THIRD INTERNATIONAL
SYMPOSIUM ON COLD
REGION DEVELOPMENT

Extended Abstracts

Edmonton, Alberta, Canada
June 16-21, 1991

THIRD INTERNATIONAL SYMPOSIUM ON COLD REGION DEVELOPMENT

EXTENDED ABSTRACTS

Edmonton, Alberta Canada
1991-06-16/21

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PREFACE

This volume contains the extended abstracts of all talks scheduled for presentation at the Third International Symposium on Cold Region Development, held in Edmonton, Alberta, Canada, 1991-06-16/20 (ISCORD '91). Following the 1990 call for presentations, the submitted titles and short abstracts were subjected to technical scrutiny, as to their appropriateness for presentation, by the pertinent session chairmen and their associates. Authors of accepted abstracts then provided an extended abstract, which was edited by the Program Chairman and then retyped into a common format. The final product is therefore the result of a team effort. The Session Chairmen (Andy Jones, David Kinnaird, John Powell, Grant Ross, Les Sladen, Ryan Tajcnar, David Wong and Tom Zimmerman) are thanked for their efforts both as organizers and scrutineers of the technical aspects of the program, and for arranging the pertinent technical tours to complement the oral and written presentations. Without the dedicated and concerted efforts of Kathie Skogg and Joan Checholik this volume would never have been the elegant production that it is. The cover design was by Dale Hite. However, none of this would have been possible without the generous financial support for the preparation and publication of this volume from the National Research Council of Canada, which support is most gratefully acknowledged.

The ISCORD theme, 'cold region development', is almost all-encompassing; depending on how it is defined, even space could be included. Certainly, the tropics would seem to be excluded, yet, in a future ISCORD, there may be presentations on ski resort development on Kilimanjaro. ISCORD meetings, so far, have been dominated by presentations from the northern hemisphere. This will surely change in the future as the Antarctic comes more into focus either through plans for development or pleas for preservation. For ISCORD '91, the decision was made to publish only extended abstracts, thereby leaving authors free to publish full papers elsewhere. Additionally, the rather burdensome task of editing and retyping was undertaken. This resulted in minimizing the impact of keynote contributions - - which should really serve to tie together all papers delivered under the same topic. Experience suggests that more keynote speakers presenting significant review papers, together with shorter talks by other participants, and generally more focussed session topics would result in a program with wider international appeal, as befits symposia attempting to cover development in cold regions.

Brian Hitchon,
Program Chairman

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David Kinnaird (Kinnaird Planning and Research Ltd.)

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• SESSION E. CONSTRUCTION, ENERGY AND PLANNING

THE PREMIER OF ALBERTA
Legislature Building, Edmonton, Alberta, Canada T5K 2B7 / 403/427-2251

MESSAGE FROM PREMIER GETTY

On behalf of the Government of Alberta, I am very pleased to welcome you to the third International Symposium on Cold Region Development (ISCORD).

It is most appropriate that the 1991 meeting of ISCORD should be held in Alberta. Blessed with abundant natural resources, our oil and gas industries have demanded a continuing commitment to cold weather technologies.

Alberta's resource-based activity is just part of a larger picture. More than 500 companies in Alberta have an interest in cold climate technologies, in such diverse areas as construction, manufacturing, services, research and development and training. Recently, there has also been a growing demand for cold-proof technology in high-tech areas such as telecommunications, aerospace and meteorology.

But Alberta is more than just a province of opportunity. While you are here, I invite you to experience the beauty of our varied western landscape, from the snow-capped peaks of the Rocky Mountains to the vast northern forests and the southern Badlands, where dinosaurs once roamed.

Welcome to Alberta, a land where stunning natural beauty and old-fashioned western hospitality meet the promise of a bright future.

Don R. Getty

June, 1991

Jan Reimer
Mayor

5th Floor, Centennial Building
10015 - 103 Avenue
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MESSAGE FROM THE MAYOR

Welcome to our city for the third International Symposium on Cold Region Development.

Edmonton is a natural setting for a conference devoted to cold region development. Known as the "Gateway to the North," the city hosted the world's first Winter Cities conference in 1988.

Thriving in a cold climate has been one of the keys to Edmonton's dynamic growth. The city is strategically situated on an economic divide between the productive farmlands of central Alberta and a vast, resource-rich northern hinterland. Edmonton has grown into a sophisticated industrialized city by using technology to cope with winter weather. Each innovation has improved efficiency, lowered production costs and enhanced the value of our natural resources.

Recently, maintaining our quality of life while safeguarding our environment has become a particular concern for Edmontonians, as it has for many people across Canada and around the world. I hope that the expertise and knowledge shared at ISCORD will provide future benefits in that area.

While in Edmonton, do take time to enjoy the natural beauty of our spectacular river valley, sample our rich and varied cultural life, explore our history at the Fort Edmonton Historical Park or enjoy our world-class shops and restaurants.

Welcome to Edmonton, one of the world's great northern cities.

Yours truly,

Jan Reimer

Jan Reimer
Mayor

THE CITY OF Edmonton

A Message from the Chairman

This volume contains the extended abstracts of the papers presented at the Third International Symposium on Cold Region Development, held in Edmonton, Alberta, June 16 to 21, 1991.

The program includes papers in the areas of land and renewable resources, the environment and its protection, transportation, building design and construction, energy and planning. A technology showcase displays the products and services of companies specializing in cold climate technology. The wide range of topics covered reflects the many challenges faced by those working in cold regions.

How you define a cold region depends very much on your perspective. To someone living in the tropics, half of the rest of the world may seem cold, whereas to an Inuit, three quarters of the globe appears warm! Immediately following this message, I have included quotations from a paper by David Phillips, because they provide a good context for the theme of the symposium.

The first symposium was held in 1985 in Sapporo, Hokkaido, Japan and the second in Harbin, Heilongjiang, People's Republic of China, and both were very successful. I am certain that the third symposium held in Edmonton will meet the expectations raised by its predecessors.

This symposium is organized by the Hokkaido Development Engineering Centre, the Science and Technology Commission of the Heilongjiang Provincial Government, the Government of Alberta and the Alberta Association of the Canadian Institute of Planners (AACIP). The organizing committee consists of representatives from the Alberta Departments of Municipal Affairs, Transportation and Utilities, Technology, Research and Telecommunications, Federal and Intergovernmental Affairs, Economic Development and Trade, Agriculture and Energy; from the Alberta Research Council; the Centre for Frontier Engineering Research; Monenco Consultants; Forestry Canada; AACIP; Info-Tech; the City of Edmonton; Western Convention Consulting; John Kulba, Educational Consulting; and the University of Calgary. Dr. Duncan Currie, the initial chairman, put the committee together. Without their hard work this symposium could not have taken place and I thank both present and previous members for their contributions.

I want to give special thanks to Kathie Skogg, Assistant to both the Chairman and the Program Chairman, who carried much of the load; and to Brian Hitchon, Program Chairman. Both joined the team at a late date and in a very short time became key to the success of ISCORD '91.

I am grateful for the support we received from many quarters: the Government of Alberta is hosting ISCORD '91, with supporting contributions from the Government of the Northwest Territories, the Cities of Fort McMurray and Edmonton, and from the organizations and businesses featured in the back of this volume. The National Research Council of Canada provided a grant toward the production of this abstract volume. Thanks to all!

I wish all participants a productive and enjoyable week.

Jan Boon, Chairman, ISCORD '91

WHAT IS A COLD REGION?

In view of the title of this symposium, it seemed useful to provide some context to the term *'cold region'*. The following editorially modified quotes (reproduced with permission of the author and the Winter Cities Conference Corporation) are from the paper "Understanding Winter Climate" that was presented by David W. Phillips at the Winter Cities Forum (February 15-19, 1986, Edmonton, Alberta, Canada, Proceedings from the First International Winter Cities Symposium, pp. 23-40).

"What is Winter?"

Beyond the astronomical meaning, there are no official definitions of winter only several interpretations. Astronomical winter in the Northern Hemisphere is the period from the winter solstice (December 22, on average) to the vernal equinox (March 21). On December 22, the Northern Hemisphere is tilted as far away from the sun as it will be all year. At this time the sun is nearer to the Earth than it is in July, by about $5x10^6$ km. Winter occurs because the Earth's axis is tipped with respect to its plane of revolution around the sun.

In contrast, climatology uses four three-month periods to describe the seasons. Winter is December, January and February, the three coldest months of the year in the Northern Hemisphere. Climatological seasons or farmer's year is largely a convenient division of the calendar that facilitates the statistical analysis of weather data. There are many other arbitrary definitions of winter that relate to certain weather elements (temperature), certain events (freeze-over), or specific activities (slowdown of growth).

The table on the following pages summarizes the many definitions of winter at Edmonton. Of special note are the times and periods for the longest and shortest winters. On average, at Edmonton, winter can last between 89 and 225 d.

For most Canadians, the abundance, duration, and severity of winter's unpleasantness may justifiably be used as the criteria for answering what is winter! Each winter Canadians are resigned to a five-month indoor living ordeal. The alternative, it appears, is to deny the very existence of winter. Apparently, this is just what Winnipegers do!

"Winnipegers secretly revel in the denial of the excesses of winter. We pride ourselves a superior and hardy breed with a depth of character built on our perennial success at survival" (Vopnfjord, 1982).

Locally and globally some seasons and years are colder, warmer or stormier than others. Seventeen years ago Edmontonians received certificates for surviving a record cold winter - twenty-six consecutive days below zero (°F; -17.8°C) and that was only their fourth coldest since 1881 (103 a of record). In 1984 these same people had the balmiest January to March period on record, more than seven degrees above normal and milder than Toronto that year. Variability is a normal characteristic of climate.

Average starting and ending dates and length of winter at Edmonton for various definitions. Longest and shortest periods are given were applicable and available.

Definition of Winter	*Average*	*Longest*	*Shortest*
Astronomical	*89 d* *22 Dec - 21 March*	-	-
Climatological	*91 d* *1 Dec - 28 Feb*	-	-
Freeze-over period (ice)	*153 d* *16 Nov - 18 April*	*177 d* *13 Nov - 5 May* *1966*	*126 d* *6 Dec - 12 April* *1951*
Frost period	*225 d* *24 Sept - 6 May*	*301 d* *29 Aug 1956* *25 June 1957*	*154 d* *21 Oct 1975* *23 April 1976*
Snow season (recreational winter)	*170 d* *27 Oct - 14 April*	*215 d* *(1965-1966)*	*81 d* *(1976-1977)*
Coldest 91 day period	*91 d* *2 Dec - 2 March*	-	-
Mean maximum temperature below freezing	*122 d* *16 Nov - 17 March*	-	-
Windchill reading of 1200 (analysis from 1975-1984)	*95 d* *20 Nov - 4 March*	*145 d* *9 Nov 1976 -* *5 April 1977*	*111 d* *23 Nov 1983 -* *15 Mar 1984*

"What is Livable?"

Much has been written about acclimatization which is the process by which human beings adapt to an unfamiliar set of climate conditions and altitude changes. In the broad, popular sense, acclimatization implies adjustment to all phases of a new environment, both physical and cultural. In the narrower sense, it entails actual changes of certain bodily functions brought about by stressful environmental influences.

Western Canadians seem less affected by cold extremes than non-acclimatized persons. One explanation is that they have learned to increase their ability to conserve heat by dressing properly. But further, they have benefited from the work of some enlightened urban professionals who have begun to accept winter and work with it to plan communities that mitigate winter's extremes. Needless to say, much more can and needs to be done. There is strong evidence to suggest that residents in most climates become adjusted to the weather norms in their region. Large deviations from normal occur from time to time. It is then, when conditions get uncomfortable and stressful. For example, if it were -10°C with light snow and a wind speed of 8 km/h at Vancouver on a particular winter day, this would represent a most uncomfortable and dangerous situation and Vancouverites would be suffering accordingly. However, a similar situation in Edmonton or Winnipeg would be relatively common to most natives who are accustomed to such weather and are prepared for it.

"Classifying Canadian Winter: Winter Severity Index"

Climatologists are fond of classifying the climates of different areas using such basic elements as temperature, precipitation, humidity and insolation. Most classical schemes relate climate to agriculture and vegetation and place special emphasis on defining the boundary between climate types. Another approach is to calculate a climate index in which all the elements are individually weighted and then aggregated into a single discrete value.

In 1984, Phillips and Crowe developed the climate severity index, a human climate classification that describes in a single number many of the unfavorable (uncomfortable, depressing, confining, and hazardous) aspects of the Canadian climate. Extremeness of eighteen climate parameters, including wind-chill, humidex and length of winter/summer are combined into an index that ranges from zero to one hundred. The selection of data and the assignment of weights is arbitrary. The index has proved quite popular as a guide for those selecting the more amenable climates for recreational and retirement living, for those employers concerned about the timing of outdoor activities and performance, and for workers seeking fair and equitable remuneration for working outdoors.

The table below shows the winter climate severity index for selected metropolitan areas of Canada (ranked by order of population, 1981 census)

Population Rank	Metropolitan Area	Severity Index
1	Toronto	34
2	Montreal	47
3	Vancouver	10
4	Ottawa-Hull	46
5	Edmonton	49
6	Calgary	44
7	Winnipeg	62
15	Victoria	8
16	Regina	61

"Exaggerating Winter Severity"

Most people's perception of Canadian winter is based on the occasional newsfilm and front page story of city residents struggling against winter's latest storm. There is no question that winter, especially in Western Canada, can be long and difficult. But how frequent do these paralyzing storms occur? Do the few that occur each year present an erroneous picture of what Canadian winter is really like? To find out, an analysis was undertaken of ten years of extreme winter weather data for the airports at Edmonton International, Edmonton Municipal, and Winnipeg International. Four

extreme weather situations were identified and the frequency of a winter misery day was abstracted. A winter misery day is one with:

- *a single-day snowfall accumulation of 10 cm or more, or,*
- *at least 4 h of blowing snow between 07-18 LST, or,*
- *two or more reports of freezing precipitation between 05 and 20 LST, or,*
- *one report with a windchill factor exceeding 1900 (conditions for outdoor travel become dangerous; exposed areas of flesh freeze in < 2 min for the average person).*

The analysis reveals a surprisingly few number of days per winter with stay home weather. At Edmonton Municipal only 5% of all days between October and April have weather misery days. Outside the city at Edmonton International, 8% of the days are misery ones (a difference of ~ 6.2 d/a).

In summary, variety is the norm in the Canadian climate. This feature is especially true in winter. South of the Arctic Circle, the January mean climate map shows temperatures ranging from -33°C to 3°C, precipitation totals from 10 mm to 400 mm and sunshine durations from 0 to 110 h. Differences across Canada are not nearly as large in July. For an individual season, month, or day, the differences can be much more pronounced with particular periods one year being quite unlike that of last year. Then again, some places are regularly struck by disastrous events such as cyclones, droughts, or floods while others rarely, if ever, suffer these hazards.

The great diversity of climate necessitates some corresponding diversity in decisions that are made when we plan or design with climate in mind. Recognition and acceptance of the assets and liabilities of our diverse climate and its variability at any place from day-to-day or year-to-year is essential if we are to optimize human comfort, safety, and efficiency in our everyday activities.

Working with climate and better living with climate are perhaps best illustrated in the fields of building, energy and urban planning.

Reference Cited

Phillips D.W. and Crowe R.B. (1984) Climate Severity Index For Canadians. CLI-7-84. Atmospheric Environment Service, Downsview, Ontario, 43 pp.

As these quotes show, there are quite a few ways to define 'winter' and consequently 'cold region'. However, they mostly differ in degree, not in the general description of cold climates. We hope that these quotes provide the reader with a useful context.

Jan Boon
Chairman, ISCORD '91

PROGRAM
ISCORD '91

All events (unless otherwise noted) will take place at the Convention Centre, Edmonton, Alberta.

SUNDAY, JUNE 16

14:00 - 21:00 Registration (Room 7)

19:00 - 21:00 Welcome the World Reception (Rooms 8,9&10)
(A casual reception featuring hot and cold hors d'oeuvres, beer, wine and soft drinks. Come and have your picture taken with a member of the Royal Canadian Mounted Police and mark on our World map where you are from.)

MONDAY, JUNE 17

07:00 - 0:800 Speakers' Breakfast
(For Monday's speakers only; Room 1)

07:30 - 16:00 Registration (Room 7)

08:00 - 09:00 Opening Plenary Ceremonies (Room 4)
- Alberta - *Honorable Fred Stewart, Minister of Technology, Research and Telecommunications*
- *Honorable Fred Bradley, Chairman of the Board, Alberta Research Council*
- Japan - *Mr. Naohiro Dogakinai, President, Hokkaido Development Engineering Centre, Hokkaido, Japan*
- China - *Professor Zhu Dianming, Chairman, Science and Technology Commission, Heilongjiang Provincial Government*

09:00 - 10:00 Keynote Speaker: *Dr. Emlyn H. Koster, Director, Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta*
"Reflections on Alberta's Prehistory"

10:00 - 10:20 Refreshment Break (Foyer)

10:20 - 12:00 Technical Sessions
A. The Land and Renewable Resources: Crops I (Room 3)
B. The Environment and its Protection: Climate I (Room 2)
C. Transportation: Roads and Bridges I: Alberta (Room 4)
D. Building Design: Design I: Canada (Rooms 5 & 6)
E. Construction, Energy and Planning: Materials I (Rooms 17 & 18)

12:00 - 14:00 Luncheon - Rooms 8,9&10 - "A Northern Noon Experience"
sponsored by the City of Fort McMurray, Syncrude, Suncor and the Chamber of Commerce of Fort McMurray
(A northern menu is featured at this luncheon. Entertainment and exhibits feature the 'north' and the native community.)

14:00 - 16:00 Technical Sessions
A. The Land and Renewable Resources: Wildlife (Room 3)
B. The Environment and its Protection: Climate II (Room 2)
C. Transportation: Roads and Bridges II: Finland and China (Room 4)
D. Building Design: Design II: Finland (Rooms 5 & 6)
E. Construction, Energy and Planning: Materials II (Rooms 17 & 18)

18:30 - 22:00 Western Barbecue at Fort Edmonton Park
"Transportation Through The Ages"
- *sponsored by Alberta Transportation and Utilities*
(Wear all your casual western wear...blue jeans, cowboy hats etc. for this steak dinner... you'll enjoy real western hospitality here. Alberta's Blue Northern Dancers are set to entertain you.)

TUESDAY, JUNE 18

07:00 - 08:00 Speakers' Breakfast
(For Tuesday's speakers only; Room 1)

08:00 - 16:00 Registration (Room 7)

08:00 - 08:40 Plenary Speaker: Mr. Makoto Niiyama, Director of Road Construction Division, Hokkaido Development Bureau, Hokkaido Development Agency, Prime Minister's Office of Japan - "Comprehensive Development Plan of Hokkaido and 'Fuyu-topia' Program". (Room 4)

08:40 - 10:00 Technical Sessions
A. The Land and Renewable Resources: Livestock (Room 3)
B. The Environment and its Protection: Pollution Abatement I (Room 2)
C. Transportation: Roads and Bridges III: Japan (Room 4)
D. Building Design: Environmental Aspects (Rooms 5 & 6)
E. Construction, Energy and Planning: Pipelines I (Rooms 17 & 18)

10:00 - 10:20 Refreshment Break (Foyer)

10:20 - 12:00 Technical Sessions

A. The Land and Renewable Resources: Crops II (Room 3)

B. The Environment and its Protection: Pollution Abatement II (Room 2)

C. Transportation: Roads and Bridges IV: Canada (Room 4)

D. Building Design: Design III: Canada (Rooms 5 & 6)

E. Construction, Energy and Planning: Pipelines II (Rooms 17 & 18)

12:00 - 13:50 Luncheon sponsored by Hokkaido Development Engineering Centre (Rooms 8,9&10)

13:50 Technology Showcase Official Opening (Rooms 11 and 12)

14:00 - 17:00 Technology Showcase (Rooms 11 and 12)

14:00 - 17:00 Technical Tours (Buses for the technical tours will depart and arrive from the upper level (front) entrance to the Convention Centre)

I. Alberta Research Council, Mill Woods, (Biotechnology, Forestry, and Manufacturing Technologies departments) and the Centre for Frontier Engineering Research

(The Alberta Research Council is a crown corporation of the Province of Alberta, with 600 employees, offering a diversified range of scientific, engineering and technological research and testing capabilities. Your tour of the Alberta Research Council's main laboratory and headquarters building will include the Forestry Department's panel development laboratory and its panel testing laboratory, a view of the Biotechnology Department's unique fermentation pilot plant and a tour of the Manufacturing Technologies Department's testing and research facilities.)

(The Centre for Frontier Engineering Research was established in 1983 as a national centre of excellence. Initially located on the University of Alberta campus, C-FER moved to its new $18 M research centre in the Edmonton Research Park in May 1990. The mandate of the organization is to conduct engineering research for the safe and economical development of frontier resources. C-FER's laboratory enables the simulation of realistic loading and environmental conditions for testing materials, structural components, and downhole systems. Laboratories include a large cold chamber (149 m^2, -60°C temperature rating), two state-of-the-art high-capacity loading systems, each capable of pushing or pulling with 15.1 MN force, and a self-contained special environments facility. The benefits of such research will be felt throughout the private sector, particularly by oil and steel companies, manufacturers of tubular goods, and a wide range of oilfield service companies. Ladies: high heels are not recommended.)

II. Alberta Research Council - Oil Sands and Hydrocarbon Recovery Department (Clover Bar) and Sherritt Gordon Limited (metal refinery and mint) (The tour of the Alberta Research Council's Clover Bar site will include the waxy crude loop, pump facility, colloid laboratories, hydrothermal geochemistry laboratories, physical simulators and the analytical laboratories. Sherritt Gordon Limited is the major local metal refiner, and a mint for coins, medals etc.)

III. Alberta Transportation and Utilities (A visit to the central testing facility and laboratory in east Edmonton to view capabilities and processes for testing of highway construction and maintenance materials. The tour will also include equipment demonstrations, both static and mobile. This aspect of the tour is aimed at materials engineers or technologists.)

IV. Alberta Transportation and Utilities (Visit to the Leduc area to observe major bridge deck repairs and preventative maintenance. The completed repairs use ELGARD Cathodic protection in pyrament concrete overlay; polymer wearing surface on high density overlay; and underside coating cathodic protection of the deck. Special tour for structural and bridge engineers.)

17:00 - 22:00 Visit to West Edmonton Mall
(Buses will take you to our fabulous mall, largest in the world, for sightseeing and shopping).

WEDNESDAY, JUNE 19

07:00 - 08:00 Speakers' Breakfast
(For Wednesday's speakers only; Room 1)

08:00 - 16:00 Registration (Room 7)

08:00 - 08:40 Plenary Speaker - Professor Zhu Dianming, Chairman, Science and Technology Commission of Heilongjiang Provincial Government. "The Development of Science and Technology in Cold Regions of Heilongjiang Province" (Room 4)

08:40 - 10:00 Technical Sessions
A. The Land and Renewable Resources: Other Topics (Room 3)
B. The Environment and its Protection: Waste Management (Room 2)
C. Transportation: Operations and Maintenance I: Japan (Room 4)
D. Building Design: Materials: Wood (Rooms 5 & 6)
E. Construction, Energy and Planning: Regional Planning (Rooms 17 & 18)

10:00 - 16:00 Technology Showcase (Rooms 11 and 12)

10:00 - 10:20 Refreshment Break (Foyer)

10:20 - 12:00 Technical Sessions

A. The Land and Renewable Resources: Other Topics (Room 3)
B. The Environment and its Protection: Other Topics (Room 2)
C. Transportation: Operations and Maintenance I: Japan (continued) (Room 4)
D. Building Design: Energy Aspects (Rooms 5 & 6)
E. Construction, Energy and Planning: Urban Studies: Japan (Rooms 17 & 18)

12:00 - 14:00 Luncheon sponsored by the City of Edmonton and the Edmonton Economic Development Authority (Rooms 8,9&10)
Guest Speaker: Ms. Jane Mandyk, L&R Wang Enterprises, Edmonton - "The Canadian Cold Buster"

14:00 - 16:00 Technical Sessions

C. Transportation: Operations and Maintenance II: Japan and China (Room 4)
E. Construction, Energy and Planning: Urban Studies: Canada and Finland (Rooms 17&18)

18:30 - 19:30 No-Host Reception (Hall C)

19:30 - 22:00 Banquet and Gala Windup (Hall C)
- sponsored by Alberta Municipal Affairs
(Dress-business attire; the Ukrainian Cheremosh Dancers are the featured entertainment.)

THURSDAY, JUNE 20

07:00 - 08:00 Speakers' Breakfast
(For Thursday's speakers only; Room 1)

08:00 - 08:40 Plenary Speaker: Professor Asko Sarja, Director of the Structural Engineering Laboratory of the Technical Research Centre of Finland - "Housing and Construction in Cold Climate" (Room 4)

08:40 - 10:00 Technical Sessions

B. The Environment and its Protection: Other Topics (Room 2)
C. Transportation: Operations and Maintenance III: Canada (Room 4)
D. Building Design: Other Topics (Rooms 5 & 6)
E. Construction, Energy and Planning: Alternate Energy (Rooms 17 & 18)

10:00 - 12:00 Technology Showcase (Rooms 11 and 12)

10:00 - 10:20 Refreshment Break (Foyer)

10:20 - 12:00 Technical Sessions

B. The Environment and its Protection: Other Topics (Room 2)
C. Transportation: Other Topics (Room 4)
D. Building Design: Other Topics (Rooms 5 & 6)
E. Construction, Energy and Planning: Alternate Energy (Rooms 17 & 18)

12:00 - 14:00 Luncheon sponsored by the Association of Finnish Civil Engineers (Rooms 8,9&10)

14:00 - 16:00 AACIP Annual General Meeting (Rooms 5 & 6)

14:00 - 17:00 Technical Tours (Buses for the technical tours will depart and arrive from the upper level (front) entrance to the Convention Centre)

V. River Valley development, the pedway system and Light Rapid Transit (LRT) facilities (This is a tour to visit developments in the river valley, the downtown pedway system linking major buildings, and the facilities of the Light Rapid Transit system.)

VI. Alberta Research Council - Coal and Hydrocarbon Processing Department (Devon) and the Keephills Power plant (This tour is designed for those interested in coal, coal processing, and open-pit coal mining.)

VII. Alberta Transportation and Utilities (Highway and bridge planning and design procedures, including computer-aided design) (This tour will visit the Design Engineering and Roadway Planning Branches. At Roadway Planning the tour will cover photogrammetry and stereo plotting, map and image processing (MIPS), location studies and design (ROADCALC demonstration), and preliminary computer drafting mainframe and pc platforms. The visit to Design Engineering will cover total stations, downloading to a PC, and PC design (EMXS) and detail drafting on Intergraph, workstation and PC platforms).

VIII. Alberta Transportation and Utilities (Visit to major bridge deck rehabilitation). (This tour will visit the North Saskatchewan River Bridge in Fort Saskatchewan. View a complete concrete deck and curb removal and replacement, deck deterioration accelerated by application of deicing salts.)

IX. University of Alberta (Ellerslie Research Station) and Alberta Agriculture Food Processing Plant (Leduc)

(This tour provides an opportunity to see two different agencies integrally related to agriculture in Alberta, located in two small towns south of Edmonton. The Ellerslie Research Station is a major research institute of the university, engaged in research and experimentation of soil, plant and animal sciences and agriculture engineering. The Food Processing Development Centre is a modern fully equipped pilot plant and product development laboratory facility with the latest equipment to develop new food products and packaging.)

X. University of Alberta Walter C. Mackenzie Health Sciences Centre and an R2000 energy efficient house

(Visit a modern, unique medical facility, which includes an HVAC system with room-specific variable air system, separate mechanical floors, a telelift delivery system, medical waste incinerator, and spectacular building design. En-route home, we will drive-by some energy efficient houses under construction in Edmonton's beautiful river valley.)

XI. City of Edmonton Municipal Airport

(The Edmonton Municipal Airport is a full service air facility and the sixth busiest airport in Canada. The tour will include a brief walk through the Air Terminal Building and an airside tour encompassing the airport to look at the two primary runway systems: Runway 16/34 (1740 x 61 m) and Runway 12/30 (1788 x 61 m). A brief overview will be provided of the Instrument Landing System, the Fiber Optic Airfield Sign Lighting System, the Airfield Maintenance Facilities as well as a brief tour of one of the Airport Managed Aircraft Hangars.)

FRIDAY, JUNE 21

08:00 - All-day Technical Tours (Buses for the technical tours will depart and arrive from the upper level (front) entrance to the Convention Centre)

XII. Alberta Special Waste Management Corporation: Swan Hills Treatment Facility

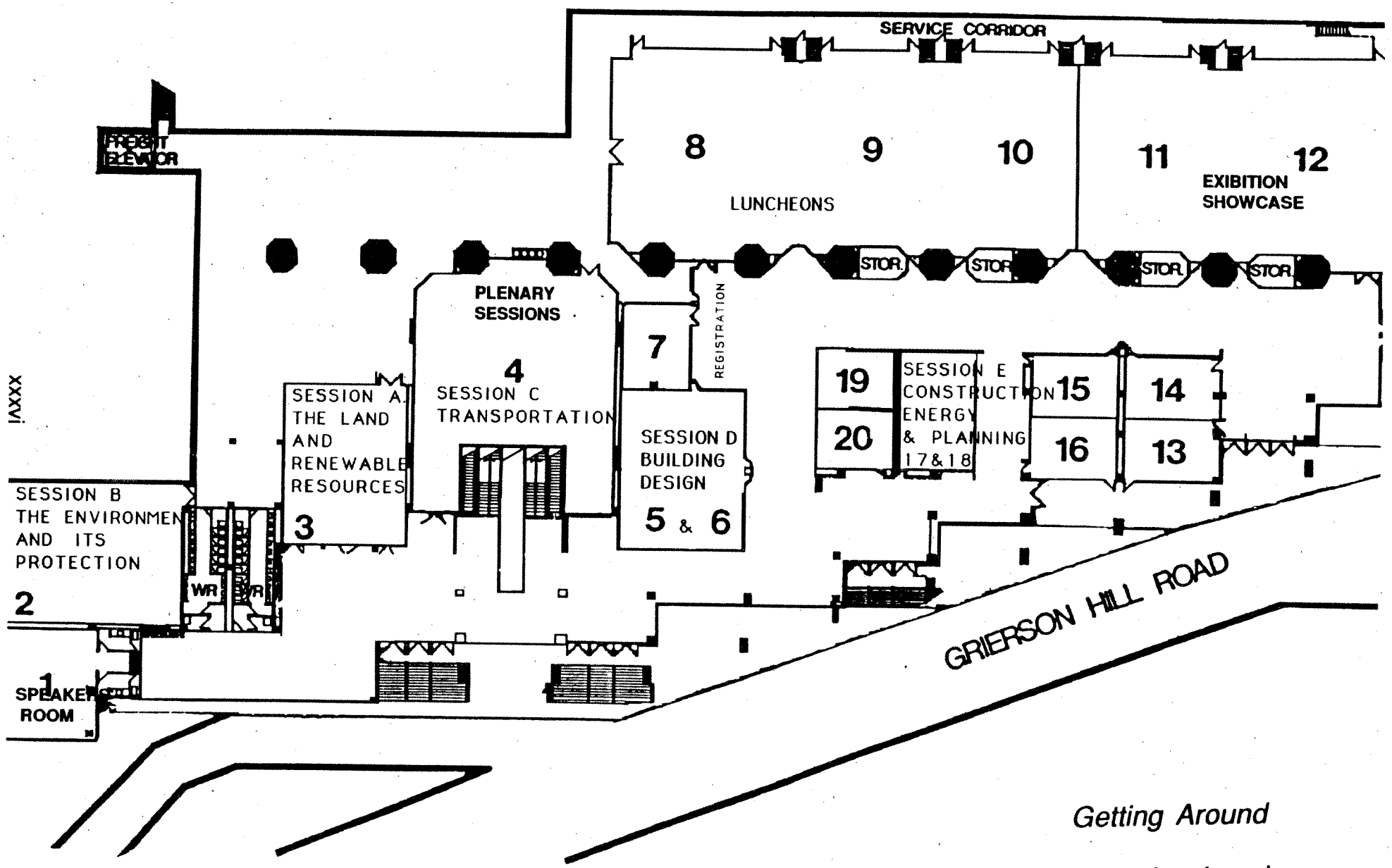
(This facility was completed in 1988, and is a zero-runoff site designed to treat the >92 kt of hazardous waste produced in Alberta annually. It includes equipment to treat both solid and liquid wastes, and a deep well disposal system.)

XIII. Alberta Environment: Alberta Environmental Centre, Vegreville

(With its four major divisions in plant, animal, chemistry and environmental technology, the Alberta Environmental Centre is an interdisciplinary research organization devoted to coping with environmental problems with a variety of expertise. This centre is newly opened and specializes in water and waste water management. A full-day tour will be very enlightening at this modern facility.)

XIV. Fort McMurray: visit to an open pit mining operation in the Athabasca oil sand deposit. (The operators will reserve the right to select applicants for security reasons).

(The Athabasca oil sand deposit is the largest accumulation of heavy oil in the world and is currently being mined using open-pit operations with gigantic equipment.)



Getting Around

The Meeting Level

EXTENDED ABSTRACTS

Reflections on Alberta's Prehistory

Emlyn H. Koster

The international image of Alberta - a large territory with low population - commonly focuses on its scenic splendour, colourful heritage and varied resources. All three features are rooted in geological history. Across the eons, there has been a constant interplay between land movement, sea-level variation, climatic change, and the evolution of life itself. For example, the layered record of rocks and fossils beneath Edmonton presents compelling evidence of ancient environmental changes from coral reefs, to shallow muddy seas, to coastal plains and coal swamps, and most recently to several advances and retreats of a continental icesheet.

In southeast Alberta, 300 to 400 km from Edmonton, there is an unusually clear "window" into the final chapter of the age of dinosaurs which ended 65 million years ago. First, this window consists of badlands which reach peak development in Dinosaur Provincial Park, designed in 1979 by UNESCO as a World Heritage Site. There, three dozen dinosaur species are represented by skeletons, bonebeds and countless fragments, buried 76 million years ago in a coastal plain under a sub-tropical climate. Second, this window is featured at the Royal Tyrrell Museum of Paleontology in Drumheller. Opened in 1985, and named after a geologist who discovered local dinosaur fossils in 1884, this is a major academic and public institution operated by the Alberta Government. Multi-media displays guide the visitor through the entire history of life on Earth, pausing to spotlight on the famous dinosaur fauna of Alberta. The Museum's initial expeditions and exhibitions have stretched around the world, most notably with China and Japan. About 20% of visitors to the Museum, averaging half a million per year, come from outside Canada.

Tourism is expected to be the world's leading industry by the end of this decade. Increasingly, motivations for our leisure travel are a mix of recreation and education. As well, business and convention trips often include opportunities to learn about the heritage of destination areas. It seems that, as society plans its future, the need to comprehend our past has never been more important. Parks and museums have a significant role to play in this endeavour.

Emlyn Koster is Director of the Royal Tyrrell Museum of Paleontology (Box 7500, Drumheller, Alberta T0J 0Y0, Canada), a branch of Alberta Culture and Multiculturalism. After obtaining a Ph.D. in geology from the University of Ottawa, and faculty positions at universities in Montreal and Saskatoon, he joined the Alberta Research Council where research projects in geology evolved a new professional interest in the public awareness of science.

Comprehensive Development Plan for Hokkaido, Japan, and the "Fuyu-topia" Program

Makoto Niiyama

The island of Hokkaido, the northernmost island of Japan, is characterized by cold winters with heavy snowfall. Over the past 120 years Hokkaido has been developed according to a national plan in order to utilize its vast land and abundant resources. The Hokkaido Development Agency, established in 1950, has been implementing these national policies.

Secondary industry is underdeveloped in Hokkaido, and so the Hokkaido Development Bureau seeks to strengthen existing industries and attract new ones.

Because the traffic system of Hokkaido is still not complete, the Hokkaido Development Bureau seeks to implement a comprehensive transport system, both extensive and of high quality, in the future. The major project in this area is the completion of the new Chitose Airport which will allow expansion into international operations. Railways are also being revitalized. In addition, the recent completion of the longest undersea tunnel in the world, the Seikan Undersea Tunnel, has given Hokkaido the opportunity to create a new economic bloc with the main island of Honshu. However, highways remain only poorly developed in Hokkaido.

The Fifth Hokkaido Development Plan aims at strengthening the economy by means of three key measures or pillars: 1. the development of vital and flexible industries; 2. the organizing of communication, information and high-speed transportation networks; and 3. creating comfortable and safe regional communities. The "Fuyu-topia" Program is an important aspect of the third pillar.

The goal of the Fuyu-topia (or winter utopia) is to overcome the negative aspects of winter and to make Hokkaido a utopia of the Northern Regions. It consists of five projects: 1. developing towns built for winter life in a cold and snow environment; 2. building model public housing which considers the quality of life in winter; 3. creating parks which provide for winter use; 4. building safe and comfortable winter roads; and 5. organizing a comprehensive inner city snow measurement system.

As one of the first measures, 'snow-flowing' gutters will be constructed to float and dispose of snow. This will ensure sufficient space for pedestrians and shoppers, and will facilitate efficient operation of both fire and rescue services, among others. Model cities will each establish a committee to devise, oversee and implement these policies. Voluntary citizen participation will be encouraged.

The second project is to create housing suitable to northern regions, and five proposals have been made: 1. houses should have a sunny space (sunroom) for relaxation; 2. they need a common gathering space; 3. there should be all-purpose meeting halls with a year-round playroom for children; 4. the availability of year-round playgrounds; and 5. safe, pleasant spaces for pedestrians, such as gangi-type gallery shelters.

The third project relates to a cross-country skiing course, with planned recreational events.

There are four planned measures in the fourth project: 1. the planting of trees as snow-windbreaks; 2. a road-weather information system; 3. parking areas where snow chains can be attached or removed from tires; and 4. additional lanes, parking areas and parking shelters during inclement weather.

The final project consists of general intra-city measures against snow.

With regard to the future of the "Fuyu-topia" Project, it is necessary to make the best use of regional energy supplies, to introduce scientific technology to winter living, and to improve city functions. The Hokkaido Development Bureau is holding symposia, meetings and trade fairs to promote the future success of the Project.

Mr. Makoto Niiyama is the Director of the Road Construction Division of the Hokkaido Development Bureau, (3 chome, 1-jo, Hiragishi, Toyohira-ku, Sapporo 062, Japan).

The Development of Science and Technology in the Cold Regions of Heilongjiang Province, People's Republic of China

Zhu Dianming

Heilongjiang Province is located in the subarctic zone. It has both a monsoonal and a continental climate with the highest summer temperature of 36°C and the lowest winter temperature in the range -42 to -40°C. The average annual temperature is ~-2 to 3°C. It is one of the regions of the world requiring further development.

Cold region development is an important research/activity of the Heilongjiang Science and Technology Commission. Three years ago, ISCORD '88 was held successfully in Harbin, Heilongjiang Province, which promotes intense development of cold region scientific research and furthers mutual understanding and friendship between the scientific and technological personnel of all countries. In the past three years, we have been working hard on cold region research. As a result, more than 80 achievements were put into practice utilizing cold region scientific and technological research. Considerable economic and social benefits have resulted.

With respect to cold region development work in Heilongjiang Province, it may be classed under: 1. agriculture; 2. livestock husbandry, poultry and aquaculture; 3. forestry; 4. energy saving technology; and 5. hydraulic and traffic engineering.

The main obstacles to agricultural production in Heilongjiang are the low temperature and injury as a result of freezing in the summer and fall, drying in the spring, and waterlogging in the fall. For these situations, the focal points of the development of cold region agriculture in Heilongjiang are as follows:

1. Seed selection of early-maturing, cold-enduring and drought-resistant varieties.

2. Use of new cultivation techniques, which have been widely applied so that the total grain yield topped 20 Mt in Heilongjiang Province for the first time in 1990.

With respect to livestock husbandry, poultry and aquaculture, the geographic and climatic characteristics of Heilongjiang have drawn attention to variety selection by means of hybridization and gene engineering, and new breeding techniques.

In recent years, Heilongjiang research and development on forestry has been mainly in the selection of fast-growing and high-yield tree seeds, planting of forests, the prediction, detection and extinguishing of forest fires, and fruit tree seed selection and fruit growing techniques.

Much research and development has been devoted to energy-saving technologies, including the utilization of energy-saving techniques in oil fields, the boiler energy-saving techniques for industry and civil usage, and technologies for saving energy in industry and construction. Success has been achieved with putting these techniques into practice efficiently.

Finally, regarding hydraulic and traffic engineering, frost heaving is still a key problem to be solved in hydraulic road, bridge and culvert engineering in Heilongjiang. After several years of research, a 'Five-grade Standard' has been set up for dealing with frost-heaving in Chinese roads, bridges and culverts which offers a scientific basis for foundation design and construction. In addition, other research has been carried out in an attempt to solve the occurrence of cracks in bituminous road surfaces caused by low temperatures in Heilongjiang. Also, the finite element method was used to set up a tension field in bituminous road surfaces to provide a guideline for road construction and material selection in Heilongjiang Province.

Research on cold region development in Heilongjiang in the future will include:

1. Cold region environment and ecology;

2. Cold region agriculture, forestry and breeding;

3. Cold region construction, hydraulic and traffic engineering; and

4. Cold region utilization of renewable energy sources and energy-saving technology.

Zhu Dianming is Chairman of the Science and Technology Commission of Heilongjiang Provincial Government (202, Zhongshan Avenue, Harbin 150001, People's Republic of China), a professor at the Harbin Shipbuilding Engineering Institute in the area of ship and ocean engineering hydrodynamics, and Vice-Chairman of the Ocean Branch of the China Society of Ocean. He is also Vice-President of the China Association of Disaster Prevention, an advisor for the China Wind Energy Development Centre and has published more than 10 papers.

The "Canadian Cold Buster"

Jane Mandyk

The "Canadian Cold Buster" is a new, high-tech cold weather nutritional snack bar which provides quick energy to help keep the body warm in the cold. It is the fruit of >15-a biomedical research conducted by scientists at the University of Alberta and sponsored by the Canadian National Defence, Canadian Medical Research Council, Natural Sciences and Engineering Research Council of Canada, and the Alberta Heritage Foundation for Medical Research. Under controlled cold tests, "Canadian Cold Buster" can significantly improve cold resistance by 40 to 50% after a single ingestion in scantily clothed people exposed to -10°C for 3 h. This is equivalent to providing the person with twice as much time to seek proper shelter or help before the body temperature reaches the dangerous level of incapacitation due to hypothermia.

The "Canadian Cold Buster" contains only natural food ingredients readily purchasable from any grocery store: milk protein, honey, complex carbohydrates such as rice and wheat starch, sugar, cocoa powder, vegetable oil, and spices. It is free of artificial sweeteners and preservatives. The formulation of these ingredients, however, is based on a novel international patent-pending formula. Each 70 g bar contains 260 calories, mostly from protein and complex carbohydrates, and little from fat. Because it is a natural food product, the "Canadian Cold Buster" is as safe as any other food product one can naturally consume. It is used as one would a nutritional snack. It may be taken either before going out to the cold or while in the cold. Generally, one bar every 2 to 3 h is recommended, but it may be taken more frequently if desired without any harm. It may be taken alone, or with coffee, tea, soft drink, or water. In its sealed pouch, it should keep up to 1 a, or even longer, at room temperature.

The danger of cold exposure is quite familiar to all Canadians. When heat production by the body cannot keep up with heat loss in the cold, the body temperature begins to fall and dire consequences, such as impairment of judgement, confusion, disorientation, and semi-consciousness, soon follow. Every year, reports of tragic incidents of cold exposure are common. The "Canadian Cold Buster" was developed to help lessen such possible incidents. Therefore, it should be useful for anyone undertaking outdoor activities in the cold; e.g. working, travelling, skiing, running, hiking, hunting, camping, or as a spectator or participant in other sports and recreational activities. It should also be useful as a preventative measure in everyone's winter safety package (along with items such as blankets, matches, candles, canned and dry foods) that are normally carried in winter travel or outings.

The physiological and biochemical responses during cold exposure are complex. To support the increased metabolic demand in the cold, the body burns more fuel, chiefly fat, along with carbohydrates. The burning of fat, however, requires a conversion process, in which the depot fat is converted to fatty acids before it can be utilized by cells. Unfortunately, this conversion process becomes a bottleneck under high metabolic demand, resulting in insufficient supply of fatty acids to cells. In addition, other biochemical constraints also come into play because of the accumulation of detrimental metabolic by-products. These combined effects result in a mismatch in fuel supply and fuel requirement, leading to an inability to sustain the high rate of heat production required to keep the body warm in the cold. Consequently, body temperature begins to fall and hypothermia may result. The "Canadian Cold Buster" contains ingredients which will do two things to the body: 1. provide a quick energy fuel to sustain the high rate of metabolism; and 2. lessen the inhibitory effect of the metabolic end products on fat conversion. Consequently, better fat conversion results and more fatty acids become available for burning by the cells to generate more heat.

Unlike taking alcohol, which makes one feel warmer but really does not add any overall physiological benefit to the heat budget, the "Canadian Cold Buster" does not give the same warm feel as alcohol. Some warmth may be felt, but the real strength of the "Canadian Cold Buster" is to help ones own physiological heat production to keep warm through enhanced and sustained muscle activities such as shivering and exercise.

Taking the "Canadian Cold Buster" in warm conditions will not make one feel hot because in the warmth, the body does not require accelerated metabolism. The quick energy contained in the "Canadian Cold Buster" will simply be processed by the body as would any other nutrient. One may feel some warmth, but certainly not hot flushes or overheating. The "Canadian Cold Buster" will be available in Canada in late 1991.

Jane Mandyk works for the inventors of the "Canadian Cold Buster", L&R Wang Enterprises Ltd. (12008 - 163 Street, Edmonton, Alberta T5V 1H4, Canada).

Housing and Construction in Cold Climates

Asko Sarja

No abstract available.

Professor Asko Sarja is the Director of the Structural Engineering Laboratory of the Technical Research Centre of Finland (P.O. Box 26 [Kemistintie 3] SF-02151 Espoo, Finland).

SESSION A
THE LAND AND RENEWABLE RESOURCES

ROOM 3, EDMONTON CONVENTION CENTRE

Monday, June 17

10:20 - 12:00 Crops I
14:00 - 16:00 Wildlife

Tuesday, June 18

08:40 - 10:00 Livestock
10:20 - 12:00 Crops II

Wednesday, June 19

08:40 - 10:00 Other Topics
10:20 - 12:00 Other Topics

Session A
Schedule of Speakers

- **Crops I**

  H.B. McEwen
  D.B. Beckman and C.A.S. Smith
  J. Maruyama and K. Fukunaga
  Li Shou-qian and Wang Ya-jun
  John G.N. Davidson

- **Wildlife**

  J. Beck, R. Bonar, R. Quinlan, A. Sikora and D. Walker
  Gilbert Proulx
  Luigi Morgantini
  T.W. McFadden
  Gao Xiao Mei
  Marta Susana Lizarralde

- **Livestock**

  Pal Prestrud
  R.J. Christopherson
  J.J. Leonard and J.J.R. Feddes
  J.R. Thompson and R.J. Christopherson

- **Crops II**

  Solomon Kibite and K.N. Harker
  Masanori Koike and Tohru Shimada
  Mohyuddin Mirza
  Qu Wenzhang, Zhu Wei, Gao Miaozheng and Bai Xianghe
  Qiao Zhihe

- **Other Topics**

  John L. Kansas
  Mohyuddin Mirza
  Ma He-Ping
  Men Qi
  Jun Dohkoshi
  Fujio Tsuchiya, Kimitoshi Ryokai and Masataka Mochizuki
  Kris Pruski, Mohyuddin Mirza and George Grainger

Agricultural Production and Food Processing in Alberta

H.B. McEwen

I welcome all the participants to the 1991 International Symposium on Cold Region Development. I trust all attendees will benefit from the opportunity the Symposium provides for sharing experiences and knowledge about "Growing, Building and Moving in a Cold Region".

The challenges of living and working in a cold climate can be daunting. We, in Alberta, probably encounter one of the harshest winters compared to many other parts of the world. I have extreme pride in what my fellow Albertans have accomplished in overcoming the limitations climate has imposed on us.

Alberta is a major producer of agricultural commodities in Canada, and more than 60% of the output is shipped out of the province, either to other parts of Canada or to the rest of the world. I am particularly gratified that Alberta has trade relations in agricultural products with almost all the countries represented in this Symposium. It is an honor for me and my Department to participate in this important conference with delegates from many nations that share the common factor of a cold climate.

I am pleased to open the session entitled "The Land and Renewable Resources". There are many difficulties associated with managing renewable resources in a cold climate. Agriculture is our most important renewable resource in this province. Alberta has developed its agricultural sector into a multi-billion dollar industry although the cold climate is a limiting factor. In 1990, Alberta farmers received more than $4.2 billion in farm cash receipts. During the same year, the value of processed agricultural products was estimated at $4.8 billion.

The topic areas that will be covered in the Land and Renewable Resources session of the Symposium will include crops, livestock, agricultural processing and wildlife. I am confident that the experts who will be presenting papers on these topics will discuss in detail and share their insights with the participants on how these activities are conducted in cold regions.

H. Benjamin McEwen is Deputy Minister of the Alberta Department of Agriculture (7000 - 113 Street, Edmonton, Alberta T6H 5T6, Canada). He is a member of the Agricultural Institute of Canada and of the Alberta Institute of Agrologists and has served as president of the Plant Food Council of Ontario and as chairman of the Edmonton branch of the Canadian Manufacturers Association.

Agricultural Capability and Production in the Yukon Territory, Canada

D.B. Beckman and C.A.S. Smith

Yukon Territory is situated north of the 60th parallel and covers a diverse area of 482,500 km^2. Within this total area, 668,000 ha of land exists with marginal agroclimatic capability to produce crops. In addition, there are 136,000 ha of land producing palatable native forage at levels of 200-700 kg/ha which is used as grazing land for domestic stock. In 1990, there were 3500 ha of cleared arable land in the territory. It is estimated that ~250 additional ha/a are being cleared in preparation for production.

Predominant soils for agricultural use are Eutric Brunisols (mildly weathered forest soils), and some Cryosols (soils underlain by near-surface permafrost). These soils are deficient in available plant nutrients. The southern and central Yukon has a semi-arid sub-arctic continental climate. At Whitehorse the mean annual temperature is -2°C, and the average annual precipitation is 250 mm. In the agricultural regions of the territory there are 900-1000 growing degree days (>5°C) and a frost-free period of 80-90 d.

