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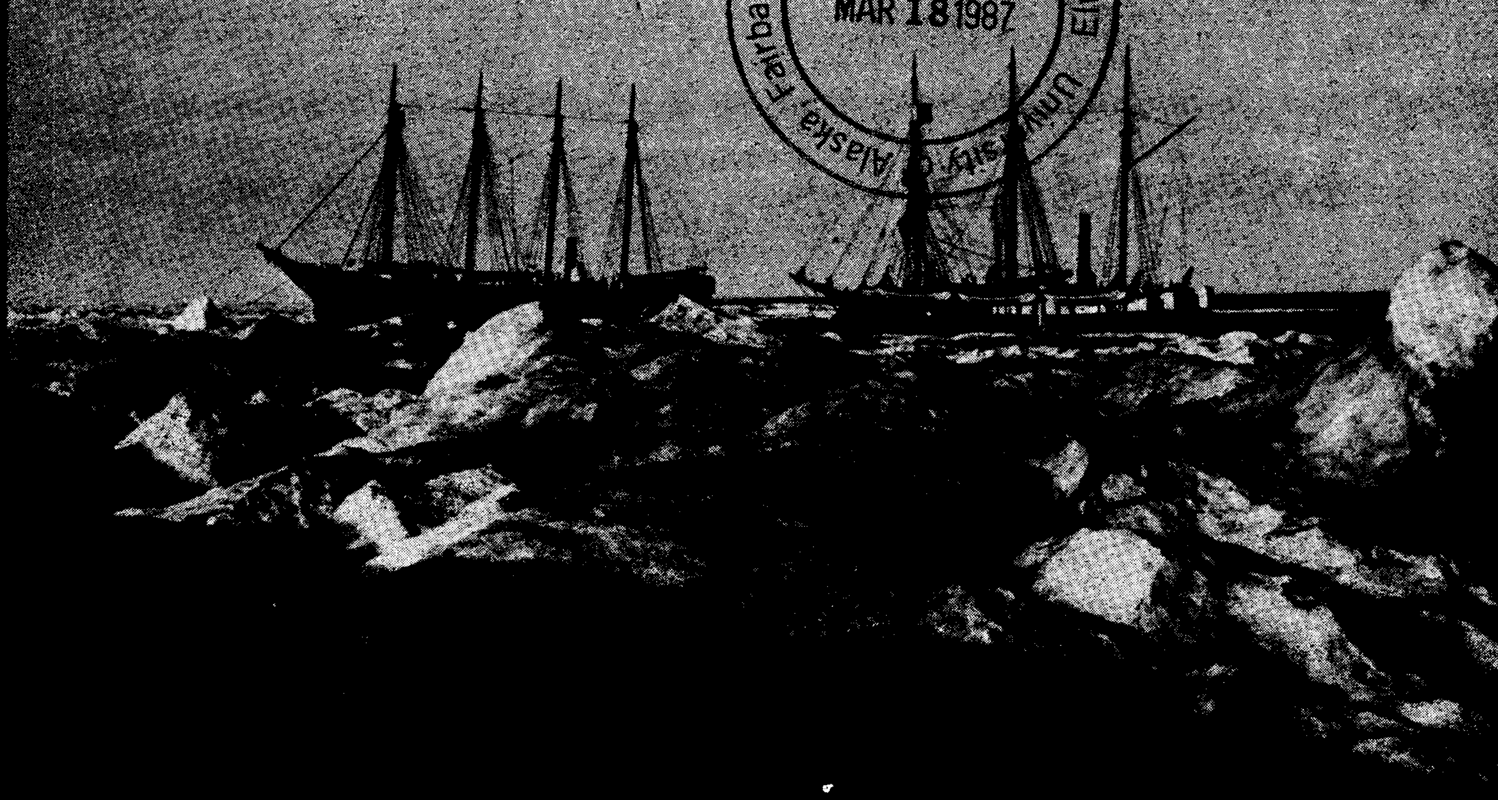

Where Are Our Winter Visitors?

Tunis Wentink is no stranger to Alaska, having served three years ago as National Science Foundation Visiting Professor in Physics with the Geophysical Institute. In 1970 he accepted appointment as Associate Director of the Institute of Arctic Environmental Engineering. After more than a year on the front line of Northern research, he comments.

Fairbanks—mid-September '71. The days are shortening markedly as the daily sun-hours skid toward the December minimum, the tourists are almost gone, the summer flood of visitors on business (plus vacation) has slowed to a trickle, the wild flowers have faded, yet the continued colorful display of interior Alaska's cultivated flowers seems to hold off the approach of fall and winter. Thus another crop of always-welcome 'outsiders' has left, mostly rabid converts to the Alaskan way. Often they have been overwhelmed by a beautiful and immense land upon which some semblances of civilization and culture have been grafted. This is so, even as they painfully realize it is a remarkably short time since the parka-clad highwayman plying his trade on the trails to the now-vanished gold camps was replaced by the friendly grocer or shopkeeper behind his cash register, or the landlord.

Sincere invitations to return in the winter are most often met with reactions of near horror and vehement disbelief. Here is one symptom of a problem central to long-term development of interior Alaska. It relates to problem knowledge, definition, and priorities for the Interior. Such development, as in the case of large areas of the forty-nine states, will require accelerated and knowledgeable partnership of federal, state, and private enterprise. The last, in most cases, certainly has done its homework and field work in evaluating the problems of year-round operations and living. However, its efforts are necessarily coupled to financial success, and directed in narrow channels.

The state, on a pragmatic basis, has a mixed success record in its arctic and subarctic sections. To a great extent, this is because planners are greatly separated from the problems by distance, geography, and climate. Planners in Anchorage subject to approval from Juneau do not always produce suitable structures on the Arctic Circle, at least the first time around.

An obvious improvement would involve maximum joint use of the state university and other state agencies, with their considerable expertise in the hostile winter environment. While any state university will always ask for greater support, and use it largely to fulfill its educational responsibility, it does have a further responsibility to help solve the sponsor's (the people) problems, if the university is so equipped. The University of Alaska is eminently qualified in this way through its many research institutes. Yet, puzzling communications problems seem to prevent or at least minimize the expoloitation of the University in the development of Alaska. Certainly the academics would resist pressure to confine themselves to dictated research areas, yet most would welcome closer cooperation with the state's many departments in problem definition and assignment of priorities for attacking the myriad of Alaskan problems.

The record of the federal government in subarctic and arctic development can also be improved. Considerable planning activity in Washington for these areas results in relatively little guidance for, or action on, Alaskan efforts. Federal support has been neither stingy nor overly generous, but the efficiency of the necessary

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proposal-review-contract process could be greatly improved if problem priorities and long-range programs were defined. We are not hopeful that the long-needed national policy for the Arctic and sub-Arctic will be issued soon.

Washington or Juneau alone should not impose priorities. Neither should the interior Alaskans let long-range plans they must help formulate and implement be obscured by short-term parochial views. Alaska can profit, with benefits enjoyed by its sister states, by improved cooperation and plans formulated together by all parties involved. Such plans, hopefully followed by early action, can only be fruitful if the planners are truly knowledgeable, born of year-round Alaskan experience.

So visit the interior of Alaska and its North Slope in winter. Sample its immensity cloaked in snow and ice, the awesome beauty of the aurora, the emptiness of a white-out, the crowded living spaces, the resulting and common cabin fever, the transportation problems resulting from vast distances, lack of public conveyances, or cars ill-designed for -50°F temperatures, and the freeze-ups of plumbing too often based on Lower 48 methods. Know our real problems, and our hopes to develop Alaska, to protect it yet exploit it in a proper way so that its wilderness and resources can contribute to the power, wealth, and strength of the entire United States.

—Tunis Wentink, Jr.

THE NORTHERN ENGINEER

THIS ISSUE . . .

PAPERS AND ARTICLES

OPINION

THE COVER

Whaling fleet stranded off Barrow, Alaska in the late 19th century. Photo courtesy of the University of Alaska Museum.

Mechanical Properties of Frozen Soil

O. B. ANDERSLAND

A review of the following data on frozen soils was presented by Dr. O. B. Andersland at the Research Seminar on Construction Problems in Permafrost held at the University of Saskatchewan on March 11-12, 1971.

Interest in the mechanical properties of frozen soil has increased with the demand for more basic design criteria for structures built in or on permafrost. Some of the questions raised include what effect do temperature, deformation rates, and relative amounts of ice and soil have on peak compressive strength? When segregated ice formations are present in the frozen soil does the overall response to loads depend primarily on ice behavior? For long term or sustained loads how can time-dependent behavior of the frozen soil be introduced into realistic design criteria? The following experimental data raise some interesting possibilities as to field design applications.

