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SCIENCE IN THE NORTH
APPROPRIATE ENERGY TECHNOLOGY
IN ARCTIC REGIONS

PROCEEDINGS

A SYMPOSIUM
SEPTEMBER [illegible]
FAIRBANKS, ALASKA

SPONSOR
THE NORTH SLOPE BOROUGH
EUGENE BROWER, [illegible]
BARROW, ALASKA

33rd Alaska Science Conference
AAAS - Arctic Division

AMERICAN **ASSOCIATION**
FOR THE
ADVANCEMENT OF SCIENCE
ARCTIC **DIVISION**

SCIENCE IN THE NORTH

Proceedings of a Symposium on Appropriate Energy Technology for Arctic Regions

Sponsored by the

North Slope Borough
Barrow, Alaska

Eugene Brewer, Mayor

Held at the

33rd Alaska Science Conference

Published by

Seton, Johnson & Odell, Inc.
Consulting Engineers
Portland, Oregon

ERRATA

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Our apologies for any inconvenience.

SETON, JOHNSON & ODELL

FORWARD

The North Slope Borough has for a long time recognized the need for effective energy conservation and the development of energy technologies which are appropriate to the rapid development of this northern region. The list of concerns is long and covers the choice of proper alternatives in industrial and domestic construction, present and future energy sources, as well as innovative and cost-effective ways to meet the needs of the residents of this region and to maintain proper and healthful living standards. Another concern of equal importance is the problem of maintenance of buildings, structures and facilities constructed in arctic regions. Over the years, numerous formal and informal conferences relating to the subject of appropriate energy technology were held or attended. During the last years of operation of the Naval Arctic Research Laboratory, Barrow (1977-80), seminars were attended by laboratory personnel, residents and officials of Barrow and the North Slope Borough, as well as outside experts in such fields as agriculture, construction and coal utilization.

The concerns of the North Slope Borough are not unique Alaskan concerns, but are also shared by our Canadian neighbors. Plans for the 33rd Alaska Science Conference, sponsored by the American Association for the Advancement of Science; also recognized a need to encourage closer ties with Canadian scientists and engineers. The name AAAS-Alaska Division was changed to AAAS-Arctic Division to reflect the desires of the membership to establish closer ties with Canada and other circumpolar nations. An opportunity arose for the North Slope Borough to consider a symposium on appropriate energy technology in arctic regions as part of the 33rd Alaska Science conference. The theme of the Alaska Science Conference was also appropriate — Science in the North — with emphasis on high northern latitude topics in science and engineering.

A steering committee was established to set the theme for a symposium and to provide for its organization. The committee decided to focus on the theme: Energy efficient building techniques and designs suitable for remote arctic regions. Major objectives included a review of present building techniques and designs and the energy systems to support them; and suggestions for new techniques and strategies which would allow for better living in far northern communities. It was further decided that invited speakers would be selected from both the United States and Canada. A panel discussion was also included to express opinion on three concerns: Is the energy crisis real and is it more, or less, critical in the arctic than elsewhere? What are the most critical factors concerning energy consumption when planning a new building to be constructed in the arctic? What will be our energy requirements and concerns when we are planning the next generation of arctic buildings ? This symposium focused on only one area of concern — construction; with the hope that experiences could be shared which would help us to understand what makes some construction techniques work while others fail.

Charles L. Hoar
John J. Kelley
1983

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The committee and all of the participants are grateful to the Honorable Eugene Brewer, Mayor of the North Slope Borough and to the North Slope Borough for sponsoring this symposium on "Appropriate Energy Technology for Arctic Regions".

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NORTH SLOPE BOROUGH
Incorporated July 2, 1972

The Honorable
EUGENE BROWER
MAYOR

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SYMPOSIUM ON APPROPRIATE TECHNOLOGY
TECHNOLOGY FOR ARCTIC REGIONS

Friday, September 17, 1982
Blue Room, Civic Center, Alaskaland

WELCOME

Vincent Haneman, Dean, School of Engineering
University of Alaska, Fairbanks

Mayor Brewer, honored guests, ladies and gentlemen. Welcome. It is an honor to be allowed the privilege of welcoming you here. You have probably been welcomed to death. But my recognition of that fact is not going to deter me from giving you a small dose of my welcome.

I am reminded of the story of old Alex Smith. Some of you from the Fairbanks area may have known Alex. He wore a blue and yellow tie, and you could always - if he wasn't talking - you could always hear him humming the Alaska flag song. He would stop sourdoughs and tourists alike and go on for hours about the virtues of the University of Alaska. He would talk to anyone about the fantastic school on the hill, about the successes of the Nanooks - sometimes I think they were pure fantasy, but that's alright. He talked about the citadel of learing of the North.

Not too long ago, Charlie Zilch, a local character, a real reprobate, died. He had nothing of any virtue that would make him outstanding, and at his funeral the minister had almost no one there, and somehow, Alex Smith showed up. And in showing up, well Charlie Zilch had so much going for him, that immediately after the silent prayer, the minister had run out of nice things to say about Charlie. So in desperation he turned to the audience and said "Has anyone anything to say?" And Alex, never at a loss for words, said "Yeah, I do. I never knew Charlie Zilch, but let me tell you about the University of Alaska."

Well since you've been so welcomed, let me tell you about the University of Alaska, Fairbanks, and principally the Engineering School. In the past two and a half years our student credit hour production or teaching has doubled.

We have, as you've probably noticed, Civil, Mechanical, and Electrical Engineering, and under the School of Mineral Industries, we have Petroleum, Mining and Geological Engineering. In the very near future, we are driving to add Chemical Engineering to our program.

With this tremendous increase in student body, our faculty are overloaded and our research activity has doubled in the last two years. Now thank goodness the chancellor has recognized the desperate straits. We have two new faculty last year, we have two new plus a visiting faculty coming this spring - that's five - and hopefully we'll have five new faculty next year. The legislature provided some funds that will provide a new wing to Duckering, and they also added some money for planning of a research laboratory building. This will then provide us with an overall Engineering complex for the School of Engineering and for the School of Mineral Industries. We're designing for a program for about 800 and 400 mineral industry students - about 1,200 students. This will not nearly meet the state's needs.

If you note, the state imports ninety percent of the engineering talent they need from outside. But one of the biggest problems we have is that we have too few Native students. I've got six Native students in the School of Engineering. It's important to bring these unique backgrounds into the field of engineering, so that we can provide engineering that's appropriate to the northern latitudes and to the native areas.

We need to be able to translate all the excellent work that is being done in the institutes into terminology and into the physical being of products which will help to assist our people live a better life here in the North.

In the schools of engineering, dedication is to the North - we're capitalizing on our northerners, and will provide the capability and intellects necessary for the northern tier to meet the demands of the future. This future has to include jobs, higher standards of living, improved quality of life; and most of all, freedom of action that we enjoy here in Alaska so much. But we also have to make sure that it stays in tune with our cultures. It's exciting for me to be a part of this search for better and best solutions.

Our number one problem and priority is energy, the topic of this meeting. The papers are excellent and I congratulate your steering committee for such depth, in finding such papers. Reluctantly, I've spoken about five minutes or more, I must yield the chair - I've slot more to say about the University of Alaska, but all I can say is welcome and introduce your co-chairman, Charlie Hoar.

Charles L. Hoar, Seton, Johnson & Odell, Portland, Oregon - Chairman and moderator, morning session

Good morning ladies and gentlemen, Mayor Brewer. My involvement in the North and the Arctic started at the end of 1969, and has been going forward ever since. My claim to fame up here is in the Alaska Village Demonstration Project at Wainwright, and at Emmonak. Emmonak's project unfortunately recently had a disasterous fire and I just found out that they had rebuilt it; and that the water treatment and waste treatment plant are back on line; and that the people are now assured good potable water again . . . . and they did it all by themselves.

The state assisted somewhat so that the units salvaged from the fire, with work by Native people in Emmonak, could build a new building, by themselves, and then put all the rebuilt equipment back in line. They accomplished this with the assistance of the former project engineer from the EPA, Conrad Christensen, who is now in business in Fairbanks.

I too would like to welcome you this Symposium on Appropriate Energy Technology for the Arctic Regions. The theme will focus on energy efficient building techniques and designs suitable for remote arctic regions. We look forward to achieving the objectives of this symposium in the papers which have been selected to be presented.

These include a review of building techniques and designs - and the energy systems to support them - and the suggestions, the new techniques and the strategies which will allow for better living in far northern communities. Our hope is to see, and hear, some innovative ideas which can be used by all in achieving maximum benefits from whatever energy sources must be utilized to realize a comfortable environment in the buildings we construct in the future.

With that in mind, it is my pleasure to introduce to you now; a gentleman whose forebearers have seen the transition in housing construction from sod huts to the present day modern home. His interest in achieving more energy efficient homes and buildings in the Arctic led him to approve the support for the sponsorship of this symposium by the North Slope Borough. It is my pleasure to introduce my friend of many years, the Mayor of the North Slope Borough, Mr. Eugene Brewer.

Eugene Brewer, Mayor, North Slope Borough, Barrow, Alaska

Good morning, for those of you whom I haven't met, I'm Eugene Brewer, Mayor of the North Slope Borough. I'm pleased to open this Symposium on Appropriate Energy Technology for Arctic Regions. The theme of this Energy Symposium is particularly appropriate. Our North Slope is undergoing a period of rapid change primarily because of oil and gas development. The economic, social and natural environment of the north makes difficult demands on those who stay and appropriate energy technology is not a new idea to the native people of the northern regions. Centuries ago our ancestors found the land surrounding the Arctic Ocean attractive and remained there. Therefore, they developed an energy technology appropriate to the cold environment of the arctic regions and transferred their knowledge from generation to generation.

The arctic environment can be friendly and not hostile. However, these cold regions do not allow many mistakes to be made without paying a very severe penalty. Our ancestors survived by practicing a form of subsistence technology which involved working with the environment not against it. An example of their appropriate technology was the sod house as a form of construction. We do not see many sod houses today, but they certainly represent an efficient building technique suitable for the arctic. Today we talk about superinsulated houses, "R" factors, aerodynamic structures and vehicles to reduce our dependence on the use of fossile fuels. The sod house utilized many of the energy saving features which are discussed in recent times. They were made with driftwood and whalebone and covered with sod. Snow provided additional insulation during the winters. They were designed so that they faced away from the wind and rounded so that the wind could pass over them. The sod houses contained storage areas, drying areas, and separate cooking and sleeping areas. Fuel efficiency was important, and there was not enough of it to use wastefully. The sod houses were insulated well enough and protected from the wind so that the whole living area could be heated by a small lamp. The point of this reflection is that our ancestors survived in equilibrium with the environment.

They had a design and construction system for which they could excercise local control. More important, they had a facility they could take care of once the construction phase was over. Today, for one reason or another, our lives have become much more complex than our ancestors. We cannot recommend, for example, the mass production of sod houses. Although, the costs of fuel and construction in the arctic may be enough for some not to dismiss the idea entirely. The wisdom of our people who survived the arctic regions before modern construction is as much important today as it was then. Local control and involvement in construction and planning is what is essential for the people who continue to make the polar regions their homeland. The result of the development of natural resources in Alaska has been an enormous increase in new construction as well as new “white elephants”. By “white elephants” I refer to a building and property that require much care or initial expense but result in something of little value. More directly, such a building or facility left on your doorstep by poor design or planning is usually not a gift but an expensive liability. Some communities, for example, have been given more sanitation facilities than they could handle and certainly much more than they could pay for. Waste disposal is another area of extreme concern where thoughtful design is critical. In Barrow, we are constantly reminded of a local “white elephant”; an incinerator built by the Navy at great cost. It has never operated, and if it did, our natural gas supply would diminish very quickly. I am sure that there are many more examples.

The most difficult situation that we will face in the future is the frustration of trying to maintain the buildings, structures, and facilities that remain long after the scientists, engineers and contractors have left. Therefore, it will be advantageous for the residents of the arctic if the design engineers are familiar with the characteristics the Arctic will bring to bear on a project.

It is reasonable to assume that future construction practices will experience the same old energy robbing mistakes, I hope that we will have enough common sense to learn from them. Conferences and workshops, such as this one, provide an opportunity to share our experiences in order to understand what makes some construction techniques work, when others seem to fail. Today, we tend to look to science and engineering technology to afford us better things for a better future.

Better living conditions will not occur tomorrow without proper preparation today. Failure to do so will result in a legacy of costly mistakes to transfer to future generations. The preparation that I speak of, involves education and searching for new techniques and methods. More important, it will also involve close involvement with, and attention to the needs of the citizens who make their home in the remote arctic communities of the world.

Thank you for the opportunity to express my views, and I wish you a very successful conference.

"THE SEARCH [illegible] APPROPRIATE [illegible] FOR RESIDENTIAL CONSTRUCTION IN NORTHERN CANADA"

Richard [illegible], [illegible] Research & [illegible]ing
Northwest Territories Housing Corp., [illegible]wknife

ABSTRACT

The production of a residential building standard to be applied to the North for the 1984 construction season has been ordered by the Treasury Board of the Government of Canada. This standard would be directed at the unique geography and climatological factors of the area and would encourage the efficient use of energy.

The North is most often defined as that area of Canada north of the southern limit of discontinuous permafrost. This boundary encompasses all Territories and Provinces except for Nova Scotia, New Brunswick and Prince Edward Island.

Over the last 2[illegible] years, governments in Canada have constructed various housing types primarily [illegible] at upgrading the health standards for Northern native people and to encourage and support resource development. Design and technology have been of conventional "Southern" standards which do not [illegible] the test of durability or energy efficiency required in the North.

A concentrated effort is now underway to learn from past experience in order to [illegible] designs, practices and equipment which would [illegible] concerns for thermal efficiency, airtightness, stability of foundations, suitability to Northern life styles and cost effectiveness.

* * * * * *

The Federal Government of Canada has ordered that a residential building standard be developed for Northern [illegible] by 1984.

The area encompasses the northern regions of most provinces and the Yukon and Northwest Territories. The reasoning behind this policy direction is two-fold; rising cost of energy in the North, and the lack of durability and energy efficiency of housing built in the past.

In order to grasp the [illegible] and complexity of the project I would like [illegible] your attention to the Northwest Territories.

The Northwest Territories [illegible] one third of the total area of Canada, over [illegible] square kilometers. It has a variety of climatic and soil conditions which vary from region to region. In the Western Sub-Arctic there are trees and [illegible] discontinuous permafrost. In the Arctic regions high winds and little precipitation are commonplace. The land is treeless, tundra covered and has continuous permafrost.

The population consists of over [illegible] people of Dene (Indian), Inuit (Eskimo), Metis and other groups scattered over some [illegible] communities. A dozen or so languages and dialects are spoken, and [illegible] of life styles are pursued.

In the Western Arctic, below the treeline, homes are traditionally owner-built of logs on wood footings. Heating is by a wood stove. [illegible] smaller [illegible] have no running water, or [illegible] facilities. However, more modern versions of these homes are being built with support to the owner-builders by a government grant program.

In Inuit communities [illegible] early 1950's the Federal government built a variety of one room, 26 square meter houses to improve health [illegible] standards by replacing the tents and igloos [illegible] year round.

To insulate the houses from the permafrost, a small gravel pad was put down and the house was built over it. Floors, walls and ceilings were made of prefabricated stressed skin plywood panels [illegible] Douglas fir plywood [illegible] mm thick, glued on both sides of a 38 by 89 mm spruce lumber frame stuffed with insulation and butted together. Vapor barriers were rarely used. [illegible] building system became the prototype for nearly all government sponsored housing programs in the North until recent years.

Heated by an oil cook stove or a space heater, the larger units provided in the [illegible] were built in the same manner and were drafty, with cold floors and not energy efficient. No running water was provided and waste or grey water drained directly onto the ground, eventually eroding it and causing the wood blocks [illegible] foundations to move, pulling apart the panels. The average erection cost for these houses in the mid [illegible] was approximately 10,000 dollars. Over [illegible] were built throughout the Canadian Arctic in the Northwest Territories and Northern Quebec.

The designs of these homes did not take into account the life styles of the people who require specialized work areas to dress game, work on [illegible] or to prepare food.

Another factor affecting house construction and the choice of building materials used in the North is the transportation system.

In the Eastern and Central Arctic yearly resupply is accomplished by ship out of Montreal, Quebec or Churchill, Manitoba.

In the West, goods are moved down the Mackenzie River by barge. Often air transport is used for isolated, ice bound settlements, and for emergencies.

Subsequently packaging, handling and storage costs become important cost factors in budgeting and planning housing development projects.

The transportation system in the Northwest Territories is very primitive by current practices. Containerized cargo is rare. And the capacity of carriers is limited by the quality of handling equipment which often dictates the type of material which is selected for housing construction.

Water damage, crushed and broken shipments are not uncommon. As a result, the quality of the building materials, especially with regard to insulation value is often destroyed.

Since ships must arrive in summer, after ice break-up, construction must be efficient and quick in order to close in a building before snowfall.

Over the years the homes built by the federal government in the 1950's and 1960's deteriorated due to poor construction, maintenance and overcrowding. The native population of Arctic Canada is one of the fastest growing groups in the world.

By the mid 1970's, rising energy costs and demand for better quality housing compelled the government to enter into a comprehensive rehabilitation program for approximately 1,000 homes across the Northwest Territories.

The goal was to create a highly insulated envelope about the house by increasing the "R" factor in the roof, walls and floor. The homes were gutted, thoroughly renovated and modernized to be energy efficient. The work was accomplished by locally trained people who are also involved in the ongoing maintenance program. The average cost for this program was $50,000 per unit and the work is ongoing.

Over the last three years the pre-fabricated, panelized erection system has been replaced by on-site, "stick built" construction. Although it is labour intensive, it is possible to achieve a tightly sealed unit.

‘Multifamily designs are replacing the single-family, detached home in communities that have the capability to service the units and provide suitable fire protection.

The next few years will see further tests of equipment, building materials and designs in the search for an appropriate super-energy efficient home for residents of the Canadian Arctic.

Richard Bushey

A THERMAL PERFORMANCE DESIGN STUDY FOR ALASKAN RURAL SCHOOLS

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ABSTRACT

The establishment of Thermal Standards for buildings has been an important topic for the nation. The rise in costs of energy have made it imperative that buildings are constructed to be energy efficient, on a nation-wide basis.

The State of Alaska has embarked on an aggressive research program to formulate standards for building thermal system construction. This work has yielded a least life cycle cost approach that selects the level of building thermal construction which is least costly to the State over the building lifetime.

The approach has been applied to small rural schools in the size range of 7,000 to 12,000 square feet. A computer program is used to model a prototype building in sixteen different cost regions of Alaska. Different mechanical and electrical systems are evaluated, together with available thermal envelope options to form a wide range of alternate building designs.

The program incorporates energy consumption, maintenance and operations, and capital cost models to compute total life cycle cost. Design alternates that yield least life cycle cost are selected, and used as one criteria for developing Thermal Standards for rural Alaskan buildings.

I. INTRODUCTION

Standards that regulate the energy efficiency of new institutional construction are currently being developed in Alaska by the State of Alaska Department of Transportation and Public Facilities. Given the extremes in climate and socio-economic environment, creation of standards is a difficult and complex process that must have a logical basis of development.

This study develops a design optimization process that defines the range of thermal construction for small rural schools in Alaska. The report establishes the types of construction that will be most economical to the State over the lifetime of the building. In the study, the most economical type of construction is termed the "Least Life Cycle'Cost" (LCC) design.

Least life cycle designs are identified for each of three building energy sub-systems, architectural exterior thermal envelopes, mechanical, and electrical systems. The results of the study (Reference 1) are currently being used as a basis for an ASHRAE 90 type standard for Alaskan rural schools (Reference 2).

A rural school of 8,960 square feet is used as the basis for the building model, as many rural schools in Alaska are of this size. In the study, many different methods of energy system construction have been viewed, using a set floor plan configuration, building size, and occupancy. The floor plan for the building is presented in Figure 1, while dimensions, areas, and occupancies are defined in Table 1.

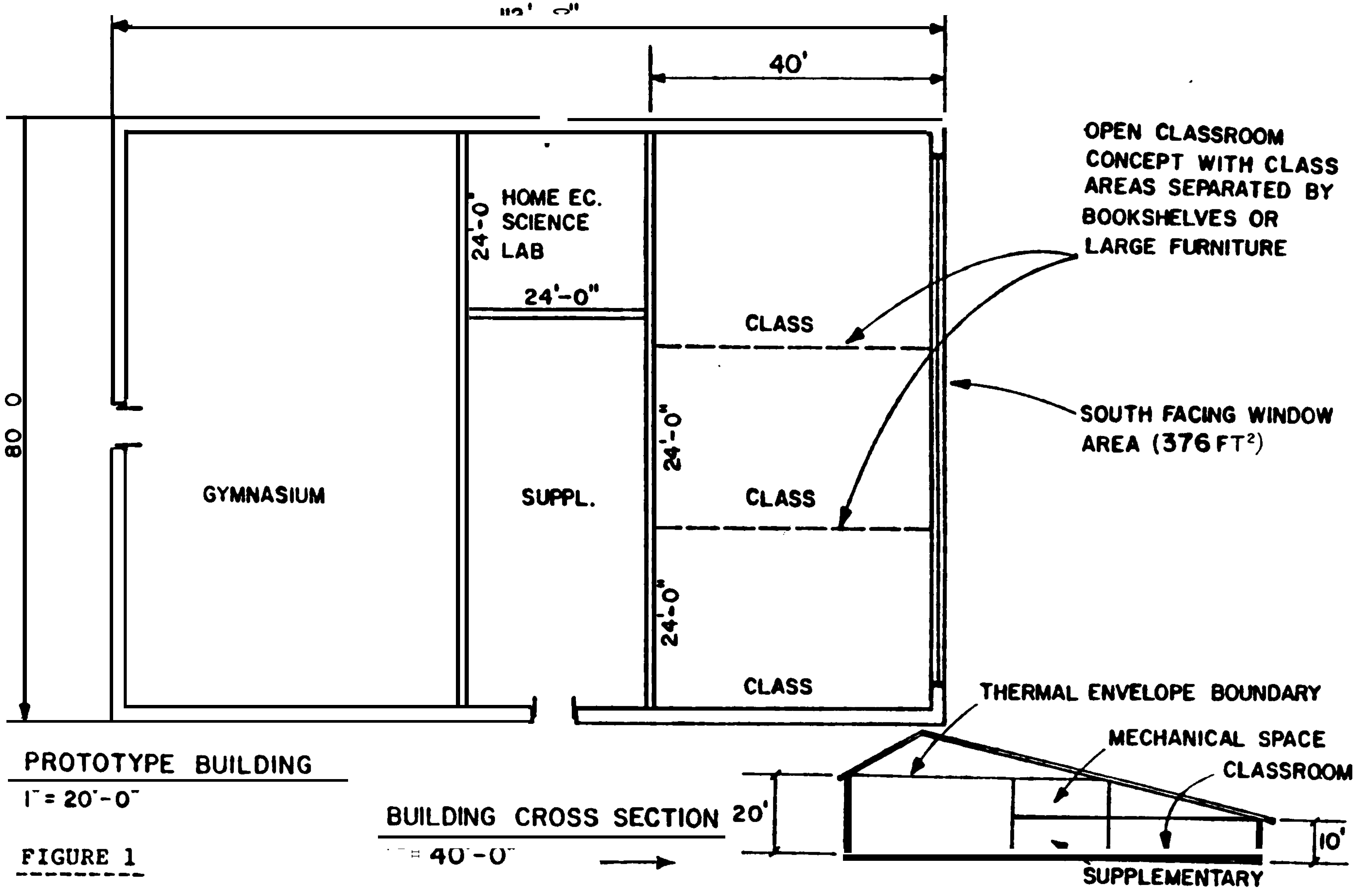
II. LIFE CYCLE COST EVALUATION

The analysis technique models a building from time of construction to time of replacement, with a series of equations simulating costs of construction and lifetime costs of energy and maintenance and operations.

These "models" deal strictly with the building's outer insulated envelope and with portions of the interior mechanical and electrical system. Only those components which influence the energy consumption of the building are dealt with in the study.

As the purpose of the study is to establish the "best" way to design the thermal systems of buildings, the analysis technique is a life cycle cost method, with the following analysis assumptions:

1. For a given size and occupancy classification there are innumerable ways that building thermal systems may be designed. Each design has its own characteristic life cycle cost. This characteristic life cycle cost is composed of three major components. First, cost of construction; second, annual cost of energy; and third, annual cost of maintaining and operating envelope and energy systems.



PROTOTYPE BUILDING

1" = 20'-0"

BUILDING CROSS SECTION

1" = 40'-0"

FIGURE 1

John Zarling
James S. Strandberg

TABLE 1

PROTOTYPE BUILDING CHARACTERISTICS

1. BUILDING GEOMETRY

Nominal Outside Dimensions	80 x 112 ft.
Nominal Outside Building Square Footage	8,960 sq.ft.
Total Exterior Envelope-Area	23,680 sq.ft.
Total Interior Volume	147,200 sq.ft.

II. ENVELOPE COMPONENT AREAS

Component	Nominal Area (Sq.Ft.)
Floors (Elevated Foundation)	8,960
Roof	8,960
Walls	6,080
Doors	100
Windows - Thermal Model	327
Cost Model	376

III. OCCUPANCY CLASSIFICATIONS

	Area Allocation (%)	Gross Area (Sq.Ft.)	Ceiling height (Ft.)
Classroom	42	3,776	10
Gymnasium	43	3,840	20
Supplementary	15	1,344	20

NOTE : No allowances made for thickness of walls in this chart.

2. The "best" design, for a given building size and occupancy is that design which gives the lowest total life cycle cost of ownership. The "best" design may not be the design with low first cost of construction.

3. The best design for one area of Alaska will not necessarily be the best design for another region of Alaska where different climate and cost conditions exist.

4. Good design practice must involve all building systems that use, -transport, or convert energy. To this-end, consideration of the thermal envelope, which represents the end use of heating energy, must be accompanied by careful treatment of interior mechanical and electrical systems.

A comparison technique that considers the full range of designs available to the industry is used. The building is conceptually separated into the exterior thermal envelope, and the energy consuming portions of mechanical and electrical systems.

Each design is evolved independently of other building systems, and defined in terms of first cost and operating characteristics. Five separate mechanical/electrical system designs are established; these designs are then combined with each of the four thermal envelope systems. This results in a total of one hundred and ninety-two different building design alternates for consideration with the life cycle cost model.

The design alternatives are modeled for sixteen cost regions and seven coincident climate regions within the state (See Table 2).

III. ENVELOPE DESIGN ALTERNATIVES

Each of the five architectural components (walls, roof, windows, doors, and floors) are dealt with separately, and four separate levels of thermal envelope construction are considered for each component, in the following categories:

Lenient:	Least thermally insulative construction presently in use.
Moderate 1:	Lower middle level of thermal insulation presently in use.
Moderate 2:	Higher middle level of thermal insulation presently in use.
Stringent:	Most highly insulative construction presently in use.

TABLE 2

COST REGION #	NAME OF COST REGION	CLIMATE REGION
1	Anchorage Zone	South Central
2	Village	South Central
3	Kodiak Island	South Central
4	Juneau Zone	South Eastern
5	Main Center	South Eastern
6	Village	South Eastern
7	Sitka	South Eastern
8	Fairbanks Zone	Southern Interior
9	Village	Southern Interior
10	Village	Aleutian
11	Bethel	Western
12	Large Village	Western
13	Coastal Village	Western
14	Village	Northern Interior
15	Barrow	Arctic Slope
16	Coastal Village	Arctic Slope

These four design levels are formulated for three separate wall design options and two foundation systems as indicated below.

Wall Concepts:	Standard Single Stud Standard Stud with Exterior Foam Double Stud Construction
Foundation Concepts:	Elevated Floor Heated Crawl Space

For each construction level, the overall thermal resistance and the overall cost are assessed. Figure 2 presents modeling information for a typical exterior wall section. As shown in the figure, both costs and thermal resistances are calculated for each envelope component.

IV. MECHANICAL SYSTEMS

The ways mechanical and electrical systems are designed can lead to wide variations in the building's energy consumption. Each interior energy system design for a given building envelope exhibits a unique behavior pattern for interior heat gains from occupants, external solar gains, and energy expended in the lighting, heating and ventilation processes. First costs of construction vary significantly with design.

There are presently two identifiable design philosophies (out of many used in Alaska) for mechanical systems that expresses ranges of system complexity. One philosophy emphasizes low first cost and simplicity of operation; using furnace systems and ducted hot air to the envelope, with a minimum of zones and system controls (termed ME1).

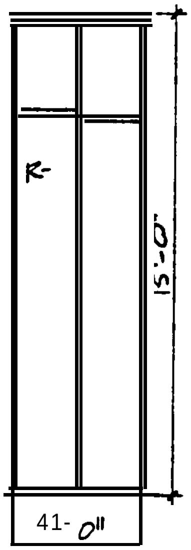
The other defined philosophy is a more complex system that uses boilers for heat generation, a glycol/water mixture for heat distribution and a separate ducted ventilation system. This more complex system exists with and without ventilation heat recovery, and is termed "ME2 with heat recovery" and "ME2 without heat recovery".

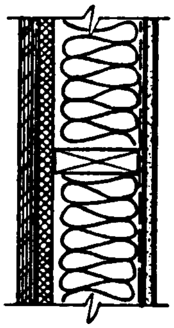
For each of these concepts, the model accounts for energy consumed in the process of moving energy from the site boundary to the end use location within the building, using the following mechanical system operating parameters to describe energy consumption characteristics:

- Heat generation conversion efficiency.
- Distribution energy consumption.
- Outside air ventilation schedule.

SANDWICH TYPE: Exterior Foam Wall **ROT FOR CONSTRUCTION**

ENERGY LEVEL: Moderate #1





Description	R-Value	cost $/Comp.SF
Inside Air	0.68	0.00
Paint Finish	0.00	0.85
5/8" Gyp.Board	0.55	1.20
4 Mil Poly-ethylene	0.00	0.24
R-19 Fiberglas Batts	19.00	0.62
1" Insulation Sheath	8.00	0.86
15# Bldg.Paper	0.06	0.32
5/8" Plywood	0.78	2.75
2X6 Stud @ 24"	6.93	1.34
Outside Air	0.17	0.00
TOTAL		8.18

$$\overset{R\text{-}1}{\left(\frac{54.37}{60}\right)}(29.24)+\overset{R\text{-}2}{\left(\frac{5.63}{60}\right)}(17.17)=28.11$$

FIGURE 2

ARCHITECTURAL WALL COMPONENT MODEL

BUILDING **COMPONENT** COB? FACTOR: 0.678

COST PER **BUILDING SQUARE FOOT:** 5.55

TOTAL THERMAL RESISTANCE: 28.11

V. ELECTRICAL SYSTEMS

Two electrical systems are outlined, one based upon a "current practice" design and the other an energy conservation design. The standard design, EE1, utilizes fixtures which are typically a 2 x 4, 4 lamp troffer type with no special features.

The alternate lighting system (EE2) uses a different layout of fixtures, and fixtures which are more efficient by virtue of their optical design and diffuser characteristics. This reduces the total number of lamps (although not necessarily the number of fixtures) and, consequently, the wattage. In terms of cost, the alternate EE2 design is more expensive.

The lamps used in the energy efficient design (EE2), are becoming quite common stock items. General Electric calls theirs "watt-mizers". Essentially they are the original F400 Cool White lamp with a different phosphorous coating.

The overall power loading of the EE1 design is 2.14 watts/sq. ft. but for EE2 is only 1.35 watts/sq. ft. This is 37% less energy for a system which will provide essentially equal results, with only moderate increase in cost.

VI. LCC COMPUTER MODEL "T-LOAD"

Twelve 256 case LCC simulations were accomplished using "T-LOAD", an in-house developed program, written in Fortran IV, and run on the University of Alaska's Honeywell computer; for seven climate regions of the state. Table 3 presents the computer run schedule for each of the twelve cases.

"T-LOAD" consists of a simplified annual energy analysis and an engineering economy analysis to calculate costs associated with operation of the building. The thermal model assures that each prototype building is heated with fuel oil, and powered by electrical energy obtained from a local utility. Passive solar gains and internal heat gains are accommodated in a modified degree day thermal model developed by Beckman, Duffie, et. al. (Reference 3).

Economic input data includes the State's minimum rate of return, fuel escalation rates for each fuel used, building useful lifetimes, first costs of construction and annual maintenance costs for energy system components. Additionally, mid-life renovations have been costed and included in the study.

TABLE 3

COMPUTER RUN SCHEDULE

COMPUTER RUN NO.	IDENTIFIER CODE	MECHANICAL SYSTEM	FOUNDATION SYSTEM	WALL SYSTEM
1	NES	NO HEAT RECOVERY	ELEVATED FLOOR	SINGLE STUD
2	NEE	NO HEAT RECOVERY	ELEVATED FLOOR	EXTERIOR FOAM
3	NED	NO HEAT RECOVERY	ELEVATED FLOOR	DOUBLE STUD
4	NHS	NO HEAT RECOVERY	HEATED CRAWLSPACE	SINGLE STUD
5	NHE	NO HEAT RECOVERY	HEATED CRAWLSPACE	EXTERIOR FOAM
6	NHD	NO HEAT RECOVERY	HEATED CRAWLSPACE	DOUBLE STUD
7	HES	HEAT RECOVERY	ELEVATED FLOOR	SINGLE STUD
8	HEE	HEAT RECOVERY	ELEVATED FLOOR	EXTERIOR FOAM
9	HED	HEAT RECOVERY	ELEVATED FLOOR	DOUBLE STUD
10	HHS	HEAT RECOVERY	HEATED CRAWLSPACE	SINGLE STUD
11	HHE	HEAT RECOVERY	HEATED CRAWLSPACE	EXTERIOR FOAM
12	HHD	HEAT RECOVERY	HEATED CRAWLSPACE	DOUBLE STUD

The program output for each of the twelve simulations consists of 16 by 16 matrices that present energy consumption, energy cost, first costs of construction, annual maintenance costs, and total life cycle cost. The total life cycle cost is expressed in $/sq ft-year, a uniform annual cost to the State for the lifetime of the building.

VII. ANALYSIS OF RESULTS

Description of Life Cycle Cost Model Results

Thirty-two plots have been formulated to show the relationship between three major analysis variables as follows:

- Level of envelope thermal construction
- Interior energy system design
- Total annual life cycle cost

Each graph presents life cycle costs for all building concept designs within a given cost region. Figure 3 presents a typical life cycle plot, for cost region 1, south central, Anchorage Zone. The horizontal axis of each graph expresses envelope stringency in terms of the total summed UA product (overall average thermal conductance factor x component area) for the prototype building. Since areas of each envelope component are held constant in the analysis, this parameter reflects the aggregate thermal conductivity for the prototype building, in units of BTU/Hr-Degree F, and thus directly reflects thermal construction level.

The vertical axis expresses total life cycle cost in units of uniform annual cost per year. Figure-3 presents the life cycle cost curve for the least expensive configurations of the interior mechanical and electrical systems. By selecting the low point on this curve the best architectural design is combined with the best mechanical and electrical designs. This low point represents the least "life cycle cost" design for that cost region; and as such, is one of the 'answers" of the study.

In this case the Moderate 1 option, which is a 6 inch stud wall with 1 inch of exterior polyurethane foam insulation, combined with complex mechanical and electrical systems using heat recovery, is the least life cycle cost option.

Least life cycle cost designs of each of the sixteen cost regions is presented in Table 4, for the Heated Craw]. Space foundation option. The tabulated results presents reasonably detailed design recommendations for rural school energy systems, in a format that can be used in an ASHRAE 90 type thermal standard.

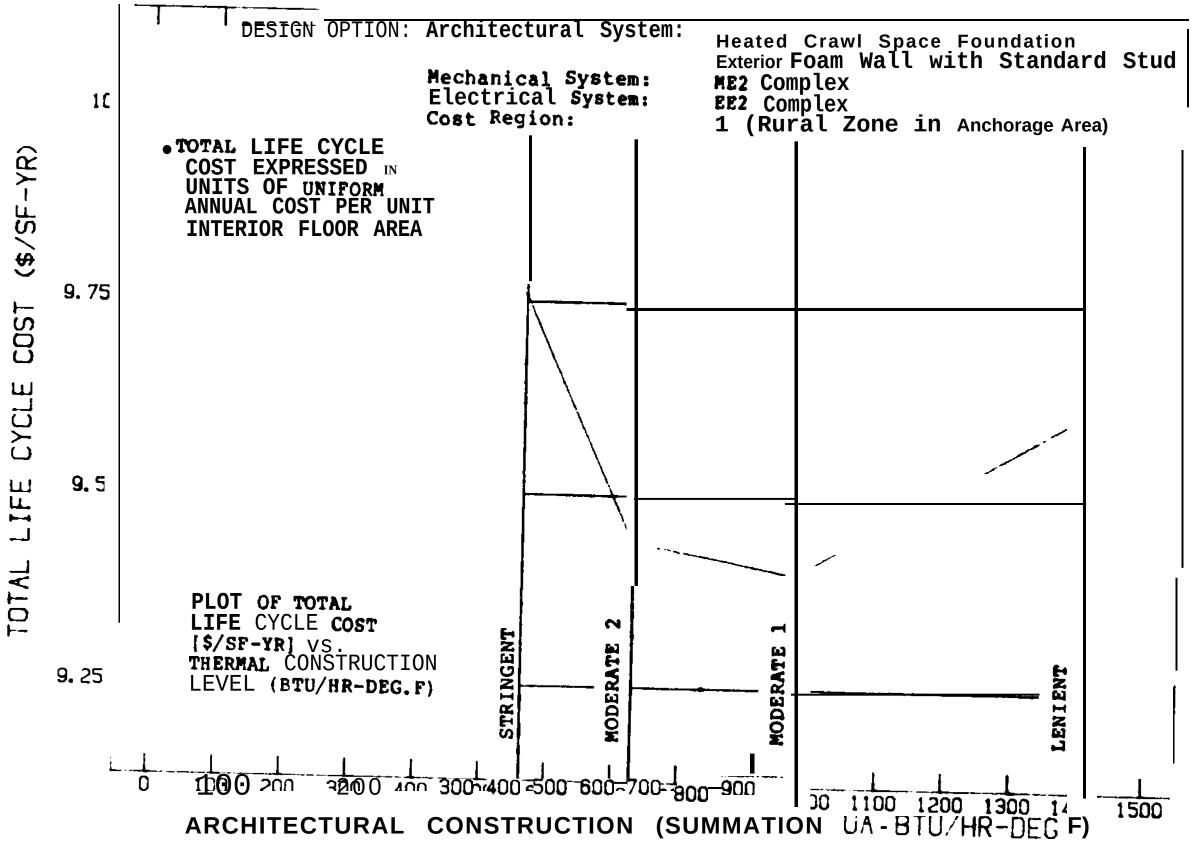

DESIGN OPTION: Architectural System:
Heated Crawl Space Foundation
Exterior Foam Wall with Standard Stud
Mechanical System: ME2 Complex
Electrical System: EE2 Complex
Cost Region: 1 (Rural Zone in Anchorage Area)
• TOTAL LIFE CYCLE COST EXPRESSED IN UNITS OF UNIFORM ANNUAL COST PER UNIT INTERIOR FLOOR AREA
PLOT OF TOTAL LIFE CYCLE COST [$/SF-YR] VS. THERMAL CONSTRUCTION LEVEL (BTU/HR-DEG.F)
TOTAL LIFE CYCLE COST ($/SF-YR)
10
9.75
9.5
9.25
STRINGENT
MODERATE 2
MODERATE 1
LENIENT
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
ARCHITECTURAL CONSTRUCTION (SUMMATION UA-BTU/HR-DEG F)

FIGURE 3

TABLE 4

LEAST LIFE CYCLE COST CONSTRUCTION METHOD BY COST REGION FOR HEATED CRAWL SPACE BASED ON ACTUAL USEABLE FLOOR AREA

COST REG.	NAME OF COST REGION	CLIMATE REGION	MECHANICAL SYSTEM	CONSTRUCTION TYPE	CONSTRUCTION LEVEL	LC COST ($/SQ. FT. -YR)
1	Anchorage Zone	South Central	M1 Heat Recovery	Exterior Foam	Moderate 1	9.40
2	Village	South Central	M2 Heat Recovery	Exterior Foam	Moderate 1	11.89
3	Kodiak Island	South Central	M2 Heat Recovery	Exterior Foam	Moderate 1	11.46
4	Juneau Zone	South Eastern	M1 Heat Recovery	Exterior Foam	Moderate 2	10.14
5	Main Center	South Eastern	M1 Heat Recovery	Exterior Foam	Moderate 1-2	10.03
6	Village	South Eastern	M1 Heat Recovery	Exterior Foam	Moderate 1	13.88
7	Sitka	South Eastern	M1 Heat Recovery	Exterior Foam	Moderate 1-2	10.01
8	Fairbanks Zone	South.Interior	M2 Heat Recovery	Exterior Foam	Moderate 2	11.63
9	Village	South.Interior	M2 Heat Recovery	Exterior Foam	Moderate 2	20.44
10	Village	Aleutian	M1 Heat Recovery	Exterior Foam	Lenient	17.06
11	Bethel	Western	M2 Heat Recovery	Exterior Foam	Moderate 2	15.14
12	Large Village	Western	M2 Heat Recovery	Exterior Foam	Moderate 2	16.07
13	Coastal Village	Western	M2 Heat Recovery	Exterior Foam	Moderate 2	26.43
14	Village	North.Interior	M2 Heat Recovery	Exterior Foam	Moderate 2	29.13
15	Barrow	Arctic Slope	M1 Heat Recovery	Exterior Foam	Lenient	14.59
16	Coastal Village	Arctic Slope	M2 Heat Recovery	Exterior Foam	Moderate 2	27.98

NOTE : EE2 Electrical System was found to be the cheapest alternative for all design cases.

VIII. CONCLUSIONS

The analysis has developed, for some sixteen cost regions, ranges of recommendations for thermal construction. These recommendations are seen to vary extensively under the influence of climate severity, the local costs of construction, and expected long term cost profiles for energy. The study results are especially sensitive to first cost of construction and to the economic assumptions regarding long term fuel escalation rates.

Selection of an integrated building thermal system is shown to be necessary. By properly selecting an interior energy system, and using an improper mechanical or electrical system, life cycle costs for a design can be raised significantly. This effect is prevalent in extremely remote areas with extremely expensive energy. In certain situations, selection of mechanical and electrical systems designs are of greater importance than architectural systems, within the bounds of normally accepted envelope design practice.

The results of the study are general, with input data for climate conditions collected for relatively few sites within each climate region. Cost data is similarly generalized. The results can thus be best applied for planning and programming functions, as opposed to individual circumstances. However, the modeling process employed can certainly be made to pertain to a certain building case merely by remodeling input data to fit that case.

Further, these studies model a building assumed to be served by a local public utility, without benefit of any alternative energy sources. This rather simplistic approach serves to put all evaluation on a fair, equitable basis. Such concepts would certainly alter results.

IX. ACKNOWLEDGEMENTS

The life cycle cost analysis work reported herein was accomplished at the University of Alaska, Fairbanks Campus; by the Mechanical Engineering Department. Major organizational work was accomplished by James S. Strandberg, under the direction of Professor John Zarling. Major design and cost input was provided by Maynard and Partch, Architects; HMS, Inc., Cost Estimators; and David Olson, P.E., Electrical Engineer, all of Anchorage, Alaska.

X. REFERENCES

ZARLING, John, P.E. ; Strandberg, James S., P. E.; "A Thermal Performance Design Optimization Study for Small Alaskan Rural Schools", Phase II Report by University of Alaska Mechanical Engineer Department for the Department of Transportation and Public Facilities, October, 1983.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS, INC., "ASHRAE Standard 90.1, 90.2, 90.3, Energy Conservation in New Building Design", 1980.

BECKMAN, Duffie and Associates, "F-Load Building Heating Load Calculation Program", Version 3.2, Middleton, Wisconsin.

ENERGY CONSIDERATIONS
FOR UTILITIES IN COLD REGIONS

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ABSTRACT

The purpose of utilities is to improve the health of, and convenience to, the users.

To accomplish this, utilities must be designed with the greatest reliability while retaining low operation and maintenance costs. Reliability is extremely important in cold regions because of the devastation that can be caused by one small malfunction in a utility system.

Operation and maintenance expenses tend to be very high in cold regions because of the high energy costs. In remote regions of Alaska, energy costs vary almost directly with the cost of fuel oil.

This paper will present several issues to consider when designing utilities to keep the fuel usage or operation and maintenance costs as low as possible. These include water conservation, the elimination of high maintenance items such as water service lines, the use of low energy sewage treatment options, and utilization of all possible heat sources and alternative forms of energy, such as wind and solar.

INTRODUCTION

Utilities must serve two primary purposes. They should maintain or improve the health of the users and they also provide greater convenience. Utility design, in any location, should provide these services at the lowest life-cycle cost. In cold regions, this usually means designing for the lowest possible operation and maintenance (O&M) cost without sacrificing reliability. O&M expenses are very high, especially in remote areas, because of the high energy costs caused by the necessity to import fuel oil. There are many ways energy use can be minimized when providing utilities in cold regions. Some of these ways are discussed below.

WATER CONSERVATION

Water conservation is also energy conservation. Water must be heated before it is distributed during a large part of the year. If less water is used, less must be heated and processed. This is especially true with hot water heaters because the water is heated to well over 100 degrees F, instead of to about 40 degrees F as it is in a distribution system. The Cold Climates Utility Delivery Design Manual (CCUDDM)[1] presents an evaluation of most water conservation devices which can be used in the home. Some are effective in cold and/or remote regions and some are not. A more detailed section on energy sources and conservation will be added to the new edition of the manual soon to be published.

Low water use sewage collection alternatives, such as pressure or vacuum systems, should be considered for small, remote communities in cold regions. In addition to reducing water use and, thus, the sewage to be treated, they do not rely on gravity and can be used in locations having frost heave and/or thaw settlement problems.

SYSTEM PLANNING AND DESIGN

The water in a piped distribution system must be continuously circulated, in addition to the necessity of adding heat. Most circulating systems use "pit-orifices" to assure circulation in the service lines. Water must be circulated at about 2 feet per second in the main line to assure a 0.2 feet per second velocity in the service line. The length of time the water is in the service line is the limiting condition when it is moving at only 0.2 feet per second. This limits service line lengths (house to main distance) to 60 to 70 feet. For longer service lines, a small, fractional horsepower circulating pump can be located in each house to assist the pit-orifice or provide all of the service line circulation.