The 1980s brought about the initial establishment of an agricultural industry in the territory. There are now >200 farm operations in the Yukon including full-time and part-time ventures. Most of the cultivated land is devoted to the growing of grass forage (primarily *Bromus inermis* var. *carleton*). Cereal crops of barley, oats, and fall rye are produced on a limited basis. A total of 50 ha are now in market garden production. The main vegetables being produced are carrots, cabbage, turnips, broccoli and cauliflower. Commercial greenhouse operations are also expanding and there are now ~10,000 m^2 in greenhouse production. The main crops being produced are tomatoes, cucumbers, bean sprouts and lettuce, in addition to bedding plants. Game farming, principally elk (*Cervus canadensis*) and reindeer (Rangifer tarandus) is the main form of livestock production. Both livestock and poultry sectors will increase substantially with the planned construction of an abattoir in the territory.

It is estimated that the value of cultivated farm land, buildings and equipment is now >$28M. Value of agricultural production is $3.2M which represents <5% of the total value of agricultural products consumed in the Yukon. Limitations to the growth of the industry are associated with scarce available capital, lack of infrastructure, as well as lack of policies and regulations related to marketing and distribution.

The agriculture industry is experimenting with innovations related to indigenous seed production, game farm handling facilities, clearing and cultivating land on permafrost, as well as greenhouse design and construction. The agriculture industry in the territory will continue to develop and expand, relying on technology developed within the territory as well as technology transferred into the Yukon from appropriate regions of the world.

David Beckman is the Director of the Agriculture Branch, Department of Renewable Resources, Yukon Territorial Government (Box 2703, Whitehorse, Yukon Y1A 2C6, Canada). He has several years experience in developing agriculture in the Yukon as well as in Africa. He has worked for the Canadian International Development Agency as well as the Food and Agriculture Organization of the United Nations. His main professional interests are developing agriculture in regions that present a climatic, social and economic challenge.

Scott Smith is the head of the Agriculture Canada Soil Survey Unit (Box 2703, Whitehorse, Yukon Y1A 2C6, Canada). He is currently president of the Alaska Society of Professional Soil Scientists. His professional interests include permafrost-affected soils, agronomic capability assessment and paleopedology.

Establishment of Early Winter Seeding of Forages in Eastern Hokkaido, Japan

J. Maruyama and K. Fukunaga

Eastern Hokkaido is located in the southern end of the subfrigid zone. It has a very cold winter, although the summer is reasonably warm and humid. The annual temperature ranges between -25°C and 30°C, averaging ~7°C in Obihiro. The precipitation averages ~900 mm/a. Soil freezing is very common in this area. Therefore, there is general agreement among researchers that forage seeding in eastern Hokkaido must be confined to spring, summer and early fall. But the success of seeding is highly dependent upon the moisture content of the soil, e.g. in some years in eastern Hokkaido grassland cannot be successfully established due to drought damage by *Tokachiharukaze* a local name for special winds in the Tokachi Plain experienced during spring time. Hence, we were very interested in studying the effect of late fall (dormant) seeding (practiced in Alberta, Canada) that ensures germination early the following spring, so that young seedlings can take advantage of moisture from the winter snowfall.

The objectives of this study were: 1. to determine the effect of seeding date on the establishment and survival of forage grasses and legumes as compared to traditional spring-sown plots; 2. to compare the early growth of two grass species that were sown in early winter and spring; and 3. to determine the range of seeding date of legumes on the grass swards in the following spring.

From the results of these studies, the following conclusions can be drawn regarding the importance of grass/legume establishment in Hokkaido:

1. Seeding grass from early winter until freeze-up helps to ensure germination early the next spring, so that the young seedlings can take full advantage of moisture from the winter snowfall. However, legume seeding is recommended from late April to the end of May.

2. Just after surface sowing of legumes on the grass swards established in spring, it is desirable to roll the soil so as to cover the seeds and to prevent water loss from the soil. This will ensure moisture for the seeds in the dry period following seeding.

Junkoh Maruyama is an associate professor at Obihiro University of Agriculture and Veterinary Medicine (Inada-cho, Obihiro, Hokkaido 080 Japan). He has published >60 papers and consultant reports in the field of grassland science.

Kazuo Fukunaga is a professor at Obihiro University of Agriculture and Veterinary Medicine. He has published >80 papers and consultant reports in the field of grassland science.

The Advance and Practice of Scientific Prediction of the Potential Productivity of Spring Wheat in the Frigid Area, North of Qilian Mountain, China

Li Shou-qian and Wang Ya-jun

The long and narrow zone with an elevation of 1700-2600 m at north of Qilian Mountain in northwest China is called the cool and irrigation spring wheat region to the north of Qilian Mountain in the Hexi Corridor of Gansu. It is a part of the spring wheat region in the frigid area of northwest China and the ancient Silk Road. In this region spring wheat is the main food crop. During the period 1980-1990, scientific inspections and experimental research revealed that four factors limit the level of spring wheat production: they are extensive cultivation, lack of soil fertility, a dry climate and field weeds. Production was lower before 1980.

The average yield for spring wheat was only 2767.5 kg/ha, or only 41% of the yield (4527 kg/ha) in the Hexi flatland irrigation region with an elevation of 1300-1700 m. But there are many advantages in this region. 1. The sunlight and heat are more abundant and better coordinated. 2. The precipitation is slightly more than that of the Hexi flatland irrigation region. 3. Damage from xerothermic wind is slight or absent. 4. The content of soil nutrition is higher than in the Hexi flatland irrigation region. 5. The amount of fertilizer application is lower and the objectives of high-yield and benefit can be realized by increasing the amount of fertilizer applied. 6. The damage from wheat aphid and wheat yellow dwarf is lower. 7. The typical height-yield models and advanced experiences have been created by experimental research. So there is tremendous potential for producing spring wheat in this region, especially where the elevation is 1800-2300 m and irrigation can be ensured; the disadvantages are fewer than in the region where the elevation is >2300 m or <1800 m. According to the above advantages, it is suggested that an irrigated sub-region with elevations of 1800-2300 m would become the high-yield zone for wheat in Gansu, and the second high-yield region of wheat in China, being only less productive than Qinhai-Zizang plateau. From 1983-1990, field tests were carried out to change the producing conditions, decrease the areas planted with wheat, rotate the crops, and develop practices to create high yields. The crop population was limited appropriately and an earlier growth period obtained in 70,000 ha covering 13 counties or cities in this region. The results indicate that the average yield of 10,000 and 70,000 ha areas for spring wheat reached 5115 and 4795.5 kg/ha, respectively, which increased 49.3 to 36.6% above that before the experimental demonstration. Typical high-yield models have an average yield of 7500 kg/ha in large areas and 10,500 kg/ha in small areas. These results have proved the reliability and applied values of scientific prediction. It is estimated that the average yield of spring wheat in this region will probably reach >6000 kg/ha in future years. So this region is an important leader for the development of spring wheat production in the frigid area of northwest China. To speed up the development of spring wheat production, cooperation with governments and scientists from all over the word is desired.

Li Shou-qian is the director at the Grain Crops Research Institute, Gansu Academy of Agricultural Sciences (Liujiabu, Lanzhou Gansu, China) and an Associate Professor. he has been engaged in research on the breeding and culture of wheat for ~30 a. He has won a national award and several provincial and departmental awards and published more than 20 papers. he is presently a member of an experts consultive group for wheat.

Wang Ya-jun is with the Gansu Academy of Agricultural Sciences (Liujiabu, Lanzhou Gansu, China).

Climate and Fruit Crops in the Northern Canadian Prairies

John G.N. Davidson

Existing Fruit Production in the Prairies. Strawberries and saskatoons (*Amelanchier alnifolia)* are currently grown commercially as principal fruit crops across the northern Canadian prairies. Secondary fruit crops, usually grown as a smaller part of strawberry or saskatoon operations, include raspberries, apples, red and black currants, gooseberries, plums, and several species of sour cherries. Commercial picking of wild berries exists in the Northwest Territories, primarily of blueberries *(Vaccinium* spp.), and commercial management of natural wild blueberry stands has been initiated in northern Saskatchewan.

Marketing. Most fruit growers sell their fruit through U-pick, farm gate or farmers' markets; and super markets are increasingly willing to sell locally grown fruits. No crop is big enough for regional or prairiewide shipments yet, but one cooperative has been started and a processing plant built to do that for saskatoons. Grade 1 saskatoons are shipped annually to major hotels in the Edmonton area, and have been test-shipped successfully to Ottawa and Vancouver. Companies in Europe and Japan have requested sales contracts. Saskatoon, raspberry and rhubarb wines are selling in Japan and have recently won international awards for Lewis Bros. Winery in Grande Prairie. Test shipments of late strawberries to the west coast were also successful. In other words, a commercial fruit industry, as opposed to cottage-type operations, is beginning to develop for the first time in the prairies.

New Technology. Recent developments in trickle irrigation and fertigation have made it possible to grow fruits almost anywhere in the prairies, whereas previously growers were restricted to the mostly narrow valley bottoms of large rivers, to areas with water wells with exceptional quality and quantity of water, or to small acreages around dugouts. Developments in tissue culture propagation and mechanical harvesting have made it possible to grow substantial acreages of saskatoons. These technologies are being adapted to other bush fruits.

Winter Survival. This is the overriding factor limiting all perennial crops in the prairies, but it is not a simple factor of minimum temperature or duration. Summer management, fall acclimation, mid- and late-winter warm spells, soil moisture, and, close to the mountains, chinook winds -- all make critical differences for at least some species or some cultivars. Nevertheless, usable cultivars have been developed for all fruits mentioned above, often by incorporating hardy germplasm from native species, although further improvements in cultivars and related agronomic studies are needed in all cases to improve commercial production.

Plant Hardiness Systems. Existing plant hardiness/climate classification schemes are not useful for making local cultivar recommendations to growers in the Peace River region of northern Alberta and British Columbia. Most schemes treat this area as a uniform zone, which is unrealistic, whereas the Agriculture Canada system, although usable in principle, has a map that is highly inaccurate for this region (and most other northern areas).

A New Empirical Hardiness/Climate Scheme. Accordingly, species and cultivar survival and vigor data were collected on a district by district basis for several years from a variety of sources including direct observation, records of longstanding nurseries and orchards, a questionnaire to growers in all major districts of the region on currently used cultivars, and direct verification wherever possible. Additional information was obtained from records of numerous trials and from the landscaping at the Beaverlodge Research Station (BRS). Three major zones (the main plateau, the northern plains, and higher elevations) and 3 subzones (the chinook belt, deep valley heat traps, and transitions from low to higher elevations) were distinguished for which different recommendations can be made.

A preliminary map of the zones was prepared with the help of physiographic and meteorological data. Two lists of recommended cultivars - fruits, vegetables - were published as BRS bulletins, available on request, and a third is in preparation on woody ornamental and windbreak species and cultivars.

Conclusions. Excellent quality fruit can be grown in the prairies, and with recent technology, commercial yields can also be obtained for some of them. However, much needs to be done in the areas of market development, fruit processing and handling, and grower training before fully-fledged fruit industries will be achieved on the prairies.

John Davidson is a research scientist in plant pathology with Agriculture Canada (Agriculture Canada Research Station, Box 29, Beaverlodge, Alberta T0H 0C0, Canada). Interest in the effects of climate on the intensity and geographic distribution of plant diseases and on the interactions between disease and plant survival, plus the needs of northern fruit growers, led to agronomic research and cultivar development work with the native bush fruit, saskatoons, plus some work on strawberries, raspberries, apples and some types of sour cherries. All this led to work on a new empirical and practical hardiness/climate scheme, and recommended varieties.

A Method for Integrated Management for Wildlife and Fibre in the Boreal Forest of Alberta, Canada

J. Beck, R. Bonar, R. Quinlan, A. Sikora and D. Walker

This paper reports on an operational method under development to predict, over time, the potential population carrying capacities (based on habitat) of all species of wildlife on an area subject to fibre extraction. This system permits managers to predict, prior to actual harvest, if a harvesting plan will endanger the population of any species and, if so, to propose alternate harvesting strategies to ameliorate the problem. As well, for specified species, desired target population goals can be set and then the model can be used to see: 1. what harvesting pattern, in terms of amount and timing, might achieve that species population goal; and 2. the effect of that harvesting pattern on all other species.

The model is currently operational for sixteen species and is tied to the timber supply model used by the Hinton Division of Weldwood of Canada. It uses the Habitat Suitability Index concept developed by the U.S. Fish and Wildlife Service (Schamberger *et al.*, 1982) to predict available habitat at 5-a intervals into the future based on predictions of the future forest inventory which are projected by the timber supply model.

Results, thus far, have shown it to be not only a powerful decision-making aid for management, but also a powerful tool to help direct future inventory and research expenditures to solve problems of inadequate data knowledge and inadequate knowledge of species/habitat relations.

Reference:

Schamberger M., Farmer A.H. and Terrell J.W. (1982) Habitat suitability index models: introduction. U.S. Department of the Interior, Fish and Wildlife Service, Rept. FWS/OBS-82/10.

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Trapping Wild Furbearers - Is There a Future?

Gilbert Proulx

Presented by Michael Badry

The fur industry has played a major role in the exploration and development of Canada. Indeed, for several centuries, it provided Canadians with the money, food and clothing required to survive long harsh winters. However, during the last 60 a, urbanized societies have given birth to animal activist groups which claim that wild furbearer trapping is unnecessary and cruel, and is doomed to disappear.

Anti-trapping organizations do not realize how important wild furbearer trapping still is for some communities. In the northern regions, where there is a lack of alternative employment opportunities, trapping remains a major industry. It provides the aboriginal people with large quantities of nutritious meat and the necessary cash to support their traditional lifestyle. In less remote areas, trapping is necessary to control some furbearers, such as muskrat and beaver, which can overpopulate and overutilize their habitat. Trapping is needed in agricultural areas to remove predators (e.g. coyote, red fox, weasel) that cause significant economic losses. Trapping is needed in urban areas to remove nuisance animals (e.g. racoon, squirrel) which damage private and public properties. Finally, in urban and wilderness areas, trapping is sometimes required to reduce diseased furbearer populations to a level that will not facilitate the spread of the disease to other wild and domestic animal populations.

Wild furbearer trapping is definitely needed and if tomorrow the fur industry had to disappear, more wildlife officers and pest controllers would be hired to play the role of trappers. However, wild furbearer trapping, be it carried out by trappers or wildlife officers, will still remain a source of societal concern unless the issue of cruelty is properly resolved. In 1985, the Fur Institute of Canada and the Alberta Government initiated a unique research program in Vegreville to address this concern. For 4-a the program operated out of the Alberta Environmental Centre (Alberta Environment) and since 1989 out of the Alberta Research Council.

In order to be humane, a killing trap must have the potential to generate a high energy level. It must consistently strike the animal in a vital region. It must be expected, at a 95% confidence level, to render >79% of all target animals irreversibly unconscious within 3 min. These requirements must be met in both simulated environments and on traplines. This testing is the most discriminating process known in the research of humane traps. It resulted in the development of several humane killing systems for marten, mink, fisher and arctic fox. The Vegreville researchers also defined a humane live-holding device as a trap that can be expected, at a 95% level of confidence, to hold >79% of all animals for 24 h without serious injury. Their work resulted in the development of a humane live-trap for raccoon. Most of these types of traps are now manufactured and as they become available to trappers and wildlife officers, the issue of cruelty in trapping will hopefully taper off.

There is a future for wild furbearer trapping. This future depends greatly on the maintenance of sound research projects, proper public and trapper education programs, and the recognition that human beings are part of a functioning environment.

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Pipeline Construction and Wildlife in Alberta, Canada: Impact and Mitigation

Luigi Morgantini

The potentially negative impact of pipeline construction on wildlife populations is a concern to wildlife biologists and managers. Major impacts may include habitat destruction, altered distribution caused by the disturbance associated with traffic and construction activities, increased legal and illegal hunting pressure along an improved road system, and the creation of barriers (e.g. snow and dirt berms) to normal animal movement patterns.

During the 1980s, the response of wild ungulates to the construction of four underground gas pipelines was monitored; three in the boreal forests of west-central Alberta (Nova Corporation and Husky Oil) and one on a mountain ridge in the Rocky Mountains of southwestern Alberta (Shell Canada Ltd.). The main objectives of the studies were to assess the impact of construction and to assist the companies in identifying and minimizing any potential conflict. These studies required continuous field monitoring of animal movements during construction.

Prior to construction, in addition to the destruction of wildlife habitat, concerns were expressed about the following: 1. the disturbance associated with pipeline construction activities during critical periods (e.g. winter, calving or lambing areas); 2. the overnight presence of open trenches across wildlife ranges; 3. the presence of pipe strung along the pipeline corridor; 4. the presence of slash and dirt berms along the corridor after backfilling and prior to reclamation; 5. the extent of the area affected at the same time by construction activities (from trenching to backfilling); and 6. the creation of vehicular access (along the pipeline right-of-way) in wildlife ranges previously undisturbed. The oil companies addressed these concerns by committing to and adopting various mitigative measures such as the selection of appropriate construction schedules, the creation of openings at crossing sites, access control and removal after construction, reclamation to protect and enhance wildlife habitats, and continuous wildlife monitoring during construction.

Continuous monitoring of animal movements in the field indicated that construction activities did have an impact on animal movements and distribution. However, the impact was significantly minimized by maintaining a very tight construction schedule, particularly in wildlife sensitive areas, and by the presence of openings in berms and pipe strings. After reclamation, Husky Oil and Shell Canada Ltd. were effective in removing vehicular access either by using slash and debris on the pipeline right-of-way or by installing locked gates. Of particular interest is the exemplary approach taken by Shell Canada Ltd. during the construction of a pipeline on a mountain ridge in southwestern Alberta. Due to concerns about the impact on bighorn sheep and newborn lambs, the company proposed, committed to and implemented a construction schedule during which no open trench was left overnight. Every day, while a section of the trench was dug out, sections of pipe were welded together in another location. When the trench was completed, the welded sections were moved and laid in it. The trench was then backfilled. Throughout construction, animal movements were continuously monitored by a biologist. Construction activities were temporarily interrupted whenever some animal approached the right-of-way to cross it.

During the construction of these four pipelines, the on-site availability of an independent qualified ungulate biologist allowed site-specific mitigation by identifying potential conflict areas and unexpected impact. Further, the biologist, acting as a liaison between Fish and Wildlife Government officials and the oil companies, gave field construction personnel the flexibility to implement mitigative measures only when really needed.

In conclusion, the impact of pipeline construction on wild ungulates can be mitigated significantly. Adequate mitigative measures, combined with continuous wildlife monitoring in wildlife sensitive areas during the construction period to detect site-specific impacts, can result in industrial operations that may ultimately benefit some wildlife species by creating additional habitat.

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Adaptions in Intensive Trout Culture Facilities to the Alberta Climate

T.W. McFadden

Frigid winters, cold (0-6°C) groundwater, undeveloped compensating technology, and available American trout and eggs long curtailed intensive trout culture in Alberta. By the late 1960s, however, modern recirculation technology had been developed. Concurrent rapid population growth and public focus on leisure placed immense pressure on fish stocks. Pothole trout pond development mushroomed. The old 'make-do' trout culture philosophy was unsatisfactory. Between 1969 and 1972 an ultramodern enclosed recirculation fish hatchery, Sam Livingston, was designed, built and opened. Initially plagued by problems of new construction and technology, the hatchery increased production annually until 1977 where it peaked. Circulating water flows (<1000 l/s, 10% make-up) held at a constant 9-11°C permitted hatching, rearing and planting 54,000 kg of trout per year. The old systems produced 22,000 kg/a, with inadequate growth and flexibility of species diversity, and no environmental control.

Concern for the spread of serious trout and salmon diseases to clean Canadian stocks resulted in the introduction of the Fish Health Protection Regulations in Canada in 1977. The supply of imported eggs to Alberta became uncertain, and Alberta trout egg production was necessary to assure continuity of trout eggs. Two brood trout egg stations were constructed. The first, Raven, in 1978 operated using surface water in summer and groundwater in winter. A second station, Allison, was constructed in 1980 using only surface water.

Egg production and quality proved unsatisfactory at both stations due to wide fluctuations of water temperature (diurnally and seasonally) and periodic water quality problems. Allison was converted to a groundwater fed and heated recirculation facility in 1984. It has since operated at 8-10°C with 20% make-up per cycle. Brood operations now have normal fecundity, egg size and survival for brown (*Salmo trutta)* and brook (*Salvelinus fontinalis)* trout. At Raven three brood sheds were converted to using groundwater in separate modularized heated recirculation systems in 1987, 1988 and 1989. This facility has since operated at 8-10°C with 10% make-up per cycle. Rainbow trout (*Oncorhynchus mykiss*) egg production at Raven has also increased significantly but egg quality remains subnormal. Work is ongoing to clarify the source of the deficiency, suspected to be either the lower level of make-up water or a less than effective bio-filter system.

Wastewater effluent from a fossil-fuel electric generating station has been adapted to supply water for a seasonal trout grow-out station. Between November and May, the Sundance facility rears 200,000 16+cm yearling rainbow trout from 5 cm fingerlings. Growth is faster than at other provincial facilities because of the higher average water temperature (11-14°C). Gravity in/outflow maximizes the cost of operations (November-April) but limits environmental control.

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Wildlife Management and Conservation in Heilongjiang Province, People's Republic of China

Gao Xiao Mei

According to a census taken several years ago, Heilongjiang has 488 species of terrestrial vertebrates, including 374 species of birds (31.5% of the total number 1186 in China), 89 species of mammals (20.8% of the total 428), 11 species of amphibians (3.7% of the total 298), and 14 species of reptiles (4.7% of the total 299). Compared with other provinces, Heilongjiang is characterized by a greater number of wildlife species, a higher yield, and fur of a higher quality. Among the species present, 26 are in the national protected animals list (17% of the total) and 30 species are furbearers. Eighty one species are animals of medical use, most of which are of important economic value, constituting a valuable resource for the development of agriculture, forestry, animal husbandry, sideline production and fisheries. Rare and precious animals in Heilongjiang, some found only in this province, include the northeastern tiger, the red-crowned crane, sable, otter, sika deer, elk, moose and the siberian white crane.

Since 1980, regulations and rules have been formulated and the following measures taken: 1. a province-wide census of wildlife resources and their division into districts was carried out, and data on the fauna, especially the distribution of endangered and rare animals, their ecology and quantity, were collected; 2. in different ecological zones, 30 nature reserves were established, among which 15 have a total area of 610,063 ha, amounting to 1.3% of the total area of Heilongjiang. Examples include the "Kingdom" of the northeastern tiger (the Qixinglazi Nature Reserve) and the "Paradise" of the red-crowned crane (the Zhalong Nature Reserve); 3. the Northeast Forest University, Harbin, Heilongjiang, is the only Department of Wildlife in China, educating special technologists for the conservation and management of wildlife for the whole country. The Heilongjiang Wildlife Research Society was also established; 4. publicity and popular science studies on the value of wildlife to human life and the significance of conservation are carried out in many ways, such as in newspapers, magazines and museums, and by radio broadcasting. Annually, the fourth week of April was declared as Provincial Bird Loving Week and November as the Wildlife Conservation Propaganda Month; 5. two scientific research wildlife institutes were established in the province. Scientific research on conservation and breeding of endangered animals are also carried out in zoos, and in nature reserves such as that for the red-crowned crane at Zhalong Nature Reserve; the survival rate of cranes in captivity reached 95.3%. A Breeding Center for Felidae was established in 1985, for the breeding and conservation of northeastern tigers, the number of which in captivity has now reached nearly 60 with the aim of releasing them back to nature in the future.

However, in recent years, as a result of serious damage to the natural environment and ecological systems, nearly 10 species of precious animals including the northeastern tiger and the red-crowned crane, have been declining rapidly, their area of distribution has been reduced, and they are close to extinction. This shows that laws and administrative measures should be strengthened in order to perfect the existing conservation regulations, and to work according to the laws so that any violation to the laws may be corrected; the fund for the development and construction work for the conservation of wildlife resources must be listed in the yearly budget of the development plan of the national economy of the provincial government. Propaganda, education and popular science work should be strengthened. A Heilongjiang Nature Museum should be founded in the near future; 15 nature reserves comprising a total of 750,295 ha or 1.6% of the total area of Heilongjiang, is already planned and should be established as soon as possible. They include the Yongxing Nature Reserve for the northeastern tiger, and the Longgu Mountain Nature Reserve for dinosaur fossils. The allocation of a special fund for scientific research into the breeding and acclimatization of endangered animal species in the province, and applying new biotechnology and other modern technologies in this research is also needed. All this is in addition to enlarging cooperation with international organizations for wildlife conservation and management.

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Current Situation of the Beaver Population *(Castor Canadensis)* Introduced into Tierra Del Fuego, Argentina

Marta Susana Lizarralde

The Archipelago of Tierra del Fuego is at the southernmost tip of the South American continent and the Andes mountain range (52-56° S latitude). Insularity and the Antarctic influence result in a cold-temperate climate. The vegetation pattern is dominated by *Nothofagus* forests with bogs of *Sphagnum* and *Carex*. A population of 25 beaver pairs *(C. canadensis)* was introduced in the Claro River forty years ago. As exotic species, the Canadian beaver successfully adapted to the fueguian system. Its introduction meant the addition of a natural agent that is modifying the interactions within the forest ecosystem. Suitable feeding and lodging conditions and the lack of natural predators and competitors favoured its successful adaptation. But, the beaver is also important economically because it is suitable to intensive management. In 1981 the Argentine government authorized a beaver hunt to control its increase. Without previous information on the beaver ecology in Tierra del Fuego the hunt created problems. Since 1988 a beaver study has been carried out to provide information on the current situation of the beaver populations and also to analyze the effects of any alteration to the forest. The history of beaver establishment and occupancy patterns in the period 1946 to 1990 was analyzed from aerial photographs, surveys and a census over the Argentina sector of the Isla Grande. Current beaver population was estimated to be between 30,000-50,000 individuals with a geographical range of ~20,000 km^2. Nearly all beaver habitats from the Isla Grande and other islands of the Archipelago are classed as aquatic.. A land classification system was developed to estimate the current capacity of the habitats colonized by the beavers. Four classes (A, B, C and D) were selected to be used in planning and resource management, in order of their suitability as habitats for beaver populations. Densities in classes D and C (4-5 colonies/km^2) are really high compared with comparable densities in the northern hemisphere. Classes D and C are suggested as top priority for beavers because not only are they more suitable and assure resource abundance and preservation of the beaver population but they are the best areas for timber exploitation in Tierra del Fuego. Both classes (D and C) are suspected to be near current capacity. The main effects of alteration of the environment by beavers were detected in uplands and wetlands of the *Nothofagus* forest. Ponds constructed by beavers during their first decades of occupancy have the greatest impact on the landscape. A census of beaver colonies showed that the population has increased during the last decades. These changes could have resulted in a substantial increase in available forms of N and C as well as their redistribution across the landscape. It is specially important to understand the dynamics of beaver impoundments in Tierra del Fuego in order both to begin to understand the role of the beaver in the southern ecosystem, and to compare the contrasting effects of beaver in the boreal forest.

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Eco-Political Factors Affecting the Management of Wildlife in Svalbard and the Northern Barents Sea

Pal Prestrud

The Svalbard archipelago is situated in the high arctic midway between Greenland and Siberia at the northwest corner of the large continental shelf extending north of the Norwegian mainland. This shelf is assumed to contain large amounts of hydrocarbons. The waters above the shelf, known as the Barents Sea, have large ongoing fisheries conducted by several nations. In the SE corner of the Barents Sea, the USSR has its largest naval base. Warships headed for the North Atlantic pass between Svalbard and the Norwegian mainland. Consequently, Svalbard and the Barents Sea have both large military and economic significance.

In biological terms, this area is one of the richest in the Arctic region. This is a consequence of a relatively warm climate for such a high latitude, and an especially productive marine ecosystem. Probably >10 million sea birds breed on the land areas adjacent to the Barents Sea. In ice covered waters, there are high densities of polar bears and marine mammals. In some respects, the terrestrial ecosystem in Svalbard is an extension of the marine ecosystem of the Barents Sea, because the high number of sea birds fertilize the vegetation and increase the primary production. The northern part of the Barents Sea with adjacent land areas have the most original ecosystems left in Europe. Protection of the wildlife here is a question about conservation of the last wilderness in Europe.

There are unsolved jurisdictional questions in the Barents Sea and a special form of international law regarding the sovereignty of Svalbard. According to the Svalbard Treaty of 1920, Norway has the "full and absolute sovereignty" over the islands. But the treaty also specifies serious limitations to this sovereignty: All nationals of the contracting parties have equal right to: 1. hunting and fishing; 2. maritime, industrial, mining and commercial operations; 3. free access and entry; and 4. Norway cannot build naval bases or fortifications. This does not imply that everyone has a free right to these activities. Norway may implement regulations as long as it is done on the principle of equality (no discrimination of any nationals, Norwegians included).

It is the Norwegian position that the continental shelf around Svalbard is a continuation of the continental shelf adjacent to the coast of Norway, and that the jurisdiction of the Svalbard Treaty extends seaward only to the territorial border (4 mi). Following this interpretation, Norwegian jurisdiction prevails offshore from Svalbard east to the USSR border and south to Norway. Several countries have taken reservations in opposition to the Norwegian view. Further, the border between the USSR and Norway in the Barents Sea has not been established because of diverging opinions on application of the sector or the mid-line principle, when marking out the boundary.

In conclusion, the unsolved jurisdictional questions together with the rich protein resources (fish) and possible resources of hydrocarbon, create a potential for conflict, and aggravate the difficulties of implementing measures to protect this unique and valuable environment.

The history of man's ruthless exploitation of the natural resources in the Svalbard area is discouraging. Over the last 10-20 a, regulation of wildlife management and mineral/hydrocarbon exploitation has improved, and more appropriate resources have been allocated to implement these regulations. About 50% of Svalbard was set aside in protected areas in 1973, and regulations concerning hunting, fishing and conduction of industrial activity were established later. The objective is to maintain the pristine, wilderness character of the Svalbard nature.

However, some nations have disputed Norway's right to implement environmental regulations which may limit their commercial activities in the archipelago. For example, the USSR, which has two mining towns (2500 residents) in Svalbard, has not formally accepted the environmental regulations which Norway has decreed. Inside the natural geographic borders of the protected areas there are still unextinguished claims on mineral/hydrocarbon resources, and the claimants maintain their right to exploit resources there. Although Norway has established a zone to protect fish populations in the northern Barents Sea, fishing vessels of several nations (including Norway) continue to refuse to comply with the regulations.

Future threats to wildlife in the area will include the following: 1. Disturbance of the marine ecosystem in the Barents Sea caused by: a) *over exploitation of the marine living resources.* In 1986, the populations of capelin and herring, the trophic level that links the zoo-plankton production with predatory fishes, sea birds and sea mammals, were depleted. This resulted in severe declines in some populations of sea birds and seals. b) *offshore petroleum activity.* The potential for large-scale oil slicks is increased when the drilling starts in ice-covered waters in 5-10 a, and responsibility for environmental protection is in dispute. c) *accidental release of radioactive material.* There is probably a higher concentration of nuclear weapons and reactors in the Barents Sea than in any other sea in the world. The only nuclear power plants in the Arctic are on the Kola peninsula. In addition, a nuclear weapons testing area was reopened in Novaja Semlja by the USSR in autumn, 1990. 2. Mineral and hydrocarbon exploitation and prospecting in Svalbard. 3. Tourism and increased traffic: Traffic all over Svalbard by boats, helicopters and over-snow machines by tourists, scientists and permanent residents has increased considerably during the last 5-10 a. 4. Long-range transportation of pollutants. Svalbard is the final destination for the Gulf current and for upper high atmospheric winds transporting pollutants from industrialized areas in Europe and the east coast of North America. Acid rain, heavy metal and chlororganic pollution are increasing. 5. Climatic change.

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Effect of Environmental Temperatures on Utilization of Feed by Ruminants - A Review

R.J. Christopherson

As the temperature of the environment decreases, the apparent digestibility of both dry matter and organic matter decreases for a wide range of forage-based diets. Decreases in organic matter digestibility average ~2.0 digestibility units per 10°C decrease in temperature for sheep and calves. The digestive responses of sheep to cold temperatures have been associated with reduction in rumen volume, turnover time of fluid and particulate digests, and the faster rate of passage appears to account for the reduced digestion of fibrous components. Data from recent studies with cattle also suggest that there are small increases in the rate of passage of digests from the rumen in a cold environment, although the responses were less pronounced than these observed in sheep. In cattle, there was no evidence of a change in rumen fluid volume with temperature. Compared to sheep, the modest changes in rumen particle and fluid kinetics during cold exposure in adult cattle were consistent with the smaller reductions observed in organic matter digestibility (1.0 unit/10°C decrease in environmental temperature for adult steers). In one study with steers, digestibility decreased markedly as temperature was reduced from 28 to 10°C but then increased slightly as temperature was further reduced to -10°C. The increase at -10°C appeared to be related, in part, to the marked reduction in voluntary water intake. It is possible that the digestive responses to temperature may vary depending on the water and electrolyte balance of the animal.

Not all of the responses to temperature are negative. The more rapid turnover of rumen digests in sheep, for example, results in an increased proportion of dietary N escaping fermentation in the rumen. The latter, together with an improvement in the efficiency of microbial protein synthesis in a cold environment, has been shown to increase the intestinal supply and net intestinal digestion of non-ammonia and amino acid nitrogen when expressed per unit of digestible organic matter.

In our laboratory, P.M. Kennedy compared four different forages (alfalfa, red clover, reed canary grass and bromegrass) fed to sheep in chopped or pelleted form. Pelleting resulted in an increase in total amino acid content of duodenal NAN. Cold exposure tended to increase the amino acid composition of duodenal NAN ($P<0.10$) by 8 to 17% for the chopped diets only. The concentrations of four essential (threonine, valine, isoleucine, leucine) and four non-essential (serine, proline, glycine, alanine) amino acids were increased ($P<0.05$) by cold exposure in sheep given chopped diets. Seven of these eight amino acids were increased in duodenal contents of sheep fed the pelleted diets and cold exposure did not cause any further increase. More recently, J.N. Kelly determined that there was an increased small intestinal absorption of total amino acid N and specific increases in net absorption of lysine, histidine, alanine and tyrosine across the small intestine in the cold when expressed per 100 g of digestible organic matter. The propionate/acetate ratio resulting from rumen fermentation was also increased during cold exposure. The end products of digestion in a cold environment are, therefore, relatively enriched in amino acids and propionate.

This favourable shift in proportion of end products of digestion is often coupled with an increase in voluntary feed consumption due to cold exposure. These latter adjustments are apparently helpful in meeting the increased energy requirements in a cold environment and may allow animals offered free access to feed to sustain a high level of growth and production, although, with reduced efficiency.

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Winter Ventilation in Animal Housing

J.J. Leonard and J.J.R. Feddes

Exchanging air in animal housing in cold climates presents a number of engineering problems. Sufficient outside air must be introduced into the animal airspace to dilute the aerial contaminants such as airborne respirable dust, ammonia, CO_2, airborne micro-organisms and water vapour to acceptable levels. Air exchange rates must be kept to a minimum during cold weather conditions to conserve the heat energy produced by the animals. The fresh air from the cold outdoors must be thoroughly mixed with the resident air to avoid chilling of the housed animals.

Air inlets have traditionally consisted of a continuous slot. This slot is fitted with an adjustable baffle designed to permit continuous control of slot width to provide changing air flows as outside air temperature varies. At low winter ventilation rates, control of air-flow rate is impossible, inconvenient or ignored. The pressure differential across the slot is generated by the operation of wall-mounted exhaust fans. Maximum pressure differentials approach 30 Pa.

Research at the Department of Agricultural Engineering has focussed on the control of inlets and the use of air-duct systems to provide additional energy for mixing. In older farm buildings, a significant amount of air can be introduced through openings other than the designed air inlet, thus the pressure differential across the inlet is less than desired and control of air flows is difficult. In a tightly constructed building, the behaviour of cold ventilation air jets can be predicted. Recent research developed the concept of drop coefficients to establish Archimedes Number (Ar) criteria for the control of cold ventilation jets. On the basis that jet trajectories with a drop coefficient <0.5 would be satisfactory for most animal housing applications, jets from full-width continuous slots or from inlets adjacent to the ceiling should have Ar values of <50. For other inlets, Ar should be <40. The design of many existing ventilation systems precludes adequate control of jet trajectories when considering pressure/flow characteristics of inlets and exhaust fans, and room/inlet temperatures. At low inlet temperatures, the majority of commercially available exhaust fans cannot generate sufficient negative pressure to cause the inlet air jet to project adequately into the airspace to promote good mixing.

The limitations of a conventional air inlet can be overcome in various ways. One possibility is to use adjustable inlets located downstream from high pressure fans. The high pressure fan would supply air to a number of discreet inlets located at regularly spaced intervals along the ceiling. A circular inlet would discharge air radially into the airspace at appropriate velocities. The velocities, based on inlet/room temperatures, would be controlled by an adjustable baffle, its operation driven by a microcontroller. Recent research indicates that automatic control of pneumatically actuated, radially discharging ventilation inlets is feasible using a pressure sensor, two temperature sensors and two solenoid actuated valves.

The limitations of conventional air inlets during low temperatures has also prompted research on design of a practical recirculation system. Recirculation ducts located beneath the air inlet are being promoted for livestock buildings. They maintain stable air circulation patterns and result in good mixing of inlet and room air above the animal zone. Research is currently underway to define the design parameters for plywood recirculation ducts. Of prime concern is the mean airspeed in the animal zone and the uniformity of air distribution along the duct. Conclusions drawn to date are that acceptable air speeds of 0.3 m/s at animal level result from recirculation rates of 7 l/sm^2 of floor space, or 12 airchanges per hour. Velocities from the duct should have a range of 3 to 6 m/s.

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Effect of Cold Environments on Protein Metabolism in Ruminant Animals

J.R. Thompson and R.J. Christopherson

Large numbers of domestic and wild ruminant animals live outdoors in cold regions of the world. In order to maintain homeostasis during cold weather these animals are often required to mobilize tissue proteins to meet metabolic demands for amino acids. Knowledge concerning the adaptive responses of protein metabolism in ruminant animals during exposure to cold environments is limited.

The amount of protein in animal tissues is determined by the relative rates of protein synthesis (k_s) and protein degradation (k_d). When k_d exceeds k_s the amount of protein in an organ will decrease, whereas when k_s exceeds k_d protein deposition occurs. Skeletal muscle is the major protein reserve in the body that can be readily mobilized to provide free amino acids to other organs in the animal. Skeletal muscle myofibrillar proteins contain the amino acid N -methylhistidine which after proteolysis is neither reincorporated into protein nor metabolized. In cattle, measurement of the daily urinary excretion of N -methylhistidine is a valid index of k_d for total body skeletal muscle.

In cattle producing areas of Alberta, environmental temperatures may drop 20-30°C within a short period of time during winter. The effect of acute reductions in environmental temperature on skeletal muscle k_d was therefore estimated in three trials. During trial I four male calves averaging 49 kg were accustomed for 7 d to restraint in metabolic crates within a controlled environmental chamber at 18°C before the temperature was dropped to -10°C for 6 d. Based on daily urinary N -methylhistidine excretion measured during the last 3 d at each temperature, skeletal muscle k_d was increased ($P>0.01$) 61% by cold exposure despite an increase in feed consumption from 3.5 to 4.4 kg/d. During trial II four calves weighing 67 kg were treated in a similar manner to trial I except that feed consumption was held constant (3.7 kg/d). Skeletal muscle k_d was significantly increased ($P<0.01$) by 35%. Animals of larger body mass are not normally stressed to the same extent as smaller animals when exposed to similar cold environments. In trial III a similar experimental approach was used to measure skeletal muscle k_d in four 560 kg steers fed 10 kg of ration per day. The steers were accustomed to a temperature of 14°C and when exposed to -20°C for 6 d skeletal muscle k_d increased ($P<0.01$) 67%.

These trials provided the first evidence that reduced environmental temperatures dramatically increase skeletal muscle k_d in ruminant animals, although the mechanism remains unknown. During acute or chronic cold exposure, plasma concentrations of both thyroxine and triiodothyronine increase. In the present trials plasma triiodothyronine concentrations increased ($P<0.01$) from 200 to 430 ng/dl. Because hyperthyroidism is known to add to increased skeletal muscle k_d, it is possible that these hormones play a role in the response of skeletal muscle protein metabolism to reduced environmental temperatures.

The effects of acute cold exposure on skeletal muscle k_s in ruminant animals has not been reported. In our laboratory, S.L. Scott estimated the effects of low environmental temperatures on k_s in tissues from 65 kg calves fed to meet NRC requirements at thermoneutrality and acclimated to -5°C for 21 d by measuring the rate of incorporation of ^{3}H-phenylalanine into protein. Compared to control animals housed at 20°C, the k_s in the skeletal musculature was decreased ($P<0.05$) 43% after 21 d of cold exposure. This effect could be overcome by providing the calves with supplementary feed.

These results demonstrate that skeletal muscle protein metabolism in cattle fed restricted or ad libitum diets is extensively influenced by cold environments. The physiological basis of these findings and the practical strategies to optimize tissue protein deposition in cold environments remain to be defined further.

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Genetic Diversity in Cultivated Oats: Diversity for Resistance to Wild Oat Herbicides

Solomon Kibite and K.N. Harker

Oats share with wheat and barley the distinction of being one of the most important cereal crops in western Canada. Statistical abstracts show large annual fluctuations in hectareage, production and value, but roughly 1.5 M ha are allocated each year to produce about 2.5 M metric tonnes of grain with an annual value of ~$395 M.

Although the older cultivars of oats grown in Canada consisted of low yielding and agronomically inferior genotypes, oat breeders have in recent years developed new cultivars that are high yielding and well adapted to the soils and climates of western Canada. However, these yield improvements have eluded many farmers because insufficient attention has been directed towards developing methods of controlling wild oat.

Wild oat causes greater yield loss than any other weed species and infests ~80% of the cultivated land in western Canada. Friesen and Shebeski (1960) estimated crop yield reductions ranging from 5 to 50% in fields in which wild oat was the dominant weed species. Although acceptable chemical control of wild oat has been obtained in wheat and barley, a similar control in oats has not been possible mainly because of a lack of suitable herbicides that can control wild oat without injuring cultivated oats. This problem could have been solved if new herbicides were developed or new cultivars with resistance to existing herbicides were bred. Research in these two areas has not been strong. Because of stringent regulations pertaining to toxicological data, and the increasing cost of research and development, herbicide manufacturers have not had the economic incentive to develop new herbicides. On the other hand, oat breeders were unable to develop herbicide resistant cultivars because genetic sources of herbicide resistance are unavailable. As a result, Canadian oat cultivars have remained extremely sensitive to wild oat herbicides.

There is a tremendous amount of genetic diversity in oats and a large collection of strains and cultivars is assembled in world oat collections. To locate the desired genes, the obvious place to turn is to these germplasm collections, which have not been previously screened for herbicide resistance. This study was conducted to search for new genes that can confer resistance to wild oat herbicides.

The experiment was carried out at Agriculture Canada, Lacombe Research Station, during the summer of 1990. A total of 3072 accession lines from the USDA World Oat Collection were screened for resistance to seven (1 pre-emergence and 6 post-emergence) herbicides. The pre-emergence herbicide Avadex was applied at the rate of 1.7 kg ha^{-1} and soil incorporated twice before planting. The post-emergence herbicides, Assert, Hoegrass, Poast, Avenge, Excel and Mataven were applied at rates of 0.50, 0.80, 0.30, 0.83, 0.20 and 0.26 kg ha^{-1}, respectively, when the majority of the seedlings were in the 2-4 leaf stage. All post-emergence herbicides were applied in 100 L/ha of water at 275 kPa using a motorized plot sprayer with TeeJet 8001 flat-fan nozzles. Two to three weeks after spraying, the accession lines were scored for herbicide resistance using a 0 (no resistance) to 9 (very resistant) scale.

From among the 3072 lines that were screened for herbicide resistance, ~131 lines representing six *Avena* species (viz. *A. sativa, A. byzantina, A. strigosa, A. brevis, A. nuda and A. abyssintica)* were found to have some resistance to wild oat herbicides. Of these 131 lines 109, 38, 8, 10, and 2 accession lines were resistant to Hoegrass, Mataven, Excel, Avenge and Assert, respectively. Since the six *Avena* species have evolved in different parts of the world and at different times on the evolutionary time-scale, it is postulated that several genes or gene combinations may confer resistance to wild oat herbicides.

Barr (1983), has previously reported the existence of genes for Hoegrass resistance in oats. However, we believe that the Hoegrass resistance genes that we discovered in *A. abyssinica, A. brevis* and *A. byzantina* may be different from the Hoegrass resistance genes discovered in *A. strigosa* (Barr, 1983). As far as we know, the existence of genes that confer resistance to Mataven, Assert, Excel, and Avenge has not been previously reported in the scientific literature. This report, therefore, represents the first scientific paper showing the existence of genes that confer resistance to the aforementioned herbicides.

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Neil Harker is a Weed Scientist at the Agriculture Canada Research Station in Lacombe. He obtained a B.Sc. degree in Agriculture at the University of Alberta and M.S. and Ph.D. degrees at the Universities of Minnesota and Guelph, respectively. He is currently studying the biology and control of annual and perennial weeds.

Selection of Verticillium Wilt-Resistant Alfalfa Through Tissue Culture

Masanori Koike and Tohru Shimada

Verticillium albo-atrum is a causal agent of Verticillium wilt in alfalfa. This wilt disease occurs throughout Europe, the U.S.A. and Canada and in the last decade it was observed in Hokkaido, Japan. The purpose of this research was to obtain plants resistant to Verticillium wilt through tissue culture from a variety cultivated in Hokkaido, Japan. Two methods of producing Verticillium wilt-resistant alfalfa plants by using tissue culture technique were evaluated.

The first involved *in vitro* selection for *Verticillium albo-atrum* culture filtrate. A number of plants were regenerated from the callus tissue resistant to culture filtrate and tested whether they were resistant or not to culture filtrate and the actual pathogen. Only one half of the regenerants were highly resistant to culture filtrate. This proportion was not significantly higher than the regenerants from non-selected callus. Further, many regenerants were found which were resistant to culture filtrate but not to pathogen.

Second, the behaviour of alfalfa cultures from resistant and susceptible alfalfa plants was examined for callus growth on culture media containing increasing concentrations of *Verticillium albo-atrum* culture filtrate and an antifungal substance synthesis elicited by *Verticillium* cell-wall components. A high correlation was found between *in vivo* resistance to the fungus and *in vitro* hypersensitive response and antifungal activity induction. On the other hand low correlation was found between *in vitro* resistance to the fungus and *in vitro* tolerance to toxic filtrate.

From these results, it was concluded that *in vitro* resistance to toxic filtrate was not a good indicator of *in vivo* resistance to *Verticillium albo-atrum.*

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Production of Vegetables and Flowers in Greenhouses under Cold Climates, Alberta, Canada

Mohyuddin Mirza

The intention of this paper is to outline the greenhouse production of vegetables and flowers in Alberta and to identify some specific practices suited to cold climates.

The province of Alberta stretches from 49° to 60° N and is considered to be a 'cold climate' area. The seasons can be separated distinctly into summer, fall, winter and spring. Each season has its own characteristics based on sunlight and plant colours. These climatic periods also affect the production of greenhouse crops. Growers have to grow crops under low light conditions and very cold outside temperatures, and thus they adopt several management tools to overcome adverse weather related factors. Research information developed by the Alberta Tree Nursery and Horticulture Centre, Edmonton, keeps the growers in the forefront of crop management in colder climates,

Among greenhouse vegetables, seedless cucumbers and tomatoes are the two major crops grown successfully. The management tools used are: 1. production of very strong seedlings by using HPS lights and higher nutrient solution electrical conductivities; 2. fertilizers to suit different developmental stages: for example, using higher K:N ratios which help control vegetative growth.

Programming of crops is done on the basis of rapid growth in the early stages, and development of a compromise between vegetative and reproductive growth. Computerized environmental and irrigation controls provide the exact needs of the plants. The computer makes very quick adjustments for temperature, relative humidity, CO_2-enrichment, ventilation and cooling. There is thus very little stress on the plants. More recently, substrate culture using Rockwool has contributed to a very high yield with seedless cucumbers. The plants are grown above ground and all these factors have combined to provide exceptionally high yields. During the 1989-90 seasons the cucumber growers achieved yields of up to 170 cucumbers per square meter.

Totally indoor production of lettuce, spinach and herbs was also started by a group of entrepreneurs in the Edmonton area using artificial lights, multi-tier productions, recycling water systems, and robots to handle the crops. In colder climates, year-round production is of great value and this is the only local successful production facility.

Production of flowering and vegetable transplants (bedding plants) is common in Alberta using heated greenhouses and unheated cold frames. Several technologies, such as the use of HPS lights, quick germination methods, better growing media, properly balanced fertilizers, and better transplanting methods, all interact to produce beautiful plants. Cut flowers, like lilies and roses, are also being grown using lights, CO_2-enrichment and other technologies.

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Physiological Basis of High-Yield Sugar Beet Cultured with Polymer Covering

Qu Wenzhang, Zhu Wei, Gao Miaozheng and Bai Xianghe

The physiological basis of high-yield sugar beet cultured with polymer covering has been studied since 1984. This paper reports the results from 1984 to 1987, which can be used as a basis for devising techniques of culturing high-yield sugar beet using polymer covering.

Under the same conditions of fertilizer level, plant density and field management, a 4-a experiment showed that the root yield of directly seeded sugar beet was 39.1 t/ha, and that of polymer-covered sugar beet was 51.6 t/ha, 32% higher than that of direct seeding. The sugar content of polymer-covered sugar beet was 0.58% higher when the polymer covering was removed at the proper time.

The early stage of beet growth (May to mid-June) coincides with the soil drought season in north China. Under polymer-covered conditions, the soil moisture content was 2.01-5.41% higher than that of direct seeding. From May to the end of September, the accumulated temperature of the 0-25 cm plough layer increased 684.1°C. The activity of soil micro-organisms increased. According to data from the first 10 d of June, the total number of micro-organisms per gram of soil in the plough layer increased 19.5% compared with that of direct seeding, and the available nutrients in the soil were improved. Before the first 10 d of July, available N in the 0-20 cm plough layer increased 8.0-26.7%, the available P increased 12.4-18.8%, and the available K increased 7.3-27.9%, compared with direct seeding. The polymer-covered culture produced advantageous ecological effects which improved the growth of sugar beet and benefitted the assimilation of environmental factors, so that many main physiological parameters were optimized.