Peak Strength

Peak strength data (Goughnour and Andersland, 1968) based on constant axial strain rate tests on ice and frozen saturated sand are summarized in Figure 1. The Ottawa sand, sized between the No. 20 and No. 30 U.S. standard sieves, was formed into samples at low sand volume concentrations by uniformly mixing natural snow with a selected proportion of precooled sand, placing this mixture into a mold, and pouring precooled water into the mixture. Little snow melted during this process and sand particles remained in dispersed positions during freezing.

The relative amounts of ice and soil have a large effect on both peak strength and creep behavior. The data show a bilinear relationship with interaction between sand particles drastically increasing the peak strength at close to 42 percent sand by volume. At low sand volume concentrations the increase in strength appears to be related to faster deformation rates required in the remaining ice matrix to accommodate the overall sample deformation. At high sand-volume concentrations interparticle friction and dilatancy of sand particles come into prominence. Dilatancy must act against the cohesion of the ice matrix and the adhesion between sand grains and ice creating an effect analogous to higher effective stresses.

Superimposed on the effect of relative amounts of ice and soil are strain-rate effects. The upper two curves in Figure 1 show the influence of strain-rate differences at the same temperature. The strain-rates shown differ only by a factor of two. This effect carries through for both the ice and the full range of sand volume concentrations. The upper and lower curves in Figure 1 show the influence of temperature on peak strength on ice over the full range of sand volume concentrations. Changes in unfrozen water content are not a factor in these tests since essentially all the water is frozen at both temperatures.

Creep Strength

Creep strength may be defined in terms of the stress level corresponding to an allowable secondary creep rate. This creep rate might be determined by the allowable total deformation less primary creep and the required service life for a frozen soil element or structure constructed in or on permafrost. To provide new information on this creep strength, a series of step-stress creep tests were conducted on samples containing 64 percent by volume Ottawa sand. Sample deformation versus time is shown in Figure 2. The axial stress was held constant by a hanger type dead load. Zero cell pressure was maintained until deformation had progressed into the secondary creep region. An increment of confining pressure was then applied and the ram load increased to keep a constant stress difference. This loading process was repeated at 30 minute intervals until the cell pressure reached 150 psi. The jump in

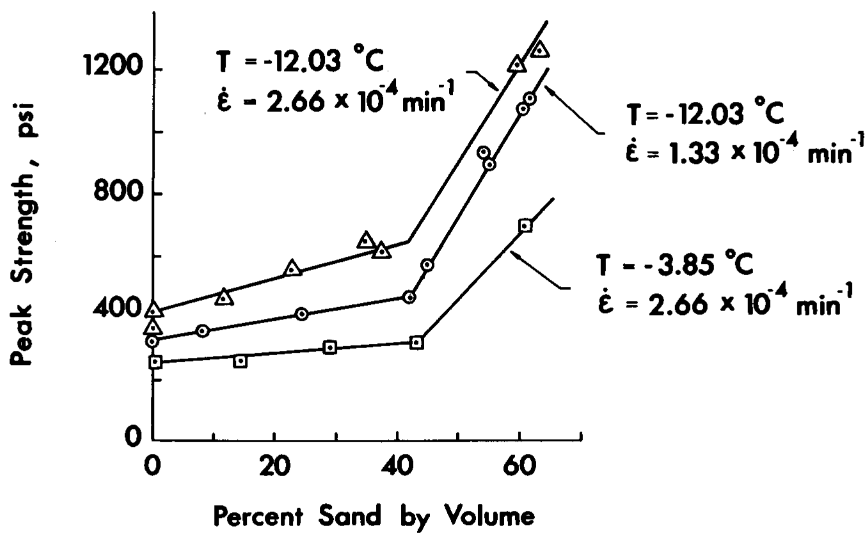

Figure 1. Peak strength versus percent Ottawa sand by volume.

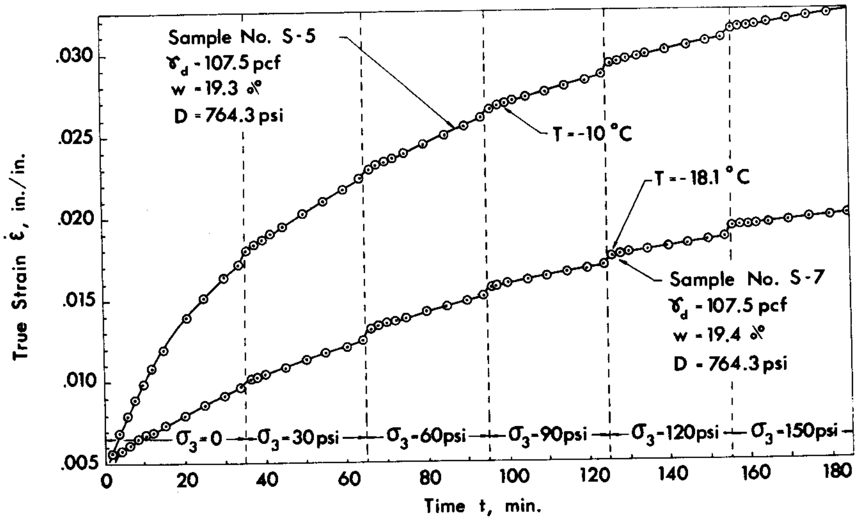

Figure 2. Step-stress creep tests on sand-ice at temperatures of -10°C and -18.1°C

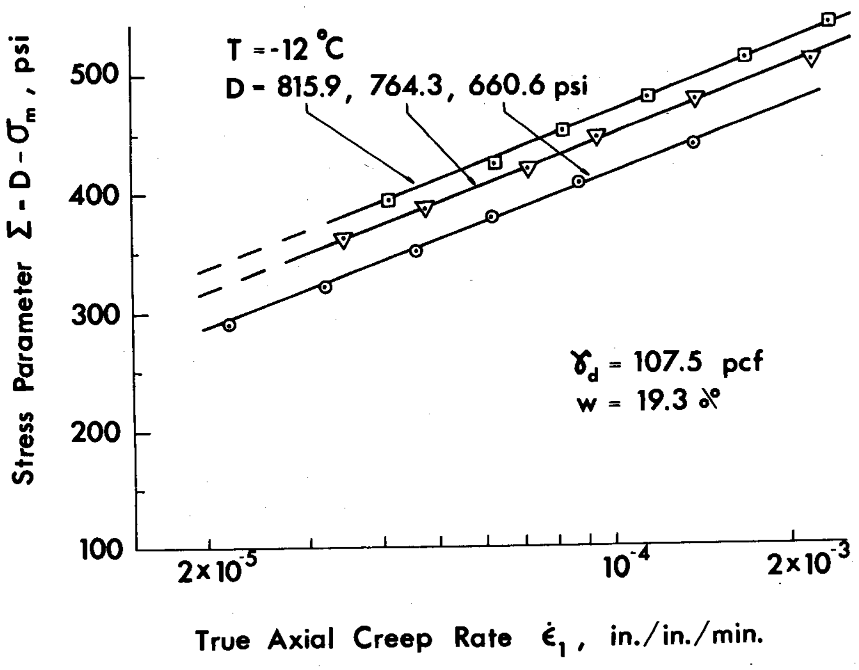

Figure 3. Effect of $D = \sigma_1 - \sigma_3$ on creep rate versus stress for sand-ice samples.

strain at each change in confining pressure corresponds to elastic expansion in the triaxial cell tie rods. Test results (Andersland and AlNouri, 1970) are summarized in Figures 3 and 4.

For any given value of stress difference D and temperature T it was found that the axial creep rate $\dot\epsilon_1$ decreased exponentially with increase in the mean stress,

$$\sigma_m = {}^1/_3\,(\sigma_1 + 2\sigma_3),$$

as shown by each of the straight lines of identical slope m in Figure 3. A stress parameter, $\Sigma = D - \sigma_m$, was selected for convenience in curve fitting the trixial type test data. The only difference in the three tests illustrated in Figure 3 is the magnitude of the stress difference D. The equation of these lines is of the type

$$\dot\epsilon_1 = b \exp (m\Sigma)$$

where b is the intercept of the line on the $\Sigma = 0$ axis. The data confirm that $b = C \exp (n\,D)$ where C and n are constants. Hence for tests at a given temperature,

$$\dot\epsilon_1 = C \exp (N\,D) \exp (-m\sigma_m) \quad (1)$$

where $N = n + m$.

Tests on four duplicate sand-ice samples all subjected to the same stress difference D with each at a different temperature T are shown in Figure 4. Again each line can be represented by an equation

$$\dot\epsilon_1 = b \exp (m\,\Sigma)$$

but now the data show that $b = C' \exp (-L/T)$ so that for a given stress difference D

$$\dot\epsilon_1 = C' \exp (-L/T) \exp (m\,\Sigma) \quad ((2)$$

where C' and L are constants. Equations (1) and (2) suggest that, more generally,

$$\dot\epsilon_1 = A \exp (-L/T) \exp (N\,D - m\sigma_m) \quad (3)$$

where A, L, N, and m are constants determined by experiment. Data (Andersland and AlNouri, 1970) show a similar relationship for frozen Sault Ste. Marie clay.