An "extended main" system is a design which can reduce energy use. The extended main concept essentially does away with service lines and, with them, the necessity to circulate water at 2 feet per second in the main lines. Also, O&M is reduced because service lines are a major O&M problem with any piped water distribution system in cold regions.

With an "extended main", the main distribution lines are routed directly, building to building, with a short riser extending through the floor or wall to provide water service. This riser can be insulated and heat traced, if needed. Circulation velocities on the order of half a foot per second can then be used in the mains. Since pumping costs are proportional to the square of the velocity, this design can reduce circulation costs by as much as 16 times and significantly cut O&M. The main disadvantage of an extended main system is that the community-owned distribution lines must necessarily cross private property. This usually makes the system unfeasible for larger communities.

Energy use can be further reduced by using low energy sewage treatment facilities. For instance, a facultative sewage lagoon, with essentially no energy requirements, can provide an acceptable level of treatment for a remote, isolated community or site. Aerated lagoons or extended aeration treatment plants may provide a higher degree of treatment; but there are many small communities that cannot afford to operate them properly. Rotating biological contactor (RBC) plants use less energy than conventional wastewater treatment plants and can be used where a higher degree of treatment is desired, where space is at a premium, or where pumping costs to a lagoon site would be excessive.

Secondary sewage treatment consumes more energy and O&M time than primary treatment. Secondary treatment should probably not be installed unless there is the possibility of a health hazard or a severe environmental problem.

WASTE HEAT UTILIZATION

Heat should not be "wasted" in cold regions. All sources of heat should be utilized to the maximum extent feasible. Consider also that, even though it may not seem feasible to recover heat today, it probably will be before the facility's design life is reached. Heat recovery units should be considered for the jacket water and exhaust stacks of all fossil fuel electrical generation units. When considering the feasibility of recovering this heat, the cost and environmental impacts of its dissipation must be included. These impacts can be significant. For instance, much of the ice fog in the Fairbanks area can be attributed to the open water created by cooling ponds or by discharges of warm cooling water into natural water bodies. If the recovery of the heat for the process is not feasible, it should be considered for other beneficial uses such as heating water for fish hatcheries, soil warming to improve agriculture potential, heating greenhouses, or melting ice and snow.

Another example of the utilization of heat that would normally be wasted is the use of heat pumps to extract heat from the final effluent at the Fairbanks Sewage Treatment Plant. Sewage is normally at 45 to 50 degrees F and is usually not thought of as a source of heat. At the treatment plant heat pumps lower the temperature of the effluent sewage (8 MGD) about 5 degrees F and use the heat to heat the plant. This also lowers the environmental or thermal impact on the receiving water.

If heat could be stored in the ground during the summer and then be extracted in the winter for heating buildings, etc., a significant amount of energy could be saved. This may be feasible using heat pumps in areas without significant depths of permafrost.

Incineration, after recycling, is considered the ultimate solution to the problem of solid waste disposal. Incineration is usually extremely expensive if fossil fuels must be used. Recovery of the incinerator stack heat could make it more economically attractive. Most incinerators currently manufactured in the U.S. are not built with waste heat recovery in mind. Two newer processes, which make energy recovery more feasible, are the suspension fired and fluidized bed units. These plants are not small enough nor have they been perfected to the point that they could be used in a remote cold regions community.

Steam collected in the waste heat recovery unit of an incinerator, turbine, engine, or boiler can be used to drive another turbine and produce power. This is currently being done in Anchorage where 40% more power is generated with the same fuel use. Their existing 40,000 kW gas turbine produced about 137 x 106 Btu/hr waste heat at full load. This heat now drives a 33,000 kW steam turbine generator. The previous overall efficiency of the system was 22% and, after the addition of the steam turbine, the overall efficiency went up to 36%. Operating costs went up about 1.3 mills/kWh and the cost of the additional plant was about 6 mills/kWh but, with a 19% increase in operating cost, output increased 40%.

Stack gasses with temperatures lower than 300 degrees F do not usually have economically recoverable heat at present fuel costs. Below is a summary of the percentage of the input fuel energy that is lost in the exhaust of typical units and approximate exhaust temperatures.

UNIT	PERCENT OF FUEL ENERGY IN EXHAUST	TEMPERATURE OF EXHAUST
Oil or gas turbine	65 to 84 percent	800 to 1,000°F
Diesel engine	35 percent	300 to 6000F
Home furnace (oil)	30 to 40 percent	350°F
Home furnace (gas)	40 percent	3000F

There are also disadvantages which must be considered in planning waste heat recovery units. Major corrosion problems can be created if the exhaust gas temperatures drop too low in coal or oil fired units. Manufacturers can usually supply the lower limits.

Air exchange can account for 25 to 40 percent of the heating load of a building. Small air-to-air heat exchangers can help recover a significant potion of this loss . Several commercially available units were tested by the University of Alaska and the State of Alaska, Division of Transportation and Public Facilities: and a report is available.

ALTERNATIVE ENERGY

To most of us, alternative energy means an energy source other than fossil fuels, such as coal, oil, gas, or wood; in other words, solar, wind, hydro-power, and others. This essentially breaks down to non-renewable or renewable resources. Wood is a renewable energy source in warmer climates but the rate of growth is relatively slow in cold regions and use rates would have to be very low for it to be considered truly renewable. We should conserve non-renewable resources and make maximum, wise use of renewable resources. In situations where non-renewable energy sources must be used, many conservation measures can be taken. Neither time nor space permit a discussion of all of the fuel conservation measures here. The CCUDDM[1] will cover this subject in detail and most utilities or fuel suppliers can provide information on ways to conserve fuel and, thus, energy.

Hydropower is probably the cleanest and, generally, the least expensive source of energy available. Small hydropower generating units have been around for years but new developments have improved their efficiency and, thus, feasibility. Hydropower can be broken down into low head sources (60 feet or less) or high head. Low head installations require higher flows to produce the same amount of power, as would be expected. Low head turbines are also usually less efficient. Hydropower sources are abundant in the subarctic areas of Alaska with low head sources also available further to the north. Arctic rivers or streams usually have high maximum to minimum flow ratios. Values of 50 to 100 are not uncommon and must be considered when designing hydropower units. As is common with most forms of alternative energy, this means that the source may not be usable on a year-round basis and that conventional fossil fuel units will need to be provided, along with the alternative fuel unit, to assure a continuous power source. This will nearly double the capital expenditures, and even though O&M costs are usually lower, can raise havoc with the feasibility of using alternative energy units.

Hydropower can often be combined with a community's water supply to recover additional energy which would normally be lost. The City of Seward is presently constructing a combination water supply-power generating project. One water source, Marathon Creek, falls some 700 feet. By -tapping the creek at the 750 foot elevation and dropping the wat'er through a pipeline to a Pelton wheel generating unit before it enters the water supply storage tanks, 250 kW of electrical energy, which would normally be lost, can be generated for use in the city's power grid.

Often, fluids, whether they be oil or water, must be pumped over higher elevations between the source and supply point. Hydropower generating units could be economically installed at the base of downhill sections of pipelines to recover a part of the pumping costs. This energy would normally be lost or have to be dissipated using pressure reducing stations. Alyeska is presently looking into the possibility of this method of energy recovery at different locations along the Trans-Alaska Oil Pipeline.

Geothermal energy is also a source to be considered. However, with present technology, the source usually must be 150 degrees F or higher, and be near the point of use. These two conditions are rarely satisfied in the cold regions of Canada and the U.S.

Even with the shortness (or lack) or daylight during arctic winters, solar energy should be considered. There are actually more hours of daylight at the Arctic Circle than the Equator, but the intensity is less, because of the angle of incidence, and it occurs during a short period of time. It is often feasible to use solar energy to heat water during the summer in Interior Alaska. However, another heat source must be available for winter.

Wind energy is the most promising form of alternative energy for most of Arctic Alaska. The wind blows almost continuously along the northern and western coast, where most of the small remote communities are located. The wind also tends to be greater and more consistent during the winter, when power and heat are most needed. There have been several wind generators installed around the state with varying degrees of success. Nearly all of them have had some problems because of wind gusting and the harshness of the climate. Many of these problems have been, or will be, corrected with second generation units. Wind, as with the other alternative energy sources, requires back-up fossil fuel generating units because it does not blow continuously at the 10 to 15 mph needed. The potential for utilizing the wind for power generation, or simply the generation of heat using resistance coils in a water storage tank, should be thoroughly evaluated for any cold regions community. As was pointed out earlier, all water must be heated during the winter before it can be distributed and a portion of this heat could possibly be provided by a wind generator on top of the water storage tank. This is energy that would otherwise go unused.

Information on the wind potential at a given location must usually be otained on-site because of the many variables which affect the wind's speed. Some general data and "loaner" anemometers are available through the University of Alaska, Arctic Environmental Information and Data Center. They can also furnish information concerning the past experiences with units throughout the state.

CONCLUSIONS AND RECOMMENDATIONS

It is important to conserve energy when providing utilities in any location, but more so in cold regions where most of the energy is imported in the form of fuel oil. When utilities are planned and designed, alternative sources of energy and the utilization of all sources of available heat should be considered. The heat wasted or dissipated to the atmosphere or water bodies must be kept to a minimum because of the cost to produce it and the environmental problems associated with its disposal. The feasibility of providing heat recovery and/or alternative energy sources must consider such factors as future fossil fuel shortages and the life cycle costs of the project, not just capital costs. If designs are carefully accomplished with these considerations in mind, utilities can be provided which will improve health and convenience to the cold regions users.

REFERENCES

1 Cold Climate Utilities Delivery Design Manual - (CCUDDM) U.S. Environmental protection Agency (EPA-600/8-79-027 - September 1979) - Environmental Research Laboratory - Corvallis, Oregon 97330

I

TODAY'S CONSTRUCTION - TOMORROW'S LIABILITY

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ABSTRACT

When a building is constructed in the arctic it may not be merely replacing an old or other existing structure. The new building will be a man-made addition to a natural environment and will change that environment.

Creating a built environment where people can live and work in comfort solves several problems for the people who will use it, while creating new problems, responsibilities? and liabilities simply because the natural environment has been changed. These liabilities are pointed in two separate directons. First the builder is liable for the way the building will effect the natural environment into which it is placed and, secondly, he is liable to the people who will use the building for its lifetime.

Throughout Alaska today there are many buildings which were built when there was an assumption that energy was a commodity which was plentiful and would become cheaper. Today we know this assumption was not correct. Yet ironically the high costs of this energy has provided the state, and local governments within Alaska, with the financial means to build more buildings for its people at an unprecedented rate. Regardless of how carefully these new buildings are planned and the long-term liabilities considered, we will inevitably be consuming more energy as we build more buildings.

The Alaska Department of Transportation and Public Facilities conducts a Program of Energy and Buildings Research which is intended to develop and identify the methods and materials which will enable Alaskans to deal in the years to come with the responsibilities and liabilities that have been created by our state owned buildings. This paper emphasizes some of the developments of that program.

INTRODUCTION

There is a fair amount of money in Alaska at the present time flowing primarily from the oil development on the

North Slope. A good portion of that money is being used, and will continue to be used, to construct new public facilities. This is a proper use of the oil revenues, as the construction of public works projects is clearly a universally accepted responsibility of government. The construction of public facilities stimulates a construction industry and is healthy for the state's economy in the short term. But what are the long term economic implications for Alaska; and in a broader context, for all of the Arctic, resulting from these capital improvement projects?

Here are three possible scenarios for what may happen to us in the future:

1. We will continue to reap budget surpluses which will allow us to maintain, operate, renovate, and replace these facilities ad-infinitum. This is "The Happy Face Scenario".
2. Or, possibly, within the next few years the oil will begin to dry up, revenues will fall, and we will be left with a multitude of buildings, highways, airports, and other miscellaneous improvements we can no longer afford to operate or maintain. This is "The Sad Face Scenario".
3. Or, in reality we can probably expect some combination of these two without a clean domination of one system extreme over the other.

But in any event the fact remains:

When we build public facilities, in the remote regions of the Arctic; especially buildings, we create a liability and a responsibility. These facilities must be maintained, and operated throughout their useful life time if they are to fulfill their intended function. This process will consume human resources in the form of labor, materials resources and energy resources. If the current trend continues, the consumption of energy in the arctic will steadily increase in absolute value, and conservation will really mean: "How can the rate of increase be brought within manageable limits?" How can we take responsibility and insure tomorrow's liability?

BACKGROUND

The Alaska Department of Transportation and Public Facilities is the one state agency which, more than any other, is responsible for all aspects of public facility stewardship; including the maintenance and operaton, as well as the design and construction. In recognition of the role technology plays [illegible] the Department maintains a [illegible] directs its effort toward the [illegible] of applied technology in the field of transportation and building science. Within the research unit are three [illegible] way new technology is applied to [illegible] on, maintenance, and operation of public facil[illegible]. These three are the Highway Research Program, the Transportation Systems Research Program [illegible] Energy [illegible] Research Program. [illegible] Energy and Buildings Program al[illegible] which I will [illegible] comment, with some discussion about the direction the program has taken since its inception [illegible]

DISCUSSION :

The Energy and Buildings [illegible] the same time the biggest bu[illegible] had ever undertaken - the construction of the Bush high schools - was winding down and just prior to the accelerated construction which the [illegible] was a time when everyone was a[illegible] consumption and a time in which [illegible] about the potential of unique alternate energy sources was the rule more than the exception [illegible] point, the program began by unde[illegible] would define the technical and economic realities about energy consumption in buildings built in the Alaskan environment. Those of you [illegible] presentation of the The m[illegible] have some idea of the complexity of one of our earliest and most ambitious projects. At the same time, we wanted to assemble as much sound [illegible] application of alternative energy systems [illegible] environment as possible. Three publications, the Wind Power Manual, the Solar Design Manual and the Heat Exchanger Report, are some examples of that ef[illegible]

Both the Wind Power Manual and the Solar Design Manual were published in response to a raft of questions from people living in the arct[illegible] type of unique technology right a[illegible] Department was also receiving a lot of proposals from architects who were responding to the latest information in the media.

It is apparent, however, [illegible] rate of [illegible] funded construction is not going to wait for energy research to come up with unique new ways to control consumption through energy [illegible]. It is impossible to stress a [illegible] which some day in the future will report that the [illegible] solu[illegible] building design in the arctic has been found; when [illegible] five percent of the needed [illegible] ready [illegible] [redacted] [redacted]

The philosophy which has been [illegible] the "Ener[illegible] Building Research Program" in [illegible] is one [illegible] assumes that the engineering problems of most [illegible] the future will be those which attempt to reduce [illegible] of maintenance and [illegible] of buildings which [illegible] likely have not been designed [illegible] optimum performance in cold region environments. These are the things [illegible] Brower mentioned in his opening statement. In [illegible] this view, I would [illegible] a few examples [illegible] current projects in [illegible] Buildings" [illegible]. These are down to earth, practical, every day engineering projects aimed at down to earth, practical every day engineering problems.

SLIDES

3 & 4 - These slides [illegible] test version of an above ground utilidor. It is [illegible] and tested in the cold chambers at the University of Alaska Engineering Department to test a phase change material which could be packed in [illegible] utilidors to store internal heat and delay freezing [illegible] and sewer pipes should intermittent power outages interrupt flow and heat. Preliminary results indicate that freezing could be forestalled for [illegible] days at sub-zero temperatures with this sort of [illegible].

5 - At Bethel a half way house operated by Bethel Social Services, was [illegible] to demonstrate that Halon fire suppression systems could be used in public buildings in the bush where installation of conventional sprinkler systems are extremely costly and have a serious risk of [illegible].

6 - Halon gas cannister installed in the half-way house.

7 - At the recently [illegible] Two Rivers School on the Chena Hot Springs [illegible] few miles northeast of Fairbanks, a joint research effort being conducted by the U.S. Department of Energy, the DOT[illegible] Research Section, and the [illegible] North Star Borough will test and monitor the passive solar features of a building designed by C.B. Bettisworth and Co., a Fairbanks architectural firm. This slide shows the South side of the building.

8 - This slide shows the South facing window wall under construction.

9 - The bright natural [illegible] interiors of the classrooms are expected to greatly reduce electrical lighting costs.

Larry Sweet

10 & 11 - These slides [illegible] space which being monitored [illegible] amounts of solar energy can be [illegible] added the south side of existing buildings

12 & 13 - A test fa[illegible] box ha[illegible] under construct[illegible] is not complete. This de[illegible] will be used to test the thermal performance of variety of arch[illegible] as window door systems, [illegible] shutter[illegible] wall secti[illegible] It is a piece of [illegible] owned and used the DOT [illegible] Research Section and the University of Alaska School [illegible]

14 - This is a photo [illegible] which is [illegible] by engineers in the Energy and Buildings Section measure the [illegible] buildings. As Mr. Ryan mentioned [illegible] many state buildings, typically rural school buildings, use as much as 50% of their heating fuel to heat cold air which is brought [illegible] to provide required ventilation [illegible] we will need a major effort t[illegible] loss and when that time comes, the Research Section hopes to have some of the ne[illegible] developed and ready for implementation.

This is not a very awe-inspiring set of slides and it wasn't intended to [illegible] we are not working on any awe-[illegible] will solve all the problems of Ala[illegible] We are not that good.

The incinerator b[illegible] the Naval Arctic Research Lab is a [illegible] we are [illegible] involved with changing.

What we have tried [illegible] to earth, realistic, engineering research program which reflects the reality of the rigorous applied engineering research needed [illegible] we, in [illegible] and appropriate and acceptable methods [illegible] rrow's liability, as Mayor Brower has called for.

[illegible] Sweet

DESIGN CONCEPTS FOR UNDERGROUND UTILITY DISTRIBUTION
IN
BARROW, ALASKA

[illegible] L. Zirjacks, P.E.
Frank Moolin & Associates, Anchorage, Alaska

ABSTRACT

Barrow, the northernmost community in the United States [illegible] population of approximately 3,200 and has no areawide piped [illegible] sewerage facilities. The North Slope Borough has been striving to improve the utility situation in Barrow in order to promote public health and personal convenience as well as to augment the physical, [illegible], and social needs of the community.

After considerable survey which began in 1964, the North Slope Borough commissioned the design of a below-ground heated utilidor system that would allow for man access for cost effective maintenance and that could be constructed and repaired by local labor. This utilidor system is presently under construction.

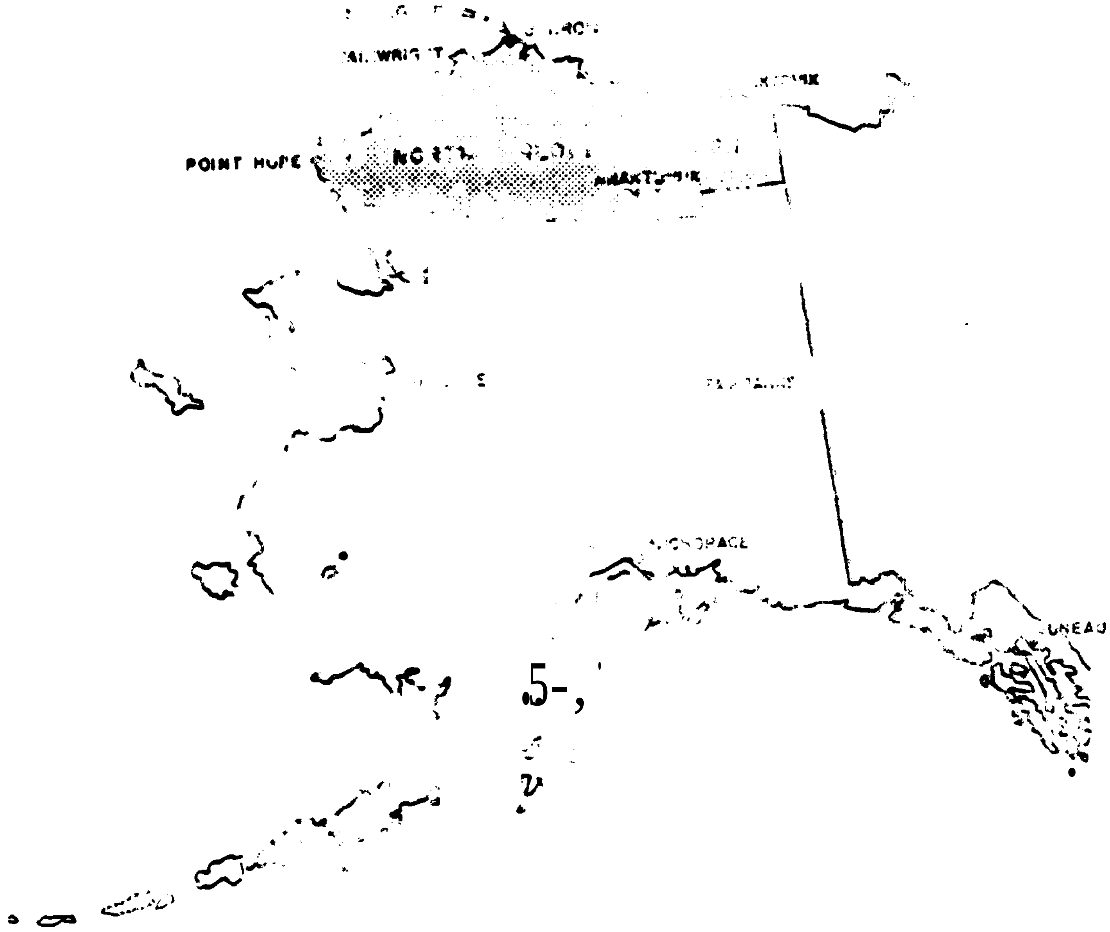
The relatively unprecedented nature of installing a heated tunnel within ice-rich permafrost, as well as the unique aspects of utility delivery in the arctic [illegible] necessitated the development of new design criteria and solutions.

This paper presents and discusses the design criteria and concepts developed by Frank Moolin and Associates for the design of the Barrow Utilities System.

INTRODUCTION

Barrow, Alaska, located on the Arctic Coastal Plain, is the northernmost community in the United States and currently has a population of approximately 3,200. The town is best described as a modern Arctic Eskimo community and it serves as the governmental center of the large North Slope Borough (see Figure 1). Whaling and game hunting still constitute a major portion of the subsistence of the town's inhabitants.

The City of Barrow currently has no area wide piped water or sewerage facilities. [illegible] is pumped from the upper portion of the Isatkoak Lagoon to the treatment facilities in Barrow. The treated water is then hauled to the residences via private carriers. Many residences also haul ice from clean water sources south of the town for potable water uses.



[illegible] VICINITY MAP

Vitjacks. W.L.

Sewage wastes are collected at residences in holding [illegible] plastic bags and then [illegible] to a privately owned "hon[illegible]" truck for deposition at [illegible] landfill at the South Salt Lagoon. [illegible] wastes are also collected [illegible] standard garbage pick ups for disposition at the same landfill.

The North Slope [illegible] to improve these conditions with piped sewerage and water facilities for reasons of sanitation, convenience, and aesthetics. Feasibility studies with respect to possible above-ground and below-ground transmission systems were performed to assist [illegible] this goal.

After evaluating the recommendations, design parameters, and risks, the North Slope Borough [illegible] upon a complete below-ground utilidor system (Figure 2). This system has the highest capital cost and the lowest maintenance cost of all the systems evaluated. It provides the greatest flexibility for further expansion of the utility system and offers the best aesthetics of all systems investigated.

Also, it was desired that the utilidor be constructed out of materials that would allow fabrication in Barrow with local labor forces.

Several different construction materials were investigated, and it appeared that a wooden utilidor could best satisfy the desires of the North Slope Borough. A wooden utilidor prototype was constructed and load-tested at Washington State University.

The North Slope Borough reviewed the prototype design, costs and available labor forces and decided to proceed in this direction. At this time, the services of Frank Moolin & Associates were engaged to prepare a design for [illegible] utility system based upon the below-ground wooden utilidor approach.

PERMAFROST

Permafrost underlies the entire Arctic Coastal Plain. The bottom of the permafrost zone in the Barrow area lies 300 to 400 metres below the surface. The mean annual air temperature in the area [illegible] 11°C (Figure 3). Seasonal variations in air temperature affect permafrost temperatures to a depth of approximately 30 metres. Polygonal or patterned ground is common in the Barrow area. It results from water collecting in the shrinkage cracks that occur when the ground contracts during extremely low winter temperatures. The process, which repeats itself over and over, eventually results in large masses of ice that can extend from the ground surface vertically downward to about 5 metres. Ground ice may constitute as much as 80 percent of the total soil volume in the upper 3 to 5 metres where fine-grained soils such as silts are present. Detailed geological descriptions of the Barrow area are available elsewhere (Black "Gubik Formation", Lewellen "Studies of the Arctic Environment").

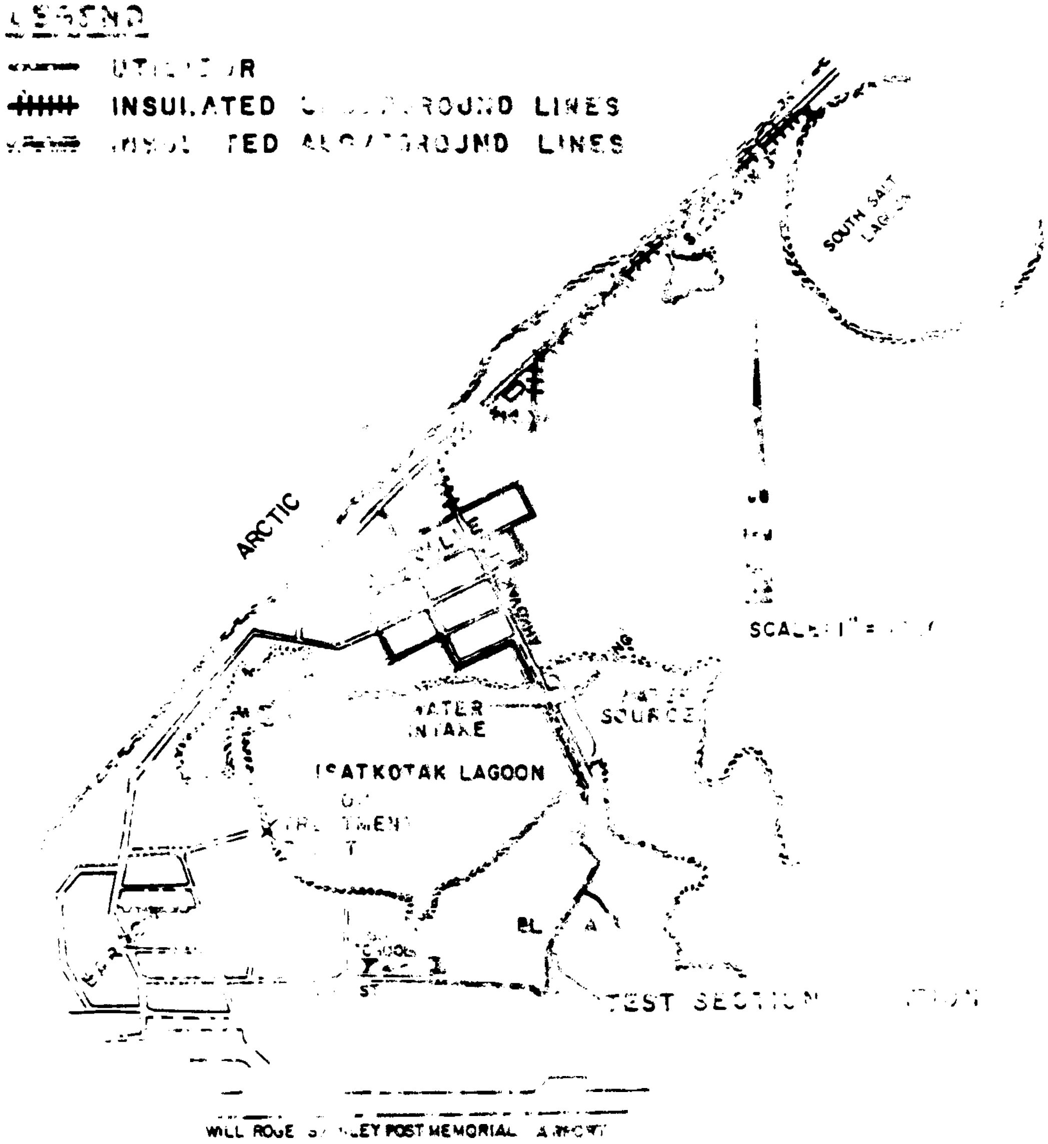


FIGURE 2 LOCATION MAP

) acks, W.L.

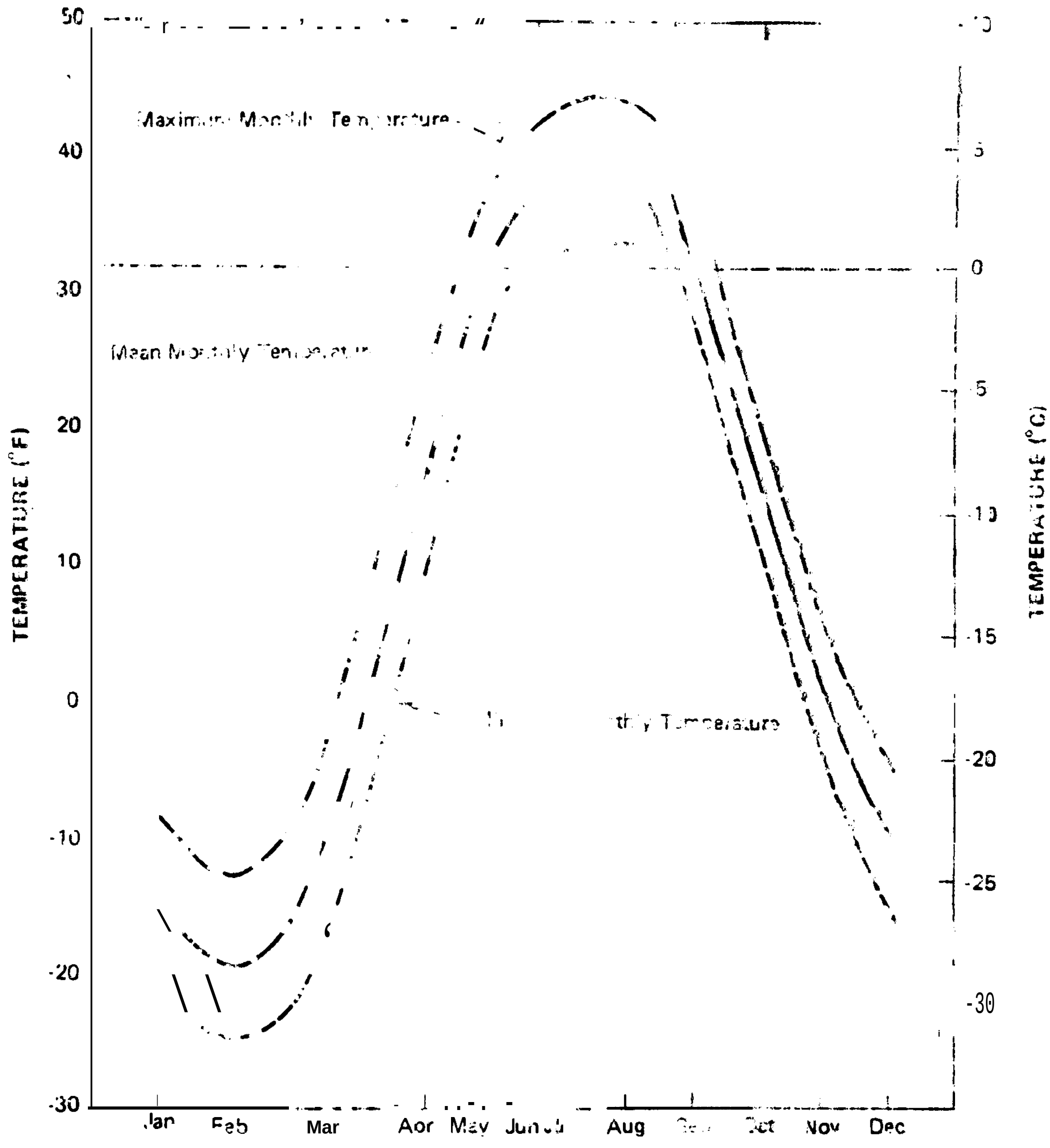


FIGURE [illegible] AIR TEMPERATURES
BARROW, ALASKA

The residential areas around and within Barrow contain dwellings and structures that are primarily of wood frame construction and supported by pile foundations to resist the seasonal ground fluctuations that are common in the arctic. The vegetation normally associated with arctic tundra has been removed in areas around the structures due to human activity. The resultant area is usually covered with gravel fill to stabilize the melting of the surrounding permaf rest.

The areas that have been left in their natural state are covered with a tundra growth of moss and sedges. The active layer of seasonal freezing and thawing is approximately 0.5 m in the undisturbed areas and varies in the disturbed areas in a manner proportional to the gravel fill.

The roadways are gravel surfaced and stabilized after many years of subsidence due to thermal degradation. Additional gravel material was placed on the roadways as they subsided, and the resulting thickness after stabilization varies between 0.9 m to 1.6 m.

The surface drainage throughout the area is poor, and major pending takes place during the spring breakup. Effective drainage is also hampered by the continual frost-jacking that occurs at drainage culvert inlets and outlets.

Sensitivity to thermal degradation of such an ice-rich permafrost around a heated utilidor requires intensive engineering analysis, as well as stringent construction procedures, to ensure that the ground thermal regime remains stable.

TEXT

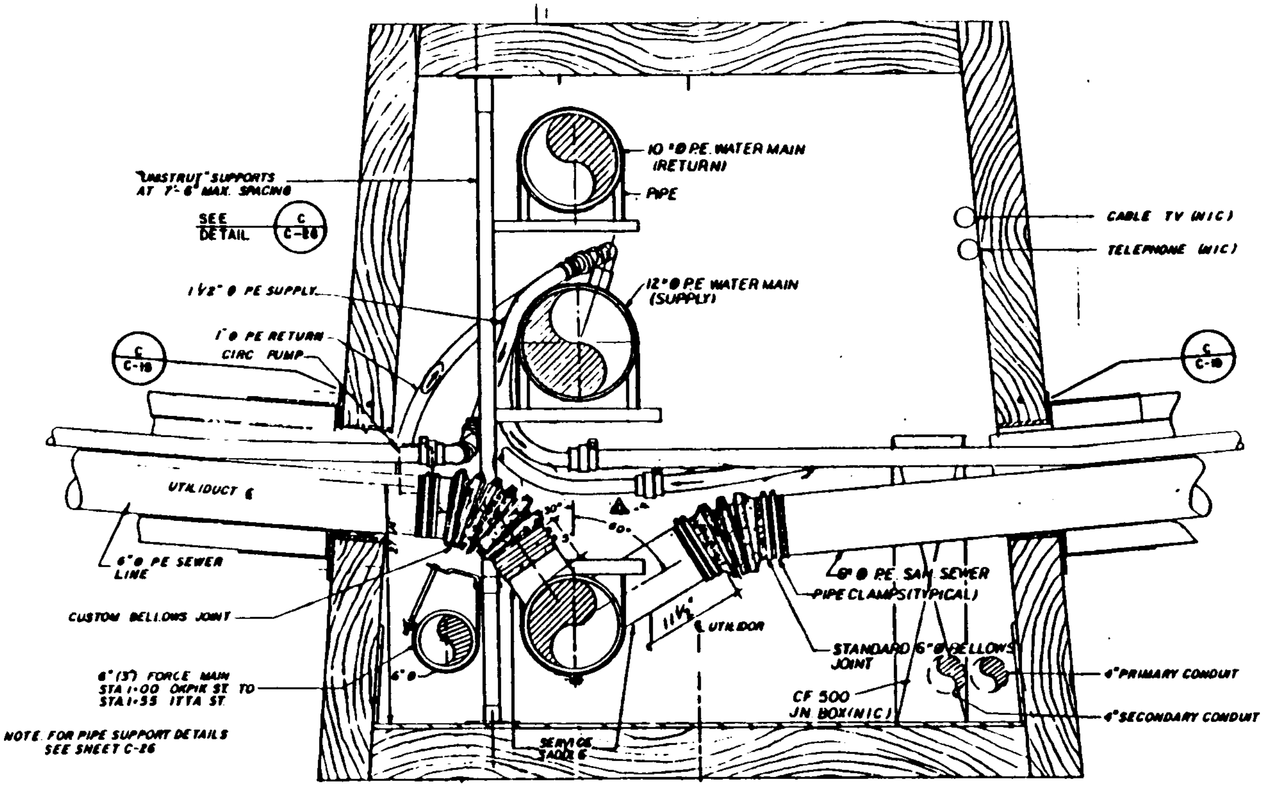
PHYSICAL UTILIDOR DESIGN

The utilidor is designed to contain water, sewage, electrical, cable T.V., and telephone transmission systeins. The interior will be kept above freezing with heated, circulating water, and space will be provided for man access for maintenance (Figure 4).

As shown in Figure 5, the utilidor is constructed with 5 cm x 15 cm Douglas Fir Lumber placed with the wide side of the boards against one another. The utilidor sections are fabricated in lengths of approximately 3 m long and contain six steel tie rods.

The design is based on a 57 kip maximum wheel loading on a 76 cm x 91 cm tire print and a soil load of 1270 kg/m^2 at 76 cm depth; 10 cm of which is occupied by polystyrene foam insulation. A resulting design load of 9760 kg/m^2 which includes soil and structure dead load was chosen as a basis for the design.

The exterior of the utilidor is covered with an impermeable vapor barrier, which is covered with 100mm (4 inches) of insulation. The vapor barrier is to eliminate damage due to f rest f ormation within the insulation layers and to also contain warm water within the utilidor from leaks or line breaks.



A C-3 SEWER & WATER SERVICE CONN DETAIL
ENTRY BELOW TIE ROD
SCALE: 1½" = 1'-0"

FIGURE 4 UTILIDOR PIPING, TYPICAL SECTION

Zirjacks, W.L.

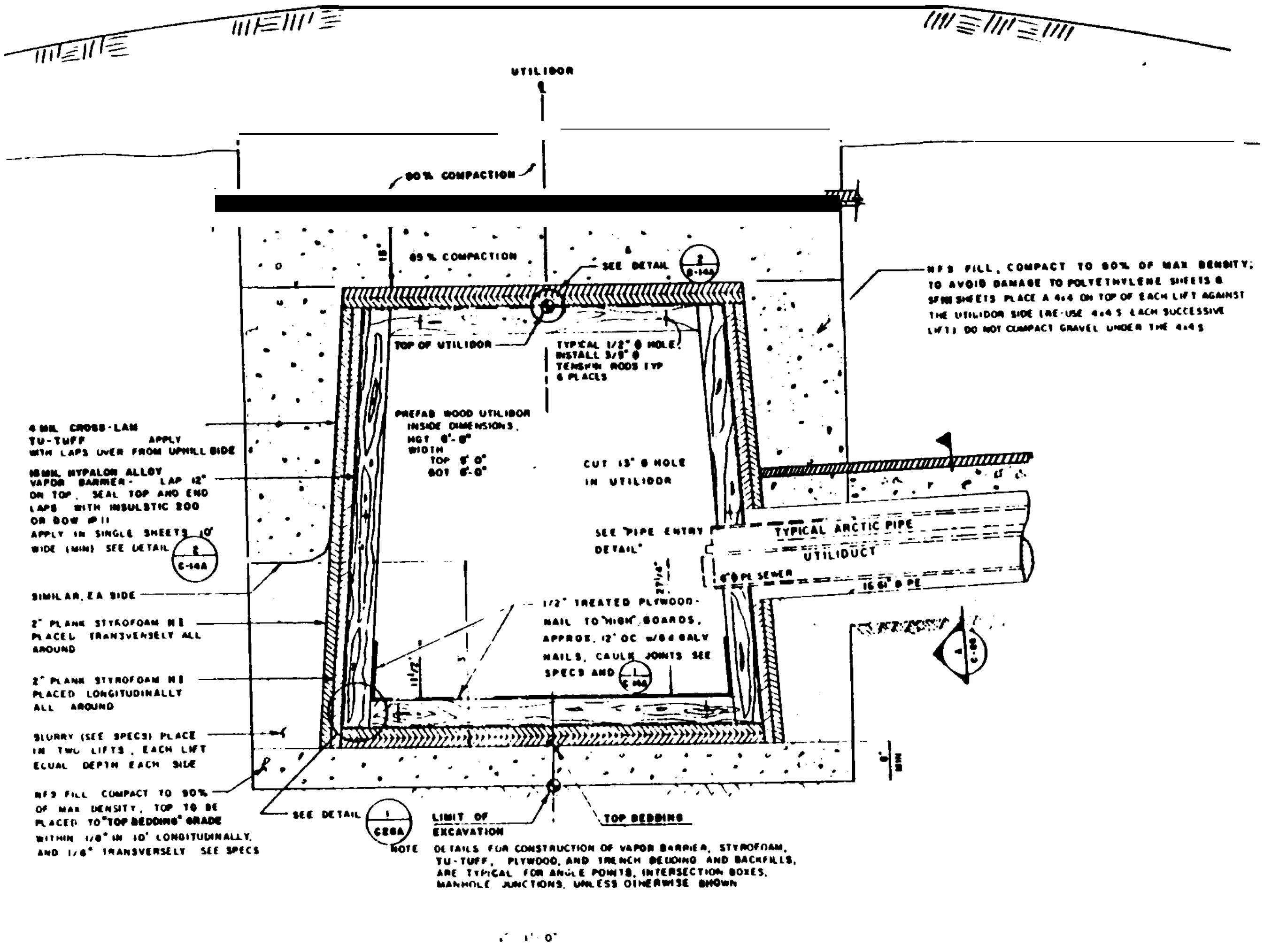


FIGURE 5 TYPICAL UTILIDOR SECTION

An impermeable moisture barrier is then placed over the utilidor insulation to direct small amounts of free moisture away from the warming front created by the utilidor. Access to the utilidor will be through prefabricated, metal manholes.

After placing the utilidor structure, dry gravelly sand is used for backfill material and water is added to achieve compaction. This material exhibits a thaw strain of approximately 2% if placed at a moisture content of 3%-4%. A similar method was used for the utiliduct installation. Ditch plugs consisting of bentonite-sand mixture were installed in all trenches to inhibit ground water movement.

SERVICES

Service to residences from the utilidor mains will be via utiliducts consisting of pre-insulated polyethylene pipe (see Figure 6). These utiliducts will carry the various service laterals to metal service boxes similar to the manholes. Multiple house services will then be distributed form the service boxes.

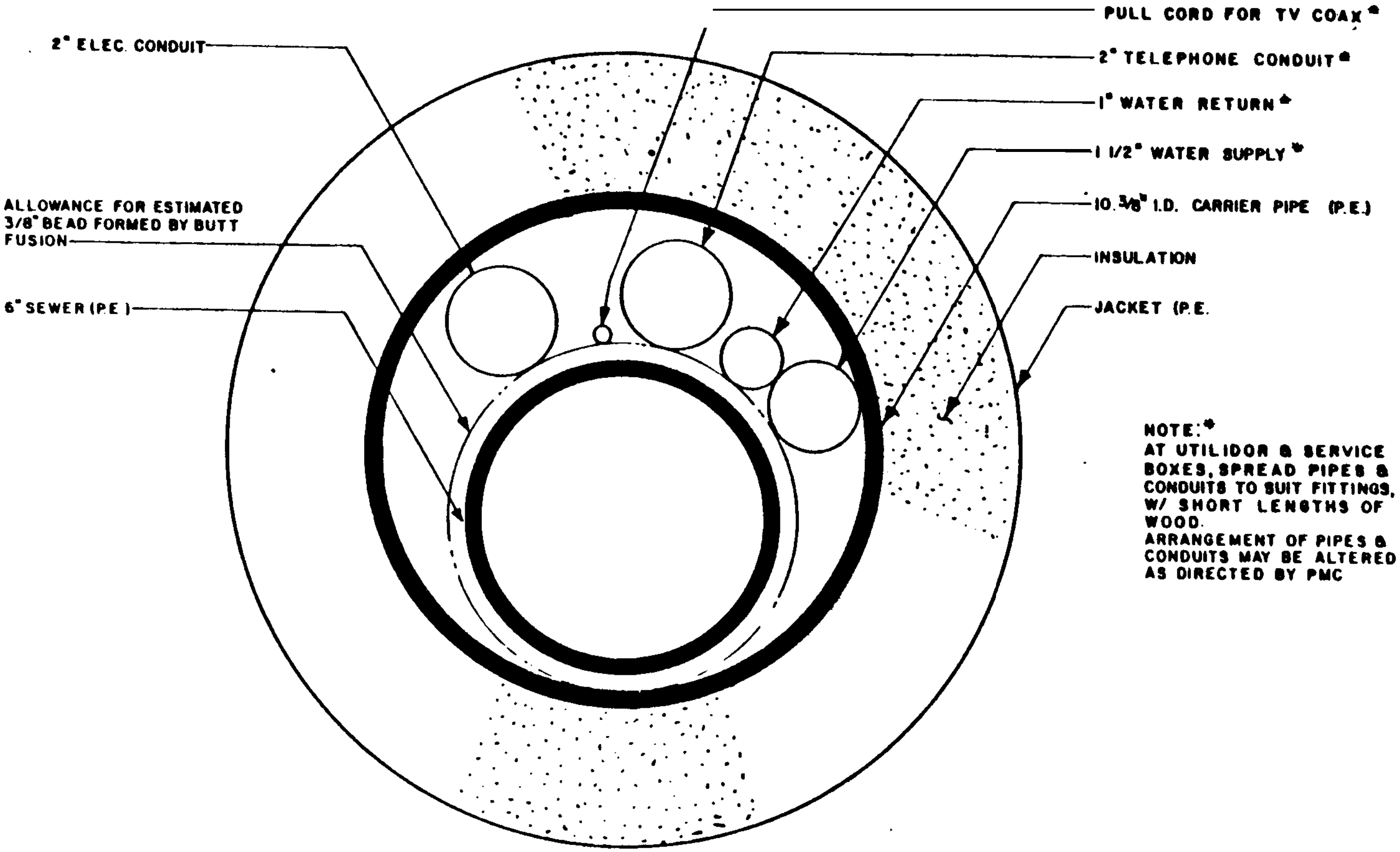
Water services will be circulated to the residences with small circulating pumps located within the utilidor. It is the desire of the North Slope Borough to eliminate the responsibility of the owner for the operational reliability of the service connection and ultimate system performance.