The emergence of seedlings using polymer-covered sugar beet was ~8 d earlier. During the early and middle stages of beet growth, both the plant height and the number of fresh leaves per plant using polymer-covers were higher than by direct seeding. An LAI of 3.0, covering the space between rows, was attained ~11 d earlier and lasted 25 d longer than that of direct seeding. The extreme value of LAI was 4.9, 0.8 higher than that of direct seeding. The total photosynthetic potential increased 36.7% and the rate of photosynthesis increased >0.57 mg/min/m^2 of CO_2. The growth centre transferred to the root region >5 d earlier. The total accumulation of dry matter and its distribution rate in polymer-covered beet were higher than that of direct seeding. During the period of root formation the accumulation of dry matter (1.9 g/plant day) increased 36%. If the polymer was kept on during the entire period of beet growth, then the accumulation of sugar in the root was faster at the early stage of beet growth; but after the middle stage of beet growth, and because the polymer prevented the soil moisture from evaporating, the accumulation rate of sugar was lower than that of direct seeding. If the polymer was removed at the proper time (post 50-60 d after the emergence of the seedlings), then the accumulation rate of sugar was higher than that of direct seeding throughout the growing period. The total utilization of light energy was 1.84%, 0.45% higher than that of direct seeding.

Qu Wenzhang is an associate professor, Department of Agronomy, Northeast Agricultural College (Harbin 150030, People's Republic of China). His research has been devoted to the study of the physiology and cultivation of sugar beet for 30 years, and he has published more than 40 papers and several books, including one on the physiology of sugar beet.

The Economic System of Agriculture in the Daching Region, People's Republic of China

Qiao Zhihe

The Daching region is located in the central part of the northeastern SunLen Plain, China, and has an area of >5000 km^2. It belongs to the chernozem subzone of meadow prairie in the temperate semi-humid zone.

In the past, the economic system in the Daching region was a single system of grazing. Due to the vigorous development of a petrochemical industry in the Daching region in the 1960s, and the opening up of large areas of wasteland, a series of significant changes have been made in the agricultural economic system of this region. As a result it has gone from an approximately closed non-flow area in a temperate semi-humid zone, to become a region with strong wind-drifted sand, many saline lakes, and many polluted areas. Therefore, the ecological environment must be improved immediately.

This can be done in two ways. First, by use of heterogeneous symbiosis, and through exploring the best land-use models, eight land-use styles of complex agroecosystems have been set up as follows:

1. The fish-reed-grass complex ecosystem built on low-lying land, meadowy swamp, and the low-level land of swampy meadow soil.

2. The reed-castor-billion-dollar grass complex ecosystem built on low land of meadowy solonchalk and the low-level land of meadowy solonetz soil.

3. The reed (billion-dollar grass) complex agroecosystem built on low-level land of salinized and solonized meadowy soil.

4. The forest-net grassland (or furrow) built on low-level land of calcareous meadowy soil and level land of calcareous meadowy chernozem.

5. The forest-net agroecosystem of grain-grass with various cropping systems built on gentle slopes of calcareous chernozem.

6. The complex grassland ecosystem mixed with arable land built on level or gently sloping meadowy and sandy soil.

7. The forest-grass-furrow complex ecosystem built on level or gently sloping chernozem sandy soil.

8. The grass-bush-wood complex forest agroecosystem built on sandy, gently sloping black sandy soil.

Second, by means of Jay W. Forrester's "Principles of Systems" (1968). The program has a flow diagram of agriculture-forestry-grazing, it lists the equations of the model structure, and collects experimental parameters. It uses the DYNAMO computer language. The output results of the model indicate that the industrial policy in this area is mainly concentrated on grazing, with agriculture and forestry playing a less important role.

The agricultural-economic system comprises the land ecological price and the agriculture-forestry-grazing structure, and with respect to quality and quantity it provides a feasible scheme for agricultural production and environmental construction in the Daching region.

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Woodland Caribou and Northern Forest Development: Constraint or Opportunity?

John L. Kansas

The western woodland caribou (*Rangifer tarandus* caribou) is a characteristic species of boreal, foothills and mountain biomes of western Canada. It is classified as a threatened species under Alberta's Wildlife Act, and rare according to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The particularly vulnerable nature of this species can be attributed to several factors: 1. a specialized feeding strategy that focuses on ground lichen and late-successional forest cover types; 2. a particular susceptibility to predation, especially by wolves in a multi-prey setting; 3. a high susceptibility to hunting pressure relative to other ungulate species; 4. relatively low reproductive rates (twinning is very rare); and 5. a relatively. strong adherence to traditional seasonal ranges.

Two "ecotypes" of woodland caribou occur in Alberta. The mountain ecotype migrates seasonally from forested wintering areas on provincial lands to high-elevation calving and summer habitats in the mountains of Alberta and British Columbia, including the northern portion of Jasper National Park. In contrast, the woodland ecotype remains year-round in lower-elevation boreal and foothills habitats on provincial lands. There are estimated to be between 300 and 400 mountain caribou, and ~1500-2000 woodland animals in Alberta; most of these north of 53° latitude.

While on provincial lands, both mountain and woodland ecotypes are influenced by a wide range of land use activities, including logging, oil and gas exploration and production, mining, and recreation. Recently, concern for caribou on certain known winter ranges has led to significant restrictions on forestry and oil and gas activities. Because most or all of these land uses are expected to expand in the future, the pressures on caribou populations and habitat will continue to increase. In order to conserve a sensitive species, such as caribou, within a complex land use system, a clear understanding of habitat needs and reactions to disturbance of the species is required.

Several steps have and are currently being taken in Alberta to understand caribou and their ability to withstand resource development pressures. In 1987 a consortium of consulting biologists initiated a study of mountain caribou in west-central Alberta designed to apply principles of the World Conservation Strategy. Called the Greater Jasper Ecosystem Caribou Research Project, this study includes radio-telemetry monitoring, habitat evaluation, snow morphology studies, and concerted public education efforts. In 1989, a round-table technical committee on caribou research was created. The committee comprises >40 members from government, industry (oil and gas, forestry and mining) and non-government organizations.

The Jasper project focussed attention on the need for a multi-sector, cooperative approach to the caribou issues in Alberta. Since then numerous initiatives have been taken by industry in an attempt to integrate caribou and resource development. In the fall of 1990, two oil companies spearheaded the formation of a working group of 10 oil companies active in the Pedigree gas field in northwest Alberta. Recently, a joint Canadian Petroleum Association-Independent Petroleum Association of Canada 'caribou committee' was struck including several petroleum companies, the provincial Energy Resources Conservation Board, Alberta Energy, and the Canadian Association of Geophysical Contractors. In June, 1991, the Canadian Petroleum Association is sponsoring a major conference on caribou. This conference will include government, industry and Native representatives, and will concentrate on research data gaps and integrated caribou/industry problem solving.

The woodland caribou situation in Alberta presents a unique challenge to all parties who have a stake in northern forest development. The worst case situation is acrimony and legal action between resource developers and conservationists, *a la* the spotted owl-old growth/forest industry clash in the northwestern U.S.A. Hopefully, in Alberta, the stage is set for a more harmonious approach where caribou concerns are addressed early in the development process through multi-sector cooperative ventures.

Given the unique sensitivities of the woodland caribou and inevitable increases in northern Alberta resource development, the long-term challenge of preserving this endangered species along with a variety of land uses will be difficult. Above all, it is imperative that the ecological requirements of caribou and their response to a range of disturbances be thoroughly understood so that planners can skillfully piece caribou into the complex integrated land-use puzzle.

The ultimate basis for sustaining caribou populations, along with acceptable levels of resource development, lies in creating a collective will among a diverse range of interests based on an understanding and acceptance of ecological realities.

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Profile of a Northern Greenhouse Grower

Mohyuddin Mirza

Growers of greenhouse crops in northern climates are a unique breed. They have to understand and integrate several diverse skills to survive the realities of a harsh climate and to produce profitable crops. It is the intention here to present a profile of a typical northern grower.

A good knowledge of crops is absolutely essential. This kind of knowledge is obtained by attending seminars and workshops in winter. Summer is a very busy time so most of the travelling is done in winter. A northern grower understands how to use this information to manage crops. The grower also has a thorough knowledge of greenhouse structures and how to use computers to integrate environmental controls. For example, in northern climates computers for environmental control are absolutely essential. So the grower understands the intricacies of computers, which are capable of integrating temperature, relative humidity, CO_2, ventilation, cooling, bottom heating and irrigation. The grower must be able to program the computers for most desirable growth parameters. For example, to grow cucumbers requires a drop in temperature to stimulate the vegetative growth of the plant and knowledge of how to decrease relative humidity to control diseases.

A northern grower has to be a plumber, an electrician and a carpenter as well. It is very expensive to pay high wages to bring in all these trades people. This experience is essential to maintain greenhouse systems and structures. During very cold weather the grower has to fix many burst water pipes or come up with innovative emergency heating ideas. For example, one northern grower used newspapers to create smoke in the greenhouse when the power failed. The smoke provided the buffering needed to slow down the temperature drop.

A northern grower is able to interpret soil and nutrient solution analytical results to make quick decisions. New research information has to be utilized for the benefit of the crops. Recently, many Alberta growers incorporated the use of potassium silicate as a part of their fertilizer programs to give strength to their plants.

Northern growers do not commit serious mistakes because of the short duration of the crops. Bedding plant growers in the north, if they miss a crop due to poor germination, cannot grow a second crop that year. The southern growers can afford to do so because of better light and temperature conditions.

The northern grower is also an expert at handling people. This quality is a must because labour pools are very small at many locations. The grower cannot afford to let these people go. Good managerial skills are absolutely essential and most of the time these skills are inherited.

A good marketer is another desirable characteristic because what is grown must also be sold. There is no time to get angry at the wholesalers who may refuse the product. The grower must have good skills to get along with other family members because they contribute time and effort toward the operation of the greenhouse.

The northern greenhouse grower is, indeed a special breed.

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Increasing Soil Productivity in Cold Regions

Ma He-Ping

The three primary factors limiting soil productivity ion cold regions are: 1. slow rise in soil temperature in the spring; 2. the low content of effective soil nutrients, which often cannot meet the needs of crop growth in the early growing season; and 3. poor soil moisture capacity which causes crop seedlings to grow slowly. The key to increasing soil productivity in cold regions is to apply organic matter to the subsoil during deep ploughing in order to improve the soil structure, nutrient effectiveness and moisture capacity. The temperature of soils can also be raised using ridge culture.

Soils in cold regions require frequent applications of organic materials to replace those removed by decomposition. The organic matter content of soils was increased 0.72% by applying pig manure at the rate of 15 t/ha. It was ploughed into the upper 12 cm of soil and mixed well in the autumn; by the following spring the soil moisture had increased 0.5%. The soil moisture was thus trapped and evaporation losses reduced. This has important significance for the germination of crop seeds. The dry weight of wheat roots at the three-leaf stage was increased 0.21 g (20x10x20 cm) as a result of applied pig manure. This caused wheat yield to increase 322.5 kg/ha.

The evaportranspiration of soil after applying pig manure was reduced 7.2% over the period July 8 to September 5. Thus the moisture-holding capacity of the soil was affected by the soil organic matter, and therefore crop growth was better because of increased available moisture in the soil.

Ridge culture also has important significance in cold regions. It is beneficial to increased soil temperature because the soil surface area is increased. The highest temperature increase of the surface was 4.6°C. The plough layer was deepened because it had more available moisture than with no ridge culture. The total moisture held in the top 40 cm of soil was raised to 61.8 t/ha using ridge culture. As a result, the corn yield increased 15.3%.

The two primary functions of organic matter in the soils of cold regions are thus improvement of the physical properties and increasing soil temperature. Another important measure is ridge culture.

Ma He-Ping is head of the Research Department, Northeast Agricultural College, People's Republic of China.

Irrigation-on-the-Film: A New Method of Irrigation in Cold and Arid Regions Using Plastic Film

Men Qi

Xinjiang, a province of The People's Republic of China, is located in the north temperate zone near the center of Eurasia. It is far from the sea and surrounded by high mountains; effectively two basins between three mountains. It has a typically continental climate in the arid or semi-arid region of China. Precipitation is the lowest of all regions in the same latitude, and the climate is cold in the winter and hot in the summer. Most of the irrigation water comes from rainfall and snowmelt from the high mountains, therefore, there is no agriculture in Xinjiang without irrigation. Accordingly, in Xinjiang, there is much experimental work on irrigation. A new irrigation method has been invented: irrigation-on-the-film, using plastic film. It may turn out to be a revolution in surface irrigation.

Irrigation-on-the-film, as it is termed, is based on advanced cultivation techniques with plastic film. It is different from traditional surface irrigation where water flows on the film and seeps into the soil through drilled holes or holes made by growing plants. There are five forms of irrigation-on-the-film: 1. Irrigation-on-the-film in greenhouses. According to the type of plant and soil, the holes are drilled in one or two rows at the bottom of the film that covers the furrows; 2. Irrigation on the seam of the film in the furrows; there is a seam of film at the bottom of the furrow; 3. Irrigation-on-the-film on ridges and dykes. The water seeps into the soil through holes where crops are growing and through specially drilled holes; 4. Irrigation-on-the-film on ridges. There are two permeation belts in addition to the film and the holes of growing crops; 5. Irrigation-on-the-film at the border; there are only the holes of growing crops for water permeation.

This new irrigation technique not only preserves moisture, heat, soil and fertilizer, but also reduces deep infiltration so it increases the efficiency of irrigation and saves water. This talk will present and expand on the concept, principles and forms of this new irrigation method and the research results.

Men Qi is an engineer at the Institute of Soil and Fertilizer, Xinjiang Academy of Agricultural Sciences (No. 38 Nanchang Road, Urumqi 830000, People's Republic of China). His research is concerned with irrigation and he is now studying the use of irrigation-on-the-film in greenhouses and the hydraulic characteristics of irrigation film.

Naturally Frozen Ice Shelter Used for Long-Term Vegetable Storage, Japan

Jun Dohkoshi

People who live in cold climates have many difficulties in economically keeping vegetables fresh for a long time under freezing winter conditions. On the other hand, it may be hard to keep vegetables fresh in a hot summer.

In the cold winter, freezing water emits considerable latent heat energy to the surrounding air, resulting in upward moving heat streams. If the warmed air streams get into the vegetable storage, the inside streams can protect the vegetables from freezing. Freezing water in winter and melting ice in summer can also keep temperatures close to zero degrees Celsius. Consequently, the coexistence of ice and water offers appropriate environmental conditions, i.e. keeping temperatures close to zero degrees Celsius with high humidity. In fact, well insulated buildings have been used for long-term vegetable storage. This experimentation of making naturally frozen ice and storing vegetables has been done for two years. The building still maintains the optimum storage conditions throughout this period, even in both hot and cold weather.

The storage consists of four rooms: 1. a main vegetable room (100-t capacity); 2. a room protected from freezing by using latent heat energy in winter (50-t capacity); 3. a bulk ice storage room used in summer (150-t capacity); and 4. a dew-free room for shipping in summer. The latent heat energy is used as a heat resource during the phase exchange between ice and water in the bulk ice room, and in the protection room it is used for cooling vegetables in the summer and warming them in the winter. The following advantages are thus obtained.

1. During the phase exchange between ice-to-water or water-to-ice the temperature of the main vegetable room can be kept at ~0°C, although the annual outside temperature changes from -30 to +30°C.

2. Vapor from the water surface results in high humidity, therefore, the weight loss of the vegetables is minimized under these high-humidity conditions.

3. The heat balance, including the respiratory heat from the vegetables and fresh air intake, can be calculated, including taking into account the many factors of the building and weather conditions.

4. The inside environmental conditions have been automatically controlled using only electric fans and air-flow dampers. The conditions have resulted in the storage system needing water supply.

Therefore, the system gives us the most economical heat resource, which is the latent heat exchanging between water and ice, as well as fresh vegetables any time by controlling the environmental conditions.

Jun Dohkoshi was born in Japan in 1922. He received his BS degree in physics in 1946 and PhD in agriculture in 1960 from Hokkaido University, Japan. For more than 30 years he has been carrying out research in both the long-term storage of vegetables and the use of livestock shelters. He is currently a senior consultant with the Japan Weather Association, Hokkaido Head Office (North 4, West 23, Sapporo 064, Japan).

Application of Artificial Permafrost using Heat Pipes for Cold Storage of Agricultural Products

Fujio Tsuchiya, Kimitoshi Ryokai and Masataka Mochizuki

A new storage system using artificial permafrost has been developed. It comprises artificial permafrost, heat pipes which use cold energy in winter, and a cold room for the storage of agricultural products. Preliminary experiments designed to form frozen soil layers were carried out using various kinds of heat pipe, and a corrugated heat pipe was selected for the present system. The stainless steel heat pipe was 46 mm outer diameter, the working fluid was Freon R-22, and the condenser had 170 fins. When the filling ratio of Freon was increased to 80% for the bottom heat pipes of the cold room, the temperatures of both the upper and lower surfaces of the heat pipe under the ground were lowered in proportion to the temperature of the cold air above the ground. In addition, the wick within the pipe was not employed because of the effective, rapid action of the gravity-effected Freon.

In December 1987, an experimental plant was constructed in the campus of Obihiro University, Hokkaido, Japan. The dimensions of the storage room were 6 m long, 3.6 m wide and 3.5 m high. The storeroom was composed of a steel framework, geotextile wall, gravel floor, and 150 mm thick thermal insulating roof. Around the room, 216 heat pipes were installed in the ground at intervals of 0.5 m in four rows, and the condensing sections of the pipes were exposed to the atmosphere. Further, the outer surface of the soil layer containing the heat pipes was waterproofed and thermally insulated.

By the end of January, the 2-m thick frozen soil layer was completed and the temperature of frozen soil lowered to -1°C. In the warmest month, August, the storeroom temperature was maintained <5°C and the humidity was kept >90%. However, in the middle of winter the room temperature became too cold, because of the high cooling capacity of the heat pipes. Next winter, water was poured onto the gravel floor and water containers placed along the walls to prevent the room temperature from dropping below the freezing point.

Consequently, 4 t of potatoes stocked in the storeroom were maintained in high quality for ~1 a.

The artificial permafrost was established one winter and maintained until the next winter. The same experiments were then conducted for the next two winters, with similar results.

Because the 2 m thick frozen soil layer was thawed over the summer by ~0.5 m until the heat pipes could operate again the next winter, it was determined that the quantity of the heat pipes could be reduced by half.

The most important thing for a storeroom is to maintain the quality of the stocked agricultural products at a maximum. To evaluate the qualitative reduction of the stored potatoes, they were sampled for appearance, taste and deliciousness at two month intervals. These evaluations showed excellent quality until June, and only good quality till October. The content of reduced sugar increased four or five times compared to that before storage.

After the stock period of 230 days, the weight losses were <3% in potatoes. The weight losses of burdock, Chinese yam, carrot and onion were 2.6, 2.4, 1.9, and 4.4%, respectively, during the 200 days.

Therefore, it is concluded that the artificial permafrost typed low temperature storage facility was a very effective and hopeful system for the storage of agricultural products.

Fujio Tsuchiya is an associate professor at Obihiro University of Agriculture and Veterinary Medicine (Inada-cho, Obihiro, Hokkaido 080, Japan) and specializes in soil physics and geotechnical engineering at the Department of Agro-Environmental Science; he is involved in research in soil freezing, frost heaving and their influences on agriculture.

Kimitoshi Ryokai is a senior research engineer at the Simizu Corporation(4-17, Etchujima 3-chome, Koto-ku, Tokyo 135, Japan); he is a registered consulting engineer and works at the Advanced Technology Department, Institute of Technology.

Masataka Mochizuki is a chief researcher in the heat pipe development section at Fujikura Ltd. (1-5-1, Kiba, Koto-ku, Tokyo 135, Japan).

Role of Micropropagation in the Development of Horticulturally Important Crops in Cold Regions

Kris Pruski, Mohyuddin Mirza and George Grainger

There are several horticulturally important crops in northern cold regions which are being used, or have the potential to be used, for commercial purposes. These crops present interesting propagation challenges because of their unique adaptation to colder climates. For example, the saskatoon berry (*Amelanchier alnifolia* Nutt.) is a unique fruit berry, with a distinct fresh, flavour; however, the species is difficult to propagate through seed because of genetic non-uniformity. The plant is so well adapted to the cold climate that it makes conventional vegetative propagation (through cuttings) very difficult because of the dormancy problem which occurs during the rooting period.

Propagation of this economically important crop through tissue culture multiplication was successfully accomplished at the Alberta Tree Nursery and Horticulture Centre. However, it took 4 a to resolve dormancy and rooting problems. No difficulties were observed with initiation and multiplication of saskatoon cultures. The best explant was a shoot tip (~6 mm long) from actively growing branches; the multiplication ratio observed was 1:5 to 1:8 over a 4-week incubation period. The ratio strongly depended on the cultivar and the amount of 6-benzylaminopurine (BAP) in the medium: 2 mg/l was found suitable for most cultivars (Harris, 1980; Pruski *et al.*, 1990). Rooting was difficult, however, and with some cultivars extremely difficult because of dormancy occurring during that period. In our studies, rooting *ex vitro* was superior to rooting *in vitro*, and the combination of two auxins (IAA and NAA) provided the best auxin gradient for root development (75-97% rooting was observed depending on the cultivar). Rooting *ex vitro* did not prevent bud dormancy in newly rooted plantlets. Application of BAP and GA (gibberellic acid) overcame bud dormancy and initiated active shoot growth.

Pincherries (*Prunus pennsylvanica*) and sour cherries (*Prunus cerasus*) are the other examples where micropropagation technology helped to overcome multiplication problems of plants suited to northern climates. Two valuable selections of pincherries 'Mary Liss' and 'Jumping Pound' were studied for micropropagation. Because there were very few specimens of these selections in Alberta, the micropropagation was the only method that could quickly multiply and restore plantings. Bud explants were used for initiation of cultures. The multiplication ratio of 1:8 to 1:15 was observed over a 4-week growing period. Plantlets rooted readily *ex vitro* when treated with auxins (commercial rooting powder Stimroot 1). Similarly, the sour cherry cultures were initiated from bud explants. The multiplication ratio was even higher than with pincherries and plantlets were rooted in the greenhouse on the misting bench.

Another commercial crop in which micropropagation plays an important role is the seed potato. The production of disease-free nuclear tubers for further seed potato planting is impossible without using the tissue culture method. Several projects on improvement of micropropagation of potatoes were undertaken, including the use of autotrophically grown potato cultures and several media additives.

The list of horticulturally important crops where micropropagation has played a role in their development is long. The authors will present information on the role of the tissue culture technique in handling crop management problems, overcoming dormancy and rooting difficulties in crops such as saskatoons, cherries, raspberries, conifers, seed potatoes and several other species.

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Pruski K., Nowak J. and Grainger G. (1990) Micropropagation of four cultivars of Saskatoon berry (*Amelanchier alnifolia* Nutt.). Plant Cell, Tissue and Organ Culture 21:103-109.

Kris Pruski is a tissue culture specialist with the Alberta Tree Nursery and Horticulture Centre (RR6, Edmonton, Alberta T5B 4K3, Canada). He has published 10 papers and abstracts in the tissue culture field.

Mohyuddin Mirza is a greenhouse specialist with the Alberta Tree Nursery and Horticulture Centre.

George Grainger is Director of the Alberta Tree Nursery and Horticulture Centre.

SESSION B
THE ENVIRONMENT AND ITS PROTECTION

ROOM 2, EDMONTON CONVENTION CENTRE

Monday, June 17

10:20 - 12:00 Climate I
14:00 - 16:00 Climate II

Tuesday, June 18

08:40 - 10:00 Pollution Abatement I
10:20 - 11:20 Pollution Abatement II

Wednesday, June 19

08:40 - 10:00 Waste Management
10:20 - 12:00 Other Topics

Thursday, June 20

08:40 - 09:40 Other Topics

Session B
Schedule of Speakers

- **Climate I**

  Ross W. Wein
  Teja Singh and Stephen Zoltai
  Rick Lanoville
  Michael J. Apps and Werner A. Kutz
  Eckhart Stoyke

- **Climate II**

  Takeshi Ito
  Kimiteru Sado
  Chris Hill and Roger Pilkington
  Claude Labine
  Takushi Nakata, Takahiko Uematsu and Yasuhiro Kaneda
  Takeshi Hasegawa, Takeshi Ito and Nobuyoshi Tamazaki

- **Pollution Abatement I**

  Eero Tikkanen
  Riaz Choudhry
  J.P. Van Praet, K.R. Johnson, B.C. Grieco and R. Kent
  Takayuki Yasui, Katsuo Kinoshita, Kohzo Akahide, Norihito Tambo, Katsuhiro Murata and Masaaki Kuribayashi

- **Pollution Abatement II**

  S.J. Stanley and D.W. Smith
  Masami Kishi and Norimoto Watanabe
  Harukuni Tachibana, Masaharu Ando and Hiroyuko Ohmori

- **Waste Management**

  Norm Nuttal, Konrad Fitchner, Jim Clare and Ian B. Macleod
  Alan R. MacDonald
  J. Henry, A. Badakhshan and M. Robinson
  Xiaoqin Yuan, Yanhua Chen and Grant Ross

- **Other Topics**

Eikichi Asari
Kazunori Fujisawa, Chuichi Shimomura and Jun Kobayashi
Yoshiharu Hosokawa
Bernie Amell, Grant Ross, Bob Dewar and Ron Wardell
L.R. Hettinger
Eikichi Asari
Dennis Stossel
Michael Apps

An Overview of the Impact of Climate Change in Northern Ecosystems

Ross W. Wein

With increasing distance northward, ecosystems become more physically dominated by lower temperatures and lower precipitation; summers become shorter and winters become longer. Ice, snow and permafrost become important features with which biological systems must contend. Periodic outbreaks of insects and fire are also characteristic of northern forested systems. Species numbers decrease northward, food chains become shorter, and animals home ranges, especially at higher trophic levels, become longer. Productivity of ecosystems is less than in more equatorial ecosystems, but decomposition is even slower; thus, peatlands are common.

There has been a steady rise in atmospheric CO_2 levels due to human activity over the past 100 a and global mean temperature has increased by 0.3 to 0.7°C. Several independent approaches that have used Global Circulation Models to explore the consequences of a doubling of the atmospheric greenhouse gases over the next 50 a, suggest that surface air temperatures may rise 1.5 to 5.5°C. The models suggest that the higher temperatures will occur toward the poles. This temperature increase in 50 a is unprecedented.

The models do not show such a clear change in precipitation but there is some suggestion that with greater heat inputs the dynamics of the hydrologic cycle may be more stochastic. With higher temperatures there could be greater evapotranspiration and less soil moisture. Recent analyses of climate change scenarios using fire management models in Australia, Canada and the U.S.A. suggest that forest fires may become more frequent and widespread.

Permafrost in the discontinuous permafrost zone could melt, and in areas of high soil ice content, thermokarst could become widespread. Thermal expansion of sea water and water released from polar ice caps and glaciers could raise sea level well beyond the 20.4 cm rise of the twentieth century, to predictions as high as 165 cm.

The biological consequences of climate change could well be spectacular. Many researchers have predicted a strong northern shift of forested communities, but not all species have the capability of moving 250-900 km within 50 a. But it must be remembered that northern species are adapted to year-to-year variability in climate and other physical forces; therefore, many species have the capability to take advantage of the new conditions. Because human activity, such as north-south transportation corridors, will continue to increase in the north as climate changes, species that are linked to human activity will likely be successful. Also, because many of the large circumpolar river systems drain northward, aquatic species will likely quickly colonize suitable habitat.

Possibly, the species components of ecosystems will show little change in abundance as the climate changes because these tend to be conservative; but if climate change triggers catastrophic events, such as fire, insect attack, thermokarst or mass soil erosion, then the new community composition could well be different.

The socioeconomic consequences could also be significant, but information transfer is so rapid and the pro-environmental attitudes so prevalent that society may be sufficiently motivated to alleviate the causes or flexible enough to accommodate the changes. Most land managers are now developing resilient strategies that achieve immediate goals while planning a long-term course that maximizes the range of future management options. Management policy should stress flexibility to accommodate gradual changes as well as wide fluctuations.

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Impact of Climatic Change on Cold Region Ecosystems in West-Central Canada

Teja Singh and Stephen Zoltai

Biological systems of northern latitudes have evolved over time to a delicate equilibrium with the local environment. Temperature, precipitation, topography, available nutrients, and photosynthetic energy alterations make such systems extremely vulnerable to even minor shifts in climate. The boreal treeline has been displaced significantly in the past due to climatic changes.

Although the estimates vary, all General Circulation Models predict a warming trend. The mean annual temperature in Alberta could increase by 3 to 7°C by 2030 to 2050 A.D. under a 2 x CO_2 scenario. Such changes will affect the present precipitation, evaporation, transpiration, and snow accumulation and melt patterns. Greater warming will occur in the high-latitudes than in areas farther south. Perennially frozen ground will respond quickly by thickening of the active layer, inducing mudflows and unstable surfaces. Flat and poorly drained permafrost sites would increase in wetland areas, sequestering more C but generating more methane. In other areas, peatlands would dry up and release CO_2. Because the forest growing in the high-latitude regions has only a marginal timber value due to edaphic limitations, the sequestering of C will be the main role for the forest-tundra transition vegetation under changed environments. Large areas near the prairie margin will not support forests because of increased temperatures and moisture limitations; areas farther north will experience improved growing conditions and enhanced ecosystem productivity. Because this will be the fastest rate of change in the history of the Earth, the migration of tree species would require human assistance in colonizing and establishing over the newly available sites.

Hydrological changes brought about by global warming could impose serious implications for the presently developed and settled region of the prairie provinces. Reductions in runoff will result in lower water levels in lakes and reservoirs. Hydro power, and municipal and irrigation supplies are at stake, including the full production potential of existing dams and hydraulic structures. Changes in snow accumulation and melt patterns will affect the current recreational use of tourist areas and facilities.

The anticipated climatic change, manifested in warm dry environments, will seriously affect the cold regions in west-central Canada. Competition is likely to develop between conflicting land uses (such as agriculture vs forestry) with the improvement in northern climates. Demands for increasingly scarce resources such as water may become severe in the arid south. Population shifts will occur, causing fresh demands for associated infrastructures such as water supply, transportation, recreation, and for developing new strategies to manage forestry, agriculture, wildlife and other natural resources under changed climate.

Teja Singh is a forest productivity and ecosystem modelling scientist at the Northern Forestry Centre (5320 - 122 Street, Edmonton, Alberta T6H 3S5, Canada). He has authored more than 100 papers and research reports in forestry, climate change, hydrology, biomass and bioenergy, environmental quality, risk analysis, and biometrics.

Stephen Zoltai is a forest ecologist with Forestry Canada. He has extensive experience with land-vegetation relations in boreal, subarctic and arctic regions of Canada.

The Impact of Global Warming on Forest Fire Management Policy in the Northwest Territories, Canada

Rick Lanoville

The forests of the Northwest Territories account for about one eighth of the treed area of Canada. These forests are fire dependent ecosystems supporting periodic, high-intensity, stand-removing forest fires. Forest fires burning, especially under extreme or severe fire weather conditions, are now major producers of "greenhouse" gases, particularly CO_2. The current fire management policy recognizes the natural role of fire (and implicitly the production of smoke and other fire effects) and in so doing allows the option of not suppressing every fire occurrence. The policy also recognizes the need for prescribed fire as a land management tool to enhance and maintain the productivity of the forest, especially wildlife habitat, which is of particular importance to northern people. Given the real possibility of global warming and national initiatives to control the production of greenhouse gases, however, the current fire management policy needs careful evaluation. The current policy is based on experience from the past, which does not explicitly consider the implications of fire management under changed climatic regimes. In this paper, both the natural role and prescribed use of fire are examined in terms of potential greenhouse gas production under some global warming scenarios. In this context, some fire management policy options are presented and discussed.

Rick Lanoville is with the Department of Renewable Resources, Territorial Forest Fire Centre, Government of the Northwest Territories (Box 7, Fort Smith, NWT X0E 0P0, Canada).

The Carbon Budget of Canadian Forests in a Changing Climate: Can Forestry be Part of the Solution?

Michael J. Apps and Werner A. Kurz

A principal factor driving global warming projections is the influence of man on the natural greenhouse effect through changes in the atmospheric loading of radiatively active gases. Carbon dioxide (CO_2) is the main anthropogenetic greenhouse gas of concern and global forest ecosystems account for ~50% (100 Gt of C) of its annual exchange with the atmosphere. In addition to their significant and dynamic role in the annual C cycle, global forest ecosystems represent huge C pools in their soils (~1500 Gt of C) and standing biomass (~650 Gt of C).

Human activities are upsetting the C balance of the Earth by burning fossil fuels and by removing active biological sinks for CO_2 through deforestation and other land-use changes. An increasingly important question to Canadians is the extent to which our forests are part of the problem or can be part of the solution. This question has several parts: how much C is currently stored in Canadian forests?; how much do they currently contribute to the atmospheric budget?; and how will these C storage pools and exchanges change in the future as a consequence of climate change and forest management?

To address these questions, development of a C budget modelling framework for the Canadian Forest sector has been initiated as a team effort between Forestry Canada and ESSA (Environmental and Social Sciences Analysts Ltd). Supported by the Federal Panel on Energy R&D (PERD) through ENFOR (ENergy from the FORest program) of Forestry Canada, the project has three phases:

Phase 1: assessment of the current C budget using best available data;

Phase 2: future C budgets - the effect of alternative management strategies; and

Phase 3: future C budgets - the effect of alternative climate assumptions.

Preliminary Phase 1 results, for a reference year 1986, indicate that the forests of Canada acted as a net sink of atmospheric C of ~51 Mt with an additional net sink of ~26 Mt of C sequestered by Canadian peatlands. After accounting for disturbances (wildfire, insect-induced stand mortality, and harvesting) and decomposition processes across all the forest regions (ecoclimatic regions) of Canada, there was a net increase of ~27 Mt of C in standing forest biomass pools, ~2 Mt of C in the associated soils (including litter) and ~21 Mt of C remaining in forest products (including land-fills) derived from forest fibre harvested over the past 40 a. These 1986 budget figures should be considered in the context of the total pool sizes which have been estimated to be 12,000 Mt of C (biomass), 76,000 Mt of C (soils), 135,000 Mt of C (peatlands) and 600 Mt of C (forest products).

The sensitivity of these results to disturbance rates, model assumptions and data is currently being determined. It is clear that the 1986 rates will change if future conditions maintain the observed trend towards increased wildfire disturbance. Increased fire risk is expected for much of the forests of Canada under the projected changes in enhanced greenhouse climate and it is unlikely that increases in fire suppression could keep apace with these changes, should they occur. The biomass and soil pools may thus become significant net sources, and climate-induced changes in forest productivity do not appear to compensate for these losses, and in some areas, may even add to the problem.

Can alternative forest resource management strategies help to maintain a positive contribution by Canadian forests to the global CO_2 problem? The significant sink in forest products found in the Phase 1 analysis offers hope. Several resource management and forest product alternatives (including bioenergy substitution for fossil fuels) have been identified for evaluation in Phases 2 and 3, which are now underway.

Mike Apps is a senior research scientist with Forestry Canada, at the Northern Forestry Centre (5320 - 122 Street, Edmonton, Alberta T6H 3S5, Canada). He is responsible for the C budget model study and for providing national scientific coordination for the climate change research program of Forestry Canada. He has been with Forestry Canada for 10 years, the last 5 of which have been devoted to forest ecosystem modelling.

Werner Kurz joined Environmental and Social Sciences Analysts Ltd. to head up the ESSA team on the C budget model. In addition, he has been actively involved in other aspects of climate change research, forest ecology, and growth and yield modelling.

The Dual Greenhouse Effect - Dangers and Opportunities

Eckhart Stoyke

The greenhouse effect as a physical phenomenon is uncontroversial. We know the wavelengths of the infrared spectrum at which each of the greenhouse gases resonates and thereby re-radiates the incident energy.

What has caused confusion was the uncertainty of climate modelers as to how to formulate cloud processes. This has represented a formidable obstacle to reliable climate prediction.

Predictions of a triple warming in the polar regions compared to the mid-latitudes accompanied by the melting of polar ice caps at doubled CO_2 levels are the result of clear-sky models.

Developments contrary to these predictions are now being reported by numerous researchers. The contradictions between calculated and observed climate changes have caused politicians to remain inactive in the face of unprecedented climate events. The "warming only' bias created by climate models led to selective reporting of heating events while extreme cooling events were treated as "normal climate variability".

Statements by renowned climatologists that the greenhouse effect will likely become clearly visible during the next decade are the result of the aforementioned bias. The greenhouse effect has been showing up for the last 60 a.

There are various greenhouse signals: global warming is not one of them. The fact that extreme warming events are neutralized by extreme cooling events resulting from intensified greenhouse induced cloud formation, make average global temperature the least useful tool for determining the advanced of climate change. In 1985 the satellite measurements carried out during the "Earth Radiation Balance Experiments" (ERBE) provided the most embarrassing result: the cloud reflectivity data obtained, suggest that the net cloud cooling effect is about three to four times greater than the predicted doubled CO_2 warming effect. The hard conclusion to be drawn from this fact is that we are moving into another ice age.

The growing of the polar ice caps confirmed for Greenland since 1978 has resulted in an additional ice accumulation of >1800 km^3 during the last 12 a, and high-latitude glaciers are growing while mid-latitude glaciers are receding. Why are these events not highlighted and put into perspective?

While global temperature change is believed to be 0.6°C for the last 100 a, the cooling of the Atlantic Arctic over the last 60 a amounted to ~2.5°C. This information was provided by Rogers in 1989.

Bradley, in 1987, published data on the relative change of precipitation at northern latitudes for the last 150 a: the cooling trend of the Atlantic Arctic coincides closely with the increased precipitation between 35° and 70° northern latitude since the 1930s. This trend appears to be accelerating.

The increasing frequency and ferocity of storms that uprooted millions of trees in Europe during 1989 and caused the greatest forest catastrophe in Germany since the beginning of forestry history in the 18th Century, is best explained as a direct consequence of the growing temperature differentials between high and mid-latitudes. What we need to realize is that the present weather anomalies are the result of the greenhouse gas levels of the 1960s. This gives us an idea of the disastrous consequences of the present greenhouse gas levels that will show up around 2010 because of the delay in ocean warming to the equilibrium temperature that goes with a given greenhouse gas level.

The need for immediate action was never more apparent. The good news is that >75% of North American energy requirements can be replaced by efficiency at average costs far below those of generating the equivalent amount of energy.

Tests carried out by the Bavarian Ministry of Forestry provide a hint in which direction we should look for CO_2 absorption: by restoring the trace mineral balance of forest soils by spreading finely ground igneous rock dust, wood plots so treated yielded four times more wood after 24 a than untreated ones. Research into this area needs to be resumed without delay.

Eckhart Stoyke is an Energy Consultant (Box 30, Site 4, RR No. 1, St. Albert, Alberta T8N 1M8, Canada).

An Index of Winter Weather in Snowy Regions

Takeshi Ito

Cold and snow are attributes of winter weather in the world's cold and snowy regions. Factors influencing them are mainly air temperature, the duration of sunshine and the quantity of snow. With respect to snow, the time of snowcover, and the occurrence of heavy snowfalls depends on the individual region. By generalizing these phenomena into one term, a characteristic index for each point in a cold region can be made.

However, weather phenomena have physical dimensions and therefore, for the purpose of evaluating them to the same standard, their variations were standardized into random variables (Z-scores) and then T-scores. Next, correlation analysis was carried out. As a result, seven parameters were selected to make the index. According to the correlation analysis, these parameters were divided into two groups: the parameters within the same group are correlated positively with each other, but the two groups are negatively correlated to each other. Based on this, an index for winter weather (Ic) which emphasizes winter weather in snowy regions was proposed as follows:

$$Ic = (Smax+St+Snt+D_{10}+Is)/(Tmin+Sd)$$

in which Smax = depth of annual maximum snowcover; St = depth of daily accumulation of snowcover; Snt = positive differences of snowcover depth between the current day and the day before; D_{10} = number of days of snowcover depth >10 cm; Is = snow depth factor depending on the region; Tmin = average of daily lowest minimum air temperature; and Sd = duration of accumulated hours of daily sunshine.

To calculate Ic, data were collected from Japanese observatories in snowy regions for the period of 1891 to 1990. Using time series analysis of Ic, 1945 showed the maximum value which means the most severe winter. On the other hand, 1989 showed the minimum value which means the warmest winter since weather observations began. In recent years, this index has had a tendency to decrease. If a value is >2.5, snow disasters occur somewhere in Japan. This coincides with past data and with a principal components analysis.

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Estimation of Areal Evapotranspiration and Heat Island Using Landsat TM Data: Kitami City, Hokkaido, Japan

Kimiteru Sado

An estimate of areal evapotranspiration (ET) has been made using an adopted complementary relationship method and utilizing LANDSAT and elevation data. In winter Kojima's equation is used to calculate the evaporation from the snow surface instead of the complementary relationship equation. Moreover, heat island phenomena are analyzed by using LANDSAT data to evaluate the function of green coverage in urban areas, i.e. control of the rise of ground-surface temperature.

The studied area is part of Kitami City, Hokkaido, Japan, with an area of 12 km x 9.5 km, which covers 400 pixels x 320 lines on the display monitor. After extraction of information on the study area from the full data set of 1989-05-19, and its geometric correction by Affine transformation, the LANDSAT TM data were classified into one of several land use categories, which gave empirical parameters for calculations of albedo. The seven land use categories were: city, residential area, plowed field, bare soil, grassland, forest and paddy field.

Elevation data were based on areas of 300 m x 300 m (10 pixels x 10 lines) and fitted to each pixel of the land use image data. The mean monthly meteorological elements for each pixel, such as air temperature, wind velocity and water vapor pressure, were linearly regressed with elevation from data at three observatories over a 13 a period. The atmospheric pressure for each pixel was estimated by applying the pressure correlation equation in terms of that at sea level, and global solar radiation and cloud-cover ratio were assumed to be constant over all pixels for each month.

Calculation of ET was executed using Morton's equation or Brutsaert and Stricker's equation for April to November, and Kojima's equation for the other months. The calculated results took the form not only of statistical quantities but also of transformed image data. The mean value and standard deviation of CCT counts in the sixth band were calculated by 20 pixels x 16 lines to evaluate the effects of green coverage for the same LANDSAT data.

The main results of this study are as follows:

1. The monthly change of estimated ET for April to November was compared with the ET of the observation field, which was calculated using the heat budget method. The agreement was reasonable, and so this system is applicable for estimating the actual ET of large areas, as much as several hundred square kilometers.

2. The mean monthly value of estimated ET of Kitami City has a maximum value in July and is almost symmetrical about this maximum point as seen in the Table. The standard deviations of ET in the summer months are larger than those in the winter months.

3. The image output was obtained for the heat island phenomena of Kitami City and it was shown that the ground surface temperature in the urban area has a negative correlation with the area of green cover.

Mean monthly ET obtained using Morton's and Kojima's equations

Month	ET (mm/month)
1	4.4
2	4.0
3	12.3
4	39.8
5	57.4
6	92.4
7	107.7
8	94.9
9	36.7
10	22.8
11	12.2
12	8.9

Kimiteru Sado is a professor at Kitami Institute of Technology (Koen-cho 165, Kitami 090, Japan). He has published about 50 papers in the field of hydraulic engineering. His doctoral thesis was titled "A study on heat balance and temperature analysis of river water". He is now very interested in remote sensing applications to hydrological modelling.

Canadian Arctic Ice Statistics

Chris Hill and Roger Pilkington

The great challenge to safe and efficient offshore petroleum operations in the Beaufort Sea is the presence of sea-ice. In this sector of the polar basin, ice covers the continental shelf waters for nine months of the year. Level ice thicknesses will progress from 0 to 1.9 m between October and May. Within this continuously moving cover are hummock fields, complex ridge structures, and ice islands >40 m thick.

Important to strategic planning in Canada's Arctic waters is the annual series of weekly ice cover conditions maps published by the Canadian government since 1959. Petroleum exploration activity in the Beaufort and Chukchi Seas has stimulated the development of various systems of rapid data extraction from this map series. The evolution of such systems and details of current related work are described here.

The first major Beaufort Sea digital archive based on ice chart data was a mainframe system developed in 1972. The data available at the time, however, were of inconsistent quality and contained many time gaps and much extraneous information. This archive and its data tabulation routines were adopted for in-house planning by Beaufort Sea petroleum operators. These companies extended the data base using the regularly published weekly ice charts of subsequent years and added tabulation routines specific to their individual operational requirements. In one case, the original archive system was ultimately supplanted by a mainframe relational database for which the original ice data were reformatted. This change facilitated the addition of graphical point data output to complement point data tabulations.

The Canadian government has brought on stream sophisticated data handling systems based, in large part, on the weekly ice chart series. The Canadian Coast Guard's MacIntosh-based 'ASPEN' focuses on ship transit simulations and requires averaged monthly values from data points of 28 km spacing (similar to industry archives) averaged over cells 56 km^2. Environment Canada's 'CRISP', serving a wider spectrum of public need, retains weekly temporal resolution, 28 km grid spacing, and incorporates as much information as possible from the data source. Output products include mapped statistics based on several data points. Currently, CRISP lacks a regular and timely updating system.

The authors have developed a DOS microcomputer ice data archive data handling system based on their experience with government and industry Beaufort Sea data systems. The following elements have guided the system development.

1. commercial profitability
2. focussed purpose
3. quality control of data input
4. use of existing micro-computer technology
5. timely expansion of data files
6. portability of data

The first element, profitability, is realized by careful application of the remaining five elements. Personnel and digitizing requirements are reduced to essentials by focussing on a specific market sector. Presently, that sector is Arctic offshore petroleum operations. Data quality has been optimized by discarding the less consistent and irregular pre-1968 data and by completely redigitizing the remaining data through a routine permitting professional level staff to identify and correct anomalies at the input stage. The limitation of the required input data volume and the need for zero-defect data demand this 'front-end' deployment of professional staff.

The hardware and software systems most commonly used by the potential client base, are favoured over customized configurations. Data files are expanded as each new weekly ice chart is received. Data portability is enhanced by maintaining files in two different formats, converted to ASCII code.

As with corporate systems, output includes point data tabulations, and graphs of operating season durations, weekly ice concentration probability, season duration probability, and weekly average ice concentration. Colour-coded contour maps display a regional picture of average weekly ice concentrations of different ice types and geographic zones of various operating season lengths.

On-going and future developments in ice data archiving must continue to address the concern to timely updating of data files for extensive geographic areas. Environment Canada, whose sea-ice monitoring responsibilities extend throughout Canadian waters, would be most sensitive to this concern. Within industry, offshore structure design requires detail on individual ice floe sizes. In addressing this data need, the authors are effecting improvements to a prototype digital archiving system for extraction of selected sea-ice feature measurements from synthetic aperture radar imagery. The principles which guide economical digital archiving of ice charts apply equally to this current development.

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Automatic Weather Monitoring in the High Arctic, Ellesmere Island, Canada: Climatology of Oasis Areas - Problems, Solutions and Data Presentations

Claude Labine

The year 1990 marked the 10th of the initiation of climatological and meteorological research at Alexandra Fiord on the eastern coast of Ellesmere Island in the Canadian Arctic. The purpose of the project was to understand and describe the meteorological and climatological processes which characterize a High Arctic oasis. A network of automatic weather stations was established to monitor the meso (regional) and micro (near-surface) climates. This was the first time that such a network of autostations was established in the High Arctic. These stations permitted unattended monitoring at several sites. Although loss of data was less than with older clock driven chart recorders, there were still some problems, mostly associated with human-generated errors. One of the major new accomplishments with the project was to operate an unattended station successfully during the entire year. In spite of the initial success at the beginning of the project, the solution was not ideal. A large enclosure requiring a small propane heater and tanks was used. The problem centred around the magnetic tape storage medium. All the rest of the equipment could operate to -50°C. In 1985, solid state storage RAM storage modules replaced the tape medium and eliminated the large enclosure and propane use. The instrumentation package is now quite small and can be easily mounted on a tower. The station has been operating continuously since then. During the decade of the project, solar/photovoltaic advances also contributed to the success of the operation.

Now that the basic instrumentation problems have been solved, the difficulties with unattended long-term monitoring are now more associated with the sensor portion of the data acquisition. The standard climatological parameters will be discussed in light of the implications of automatic monitoring. For example, how to rely on radiation data when the sensor can be covered with snow, or how to maintain wind records during severe icing conditions.

The main climatological results from the Alexandra Fiord project will also be presented. The main characteristics of the enhanced climate of the oasis area are radiation and temperature, with synoptic conditions contributing an important control. However, in concentrating on the oasis area climate and in trying to solve monitoring problems, more light has been shed on the arctic islands climate database.

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Three-dimensional Numerical Simulation of Snowdrift

Takushi Nakata, Takahiko Uematsu and Yasuhiro Kaneda

A method for the three-dimensional numerical simulation of snowdrifts has been developed, and calculations made of snowdrifts around snowfences, around a hut, on a hill, and in a forest beside a road. At the case of the hill, the calculated snowdrift showed good agreement with the observed snowdrift. In the case of the forest beside a road, the visibility on the leeward side of the road was much better than that on the forest side.

The three dimensional wind simulation model was used for three dimensional numerical simulation of snowdrifts. In wind simulation the Navier-Stokes equation and equation of continuity were calculated.

There are three types of transportation of snow: saltation, suspension and creep. Saltation probably plays a more significant role than suspension, but creep contributes little to snowdrift. During snowfall, suspension as well as saltation must be considered.

1. Basic Equation: Snowdrift density was calculated by solving the diffusion equation. We assumed that eddy diffusivity of the snow particles equaled that of the wind flow momentum. Eddy diffusivity was calculated using mixing length theory.

2. Boundary Conditions: Snow particles near the surface are considered to be in saltation, and so the snowdrift transport rate just above the surface was calculated. Snowdrift transport rate may be expressed as a function of friction velocity:

$$Q = \int_0^h (u\phi)\, dz = c \left(\frac{\rho}{g}\right) \frac{|w_f|}{u_{*t}} u_*^2 (u_{*t} - u_*)$$

where Q is the snowdrift transport rate per unit length of a flat plain with sufficient snow, h is the height of saltation, is air density, u is wind velocity, is snowdrift density, z is the vertical coordinate, c is an experimental constant, W_f is snow fall velocity, u^* is friction velocity, u^*_t is threshold friction velocity, and g is the gravity acceleration.

