh water lake or a large river, which does not freeze to the bottom in winter. At Point Barrow, a lake must be at least 9 feet deep to assure its not freezing solid.

Piping water is another problem. Burying the water lines in the ground to keep them from freezing, as is frequently done in the lower 48, is definitely unsuccessful in the Arctic. The method most used to date is to run the water lines in insulated heated utilidors or tunnels. Heavily insulated pipes can be used above ground, provided the water in the pipe is constantly flowing at a rapid rate, or if heat tape is installed along the pipe inside the insulation. Storage tanks, filter systems, and pumps must be housed in heated shelters to keep them from freezing.

At Point Barrow, water for the camp and Laboratory is drawn from a fresh water lake adjacent to the camp and pumped approximately 1,000 feet to the boiler house for filtration or distillation. In 1963, the lake was contaminated with sea water during a severe storm, and 2 Aqua Chem distillation units were installed to purify the water. By December of 1969, the saline content had dropped to an acceptable level, and the distillation units were shut down. Because of the very light snowfall in the fall of 1969, the lake ice reached a record thickness of 89 inches by April. As the lake is only a little over 9 feet deep, the camp had a restricted supply of water with increased saline content to draw on. It therefore was necessary to reactivate the distillation units.

Water lines from the lake to the boiler house, and from there to the kitchen, dispensary, shower room, and laundry run in steam-heated utilidors. Water to the new Laboratory building is piped in a 3-inch above-surface copper line, wrapped with electrical heat tape and encased in 4 inches of insulation. There is fresh water storage capacity of some 90,000 gallons in the boiler house, which feeds the distribution lines. All other buildings have individual internal water systems, consisting of 100- or 250-gallon tanks with pressure pumps or gravity flow. The tanks are filled daily from a 2000-gallon heated tank truck.

SEWAGE DISPOSAL

The usual method of disposing of sewage (other than sink and bathwater) in the Arctic has been for many years, and still is, the well-known "honeybucket." The honeybuckets are emptied into 55-gallon oil drums and the drums hauled to some shallow lake or depression and abandoned. It does not take much imagination to visualize the "forest" of these oil drums in the vicinity of Barrow Village. Attempts have been made to haul the barrels out on the sea ice in the winter, with the expectation that they would sink when the ice broke up, but unfortunately they too often would up back on the beach when the ice either drifted or was forced to shore by the winds, resulting in a worse mess than if the barrels had been hauled inland in the first place.

Pollution control is attracting much public attention throughout the world, and the Arctic is not exempted. Industry on the North Slope is under the gun, and all new installations in this area must provide for adequate disposal of sewage and waste.

Sewage plants can be, and have been, used successfully in the Arctic. Sewage lagoons are satisfactory, provided they have a depth of at least 9 feet. The new Naval Arctic Research Laboratory at Point Barrow is a modern building with flush toilets. All sewage from this building passes through a chopper and is then discharged through a well-insulated heated line into the bottom of a nearby salt water lagoon, which is from 9 to 10 feet deep. The lagoon is covered with ice for 9 months of the year and during the other 3 months is flushed by the 6-inch tides of the Arctic Ocean. After well over a year in operation, water samples indicate this to be performing as an excellent sewage lagoon.

There are several methods of sewage disposal used for the other less-modern buildings comprising the Point Barrow camp. All effluent wastes from the kitchen, dispensary, laundry, boiler plant, and shower rooms flow through pipes located in steam-heated utilidors and are discharged into the ocean. Many of the buildings are equipped only with honeybuckets; however, most of the buildings under control of the Air Force are equipped with gas-fired automatic incinerator toilets which are burned out after each use. since the camp is built on the beach, wash water is simply drained into the sand under the building. sometimes, in the early spring, the ice builds up to the point where it is necessary to throw heat under the building to thaw the accumulation of ice. This is done using portable Herman Nelson heaters with single or multiple flexible hose lines ("elephant trunks") to direct the heat.

NATURAL GAS FIELD

The South Barrow Gas Field is located approximately 5 miles south of the camp. At the present time, there are 5 producing wells which supply natural gas for the Point Barrow camp and the DEW Line station, and also for the village of Barrow. Natural gas is used for heat and for power generation.

Gas from the wells is piped to an adjacent distribution center where the well head pressure of 900 psi is reduced to 200 psi, and the gas is odorized. The camp is fed through a 4-inch line supported on empty oil drums. This is an old line in which there are no expansion loops, so in the fall of the year, after the warm summer months, it is necessary to go along the entire line and reset it on the barrels. The line to the village is a new line completed in 1968, which is mounted on piles with expansion loops every 600 feet.