The service connection will connect to the user at a single point and the transition between the below and above ground portions will be designed against the forces of frost jacking. The connection point will include emergency heat tracing as well as meters for water and electrical usage.

PIPING

The primary piping material selected for the Barrow Utilities system is High Density Polyethylene. This material was selected for the following purposes.

a. Ability to withstand forces from repeated freeze-thaw cycles under full flow conditions without damage.
b. Light weight to allow ease of installation and repair.
c. Thermal, butt fused joints to reduce the amount of mechanical connections necessary for installation and maintenance.
d. Relatively low thermal forces developed during range of design temperatures due to a low modulus of elasticity and the pipes ability to “stress relieve” itself. These properties also are beneficial in the reduction of transient forces due to surging.
e. Low coefficient of friction for enhanced flow characteristics and resistance to clogging.
f. Resistance to corrosion.



NOTE:*
AT UTILIDOR & SERVICE BOXES, SPREAD PIPES & CONDUITS TO SUIT FITTINGS, W/ SHORT LENGTHS OF WOOD.
ARRANGEMENT OF PIPES & CONDUITS MAY BE ALTERED AS DIRECTED BY PMC

FIGURE 6 UTILIDUCT

Although the low modulus of **elasticity** reduces the thermal forces, the polyethelene piping material exhibits a high coefficient of thermal expansion. Since the design temperature differentials are 16 'F and 43 'F for the below and above-ground portions, respectively, a considerable amount of deflection may take place with an unrestrained pipe.

The problem of pipe deflection is solved with the pipe installation procedure. After the pipe is placed in the racks, warm air is applied by blower into the pipe to bring its temperature to the proposed operating temperature plus 3°F. Once this temperature has stabilized and all associated expansion has taken place, the pipe is restrained at the end of tangential sections with ductile iron fittings and rigid supports. The pipe is then allowed to cool to the ambient temperatures and remain in tension.

After system start-up, the pipes will attain their respective **operating** temperatures and will still be approximately 3 'F below the installation. Since the yield stress of the polyethylene material has not been exceeded, the pipe will still be in a slight amount of tension and no lateral or vertical deflections will occur .

Mechanical fittings will be used at intersection points and at other points of restraint or connection. The **fittings are cement lined ductile iron for corrosion protection whenever possible and are of the "Victaulic" type for ease of** maintenance.

WATER SUPPLY AND DISTRIBUTION

The present water supply line from the upper portion of the Isatkoak Lagoon is a 10 cm diameter, P.V. C. insulated arctic pipe supported above ground by wooden piling. This line has experienced several freezeups during its relatively short life, and has incurred considerable damage and repairs as a result. Additionally, a 10 CM diameter line does not efficiently meet the ultimate design flow capacity.

In order to alleviate the maintenance problem of this above-ground line as well as to increase the water supply capacity, a submarine water line will be placed in the Isatkotak Lagoon. The submarine line will connect the water source to the reverse osmosis treatment plant in Barrow.

The submarine line will consist of an uninsulated 15 cm diameter raw water line with two, 10 cm diameter lines for emergency distribution of treated water back to the distribution system. The raw water will be heated at the intake structure, but the relatively constant thermal regime in the lower thaw bulb of the lagoon will provide a much less harsh environment than the one currently enjoyed by the above-ground facility. Additionally, water circulation and head tracing will be available to protect the line from freezing during periods of inactivity at the treatment plant.

Since 1972, eight estimates of projected water usage have been made for the Barrow area. A conservative estimate of 60 gpcd with a population of 5200 was selected as a design criteria.

The distribution will naturally experience a gradual increase in water and sewage flows over a period of many years until the design criteria is approached. This is due to a continuing number of service connections over a time period as well as a gradual change in the water usage habits of the Barrow residents. Constant speed pumps will be used in both the water distribution pumping as well as in the sewage lift stations to handle the unstable demands and to allow for flexibility in the usage forecasts.

The utilidor will maintain its interior thermal environment above freezing through the use of temperature controlled, circulating water. A minimum circulation rate of 750 liters per minute (200 gpm) will be required for the longest loops (Barrow through Browerville to Barrow) when service consumption is zero.

Heat exchangers will be utilized to control the water temperature. Additionally, any available heat will be used to preheat the raw, water to increase the efficiency of reverse osmosis treatment, if required.

SEWAGE DISTRIBUTION

Sewage **will be collected** from the services via gravity and directed to 4 major pumping stations located throughout the service area. The final pumping station will direct all collected wastes to the South Salt Lagoon for treatment. The South Salt Lagoon will be utilized as a facilitative sewage lagoon. Efflevent from this facility will flow naturally to another upper lagoon (Middle Salt Lagoon) &fore its ultimate deposition in the Arctic Ocean.

The sewage pumping stations utilize a below-ground wet well/dry pit pumping configuration with an above-ground building that houses the controls, ventilation equipment and heating equipment.

The helm-ground portion will be constructed with multiplate sections (7. 3 metres diameter) that have an interior application of 25 cm. thick polyurethane insulation, f- in place. Thermopiling will be placed below and around the buried portion to further insure against the thermal degradation of the surrounding permafrest.

The **design** of the components both helm and above-ground is based upon adequate roan for ease of maintenance and repair by component replacement. Hatches are placed at appropriate locations in the above-ground flooring and decking to allow complete removal of major equipment components.

The sump design for the pump station is such that should an emergency occur that would stop the dry pit pumps fran operating correctly, submersible pumps can be placed directly on the suction intake line of the dry pit pump to maintain the system. Further, comminutors have been placed in the system to reduce the potential of clogging of the pump. As a further safety factor, each of the duplex comminutors are sized to handle the full flew of the pump station.

The pumps themselves are duplexes with each pump capable of providing the full flow requirements of the pump station and the pumps have been designed with large clean-out ports on both the suction and discharge sides of the pump casing. Motors can be pulled and replaced without pulling the entire pump. Additionally, impellers can be removed within the pump station without removal of the motor or pump casing.

UTILIDOR OPERATION AND MAINTENANCE

Sumps are constructed in all intersection points in the utilidor alignment. Since the utilidor is placed at the same slope as the sewerage, the sumps will collect any drainage that occurs f ran sewage spills or water leaks.

Sump pumps are placed within the sumps for evacuation of the collected drainage. The first sump upstream f ran all pump stations will contain a major pump with a capacity of over 750 liters per minute (200 gpm). This will be capable of evacuating the flows that could occur from major waterline breaks. All other sumps will contain minor pumps (95 lpm, 25 gpm) to handle f lows fran leaks that may occur in the adjacent, upstream sections. The pumps will put the drainage into the sanitary sewer line via backflow preventors for ultimate deposition into the South ." Salt Lagoon.

Sewerage maintenance and cleaning will be accomplished with a truck mounted, water-driven jet rodder in conjunction with a vacuum evacuator. The cleanouts for use with the vacuum jet rodding device are located in con junction with the manholes for access with a maximum spacing of 150 meters.

In order to be able to use the vacuum jet rodding device in the harsh arctic conditions, many modif ications had to be made. In addition to the normal automotive modif ications to the truck carrier, the vacuum-/rOdder received the following major modifications:

a. Water supply tank heaters.
b. Insulated water tanks.
c. Airtank moisture ejectors.
d. Connections for continuous circulation of warm water through the rodding hose while in-transit or standby.
e. Arctic hoses.

The water system is designed to allow for water return/supply cross-connects at critical points to allow for circulation of a position of the system while repairs are performed.

A. telemetry center located in the central water pumping station will constantly monitor the operational features of the utilidor system as well as other personal and area-wide safety aspects to be discussed later. Operational aspects include water temperature, air temperature, presence of sump water, service circulation pump operation and personal ingress and egress in the utilidor.

FIRE PROTECTION AND SAFETY

The water system will provide area-wide fire support capabilities to the community. Fire hydrants capable of delivering 4500 liters per 'minute (1200 gpm) of water flow are located on the manholes for use by the local volunteer fire department.

The fire hydrants are the "dry barrel" type. After each use, the barrels will be pumped dry and non-toxic anti-freeze added to protect against freezeup from a leaky valve. A water detector will be located in the stem to indicate the presence of an habitual leak that requires repair.

The utilidor is protected from an interior fire with self closing fire doors and alarms. The fire doors will close and audible alarms will actuate upon the detection of smoke or the products of combustion. Once closed, the oxygen supply to the fire will be stopped and the fire will extinguish. Emergency power will be provided to the fire doors to prevent premature closure due to a brief loss of power.

Pumping stations and other areas of critical equipment and higher fire hazards will be protected with automatically actuated Halon systems.

Illuminated exit signs will be placed at all points of egress from the utilidor. Emergency power will be provided to these signs to protect against power failure that would be caused by an emergency that would require the use of the signs.

The utilidor and sewage pumping stations will be continuously ventilated for worker safety. In conjunction with ventilation, the presence of hazardous gases (oxygen depletion, methane and carbon monoxide) will be continuously monitored.

THERMAL DESIGN

The compatibility of a buried utilities system and the surrounding permafrost is of utmost importance in the design of the system. Sensitivity of the ice-rich permafrost common in the Barrow area to thermal degradation requires intensive engineering analyses, as well as stringent construction procedure to ensure that the ground thermal regime around the utilities system remains stable. Design considerations for the utility structures are:

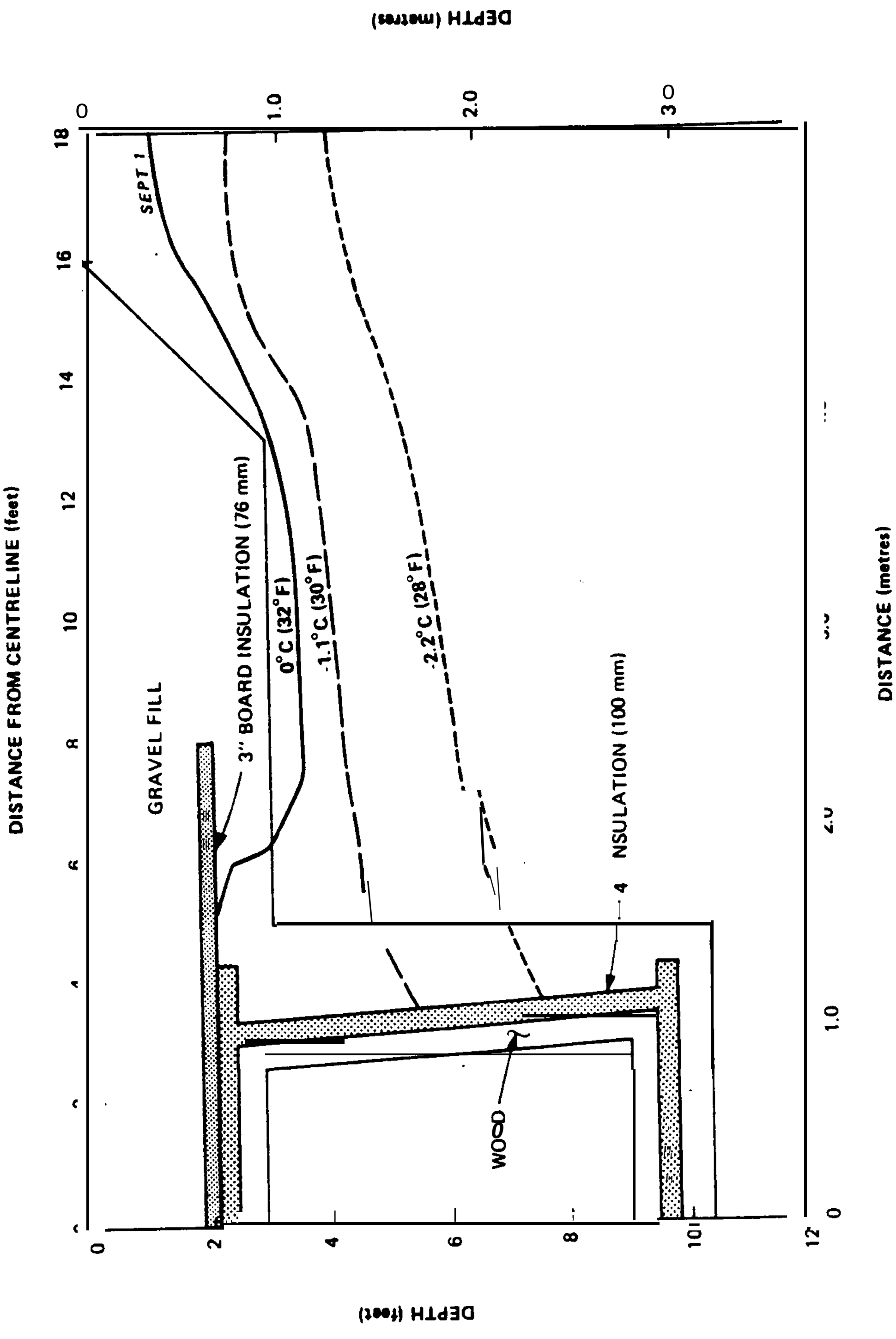


FIGURE 7 MAXIMUM PENETRATION OF 0°C ISOTHERMS AROUND UTILIDOR

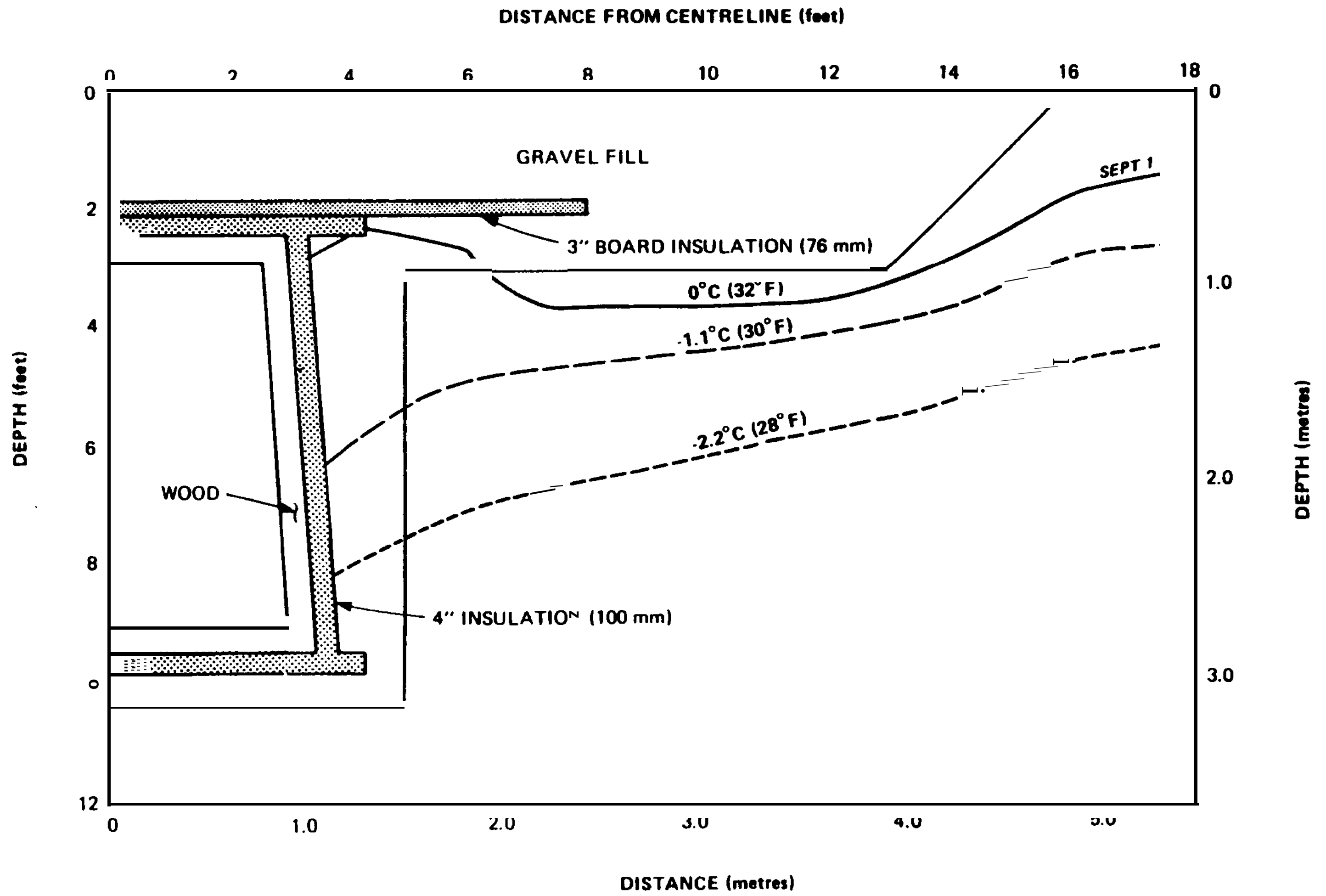


FIGURE 8 MAXIMUM PENETRATION OF 0°C ISOTHERMS AROUND UTILIDOR (Standard Case 1 'Normal' Year after 2 Successive Warm Years)

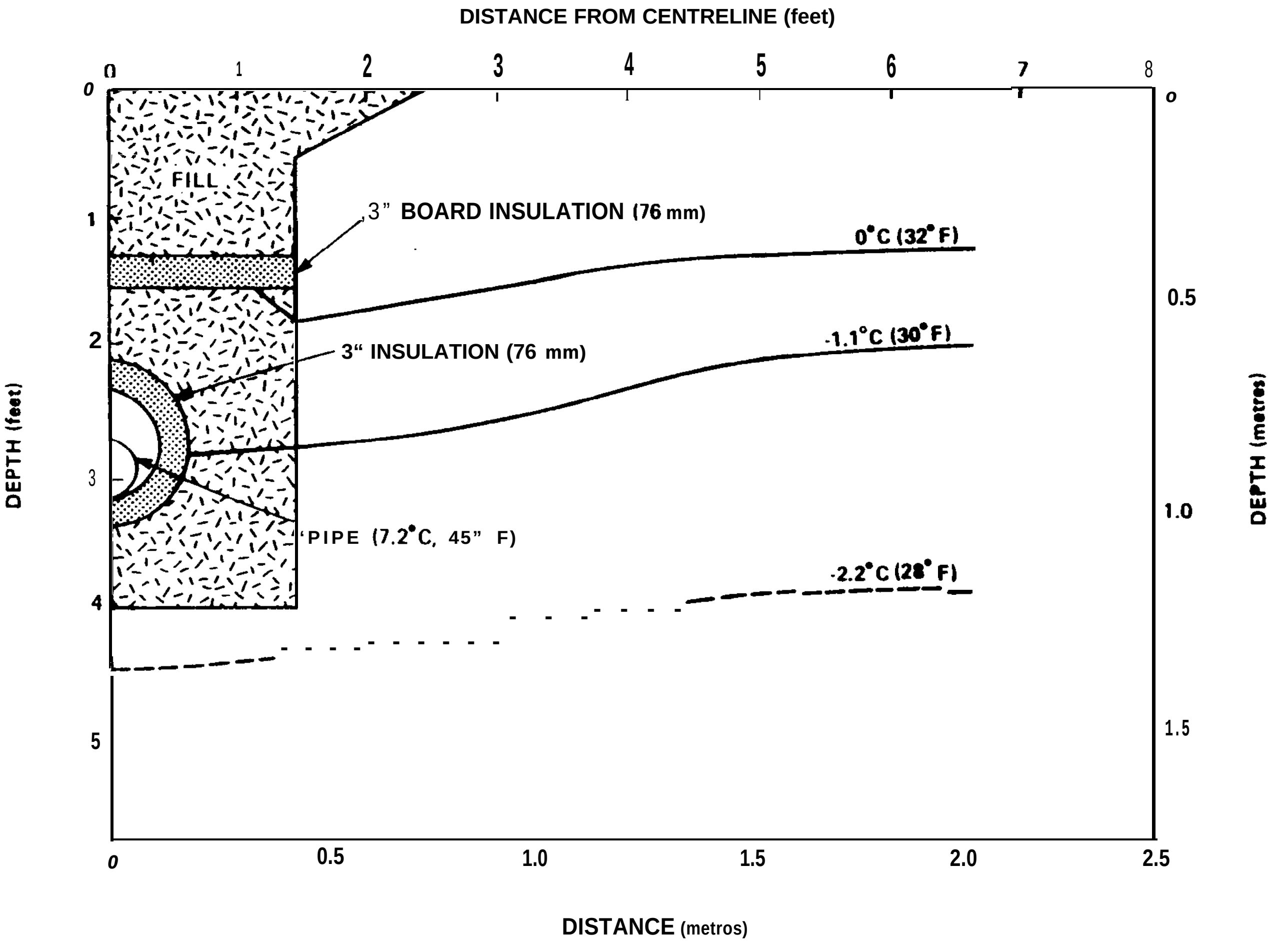


FIGURE 9 MAXIMUM PENETRATION OF 0°C ISOTHERM AROUND UTILIDUCT

a. frost heave, thaw settlement and buoyancy problems, as a result of seasonal freezing and thawing of the surrounding soils and/or underground ice wedges;
b. structural integrity in response to the freeze/thaw mechanism;
c. possible groundwater seepage ef feet on the thermal regime;
d. possible freeze-up of the utility pipes within the utilidor or utiliduct during shut-down or maintenance periods; and
e. influence on the ground thermal regime of neighboring structures, roadway, etc.

The EBA geothermal model (Hwang, 1976) was used to perform extensive thermal analyses with respect to:

a. insulation configuration of the utility structures;
b. effect of burial depth;
c. soil stratigraphy, such as areas of ice-rich versus low ice content roils;
d. freezing point depression due to groundwater salinity; and
e. upset weather condition, such as two successive 'warm' years, following construction and their long-term ef feet on the ground thermal regime.

Input parameters to the geothermal model are:

a. Barrow meteorological data which includes air temperatures, wind velocity, snow depth, longwave and shortwave radiation and evapotranspiration of the ground surface; and
b. thermal properties of the soils.

The design criteria considered in the analyses are:

a. soil /fill around the structure should stay permanent ly frozen as to prevent seasonal freeze/thaw action;
b. half or more of the utilidor and utiliduct should lie below the maximum depth of penetration of the -1. 1°C (30°F) isotherm to account for possible freezing point depression due to soil salinity.

Figure 7 shows the design maximum penetration of the 0°C, -1. 1°C, and -2.2 "C isotherms around a typical utilidor section. Figure 8 shrew the penetration of these isotherms f ollowing 2 successive 'warm' years, which then return to the position as shown in Figure 7, following one normal year. The 'warm' year simulation uses the maximum monthly air temperatures of the Barrow Climate date, while the normal year uses mean air temperature values (Figure 3) .

Figure 9 shows the temperature isotherms around a typical utiliduct section for normal air temperatures.

DISCUSSION-RESULTS-CONCLUSIONS

This paper is intended to address the general design parameters and physical features incorporated into the design of the Barrow Utilities system. However, it is noted that the overall thrust of the design is to exercise judicial use of capitol funds to achieve a facility that requires a minimum amount of long term maintenance funds. All materials and design parameters are selected with this criteria in mind.

Another important design criteria that must be noted is the one of flegibility. Due to a lack of statistical data, the best planning procedures for utility use and other conditions for design in the arctic are realistically reduced to guidelines. The designer in the lower forty-eight states has the luxury of discreet parameter that easily identify the most efficient approach; the arctic designer does not.

The design presented is one that will function over a wide range of flows, maintenance attention, electrical power availability, soil conditions and temperatures. Also, the system may be easily modified to accept conditions that are not evident at this time.

The use of local labor is also an important point in arctic village design. The Barrow Utilities System is designed to be built primarily with the local labor. This provides the following desirable aspects:

a. The local population will be generally more familiar with the project and its parts.
b. Portions of the local labor force will learn a trade.
c. The unemployment aspects of the community are drastically reduced.

After the system is operating, it will be used as a vehicle to train portions of the local labor force in all areas of utility operation. These people can take that knowledge and put it to use in other villages to the benefit of all.

At the time of this paper, the first phase of the project is presently nearing completion. This portion will be able to accept sewage from the new High School and is shown in Figure 2. The second phase of the project will be completed in May, 1983. The completion of the second stage will activate the system with full operational characteristics. Phase three will consist of the installation of secondary street laterals in Barrow and completion of the house services.

A portion of utilidor was installed in Block A during May, 1981 for testing purposes. The test utilidor segment was instrumented and has been constantly subjected to full operational thermal parameters. Information received from this test has indicated a conservative design with a successful application. The information received from the installation of Phase one supports these conclusions.

ACKNOWLEDGEMENTS

The utility project that is briefly discussed within this technical paper describes a small portion of the effort that the North Slope Borough is inking to upgrade the quality of life in the Arctic communities. Additional work under the North Slope Borough's overall Capital Improvements Program includes improved water supplies, schools, hospitals, roadways, and other community facilities for the villages within its territorial boundaries.

The Barrow **Utility** System (BUS) is much more than a construction project; it will bring benefit to the community beyond those of convenience and health. Construction of the **BUS is an opportunity for training in the techniques of arctic construction.** Once it is completed **and functioning, the BUS will also serve as a facility for training** local community members **in the operation of water and sewage system. In both instances,** the **construction project satisfies an** important **task pursued by the North Slope Borough: the** development **of local technical expertise for** the **maintenance and operation of** community **facilities.**

The interest that the North Slope Borough has in providing a quality environment for the arctic is evidenced by their sponsorship of the Symposium on appropriate Energy Technology for Arctic Regions during the - 33rd Alaska Science Conference

REFERENCES

Black, R.F. "Gubik Formation of Quaternary Age in Northern Alaska". U.S. Geological Survey Professional Paper 302-C. 1964

Cerutti, J.L., Zirjacks, W.L., Hwang, C.T., Bruggars, D.E., Underground Utilities in Barrow, Alaska. Symposium on Utilities Delivery in Cold Regions, Sponsored by the Department of Civil Engineering, University of Alberta, et. al., May, 1982

CH. M. Hill, Harding Lawson and Associates, :Geotechnical Investigations, Utilities for Barrow, Alaska". February 1979

Hwang, C.T. "Predictions and Observations on the Behaviour of a Warm Gas Pipeline on permafrost", Canadian Geotechnical Journal, Volume 13, No. 4, pp. 452-480, 1976

Lewellen, Robert I. :Studies on the Fluvial Environment, Arctic Coastal Plain Province, Northern Alaska:, Volumes I and II. 1972

Robertson, W.A., Martin, R.W. III, "Sewage Pump Station Design For Barrow, Alaska", Symposium on Utilities Delivery In Cold Regions, sponsored by Department of Civil Engineering, university of Alberta, et. al. , May, 1982.

'Ground Source Heat-Pump: Results from First Winter's Operation

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Abstract

Home-heating systems using the ground as a heat source are produced commercially and two units, a Cantherm DUO-500, 12 kW nominal capacity, and a Command-Aire SWP-541, nominal capacity 16 kW were installed at the University of Alaska, Fairbanks, in the fall of 1981. Routine operations were commenced in January 1982. Analysis of the data from the Cantherm unit shows a coefficient of performance (C.O.P.) of 2-2.3 for baseboard water temperature 55-45°C. If temperatures of ~ 30"C can be used (radiant slab) a C.O.P. of three may be obtained. Similar C.O.P.S have been obtained for the Command-Aire unit. The temperature decrease of the soil has only been about 0.5°C, and the soil recovered thermally very rapidly after the units were turned off at the end of the heating season. The extraction has only covered half of the heating . season, and a full winter's heating load may change these numbers somewhat. Also one year of operation is not enough to predict long-term effects on the soil.

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Introduction

The basic idea in a ground-coupled heat pump is to extract heat energy from the ground through refrigeration techniques, and then use the extracted energy for home heating. The technique is described in many standard textbooks on refrigeration and air-conditioning; Figure 1 shows a schematic as given by Althouse et al. (1968).

In Figure 1, the refrigerant is circulated in the ground. This is for both practical, economic and environmental reasons undesirable. Instead an extra heat exchanger is used and the ground heat is collected by a brine circulating through a buried pipe.

Because the temperature of the ground at a depth of a few feet is relatively constant year-round, a ground-coupled heat pump system is relatively unaffected by the seasons and, in contrast to many other alternative energy systems, also can deliver heat during the middle of winter. This makes it of particular interest for use in Alaska.

Ground-coupled heat pump systems are commercially available and are gaining popularity; there are for example more than 15,000 units in use in private homes in Scandinavia. A description of some larger installations have recently been given by Stenbaek-Nielsen and Zarling (1982).

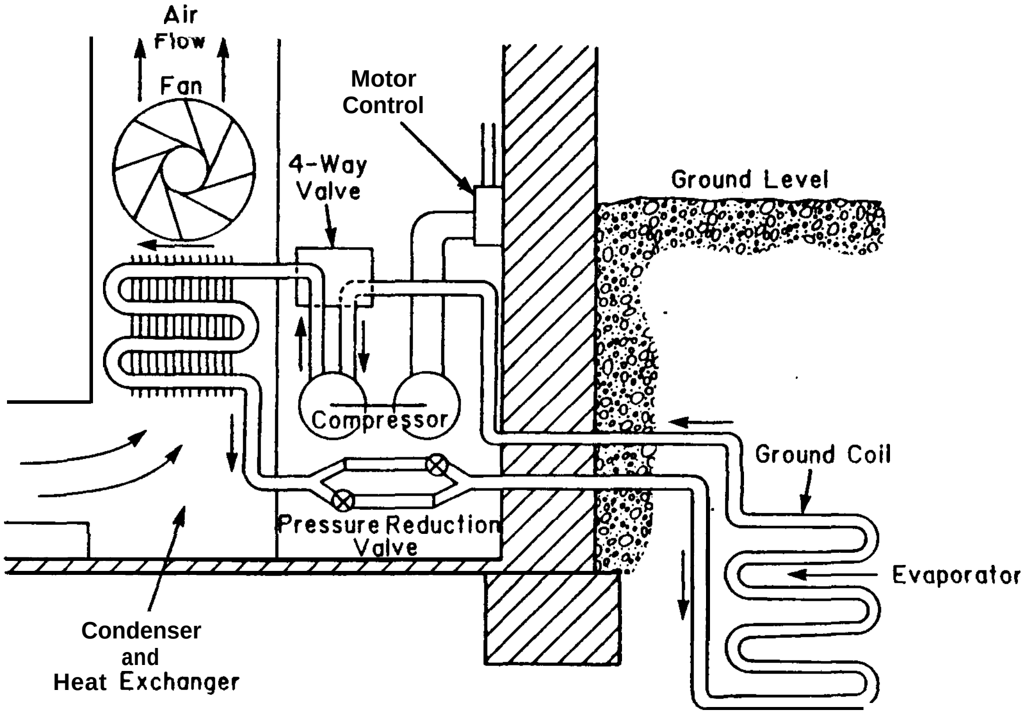

Figure 1. Schematic of a heat pump installation. The principle is the same as employed in refrigerators. The liquid refrigerant boils off in the ground coil, extracting the heat for its evaporation from the ground. The vapor is then compressed and thereby heated. In this example, the home is heated by circulating air passed over the condenser by a fan. The unit could be used for cooling during the summer simply by reversing the circulation of the refrigerant, letting the ground coil function as the condenser.

To investigate how such systems would perform under Alaskan climatic conditions two units were purchased and installed for testing on the on the University of Alaska, Fairbanks campus. Routine operations were started in January 1982 giving us about 4 1/2 months of heating data before the pumps were turned off at the end of the heating season.

Project Objectives

The overall aims of the project are:

1) To understand the response of cold soils to heat extraction.
2) To demonstrate and gain experience with different heat pump systems .
3) To develop safe and reliable guidelines for the design and use of ground-coupled heat pump systems in Alaska.
4) To provide cost/benefit analysis of various designs.

The most serious problem is that soil temperatures in Alaska are colder than those found elsewhere where similar systems are being tested or employed, even in Scandinavia. A typical Alaskan installation will be in soils very near freezing temperature, which presents a number of problems that have not been addressed directly elsewhere. Will repeated freezing and thawing of the soil threaten the structural integrity of the system? How will the extraction of the heat affect surface vegetation? How well does the soil recover thermally after both short periods of heat extraction (a cold spell) and following an entire heating season? (Note that the extracted heat entered the ground from the surface during summer; i.e., it is ultimately solar heat.) Can heat be stored in the ground in summer and held for use in winter?

Without an answer to these questions it is highly unlikely that any industry would consider manufacturing or marketing ground-coupled heat pumps for use in Alaska.

Installation

Our test installation is located in an open area on the West Ridge of the University of Alaska-Fairbanks campus (Figure 2). The soil is Fairbanks silt. Part of the site has been back-filled, but the soil conditions appear to be fairly uniform across the site. The dry density of the silt varies between 80 lb/ft^3 (1.27 g/cm^3) and 97 lb/ft^3 (1 .55 g/cm^3) . The south field is more moist (16-20% of dry weight) than the west field (8-14% of dry weight). This difference is most likely caused by runoff from the Arctic Health Laboratory parking lot draining across the south field.

The ground grid (Fig. 2) consists of four 500-foot “lengths of 1 1/2” polyvinyl chloride pipe (PVC) in which circulates a brine (a 25% calcium chloride solution and a corrosion inhibitor). The two sections in the south field are buried at a depth of three feet, while those in the west field are at a depth of four feet. Originally we had planned to bury the grid at a depth of five feet, but for installations in Sweden, AGA-Thermia, the leading Swedish manufacturer of ground-coupled heat pumps, is recommending depths of only two to four feet. Their reason is that although the temperature at this shallower depth varies more from season to season, it is possible to extract more energy per unit grid length, which, because of the large investment in the grid, improves system economics.

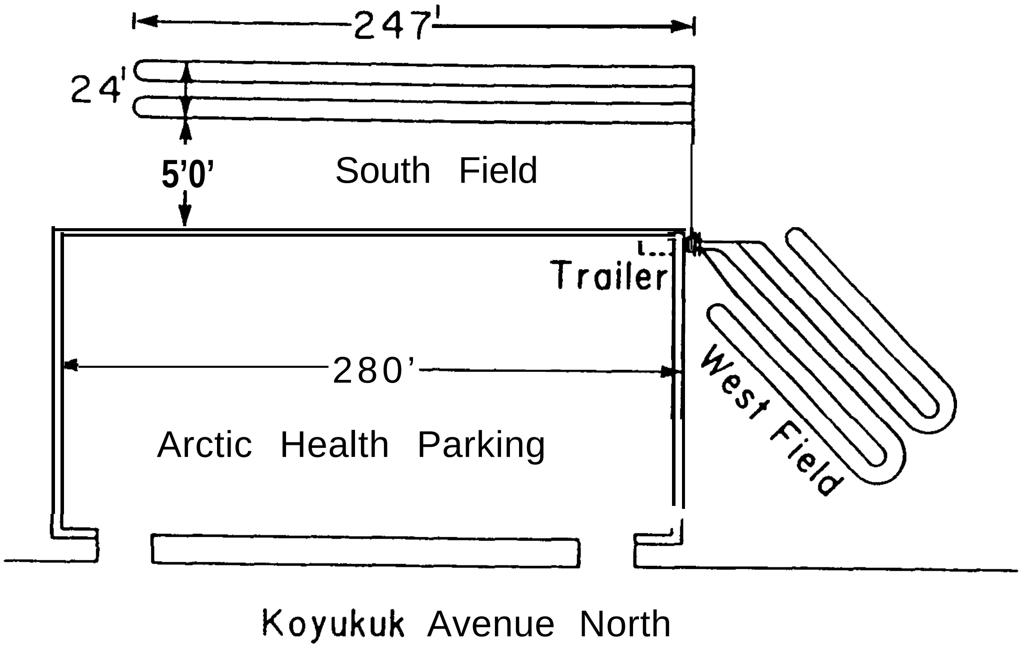

Figure 2. Location of the test installation and layout of the four 500-foot pipe sections.

The two heat pumps are installed in a 12 x 30-foot ATCO trailer belonging to the University of Alaska's Institute of Arctic Biology. The units are connected to the buried pipe through a manifold which allows us to select the number and configuration of coils associated with each unit. The two units are manufactured by Cantherm Ltd. in Montreal, Canada, and by Command-Aire in Waco, Texas, respectively. The Cantherm unit (model DUO-500, 12 kW nominal capacity) is a liquid-to-liquid system modelled on the Swedish AGA-Thermia ground-coupled heat pump series, while the Command-Aire system (model SWP-541, 16 kW nominal capacity) is a forced hot-air unit.

Both units and the buried pipe grid are instrumented to give information about the thermal response of the soil to the heat extraction and the energy transfer rates to the heat pumps. All sensors were calibrated before they were installed.

The Cantherm unit has been working routinely since January 4, 1982. The Command-Aire unit was damaged in shipping, but a new unit was installed in late February, and is functioning well. Both were operated routinely until May 12, 1982, when they were shut down for the summer. Present plans call for a restart in September 1982 and for operation through the 1982/83 heating season.

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Results

Preliminary results from the first winter's operation of the Cantherm DUO-500 heat pump were evaluated to give the observed coefficient of performance, amount of heat extracted from the soil, and the thermal response of the soil. These aspects are the important ones for an evaluation of the feasibility of large-scale use of ground-coupled heat pump systems in Alaska.

The 2 1/2 months of data on the Command-Aire unit have not yet been analyzed. A cursory inspection of the data indicate that its performance and the soil response are very similar to what is seen in the Cantherm data.

Coefficient of Performance

The coefficient of performance is the ratio of the delivered energy (in the form of heat) to the purchased electric energy required to run the system. In an ideal Carnot process, the coefficient of performance depends only upon the absolute temperature of the evaporator, T_1, and of the condenser, T2:

$$\text{C.O.P.} = T_1/(T_2-T_1)$$

However, that cannot be achieved in practice, and the actual C.O.P. is always less. Nevertheless, the formula is very useful since it points out in a simple way the principal relation between the performance and the soil and building temperatures.

Performance data for both heat pumps that we are using have been provided to us by the manufacturers (both heat pumps are commercially available). Figure 3 shows such data for the Cantherm uit. The coefficient of performance for any given soil temperature and baseboard water temperature can be derived from the figure. For example, if the soil temperature is + 1°C and the baseboard water leaves the pump at 45°C, the system would deliver 12.4 kW heat while drawing 4.9 kW of electric power, giving a C.O.P. of 2.5.

In our installation the brine temperatures have not varied much. Extremes have been ± 3°C, and most of the data analyzed have been for a brine temperature near - 1°C. Because of this it is more useful to p" Ot heat output and power consumption as a function of baseboard water temperature, as shown in Figure 4 (top). The derived coefficient of performance is plotted in Figure 4 (bottom).

For comparison, three data points from our measurements are included with the factory-provided data in Figure 3. Our data appear to be in reasonable agreement with those from the factory, although the unit seems to draw slightly more power and the heat output is somewhat more temperature dependent than expected.

These preliminary results indicate that for Alaskan operations one can expect a coefficient of performance of 2.0-2.3 for heating with baseboard hot water at 45°-55°C. If radiating floor slabs are used

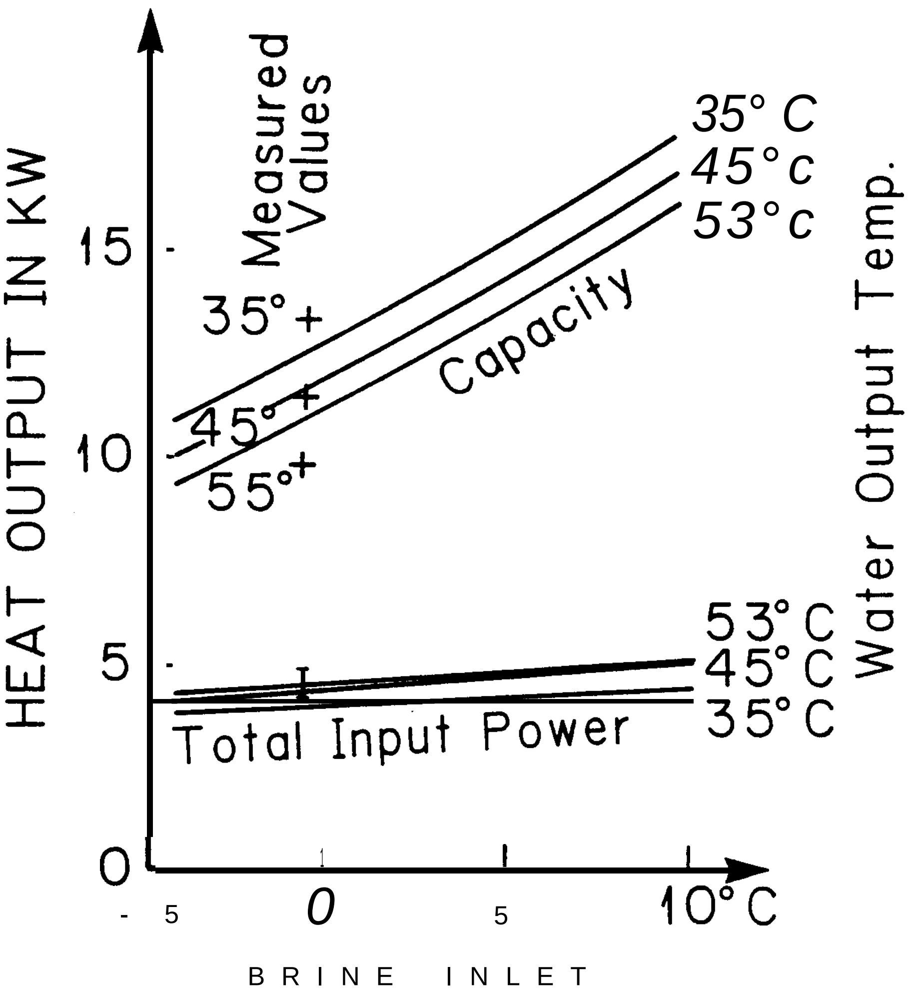

Figure 3. Heat capacity output and consumption diagram for the Cantherm DUO-500 heat pump. Values measured on our installation are added.

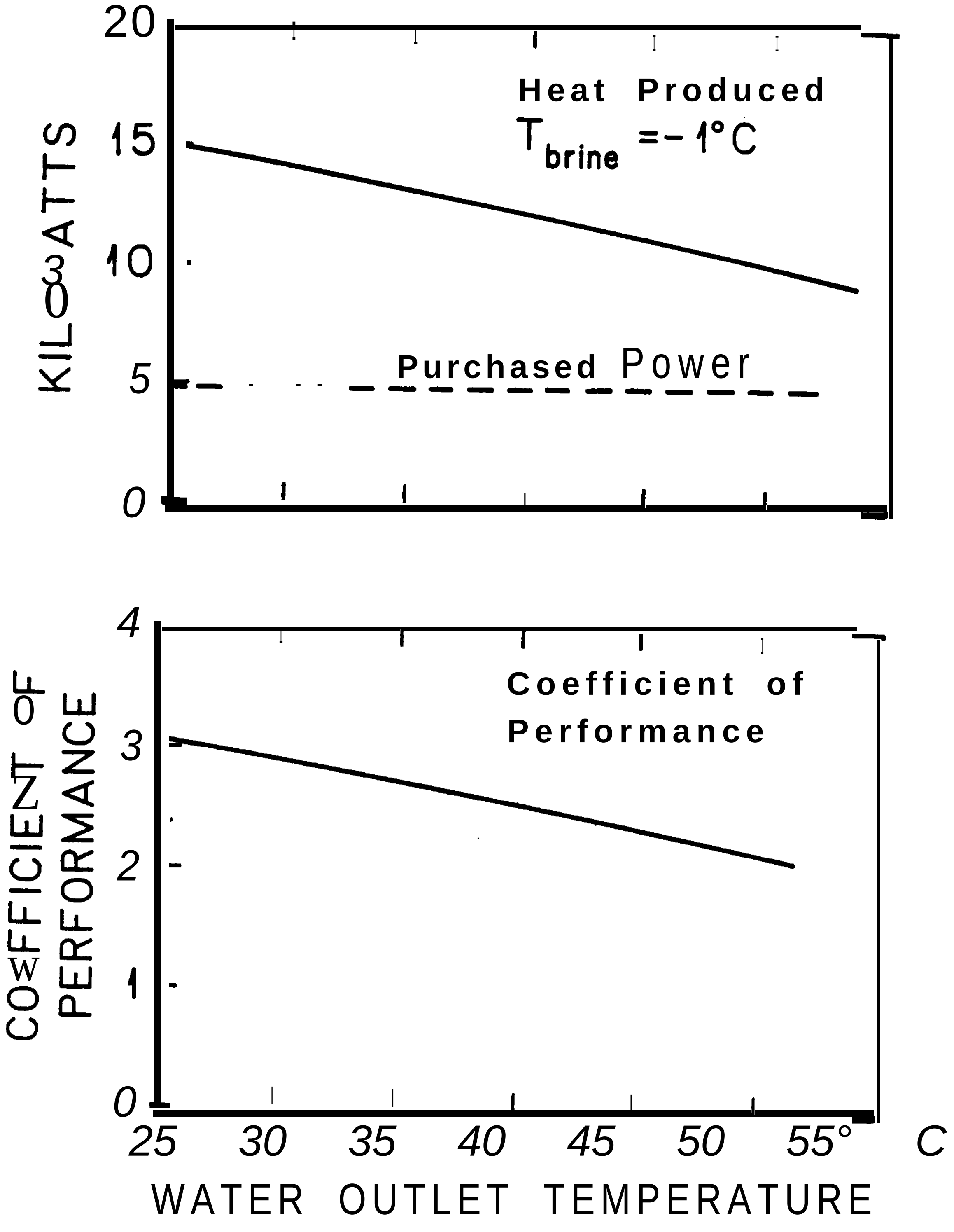

Figure 4. Measured heat produced, power consumed and coefficient of performance for the Cantherm DUO-500 heat pump.

instead, at temperatures around 30″ C, a coefficient of performance of almost 3 may be obtained.

