THE NORTHERN ENGINEER

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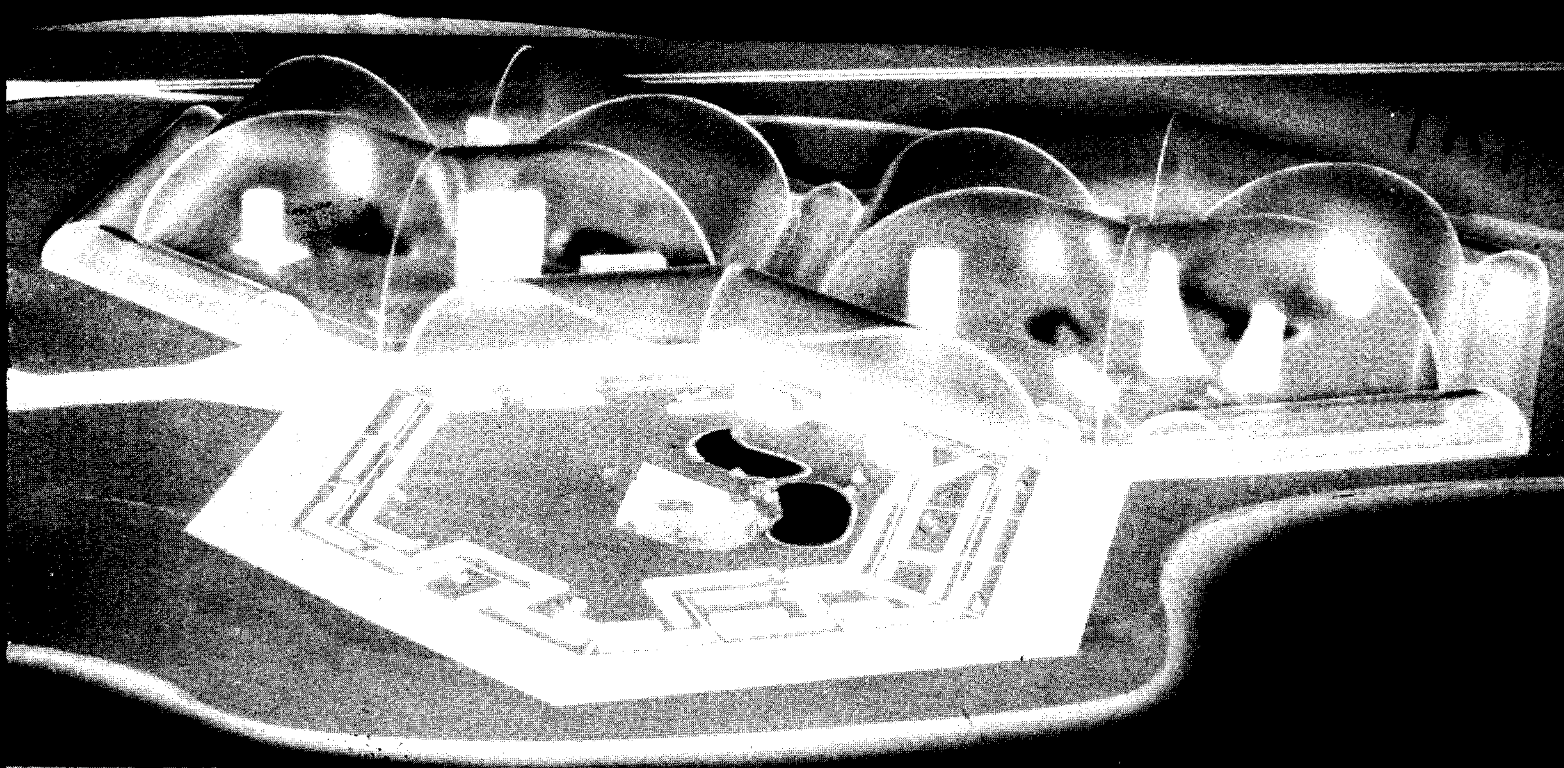

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Northern Architecture

John Eberhard, now dean of the School of Architecture and Environmental Design at New York State University at Buffalo, is rattling the foundation of the architectural-engineering establishment. His progressive approach to design of communities as well as individual buildings is refreshing. THE NORTHERN ENGINEER is fortunate to be able to publish Mr. Eberhard's comments on northern architecture.

Architecture, in its most comprehensive sense, is the bringing together of art, science and technology in the realization of the built environment. Many skills are used by society in accomplishing this end, only some of which are specifically embodied in those professionals called architects. This is not meant to detract from the contribution which architects can make, but to point out that the concept of "architecture" is broader than one would define by saying that it is what architects do.

Those of you who live and work in the North know of the history of indigenous shelters which natives of your part of the world have been building for themselves for centuries. The igloo is not designed by someone, manufactured by an industrial firm and constructed by a contractor and yet it is part of your architectural heritage. In the best sense of the word, the igloo is a systems response to a unique environmental shelter problem. It is the result of a systems approach that developed naturally over the centuries, because it utilized the available resources and skills of its producers and met their basic human needs.

It is strange that with all of our advanced notions of art, our advanced scientific knowledge, and our advanced technology capability, we are doing such a poor job of providing basic shelter for man in this part of the world. We could learn lessons from the history of igloo "technology". If our designers addressed themselves to questions of how to design systems of building which utilized the resources and skills of our society in an effective manner, and if such systems designs derived their criteria of goodness from user satisfactions (not designers ego satisfactions, but the users of the buildings needs as men who need psychological, physiological and sociological satisfactions) then we would be well on our way to a more responsible role. Your climate and geographical characteristics add the special requirements that any such system of building recognize these environmental constraints as well.

If those of us who are concerned about socially responsible architecture were to move in the direction of systems design, then no skill is unneeded and no challenge too great. Engineering, after all, is the practice of bringing ideas into the marketplace and making something happen.

—John P. Eberhard

THE NORTHERN ENGINEER

is a quarterly publication of the College of Mathematics, Physical Sciences and Engineering of the University of Alaska, Charles E. Behlke, Dean.

EDITORIAL STAFF: Mark W. Fryer, E. Staples Brown, William R. Hunt, Norma H. Martin, and Nancy S. McRoy.

We will consider manuscripts of any length, whether short descriptions of current projects relating to Arctic Science and Engineering, or fully developed research reports. While our focus is on technology, we view it broadly, thus are interested in the social, natural and political aspects related to cold regions engineering.

All correspondence should be addressed to THE NORTHERN ENGINEER, University of Alaska, College, Alaska 99701. Subscription rates are $6.00 per year, $10.00 for two years, $20.00 for five years. Single and back issues may be obtained for $2.00 each.

Looking Forward

THE NORTHERN ENGINEER has grown over the past year from an idea to a circulation of 1,500. The circulation breakdown is as follows:

Canada	20.5%
Contiguous U.S.A.	11.0
Western Europe	1.9
Eastern Europe, Japan & the U.S.S.R.	0.5
Alaska	26.5
University of Alaska	39.6

Recent interest in the North has required scientists and engineers throughout the Northern Hemisphere to become more knowledgeable in the technology of the North. It is our intention to assist people just starting to work in the Arctic as well as to keep the practicing Arctic engineer informed.

The Winter 1969 issue of THE NORTHERN ENGINEER will, as reported earlier, highlight environmental engineering. Dr. R. Sage Murphy, director of the Institute of Water Resources, University of Alaska, head of the Department of Environmental Health Engineering, University of Alaska, and special consultant to the World Health Organization, is guest editor for this issue.

For the Spring issue of THE NORTHERN ENGINEER we will again orient the magazine toward a single topic. Arctic Ocean and coastal engineering will be featured. Articles on satelite surveys of sea ice coverage, the Manhattan tanker/icebreaker and ice structures will be among the topics covered.

We wish the readers to be aware that THE NORTHERN ENGINEER will conform its content to the wants of the reader. We are not specifically dedicated to affairs of Alaska, rather we are dedicated to the problems and accomplishments of the northern technologist, who is our reader.

—Editor

TO COUNTER

The Hostile Environment

Only in recent times has man begun to appreciate the full potential of the air around him. It was less than a lifetime ago that we learned that free air can support a moving airfoil, and that captive air in a pneumatic tire can support the heaviest vehicles we build. Even more recently we used semi-captive air to support "Hovercrafts", and the friction-free turning platforms for 300,000 pound jets.

We can also use semi-captive air to support transparent plastic membranes. These membranes, almost unaided, can provide a method of controlling our thermal environment. We can do this on a scale and at a cost which, until now, would have been regarded as impossible. It would now appear logical to consider placing an air-supported membrane between ourselves, our construction projects, or our communities and any environment which is unreasonably hostile.