One of the hazards of producing gas through permafrost is ice. If a well produces any water at all, there is the constant possibility of the well freezing up. At the South Barrow Field, the wells are lubricated with alcohol and blown at least once every 2 weeks. The alcohol melts any accumulation of ice and allows the water in the well to be blown off. In 15 years of operation of the South Barrow Field, there has not been any case of a well completely freezing up.

One of the major construction efforts of Holmes & Narver in the Arctic during the past 2 years has been the drilling of additional gas wells in the South Barrow Field. In the spring of 1969, Gas Well No. 8 was drilled and came in with a potential of approximately 3 million cubic feet per day. Gas Well No. 9 was brought in with a potential of 7.8 million cubic feet per day in 1970. These wells are relatively shallow; from 2,300 to 2,500 feet in depth. It takes longer to prepare for the drilling than it does to actually drill the well. The drill rig is an old Cardwell Model H unitized rotary rig with double drum, powered by a D-8800 Caterpillar engine. The derrick is an 80-foot American Standard Derrick reinforced with 4-inch drill pipe. This equipment was left over from the Navy drilling days during World War II. The rig is mounted on runners and is usually skidded off the site upon completion of the well to an already prepared gravel pad at the site of the next well.

Preparatory work for the drilling of a new well begins with skidding the drill rig to the new site during the season prior to the drilling period. At the beginning of the new drill season, when sufficient snow has accumulated to protect the tundra, a snow road is constructed to the new drilling site. About late January, equipment for the drilling operation is moved to the drill rig area. The mud pumps, mud tanks, power plant, water tanks, cement pumps, boiler, shop, and other small buildings are all mounted on skids for ease of moving to the site. Most of the buildings are heated with oil-fired space heaters. The well is usually spudded in early in April and, with the shallow depth, drilling is completed in from 3 to 4 weeks. The rig is completely enclosed with canvas and equipped with 3 steam forced air heaters on the rig floor and 3 under the floor. During drilling operations, the drill crews can work on the floor quite comfortably without extra heavy clothing. In the Prudhoe Bay area, the drill rigs are not totally enclosed, and the crews work on the floor without benefit of heat. The feeling at Prudhoe is that the hazard of gas accumulation in an enclosed rig is too great. However, at Barrow during drill stem tests and other occasions susceptible to gas accumulation, all doors of the rig are opened, and there has been no problem in maintaining adequate ventilation.

Another one of the problems with drilling for oil or gas in the Arctic is the cementing of casing in the permafrost. This last spring, Holmes & Narver switched from type G cement to Fondu cement (specially developed for permafrost areas) and had excellent results.

When the well is completed, the drill rig is moved off to a new site; buildings and equipment are skidded back to storage pads; and a well-insulated, electrically-heated well house (prefabricated in the camp carpenter shop) is placed over the well head. The well is connected to the main distribution center with a 2-inch line flow line mounted on pipe supports above ground.

HEATING SYSTEMS

Adequate heating systems are of prime importance in the Arctic, not only to sustain life but also to provide a reasonably comfortable living and working environment. This in turn promotes the efficiency of the work force. Several types of space heaters are used effectively at Point Barrow. Buildings are equipped with fixed heater installations; most of them are natural gas-fired, although some are dual fuel (diesel/gas) operated. Temporary structures, such as the rig accessory buildings used in conjunction with the drilling of a gas well, are heated with individual diesel-fired circulator-type stoves. Extensive use is made of portable Herman Nelson heaters with "elephant trunks" to feed heat to desired locations such as at the gas well drilling rig, aircraft cabins, and other locations not requiring or not susceptible to permanent installations. The boiler plant provides steam heat for utilidors, the galley, and the laundry and dry cleaning plant. Maintenance problems with these heating systems differ very little from those with similar types of heating systems in less rigorous environments.

REFRIGERATION

Although the Arctic for nearly 9 months of the year is one big "deep freeze," it is still necessary to operate standard type freezers for controlled refrigeration of food supplies and for uses in the Research Laboratory. The camp freezer and cold storage facilities are composed of a refrigeration building containing 8 prefabricated boxes totalling 10,800 cubic feet, 3 prefabricated boxes adjacent to the Dining Hall containing approximately 4,050 cubic feet, and miscellaneous reach-in boxes in the Dining Hall proper. Again, maintenance problems are similar to those in locations outside the Arctic. An alternative to the use of conventional freezers, if it becomes necessary, is the storage of frozen food in underground pits excavated in the permafrost. An old cellar is currently being used at Point Barrow for the preservation of food for animals under study by the Naval Arctic Research Laboratory.