The depositional rate of snow, D, can be calculated from the snowfall velocity and snowdrift density.

$$D = W_f \phi_h$$

where $_h$ is snowdrift density in the saltation layer. If the maximum erosion rate is assumed to be equal to the maximum erosion rate E, then E can be expressed as follows:

$$E = \frac{Q \quad w_f}{u_h \quad h}$$

where u_h is the wind velocity at the saltation layer.

Finally, we can calculate the snowdrift rate S as

$$S = D + E$$

The following are constants: h = 20 cm, c = 1.0, u^*_t = 0.2 m/s and w_f = 0.5 m/s; c and u^*_t may be dependent upon snow surface condition.

The precipitation rate was 1 mm/h at the upper boundary layer. Visibility was calculated from snowdrift density and wind speed, using the relation between snow drift rate and visibility.

The results for the four cases are:

1. *Snow fences:* Snowdrifts were calculated for around snow fences (2 m high) using gaps at the bottom. When the gas is 0 cm, a large peak in snowdrift rate appeared just leeward of the fence and a wide erosion area farther leeward. As the gap increased from 10 to 40 cm, the peak of the snowdrift rate appeared even farther leeward of the fences. These results show a good agreement with the field data of many investigators.

2. *A hut:* Calculated snowdrift rate around a hut (18 m x 1.8 m x 2.4 m) showed a peculiarity called 'wind scoop'. An erosion area occurred around the hut, and snowdrift appeared on the leeward side of the hut.

3. *A hill:* Snowdrift around a hill (~200 m x 300 m x 16 m) was calculated, and the snowdrift rate converted into snow depth by multiplying the ratio of observed snow depth and snowdrift rate at an open area where the snow accumulation was not influenced by the hill. The results showed good agreement with the observed field data except on the top of the hill where snow was plowed out.

4. *A forest beside a road:* Snowdrift around a forest which protected the road from snowdrift was calculated, and it was noted that the wind speed on the leeward side of the forest was weakened by comparison with that on the windward side. Wind profiles in and around the forest showed good agreement with those observed by other investigators. Calculated snowdrift appears in and on the leeward side of the forest. Calculated visibility on the road at a height of 1.35 m was much better than that in the forest side, mainly due to decreased wind speed. Wind speed and visibility at the road at 1.35 m were calculated for various tree arrangements. Better visibility and weaker wind speed were obtained when there were several lines of trees.

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Observation of Snowflake Characteristics Using a Newly Developed Snowfall Detector

Takeshi Hasegawa, Takeshi Ito and Nobuyoshi Yamazaki

A new detecting system for determining the size of falling snowflakes was developed on a basis of optical measurement. The measuring apparatus consists of a pair of transmitters using two light emission diodes (LED) and a receiver using three photo sensitive diodes (PD). In order to cancel 'noise' from sunlight or artificial light, the LEDs are driven by a 10 kHz alternating current, and the front of the PDs are covered by a high-pass filter limited to 800 nm in wave length. When there are no snowflakes, the three electrical outputs of the receiver should be same value V_o. The relations of these outputs are defined as:

$$V_l = V_c = V_r = V_o$$

where the letters l, c and r mean the left PD, the centre PD and the right PD, respectively. When a falling snowflake passes between the transmitter and the centre PD, transmission loss of light intensity occurs and V_c decreases in proportion to the effective cross sectional area. Then the following relations apply:

$$V_l = V_r = V_o, \qquad V_c = k\,V_o$$

where k is the coefficient of exposure. The target signal V_{out}, which indicates the size of the snowflake is written as:

$$V_{out} = (V_l+V_r)/2 - V_c = (1-k)V_o$$

Static sensitivity of the new measuring apparatus was examined using various sizes of paper and given as 1 V/cm^2. The practical range of observation on the radius of snowflakes is up to 5 mm, and is limited by the dimensions of receiver. Because of time delay in the PDs and the electrical circuit of this system, a matching velocity of falling snowflakes must be determined. On this system, we tuned it around 60 cm/sec.

A pilot observation was performed using the new system in the winter of 1989. There was not much snowfall, but some important results were found, as follows:

1. Heavy snowfall over 60 counts per minute sometimes has no relation to an increase of snow depth.
2. The size of snowflakes grows when the temperature rises.
3. Plots of the size of snowflakes versus their cumulative frequency on log-log graph paper show an almost linear relation. This amplitude distribution of snowflakes is represented by:

   $$n(A)dA = K\,A^{-Sf}\,dA$$

   where n(A) is the number of the amplitude between A and A+dA, and K and Sf are numerical constants. The exponent of this distribution, Sf, showed the snowfall type and must be connected with an increase of snow depth. As a consequence, Sf may be used for predicting the increase of snow depth.
4. The relation between the time interval (T) of passing snowflakes and their cumulative frequency (N(T)) is also represented by a straight line on a log N(T)-logT diagram. This phenomenon implies that the snowfall has the tendency of group occurrence.

Our old equipment for measuring snowfall intensity, which radiated pulses of infrared rays horizontally and detected reflected pulses from the snowflakes, only counted them. From long term observation, the relation between the number of pulses and an increase of snow depth is well expressed as an algebraic function of the first degree. But these coefficients of the function have "locality" (Ito and Hasegawa, 1990). This means that the counts are affected by the sizes or velocities or reflective coefficients of snowflakes. It was for these reasons that the new system was developed.

Reference:

Ito T. and Hasegawa T. (1990) Observation and analysis of snowfall in the main snow covered regions of Akita Prefecture. Research project on Development of Instrumentation for the Property of Snow-flakes.

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Environmental Cooperation in Research and Technology Between Finland, Norway and the Kola Region of the USSR

Eero Tikkanen

Until very recently, Lapland was considered to be one of the least polluted areas in Europe. The massive SO_2 and heavy metal pollution, mainly emitted by nickel and copper smelters in the Kola Peninsula, was firmly established at the end of 1987, and the first signs of forest damage in Finnish Lapland were observed. High metal contents were measured in lichens and mosses in eastern Lapland and around Inari, in northeastern Lapland, researchers noted a scarcity of lichens which are sensitive to pollutants and a relative abundance of hardy species. The concern over the state of the environment in Lapland was increased further when the first report on the state of the environment in the USSR was published in 1989.

In order to intensify research in Finnish Lapland concerning forest damage connected with air pollutants, the Lapland Forest Damage Project, funded by the Ministry of Agriculture and Forestry, was established in May, 1989. The main objective of this 5-a project is to determine the effect on Lapland forests of pollutants from the Kola Peninsula. Such research is needed for decision making on limiting emissions. The implementation of the project requires ~FIM 15 M. An interim project report is to be published at the end of 1992 to provide more information about the critical load of the northern forests. A final project report will be published when the project is completed in 1994. The project is coordinated by the Rovaniemi Research Station of the Finnish Forest Research Institute (FFRI).

A series of permanent sample plots has been established by FFRI for the project. These have been set out as clusters of three or four plots per sampled forest stand, a sample point, along three lines radiating SW, W and NW from Monchegorsk and another four lines from Nickel in the Kola Peninsula. Near the Finno-Soviet frontier, the investigation points have been spaced at intervals of 4 km, but with distance from the border the interval increases to 8, 16, and then 32 km.

Each plot must be located in a Scots pine dominated heath forest susceptible to acidification, and the age of the Scots pines must be within the range 80-220 a and the topography flat or with an eastward slope.

The investigation points have been located using maps provided by the Finnish National Board of Forestry and private forest organizations. The investigation points were established as close to the lines as possible. At each investigation point, the sample plots were located at random in various directions 40 m from the centre of the stand. Each sample plot is 300 m^2 in area. Altogether 430 sample plots have been established at 121 points along the gradient lines, of which 14 are so-called intensive sample plots on which the research work is more extensive and thorough. The number of investigation points on a gradient line varies from 20 to 25, depending on the length of the line. Various measurements will be carried out on the sample plots and some measurements and sampling will be conducted outside the sample plots. All material destined for laboratory analysis will be collected outside the sample plots.

The Lapland Forest Damage Project is an international multidisciplinary cooperation project comprising ~60 researchers from five Finnish universities and five research institutes. The participating universities are Helsinki, Joensuu, Kuopio, Oulu and Turku, and the research institutes are the Arctic Centre, the Finnish Forest Research Institute, the Finnish Meteorological Institute, the Geological Survey of Finland and the National Board of Waters and Environment.

The Lapland Forest Damage Project consists of 14 subprojects, covering the disciplines of biochemistry, botany, environmental and forest sciences, geology, limnology, meteorology, and zoology.

In addition to the cooperation within Finland, an agreement concerning scientific cooperation has been made with researchers employed in Apatity in the Kola Science Centre of the USSR Academy of Sciences. During the summer of 1990 the Soviets established sample plots with the help of Finnish field workers. The investigation points lie between the border and the emission sources. The work will continue in the summer of 1991.

Environmental cooperation in the field of technology is also beginning between Finland, Norway and the Kola region. Finnish and Norwegian technology for nickel smelting will be delivered to the Kola Peninsula. The upgrading of the nickel smelters in Monchegorsk and Nickel will take place from 1991 to 1994 at a cost of FIM 3000 M. Sulfur dioxide and heavy metal emissions by the smelters will diminish by ~80% after the upgrading. At the moment, SO_2 emission in the Kola Peninsula is ~700,000 t/a.

In conclusion, specific environmental cooperation in research and technology between Finland, Norway and the Kola region of the USSR has been initiated. This kind of international cooperation is necessary and it will increase between scientists, politicians, state and public authorities, and public organizations in the arctic and subarctic regions. The Arctic Centre, a separate institute within the University of Lapland, is promoting this kind of activity in each of its three functional units, i.e. the science centre, the information service unit and the research institute.

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Pollution Abatement Options for the City of Edmonton, Alberta, Canada

Riaz Choudhry

The City of Edmonton contributes pollution to local surface waters in the form of urban discharges to the North Saskatchewan River, which traverses the middle of the city. These urban discharges consist of 22 combined sewer overflows and 215 storm sewer outfalls. The combined sewers contribute biodegradable pollutants, while the storm sewers contribute non-biodegradable pollutants in large quantities. Therefore, effective pollution abatement involves reduction/elimination of both combined and storm sewer discharges.

The options developed and analyzed to reduce the combined sewer overflows include:

Combined Area Separation - involves the provision and connection of an additional sewer for each road and lane, and the disconnection of the existing services for separate conveyance of sanitary and storm flows. The total cost is estimated at $1300 M with completion time of 50 a.

Underground Storage - involves the temporary retention of combined sewer overflows in an underground storage facility, with flows released back into the system after rainstorms. This option reduces the risk of direct contaminant discharge to the river. The storage cost for the 5- and 1-year design storm system was estimated at $400 M and $150 M, respectively.

The system separation option is very costly. It creates additional storm outfalls for newly separated areas which may require treatment storage to reduce direct pollutant loading of the river.

The storage option, which can be staged, will effectively reduce combined sewer overflows from all frequent storms up to the chosen storm frequency.

The options considered for pollution reduction from storm discharges were:

First Flush Storage - involves the detention of the first 1.27 cm of runoff from a storm which contains 80-90% of the pollutants discharged to the river. A system of ponds and wetlands is proposed in order to achieve the required treatment. The total cost of providing reduction from major outfalls is estimated at $100 M.

Alum Injection - involves injecting alum into the storm sewers during storms. Alum attracts suspended solids as it moves and rolls into the receiving bodies in the form of large lumps. Field results show 85% removal rate.

Flow Balance Method - involves the equalization of urban runoff in a pontoon tank system in accordance with the plug-flow principle. The flow into the tank system is controlled. The resident time for pollutant removal will be 48 to 72 h.

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Alternative Concepts for Access to Water and Sewer Mains, Northwest Territories, Canada

J.P. Van Praet, K.R. Johnson, B.C. Grieco and R. Kent

A study to investigate alternate, less costly, access systems for underground servicing of water and sewer mains was undertaken in 1989 on behalf of the Department of Municipal and Community Affairs, Government of the Northwest Territories. The current system used in permafrost areas of the Northwest Territories is a buried insulated steel access vault. This design is a result of nearly 20 a of development; however, the supply and installation of these vaults accounts for ~30% of the contract price for the construction of a piped utility system.

The study involved a decision analysis of a number of alternative concepts. Information for the alternatives was based on a survey of access systems in Alaska, the Yukon Territory, and the Northwest Territories. These concepts were then refined, and combined to provide a large number of potential access systems. A preliminary analysis was completed on these alternative systems to remove the impractical and undesirable options, leaving 17 access system alternatives for detailed analysis.

The detailed analysis of the remaining alternatives consisted of a Kepner-Tregoe Decision Analysis. A list of system performance 'must' and weighted 'want' objectives was developed which formed the basis for the analysis. The 'must' objectives included access for cleaning and thawing sewer mains, access for draining and thawing water mains, and access to operate, maintain and repair appurtenances. The 'want' objectives included capital cost objectives, and maintenance objectives.

The 17 alternatives remaining after the preliminary analysis were evaluated using the 'must' criteria, with 13 passing all 12 'must' criteria. The remaining 13 alternatives were then analyzed using the 18 weighted 'want' criteria.

The evaluation using the weighted 'want' criteria indicated that the three highest ranking alternatives for access to sewer and water mains (in decreasing rank) are:

1. Common underground mains with insulated steel access vaults (existing system).
2. Common underground mains with insulated High Density Polyethylene (HDPE) access vaults.
3. Separate underground mains with shallow insulated HDPE water-access vaults, (requiring a portable shelter), and insulated HDPE sewer-access vaults.

The common underground mains with insulated steel access vaults (existing system) ranked highest in the subgroup of "Operation and Maintenance Objectives", but it ranked eighth in the "Capital Cost Objectives" subgroup. The low ranking in the latter subgroup is largely due to high fabrication costs.

A buried insulated HDPE access vault was identified as a potential lower cost alternative to the insulated steel access vault, which may be suited for certain applications. However, the suitability of the HDPE access vault requires more investigation before it can be considered for widespread use in the permafrost region of the Northwest Territories.

The final step of the analysis consisted of a Risk Analysis to examine the probability and seriousness of any risks related to the three highest ranking access systems. The highest ranking access system, which is the existing insulated steel access vault, is not associated with any risks serious enough to discontinue its use.

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B.C. Grieco is the Chief Engineer in the Arctic Engineering Division of UMA Engineering Ltd. in Edmonton. He has 27 years professional experience, 20 of which were involved almost exclusively in the planning and engineering of northern municipal water supply, sewage disposal, and subdivision development projects.

R. Kent is the manager, Community Works Management and Training, Department of Municipal and Community Affairs, Government of the Northwest Territories (Box 1320, Yellowknife, NWT X1A 2L9, Canada) and has approximately 10 years experience in water and sanitation planning, and municipal planning and management.

Advanced Wastewater Treatment by Contact-Aeration and Soil-Trench System

Takayuki Yasui, Katsuo Kinoshita, Kohzo Akahide, Norihito Tambo, Katsuhiro Murata and Masaaki Kuribayashi

In the cold regions of Japan, a lot of resorts have been developed in the expectation of visitors for both skiing and summer activities. The disposal of gray water and the secondary treated wastewater from hotels, restaurants and so on causes a serious problem so that the water environment becomes worse. One of the main difficulties in this regard is the inefficiency of the conventional biological treatment in cold regions.

The proposed system, which is composed of a contact aeration tank and a soil trench system, was developed to solve this problem. The characteristics of the system are as follows: (a) the efficient removal of organic matter and nutrient salts from gray water and the secondary treated wastewater can be performed by combining a soil trench system with a contact aeration tank; (b) the total system is installed in the ground below the frost line in order to maintain the efficient treatment of the wastewater in cold regions.

This system consists of two tanks, one for contact aeration and the other for upflow filtration, as well as a soil trench system. The contact aeration tank biodegrades organic matter and nitrifies ammonia nitrogen. The upflow filter tank removes suspended solids from the contact aeration tank. The soil trench system consists of three elements: i.e. upper trenches, lower trenches and the surrounding soil which is enclosed with an impermeable film. The effluent from the upflow filter tank permeates from the upper trenches and is purified through the soil, while the lower trenches collect the treated wastewater. The soil trench system not only removes non-biodegradable organic matter and P through adsorption on to soil particles, but also removes nitrogen by denitrifiers in the soil.

An experimental study was carried out with the mixed wastewater of the effluent from a septic tank and gray water. The results were as follows:

1. In the influent, biochemical oxygen demand (BOD5), total nitrogen (T-N), and total phosphorus (T-P) are 70 mg/l. 100 mg/l and 7.1 mg/l on the average for a year, respectively.
2. The effluent BOD5 is 4 mg/l (removal efficiency 94%) on the average for a year. This value is one-fifth of the effluent standard in Japanese wastewater works. Even when the influent temperature is <10°C, the effluent BOD5 is 6 mg/l (removal efficiency 91%).
3. The effluent T-N is 47 mg/l (removal efficiency 53%) on average for a year. When the influent temperature is >10°C, the effluent nitrogen consists of ammonia and nitrate nitrogen. If the influent temperature is <10°C, however, nitrate nitrogen is also found in the effluent, which causes an increase in the chemical oxygen demand of the effluent.
4. The effluent T-P is 0.16 mg/l (removal efficiency 98%) on the average for a year. This value is one-third that of the effluent standard in the ordinance on the prevention of eutrophication in Japanese closed-water bodies. The effluent T-P is 0.22 mg/l (removal efficiency 97%) if the influent temperature is <10°C.

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Technical and Economic Evaluation of Ice Reduction Methods for Northern Potable Water Reservoirs

S.J. Stanley and D.W. Smith

In many communities in cold climates a continuous year-round water source cannot be assured. As a result, water must be stored to supply demand during the periods of source failure. One of the most commonly used methods of storage is open reservoirs.

In cold climates these reservoirs can experience ice thicknesses of >2 m. The volume of water taken up by the ice may be up to 50% of the total reservoir volume. This loss of storage volume to ice must be taken into account in the design of the reservoir, which results in the actual volume of the reservoir being much larger than that required just to meet the demand. An effective method of reducing the ice growth would decrease the quantity of storage capacity lost to ice and therefore reduce the required total volume of new reservoirs. For existing reservoirs a reduction in ice growth would increase the volume of useable water and hence increase the service life of the reservoir. Because of the sometimes severe and difficult construction conditions that exist in cold climates, the cost of reservoirs can be substantial. Therefore, the reduction in total reservoir size could result in significant savings. In existing reservoirs the increase in the service life would delay the high costs of new construction.

A study was completed to evaluate available methods of reducing ice growth, and to determine if it is feasible to use them in the design of new reservoirs or to increase the service life of existing reservoirs. Methods were evaluated for their effectiveness at reducing the loss of storage capacity to ice, based mostly on technical considerations. For many options a numerical ice growth model, which was developed as part of the study, was used in the evaluation. Based on the sound technical information obtained, each option was evaluated both for its economic efficiency, and for its general acceptability for use on a potable water source. Methods considered include: geometric optimization of the design of the reservoir; reducing ice thickness; and shortening the period that storage is required.

The study found that the geometry of a reservoir can effect the quantity of water lost to ice. Factors considered were sideslope, shape and depth; depth was the most important factor.

To reduce ice thickness, the study considered methods that altered the heat exchange at the top surface of the ice, methods that altered the heat exchange at the bottom surface of the ice, and methods that altered the chemical properties of the ice. Of the methods considered only two proved to be effective, economically viable, and acceptable for use at a potable water source. They were, accumulating snow on the surface through the use of snow fences, and the placement of insulation on the ice surface. The greatest economic saving resulted from snow accumulation. However, this method involves a greater risk because sufficient snow must be present to be collected by the snow fences. Economic savings were evident for the use of insulation. Economically, it was found that these methods were most beneficial in extending the life of existing reservoirs.

The study found that it was possible to reduce ice thickness on reservoirs in a manner that would result in economic savings. The study also strongly recommended that field tests be used for the two best options, which would provide needed information on some of the operational difficulties associated with the methods.

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Daniel W. Smith is a professor and Chairman of the Department of Civil Engineering, University of Alberta. He has worked extensively in cold climate engineering and has published more than 170 papers and reports, many in the field of cold climate engineering.

Adsorption of Heavy Metal Cations by Various Slimes Originating from the Undersea Seikan Tunnel, Japan

Masami Kishi and Norimoto Watanabe

The Seikan Tunnel connects Hokkaido and Honshu. The under sea tunnel is located 240 m below the sea surface, and is 53.85 km in length, making it the longest in the world. Seawater and underground water enter the tunnel from adjacent rocks and are pumped out at a rate of 28 t/min. The sedimentary slimes formed in the tunnel are caused by these waters. The slimes have very high CEC (Cation Exchange Capacity) and are expected to adsorb heavy metal ions.

Four kinds of coloured slimes (Y-1 - Y-4) were collected from Yoshioka Kaitei Station on the Hokkaido side. The characteristics of these slimes are indicated in Table 1.

Table 1. Properties of slimes studied

Slime	Moisture content (%)	Loss on ignition (%)	Total Carbon (%)	Total Nitrogen (%)	Total Phosphorus (%)	pH	EC μ(S/cm)	CEC (meq/100g)	Metal contained
Y-1(black)	28 6	15 2	1 05	0 19	0 03	6 80	41 1	120	Mn
Y-2(white)	2 6	39 9	5 52	0 04	tr	9 89	9 7	2	Ca, Al, Mn
Y-3(red)	9 5	14 8	2 05	0 26	0 36	7 68	47 1	36	Fe, Na
Y-4(brown)	13 7	19 0	4 71	0 43	0 16	7 30	34 4	24	Fe

DTA curves of Y-1 and Y-4 slimes up to 600°C showed broad endothermic peaks at ~150°C due to dehydration of water and also small exothermic peaks from 300 to 400°C. There were no peaks in the Y-2 and Y-3 slimes. The infrared spectrum by Y-2 slime was in good agreement with that of calcite, and clay mineral patterns wee found in the Y-3 and Y-4 slimes. All slimes showed a noncrystalline state by powder XRD patterns without peaks.

The slimes were desalted with distilled water and used for adsorption and desorption experiments for Cu^{2+}, Zn^{2+}, Cd^{2+}, Pb^{2+}, Hg^{2+}, Mn^{2+}, Fe^{2+}, Fe^{3+} and Cr^{3+} ions.

The adsorption of heavy metal cations was determined by a batch method. A solution containing 1 g of slime and 50 ml of 10^{-2} M/l heavy metal ions was centrifuged for 2 h. Complete adsorption was observed for Cu^{2+}, Zn^{2+}, Pb^{2+}, Hg^{2+}, and Fe^{2+} ions by Y-1, for Zn^{2+}, Cd^{2+} and Fe^{2+} ions by Y-2, and for Pb^{2+} by Y-4. Adsorption >93% was attained for Pb^{2+} and Hg^{2+} ions by Y-3. Extremely high adsorption was observed for the trivalent ions Fe^{3+} and Cr^{3+} by Y-2 and Y-3. The increased adsorption of these ions is attributed to precipitation as hydroxide.

Adsorption experiments using a leaching method were also conducted. A glass column (4.2 cm x 150 cm) was packed with 100 g of desalted slime. The Y-1 slime showed remarkable adsorption of all heavy metal ions. A mixed solution of 10^{-3} M heavy metal ions (Cu^{2+}, Zn^{2+}, Cd^{2+}, Pb^{2+}, Hg^{2+}, Mn^{2+}, Cr^{3+}) was added to the glass column, one l at a time, 10 times. The heavy metal ions were adsorbed 100% after leaching only two l of the solution. The adsorption for the total solution (10 l) leached was in the order:

$$Pb^{2+}>Cu^{2+}>Cr^{3+}>Cd^{2+}>Zn^{2+}>Mn^{2+}>Hg^{2+}.$$

It is suggested that the adsorption differences are caused by an affinity of each heavy metal ion species on the surface of Y-1 slimes.

The desorption of heavy metal ions from the slimes was determined by a batch method, with 50 ml of distilled water for 2 h. Extremely low desorption was found, ranging from 0% to 0.28% for Cu^{2+}, Zn^{2+}, Cd^{2+}, Pb^{2+}, Hg^{2+} and Fe^{2+} ions by Y-1, and <0.04% for Fe^{3+} and Cr^{3+} ions.

The desorption of heavy metal ions by Seikan Tunnel slimes was particularly low, so that the slimes could be useful materials as adsorbent of heavy metal cations.

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Water Quality During the Snow Melting Period: Ogawa River, Japan

Harukuni Tachibana, Masaharu Ando and Hiroyuki Ohmori

In spring in northern regions, a large quantity of snow-melt water and chemical components which accumulated in the snow and soil flow into local rivers. These cause many peculiar seasonal changes in the ecology of the rivers and lakes. Snow-melt water is now attracting attention as a good water resource, and its quality is an important factor in deciding its value. This study is concerned with the quality of snow-melt water, mainly nutrients, and its run-off characteristics in a forest river as a basic study for conservation and utilization of rivers and lakes during the snow melting period. The study is of value with respect to the forest ecology and the management of forests because it is possible to estimate the budget of chemical components.

The waterway studied near Sapporo City was the Ogawa River (mean flux 0.8 m^3; catchment area 11 km^2; length 7 km), a small branch of the Ishikari River (269 km long), the second longest river in Japan. The Ogawa River starts from Mt. Muine (1461 m) and Mt. Nagao (1205 m). Its catchment area is covered with spruce, white birch, alder and other trees, and the bedrock consists of easily eroded rocks. The mountains in the catchment area are covered with snow until late spring. The snow melting season is from April to May, and annually changes the flux of the river. Summer is from June to August, autumn from September to November, and winter from December to March.

The water was sampled 370 m from the source of the Ogawa River from September 1980 to August 1988. Generally, samples were taken weekly (every 10 d in winter). From spring to autumn, the water was sampled daily at a fixed time, usually noon, using an auto sampler (ISCO-1680). On rainy days, the water was sampled about twelve times a day corresponding to the flux changes. The air temperature, water temperature, flux, and depth of snow were measured at the same time.

The water was analyzed for 30 chemical components related to eutrophication: total N, total P, some nutrient compounds (nitrate-N, nitrite-N, ammonium-N, organic-N, phosphate-P, organic C), suspended solids and the main inorganic ions.

The results mainly describe the behaviour of the nutrients, and are summarized as follows:

1. Water run-off from melting snow was recognized from early April to late May. The rate of water load during this season is ~60% of the yearly flux, and the rate of nutrient load exceeds that of the water load.

2. During the snow melting period, N in the water occurs mainly in dissolved form, and P in particulate form. Nitrate was the dominant form of dissolved N. Variation of the N/P ratio was not large.

3. The mean water quality during this period indicates a meso-eutrophic condition. At an early stage, an eutrophic condition was observed.

4. Most of the nutrients during this period were scrubbed from the soil and some were eluted out of accumulated organic matter.

5. Run-off patterns of the chemical loads during this period were related by $L = c \cdot Q^n$ (L = chemical component load; Q = water flux, c,n = constants) and showed nearly the same tendency throughout the year.

6. Concentration of nutrients ($C = c \cdot Q^{n-1}$), except ammonium, increased as the water flux increased (n>1). Concentration of ammonium and ordinary inorganic components was nearly constant or somewhat decreased (n = 1 or <1).

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Solid Waste Management Study for the City of Yellowknife, Northwest Territories, Canada

Norm Nuttal, Konrad Fitchner, Jim Clare and Ian B. Macleod

The city of Yellowknife came under scrutiny from public and environmental groups due to the uncontrolled burning and resulting smoke nuisance from the existing dump site. The ultimate aim of this study was to create a waste management master plan for Yellowknife. The project was divided into two phases.

Phase I involved developing a catalogue of possible alternatives for review by the city. Phase II involves developing a plan for implementing the options of Phase I.

To determine which of several waste management alternatives would be suitable for Yellowknife required the development of a data base, which was a detailed breakdown of the nature and quantity of the waste material.

An investigation of the existing dump site was completed to determine what steps could be taken to operate the site as a proper sanitary landfill and to determine its potential life. The final contours and life of the site are dependent on the future use of the site, e.g. parkland 5 to 10 a; ski hill 15 to 20 a.

A review of possible new locations for a sanitary landfill for the long term was also completed.

Ten waste management alternatives were prepared:

1. Existing Modified Landfill Operations: continued use of the existing site and continued use of uncontrolled waste burning as a means of volume reduction and lessening of cover material requirements.
2. Sanitary Landfill Operations at the Existing Site: conversion of the existing site to a sanitary landfill.
3. Sanitary Landfill Operations at a New Site: sanitary landfill operations at a site located at least 8 km from the airport.
4. Shredding and Shred-fill: new site for shred-fill operations, continued use of existing site for construction and demolition debris and large scrap steel waste.
5. Baling and Bale-Fill: new bale-fill site with continued use of existing site for construction and demolition debris and large scrap steel waste.
6. Curbside Recycling: citywide curbside recycling program in conjunction with sanitary landfill operation.
7. Drop Off Recycling: establishment of a drop off recycling depot in conjunction with sanitary landfill operations.
8. Incineration Without Waste Heat Recovery.
9. Incineration With Waste Heat Recovery for District Heating.
10. Incineration With Power Generation: dependant on functionality, suitability, environmental and community benefits, and capital/operating costs.

Five locations were identified for consideration as potential sites for a sanitary landfill, all within 10 km of the city centre.

Phase II. All the options were presented to city council and the residents of Yellowknife at several open meetings. Following these meetings, the city gave notice to proceed with further study and to develop the following options:

1. Sanitary Landfill Operations at the Existing Site;
2. Sanitary Landfill Operations at a New Site;
3. Baling and Bale-fill; and
4. Curbside Recycling.

The following is a brief discussion of the work performed in developing these options.

1. Sanitary Landfill Operations at the Existing Site. The primary goals of the conversion were to change the existing method of operation to reduce the size of the working face of waste exposed, increase the amount of compaction using heavy equipment and increase the frequency of covering with granular material. For the conversion of the existing site, a manual was prepared to assist the city in operating the site as a sanitary landfill. This manual showed the present site broken down into a series of cells which would be operated until they reached a specific elevation.
2. Sanitary Landfill Operations at a New Site. A new site was to be found to be developed as a sanitary landfill. As per guidelines developed by Transport Canada, a collection facility for waste material cannot be sited within an 8 km radius of the center of the airport in an attempt to eliminate bird strikes at airports. On the advice of the city, a site to the west of Yellowknife was to be investigated in the area of the sewage lagoon, so as to have all the 'undesirables' in one area.
3. Baling and Bale-Fill. This involves the development of a baling facility at the existing site. Bales will then be disposed at the existing site for the short term and hauled to a new landfill after its development.
4. Curbside Recycling. The development of this option involves preparing cost estimates to demonstrate the initial capital costs and the annual operating costs for a city-wide recycling program. These would be offset against the revenue generated by the recycling to determine the net annual subsidy by the city to maintain the program. The recycling program would include aluminum and steel cans, glass, newsprint and cardboard. These materials are highly visible in the Yellowknife waste stream and are easily segregated. Long-term markets are expected for all of these materials but presently aluminum cans are the only economically viable recyclable commodity.

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Evaluation of Alternative Technologies for the Management of Industrial Wastes, Nalluk Base, Tuktoyaktuk, Northwest Territories, Canada

Alan R. MacDonald

BeauDril Limited (a division of Gulf Canada Resources Limited) operates an offshore drilling program in the Beaufort Sea from Nalluk Base near Tuktoyaktuk, Northwest Territories. Waste generated by offshore activities which is not suitable for offshore disposal is transported via ice road or barge to the Nalluk Base Waste Management Facility for handling, treatment and disposal.

Conventional waste management techniques, such as landfilling, lagooning, cementation, biological treatment and incineration are all made difficult or unacceptable due to the unique climatic, logistic and geotechnical concerns associated with the north.

Integrated Environments Ltd. (IEL) has acted as the waste management facility operator and environmental consultant to BeauDril Limited has developed site-specific facility operating procedures and options for the treatment and disposal of the four major waste streams. These technologies were evaluated in terms of logistic, regulatory and economic considerations in a matrix format.

Among the numerous wastes received at Nalluk Base four waste streams represent the majority of the volume handled. These are, slop oils (waste fuel/waste oil), oily waste water, used ethylene glycol, and industrial solid wastes (burn barrel ash, empty paint cans, dead batteries, scrap metal, banding, and so on).

Domestic camp wastes such as sewage and kitchen wastes are generally not handled at the waste management facility. Kitchen wastes are transferred via loader from metal containers on site to be dumped at a landfill ~4 km NW of Nalluk Base. Sewage is transferred by truck to a lagoon ~9 km W of Nalluk Base. Both the lagoon and the landfill are operated by the hamlet of Tuktoyaktuk.

Chemical wastes listed in Schedule II of the Canadian Transportation of Dangerous Goods Act and Regulations are held in a contained storage compound until the end of the operating season, then transferred to a regulated waste disposal facility at the Tricil Plant, Sarnia, Ontario.

Current practice for the disposal of slop oils involves bulking, decanting of water, and incineration through a skid-mounted, open-air rotary cup waste oil burner (Saacke SKV 150 manufactured in Germany) operating at a rate of 8 l/min. Little to no visible smoke emissions are produced. An air monitoring program conducted by Hardy BBT Ltd. in 1989 indicated that 'the operation of BeauDril's Saacke Burner had no appreciable effect on air quality in the vicinity of the BeauDril camp'.

In the past, oily waste water and used glycol were evaporated in front of the Saacke Burner in a 1600 l steel tray. Concerns for operator safety, environmental fall-out, and the need for increased disposal efficiency required new options for treatment of the water. This study addressed these options.

Industrial solid waste is segregated at Nalluk Base. Waste batteries are shipped to a battery recycling facility. Dry burn barrel ash is screened for As, Pb and Cr with the portable HAZCAT Chemical Identification System. Ash deemed safe is sent to the Hamlet of Tuktoyaktuk landfill, as is scrap metal waste. The use of this landfill is of concern because it is poorly sited and disposal of metallic solid wastes can cause changes in the thermal conductivity of permafrost sites, resulting in permafrost melting or frost jacking. Use of this method of disposal must be minimized.

Numerous waste management options were reviewed for the treatment and disposal of the four major waste streams. These options included recovery, thermal, biological, physical-chemical and land disposal methods. Within each of these areas specific technologies or methods were assessed in terms of economic, regulatory and logistic considerations. Information on the costs, performance, pollution control efficiency, operational requirements and transportability of individual technologies was reviewed. Matrices were developed from this information to enable decision-makers to evaluate the engineering, economic and environmental consequences when choosing a treatment or disposal method.

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Considerations for Waste Management in Remote Arctic Regions

J. Henry, A. Badakhshan and M. Robinson

This paper reports an investigation of a northern waste treatment problem at the Kluane Lake Research Station (KLRS), of the Arctic Institute of North America, located ~200 km northwest of Whitehorse, Yukon Territory. In recent years the number of researchers using this site has climbed dramatically and there is now a human and solid waste disposal problem. A study of the problems faced by KLRS presented an opportunity to evaluate the similar difficulties faced by many small northern communities. Specifically, northern communities lack energy resources and a skilled labour pool, while possessing a seasonal population and a climate which suppresses biological activity for much of the year.

Traditional solutions to these constraints have been simplistic, the most common practice being the dumping of untreated waste with the subsequent use of gasoline to burn it. Potential modern solutions to the problem include marsh treatment, biological systems, shipment of wastes out of the area by truck or plane, and incineration.

The first three modern alternatives have one or more significant disadvantages that preclude their use. Marsh treatment, where raw waste is piped into marshland, possesses potential aesthetic and health problems if handled improperly. All biological systems have their activity suppressed for much of the year unless there is sufficient energy available to heat them, and they require uninterrupted operation with continual supervision. Finally, the shipment of wastes by truck or plane is expensive, offers the potential of improper disposal, and essentially exports the problem to another Arctic location with identical difficulties.

It is suggested that the best solution is the use of well-designed, small-scale incineration units with efficient emission controls. These units are available commercially and provide an opportunity for communities like KLRS to deal with their human and solid waste problems efficiently. A discussion of the economic aspects of incinerator purchase are also presented.

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Water - Resource Management in Beijing

Xiaoqin Yuan, Yanhua Chen and Grant Ross

Beijing has been the political and cultural center of China since the Ming Dynasty about 500 years ago, its plentiful groundwater and surface water are historically important to the capital city of China. However, in recent years high population density and inappropriately rapid industrial development have resulted in severe water shortage. In response, the Beijing municipal government is developing new policies and adopting modern technology to prevent escalation of the crisis.

Hydrometeorological Conditions. Beijing, located in the temperature zone, has a monsoon climate with high temperatures in summer and cold, dry weather in winter. The precipitation regime is typically several dry years followed by several wet years, alternatively. Average precipitation is 626 mm (range 240 to 1400 mm).

Beijing uses 2.7 to 2.8 billion m^3 of groundwater. Miyun and Guantin reservoirs, plus some smaller reservoirs, provide 1.2 to 1.3 billion m^3.

Groundwater. Of the 2.7 to 2.8 billion m^3 of groundwater used, 2.5 to 2.6 billion m^3 is considered allowable extraction and 0.2 billion m^3 overextraction. The consequence of overextraction is rapid decrease in underground water level, especially in urban Beijing. The thickness of the water-bearing stratum has been halved over much of Beijing's area; in some areas, the aquifer is dry.

Overextraction of groundwater has also led to ground subsidence up to 0.1 m over 200 km^2.

Surface Water. Miyun and Guantin reservoirs, with design capacities of 4.3 and 2.0 billion m^3, respectively, are located in Miyun and Yanqin counties about 200 to 300 km from Beijing. These two reservoirs are now able to contribute only one to two billion m^3 of fresh water to Beijing depending on annual precipitation. The reservoirs' capacities have been reduced to 1.5 and 0.6 billion m^3, respectively, by sedimentation caused by shoreline erosion.

Pollution of the Water Resource. Overextraction of groundwater increases its flow rate which scours the surrounding water-bearing stratum, resulting in increased hardness (concentration of ions such as CA^{2+}, Mg^{2+}, HCO_3^-), in some areas much higher than established limits.

Elements such as nitrates, phenols and mercury from municipal, industrial and agricultural waste are found beyond established limits in Beijing ground and surface water.

Water treatment technology is changing and water reuse facilities are mandatory in new large-scale construction in Beijing. Water is no longer viewed as an inexhaustible public resource.

Water Reuse. Beijing is the first Chinese city to require water reuse facilities for medium- and large-scale construction projects (since 1988). Each project over 20,000 m^2 in floor area must incorporate a water reuse system. The waste stream is divided, with toilet waste directed to the city sanitary system and the remainder processed "in-house" to an established standard. The recovered water is for exterior uses such as car washing and garden watering. The extent of water reuse is, however, hindered by system costs, technology complexity and a lack of training for operators. Another problem is that the public is not yet readily receptive psychologically to water reuse.

Water Conservation Projects. Public attitudes regarding water as a public resource are changing with serious shortages. In the late 1980s, conservation legislation took hold. Companies have to pay water-use fees and waste water discharge fees on schedules that increase with project consumption and volume of waste water.

For existing buildings, the fees increase dramatically in successive increments beyond established use levels.

Legislative Structure for Water Management in Beijing. The Beijing municipal government public resource bureau is responsible for the supply and distribution of water after treatment. The environmental protection bureau is charged with maintaining water quality and protecting the water resource from pollution and other damage. Water resource planning is handled by the planning bureau. However, senior city administration may directly control large planning projects, bypassing these regulatory bureaus.

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Method of Early Forecasting of Local Heavy Snowfall Weather Using Meteorological Noises

Eikichi Asari

There are two methods of forecasting weather that results in heavy snowfalls. One is an 'early warning' method which detects an approaching weather system, and the other is 'local' which examines the detailed nature of the approaching weather system.

Early warning is necessary to protect from disasters, but it is also necessary to use an efficient, high-cost local system on a large scale like a radar system.

Heavy snowfall weather emits special electro-magnetic radiation - noise waves. If these waves are examined and analyzed, it is possible to give an early warning for the weather at a distance several times as far as the radar-detection area, where the storm can be 24 h away.

Radio engineering was developed and utilized for this forecasting method. The cost is among the lowest of the many weather forecasting methods, but the accuracy is very high. Besides, this method results in an instantaneous warning at any time, and it is complementary to and supported by other weather forecasting methods, so that when they are all combined, it has the characteristic to raise the overall reliability rapidly.

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Primary Experiments with Snow Avalanche Deflecting Structures

Kazunori Fujisawa, Chuichi Shimomura and Jun Kobayashi

Low temperature model experiments were conducted to determine the height and distance of the snow waves that occur when an avalanche strikes a deflecting structure. The heights and distances of snow waves were measured using a high-speed video camera. As a result of these close observations, it was learned that the behaviour of avalanches striking against the model deflecting structure varied greatly, depending on the angle of collision and the gradient of the impacted surfaces. Significant variations in behaviour were observed more frequently with variations in the slope of impacted surfaces than with various angles of collision. When the leading edge of an avalanche collides with a deflector with a slope of 90° the first snow is thrust up by the following avalanche and forms a curved front toward the direction of flow. The upper part of the avalanche is pushed up farther by the succeeding avalanche and collapses to form an overhang. With deflectors having slope angles of 45° and 60° the first part of the avalanche is pushed forward by the succeeding avalanche and continues to flow, retaining a constant width in the form of a roll which contains a void inside. The only difference noted between the two angles (45 and 60°) is that the tip of the avalanche is pushed forward more with a slope of 45° and is pushed upward more with a slope of 60°. The height and distance of the snow waves observed from the model experiments can be expressed by the following formulae.

1. Height of snow waves

$$H = \frac{(k \cdot V\phi \cdot \sin\theta)^2}{2 \cdot g \cdot (\sin\beta + \mu \cos\beta)}$$

2. Distance of snow waves

$$L_1 = 0.6 \times \frac{k\, V\phi^2 \cdot \sin\theta}{2 \cdot g \cdot \Phi^2} \cdot (2 \cdot \Phi \cdot \cos\beta - \mu \cdot k \cdot \sin\theta \cdot \cos\beta)$$

Where, $\Phi = \sin\beta + \mu \cos\beta$

From the above formulae, the height and length required for deflecting structures are:

3. Height, $Hd = Hs + Ha + H$

   Where Hs = maximum depth of snowfall; Ha = depth of avalanche; H = height of snow wave.

4. Length, $L_d = 2L_1 + B/\sin\theta$

   Where L_1 = distance of snow waves,; B = width of snowflow; θ = angle of collision

Large structures are required in order to properly deflect the surface layers of an avalanche, and the cost of construction is accordingly quite high. Therefore, the immediate problem is to determine the amount of overflow when the height of the deflecting structure is lower than Hd. In other words, it is necessary to find the relation between the required height of the deflecting structure with respect to the thickness of the surface layers of the avalanche, and to determine the amount of overflow.

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Development of a Fencing System to Reduce Snow Damage in Snowy Areas, Japan

Yoshiharu Hosokawa

A suitable fence is one of the important factors in managing grazing cattle in pastures. Fence materials in Japan are generally composed of steel posts, barbed wired, and the metallic parts to hang the barbed wire on to the posts. Fence damage, e.g. the breaking or sagging of barbed wire and the leaning, bending or falling of posts caused by snowfall, however, takes place frequently in the snowy areas of Japan (Hosokawa, 1985). Repairing damaged fences has become troublesome in many public pastures. Further, the high maintenance costs have resulted in deficit operations for public pastures every year. Snowy areas can therefore expect damaged fences. A suitable fencing system was developed by studying existing fence materials and structures, and fence maintenance after construction. With respect to materials, high-tensile wire was used in the new fencing system instead of barbed wire. Although barbed wire actually functions to prevent the cattle straying outside the fence, the barbed wire bears heavier snow loads because of the barbs, compared with plain wire like the high-tensile wire. The other materials developed comprised wire-strainers, sub-posts made from scaffolding steel pipes, droppers instead of steel posts, and line or anchor posts for fixing uneven fence lines. High-tensile wire is more advantageous than barbed wire for keeping the fence taut in rolling country. Cattle were prevented from straying outside the fence if it was composed of 4-high tensile wires of 785 to 981 N tension, and if droppers were set up on a 2 to 4 m spacing; this system was as effective as a 4-barbed wire fence. Laying down the fence after the grazing in the autumn was the best way to avoid snow damage. This system could be called the lay-down fencing system.

In the construction costs shown in the Table below, the high-tensile wire fences, including electric fences, were <250 yen/m using the 4-, 3-, or 2-high tensile wire of 12 yen/m and droppers of 100 yen each. The conventional 4-barbed wire fences were 1000 yen/m, using driven steel posts of 1700 yen each at 4 m intervals and by hanging the barbed wire at 20 yen/m. Because hanging barbed wire on posts is troublesome due to the barbs, it takes a long time to construct and the construction cost is high. By comparison, the high-tensile wire fence reduces the construction cost because of the absence of barbs.

Comparison of fence structures and costs

Type of fence		Structure				Costs (yen/m)			
		Fence length (m)	Post spacing (m)	Dropper spacing (m)	No. of wires	Construction			Maintenance
						Material	Labor	Total	
High tensile wire fence*	A	825	-	4	4	183.7	53.9	237.8	5.5
	B**	350	-	12	2	145.5	49.0	194.5	4.8
	C**	1456	-	12	3	140.8	44.2	185.0	4.9
Barbed wire fence		-	4	-	4	600.0	400.0	1000.0	12.0

*The lay-down fencing system
**Electric fence

In the maintenance costs as shown in the Table, the barbed wire fence was 12 yen/m but the high-tensile wire fences were 5 yen/m. In the former, the barbed wire was taken off the posts after the grazing in late autumn to avoid snow damage, and rehung on the posts before grazing commenced in the spring. In spite of this costly maintenance, fences on sloping pasture were still damaged by snow. The barbed wire fences needed labour and material costs to repair them, whereas, because the high-tensile wire fences were laid down on the ground after loosening the wire using the wire-strainers, there was no snow damage. Following re-tensioning the wire in spring, the fences were easily raised as before. These easy efforts reduced maintenance costs. Consequently, the lay-down fencing system has a lower cost for fence construction and maintenance, compared with the conventional barbed wire fence.

Reference:

Hosokawa Y. (1985) Snow damage to pasture fences in the highland of Tohoku District of Japan, Proc. XVth International Grassland Congress, 1349-1350.

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Canada Olympic Park Ski Jump Bowl, Spectator Capacity Study

Bernie Amell, Grant Ross, Bob Dewar and Ron Wardell

The ski jump bowl at Canada Olympic Park was initially programmed to accommodate an estimated 50,000 spectators for the XV Olympic Winter Games (Calgary, February 1988). In September 1986, after the ski bowl had been excavated and the number of tickets for the ski jump events rose, the authors were commissioned to review the realizable spectator capacity.

An initial assessment involved a review of similar facilities and of applicable building codes from North America and Europe. During this assessment, it became clear that there had been very little empirical research directed toward spectator safety and capacity on standing terraces and ramps under cold region winter conditions. In lieu of such data, the authors collected information on English soccer fields, which included standing terraces, and various European ski venues which included standing terraces and ramps. This data was extrapolated to suit the conditions that were being proposed at Canada Olympic Park.

Standing terraces are large steps perpendicular to the side slopes of the bowl (which were constructed at an overall slope of 1.5:1 [67%] in the Calgary ski bowl). Standing ramps are graded areas with 8 to 20%+ slope oriented toward the sport activity area.

European experience has highlighted the importance of adequately designed gangways (horizontal terrace areas kept clear of stationary spectators), crush barriers (horizontal structural railings designed to resist downslope dynamic spectator loads) and stairs with guide rails (to limit stationary spectators' intrusion on stair movement areas).

The authors predicted the capacity of the ski bowl under the conditions of the original design, as well as with potential design and operational modifications.

The ski bowl as originally designed was predicted by the authors to have a spectator capacity of 33,000 to 36,000. It was further estimated that the total capacity could be increased to 42,000 with the installation of guardrails, crush barriers and gangways, all of which would also contribute to spectator safety. A further increase to 59,000 would have required subdividing the standing terraces into thirds, vertically, and separating them into blocks, laterally, utilizing crush barriers and gangways.

Capacity Estimates:	
per Alberta Building Code	7324
Per Uniform Building code	8750
Original Design	
- used as seating and standing terraces	25250
Original Design	
- used as standing terraces	28500
Standing Terrace improvements	
- proposed additional construction	42750
Top Rim Standing Room	8100

The next phase of assessment, conducted during March 1987, was a capacity study in which high school students were used to measure the density of use and rates of access and egress. The results of this test further emphasized the need to extend spectator capacity.

OCO '88 management was unwilling to make the substantial capital investment that would have been required to increase safe capacity within the ski bowl. As a result, the authors proposed that an adjacent site area be regraded to create standing ramp areas with visual access to the ski ramp. This concept was adopted by CODA (the agency controlling the venue) and standing ramps to accommodate approximately 20,000 spectators were developed to the north and east of the ski bowl. A similar technique was employed to increase spectator capacities at other activity areas of the Canada Olympic Park site.

Recognizing that there was a shortage of data on winter use of outdoor spectator facilities, the authors undertook to collect information at various Winter Olympic venues. The ski bowl was one of four sites where spectator movement, density and behaviour were recorded. Others were: Canmore Nordic Centre, the Bobsled and Luge facility at Canada Olympic Park, and the Opening and Closing Ceremonies at McMahon Stadium.

Recording methods included video and still photography, written notes and audio narrative. Recording methods were coordinated to ensure correlation between visual imagery and narrative information. In total, about 30 h of video/narrative recording and 800 still photographs were acquired.

The results generally validate the analyses previously performed, and provide an initial basis for the generation of design standards for spectator capacity and safety at outdoor winter events. Some preliminary results have been provided to the organizers of the 1992 Olympic Winter Games at Albertville, France.

Funding is being sought to allow a detailed analysis of the data, to provide a defensible basis for the development of spectator facility design and capacity standards. The need for such an analysis is driven by the international shortage of information directly related to outdoor winter conditions, and by the increasing popularity of winter spectator sports events.