Amount of Heat Extracted from the Soil

The controlling computer has been programmed to operate each system twice per hour. Various problems in the-data collection system, especially an infrequent computer malfunction, have caused gaps in the operation schedule. Although we still do not know the cause of the computer problem, the manufacturer has provided us with a usable software fix. We were also shut down for 10 days at the end of February 1982 for the repair of some leaking probes and for the replacement of the Command-Aire unit. No problems have been encountered since mid-March, although we were forced to reduce the duty-cycle of the heat-pumps in early April and again in May due to overheating of the trailer (and thereby the heat-pumps).

The energy extracted from the ground by the Cantherm DUO-500 system from the start of routine operations on January 2, 1982 until the summer shut down on May 12, 1982 is tabulated below:

	kWh	10^6 BTU
January	821	2.8
February	761	2.6
March	851	2.9
April	584	2.0
May (12 days)	159	0.5

The heat is extracted from the soil through a 1000-foot buried pipe section. Design guidelines developed in Sweden would, for a normal one-family home under our climatic conditions, dictate a length of 2500-3000 feet. Thus we are operating with a grid of about 1/3 the recommended size. Assuming a full grid and coefficient of performance of 2.2, the corresponding generated heat would be in the range 4680 to 1750 kWH per month.

This should be sufficient to heat most modest-sized homes in Alaska.

Thermal Response of the Ground

This is the key objective of the project. What heat extraction rates can be maintained without adversely affecting the soil?

Temperature profiles for the south field measured on January 2, February 13, March 16, April 21, May 31 and July 16 are shown in Figure 5. The pipe is buried at a depth of three feet. In addition to the undisturbed profile two vertical profiles are given, one containing the

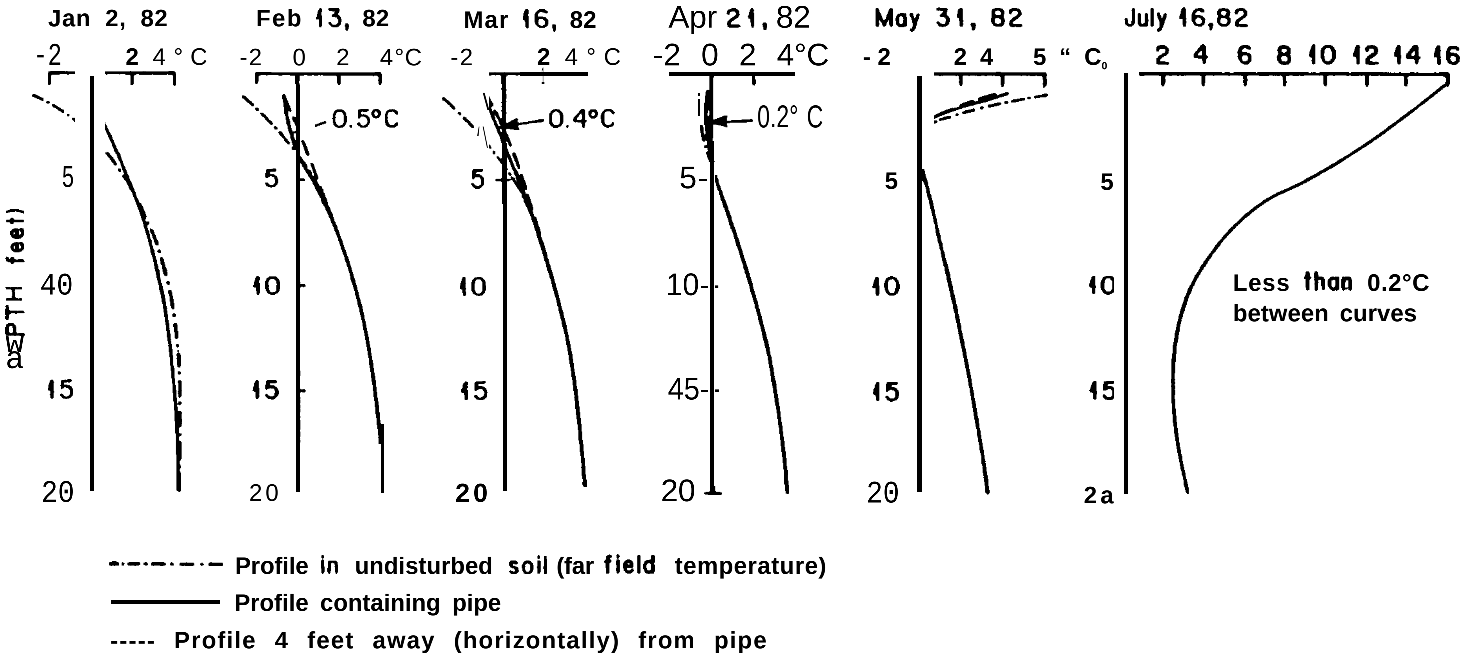

Figure 5. Soil temperature (°C) as function of depth (feet). Arrow points to the effect of the heat extraction.

pipe and one about four feet away. A very obvious effect of the heat extraction is that the profile containing the pipe should show a decrease near the depth of the pipe relative to the profile four feet away. This decrease is observable on the plots from February 13 and March 16; the depression is on the order of 0.5°C.

The soil recovered thermally very rapidly after the heat pumps were turned off May 12. The soil temperature near the pipe immediately increased to - 0°C and the ground was thawed on June 1 after which date the soil temperature rose rapidly reaching the maximum temperature of 13°C (at a depth of 3 feet near the pipe) in mid-July.

The melting of the snow cover over the two fields showed no evidence of the heat extraction. We had expected to see some retardation in the melting process. In retrospect this may not be too surprising given the small change in soil temperature due to the heat-extraction.

The temperature response of the soil is very favorable. Based on computer models and data from Scandinavia, we expected a drop of 2-5°C near the buried pipe. We have not had a chance to analyze why the temperature decrease has been only 0.5°C, but a contributing factor is presumably the insulating properties of the snow cover which was not included in the model. One implication is that smaller grids may be used, which would significantly reduce installation costs (and thereby improve the economics). Obviously more tests are required, but the other very important aspect to be considered remains: What are the long-term effects on the soil? Will the soil recover thermally by itself or are we gradually creating permafrost? Installations elsewhere show that the average soil temperature does decrease as a result of the heat extraction and that a new equilibrium value is reached after about five years of operation. So, how much heat can we safely extract? This problem can only be addressed by monitoring the soil temperature through several yearly heating cycles.

Conclusion

Results from the operation of two ground-coupled heat pump heating system in Fairbanks, Alaska have been very encouraging. Especially, the thermal response of the soil to the heat extraction indicate that more heat can be extracted per unit length of buried pipe than existing design guidelines and model calculations would predict, impliying that smaller ground grids may be used. This could signficiantly reduce the installation costs of such systems which are quite high (Stenbaek-Nielsen and Zarling, 1982) However our results have been obtained from data covering only half of the heating season. Clearly more data are needed as basis for the development of design guidelines. Also several years of operation are required to ensure that the heat-extraction does not cause any undesirable effects in the soil, such as the creation of permafrost.

Compared with other alternate energy systems, the ground-coupled heat pump has several advantages: 1) it works year-round, 2) makes use of well-known technology, 3) high degree of reliability, 4) minimal fire-hazard, 5) can operate automatically and 6) it is non-polluting.

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The main disadvantage is the high installation cost which with present Fairbanks energy prices makes it marginal economically when compared with oil-heat (Stenbaek-Nielsen and Zarling, 1982).

In the test installation described here the heat pumps are driven electrically with power drawn from the local net. The system could also make use of wind power or power from small hydroelectric power plants. Actually, the combination of the ground-coupled heat punp with other alternate energy technologies may be the most attractive in the smaller villages and towns throughout Alaska. In closing, we mention one possibility: The heat pumps could be operated by diesel engines with waste heat recovery and heat may be stored in the ground during the summer by circulating the brine through solar panels. Such a system was built in 1981 in Sweden to heat a school for an estimated 700 students, and it was estimated that the cost of the installation would be recovered in 7 years through the savings over conventional heating.

Acknowledgement

Doug Goering, a research mechanical engineer at the University of Alaska-Fairbanks, did the procurement and installation of the heat pump system. This research was sponsored by a grant from the State of Alaska.

References

Althouse, A. D., C. H. Turnquist, and A. F. Bracciano. 1968. Modern Refrigeration and Air Conditioning. Goodheart-Willcox Company, Inc., South Holland, IL.

Stenbaek-Nielsen, H. C., and John Zarling, Ground-Coupled Heat Pumps; An Alaskan Experiment, The Northern Engineer, Vol. 14, No. 2, 1982.

ACTIVE SOLAR SPACE HEATING IN FAIRBANKS

AN EXAMPLE

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ABSTRACT

This paper will discuss the performance, based on approximately one year of data, of an active solar, liquid based heating system. The heating system has been monitored on a daily basis since August, 1981. The system consists of a large flat plate array, 203 square feet in area, pumped through a basement pad for direct panel heating. The system uses a one-sixth horsepower pump. The monitoring system consists of a B.T.U. meter for measuring the actual net heat gain to the basement, and a solar pyronometer which measures the actual solar radiation received on the surface seat. Collectors are tilted at approximately seventy degrees and face south. They are made of a synthetic rubber material called Solaroll, covered with one glazing panel of a material called Kalwall, a fiber-reinforced plastic. Plumbing is partially copper and partially steel, with rubber connections. The system is used to heat a home with 1,940 square feet of floor area, of which 970 square feet are in the basement. It is regarded as a supplementary system and its contribution to annual heat will be discussed, as well as the system's daily and seasonal efficiency and economic worth.

BACKGROUND AND DESCRIPTION OF SYSTEM

Active solar heating at high latitudes suffers from the predictable problem of the solar availability being out of phase with the heating requirements of a building. Because the heat from the sun is least available when most needed, active solar heating systems often do not warrant heavy capital investment, they can only supplement the heating requirements of a standard structure. Simulations have predicted that at best, 30-35% of a home's annual heating energy needs could be met with an optimum active solar energy system (Seifert, 1981).

With this sobering reality in mind, the author proceeded to attempt to build and monitor an owner-built, solar heating system. It was felt that by cutting the capital cost through owner-built construction, an economically viable solar energy system could be built and operated. Since the author's home is log and not optimally oriented for passive solar retrofit, the active solar option was chosen.

The system consists of three major components:

(1) A large, 203 ft^2 collector array, framed in wood, with copper headers and Solaroll tube mat as the collector material (see Table 1 for further specifications of collector, and figures 1 and 2).

(2) Pump, differential controller and thermal monitoring system.

(3) The integral concrete basement floor--serpentine pipe heat distribution and storage system.

TABLE 1

COLLECTOR SPECIFICATIONS

NOMINAL COLLECTOR AREA:	228 ft^2
ACTUAL SOLAR APERTURE AREA (NET AREA FoR SOLAR GAIN):	203.3 ft^2
BACK INSULATION:	R 11, 3.5 inches fiberglass.
COLLECTOR TILT:	70°
COLLECTOR FLUID:	50/50 Water/Propylene Glycol.
HEADERS :	2 inch diameter SOLAROLL brand.
SAFETY PLUMBING:	Air eliminator and standard hot water P-T relief valve.
COLLECTOR FRAME AND MOUNT:	Local spruce and plywood with SOLAROLL glazing frame.
GLAZING :	Single-glazed, KALWALL KAL-LITE II; 40 roil, Butyl Rubber Caulk as sealant.
ORIENTATION:	South 30° East.

The pump is a one-sixth horsepower Bell and Gossett circulation pump. It is controlled by a Heliotrope General DDT-90T differential thermostat, which turns on the pump whenever the collector temperature is 8° warmer than the basement pad, sensed at the outlet pipe from the pad. The thermostat sensor for the collector is mounted in the collector, approximately one foot from the header outlet and near the top of the collector. The thermostat turns the pump off when the difference between the two temperature points is 3° or less. Thus, the basement temperature will "float" up or down depending on available solar gain because the collector will provide heat based only on the difference between the pad temperature and the collector. This is unlike' the case for most heating system control thermostats which just provide heat above or below a set point. The system also does not have a high temperature cut-off.

Both the inlet and outlet lines from the collector should be, and are, insulated to keep the inlet fluid temperatures as high as possible. This improves efficiency, since a large loss in the return will "load" the collector more and decrease its useful gain.

Whenever a surplus of solar heat was available, the basement was allowed to overheat. Ample storage mass in the insulated concrete basement made this event less disquieting than one might expect since, even on the very hottest sunny days, the basement air temperature did not exceed 85°F.

When the basement was constructed, a crude panel heat exchanger was "roughed in" for use as the solar heating distribution system within the four-inch concrete pad. It consisted of fourteen, twenty-foot lengths of one-inch diameter steel pipe which the author obtained for the price of threading the ends and buying couplings. The basement pad and the concrete block walls of the basement are both insulated on the outside (the pad has two inches of DOW blue styrofoam SM, and the walls, four inches of the same). Therefore, the concrete provides a substantial "thermal flywheel" to moderate any overheating possibilities. The pad and concrete walls contain approximately sixteen (16) cubic yards of concrete with a weight of 62,000 pounds. For a temperature difference of 20°F, this mass can absorb 248,000 BTU'S, which is a very desirable storage capacity, as will be shown later in the paper.

A system schematic is shown in figure 3 and two photographs of the collector under construction are shown in figures 4 and 5.

The system was completed in August 1981, at an equipment cost of $2,600, a nominal cost of $11.40 per square foot of collector area. The monitoring system cost an additional $1,400 and was purchased through a grant from the Alaska Council on Science and Technology's Northern Grant Program, for the purpose of monitoring an active solar heating system for high latitudes.

MONITORING SYSTEM

The monitoring system enabled the evaluation of the daily, monthly and annual performance of the collector system. It consisted of the following elements:

(1) Pyranometer: a Hollis observatories model LM-3000 solar integrator was used to measure incident solar radiation at the site. The pyranometer is the Hollis model MR-5 and it was mounted in the plane of the collector surface. Its accuracy is ±3% of full scale. Recording is accomplished by marks made on inkless pressure-sensitive paper for increments of 20 BTU/ft^2. This measurement allowed for a daily tally of total incident radiation on the surface of the collector glazing, at an orientation of south 30° east.

(2) BTU-meter: an ISTA model 2/50 integrating BTU meter was used to measure the net heat delivered from the collectors to the

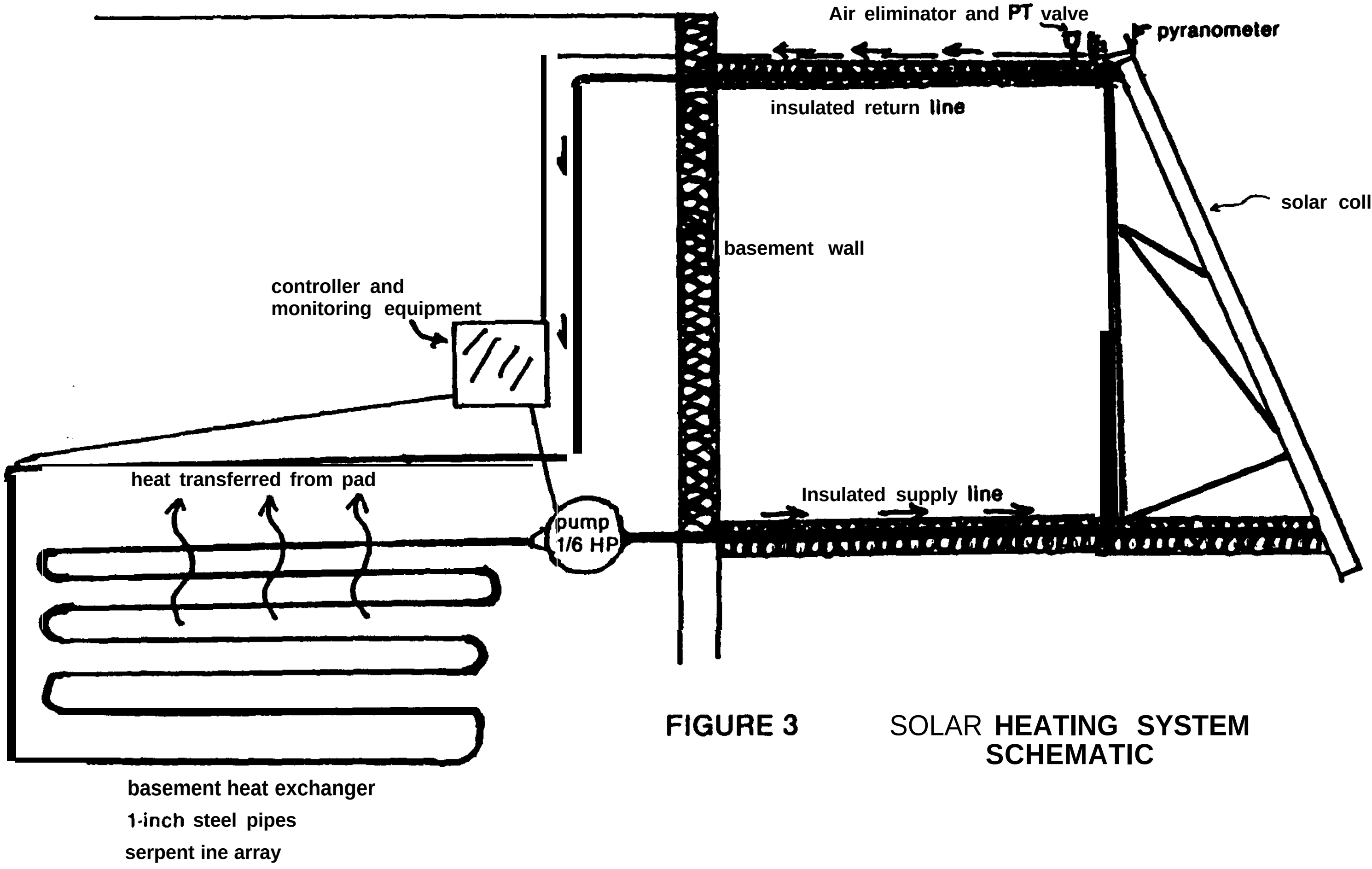

FIGURE 3 SOLAR **HEATING SYSTEM SCHEMATIC**

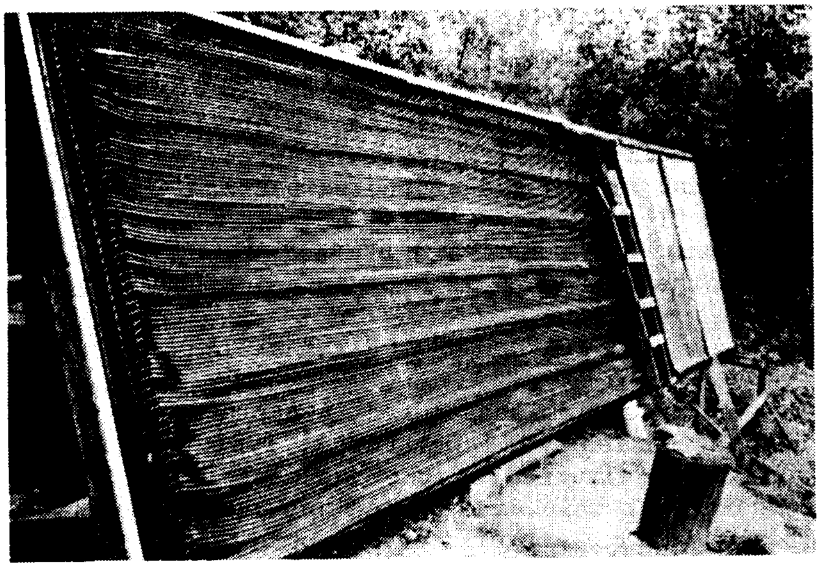

FIGURE 4

A view of the collector as glazing is being put in place. Header set is on the left.

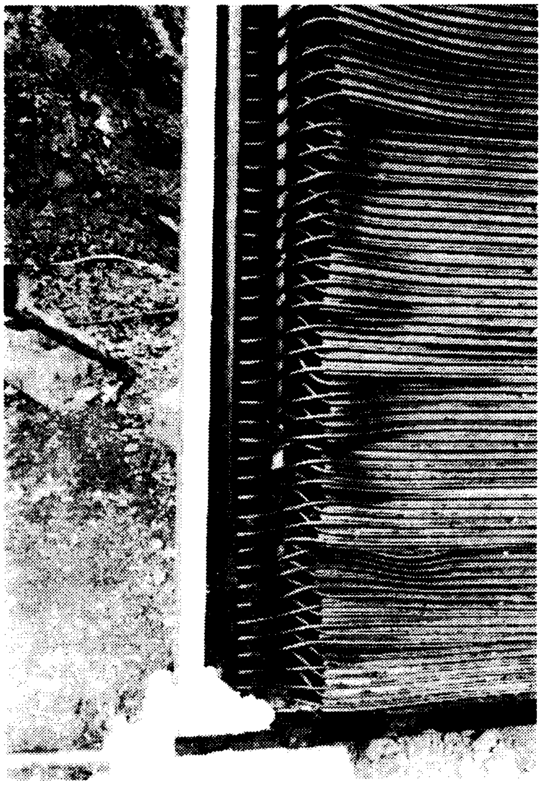

FIGURE 5

A detail of the collector header set showing the alternating inlet/outlet arrangement of the tubes. Left header is supply, right is return.

basement pad. This meter is an integrating mechanical flowmeter with an integrating temperature differential device. The output is in Killowatt-hours, and therefore, accuracy is ±3,400 BTU's per day. It requires a five volt DC power supply or batteries in order to function. The temperature differential is measured in the inlet line from the collectors and at the flowmeter, which is mounted two feet from the pump intake, and at the end of the serpentine array of pipes in the basement floor.

Solar radiation data was measured daily and a continuous record of the heat delivered to the basement was kept in a journal of the system.

PERFORMANCE OF THE SYSTEM

The active solar system was placed in operation on August 20, 1981, and ran without attention until October 2, 1981. During this interval 956 KWH of heat was delivered to the basement pad. This is 3,262,800 BTU's. Solar gain over this same period was cumulatively measured to be 8,586,300 BTU's on the collector surface, a total of 42,260 BTU/ft for this period. The net heating efficiency for this period was 38%, as determined from the relation N = efficiency = Q/H, where Q is the useful heat to the basement, H is the total solar gain.

However, weather in October was as bad or worse than usual (October is statistically the cloudiest month). On October 5, the system gained 16 kwh of heat, but didn't gain any more until October 21, when 1 kwh was added to the basement. On October 22, 2 kwh more were added. On October 28, 1981, 5 kwh were added but the system was shut down because it was clear that very little useful heat was being gained. The system was drained and was idle until February 7, 1982. This date began a month long struggle to get the system filled and functioning. At one point, a pocket of unmixed water froze in the system and blocked the system for more than two weeks while the author struggled to install heat tapes and replace the line insulation to the system. The fundamental problem which caused this down time and lost performance was a design error: The system does not have a filling reservoir and pressurizing it with water from a house line adds unmixed water to the system, which mixes very slowly. Consequently, freezing problems, a most embarrassing event for a solar collector, kept the system operation intermittent until March 13, 1982.

From March 13 to March 24, 56 kwh of heat were transferred to the basement. This is 191,000 BTU's. Solar radiation during the same period was 1,751,600 BTU, which yields a net efficiency of 11% for the period. This is a low efficiency and is a strong indication that this collector system's efficiency is affected adversely by low outdoor ambient temperatures, even when solar availability is high.

The system developed a leak on March 25, and was shut down again for repairs. It was turned on again on April 11, and functioned uninterrupted until August 31, when documentation for this paper was terminated.

Table 2 shows the tabulated monthly and total year's performance of the solar system.

TABLE 2

SOLAR COLLECTION HISTORY

TIME PERIOD	TOTAL BTU's DELIVERED	TOTAL INCIDENT SOLAR ENERGY B	NET EFFICIENCY FOR PERIOD
August 20, 1981- October 4, 1981	3,262,800	8,586,300	38%
October 5, 1981- October 24, 1981	81,900	409,600	20%
October 24, 1981- March 15, 1982		System Down	
March 15, 1982- March 24, 1982	174,000	1,113,500	16%
March 25, 1982- April 10, 1982		System Down, Leak	
April 11, 1982- April 30, 1982	757,700	4,980,600	15%
May 1, 1982- May 31, 1982	2,143,200	5,825,300	37%
June 1, 1982- June 30, 1982 (10 days missing)	1,921,500	4,082,300	47%
July 1, 1982- July 31, 1982	2,214,300	4,986,500	44%
August 1, 1982- August 30, 1982	1,690,600	4,929,600	34%
*TOTAL FOR PERIOD August 20, 1981- August 30, 1982	12,246,000	34,913,700	35%

*It would be a misrepresentation to call this an "annual" sum, since the data for February, March and April were not complete.

Another factor on performance of the collector system is the aspect: it looks to the morning sun and does not receive late afternoon sun at all. The collectors and the pyranometer are shadowed after 3 p.m. For comparison, table 3 has been constructed to show how the actual average daily solar radiation for the months of May thru August for the system compares with the ASHRAE predicted incident solar radiation on a surface oriented due south and tilted at 74° from the horizontal. (This data is the closest to the 70° tilt on the collector system that is available). The ASHRAE numbers are derived by the method of Liu and Jordan (1961), and are estimates for incident radiation on the 21st day of each month. Table 3 also shows the data for May through August generated by the f-chart computer program using SOLMET solar radiation data for a 70° collection tilt, oriented 30° east of south. These numbers compare more favorably with the measured numbers, but both are higher than the actual measurements, in most cases by 30% to 50%.

TABLE 3

MONTHLY AVERAGE DAILY SOLAR RADIATION
COMPARISON OF MEASURED AND PREDICTED VALUES

MONTH	**AVERAGE MONTHLY MEASURED VALUE (BTU/ft^2-day) IN COLLECTOR PLANE**	**SOLMET VALUE 70° TILT (BTU/ft^2-day) 30° AZIMUTH ANGLE**	**ASHRAE VALUE FOR 21st DAY OF MONTH (BTU/ft^2-day) 74° TILT, SOUTH**
MAY	**925**	**1,474**	**1,898**
JUNE	**1,004**	**1,371**	**1,862**
JULY	792	1,230	1,864
AUGUST	**809**	**987**	**1,860**

This data clearly shows that the solar system is obtaining 50% of the predicted solar radiation available at latitude 64° N, for 74° collector tilt and due south orientation, and 50-70% of the average solar radiation predicted by the f-chart program using Solmet.

For additional comparative interest, a simulation, utilizing the f-chart computer program was run for this home-built, active solar system. The specifications for the system are shown in Table 4, and the predicted average performance and economic analysis are shown in Table 5. The numbers in the column labeled "incident solar," in Table 5, are the numbers used to generate the SOLMET solar data used in Table 3. The results of this simulation show that the collector provides a nominal 13.5% of the space heating load during the year and most of that is during the spring and summer, a result confirmed with the first year's experience. The economic analysis shows that the rate of return on the solar investment is about equal to the money market rate, 15.7%, even with the small portion of annual heating supplied. The payback is based on a comparison of buying fuel oil at $1.25 per gallon today, and inflating the cost at 10% per year. The time payback (undiscounted) is eight(8) years.

TABLE 4

LIST OF VARIABLES USED FOR F-CHART SOLAR HEATING SYSTEM SIMULATION

```
CODE        VARIABLE DESCRIPTION                                  VALUE UNITS
  1 AIR SH&WH=1,LIQ SH&WH=2,AIR OR LIQ WH ONLY=3.                  2*OO
  2 IF 1,WHAT IS (FLOW RATE/COL.AREA)(SPEC.HEAT)?                  2.15 BTU/H-F-F2
  3 IF 2,WHAT IS (EPSILON)(CMIN)/(UA)?.... ..........              2400
  4 COLLECTOR AREA................................               203.20 FT2
  5 FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..                  0.70
  6 FRPRIME-UL PRODUCT.............................                0.83 BTU/H-F-F2
  7 INCIDENCE ANGLE MODIFIER (ZERO IF NOT AVAIL.)                  o.
  8 NUMBER OF TRANSPARENT COVERS.................                  1*OO
  9 COLLECTOR SLOPE........ .......................               70.00 DEGREES
 10 AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)...... ...               30.00 DEGREES
 11 STORAGE CAPACITY.............................                15.00 BTU/F-FT2
 12 EFFECTIVE BUILDING UA.........................             9000,00 BTU/F-DAY
 13 CONSTANT DAILY BLDG HEAT GENERATION..........                  0.   BTU/DAY
 14 HOT WATER USAGE................................                0.   GAL/DAY
 15 WATER SET TEMP. (TO VARY BY MONTHSINPUT NEG.\)               140.00 F
 16 WATER MAIN TEMP(TO VARY BY MONTH,INPUT NEG.\)                 35.00 F
 17 CITY CALL NUMBER. ....... ......................               6.00
 18 THERMAL PRINT OUT BY MONTH=1, BY YEAR=2...... ...              1.00
 19 ECONOMIC ANALYSIS ? YES=1, NO=2.. ... .........               1,00
 20 USE OPTMZD. COLLECTOR AREA=1,SPECFD.AREA=2.                    2*OO
 21 SOLAR SYSTEM THERMAL PERFORMANCE DEGRADATION.                  0.     /YR
 22 PERIOD OF THE ECONOMIC ANALYSIS. .............                20.00 YEARS
 23 COLLECTOR AREA DEPENDENT SYSTEM COSTS........                11.40 $/FT2 COLL
 24 CONSTANT SOLAR COSTS... . .....................                0.   $
 25 DOWN PAYMENT(Z OF ORIGINAL INVESTMENT)......               100000
 26 ANNUAL INTEREST RATE ON MORTGAGE,............                  8,00
 27 TERM OF MORTGAGE..............................                20.00 YEARS
 28 ANNUAL NOMINAL(MARKET) DISCOUNT RATE.........                  8.00
 29 EXTRA INSUR.,MAINT.IN YEAR 1(% OF ORIG.INV.                    1,00
 30 ANNUAL % INCREASE IN ABOVE EXPENSES, .........                 6,00
 31 PRESENT COST OF SOLAR BACKUP FUEL (BF).......                 13.93 $/MMBTU
 32 BF RISE: %/YR=1,SEQUENCE OF VALUES=2.........                  1.00
 33 IF 1, WHAT IS THE ANNUAL RATE OF BF RISE.....                 10.00
 34 PRESENT COST OF CONVENTIONAL FUEL (CF).......                 13.93 $/MMBTU
 35 CF RISE: %/YR=1,SEQUENCE OF VALUES=2.........                  1,00
 36 IF 1, WHAT IS THE ANNUAL RATE OF CF RISE.....                 10.00
 37 ECONOMIC PRINT OUT BY YEAR=1,CUMULATIVE=2...                   2*00
 38 EFFECTIVE FEDERAL-STATE INCOME TAX RATE......                 50.00
 39 TRUE PROP. TAX RATE PER $ OF ORIGINAL INVEST.                  2*00
 40 ANNUAL % INCREASE IN PROPERTY TAX RATE....,..                  6 .00
 41 CALC.RT. OF RETURN ON SOLAR INVTMT?YES=1,NO=2                  1*00
 42 RESALE VALUE  (% OF ORIGINAL INVESTMENT)....                   0.
 43 INCOME PRODUCING BUILDING? YES=1,NO=2........                  2*00
```

TABLE 5

RESULTS OF F-CHART COMPUTER SIMULATION OF SOLAR HEATING SYSTEM

```
FAIRBANKS         AK    64,82

****THERMAL  ANALYSIS****
 TIME PERCENT  INCIDENT  HEATING WATER DEGREE AMBIENT
        SOLAR      SOLAR     LOAD    LOAD   DAYS    TEMP
                 (MMBTU)(MMBTU)(MMBTU) (F-DAY)  (F)
 JAN      0.        0.45    21.45    0.     2383.  -11,2
 FEB     1.9        2.80    17.01    o*     1890.   -2.2
 MAR    20.1        7.51    15,49    o*     1721.   10.4
 APR    38.2        8.89     9.75    0.     1084.   28.4
 MAY    66.7        9.29     4.94    0.      549.   46,4
 JUN    95.8        8,36     I*9O    o*      211.   59*O
 JUL    97,3        7.75     1.33    o*      148.   60.8
 AUG    65.6        6.22     2.74    0.      304.   55*4
 SEP    29.5        4.92     5.56    0.      617.   44,6
 OCT     4,3        3.01    11.11    0.     1235.   24.8
 NOV      0.        1.44    16.80    0.     1867.    3.2
 DEC     0,         0*03    21.03    0.     2336 . -11*2
 YR     13.5       60.68   129.10    0.    14344,
****ECONOMIC  ANALYSIS****
SPECIFIED COLLECTOR AREA =          203. FT2
INITIAL COST OF SOLAR SYSTEM = $    2316.
THE ANNUAL MORTGAGE PAYMENT FOR  20  YEARS = $                0.
THE RATE OF RETURN ON THE SOLAR INVESTMENT(%)=  15.7
YRS UNTIL UNDISC. FUEL SAVINGS  =  INVESTMENT                 8.
YRS UNTIL UNDISC. SOLAR SAVINGS  =  MORTGAGE PRINCIPAL        1.
UNDISCOUNTED CUMULATIVE SOLAR SAVINGS = $                  9929,
PRESENT WORTH OF YEARLY TOTAL COSTS WITH SOLAR=$          37506 .
PRESENT WORTH OF YEARLY TOTAL COSTS W/O SOLAR = $        :39867,
PRESENT  WORTH  OF  CUMULATIVE SOLAR SAVINGS = $           2360 .
```

DISCUSSION

The indicators of the utility and quantity of solar heating for a Fairbanks location shown in this report are not encouraging. Although the two important months of February and March were not monitored completely for this first year, it is clear that the annual heating fraction is unlikely to be more than 15%. If it were not for the heat needed to warm the basement in summer and the heat capacity of the basement concrete, the heat would have less utility. As the system now functions, heat gained can be credited to the heating of the basement, with only minor overheating of the basement on the very hottest summer days.

Although this system is economic as evaluated, it would not be so if the labor costs of assembling and installing it were tallied at standard Fairbanks rates. The system would be much more economic if it were supplying hot water for domestic use, and this addition to the system is planned.

Both the f-chart simulation and the actual performance in early spring, February and March, indicate very low collection efficiency during those periods when the outdoor ambient temperature is low. This is to be expected from the relationship for expressing the useful gain from a collector (after Duffie and Beckman, 1974):

$$q' \text{ useful} = WF' [S - U_l (T_f - T_a)]$$

where: W is the distance between the collector.

F' is the collector efficiency factor, which can be interpreted as the ratio of useful energy gain to the useful energy gain if the collector absorbing surface had been at the local fluid temperature.

S is absorbed solar energy per unit area.

U_l is the overall heat loss coefficient.

T_f is the collector fluid inlet temperature.

T_a is the ambient outdoor temperature.

It is seen from this relation that, as the temperature difference $(T_f - T_a)$ increases, the thermal losses increase and the useful heat gained (q useful) will decrease.

Present plans are to continue to use the collector in a supplementary mode and monitor its performance. The collector framing will be replaced from its present Solaroll system to wood framing, as the Solaroll system is inadequate and inelegant.

As an exemplary active solar heating system, this experience is valuable in both its positive and negative aspects. Active solar energy systems which are retrofit or add-on systems requiring pumping, are a supplemental heat source and only economic if construction labor is discounted. The system is likely to be much more economic for supplying hot water for domestic use, than as a heating system.

ACKNOWLEDGEMENTS

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REFERENCES

DUFFIE, J.A. and BECKMAN, W.A., 1974, Solar Energy Thermal Processes, John Wiley and Sons, New York, 386 pp.

LIU, B.Y.H. and JORDAN, R.C., 1961, "Daily Insolation on Surfaces Tilted Toward The Equator," ASHRAE Journal, American Society of Heating, Refrigerating and Air Conditioning Engineers, 3(10): 53-59.

SEIFERT, R.D., 1981, A Solar Design Manual For Alaska, Bulletin #1 of the Institute of Water Resources, University of Alaska, Fairbanks, 163 pp, July.

ELECTRIC POWER GENERATION IN MANLEY, ALASKA FROM A GEOTHERMAL SOURCE UTILIZING A LOW-TEMPERATURE ORGANIC RANKINE CYCLE TURBINE

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ABSTRACT

The problem addressed in this paper is the utilization of low-temperature (49°C) water from a geothermal source for electric power generation in a rural Alaskan village location. A demonstration project was undertaken to establish feasibility of the concept using a low-temperature organic Rankine cycle turbine generator for this purpose. Although able to operate on a stand-alone basis, the generator was used to supplement existing diesel-driven electric generators and was not used as a sole electrical source for an isolated load. Operating data and a set of conclusions are presented detailing problems and recommendations for others contemplating this approach to-electric power generation.

INTRODUCTION

This demonstration project was conducted in Manley, Alaska, which is located ninety air miles northwest of Fairbanks in interior Alaska. Manley is accessible from Fairbanks by the Elliot Highway. This road includes 140 miles of gravel surface with the last 50 miles maintained only during the summer months.

The geothermal hot springs at Manley, Alaska, were originally discovered by J.F. Kastner at the turn of the century when he gave up gold mining for homesteading the Hot Spring site. A year later, in 1902, he went into business with Frank Manley, built a hotel and developed a vegetable, poultry and hog business to serve the gold miners in the Eureka and Tofty districts. Presently, Gladys and Charles Dart own the property and have a geothermally-heated greenhouse operation growing some of the finest tasting tomatoes in Alaska and operate a popular community bathhouse.

The geothermal springs are located on the east side of the greenhouse and on the northwest side as well. Figure 1 shows a view of the greenhouse taken from the southeast. Hot water from the upper spring (east) flows through an underground conduit to the lower springs. Water temperatures vary from 140°F to 120°F. Flow rate from the upper spring is approximately 15 gallons per minute (GPM) and about 25 GPM from the lower spring. Flow in Kastner Creek varies throughout the year de-

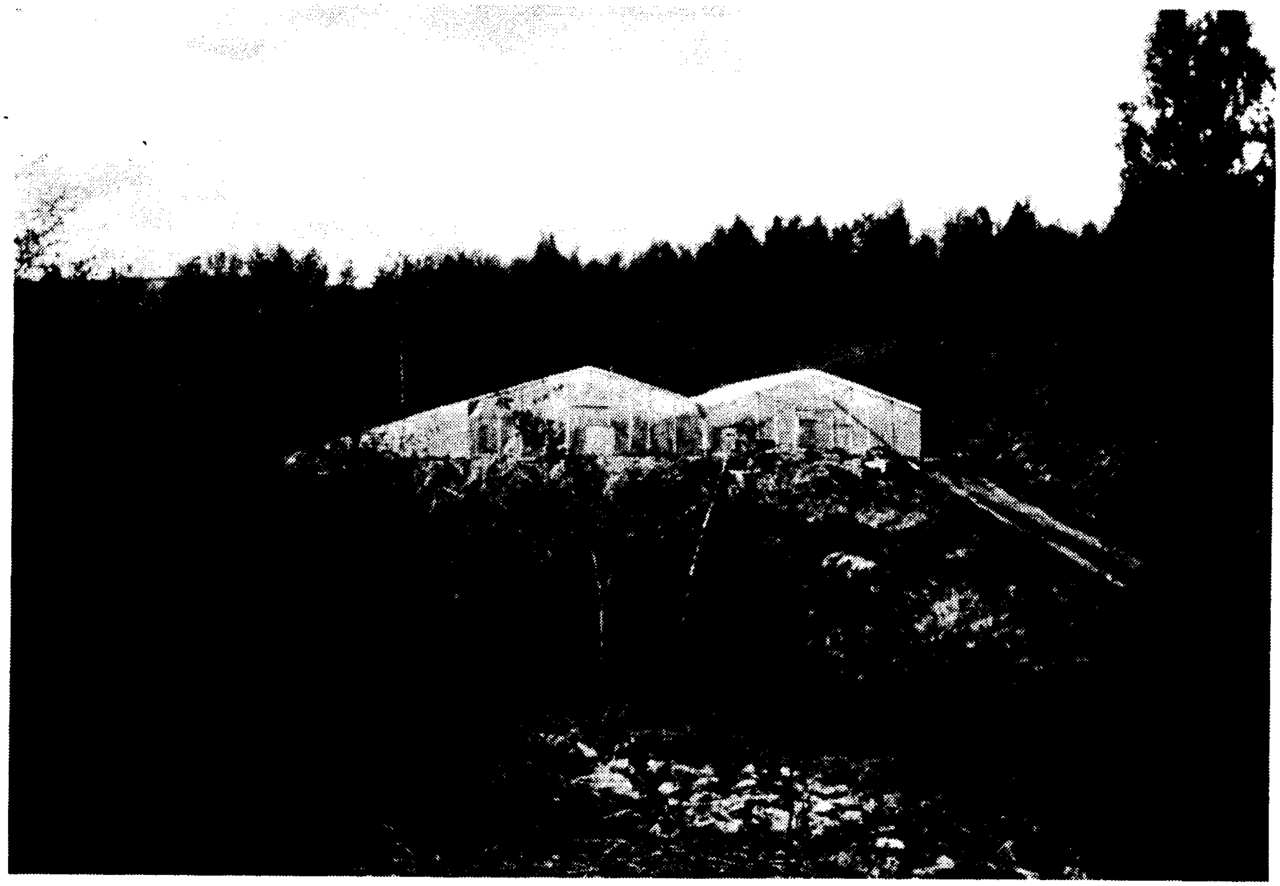

Figure 1. Greenhouses at Manley Hot Springs. The springs are located on right side and rear left side of greenhouses.

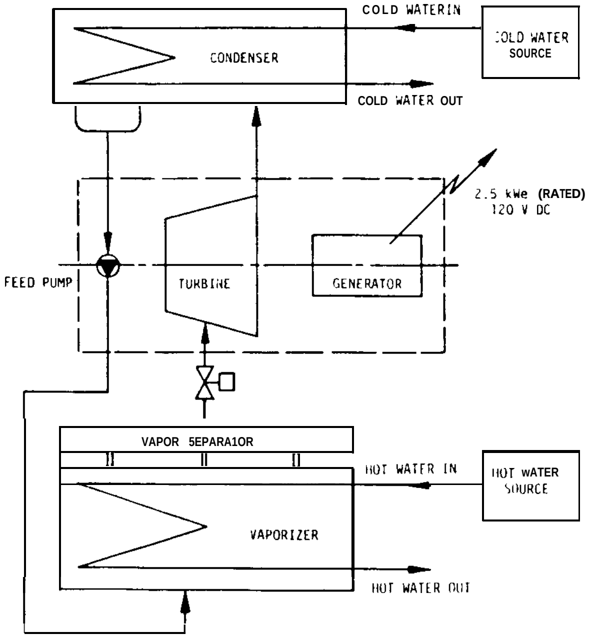

Figure 2. Flow diagram of organic Rankine cycle turbine generator.

pending on the year, depending on the season and the amount of rainfall. The lowest flow noted during summer was 70 GPM at a temperature of 39°F. Water from the hot springs and Kastner Creek flow together and mix at the west side of the greenhouse.

Organic Rankine Cycle (ORC) turbines have been commercially available for many years and the use of organic working fluids in Rankine engines has been reported as early as 1926 [1]. As of 1979, the major manufacturer of such turbines had approximately 2,000 units in use world-wide with 18 million operating hours. Although low in efficiency because of the small temperature difference between hot and cold sides of the engine, the most attractive aspect of this class of turbines is the extremely high level of long-term reliability reportedly attained by commercially available units. These units are claimed to have 95% probability of greater than 300,000 hours mean time between failures (MTBF) for the turbine-alternator unit. Because of this large MTBF, there is a small probability of overhaul requirements during a 20 year equipment lifetime [2]. Present electrical generation in remote Alaskan villages is almost exclusively diesel engine-powered. Reliability of such equipment, when inadequately maintained, is not good on a long-term basis. Consistent, high-quality maintenance is not always available in rural Alaska. Where adequate maintenance exists, diesel generator suppliers assume approximately 20,000 operating hours before a minor engine overhaul is required [3]. Also, high cost of diesel fuel in villages (approximately $2.00 per gallon) contributes to electric energy prices in the $0.40 per kilowatt-hour range. Because of these unique economic conditions, modes of electric power generation that would be unjustifiably expensive elsewhere could be economically feasible in remote Alaskan locations.

A flow diagram of a commercially available organic Rankine cycle turbine is shown in Figure 2. It is a classical Rankine cycle engine with Freon working fluid operating between two temperature levels. This particular unit was supplied by ORMAT Turbines, Ltd. of Israel. A particularly noteworthy aspect of this system is the extremely low temperature difference between the hot and cold water sources. Inlet hot water temperature is only 49°c while cold water inlet temperature is 3.8°C. The resulting Carnot efficiency for this thermodynamic cycle is approximately 12%. The turbine, generator and working fluid feed pump all operate on a common shaft and are housed in a hermetically sealed enclosure. Shaft bearing lubrication is supplied by the working fluid.

Initially, the project was to demonstrate the feasibility of generating electrical power from diesel-generator waste heat. Jerry Hook, owner of the Manley Power Company, granted permission to tie into the jacket water cooling system of his diesel engines. His power plant contains two Caterpillar diesels and a GMC diesel all in the 60 KW to 90 KW range. The load on the system averages about 30 KW on an annual basis with a peak of 80 KW in August during the fishing season. A small building adjacent to the power plant was built to house the organic Rankine cycle turbine-generator'. Electrical equipment used to-provide an interface between the ORC turbine-generator and the Manley electric distribution network is shown in Figure 3.