At any stage of these creep tests the major and minor principal stresses are

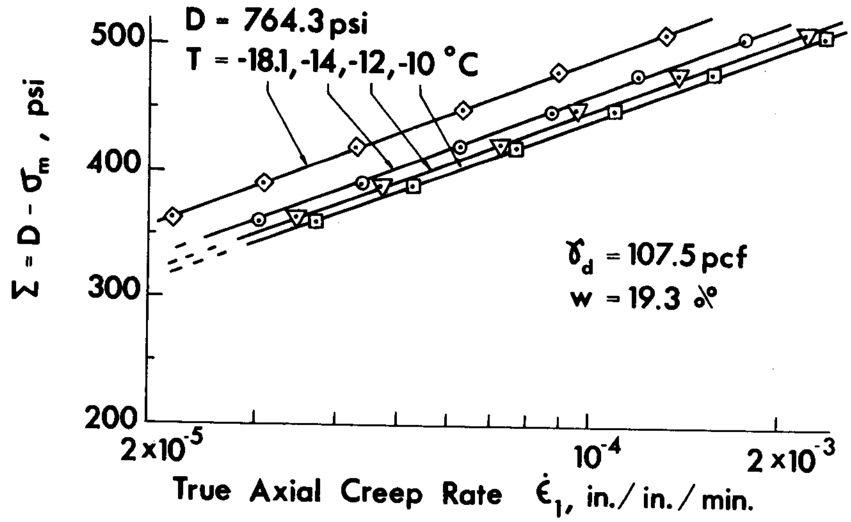

Figure 4. Temperature effect on creep rate of sand-ice samples at D = 764.3 psi.

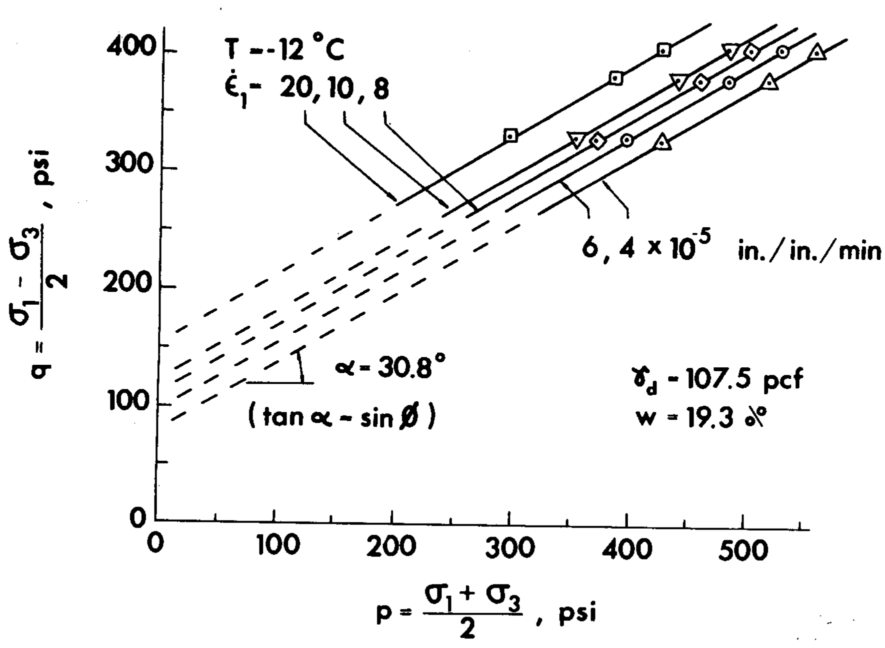

Figure 5. Creep rate effect on strength of frozen saturated Ottawa sand samples at -12° C.

$$p = \frac{\sigma_1 + \sigma_3}{2} \qquad q = \frac{\sigma_1 - \sigma_3}{2}$$

plot. From the data for all creep tests on the sand-ice material it was possible, for any specified creep rate and temperature, to plot several such stress circles; these were found to have a straight line envelope as illustrated for several creep rates and one temperature in Figure 5. The intercepts on the q axis and the slopes of these lines showed that for the saturated frozen Ottawa sand: (1) the angle of internal friction was constant (equals 37 degrees) and independent of creep rate, and (2) the cohesion is smaller at slower creep rates and is some function of temperature. In contrast to the step-stress creep test results, constant axial, strain-rate tests (Andersland and AlNouri, 1970) showed a much smaller effect on confining pressure on the peak strength of the frozen saturated sand.

These experimental results show that the peak strength of frozen soil will be influence by deformation rates, temperature, and relative ice and soil contents. Unfrozen water content will influence strength indirectly by reducing the ice content. Creep strength is improtant for long term or sustained loads. Either lengthy creep tests or special test techniques are needed to evaluate creep strength. The step-stress creep test discussed above appears to have merit for obtaining design parameters. More laboratory and field research is needed to expand our knowledge on the strength behavior of frozen soils.

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Global Weather Modification and the Arctic Basin

P.M. BORISON
(Translated by Donald F. Lynch)

P. M. Borisov's idea to dam the Bering Straits to control the world's climate is not new. Russians have been proposing this and other schemes for altering weather patterns for many decades. One ambition attempt at "reforming" nature occurred in the late 1940's and early 1950's when large shelter belts were planted in the steppes of Russia to increase rainfall and reduce the frequency of drought. The truly large belts evidently failed, but many local ones remain. Russia, although a large country, is not blessed with the same agricultural abundance as the United States, due to a generally cold and dry climate which causes frosts in the north and drought in the south. On occasion, cold, dry air masses have created weather conditions that have destroyed crops for years on end, resulting in widespread famine.

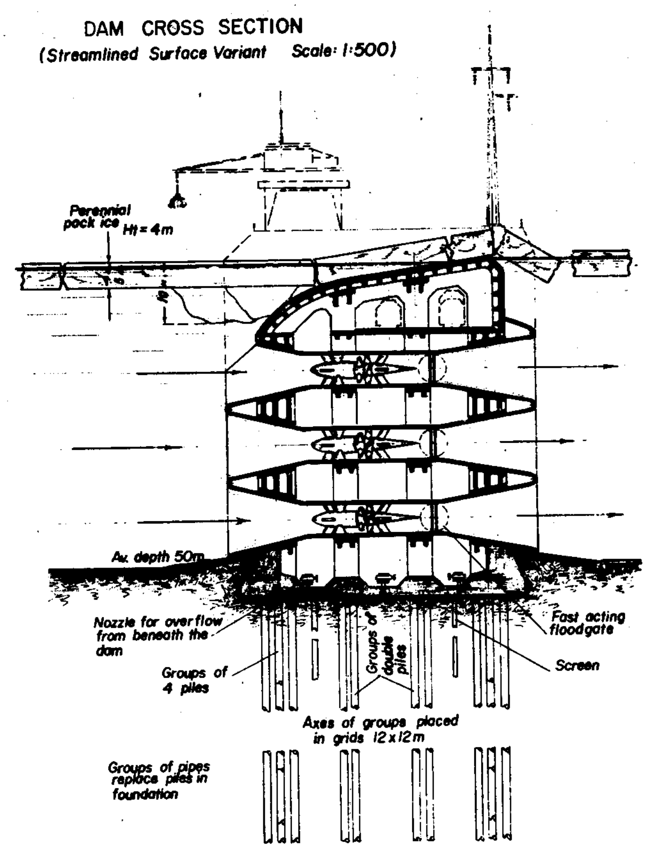
From certainly the early 1920's, Soviet scientists have been actively interested in studying, predicting, and controlling climate in order to reduce the frequency of harvest failure and increase the cultivable area of the Soviet Union. Drought and frost have particularly been studied, as has artificial rain-making and other techniques for weather modification. In their analyses, Soviet climatologists recognize that air masses are formed in specific locations, and many believe that changing the characteristics of these source regions can alter dramatically the nature of the air masses themselves.

Since the Arctic Basin is an important source region for air masses adversely affecting Russia's agricultural lands, it is not surprising that Soviet scientists are concerned with changing the nature of the Arctic. Borisov's proposal recognizes that removing the Arctic ice and introducing warm Atlantic waters in the Arctic Basin will cause the air masses to have warmer temperatures and increased moisture. A Bering Strait dam might therefore result in a dramatic improvement in Russia's climate. A propensity to think in these terms results in large part from the pragmatic orientation of most Soviet science.

An appeal to study the problem of climatic change and the role of the Arctic in world climate is certainly welcome. One is, perhaps, permitted to wonder how much attention may have been given to the possible affects of the dam on the nations of the North Pacific. What would be the effect on Alaska's climate of some 140,000 cubic kilometers of cold water pouring south through the Bering Strait every year? Borisov's approach is a provoking challenge, not only for engineers to design prefabricated dams and powerful pumping systems, but also for oceanographers and climatologists to analyze the true role of the Arctic Basin in creating global climates. If, as Borisov suggests, the Arctic is indeed the major control in the world's climate, then research there should provide a basis for long range weather forecasting and prediction of future climatic changes.