Bernie Amell is a landscape architect and environmental planner, and the Manager of Environmental Services, Canadian Prairie Region, Dames and Moore (Ste. 640, 602 - 12 Avenue SW, Calgary, Alberta T2R 1J3, Canada); an International environmental and geotechnical firm.
Grant Ross is a professor of engineering and environmental science, Faculty of Environment Design, The University of Calgary, and principal of a consulting group specializing in transportation, remote sensing and environmental systems.
Bob Dewar is a retired professor of Psychology, The University of Calgary, and an active consultant in perceptual psychology and ergonomics, particularly relating to visual performance in transportation systems.
Ron Wardell is a professor and director of Industrial Design, The University of Calgary. He specializes in Ergonomics for industrial product design and architectural applications.

Reclamation of Gravel Scatter, Kuparuk River Oil Field, Alaska

L.R. Hettinger

Thawing of permafrost during oilfield development in northern Alaska and Canada causes surface instability and erosion. Gravel was used to insulate permafrost from work areas and used extensively to construct roads and drill pads. Gravel from a newly constructed road in the Kuparuk River Oil Field of Alaska was washed onto arctic tundra during spring breakups in 1983 and 1984, prior to proper culverting. Both machine and hand methods were used to remove as much gravel as possible without damaging the underlying tundra. ARCO Alaska, Inc. initiated a study in 1984 to assess the potential for in situ species to revegetate the site.

Data on plant species cover, density, and whether regeneration was vegetative or from seed, were recorded in 1984, 1985, and 1987 from 24 permanently located plots that were established in 1984. The point-frame technique was used to record leaf area indices and species cover. An inclined (32.5°) point-frame with 100 points per 1 m^2 (10.8 ft^2) was used to record data on species abundance and cover at each plot, including the presence of gravel. Data were recorded in 1984 and 1985 on species cover, density and whether foliage was from vegetative growth or from seed. Species cover was visually estimated in 1987. Percent cover was converted to leaf area index (LAI) using:

$$LAI = C\ (1.1) / N$$

where: C is the number of contacts with each species or other category (e.g. litter, gravel), 1.1 is the correction factor for the 32.5° inclination, and N is the number of times the pins were lowered into each quadrant (100).

Leaf area indices and frequency (the number of plots containing the species) were tabulated as a check of plant regeneration progress over the study period. Vegetative regrowth has primarily been of *Carex aquatilis*. Invasion by *Poa* spp., *Equisetum* spp., mustards, and mosses has become increasingly important over the 4-a study period and a 5-fold increase in leaf area was also observed between 1984 and 1987. Gravel depth and coarseness, however, have been a deterrent to natural revegetation of the site. In situ regeneration occurred where gravel was <10 cm (3.9 in) deep, and in areas where finer-textured soil had accumulated. Projection of the increases in LAI from 1984 to 1987 indicates complete revegetation of the site would require ~37 a.

Loren Hettinger is a Senior Ecologist with Dames & Moore (Suite 1200, 1125 - 17 Street, Denver, Colorado 80202, U.S.A.). He completed a PhD program in the Department of Botany at The University of Alberta in plant ecology.

Development of Ski Resort Districts Using Radio Information Systems

Eikichi Asari

With the recent growth in the number of ski resorts, demands for various informational and communications systems have increased, as has the need for appropriate plants and operations technology. Radio is prime among the communication systems studied.

In 1989 the Ministry of Posts and Telecommunications established a Research Committee on Ski Ground Information Systems, in cooperation with industry and academia. The committee has examined many technical problems related to the establishment of various systems, such as ski-ground guided information, instruction radio, ski slope information, radio for contact, ski-ground paging, rescue radio, and small channel MCA.

In 1990, four of the above mentioned systems were set up successfully. They are expected to contribute to making skiing more attractive in the future. Besides, it is also possible to extend the systems immediately into aero-sports.

All ground problems will be reported, including the possibility for development and promotion in cold resort districts through both summer and winter.

Eikichi Asari is with the Department of Electronic and Information Engineering, School of Engineering, Hokkaido Tokai University, (Minami-no-sawa, 5-jo 1-chome, Minami-ku, Sapporo, Japan).

High Arctic Weather Station (HAWS) Operations

Dennis Stossel

An audio-visual presentation will be made to familiarize attendees with AES operations at Alert, Eureka, Mould Bay, Resolute, Hall Beach and Baker Lake. The operation of an automatic weather station at the decommissioned Isachsen site and the conduct of a Polar Psychology Project there will be briefly described. Other facilities and operations, including the Canadian Parks Service Reception Centre at Tanquary Fiord, the North Pole expedition departure site at Ward Hunt Island, and the Lake Hazen automatic weather station, all within the Northern Ellesmere Island park Reserve, will be described. A number of significant projects and initiatives planned or underway at the HAWS will be discussed. These include the construction of a Prototype Operational Polar Station (POPS) or alternate major refurbishment at Mould Bay on Prince Patrick Island, a diesel fuel storage tank farm with a capacity of over one million litres at Eureka, a stratospheric ozone detection observatory near Eureka as announced in the Green Plan, and a Special Studies Laboratory (SSL) and expanded Background Air Pollution Monitoring Laboratory (BAPMON) at Alert. Reference will also be made to a mesosphere auroral study to be undertaken by the Institute for Space and Atmospheric Studies (ISAS) of the University of Saskatchewan. Research support opportunities made available by the Atmospheric Environment Service at Eureka and Mould Bay to graduate students in the physical and/or biological sciences will be discussed.

Dennis Stossel is with the National Hydrology Research Centre, Canadian Meteorological and Oceanographic Society (11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5, Canada).

BOREAS - An International **BOR**eal **E**cosystem **A**tmospheric **S**tudy of Canada's West-Central Boreal Forests

Michael J. Apps

The sensitivity of the boreal forest to potentially rapid changes in the global environment is an issue of significant concern with economic, social, and environmental dimensions. The boreal forest is a large, relatively unperturbed-by-industrial-man biome which is almost contiguous in the circumpolar region. Its borders fall entirely within many of the world's developed nations (including Canada, the European and Scandinavian communities, the USA and the USSR), all of which draw heavily on it for economic, social and aesthetic values. Changes in the boreal forest in response to potential changes in the global environment will have profound economic and social consequences for these nations. Moreover, comprising ~30% of the forested land of the world, the boreal forest may play a vital role in the short-term regulation of the physical climate system through its contribution to the global C cycle and through other biophysical feedback effects (e.g. albedo, surface roughness, and biophysical control of evapotranspiration).

Although containing lower species diversity than, for example, the tropical forests, it is a complex biome having complex spatial structures and interacting processes covering a wide range of time scales. To predict the role the boreal forest might play in regulating climate changes, it is first necessary to understand how the forest responds to these changes. One of the significant scientific challenges is the "scaling up" problem: extending scientific understanding of processes at the leaf level (10^{-3} s, 10^{-6} ha) in order to predict response at the whole forest level (10^{9} s, 10^{6} ha).

A new international study lasting from 1990-1996 will focus on the interactions between the boreal forest biome and the atmosphere to clarify their role in global change. BOREAS (Boreal Ecosystem-Atmospheric Study, god of the North wind) will address the scaling-up issue in two ways: a set of synchronous, nested observations at a series of spatial scales will be made and a system of integrating, synthesizing simulation models will be adapted, developed and tested with these data. The main experiment will take place in 1994 at two 400 km^2 sites (Prince Albert National Park, Saskatchewan and Nelson House, Manitoba) near the two ecotones of the continental boreal forest. The two sites span a major ecoclimatic gradient in an area where projected climate change is expected to be most significant and most rapid, with both temperature increases (northern site) and soil moisture conditions (southern site) being critical controlling factors of ecosystem dynamics.

Simultaneous ground-based process measurements, tower-based observations, aircraft overflights and satellite imagery will be used to compare, quantitatively, the ecoclimatic processes controlling the exchanges of momentum, water, energy and gas fluxes between the forest surface and the atmosphere. Three intensive, coordinated field campaigns will be conducted during the growing season, with a possible fourth being added for the shoulder (late winter) season. Simulation models of ecosystem productivity and C cycling will be used to synthesize and interpret the nested observations. Canadian scientists are planning a longer term extension of the BOREAS project with a broader transect through the two BOREAS sites in order to study the ecosystem dynamics on broader scales of time and space.

Mike Apps is a senior research scientist with Forestry Canada, at the Northern Forestry Centre (5320 - 122 Street, Edmonton, Alberta T6H 3S5, Canada). He is a member of the Science Steering Committees of both BOREAS and NBIOME (a Canadian project within the NASA Earth Observing System program) and is responsible for providing national scientific coordination of the climate change research program of Forestry Canada, as well as the Carbon Budget Model of the Canadian Forest Sector. He has been with Forestry Canada for 10 years, the last 5 of which have been devoted to forest ecosystem modelling.

SESSION C
TRANSPORTATION

ROOM 4, EDMONTON CONVENTION CENTRE

Monday, June 17

10:20 - 12:00 Roads and Bridges I: Alberta
14:00 - 16:00 Roads and Bridges II: Finland and China

Tuesday, June 18

08:40 - 10:00 Roads and Bridges III: Japan
10:20 - 12:00 Roads and Bridges IV: Canada

Wednesday, June 19

08:40 - 09:40 Operations and Maintenance I: Japan
10:20 - 12:00 Operations and Maintenance I: Japan

14:00 - 15:40 Operations and Maintenance II:
Japan and China

Thursday, June 20

08:40 - 10:00 Operations and Maintenance III: Canada
10:20 - 11:40 Other Topics

Session C
Schedule of Speakers

- **Roads and Bridges I: Alberta**

  J. McGoldrick
  Allan Kwan and Bill Kenny
  V.A. Diyaljee and M. Parti
  Leonard Dunn and Mike Marlow
  V.A. Diyaljee and M. Pariti

- **Roads and Bridges II: Finland and China**

  Olli Ravaska, Timo Saarenketo and Simo Kerkela
  Timo Saarenketo
  Wang Duanyi, Wang Zheren and Zhang Xiaoning
  Chen Xiao-bai and Wang Yaqing
  Xi Yuanwei
  Huang Lidu and Xi Yuanwei

- **Roads and Bridges III: Japan**

  Teruyuki Suzuki, Seigo Sawada and Takayoshi Onaka
  Masao Inuzuka
  Y. Takahashi, F. Hara and H. Saeki
  Yoichi Takahashi, Makoto Niiyama, Fumihiro Hara and Naoki Nakazawa

- **Roads and Bridges IV: Canada**

  W.W. Krause
  Robin Walsh
  Garry W. Hollingshead
  D.E. Pufhahl and R.K. Lytton
  T.L. White and L.E. Goodrich

- **Operations and Maintenance I: Japan**

H. Ueda and H. Masaoka
Hiroji Oku
Akira Yoshimura, Yuichi Kobayashi, Shigechiyo Takeuchi and Hiroki Hasegawa
K. Shibuya, Y. Hasegawa, S. Yoshida, M. Mochizuki and S. Sugihara
K. Fujino, M. Inoue, N. Kodan and Y. Yamauchi
Ryuichi Yamada and Hiroyuki Shinjyo
S. Sayama, N. Umeda, R. Sakaguchi, H. Wakaumi and S. Yokoyama
Ei-ichi Tazawa, Yuji Mizoue and Takeo Kojima

- **Operations and Maintenance II: Japan and China**

Nobuyuki Fujiki, Makoto Sanada, Fujio Hoshi and Shuji Mifune
Sun Ji and Pang Guoliang
Liang Zhaochun, Wang Luyi, Jiang Defeng, Wu Jie and Wei Wenchun
Kazao Shibuya and Iwao Sato
Don Burgess

- **Operations and Maintenance III: Canada**

Paul D. Carter
Richard Chow and Li-Fan Chen
Ivan T. Perich
Alan Mah

- **Other Topics**

D.B. Coveney
Tim Murphy and Neil Parry
Kauko Kujala and Leena Huttunen
Xie Yinqi and Wang Jianguo

Effects of Aviation on the Canadian North: A Brief Overview

E.J. (Joe) McGoldrick

Aviators and aviation have played a major part in developing the Canadian north. Bush pilots first began flying in the north in the early 1920s and continue to do so to this day. Aerial enterprises have flourished with the development of aircraft and for Canada's north, Edmonton is a major starting point. Geologists, cartographers and engineers, to name a few, have made significant use of the aviation facilities developed over the decades. Equipment has changed, but the problems and solutions have also changed. Float-equipped aircraft have played a major role and natural harbours have been extensively utilized, although there are now many conventional airports in the north. World War II had a major impact on the technology of flying, including the development of jet aircraft, radar and many other navigational and safety features. Not the least effect of the post-war period was the development of the so-called DEW line (distant early warning). Today, aircraft still play a part in the north, and will continue to do so long into the future.

Capt. E.J. (Joe) McGoldrick is Base Chief Pilot, Edmonton and Calgary, for Canadian Air Lines. He was educated in Calgary and joined the Royal Canadian Air Force in 1962 where he trained as a navigator. He obtained his civilian license at the Edmonton Flying Club (1964-65), Civil Flying Instructor (1965-67). Flew DC-3s for Pan Am Petroleum in northern Alberta and British Columbia (1967) and operated fire bombers for two season in Alberta (1967-68). He joined Pacific Western Airlines in 1968 and flew DC-4s, DC-6s, Convairs and Boeing 737s. He rejoined the Canadian Armed Forces Reserve in 1978 as a pilot in search and rescue with 418 (City of Edmonton) Squadron until 1984. He has flown air shows in a variety of aircraft since 1968 and currently owns his third Harvard aircraft and flies as part of the Western Warbirds Group. He is an amateur aviation historian.

Highway Design Standards and Practices in Alberta, Canada Relative to Cold Region Factors

Allan Kwan and Bill Kenny

This paper is an overview on highway design standards and practices adopted in Alberta due to snow and ice factors. Relevant implications on construction, maintenance and user costs and operational requirements are considered. The focus is on the influence of cold climate on six geometric design elements: 1. right-of-way clearing design; 2. roadway cross section; 3. median selection; 4. grade design; 5. superelevation; and 6. intersection design.

In Alberta, winter sun orientation is used to determine additional right-of-way clearing to expose the roadway surface to more hours of direct sunlight and hence reduce snow and ice build-up on east-west roads in normal forest areas. To this effect, a graph has been developed based on the daytime angle of the sun in relation to the height of trees to calculate additional right-of-way clearing requirements.

Cross section attributes (sideslope, backslope and ditch width) are adopted to minimize snow drifting, guardrail construction and erosion. On some highway rehabilitation projects, sideslopes and backslopes are flattened to minimize snow drifting problems on highways. In areas of high fills, sideslopes are flattened to eliminate the need for guardrails, which cause snow drifting and thus reduce the effective roadway width in winter. A trapezoidal ditch configuration is effective in terms of safety, snow storage capacity and erosion potential in comparison to 'vee' ditch design.

For divided highways in rural areas, a depressed median design is superior to a raised median design. Depressed medians permit snow storage, which eliminates the need to haul snow. Moreover, residual snow along raised medians impedes driver visibility.

Control of snow and ice was a major factor in assessing the feasibility of each median treatment option to reduce the high median-crash accident rate on Highway 2 between Airdrie and Red Deer, central Alberta. The median treatment options considered were: increase median width; F-shape barrier; flex beam installation; and arrestor bed. The F-shape barrier, flex beam installation and arrestor bed were ineffective due to snow and ice concerns.

Highway grades in Alberta are generally designed to minimize the impact of frost action. Alberta contains regions of highly frost susceptible soils and therefore preventative measures are taken during grade construction to minimize future damage. These measures are soil selection, soil compaction to specified densities at optimum moisture content, the use of a standard height of embankment (1 m), and undercut depth of 0.6 m below final subgrade elevation in cut situations.

Alberta Transportation and Utilities has recently revised its superelevation policy to achieve a more balanced approach to accommodate overdriving and underdriving vehicles during snow and ice conditions. The principle changes to the policy are: 1. adoption of 0.06 m/m maximum superelevation rate to improve low speed operations in snow and ice conditions on sharp curves; 2. the use of the 85th percentile running speed to set the superelevation rate; 3. the use of spiral curves; and 4. the use of lower superelevation rates where some vehicles may travel slower (e.g. intersections).

Several aspects of intersection design in Alberta are influenced by considerations of snow and ice. They are: 1. the banning of intersections if the superelevation on the main alignment is >4.5%; 2. discouraging intersections on portions of roadway where the grade on the through alignment is >3%; 3. the grade on the minor road at an intersection is designed so that it falls away from the major road at between 1 and 2% for drainage and safety reasons; 4. raised medians are not normally used at rural intersections because of the difficulties with winter maintenance (especially snowdrifting); and 5. rural intersections are normally designed to provide a smooth high-speed operation, i.e. turning lanes are frequently provided to ensure that the main traffic stream does not have to stop, even though the turning lane may not be required for capacity reasons.

Allan Kwan is Assistant Director and Bill Kenny is Roadway Geometric Standards Engineer with Alberta Transportation and Utilities (Twin Atria Building, 4999 - 98 Avenue, Edmonton, Alberta T6B 2X3, Canada).

Remedial Measures to Combat Frost Heave Problems on Alberta Highways

V.A. Diyaljee and M. Pariti

It is generally well established and accepted by the engineering community that a freezing temperature, a frost-susceptible soil, and the presence of water are the three main factors required to promote the phenomenon known as frost heaving. In the absence of any one of these factors the frost heaving phenomenon is generally non-existent, except for possibly minor or limited heaving caused by the expansion of free water in non-frost susceptible materials; this heave is generally limited to ~9% of the volume of the free water and does not result in the growth of ice lenses traditional to the classical frost-heave scenario. This heave, however, may result in rough riding conditions during winter, especially at transverse joint locations.

The geographic location, climatic cycle and glaciated landscape of Alberta guarantee that the factors for frost heave propagation are present singly or in combination. Likewise the utilization of locally available materials in construction and the topography of the natural landscape provide, in many instances, an environment conducive to the promotion of the frost heave phenomenon.

Silts, clays, sands and gravels, and combinations of these materials whether occurring naturally or through man-made processes, are utilized for construction of embankments and also, in the majority of instances, form the support for these embankments. Select materials such as processed granular materials and asphaltic concrete are costlier than naturally occurring soil materials and cannot be economically used in all cases to eliminate the frost heave problems. In other words, while it is technically feasible to eliminate frost heave problems on roadways the cost of such construction techniques would not be economically viable. Hence, highway agencies throughout the world have adopted methods that provide the best balance between cost for construction and maintenance, and safety to the motoring public.

Alberta Transportation and Utilities have utilized a general 'wait and see' approach to the frost heave problem, because of cost considerations, the availability of select materials, practical considerations of construction, and the changed environment following construction. As a result, it is well known that frost heave problems are an annual occurrence, with the intensity of the problem depending, to varying degrees, on climatic conditions before and during the winter. The objective of this paper is to present an overview of the approaches used to combat problems of frost heaving in Alberta highways over the past 5 a. These approaches will be demonstrated through a discussion of about 8 case histories covering remedial measures such as subsurface drainage, soil replacement, use of geosynthetics and use of insulation. Emphasis will be placed on the remediation using insulation because monitoring of frost heave and frost penetration was undertaken at 3 of the 6 sites where the insulation technique was utilized. The use of insulation appears to be efficient and cost effective in areas where constraints exist in implementing subsurface drainage and soil replacement, either because of topographic constraints or cost considerations. It is hoped that these case studies serve to provide insights to other highway agencies in the approach to diagnosis and treatment of frost heave problems in the highway network.

Vishnu Diyaljee and Murthy Pariti are Assistant Director and Senior Geotechnical Engineer, respectively, of the Geotechnical Services Section, Materials Engineering Branch, Alberta Transportation (4th Floor, Twin Atria Building, 4999 - 98 Avenue, Edmonton, Alberta T6B 2X3, Canada). Diyaljee is responsible for the technical, financial and administrative functions of the section in support of the Department's programs, while Pariti is responsible for investigating, analyzing and designing of a wide variety of problems in geotechnical engineering related to the highway infrastructure.

Insulated Roadways, West Edmonton, Alberta, Canada

Leonard Dunn and Mike Marlow

In 1988 during initial construction of two major arterial roadways in west Edmonton, namely Whitemud and Anthony Henday Drives, difficult soil conditions were encountered in the form of high groundwater levels and frost susceptible soils. Construction of a temporary detour road for Whitemud Drive, using a conventional roadway section (gravel and asphalt) over similar poor soil conditions served as a good prototype for predicting the performance of Whitemud and Anthony Henday Drives. Instrumentation and monitoring of the detour road and Anthony Henday Drive during the winter of 1988/1989 indicated that significant differential frost heave movements of up to 300 mm could be expected.

As a result, several alternatives were evaluated and implemented during the design and construction of Whitemud and Anthony Henday Drives in 1989-1990 to eliminate these frost heave movements. The alternatives used consisted of:

1. Raising the roadway grades to increase the depth of cover over the frost susceptible soils using 2.5-3.0 m of high plastic clay cover. This alternative was possible due to the existence of low frost susceptible, high plastic clays encountered in portions of the project and the fact that frost penetration is usually <2.5 m in this material. Due to design constraints at the existing and future underpasses, this was only possible on short sections.
2. The use of rigid polystyrene insulation to prevent the frost front from reaching the frost susceptible soils. The design required that no frost heave movement occur at any existing or future underpass locations in order that there be no reduction in clearance. Selection of the design freezing index was based on historical meteorological data and the thickness of insulation requir[illegible] was determined using the finite element therm[illegible] program GEOTHERM of EBA Engineering Consu[illegible]nts Ltd.
3. A combination of both rigid polystyrene insulation and remixing the native soils to a 900 mm depth. During investigation of the frost heaving which occurred on the Whitemud Drive detour road it was noted that ice lenses occurred in thin silty layers within the overall clay matrix. In order to eliminate these silt layers the material was mixed in place and recompacted. The insulation thickness design then made allowances for this less frost susceptible material.

In addition to these alternatives, and in order to provide a working platform for construction equipment in areas of the saturated flowable silts particularly at underpass locations, geotextiles were utilized in combination with pit-run gravel. Once the working platform was established and a suitable cover of pit-run gravel achieved subsequent construction activities went smoothly. In areas of poorest soil conditions the roadway section consisted of a high strength woven geotextile, 600-950 mm of pit-run gravel, 25-100 mm of rigid polystyrene insulation, and 300 mm of crushed gravel overlain by 250-300 mm of hot mix asphalt pavement. Prefabricated edge drains were also installed at the gravel/insulation interface on depressed roadway sections to prevent water intrusion. Traffic criteria for the roadway design were based on a 20 a projection of 80,000 Average Annual Weekday Traffic (AAWT) for Anthony Henday Drive and 43,000 AAWT for Whitemud Drive.

On Whitemud Drive, ~13 lane-kilometers were constructed in 1989 of which 9 lane-kilometers or 69% were insulated. Future work on this section will involve construction of the second half of the four lane arterial roadway of which an additional 1.8 lane-kilometers will need to be insulated.

On Anthony Henday Drive ~30 lane-kilometers were constructed in 1989 and 1990, of which 13 lane-kilometers or 43% were insulated. Future work on this roadway involves constructing a northerly segment of which 4.2 lane-kilometers will be insulated.

These two roadways required ~405,800 m^2 (4.4 million board feet) of 25 mm-equivalent Dow Styrofoam HI-40 extruded polystyrene insulation in 1989, and ~59,500 m^2 (0.6 million board feet) in 1990. This is >465,300 m^2 (5 million board feet), making it the largest single project in the world to use Styrofoam insulation to prevent roadway frost heaving.

Supply and installation costs per square meter (in 1989 $Can) for the insulation was $7.92, $13.84, $20.93 and $27.30 for thicknesses of 25, 50, 75 and 100 mm, respectively. The insulation costs per square meter of the 25 mm thickness ($Can) was $5.08 and $5.40 for 1989 and 1990, respectively.

Whitemud Drive was instrumented during construction in order to monitor the frost penetration beneath the various thicknesses of insulation. Results of the monitoring program will be used to refine the insulation requirements for other roadways in west Edmonton. To date, the insulated roadway areas are performing very well, showing no signs of frost heaving.

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Mike Marlow is General Supervisor, Special Projects Construction for the Public Works Department, City of Edmonton, (11th Floor, Century Place, 9803 - 102A Avenue, Edmonton, Alberta T5J 3A3, Canada).

The Twinning of Highway 16 West, Alberta, Canada Winter Construction Practices in Muskeg Areas

V.A. Diyaljee and M. Pariti

In 1986, a program to twin the Yellowhead Trail (Hwy 16 West) within Alberta was announced, with completion of the twinning from the Saskatchewan border to the British Columbia border within 5 a. The initial construction priority was identified for the Edson, Hinton and Entwistle areas, where traffic volumes and consequent accident rates were the highest. About 55 km of the alignment between Hinton and Entwistle traverses muskeg (organic soils with very high compressibility characteristics and low shear strengths). Several of the muskeg deposits were located in bowl-shaped depressions with poor drainage and underlying soil moisture conditions ranging from 2 to 10% above optimum. The length of individual muskeg deposits varied from 100 m to nearly 3 km, with depths at most locations varying from 2 to 9 m, with ~4 m being the commonest depth.

Settlement and attendant poor rideability problems and consequent frequent maintenance procedures characterized overlays completed through the muskeg sections of the existing two lane facility and in the twinned section between Edmonton and Gainford. These problems prompted the need for a different approach to the design and construction through the muskeg areas of the new twinned sections. It was agreed at the highest engineering review level that, if at all possible, a minimum waiting period of ~2 a should be allowed between completion of grading and paving through the muskeg sections. This would entail placement of embankment fills and allow maximum time for the consolidation of the muskeg and underlying soil.

Because of both the tightness of the overall construction schedule for the entire twinning program and the short duration of the summer construction season in Alberta, different approaches to embankment construction through the muskeg areas were envisaged and adopted.

The objective of this paper is to describe, in general, through a case study approach, the different investigation, design and construction techniques used to build on muskeg during the winter period for the section between Edson and Wolf Creek and to highlight both satisfactory and unsatisfactory approaches.

A common procedure in the western Canadian provinces is to allow embankment construction through the winter months. This procedure has some advantages because some of the muskeg terrains can only be traversed in the winter when the muskeg deposits can still undergo consolidation because of their high permeability. However, a major drawback is that frost can be trapped within the fill and hence the fill may require considerable time for thawing before additional fill material can be placed on such sections. Further, grade settlement is accelerated as the thawing occurs.

Alberta Transportation initially rejected the proposal for this type of winter construction proposal, but conceded to it subsequently, to keep pace with the tight schedule of the overall twinning program as well as to utilize more usefully an excessively wet silty clay borrow material. This work was subject to the condition that the embankment construction was carried according to a modified form of cross section.

In addition to the case study, information will also be presented with respect to embankment construction through muskeg areas, in relation to the effect of muskeg ditches, stage construction procedures and its guidelines, use of geotextiles and granular padding, and estimation of borrow quantities requirement to offset muskeg settlement.

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Ground Penetrating Radar for Quality Control in Road Structural Courses, Finland

Olli Ravaska, Timo Saarenketo and Simo Kerkela

Ground Penetrating Radar (GPR) measurements have become increasingly common in road construction and design in Finland during the past few years. One of the most important and promising applications has been the measurement of the thicknesses of structural courses. There has been a lack of knowledge to date on relative dielectric constants and their variations in the structural courses of roads. The estimation of dielectric constants plays a crucial role in GPR data interpretation, because it is these that determine the depth scale of the profile. The primary aim of this work was to measure dielectric values under different conditions, e.g. temperatures above and below 0°C in order to study the applicability and accuracy of GPR for quality control with respect to road structures.

Dielectric measurements using a Time Domain Reflectometer (TDR) were made for the most common road course materials in Finland: crushed rock, crushed gravel and natural sand. The materials were taken from existing road structures, and the measurements were made under different temperature and water content conditions in the geotechnical laboratory of the University of Oulu. A few tests were also made directly on existing road structures in Finnish Lapland.

The dielectric constants of road aggregates depend mostly on their unfrozen water content, even at temperatures <0°C. Above 0°C, they show minor changes until the materials are saturated, whereupon they increase significantly. The dielectric constants of frozen materials exhibited only minor changes at <2°C, but the drop in dielectric values between 0°C and -2°C was significant compared with those >0°C.

GPR measurements using 900 MHz and 500 MHz antennas were made in the laboratory and in the field. The 900 MHz antenna proved to be better for structural course measurements because of its better resolution. If information is desired on the base course and subbase, a 500 MHz antenna is recommended.

The GPR data were processed and interpreted and the results compared with the measured thicknesses of the structural courses. The measurements were made on a special road model and in the field. Because the course thicknesses in the model were known exactly, direct comparisons could be made between the real and measured thicknesses. The results are shown in the following table:

Real and measured thicknesses of the structural courses in the road model. Measurements were made by TDR and GPR with a 900 MHz antenna.

Course	Dielectric constant	Real thickness (m)	Measured thickness (m)
Crushed rock	3.6	0.15	0.17
Crushed gravel	4.1	0.30	0.29
Sand	4.3	0.55	0.52

The field measurements were made in winter, spring and summer 1990. Dielectric constants were measured in situ and in the laboratory from samples taken from a test pit. The results showed that the boundary between the structural courses and the sub-base was very clear, but that the boundaries between the structural courses could be found only if the difference between the course materials was large enough.

The results of these tests showed that GPR is a suitable means of measuring the thicknesses of structural courses for road construction quality control purposes. These tests allowed dielectric constant values at temperatures >0°C and <-2°C to be recommended for the materials tests. One should always use the recommended dielectric constants for each aggregate, but one should avoid measurements in circumstances where temperatures in the road structure are between 0°C and -2°C.

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Applications of Ground Penetrating Radar in Road Design, Construction and Maintenance, Northern Finland

Timo Saarenketo

The Road District of Lapland has been using Ground Penetrating Radar (GPR) for various purposes related to road construction and maintenance since 1986. Experiences with the method have been extremely promising and it is widely used in the field.

GPR is based on the use of high frequency radiowaves, 10-1000 MHz, to resolve the locations and dimensions of electrically distinctive layers and objects within materials. Pulse radars transmit pulses of few nanoseconds into the ground and record reflections from electrical boundaries. The electrical properties affecting GPR in road surveys are dielectric value and conductivity. Dielectric value and other electrical properties of the ground are primarily controlled by water content.

GPR has been used in road design projects for estimating subgrade soils and their interlayers and probing the depth of the overburden. It also gives information on groundwater conditions especially in coarse grained soils. It has been used in winter to estimate the frost susceptibility of soils.

In bridge site investigations GPR has been used to survey the bottom topography of lakes and rivers. It can only be used in freshwater, however.

Sounding in the structural courses of roads is another successful application of GPR. It has been possible, with high frequency antennas (500, 900 MHz) to evaluate the thicknesses of the different layers in pavement structures with a minimum resolution of 0.04 m. GPR data also give information on the causes of frost damage, settlement and other road damage. In quality control tests during the construction phase, GPR has been used to measure the thickness of structural courses and to locate the boundaries of the replacement soil.

The method has proved effective in bridge deck surveys for locating weathering damage in the concrete layers and waterproofing. The best results have been obtained with a 1000 MHz antenna, but the measurement data usually need signal processing.

One popular application in road surveys has been for locating buried cables, pipes, culverts and other objects, for which it has proved very reliable.

GPR is also a cost-effective method for use in road aggregate prospecting. The main application to date has been for locating aggregate deposits, estimating their thickness, quality and amounts and assessing the groundwater conditions.

GPR has been of help in road maintenance during winter for monitoring the thickness of ice on frozen lakes and rivers over which roads have been or are to be cleaned. The accuracy of these measurements (0.01 m) has been extremely good with the 900 MHz antenna.

The greatest advantage of GPR is the continuous profile it provides over the target examined. The radar profile helps road design staff to direct other site investigations toward the most interesting targets and so cut down costs. This reduces the likelihood of unpleasant or expensive surprises emerging after road construction has started. The best results have been obtained using GPR together with other geophysical methods (e.g. refraction seismic and electrical resistivity sounding).

There are still some problems with GPR however, the most important of which has arisen when soundings are made over soils and other materials with a high electrical conductivity value, e.g. clays and road structures with high salt content. Some interference in the radar data can nevertheless be removed by data processing. Another problem has been interpretation of the radar data, which takes time and needs a very experienced staff.

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Analysis of Structural Factors That Influence the Low-Temperature Cracking of Asphalt Pavement

Wang Duanyi, Wang Zheren and Zhang Xiaoning

Heilongjiang Province, People's Republic of China is in a cold region, and low-temperature cracking is a common problem of asphalt pavements in this region. Once the asphalt surface cracks, the pavement will soon disintegrate. Therefore, low temperatures are the main cause of premature distress of the asphalt pavement, with resulting huge economic loss, both directly and indirectly.

Since the early 1980s, systematic studies on low-temperature cracking of asphalt pavement have been carried out. In the early studies, the influence of the thermal environment and the distribution of thermal stress in the asphalt surface on cracking was not considered, and it was deemed that the low-temperature cracking of asphalt pavement related only to the use of asphalt cement. This conclusion was of limited use; for example, it did not explain why the rate of cracking is different with the same climatic environment, asphalt mix and different thicknesses of base course materials. Meantime, there is not enough high-quality asphalt in China. The asphalt used contains a high percentage of wax and has high temperature susceptibility. Selecting suitable asphalt or improving the characteristics of asphalt at low temperature, means that the stability at high temperatures often deteriorates. So, the ability to crack-proof asphalt cannot be improved by this means.

Under these circumstances, it was natural that attention was shifted to structural combinations, because there were many examples where structure influenced the cracking rate of pavement. In further studies, the thermal characteristics and mechanical behavior of entire pavement structures were regarded as a single system and some conditions were assumed: 1. Only longitudinal restraint exists when the surface course contracts. Thus, the thermal stress becomes one-dimensional; 2. The base course material of pavement does not contract; 3. Both thermal stress and its increment vary linearly; they depend only on temperature and time.

According to the principles of the transmission of heat in viscoelastic materials, the thermal and thermal stress field of asphalt pavement have been developed using a finite element method. This stress field takes into account not only the thermal and viscoelastic properties of the asphalt surfaces, but also the influence of thermal properties of other courses on the thermal stress of the surface. Using field data, the structural factors that influence the thermal stress of a pavement were analyzed by means of a cross-correlation table with four factors 3 levels (lg(3)4). These factors consist of the thickness of every course and the thermal conductivity. The analyzed results indicate that thermal conductivity of the base course is the most important factor. Further calculation on the thermal conductivity of the base course showed that the higher its thermal conductivity, the lower the thermal stress of the asphalt pavement. This explains why the cracks of an asphalt pavement with a granular base course are less, because of its higher thermal conductivity.

After analyzing practical low-temperature cracking of asphalt pavement in Heilongjiang Province, some conclusions can be drawn: 1. The new method can completely analyze the influence of materials and structures on the low-temperature cracking of asphalt pavement; the calculated results are in reasonable agreement with actual measured data, indicating that the method is applicable; 2. Both the calculated results and the actual measured data point out that the distribution of either temperature or thermal stress with depth of asphalt pavement is not even. The low-temperature cracking rate of pavement is dependent on the thermal stress level in all thicknesses of asphalt surface course. This explains why the low-temperature cracking rate is different with different forms of pavement structure; 3. The influence of the thermal properties of base course material on distribution of thermal stress is striking. So far in Heilongjiang Province there is no source of high quality asphalt and that which is available is expensive. On this account, improving the thermal property of the base course material and rationalizing the combinations of pavement structure can be an economic means for reducing the low-temperature cracking rate.

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Countermeasures for Preventing Frost damage of Engineering Projects, People's Republic of China

Chen Xiao-bai and Wang Yaqing

Frost heave and salt heave are the main reasons for frost damage to engineering projects in seasonally frozen areas, and this strongly influences development in cold regions. Based on the author's many years of experimental results and engineering practice in China, countermeasures for preventing engineering projects from frost damage are proposed as follows:

1. Replacement of clayey soil with sandy gravel, i.e. controlling the quality and the thickness of the sandy gravel, as well as for drainage. The index of frost susceptibility of sandy gravel in an open system, η, mainly depends not only on the content of particles less than a given particle size d (0.1, 0.02 or 0.05 mm), C_d, by weight, but also on the frost penetration rate, V_f, and is expressed by: $\eta = B_0 V_f^{B1} C_d^{B2}$, where B_0 to B_2 are characteristic constants of the soils.
2. A comprehensive prediction model of the frost heave ratio, , for clayey soils includes consideration of the initial water content W, the unit weight γ_d, frost penetration rate V_f, groundwater level H_w, plasticity index I_p, ion content S, and overburden pressure P. The function is stated as: $\eta = B_0 W^{B1} \gamma_d^{B2} V_f^{B3} \exp(B_4 H_w) \exp(B_5 I_p) \exp(B_6 S)$ and $\eta_p = \eta \exp(-bP)$, where B_0 to B_6 and b are the characteristic constants of the soils, and η_p is the heave ratio under pressure P.
3. An anti-heave filled base. In an area with high frost susceptibility, and a heave of 30 to 40 cm, as long as the height of the filled base, with a moisture content less than its plastic limit, is close to the maximum frost depth and its bottom is insulated by a plastic film to prevent groundwater migrating into the base through capillarity, then a building set upon the base will be completely stable.
4. A special type of soft lining for irrigation canals. The authors have suggested that a reasonable design for an irrigation canal is a plastic film lining covered by non-compacted fill, with an initial dry density of 1100 to 1300 kg/m^3, as a protection layer with consolidation by the method of saturation-dehydration consolidation, the dry density of the protection layer will be 1400 kg/m^3, which is required to keep the canal slopes stabilized. Canals 20 km in length with such structures have been working satisfactorily for 6 a; the cost was about one quarter to one half that of a concrete lining, seepage decreased 30%, and the amount of frost heave at the canal bottom was only about 20 to 30 cm.
5. Treatment for preventing salt heave on national highways. The authors experimental results show that the peak of salt heave occurs in specific temperature zones, e.g. when the total salt content by weight of silty loam is 15%, the salt heave peak occurs at 4 to 6°C, -4 to -6°C, and -8 to -11°C. When the total salt content of clay is ~7%, the peak occurs at 4 to 6°C, -4 to -5°C, and -9 to -11°C. Further, salt heave is reduced considerably under overburden pressure, P, with the function $\eta_p' = \eta' \exp(-b'p)$, where η_p' is the salt heave ratio of soil under pressure, P. Salt heave can also be controlled by decreasing the moisture content, increasing the density, and increasing the cooling rate.

With the help of these results and in situ ground temperature profiles of the subgrade, a new non-salt heave fill of a reasonable thickness was suggested for covering an old pavement, resulting in a decrease of salt heave by 1/5 to 1/10 of its former value. After running for 5 to 6-a, the highway works very well with truck speeds of 80 to 100 km/h.

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Research on Salt Heaving Forces in Heavily Saline Areas, People's Republic of China

Xi Yuanwei

Roads of XinJiang Province, People's Republic of China are built on saline soils and as much as several hundred kilometers are deformed and damaged by saline heaving forces as the temperature drops during the winter. Through field tests, the variation of heaving force during the course of subsoil heaving can be obtained and so provide a design basis for curing saline heaving damage.

As the temperature drops, the excess Na_2SO_4 in the subsoil expands. Because of restraint due to the load above, it cannot expand freely and produces an upward force (the saline heaving force). As the ambient temperature drops to <9°C, a heaving force will be produced. This coincides with the temperature at which the subsoil starts expanding. The heaving force increases in a parabolic pattern as the temperature drops. The rate of the heaving force in different temperature regions is different, and when the temperature is in the range 9°C to -12°C the heaving force is greatest. The content of Na_2SO_4 is the key factor in determining the heaving force, and the magnitude of the saline heaving force is proportional to the content of Na_2SO_4 in the subsoil. This agrees with the law of sulfate soil expansion. The heaving force decreases in a parabolic pattern as the depth of subsoil increases. The load above acts as a strong restraint on the heaving force, and so the heaving force under a road pavement decreases greatly as the structural thickness of the pavement increases. The relation is as follows:

$$F=H/(a+bH+cH^2)$$

where

F = heaving force;
H = the structural thickness of pavement; and
a,b,c, = regression coefficients

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Cause of Winter Highway Damage in Saline Soil Regions People's Republic of China

Huang Lidu and Xi Yuanwei

Hundreds of kilometers of trunk highway cut through the saline soil region in XinJiang Province, People's Republic of China. From the beginning of October each year, sulfate in the saline soil gradually crystallizes and separates out as the temperature drops, resulting in volume expansion of the saline subsoil, and heaving and cracking of the pavement. As the temperature continues to drop, pavement failure increases. Pavement damage is the most serious when the temperature is at its lowest point during the last ten days of January. After February, as the temperature increases again, part of the solute salt is gradually dissolved, which increases the porosity of the saline soil. Under the action of the combined surcharging load and driving load, the saline subsoil drops after rising, and so the heaving and cracking of the pavement is somewhat lessened. The salt heaving problem leads to bumps on the road and the slowing of vehicles, which in turns causes increased transport costs. After more than 10 a research into this problem, it turns out that the phase change of Na_2SO_4 at low temperature is the main reason of causing salt heaving. There is virtually a linear relation between the crystal volume and the expansion rate. The sulfate crystal changes density and produces ice, the action of which results in subgrade deformation and damage. There are four principles and models that can be used to improve the subgrade soil. The main points include: 1. cutting off the subgrade and adapting the whole structure of the pavement for a newly built road; and 2. using geotextiles to cut off and set up a semi-rigid subgrade for a rebuilt road. In addition, it is necessary to include allowance for salt heaving in computations for the design of pavement structures and the thickness of roads in saline soil regions. More than 50 km of trunk highway has been built, which has been in use from 1 to 9 a, with good results.

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Preventive Measures Against Frost Damage of Small Sized Concrete U-Troughs in Seasonally Frozen Regions

Teruyuki Suzuki, Seigo Sawada and Takayoshi Onaka

Concrete U-troughs used as road drainage gutters are often damaged by frost heaving during the winter season. In this study, ready-made concrete U-troughs specified in JIS A5305 were experimentally set, and the frost-heaving force, deformation, and other parameters were measured. The inner cross-section of these troughs was nearly square having a side of 45 cm. The dimensions of the side walls were 45 cm inner height, and 60 cm wide. The required number of troughs were set at the toe of man-made slope.

The setting conditions of these troughs were as follows:

1. Backfilled with in situ soil - no preventive measures taken.
2. Backfilled with gravel; the thickness of the backfill was varied at 15, 30, 40 and 50 cm.
3. Setting 5-cm thick adiabatic material in contact with the outer surface of the side walls.

At some troughs which were set under each of these conditions, the lateral forces acting on the side walls were measured with load cells which were inserted between side walls. To each of these troughs, a pair of load cells were attached at 5 cm below the top of the side walls, and 50 cm from each other. The frost-heaving forces, namely the forces which were measured with this pair of load cells, can be considered as an index of the effect of the preventive measures.

In other troughs, where load cells were not attached, the inner distance of side walls were decreased by frost-heaving force arising from the winter season. These decreases of the side wall distance were measured at the top of the side walls using a precise scale. These trough deformations show the extent of the damage directly. Some results are shown in the table below:

Effect of Preventive Measures

	No Preventive Measure	30 cm thick gravel backfill	5 cm thick Adiabatic material
Maximum frost-heaving force (kN)	25.5	13.5	7.5
Maximum decrease of wall distance (mm)	5.5	1.3	1.4

From the table and other data gathered in this experiment, the following conclusions were reached:

1. The collapse of concrete U-troughs occurred after ground freezing, and resulted from lateral frost-heaving forces which act on the side walls of the trough.
2. Under certain ground conditions, this frost heaving far exceeded the strength of the tested trough. As measured by the load cells, the strength of the trough was ~8 kN.
3. The effect of gravel backfill and adiabatic treatment for reducing the frost-heaving force was evidently recognized. These preventive measures decreased the value of deformation which occurred on the troughs to ~25%.
4. The frost-heaving force and deformation of the trough are at a minimum value at the gravel backfill just behind the trough at the base of the man-made slope. In this experiment, the thickness of the gravel backfill was 30 cm.

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On a Retractable Anti-Skid Device for Automobiles

Masao Inuzuka

Drivers have to face skid problems in cold regions. Present solutions are either anti-freeze agents spread on frozen roads or snow chains. Both solutions have their inherent problems. Anti-freeze agents not only cause rusting of steel but harm trees along roadsides. Snow chains damage roads. What is proposed here is the use of a retractable anti-skid device which has an endless chain with many rubber fins. Each fin has a metal stud on the tip. The chain rotates by means of two small sprockets in order to carry each fin under the tire tread on the road. These sprockets are held in place by a retractable retainer. The locus of each fin as it touches the road surface is linear with respect to the sprockets. Therefore, each stud stays at a fixed point only intermittently. If the locus is circular as in conventional devices, the stud keeps moving under the tread so that the coefficient of friction is lower and the locus therefore unstable. Because the gyration plane of the fins is independent from that of the wheel, a buffering system is necessary for the fins and the rotating system. The retraction mechanism is used for this buffering.

The device enables the studs to be packed on the road beneath the tires of an automobile. Because the device is easy to operate from the driver's seat, the use of studs can be limited to only when frozen conditions warrant. Therefore, current problems of conventional anti-skid devices may be considerably mitigated. The background of the device is closely related to the general system of winter traffic in cold regions. The study centered on experiments on the effects of the device. The tests were carried out on flat ice under varying conditions. There is a mechanical system for carrying the studs to the right position by means of a rotating system. Every part, even the rubber fins, are subject to future developments and changes. A mechanical system of buffering will also be discussed from the viewpoint of retraction and engagement of the device.

Experimental models were also produced for bicycles and four wheel drive vehicles. In bicycles, wheels rotate in one direction and therefore the mechanism is much simpler than in four wheel drive vehicles. The main point is to lighten the weight, because the engines are not so powerful as in the latter. When two-way rotation is considered, the mechanism needs to satisfy stability and flexibility in order to avoid shocks due to bumps on the roads. The characteristic points of the mechanism and the device can also be applied to winter sports.

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Abrasion of Bridge Piers due to Ice Movement

Y. Takahashi, F. Hara and H. Saeki

Movement of an ice sheet in a river is both horizontal, caused by the current, and vertical, due to changes in water level. Abrasion from the movement of river ice must be considered during the design of concrete bridge piers in regions where rivers freeze in winter. Therefore, it is very important and useful for the design of concrete bridge piers in very cold regions to determine the amount of ice-concrete sliding abrasion.

A new ice-concrete sliding abrasion test apparatus has been developed and systematic experiments have been carried out on ice-concrete sliding abrasion for 7 a. The fundamental principle of the apparatus that the authors adopted is a specially designed reciprocating motion of the concrete specimen on the upper surface of a rectangular prism of ice; the revolutionary motion of the specimen on the ice under consideration during test results of friction between ice and various materials is not involved. The authors have obtained the following conclusions and results through systematic experiments and observation of old bridge piers:

1. The relation between sliding distance and abrasion amount for various concretes was determined.
2. The relation between ice pressure acting on a concrete specimen (contact pressure) and the amount of abrasion on the concrete surface was determined.
3. The relation between ice strength and amount of abrasion on the concrete surface was determined.
4. The relation between abrasion rate of various concretes and ice with ingrained fine sand (D_{sg} = 0.14 mm, d_{sg} = 0.70 mm) was determined.
5. Surveys were made of the concentration of contaminating sand in actual river and lake ice in Hokkaido.
6. The amount of abrasion of actual concrete piers constructed in the Teshio River, in the northern part of Hokkaido, was measured.

Finally, a method for estimating the abrasion amount on concrete bridge piers due to the movement of fresh water ice sheets was determined.

In order to estimate the amount of abrasion of concrete piers, the following information is needed:

1. Type of bridge pier (size of pier, shape and angle of pier nose).
2. Ice conditions (thickness, temperature, size and concentration of fine sand included in the ice).
3. Movement of ice (horizontal velocity of ice sheet, distance of horizontal movement of ice sheet).

Using the abovementioned data, the distribution of ice pressure (contact pressure) on the pier surface and the abrasion rate can be determined. The distribution of the amount of abrasion on the surface of the bridge pier can be calculated from the abrasion rate and the distance of horizontal movement. When this estimation method was applied to an actual concrete pier constructed on the Teshio River, the estimated value was in good agreement with the observed amount of abrasion.

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Damage to Bridge Piers due to River Ice Movement and Their Maintenance and Repair, Hokkaido, Japan

Yoichi Takahashi, Makoto Niiyama, Fumihiro Hara and Naoki Nakazawa

In Hokkaido, the northernmost island of Japan, most rivers are frozen during the winter. In designing road and railroad bridges to be built over rivers, , little consideration has been given to ice forces and other influences of ice on the bridges. Principally, this is because the Japanese Bridge Design Code does not describe the relation between the bridge and the ice, including the ice force. This research consisted of evaluating the damage to road bridges in Hokkaido caused by the movement of ice sheets, and particularly with nose abrasion of bridge piers, and methods of maintenance and repair to protect the piers against abrasion by the movement of the ice sheet.

The principal rivers in Hokkaido are ~200 km long, i.e. generally less than those in North American or the U.S.S.R. But, the difference in altitude between the upper reaches and the river mouths is >600 m, with accumulated 1000-1200 degree-days in the upper reaches, and 400-800 degree-days at the mouths.

For this reason most rivers begin to freeze at the upper reaches while they begin to thaw at the lower reaches, and ice jams, such as occur in North America are scarcely formed in Hokkaido.

In the days of timber bridges, there were some cases where destruction of a bridge itself resulted from the ice force on the piers as a result of movement of the ice sheet. But no such damage to bridge piers or upper structures has been reported since steel or concrete bridges replaced timber ones. This is because bridges are designed to withstand earthquakes. Therefore, abrasions of concrete bridges caused by the ice sheet movement are typical in the Hokkaido area. Damage to the piers of 13 bridges over the rivers in Hokkaido where ice sheets move relatively fast were investigated. The following are the results:

1. Regarding the sectional form of road bridge-piers in Hokkaido, most noses are semicircular, and abraded parts correspond to the water level at times when the ice sheets were moving.
2. Abrasion loss is most serious at the tip of the semicircular nose facing upstream; next is the sidewall, parallel with the flow.
3. The highest abrasion rate was 1 to 5 mm/a, and the wear rate (millimeters per kilometer - average abrasion loss per 1 km of ice sheet movement) was fastest at the point where the ice was thickest and moved a great distance.
4. No surface degradation or separation of concrete piers by freeze-thaw action was found.
5. Before repair work, there was a case where the maximum abrasion loss was >10 cm, with the ferroconcrete exposed.
6. Because the Japanese Bridge Design Code does not provide criteria for the influence of ice, no protective measures against abrasion are being taken for bridge piers now under construction.