This article is written to outline a method by which this can be done quite easily—with equipment which is readily available and with materials that are all "home-grown". In northern areas the key question will probably be the availability of power. It will be required in moderate quantities—perhaps ½ h.p. per 1,000 sq. ft. of enclosed area—but the supply in some form must be continuous for small enclosures and available on demand for major enclosures.

What is new in our technology which makes all this possible? These things—plastics, power and polydomes.

Plastics and power are not basically new, obviously. The new element in each is its cost relationship to our economy as a whole. In each case, the cost is decreasing, either relatively or absolutely. Furthermore, the physical properties of plastics are improving sharply, as is our ability to use power to supply air continuously and economically.

The third member of our new triumverate, the polydome, is a device for containing semi-captive air under pressure. The pressure is very small, about one per cent of atmospheric pressure, but the enclosure may be large. Its structure is shown in Figs. 1, 2 and 3.

Atmospheric pressure at sea level is 14.7 lbs. per sq. in, or 2100 lbs. per sq. ft. With that kind of pressure around us, we need make a very small change, less than one per cent, to support our membrane, its reinforcing and tethering cables, and, if necessary, a snow load of 15 lbs. per sq. ft. A one per cent increase in atmospheric pressure is much less than the natural variation in barometric pressure from, say, 29 to 31 inches of mercury. Each time we descend to street level in an elevator from the 25th floor we encounter a pressure change of about one per cent.

The problem is that of containing air under pressure. It is only after we have mastered the art of containing air that we can use it as a structural member.

If we think of large pressurized enclosures of hemispherical form, we encounter tremendous stresses in the membrane even at very low pressures; these stresses increase as the square of the diameter. The secret of success lies in dividing the area we wish to cover into modules of reasonable size, and incorporating a system of reinforcing cables to carry the stress in the cable system rather than in the membrane itself. With this approach, the stress in the membrane becomes a function of the size and shape of the module but it is independent of the size of the total enclosure. Further, if we use the membrane as a membrane—carrying the stress only as far as the first element of our reinforcing system—we can make it as transparent to light and heat as is necessary to meet the visual and thermal requirements of our enclosure.

The Polydome

Fig. 1 shows a single dome in a polydome system and the tree-like reinforcing system to transfer the stress from the membrane through to the lateral cables, the quadrant and perimeter cables, and the tethering cables to ground. The air outlet at the top of each subdome is controlled by dampers returning to a closed position in the event of power failure.

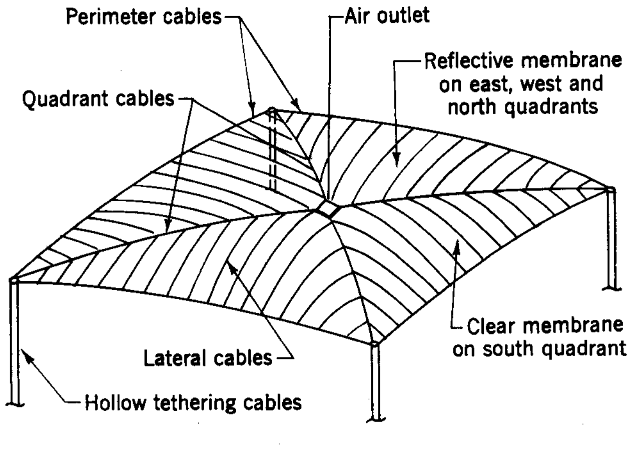


Figure 1: Typical module of polydome structure.

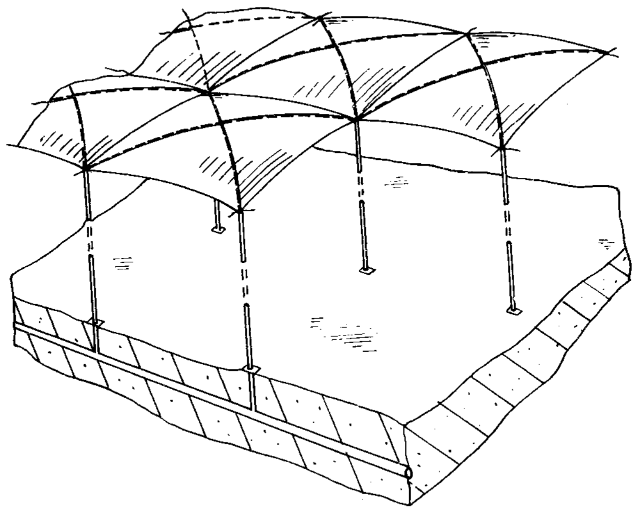


Figure 2: Subdomes linked to form a continuous enclosure.

Fig. 2 shows the individual "subdomes" linked to form a continuous enclosure. This drawing shows only part of the total enclosure. We have to close in the perimeter, nesting the dome into the topography, or grounding it on high-rise buildings ringing the enclosure, or on a wall, or a chain link fence lined with the membrane.

Fig. 3 shows an application of this thinking to a community. Although the hollow tethering cables are connected to storm sewers in this diagram, they could also be led to reservoirs to capture the relatively pure rain that falls on the upper surfaces of the enclosure.

Stability of the Structure

Fig. 4 shows the geometry of a module and provides the basis for an elementary mathematical analysis of the upward lift on an individual subdome due to the elevation in temperature of the air captive to each subdome. The objective here was to determine the conditions necessary to make each subdome self-supporting. Whenever these conditions are present, we eliminate the need for power to drive the fans and for airlocks at entrances and exits. In the event of a total failure of the supply fans or the loss of one or more subdomes within a large enclosure, the structure as a whole remains stable.

Our present capability permits us to construct single domes up to about 500 ft. in diameter if we use cables to reinforce the fabric. The air-supported dome designed by David Geiger of Geiger & Berger in New York as the U.S. Pavilion for EXPO '70 in Osaka, Japan is essentially rectangular, approximately 500 ft. by 300 ft., with two sets of reinforcing cables, one running parallel to each diagonal, and spaced on 20 ft. centers. These cables are anchored to a concrete perimeter ring carrying the compression load and providing the weight necessary to ground the structure.

Taking this as the most advanced example of the present state of the art, we based our calculations on polydomes 500 ft. and 600 ft. square. These calculations indicate that, in the case of a 500 ft. subdome and a 20°F temperature elevation, we have an upward lift of 0.178 lbs. per sq. ft. of subdome surface. The membrane itself weighs about 0.04 lbs. per sq. ft. The weight of the reinforcing system will vary somewhat with the design of the enclosure as a whole, but a reasonable design figure would be 0.10 lbs. per sq. ft.

From this it would appear that our system will go "critical"—if we can bend the meaning of that term—with subdomes 500 ft. square and larger, and temperature elevations of 20-30°F from a base of 40°F, modules of 400 ft. to 600 ft., and "leaving angles" of 45 degrees and 60 degrees—due only to buoyancy of the air captive to each subdome.

Is It Feasible?

Two of the more obvious hazards which our structures must face are snow and wind. We now hold some of the answers to the questions posed by these two hazards.

SNOW — We can expect to encounter snow when the temperature inside the dome is substantially higher than the temperature outside. Assum-

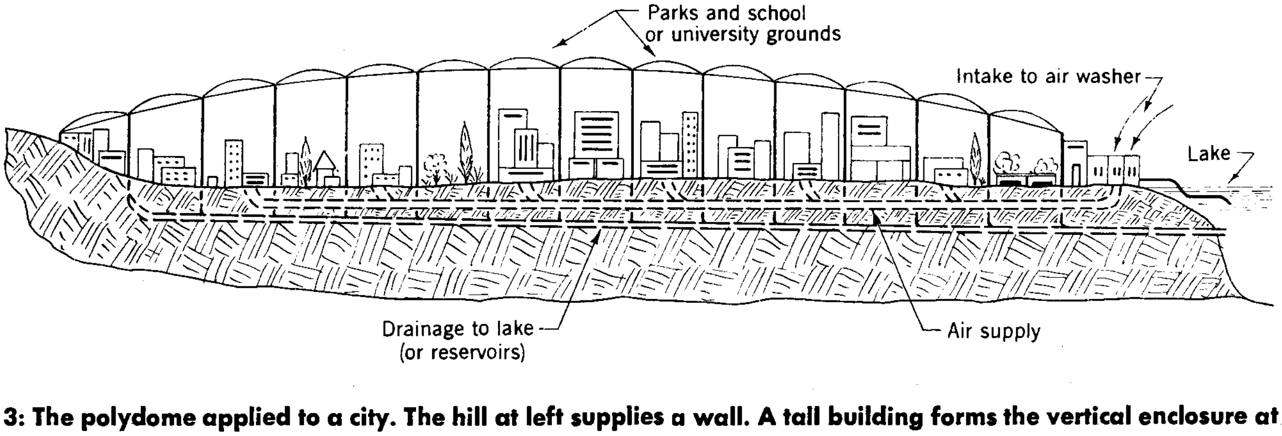


Figure 3: The polydome applied to a city. The hill at left supplies a wall. A tall building forms the vertical enclosure at right.

ing a mean height of 600 ft., an outside temperature of 30°F and an average inside temperature of 60°F, we will have to plan for a lift due to the "stack" effect of 3.0 lbs. per sq. ft. without any positive pressure within the enclosure as a whole. As noted above, we can easily provide a positive pressure of, say, 4 in. H_2O. This would allow us to support a total weight of 23 lbs. per sq. ft.