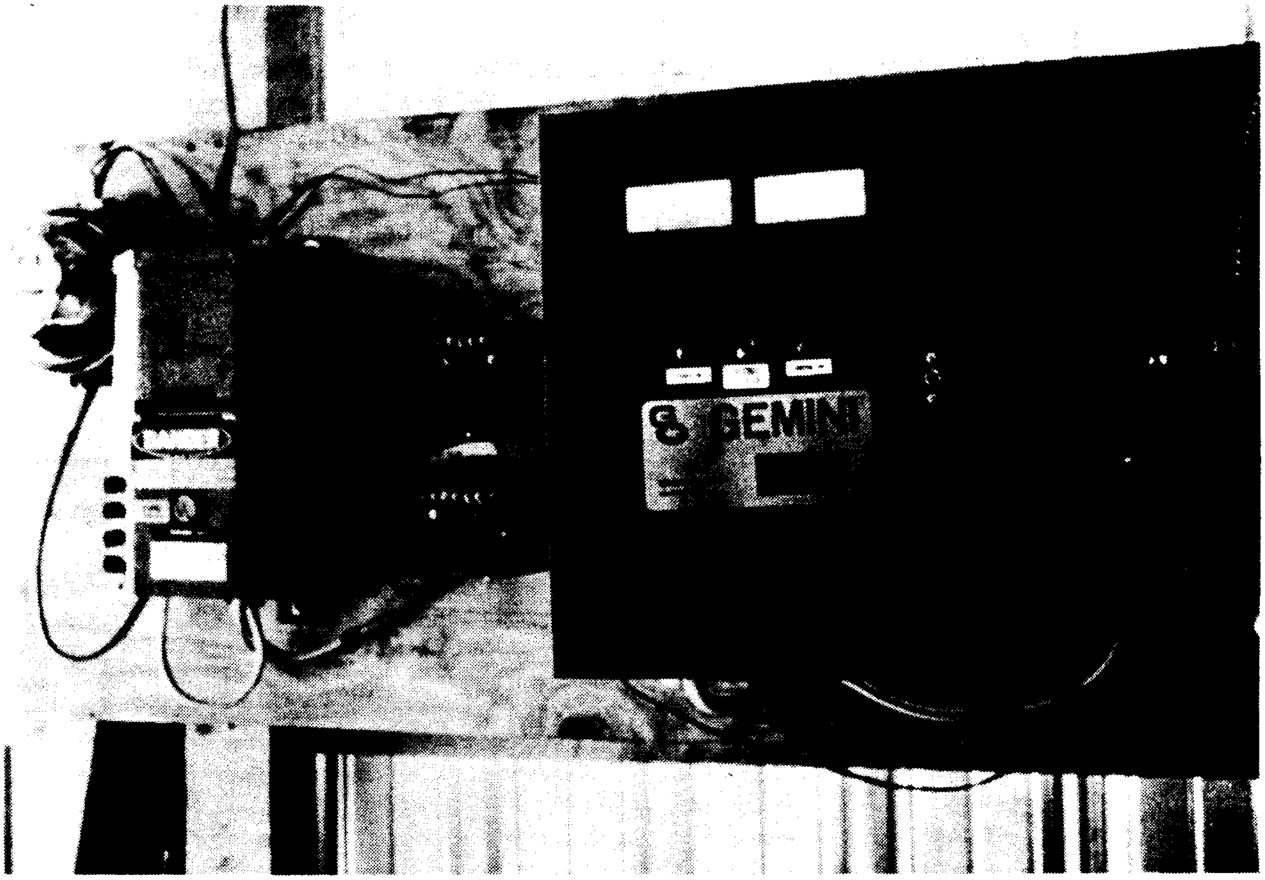

Figure 3. Electrical equipment used to interface ORC turbine generator with Manley electric distribution grid.

After the turbine-generator was transported from Fairbanks to Manley and moved into the building, the piping on the hot water side, (heat source) and cold water side (heat sink) were completed. The hot water piping connected to the ORC evaporator by 2 inch copper pipe to a heat exchanger placed in the diesel generator cooling jacket water system. Flow was maintained by a 40 GPM circulating pump. The condenser on the ORC unit was connected by 2 inch copper pipe to an air cooled heat exchanger mounted on the roof of the building housing the ORC unit. A water/glycol mixture was circulated at 40 GPM in this cooling circuit by another electrically-driven pump.

In March, 1981, an attempt to operate the ORC generator in this configuration was made. However, it quickly became apparent that: (a) there was an insufficient amount of diesel engine jacket water waste heat available on a year-round basis, and (b) the capacity of the air cooled heat exchanger during the summer months when higher air temperatures occurred was less than required to operate the unit. The reason why these problems did not surface until this point in time was due to poor or no communication from Ormat's development engineers in Israel to ourselves. (This situation did not improve as the project progressed.)

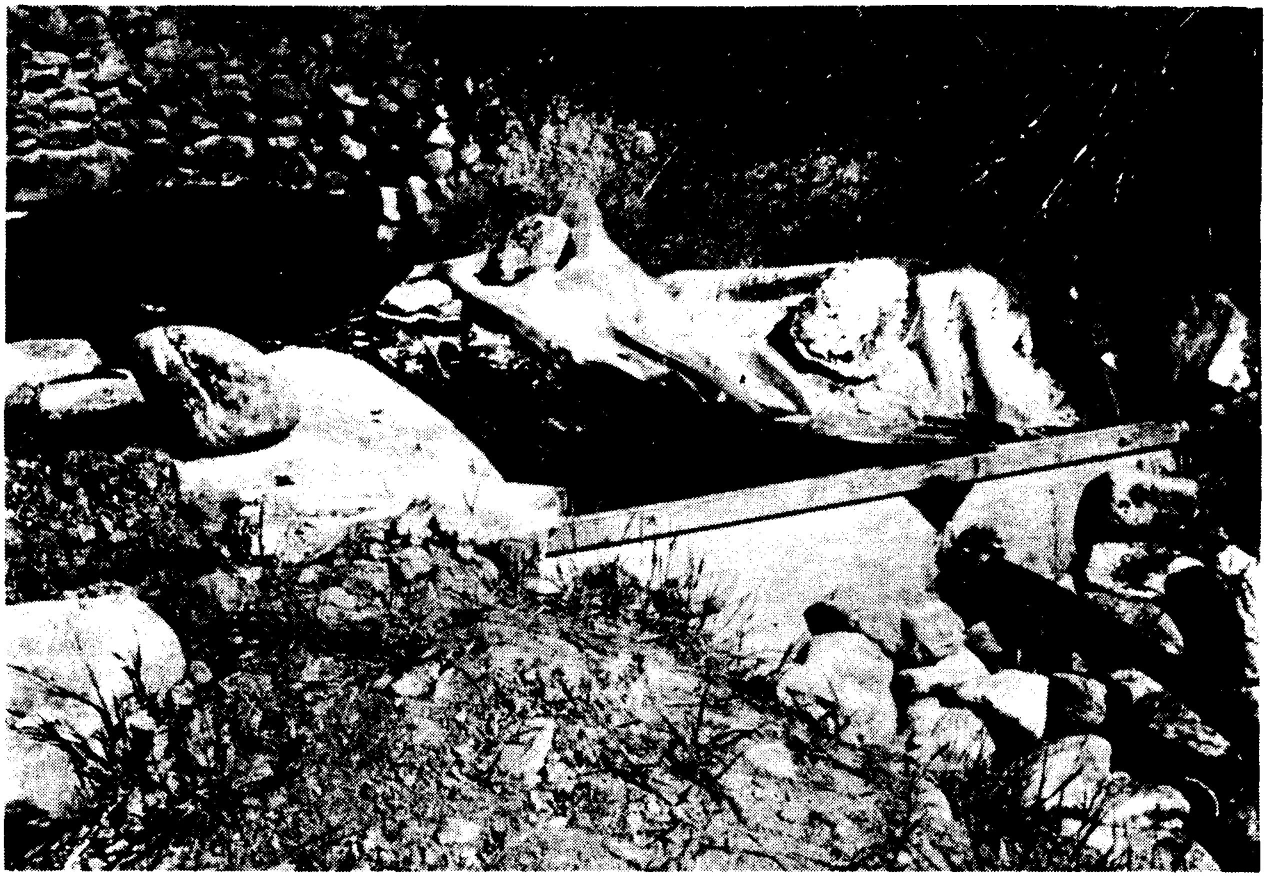

Figure 4. Plywood weir placed in creek from upper hot spring to dam water. Pipe carrying hot water to ORC turbine-generator can be seen.

At that time the decision was made collectively between ORMAT, Division of Energy and Power Development of the State of Alaska and the University of Alaska, School of Engineering staff to discontinue further efforts to produce power with the ORC operating on waste thermal energy. Although the heat source problem could be solved with the addition of a waste heat boiler on the diesel exhaust and the cooling problem could be solved with either well-water cooling or a much larger heat exchanger, the cost of this equipment was prohibitive. Furthermore, and perhaps most important, degrading waste-heat at 180°F to 40"F with a corresponding electrical to thermal energy conversion efficiency of 2-3% does not appear to be the best use of the initial thermal energy. Using diesel jacket water waste heat for space heating is a more effective use of this thermal energy.

Because the ORC unit was already in Manley and several surface geothermal springs exist on the Charles Dart property there, it was decided to attempt to generate electrical power from these geothermal springs. The ORC unit was originally designed for operation using a geothermal

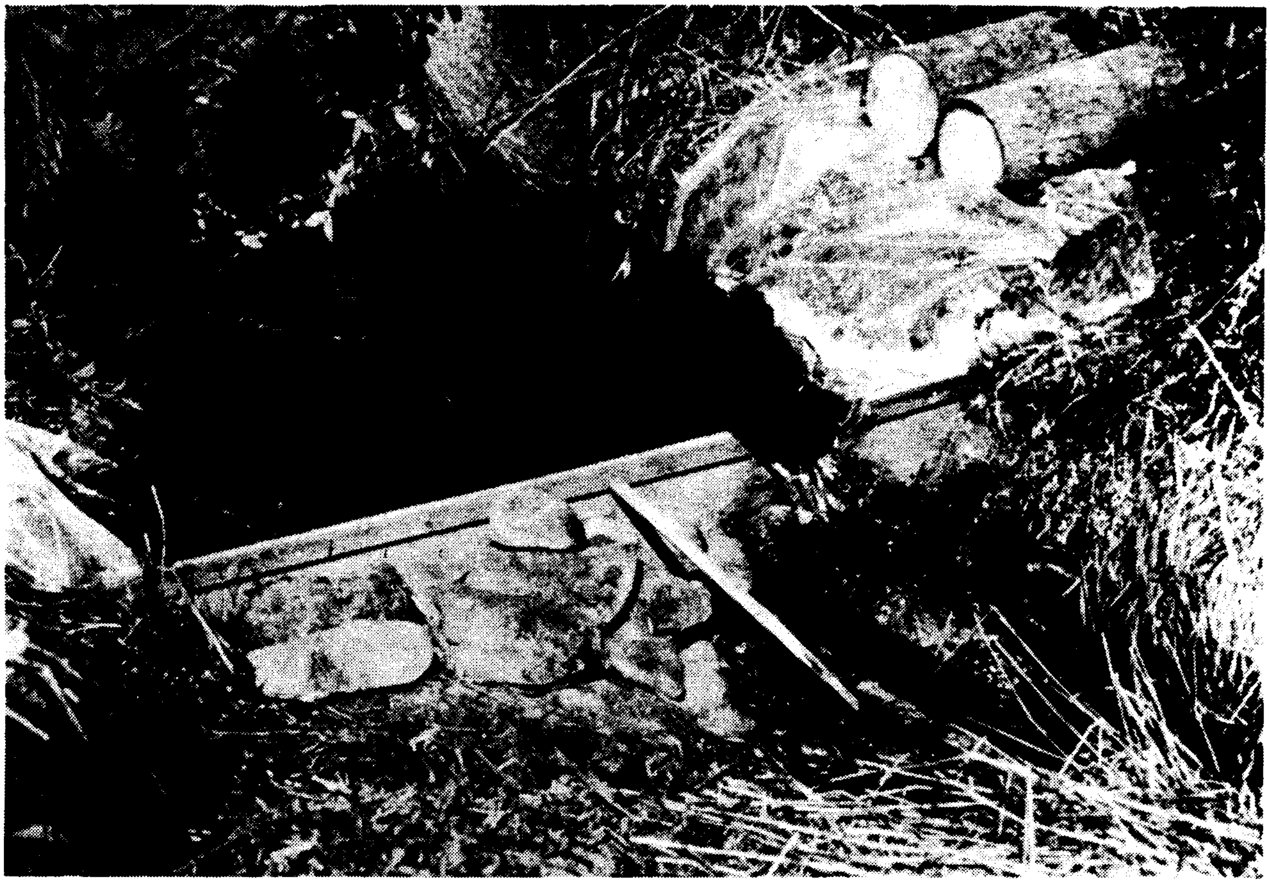

Figure 5. Plywood weir placed in Kastner Creek. Two 2-inch polyethylene pipes carrying cold water to ORC turbine-generator can also be seen.

source and discussions with the Ormat engineers resulted in the consensus that the unit would operate at the Manley Hot Springs, although not at rated capacity.

With the permission of Charles Dart, the ORC unit was moved from the Manley Power Company to his property. The site chosen for the unit was 250 feet from the upper spring, 300 feet from the lower springs, and 400 feet from a favorable weir location on Kastner Creek.

At the hot springs the design conditions were 20 GMP of hot water at 130°F and 80 GPM of cold water at 38°F. (Higher flow rates and larger temperature differences improve the ORMAT unit's performance.)

Polyethylene pipe was purchased in 1-1/2 inch diameter to transport water from both the upper and lower hot springs to the ORMAT unit. Two 2-inch diameter polyethylene pipes were laid along Kastner Creek to bring cold water to the unit. It was necessary to install a plywood weir at the upper spring to dam the flow in order to pipe hot water to the unit as shown in Figure 4. This produced about 12 GPM flow. The balance, 8 GPM, was taken from the lower spring by submerging the suction end of the pipe in a deep pool. Cold water in Kastner Creek was obtained by installing another weir to dam the flow so the suction ends of the 2-inch pipes would remain submerged. See Figure 5. The back water from the dam also served as a settling basin.

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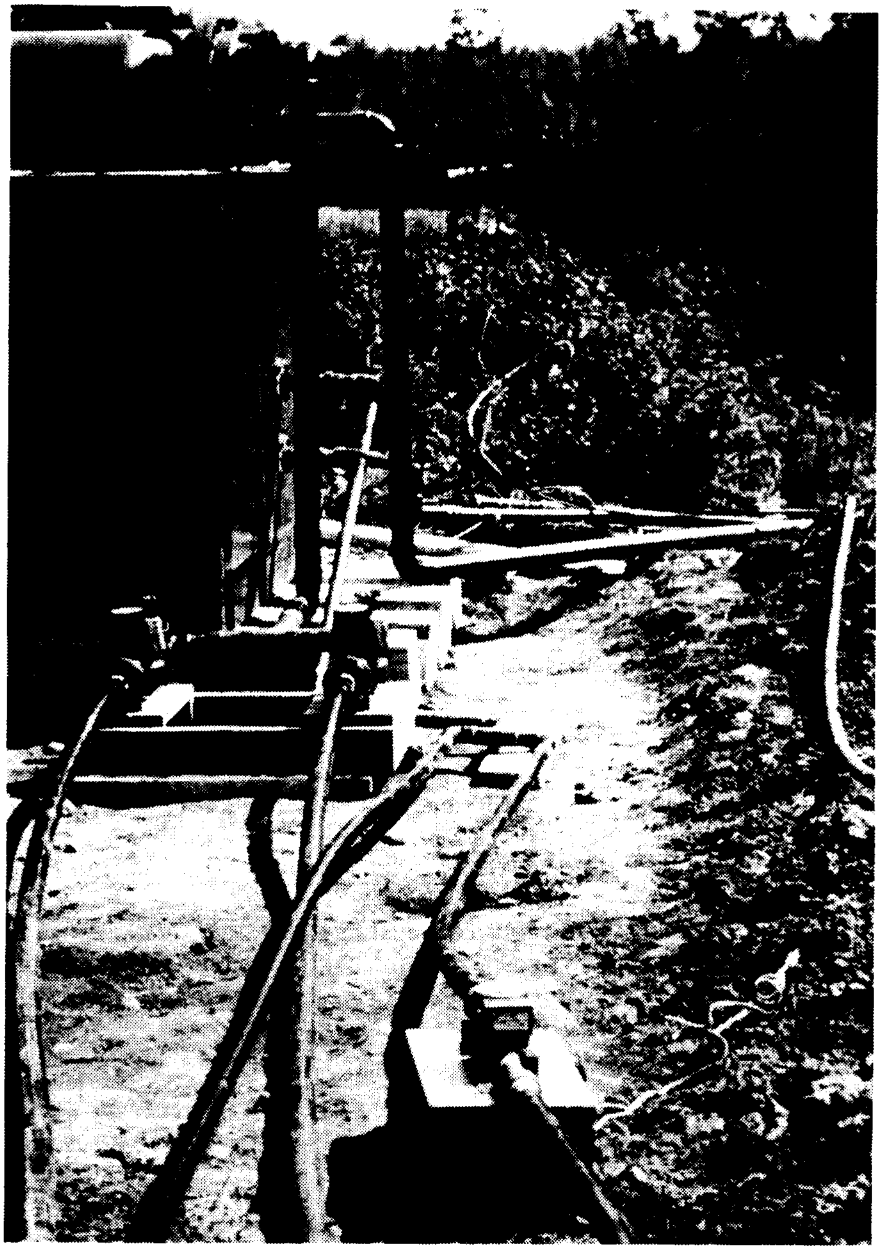

Figure 6. Completed--hot water and cold water plumbing to ORC turbine-generator

Pumps were installed in the cold water pipes as well as the hot water line from the lower spring. Using the inverted syphon principle, i.e. running the cold water and hot water returns to creek level, allowed the flows to be maintained without operating the pumps as shown in Figure 6. The pumps were necessary to prime the system initially.

An overhead power line 450 feet in length was installed from Charles Dart's house to the ORC unit. After the building housing the unit was completed, the power lines were brought into the building through a mast head mounted in the roof. Electrical connections were made to the ORC unit from this pointandaredetailedin another section of this paper.

Tables I and II list representative thermal and electrical operating data.

Table I. Representative Thermal Operating Data

49°C ± .2°C	hot water inlet temperature
38°C ± .2°C	hot water exit temperature
4.97 kg/s	cold water flow rate
3.8°C ± .2°C	cold water inlet temperature
6°C ± .2°C	cold water exit temperature

Applying the first law of thermodynamics to the turbine working fluid vaporizer yields [4]

$$\dot{Q} = \dot{m}\, C_p\, \Delta T = 50.7 \pm 1.1 \text{ KW}$$

$\dot{Q}$ = heat (thermal energy) transfer rate (W)

$\dot{m}$ = mass flow rate of water (kg/s)

C_p = specific heat of water (J/kg°C)

AT = temperature change of water (Co)

Table II. Representative Electrical Operating Data

9.0 A	DC generator output current
7.0 A	DC inverter input current
133.3V	DC battery bank voltage (generator output voltage)
132.3V	DC inverter input voltage

(9A)(133.3V) = 1200W electrical power output from generator

(7A)(132.3V) = 926W electrical power input to inverter

1200-926 = 274W electrical power input to battery bank

876W ± 15W RMS measured AC power out of inverter

$\frac{926-876}{926} = \frac{50}{926} = 0.054 = 5.4\%$ power loss in inverter at these operating conditions

50W = electrical power loss in inverter

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Heat Input}} \;.\; \frac{1200\text{W} \times 100\%}{51{,}300 \text{ w}} = 2.4\%$$

$$\text{Carnot Efficiency} = \frac{'H - 'c}{'H} = \frac{570 - 501}{570}(100\%) = 12.1\%$$

where T_H and T_c are the absolute temperatures (K) of the hot and cold water flows to the unit.

ELECTRICAL CONSIDERATIONS

Components

The turbine-generator electrical output is DC (direct current) derived from a three phase alternator-type generator configuration supplying a set of rectifiers. A bank of ten series-connected 12-volt lead-acid batteries makes the unit independent of any external electrical supply and forms the generator load when no external electrical load is present. Thus, the generator output is nominally 120 DC volts with the battery bank and alternator electrically in parallel as viewed by an external electrical load. Nominal output electrical power rating is 2500 watts. Therefore, rated current is 2500W/120V = 20.8A (DC).

The turbine generator DC output must be made compatible with the external load. In this case, that load is the existing 60 Hz AC electrical power system. The average generation requirement of this village is approximately 40 kVA. The most cost-effective interface was determined to be a synchronous single-phase line-commutated, line-feeding inverter. Nominal specifications are: 4 kW power transfer capacity; 0-200 VDC input voltage range: 20A maximum current; and 240 VAC output voltage. A commercially available inverter permits great flexibility of operation in that the volt-ampere (V-I) characteristic of the unit may be completely specified by the user. With reference to Figure 7, cut-in voltage, I_{max}, V-I characteristic rate of change (slope) and therefore V_{max} are all easily field-adjustable.

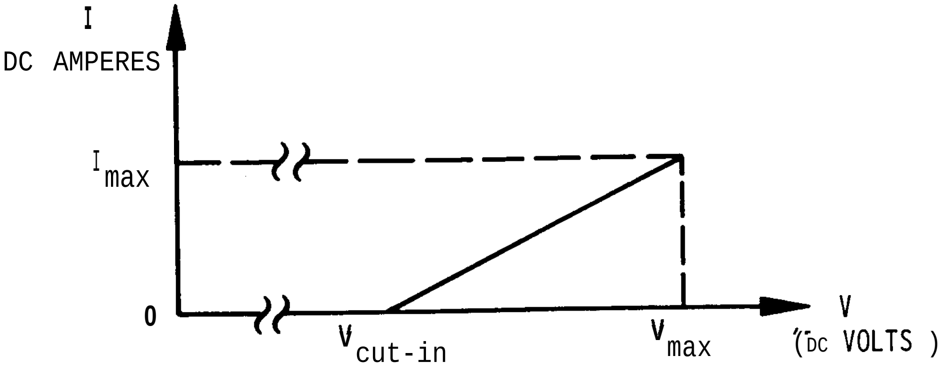

Figure 7. Inverter volt-ampere characteristic

The low output impedance of the generator requires that a filter consisting of a capacitor and iron-core reactor be connected in cascade with the inverter and generator as shown in Figure 8. A diode is used to prevent reverse voltage polarity transients from damaging the capacitor.

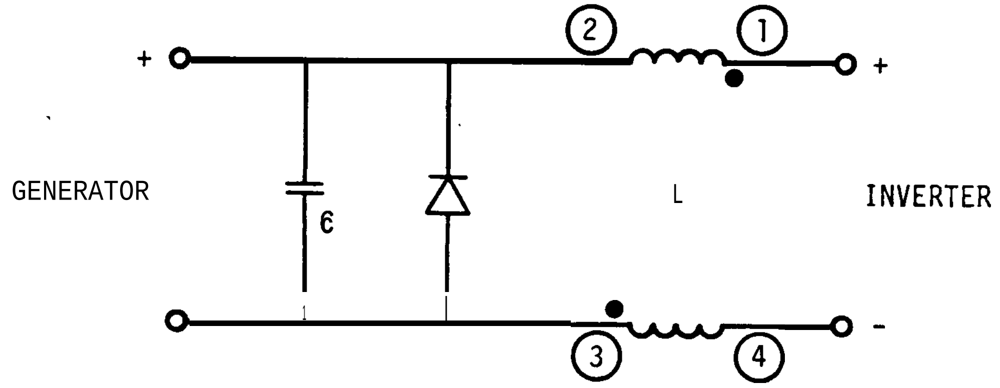

Figure 8. Filter interface between generator and inverter

C = 4000 microfarads, L = 24 millihenries (iron core reactor) with 20 A average current and 40 A peak current ratings. Circled numbers refer to lead markings on iron core reactor.

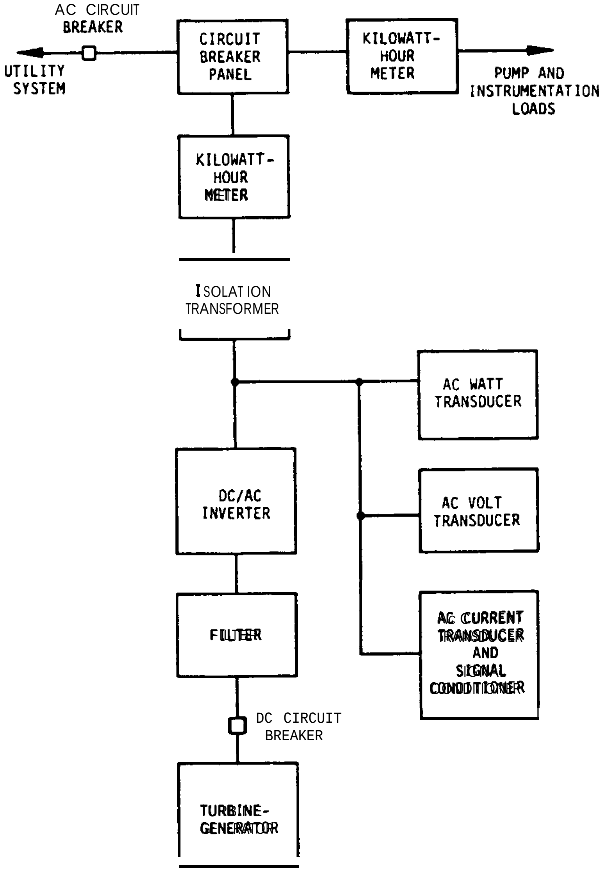

Figure 9. Electrical system block diagram

A line-commutated inverter is designed so that on alternate half-cycles of AC voltage, alternate sides of the DC source are connected directly to the 240 V AC power lines. Therefore, it is essential that neither side of the DC source be grounded unless an isolation transformer is connected between the inverter and the AC power system. Since numerous waveform measurements were required, a 240V to 240V two-winding isolation transformer was used to allow grounding of either side of the DC source. A block diagram of the entire electrical system is shown in Figure 9. Additional electrical operating data and waveforms are published in [5].

The purpose of this paper is to describe results and identify operational problems of utilizing a very low-temperature geothermal water source to drive an organic Rankine cycle turbine-generator. The data presented was obtained from operating tests during which the turbine generator was run for approximately 15 hours. Additional operating experience was not pursued for the following reasons: Unattended operation was inappropriate because of (1) water intake filter maintenance requirements and (2) because automatic start-up and shut-down equipment associated with the turbine-generator did not operate normally, requiring manual operation.

CONCLUSIONS

The following conclusions may be drawn from data presented in this paper: (1) It is possible to convert low-grade (49°C) thermal energy from a geothermal source into electrical energy. However, very low efficiencies may be expected. Table 1 data show 2.4% efficiency for the system described in this paper while the Carnot or ideal machine efficiency is 12.1% based on the temperature difference between the hot and cold sides of the Rankine cycle turbine. Efficiency is defined here as electrical power out divided by rate of thermal energy input. (2) The choice of inverter was dictated by cost and availability of an existing AC power system. Since a line-commutated, line-feeding inverter requires an AC line to operate, it would obviously be necessary to use a stand-alone inverter if an isolated AC power source were required. Alternately, no inversion would be required if only a DC load requirement exists. (3) The inverter used for this application did not produce harmonics that interfered in any way with the instrumentation. A power system disturbance analyzer was unable to detect any inverter-caused disturbances.

Also of considerable importance to potential designs of similar systems are the following considerations: (1) Filter system: The cold water intakes and hot water intakes were designed with a static filtering screen. Debris collecting on the screens was a constant maintenance problem. Algae, in the case of the hot water intakes, and leaves and twigs in the case of the cold water intakes had to be removed after only several hours of operation to maintain flow. Self-cleaning mechanical filtering systems would have to be installed on the hot and cold water supplies to avoid this problem. The added expense and power required to operate them would hardly be justified for a generator of this size. Alternately, both cold water and hot water wells could be drilled to provide clean water but again the economics are prohibitive on this small scale unit. However, it is possible that a larger unit might justify the added cost. (2) Freeze protection: For wintertime operation, the turbine as well as the hot and cold water lines would have to be thermally insulated. In addition, all water lines would have to be heat traced to avoid freeze-up during shut-down periods. The cost of doing this in rural Alaska could easily be prohibitive. (3) Efficiency: As with all thermal power plants, efficiency is a primary consideration. In the case of a low temperature organic cycle turbine, efficiencies below 10 percent are usual. This means that cooling requirements are very stringent and that a large amount of thermal energy must be dissipated for a relatively modest turbine size. For example, since

$$P_{waste} = \left(\frac{1-\eta}{\eta}\right) P_{out}$$

where

P_{waste} = rejected heat (thermal power)

P_{out} = useful output (electrical power)

η = cycle efficiency

a 50 kW (output) turbine generator with 10% efficiency would exhaust

$$P_{waste} = \left(\frac{1-0.1}{0.1}\right)(50kW) = 450 \text{ kW}.$$

Input thermal energy rate (thermal power) would, in this example, equal 500 kW. The exhausted thermal energy is of no real value since the cooling water exit temperature would likely be only a few degrees above 0"C. The potential user of a low-efficiency system as described in this paper must ascertain if there is a higher use for the initial thermal energy, such as space heating, for example, which might result in more efficient utilization and less capital cost.

ACKNOWLEDGEMENTS

The authors greatly appreciate the cooperation and assistance of Ormat Turbines Ltd., Manley Utility Company, Golden Valley Electric Association, Charles Dart and Scott Bell. The work described in this paper was supported in part by a grant from the State of Alaska, Department of Commerce, Division of Energy and Power Development and also by the School of Engineering, University of Alaska-Fairbanks.

REFERENCES

[1] H.M. Curran, "The Use of Organic Working Fluids in Rankine Engines," H-C1007/2000-79-902, prepared for the U.S. Dept. of Energy, Systems Development Division, Conservation and Solar Applications, Contract No. DE-AC03-79CS-30202, 21 pages, September, 1979.

[2] Ormat Systems Inc., "For Really Reliable Remote Power. ..," 1979 data in product literature.

[3] Unpublished communications between authors and managers of rural electric utilities and suppliers of diesel generators in Alaska.

J.D. Aspnes
J.P. Zarling

[4] D.C. Look, Jr., and H.J. Sauer, Jr., Thermodynamics. Monterey: Brooks/Cole Engineering Division, 1982.

[5] J.D. Aspnes, and J.P. Zarling, "Electric Power Generation From a Geothermal Source Utilizing a Low-Temperature Organic Rankine Cycle Turbine," IEEE Paper No. 82 SM 486-9, presented at the IEEE PES 1982 Summer Meeting, San Francisco, California, July, 1982.

THE HOUSE AS A SYSTEM

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ABSTRACT

The last major change in residential construction practice occurred in the 1930's, , when there was a rapid growth in the use of insulation of various types. This created a number of new problems, and led to the first use of vapor barriers.

We are now in the process of another, and much greater change in building practice. We are attacking all the components of the house on a broad front, in an attempt to make the house optimally energy-efficient. As in the 1930's, we are learning that the house is a balanced system made up of interacting components; when one component is changed it may sometimes have far-reaching, unforseen consequences on the others.

In the author's view, energy-efficient house construction is proceeding generally in the right direction. However, if it is to continue in this direction, and if we are to avoid major errors, we must give high priority to looking at the house as a 'system' . We must try to identify or foresee the consequences of various changes, and devise ways of overcoming them.

This paper looks at the state of the art of energy-efficient house construction in Canada. It discusses some of the interaction problems that are now starting to emerge, and it looks at some of the ideas and techniques that have been devised to overcome them. Specific problem areas include furnaces, combustion air supply, air quality, structural integrity and structural moisture problems.

INTRODUCTION

When technological change is applied to a product - whether it be something like a car or a ball-point pen or a house - the process of change tends to follow a fairly well-charted route, in terms of time scale, market adoption and developmental problems. The size and frequency of the problems appear to be related to the scale of the technological change, and it also appears that the problems can be aggravated by attempts to accelerate the process of change - such as might happen in a competitive situation, or when tight deadlines are imposed.

These problems will occur even in the most controlled development program, of the sort that is possible in the automobile industry. Compared with this industry, the building industry is a highly uncontrolled, diffuse and de-centralized one. Therefore, when applying the major technological changes of energy conservation to the housing industry, it would be unrealistic to expect a smooth, problem-free transition.

In the author's view, residential energy conservation contains many of the elements that lead to developmental problems. The scale of the technological change is large, when seen against the general technical level in the industry. The process of change is being accelerated by government intervention - though one would not quarrel with the reasons for this intervention. The uncontrolled nature of the building industry, and the lack of mechanisms for technical development within the industry, make it difficult to achieve effective transfer of the technology to the industry.

Energy-efficient housing, of the sort that has been pioneered in the Saskatchewan Conservation House, the Copenhagen Zero Energy House and the prototypes built by Leger in Massachusetts, has been with us for five years or more We are now into second and third generation designs, and we are also beginning to encounter some of the problems associated with these designs.

Most of the problems are the result of interactions: a significant change is applied to some feature of the house, and this is found to have some undesirable effect on another feature. This type of interaction was first encountered in the 1930's, when there was a rapid growth in the use of thermal insulation. This lead to moisture problems, which were eventually solved by the development of vapor barrier technology. With energy-efficient housing, we are now encountering similar interfactional problems over a wider range.

The majority of the problems can be overcome, or avoided, by respecting the fact that a house is a 'system' in which all the interacting components should be in balance. This system approach to energy-efficient housing was a major feature in the design of the Saskatchewan Conservation House. It was appreciated that super-insulation might aggravate moisture problems, which could be minimized by the use of air-vapor barrier techniques. In turn, the airtight construction that resulted from these techniques made it necessary to install a controlled ventilation system to ensure good air quality.

Experience has shown that this is still a good approach, provided it is applied properly. So why all this talk about problems? The newly emerging problems fall into two categories:

- A range of subtle interactions that were not foreseen in the Saskatchewan Conservation House, or that were not relevant because the house had no combustion heating systems and no basement.
- A tendency, on the part of some builders and homeowners, to overlook the system approach and treat the various energy conservation features as options from which they can pick and choose, as in a supermarket.

Conventional house designs, though unsatisfactory from an energy conservation point of view, are very ‘forgiving’ in their operation. The leaky envelope ensures a large flow of air through the house. This generally prevents hazardous air quality problems, and provides adequate air supply for the various combustion systems. Conversely, the high level of combustion induces the flow of cold air inwards through the house envelope, which inhibits the development of moisture problems in the envelope. Such houses, though inefficient, have a fairly well-balanced system which can tolerate some design errors - provided these are not too severe.

The energy-efficient house, on the other hand, is less forgiving. The various features are much more delicately in balance, and the house is not so tolerant of errors. It is therefore very important to approach energy-efficient design as a ‘system’. This concept appears to be gaining ground in the technical community, but it has not yet found its way into the building industry - to any significant degree. It is hoped that this paper, which stresses the ‘system’ concept, will give builders and homeowners a better perspective on energy-efficient house design.

A REVIEW OF PROBLEMS

The following is a brief summary of some of the actual or suspected problems associated with energy-efficient housing, based on various research findings in Canada and the U.S.A.

Attic insulation

Quality control: depth and density.

Long term deterioration: settling, humidity effects.

Chemical interactions of some insulations with metal truss gussets.

Overheating on recessed ceiling lights.

Overheating of electrical cables beyond rated temperature.

Blockage of ventilation at soffits.

Fire hazard due to piling of some insulation types against a hot flue or chimney.

Potential for increased frost build-up if the ceiling vapor barrier is not adequately sealed.

Possible enhancement of truss lift.

Effective thermal resistance impaired by thermal convection or wind effect.

Wall insulation

Effect on infiltration levels.

Potential for increased moisture build-up.

Corrosion of electrical.

Electrical cable overheating.

Pollutant effect of some insulation materials.

Vapor barrier position during retrofit.

Double vapor barrier during retrofit, or with use of low permeability sheathing.

Deformation of double wall systems.

Siding attachment through insulated sheathing.

Compatibility of various multi-layer wall designs.

Design of walls to ensure adequate moisture dispersal without impairment of insulation levels by wind effect.

Basement insulation

Wall temperature cycling when basement is insulated on inside.

- Entrapment of vapor or seepage water behind vapor barrier, leading to rot of frame.

Insulation and vapor barrier design at headers.

Insulation attachment to outside of basement.

Hydrostatic loading when porous insulation is attached to outside of basement.

Protection of insulation above grade.

Protection of insulation against soil interactions.

Deeper frost penetration, perhaps to the footings and weeping tile system.

Aggravated soil activity due to greater thermal cycling.

Difficulty of insulating basement floor.

Curing of basement floor concrete over insulation or vapor/moisture barrier.

Vapor barrier and sealing

Lower level of air change leads to air quality problems (odor, humidity, pollutant build-up).

Long-term stability of vapor barrier construction and material.

Possible harmful chemicals emitted by some caulks and sealants.

Combustion air supply problems induced by airtight construction.

Impaired air circulation, induced by airtight construction and insulation. This leads to stale air problems in some parts of the house.

Quality control of air-vapor barrier installation.

Re-appraisal of the actual overall eneregy-efficiency of the air-vapor barrier, taking into account the ventilation and combustion air supplies that are made necessary by this practice.

- The role of the air-vapor barrier in control of moisture movement.

Ventilation

- The necessity of a controlled ventilation system in an airtight house.
- Development and research needed to come up with appropriate ventilation system designs.
- Difficulty of connecting ventilation systems to existing air-handling systems in retrofit.
- Location of exhaust and inlet vents to eliminate wind loading, cross-flow and interaction with gas connections.
- Neutral pressure plane effects arising from location of vents, with potential for aggravating moisture problems.
- Effectiveness of existing air circulation systems and designs, in reaching all parts of the house.
- Pressure fields set up by forced ventilation systems.
- Heat exchangers: cost, level of development, operational problems, installation, pollution.
- Correct treatment of dryer exhaust systems.
- Special ventilation needs for handling high concentrations of some pollutants (radon, formaldehyde) .

Combustion air supply

- Adequacy of air supply.
- Desirability or undesirability of using ventilation system as air supply.
- Interaction of furnaces with open fires, stoves, etc. in an airtight house.
- Effectiveness and side effects of furnace rooms.
- Wind loading effects.

Furnaces

- Effects of oversizing, induced by retrofit of house (seasonal efficiency, flue icing).

- problems with installing energy-efficient furnaces and electrical furnaces in poorly-sealed houses.
- Quality control of installation, with attention to control systems (thermostat, anticipator) .
- Limitations on effectiveness of automatic dampers (interaction with domestic hot water heater).
- Limitations and permissible modifications of furnace units.

SOLUTIONS FOR NEW HOUSING

The Saskatchewan Conservation House was one of the first examples of the super-energy-efficient design. It is based on a system approach that incorporates four basic principles:

- High levels of insulation.
- Airtight construction.
- Controlled air management system.
- Passive solar design.

These concepts have now been adopted in a large number of second and third generation designs across Canada and in the U.S.A. The concepts are sound, and the main problem is to make sure that builders understand these concepts and the necessity for a system approach. A publication on air-vapor barrier construction (1) and an audio-visual presentation on super-energy-efficient housing (2) are helping to promote the technology in the building industry in Canada.

Saskatchewan Research Council has now progressed beyond the super-energy-efficient design, and is looking at ways of achieving high levels of energy conservation at low cost - in recognition of the current affordability problems that are generally threatening the housing industry. This new design has been called the ‘retrofit-ready’ house, since it concentrates on those features that will be difficult or costly to retrofit at a later date, and leaves the home owner to upgrade the remaining features at his leisure. The design is a carefully evolved package that goes a long way toward overcoming most of the known interfactional problems. It has evolved, in part, from the Home Energy Loan Program standards, which Saskatchewan Research Council helped to develop for the Saskatchewan provincial government.

The main constructional features of the retrofit-ready house are shown in Figure 1. The following numbered items refer to the labels in the figure:

1. Ceiling insulation level R20 or more, at home owner's discretion. This can easily be added to at a later date, with correct built-in features.

2. Insulation stop around flue and attic hatch is at least 24″ high to accommodate more insulation. Attic hatch should-be on outside wall of attic for preference.

3. High hip truss to allow extra insulation over top of exterior wall, or use cantilever truss design as shown in 3a.

4. Ceiling plasterboard is 5/8″ thick to bear extra insulation load.

5. Adequate soffit ventilation paths as a fail-safe, with insulation stops high enough to contain later additions of insulation. Note that over-ventilation should also be avoided.

6. Thermal bridging at top and bottom plates is reduced by rigid insulation sheathing.

7. Basic wall structure is 2 x 6 stud on 16” centers. Many builders find this easy to work with.

8. Exterior insulated sheathing is a desirable option. It prevents dewpoint problems on the warm face of the 2 x 6 studs. Thickness should not exceed 1.5″, otherwise the nailing attachment of the siding will be weakened.

9. The strapped wall allows the addition of another R8 of batt insulation, and allows the location of the vapour barrier in a set-back position, where it will suffer less damage from electrical and drywall installation work (2 x 3 straps on edge).

10. The vapour barrier is continuous and is constructed to high standards of airtightness.

11. Condensation can occur on the warm side of the vapour barrier where it passes close to the 2 x 6 studs. The exterior insulated sheathing prevents this.

12. Vapour barrier is continuous around header.

9.

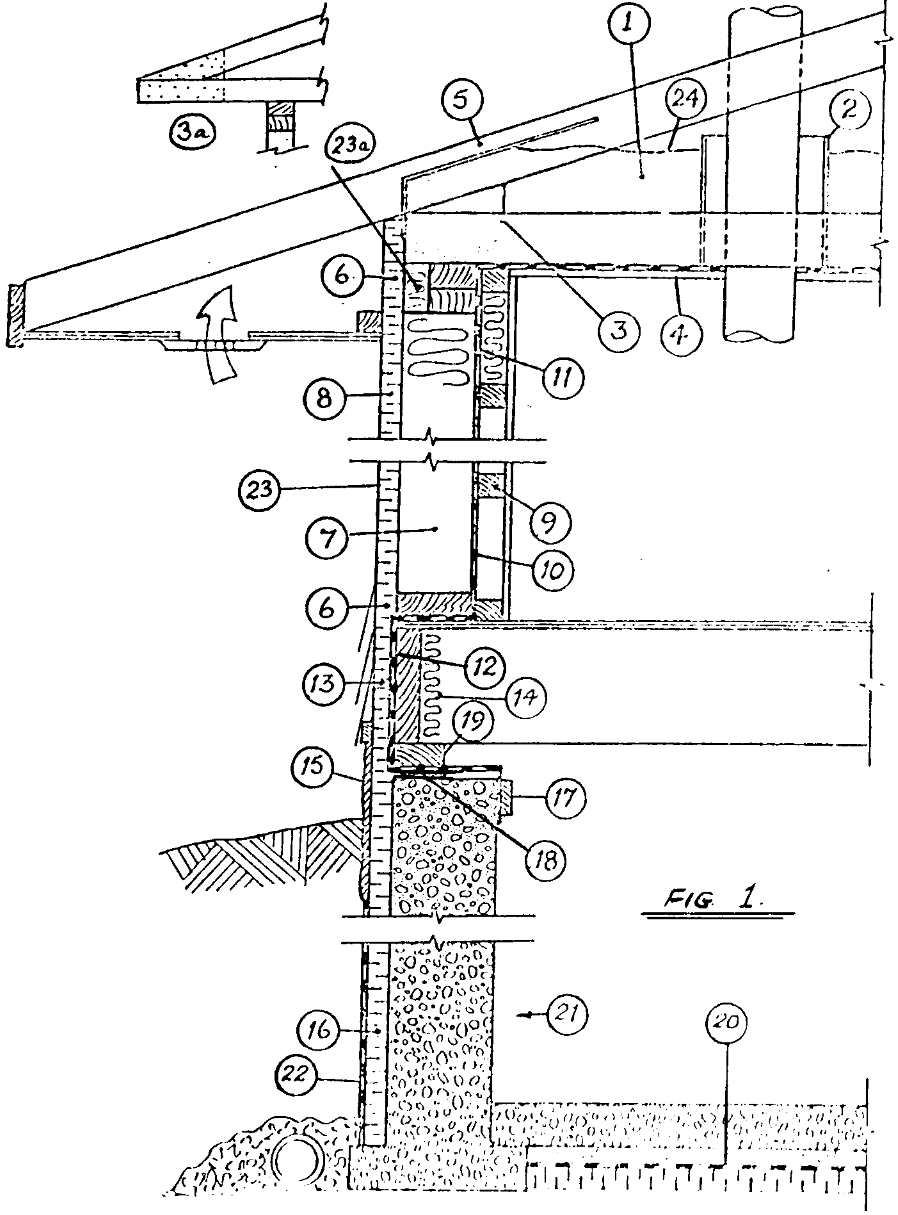

FIG 1.

13. There should always be some insulation outside the header, otherwise condensation will occur at the vapour barrier.

14. Insulation level inside vapour barrier should be less than half insulation level outside, otherwise dewpoint location will be inside vapour barrier and condensation will occur.

15. Insulation above grade is protected with parge* on mesh, secured to concrete with mesh nails through insulation.

16. Rigid insulation carried to footing. Recommended thickness of 1.5" allows rigid insulation to be carried right down exterior wall without any jogs in the wall line. Top of insulation is secured with mesh nails; bottom is secured with backfill.

17. Vapour barrier is carried to top of concrete foundation wall, caulked to concrete and fixed in place with nailing strip. This strip is used as a starting point for basement vapour barrier, if the foundation wall is framed and insulated at a later stage.

18. Felt or foam strip under vapour barrier prevents penetration by concrete.

19. Sill plate over vapour barrier prevents damage during floor joist installation.

20. Basement floor should preferably be insulated and provided with moisture barrier. Care is needed to avoid damage to these during concrete pouring. A layer of compacted sand gives protection, and assists the curing of the concrete.

21. It is preferable to insulate the concrete on the outside where possible. This protects the concrete against thermal cycling, and allows the wall to act as a thermal storage medium. The interior should not be insulated and vapour barriered until the concrete has cured for six months, and then any cracks or seepage points must be repaired before insulation. When water enters the basement through the foundation wall, it has no way of escaping if a vapour barrier is installed. The build-up of water can lead to rot of the wood frame. Therefore, the vapour barrier should not be installed until seepage is corrected and curing is complete.

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* Plaster

22. A slip-coat of polyethylene should be attached on the outside of the rigid insulation to prevent lift-off or other damage resulting from soil reaction.

23. Whatever sheating is used on the wall, it is essential to allow the wall to dissipate any excess moisture. If the wall is sheathed with a low-permeability material such as styrofoan SM, it is bad practice to seal the joints between the sheets. The wall must be allowed to breathe, but at the same time the wind movement through the wall must be kept to a minimum. Detail 23a shows one way of achieving a good moisture dissipation path. The double top plate is made of 2 x 41s, and the gap is filled with batt insulation. This allows moisture to dissipate into the attic, and it also reduces thermal bridging through the top plates.