The three main methods of repairing seriously abraded bridge piers are as follows:

1. Chip away the abraded part and the surrounding concrete to a thickness of ~10 cm and cover with ~30 cm or ~20 cm of additional concrete. Further, cover seriously abraded nose parts with semicircular steel sheets.
2. Chip away the seriously abraded part and the surrounding concrete and cover the nose part of the pier with ~30 cm of stone.
3. Chip away the seriously abraded part of a semicircular nose and add concrete to result in a wedge-shaped section, then coat with steel sheets.

Because repair includes underwater work, it is expensive. In the future, therefore, abrasion loss of bridge piers should be estimated before construction and, based on the estimation, proper choices of sectional forms and surface-coating materials should be used. At the same time, the Bridge Design Code intended for bridges in cold districts should be formulated.

In conclusion, the principal influences on the wear rate include ice temperature, contact pressure (ice pressure on the nose part of a pier), average grain diameter and density of solid grain (including sand) contained in the ice. When these factors are given, the wear rate of surface materials can be calculated and the range of abrasion loss can be estimated from water-level changes as well as the distance of horizontal movement. Based on the abrasion loss and durability of the piers, the thickness of coating concrete for the nose, steel sheets and piled timber to reduce abrasion should be decided properly.

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A Unique Method of Constructing Bridge Piers From an Ice Bridge, Peace River, Alberta, Canada

W.W. Krause

Fort Vermillion is one of the oldest communities in Alberta. The new Peace River Bridge near the town was completed in 1974 and has opened up better opportunities and increased benefits for the residents of the entire region, which, until its construction, had been served by a ferry with limited capacity and restricted usage in the spring and fall months.

Construction of the Peace River Bridge started in January 1972 and was completed in September 1974 at a total cost of $6 M. Three of the four piers for this 530 m bridge are founded on steel H-piling driven through sand to bedrock, 40 m below water level. This unusual feature required the contractor to use unique construction methods, of a magnitude not formerly employed in bridge construction, for the excavation, pile driving and forming of the piers, all below water level.

Construction of Piers 1, 2 and 3 was carried out from an ice bridge built at temperatures ranging from -20 to -40°C. The presentation includes the methods used to construct the ice bridge and also covers such items as the strength and deflection of the ice during construction of the piers.

Excavation of the sand to the bottom of the footings was accomplished by an unusual method. The sand was removed by use of airlift pumps that had to be insulated to prevent freezing. Special attention was given to the deposit area to ensure that the sand was not being recycled. Upon completion of the excavation, 350 H-piles were driven into the three pier footings through pre-excavated holes in the ice bridge. A well planned driving sequence had to be worked out to avoid placing the pile driver on an excavated area. In addition to driving the battered piles, two groups of four vertical tower piles were driven in each pier from which the footing forms and steel shaft were lowered into position with winches.

The footing forms and reinforcing steel were pre-assembled on the ice surface near the pier and hauled into position on a skid. The contractor then lowered the forms into position at the bottom of the excavation and had divers place the remaining reinforcing steel in the footing mats. Prior to placing the tremie concrete in the footings, it was necessary to lower a steel form into position that acted as the formwork for construction of the pier shafts below water level. Each pier footing contained of the order of 80 m^3 of tremie concrete.

The bridge was designed and the construction supervised by the Bridge Engineering Branch of Alberta Transportation and Utilities. A notable feature of the inspection was the utilization of an underwater camera which was used to monitor the placement of the reinforcing steel in the footings. The divers were able to focus the camera on specific areas that could be seen on a monitor located on the ice near the pier. A model of the Pier 3 footing showing the piling and reinforcing steel proved very valuable in orientating the divers to the problems that they would encounter.

An overview of the approach used to construct one of the piers from the ice during winter conditions will illustrate the techniques used, and will focus on the special construction techniques used for creating the ice bridge, removing the river bed sand to the bottom the footing elevation, driving of the footing piling from the ice bridge, and placing and constructing the remaining underwater portion of the pier. This unique approach to pier construction may provide other agencies with an alternative method that can be used to construct major river piers from an ice bridge under similar conditions.

Wayne Krause has been in the Bridge Engineering Branch of Alberta Transportation and Utilities (3rd Floor, Twin Atria Building, 4999 - 98 Avenue, Edmonton, Alberta T6B 2X3, Canada), for the past 19 years and is presently involved with a railway and interchange grade separation program. He was the Resident Bridge Engineer for the construction of the Peace River Bridge at Fort Vermilion from 1971 to 1974.

Bituminous Treated Roads: A Realistic Alternative to Asphaltic Concrete for Northern Regions

Robin Walsh

The usage of bituminous surface treatment on Yukon highways has evolved over the past 15 a from a dust control treatment to a substitute for hot-mix asphaltic concrete on designed sub-base and basecourse layers. Good success has been achieved both on low volume recreational roads and on industrial haul routes carrying in excess of 100,000 ESALs per annum. There are 1860 km of Bituminous Treated Road (BTR) in the Yukon Territory highway system and expansion occurs annually. Detailed monitoring of the BTR network has been ongoing since 1984 and an extensive data bank has been accumulated with respect to performance.

BTRs in the Yukon consist of a single application of high-float emulsified asphalt overlaid by a graded aggregate which provides a surface seal ~20 mm thick. HF350 and HF250 are the most commonly used emulsions. Normally -20 mm graded aggregate is used for the initial surface treatment and for subsequent overlays; graded aggregate with a 12 mm top size has also been used. The application process requires a distributor truck, chipspreader, and rubber tired compaction equipment and is similar to seal-coating asphaltic concrete pavement.

BTRs have been divided into three classes as follows:

Class 1 includes roads on which the bituminous surface treatment is typically used for dust control. The application is usually on an unimproved road structure which has not been designed to any particular standard.

Class 2 includes roads on which a 75 to 150 mm thick layer of clean crushed gravel basecourse is placed on the subgrade prior to the bituminous surface treatment. Roads in this class are normally low volume highways and recreational roads.

Class 3 comprises the main highways with fully designed sub-base and basecourse layers on which the bituminous surface has been applied as a substitute for hot-mix asphaltic concrete.

Class 1 and 2 BTRs would typically be gravel surfaced. An analysis of rehabilitation, maintenance, and user costs indicates that such BTRs have economic advantages over gravel surfaces for AADTs in excess of 50. At present the type and volume of traffic on Class 3 BTRs would normally warrant a paved surface.

Performance of Class 3 BTRs is comparable to that of hot-mix asphaltic concrete except for a noisier ride due to the coarser surface texture. The advantages of Class 3 BTRs over asphaltic concrete relate to subgrade performance and economics.

Many northern highways are located in discontinuous and continuous permafrost zones where settlement related to permafrost degradation can be expected in the years immediately following construction. BTRs provide a low cost surface during the period of roadbed stabilization, and correction of settlement problems does not result in wastage of expensive asphalt concrete.

Life cycle costing demonstrates that Class 3 BTRs compare favourably with asphaltic concrete pavements. The initial investment required for bituminous surfacing is ~20% that required for asphaltic concrete. This is particularly attractive in northern regions where the ratio of highway kilometres to population is quite high and the low cost of BTRs helps to keep highway expenditures within realistic limits.

The BTR network can be managed from a planning and programming perspective in a similar manner to an asphaltic concrete road network. In the Yukon a BTR Management System has been specifically developed for this purpose.

A relatively simple rating process has been developed for evaluating the condition of BTRs. The distresses rated are ravelling, bleeding, rutting, subgrade failures, shoulder disintegration, potholes, cracking, patching, distortions, corrugations, streaking and joints. A subjective evaluation of the riding comfort is also made. Over 6 a of condition rating the most significant distresses have been bleeding and rutting, from a safety perspective, and subgrade failure and to some extent shoulder disintegration from the perspective of maintenance costs.

The surface condition information is used as the basis of the Management System in two ways:

1. On a section by section basis the individual distress measurements are used to identify sections for consideration in a detailed project level analysis.

2. At the network level a weighting index is used for selecting rehabilitation priorities and strategies and for investigating the impact of varying funding levels. An overall rating called the BCI combines the weighted distresses and the ride comfort score for a single index of overall BTR highway condition.

Robin Walsh is Director of Transportation Engineering for the Government of the Yukon (PO Box 2703, Whitehorse, Yukon Y1A 2C6, Canada) and has spent the past nine years in the field of highway and airport design and construction in northern Canada. He played a leading role in developing and implementing a Management System for the Yukon's BTR network.

A New Soil Cement for Permafrost Regions, Yellowknife, NWT, Canada

Garry W. Hollingshead

Paved streets within the city of Yellowknife, NWT, Canada often suffer from severe distress because of the thaw-consolidation of ice-rich permafrost. The problem is compounded by a severe shortage of suitable aggregate to replace the ice-rich and/or frost susceptible subgrade soils.

At the present time, Yellowknife is desperately short of sand and gravel and is taking measures to conserve this scarce resource. Nevertheless, many thousands of tons of sand are used each year where alternative materials might well be used, such as for trench backfill, embankment and road subbase.

At the same time, the city is surrounded by vast quantities of waste tailings for which there is a shortage of disposal space.

Thurber Engineering, in cooperation with Goodson Associates, Inc. of Denver, Colorado, has embarked on a program to test a new soil-cement product which will bind the undesirable waste products in a manner useful for trench backfill or road subbase and also insulate the permafrost subgrade.

Historically, soil cement has been used for road base where suitable aggregates are not available. Its weakness has been that it does not withstand freeze-thaw action; i.e. it does not have adequate durability.

Recently, foamed products have come on the market and are used for light weight concrete. 'Foamcell' is a controlled low strength material that owed its distinctive properties to a multitude of macroscopic, non-interconnecting air cells uniformly distributed throughout the mass. These cells may account for up to 90% of the total volume. Although various gases may be used to achieve the expansion desired, air is used as the expansion matrix for reasons of economy,

'Foamcell' consists of aggregate, portland cement, water and proprietary organic admixtures. The admixture components are responsible for the expansion of the cement slurry. The mixing system required to assimilate the foam into the slurry can be either a rotary (batch) or incline (continuous) system. 'Foamcell' density can be controlled within a specific gravity range of 0.3 to 2.3. The resultant product can then be placed by using conventional positive displacement piston-type pumps over distances in excess of 300 m.

The key features of the new product are that it is non-toxic, heat resistant, and can be produced easily and pumped over long distances. It therefore lends itself to solving the problems noted above.

Twenty-seven test specimens were made using fine sand from a Yellowknife source. Four levels of expansion were provided to each of two different original mix designs. The two ratios of cement to sand were 8.7 and 13.2%, and the four expansion levels were 15%, 28%, 50% and 78%.

Two samples of each mix were subjected to freeze-thaw cycling. The remainder were tested for unconfined compressive strength.

After initial weighings and measuring, the specimens were soaked and put through 12 cycles of freezing and thawing, generally in accord with ASTM guidelines. For each cycle the samples were soaked for several hours, and placed in a home freezer at -14°C in a saturated, surface-dry condition. They were allowed to freeze for 24 h, thawed, brushed and reweighed to determine loss of material.

In general, the specimen densities were observed to increase 10 to 20% over the first 5 or 6 cycles and then stabilize. Several days following the last freezing cycle the weight of each specimen was slightly greater than the original weight indicating they were not thoroughly dry following the last cycle. In any event, the weight loss resulting from the cyclical freezing was not significant. Further, there was no evidence of cracking or spalling of any of the specimens.

The program will be continued by:

1. reducing the cement content at 80% expansion to determine the most economical product which will be durable;
2. replacing the sand with mine tailings;
3. testing the leanest surviving mix for heat flow resistance;
4. going to a field trial during the summer of 1991.

The road test section will be located in Yellowknife over ice-rich permafrost and will be fully instrumental with thermistors.

Garry Hollingshead is an associate of Thurber Engineering Ltd. (PO Box 1317, Yellowknife, NWT X1A 2N9, Canada), a member of NAPEGG and Chairman of the Cold Regions Division of the Canadian Society for Civil Engineering. He has been active in permafrost, muskeg and northern river engineering for 30 years.

Computer Simulations to Estimate Moisture and Temperature Effects Beneath Pavement Structures

D.E. Pufahl and R.L. Lytton

The Integrated Computer Model of the Climatic Effects on Pavements (ICMCEP) was developed primarily for highway engineers involved in pavement design and management. The program determines the effect of climate on pavement materials and on subgrade conditions and properties over several years of operation of flexible pavements, rigid pavements, or rigid pavements with an asphalt overlay.

The program has been developed to run on an IBM compatible microcomputer with a minimum of 286 kilobytes of memory.

The ICMCEP is a one-dimensional coupled heat and moisture flow program which has the capability of generating internally realistic patterns of rainfall, solar radiation, cloud cover, wind speed, and air temperature to simulate the upper boundary conditions. It also contains a variety of options for specifying the moisture and temperature, or the flux of these variables at the lower boundary and at the interface between the subgrade and the base course. The program has the unique ability to consider the lateral and vertical drainage of the base course, which is a two-dimensional problem, in determining the amount of water that enters the subgrade by infiltration through the pavement surface and base. Using 30 a of accumulated weather data as a basis, the model generates its own weather patterns that are representative of typical climatic conditions for a particular region of application. While the program was originally designed to accommodate users in the U.S.A., useful application of this program is by no means restricted to that region of the world. Provision is made for users to enter their own weather data whenever it is available. The required weather data consist of average monthly wind speed, percent sunshine, average monthly temperature, monthly precipitation, number of wet days per month, and number of thunderstorms per month.

The number of input variables has been reduced to a minimum, and they have been assembled so that they are input in a free format on input user screens that appear sequentially in the course of data entry.

Carefully selected default options that are representative of material properties of many typical highway pavement structures may be used if site specific data are not available. There is also a compendium of alternative data for a variety of different soils based on texture and index properties in the User's Manual. Graphical displays of the output are an important feature of the ICMCEP.

The ICMCEP does not 'predict' but instead computes expected results based on historical weather trends and is intended to be used for design purposes. In design, it is not essential to match exactly the measured temperatures, suction, and layer moduli at the exact time they occur, but it is important to determine their realistic ranges during each month and each season. This capability is more useful in design than any other.

The program estimates the depth of the frost zone, the amount of ice that has formed in each vertical increment, the negative pore-water pressure in the unfrozen water at temperatures below freezing, the mean and maximum frost heave that may be expected each day, and the elastic moduli of the pavement layers as they are affected by the computed moisture and temperature.

Comparisons between measured and computed values of suction and temperature throughout one year of simulation have been made at three locations in the U.S.A. The results show remarkable correlation, especially at a site near Chicago, Illinois, where the suction is low, the water table is quite high and where minimum temperatures drop below freezing from November to March.

The ICMCEP is being used at several Strategic Highway Research Program Long Term Pavement Performance sites in the U.S.A. The authors encourage Canadian highway engineers to use this program in an effort to establish its reliability in a variety of climatic and subgrade conditions.

The program, which is contained on IBM compatible floppy discs, and the User's Manual are available through the National Technical Information Services, Springfield VA 22161, U.S.A. The results of the simulation procedures are providing an important contribution to the complex process of assessing climatic effects on pavement design and management.

Two publications, not including the Final Report, describing aspects of this research project are given below.

References

Pufahl D.E. and Lytton R.L. (1991) Temperature and suction profiles beneath highway pavements: computed and measured. Presented at Transportation Research Board Annual Meeting, Washington, DC, January 1991.

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Dennis E. Pufahl is a professor of civil engineering at the University of Saskatchewan, (Saskatoon, Saskatchewan S7N 0W0, Canada). The co-author and principal investigator of this research project is Robert L. Lytton, Head of Materials, Pavement and Construction (Texas Transportation Institute, Texas A&M University, College Station, Texas 77043, USA).

Evaluation of the Potential of Lightweight Aggregate for Use as Thermal Insulation in Road Embankments

T.L. White and L.E. Goodrich

Observations of the thermal properties and phase composition of a coarse, expanded-clay, lightweight aggregate for both laboratory and field studies are reported. Results from one-dimensional finite difference computer simulations performed on model embankments of different stratigraphic configurations comprising lightweight aggregate at different degrees of saturation are also reported.

Thermal conductivity and phase composition measurements were made at degrees of saturation from 0 to 33% over a temperature range of -10 to 20°C, using the transient heat flow (thermal probe) method and a time-domain reflectometry (TDR) procedure, respectively. Under typically well drained field conditions gravimetric moisture contents will generally fall in the range of 10 to 18%. Thermal conductivity values for the lightweight aggregate in the unfrozen state increased from 0.08 W/m.K to 0.25 W/m.K as the degree of saturation increased from 0 to 32%. The material retains its low thermal conductivity characteristics in the frozen state for initial (unfrozen) saturations <26%. For higher degrees of saturation frozen thermal conductivity increased to 0.65 W/m.K (32% saturation). Values as high as 1.25 W/m.K were observed under fully saturated conditions. This behaviour is consistent with the effect of freezing on the thermal conductivity of soils at low moisture contents. When freezing occurs, not only is the thermal contact between aggregate particles enhanced, but also the thermal conductivity of the moist particles themselves increases significantly.

The phase composition study indicates that a high proportion of the water held in the micropore structure of the aggregate remains unfrozen below 0°C. The water to ice phase change is, however, essentially complete at -5.5°C.

One-dimensional computer simulations of road embankments of different stratigraphic configurations, including lightweight aggregate at different degrees of saturation, were conducted to evaluate the effectiveness of this material for frost protection of the subgrade. The depth of frost penetration for a multilayered embankment insulated with a 50 cm thick layer of dry aggregate was reduced by 45% compared to an uninsulated road embankment. A 50 cm layer of lightweight aggregate with an initial degree of saturation of 26% further decreased frost penetration by 12%. The additional frost attenuation can be attributed to the release of latent heat which accompanies the water to ice phase change. Conversely, a multilayered road embankment incorporating a 50 cm layer of aggregate with an initial degree of saturation of 32% was observed to decrease frost penetration by only 20%. At a higher degree of saturation, therefore, the phase change/latent heat release is strongly counteracted by the much higher frozen thermal conductivity properties of the aggregate.

Model calculations suggest that precautions should be taken to ensure that the degree of saturation for lightweight aggregate used in road embankments not be permitted to exceed ~26%. Further research should be undertaken to establish the most practical ways of achieving this.

The use of coarse, expanded-clay, lightweight aggregate as an antifrost thermal insulation in highway construction merits further consideration. This material has, upon evaluation, proven to be capable of providing a high level of protection from frost action while at the same time offering a viable alternative to conventional, increasingly scarce gravel resources.

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Dr. L.E. (Laurel) Goodrich is a senior research officer in the Geotechnical Section, Institute for Research in Construction, National Research Council of Canada. He is a graduate of the University of Alberta and McGill University and an authority on heat transfer in the ground. He has performed research on computer modelling of the ground thermal regime, on the development of techniques for measuring soil thermal properties, on passive and active methods of controlling ground temperatures, and has carried out various field studies for engineered structures in cold climates.

Outline of Different Types of Road-Heating Systems and Their Design Procedures

H. Ueda and H. Masaoka

Sapporo City experiences cold weather and heavy snowfalls. Its average annual snowfall is 5 m and the outside air temperature often reaches -10°C. Snow falls nearly half the year, from November to April. Therefore, the maintenance of safe vehicle transportation during the winter season is an important concern of the local government.

One of the measures employed to assure safe transport during winter is the installation of road-heating systems where required, including steep slopes with relatively heavy traffic. Road-heating system, as used in this paper, refers to overall combinations of heat source, heat generator, underground heater, paving material, control system and senors.

In addition to the conventional road-heating method in Japan, the exothermic wire method using electricity as its source of heat, new road-heating systems have been developed and put to practical use.

This paper introduces the six major road-heating systems currently installed in Japan, and outlines their design procedures and other important information. All the methods use fossil fuel, natural heat, or electricity as their heat sources. The six types are:

1. Hot-water circulation method using a hot-water boiler with fossil fuel as the heat source.
2. Hot-water circulation method using a heat-pump with natural heat as the heat source.
3. Hot-water circulation method using a heat exchanger with hot spring water as the heat source.
4. Direct hot-water circulation method with hot spring water as the heat source.
5. Natural flow method using heat pipes with hot spring water as the heat source.
5. Exothermic wire method with electricity as the heat source.

The circumstances at the installation site must be understood thoroughly in order to design an effective road-heating system. The following conditions are among those which must be considered when formulating the design:

1. Weather conditions (such as snowfall, outside air temperature and wind velocity)
2. Availability of a heat source
3. Location for installation of the heat generator
4. Traffic flow
5. Road gradient, width and length
6. Management system: paving material, facilities, supply and control of heat source

The general procedure followed in designing a road-heating system is shown below (road heating system as used in this paper refers to an overall integration of heat source, heat generator, underground heater, paving material, control system and sensors):

1. Determination of design conditions
2. Selection of heat source
3. Selection of heating method
4. Selection of underground heater
5. Selection of paving material
6. Selection of control method
7. Selection of sensors

Brief comparison of the six types of road-heating systems was made with respect to the following items.

1. Initial cost
2. Operating cost
3. Ease of circuit repair
4. Evenness of snow melt
5. Size of the heat generator
6. Maintenance
7. Results

It was concluded that no clear, specific design procedures for road-heating systems yet exist in Japan. Although this paper has presented the basic characteristics, design conditions and procedures and a brief comparison of different types of road-heating systems, it is clear that the design of a road-heating system requires extensive and careful examination of all relevant conditions, because the design significantly affects initial cost, operating cost, installation, workability, durability and maintenance.

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Trees as Snow and Wind Breaks, Hokkaido, Japan

Hiroji Oku

In Hokkaido, winters are long and severe, and the land is snow-covered from mid-December to the end of March. Winter precipitation at lower elevations ranges from 180 to 690 mm (mean, 330 mm); the mean temperature is -4°C and the mean wind speed is 4 m/s. Snowstorms blow from W to NW when low pressure centres, located N of Hokkaido, are reinforced by high pressure cells over Siberia.

In these weather conditions, snow removal is necessary to keep road traffic moving smoothly.

Both road and snow removal equipment have been improving, and presently snow is removed from 98% (5800 km) of the national highways in Hokkaido.

Poor visibility and drifting snow in snowstorms, however, are responsible for road closures and traffic accidents. Various approaches, such as snow fences and snow sheds, have been used to keep highways clear of snow during blowing weather.

Increasingly, rows of trees have become popular as snow and wind breaks because they are permanent, provide beautiful road scenery, and are effective deterrents to drifting snow.

Rows of trees planted thickly on the windward side of the road, both reduce wind speed and catch snow. The first treed snow breaks were planted in 1893 in Tohoku Prefecture, along the national railroad. In this case trees were planted in comparatively wide belts (60 to 80 m).

Although the use of very wide tree belts is restricted by the narrow highway right of way, in 1978 the highway authorities in Hokkaido started to plant trees along the available lots of national highways to improve visibility.

This paper describes 3 of the 10 planted tree belts; including aspects of design, effect, and problems.

1. *The Onobunai Site* - National Highway 40 at Onobunai Teshiocho, Hokkaido; established 1981-1990 (currently being set up); length 3500 m (W side of the road); Norway spruce, Sakhalin fir, Japanese rowan, Japanese ash, willow, Japanese poplar, white poplar.

This site is in the northernmost part of Hokkaido, and is surrounded by meadows. Strong winds blow from the NW and blowing snow conditions sometimes initiate road closures. Trees are planted in the order willow, Norway spruce, Japanese ash, Norway spruce, Japanese rowan. The width of the tree belt is 28 m. Originally 2-3 m high, the trees are now contributing to improved winter visibility.

2) *The Kokufu Site:* National Highway 40 at Kokufu Nakagawacho, Hokkaido; established 1983-1990 (currently being set up); length 1900 m (E side of the road); Norway spruce, Japanese white birch, Sakhalin spruce, Japanese ash.

The site is 15 km S of Onobunai, and is surrounded by meadows. Winds associated with severe blowing snow conditions range from W to NE. The order of trees is Japanese ash (3-rows), Sakhalin spruce (2-rows), Japanese white birch (2-rows) and Norway spruce (3-rows). The width of the tree belt is 15.5 m, and the trees range from 2 to 3 m in height.

3. *The Yamausu Site:* National Highway 238 at Yamausu Esashicho, Hokkaido; established 1987-1990 (currently being set up); length 600 m (E side of the road); Japanese ash, Sakhalin spruce, Sakhalin fir.

The Sea of Okhotsk lies on the E side of this site and snow drifts and poor visibility caused by severe E winds sometimes result in road closures. Sakhalin spruce (120 cm), Japanese ash (250 cm), Sakhalin fir (30 cm) were planted from E (sea side) to W (road side) in many rows. The tree belt is 28 m wide and its effect will be determined in several years.

Hiroji Oku is a consulting engineer (specializing in road construction engineering) and has his own civil engineering company (Kitamichi Sangyo Co. Ltd. W-19, N-1, Sapporo, Hokkaido 060, Japan). His company is involved in many types of highway work, including construction, maintenance, snow removal, and surveying.

Field Tests of Road Heating Applied Heat Pumps, Hokkaido, Japan

Akira Yoshimura, Yuichi Kobayashi, Shigechiyo Takeuchi and Hiroki Hasegawa

Road heating is one way to ease traffic problems caused by snow or ice on the road surface and to save labour in snow removal. In Hokkaido, road heating systems are used in various circumstances, and the number of systems is increasing significantly because studded tires are banned and there is a demand in the region for a better winter living environment.

Since 1986, the Hokkaido Electric Power Co. has been studying how to make road heating systems more energy efficient. As part of these studies, applied heat pumps for practical heating systems have been designed. They are classified according to heat source.

In these systems, a solution of ethylene glycol is heated by the heat pump, and circulated through tubes buried in the pavement. Because the temperature of the solution needed for road heating is 298-303 K (lower than that for air-conditioners) a high energy efficiency is anticipated.

Three heat sources for heat pumps are used: underground water, open air, and a mixture of open air and ventilation exhaust from a subway station.

The systems allow for secure safe, smooth, and economic traffic flow through appropriate system designs, and for automatic controls depending on the weather conditions.

The heating capacity of a system is significant in determining the essential capabilities and cost effectiveness. A road heating system has two functions: snow melting and prevention of freezing. In designing the heating capacity, priority was given to freeze prevention as a counter measure to traffic trouble. Using past weather data, a system was designed where the heating capacity significantly reduced the risks of road surface freezing. In many cases, this capacity is also sufficient to melt snow.

Automatic controls for the system are also significant so that the capabilities of the system can be fully utilized and wasteful energy consumption eliminated. The present systems have two distinct control units: one for the heat source apparatus, and the other for the road heating apparatus.

The control unit of the heat source apparatus keeps the temperature of the solution in the storage tank steady, and starts and stops the heat pump.

The control unit of the road-heating apparatus regulates the temperature of the pavement by stopping and starting the solution-circulation pump. Pavement temperature is determined based on information provided by detectors which monitor snow, road surface moisture, and outdoor temperature. In the case of the prevention of freezing of the road surface, the target value for the pavement temperature is governed by the air temperature, resulting in energy saving.

Two of the systems, the air source system and the system using subway exhaust, have been adopted by the road maintenance division of Sapporo city. In Sapporo, the average winter temperature (December through March) is 270.3 K with 386 mm precipitation. Accumulated snow reaches 434 cm.

The operation of the systems was observed and favourable results obtained regarding their snow-melting and freeze-preventing capabilities. The energy-saving capabilities are as follows:

1. Air-source system

In order to improve the heat collection capability, the fin pitch of the heat exchanger was expanded, fan capacity was reinforced, and the defrost control and refrigerant control apparatus modified. As a result, the ratio of energy produced to energy consumed during the observation period was 1.95. By slight modification of the freeze prevention heater installed in the heat exchanger used in heat collection, this ratio could be increased to >2.2.

2. Subway-exhaust system

Subway exhaust is available during business hours (6:00 am to midnight) and the ventilator operates according to the air-conditioning of the station. The temperature of the subway exhaust was 278-281 K. The heat pump used is a general purpose one, but the heat exchanger used in heat collection is attached to a ventilation tower of a subway station. In addition, because temperature fluctuation is considerable due to the open air and exhaust used as heat sources, a refrigerant control apparatus was modified to assure steady efficiency. As a result, the ratio of energy produced to energy consumed was high (3.22) during the observation period.

Regarding the underground water type, some equipment is used in Hokkaido. One of them, installed in our head office in Sapporo gets an energy efficiency ratio >3.5.

Hiroki Hasegawa is a researcher in charge of electricity utilization in the Department of Research and Development, Hokkaido Electric Power Co. Inc., (461-6, Satoduka, Toyohira-ku, Sapporo, Hokkaido 004, Japan). His section has carried out research and development of activities on heat pumps for cold regions, electric heating and drying technologies, electric equipment for agriculture, aquaculture and forestry, and measures to counter snow and cold weather.

Snow Melting and Deicing System for Sloping Roads Using Long Corrugated Heat Pipes, Sapporo, Japan

K. Shibuya, Y. Hasegawa, S. Yoshida, M. Mochizuki and S. Sugihara

In Sapporo, Japan, studded tires have been banned to prevent dust pollution from comminuted asphalt, and thus safety measures such as snow melting and deicing systems have become indispensable at slopes and intersections. In 1989, a heat pipe road heating system was constructed at the sloped road of Asahiyama Park-Yonesato Route, and a favourable result obtained.

A heat pipe consists of a closed pipe which is held under vacuum and charged with a small amount of working fluid. When one end of the heat pipe is heated, the working fluid evaporates and the vapour flows to the condensing end where it becomes liquid again. Then, the condensed liquid is brought back to the evaporating end by gravity. In this way the heat can rapidly be transferred through the heat pipe without power under uniform temperature conditions. Accordingly, the heat pipe can transfer much heat at a high efficiency even if the temperature difference in the heat pipe is very small, and a good result can be obtained by a heat-pipe road heating system without uneven snow melting.

The heat pipe as a heating element has a diameter of 26.5 mm and is made of corrugated stainless steel pipe which is excellent for both corrosion and compressive strength, and hence suitable as structural material within a paved road. As a heat source, the gas boiler was installed under the sidewalk in order to reduce construction space. The system can be controlled economically based on four factors: snowfall intensity; road surface temperature; ambient temperature; and the presence of water on the road surface.

The Asahiyama Park-Yonesato Route road has an upward sloped lane 6 m in width and 68 m in length, which was divided into four blocks of 17 m each. Hot water for heating the heat pipe to 27 to 30°C was supplied from a boiler and sent to header pipes installed at the hot end of the heat pipe at a flow rate of 1.6 m^3/h. The heat pipes were installed at 200 mm intervals and a depth of 100 mm below the pavement material (Inter Locking Block); a heat flux of ~200 W/m^2 was measured at the road surface. This road heating system was effective in ensuring safety when motor vehicles started and stopped.

Over an elapsed time of 1529 h, the total boiler operating time was 258 h, for an average operation rate of the boiler of 17%.

The cost of the above operation was rather low, because the amount of the snowfall in the last year (1989) was small. Assuming the operation rate of the boiler is ~25% in an average year, the average operation cost is estimated at 1900 yen/m^2 for one season.

To advance the practical use of the heat pipe system for road heating, an effort should be made to improve a construction method for reduction of the initial cost, so that the improved system can be usefully applied in the near future.

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Utilization of Water Waves for Snow Melting

K. Fujino, M. Inoue, N. Kodan and Y. Yamauchi

In recent years, the demand for snow removal from urban areas has been increasing in heavy snowfall regions in Japan. Various infrastructures such as channels, melting pipelines and road heating systems have been developed so far as effective means for that purpose and are in practical use. However, the amount of snow removed by these methods is relatively small, so that the rest has to be removed by plowing, with the plowed snow disposed of by truck hauling to dumping grounds. A concept of a relatively large snow-melting tank has been proposed using waste heat in urban areas. Before realizing this plan, it is essential to investigate effective methods for snow melting from the point of view of energy.

This study deals with various methods for promoting snow melt in a tank to which a certain amount of heat is supplied, and shows that the use of water waves generated in the tank is the most effective means to melt snow in comparison with other mixing methods. In addition, a snowmelt simulation model corresponding to the actual case is presented.

A series of snow melt experiments were carried out using three different mixing devices: a specially designed wave generator, a screw propeller, and horizontally rotating blades. The model tank was 1.9 m x 1.3 m, and 0.9 m deep, having a water volume of ~1.6 m^3. A newly designed artificial beach was installed on one wall of the tank so that waves generated by the wave-maker gave significant impact pressures on dumped snow. A 5 kW electric heater was installed in the inner side wallow of the tank. A 5 kg block was prepared (density 500 kg/m^3). Ten snow blocks were thrown into the tank, and the time taken for the snow to melt determined, and the change of water temperature measured. Each mixing device was operated under a constant 20 W electric power and the initial temperature of the water was 10°C. Room temperature was almost unchanged at ~20°C during each run.

The test results are tabulated below in terms of snowmelt rate, i.e., the snow amount divided by the time taken to melt. Clearly, the use of water waves is the most effective method.

Type of Mixing	Snowmelt Rate (kg/h)
none	31
screw propeller	67
horizontally rotating blades	59
water waves	115

This could be due not only to the mixing effect but also to erosive action on snow blocks. In fact, significant erosion was observed, forming many small holes on snow surfaces. The increased surface area brings about greater heat exchange between the snow and surrounding water, resulting in a higher snowmelt rate.

To examine how dumped snow accumulates and melts in an actual melting tank, a snowmelt simulation model was developed, based on a snow-water heat budget equation taking into account the snowmelt rate. The snowmelt rate was determined, from another series of experiments, as a function of water temperature and the ratio of snow volume to tank volume.

This simulation model was verified by experimental data obtained under a large amount of snow dumped. By applying the model to an actual case, time-variations in the amount of snow remaining and water temperature were simulated for both cases of waves and non-mixing. The result indicated that a larger amount of snow was melted through the use of water waves than through non-mixing.

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Snow-melting System Using City Gas, Sapporo, Japan

Ryuichi Yamada and Hiroyuki Shinjyo

The major service of the Hokkaido Gas Co. Ltd. is the production, distribution, and sale of city gas. In addition, the company develops and sells many kinds of equipment and systems that utilize city gas.

Hokkaido Gas specifically carries out research and development of heating systems and snow-melting systems for colder regions. This paper introduces the company road snow-melting system.

The city of Sapporo has been developing steadily and has become one of the largest cities in Japan, with a population of 1.6 million. However, in winter, it receives ~5 m of snow, which causes traffic problems and economic loss. This amount of snow requires constant road maintenance, as the most effective means currently available to remove snow. A road snow-melting system is a more effective way to solve the problem, but conventional snow-melting systems have very high operating costs. For this reason, Hokkaido Gas has developed a system with a low operating cost.

The principle of this road snow-melting system is circulating hot water. Water is heated by a gas water heater, and pumped through heating pipes placed under the pavement. The heat of the hot water is then conducted to the road surface, melting the snow.

The main component of the system is a gas water heater which is underground., A pulse combustion method has been used for the burner of the unit. In addition to pulse combustion, features of the laid underground system are as follows:

1. High efficiency (94%) is achieved.
2. Ultra-compact design is achieved thanks to the small size of its burning equipment and heat exchanger.
3. Installation is made possible even under sidewalks.

The hot water produced by the gas water heater is fed by a pump through hot water heaters and circulated by heating pipes. The heating pipes are special nylon resin pipes, considered to be best for performance, workability, and cost. First, they have a superior ability to withstand heavy loads and creep and are completely rust proof. As a result, a consistent snow melting performance is guaranteed for at least 10 a. Second, the pipe is very flexible, and because or its high softening and melting points (182oC and 215°C, respectively) it can be installed even during the laying of asphalt pavement. Lastly, a long heating pipe (~100 m) is used to avoid the presence of seams under the road pavement, which could cause problems such as water leakage.

It is necessary that road snow melting systems operate automatically. Ideal control is only possible through accurate monitoring of snowfall or freezing conditions at the road surface. The present system monitors these conditions by means of four types of sensor: snowfall, road moisture, road temperature, and outside air temperature. A special feature of this system if that two road moisture sensors monitor road surface for frozen, wet or dry conditions.

The system operates automatically depending upon the temperature of the road surface under different conditions. In snowfall conditions, the system begins operation once the road surface falls to +6°C. And when the road surface is frozen, wet, or dry, the threshold temperatures are +4°, +2°, and 0°C, respectively. This control system permits a low operating time (~800 h/a for Sapporo) and enables economical and optimum operation.

As a result, the operating cost of this system is about half that of a conventional one. In Sapporo, the cost would be ~2000 yen/m^2/a ($14/m^2/a).

As has been shown the Hokkaido Gas Company's snow-melting system has a low operating cost and saves space, and is therefore receiving much favourable attention. Further, Hokkaido Gas will strive, through research and development, to continue to improve this system.

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An Automatic Snow Blower Guided by a Ferrite Marker

S. Sayama, N. Umeda, R. Sakaguchi, H. Wakaumi and S. Yokoyama

Snow removal work commonly involves two operators to take care of steering and the snow blowing operations. Therefore, it is necessary to rationalize the operation system of the snow blower in order to save labour. For this purpose an automatic snow blower has been developed.

The machine is guided by a ferrite marker placed in the pavement. The ferrite marker is made of magnetite powder and asphalt, and is 10 cm in width and 15 mm in thickness.

A magnetic sensor is attached to the machine frame with one exciting coil at its center and two detecting coils at the sides. The marker is magnetized by the exciting coil applying 40 kHz. The two side coils detect the difference in the magnetic field which is formed by the ferrite marker.

Even if the induced alternating currents VL and VR change by α time (αVL, αVr) according to the vertical movement of the sensor, the ratio VL/VR does not change with time. Therefore, the position differential signal VS, that is a measure of the distance between the ferrite and the sensor, is expressed with the following equation:

VS = 1-VL/VR at VR > VL
VS = -(1-VR/VL) at VR < VL

Using the VS signal the steering of the machine is PID controlled.

By this procedure the magnetic sensor on the machine can recognize the shift from the marker installed at the road surface, and correct the direction of movement of the machine.

Running tests applying this navigation system were made using an 80-PS snow blower running at 5 km/h.

The result confirmed that this system was useful for the improvement of the efficiency in snow removal work, because the operators load was reduced.

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Interfacial Debonding of Ice-Asphalt Concrete

Ei-ichi Tazawa, Yuji Mizoue and Takeo Kojima

In order to clarify the nature of the bonding mechanism between ice and asphalt pavement and to develop new techniques to reduce bonding resistance, a series of experimental investigations was conducted.

Interfacial debonding resistance was measured by three different methods. The first method was a single plane shear test which was originally designed for a soil test; the second was a pure tensile test in which the tensile stress field was generated at the interface as a reflected wave dynamically induced by a drop hammer; and the third method was a local compression test carried out under static or dynamic conditions. In the second method, the cycles were repeated until debonding occurred and the total energy spent for debonding was taken as a measure. The bulk specific gravity of the compacted snow was adjusted to 0.8 by compressing crushed ice particles together. Tests were also carried out for pure ice. Surface energy, surface roughness, and the stiffness of the asphalt concrete were chosen as the main variables. Surface energy was varied by using various water repellents applied by brush-painting or by mixing with the asphalt. In order to simulate the actual pavement surface, roughness was varied by wearing the surface with sandpaper. Stiffness of asphalt concrete was varied by mixing crushed rubber particles with the asphalt. Correlations between these variables were investigated and the following conclusions were obtained.

1. Reducing surface energy and/or increasing deformability of the asphalt concrete was an effective way to decrease interfacial bonding between ice and asphalt. In this regard, use of water repellents or replacement of aggregate with rubber particles is a promising method to facilitate debonding of ice and pavement.

2. For a repellent-coated surface, shear debonding strength was linearly related to the energy required for debonding as measured by dynamic tension. For a normal pavement surface, however, no relation was found between these two variables. Shear debonding strength was actually constant for normal pavement even if roughness varied widely.

3. For a normal pavement surface, shear debonding strength was not influenced by roughness of the pavement. But for a coated surface, shear strength was linearly increased with roughness of the pavement.

4. The energy required for tensile debonding was linearly related to the roughness of the pavement both for repellent-coated and non-coated surfaces.

5. When bonding between ice and pavement was weakened, either by surface chemical or mechanical methods, radial cracks started from the spot where the dynamic or static load was applied, and formed in the ice by local compression; and ice pieces flaked off easily.

6. Shear debonding strength was related to bonding energy between water and the pavement surface at 20°C, which was experimentally determined by contact angle measurement.

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Snowdrift Investigations, Chitose Airport, Hokkaido, Japan

Nobuyuki Fujiki, Makoto Sanada, Fujio Hoshi and Shuji Mifune

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This paper reports the results of the field measurement of snow accumulation and snowdrift analysis at Chitose International Airport, Hokkaido, Japan. The airport is the northernmost principal airport for domestic flights and is rapidly growing as an international gateway to the northern part of Japan. Snow accumulation and ambient air temperature in this region in winter are 100-150 cm and -6°C, respectively.

Observations of snow were conducted at several points at the airport such as the apron and underpass areas. Snow accumulation, snow density and snow types were observed at the apron by making a 1 m deep rectangular hole, and the snow removal method and operating system were investigated.

At an entrance and exit to the underpass area, snow depth, snow-drift formation and condition, wind-induced snow distribution patterns and wind speed distribution were measured. Plans for countering blowing snow in the underpass and the methods for thawing the access roads were examined.

Theoretical analyses of snowdrift were conducted using a model which consisted of the wind speed, the magnitude of blowing snow, and the type of drifted snow. The results from the theoretical snowdrift model coincide with the field observations. As a result, snow and ice control systems, e.g. the method of snow removal, snow fences, and the method of sweeping snow, were established based on the above studies.

The basic equations used in the theoretical analysis were as follows:

Wind Field Model

The two-dimensional Navier-Stokes and continuity equations for an incompressible viscous fluid are:

$$\partial q/\partial t+(q.\nabla) = -\nabla p+v\nabla^2 q,$$
$$\nabla.q = 0.$$

Here q = (u,v), where u and v are velocity components in the x- and y-directions, respectively, in a Cartesian reference frame, p is the ratio of pressure to constant density, v is kinematic viscosity, and t is time.

Method of Tracking Snow Particles

The new position λ' of the snow particle after the small time interval Δt is given by

$$\lambda' = \lambda + (u + W)\Delta t$$

where u and W denote the velocity of snowfall and the wind velocity at the position λ, respectively.

Highway Snow and Ice Damage, Heilongjiang, People's Republic of China

Sun Ji and Pang Guoliang

Heilongjiang Province is situated in the northernmost part of the People's Republic of China and has long and rigorous cold winters and short humid summers. The lowest air temperature is -52°C, and the annual mean value from north to south is within the range -4° to 4°C. Ice- and snow-induced damage such as frost boils, snow-blocked highways, and frost heaving of bridges and culverts, exist all over the province, causing great harm to highway transportation, national construction and people's lives.

Based on extensive observations and engineering practice, the authors present examples of the formation, the preventive principles and the countermeasures used against snow and ice damage. During snow storms, when the wind speed exceeds that of the moving snow particles, the wind blows off the accumulated snow and wind-blown damage results. In the formation of this type of damage, wind is the motive force and topography is a crucial condition which makes it possible. In cases where the topography near the highway changes greatly, the wind speed decreases below that for moving the snow, or turbulent motion occurs. Then, the snow is deposited on the road and snow damage occurs.

The formation of sheet ice mainly depends on hydrogeology and special geological conditions, as well as topography, geomorphology and hydrology. The water source is usually a high water table. In cold climates the soil freezes slowly, allowing water a long time in a liquid state. This continuously overflowing water freezes creating ice sheets or an ice bank. Periodic changes of the dynamic features of ground water are the key to forming sheet ice. Topography and geomorphology are the dominant factors controlling the development of ground water and sheet ice.

According to traditional theory and practical experience, countermeasures to snow and ice damage were adopted, namely: 1. the installation of snow guides of varied sizes and structures; 2. raised road beds, changes in the road location, the digging of snow-storage fields, and increasing the radius of road curves; 3. planting an anti-snow forest, and setting up snow fences; and 4. removal of snow by machine or man power, and melting snow using chemicals. In this paper the construction of anti-snow forests is emphasized from the point of view of simplicity and economy.

With regard to the situation in Heilongjiang Province, blocking and guiding methods to eliminate or decrease ice damage are recommended. Among ice-preventive structures are the digging of ditches for ice accumulation, water-collecting pits, freezing ditches, embankments for obstructing ice, anti-ice walls, raised road beds, blind seepage ditches, and permeable road embankments. In general, sheet ice is a special phenomenon of physical geology. The most disastrous sheet ice commonly occurs soon after the completion of highway construction, because it is at this time that the original natural ground water balance is destroyed.

On this basis of practical experience, road boils are classified in terms of different water sources, e.g. underground water type, surface water type and soil water type. These classifications and corresponding countermeasures will all be discussed in detail.

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Characteristics of Snow Cleaning in the Three North Regions in China and Ideas for Improvement

Liang Zhaochun, Wang Luyi, Jiang Defeng, Wu Jie, and Wei Wenchun

Conventionally, the northern part of China is divided into three regions: the Northeast, the North-China and the Northwest. These three regions studied consist of six provinces (Heilongjiang, Jilin, Liaoning, Hebei, Shanxi, Qinghai) and three autonomous zones (Xinjiang, Inner Mongolia and Tibet).

About 640 million people (64.77% of China's population) are spread over 25.9 Mkm^2 (21.64% of the land area) in these regions. Highway systems total 3.6 Mkm (37.04% of the national highway system) with 1.4 million motor vehicles transporting >39.98 billion man-kilometers for passengers and 12.6 billion ton-kilometers for goods per year. The cold climate in the region presents constraints for railway construction, so highways play a very important role. The lowest temperature at Mehe, the coldest place in the Northeast, was -53.3°C, while the low temperature averages are -49.6°C at Genhe (North China) and -51.5°C at Fuyun (Northwest). Each year, winter lasts >100 days, with 40-60 days of snowfall. Annual snowfall averages 10-60 cm. A study of the climate and roads in the area helps to see the characteristics of winter road traffic in these regions in perspective.

Typical patterns of snow-related traffic problems in the regions are summarized next. In the Northeast and North China, where 80% of the highways are located on the plains, wind-drifted snow often piles on roads in drifts 0.5-3 m deep. In the Northwest, Qinghai and Tibet, where most of the highways are constructed in mountains and on plateaus in snow-covered tundra, avalanches and wind-drifted snow often break traffic and make snow removal a hard task. Some roads have to be closed for six months each year. In urban areas, there are 27 cities needing routine snow removal. In-town traffic suffers mostly from compacted snow, icing, and snow-ice mixtures.

It is suggested that precautionary projects should be given top priority. Local facilities such as forest belts, snowfences, wind-guide-panels and roadside snow guides, should be reinforced according to the local conditions. Mechanical methods can also be applied, especially in emergencies. In cities, the application of mechanical methods, such as truck-mounted snowplows, screw cleaners proves practical. The use of human power may be more cost-effective, however.

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Guidelines for Designing and Installing Road Heating Systems

Kazuo Shibuya and Iwao Sato

In cold, snowy areas of Japan, road-heating systems have been installed in city centers which have large traffic volumes, and on slopes where traffic congestion often occurs when it snows.

Road-heating systems are facilities which directly melt snow and ice on roads. The heat used by these systems is obtained by utilizing various resources including electricity, gas, underground water and exhaust heat from the city. Various kinds of facilities are available by using different combinations of heat resources and equipment. It is necessary to select appropriate systems which meet the requirements and conditions of the installation site.

However, to date, there are no reliable data or standardized materials to aid in overall planning, designing, installing and maintaining of the various road-heating systems. Consequently, each time a new system is installed, many hours are spent selecting the most suitable methods and materials.

Therefore, in order to enhance the efficient planning, designing and installing of road-heating systems, and the selection of appropriate systems for the sites, a "Guidelines for Designing and Installing Road-Heating Systems" is under development. The contents are, briefly, as follows:

Chapter 1: Introduction; 1.1 General Rules; 1.2 Outline of Road-Heating Systems.

Chapter 2: Research; 2.1 Basic Research; 2.2 Operations Research.

Chapter 3: Planning; 3.1 Heating Methods; 3.2 Operations; 3.3 Paving Structures; 3.4 Maintenance.

Chapter 4: Designing; 4.1 Paving Structures; 4.2 Heating Structures; 4.3 City Gas Road-Heating System; 4.4 Oil Road-Heating System; 4.5 Electric Road-Heating System; 4.6 Underground Water Road-Heating System; 4.7 Other Road-Heating Systems.

Chapter 5: Example of Currently Running Facilities; 5.1 Heated Water; 5.2 Electricity; 5.3 Air.

Chapter 6: Quality Control and Inspection.

Chapter 7: Maintenance.

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Bulk Fuel Storage and Handling Facilities in the Northwest Territories, Canada

Don Burgess

Due to the remoteness of communities in the Northwest Territories, fuel storage and handling facilities must be constructed to accommodate a full year's supply of fuel to power and heat the vehicles, buildings and electrical generating plants for the entire community.

The Government of the Northwest Territories has the mandate to maintain the facilities in all the non-tax based communities in the Northwest Territories.

Fuel storage facilities are typically a series of vertical or horizontal tanks to store up to four different types of fuel. These include P-50 Fuel Oil for home heating and powering diesel generators, gasoline for motor vehicles including trucks, power boats, snowmobiles and ATVs, and Turbo and AvGas aviation fuels to service the airlines that fly into the communities.

Design, construction and operation of these facilities are all affected by the inaccessibility of the communities and the limitations imposed by the harsh climatic conditions.

Access for personnel, materials and fuel delivery to nearly all the communities is by air or water only. Land transport is available only to some of the communities in the far southwest and northwest of the Territories. The air freight services emanate from major centres in the south. The delivery service by water is by barge service from Hay River, N.W.T., Churchill, Manitoba or by the Canadian Coast Guard Sea-Lift from Montreal, Quebec.

Due to the extreme cost of air freight, water transportation is the preferred means of delivering materials and fuel to these communities.

Because there is only a 6 to 10 week shipping window when the waters surrounding these communities are ice-free, timing and scheduling become a major part of any project being undertaken.