From this, two conclusions are suggested. Firstly, there is no need to melt the snow as it falls—provided the total uplift is at least equal to the maximum predictable single snowfall, and we can melt the snow between snowfalls. Secondly, the structural stability of the system is linked to the thermal stability.

It is also obvious that the overall feasibility of this approach depends to a considerable degree on the weather patterns. It may be quite feasible in Arctic regions, where snow loads are generally light, and yet impossible to propose in areas directly south of the Great Lakes, where a single snowfall may bring 20 inches of heavy snow.

We can well be concerned with the reduction in light levels within the enclosure following a heavy snowfall, particularly if the wind has been too light to blow the snow off the top of each subdome. Snow is not opaque, however, and as soon as a portion at the top of each dome is clear, it will act as a skylight.

WIND — Air-supported structures of the polydome type are inherently more resistant to high winds than those of the "first generation" or single dome type. If, in the latter case, we assume an essentially hemispherical cross-section, we encounter comprehensive forces on the lower windward portion of the bubble due to the ram effect of the wind velocity, plus negative or tensile forces due to the airfoil effect on the upper and leeward portions.

To stabilize the fabric, the internal pressure must be sufficient to counterbalance the ram effect. This becomes additive to the negative pressure in calculating the total stress in the fabric. In spite of this, single-dome structures have withstood wind velocities of 124 mph.

The cross-section of a polydome is relatively flat and presents very little area on which the ram effect of the wind can act. It is highly probable that a typical polydome can be designed to react only to the tensile forces due to the airfoil effect. This would make it unnecessary to raise the internal pressure during periods of high wind.

Qualitatively, it is interesting that David Geiger's model of the U.S. Pavilion displays a cross-section comparable to that of a single module in a polydome. His model was completely stable at simulated wind speeds of 130 mph, the design figure, and withstood a wind speed of 200 mph before it started to flutter.

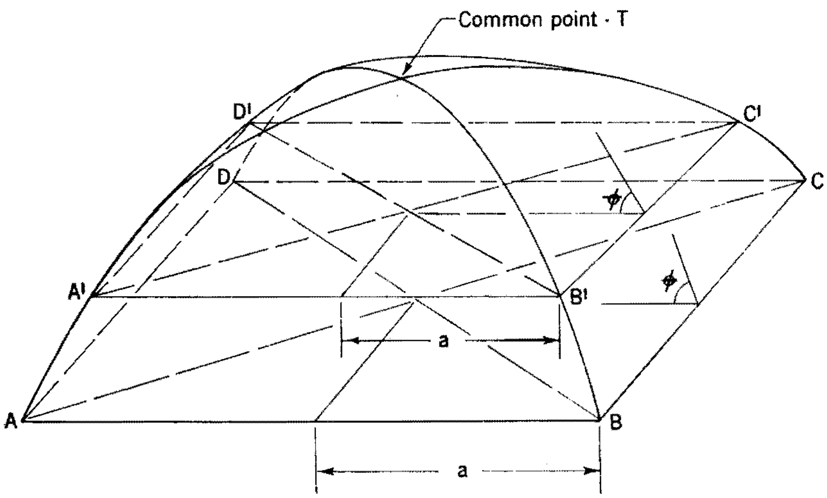


Figure 4: Mathematical analysis of the buoyant effect of warm air within an enclosure. The module is defined by two intersecting cylinders (or portions of cylinders) with one common point, T, and a common base plane, ABCD or A'B'C'D'. Height of the base plane can be defined in terms of the "leaving angle", ϕ: Volume $= (4^3/3 \sin^3\phi)(2 - 3\cos\phi - \cos^3\phi)$; Area $= (8a^2/\sin^2\phi)(1 - \cos\phi)$. (The author acknowledges the help of Dr. Bernard Maissen of the University of Toronto in deriving these formulae.)

How Long Will It Last?

Presently, "first-generation", single-dome, stressed-fabric structures operate for about five years before the double-coated nylon fabric must be recoated or replaced. It is imperative that the nylon be protected against degrading due to ultraviolet as the nylon itself carries the stress.

Cable-reinforced structures can be made from at least three types of membranes, each with its own life expectancy. Polyvinyl fluoride film reinforced with a fiberglass "scrim" is good for perhaps 15 years. Woven glass fiber fabric coated with polyvinyl chloride is good for 5 to 10 years. Woven fabric of elongated polyethylene fibers melt-bonded to a layer of polyethylene is good for 3 to 5 years.

Polyvinyl fluoride film made by Dupont under the trade name "Tedlar" is essentially transparent to and unaffected by ultraviolet rays. It is also so resistant to soiling that it is now being used to line air-conditioning ducts serving hospital operating rooms.

Woven glass fiber fabric made by Ferro Corp. Cordo Division is highly translucent, highly resistant to flame, and obtains very high tensile properties through the use of Beta glass fiber yarns in both warp and fill.

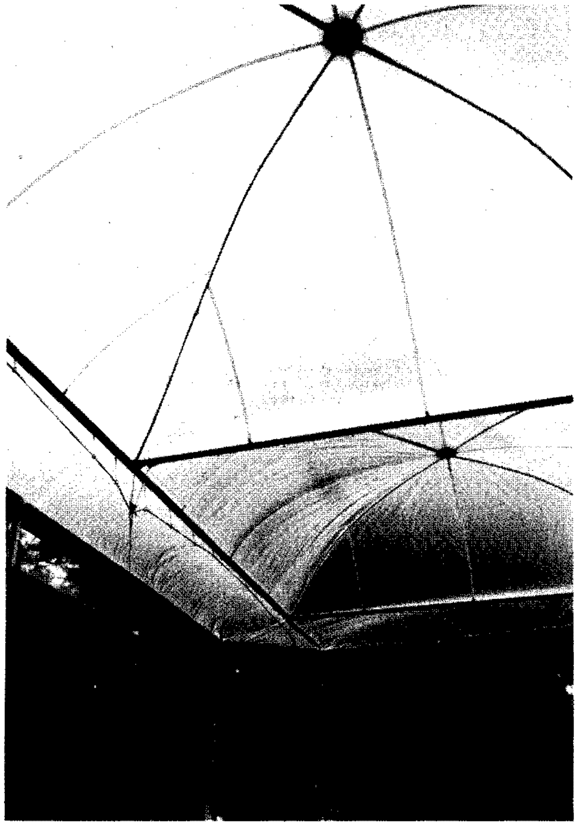
Woven material made by Dupont under the trade name "Fabrene" uses ultraviolet-inhibited polyethylene or a similar low-cost material, elongated to orient the molecular structure in line with the strands, and woven into a fabric that displays reasonable resistance to degrading, excellent tear resistance, moderately high tensile properties, and excitingly low cost.

Thermal Stability

To those of us born and bred in the air-conditioning field, the most challenging questions surround the thermal stability of these enclosures. A few starting points are obvious.

—The larger the enclosure, the greater will be its volume in relation to its surface, and, therefore, the higher its thermal stability. The phenomena involved are complex, however, and to date very little data have been developed to give us the answers we need. We all know that the top of the bathroom mirror gets fogged first when we shower. But what parameters govern the temperature and humidity gradients within "open" enclosures hundreds of feet in height? How much latent and sensible heat can we exhaust through the controlled openings at the top of each subdome? What minimum temperature elevation can we expect in the air captive within each subdome?

—To control radiation inflow and outflow, reflective films of the type made by 3M under the trade name Scotchtint can be incorporated in the polydome membrane. One obvious approach is to use reflective film on the north, east and west quadrants of each subdome. This will limit solar load during the summer when the sun is high and admit and retain most of the heat available in winter through the clear southern quadrant when the sun is low.



A prototype polydome, inside view, recently erected in Toronto.

The Path Ahead

If we hope to place second-generation air structures at the disposal of those planning the development of the North, we must translate this thinking into a model "polydome" and then move through a scaling-up process. The first step on this path has been taken.

The prototype polydome covering 1,400 sq. ft. is now entering a one-year test period in Toronto. This structure incorporates six modules. Three of these are completely independent of any rigid structure and function as true elements of a polydome; three are mated to the author's house. The membrane material is "Fabrene". Each module is fitted with an air-relief valve adjustable to open at any pressure between 1 in. H_2O and 4 in. H_2O. The fan can be operated to deliver air at pressures up to 3½ in. H_2O. The perimeter member is a 5 ft. chain link fence with about 3 feet of clear vinyl running to the 8 ft. level at which the modules are anchored.