PETROLEUM, OILS, AND LUBRICANTS (POL)

The POL system at Point Barrow is comprised of storage tanks, transfer lines, pumping stations, filter/separator stations, and supporting appurtenances for Aviation Gasoline (AVGAS), Motor Gasoline (MOGAS), and Diesel Oil. AVGAS fill facilities are located on the ramp at the airstrip. Diesel oil is transferred by pipeline from the bulk storage tank farm to service storage tanks within the Camp area, and to the DEW Line station. The tank farm is an arrangement of five 427,000-gallon tanks. Maintenance practices for the POL system are practically the same as in warmer geographical areas. The major difference in the outstanding storage of POL products in the Arctic is the necessity to add a de-icer to the tanks in September before the cold weather sets in.

INSECT AND RODENT CONTROL

In most camps throughout the world, an insect and rodent control program is a necessity.

Not so at Point Barrow. Rodents are nonexistent, and insects are not a real problem. A few mosquitoes appear in the warm summer months, but are not so numerous as to require much in the way of control effort.

VEHICLES AND CONSTRUCTION EQUIPMENT

This is not the land of "shade tree mechanics." With the exception of a few days in the summer, all equipment maintenance and repair must be done in well-heated shops. The Arctic is not easy on equipment or its operation. For at least 9 months of the year, as much of the daily-use equipment as possible is kept inside warm buildings when it is not in operation. If a piece of equipment is left outside overnight in -30°F weather, even though plugged into electrical head bolts and radiator heaters, it takes a minimum of 1 hour, and often 2 hours, to warm it up with the aid of Herman Nelson space heaters before it will operate properly. Vehicles are never shut down when outside during the winter; they are kept running continuously. Some of the trucks and pickups at Point Barrow may travel only 10 miles a day, yet their engines are running 10 hours a day. This, of course, increases the normal maintenance and repair load. All rolling stock is subjected to particularly rough treatment in the Arctic. Probably those giving the most trouble are tractors and other hydraulically-operated equipment which takes time to warm up.

SUPPLY

Except for a relatively small quantity of open market purchases, all of the supplies for the Point Barrow camp are requisitioned on the Air Force. Once each year, when the sea ice has broken up, Point Barrow is resupplied by barge from Seattle and southern Alaska. The barges deliver a full year's supply of dry foods, POL products, lumber, pipe, paint, steel, etc., and much of the frozen food products. Theoretically the camp is supposed to have a 2-year supply of all necessities when the barges depart. This provides a reserve against the possibility that the barges may not be able to get in the following year. During the summer of 1969, there was somewhat of a problem in getting barges into Point Barrow and Prudhoe Bay. On July 27, 1969, the ice will still packed in against the shore of Point Barrow, held there by the wind. About a week later, with a shift of the wind, the ice moved enough to let the barges in, but again moved back, and it was not possible for the barges to leave until the end of August.

Shortages in supplies, such as specially required repair parts, as well as fresh meats and fresh produce, are shipped in by air from Elmendorf Air Force Base in Anchorage at about 10-day intervals. The Air Force authorizes a supplemental meat allowance of 1/3 pound per man per day in the Arctic.

CONCLUSION

This has been but a short sketch of a few of the problems attached to living and working in the Arctic. Much has been learned about this remote and hostile area of the world; there is much more knowledge and experience required, as has been demonstrated by the controversy surrounding the routing and construction of the Trans-Alaska Pipeline. Man's progress depends not only on means for his survival, but also on deep ecological considerations and solid engineering.

Charles C. Norris

Charles C. Norris, Vice President of Williams Brothers Engineering Company, Tulsa, Oklahoma, has been affiliated with the oil and gas business his entire career. He is a graduate in civil engineering from the State University of Iowa at Iowa City.

Mr. Norris was a gas engineer for Iowa-Illinois Gas and Electric Company during which time his responsibilities included the layout and design of natural gas distribution systems and associated facilities. He joined Consumers Power Company in Michigan as a gas engineer where his work included both engineering and operation of gas facilities. His engineering work there included that of coordinator for the company in the design of pipeline, compressor stations, storage field and gas plant facilities. He also served as supervisor of operations in the compression department and was responsible for the day-to-day operation of 200,000 horse power at some 10 locations.

After joining Williams Brothers in 1965, Mr. Norris worked as senior engineer for the supervision and design of pipeline and station facilities. This included the responsibilities for a recent 1,000 mile, 36-inch pipe-line facility which included 13 compressor stations. His present capacity as vice president of Williams Brothers Engineering Company includes the responsibility for project development on a variety of oil and gas projects. These include detailed feasibility proposals for arctic engineering and construction.

He is a registered professional engineer in the states of Michigan, Oklahoma, Wisconsin, Minnesota, New Mexico and Pennsylvania. He is a member of ASCE, ASME, SGA and Tulsa Pipeliners Club.