24. A covering of olefin-spun paper on top of the insulation will potentially inhibit the impairment of the insulation by wind effect, and at the same time this will be porous enough to allow the passage of moisture. The technique is currently being studied, and its effectiveness has not yet been established.

Cost analysis shows that this design can be one of the most cost-effective options in some circumstances. Its low incremental cost makes it a good option at a time when affordability is a major issue in the building industry.

CONCLUSIONS

Experience with energy-efficient housing over the last five years has shown that a number of problems can arise from interactions of the various components and features. This means that energy conservation options cannot be selected according to the fancy of the home owner or builder, but have to be selected in the light of how they will interact with each other. The house design must therefore be evolved as a system or package, that is suited to its environment.

Such system designs are now starting to emerge, but there is still a lack of understanding of these systems in the building industry at large. This problem can be overcome only by better technology transfer to the building industry. The industry, for its part, must be prepared to make some effort to understand the new designs and concepts, if serious problems are to be avoided.

The housing industry in Canada, and to a lesser extent in the u.S.A., is currently facing problems due to the combined effects of recession and high mortgage rates. Affordability has become a general problem, and the energy-efficient house, with its extra capital cost, is particularly threatened. A more moderate approach to energy-efficient design, with a matching concern for incremental costs and structural integrity, would appear to be the most marketable option at the present time.

REFERENCES

1. Eyre, D. and Jennings, D. Air-Vapour Barriers Published and distributed by Energy Demand Branch. Energy, Mines and Resources. Ottawa.

2. Canada Mortgage and Housing Corporation. Envelope Construction of Energy-Efficient Housing. Details available through CMHC, National Office, Montreal Road, Ottawa.

COLLECTION AND STORAGE OF SOLAR HEAT IN A WATER CISTERN SYSTEM

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ABSTRACT

This project involved fabricating solar water heaters, installing them on the roof and storing the collected heat in a basement water cistern. The value of the collected heat was calculated from temperature and flow measurements. The cost of water heating with fuel oil and electricity was also calculated and an economic comparison was made to see if the cost of the solar collectors in the interior of Alaska could be profitably amortized. Without free labor the solar panels were not found to be economically feasible. However, a modified version without glazing could capture insolation at a price below electric heating.

This project was funded by the State of Alaska and the U.S. Department of Energy.

I. INTRODUCTION

A. Background

This investigator who lives in a rural area decided for economic reasons to use precipitation rather than ground water for domestic water supply. Rainwater and snow melt is stored in an outside melter tank. It is then filtered and chlorinated and pumped into an inside 1500 gallon water cistern in the basement of the house for use as a domestic water supply. The water supply system was described in the spring 1976 issue of the Northern Engineer (Vol. 8, No. 1)*. The roof of the house has a one on 8 slope facing south and it was thought that since there is considerable sunshine in the summer in interior Alaska it might be economical to collect and store some of the solar energy in the water cistern system. In 1980 an application was made to the U.S. Department of Energy (DOE) for their Appropriate Technology Small Grants Program to build solar collectors, monitor their performance and figure out their economics. The grant was awarded in July 1980. It was jointly funded by the U.S. DOE and the Alaska Division of Energy and Power Development.

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*A publication of the Geophysical Institute, University of Alaska, Fairbanks

B. Scope

This project involved fabricating solar heaters, installing them on the roof and storing the heat in a basement cistern. The value of captured heat was to be calculated from temperature and flow measurements. The solar heaters were made from 2 x 20 foot sheets of corrugated aluminum roofing panels painted with a non-toxic waterproof black paint. Three panels each 8 x 20 foot long were covered with plastic and fiberglass glazing to capture the insolation and prevent water evaporation and contamination.

The panels were to be mounted on the house roof giving them a south slope of one on eight. It was originally planned to have just one 20 x 20 foot panel with one manifold and a solenoid valve to feed cold water to the assembly. An outlet collector would then take the hot water back to to the top of the cistern. The cold water would, of course, be drawn from the normal water supply shallow well pump system and pumped to the top of the solar heaters. Thermal strafication would inhibit the hot water from mixing with the cold water in the cistern. It was planned that the solenoid valve would be actuated by a thermostatic switch inside the solar panel. The system would be set up to operate and record data for heat storage automatically. The system was set up on a house atop a 1700 foot hill located 15 miles west of Fairbanks, Alaska.

II. CONSTRUCTION

A. Materials

It was decided to build the solar heaters in 8 x 20 foot panels rather than one 20 x 20 panel because an 8 x 20 panel is as large as one individual can physically handle. The materials cost for one 8 x 20 solar panel is shown in Table 1. Notice that the fiberglass glazing material and the plastic foam insulation under the panel are the two most expensive parts of the solar panels. Of course one thermostat and one solenoid can serve all the panels if they are fed from the same pump. However, one solenoid is designed to free-drain the inlet water system for freeze protection for operation during May and September. The water filter is required to keep particulate matter, such as insects that might crawl into the panels from recirculating and clogging the inlet manifolds which contain small 1/16" diameter holes. It also reduces the water supply contamination.

B. Assembly

Three panels were built. Only the first was assembled on the ground. It was very difficult to drag up onto the roof. In an attempt to make the solar panels as least costly as possible, it was decided to not make the second

TABLE 1

Solar Panel 8x 20ft.
Construction Cost 1982 FOB Fairbanks

	Item	Materials
1.	(4) 2' x 20' corrugated AL roofing	$ 90.00
2.	(5) 2" X 4" X 8'	15.00
3.	1/2 gal. waterproof flat BLK paint	15.00
4.	48' wiggle moulding	12.00
5.	20' double batten joining (glazing) strip	12.00
6.	50' 1/2" PVC/POLY C_2 pipe, inlet and manifold	20.00
7.	1 1/2" PVC DWV outlet collector w/fittings	15.00
8.	4' x 40' - 25 mil fiberglass glazing	230.00
9.	Bimetalstrip thermostat 110°F, 110 VAC 10A	14.00
10.	2 solenoids 110 VAC	40.00
11.	Water filter, cartridge type, 3/4" NPS IN-OUTLET	40.00
12.	5 sheets 4' x 8' x 1 1/2" plastic foam insulation	100.00
13.	Nails, screws and other fasteners	10.00
	Labor: 20 hours @ $20/hr. =	400.00
	TOTAL MATERIALS w/labor $603 + $400 =	1,013.00
	Without roofing, insulation and glazing w/labor $193 + $100 labor =	293.00

two structurally strong, but to use the roof for structural supper t. That way, one could save a considerable amount in labor and lumber. The disadvantage to this, is of course, that you are not able to get the collectors to directly face the sun; they are fixed to the roof angle. The second two solar panels were assembled on the roof of the house since they were too fragile to carry up if they were assembled on the ground. To build the panels, 4 sheets of 2 foot wide by 20 foot long aluminum roofing panels were nailed to 8 foot lengths of wiggle molding which exactly fit the corrugations in the panel to make up one 8 x 20 foot panel. The wiggle molding was spaced about every 50 inches to allow 1 1/2" x 4' x 8' insulating board panels to be put under the aluminum between the molding strips. Since the wiggle molding is only 1/4" thick, a 1 1/4" x 2" x 8 foot runner was nailed under the wiggle molding, Such that when the whole panel was laid against the roof, it was continuously supported so it could handle snow load or foot traffic. The water inlet header for the panel was 1/2" PVC pipe. It was wired over the top end of the panel and 1/16" holes were drilled to match each trough in the corrugated aluminum roofing. The roofing was then painted black and at its outlet end a 10 foot length of PVC DWV pipe was notched with a 9 foot slot slightly over 3/4" wide such that it could be slid over the end of the aluminum roofing. The entire panel then, from inlet to outlet was covered with the 20 mil fiberglass glazing. The glazing was held onto the panels by nails through it and the aluminum into the wiggle molding or by sheetmetal screws through the glazing gripping the aluminum roofing. The edges were then caulked with a caulking suitable for use at temperatures up to 150 degrees F. The construction details are shown in Figure 1. Two of the panels have a thermostat mounted about 1/3 of the way down under the aluminum roofing, but in thermal contact with the aluminum roofing. One thermostat is a typical snap disc air switch found in oil furnaces. The other is a hi-metal strip adjustable thermostat. They both actuate, turn on the water at 110-120 degrees F and shut it off when they are cooled to about 80-90 degrees F.

The first solar panel was constructed on a 1 x 4 and 2 x 4 frame. It was strong enough to easily be moved around, but it had a high profile of about 5 inches above the roof. The other two were closer to the roof, no more than 3 inches high.

The first panel required about 40 man hours to assemble. The last 2 panels were assembled with about 20 man hours of effort each because by then the constructor was quite experienced at building the panels.

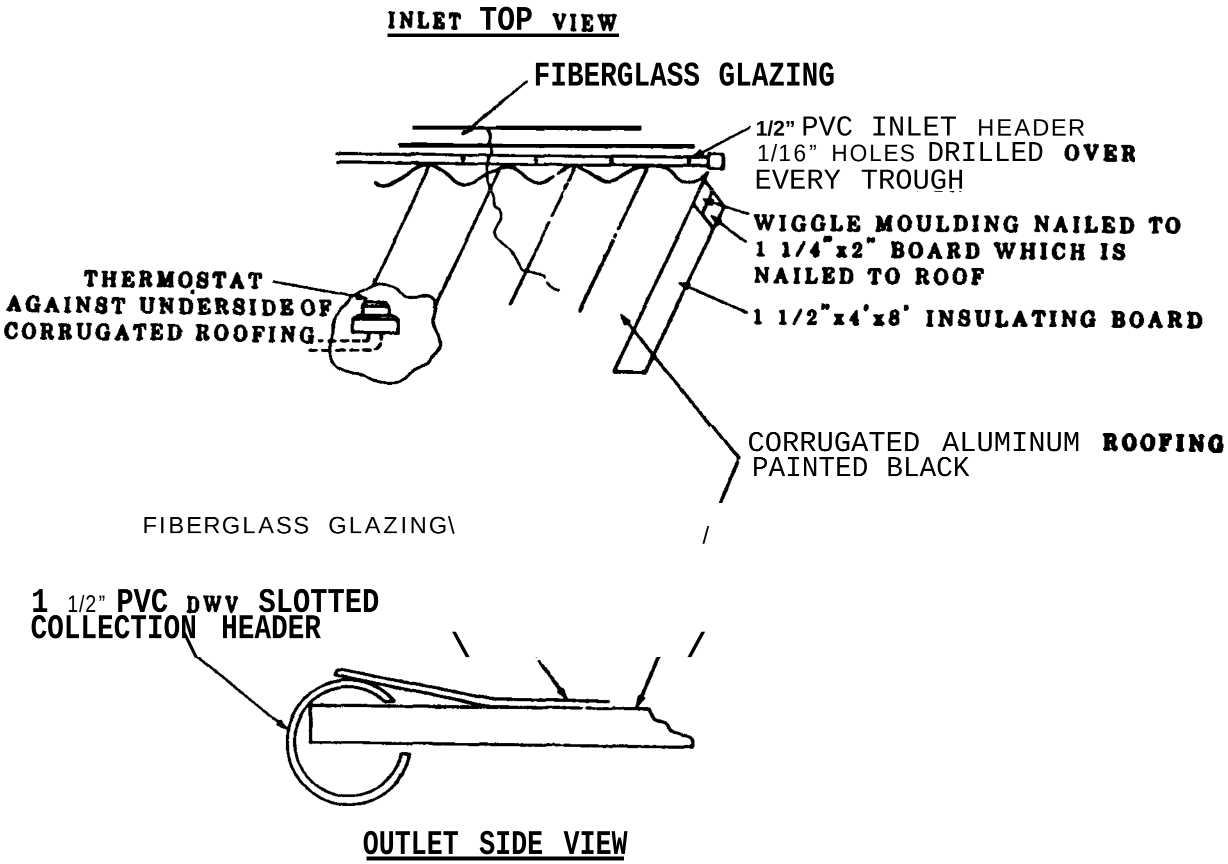

FIGURE 1 - SOLAR PANEL CONSTRUCTION DETAILS

III. OPERATION

The solar panels were integrated into the water system by use of both the snow melter tank and the inside cistern. This was mainly because the DWV collector pipe was not perfect and there was some leakage which was collected in the rain guttering and returned to the snow melter tank. The leakage is partly attributed to the low roof slope which allows some of the water to wick far enough up the underside of the roofing to escape the collector pipe. No gradient on the collector pipe also contributed to leakage. Since the leakage rate was less than 5% it was not considered worth the effort to control it.

The melter tank collects rainwater during the summer. The layout of the collection system is shown in Figure 2. One panel was directly connected to the inside cistern and another panel was directly Connected to the outside snow melter tank. The third (#2) panel would feed water from the snow melter tank after purification and heating into the inside cistern to make up for summer's water use. When the inside cistern becomes completely full, the panel would be put in parallel flow with panel #3. The thermostat on solar panel #3 causes the control solenoid to open when the panel temperature exceeds 110 degrees F. Cold water from the inside Cistern then trickles into the troughs at the top of the panel. From the outlet collector the heated water then flows back into the inside cistern. A 24 hour timer switch is used to open the drain (normally open, N.O.) solenoid for freeze protection at the end of each solar heat day - approximately 6 p.m.

A minute meter totalizes the time that the solenoid is open for calculating the actual heat recovery by the one solar panel. When the flow rate though solar panel 3# is measured, the thermostat that controls the inlet water to panel #2 is shut off so the reading is a true flow reading from the shallow well pump. In normal operation rainwater from the snow melter tank is run through an activated carbon filter through solar panel #2 and into the Collection manifold for panel #3, (hence to the inside cistern) . The outlet from panel #1 and leakage from panel #2 and 3 is collected in the rain guttering and is returned to the snow melter tank.

Water from the snow melter tank is taken directly from a sump pump, Controlled by a thermostat under the skin of panel #1. Hence, its line is free-draining and does not need an additional solenoid to drain it for freeze protection because as soon as the thermostat opens on panel #1 the entire inlet manifold system drains back down to the water level in the melter tank. That is the advantage of a sump pump over a tapped pressure system with a control solenoid (as in the inside cistern).

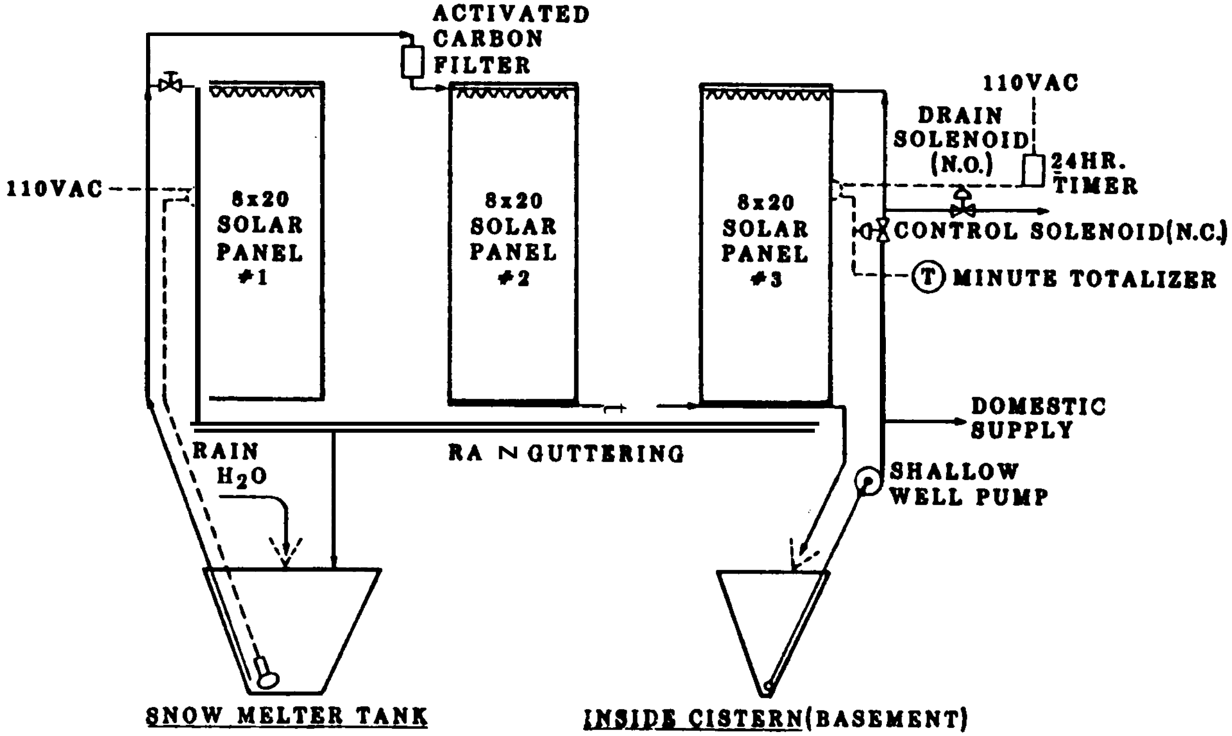

FIGURE 2 - LAYOUT OF INSOLATION COLLECTION SYSTEM

Solar panel #1 is the only one that does not have the fiberglass glazing. It was the first one built and due to considerable weathering of the black paint, it will have to be repainted before it can be covered with a fiberglass glazing. It presently has clear polyethylene sheeting over it.. The polyethylene sheeting is only suitable for about one summer because sunlight will cause it to become brittle and break.

The solar heaters have nothing more than the fiberglass glazing between them and the ambient air, so the thermostats generally do not get above 110 degrees F until the ambient air temperature exceeds 45 degrees F in direct sunlight. However, if it is raining, and temperatures are below 60 degrees F, the solar heater thermostats do not close so there is no heat collection under rainy, overcast, cooler days.

IV. DATA COLLECTION

A dual probe thermograph was set on top of the inside cistern to measure the water temperature at the water surface and the bottom of the tank. The thermograph did not work very well, but when it was working, it indicated that the surface temperature exceeded 90 degrees F and the bottom temperature slowly increased from 40 to 60 degrees F - an indication of thermal stratification.

The minute totalizer was installed on July 2, 1981 and data was collected until August 18, 1981. During that time period, the solar collectors collected heat for 14.6 hours. It should be remembered that August and July of 1981 were very poor summer conditions since July and August were cool rainy months. However, the data were extrapolated to estimate the total heat collected during the entire summer of 1981. To estimate the heat recovery per panel, all that is required is an accurate bathroom scale, a large 5 plus gallon container, an accurate thermometer and readings from the minute totalizer. The heat recovered is the product of the flow rate, flow time, temperature difference (between the water into the panel and the water returning to the cistern) and specific heat (1 BTU/lb-degree F) . From July to August 18, 1981 panel. #3 captured 43 X 104 BTU's of heat. Data from the Geophysical Institute tabulation of solar radiation for Fairbanks for their normal incident pyroheliometer, was used to extrapolate that data to estimate heat collected during the entire summer of 1981. Data from the months of May through September when the average temperature was above 10 degrees C was used. The total captured heat for 1981 was then found to be 1.7 million BTU's.

V. ECONOMICS

To look at the economics of the solar collector system, it is first necessary to calculate the heat recovery from the collectors, then compare its cost to the value of heat from #2 fuel oil or from electricity in the Fairbanks area. The cost of solar heaters is amortized against the value of heat recovered to estimate what the payout would be. During the summer of 1981 solar panel #3 collected 1.7 x 106 BTU's.

Assuming an oil furnace efficiency of 80%, there is 105 BTU's available per gallon. So the savings from the solar panel was equivalent to about 17 gallons of fuel oil. At a 1981 price of $1.24/gal* that represents about a $21 savings per year. The electricity equivalent at 11.3 cents per kilowatt hour* represents a savings of about $53.6 per year. The only operating costs for the solar heaters was electricity for the solenoids and the pumps. For the solenoid valve pressure pump operation, electricity cost was $.28 for 1981. If a sump pump was used only, assuming 50% pump efficiency, the cost was $.07. Since the electricity costs for pumping and controls is less than $1/year, they will be neglected.

To figure the annual cost benefit, assume half of the heat savings is electric water heating and half reduces the winter house heating system fuel oil load. Therefore, yearly estimated savings is 21 - 2 + 56 - 2 = $38.50 per year. To calculate an annual cost for the system, assume that the capital cost for the system is at a lost interest rate of 10% and the solar heating system has a 20 year life. The capital recovery factor for that interest rate and life is 0.1175. Therefore, the annual cost is 0.1175 x 1013 = $119. That is 3 times the value of heat captured during 1981. Therefore, that summer the solar heater cost more than it saved. Even if one built the heaters themselves and had no labor charge and the summers turned out to be warmer and drier, the solar heater would still not be profitable.

About the only way to make solar heating in Fairbanks very economical is to do away with expensive glazing and the underlying plastic foam insulation. That would then cut the materials cost down to about $193 and a total cost of $293 assuming $100 for labor. In this case, it is assumed that the aluminum roofing is the actual outer roof skin and all one has to do is install piping and black paint and have a large heat storage system. In this case the heat storage reservoir is the water supply cistern so its

*Energy cost data from: Fairbanks North Star Borough, Community Research Center. “Community Research Quarterly A Socio-Economic Review”. Vol. IV, No. 4, Winter 1981.

cost is not charged to the solar system. Since the water probably cannot be heated to 120 degrees F without the glazing, we will assume that only 75% of the prior heat recovery was obtained. Therefore, the yearly savings is .75 X 38.5 = $29. Assuming a 50-year life on the roof, the low cost at 10% interest is 0.1175 x 293 = $34. Therefore, with a rainy summer that we had in 1981 the solar heaters would still not be worth it. However, if summers were a little bit drier, then the solar heating might be marginally worth it. But when compared strictly to electric water heating ($53.60) the solar panels are less costly.

If the economics were figured during a warmer summer the solar panels would have performed much better, because beside insolation there is considerable heat transferred to the cold water from the ambient air. Also summer temperatures on thr Chena River flood plain (Fairbanks at 440 ft. elevation) are 5 to 10 degrees F warmer, and rainfall is less than at this project location of 1700 ft. That difference might be enough to tip the economic scale in favor of solar heaters in Fairbanks, especially if they are tilted more to face the sun.

VI. CONCLUSIONS AND OTHER CONSIDERATIONS

Based upon the poor economic showing of the glazed panels during 1981, they may not be worth the investment. The economics based on the warmer summer of 1982 might look better. Therefore, I recommend that data collection and economic analysis continue.

If one can get materials at a much lower cost and provide his own labor, then it's worth the effort, especially for the hobbyist or one who is interested in conserving natural resources. My recommendation in this case, would then be to design a house with a south sloping roof painted black and install spray manifolds such that water can trickle down the hot roof allowing heat to be captured, for use below the foundation (buried pipes) , or in a water cistern. This is about the only way it can be ecnomical. The disadvantage to this is that one has to maintain a large filtering system (such as a swimming pool filter) to remove tree debris, insects and pollen from the system or else they will plug the spray holes in the manifold or drastically reduce the heat transfer in the piping under the basement or slab at grade.

Ground heat storage is, of course, a 'No-No" if the house is built on or adjacent to permafrost.

Other problems with the present system were: 1) there was some leakage, and make-up water was required and 2) the panels and controls are another piece of equipment that has to be maintained.

PRELIMINARY EVALUATION OF HYDROELECTRIC POWER GENERATION IN COLD CLIMATES

J. P. Gosink and T. E. Osterkamp

ABSTRACT

Alaska has about 1/3 of the total United States reserves of hydroelectric energy--more than enough to satisfy all of the state's energy needs for the foreseeable future! A technological barrier to the development of the hydroelectric energy resources in Alaska is that of ice formation in the rivers and reservoirs of the power generation systems. The ice problems include winter flooding caused by hanging ice dams, blockage of inlet structures and turbines, icing of structures and power transmission lines, adverse temperature and water quality changes due to reservoir construction, long open water reaches downstream of dams with associated ice fog, sloping ice-covered reservoir shores which are hazardous to man and animals, destruction of the downstream ice cover by fluctuating stage and power demands with associated ice jam formation and flooding, and increased ice formation due to increased winter discharge of fresh water into bays and estuaries. Some of these ice problems are potentially serious and have resulted in the abandonment of hydroelectric generating facilities; others are bothersome from an operational viewpoint and some can be partially eliminated or even totally avoided by proper design and operational procedures.

We are investigating ways to eliminate or minimize these ice problems. This study includes compilation of state-of-the-art engineering technology and applied research for quantitative analysis of particular ice problems. We have also identified some of the ice problems at hydroelectric facilities in Canada, Iceland and Scandinavia, and alleviation techniques and procedures used at these sites.

INTRODUCTION

More than one-third the total United States reserves of undeveloped hydroelectric energy are found in Alaska! Seventy-six potential hydroelectric sites were identified by the Alaska Power Authority and the U.S. Army Corps of Engineers in its 1974 assessment of hydro-

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electric resources in Alaska. These 76 sites could generate 450 x 10^6 KW hours annually, of which only 2% is needed in Alaska! These reserves are in addition to already-existing small-scale hydroelectric power plants which produce about one-third of all the power requirements of southeastern Alaska. Most of the identified sites are small-scale, with drainage areas less than a few thousand square miles. The identified hydroelectric reserves do not include numerous "micro-scale hydro" sites (less than 25 foot head) in Alaska which were ignored in the original survey.

The advantages of hydroelectric power are well known. Both large and small-scale hydroelectric power plants are non-polluting renewable resources. In contrast, burning fossil fuels not only pollutes the atmosphere, but may play a significant role in climate modification through the production of carbon dioxide and other trace gases (the "greenhouse effect"). Small and micro-scale hydroelectric power are particularly well-suited to Alaska where population densities are low and transportation of fuels is limited to a few narrow corridors. Another important factor favoring the development of small-scale hydroelectric power is the typical Alaskan life-style with its emphasis on self-reliance and independence. A recent federal government directive stipulates that hydroelectric plants producing less than 5 MW are exempt from Federal Energy Regulation Commission (FERC) licensing procedures. This exception should act as a stimulus for the development of small and micro-scale hydropower through the elimination of expensive and time consuming legal procedures.

However, there are severe and unique problems associated with the development and operation of hydroelectric power plants in cold climates. These problems are caused by ice in various forms and can result in reductions in power generation (brownouts), cessations of power generation (blackouts) and in the complete abandonment of the hydropower generating facility (Michel, 1971). Engineering procedures used to mitigate these problems include avoidance, for example by proper siting or design, and direct solutions such as the heating of trash racks.

The purpose of this report is to discuss some of the severe ice problems noted in hydroelectric facilities in Scandinavia, Canada, Iceland and other northern regions and their appropriate mitigation techniques. Applied research for quantitative analysis of particular ice problems is also discussed.

ICE TYPES

Ice problems in hydroelectric power generation systems are associated with four ice types that grow in the rivers and reservoirs - frazil ice, anchor ice, sheet ice and aufeis (Yould and Osterkamp, 1977).

Frazil ice grows in turbulent water that is slightly supercooled. The initial form observed is that of thin, circular discs called frazil ice crystals. These crystals flocculate, form frazil pans and frazil slush and may eventually evolve into large floes. Freeze-up of a river occurs when **frazil** ice--in the form of slush, pans or floes--jams in reaches with suitable hydraulic conditions. The initial ice cover may consist of up to a meter thickness of **frazil** ice which consolidates and then freezes downward by heat transfer from the ice surface (Osterkamp, 1975). The origin of anchor ice (ice anchored or fixed in position in the flow, as on the river bed) is uncertain; however, it is generally believed that it forms by the attachment of **frazil** ice crystals to the river bed and to objects in the flow (Osterkamp and Gosink, 1982). The crystals are transported by the turbulence, and once they become attached may grow substantially faster than when moving with the water because of the enhanced heat transfer caused by supercooled water flowing past them (Osterkamp, 1978). Sheet ice forms on slowly-moving or quiescent water, probably by the same mechanisms responsible for producing **frazil** ice crystals. In the case of sheet ice formation, the water turbulence is insufficient to draw the ice formed at the surface into suspension, so that ice growth propagates across the water surface rather than within the body of the water. Aufeis (meaning ice on ice) formations develop when water repeatedly flows over an ice surface and freezes in layers in the cold environment. Aufeis formations approaching 10 m in thickness can be generated in this fashion. Accumulations of ice on structures (icings) may form by several mechanisms; those formed by windspray and water mist would probably be the most serious for hydroelectric facilities, although those formed on power transmission lines by the accumulation of freezing rain and snow can also be serious problems.

PROBLEMS AND ALLEVIATION TECHNIQUES

Problems associated with the four types of ice and their alleviation techniques or applied research used to minimize them are listed in Table 1.

TABLE 1. Ice Problems and Alleviation Techniques

Problem	Technique
*1. Frazil ice a) jams, flooding b) blockage of trash racks, intake structures, etc. i) run-of-the river ii) reservoir	1. Ice cover formation, e.g., ice booms, groins a) Siting, modeling b) Heating, diversion canals
*2. Reservoir shores a) sloping ice cover b) ice forces on structures	2. Mechanical strength tests, structural regulations, modeling.
*3. Water quality and temperature	3. Modeling, siting, outfall configuration

4. Icings	4. Heating; modeling, splash design.
*5. Open 'water reaches downstream of dam	5. Prediction; possible bridge construction, regulation.
***6.** Fluctuating discharge causing recurrent break-up and ice jam formation	6. Transient open water prediction modeling, ad hoc procedures to minimize fluctuations, regulation.
***7.** Increased ice production in bays and estuaries	7. Modeling and field studies.

While this table by no means represents an exhaustive compilation of ice problems, it offers a survey of the major problems which have received some attention in hydroelectric design in northern climates. The order of the problems is meant to follow the river from upstream to downstream rather than to convey any sense of importance or severity. Clearly the severity of a particular problem will be controlled by local conditions and will vary accordingly. The starred problems in the table represent areas that have been addressed in research studies at the University of Alaska.

1) Frazil ice

The first problem is related to frazil ice production in rivers. A steep, turbulent river reach is often referred to as a "frazil factory" where large quantities of frazil ice are generated due to exposure to the atmosphere and subsequent supercooling. In contrast, an ice-covered river reach is protected from supercooling with the ice acting as an insulative cover. Hence, ice booms are often used upstream of sites where frazil accumulation must be held to a minimum. The booms hasten the formation of an ice cover, thus minimizing supercooling. Booms have been used successfully in Canadian, Scandinavian and Russian installations, for example, at the Beauharnois Canal upstream of Montreal. Another method to stimulate upstream growth of an ice cover was used at the Burntwood River hydroelectric plant in Manitoba where rock and earthfall groins were built 6 km upstream of the city of Thompson, substantially reducing frazil ice accumulations and the attendant possibility of flooding.

Frazil ice is known to deposit on the underside of an ice cover where the river bottom slope decreases substantially. Thus, if a hydropower reservoir is covered with sheet ice while the frazil ice load in the river or stream feeding the reservoir is heavy, frazil ice may accumulate in a "hanging dam" at the inlet to the reservoir. These dams are a potential hazard causing winter flooding and overflows and associated aufeis formation.

During the last 10 years, the town of Terrebonne on the lower reach of the Mine Iles river north of Montreal has been hit by three spring floods (Tremblay and Thibeault, 1980). Field data and analyses showed that "the water levels at Terrebonne increase with the length and thickness of frazil accumulation". During the winter of 1964-65 an aufeis formation of the Klutina River damaged all the buildings of Copper Center, Alaska and brought an end to habitation in that city for the rest of the winter. Similar but less disastrous floods have occurred at Clear and at Willow. A hanging dam may also be formed just downstream of a natural or man-made falls or dam constructed for a small or micro-scale hydro project. In the latter case, the flow would be restricted and a backwater extending up to the dam would reduce the efficiency of the hydroelectric plant. This problem has occurred in Russian rivers (Sokolov and Gotlib, 1975) where a cascade of several hydroelectric plants alters the natural river flow into one consisting of alternating pools and falls.

Current research has focused on the measurement of frazil concentrations as a function of meteorologic and hydrologic parameters. These concentrations are, however, exceedingly difficult to determine so that a need for empirical formulations exists relating frazil ice loads to local conditions. Practical results include predictions of the severity of hanging dams for a hydroelectric project at a given site. Once the frazil load is known, backwater curves may be drawn from the site of the obstruction. Hence, the possibility of flooding may be rationally assessed, and recommendations made regarding siting and the use of ice booms.

The effectiveness of an ice boom depends to a large degree on whether the frazil is well mixed throughout the water column, or whether it is concentrated as a slurry at the top of the flow. Our research (Gosink and Osterkamp, 1982) has produced a new and promising method to assess this factor; namely a criteria for the establishment of a slush layer at the surface of the flow.

High flow velocity on river reaches with steep slopes, where no ice cover is formed, present severe problems related to ice. Generally, run-of-river power plants must be built in these locations due to engineering constraints. Hence it is necessary to keep the river open and flush the ice through or over the dam. During times of heavy frazil production much of the frazil ice in the form of pans and floes may enter the power station intake. This has occurred repeatedly at the Burfell Power Plant in Iceland (Mariusson, et al., 1975) resulting in damage to turbines and reduction in power. It is expected that many micro-hydro plants will be run-of-river type with similar ice problems. It is important to notice that the use of a trash rack alone will not alleviate this problem where frazil ice loads are heavy. In this case, the trash rack will rather rapidly freeze over, thus curtailing power production.

Methods to address this ice problem include the techniques cited above to minimize frazil ice production. The object is the quick -formation of a complete insulative ice cover upstream of the hydroelectric 'system. However, it is expected that micro-scale hydro projects will often be constructed in very steep, shallow streams where ice cover formation is impossible. The Icelandic power authorities address this problem, along with the silt transport problem, by separating the flow into three components: a) silty bottom water into one channel, b) icy surface water into another by the use of skimmer walls which direct the flow to a diversion canal, and c) silt-free and ice free water to the power station.

The application of the Icelandic approach to this problem and the use of skimmer walls depends critically upon the depth of the blockage. The question to be answered is whether an ice block moving downstream can overcome buoyant forces, submerge, and be transported below a given depth. This area of ice research has received considerable attention in recent years, and it is generally agreed among ice engineers that the method of analysis described by Uzuner and Kennedy (1972) provides good predictive capability in this area. The usefulness of this research has its application in the proper siting of the hydroelectric system. In particular, if the stream velocity at the proposed site is sufficiently high, or the water depth too shallow to permit the construction of a skimmer wall of sufficient depth for the anticipated ice load, as determined by the Uzuner and Kennedy criteria, then the proposed site would inevitably suffer substantial ice damage.

Another method of dealing with the impingement of frazil ice upon trash racks, gates and other intake structures involves heating of the affected devices. Swedish power authorities (Larsen, 1978) recommend 0.5 KW/m^2 as the appropriate heat energy per square meter of surface area to prevent frazil growth and accumulation. They also state that frazil ice problems are their single greatest source of concern, and that these problems are most severe in the central and southern portions of Sweden where temperature cycling often prevents formation of an insulative ice cover.

2) Reservoir shores

An extensive ice cover on a reservoir interacts with the shore and hydroelectric facility producing several kinds of problems. Ice piling on shores may be generated by wind or currents and also by thermal expansion of the ice sheet after a cold spell followed by a fast warming. Damage to shoreside structures can be very severe in such cases.

Water levels in a reservoir are generally maintained at a high level throughout the summer. During the winter water is discharged for power generation until a minimum water level is reached just before break-up in the spring. As the water level falls, the ice cover will sag under its own weight, producing a sloping ice covered shoreline, often steep, and usually fractured. The hazard to vehicles, man and animal life is clear, and the concave ice cover on the reservoir may act as a trap for large mammals (Hanscom and Osterkamp, 1980). Furthermore, the ice may produce a vertical stress component on hydroelectric facility structures.

The latter structural problem must be addressed by proper engineering design of possible loading configurations and also by research into the mechanical properties of ice for determination of appropriate constitutive laws.

The approach used to minimize the former problems is avoidance by careful siting. The correct determination of hydroelectric plant locations must include inventories of the migratory patterns of caribou and seasonal migrations of moose, for example. In some locations it may be necessary to construct fences to divert animals away from areas with steep, ice covered shores.

Inventories of the migratory patterns of large animals in Alaska are the responsibility of the Dept. of Fish and Game. Where avoidance is impossible, two types of research are needed to evaluate this hazard and its effect on the animals. The first type is an assessment of the capability and willingness of the animals to negotiate icy slopes, an area of research within the province of the Dept. of Fish and Game. A second area of appropriate research is concerned with the occurrence, timing, thickness and strength of the ice cover and with the determination of the slope angle for given drawdown conditions. Except for the case of ice cover strength, there is practically no information available on these problems, although Russian investigators have noted their importance.

Although there is no widely accepted technology used to alleviate ice piling on shores and subsequent erosion and shoreline damage, it would appear that current research into the dynamics of ice piling (Tsang, 1975) will aid in the assessment of the severity of the problem at a particular site. In particular, Tsang has delineated the meterologic and hydraulic factors which favor ice piling.

3) Water quality and temperature

The impoundment of a large water reservoir may create serious water quality and temperature problems both for the stored and discharged water. The water released from a large reservoir will be warmer in winter and colder in summer than it would be in an unregulated river. Water quality will also suffer due to the stratification effects in the reservoir and to the gradual increase in average salinity of about 10 ppm y^{-1} typical of large reservoirs.

The potential for damage of sensitive arctic water basins is severe. Time scales required for adjustment to parametric forcing are considerably longer in arctic climates than in more southerly environments. Many biological species, especially fish , are intensely sensitive to small temperature variations near the freezing point. Since the ice cover may remain in place for the greater portion of the year in northern latitudes (7-9 months), these lakes and reservoirs are characterized by minimal 'light penetration and wind mixing during this portion of the annual cycle. In addition, many northern lakes are glacier-fed resulting in a high flux of sediment from glacier scour and high turbidity levels.

Changes in drainage basins may result in increased erosion, permafrost degradation, increased sediment deposition in lake bottoms and subsequent damage to biological communities. Permafrost degradation will occur under reservoirs and also wherever lake volume increases or where flow-through rates increase. This can result in slumping of shoreline sediments and possible flooding of low-lying areas. Changes in northern lake hydrology caused by nearby construction and transportation may adversely affect aquatic life by altering turbidity and light transmission in the lakes. The problems produced by these drastic changes in the natural environment would adversely affect wildlife and ultimately the subsistence lifestyles of many people.

Damming of large basins of water for hydroelectric facilities will initiate the melting of extensive thaw bulbs in permafrost terrain. Knowledge of the temperature regime in the reservoir is necessary for assessment of heat flux through the bottom and subsequent permafrost degradation rates. The temperature of the released water controls the length of the open water reach downstream from the dam and thus affects the formation and location of ice jams downstream. Since the water in the reservoir is stratified, a rational outfall configuration will depend in large measure on the expected vertical temperature distribution in the reservoir.

The procedure used for the determination of water temperature and quality variations after construction of a reservoir involves the development of a deterministic model of lake behavior that can be tested and refined under natural environmental changes. Although several realistic water temperature and quality models have recently become available for temperate conditions, no model is presently available which can make reasonable predictions during ice cover formation, growth and decay. However, several researchers, including the authors, have recently begun studies in this area aimed at the extension of a proven temperate zone reservoir model to include ice processes.

4) Icings

Water spray and mist can be carried by wind to structures near the dam and outfall where it can freeze at low air temperatures on any cold surface. Equipment, structures and power lines can be coated with ice making them hazardous to work with and creating large ice loads on them. Numerous documented instances of these problems exist. In some cases, power lines or their supports can be broken by the accumulated ice load.

Current engineering practice involves the application of special coatings on surfaces, heating the surfaces, proper surface drainage design and a variety of other techniques. The research need is for a better understanding of the ice accretion processes which can be used to prevent or reduce the problem and for an understanding of the physical and meteorological conditions conducive to ice accretion which can be used to assess the problem at a specific site.

5) Open water reaches downstream of dams

Water reaches its maximum density at 4°C (39.2°F). Because of this peculiar characteristic, bottom water in a deep reservoir averages several degrees above O″C, usually +2 to +4°C. Water discharged from a deep reservoir must travel some distance downstream before being cooled by the environment to 0°C, and then converted to ice. This travel distance is surprisingly long, even at high latitudes. For example, at the Bennett Dam on the Peace River in British Columbia, water discharge temperatures average 2.5°C and the minimum length of the open water is about 100 miles downstream from the dam. The same phenomenon has been observed at numerous other locations including Russia (Pivovarov, 1973) and Norway (Asvall, 1972).

Consequences of a long open water reach include ice fog formation, loss of the ice cover as a river crossing or transportation corridor, and loss of the insulative cover for the prevention of frazil growth and subsequent downstream deposition. In addition, due to a discharge of relatively warm water into a river with supercooled shores (i.e., at ambient temperatures) there is likely to be edge ice growth of variable and questionable strength along part of the open water reach.

Note that the town of Talkeetna and the Parks Highway Bridge are located less than 60 miles below the Devil Canyon section of the Susitna hydroelectric system. Our calculations have shown that the town and bridge will most likely be subject to ice fog for the large discharge rates under consideration.

There is no technology developed to eliminate the open water reach associated with an above O″C water discharge. It may be necessary in some instances to construct a bridge in order to maintain a traditional winter crossing. The techniques used to stimulate ice growth in O″C water, including ice booms, groin construction, and anchored floating barriers (Perham 1980), are appropriate in the downstream portion of the open water reach where the water temperature has reached O″C. The location of the O″C isotherm, which predicts the length of open water reach, is a matter of current research. Engineering attempts to alleviate ice fog at power plant cooling ponds have focused on a variety of techniques (McFadden, 1974). However, the presently known techniques are not suitable to the cases where the water is undergoing highly turbulent flow.

Current engineering research focuses on the extent of the open water reach which depends critically upon the discharge rate and upon meteorological conditions. Hence the length of open water reach is highly variable and changes from day to day or even hour to hour as meteorological conditions change and as power requirements alter the discharge rate. We have carried out a comparison of several analytical methods for determining the length of the open water reach including methods by Asvall (1972), Pailey, et al. (1974), Robillard and Vasseur (1978), and Rimsha and Donchenko (1957). This comparison indicated that the surface heat loss formulation prescribed by Rimsha and Donchenko was consistently more accurate in the calculation of the open water reach. It appears that several of the other models were devised primarily for temperate conditions, while their model has been used successfully for calculations in Siberia. Our comparisons have indicated its superiority for rivers ranging from the Chena River in Fairbanks to the Peace River in British Columbia. Unfortunately, this model does not take into account variable and transient meteorological conditions nor the dynamics of the leading edge of the ice cover.

Research to determine the length of open water reach below hydroelectric sites defines the area that will be subject to ice fog conditions, however, it appears that there are no economical solutions to the ice fog problem.

6) Fluctuating discharge causing recurrent break-up and ice jam formation

It was noted in (5) above that an open water reach of variable length will exist downstream of hydroelectric power reservoirs as a result of warm water discharge from them. Natural winter ice covers in Alaska are normally stable due to stable or slowly decreasing river discharges. However, the daily fluctuating demands of power production require daily variations in the discharge from the power reservoir causing daily variations in river stage. These stage variations cause break-up of the downstream ice cover thus preventing a stable ice cover from forming on the river. The process is equivalent, on a smaller scale, to a daily occurrence of spring break-up and similarly has the potential for ice jams and associated winter flooding due to downstream accumulation of the broken ice cover.

The open water reach below a dam is also a "frazil ice factory" producing a large frazil load under cold air temperatures. Even when the ice cover is stabilized by proper design and operational procedures the frazil may be carried under the ice cover and deposited in the form of a hanging dam which has the same effect as an ice jam (i.e., it creates overflows, winter flooding and aufeis deposits).

Current engineering practice focuses on stabilizing the downstream ice cover. Design solutions include stilling basins which stabilize the flow coupled with operational procedures for accomplishing the same result. Prediction of the length of open water reach is needed to assess the length and location of the problem area. Quite possibly, operational procedures (such as drawing water from different temperature levels) during periods of frazil formation may help to alleviate the "problem..

7) increased ice production in bays and estuaries

Alaska has many hydroelectric sites and population centers located along its coasts. Generally these sites are fed by high mountain lakes or streams which discharge into bays or estuaries. This discharge normally becomes very small during winter but with hydroelectric development it would be maintained at a high level. If the site is in an area where sea ice forms during winter (not necessarily a continuous sea ice cover, but any sea ice such as slush, pans, floes, etc.) then part or all of the increased fresh water discharge may become ice when it mixes with the colder sea water (-1.8°C). The increased ice production then becomes a hazard for local fishermen and for local port and dock facilities.

This problem has only been recently identified. For example, the Us. Army Corps of Engineers was concerned that the increased winter discharge from the Bradley Lake hydroelectric project would create problems for local fishermen in Kachemak Bay and for the port and dock facilities at Homer. Unfortunately, no general engineering solutions have been devised for this problem. In 1981 we devised a box model solution appropriate for Kachemak Bay, based on mass and energy conservation, which suggested that increased ice production would not be a problem at this site (Gosink and Osterkamp, 1981). The model depends critically upon local mixing conditions, and therefore could not be directly applied to a different site. There is a real need for a continuation or extension of this type of predictive model for the general case.

Summarv and Conclusions

Seven problem areas associated with ice and its effects on hydroelectric facilities have been discussed, along with the appropriate engineering technology, or the direction of current applied research. Avoidance is the primary tool used to minimize ice problems. This is accomplished by such procedures as protective ice cover stimulation via ice booms and groins, ice diversion canals, splash design and hydraulic or numerical modeling of the system ice dynamics and hydrodynamics as a predictive design tool. Where avoidance is impossible, the ice problems may be minimized by much more expensive solutions including the heating of trash racks, bridge construction over open water reaches, and the construction of ice passage gates.

There is a real need for greater predictive capability of ice jam formation especially under transient discharge conditions. The daily stage variations associated with peaking hydropower procedures imply the existence of a potentially dangerous situation near the ice front.

Modeling techniques offer predictive capability for many ice problems; these include reservoir temperature and water quality, transient open water lengths. and frazil ice concentration assessment. Combined programs of field and theoretical studies are needed for model development.

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REFERENCES

Asvall, R. P., 1972 - "Changes in ice conditions in regulated river basins", Proc. of the Banff Symp. on the role of snow and ice in hydrology WMO and IAHR.

Gosink, J. P. and T. E. Osterkamp, 1981 - "A theoretical investigation of the potential modification of ice formation in Kachmak Bay by the Bradley Lake hydroelectric power project", Final report to U.S. Army CRREL, Hanover, N.H.