To provide the contractors and suppliers sufficient time to order equipment, the engineering drawings and specifications must be completed, tendered and the project awarded well before the final shipping dates of June or July to ensure they "make the sea-lift". Depending on the location of the community, materials and fuel deliveries will not arrive until August or September.

Therefore, construction projects are generally scheduled to extend over two or three construction periods. With limited materials and equipment which may be air freighted in prior to arrival of the "sea lift", construction in the first year is generally limited to ordering materials, shipping to site, and commencement of the earthworks for construction of the berms and access roads. During the second year the major modifications of existing tanks and construction of new tanks occurs. The tanks have to be completed and ready to accept fuel from the ships at the end of this second year. Failure to have the tanks ready to accept fuel can lead to high demurrage charges being assessed. The third year is left for completing the painting of the facilities and rectifying deficiencies from the inspection at the end of the second year.

The harsh climatic conditions of extreme cold temperatures and snow drifting, which can be up to 3 m deep, also impose restrictions on the design and construction of these facilities which must all be considered.

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Cost Effective Systems for Bridge Deck Repair and Maintenance in a Cold Weather Climate, Alberta, Canada

Paul D. Carter

The climate of Alberta is one of the most severe in North America for its effect on the rate of deterioration of concrete bridge decks. Deck temperatures vary from +50°C to -50°C. As many as 135 freeze-thaw cycles over an eight month period result in a short construction season and a reduction in the amount of curing time that concrete receives prior to its first freeze-thaw cycle. Many deck repair systems and products that are suitable for milder climates are not suitable in Alberta. The extreme cold creates tensile stresses and an increased modulus of elasticity in materials that are subjected to dynamic loads. The unique climate of Alberta requires unique solutions to the problems of maintaining and repairing bridge decks with limited funds.

The decision-making process for the selection of appropriate economical bridge deck repair methods involves five steps:

1. An assessment of the present bridge deck condition, including the amount of deck concrete deterioration, the extent of reinforcing steel corrosion, the condition of the existing wearing surface, and the depth of rebar cover;
2. An assessment of the present and future exposure conditions, including the amount of de-icing salt being applied, the traffic volume, and the deck drainage condition;
3. A review of the future plans for the site and adjacent roadway to ensure that any funds spent on repairs will not be wasted due to an early replacement of the entire structure. Normally a 20 a expected life is justification for major repairs;
4. Selection of the optimum time for repair, considering the deck condition, the exposure conditions, and the predicted rate of deterioration;
5. Selection of the actual repair method from a list of options, including thin polymer wearing surfaces, water proofing membranes covered with a 50-mm thick asphalt wearing surface, concrete wearing surfaces incorporating steel fibre, silica fume, or fast-setting cements to improve the physical properties, and cathodic protection systems to stop further rebar corrosion. In general, impermeability, crack-resistance, and bond strength are desired properties in any repair system.

Most of the bridge wearing surfaces in Alberta are concrete or asphalt. If concrete, the deck proposed for repair is assessed for existing condition and exposure. If deterioration is not far advanced, a thin polymer wearing surface is applied for preventive maintenance to reduce the rate of change of future deterioration by freeze-thaw, rebar corrosion, and delamination. If existing deterioration is further advanced, the concrete wearing surface is removed to expose any delaminated areas and corroded rebar, and a new concrete wearing surface is installed. Admixtures such as silica fume and steel fibre may be incorporated if extra impermeability and surface cracking protection is needed. If deck deterioration is too far advanced, the selected option is to monitor the condition until total deck replacement is required, usually in ~10 a. Asphalt may be used to improve rideability and reduce live load impact stresses during this interim period.

If the wearing surface is asphalt, the number of repair options increases. Depending on the condition of the deck, the estimated rate of deterioration, and the service life desired, the options include:

1. Asphalt replacement after installing a waterproof polymer membrane;
2. Concrete overlay using silica fume, steel fibre, or fast-setting cement, if the existing deck is delaminated or has poor rebar cover;
3. Concrete overlay incorporating a mesh anode cathodic protection system, if severe rebar corrosion is expected to continue;
4. Deck replacement with epoxy-coated rebar, if deterioration is too far advanced (>40% delamination) and 20 or more years of service are needed;
5. No major repairs, if deck deterioration is too far advanced but replacement is expected within 10 a.

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Experience in Alberta on the SCAN-16EF Ice Detection System for Highway Maintenance Operations

Richard Chow and Li-Fan Chen

During winter, northern Alberta highways and bridges in river valleys are frequently subjected to hazardous differential icing conditions, in which bridge decks become icy earlier than the highway approaches, creating a surprise situation for drivers and causing some of them to lose control of vehicles on bridges. Although special attention has been taken in winter highway maintenance to eliminate this dangerous condition, it is not always possible to schedule maintenance equipment and personnel for an isolated bridge location based on a macro weather forecast, within a vast highway network maintained by the district staff.

In the early 1980s, Alberta Transportation and Utilities noted that several river crossings in the northern region of the province had high incidents of vehicle crashes under the differential icing condition. Various alternatives were considered as countermeasures, including an ice detection system on sites to provide just-in-time warning messages to help the district staff make better decisions on mobilizing resources for surface treatment in order to reduce or eliminate the icy road conditions.

In 1986, an experimental ice detection system (SCAN-16EF) was installed on the North Saskatchewan River Bridge at the outskirts of the City of Fort Saskatchewan, 20 km NE of Edmonton. This 350 m bridge, carrying an AADT of 9500 vehicles at the time of installation, is particularly vulnerable to differential icing conditions because of the high moisture content in the exhaust from the chemical plants along the nearby river bank. The location was also selected for its proximity to Edmonton for easier monitoring and adjustments during the experimental stage.

The SCAN-16EF ice detection system installed includes five major hardware parts:

1. Surface Sensors - measuring the conditions of the bridge deck and approach pavement;
2. Atmospheric Sensors - measuring ice temperatures and precipitation;
3. Remote Processing Unit (RPU) - supporting data processing, storage and transmission from the bridge site;
4. Central Processing Unit (CPU) - data retrieval and processing, prediction and presentation;
5. Network Computer Stations - for monitoring and decision-making purposes at various locations.

Since the installation of the system in 1986, there has been some reduction of crashes related to icy conditions on the bridge. However, the improvement might not be wholly attributed to the system. Overall, the district maintenance staff acknowledges that the system computer was an enhancement in their decision making, but the system still has some problems in predicting the actual road condition. While the system might help in reducing the waste of chemicals used in highway maintenance operations, the staff are still generally not very confident in the application of this system.

The total cost of the system installed was $143,000 Can, including $88,000 for equipment and computer software. Maintenance of the system to date has been averaging $1500/a.

In 1991, it is planned to redeck the North Saskatchewan River Bridge. If this project proceeds, the sensors on the bridge will be destroyed. Currently, the district is reviewing the possibility of relocating the system to where it can be better monitored and utilized by the area maintenance staff. To further enhance the operations of the system, the following should be incorporated when it is relocated:

1. The existing precipitation sensors should be upgraded to a new model (Ruldoph model) for improved accuracy. A wind sensor has also been requested by the maintenance staff to assist them in assessing the wind effect on snow drifts and chemical spread.
2. More sensors should be installed at the new site to improve areal coverage. A subsurface probe sensor for reading subsurface temperatures should be considered to improve the collection and interpretation of the data.
3. A rugged laptop computer could be used to allow the foreman or his staff on duty to access the system even when they are away from the maintenance office.
4. The foreman and designated operators of the system should be trained in microcomputer operations. More training on SCAN data interpretation and analysis is also needed.

Richard Chow and Li-Fan Chen are traffic studies and traffic operations engineers, respectively, with Alberta Transportation and Utilities (4th Floor, Twin Atria Building, 4999 - 98 Avenue, Edmonton, Alberta T6B 2X3, Canada). This paper represents their own views and not that of Alberta Transportation and Utilities.

Backsloping for Reduced Snow and Ice Control Costs, Alberta, Canada

Ivan T. Perich

Several years ago senior staff of Alberta Transportation and Utilities in the Hanna District proposed some radical measures to reduce ice and snow control costs. Initial field trials showed that constructing highways with flatter backslopes resulted in a number of positive benefits. One of the significant measurable primary benefits was the reduced amount of time and effort expended on ice and snow control operations while providing the same level of service. Another measurable benefit was the cost reduction resulting from the fact that less right-of-way must be purchased for road construction. Lower right-of-way maintenance costs were then experienced because of the reduced right-of-way width. Benefits which were less measurable include fewer traffic accidents because of better road conditions, improved relations with the motoring public because the roads are not plugged with snow drifts, and better relations with adjoining landowners because less right-of-way was required for road construction.

In essence, the backslope of a standard high cross-section was reduced from the standard 3:1 slope to a flatter 6:1 slope. The 3:1 backslope provided a quieter zone where the velocity of the wind was reduced. Because the wind velocity was reduced it did not have the ability to carry as large a volume of snow. This excess snow settles out in the form of a snowdrift. The flatter 6:1 backslope permitted the wind to maintain its velocity. Its ability to carry a continuous snow load was not changed across the highway right-of-way.

Expenditures to perform this work in 1984, 1985 and 1988 were about $0.5 M. Because of flatter backslopes the estimated annual snow and ice control cost savings on a 128 km section of highway is about $60,000/a. Additional cost savings were realized because less salt was required in the winter to melt packed-on snow. Further, in the summer months less right-of-way maintenance was required, and the maintenance work that had to be done was easier, and less costly to perform because of the smoother and flatter right-of-way.

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Laboratory Testing of Anti-Corrosive Deicing Chemicals

Alan Mah

Sodium chloride (common salt) is the most commonly used highway deicing chemical. Its ice-melting ability and availability at low cost make it an almost ideal deicer for winter maintenance. However, salt also causes corrosion to reinforcing bars in concrete, steel structures, and automobiles. In addition, it accelerates scaling of concrete under freeze-thaw conditions. To combat these problems, many jurisdictions are searching for less damaging alternative deicers.

A number of 'anti-corrosive' deicers have been introduced recently that claim to reduce or inhibit corrosion. In 1989, the Research and Development Branch of Alberta Transportation and Utilities initiated a project which involved laboratory testing of four anti-corrosive deicers as possible alternatives to salt.

The objectives of the testing program were to evaluate the deicing ability, the concrete compatibility and the corrosion inhibiting properties of four deicers namely: Freezgard+PCI, Qwiksalt+PCI, TCI and CG-90. Sodium and/or magnesium chlorides are the major components in all of these four salt alternatives. A proprietary additive is said to provide each deicer with its corrosion inhibiting properties.

The testing program started in January 1990 and was completed by March 1991. Three test methods were used to assess the performance of these anti-corrosive deicers.

1. An Ice Melting Ability Test was performed which measured the deicing ability of the deicers based on the amount of brine formed when the deicers were applied to ice blocks under varying temperatures and times. It was concluded that the ice-melting performance of the four deicers were similar to conventional salt.

2. A Salt-Scaling Resistance Test (ASTM C672) measured the scaling resistance of concrete surfaces exposed to freeze-thaw cycles in the presence of the deicing chemicals. This test showed high levels of surface scaling with conventional sodium chloride. Freezgard+PCI and CG-90 caused minimal surface scaling.

3. A Time-to-Corrosion Test (developed by Wiss, Janney, Elstner Associates Inc., USA) determined the ability of the deicers to inhibit corrosion by monitoring the onset and rate of corrosion with time. The test showed that the sodium chloride and TCI solutions had the highest degree of corrosion activity.

Both the salt-scaling resistance and time-to-corrosion tests were conducted by a local consultant. In addition, chloride ion tests and a visual inspection of the reinforcing bars were conducted. A report detailing the test procedures and results was prepared by the consultant.

The laboratory test results concluded that all four anti-corrosive deicers were more compatible with concrete and less corrosive to steel than conventional sodium chloride. As the deicing performance of these deicers are similar to sodium chloride, the use of these anti-corrosive deicers for winter maintenance should be considered.

Alberta Transportation and Utilities plans to investigate the cost-benefits and to discuss implementation options to determine if any of the deicers tested would be suitable for use in Alberta.

Alan Mah is a research engineer with the Research and Development Branch of Alberta Transportation and Utilities (1st Floor, 4999 - 98 Avenue, Edmonton, Alberta T6B 2X3, Canada), and has managed numerous projects relating to highway materials and operations.

Evaluation of Equipment for Use in Cold Regions

D.B. Coveney

Cold, windy, snowy, and icy environments are very demanding on engineering equipment. In addition, a failure to perform reliably in such environments could endanger human life and/or the survival of expensive equipment. Performance under such conditions will be poor unless care is taken in the planning and design, and special attention is paid to the environment in which it must work. Consequently, equipment should be, and often is, evaluated for its ability to perform the tasks for which it was designed before it is actually put into service. Evaluation in the natural environment variably encounters expensive delays and compromises; the severe weather conditions needed to test the equipment fully, normally occur infrequently and last only for a short time. If the right conditions are missed, it may require a wait of a full year before they reappear. Controlled environment chambers offer a reliable alternative, usually at lower cost. In addition, they offer the capability to time-shift the testing, i.e. test in cold conditions during the summer so that the equipment is ready for use by the winter.

The Cold Regions Engineering Program at the Institute for Mechanical Engineering, National Research Council of Canada (NRC), Ottawa, operate two large controlled-climate test chambers. The Climatic Engineering Facility, one of the largest such chambers in the world, is 30 m long and is capable of accommodating almost any railway car currently existing, while the No. 2 Climatic Chamber is 7 m long and can accommodate most automobiles and light trucks. Temperatures as low as -45°C can be attained (and as high as +55°C). Localized winds up to 100 km/h can be produced by several wind fans. Ice, snow, freezing rain, and fog are made as required at various temperatures using a variety of water and air atomizing nozzles. Vehicle exhaust can be extracted from the chamber and refrigerated make-up air can be supplied. Under some conditions the relative humidity in the chamber can be controlled. Electrical power up to 600 V AC and up to 900 V DC is available, as is compressed air up to 700 kPa and steam up to 400 kPa. A wide variety of instrumentation is on site, with up to 190 channels of computer-based data acquisition.

In the 8-a since the Climatic Engineering Facility replaced the original large, 15 m long, No. 1 Cold Chamber, about one-quarter of the tests have involved the cold starting of engines, mostly diesel and mostly for military use. Another one-quarter have involved the manufacture of ice, snow, freezing rain, or fog. Heating, ventilating, and air conditioning tests, usually for compliance to specifications, accounted for about one-tenth of the tests, while the remainder of the tests were devoted to a wide variety of mostly cold weather problems, but also a significant number of hot weather problems. The No. 2 Climatic Chamber, operational since 1974, has been used for variety of material, component and system evaluations.

Various starting aids for diesel engines operating at temperatures down to -40°C have been evaluated extensively. However, an aid which may perform well in one application may not in a different application. Therefore, current testing now involves evaluation of the full system as installed on each particular vehicle type.

Ice has been made for the evaluation of a variety of equipment and systems, in some cases simulating various specific mechanism of ice growth such as freezing rain, and splash-icing. Snow, with a range of characteristics, has been made to evaluate design solutions to problems, and to evaluate snow removal equipment. Fog has been made at temperatures just above freezing to evaluate the condensation of moisture inside equipment, moisture which itself may damage instrumentation or which may later turn to ice and then cause a malfunction.

Heating, ventilating, and air conditioning systems of some types of passenger vehicles must comply with the requirements of the final customers. Working with the manufacturers of the equipment, NRC has jointly evaluated the ability of a variety of specific vehicles to comply with the requirements of temperatures from ~-30° to ~+45°C.

Other problems investigated range from padlock performance at -40°C to locomotive automatic-train-control braking systems at -30°C; from the integrity of an air-droppable fuel tank at -40°C to reverse osmosis water purifier performance at +55°C; and from the effectiveness of metal chimney insulation to the cold starting performance of snowmobile engines.

The talk will discuss some of the problems and some of the solutions for a variety of tests.

Don Coveney is a senior research officer with the National Research Council of Canada (Ottawa, Ontario K1A 0R6, Canada) and is a project officer for the National Facilities climatic test chambers including the Climatic Engineering Facility, the largest such facility in Canada.

Application of Ground Penetrating Radar To Cold Region Civil Engineering Projects

Tim Murphy and Neil Parry

Application of Ground Penetrating Radar (GPR) to cold region civil engineering projects has gained recognition as an effective tool over the past 10 a. EBA Engineering Consultants Ltd. of Edmonton, Alberta owns and operates a GSSI System 8 Surface Interface Radar (SIR) unit.

GPR is a non-destructive geophysical technique capable of delineating materials having contrasting electrical properties. Specifically, the contrast is characterized by variations in the dielectric constant of different materials. Depth of penetration and resolution of the signal are controlled by the conductivity of the material and the transmitted signal frequency. Higher frequencies provide better resolution but lower penetration. The central control unit generates a radio frequency monocycle pulse which is fed into the transmitting antenna. This signal is then radiated downward into the ground, and on encountering a change in the dielectric properties of the subsurface material, some of the pulse energy is reflected back to the surface, and some continues downward through the interface.

The ratio of the reflected signal to the transmitted signal is proportional to the degree of dielectric contrast at the interface. The reflected signal is detected by the receiving antenna and the waveform is then displayed in a line-scan format to a video monitor. Both the video image and the raw analog signals are recorded on standard VHS format tapes. Additional equipment allows split screen imaging incorporating both surface video images of the antenna location and the radar data to be displayed simultaneously.

Experience has shown that GPR provides a more complete and cost effective picture of the subsurface than does conventional drilling and sampling. It is often possible to improve the effectiveness of the drilling program by using the GPR results to target borehole locations in areas of particular interest, sometimes reducing the number of boreholes required.

GPR has been applied to many civil engineering areas including: pavement applications (pavement thickness, overlay thickness, and base and subbase thickness, cracks prior to their propagation to the surface, voids beneath pavement, ice lensing, deleterious materials in base materials, salt buildup in asphalt and subbase), locating reinforcing bars in concrete and buried services, general site characterization, ice thickness, profiling, fresh water bathometry, and bedrock profiling. Some examples of permafrost studies follow:

Melville Island, NWT (1983)
A GPR survey was conducted on Melville Island to determine the extent of permafrost soils for a trial ditching program. Ice wedges and subtle changes in the ice-rich soils were identified prior to excavation, and identification confirmed by examination of soils subsequently exposed in trenches.

Dempster Highway, NWT (1987)
This was the first Canadian highway constructed across mountainous regions where terrain is underlain by ice-rich permafrost. A continuous GPR survey was run from the Yukon/NWT border to Fort McPherson, a distance of ~85 km. The survey data identified subgrade thickness <2 m, underlying natural soils that contain particularly high concentrations of ground ice, and anomalous features that turned out to be drum dumps.

Dawson City, Yukon (1987)
The city is built on deltaic deposit of ice-rich organic silt. GPR techniques were used to evaluate a section of city core street proposed for BST surfacing. The survey determined existing fill depths and also qualitatively identified conditions of interest within 3 m of the road surface. These anomalies comprised buried pipes, ice-rich zones, and zones of deleterious materials in the base aggregates.

Hudson Bay Railroad (1985-1988)
GPR was used successfully on >100 km of the Hudson Bay Railroad over discontinuous permafrost. The survey was able to measure ballast thickness along the track, ice-rich soils and thawing zones. The GPR data was used to select the heat pipe locations that were required to keep the permafrost from thawing further. Finally, it was used extensively in providing site condition data for use in planning and constructing two 4 km heat pipe test sections.

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Neil Parry is Project Engineer/Geophysicist with EBA Engineering Consultants. Both Tim and Neil work out of the Frontier Division and together have more than 15 years Arctic experience in locations covering Ellesmere Island to the north, Baffin Island to the east and the Alaskan Aleutian Islands to the west. Neil Parry has a background in electronic engineering and geophysics. Over the last eight years he has developed broad experience in engineering geophysics applications.

Applicability of Various Methods for Calculating Frost Depth and Frost Heave

Kauko Kujala and Leena Huttunen

Soil freezing and frost affect a number of fields such as agriculture, ecology, hydrology and construction, the main problem in the evaluation of the latter being the calculation of freezing and thawing depths and frost heave. Frost depth is examined here by means of various empirical calculation models, numerical models using heat transfer, and hydrodynamic models, which are then evaluated on the basis of in situ measurements. Frost measuring stations established on different soil types were used to measure frost depth, temperature profile, groundwater table, frost heave, water content and thermal conductivity, in addition to which these properties, together with heat flow, were measured at one automatic recording station. All measurements were recorded every hour by means of a data acquisition unit.

Significant parameters from the point of view of frost depth are the phase transition zone and the thermal conductivity of both unfrozen and frozen soil, while freezing is greatly affected by the amount of water remaining unfrozen in an otherwise frozen soil because this acts as a water-conducting element in the partly frozen zone. The amount of such water was measured by means of both a nuclear magnetic resonance method (NMR) and time domain reflectometry (TDR), of which the latter is currently the only method which allows such measurements to be made in situ.

The calculation method based on heat transfer, which takes account of phase transitions, can be used to predict frost depth reliably only in the case of non-frost susceptible soils. The difference between the calculated and measured frost depth is explained by the inability of the program to handle increasing water content and its effect on the thermal balance at the freezing front. In the case of soils with a high frost susceptibility, measurement deviations are also caused by the extensive temperature range over which phase transition takes place. Thermal conductivity is also found to play an important role in the calculation of frost depth, while hydrodynamic models provide a reliable means of predicting frost depth and water content in frost susceptible soils. Changes taking place in water content are examined here by TDR using test probes installed at various depths to obtain a soil dielectricity constant, and an empirical function w_{vol} -3.273 + 2.401*k - 0.027*k^2 is obtained for the relation between this and water content, allowing the water content of both fine and coarse-grained soils to be predicted from the dielectric constant. An excellent correlation was obtained between volumetric water content as calculated using the hydrodynamic model and that derived from the above function.

Kauko Kujala is the laboratory manager of the Geotechnical Laboratory of the University of Oulu (PO Box 191, SF-90101 Oulu, Finland). He has worked 7 years as a researcher of the Academy of Finland and published more than 40 papers dealing with soil stabilization, environmental geotechnology and frost and frozen soil mechanics.

Leena Huttunen, MSc, is working as a researcher in the hydrological office of the National Board of Waters and the Environment (PO Box 436, SF-00101 Helsinki, Finland). She has published several articles in the field of frost modelling.

Study of Using Compacted Soil as Avoiding Frost Heaving Foundation

Xie Yinqi and Wang Jianguo

Presented by Cui Wei

Seasonally frozen soils account for 53.5% of the total area of China. Frost heaving of soils influences hydraulic engineering, building, highway, bridge, pipeline and airport construction with different degrees of damage every year.

This paper introduces research results on frost heaving and puts forward the idea that we should break with the convention using the "original natural state of the soil" as the engineering foundation and should apply the use of compacted soil (certain design dry unit weight) which will increase the bearing load, decrease the permeability, and will prevent the migration and concentration of moisture in the foundation soil during freezing, thereby decreasing and even avoiding foundation soil frost heaving.

Studies have shown that the strength of soil frost heaving decreased with increase of foundation dry unit weight and increased overburden, as follows:

The attenuation coefficient of soil body density is:

$$\alpha_{\gamma,1} = 4.78 - 2.7\gamma_d \text{ (closed system)}$$

$$\alpha\gamma_2 = e\text{-}5^{(\gamma_d - 1.36)} \quad \text{(open system)}$$

The attenuation coefficient of the overburden is:

$$P = e^{-B \cdot P_1}$$

where P is overburden, B = 0.025-0.003)

Thus, once the design dry unit weight of the proposed construction is known then the appropriate compacted soil can be used to avoid frost heaving of the foundation.

Xie Yinqi is a senior engineer and chief engineer (Prof.) at Heilongjiang Provincial Research Institute of Water Conservancy (P.O. No. 150080, 12-Yanxing Road, Harbin, People's Republic of China). He graduated from the Civil Engineering Department of Dalian University and has published more than 30 papers and consultant reports on frozen soils.

SESSION D
BUILDING DESIGN

ROOMS 5 AND 6, EDMONTON CONVENTION CENTRE

Monday, June 17

10:20 - 11:40. Design I: Canada
14:00 - 15:20 Design II: Finland

Tuesday, June 18

08:40 - 10:00 Environmental Aspects
10:20 - 12:00 Design III: Canada

Wednesday, June 19

08:40 - 10:00 Materials - Wood
10:20 - 12:00 Energy Aspects

Thursday, June 20

08:40 - 10:00 Other Topics

Session D
Schedule of Speakers

- **Design I: Canada**

  Dave Panar
  Laura O'Neill, Gerry Hartel, Paul Goettler and Max Berretti
  Jim Sawers
  Vivian Manasc

- **Design II: Finland**

  Kari Saari
  Asko Sarja
  Reijo Yla-Mattila
  Jyri Nieminen

- **Environmental Aspects**

  Don Wharton
  Bertil G. Johnson, Johnny Kronvall, Thomas Lindvall, Allan Wallin and Hanne Weiss Lindencrona
  Thomas M. Nelson, Gordon W. Hopkins and Thomy H. Nilsson
  Tang G. Lee

- **Design III: Canada**

  P. Abrol, J. Tepper and B. Tong
  Tony Argento
  Tang G. Lee
  D.A. Chambers, T.H.W. Baker and L.E. Goodrich
  David Greeley

- **Materials - Wood**

  Lars Bach and Rob Leitch
  Jiro Sato
  Yukio Tadaishi
  Sadahiro Inoue

- **Energy Aspects**

  Tian Da Fang
  J.D. Dale and M.Y. Ackerman
  Xu Li Bai
  D. Feldman, D. Banu, D. Hawes and E. Ghanbari
  Mitsuo Kato

- **Other Topics**

  J.M. Jamil Brownson
  K. Tusima
  Katuo Sasaki, Masao Inuzuka, Masanori Miyajima and Masahiro Imai
  Yoshihiro Hiraoka

Forty Years of Building and Energy in Alberta

Dave Panar

No abstract available.

Dave Panar, Principle, D. Panar and Associates.

Building Technology, Building Design and Communication Bridges in Cold Region Development from the Perspective of the Design Team

Laura O'Neill, Gerry Hartel, Paul Goettler and Max Berretti

The process of developing, designing and constructing buildings for northern cold climate areas offers specific challenges to the design team. To meet these challenges, architects and engineers must possess the required knowledge and experience in both the building type under consideration and the process of building in cold regions. The design team must also empathize with people of different cultures and be good communicators.

If the infrastructure is not present locally to support a project, then the client, in putting the design team together, may recognize a need to import the technology required. In this instance, an Edmonton-based consultant team, like ours, may become involved in a project.

Clear communications between the client/user and the design team, relative to the specific needs for the project, are essential. In this age of instant contact by electronic means, utilizing telephone, facsimile, computer, microwave or satellite dish, regardless of their location, design consultants can ensure instant communication with their client and others involved in the process. Good communication only follows if the participants continually maintain a clear understanding of the real needs of the project as they emerge.

"Are we giving you what you want, what we think you need, or what we want you to have?" is a question that requires frequent repeating.

When considering a cold region development, location, timing, access, and supply of building materials and fuels, are all critical interrelated factors. In extreme cases, access to remote areas, by routes such as ice bridges, barges and even sea lifts, will determine the time frame for the project. This, together with the cost of freight, will often dictate the use of certain lightweight or local materials and the method of providing electrical power. It may also suggest the use of a modular or prefabrication approach, while restricting the scope and use of certain other materials and systems.

Foundations in permafrost are a common occurrence in the north. Permanently frozen soils constitute an excellent permanent foundation material, if they are kept in their frozen state. Several foundation types are possible, one being timber piles, which are frequently used, and are ideal when placed in the autumn, with the superstructure starting the following spring. In cases where permafrost is of a delicate nature, it is not a reliable foundation material. If bedrock is not reasonably accessible, mechanical or chemical devises may be used to maintain the permafrost in a frozen condition, thereby making it a suitable foundation base.

The challenge to the design team may be described simply, as follows:

1. To acknowledge the specific cultural or ethnic ownership of the building in the architecture, and to ensure that all of the functional needs of the owner are addressed, e.g. historical context or security;
2. To acknowledge in the design the importance of the interior environment, of lighting, both natural and artificial, and of interior landscaping, given the reality of long winter nights and summer days;
3. To ensure that the technology used in the design of the building envelope provides the best possible continuous air-barrier in combination with high insulation values;
4. To recognize the local resources and talent available, with their inherent ability to improvise, and to utilize this expertise throughout the design and construction phases;
5. To design building systems which will compliment the building design, be reliable, energy-efficient and easy to operate and maintain for the life of the building;
6. To ensure that all of the designs proposed can be executed in the field, however remote;
7. To maintain excellent channels of communication between the site and the design team so that the integrity of the design is carried out in accordance with plans and specifications;
8. To achieve all of the above within the prescribed budget, given the knowledge of northern construction and its impact on costs.

The dilemma often faced by the design team becomes:

1. How to overcome more-complicated-than-normal technical problems with more-simple-than-usual solutions;
2. How to maintain the integrity of the design in the field, particularly if the client wants to minimize normal supervision services;
3. How to deal positively with the understandable, though not always advisable, requests to use local materials, which may not always meet required standards;
4. How to keep a building budget on track when experience shows that the 'local preference' factor often has an inflationary impact;
5. How to minimize negative impact on the environment.

Laura O'Neill is an architect and principal of Wood Gardener O'Neill O'Neill Architects Ltd. (10633 - 124 Street, Edmonton, Alberta T5N 1S5, Canada). The company has been prime consultant for numerous projects in northern Alberta, the Yukon Territory and Northwest Territories since 1960.
Paul Goettler, Senior Electrical Engineer and Gerry Hartel, Principal, represent Hemisphere Engineering Inc. (10950 - 119 Street, Edmonton, Alberta T5H 3P5, Canada). They have successfully completed numerous projects in northern Alberta and north of the 60th parallel.
Max Berretti is a structural engineer and president of MB Engineering Ltd. (2nd Floor, 15203 - 123 Avenue, Edmonton, Alberta T5V 1J7, Canada). He has considerable experience in construction on permafrost and in other unique northern conditions.

Canada's First R-2000 Multi-Unit Apartment Building

Jim Sawers

There is a considerable challenge in providing both energy efficiency and good indoor air quality in an apartment building located in a cold climate region.

The Closeleigh Manor project in Whitehorse, Yukon Territory, represents the first time that the technology developed by the R-2000 energy efficient home program has been applied to anything other than a detached single family home. The building is a 30 unit, three-storey senior citizens' residence.

The R-2000 Home Program is intended to assist the housing industry to design, construct and market homes that are energy efficient, heathy and cost effective. The three technical cornerstones of the R-2000 home are: superior insulation levels, a tight air barrier, and controlled ventilation.

Three criteria were used to evaluate building options. They were energy-use simulation, life cycle cost analysis and the R-2000 standards. On the basis of these criteria the major building systems employed were:

- a central fuel oil fired hot water perimeter heating system
- RSI 5 walls
- RSI 7 roof
- double glazing, with triple glazing on the N face
- air to air heat recovery between the supply and exhaust air streams

One of the most interesting challenges was to determine how the controlled room ventilation required by the R-2000 program could be provided. In the R-2000 approach, continuous ventilation is provided by means of a heat recovery ventilator. The solution implemented utilized central supply and exhaust air systems with glycol-run-around heat recovery to provide continuous room ventilation through a residential-like system of individual 250 mm x 75 mm duct risers.

The air quantity supplied to the individual rooms resulted in air change rates of between 0.7 to 1.4 air changes per hour. The overall air change rate for the entire apartment was between 0.5 and 0.7 per hour.

One of the cornerstones of the R-2000 program is a tight air barrier. The wall insulation consisted of batt insulation between the studs and exterior rigid insulation. Every joint of the exterior insulation was taped. All joints in the interior air barrier were caulked and the corners of all windows were taped.

To verify the effectiveness of the air barrier the R-2000 program requires that a home must pass an air tightness test. For the Whitehorse building, the results were:

1. It passed on the basis of the whole-building test, with an air change rate of 0.72 per hour. The standard is 1.5 air changes per hour.
2. While the building passed the test on the basis of the first criteria, the leakage area was slightly higher (0.8 cm^2/m^2) than the R-2000 standard (0.7 cm^2/m^2).
3. The external envelope was considerably better sealed than the interior partitions between units.

A computerized monitoring system was installed to:

- assess the effectiveness of the ventilation system,
- determine the operating efficiency of the heating system,
- determine the efficiency of the DHW system,
- aid in understanding energy use patterns.

Approximately 65 sensors have been installed throughout the building to measure parameters from CO_2 concentrations to fuel oil use.
Despite several startup problems, the building performed well over its first year of operation. The total annual energy consumption for all units was:

	GJ/a
R-2000 target	1258
Predicted	1216
Actual	1241

While meeting these energy use figures, the air quality, as indicated by CO_2 levels, was maintained well within acceptable limits. The upper limit on CO_2 set by ASHRAE is 1000 ppm; the recorded levels were 500 ppm or less.

The finished building shows no obvious signs that it is an R-2000 building, a fact that is very important to the R-2000 program and the building owners.

Jim Sawers is Mechanical Technical Director with Reid Crowther and Partners Ltd. (7410 Blackfoot Trail SE, Calgary, Alberta T2H 1M5, Canada), and a member of the ASHRAE Task Group on Cold Climate Design.

The Building Envelope in Transition

Vivian Manasc

Building envelopes, the details of walls, windows and roofs, of northern buildings have been the subject of significant controversy among engineers, architects and federal and territorial government agencies who have been building north of the 60th parallel for the past 30 a.

1991 gives us the vantage point from which to look back over the last 20 a of building envelope design to examine how designs have evolved, to assess how these envelopes have performed in the field, and to predict the trend in northern building envelope design for the next decades.

This paper examines a series of buildings - in particular, health centres (nursing stations) built, first by Health and Welfare Canada, then by Public Works Canada, and most recently by the Government of the Northwest Territories, in the Baffin Region.

The building stock of health centres, staff residences and associated buildings in the Baffin Region represents an interesting archeological record of the changing attitude of designers and government agencies to northern buildings. Of the health centres under consideration, their date of construction is significant:

1970, 1972	Broughton Island, Clyde River
1975, 1976, 1977	Igloolik, Pangnirtung, Pond Inlet
1980	Cape Dorset
1983	Arctic Bay, Resolute
1985, 1986	Hall Beach, Lake Harbour

The earliest facilities at Clyde River and Broughton Island were built of modular trailers. Little attention was paid to the energy efficiency (pre-energy crisis) or to the unique requirements of the Arctic environment. By the mid-1970s, modular buildings were out of style but forced air furnaces and vented attic roofs were in style. So were buildings which had minimal capital cost.

By 1980 the concern with energy-efficient buildings was evident. With energy efficiency came the design of better building envelopes, and buildings which might last longer. Then came a challenging combination - the desire to build cheaper energy-efficient buildings. The centres in Resolute and Arctic Bay were the result of a design-build experiment where Health and Welfare Canada set criteria and got the cheapest possible buildings which met their criteria. While these buildings are in fact energy efficient, there are many quality-reducing details which may limit the life of those buildings.

By the mid-1980s the federal government had concluded that high quality buildings which have super-insulated walls and roofs were needed in the north. Health centres in Hall Beach and Lake Harbour were designed to last at least 30 a.

This series of buildings offer a useful laboratory - there have been one or two built about every second year since 1970, there are drawings available for all of them, and the buildings all operate for the same purpose under very similar operating conditions. This situation represents as good an 'experiment' as we can hope to set up in building design - constant use and occupancy, constant operating conditions, and a chronological pattern of construction which allows the tracking of changes in design very consistently over time.

Using a case-study chronology approach, this paper illustrates how design decisions changed over time. Reasons for the changes are identified. A parallel analysis is made of Building Envelope Research which was published over the same time period by the Division of Building Research of the National Research Council. This enables an assessment to be made of the time-lag in technology transfer in the building envelope field.

Based on field observation of 10 buildings the performance of each of the building envelope designs is discussed, concluding with both positive and negative trends for future building envelope detailing in the north. A balance between capital cost and operating costs over the life of the building is still trying to be struck in the high Arctic.

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Finnish Cold Climate Construction Technology

Kari Saari

Finland is one of the few countries in the world which entirely belongs in the sub-arctic climatic zone. There are fifteen other countries which have arctic or sub-arctic regions: Sweden, Norway, USSR, People's Republic of Mongolia, People's Republic of China, Democratic People's Republic of North Korea, Japan, Canada, USA, Iceland, Denmark, Australia, New Zealand, Argentina and Chile.

If cold climate areas are defined as areas where it snows and freezes for more than just a few days during a year, then most of the industrialized countries belong to this category. Mountainous countries, worldwide, naturally have cold climate areas at higher elevations. According to the above definition, almost all construction in Finland is cold climate construction because most buildings and structures are affected by winter weather and many of them are even built during the winter. Finland is one of the few countries where construction work continues during the winter months.

During the past 15 a arctic construction was actively studied in Finland and significant results were obtained especially in marine construction and ship building. The Finnish construction industry has also been actively involved in the development of the arctic and other cold climate areas in the USSR. The decreased price of oil has resulted in the postponement of many large arctic construction projects, and research projects on arctic engineering were put on hold.

The Finnish industry and research organizations are aware of the importance, to the world economy, of the development of the northern areas in the world, and are ready to offer their services when the situation changes again.

The Finnish building industry has realized the importance of research and development for their ability to retain and improve their competitiveness in Finland and in countries where Finnish construction products are exported. Finland will probably join the economic cooperation of European Community in 1992. After that the Finnish building industry will have to compete with foreign companies, even in Finland.

There is a large amount of knowledge on cold climate construction in Finland, but that knowledge has not yet been collected and presented in an easily assimilated form. So far it has only been possible to learn about this subject on the job at construction sites.

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New Generation of Industrialized Building Technology

Asko Sarja

The basic demands for building technology in cold regions are the effective and economical production under difficult cold conditions and the energy effectiveness throughout the life of the building.

The post-industrialized information era, accompanied by increasing economic integration, poses new and demanding challenges to industrialized building technology. The keywords are good architectural and technical quality and flexibility of design and operation. The resulting achievements in the basic technologies have created, and continue to produce, drastic advancement, to the extent that we now talk of an entirely new generation of building technology.

A major research programme on industrialized building technology is currently in progress in Finland, under the cooperation of several research organizations, companies and industrial and designer associations. It started in 1986, and should be completed in 1991, at a cost of $8M US.

The main projects of the research program are:

1. Architectural planning of the building milieu and the buildings, including experimental buildings.
2. Development of an open building system and its applications for apartment and office buildings.
3. Energy efficient buildings and structures.
4. Energy efficient HVAC-installation systems and components (HVAC-2000).
5. Computer-aided building design and management systems (RATAS).
6. New planning and production process.

The main solutions required include new models and concepts for building systems, product infrastructure and manufacture, and information processing. Interaction between material and information processes and the building system plays an important role.

To meet the requirements for quality and flexibility, our thinking about systems must be revised. We can no longer treat only the structural system, but should focus on the entire building system, with solutions lying in a modulated hierarchical system.

A flexible modulated building system creates the demand for a corresponding modular dimensioning and tolerance system. The open modulated building system is not too stringently defined, but aims rather at continuous development through product development and creative design and production. New building concepts serve as bases for the application of the modulated building system. Examples of such concepts are low energy houses and individual 'privatized' multistorey residential buildings.

The modulated building system serves as a starting point for the production infrastructure and process, which can be scheduled according to the hierarchical levels of the products, such as building, subbuilding, module, component and basic element.

An important application area of the new technology is the integration of installations within the structures for heat transfer, storage and regulation. The heating, piping, ventilation and electrical systems and structures of apartment buildings have generally been studied as separate, independent parts. Controlled indoor climate, good energy economy, good sound insulation and long service life can be achieved only with controlled joint function of these parts.

Increasingly, it has been possible to use the hollows in the buildings with hollow core slab floors for air ducts in horizontal directions. Naturally, this development called for studies of the possibilities of integrating other heating, piping, ventilation and electrical installations into the hollow core slab building frame or into corresponding with duct equipped floor and wall elements. When preheated supply air ($t > 10°C$) is led into the hollows of the hollow core slab the indoor air moisture does not condense on the surface of the hollow core slab. The energy recovered from the heat transmission losses of hollow core slabs insulated on the outside is small and energy savings marginal.

The exploitation of the building mass for energy storage and part of the heating system is profitable when combined radiation and warm air heating are used. The objective values imposed on the indoor climate of apartment houses meet the recommendations in the Compiled Finnish Building Regulations. The indoor air temperature can also be controlled to 21 +/- 2°C, air change to 0.65 - 1.01 l/h and the highest allowed sound level to 25 - 30 dB(A).

At the production process, subcontractors, module factories and, in some cases, even component and basic element factories are increasingly including services such as detailed design, transport, installation and finishing work in their deliveries. This enables them to develop their delivery service as a whole, taking into account all phases from design to manufacture installation and operation. With the new production process, sequential production has changed to parallel production.

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Masonry In Cold Climates: Example from Finland

Reijo Yla-Mattila

Winter near the Arctic Circle is long and cold. In earlier times, construction work came to a halt during the winter season. Various methods of building during the winter have been developed in order to reduce the amount of winter unemployment. Indeed, nowadays, work on building sites is only halted on the very coldest days of the year, the minimum temperature for continued working being ~-18°C.

Two methods of winter masonry work are used in Finland. In one of these the mortar is not allowed to freeze until the adsorptiveness of the masonry unit has reduced the water content of the mortar to such an extent that freezing of the remaining water will no longer damage the mortar. At the moment of freezing the water content of the mortar may be a maximum of 6% of the dry weight. In the other method the mortar is not allowed to freeze for at least 2 d after it has hardened at a temperature >0°C. The heating of materials and the protection of already laid masonry give the mortar time to harden. Use is also made of weather shielding mounted on construction scaffolding. The work behind this shielding can be heated with the aid of heating radiators. Frost hardening mortar has also been developed for the laying of lightweight aggregate concrete blocks. With a working temperature range of -15°C to +5°C, this factory-made, packaged mortar is mixed on site with only water.

Prefabricated building frame components, columns, beams, slabs and wall units are made in factories, with the actual building frame being assembled on the building site. The drawbacks of winter conditions are therefore minimized, and the final structure can be erected more or less under cover. The outer skin of the facade units are made of tiles, bricks, clinker slabs, or various kinds of concrete. In Finland, more than half of the houses built use prefabricated construction.

A typical wall structure comprises a half-brick leaf of overlapping stretcher masonry, thermal insulation, and a load-bearing inner leaf which is either made from masonry or timber. The thickness of the thermal insulation layer normally varies between 125 and 175 mm. When mineral wool is used, the corresponding range of thermal transmittance coefficients (U values) of the structures is 0.33 - 0.25 W/m^2K. Structural details are made so that cold bridges are not created. Foundations are either laid using insulating blocks or are insulated, and shallow foundations are also insulated against frost action.

Frost only causes loading damage when structures are wet. A modern, well-insulated masonry skin is much more susceptible to frost action than an old solid wall. The outer skin is sensitive to outside air temperature variations. The temperature falls below freezing many times during the course of a Finnish winter. The sunshine of the late winter and early spring thaws out the wall daily, even when the air temperature remains >-10°C. The number of freeze-thaw events is slightly higher for a dark wall than it is for a light wall, because the darker the colour of the wall, the greater the temperature-raising effect of solar radiation. The temperature variation in winter is, at most, 20 to 40°C, depending on the colour of the wall. In conditions of severe frost, the temperature of the outer skin falls to -20 to -30°C.

Frost damage comes about, for instance, as a consequence of obliquely falling rain that soaks the upper parts and corners of high buildings. Masonry flues are also susceptible to damage. This is especially the case when the fuel is oil, because this burns to produce large amounts of sulphurous compounds and water vapour, which condense in the flue.

Damage can be avoided to quite a large extent at the design stage, however, by shaping the details of the building so that water does not soak the structures. Generous eaves shelter skin walls from excessive soaking in all but immoderately windy conditions. Weather strips, the joints of balconies and walls, plinth heights and other details must be designed with care. Special consideration must be given to points where snow can accumulate, so that meltwater does not soak the wall. After the building has been brought into service, the condition of gutters, downpipes and other details must be taken care of.

In the development and implementation of new materials and structural solutions, reliable knowledge of frost resistance is always necessary and the need for information is always immediate. Thus frost resistance assessment relies on the fastest and simplest tests, because information on actual durability is not available until after years of use. In fact, the testing methods conforming to frost resistance standards are based on the repetitive freezing and thawing of a water-saturated test specimen, the number of freezings being a constant. This explains why the correlation between test results and frost damage occurring in practice is often poor. Nevertheless, the reliability of the testing could be improved if the test specimens were frozen to destruction and the result compared to some test result that is well known to describe the frost resistance of the material. Further, instead of freezing individual bricks or mortar prisms, one could build a wall from the material under study, which could then be frozen and thawed on only one side. Of course, information on the long term durability of materials that is based on practical experience can still be used to support the assessment of frost resistance.

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Building Structures in Extreme Weather Conditions: Measurements at the Finnish Antarctic Research Station

Jyri Nieminen

Finland's Antarctic research station, Aboa, was set up at the beginning of 1989 and serves as the base for researchers in the Antarctic. The building itself is also a test structure and the performance of the building envelope is being studied by means of measurements.

The station building was constructed from completely finished prefabricated modules. The structures of the modules are sheet steel sandwich panels with polystyrene core. The modules were shipped in containers to the Antarctic and hauled on sledges to the building site. The modules were fully fitted out, and other supplies needed at the station were also packed inside them. Apparently the weight of these materials caused some bending of the steel frame during transportation, which damaged the jointing structures of the modules.

The airtightness of the building envelope is therefore somewhat worse than that typical of buildings constructed from sheet steel sandwich structures. The air leakage rate at a negative pressure of 50 Pa was 3.5 l/h. A comparison of the measurements carried out in Finland with those actually made at the station show that there has been a marked increase in the local air leakage of the jointing structures. The deterioration of the airtightness comes mainly from damage during transportation.

Temperatures of the structures recorded during the first year of monitoring varied between -35 and 35°C. The largest daily temperature variation at the outer surface of the envelope was ~45°C. The climatic conditions were mild by Antarctic standards. It will not be possible to evaluate the effect of the climate on the airtightness of the envelope until measurements have been carried out the beginning of 1992.

A small-scale model of the module unit used in the station building was built into a weather testing device as a partition wall between a cold and a warm chamber. The dimensions of the test structure were 3x2.4x1.2 m. Temperature and relative humidity of the interior air were maintained at constant level (21-22°C and 30-40%). The temperature of the cold side air was varied between annual extremes measured at the research station. The test structure was also subjected to IR-radiation, which raised the temperature of the outer surface to a maximum of ~30°C. No changes were observed in the airtightness of the test structure during the course of the test. The moisture content of the structures was monitored by means of time-of-wetness sensors attached to the inner side of the outer steel facing. No significant amounts of moisture were observed in the structure despite the deliberately poor sealing of a joint between sheet steel panels. Condensation occurred on the window and its framing. When a positive pressure of 10-20 Pa was maintained inside the test structure, frost and ice were observed to form on the inner surface of the outermost pane of the triple-glazed window. The lowest inner surface temperature of the test structure was ~16°C in the corner, when the air temperature on the cold side of the structure was ~-34°C.

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The Clean Air Strategy for Alberta

Don Wharton

No abstract available.

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Buildings, Health and Energy

Bertil G. Johnson, Johnny Kronvall, Thomas Lindvall, Allan Wallin and Hanne Weiss Lindencrona

A building must be capable of protecting us from cold, rain, wind, noise and air pollution. We should be able to stay in it and carry out various activities without suffering from ill-health or discomfort. The indoor climate should contribute to congeniality and wellbeing.

In point of fact, however, many people experience some form of ill-health - allergies, irritation of mucous membranes, etc. - when spending time indoors. Some problems of this kind are attributable to the indoor climate of buildings. In many cases the troubles are difficult to explain. It is problems of this kind that lie behind the concept of 'sick building syndrome'.

Shortcomings of the indoor climate thus constitute a problem in both the home and work place. It is particularly disquieting to note that the problems are experienced mainly in environments in which we spend the major share of our lives; in homes, schools, day nurseries and care premises. In all probability, persons suffering from allergies or other types of hypersensitivity are affected to a greater extent than others by shortcomings of the indoor climate. The frequency of hypersensitivity is alarmingly high and seems to be rising, by no means least among children.

This talk comprises a summary of two books: the knowledge survey *Buildings and Health* and the booklet *Indoor climate and energy conservation.* The books will be available in English by the middle of 1992. The work with the publications has been sponsored by the Swedish Council for Building Research.

One central conclusion presented in both these publications is that hygienic and climatic requirements are frequently neglected today and that they must reassume a central position in the building and the building management process.

This means that the requirements must be stepped up so that greater demands are made on the quality of the materials, on responsibility and competence in the building process and on the overall strategy for energy conservation in conjunction with both new construction and modernization.

Unless such requirements can be satisfied in practical building, the price will have to be paid in the form of more energy used.

More stringent demands are imposed on municipal and regional planning with accompanying supply and use of energy. At the same time a prerequisite for successful energy conservation in buildings is for there to be a long-term national strategy with clear goals for the environment and energy policy.

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Steps Toward Convergence of Optimal Human and Energy Effectiveness

Thomas M. Nelson, Gordon W. Hopkins and Thomy H. Nilsson

A need for broader understanding of the effects of indoor environment upon humans performing sedentary work becomes evident when a review is made of research literature relating temperature, humidity, and season to consequent subjective response. An investigation was undertaken with 648 young male adults doing sedentary tasks in a controlled environmental chamber with temperature-humidity combinations ranging between 16.1 to 29°C and 22 to 70% R.H. The effects of 3.5 h exposure to these conditions were measured as thermal experience, consciousness of comfort and discomfort, awareness of foot and hand temperature, mood sleepiness (alertness), and subjective fatigue. The results show that temperature was more potent than humidity, especially when the temperature was <25°C. The effects of temperature appeared to decrease over time with apparent decrease being largest for the lower temperatures. The greatest body comfort was reported in the 20.1 to 26.1°C range. Foot and hand perception were relatively unaffected during the earlier periods of work but converged with general body assessments at the end of the work session. Non-optimal temperatures gave rise to more rapid development of aggressive and depressive mood. However, subjective fatigue was affected asymmetrically by the temperature-humidity conditions. Warm and hot conditions developed fatigue rapidly; but in cool and cold conditions, there was still a level of activation after 3.5 h. Sleepiness decreased (alertness increased) as temperature decreased. The outcome is discussed with reference to prior literature making reference to individual differences, sex, age, duration of exposure and research methodology.