–Donald F. Lynch

A temperature of 15-25°C is most conducive to human activities. One of 25-30°C year around is best for plant growth, optimal conditions found in the lower latitudes, but certainly not in the North where severe cold, deep snows and high winds cause extremely high construction costs and practically exclude farming altogether. The cold North also adversely affects the environment of temperate and in some cases tropical



Cross section of the dam's design to date. Modifications notwithstanding, the basic concept would undoubtedly be retained. Prefabricated pontoon blocks, each 200 meters long, would be used in construction. Horizontal pumping systems would control flow, and along the dam's upper surface would eventually run a double-tracked railroad and a highway.

latitudes. For example, the cold Labrador current is largely responsible for New foundland's tundra vegetation, while at the same latitude Champagne, France, is famous for fine wines and excellent vineyards. The out-flow of cold water from the North reduces surface ocean temperatures resulting in low evaporation rates, reduced atmospheric moisture, and consequently decreased precipitation over the continents. Because of this, the world's arid zones reached their largest extent during the glacial periods. During their movement southward during spring and summer, the cold and dry Arctic air masses absorb heat which raises their saturation point, and leads to desiccation of the vegetation and soils, in some circumstances so severe that drought and extremely hot and dry winds result.

And at the same time the icy North guards vast underground treasures of fuels, minerals, chemical raw materials, and diamonds. A universal race for oil and gas is under way today, with the search including islands in the far north of Canada. Alaska is already one of the U.S.'s most important petroleum bearing provinces, although many of its wells are in the open sea exposed to floating ice, while the Siberian North, rich in oil and gas, will soon join the ranks of the world's major producers of petroleum. Realistically, the time is not far off when the harsh "Top of the World", the Arctic Basin, its adjoining seas and especially the continental shelves, will be the brilliant crown of our planet, with myriads of wells penetrating the coasts and shelves and sucking oil and gas out of gigantic subterranean reserves.

Industrial use of the sparsely populated North involves high costs because of the harsh climate, and it is now both easier and cheaper to remove the causes of the severe conditions than to continue accepting irretrievable losses in fighting the evironment. Improving the climate of the North is therefore a matter of great economic significance, an important challenge for scientists and engineers. However, attempts restricted only to a separate cold region of the world will encounter insuperable obstacles and fail. One must recognize that after solar radiation the most important climatic controls are the atmosphere and hydrosphere, which are inseparably linked together, and that the only promising approach is to address climatic change on a truly global scale. The key to the problem and to the future lies in the past, particularly the last 20,000 years, an interesting period of geologically rapid, complex and varied climatic changes, at the beginning of which ice sheets covered 27 million square kilometers of the continents and drifting ice spread over still larger areas of the oceans. The ice sheets reached depths of several hundreds of meters over the continents and two to three kilometers at their centers. The European ice sheet covered all of Scandinavia and the Baltic Sea and extended far into Central and Eastern Europe, while the North American ice sheet was even larger and covered almost all of the northern part of the Continent, reaching to Cincinatti, Pittsburgh and New York City. The decline in temperatures, however, was not constant, and six major and many minor variations occurred even up to the present which caused both the European and North American ice sheets to advance and retreat.

Research has shown that dynamic changes in the earth's heat balance are possible in nature and that these can be

TABLE 1

Water Balance of the Arctic Ocean (km^3 per year)*

Inflow from		**Outflow to**	
Atlantic	135,000	Greenland Sea	135,000
Pacific	36,000	Baffin Bay	40,000
Coastal Runoff	4,000	Bering Sea	0
Totals	175,000		175,000

*Data from the Arctic and Antarctic Research Institute

TABLE 2

Thermal Conditions of Atlantic Water Entering the Arctic Basin

	Present Conditions	**New Conditions after Bering Strait Dam**	**Percent Change** [Increase]
Vol. of Atlantic water per year	135,000 km^3	140,000 km^3	104 [4%]
Water temperature: degrees above -1.6°, freezing point	3.5°C	9.8°C	280 [180%]
Heat quantity (thermal content) in kilocalories per year	472 x 10^{18}	1,370 x 10^{18}	290 [190%]

related to variations in the amount of heat absorbed over a relatively short period of time. Two main factors control atmospheric heat distribution: the movement of warm equatorial waters northward; and, of lesser importance, variations in the albedo, that is reflectivity of sea surfaces. An increase in the flow of warm waters from south to north will alter both the reflectivity of the Arctic and general atmospheric circulation, as has happened in the past. A global period of warming up occurred 7,700-2,500 years ago, reaching its peak in the Climatic Optimum, 6,000-4,000 years ago, when Atlantic waters carried large quantities of heat into the Arctic, drift ice disappeared, vegetation and animal life shifted 500-600 kilometers northward, with the limits of some species lying 1,000 kilometers north of their present location, and mountain glaciers shrank and in some places completely disappeared. Sea temperatures just north of the Kola peninsula were 2.5°C higher than today and general ocean temperatures rose causing greater evaporation and increased precipitation even over the world's greatest desert, the Sahara, which then had a moister climate and a more widely distributed human population.

A number of investigators examined the possibilities of altering the Arctic's heat balance by changing the direction of some ocean currents, based on the realization that these have a major impact on climate. Before doing this, however, consideration must be given to the three factors which condition cooling in the Arctic, the glaciation center of the northern latitudes: the low salinity of Arctic surface water, the ice cover's high albedo, and, most importantly, the unfavorable counterflow of surface waters in the North Atlantic and European basin. Cold water moving south cools the warm equatorial water moving north and prevents warming of the Arctic. Therefore the idea of replacing counterflow with a direct flow appears highly promising and most practical. This could be done by shifting Arctic water, in a volume determined by the water balance of the Arctic Basin, from the Atlantic, as at present, to the Pacific, thereby permitting warm Atlantic currents to penetrate far to the north, crossing the Arctic and existing through the Bering Straits. The volume of water outflow to be transferred can be determined from the present Arctic water balance, shown in Table 1.

A dam constructed across the Bering Straits would block the entry of Pacific water into the Arctic, and then about 140,000 cubic kilometers of cold water per year will have to be pumped over from the Chukchi to the Bering Sea in order to prevent the cooling of Atlantic waters by the Arctic waters and ice. This will radically reduce the Arctic outflow into the Atlantic, and then the currents of the Gulf Stream, the dominate system in the Atlantic, will no longer be subject to cooling and instead will move warm Equatorial waters toward the north pole, causing changes in the temperature and the heat content of the Arctic Basin as shown in Table 2.

The direct flow of water through the Arctic Basin from the Atlantic to the Pacific would be a well regulated process, and the consequent artifical effect on climate will occur along lines similar to those of the recent past, which resulted from natural causes, and therefore reconstructed paleoclimates can serve as models for forecasting the sequence of climatic changes anticipated. The first stage would be a climate like that of a thousand years ago when the Arctic ice cover disintegrated in summer and reformed on a small scale in winter. Winters were milder, early fall and late spring frosts less common, the growing season in temperate latitudes longer, and drought less frequent. The second stage would approximate the Climatic Optimum of 4,000-6,000 years ago when the Arctic Basin and almost all the seas of the northern hemisphere were perpetually ice free, January temperatures in the polar regions and the area of the pole of cold reached 30-35°C, the tundra and forest tundra were suitable for large scale livestock raising, permafrost disappeared from the uppermost horizon, the dry river beds of the Sahara contained water, and the dry steppes and savannas spread into the broad areas of the present deserts. Finally the ecological conditions of the inter-glacial period would return with the remnants of tundra on the Arctic shores disappearing and moisture increasing in the arid climates of the south. Subsequently, Arctic surface temperatures could be raised higher by increasing the capacity of the pumping systems for transferring warm Atlantic water through the Arctic to the Pacific, and this might further reduce the climatic contrasts between the Arctic and subtropics. In any case, the climate will begin to improve with the first year of water transfer and the Arctic Basin will be ice-free within approximately four years.

The interoceanic water exchange would be accomplished by constructing a dam across the Bering Straits, which are 74 km. wide through Diomede Is., have an average depth of 50 m. and a maximum of 59 m. and a cross section of 3.76 km.^{2} In concept the dam is built of cells of reinforced concrete blocks laid in three tiers with each cell containing a pump, electric motor and a reducing gear all enclosed within a streamlined single block. After the drifting ice disappears, the top of the dam would be rebuilt and would be crossed by a double tracked railroad and a superhighway.

The potentials for changing ocean current circulation and global climates by artifical inter-oceanic water transfer testify to the fact that man can and shall control the climate of his planet and illuminate on a broad scale the pathway to a new stage in the relationship between human society and Nature, a level of the planetary reconstruction of the natural environment to liberate mankind from the blind, natural elements. Present food shortages and the headlong growth of population give enormous social significance to the need for a fundamental improvement in climate. And this can be accomplished if people will live in peace on their Earth and not bring to each other the terror of instant atomic death. Bearing this in mind, the scientists and engineers of different nations should meet at the conference table and establish guidelines for further research and decisions on this noble task of our days which has been set before us.