Gosink, J. P. and T. E. Osterkamp, 1982 - "Measurements and analyses of velocity profiles and frazil ice crystal rise velocities during periods of frazil ice formation in rivers", Paper presented at the International Glaciological Society Second Symposium on Applied Glaciology, Hanover, N.H.

Hanscom, J. T. and T. E, Osterkamp, 1980 - "Potential caribou-ice problems in the Watana Reservoir, Susitna hydroelectric project", The Northern Engineer, Vol. 12, No. 1, p. 4-8.

Larsen, P., 1978 - "Ice Problems in Swedish Hydro Power Operation", Int. Assoc. Hydraulic Research, IAHR Symp. on Ice Problems, pp. 235-243, Lulea, Sweden.

Mariussen, J. M., S. Freysteinsson and E. B. Eliasson, 1975 - "Ice jam control", Experience from the Burfell Power Plant, Iceland, Proc. of Third Int. Symp. on Ice Problems, Hanover, New Hampshire, IAHR.

McFadden, T., 1974 - "Suppression of ice fog from power plant cooling ponds", Ph.D. Thesis, University of Alaska, Fairbanks, Alaska, 171 pp.

Michel, B., 1971 - "Winter regime of rivers and lakes", Cold Regions Science and Engineering Monograph III - Bla.

Osterkamp, T. E., 1975 - "Tanana River ice cover", Proc. of the Third Int. Symposium of Ice problems, Hanover, New Hampshire, published by the IAHR Committee on Ice Problems.

Osterkamp, T. E., 1978 - "Frazil ice formation: A review", J. Hydraul. Div., ASCE 104: 1239-1255.

Osterkamp, T. E. and J. P. Gosink, 1982 - "Selected aspects of frazil ice formation and ice cover development in turbulent streams", Paper presented at the Workshop on the Hydraulics of Ice Covered Rivers, Edmonton, Alberta, June 1st and 2nd.

Paily, P. P., E. A. Macagno and J. R. Kennedy, 1974 - "Winter-regime thermal response of heat streams", J. Hydraulic Div. ASCE. 100.

Perham, R. E., 1980 - "Harnessing frazil ice", Proceedings of Workshop on Hydraulic Resistance of River Ice, Canadian Centre for Inland Waters, Burlington, Ontario, G. Tsang and S. Beltaos, editors, pp. 227-237.

Pivovarov, A. A., 1973 - "Thermal conditions in freezing lakes and rivers", New York: Wiley.

Rimsha, V. A. and R. V. Donchenko, 1957 - "The investigation of heat loss from free water surfaces in wintertime", Tr. Leningrad Gos., Gidrol. Inst. 65, pp. 58-83 (fr. Russian).

Robillard, L., and P. Vasseur, 1978 - "Thermal discharges in winter conditions", Interaction with ice cover. IAHR Symp. on Ice Problems, Pt. 2, Lulea, Sweden.

Russell, B. E., 1972 - "Ice formation in Lake Erie and the Niagara River, its effects and control", Proc. of the Banff Symp. on the role of snow and is in hydrology, WMO and IAHR.

Sokolov, I. N. and A. L. Gotlib, 1975 - "Ice jam control upstream and downstream from hydro plants", Proc. of Third Int. Symp. on Ice Problems, . Hanover, N. Hampshire, IAHR.

Tremblay, P. R. and D. Thibeault, 1980 - "Analysis of hydraulic and ice conditions responsible for winter and spring floods at Terrabonne, Quebec", Proc. of Workshop on Hydraulic Resistance of River Ice, Burlington, Canada.

Tsang, G., 1975 - "A field studyon ice piling on shores and the associated hydro-meteorological parameters", Proc. of Third Int. Symp. on Ice Problems, Hanover, New Hampshire.

Uzuner, M. S. and J. F. Kennedy, 1972 - "Theoretical model of river ice jams", J. Hydraulics Div., ASCE. 102.

Yould, E. P. and T. E. Osterkamp, 1978 - "Cold regions considerations relative to development of the Susitna Hydroelectric Project", Proc. of the Cold Regions Specialty Conference, Anchorage, Alaska, May 17-19, 1978, published by the American Society of Civil Engineers, New York, N.Y.

ORGANIC RANKINE CYCLES AND STIRLING ENGINES

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ABSTRACT

Technologies for Arctic energy needs must be uniquely rugged and reliable to be effective. The desired characteristics include multi-fuel capability, quietness, high efficiency, environmental acceptability, ease of operation, and a long lifetime. Technologies now in first applications may soon be brought to Alaska to serve these needs. For central power generation, organic Rankine cycle equipment may provide needed electricity with additional heat available for schools, hospitals, stores, and public buildings. This organic Rankine cycle equipment may be envisioned to operate from the waste heat available in present powerplants or energy provided from locally available fuels such as coal. Hermetically sealed systems, providing the added safety and reliability of a leak-proof design, are now being built in sizes ranging from 300 kilowatts up to 5 megawatts.

For smaller energy needs such as a group of homes or a fishing camp, Stirling engine equipment is expected to provide quiet, multi-fuel electric generation and space heating. Stirling engines are now operating in sizes ranging from 3 kilowatts Up to 60 kilowatts on a wide variety of fuels. A program beginning in the Alaskan Division of Energy and Power Development is expected to broaden Stirling engine fuel use to solid fuel. A feature of both the Stirling engines and organic Rankine cycle equipment is that the colder it gets, the more efficient the equipment is.

In the future, Arctic villages can be envisioned to be powered with whatever fuel is available in equipment that will operate reliably for many years. Lubrication will not be needed and maintenance will be minimal. The equipment will be silent and environmentally benign, providing Arctic residents with an improved standard of living.

INTRODUCTION

Many volumes have been written describing the intense energy problems encountered in rural Alaskan villages, yet little has been done to correct the situation. Electric generation continues to be accomplished through the use of oil-fueled diesel engines operating at efficiencies as low as 12% (Ref. 1) in the smaller villages, to as high as 32% '(Ref. 1) in Kotzebue. Village electric availability is characteristically in the range of 50-75% (Ref. 2), and smaller maintenance items such as the replacement of diesel crankshaft seals cost as much as $2,500.00. Electricity costs range from .306/kWh to as high as $1.87/kWh (Ref. 3), with State subsidies holding actual consumer costs to 12¢/kWh. Even the 12¢ figure is higher than nearly all customers in the lower 48 are paying at this time.

The community of Barrow faces a unique problem. In the 1940's, Barrow's energy needs were served by coal from Ed Bunnell's mine in Atqasuk. This included a small steam plant which generated electricity. With the establishment of NARL and federal involvement, gas wells were drilled in the area of Barrow, and natural gas was supplied to the community at exceptionally low rates. The latest gas well, drilled by the government, is providing fuel for gas turbines in the BUECI powerhouse and fuel for heating and cooking in Barrow homes. The government subsidized price of this fuel for the gas turbines is $.33/mcf, or approximately 1/10 of the going rate in the lower 48.

Barrow will soon face a substantial energy shock. Indications are that within the next 3-5 years, the pressure in the present gas wells will drop below the value required to operate the gas turbine generators (Ref. 4). At that time, new gas supply must be found to fuel Barrow's needs, and U.S. Government sources indicate that this new gas will cost customers $6.00/mcf (Ref. 5). This factor will also be directly reflected in electric costs since the gas turbine generator fuel costs will also rise to this amount, and the gas turbines are presently responsible for 42% of the gas use.

Whether in small isolated villages or in communities the size of Barrow, it is apparent that Alaskan rural energy problems are increasing, not decreasing, and positive action must be taken.

To date, although much discussion has taken place and many studies have been accomplished? very limited implementation of new technology has been accomplished? with the exception of wind power. In some cases, new technology implementation has been found unworkable, with "skeletons left on the landscape", leading to reticence against different options. Before new equipment is tried in Alaskan applications, it should be carefully examined for design parameters of:

a. reliability
b. availability
c. multi-fuel capability
d. efficiency
e. quietness
f. ease of operation
g. maintenance requirements
h. environmental acceptability
i. expected lifetime
j. life-cycle cost

There is no question that with the growing severity of Alaskan rural energy problems, promising technologies and concepts must be tried. Two of the more promising types of equipment are Stirling engines, for smaller power generation, and ORC equipment in larger applications.

ORGANIC RANKINE CYCLES (ORC's)

The term "organic Rankine Cycle" is a complex term describing a relatively simple concept. The most familiar Rankine cycle is the Steam Rankine Cycle using a Steam Turbine. Steam turbines are present in every large fossil-fired electric generation plant, and represent a well-known technology in which water is boiled to create steam, the steam is expanded through a turbine (which turns a generator), and finally, the steam is condensed back into water and hence the cycle starts over again. An organic Rankine cycle simply substitutes some other fluid for water in the turbine system, and the substitute fluid is generally a hydro-carbon fluid, or "organic". Thus an organic Rankine cycle has a turbo-generator which uses a working fluid other than water.

Why an organic fluid? Why not just water?

In the Alaskan rural environment, steam systems present two major problems; a) they require highly trained operators; and b) if they ever are shut down for any period of time, they can freeze up and become inoperable. A careful choice of a substitute, organic fluid cycle, turbo-generator can relive these problems.

Organic Rankine cycle (ORC) systems are manufactured in a number of sizes and designs by a variety of firms, both American and foreign. They have not enjoyed wide application and use in sizes above 3kW because of two classic problems:

a. They generally use dynamic shaft seals (Fig. 1) which are prone to leak, and;

b. They have had low efficiencies (below 10%).

The low efficiency leads to a necessity for large sized equipment for low power output (a 3kW system, manufactured in the Middle East, is 12′ by 4′ by 4′); with associated high capital cost. Dynamic shaft seals have caused reliability and maintenance problems.

Recent advances in design philosophy by Mechanical Technology Incorporated (MTI) appear to have overcome these two classic problems. By developing a high efficiency, hermetically sealed unit (Fig. 2), MTI/Turbonetics Energy equipment can generate up to 4MW with a turbo-generator of an acceptable size (6′ by 3' by 3′ not including heat exchangers). The hermetically sealed system is leakproof, reducing required maintenance to a bare minimum The higher efficiency reduces the equipment size, and therefore cost. Availability and reliability are expected to be similar to other MTI equipment experience (Table 1).

ORC's and Waste Heat

An advantage of ORC equipment is its ability to operate from lower temperature heat sources, such as the waste heat on diesels and gas turbines. In the case of the Barrow powerhouse, several ORC installation (Fig. 3) options have been examined, and the MTI equipment has been selected for eventual installation. The ORC equipment has a projected lifetime of 30 years and can be modified or moved to match changing powerplant requirements or physical location. The low average ambient temperature in Barrow is an advantage in this installation, since a lower condensing temperature increases ORC efficiency (Fig. 4). Through the installation of the MTI unit, the system load can be met using 20-30% less gas than with the gas turbines, alone. This will delay the expected Barrow gas crisis, and lessen its impact substantially when it arrives.

ORC's for Village Applications

In Arctic and sub-Arctic villages, the multi-fuel capabilities of hermetically sealed ORC systems is extremely attractive. In this application, the vaporizing

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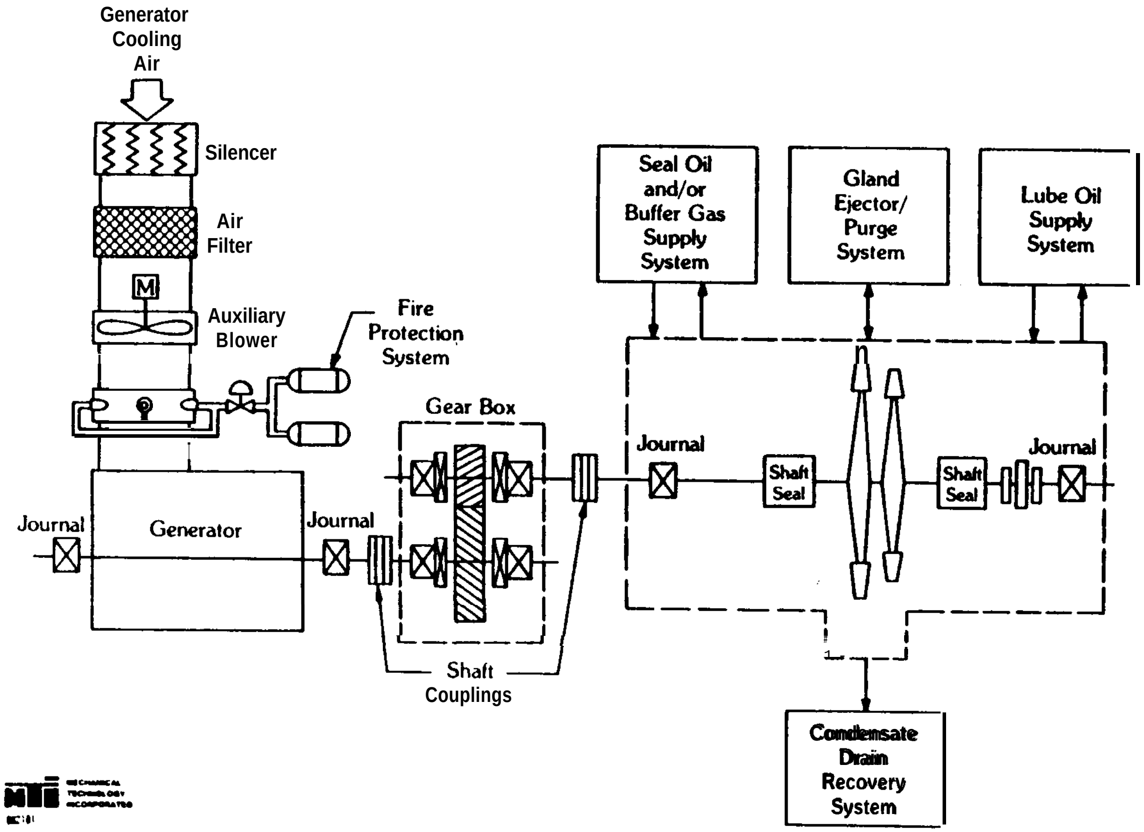

Figure 1 Conventional Turbine-Generator Design

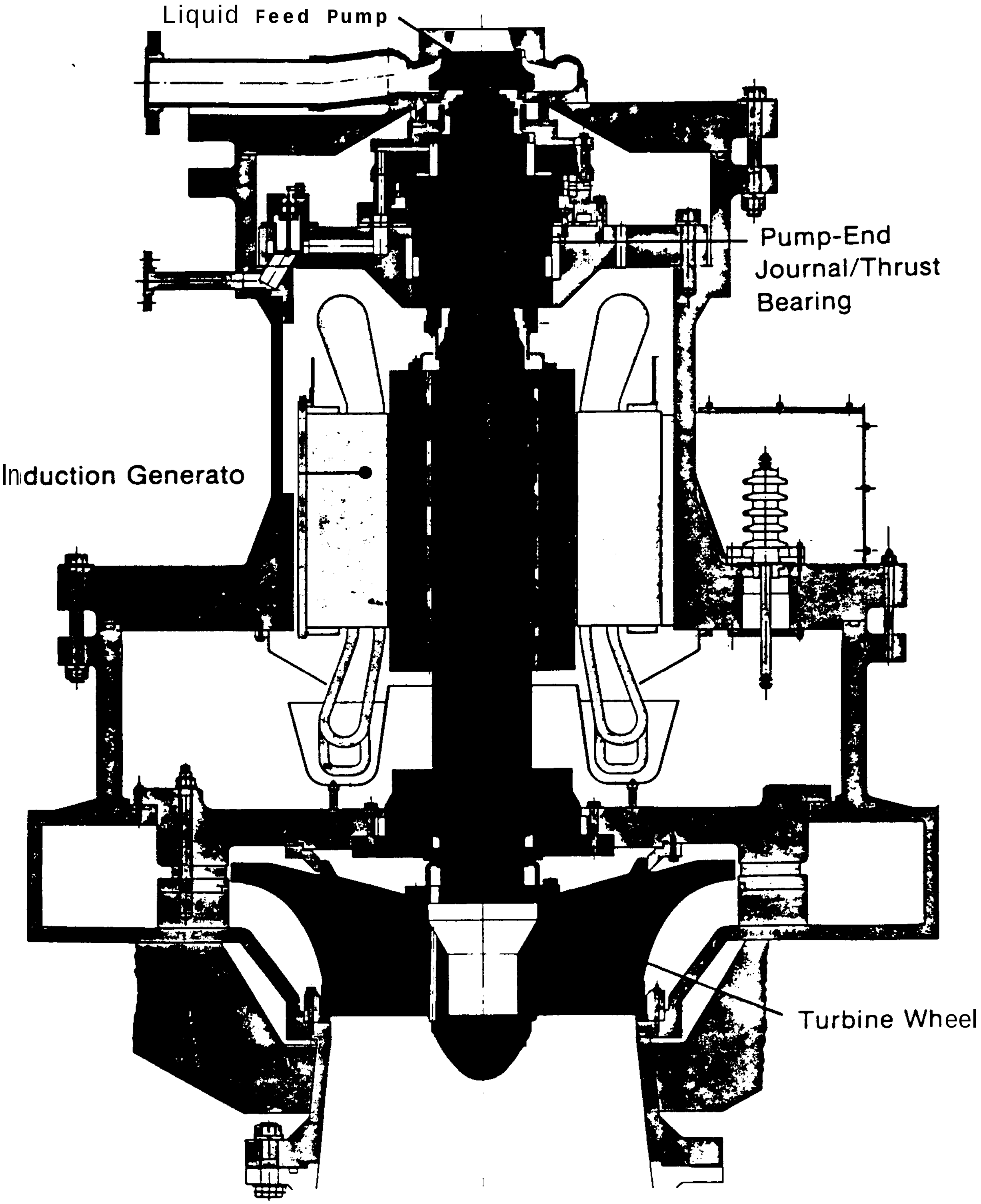

Fig. 2

MTI Organic Turbine Cross Section

TABLE 1

RELIABILITY OF MTI HIGH-SPEED CENTRIFUGAL COMPRESSORS

Model No.	Maximum Flow acfm	Maximum Horsepower bhp	Maximum Speed rpm	Operating Time hr	Availability Percent[1]		MTBF[2] Years		MTTR[3] Hours	
					High-Speed Components	All Others	High-Speed Components	All Others	High-Speed Components	All Others
SC-6	1,500	700	52,000	950,000	99.97	99.65	13.5	1.2	29	34
Se-lo	4,500	1,500	33,000	700,000	99.98	99.81	20.0	3.8	26	59
SC-14	11,000	2,000	21,000	815,000	99.98	99.95	31.0	9.3	46	23
SC-20	20,000	2,000	17,000	122,000	99.98	99.78	13.9	2.3	27	40
SC-28	30,000	2,500	13,000	593,000	99.94	99.85	7.5	4.5	42	35
Total or Average	–	—	=	3,180,000	99.97	99.80	14.5	2.5	34	38

[1] Availability $= 1 - \frac{\text{Repair Hours}}{\text{Operating Hours}}$

[2] MTBF (years) $= \frac{\text{Operating Hours}}{\text{No. of Failures x Hours Per Year}}$

[3] MTTR (hours) $= \frac{\text{Hours to Repair}}{\text{No of Failures}}$

Note: High-Speed components include rotor assembly, drive gears, bearings and seals

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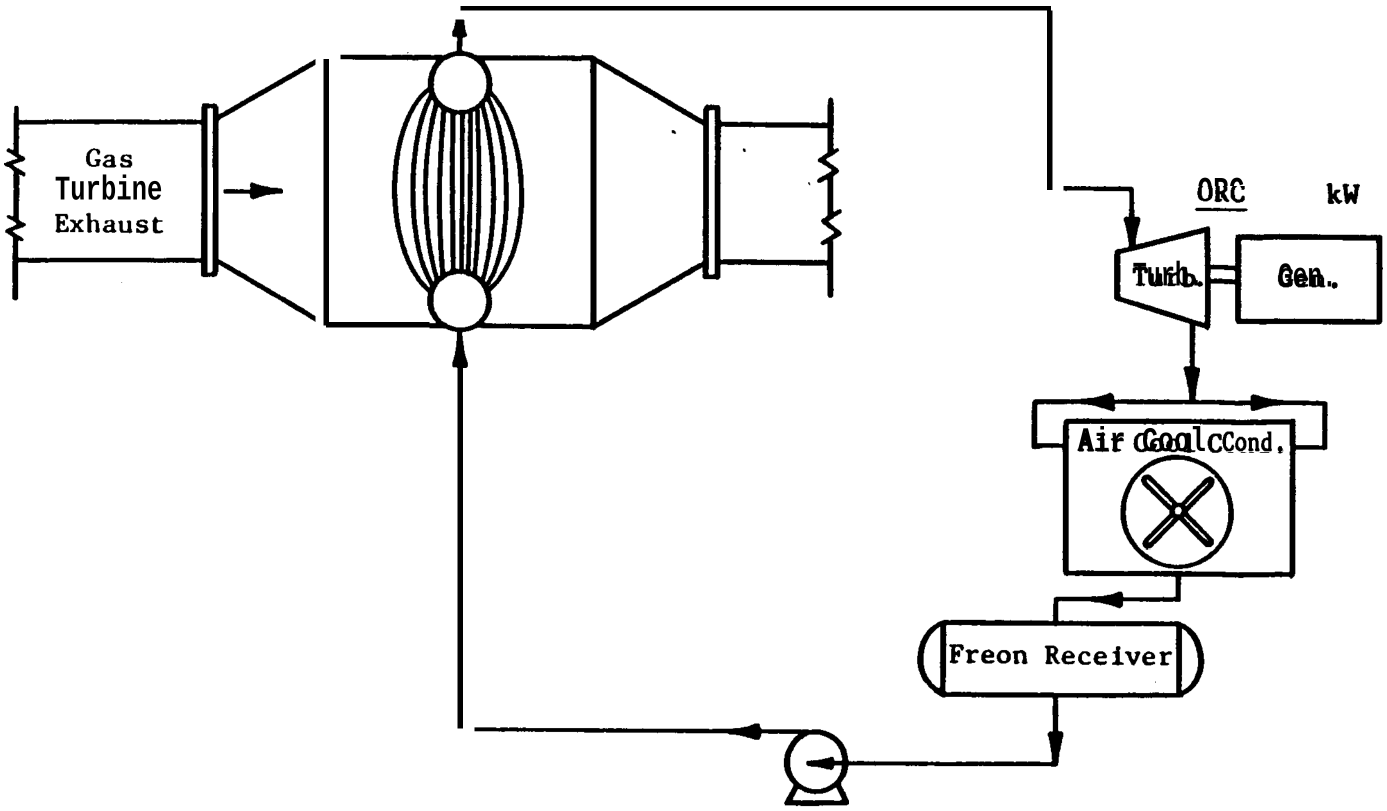

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Figure 3 Conceptual Design: Barrow Power Plant Installation

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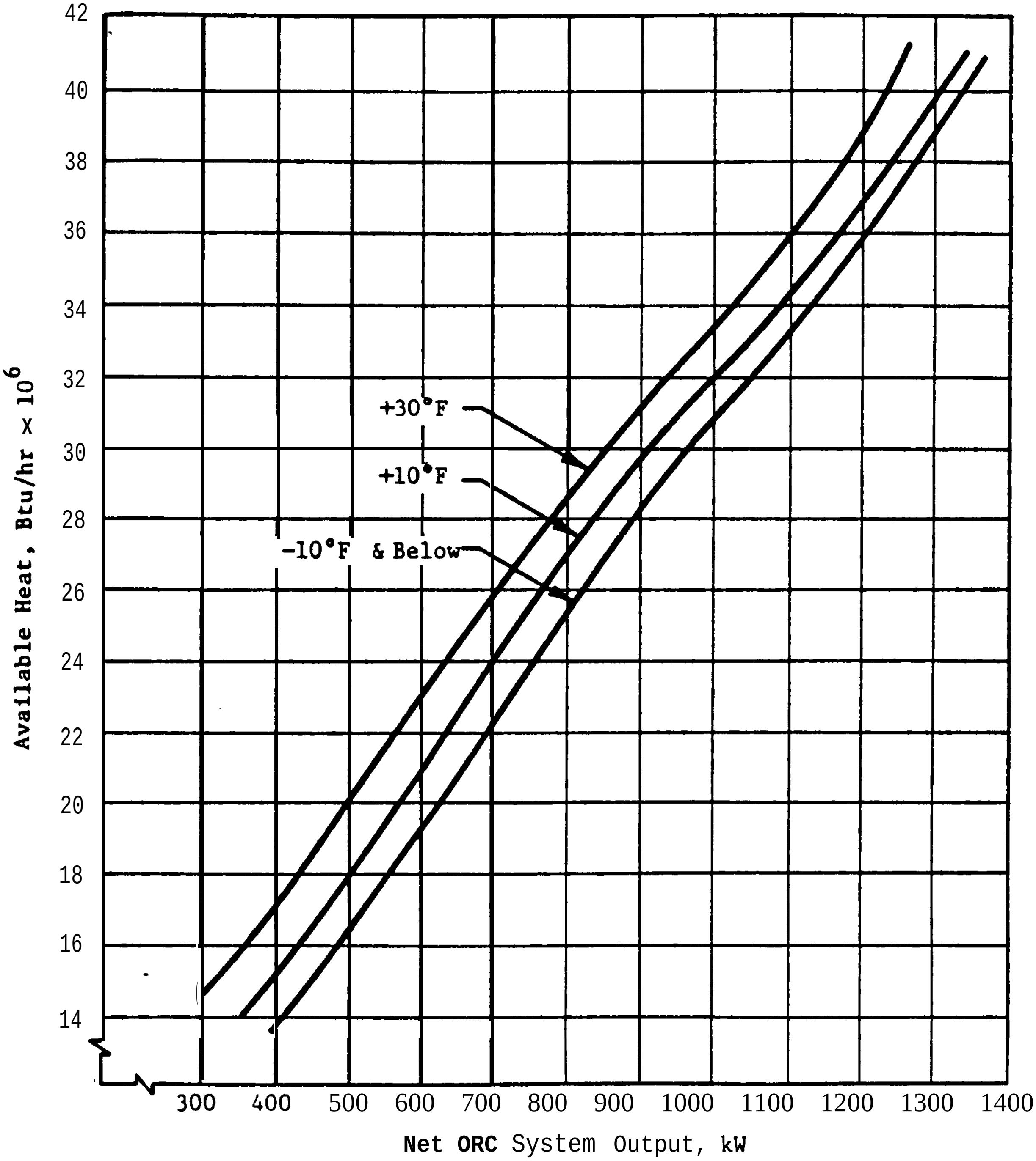

Figure 4 Predicted ORC Output (Net) for Various Ambient Temperatures

heat exchanger ("hot-side" heat exchanger) is, in fact, a multi-fuel furnace or boiler. The ORC unit requires heat, but is oblivious to the heat source. Therefore, heat supplied from any burning fuel is sufficient. On the North Slope, coal resources in villages such as Atqasuk and Wainwright could be used either directly, or in a coal gasification process to provide fuel for ORC electric generation. Along the Yukon, in the villages of the interior region, wood is now routinely used for cooking and heating; and interest has been shown in utilizing this resource for electric generation, as well. In Northwest Alaska, interest has been shown in utilizing local coal resources. Coal-fired electric generation is not a new concept in Alaska. Before oil and gas was available in Arctic and sub-Arctic regions, the Atqasuk mine provided coal fuel to an electric generator in Barrow, as mentioned earlier.

The equipment for a multi-fuel ORC system is shown in Figure 5. The use of an hermetically sealed system eliminates the normal high maintenance items found on diesel generator sets and conventional ORC's (Fig. 1-2), thereby adding to the economic viability of the system. Systems designed for high efficiency operation can match, or exceed the 12-18% generation efficiencies now prevalent in the villages (Ref. 1), thereby maintaining, or lowering fuel costs. With no lube oil system, no couplings, no seals, no gearbox, and associated minimized maintenance, these systems should provide lower village electric operating costs even when operating on oil.

There are key questions which need to be answered before widespread implementation of village central generation using multi-fuel ORC packages is possible. A major question concerns the socio-economics of fuel logistics. Is it possible for a given village to establish a structure for fuel gathering, delivery, and use? l-f so, dollars presently paying for imported oil will go, instead, into village economies. If this is not done, oil will still be the primary fuel source, with local energy providing a backup for crises or emergencies.

Alaskan village power generation system criteria, then, should include the following:

Electrical system output properly sized;

High-reliability plant operation at remote Alaskan village sites;

Output electric power at stable frequency and voltage with power factors consistent with commercial motor requirements;

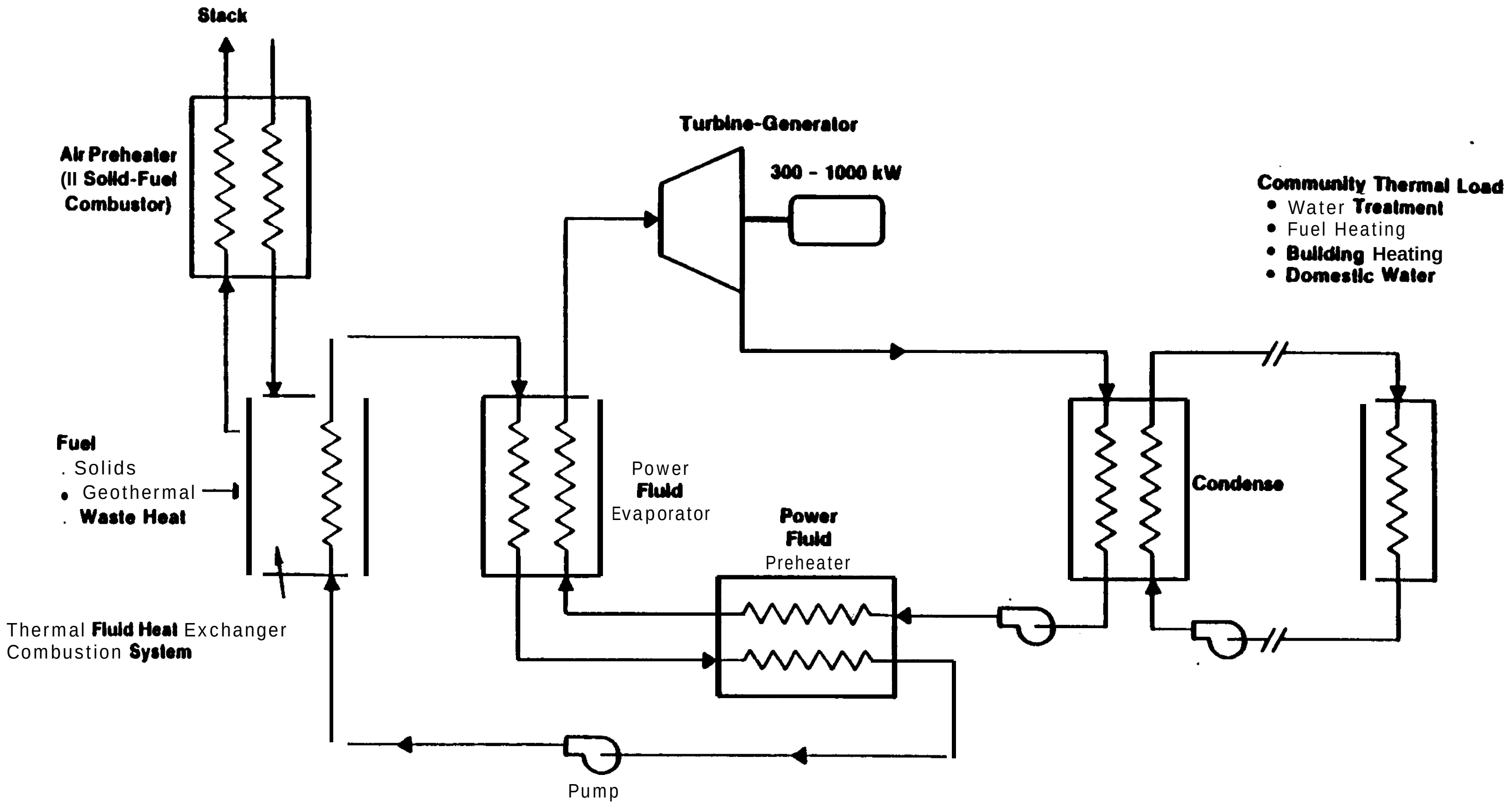

Figure 5 Solid Fueled ORC Generator

Solid-fuel-fired capability using indigenous coal, peat, biomass, or waste and equipped with fuel-forwarding equipment;

- Low-maintenance design stressing simplicity of operation and service by local labor;

Design for extremely cold climates (-60 degrees F);

Modular package, preferably skid-mounted with segments dimensioned for air transport or minimum volume shipment by land or sea;

Maximum energy conversion and heat recovery utilization, tailored to village utility requirements in terms of heated domestic water, space heating and sewage treatment operations;

Sufficient redundancy of support subsystems to ensure maximum reliability;

Sound pressure levels (dba) compatible with community concerns and preferences.

Obviously, no installation or demonstration of such equipment should take place unless the proper economic potential is present. The following requirements are suggested:

Operating and maintenance costs should be competitive with generation of electricity using existing diesel generator sets;

Annual amortized cost of electricity and life-cycle cost for the power plant option should show improvement over the present diesel-generator sets;

First-generation alternative systems should be operational in the near term;

Package design options should be reviewed on a comparative basis in terms of initial cost and payback with respect to diesels (based on gross savings) with various regional economic scenarios (population, load, business);

The power plant should have a useful life of 20 years without major equipment replacement;

Equipment should satisfy electric utlity requirements in terms of acceptability for financing though bond issues (REA, state, oil revenue, etc.) , as well as present power equipment insurability provisions.

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Although there are many unknowns in addressing village electrification with ORC systems, the known alternative is unacceptable; i.e., continued, subsidized, low reliability, oil dependent, noisy, smoky, high maintenance, high cost, electric generation.

STIRLING ENGINES

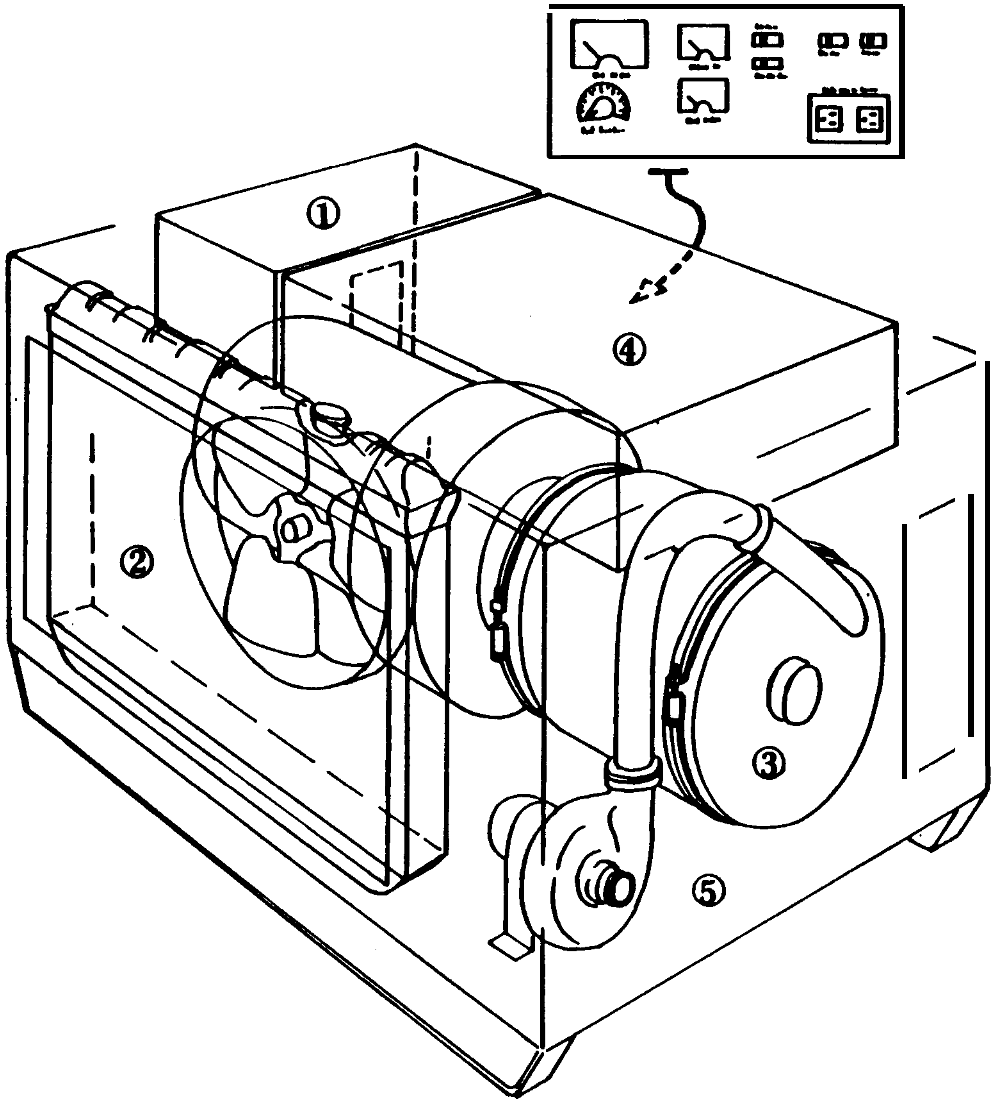
For applications where 1-100kW are needed, a new, high efficiency, multi-fuel option is evolving. This option is the Stirling engine. The concept of an engine running on the Stirling cycle is not new, and Stirling engines have been designed in many shapes, sizes, and designs. A Stirling engine is an engine which works on the principle of coupling a sealed volume of gas to a piston. The enclosed gas is alternately heated and cooled. As it is heated, the gas develops a pressure and expands, pushing on the piston. When the gas is cooled, it contracts, thereby pulling on the piston. Therefore, the heating and cooling of the sealed gas imparts an oscillatory motion on the piston, thereby running the engine.

The original engine, invented in 1816 by Robert Stirling, was used primarily for driving water pumps in mines. Engines similar to this were used fairly extensively in the 1800's until the turn of the century brought cheap oil fuels and spark ignition engines. Efficiency fuel flexibility, and environmental advantages took a back seat.

With the renewed interest in these attributes in the 1970's, the Stirling concepts again became attractive. major contracts were let to develop Stirling engines for automotive use, gas heat pumps, and generator sets (Figure 6). A contract involving Mechanical Technology Incorporated (MTI) and American Motors has resulted in automotive Stirling engines now being driven at 37.5% efficiency, meeting 1985 emissions standards, with an associated sound level like a modern sewing machine. These engines run interchangeably on various liquid fuels with no noticeable change in performance.

In smaller sizes (1-3kW), the military has taken a strong interest in free-piston, hermetically sealed Stirling engine generator sets for military field power. Pre-production units are to be delivered within two years. Concurrent with this effort, the Division of Energy and Power Development will cost-share a program to develop solid-fueled units for the Alaskan marketplace. These units are expected to be able to produce 1-3kW from a wide variety of fuels. Later versions of these generators will be produced in sizes up to 25kW.

MTI **Engineering Model System**



① Fuel
② Cooling
③ Engineering **Model**
④ controls
⑤ Frame

FIGURE 6

Stirling applications will be made in the smaller villages. For villages of 75-200 people, Stirling engine generator sets based on the automotive engine design are expected to be used. For smaller villages, lodges, fish camps, and outposts, the free-piston Stirling engine generator sets, from 1-25kW, will be employed. In all cases, these new engines are expected to provide reliable, rugged, quiet service from a variety of fuels. The hermetically sealed design is expected to provide a lifetime on the order of 50,000 hours.

CONCLUSION

Energy problems faced by rural Alaska and the North Slope are the most difficult in the State. Fuel supplies are either expensive to transport, or are diminishing in quantity, with no relief in sight. There are, however, some promising options which need to be considered in this environment. Thanks to the innovation and leadership of the North Slope Borough, both ORC's and Stirling engines are being studied in detail, and are expected to be implemented in the Alaskan environment in the near future. With implementation of this equipment, the Barrow gas fields will be conserved, and reliable, cost-conscious electric service maintained. Villages are expected to have lower cost, fuel-flexible, environmentally benign electric service, and isolated lodges and fish camps will be electrified with maintenance-free Stirling generators.

It will take time for the full implementaton of ORC and Stirling technologies in the Alaskan environment. It must be done together between Alaskan interests, and a highly involved equipment manufacturer. Success is a must, for a viable rural energy future.

REFERENCES

1. Booz-Allen & Hamilton, Inc. - State of Alaska Long Term Energy Plan; Division of Energy and Power Development, 1982 Executive Summary.

2. North Slope Borough personnel; private communication.

3. Division of Energy and Power Development personnel; private communication.

4. Van Gulik & Associates - Report to the North Slope Borough, April 1982.

5. U.S. Senate Interior Subcommittee Staff; private communication.

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DISCUSSION

Alternative Energy Symposium, Appropriate Energy Technology
Lee Leonard, State of Alaska, Department of Transportation
- Discussion Moderator

<u>Lee Leonard</u>: We have covered a lot of ground in the presentations today. What I would like to do is start this conversation by just making a couple of points.

One is that there are some people who still feel that there is no energy crisis, and that all we have to do is discover more oil, and that it is easy enough to do. I talked to Mr. Reagan about that just the other day, and we tried to agree on a few limitations. One limitation that we agreed on is that we assumed that there could be no more oil in the world than the volume of the upper 10 miles of the earth's crust. We started with that premise, and we took that as an absolute maximum volume that we could expect, and we found that it gives us an upper limit of 5.8×10^{20} barrels of oil left. If we use that amount at our current rate of consumption, increasing at the rate that our consumption does every year, and has been since the oil was first discovered; basically a little over a century ago, (we have been increasing every year at an average rate of 7% a year) and if we continue to increase, our consumption of petroleum at that rate we only have, with the top 10 miles of the earth's crust flooded with oil, 293 years left. So that is our upper limit, that is as far as we can go with oil.

And then to go from the ridiculous to the mundane, I happened to be reading a publication which comes out in Fairbanks; I think quarterly. It is a publication of the Fairbanks-North Star Borough. It is called the Energy Report, and I would encourage any of you who have not seen it to do so. The Fairbanks-North Star Borough tells us that in Fairbanks in 1973, remember 1973 - that is when the energy crisis began (supposedly) , the average cost of electricity in this town was about $45.37 for 1000 Kwh. Today, 10 years down the road from the energy crisis, the average cost of electricity in Fairbanks is, in 1973 dollars, $44.30. So we've saved a buck since 1973, and it also brings us up to a dilema since we only have, obviously, 293 years left. So we do not have any more than that, and electricity is cheaper than it was at the beginning of the energy crisis.

So - to the members of the panel, I propose the first question - "In recent years we have seen the extremes of near panic during gasoline shortages, school closures during natural gas shortages; and then oil gluts, fallen fuel prices, and in Alaska, shrinking petroleum revenues. From your individual perspectives, is the energy crisis real? And is it more or less critical in the Arctic than elsewhere?"

Jim Strandberg: I would say from my involvement in evaluation of life cycle costs of institutional buildings over the lifetime; that energy considerations are major. As a matter of fact, our studies indicate that one of the most sensitive variables in life cycle cost analyses of building systems does happen to be fuel escalation rates. And that goes for both the heating fuel as well as electricity. I would say that on a dollar for dollar basis, we that live in the northern reaches of the state are to be drastically affected by any unusual rises in price of fuel oil, and that our utility bills will tend to go up considerably more than people in certain other parts of the United States. I would say that we are kind of special up here because we generally do not have a lot of cooling. In the southern parts of the nation I think they would be faced with similar problems, because cooling is quite expensive.

William Ryan: As far as whether there's an energy crisis or not; I don't think there is an energy crisis, but there may be an oil crisis. I think if you look at what has happened over the past 293 years and in the development of energy sources, I think we will find a multitude of other energy sources that are going to replace the oil that we are going to run out of. So I would say that there may be an oil crisis, but that there is not an energy crisis.

Chris Noah: I would agree with Bill. In thinking about this question I thought, there really is not an energy crisis, there is more of a crisis of oil and gas; especially in Alaska. Most of the state has to re-import the oil that we ship out. So I tend to call it an energy situation, rather than a crisis. However, I do think it is more critical in the Arctic in human terms because the remedies are so diverse and complex, and the consequences are more severe in the Arctic.

David Eyre: I think there is no energy crisis and I do not think there ever was one, but I think there may be one. So let me explain this - tough first point - about crises in the past. Occasionally I execute a particularly imaginative piece of driving which leaves other drivers climbing up their house siding, or something like that; and my main attitude is this - is if they've got a chance to sound their horn and make a lot of noise, I have not created any crisis. And if they are too busy thinking about what else to do then there is a crisis. So all the noise that happened in 1973 is not, to me, indicative of a crisis. It is indicative of a panic maybe, but not a real shortage.

The problem, and I think the crisis that we have to face at the moment, is the crisis of smugness. We talk about world lots and so on, and it is very easy for even people in my position to lose faith in what we are trying to promote. Certainly, I sense the feeling of the people in Canada that they feel that we are trying to sell a bill of goods here, and there is really no energy situation, not even on the horizon. And I tend to go along with them until I pull up short against the sort of things that Lee Leonard has given us; the resources are finite and we are headed very rapidly toward complete usage of them. So this is the only real sort of cornerstone upon which I can dump all my activities.

Now as to how we go about addressing the future, it depends on too many factors. When one starts to make predictions about the future, one is usually left looking pretty silly in a couple of years time, and it is all going to depend on phases it seems; like fusion, solar cells, energy conservation, renewable power. These things come together to shake the energy future. I do not think there is an inherent crisis in the future. But let me tell you this - after 26 years in government research, I have complete faith in the ability of bureaucrats to orchestrate such a crisis; out of nothing at all.

Richard Bushey: The proper perspective that I would like to speak of is basically out of three points; and these are fundamentally this; and I want to speak from the perspective of Canada and from the Canadian Arctic, where I have lived for the last 10 years. There are basically three fundamental changes. The first one is that if you look at statistics they show that for Canadians, real wages have dropped in the last 5 years; and their economy is still basically one of resource development. What it really means is that the standard of living is not going up, it is either remaining even (depending if they can get as many people as possible in their families to work); or it is going down. So that has created real fundamental changes (that David pointed out) in the way people think, and yet that type of thinking, which relates to energy, the way you live, your expectation for housing, whatever; has really not affected the bureaucrats or the people who make the decisions in government, and those of us who are fortunate to travel or live or work in other countries, are going to get to see the same problem.