This prototype will provide an opportunity to live with and in a polydome—to test its performance under snow and wind loads, to determine the natural temperature elevation, to walk about under, perhaps, 12 in. of snow, to experiment with tulips in February, roses in March, and lettuce in May and to learn most of the things we can do better in the next, larger model.

It remains for all of us interested in modifying our more hostile climates to carry forward the development of these environmental envelopes, and to apply both intelligence and imagination to probe the limits of their application possibilities.

—T. W. McLorg

Table 1: Uplift available for dome support.

Temperature Difference, Inside Air (above 40F) to Outside Air, Deg F	Module Size, Feet					
	400		500		600	
	Leaving Angle, Degrees					
	45	60	45	60	45	60
	Uplift Due to Buoyancy of Captive Air, Pounds per Square Foot of Membrane*					
20	0.094	0.145	0.115	0.178	0.140	0.221
30	0.138	0.213	0.158	0.252	0.205	0.325

*Assumptions: Dewpoint is constant 35F and base of each module is a flat plane.

Architecture and Town Planning in the North

Ralph Erskine, originally from England and now a permanent resident of Drottingholm, Sweden, is well known as an architect who deals creatively with the severe environment problems of Arctic and sub-Arctic living.

THE NORTHERN ENGINEER invited Mr. Erskine's thoughts on northern architecture for this issue. Mr. Erskine was kind enough to suggest that we reprint the following article, which appeared in 1968 in Vol. 14 (89) of the POLAR RECORD.

When considering the problems of building in the North, to talk of an architecture of climate would be to tell only half of the story. It is people in the climate, the cities and the landscape, in families or crowds that count. Ordinary people, not architects, people who are moving from more populous areas to small isolated communities in the wilderness, and must be given the amenities they previously enjoyed.

I try to base my work on that seasonal rhythm of the North which I find so enthralling, and form communities which encompass all its richness of contrasting experiences. I shape my buildings with a completely protected winter part surrounded by sheltering outdoor places for spring and for fall. Beyond these is free summer life in the natural landscape with which the North is so richly endowed.

It can be difficult enough to express these thoughts in words—how much more difficult to say them in concrete and wood, in asphalt and glass, to say them with precision and warmth but without unnecessary pathos and exaggeration.

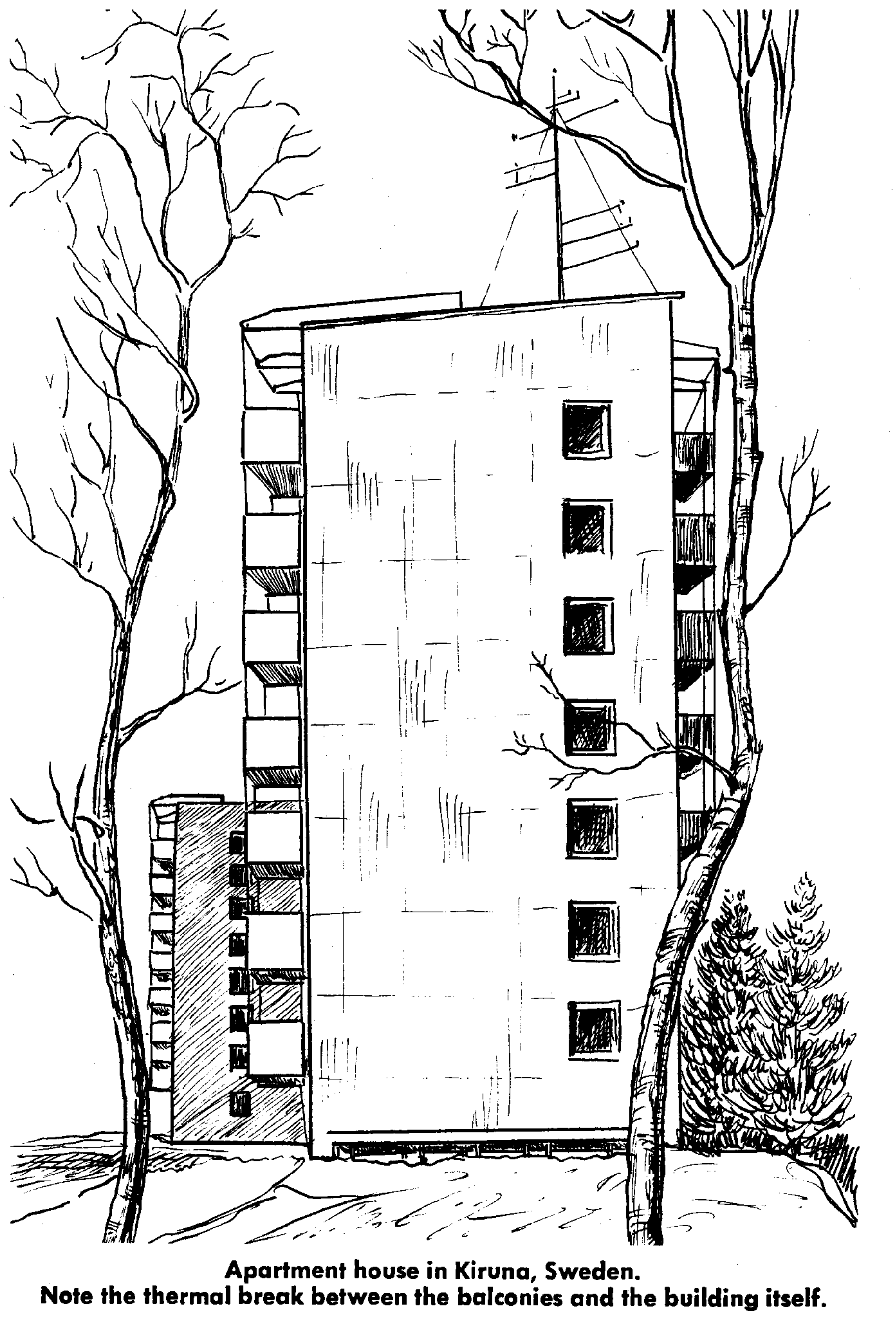
For it is surely buildings, and streets, gardens and trees, not economy, technique and aesthetics that people dream about when they seek a home, or a place in which to work or play; these are only as the bricks with which to build a great and complicated dwelling, a place to find warmth and protection, to find both togetherness and privacy and feeling that "this is where I belong, this is my dwelling and here I will like to be".

I hope that we architects could give such a dwelling a form, make a space with a potential for contentment. But in the final count it is the inhabitants who will give the same dwelling its meaning and will change our architectural space to place.

My question is, "Do the cities and buildings of the North well serve the needs of their inhabitants"? My answer is "No".

Man in his ingenuity has invented many ways of protecting his puny body—of maintaining its surface within the narrow range of temperatures and humidity which allows for survival. As his inventiveness and artistry increased he has moreover created conditions of convenience, comfort and pleasure.

Where could this protection be of greater need than in the North? But



Apartment house in Kiruna, Sweden.
Note the thermal break between the balconies and the building itself.

cities—our most concrete artifacts, which represent nothing other than their own existence—are none the less liable to the laws of symbolics and fashion, and a house not only has to be a house, to shelter, protect and function, but it must also symbolize a house, a city must represent a city.

When I came to Scandinavia and the North at the end of the 1930s I found, after living there some time, that this symbolic aspect of architecture in some ways seemed to be regarded as of greater import and urgency than that primary purpose—to clothe, to comfort and to protect. What little I have seen in Canada and Alaska convinces me that the situation there is no different. Neither in Canada, Alaska, Scandinavia nor Siberia will I find communities intelligently and inventively built to give pleasing and effective comfort and protection in the specific conditions of the North. I can find Arctic outposts or alpinist huts technically giving survival conditions in situations of extreme stress, or cities with overheated buildings and draughty streets, but nowhere can I find a sector of our modern culture which has a special local flavour of the North due to a combination of understanding, inventiveness and, not least, artistry in satisfying special human needs in this special part of the world.

Since I was caught by the fascination of the North and began to sense the challenge as well as the needs and possibilities of the situation there, I found it difficult to reconcile the northerners' love of their forests, rocks and islands with their longing for southern ways, and to explain why their modern buildings so often had the arcades, pergolas and **bris-soleil** which belong to a far more southern climate, but have become symbols to be used in the architectural rat-race.