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An Arch-Rib Building for Northern Use

G. McCORMICK

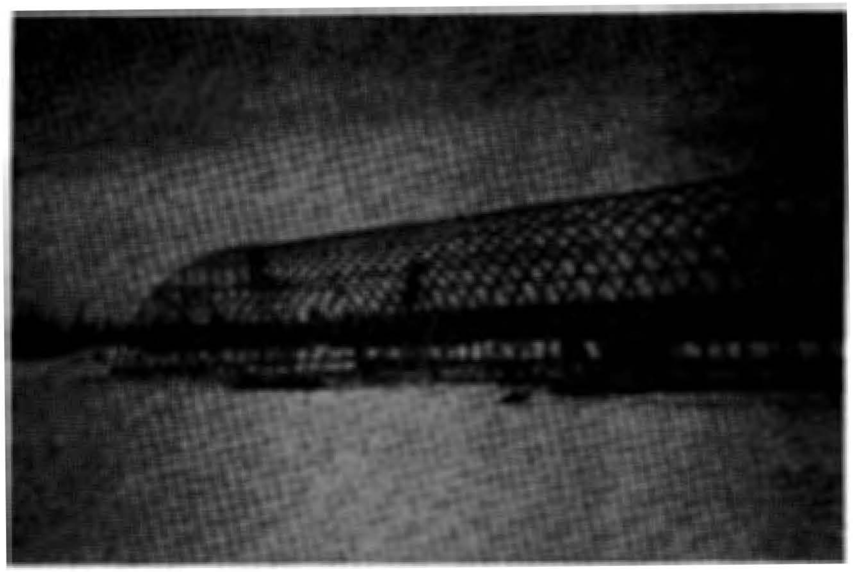
In most northern construction projects a serious problem is the provision of large span buildings for such purposes as: equipment maintenance, temporary shelters for construction, warehouses and mess halls. Such buildings must be able to stand up to fairly high snow and wind loads. If the installation is only temporary the buildings must be erectible with a minimum of on-site labor; the use of salvageable components is very often a great advantage.

One type of building which is usually economical for remote areas is an arch building made up of laminated timber arches. A number of such buildings are available for purchase from various manufacturers. Many of these were originally designed for use on farms. They generally consist of small cross-section laminated timber arches with each arch being provided in two sections which are joined by a metal clamp at the top. The exterior sheathing is usually plywood. One difficulty with these pre-fabricated buildings is the amount of space required when shipping the laminated arches. In many northern locations, the material must be shipped in by aircraft and such arches are very difficult if not impossible to fit into a standard cargo plane.

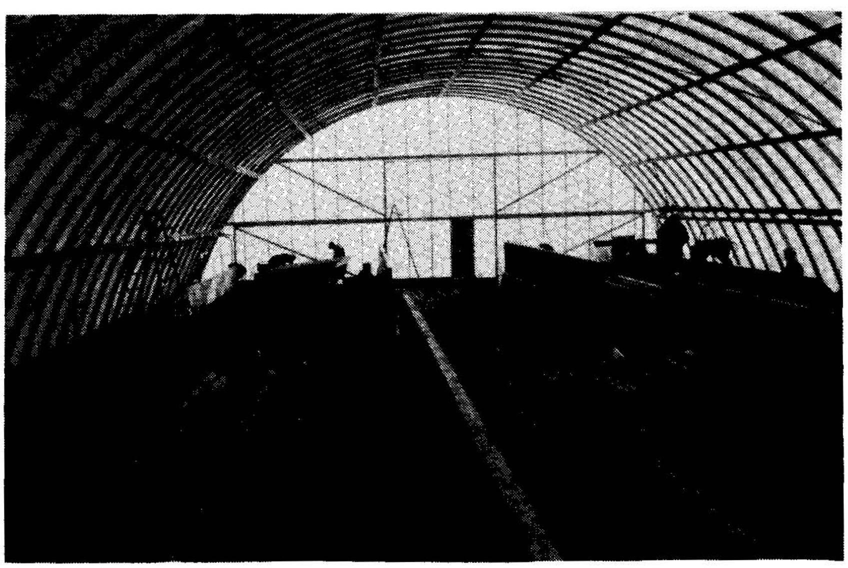
Some years ago the writer was engaged as an engineer on a construction project in Northern Alberta. It was essential that work should proceed through the winter, so the construction of temporary shelters over various parts of the job site was necessary. A number of extremely large precast concrete beams were required on the job and it was necessary, in order to maintain the construction schedule, to case these members during the winter. They are usually cast with the aid of a gantry crane. In this case no such equipment was available and it was not possible to move such equipment onto the site. However, there were available on the site several large truck-mounted cranes of adequate capacity.

It was finally decided that the only solution to the problem was to erect a building in which the members could be cast and then to move the building so that cranes could lift the members onto large flat bed trucks. The building could be placed on rails and could be pushed along the rails by trucks or other mechanical equipment.

An arch building, orginally designed by A. W. Smith (see "A Plastic Shelter for House Building in Winter" by A. W. Smith, **National Builder**, November 1958) was adapted for this job. This design consists of arch-ribs which are made up of 1 x 4 boards. In the original design, each arch was laminated from three boards which were nailed together with spiral nails. A simple jig can be laid out on the ground and the boards bent around it. The dimensions



Arch-rib building under construction



Building in use as a shelter for the manufacture of pre-cast beams.

chosen for the job in question are shown in Figure 1. It will be observed that the arch is a simple one, that is, of constant radius, and the center of the circle is about five feet below the ground line. In this particular case, only six-inch-wide boards of nominal one-inch thickness were available and it was decided, because of the increased span, to use four boards in each arch. The total length of the building was 140 feet and the distance between the centers of arches was four feet. The accompanying photographs show the building under construction, when in use, and during movement. On this last photograph the rails on which the building was seated can be clearly seen in the foreground. Each rail simply consisted of a wide timber piece with two 2 x 4's nailed to it to act as guides. The covering of the building was polyethelene plastic of six mil thickness. The longitudinal members were 2 x 4 timbers and bracing was provided by 1 x 6 boards which were laid diagonally across the inside of the roof. The total weight of the structure was about 16,000 pounds. Heating was by means of steam heaters, fed from a central heating plant, which were connected to a steam supply line by flexible hoses. The large door at the front was made high enough to accommodate concrete delivery trucks of six cubic yards capacity.

After each set of beams had been poured, and allowed to cure for a few days, the building was moved along the rails for a distance of about 150 feet and the formwork was then constructed inside it to take another set of concrete members. When the first set of concrete members had cured sufficiently to be moved, a crane was brought to the site and the members were loaded onto trucks for transportation to their destination. By this time the second set of members had cured sufficiently so the building could be moved back to its original position.

The building proved to be far more rigid than had been anticipated. When moving the building, two trucks were used. At one time, one of these vehicles stalled and the

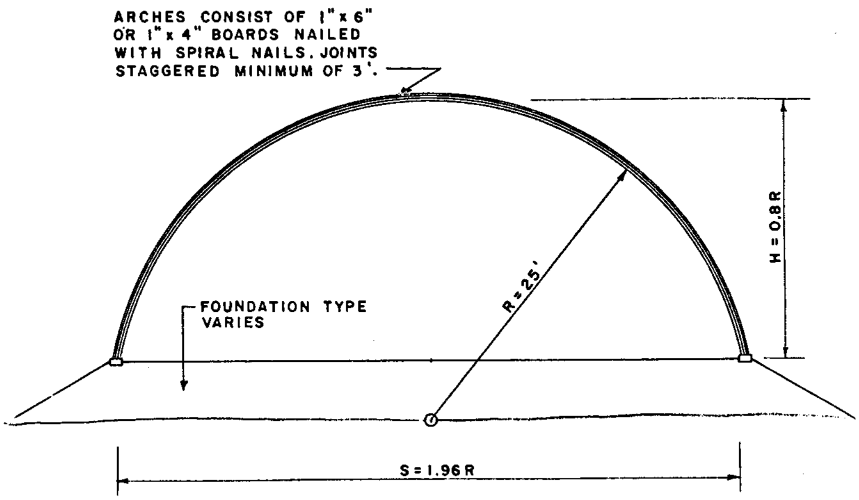
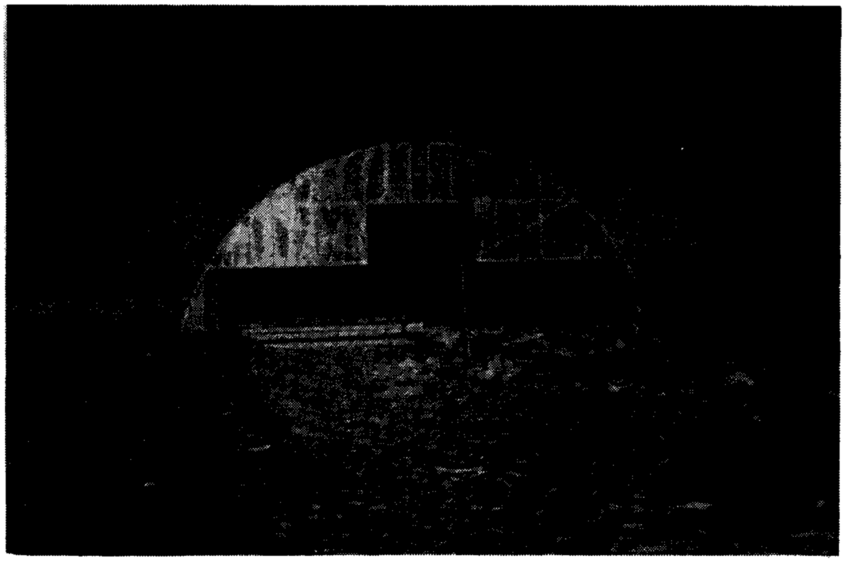


Figure 1. Arch building with suggested proportions.