Once we were in a discussion with a group in the Soviet Union, and they were saying that those guys who are running the country are still fighting the war in the trenches in w w2. I mean, they have the same problems as America of making change, fundamental change, in the thinking of society; in terms of the politicians and the leaders who seem to be caught in one direction whereas the people seem to want fundamental change in another.

In the Northwest Territories we have fundamental problems in the fact that, for example; in housing, our energy costs have gone up something like 40% of our foregoing costs to about 60% or more in a period of 3 years, and we have a national policy, which means that our prices will have to become world prices in terms of oil and other energy. Subsequently, in the near future, we know that our energy costs are going to dramatically increase, and continue to increase to the point where it is not going to go back to 60%. It is going to remain that level or go higher. So the energy crisis, especially in remote areas; the Northwest Territories, Arctic Circle, the Baffin Basin, etc.; is that everyone has to live with the wage factor and that people are not going to get more money to buy their way out of their problems. In fact the value of the money is becoming even less, so I would say, for our area, it is a real problem.

Tom Albert: The situation in the North Slope Borough is a little bit different in that as far as the energy problem is concerned, I do not think it is proper to term it a crisis. That is my opinion. But it should certainly be termed a problem. Whereas most of the United States deals with the energy problem, that is, the price they pay for fuel is higher, the car fuel, heating the house, whatever; that is the thing that most of us see. The North Slope Borough sees two aspects. The same aspect that everyone else sees, that is, the price of heating oil goes up, the price of fuel for vehicles, diesel fuel, goes up; they see that too. But they also see the way that the nation is responding to this energy problem. That is, a tremendous increase in resource development in their backyard. Most of the rest of the United States is spared this problem. So the energy problem in the Borough has at least these two components.

The one problem that we all face is the direct price of fuel and then how the nation itself is responding. They are not drilling for oil, or not very likely to do it in Fairbanks or in Laurel, Maryland (where I come from). But in the North Slope Borough, they are getting ready to significantly alter the place.

In the "down to a more practical level" for the average person up there, the price as people move into, let us say, more modern, westernized housing means that the need for more and more fuel to heat these places comes on-line. So the number of people, particularly in the remote villages as they move into the more modern houses, have absolutely staggering heat bills that they have to pay, because the fuel oil has to be flown into them. I think then, that this is obvious. There is a problem.

Lee Leonard: Maybe I can just recap for the speakers. There has been a slight change in the last 10 years. We are now referring to a energy situation or an energy problem. Perhaps our fear of what we might do in the future has lessened since 1973. The energy crisis has created a fundamental change in the way we look at the use of our technology. In the Arctic we are continuing to build more facilities, more buildings, more projects, more things that consume energy; and so, even though we all agree now to make these more energy efficient because of the results of the last ten years, we seem to be willing to at least continue to build more and more.

Well, on that basis and based on your answers to question 1, we come to question 2, and that is: "What do you think, therefore, are the most critical factors concerning energy consumption when we are planning a building to be constructed in the Arctic?" Now, I guess what we're saying is that we are at an uncertainty level. We have been confronted with the problems of an energy crisis, and certain scenarios which that energy crisis might lead to. We are not sure anymore that we have an energy crisis; but, we now have to proceed. We now have to continue into the future, and I do not think we are entirely certain about the way we continue. So, from these different perspectives I would like to see if we can find a thread of agreement in how we might perceive; "what then are the critical factors concerning energy consumption in the Arctic when we are planning new structures in 1982?"

Jim Strandberg: From my perspective which is from a professional engineering level; I view many, many buildings from a standpoint of how we can improve their energy operation; and have dealt with some new building construction projects where we were attempting to evaluate what was the best way to build that building. Given the future uncertainties of fuel oil prices, or, shall we say, energy crisis, I think we have a cohesive course of action that we must take as a group of people (I guess I can speak as the people of the state of Alaska) . We must, I think, direct capital expenditures of public funds to the idea of improving the efficiency of our building all the way from residences up to institutional buildings. I think we consume a lot of energy and we pay for a lot of energy. I think that the state is very lucky now. We have available funds, public funds, which could conceivably be routed into a number of different programs which would - reduce the impact of any future massive hikes in fuel prices. I think that the program should not only include what we are going to do with new buildings, but it also needs to include how are we going to fix these existing dogs that we already have.

As far as new construction, I think we need an integrated approach to thermal standards. These standards could be advisory or they could be requirements for new buildings. I am not even going to address that right now. But we do need to tell people what is the best way for us to put our new buildings together, and make them be guidelines. I think people within the state can work very well with guidelines, and people generally want to do what the responsible thing is.

Bill Ryan: I think the primary thing we want to do in designing new buildings is keep them as energy efficient as we possibly can. I think we should probably try to keep buildings as adaptable to different sources as we can. If oil proves to be too expensive and we have to go to coal, for instance, or something else in a remote community; is it going to be a major renovation to change that building over to another source. It is something to keep in mind in designing buildings.

I think we should probably be looking at operations and maintenance costs a little more than designing things on the basis of life cycle cost. I think that O&M costs are really the big unknown because we don't know what the cost of energy is going to be in the future. Life cycle costs are sometimes weighted a little too heavy by initial construction costs, and I do not think that should be that heavy a consideration as compared to operating and maintenance costs.

Chris Noah: Well, not being an engineer but being one of the bureaucrats that David was talking about, I cannot give you a specific watchword. What I would like to mention is that what I think the most important thing to do is to remain flexible. I think that was the thread that came out in a lot of the talks throughout the day. Rich Seifert talked about the ability to be flexible and change with the needs and the times. You may remember his slides showing us the 50's, 60's, and 70's. Bill talked about remaining flexible in the buildings and collecting of waste heat. Winston talked about maintaining the flexibility of design in utility distribution systems.

Hans mentioned flexibility; and David did as well, to meet the different situations as they occur. So that is the main point I would like to make, that people realize that each situation is different; and not put the same standards to use just because that is-a government standard.

David Eyre: I want to take a different track. I think along technical and general policy matters there is a certain amount of concensus. The thing that we have learned recently from the energy shortage in Saskatoon, is that you can make an "energy aware builder". He will build an "energy efficient" house and we can put an "energy aware" family in that house; and they will consume more energy then they've any right to do; because they're not as energy aware as they should be. Studies have been done in Canada and the U.S.A. on people's attitudes to energy conservation. To my regret, Canada emerges as a very poor second against the U.S.A. Whereas the U.S.A. people admit to an energy problem, and are prepared to suffer a certain amount of impairment of lifestyle to correct the problem, in Canada there's no such willingness. A Canadian, according to surveys I've seen, will do whatever is in his power to conserve energy as long as it does not hurt at all. This I think is leading me to the point I want to make - the occupant of the house is perhaps one of the most important factors in the energy performance of that house. If you are aware, and live in a fairly rattley old house; you will probably run the house more efficiently than a second time buyer of an energy efficient house who does not really care.

Now, to me then - you talk about planning a new building to be constructed in the Arctic; I think occupants' awareness, occupants' education are important factors. As far as asking the people in the Arctic whether they are prepared to tolerate some impairment of their lifecycle or lifestyle; having seen some of the photographs that were on today, I certainly would not wish to do that. It seems to me they're living a borderline lifestyle anyway, in some cases; and rather we should look on energy conservation as a way of raising their lifestyle, rather than jeopardizing it.

Lastly; I would like to quote Shakespeare, or paraphrase him. The first thing we do, we kill all the architects. My experience is that energy construction, if one lists the energy wastage factors in a building in the order of sequence; probably the biggest is the architect. Then you go to the plumber, and then you go to the structure. I find that architects still do not seem to have learned yet that small is beautiful. Energy conservation is simple.

Richard Bushey: We absolutely have no consensus whatsoever on this question. For example, in the Northwest Territories there are approximately SO or more organized communities. Most have little or no economic base; and as we pointed out before, everyone wants a new school, or a satellite and telephone service and color TV. That means 'more power generation, more sewage disposal, etc., etc. Well, there is just not enough capital money to go around, to expand and support the remote communities. So should we do like the Greenlanders did; and just lay out a plan, and just say, "Well we are going to take 4 or 5 or 6 or 7 major communities where there are possibilities for education, health care, housing, jobs; and say we are going to put our resources into these communities, and we are going to use new technology, and we are going to go into multiple family units, and we are going to have all these progressive ideas centered in major centers; because that is the only way we can do it"; and go on from there and build communities from that point.

Obviously, if one were rational and logical, that sounds like a good idea. But I would say that there is no consensus for that because even the Greenlanders feel that they have created concrete highrise ghettos in a few of the communities where they tried this. Secondly, there are other issues at stake. In the Northwest Territories where we still have the problem of the land claim issue between the Dene units and other groups in which again; amongst themselves there is no consensus on where to go on that issue. We have for example, a plan for two or three major mega-projects that were delayed, postponed; and probably now cancelled forever. The resources from these mega-projects were going to be the spigot that would turn on the valve for the big game plan. Well obviously, there is not going to be any big game plan. So what are we left with.

I said we do not have any answers. These little experiments that we do with an energy efficient house, or something like that, are merely little attempts to look at models. But right now our real problem in the territories, is we do not have a plan and it appears on the horizon that no one has a plan; and no one has leadership and direction to give us to help create one. So in that sense it is a very frustrating situation to be in, but one in which obviously there is going to have to be a decision made in the near future.

Tom Albert: I have several items that I jotted down that I think are appropriate to bring up at this time. One of the more obvious ones I think to everyone is that the North Slope Borough will be, or is now, and will be in the foreseeable future a major constructor of Arctic structures. That is, houses, warehouses, community centers, you name it. Since a lot of this construction is going to take place in the next 5 to 10 years; what exists in the way of new technology will be used; and many facets of new technology, I'm sure, will appear. As many people have pointed out today in the proceedings of this meeting; that as we try new techniques the opportunity for the construction of "lemons" of one kind and another pops up. So that probably 10 or 15 years from now we will see that the Borough like other major constructors will have made a mistake or two. But in a time of trying to get something very rapidly; (5 to 10 years), using a multitude of new technologies, perhaps with these few errors, hopefully the number of right decisions will far exceed those that were not so good.

This is one of the reasons that the Borough was so interested in sponsoring a symposium like this. Because the findings of this symposium will be used by the 8 or 10 Borough people that are in here from the utility department, the planning department, and so on. As we will be an immediate user of the information presented here, I must thank Dr. Kelley, Charlie Hoar and all the rest of you folks for providing us with some information that we will probably use as quickly as anyone will.

But now a few specific comments. In talking to Dick Hedderman of the North Slope School District a little while ago; he suggested something that I had not really thought of; and a few other people have alluded to it and even mentioned it. That is, that as the new techniques come on line, there has to be some revision in building codes, somewhere along the line, to facilitate use of them. Public structures can be properly insured and adequately fire protected. That is also going to be a problem.

Another problem that many people have already mentioned is the need for low-cost operation and maintenance. The simplest, most effective design is obviously what is needed in many of these very remote areas where the maintenance ability in some of the remote villages is not nearly what it is in Barrow; and what it is in Barrow is not nearly what it is in Fairbanks. So, it is a draw at some sort of a happy medium somewhere between super-insulated or super-sophisticated heat exchangers and the ability to maintain this structure.

Another thing that at least one person alluded to today is the health factors to be considered here. Especially in very remote areas where, if buildings are super-insulated, adequacy of ventilation must be maintained; that is, the bringing in of oxygen and the getting rid of products of combustion, (both of the human and the machine). Unless the technology that is in place in the structure is very reliable; it has got to do what other fairly sophisticated things do; and that is break down with amazing regularity. In these very remote villages, the ability to get it maintained correctly and promptly is small. We then have an immediate health risk to the people in the structure; that is, from freezing or from severe chilling. Another point that is not quite so obvious is the health effects of breathing stale air where the level of pathogens in the air can rise. One infected person, let us say, in a household can seed the air with enough microbes to infect more readily the other people in the household, as well as visitors. So this is another little thing we have to keep in mind.

One of the other little things we have to keep in mind in a place like the Borough, is to try to obtain new and Innovative technologies as quickly as we can; if they seem to have some direct application. I was particularly struck by the presentation on the ground source heat pump by Dr. Stenbaek-Nielson Since it is already working in areas of Sweden, maybe it might work around here and might be something that could be utilized for individual housing in very remote areas in the Arctic in the near future, I do not know! But it certainly is something we need to look at.

Lee Leonard: If I could summarize perhaps what I think I heard in the answers to this question, it is something like this. Again we are 10 years down the road from the beginning of our energy awareness. At the beginning, we were all 10 years younger, and maybe ready to embrace ideas and concepts which now, in the light of scrutiny over the past 10 years, have shown that we need to be more careful of what we do.

We need to weigh our economic analysis toward maintenance and operations. We do not know what fuel costs are going to do. We do know what money we have now. We cannot afford not to put a little more in the front end as an insurance policy against what might happen in the costs of our energy later on. This is the same thing as I think some of the other members of the panel talked about when they were talking about flexibility. We are uncertain at this point as to the way we need to proceed exactly, but we are at last; perhaps 10 years down the road from the beginning of our energy awareness and all in agreement that we do have to proceed seriously in energy conservation.

That brings us to our last question, and this is where everybody can pull out all the stops that they like, or they can play it close to the vest. Considering the discussion so far, let us try to project ourselves forward in time for the 30 or 40 years which will be required to use up the useful lifetimes of buildings that we are constructing today. Now here is where we want to draw on the experience of people who have been in this business now for the last 10 years or so and many more.

So the question now is purely speculative. "What do you think will be our energy requirements and concerns when we are planning, not the buildings we are planning today; but the next generation of buildings that are 20 and 40 years away from the beginning of construction", and this of course in terms of cold regions of the Arctic.

Jim Strandberg: I guess I will track myself to one point, and trust that the other gentlemen will have other opinions and other issues. Speaking as an engineer, we have a real social problem in our rural areas where we are attempting to install and fabricate new energy efficient, high-tech structures in our bush areas; and we lack the available technically trained manpower to keep this equipment, these houses, these buildings, in proper operating order. So in a way, we are beating our head against a wall. Certainly a lot of you know all about some of the horror stories you have heard about some of the small schools being constructed in villages and some of the horrid housing that has gone into some of the villages that you could spill water on the floor and freeze wire and things like this. I think that this is a real social problem that we have; that even if we put good stuff in our rural areas that is going to be very energy efficient, it's not operated correctly. If our bureaucratic brothers continue with their foresight, I think that we're going to need to put more emphasis on making the operation and maintenance capabilities of the rural areas match more closely the energy systems that we install in those areas. Within the next 25 to 30 years, I really see that as changing. I think we are going to gradually form a cadre of trained operations and maintenance people that circulate around the state. Certainly we know that the rural areas are kind of transient right now. There are a lot of workmen moving around. We are going to get our people trained. So 30 years from now when we are looking at putting in a new building, we are going to be looking at putting in a higher-tech building, and we're going to be a little bit more sure then we are right now; and maybe our forehead isn't going to be so bloody. That building will be operated correctly. I will not even address the other aspects of how much space people are going to need. I think that is the kind of question for the architecturally trained people. I want to just relegate my answer to this one question; I think it is a highly serious question that needs to be addressed; and I do not think it is being addressed properly by our legislature.

Bill Ryan: I think that Jim mentioned one point that I think is very important, and it is an education process; no matter how you look at it. I am not so much thinking of education along the lines of technical education on how to take care of the facilities because I think that can be done. I do not think that is a major problem. I think the education that is needed, and it is not only in the bush, it is everywhere; is just on the need to conserve energy. I had an experience about 4 years ago where I tried to work with the building department in the City of Anchorage to require 2 x 6 walls in apartment buildings. We felt it was just like beating our head against a stone wall. The city wanted to go this route. But we had the homebuilder's association ready to ride us out of town on a rail. We finally got the problem down to the bankers and the "home loan" people. They were not willing to loan any more money on a 2 x 6 wall house than they were on a 2 x 4 wall. So that meant that the contractor could not charge any more for the house, and he had to absorb the extra cost. It is a vicious circle. I think it is an education process and it has got to start right at the bottom. I think that if you get enough homeowners that are trying to buy 2 x 6 wall houses, then the bankers will have to change their idea on loaning money out to prospective buyers.

I was at a workshop in Copenhagen that was sponsored by World Health Organization last year; and the Russians were there. Their problem was the same. They are not just worried about putting small water systems or anything into villages in their Arctic areas. They are worried about building cities of 20 to 30,000 people. Building these buildings as tight as they possibly can to reduce energy losses. They too were having a lot more problems with respiratory diseases and things like that.

The other thing you want to remember also, is some of these building products that we have been using for years; asbestos, formaldehyde in the insulation have never been a problem, because we have a lot of air exchange. It was all going out through the walls of the house and we were not absorbing that much of it, or taking that much in. You start tightening these buildings up and just the emission products given out by building products are going to be a factor to consider. You solve one problem, but you're creating others and then you have got a lot of headaches. In the long run I think it is an education process for all of us.

Chris Noah: I would like to amplify what Jim Strandberg has said, that the question of "what do we do in 30 or 40 years". I do not know if I can look that far ahead. We may want to worry about the next five years. The problem is we would be too successful in the short run and people would think that the energy situation, problem, crisis or whatever, is solved; when in fact I think it is a long term, very slowly developed problem that will be a problem that will take a long time to solve. I think we have to learn from the successful projects. Speaking for the Alaska Council on Science and Technology that sponsored 117 Northern Technology projects from many, many greenhouses to a belt powered washing machine, and a few other ones that seem to make the papers, and get the attention of the legislature. There are things to learn from all of the projects. There are people today that gave the presentation that they were a little dismayed that their research project did not quite measure up to their expectations. I think that is part of the learning process and that is something that we have to convince the people that fund research, or draft a set of regulations. We have to convince them of it. This raises the question about what John Kelley was saying: that the answer to this problem is more money for research. Someone said during the science policy meeting yesterday that he had the feeling that he was talking to the converted, which we may well be here. But I think we have to keep the pressure on to people, the individual citizens, and the people who ultimately sign the checks.

As far as the requirements, I think they will remain the same - cheap light and electricity. I do hope that we would maintain flexibility to adapt ourselves to situations rather than getting stuck with what we may decide now, or in the next 3 or 4 years. This is the way to solve the energy problem.

David Eyre: I guess the best idea of the group is that of learning from our mistakes. One of the biggest problems in housing is this; one is not very often given the opportunity to learn from one's mistakes. Builders do not like to advertize the fact that their houses fall down. I find it very difficult to get feedback from the building industry at large, because we as scientists have to say what we think in public; and the builders do not like this sort of publicity. They like to get in there, put the things right (if they are good builders), and get out again. It is very difficult to get the sort of negative feedback we need to put us on the right track. The other thing is (I will certainly agree it is essential), is that we need a lot more money for research than we are getting at the moment.

But in my own little group, Building Technology Support program, where we try to coordinate research on housing across Canada; we have enough advisory committees consisting of-builders who grew very skilled at getting their message out to other builders. They are very well spoken, well written people who happen to be earning a living primarily by putting houses up. What they say is that the big issue we are going to get into in energy conservation is marketing. It is generally accepted amoung my little group that the energy efficient house is intrinsically non-marketable. That really what we are trying to do is bring down government force from the above, to force a non-marketable product on an unreceptive market. So we have to get clever and start thinking about how we can make this marketable. I do not think in the U.S.A. or in Canada we have started to utilize all the tricks that are available to us to persuade the public to move in this direction. I am talking now about the simple basic techniques and high cost of the challenge. We have not gone nearly that far into promoting energy conservation. So I think that is where we have to move in the near future if we are going to take energy conservation where it is headed.

I am linking 40 years ahead, and the things I see shaping up are not much advanced in high-tech solutions to the problems. When I am talking about high-tech I am talking about fusion, solar platforms in space; this sort of thing. I think we will be edging into that, but I do not think we will be getting any significant energy input from it. So I think that when you start talking about planning houses in the Arctic, you will be looking at low-tech options. Low-tech energy options will be utilizing all the options that you could possibly call on that have been developed to that point. I can see the way things are shaping up right now. Solar cells will be here by the turn of the century. Energy conservation, I think, will also be a very important part and I think we will be using houses which are very much using a mix of all the sensible and prudent techniques that we have arrived at at that point. We will have energy conservation. The point is, I do not think we are going to get there smoothly. I think in the next five years we are going to have, not a crisis; but a real problem; an energy supply problem. I think we are going to bumble along until we bump up against the problem of this sort, and then I think there is going to be a regrouping, a reconsideration of where we are going in the energy field. I think we are going to have to reaffirm internationally the sort of things we had back in 1974. So in the world sphere, I think we have got to see an international energy bank rather like the international monetary fund taking shape. The emergence of a world community is already evident. I think that Alaska and Canada, which have resources, will see themselves in a sort of custodial role for the supplies of some of the world's energy resources of which they will have more than their fair share. I think that in that custodial role the custodians have to be manifestly deemed as taking the proper road; mainly making the world take better care of their own resources as well as, if not better than, everybody else's; for the reason of saving resources for the rest of the world. This is sort of taking shape right now in Canada, in a sense that the uneven distribution of resources is bringing federal/provincial disputes up to the front. The third world is going to be exerting far more pressure in trying to get a balance. We need to understand all the factors that have to be taken into account. I can see prices increasing. I can see high-tech not really meeting those prices, and I can see it working for a lot of low-tech options which do not have the pure hassle of maintenance and so on; the "de-bugs", and the service techniques. But I think generally with this combination, the pressures will be off. I don't think we will see as much energy pressure as we see at the moment.

Richard Bushey: Well, I think I would agree with what David has to say. Such a question was given to a friend of mine, who went to an international conference in Calgary on research and development about a month ago. And he asked the manager for the Mitsubishi Corporation in Japan; "What do the Japanese do that we do not do right?" and he said he did not know. So this Japanese man said to this friend of mine, "Well, for one thing, we do not hire people to be managers or researchers or planners or economists unless they can think 5, 10 and 15 years down the road. If they cannot think that way, we do not hire them." He said to my friend, "Well, how do people think where you work?" and my friend said "Well, I guess they worry about the next paycheck." That is the difference in thinking; between them and us, and there is a difference in developing countries, between them and us. The whole concept of thinking.

When we discuss our own region, we target a date. Our crisis date is 1985. We miss Orwell by a year. Maybe we'll have a break and catch up. The majority of the people in the Northwest Territories and Arctic backyard regions are native people. People who stay, who do not leave, and who do not want to leave. They do not want to go south or anywhere else. They want to stay where they are. Half the population is under 15 years of age. Subsequently, they will have families. If you look towards the future, what does the future indicate? Well, people will be living closer together. Whether it will be in apartments or low-rise, but the idea of a single family unit living with a large flock away from another person just does not make any sense. For the shear fact of health standards. Water; drinkable water is in short supply in many isolated communities; and waste disposal, sewage disposal is a critical problem.

People are becoming older, the segment of the population in the north is becoming older, and they do not go to Florida. They stay there, and there are no facilities for the elderly and the handicapped. Facilities will have to be developed. So in terms of housing design and technology; yes there will probably be a mix of a little bit high-tech but a lot more practical type housing. Denser, closer together, a mixture of single people, elderly and young with families intermixed within them. Sharing maybe common facilities together like laundry facilities; where most of the other facilities, like shopping etc., are built into the units somehow like a mole concept. Energy sources probably will be diesel generation, but a lot of that diesel generation waste heat that was spoken of earlier, will be recovered. Wind energy will prove to be an alternative. In many communities, wind energy has not been tapped.

That is the picture of the future that people see. But between the concept and it's realization, is that they are between periods. We see the in-between period peaking about 1985; where overcrowding, a lack of fresh water, a lack of sewage facilities, etc. Again, as David pointed out, there is a fundamental battle going on in Canada concerning sharing of wealth from resources between provinces. The fact that all these points have been made, I do not think has yet been realized at many levels of government. It is going to be a very expensive solution; and it is going to take a lot of work and energy by a great many people in order to resolve it.

Tom Albert: I have just a few comments about what I think may happen 20 years from now in the Arctic housing business. Not being an architect or an engineer, you will have to take some of these comments with a grain of salt. But it seems fairly obvious to me, that within the next 20 years, with development going on in the U.S./Canadian/Arctic/Greenland (and maybe someday we'll get information from the Soviet Union too), there should be a tremendous breakthrough by that time in certain fundamental understandings; not the least of which should be the basic design of a habitable structure for a family. That is, should the walls be constructed of this or that, and should they be 2 feet thick or 3 feet thick.

So my guess is that in 20 years and after much experimentation, there will be a fairly standardized housing structure available for use throughout the Arctic, no matter where you are. There will always be new and improved versions, no doubt; but there should soon be something fairly standard. My guess is that it would be a super-insulated structure and that it would be composed of add-on units such that several units, for instance, could be delivered to the site intact. By this I mean a room, or the walls, floors, etc. could be brought in separately and put together upon the site. You might almost say a pre-fabricated type package. The structure could be made large by adding on these basic units, so that a dwelling that has maybe 6 or 8 people in the family would be very similar to that of a dwelling that has only 2 people in it, except it has more of these basic units attached to it. This would allow for a simplification of maintenance.

Another thing that I think will surely happen in the next 20 or more years is that sooner or later a very efficient heating and air handling system will emerge. Although from what I have heard today, the heat exchange systems for air handling apparently are not too reliable at present. I am certain that in 20 years or more a fairly standardized, somewhat sophisticated, but very reliable, technology will emerge; which can always be improved upon. What we are looking for is an efficient and very reliable device.

Something such as this might even be containerized, so that in the utility room of the average Arctic house, for instance; there could be a self-contained unit the size perhaps of a table that handles the air treatment, the pumping of the air, the heating of the air, the degerming of the air, the humidifying of the air, the dedusting or whatever you want of the air. This unit, would be standardized and very reliable. Ordinary maintenance would be low cost in the first place, and secondly, some of it, hopefully, could be handled by the householder or designated people in the village. In a real emergency, (in the middle of winter), this unit could be just pulled out and another one, (kept in storage; or several kept in storage in the village), could be maybe inserted into the home. These are just things that appear to seem reasonable to me.

<u>Lee Leonard</u>: Well, I am glad to hear Dr. Albert has that much confidence in the architects and engineers. You have heard many papers presented today on the general subject of energy conservation. We all stood on similar platforms 10 years ago, and said that we knew what the problem was. The problem is that we are just not conserving energy. All we have to do is go out and start conserving energy. We knew about heat exchangers 10 years ago, and today we have some good paperweights but we do not necessarily have some good heat exchangers.

That was the last ten years, I do not know what the next 10 years is going to bring, but it is interesting to reflect on these viewpoints. I think at this point we just open the discussion to general questions from the audience. I am sure there are a lot of questions that did not get answered.

QUESTIONS AND COMMENTS

Directed to Richard Bushey:

Q - What would be the labor costs for construction in Canada?

Richard Bushey: They are usually set by the government under Supply Services manual, so it can vary. It depends on what the skill would be. It could be $7 or $8 for a laborer. It could be $12 or $14 or $15 an hour for an electrical or a plumber. Usually most of the work is contracted out, (tendered out), as you were pointing out, to the lowest bidder. Oftentimes, you know, the real problem from the construction angle is not so much the skills of the people employed, it is the supervision of those skills.

Many of the people who work in maintaining these villages are local people; and often they have higher skills. They are more conscientious and put more into it than people brought in from the outside, who are more interested in making a profit.

Directed to William Ryan:

Q - 1 am very familiar with that new publication "Cold Regions Utility Delivery" Design Manual. It is not clear to me how you get it, and it would be extremely useful to get it to a lot more people. There is no address on the manual, no price, and there is an identification of the Minister of Supply Services of Canada, and that is it.

William Ryan: If you'll address your letter to Barry Reid at U.S. EPA Corvallis, at 330 S.W. 35th Street, Corvallis. That is the gentleman who has them.

Doctor Solantz: I just want to make a commercial plug. The Science Advisory of the Northwest Territories has just finished a paper on the distribution of wind energy throughout the northwest territories. We found so much discussion about the use of wind power which was based on pure fantasy. Everybody in the windless areas wanted to put up wind power and the others have come to think it is a good idea. So we thought the first thing to do was just

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to get the best meteorological data pertinent to wind energy, things like probability, times the wind moves and the wind various velocities. We have just brought that paper out. Bob Bell, who is here; has a few copies. You may have something like it for Alaska now, but it just did not exist for the Northwest Territories. It seems such a fundamental document, it focuses the discussion very sharply.

Charles Hoar: There have been two or three papers on wind energy in the State of Oregon. One is currently being done by the Boeing Airplane Company and their three windmill location in Goldendale that was originally quite successful, but was shut down for mechanical problems caused by high winds.

John Kelley: I would like to follow up with Dr. Solandt's last comment, maybe one with a more humorous note. I have flown around a lot of communities in Alaska, and I have noticed a lot of interest in wind generators - but most of them seem to be horizontal. The enthusiam seems to be very high. The individual gets the wind generator as it was manufactured, and soon afterward, it is literally junk. Is there any merit, (and of course this is addressed to anyone who can answer) to the community looking at wind generation on a community-wide basis with the responsibility of that administrative entity taking over for the common good? Does this make any sense?

William Ryan: I think there is a little bit of a problem here with the wind deal. It is that these little units have been around for years, and these little units have now had some of the bugs worked out of them; but when you start talking about units as such for a community, (to provide electricity for a community), you are talking about something that is really in the development stage yet. I think that the place to develop those is not Gambel. The place to develop them is Goldendale, or someplace like it.

The other thing on wind is do not take one of those handbooks (and I am sure the handbook mentions this), and look on the chart and see your community falling under a 20 mph wind speed for 300 days a year; and then go out and buy your wind generator on the basis of that. The Department of Energy has loaner anemometers. What you need to do before you put one of those units in, is either get your own anemometer or borrow one of these mentioned. Go out and wait, and measure the wind speed where you are figuring on putting your wind generator, because those bar charts in these handbooks can really lead you astray. They vary so much from one period to another.

Directed to Richard Bushey:

Q - You mentioned in your discussion that you would spend up to $100,000 rehabilitating a structure - putting a new roof on it and some wall work as well. I was wondering if you had given any simplistic considerations to perhaps life-cycle costing (or some other economical analysis) in undertaking that kind of a retrofit.

Richard Bushey: This is a big controversy, it is sort of a political problem, as well as an economic one. The problem with most of the communities in the North is that there is overcrowding. The population growth is something like a little over three percent. So you have a geometric exposure with something like Mexico, rather than typical North America.

Also in terms of financing; it would cost us $50,000 to rehabilitate a home. If you try to build a new unit for $125-150 thousand (which seems to be what they cost), then obviously if one life expectancy for the $50 thousand unit is the same, or were slightly less, it is a pretty good trade-off.

The problem is capital money. The housing corporation and the NWT are building no houses this year primarily because of shortages of capital money from the Federal Government, which is the source of money through the territorial government. So, there is a crisis. In about three years, what will happen is; that the population will greatly expand - that no or little housing will be built - and the technology part for any conservation is not moving rapidly enough - that we are still experimenting, so we cannot meet the demand.

It is a very difficult issue and it is quite complicated to argue; but in costing these units out, we think it is worth the $50,000. But people argue that we should put it into new housing. But new housing is running, for us, about $125-$150 thousand dollars per unit. I do not know what your costs are on it.

Dr. Kelley: Is this stick-built housing, modular housing or prefab?

Richard Bushey: The multiple units that you saw were mostly stick-built buildings; which are slightly less than single family units; which are a combination of stick-built and prefabricated panelized construction.

Q - What is the normal type of construction?

Richard Bushey: Well, the controversy that I tried to point out is the mechanical one of the transportation. The transportation may break up the paneling and you may have a problem transporting the right kind of materials. So you have to balance these factors out. There is no real solution to that problem of balance. Every community stands on its own.

Lee Leonard: Mr. Ryan mentioned that the loaner anemometers were available through DOE. These anemometers are now available through AEIDC (Alaska Environmental Information Data Center). They have been turned over to them.

Q - 1 was wondering if we could make any analogy or a physical analysis of double-wall residential construction. Is there any indication that the builders are making progress toward building a prototype on a double-wall basis. How far behind is the double-wall from 'the 2 x 6 standard construction and what are the problems with the 'short presentation" about exterior foam insulation?

Jim Strandberg: The exterior foam option was the cheapest for smaller rural schools. There are so many factors that go into an institution building construction program that are totally different from the residential construction program.

Lee Leonard: I would like to stress an important factor here. What you saw Jim present this morning that may not have been totally clear, is the analysis of institutional buildings. The reason we picked schools is because they are very typical of the majority of the construction today. We do a lot of kind of medium-range stick buildings. The fact is that an institutional building and a residential building present different money constraints. When you do a life-cycle cost analysis it is not going to be the same. We should stress that the economical analysis is not directly applied, and probably should not be directly applied to either residential construction or light commercial construction; or commercial construction of the same size. You have tax advantages and all kinds of other economic parameters that apply in commercial construction, as well as residential.

The approach, I think, is going through and analyzing the least life-cycle cost for a certain type of the construction, and then taking that information and using it to develop a rational set of thermal standards. I am not saying that anyone should take one of our results from Jim's projects and say that if it says in Barrow, that a 7500 sq. ft. building should be built exactly like this; this does not mean that your architect should go out and build it just like that. Those thermal standards will be a guideline for an architect or engineer. When he builds a building, he will know how to plan.

" The problem was, why we had to do so much background work, and why it had become so tedious and drawn out. If you look at thermal standards for the rest of the world, you will not find any adequate technical data which is relevant for arctic conditions. So we really had to start from scratch here to develop a thermal standard, which was a mandate of the Legislature for the Department of Transportation. 1 would be careful in making a direct analog in saying "...well, Strandberg said you could use six inch studs and six inches of foam instead of using double stud walls." That has to be worked out on an individual basis.

Charles Hoar: There are a number of these studies going on sponsored by the different states and the Department of Energy. A lot of it has to do with houses that have been constructed. In the past, I have been involved in some of the studies. Some of them as far back as 80 years ago, which have since been retrofitted with 'foam in place" insulation.

Now they are going beyond this. What they are doing now, is to find out if this retrofitted foam has created a moisture problem within the wall which leads to dry rot. That was the first reason. They are doing it through the moderate temperature zones of middle Oregon and Washington.

Reports are available from the different states. I do not have the addresses and the people to contact, unfortunately. The U.S. Department of Energy has a number of other studies that have been done; far across the United States; in Minnesota, in Wisconsin and Michigan, Connecticut, Rhode Island, and New York State. The Cold Region Research Laboratory in New Hampshire has done some studies along the same line as mentioned by Lee Leonard.

None of these studies have been coordinated, or compiled in an overall set of data that we could use. Jim's is just another set. Fortunately his has been addressed to the problem area which has been a great problem here in Alaska and it would be applicable, I think, across the cold regions of the world. It is good to see that something has been established as a data base.

Directed to Richard Siefert:

Q - How did you measure your heating units?

Richard Siefert: I bought what was essentially was called a Btu meter; it was simply a hot water meter that is made in Germany. It has a thermister that you insert into the intake line. It measures the temperature at the flow meter which is in line right before the pump, as it comes out of the "OFI" unit and obtains the temperature difference at the inlet and outlet at the floor, and then at the flow meter after it comes into the cellar. It's accuracy was ± 1 Kwh. The meter was calibrated in kilowatt hours. The average heat input I got was + 3500 Btu's. So, my data is really not too bad, because-on a good day you would get 25 or 35 Btu/kilowatt hours apiece.

Q - Did you insulate under the slab?

Richard Siefert: Yes, I insulated under the slab. You can physically trace the position of the pipe. If you walk across the floor in your bare feet, you can feel where the plumbing is and the heating runs are located. It is a 4" slab. The pipes are on the insulation at the base of the slab. I have not had any problem with the thermal expansion of the pipes or cracking of the concrete or anything of that nature. The operating temperatures have not been to the warning level; though some of the inlet temperatures from the collector have been very high, 130 degrees F.

Q - Do you have other insulation in the cellar?

Richard Siefert: All "Blue Dot" styrofoam. There is 4" around the outside walls and 2" under the pad. It is stepped down under the front porch to keep it below grade.

Directed to John Zarling:

Q - What temperatures did the Israelis have as sources when they use their ORMAT devices?

John Zarling: Maybe I can answer this in a number of ways. There are many organic rankine cycle turbine generators in the state. Up and down the pipeline we have remote valve sites. Those remote valve sites are being powered by this type of generator. They are using a propane fired burner and they have much higher temperatures on the hot end. They have an air cooled condenser so they have slightly warmer temperatures on the cold end sometimes during the year. That is one application where you have a very large spread in temperatures and very great reliability! They are just remarkably reliable machines.

Directed to David Eyre:

Q - A question was asked about heat exchangers in ventilation design.

David Eyre: In a good part of design of the ventilation system which I cover, we are suggesting a simple ventilation system which consists of one exhaust, one inlet; a fan on each, and solar range that you can cook with and heat exchange through it when the industry gets to learn how to make them. You can put them in at a later stage, when the technology is common. Let's say that about ventilation systems, they are a problem. What do you do with a dryer? Do you save energy, or do you waste energy, and so on? There is no need to question - there is a long way to go before we know how to design a group ventilation system for a house.

Q - Is there a specific figure with the ventilation of your wall space. For instance, in Fairbanks the top plate must be solid which would still give you problems.

David Eyre: The energy efficient house design that I have given you conflicts with the codes in Canada on a lot of points. For instance at the vapor barrier; it states they should be totally on the wall side of the insulation. In the city of Winnipeg, you cannot wrap a vapor barrier around the outside of a header; I do not know why, it is probably some fire regulation. I think you have to be putting pressure on some of the old codes which are questionable to see whether they cannot be eased a little bit.

Directed to H.J. Coutts:

Q - What kind of paint did you use to keep away from polluting your water system?

H.J. Coutts: Paint was just standard black latex, flat lack paint. It worked for the water, but when the glazing moves against the panels when they are wet all the time, it will tend to rub off and tend to adhere to the fiberglass.

Q - You do not worry about that getting into your water system?

H.J. Coutts: No, I have a screen at the water collection point for the panels because there is also rainwater and stuff can get into panels. The first one does not have very good glazing on it so rainwater can get through that and I have to filter it.

Comment:

I am Doctor Solandt, Chairman of the Science Advisory Board for the Northwest Territories and I have never lived in the north; but have been in and out of the north for 35 years and concerned with Arctic research of various kinds. I gather that the speakers were instructed to confine themselves to houses, but I think the discussion was far too sharply defined. You cannot design a proper Arctic house without designing a proper Arctic community; and nobody said a word about the community, and there are not only the social problems of the communities which are probably not appropriate for here, but the actual energy-saving elements for the communities. For instance, when you look at the Northwest Territories the easiest thing to do is heat recovery on the diesel. It is quite easy to do it on both cooling water and exhaust gas; provided you are not wanting to have too elegant a solution. You can get a good one. But in many of the communities there is no use doing this because there is nothing near the diesel that you can transfer the heat to. That is because the original community design was based on the fact that the diesel is noisy, which it did not need to be; but it was. So the community gravitated away from the diesel. Now all community buildings in modern remote communities ought to be placed in relationship to the diesel engine and heated from it; quite easily done but not thought about in time in most cases. I bet that the average utilidoor in Barrow will cost a pretty high fraction of the cost of the house layout of an existing community. There have been communities designed that were made with short utilidoors and yet without each house facing separately so that there was an independent house. The best of these was built in Churchill, in northern Manitoba, about 35 years ago; and has since been torn down, but it was a beautiful example of a good layout.

Snow removal - never mentioned. As you get to more and more use of vehicles this becomes a more important point and can be relatively easily dealt with in community design. You have to regard the house as a subsystem in the community; and then I think you have to regard the community as a subsystem in a social order. Here again, I think we are losing sight of the fact that we are talking now from the point of view of southern technology and southern communities. We are probably seeking to impose on the native communities our view of how their society ought to be converted into bricks and mortar. Well, I should say wood and fiberglass. An example is the care of the aged. Old folks homes are not part of a social background in the Inuit setting. Are we going to force them to have old folks homes; to take the old folks out of the family, from the old ways where they have been so successful over generations? I think it is a great mistake. But this again is an example of the interaction of social factors with community design factors as with house design; so that the house design is just the last part. Well, it is one of the subsystems of the complex system.

I hope that in talking about the technology, we will not lose sight of this fact. I wanted to reemphasize what has been said by several people. Do not do experimenting in the small Arctic communities. Do not put anything up there until it really works.

I will always remember when the message first came home to me when I was in England talking to the designers for one of the biggest, most successful heavy diesel engines. It was 5,000 HP. They had put the first one down in central Tanzania, and they wondered why they were having trouble developing it. It did not work. There was a large distance between Tanzania and the service center. We tend to do the same thing in the North. We're putting relatively untried technology into the communities that really need a simpler solution.

I would be willing to bet that because of what the North Slope Borough has embarked on now, in putting technology into the lives of the people there, that it will not be more than 5 or 10 years until they are strongly supportive of the development of offshore oil because they have to have the revenue to keep the thing going. Expanding by technology, they are locking themselves into a decision on their way of life; which they have not intended to do at all; and which maybe we have sort of backed them into. But here again is an example of this complex interaction of technology and society. We have to keep this in mind even more in designing the ideal house. Housing of the future in northern communities may well be multi-family dwellings. But even there we have to be a little careful of how much we impose our acceptance of this type of thing on other people. I have been in Alaska now for about a week, so I probably know more about Alaska than I would if I lived here for 20 years. It is rather scary that if you are anywhere for a short while, and look around, you immediately know the answers.

Finally, could I take this opportunity just to thank you very much for inviting the Science Advisory Board to be here; and tell you how much we have enjoyed every minute of our stay in Alaska and will, I am sure, enjoy the rest of the stay in this very interesting and beautiful state. Thank you.

Dr. John Kelley: Thank you for your remarks Dr. Solandt. We are very pleased to have you here. Your remarks are well taken. We sometimes do become prisoners of our own technology. The real problem is to keep it tidy; otherwise that technology can become a very cruel jailer.

Al Dunn (North Slope Borough Department of Housing). I feel that the more sophisticated and the more complicated the construction, the higher the maintenance cost, in relation to liability. You can design and engineer a perfect system for the structures; but you do not design and engineer people. I have been fighting that factor for the last 20 years and probably the next 20.

John Kelley: Thank you Al, in fact, I think that that remark complements Dr. Solandt's and perhaps there is a challenge here. Of necessity we have to find the focus. We discussed this on the steering committee and we came to the conclusion, very early on, that we had to take a critical issue and deal with the issue in a one day symposium. But the challenge that I would like to offer Dr. Solandt, for example, and to his colleagues in Canada is that next year, you pick this issue up again and take some other focus, perhaps something we missed, to compliment what happened here.

Dr. Solandt: I think it would be fascinating to try to have a discussion on the design of Arctic communities. Limit it quite definitely to a certain size and remoteness, and climate, and so on. But there must be a hundred Arctic communities scattered across Alaska, the Northwest Territories and northern Quebec that would fit into a group that would be fairly well defined. You have got to imagine what you would do if you could start all over again. You never can. But it would be fun to see what you would do.

Jim Strandberg: I would just like to add to the Dr. Solandt's statement that perhaps we could widen the scope of that discussion. There are a lot of small villages which have been, perhaps, improperly planned. Perhaps we can widen scope of our discussions about buildings in typical existing communities. What can we do with those communities to make them better, as opposed to planning new communities. We know we have got a lot of communities around that really need help from a planning aspect, but how are we going to fix them over on an interim term basis.

Directed to David Eyre:

My name is John Allen: You were mentioning the problem of marketing an unmarketable idea. It may very well come to pass where we do not design houses so much to house one's ego but to house one's body; and the dimensions are human rather than spiritual interpretations.

David Eyre: I agree it is going to take a long time to turn our attitudes around.

John Allen: Do you think that there is possibly the same reason that the automobile business was turned around was in that the cost of fuel will bring about the tapping of the pocketbook; and that's a pretty sensitive place for most people?

David Eyre: It is, but I think we are going about the present attitude wrong. First of all we are not providing people with viable houses that are equivalent to these small cars. These small cars have got their problems, but to my mind they are viable. The houses that we have, are generally doubtful in their credibility because of instances like urea foam. Also, I think that we are taking the wrong track. I do not know how we got into this; but we are all selling this energy efficiency on the basis of cost effectiveness. Now there was the point five years ago when the government was getting an act straight on energy conservation. We would have to use cost effectiveness as a tool to sort out what was good and what was bad. I think that the time is now past. I think the options that we are all talking about now are, more or less, cost effective. They are fairly good technically and are falling into a fairly wide bracket of cost effectiveness. The point is when the homeowner goes into a house, to buy a house; does he say, "OK, I like that double car garage. Here is an R60 wall". Is cost effectiveness enough? He is going to look at it the same way as he looks at the rest of the house. It is just one more feature. He is wondering if it is going to hit his pocketbook, right now, in terms of extra taxes, because yOu have got a little extra thickness of wall all around the house, and so on. These are features that can make the decision. Now what we are planning to do I think, is sell the houses in correct fashion. The reason why we are buying houses is for comfort.

I was involved in a New Indian commuity in Mallosh, which is in Saskatchewan. The government started to build four level split housing for the natives, and we had to go there to inspect them. We knocked on the front door to see if he could put thermocouples in the house, and there was no answer. But we heard some noise around the back. We went around the back, and this house, I should explain, a beautiful 4 level split, all double glazing, fridge, stove, everything provided, all electrical. There was no electrical hook-up to it, but you can always get it. However, you cannot afford it. Out in the back was a little old native women. She must have been about 80 years old, from the look of her. There was a ring of stones on the floor, and she was cooking potatoes cut in half in a pot. The absolute disparity between the two was just really jarring.

SYMPOSIUM CLOSING

Dr. Kelley: If there are no further questions, then we will bring this symposium to an end, and on behalf of Charles Hoar and myself and members of the steering committee; I would like to thank all our contributors, participants, those of you who attended the conference. I would especially like to thank the North Slope Borough for making this conference possible, and hope it will be carried forward again next year by our collegues in Canada.