With time, I realized that one of the characteristics of the northerner is that he is conscious of living at the outer edge of the happenings which are central in the interests of the time, far from the metropolitan centres where the fashions and culture of the age are created. He longs to belong to these happenings, or if he himself has no greater interest, his wife, his children and his artists are all drawn to these great magnets. One of his methods for maintaining the emotional threads of contact is by imitation of the styles and thoughts of the innovators in the great capitals of the world, and he does this even if the styles serve no more useful purpose in this special situation than do city hats or silk stockings at the polar circle. In the outlying parts of the region, where practical and self-reliant people—hunters, fishermen, traders or engineers—live in small isolated communities without contact with or great interest for artists and other culture-bearers, this tendency is particularly apparent, and such communities are very ill-equipped for creating a specific and indigenous branch of modern culture fitted to the land in which they live. The cultures of Lapps or Eskimos, which are excellently adapted for the life of a northern huntsman, degenerate and finally collapse as these native people also feel the drag and fascination of the new ways of the southern cities. Nor does the southerner who moves into the region find these nomad cultures of help other than in his hunting journeys or his sports—the northern community culture of the industrial age must be newly invented, and social scientists, artists and architects must help.

This is a task which grows in importance as minerals and other natural resources are developed and the role of the North changes. Instead of huntsmen and traders, northern communities must attract engineers and technicians and their wives, people with special knowledge and capacities. It cannot only rely on the adventurers and "Arctic enthusiasts" who are prepared to enjoy a wilderness life.

What then are the characteristics of this sub-Arctic realm, lying between the empty Arctic wastes and the bountiful fields and teeming populations of the temperate zone? How does it form our lives, how should it, with our sensitive help, mould the buildings and cities we use?

Above all it is a world where it is only with the advent of our technical civilization that man became free from a long and constant warring with the difficulties of an inhospitable climate, and with wresting meagre returns from its meagre soil. It is a world without a rich history of city culture and techniques precisely adapted to its special demands.

It is a world of great contrasts, of the yearly rush from the cold, dark sterility of winter through a short and explosive spring to a few green months of life under the night-time sun. And so the swing back through rapidly shortening days of mist, rain and frost to winter, snow and ice.

These are happenings of great import to the people who experience them and it can be seen how spirits lift as the days lengthen and melting snow runs in the gutters, how people put up their defenses as autumn frost and darkness grips the land. In summer they plunge into the chilly lakes and wander the streets in the midnight sun, in winter they draw up their fur collars and hurry from house to house, and spirits droop unless lights are lit both indoors and out.

Here houses and towns should open like flowers to the sun of spring and summer but, also like flowers, turn their backs on the shadows and the cold northern winds, offering sun-warmth and wind-protection to their terraces, gardens and streets. They should be most unlike the colonaded buildings, the arcaded towns and mat-shadowed streets of the south Europeans and Arabs, but most similar in the basic function—of helping people to maintain their skin at about a comfortable 30°C. When studying the beautiful towns of the south, whether old or new, it is not the forms in themselves which should interest us, but the inventiveness and artistry with which people solved the needs which were peculiar to their situation and time, the comfort and beauty which they created. Only by such methods can arise a personal and indigenous

Alaskan, Canadian, Scandinavian or North Russian tradition.

The implements of city building for creating these conditions in the North are many, but several changes must be made in the present thin tradition of community building.

The greatest change is that of introducing a considerably greater degree of concentration than has so far been usual. The loosely scattered villages of the North seem to be built by wilderness dwellers who were in harmony with abundant space and wished it to flow through their towns and around their houses. At best, northern towns have become very like all others; similar in appearance, function and structure, but less pleasant and convenient due to their isolated situation and exposure to a harsh and extreme climate.

Concentration gives exceptional advantages in the North if once it is emotionally acceptable, but I have experienced the difficulty of this type of innovation when working in the town of Kiruna, in northern Sweden. It was possible, for example, to point out the exceptional costs of road building, maintenance and snow clearance, of laying drains and water mains at a depth of 3 m often in rock, to protect against frost, as well as the discomfort of moving in an open windy community in the winter blizzards. When I prepared a scheme for the complete renewal of Kiruna, I suggested continuous runs of buildings where people could move outdoors in wind protected sunny streets, or indoors in enclosed and heated walkways—the warm, northern equivalent of the cool arcades of Perugia and Venice. In the floors and ceilings of these walkways, instead of under the streets, easily accessible for repairs and for laying of additional services, were ducts for the sewers, pipes and cables. There were many characteristics of the project which were particularly suited to Kiruna dwellers' needs, but, though the proposal for central redevelopment of ten city blocks of this township of 20,000 people was accepted, the strength of a mere fifty year tradition on the one hand, and the unfamiliarity of the vision I gave on the other, were such that the town has been built on its original street pattern and with a largely traditional structure. One central city block, is, however, so built that it reminds one of the original concept, and has for me been of great interest to design and execute.

In the project for a new mining village of Svappavaara there have been far too many deeply regrettable compromises but sufficient of the original idea has remained to give experience and to win approval from the inhabitants. It is proposed to build a second stage according to the same principles.

It is curious, but perhaps inevitable, that farther south, where the need for these ideas is far less urgent, I have usually found them more readily acceptable. Possibly the new building types for northern Canada must first be built in Montreal or Vancouver?

However this may be, having experienced the successes of these schemes, and seen the unsuitability of the compromises, I am even more convinced of the need to find new forms for northern communities and consider that, with certain adjustments and additions, my general thesis of their structure is still valid.

For microclimatic reasons, a township should be built on a south slope where the radiation from the low Arctic sun is more intensive than on the flat country, and where protection from the cold northerly winds is greater. Further advantage can be gained by turning to the south-east to catch the early morning radiation which tempers the cold night air. The validity of such a placing is well supported by observing vegetation on the sterile northern screes and the luxurious southern pastures of Norway, the vineyards on the south slopes of Lausanne or the potato fields on southern slopes in north Finland. The exposed tops of hills, or shadowed northern slopes, should clearly be avoided, and I wonder whether new towns should be built on the crown of a windy, Scottish hill with dwellings on the northern slope facing the Highlands —I remember that farmers built long rows of trees across the Lowlands to break the winds, and placed their farms in coppices or in the valleys. But in more extreme climates the low parts of valleys should also be avoided, for in the still of intensively cold weather the heavy cold air flows from the hills and collects in the hollows and valleys.

The structure of the town itself can be of vital importance in improving the climate within its boundaries, and with modern techniques almost any degree of protection can be achieved. One of the most exciting ideas which comes to mind when first presented with these problems is that of the township which is a single enormous building complex, or a township covered by domes or suspended membranes. In the most extreme conditions of the Arctic or Antarctic, these could be the most suitable ways of providing climatic defense. The physical convenience of such a township would be very great, and it would tend to be economical to run and to heat. The greatest difficulties would probably be of social and psychological nature since such a town could easily be institutional and introvert, and though openable parts of the structure could give certain contact with the outer world, this would tend to be indirect and tenuous. Negative experience has been reported from northern encampments where people have been able to live without contact with the outer world that surrounded them, and it has been suggested that less sophisticated organization has been more successful.

To me it seems, however, that in the most extreme situations such techniques should be deployed, but with an even greater degree of sophistication and fantasy which would take into account the problems I have mentioned.

In such a town, or indeed in the central part of a sub-Arctic town where partial use of these planning techniques could be suitable, a multitude of varying functions would cluster together for common protection and warmth, and an assessment of the needs for external contact and daylight would need to be established. The dwellings, schools, workshops, meeting places and shops find their place within the general structure in relation to the urgency of their demand for contact with the outer world or with internal parks.

Due to the fascination that such structures have for engineers and architects, it is necessary to warn against the science-fiction aspects of the concept and the over-exaggeration of their importance. High-Arctic establishments will probably neither be numerous, large, nor places of long-term dwelling. In the sub-Arctic there are long, light nights and the cool summer warmth which are so precious that they are the dream of the northerner moved south. There is the brilliant sun on snow and the crisp clean air of spring which Kiruna dwellers look upon as the loveliest time of the whole year, more precious than their three green summer months; there is the blaze of autumn colours and the first thin blue ice on lakes. It would seem that other more subtle instruments than total coverage, a wider range of experiences must be sought in the low-Arctic. There should be offered a system of sheltered, outdoor walkways, open to the sky, the sun and to falling snow, and interlocking with this a system of enclosed, heated and daylit streets for bad weather. A third system, covered where possible to reduce snow clearance costs, would be the car routes which can lie on the northern sides or in the cellars of buildings.

Continuous strips of buildings can encompass and protect zones for gardens and for smaller buildings, they will reflect warmth and sunlight to their southern side and protect from the coldest winds. Accumulation of snow on the lee sides of such buildings, in regions with heavy snow drift can, however, be a very real problem and study of aerodynamic forms is necessary. Adjustable shutters, a type of brise-vent, and buildings with aerodynamic form giving "stalling" characteristics are two of the methods to be considered. These can protect against storms without hindering quieter breezes, normally give still air for comfort but air movement to clear snow, or mosquitoes when necessary.

Since they only have a limited sphere of influence, such strip buildings would need to be repeated at intervals or additional windbreaks created by tree belts, a structure which would sub-divide and give character to a town. Such tree belts, combined with snow traps of bushes, are known to road engineers and to prairie farmers, but I sought them in vain in the township of Winnipeg.