Building being prepared for trial move.

other, unaware of what had happened, continued to push, oblivious of the warning shouts of the spectators. It moved the building about 100 feet on its own without wracking or deforming the members.

During the winter, snow was blown clear of the surfact except on the crown at the very top. Here the snow would settle to a depth of perhaps two inches. Heat from the building would melt it, and consequently sheets of ice formed. During high winds some fear was expressed that these sheets of ice might puncture the skin of the building. However, the only time the outer skin was damaged was when a laborer poked a corner of his shovel through it. Owing to limitations of space, this building had to be placed with its long axis parallel to the prevailing winter wind. Wherever possible, such buildings should be placed with the long axis at right angles to the prevailing wind so that snow will be blown completely clear of the building.

A similar building was later constructed under the writer's supervision in central Labrador where it was used temporarily for housing water treatment facilities.

These buildings can be easily erected from timber which is shipped into the site in straight pieces and which can be easily loaded into such aircraft as: the DC-6, DC-4, the Bristol Britannia, the Lockheed Electra, and the Lockheed Hercules. Fabrication is simple and does not require anything more complicated that a saw and a hammer. If it is desired, plywood sheating can be used on the outside of the building and insulation can be applied to the inside. In such a case, the shell would provide an excellent basis for a mess hall or a warehouse. In its original form, where it was intended to be used as a temporary shelter during house construction in winter, this type of arch building could be used to shelter parts of building projects. Theoretically, there is no limit to the span which can be used and it would be interesting to speculate on combining such arch construction with air pressure which could be used during periods of storm or heavy snow.

G. McCormick, R.M. Hardy & Associates, Ltd. 10214 112 Street, Edmonton, Alberta, Canada

From Meta Incognita to Prudhoe Bay

BILL HUNT

The first expoitation of the mineral resources of the North American Arctic was made in 1577 when Martin Frobisher, hearty Elizabethan sea dog, after killing five Eskimos and capturing two others, loaded his ship with 200 tons of black stone gistening with gold. This joyous discovery prompted Queen Elizabeth I to sponsor the first settlement of the English in North America. Fifteen ships carrying 100 settlers (or miners) and the first prefabricated house designed for the Arctic went out the next year to develop the richness of Meta Incognita. But, to the detriment of the Early progress of the North, a great storm damaged the fleet and made the establishment of the colony impossible. Making the best of the situation, Frobisher loaded what ships were still floating with more gold and returned to England. No cheers heralded his arrival. In his absence cold eyed assayers had determined that Frobisher's rocks held fool's gold only. This reverse set the mineral development of the North back by several hundreds of years.

It may be 1977, the four hundred year anniversary of Frobisher's "discovery" before the black gold of Alaska's Arctic slope flows to market. Seen in historical perspective, the current delay in the building of the pipeline seems trifling. If Frobisher could wait four hundred years for vindication of his belief in the mineral wealth of the Arctic then we can wait a bit too!

But there are perhaps closer historic parallels to the contemporary North Slope situation to be observed. Take the Ballinger-Pinchot Affair, a chapter in the national struggle for conservationist policy that roused the country in the early years of the century.

Then as now the dispute revolved around the utilization of public lands, in particular, coal lands of the Chugach National Forest. Battle lines were sharply drawn between the conservationists, who rallied to the leadership of Gifford Pinchot, head of the Bureau of Forestry and Richard Ballinger, Secretary of the Interior. In summary, Pinchot insisted that entry to the coal lands in Alaska be restricted until a sound national conservationist policy be legislated. He contended that the prevailing situation permitted a giant syndicate, controlled by the powerful financial syndicate of the Morgans and the Guggenheims, to monopolistic expolitation of the coal resources.

Most Alaskans supported the view of Ballinger who argued that Alaska and the nation would be best served by allowing the Syndicate to carry out their mining operations. They accused Pinchot of attempting to lock up the resources of Alaska for posterity. Not so, responded Pinchot, he only wanted the land laws revised so that all miners could be on a par with the Syndicate. Individual miners were restricted to tracts of 160 acres by law and could not operate profitably, yet fraudulent land transfers allowed the Syndicate to exercise a coal mining monopoly.

The conflict raged from 1906, when President Theodore Roosevelt withdrew coal lands from public entry until mining was once again made legal in 1915. A revision of the land laws terminated the menace of monopolistic practices, but the coal remained in the ground. On the national scene the affair seemed a victory for proponents of rational planning and conservationist practice; to Alaskans it seemed an unwarranted interference with industrial development by an absentee national government. It pained Alaskans to feel they had no control over their destiny. They felt exploited rather than protected.

Statehood has done much to alleviate the Alaskans' feeling of frustration over domination by the distant authorities in Washington, D.C. The State has the responsibility for planning for present social needs and future development for the lands over which it has dominion. Yet most of Alaska is federally owned and this will still be true after the State is permitted to make the selection of 104 million acres according to the terms of the Statehood Act. Thus national policies will continue to determine to a great extent land utilization in Alaska.

We cannot cry out at the indifference of the national government as in the days of the Ballinger-Pinchot Affair. The situation cannot be seen in such simplistic terms any longer. No magic formula for the wise use of our natural resources exists. Decisions will have to be made that could prove in the long run to be ruinous to the State's economy or disadvantageous to a segment of its people. Some of the decisions will be made in Juneau and some in Washington, D.C. and all will be colored to some extent by past events and attitudes. Against the background of the frontier settlers' treatment of the aboriginal Americans the Alaska Natives land claims will be determined by Congress. In the anxiety of a community finally awakening to the perils of unchecked industrial growth on the natural environment, decisions on the pipeline and related projects will be made. Policy planners may still wish longingly for a crystal ball with which to clarify their view of the future, but they will also need an understanding of the past.

Northern Studies At U. of Alaska

Student interest in the new interdisciplinary Bachelor of Arts program in Northern Studies was evident by the fall term registration. Courses in history, geography, engineering, anthropology, geology, biology, archaeology, linguistics and ecology can be utilized to make up the major requirement. A new offering, Inupiaq Eskimo, has been added to the curriculum.

The focus of the Northern Studies Seminar last spring was on the planning of a scientific expedition to the Arctic. Experts in various fields advised members of the Seminar in their expedition planning and each class member drafted a particular proposal. This term the Seminar concerns public policy planning in Alaska.

Mrs. Evelyn Stefansson Nef visited the campus in May and was consulted by members of the Committee. Mrs. Nef acted as Coordinator of the Arctic Seminar at Dartmouth College during the period that Vilhjalmur Stefansson was associated with the College's Baker Library.

The Northern Studies Steering Committee is comprised of representatives of all the colleges at the University. Its members are William Hunt, Business, Economics and Government (Chairman); Mark Fryer, Mathematics, Physical Sciences and Engineering; David Murray, Biological Sciences and Renewable Resources; Michael Krauss and Lee Salisbury, Arts and Letters; Donald Lynch, Earth Sciences and Mineral Industry; John Cook, Behavioral Sciences; and student representatives.

Planning is under way for a program that will lead to a Master of Science degree in Northern Studies.

Requests for information on the program can be directed to Steering Committee members.

IAEE RECEIVES GRANT

An unrestricted grant of $5,000 was presented in September to the Institute of Arctic Environmental Engineering by the Chevron Research Company of Richmond, California, a subsidiary of the Standard Oil Company of California.

Chevron's granting program is intended to support university research in fields of mutual interest. Funds may be used, however, as the Institute deems necessary, for support of graduate students, equipment purchases, or in other ways helpful to its science and engineering programs.

In accepting the grant on behalf of the University of Alaska and President Wood, Dr. Kenneth M. Rae, Vice President for Research and Advanced Study said, "We are most appreciative of this support and of the philosophy under which it is given. The flexibility of unrestricted grants offers great opportunity and you can be sure that the Institute will put it to good use."

A late acknowledgment for our Summer 1971 cover picture. Driver is Allen Chase of the Alaska Dog Mushers Association. Photograph was taken by James Coccia.

Frost Penetration Factors

G. McCORMICK

Reliable estimates of the probable depths of frost penetration are required for the design of roads, runways and buried utility systems in most parts of North America. The depth of frost penetration can be closely calculated from the Modified Berggren equation:

$$X = \lambda \frac{48KF}{1.43WD} \quad \ldots\ldots\ldots\ (1)$$

where:

- X = depth of frost penetration in feet
- λ = a dimensionless coefficient
- K = thermal conductivity of frozen soil (BTU/FT/HR/DEG.F.)
- F = surface freezing index (degree-days F.)
- W = moisture content (%)
- D = dry density of soil (pcf)

λ is a dimensionless coefficient that is a complex function of the temperature, the volumetric latent heat of the soil, and the volumetric heat capacity of the soil. Sanger (7) has published a nomograph showing the relationship of the air freezing index, the water content of the soil and the lambda coefficient.

The surface freezing index can be estimated from the air freezing index by multiplying the latter by a factor which has been found to vary according to the type of surface, topographic position, and latitude. Sanger (7) has given a value of 0.9 for this factor while Moulton and Schaub (6) found that in West Virginia the factor varied between 0.5 and 0.7. These last two authors are also of the opinion that this ratio (called the n-factor) becomes larger as the severity of the winter increases. The writer has found that an n-factor of 0.8 is a reasonable value to use in the southern part of Canada and a factor of 0.9 is a reasonable one in more northerly areas.

Kersten (3) has shown that, for moisture contents in excess of 4 per cent, the thermal conductivity of any soil can be expressed by the relationship

$$K = A + BW$$

where A and B are constants for a particular type of soil at a given density. Kersten has given values for A and B. Equation 1 can now be rewritten as:

$$X(\text{in}) = 12\lambda \frac{48\,(A+BW)nF_a}{1.43\,WD} \quad \ldots\ldots\ (2)$$

$$= 12\lambda\ n\ \frac{48\,(A+BW)F_a}{1.43\,WD} \quad \ldots\ldots\ (3)$$

where:

- X = depth of penetration of frost (inches)
- F_a = air freezing index

Equation 3 can be re-written in the form:

$$X(\text{in}) = 12\ \frac{48\,(A+BW)}{1.43\ WD}\ F_a\ \lambda\ n$$

Values of λ n have been plotted on Figure 1 using a value for n which varies with the Air Freezing Index and values for λ taken from Sanger (7).

The expression $12\ \frac{48\ (A+BW)}{1.43\ WD}$ has been evaluated for a range of soil types, water contents and dry densities, using the data of Kersten (3), and the values plotted on the two charts in Figures 2 and 3. This expression has been termed by the writer the Frost Penetration Factor. If the Frost Penetration Factor for a soil type can be reliably found or estimated and the probable or design freezing index is known, then the probable depth of frost penetration can be found quite easily.

In choosing the design freezing index, it is necessary to choose some return period or recurrence interval and to estimate the most severe winter liable to occur within that period. The Corps of Engineers Method (4) is to use either the most severe winter of the previous ten years or the average of the three most severe winters in the previous 30 years. In the Prairie Provinces of Canada the writer has found that for a return period of 25 years the design freezing index may be

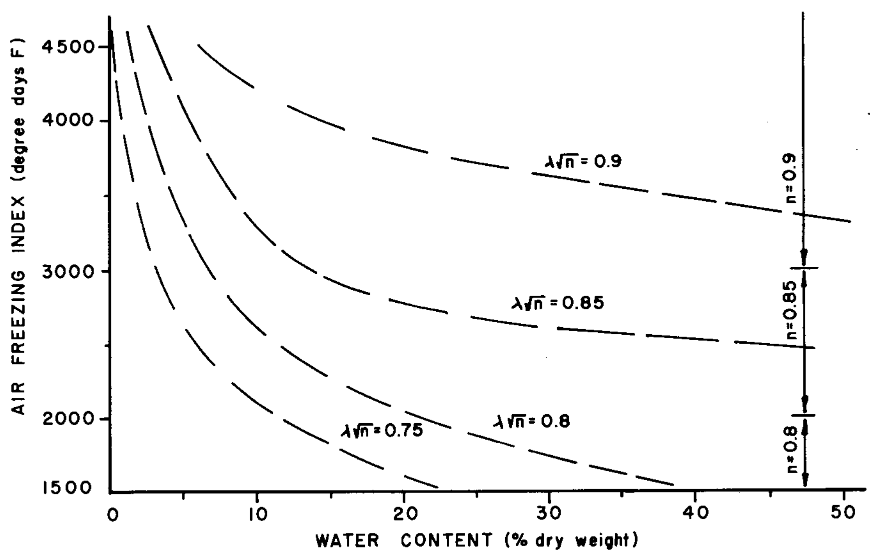


Figure 1. Relationship of air freezing index and soil water content to λ and surface correction factor.

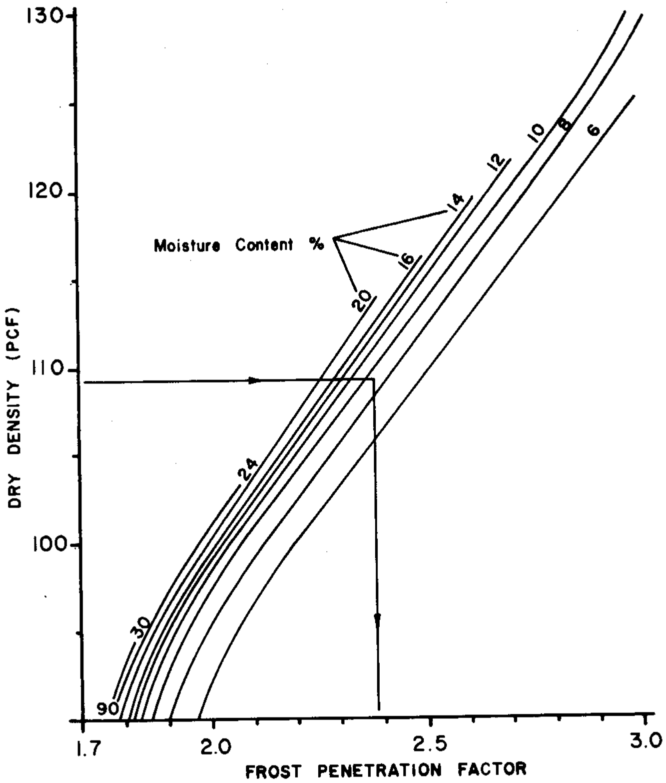


Figure 2. Sand and gravel

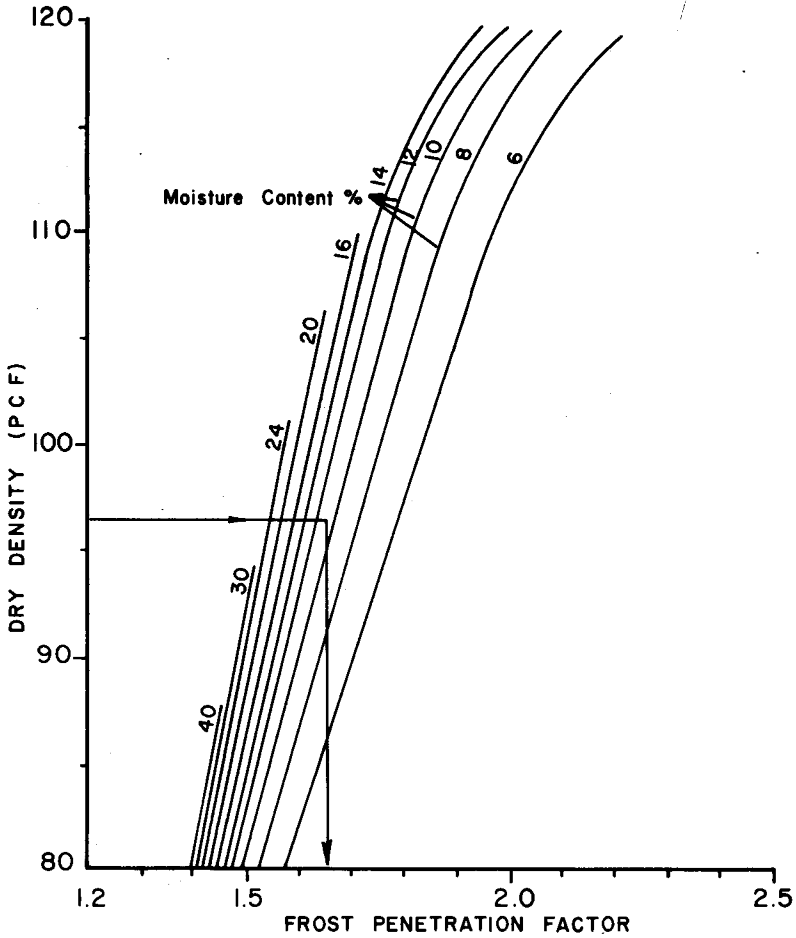


Figure 3. Clay and silt

found from the relationship:

$$F_D = (F_M)(0.8) + 1{,}850$$

where:

F_D = the design freezing

F_M = the mean freezing index

Thompson (7) has discussed the values for the freezing index in the arctic areas of Canada and the University of Alaska has published an **Environmental Atlas of Alaska** (1) in which the mean and ten year freezing indices are shown. In most areas it will be possible to obtain the necessary information from the local office of the Weather Bureau.