Each individual building should also be given such form and equipment that it would protect both itself and its own outdoor-room, should present its inhabitants with sheltering sun catchers, and a wind-protected entrance for an arriving guest or a householder unlocking his door.

Should these characteristics be applied to the design of a whole township, to its buildings, its streets and its parks, the result would not only be an instrument for comfort and convenience, but also a structure with elements of aesthetic harmony in all its parts, the kind of harmony to be seen in the desert village, or in fishing villages pressed in amongst the rocks.

The snow is another factor of considerable import. Not only does it hinder traffic when it falls, but the costs of clearance are considerable, especially if it has to be driven from the streets. Where it is not driven away the space demanded for the street and sidewalk, as well as for ploughed-up snow is considerable. The wider the carriage-way the more space is required, and the town expands and loosens in order to accommodate this snow storage, more land is used, distances increase, and the protective effect of buildings reduces. When cars take longer to stop due to snow and ice it is unallowable that snow-piles at street corners hinder sight, or that sidewalks are cleared later and less well than carriage-ways, so that children run in the street; yet the problems of snow clearance are such that this is very common.

Separation of pedestrian and mechanical traffic is therefore even more important in the North than elsewhere, and the temptation to ignore it just because of snow difficulties must be firmly resisted. Narrow outdoor pedestrian ways can be cleared by tractors, by small equipment or by underground heat, and can offer safety, wind protection and intimacy, a contrast to the wide curves and easy gradients of car roads which must facilitate the use of rapid and large-scale clearing equipment.

Whilst in the south distance of thirty to fifty metres from dwellings to cars can well be accepted, people will not readily enjoy walks in a blizzard or in loose snow, and car pick-up possibilities near to dwellings become essential in the North.

Also movement on the snow should be planned for, snowmobiles and snow-scooters, for ski-running or tobogganing on non-sanded paths, for ice-hockey rinks, ski-jumps and slopes, and snow play places for small children to climb and build in, and all these should be lit for evening use.

The beauty of snow and of rime frost in trees or on the ground, the sweeps and spirals of wind-blown snow, the reflection of lights from the white ground and roofs, the springtime run of icy water in gutters—all these and more are part of the aesthetic of the outdoor North, and should be part of city planning.

The low temperatures of winter do not in still weather present problems of great complexity since it is fairly easy for people to protect themselves against the dry cold of the high latitudes, but the impact of the cold on the design of buildings will be the more noticeable, tending to make them simple and compact in form, without unnecessary articulation of walls and over-dimensioned windows. Verandas, balconies and other wind-protecting sun-traps would be separated from the heated building so that thermal bridges which give movements, stresses and heat losses are reduced. They would be formed with a view to their function—to keep out wind and to reflect inwards the sunlight and warmth.

The dark winters would demand a highly illuminated city, with lighting which gives beauty in form and in colour and which uses reflection from the snow. Night shutters cut out the dark and the cold, but occasional large glass areas in the ground floors of buildings give contact with the warmth inside, and a flood of welcoming interior light over the street.

Windows also are needed for the spring and winter, to feed solar heat into the buildings, but shutters on bedroom windows, or no bedrooms to the north, so that people are not kept awake by the light and the heat of the midnight sun.

Buildings should if possible be given such form that south elevations are large to catch the light and warmth from the south, while north elevations are low, to avoid creating long shadows on the ground behind. Buildings so created will turn to the south, and their shutters will open and close with the changes of seasons and of temperature and light that fall upon them, responding sensitively to the variations of climate like the sun-excluding shutters of Italy.

The very limited choice of vegetation for planting can give an enforced stringency to parks and open spaces and lead to the use of other means to introduce variation into the landscaping.

In Svappavaara only fir, birch, and rowan trees, two types of bushes and a few flowers could be planted with confidence, it was necessary to dispose these few plants in a large number of formal and informal ways, in blocks, in spread planting or in rows. To add further variation the ground was modelled in sculptural forms and granite blocks from the iron mine placed in groups or as "individuals". Both the summer effect and the fall and drift of snow in the winter were part of garden planning in the town, and I have proposed that the fir forest be cut in sweeps and blocks, both for the landscape effect and to provide family ski slopes, steep slalom pistes and bobsleigh runs.

—Ralph Erskine

An Engineering Approach to Architectural Design for Cold Regions

Let us try to forget, for a moment, what a house, school or other architectural structure looks like, and attempt to describe what a structure that shelters people should be like using only engineering design criteria.

To start with, a shelter is nothing more than an envelope that contains a desired environment. In rigorous climates, large potential differences exist between the desired and the natural environments. Air pressure, humidity and temperature are probably the most noticeable environmental differences, although light values as well as color and texture might be included as important environmental parameters. The design of shelters for cold regions use should include more than a passing consideration of moisture-temperature relationships, heat transmission and the overall shape of the structure.

The Relationship Between Heat, Moisture and Cost

Moisture in the vapor state will migrate along a thermal gradient in the same direction as heat flow. The steeper the thermal gradient the more freely moisture will tend to move, unless inhibited in some way. The potential differential that drives moisture migration is the vapor pressure difference that may exist between a natural and a contained environment.

Assume that the temperature inside of our envelope is 75°F, and the relative humidity is 40 per cent. Under this condition the air will hold .0074 pounds of water per pound of dry air. If the amount of moisture in the air remains constant and the temperature of the air is lowered to 48°F, the relative humidity will become in excess of 100 per cent and condensation will result. Water in vapor form will move to replace the moisture as it condenses on cold surfaces. If a constant supply of water is available, moisture will continue to move unless the system is brought into equilibrium. The two options available for forcing the equilibrium to occur are 1) controlling the amount of water held in the air, or 2) controlling the inside surface temperatures of the shelter.

If a permeable skin is used to cover our shelter and the temperature inside is above freezing while the outside temperature is below freezing, moisture will condense in the material of the skin and at some point ice will form. Since an accumulation of ice on the inside of the walls or the covering of the structure is generally undesirable, a vapor barrier is normally required.

The results of poor thermal design in architectural structures are seen by the owner of the structure in the form of excessive annual maintenance and heating bills. Energy costs in northern Canada and interior Alaska range around $4.00 per year for every 100 square feet of surface area. (The basis for this figure is a heating index of 14,000°F days and a fuel cost of $3.00/million BTUs. Only heat loss through conduction is taken into account.) A typical single family dwelling will require in the neighborhood of 14,000 square feet of skin surface. A reduction of 25 per cent in the surface area of the structure would reflect a $140 per year saving in heating through conduction heat loss alone.

In summary, the basic restraints on architectural design associated with containing a desired environment in a rigorous natural environment are four: 1) inner surfaces must be kept warm because dew and, on occasion, frost will appear on cold surfaces, 2) the skin that covers a shelter must be impervious to moisture, 3) the skin must be highly resistant to heat transmission, and 4) the surface area of the skin should be minimized to economize on heat losses as well as building cost.

The Shape of a Structure

Shape is probably the least considered aspect—in terms of engineering significance—of the structures that we see around us. Because of this observation, shape will be discussed in some detail.

From a purely engineering viewpoint the shape that is most efficient for minimizing surface area and maximizing volume is the sphere. The people of the central Canadian Arctic have used the hemisphere shape for shelter design for at least 1,000 years. The Eskimo called the design an igloo; it was used as a temporary shelter usually at winter hunting camps. In more recent years Buckminster Fuller has developed the dome or sphere as an integral part of modern architecture. Two types of shapes have more efficient surface to volume ratios than a hemisphere: they are the spheroid and some kinds of right cylinders. However, since the dome is so widely used, the hemisphere will be used here as a standard for comparing shapes of structures.

In order to put the shelter shape design into perspective a shape factor, f, will be used. f is defined as the ratio of the area of the structure's skin surface to the volume of the space enclosed by the skin and f′ is the ratio of surface area of a structure to the surface area of an igloo of equal volume.

$$f = \frac{\text{surface area}}{\text{volume}}$$

$$f' = \frac{f\ (\text{shelter})}{f\ (\text{igloo})}$$

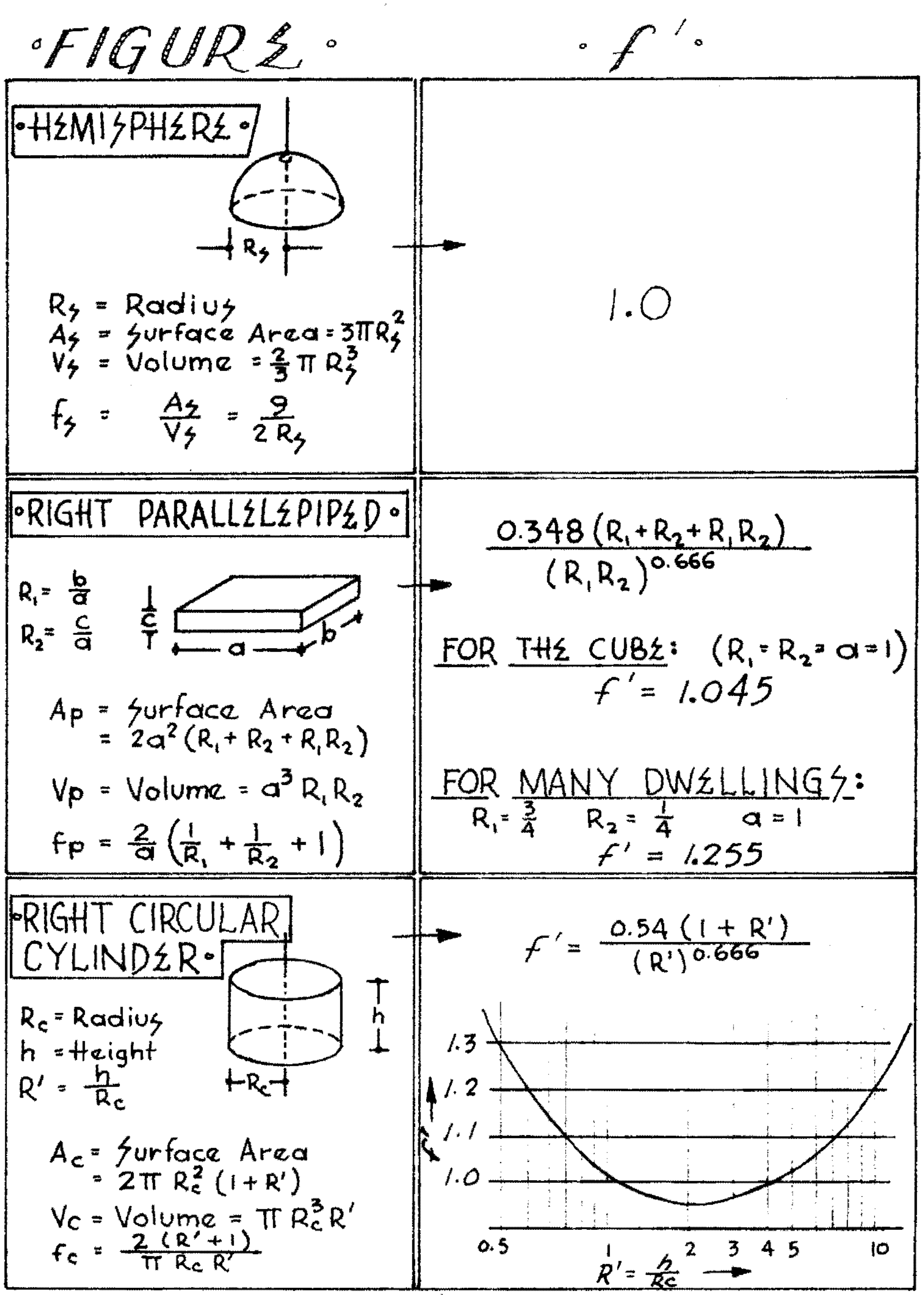


Figure 1: Shape factors f′ for various shelter designs.

Figure 1 lists f′ values for various shapes. The base area is included in the derivation of f′ values, therefore the f′ value may not reflect heat transmission quantities directly, but in many cases it does act as an indicator of design efficiency. As the value of f′ increases the surface area of the unit shape listed also increases. A change in f′ is directly proportional to the change in the surface area, thus the f′ value may be multiplied by 100 and taken as a per cent. For example: a cube has an f′ value of 1.045 and has 4.5 per cent more surface area than does a hemisphere (or igloo) of equal volume.

Figures 2 and 3 show buildings that adhere to basic engineering criteria for shape. The f′ for each of these structures is on the order of 1, and they are not architecturally unattractive. A new building designed to house the library and fine arts facilities is now being erected on the University of Alaska campus at College, Alaska. The f′ factor for the structure is on the order of 2. The shape of the

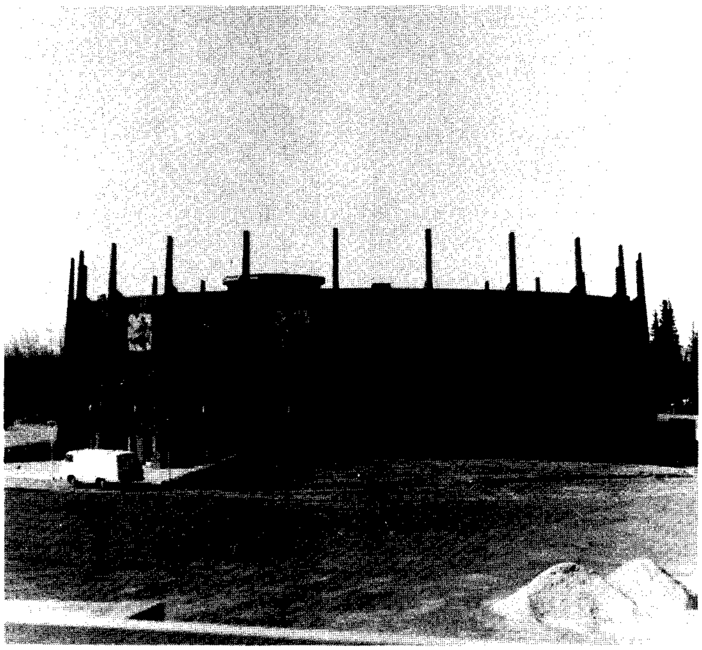


Figure 2: Civic Building, Alaskaland, Fairbanks. (Photo by Stetson). Architect: D. W. Stetson, Philleo Engineering & Architectural Service, Fairbanks, Alaska.

Figure 3: Foodland, Fairbanks, Alaska. Architect: Johnson-Campanella-Murakami & Co., Renton, Washington.

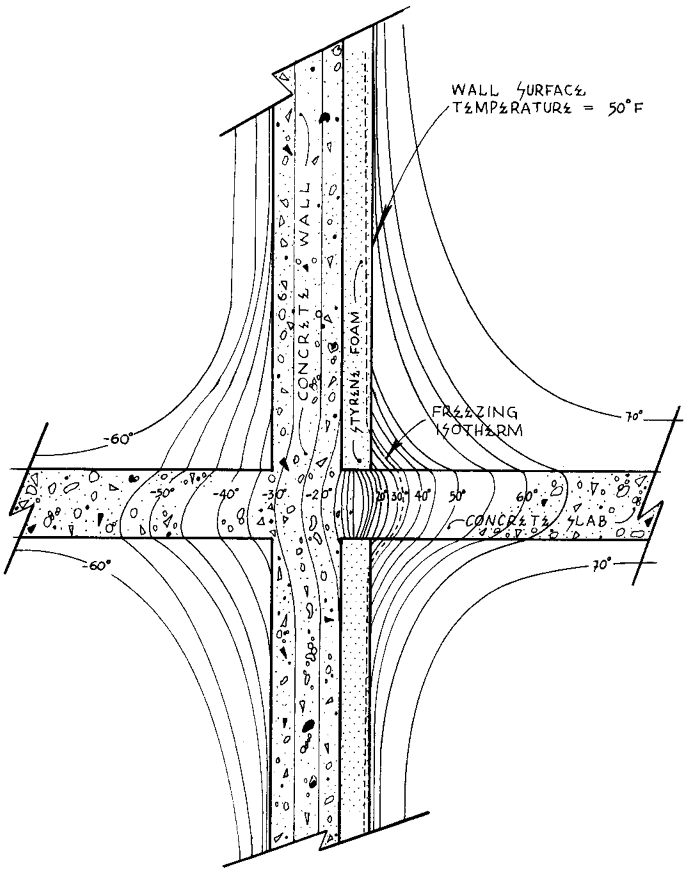


Figure 4: Isothermal map of a wall with attached cantilevered walkway in the fine arts facility, nearing completion on the University of Alaska campus. It is apparent that moisture will condense out to the 45° isotherm.

building seems inefficient for cold regions design and the architectural details indicate some disregard for the basic rules enumerated above. Large extended surfaces make up in excess of 7 per cent of the building surface. Figure 4 shows an isothermal map of the intersection of one of the finned surfaces of the building. Detailing such as this may be well suited to temperate regions, but the adverse effect of extreme temperature potentials upon the design is obvious.

The architect who designs structures for cold regions must realize that there are more restraints to contend with than he might like, but therein lies the challenge. Although the hemisphere, the right cylinder and the cube seem most efficient as envelope shapes, the general adoption of such figures as basic building design is not realistic. It is the job of the architect to invent new design shapes that conform to the engineering and human demands of the environment in which he chooses to work.