The procedure for estimating the probable depth of frost penetration, therefore, is as follows:

1. Obtain information as to the nature of the subgrade soils, their types, classifications, densities and moisture contents.
2. Decide on some value of the design freezing index which is to be used.
3. Using charts either 2 or 3, according to the soil type, find the frost penetration factor and multiply this by the square root of the air freezing index.
4. Multiply again by the factor λ n taken from Figure 1.

The resulting value of frost penetration in inches can be used for design purposes where detailed local information on frost penetration is not available. The value obtained for frost penetration is based on the assumption that the ground surface will be clear of snow. If the snow cover is to be left undisturbed during the winter, local investigation as to the frost penetration beneath the snow cover at the end of a winter should be undertaken.

The writer has compared values found by the above method with the actual depth of frost penetration beneath road and aircraft runways and has found the correlation to be excellent. The calculated depth of frost penetration using the above method has invariably been found to be conservative which is in accordance with the work of Jumikis (2) and Yong and Warkentin (9).

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22nd Alaska Science Conference

The twenty-second Alaska Science Conference sponsored by the Alaska Division, American Association for the Advancement of Science, was held at the University of Alaska, August 17-19, 1971. The focus of this year's conference was biological sciences. Sessions ran concurrently and provided a full schedule for participants.

The them of the conference was Adaption for Northern Life. Most of the sixteen sessions dealt with northern plants and animals. Others centered on social, medical and physical sciences. Approximately 140 papers were presented over three days and over 500 people attended.

A single jam-packed session on Engineering and Arctic Health resulted in some very interesting papers on pollution, sewage treatment and northern community development. Papers by C. Bettignies on wind power utilization and L. Garinger on freezing of waste water sludge stirred considerable interest.

Abstracts of papers presented will be published in late November and may be obtained by writing (Mrs.) Helga Wakefield, Laurence Irving Building, University of Alaska, College, Alaska 99701.

Letters To The Editor

Sir:

Whereas the inner world reached via Symmes' Hole seemed like a perfect repository for criminals and rascals to folks a hundred and fifty years ago, I suggest that it could serve a better purpose in our present technology and current environmental problems. Would it not be the perfect place for depositing radioactive wastes? This would be economically feasible immediately.

The next step would be to use The Hole for dumping the world's garbage, or at least the non-biodegradable garbage. The heat from a few years accumulation of radioactive waste products would melt down the old car bodies which could eventually be mined and reused in the conventional manner.

At the present time I am uncertain whether or not The Hole should be reached for this latter purpose via transport airplanes, or railroads, or both. However, a NSF grant in the amount of approximately 150K should provide the answers.

Perhaps this idea is even patentable.

LARRY R. SWEET
Fairbanks, Alaska

IAEE publications

Latest Notes, Bulletins and Reports by the Institute of Arctic Environmental Engineering, University of Alaska, College, Alaska 99701. These are provided to subscribers of The Northern Engineer free of charge upon request.

R 7101 Storage of Winter Natural Refrigeration For Summer Use Utilizing Partially Frozen Brines, Philip R. Johnson

Storage of winter refrigeration capacity for summer use utilizing partially or completely frozen salty brines was studied. The freezing of ice provides the capacity while the salt lowers the freezing and thawing temperatures to make that capacity directly usable. Four brines were evaluated and both NaC1 brine and NaC1-enriched sea water were found to be well suited for use. $CaC1_2$ brine was found to be undesirable because of poor performance, low capacity and the irritant qualities of the solution. Concentrated sea water was also found unsuitable.

The compositions and heat capacities of $CaC1_2$ and NaC1 brines at different temperatures and concentrations were determined. The NaC1 data can also be used for NaC1-enriched sea water. While the primary interest was on partially-frozen brines, the use of eutectic NaC1 brines was also examined. One example of the design of a brine heat sink is contained in the report.

1970-71 Annual Report

The Annual Report of the Institute of Arctic Environmental Engineering for 1970-71 has just been published. In the report the activities of the Institute are summarized. Among the projects described are the successful completion of the walrus storage freezer at Savoonga, St. Lawrence Island, the test road facility at Prudhoe Bay, the experimental buried pipeline at Barrow, various studies of the properties of sea ice and others.

The report may be obtained upon request from:

Secretary
Institute of Arctic Environmental Engineering
University of Alaska
College, Alaska 99701

Book Reviews

Gosta E. Sandstrom, **Man The Builder,** McGraw-Hill, 1970, Hard-bound $16.00.

Throughout history man has been involved in military evolutions and political intrigues. He has also been a builder striving to build bigger and better. From reed houses have come Gothic cathedrals and castles, from burial pits vast pyramids. From trails he has developed expressways and railroads. From a simple irrigation system have come canals and hydraulic dams. And yet even though man has built out of necessity, he has also built for the sheer creativity.

Building has no borders, no language, but is the workings of economics, hard labor, and man's struggle to survive. It is building that "forges the tools of conquest and empire building, and stokes up the pressures that bubbling up to the surface produce material for the establishment historian."

Through extensive research Gosta E. Sandstrom has described this part of history usually left untouched by most historians. He has done so in a technical way for he is more concerned with management, methods and materials used in building the structures that have come to be known as the Seven Wonders of the World. It is this detailed approach to building and its path through history that not only the technical oriented, but those interested in the development of civilization and culture, will find most rewarding.

—James McDougall

Muskeg Engineering Handbook, edited by Ivan C. MacFarlane, Canadian Building Series, University of Toronto Press, index, 1969, $15.00.

Canada contains some half million square miles of muskeg, an area nearly the size of Alaska. With all this muskeg to ponder over, much of it in the permafrost zone, the Canadians have logically assumed leadership in muskeg research. **Muskeg Engineering Handbook,** number three in the Canadian Building Series by the National Research Council, is a comprehensive treatise of muskeg engineering in Canada.

Basically a state-of-the-art, chapters include: muskeg classification, air-photo interpretation, engineering characteristics of peat, engineering investigation, construction and vehicle trafficability. It reflects primarily Canadian research efforts and experience but makes use of information from other northern countries. Information is drawn from experience gained since man has had to transport himself or his effects over muskeg areas, though by far the bulk of the knowledge has accrued in the past two decades. Much of the material, and the impetus for this book, comes from the annual Canadian Muskeg Research Conferences, which began in 1955 and attract scientists and engineers from all phases of muskeg research, construction and operations.

The book is directed to engineers in engineering language. Most chapters contain a significant amount of empirical information—a pragmatic blend of experience and engineering investigation. Some soil theory is presented by it is not dominant simply because of the infancy of muskeg research. The evidence indicates, however, that organic soils can be treated

much as inorganic soils with proper cautions. Techniques that have been shown to work or fail in specific instance emphasize much of the text.
For a basic work the editors have carefully provided the Handbook with an index, glossary, list of symbols and an abundance of illustrations, graphs, and tables. Chapters are broken down into numbered sections and subsections for easy reference. Each chapter is followed by a substantial bibliography.

Muskeg Engineering reflects the wide range of research and interest that went into it and is an excellent effort of presenting, in readable fashion, the current state of knowledge of engineering in muskeg. It is an excellent addition to the Canadian Building Series.

Although the chapters have been coordinated by various experts, therefore reflecting individual styles, the editing has been well done so that symbols and terminology are uniform throughout and the chapters fit in logical order. However, though the first three chapters are informative and solid material for the introduction, the style is a bit stiff and doesn't read as easily as the rest of the book. The third chapter particularly, which throws a lot of classification symbols at the reader, could stand a little better editing.

The material is thorough enough to present the basics of each problem type and carry through the mechanics of various solutions and also provide economic factors and some theory for the engineer to wrestle with. Areas where additional research and practice must be applied are pointed out: this is a new discipline and much of it is seat-of-the-pants engineering.

Prior to this book, considerable engineering information was available on muskeg but scattered throughout myriad papers, publications and conference proceedings. Engineers concerned with operations in muskeg areas would do well to peruse **Muskeg Engineering Handbook** and make use of its comprehensive treatment of muskeg utilization.

—Mike Tauriainen

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