—Mark W. Fryer

REPORT ON

Alaska Science Conference

The 20th Alaska Science Conference held at the University of Alaska (August 24-27, 1969) was a stimulating experience It focused on the impact of the North Slope oil development on the state's finances, peoples, economy and ecology. Since the meetings took place on the eve of the sale of oil leases, which netted almost $900,000,000 for the state, the timing was appropriate.

Controversy and some acrimonious debate enlivened several sessions, particularly where battle lines between conservationists and developers were most sharply drawn. A representative of the Sierra Club argued that the entire Brooks Range should be set aside as a reserve before it was too late. It was his feeling that the ecology of the North Slope was irreparably disrupted and that the wildlife reserve previously established in the northeast corner of the state could be written off as well. This reserve, approximately 20,000 sq. miles, is bounded by the Arctic Ocean, Canada and the Brooks Range. An intemperate rebuttal to such observations by Alaska's Senator Ted Stevens caused him to be labeled as "a Neanderthal" by another speaker. Alaskans resent "outsiders" interfering with the development of **their** resources, while "outsiders" feel that Alaska is also a part of America, thus properly within the scope of their interest. This undercurrent generated much of the heat on the question. It should be noted, however, that engineers are sensitive to the ecological problems involved, and several papers presented offered practical solutions.

Meetings were organized around three distinct themes: petroleum development in the North, which included consideration of geology, government, engineering and transportation; social change and native people; and impact of development on the environment.

The proceedings of the conference will be published and may be secured by contacting:

Susan Foster
Institute of Social, Economic &
Government Research
University of Alaska
College, Alaska 99701

A Seminar on the North

The University of Alaska has instituted an interdisciplinary seminar on the North. Readers who should happen through Fairbanks, Alaska are welcome to participate in the seminar as speakers or simply to attend and meet others who are active in northern work.

The list of speakers is impressive. The interests of the seminar group are all inclusive, ranging from the social sciences to liberal arts and the hard physical sciences including engineering, physics and marine science.

If you would like to attend any of the sessions, please write the editor of THE NORTHERN ENGINEER and you will be supplied with the time, place and subject that will correspond with your visit to Fairbanks.

Environmental Atlas of Alaska

The ENVIRONMENTAL ATLAS OF ALASKA, announced in our Fall 1968 issue, has just been published by the Institute of Arctic Environmental Engineering and the Institute of Water Resources at the University of Alaska. Five main topics are covered: physical description of Alaska, light, waters, climate, and engineering information. Philip R. Johnson and Charles W. Hartman prepared the atlas. Requests for copies should be made to the Institute of Arctic Environmental Engineering, University of Alaska, College, Alaska 99701.

A Means of Acquiring Technical Information

Mr. Robert H. Rea, Liaison Officer, Office of Customer Relations, Defense Supply Agency, DoD, has suggested that the readers of THE NORTHERN ENGINEER might like to learn of the services that his agency is prepared to offer the engineer or scientist.

Many engineers and scientists involved in federally sponsored cold regions technology studies are overlooking a valuable source of technical information. Thousands of Defense sponsored technical reports pertaining to cold regions technology are readily available to federal agencies and to their contractors, subcontractors and grantees from the Defense Documentation Center, a field activity of the Defense Supply Agency in Alexandria, Virginia.

Studies of snow and permafrost, soil mechanics, glaciers, weather patterns, special lubricants, heat transfer, ground effects machines, Alaska flora, aerial photography, mosquitoes, cold weather clothing, winterization of vehicles, civil engineering, seismology and insulation materials are included in the vast collection of technical reports maintained by DDC. The Center also operates computer-based data banks of management and technical information and is responsible for the development of information storage and retrieval systems. The DDC document collection totals nearly a million titles, covering all areas of science and technology. About 50,000 titles are added to the collection each year.

New accessions to the collection are announced in two government publications. Unclassified Defense reports with unlimited distribution are listed in the Department of Commerce publication, U.S. GOVERNMENT RESEARCH AND DEVELOPMENT REPORTS. These Defense documents, and technical reports produced by more than 50 other federal departments and agencies, are available for purchase by the general public through the Commerce Department's Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151. The DoD classified reports and unclassified reports of limited distribution are described in the DDC TECHNICAL ABSTRACT BULLETIN, a confidential publication provided only to registered organizations cleared to receive classified information.

The Center provides a bibliography service which includes scheduled bibliographies of interest to major segments of the DDC user public, and report bibliographies which are tailored to provide specific references covering a particular user problem or project. More than 20,000 report bibliographies are prepared annually at the Center.

The Center's referral system extends the scope of its documentation function to include the acquisition, storage and retrieval of information concerning Defense sponsored, specialized sources of scientific and technical knowledge. When authorized users require information exceeding that contained in technical reports, DDC refers the requests to organizations or individuals which are known as potential sources of such expert knowledge, or to the National Referral Center for Science and Technology at the Library of Congress. Such references are included, when pertinent, in report bibliographies.

NORTHERN ENGINEER readers who desire more information concerning the programs and services of DDC may write to the:

Defense Documentation Center
Attention: DDC-4-LC
Cameron Station
Alexandria, Virginia 22314

CONFERENCE
Northern Circumpolar Lands

Productivity and conservation in northern circumpolar lands will be discussed October 15-17, 1969, at a conference to be held at Edmonton, Alberta. For further information contact: Dr. W. A. Fuller, P.O. Box 500, University of Alberta, Edmonton, Alberta, Canada.

Current Publications

United States Geological Survey
Distribution Section
Federal Center
Denver, Colorado 80225

LIST 729 – Publications issued in April 1969

Topographic Maps—Alaska:
- Baird Inlet A-1 (1954) (AMS) – new map
- Baird Inlet B-1 (1954) (AMS) – new map
- Goodnews A-3 (1954) (AMS)—new map
- Goodnews A-4 (1954) (AMS)—new map
- Gulkana C-2 (1949)—reprinted map
- Kenai C-2 (1951)—reprinted map
- McCarthy C-2 (1959) – reprinted map
- McCarthy C-6 (1959) – reprinted map
- Nebesna B-2 (1960)—reprinted map
- Seward B-8 (1951)—reprinted map

River Survey Maps—Alaska:
- Tazimina Lakes (1966)

LIST 723

Topographic Maps—Alaska:
- Taylor Mountains D-2 (1954) (AMS) —new map

National Research Council (NRC)
Division of Building Research
Ottawa 7, Ontario, Canada

NRC 10629 **Calculations of transient heat flow through walls and roofs,** by G. P. Mitalis – reprint from ASHRAE Transactions, Vol. 74, Part II, 1968, p.182-188. (DBR Research Paper No. 393)

NRC 10702 **Trends in Canadian house production,** by H. B. Dickens—reprint from Canadian Forest Industries, Vol. 89, No. 2, February 1969, p.55. (DBR Technical Paper No. 299)

CBD 115 **Performance of building materials,** by P. J. Sereda. July 1969, 4p.

TT 1353 **Construction of a water storage dam on permafrost,** by G. F. Biyanov. Gidrotekhnicheskoe Stroitel'stvo, (10): 15-23, 1965. **Discharge and blocking up the river during construction of the Vilyui Hydro-Electric power station,** by G. F. Biyanov. Gidrotekhnicheskoe Stroitel'stvo, (2): 1-5, 1966.

Department of National Health and Welfare
Public Health Engineering Division
541 Federal Public Building
Edmonton, Alberta, Canada

Manuscript Report No. NR-68-8 **Pipeline research water and sewer lines in permafrost regions,** by R. N. Dawson and J. W. Slupsky, December 9, 1968, 78p.

Universities Council for Earthquake Engineering Research
1201 East California Boulevard
Pasadena, California 91109

Report on **NSF-UCEER conference on earthquake engineering research, March 27-28, 1969, University of California, Berkeley, California,** May 1969, 310p.

SYMPOSIUM
Remote Sensing

A remote sensing symposium will be held by the American Society of Photogrammetry at the Anchorage Westward Hotel on November 4-6, 1969. The only seminar on remote sensing in Alaska this year, the theme will be the use of remote sensing in the conservation, development and management of the natural resources of the state of Alaska.

Among the speakers on the preliminary program are Hollis Dole, Assistant Secretary of the Interior; Tom Kelly, Commissioner, Alaska Department of Natural Resources; Dr. William Pecora, Director, U.S. Geological Survey; Russell Train, Undersecretary, Department of the Interior; Robert Finch, Secretary, Health, Education and Welfare; Reginald N. Whitman, Administrator, Federal Railroad Administration and many others. Secretary of the Interior Walter J. Hickel will be the banquet speaker at the end of the symposium and discuss the significance of Alaska's resources to national goals.

A slight increase in air pressure supports the transparent plastic membranes in this model of a "domed community". The three hexagonal domes are residential areas, each housing 3,000 people. The square domes, or polydomes, are essentially industrial areas or natural resources on which the community is based. An article on polydomes by T. W. McLorg is included in this issue of the NORTHERN ENGINEER.