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Architectural Strategies for Indoor Air Quality

Tang G. Lee

People spend 80-98% of their time in an indoor environment. They need not be environmentally hypersensitive to be affected by the lack of indoor air quality. The respiratory system of the average person has to eliminate, every day, ~40 ml of particulate matter including dust, pollen, tar, acids, smoke, bacteria, Carbon, metals and many other particles. The body automatically copes with such foreign matter by increasing blood flow and increasing air intake, and by tearing and sneezing, thus decreasing an individual's alertness and efficiency. Considering the loss in productivity and perhaps in creativity, company owners should be willing to pay more for buildings that provde good air quality for their employees.

The desire to reduce heating costs in Canadian buildings through air-tight construction has resulted in higher levels of indoor air contaminates. It is recognized that building materials outgas fumes which can affect the health of humans. Careful selection of building materials to avoid those with high outgassing rates can improve the indoor air quality. Unfortunately, finishes, furnishings and air flow patterns are also a contributing factor.

In addition to the selection of building materials and furnishings, the degree of indoor air quality in buildings is affected by the adequacy of the ventilation system. This assumes the outdoor air is sufficiently clean for this purpose. Obviously, the quality of the outdoor air is affected by it proximity to such things as vehicular traffic and adjacent buildings. There are, however, other decisions made during the design, construction and operations of a building which can neutralize such efforts.

For example, the required degree of indoor air quality varies with the type of building and its occupancts. Laboratories and hospital operating rooms require a very high degree of indoor air quality, whereas garbage rooms can tolerate some level of air pollutants. Similarly, buildings designed to house individuals who are classified as environmentally hypersensitive need special air quality considerations.

Site selection and building layout are important factors to consider in the design of a building. Locating fresh air intake grilles adjacent to exhaust vents or near a loading dock can bring contaminated air into the building. It is desirable to provide fresh air to spaces such as photocopying rooms, kitchens, and laboratories, which generate pollution due to their use. However, it is undesirable if the air in these polluted rooms is exhausted through other rooms. A mechanical zoning strategy is necessary to provide fresh air to the cleanest rooms, and progressively flow to the most pollution generating rooms.

During the construction stages, workers may contaminate non-outgassing materials through the use of adhesives, or depositing dirt and tobacco ashes onto the materials. Further, substituting materials commonly occurs in construction. In a building where indoor air quality is important, any substituted material must also have non-outgassing properties. To ensure materials are not contaminated, workers need to be made aware of, and committed to, the project requirements.

This paper addresses various strategies for achieving indoor air quality in buildings throughout the entire building process such as site selection, site analysis, architectural programming, building layout, preparation of construction documents, and during construction, commissioning, and maintenance. Some interesting recommendations are proposed such as the need to 'burn-off' gases in the building prior to occupancy. Simple maintenance procedures such as disinfecting mold growths and replacing the air filters at regular intervals will also be discussed.

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Meeting the Challenge of Designing Hospitals in Cold Regions

P. Abrol, J. Tepper and B. Tong

The design of hospitals has always presented a challenge in complying with the many, often conflicting, requirements inherent in these facilities. The challenges have become more pronounced throughout the last decades as hospitals grew in complexity to the present 'high-tech', state-of-the-art modern health care facilities. Hospitals operate continuously and call for special design considerations. It is not feasible, for example, to evacuate a building in an emergency where the occupants are infirm or bed ridden. The design of hospitals in cold regions poses an even greater challenge. It would not be possible, in the example above, to evacuate the building when the outdoor temperature dropped below -40°C.

The design of health care facilities must provide for an environment conducive to healing and wellness, and must address the need for the highest level of reliability to sustain operations. Some of the issues the designer encounters include emergency power supply, protection against power supply interruptions, mitigation of interference with the operation of biomedical equipment, reliable water supply, heating and steam generation, fail-proof structure and shelter, and fire and life safety systems.

The following examples illustrate salient issues and the approach which has been taken to address them:

The occurrence of defects such as uneven floors and air infiltration is detrimental to the operation of health care facilities. The freeze-thaw cycle and the extreme temperature fluctuations pose unique design and detailing requirements in order to accommodate snow accumulation, structural movement and differential expansion of the various components.

Patients and staff expect a high level of thermal comfort. The insulation of the building envelope is often deemed appropriate at higher levels beyond what the cost effectiveness criteria dictate.

The view to the outside has a positive effect on the recovery rate of patients who have undergone surgical procedures. This often leads to lavish provision of windows and skylights which may compromise the integrity of the building envelope.

The relative humidity in patient care areas, such as operating rooms, must be as high as 50%, irrespective of the outdoor temperatures; this is often at odds with the resulting condensation on the glazing and wall surfaces. Failure to address this issue causes premature damage to the building envelope. Thus, operating rooms, for example, are generally situated in the core of the building and are windowless.

Sepsis control is very important in health care facilities. Efforts to conserve energy and the implied reduction in the ventilation rate must not contravene measures for sepsis control. The number of air changes per hour can be as high as 25 in certain areas. Air heat exchanger is considered in larger facilities, where it is economical, to enhance energy conservation. Other areas, such as administration offices, can be designed for partially recirculated air.

Special design techniques have to be employed in the implementation of fire and life safety systems that are not susceptible to failure or to freezing in the winter. Total sprinklering is generally the method of choice for new projects, However, in areas such as ambulance bays, special provisions are warranted, such as a dry-pipe system, or a glycol pre-loaded system. Rate-of-rise temperature detectors should not be employed in these areas as they may falsely trigger an alarm when a door is opened and closed for ambulance traffic.

Health care facilities utilize ever increasing numbers of sophisticated electronic equipment. This equipment is very sensitive to static electricity discharge, particularly in cold regions where it is difficult to maintain high levels of indoor humidity. Anti-static measures implemented include specifications for floor covering materials with anti-static requirements in areas where electronic equipment is extensively utilized. The equipment and systems should also be specified to incorporate self-contained protection against failure from the discharge of static electricity.

Redundancy in heat generation (steam/water boiler), power distribution and emergency power generation is a key consideration in system design. Provision for multiple boilers and redundant heat distribution systems is especially crucial in cold climates. Emergency power generation is essential for health care facilities. In cold regions, the reliability of the electrical supply suffers from frequent interruptions due to icing on overhead lines, and lightning strikes in the summer. Where possible, a dual supply from two different power grids is provided. Proper sensing equipment is needed to recognize partial failure of a three-phase supply system to prevent damage to loads, such as motors. Computerized electronic equipment should be designed with adequate memory protection to guard against brief power interruptions.

The foregoing demonstrate the challenge of designing hospitals in cold regions and hopefully would prompt further discussion and development of standards for hospital projects in meeting the ever changing medical practices and technologies.

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Design of a Generic 'Sustainable House' for Tract Builders

Tony Argento

Conventional western houses use extraordinary amounts of energy, from the actual extraction of materials, to manufacturing, transportation, and for the construction and assembly of the house. This has had a negative impact on the environment and on its occupants.

The 'sustainable house' reduces environmental impact and degradation in a cost-effective manner. The premise for this home is that it must be affordable, accessible and desirable by the consumer. Ultimately, it is a means of rethinking the way houses are designed and constructed.

The following list represents features that will contribute to the 'sustainability' of a house:

1. Smaller house and lot: a reduction in size will reduce materials and operational costs, thereby enhancing energy conservation and environment preservation. Typical size: Conventional 151 m^2; Sustainable 120.77 m^2.
2. Energy conservation: higher levels of insulation in wall cavities, under the slab and in the roof. Conventional: 2.5-3.7 RSI (R15-20) walls, 5.9 RSI (R34) roof; Sustainable: 5-9 RSI (R30-50) walls, 9 RSI (R50) roof
3. Water conservation: use of a water meter, low-flush toilets and low-flow fixtures. Greywater and rainwater can be collected and recycled. Conventional toilet (18.9 l): Family of 4 uses 2070 l of water per month. Low-flush toilet (0.568 l): Family of 4 uses 51.12 l of water per month.
4. Reduce materials and wastage: Conventional: to construct a 115.2 m^2 house with 400 mm on center framing requires 170-215 (Alberta) trees; Sustainable: to construct a 115.2 m^2 house with 600 mm on center framing requires 128-162 (Alberta) trees. The 42-53 trees that are saved can absorb @ 371.7 km/a of CO_2.
5. Low embodied energy materials: use and choice of materials that do not require extensive energy to produce, are being specified, e.g. use of wood shingles (4,393 BTU/unit of energy) instead of asphalt shingles (24,553 BTU/unit of energy to produce).
6. Energy efficient lighting and appliances: fluorescent bulbs can last 20 times longer than incandescent bulbs and reduce electric consumption by 13-20%. Task lighting, maximum daylighting, DC-lighting and DC-refrigeration can contribute to energy savings. Conventional: in a 115.2 m^2 house, a family of 4 uses 930 kWh/month; Sustainable: in a 115.2 m^2 house a family of 4 uses 200 kWh/month.
7. Photovoltaics: solar electrical modules can replace fossil fuel generated electricity (e.g. coal or natural gas in Alberta). A clean and simple way of converting a natural resource into energy to power lighting and heating needs. Photovoltaics drastically reduce electromagnetic pollution, servicing, line losses and protect against power outages.
8. Passive solar heating/cooling: a greenhouse/solarium, large south-facing windows, a breadbox solar preheater and natural ventilation. A breadbox solar preheater preheats water (to 45°C) before it is stored in a boiler or domestic hot water tank. This reduces fossil fuel burning required to heat water, thereby reducing CO_2 emissions.
9. Slab-on-Grade construction: eliminating the basement results in saving energy, money and materials. The slab becomes the interior solar heat sink and the substrate for the finished flooring. The basement is replace with a livable attic.
10. Radiant floor heating: provides greater comfort, no noise, and a more pleasant indoor environment. The temperature remains constant and promotes a higher air quality because the air does not recycle itself through the system. As a result, there is less dust and no ozone from electrostatic filters.
11. Airtight construction: the use of the drywall approach, expanded polystyrene, stucco, insulated doors and airlocks control the infiltration of outdoor air pollutants and exfiltration of heated air.
12. High performance windows: the use of airtight heat-mirror windows reduces heat loss. The use of dual tone venetian blinds can be used to reflect and generate heat.
13. Improved indoor air quality: use of natural materials that do not contain phenols, aldehydes (e.g. area rugs versus wall-to-wall carpets, solid wood cabinets versus particleboard and laminates) are being specified.
14. Recycling centre: an integrated convenience placed in the kitchen design as a means of separating waste at the source.
15. Multi-purpose areas: space optimization and elimination of duplicate spaces with an open plan concept.

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Tony Argento, project manager for the 'Sustainable House', works with Jorg and Helen Ostrowski, principles of A.C.E.-Alternative & Conservation Energies, Inc. (Varsity Execucenter, 1700 Varsity Estates Drive N.W., Calgary, Alberta T3B 2W9, Canada). The firm provides several services including: architectural design for new housing, retrofits, and community planning photovoltaic technology and research studies.

Architectural Integrating of Solar Heating Components

Tang G. Lee

Solar space heating in Canada is not widespread due to its high capital cost and rather low heating fuel cost. One of the most important challenges of the solar heating industry, therefore, is to reduce costly component-based solar heating systems. This paper describes an approach to solar heating by architecturally integrating solar heating components with traditional building elements.

In 1981, the first Canadian application of a building-integrated solar heating system for heat storage was in the Calgary Chinese Alliance Church. Solar heat is stored in concrete block walls positioned on the inside of north walls. The interior concrete block walls are used as a finishing material, as a structural wall and for storing solar heat. The blocks are stacked bonded to ensure the holes line up vertically. Core-filled blocks and bond beams occur where necessary for structural reasons. As such, the design and construction of the block wall is no different than that currently in practice.

Solar heated air is ducted into the concrete block wall. As the hot air migrates from the top of the wall to the bottom, heat is transferred to the blocks. At the bottom of the wall, the exhausted air is at room temperature, indicating the heat was successfully extracted and stored in the block wall.

To increase thermal storage and extend lag time, high water-ratio concrete, or sand, filled every other hollow core of the block wall. Tests indicate there is very little difference in storage capacity and thermal lag time between walls filled with concrete or sand. The additional thermal mass took longer before it started to radiate heat into the building, and is thus more suitable for this type of application and building occupancy.

With the success of storing solar heat in concrete block walls, the focus turned to integrating the solar collectors. A house was constructed in 1984 in which solar heated air is generated from the top of a two storey sunspace. The heated air is ducted to the bottom of a masonry wall to warm the basement first because it is the coolest level. As the solar heated air migrates up inside the blocks, the air loses its heat to the block wall. As an added feature, the air flow helps de-stratify the air at the top of the house. Solar contribution is ~30%.

Other buildings have been designed by the author which incorporate solar storage and collection as an architectural element. A recent example is the 3200 m² Sandstone Valley Ecumenical Centre, a Catholic and Lutheran church built in 1988. In this building, the solar heated air is generated by vertical south-facing solar collectors which appear to be windows. The solar collectors use curtain wall technology which was site installed at the time of construction. The curtain wall solar collectors replace the brick veneer which is about the same cost. In essence, the solar collectors are purchased and installed at little additional cost.

During the summer, the concrete block wall can be used to cool the building. Using the components for solar heating, cool night air is ducted through the block walls. The cooled block walls provide a large thermal mass to keep the building cool throughout the hot summer days. A simple timer turns on the fan at night and off at sunrise. The amount of electricity consumed by the fan is considerably less than what is consumed by an air conditioner. In addition, the fan uses electricity during off-peak hours, i.e. midnight to 6:00 a.m.

Computer simulation (Byrne and Lee, 1986) of the masonry heat storing walls suggests a minimum ratio of 2:1 for wall surface area to solar collector area or, window area. Ratio of wall to solar collector area should not exceed 5:1 as this will compromise the rate of re-radiation from the block wall. other parameters are noted in Table 1.

Table 1. Rules of Thumb for Storage Geometry

1. Thickness	100 to 200 mm thick walls; down to 50 mm acceptable with large surface wall area
2. Surface area	3 to 4 times the aperture
3. Distribution	as evenly distributed as possible
4. Orientation	vertical walls preferred; horizontal position requires more mass on top
5. Location	Interior of building away from windows: lower level preferred

Sizing Rules:

1. Aperture - 1 m² per 800-1200 kJ (°C.day) of load
2. Storage capacity - 800-1200 kJ/°C per m² of glazing

In conclusion, significant cost reduction is achieved by using architectural components for solar heat collection and storage. This assumes the architect strategically positions the architecturally integrated solar components to effectively serve other purposes. Whereas traditional solar heat storage dedicates material strictly for heat storage and it occupies valuable interior space, the block walls described here do not require such additional space. For solar collection, replacing the cladding with site-built solar collectors demonstrates the potential for further savings in the capital cost of solar heating.

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Foundation Methods Case Study, Alert, NWT, Canada

D.A. Chambers, T.H.W. Baker and L.E. Goodrich

presented by J.A. Fedoruk

One of the coldest locations in the Canadian Arctic is Canadian Forces Station Alert, NWT, with temperature fluctuations from 6°C down to -37°C and a mean annual air temperature of -18°C. A very stable ground thermal regime exists with a mean annual ground temperature of -17°C. These temperatures may suggest that foundations at CFS Alert should be extremely stable, safe and predictable; however, slab-on-grade foundation cooling methods used over the last 12-a have resulted in varying levels of success. Slab-on-ground buildings with warm internal temperatures cause heat loss through the floor which eventually penetrates into the underlying permafrost, unless a cooling system is installed to prevent thaw. Thermal performance monitoring equipment was installed during the construction of three slab-on-grade building foundations in order to evaluate the various cooling systems. All three buildings were insulated under the slab-on-grade concrete with a minimum of 100 mm of rigid insulation. Because very little preventative maintenance was performed on these buildings, they represent ideal cases to conduct performance evaluation of the original design.

The water treatment plant (20 m by 16 m), built in 1978, was placed on a ducted pad foundation. The four ducts were placed 5 m on centre and were constructed of 600 mm diameter culverts. The culverts were intended to be open to allow cold air to blow through during the winter months and closed during the summer months. The ducts are commonly obstructed by ice and drifting snow, despite which thermal performance has been satisfactory with very little foundation thawing. Indeed, the foundation performed well despite the failure of the ducts. This is due to a fortunate combination of cold ground temperatures, deep foundation fill, narrow dimensions building and foundation pad, and relatively low floor temperatures.

A 24 m by 37 m supply warehouse was constructed in 1985 which also contained a ducted pad foundation. The ventilation system consists of vertical air intake stacks, horizontal air ducts, horizontal drain ducts and vertical air exhaust stacks. Eight 300 mm diameter horizontal air ducts were placed 4 m on centre. Air movement was to be facilitated by wind-driven turbines mounted on the exhaust stacks, but this system has exhibited difficulties including ice blocked air ducts and drain ducts, snow covered air intake stacks and loss of wind turbines due to excessive winds. Thermal performance monitoring indicates that thawing takes place in the foundation sub-grade. Although engineering and architectural failures have not occurred it is apparent that an investigation of the ventilation system and foundation will be necessary. Possible actions may include site drainage improvements, the clearance of duct obstructions, the installation of air intake goosenecks, and possibly the installation of electric fans to replace the wind turbines.

The third building, a 37 m by 18 m firehall, was built in 1986 and was constructed on a pad refrigerated by a CO_2 charged thermosyphon system. Eleven thermosyphons, 50 mm in diameter were spaced 3.5 m apart. Vertical segmented fin type radiators were attached to each pipe on the north side of the building. The thermosyphons, as a passive system, only operate when air temperatures are lower than the soil temperatures under the building. Physical and thermal evaluation determined that the thermosyphons are operating as designed. The 0°C isotherm remained in the insulation layer immediately below the concrete slab throughout the year. Further, the system requires minimal maintenance.

Further evaluation of these foundation methods requires that preventative maintenance and an installation cost comparison be considered. The ventilated foundations require intensive maintenance to clear the ducts of ice and snow. A simple cost comparison indicated that a simply ventilated slab such as the water treatment plant is the cheapest. The thermosyphon foundation is the next most cost effective.

It is concluded that the thermosyphons at CFS Alert are performing well in maintaining frozen foundation conditions and are cost effective. Ventilation systems must be carefully designed considering weather conditions and snow drifting. Maintenance is of paramount importance for ventilated systems. A thermal performance monitoring program, conducted throughout the life of structures built on permafrost, is an invaluable maintenance tool.

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Frost Protection of a Shallow Foundation with Rigid, Extruded Polystyrene Insulation: A Case Study, Pefferlaw, Ontario, Canada

David Greeley

In the fall of 1985, the federal mortgage funding and insurance agency requested that instrumentation to record soil temperatures be installed adjacent to the insulated shallow foundation of a 26-unit senior citizens' apartment complex being built in the village of Pefferlaw, Ontario (normal air freezing index = 735 degree-days °C). The extremely frost-susceptible site soils were characterized as shallow, loose to dense fine sands underlain by firm to stiff clay, over limestone bedrock. The groundwater table was found 500 mm below the ground surface.

Five separate areas around the perimeter of the building were instrumented with thermocouples. Examination of collected soil temperature data above and below a 75 mm thick horizontal layer of rigid, extruded polystyrene thermal insulation (RSI=2.61 m^2 C/W) showed the effectiveness of the insulation at resisting frost penetration and potential frost heave damage to the shallow buried building footing. During the 1986-1987 and 1987-1988 winter seasons, the first two full winters of observation, soil temperatures beneath the 1200 mm wide insulation layer and adjacent to the shallow footings remained above freezing at all five monitoring locations, while soil temperatures above the insulation dropped to as low as -12°C.

Three-dimensional heat losses at the building foundation corners resulted in measured soil temperatures beneath the insulation on the average 2.0°C cooler than those beneath the insulation along foundation walls where two-dimensional heat losses occur. To what extent the increased insulation length (1800 mm vs 1200 mm) at the corners helped reduce this observed temperature difference is unknown.

Soil temperatures measured above and below the insulation layers on the north-facing side of the building were cooler than those recorded on the south-facing exposure. Differences of as much as 2.8°C were observed.

The greater the thermal resistance of the horizontal insulation layer, the warmer the soil and footings beneath it. Mean winter soil and footing temperatures beneath RSI = 2.61 m^2 C/W insulation were approximately 1.5°C warmer, respectively, than the corresponding temperatures beneath an area with only RSI = 1.3 m^2 C/W insulation.

The design of the insulated shallow depth building footings on this apartment complex proved to be a cost-effective alternative to a more conventional, deep piled footing design. Savings of $219,700 (which was 68% of the next lowest alternative foundation design cost) were possible for the owner of the building.

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Modelling of Temperature and Moisture Movements in Composite Building Panels Manufactured from Alberta-Grown Wood

Lars Bach and Rob Leitch

In buildings and other structures the performance of solid lumber and wood based panels is dependent on temperature and moisture content. In practice, the indoor and outdoor climatic environment is almost always changing resulting in material behaviour that cannot be readily predicted from isothermal and constant humidity controlled experiments.

Knowledge of changing moisture content and temperature, and their time-dependent distribution in wood products, is important in connection with several wood engineering problems related to design and manufacture.

The main objective of this study was to model the movement of moisture in wood-based panel products used for structural purposes because the viscoelastic properties of wood material are strongly influenced by changes of moisture gradient within the panels.

The modelling applied to flat homogeneous panels and was based on a one-dimensional version of the diffusion equation:

$$\delta C/\delta t = D\ \delta C/\delta x$$

where C = concentration of diffusing matter (moisture or temperature), t = time, x = position depth in the panel, and D = diffusion coefficient.

J. Crank (The Mathematics of Diffusion, Clarendon Press, 1967) has described various methods for solving the diffusion equation. In this study the "Schmidth method" was used to solve the diffusion equation for the variation of cyclic relative humidity at isothermal conditions.

Computer programs were written that gave solutions in the form of concentration vs time curves for different depths within the thickness of the panel. Results were calculated for thin 'slices' taken out of the plane at regular intervals between the wood surface and the middle of its thickness. The number of 'slices' or layers is specified by the program user. An important assumption made in the calculations is that the surface layer of the wood or the 'thin' slice which is in direct contact with the air, immediately gains equilibrium with the changing environment. For example, if a piece of wood is in a climate when there is a sudden increase of temperature or humidity, then the surface layer is assumed to adopt these new characteristics instantaneously. The program also assumes that initially, before change takes place, the wood is in equilibrium with its environment, i.e. no moisture or heat flow occurs at any point within the wood. When the climate changes the different layers in the wood take some time to reach a new equilibrium point. The rate at which this occurs is reflected by the diffusion coefficient (D) that was assumed to be a constant and not to be dependent on concentration or time.

Computer simulation runs were carried out with imposed sinusoidal and square-wave surface changes of moisture. The time effect on moisture content at various depths in the panel was calculated. The results clearly showed the effect of the panel thickness and frequency on the moisture gradient at various depths. This appears to relate closely to the observed differences in the behaviour of wood-based panels of various thicknesses. Studies are presently ongoing to explore this phenomena in more detail.

In summary, the techniques outlined for moisture and temperature modelling appear useful to predict aspects of the behaviour of structural panels from Alberta wood species in changing climates.

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Far-Infrared Drying is Effective for Lumber in the Northern Regions

Jiro Sato

The history of lumber drying is almost a century old. Although contemporary drying machines are automatically controlled, the basic nature of the drier has not evolved since its introduction. The conventional drying method wastes time and money. In addition, cracks and distortion are often found in dried lumber, impairing the appearance of the product. What is needed is a new method for drying lumber. Unexpectedly, a far-infrared light drier turned out to be effective for lumber drying, especially for coniferous lumber; and beautiful lumber has a broader range of applications.

First, a very beautiful finish can be obtained with far-infrared-light dried lumber. Lumber dried by the conventional method has many cracks and distortions, especially coniferous lumber. But, far-infrared-light dried lumber has few cracks or distortions. In addition, this method effectively removes greases during drying, which results in an exceptionally nice finish.

Second, the drying speed is very fast. Far-infrared drying often requires only half the time of the conventional method. The speed is especially faster at high temperatures, thus saving a lot of time. And, still, the finish is more beautiful than with the conventional method.

Third, the drying cost is low, because heat penetration is very effective in producing a shorter drying time. The conventional drier requires many motors, but far-infrared drying can save the great amount of electricity required for running these motors. The number of drying cycles may also be increased. In addition, the depreciation of capital investment is quickly recovered. This new method is far more economical than the old one.

These results are hard to imagine from knowledge of far-infrared light, and an explanation of the results is difficult. We have to study what caused these favourable results. The northern regions share a greater part of the lumber production on earth. It is important to supply high-quality lumber with more effective equipment. Lumber production communities must appreciate the far-infrared-light drying method because this method is more effective and produces a more beautiful product than the conventional method.

The northern regions abound in high-quality wood from both coniferous and deciduous trees. Beautiful wood with clearly defined annual rings inspires a sense of tranquility and adds a lovely atmosphere to anyone's lifestyle. However, these trees are not inexhaustible. Therefore, attention must be paid to their use. The process essential to creating something beautiful from raw lumber is drying. The following problems occur if a house is build with undried lumber.

1. Cracks, distortion, contractions
2. Poor durability
3. Mold propagation
4. Insect propagation
5. Poor insulation
6. Painting and gluing difficulties
7. Discoloration
8. Poor elasticity

These are the reasons drying is indispensable, and of the various methods used, far-infrared drying is the best.

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Research and Development on Chemical Processing of Larch-wood Produced in Hokkaido, Japan

Yukio Tadaishi

Hokkaido changes its natural scenery and displays four seasons beautifully to us. Its rich nature includes animals and plants, among which the larch tree is particularly beautiful. Larch trees are distributed throughout the natural environment of Hokkaido.

Larch-wood is a strong material with a beautiful, shining surface. However, after felling, drying and contraction specific to this wood cause torsion and cracks more frequently than in other kinds of wood, thus impairing its quality as a product. Wood other than larch-wood is used in many fields because it is easy to process. However, irresponsible development, including the unnecessary felling of trees, is becoming a major issue and a growing environmental concern. With larch-wood, however, many thinning operations can be carried out because the tree produces a great amount of lumber. However, the uses of larch-wood are limited to logs for stakes and a few other purposes primarily due to processing difficulties. Recently, larch-wood trees have been left to stand in forests after thinning because the selling price does not repay adequately the production cost. The remaining larch-woods attract unwanted insects which damage other trees, thereby causing economic concerns.

The Tadaishi Group has been considering this issue seriously in research and development and has been seeking a solution which makes effective use of the abundant larch-wood produced by thinning, and at the same time, protects other trees from noxious insects, reduces the unnecessary felling of other trees, and enriches people's lives.

A new fast-drying technology has been developed in which a contraction-prevention liquid replaces the moisture naturally contained in the larch-wood immediately after felling. So far, the system allows drying with 5% of natural moisture remaining and also eliminates cracking. As a secondary effect of the prevention of drying contraction, the bark is prevented from falling off and thus the wood retains the unique character of the tree. This natural appearance allows for more varied product applications. This, in turn, enriches our modern lifestyle by the introduction of a natural material. Although this technology is still in the research and development stage, the same results have been observed with several other kinds of wood.

It would be of value to put to effective use the lumber obtained from the thinning of trees, which would otherwise be considered a nuisance, however unique they may be to our region. This makes more products which contribute to the quality of life, and add somewhat to environmental protection.

It is hoped that this technology finds more applications in other fields, increases the uses of wood, and contributes to effective environmental protection.

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Ten-year Outdoor Exposure Test of Sidings and Panels for External Wall Finishing of Houses in Cold Regions in Three Cities, Hokkaido, Japan

Sadahiro Inoue

Sidings and panels are used in most external walls of newly built houses in Hokkaido, and various defects have come to light. No studies of the durability of sidings and panels have been conducted, which can show various defects, e.g., frost damage, rust, contamination, and discoloration by solar radiation and exposure to the weather. The purposes of this research were to determine the weatherability and regional differences in deterioration of sidings and panels in Hokkaido.

An outdoor exposure test was conducted from 1980 to 1990 with 17 different board sidings, 3 types of metallic sidings, and 2 kinds of ALC panels for houses in cold regions at three cities in Hokkaido:

1. in the Japan Sea Coastal Climate Region, at Rumoi, a small city near the Japan Sea;
2. at Sapporo, a large inland city; and
3. in the Okhotsk Sea Coastal Climate Region, at Kitami, a medium-size inland city. The sizes of test specimens were 15 cm x 7 cm, with 4 specimens for each test material.

The test was conducted according to a Japanese Industrial Standard. Test specimens were fixed to exposure racks turned to the south and were elevated 30° above the horizontal. After the end of prescribed test terms, specimens were detached from the exposure racks, wedged into phonographic record stands, and conditioned for 7 d on a shelf which was put in a laboratory at normal temperature.

Weatherability of the sidings and panels was established by annual observation, by the naked eye, of defects such as cracking, peeling, rusting, and the growth of moss; and annual measurements of a variety of conditions, including colour, by a colour difference meter, and weight, by an analytical balance. Discoloration of the test specimens by solar radiation, adhesion of dust and soot, changes in weight, and the incidence of defects in the test specimens were determined. At the same time, regional differences in the degree of changes in quality of the sidings and panels were established.

The board sidings that contained calcium silicate (4 kinds), wood chips (2 kinds), lapilli (4 kinds), and ALC panels (2 kinds) had large average weight-gain ratios, caused by water absorption. Metallic sidings (3 kinds) had large average weight-loss ratios, caused by the peeling of paint and rust. The average weight change ratios in Rumoi were larger than those in the other two cities. Metallic sidings (2 kinds) showed the largest regional difference in their weight-loss ratios. Hard-cemented chip board showed weight gain, but regional differences were not clear. ALC panels (2 kinds) showed large regional differences in weight-gain ratios.

The average values of colour difference were largest in Sapporo, and smallest in Kitami, and were also larger in the 9 test specimens that were hardened at normal temperature than in the 6 test specimens that were cured at high temperature (thermosetting paints). Changes of colour difference were larger in test specimens that were hardened at normal temperature than in test specimens that were cured at high temperature, and the values found at Sapporo were larger than the values found in the other cities.

The average years without cracking were largest in Kitami; the values in Rumoi and Sapporo showed hardly any differences. The specimens that most easily cracked at the three cities were board sidings (4 kinds); 3 kinds of board sidings and an ALC panel did not crack.

The average years without peeling were lowest in Rumoi; the values in Sapporo and Kitami showed hardly any differences. The test specimens that most easily peeled at the three cities were board sidings (4 kinds) and a metallic siding; 2 kinds of board sidings did not peel.

Cracking and peeling occurred on board sidings with uneven patterned surfaces, and board sidings containing calcium silicate, wood chips, and lapilli. There was no cracking or peeling in board sidings containing asbestos and cement. Rust appeared in Rumoi on some of the metallic sidings. Moss grew in Sapporo on board sidings that contained lapilli.

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Building Energy Conservation Systems, Harbin, People's Republic of China

Tian Da Fang

Presented by Xu Li Bai

The details presented in this paper are based on the analysis, study and demonstration of the conditions of new building materials, on scientific research results and technical competence, and on construction practices of production facilities in Harbin, People's Republic of China, specifically, the use of rockwool sandwiched walls, frame and light board walls, and hollow brick walls as the three main building energy conservation systems.

Following comprehensive analysis of the building structure, the different experimental conditions and measured data on the three different building systems noted, attention is given to the technical criteria of each system.

First, the light board frame system: recently, >1 M m^2 of light board frame buildings have been completed in Harbin, resulting in considerable construction experience. This system needs to be improved through both a decrease in the height of the walls, and in an increase in the thermal insulation. The board and column system will be studied further so as to increase its use for functional living and thermal insulation.

Second, the complex wall system: this is mainly composed of rockwool and red clay brick, hollow clay brick, or hollow, powdered coal brick. In construction, there are two ways of applying thermal insulation, attached from the inside or the outside, and two kinds of load-bearing using vertical walls or cross walls.

Third, the hollow brick wall system: at present, the hollow rate of KP1 hollow brick is 20%. We intend to introduce a No. 400 model, whose hollow rate is 50%, so that 400 mm hollow brick can replace 490 mm red brick. The heat conductivity will be decreased (0.90). As a result, load bearing, thermal insulation and elevation modelling can be accomplished in one system, which is very economical and easy to construct. At the same time, building energy conservation in architectural design should be enhanced.

The decrease of the body-form coefficient includes a decrease of unnecessary heat loss and gain, and an increase of both building length and building depth. Full use is made of various forms of natural energy, particularly solar energy. This includes the improvement of lighting conditions, and the increase of the building distances from 1.3 to up to up to ~2.1 times. Attention is also paid to wind pressures close to the northwest corners. Solar hot water facilities and solar batteries are also introduced. Consideration of the decrease of heat consumption includes increasing the heat retention of each unit using double doors and a buffer doorway, the outer door facing south if possible, and the closure of the balcony. Changes in the design of windows includes having them facing north or south, according to their functions. Windows are designed with a single wooden frame, double leaves with triple glass and having only one leaf that opens, so that the functions of ventilation and lighting are separated. The energy conservation window has the characters of little loophole, good closure and low heat transmission coefficient. The thermal insulation of the walls, roof and floor are increased; an example will be given of the plan and design of the Song San Energy Conservation Building District, outlining in detail the three energy conservation building systems in the design. it includes eleven different building energy conservation plans, such as a red brick and rockwool sandwiched wall with thermal insulation attached from inside and outside; the type of hollow brick and rockwool sandwiched wall with vertical bearing and cross-bearing functions; the type of frame and foamed concrete board; the type of board and column system; the plan of KP1 hollow brick; and the plan of dense hollow brick. Each design achieves an energy conservation index of 30% or 50%.

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Radiant Panel or Forced Air Heating: A Comparative Study of Performance

J.D. Dale and M.Y. Ackerman

Radiant floor panel heating systems, used in various forms since the time of the Ancient Romans, are presently being installed in an increasing number of new homes in western Canada. Commonly held beliefs about the systems include increased thermal comfort and lower energy usage. A two year project at the University of Alberta examined the performance of two variations of hydronic floor panel system and a more conventional forced air heating system. The testing of the three systems took place in an unoccupied, fully instrumented, test house at the Alberta Home Heating Research Facility. Results from the study included measured globe temperatures, a measure of thermal comfort, as well as comparative energy efficiency.

Based on total energy usage, it was found that none of the heating systems evaluated had a distinct advantage in terms of energy efficiency. The overall energy usage was within 5% of the forced air system results with either of the radiant panel systems in operation. It was noted that the losses through the ceiling were higher when the radiant panel systems were operated, primarily due to enhanced radiant exchange between the floor and the ceiling. It was also noted that the measured basement floor losses were significantly higher (45%) when the floor panel systems were operated.

The test house used had a large amount of south-facing glazing so that the cold glass surfaces produced strongly asymmetric radiant fields during periods of cold ambient temperature. Thermal comfort was found to be better with the radiant floor panel system, primarily due to a higher mean radiant temperature and the fact that the warm floor counteracted the cold plume of air that falls off the windows. During periods with similar ambient temperatures, globe temperatures were found to be ~1°C higher with the panel systems in operation than with the forced air system. The reason for the small differences in globe temperature with the two types of heating system is primarily because houses in western Canada are moderately well insulated and require a limited amount of space heat. The relatively low energy requirement means that the panel surface temperature need not be more than a few degrees above air temperature to meet the heating load. The low surface temperature results in globe temperatures that are only slightly above air temperature, not enough to allow lowering of the air temperature set-point to achieve energy savings.

Several control strategies were examined to see if changes would result in increased energy savings. Simple on/off thermostat control, proportional control with ambient temperature reset and a combination of the two were evaluated. Proportional control with ambient temperature reset provided the greatest potential for energy savings, but the savings would be as a result of lower boiler standby losses due to the reset of boiler temperature. On/off thermostat, the least complicated system, resulted in satisfactory control, but would require periodic manual adjustment of boiler temperature in order to minimize energy usage.

The paper will present measured energy usage, globe temperatures, thermal stratification measurements as well as examine system response and the effects of the three control strategies evaluated.

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Dr. Dale is a professor and chairman of the Department of Mechanical Engineering at The University of Alberta. He is director of research at the Alberta Home Heating Research Facility and has authored more than 90 publications in the areas of combustion and energy conservation in housing. His present research interests include combustion processes, heat transfer, and the evaluation of protective clothing for use in short duration, high intensity, flash fires.

Study and Practice of Wall Reforming and Building Energy Conservation in Harbin, People's Republic of China

Xu Li Bai

The largest part of the total energy production of China is consumed in buildings, where heating makes up the major part. This paper points out that in China, building energy conservation is one of the most economic and efficient items among all energy saving measures. Therefore, it is a program which should be studied immediately.

Building energy conservation has three characteristics:

1. the technique is complicated;
2. the measures are economic; and
3. the energy saving is large.

Quite a lot of problems will be covered and apply to the whole society. It was decided to investigate and study three aspects:

1. policies and regulations;
2. enterprise reform; and
3. planning; and then put forward the appropriate contents and steps.

In the field of policies and regulations, economic policies and technical policies must be formulated. Already, there are "Regulations for Wall Materials, Reforming, and Building Energy Conservation in Harbin", and "Detailed Rules for Implementing Energy Conservation Design Standards of Civil Buildings in Harbin" and so forth. A total of 23 items are covered by government legislation.

In the field of enterprise reform, a technological plan for every building-material enterprise has been performed, as well as plans for funding. These include nine new production lines of five main building-material enterprises, and nineteen brick factories in villages and towns. All the above will cost 38 M yuan.

In the field of planning, six soft and eight hard subjects as well as four scientific research tasks for perfecting the functions of the district have been put forward and the design and construction of the Song San Energy Conservation Residential District has been determined. The scientific research includes the types of residential energy conservation, the indoor and outdoor environment properties in cold areas, the design of energy-conserving doors and windows, the measurement of heating effects in the Song San heating network, the study of rockwool complex walls, the study of land utilization, energy saving and policies, the study of a favourable system for the Song San district, the study of costs during the manufacture of wall-bodies, the study of a computer-aided management information system and so on, for a total of 18 items. After having carried out a thorough investigation into these three aspects of the policies and laws, business reform and scientific research plan, a huge system project was drawn up, consisting of eight branch-systems as follows: policies (as the starting point), legislation (as the fulcrum), the application of matching funds (as the feature), business reforms (as the conditions), scientific research (as the premise), plan design (as a guide), construction of the little experimental area (as the example), and the involvement of the whole society (as the purpose). This huge group system project will direct the practice.

In the plan and design of the Song San Energy Conservation Residential District in Harbin, several building energy conservation techniques have been applied. At first, three building systems were studied, consisting of rockwool sandwiched walls, frame and light board and hollow brick walls. Then a theoretical plan and design was drawn up with four aspects: the plan and design, building construction, the application of new materials, and the efficiency of boilers and heating distribution throughout. As a result, heating energy saving is expected to reach 30 and 50%, which means that the heating-coal consumption will decrease from 45 to in the range of 22.5 to 27 kg/m^2/a.

Harbin has been appointed as an experimental city for wall reforming and building energy conservation in China. The Song San Energy Conservation Residential District is the experimental unit of building energy conservation and is one of two experimental residential districts in the city with completion of construction expected in 1992.

Xu Li Bai is deputy director of the City Planning Department of Harbin City Plan Bureau (173 Diduan Street, Daoli District, Harbin, People's Republic of China), and holds a concurrent post of vice head of the Harbin Wall Reforming and Building Energy Conservation Office.

Energy Storing Wallboard Based On An Organic Phase Change Material

D. Feldman, D. Banu, D. Hawes and E. Ghanbari

Thermal storage is an important factor in the effective use of solar heating and in the conservation of energy. Unfortunately, practical applications of research in this area have lagged that of other advances in the field. To rectify this situation, the approach taken in the present work involved the introduction of an organic phase change material (PCM) in gypsum wallboard to provide a cost effective thermal storage of adequate capacity which is easy to install. The PCMs absorb and release heat while changing their state from solid (S) to liquid (L) and L to S, respectively.

If properly selected, S-L PCMs can function very well in porous materials such as gypsum, concrete, their mixtures, composites, etc. because, even in its L state, the PCM will be retained in the structure of the host material by virtue of surface tension.

Gypsum wallboard was chosen as an appropriate container for PCM because it is a common building product which is easily adapted to energy storing applications and which could be produced and marketed by existing manufacturing and sales facilities.

After studying a series of organic PCMs that melt at or near the comfort zone, a commercial product (BS) containing 49% butyl stearate and 48% butyl palmitate which permits thermal storage capacity up to 350 KJ/m^2 was selected.

If the PCM content of the wallboard is kept at <25% by weight, the high surface tension of BS prevents weeping of the liquid at temperatures above its melting range, so no protective envelope, which might impede heat transfer, is required.

Two techniques were used to produce laboratory-scale gypsum wallboard with BS: immersion and direct incorporation.

The first procedure used 20 cm^2 samples cut from panels of regular 12.5 mm (0.5 in) wallboard. The specimens were loaded with PCM simply by dipping them at room temperature into a container of PCM at 80°C. Weighing the samples before and after immersion established the amount of BS retained in the wallboard.

The second technique was based on the production of an energy storage gypsum wallboard by direct incorporation of 21-22% BS at the mixing stage of conventional gypsum board production. The incorporation of BS was strongly facilitated by the presence and type of small amounts of dispersing agents.

The results obtained show that in both above-mentioned procedures the physio-mechanical properties of the laboratory produced thermal storage wallboard compare quite well with values for standard gypsum board. The energy storing has a tenfold increase in capacity for the storage and discharge of heat when compared with untreated gypsum wallboard. PCM wallboard is also more waterproof than conventional wallboard.

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Dr. D.W. Hawes is a research associate with the Centre for Building Studies, Concordia University and has worked largely on research relating to the energetic aspects of building heating and cooling. His principal field of interest is energy storage with particular reference to the use of phase change materials in building products.

Dorina Banu is a research associate with the Centre for Building Studies, Concordia University. Her present research activities include the formulation and improvement of organic PCMs, their application to thermal storage in different building elements, polymer building materials and polymer blends.

Bioregional Design Principles and Sustainable Cold Region Housing Development Systems

J.M. Jamil Brownson

This paper addresses problems and prospects in the design and production of housing for northern bioregions based on adaptable architecture and sustainable production and use; five philosophical and practical systems of architectural and housing construction are compared.

Discussed chronologically, the first set of principles derive from two of my Environmental Design teachers at the University of Berkeley. Sym van der Ryn told students to choose a complex real world environmental problem and find a local design solution using simple technology. Christopher Alexander taught his students to think of building production as a whole system with both symbolic and material aspects. Together, these two philosophies lay a foundation for a sustainable architecture.

The second example comes from Saudi Arabia where I worked with Fred Otto. Primarily a designer of lightweight, wide-span structures, Otto bases his system on two architectural principles:

1. a time-cost investment formula of 90% design, 10% fabrication and 1% construction; and

2. all building systems must adapt to local social and environmental conditions, and integrate local fabrication, construction and materials technologies; a philosophy of adaptable architecture.

Third, Steve Loken a Montana builder-designer has established a Center for Resourceful Building Technology to do research on how to find and use secondary source building materials, and to educate other builders, architects, and the public about resource conserving building technologies. Loken represents a philosophy of innovation in architectural materials.

Fourth, the "whole systems' concept as developed by Akira Yamaguchi in the production of Kinoshiro Taisetsu houses sets a model for northern regions housing. The "whole systems" approach develops a "backward" and "forward" integration of all levels of the production process. In this innovative and integrative model, environmental and energy conservation are considered at each level of the production system, from raw material sources, such as forest ecosystems, through processing and production processes to marketing and consumer services. Kinoshiro houses are also adapted to cold climates and severe snowfall, and for building on restricted lot sizes in densely packed settlements, and hence represent bioregional architecture.

Fifth, the co-housing movement of Denmark involves small groups in planning, designing and developing locally adapted individual and collective housing at a range of scales. Following a long Scandinavian tradition of innovation in cold climate social housing, co-housing has taken root in both the Canadian cooperative housing movement, and in the U.S.A. Because co-housing takes a middle path between private and public markets, it holds great potential for Hokkaido and Heilongjiang, as well as the USSR. In many ways the co-housing movement offers the best model for integrating all of the preceding factors into the most bioregionally adapted, sustainably developed, resourcefully built, and socially and environmentally appropriate vehicle for delivering cold climate housing systems.

Individual structures that provide housing and work-related space constitute by far the largest number of buildings in the world. As the basic unit in any built environment, to build sustainable communities, houses must be socially and environmentally sound in design and manufacture. As such, houses must be designed bioregionally, i.e. form, fabrication, construction, and materials technologies should directly relate to local social and environmental conditions and also conserve energy in both production and use. Thus integrated into a strategy of conserving and renewing natural resource and housing systems, these five approaches lay the groundwork for sustainable community futures in northern environments.

J.M. Jamil Brownson is Assistant Professor of Geography, Faculty Affiliate in Environmental Studies, Rural, Town and Regional planning and Wilderness and Civilization Programs at the University of Montana (Missoula, Montana 59812, USA). As a planner and geographer, he specializes in issues of cultural , social and environmental policy relating to sustainable development, environmental design, and ecodevelopment. His research has included bioregional adaptations to harsh environments, designs and developments of new towns, and rural resource communities in Africa, Saudi Arabia, Asia, Alaska and Canada. Current research focuses on strategic futures planning and transfer of resourceful socio-technical systems, primarily between Hokkaido, Montana and Alberta.

Storage of Snow

K. Tusima

K. Tusima is with the Faculty of Science, Toyama University (Gofuku 3190, Toyama-shi 930, Japan).

Snow can be used as a coolant for the storage of vegetable and grains, and as an energy source for air conditioning. It is also studied for its use as a cold source for thermal difference apparatuses and thermo-siphon power. Thus, the economical storage of snow is important for these practical purposes. Further, electrical demand shows a large change from a maximum in summer to a minimum in spring or autumn because of a summer peak due to air conditioning. Therefore, the introduction of ice and snow for cooling is important as an alternative to air conditioning systems using electricity.

The process of melting snow was examined using several thermal insulators to find the most effective storage method. A small hill of snow was made: 100 m^3 in volume, 9x9 m. basal area, 3x3 m in the top and 3.3 m high; the angle of inclination was 45°. The surface was covered by insulation and a sheet to avoid melting by solar radiation, wind and rain. Melted water was collected at the center of the bottom and then led to a flow meter, for recording the volume automatically. The shape of the hill was photographed and the process of melting analyzed.

The snow hill was made at the beginning of March with snow transported from mountain areas by dump truck. Four kinds of insulators were tested.

Using soil, the surface of the snow was covered by a layer 0.3 m thick; the snow melted at a constant rate (by volume) and disappeared by the middle of August. The soil soaked up the melt water and became wet in the first stage, which led to rapid melting. During stormy weather, the wind agitated the inside of the sheet, the soil was dried out, and a number of large cracks appeared in the soil. Therefore, the ability of the insulation became worse.

Unhulled rice in a layer 0.3 m thick, gave excellent insulation, and the snow remained until the following winter in a band 1 m thick. Slippage of the grain was the main problem, which was overcome by placing the grain in plastic bags first.

When the surface was covered by a 0.1 m thick layer of glass wool, the snow melted by the end of September. Because particles were torn off the glass wool a uniform thickness was not maintained, and besides, the glass wool was expensive for thick insulation.

A special foam was coated on the snow surface, only 0.1 m thick. In this case, the hill tested was smaller in size, being only 1.8 m high. The top surface was covered by plastic film coated aluminum. This foam gave excellent insulation even in wet conditions. Unfortunately, a small hole was made in this cover, which led to the drying of the foam and the acceleration of the melting. Another defect was the difficulty of getting a thick film, because the foam collapsed and it was difficult to repair the hole in the cover.

The residual mass of snow was estimated every month. The relations of mean air temperature, total radiation and rain to melting were also analyzed monthly.

On Removable Joints with Sulphur Mortar

Katuo Sasaki, Masao Inuzuka, Masanori Miyajima and Masahiro Imai

A cylinder joint is a joint reinforced by a steel pipe restricting the inner mortar. Restrictions causing three-dimensional compression can increase the shear strength of the mortar considerably. This type of joint is advantageous when used for connecting precast concrete members. In practice at the construction site only mortar fills the pipe, in which a reinforcing bar is inserted. Therefore, the connecting procedure is quick and simple. The application of sulphur mortar to this practice has many advantages, one of which is to enable the joint to be removable, because the mortar requires only heating to loose its strength. Another significant factor is to make a resilient concrete structure joint which can easily be repaired by heating the mortar. This point is particularly important in cold regions where structures are often subjected to high stresses due to heavy snow. Those structures, broken in winter, may be repaired in spring by reheating. The object of this work was to obtain information on the use of removable sulphur joints, because sulphur mortar can change from being fluid to being solid alternatively according to the change in temperature. The experiments were made in two series, one of which was on the pullout strength and the other on influencing factors.

The results of the first series of experiments are shown in the following table:

Factors/Levels	1	2	3
1. pipe diameter (mm)	60.5	76.3	121.0
2. Bar diameter (mm)	13.0	16.0	19.0
3. Surface condition (%)	100	50	0

The experimental results showed that factor 1 and factor 2 were statistically significant according to F values. No difference was found between sulphur mortar and cement paste. Data showed that shrinkage seemed to play an important role.

In the second series of experiments two types of specimen were heated for varying periods. The specimens were tested in two types of steel bar loop number. Specimens of different loops of nickrome wire were tested, keeping the energy consumption constant. The results showed that a cylindrical fracture surface can be formed near the surface of the steel bar. Therefore, only short heating times are necessary for removal of the joints at normal temperatures because the fracture takes place at the boundary of the sulphur mortar as a result of the steel surface area being much less than the surface area of the sulphur mortar. It is preferable to use steel with the lowest thermal conductivity for joint removal.

Katuo Sasaki is a research assistant at the Hokkaido Institute of Technology (419-2 Teine-Maeda, Teine, Sapporo 060, Japan).

Masao Inuzuka is a professor at the Hokkaido Institute of Technology.

Masanori Miyajima is the chief engineer at Iwata Construction Co. Ltd.

Masahiro Imai is an engineer at Iwata Construction Co. Ltd.

Research and Development on a Waterproof and Snowfall-free Roof for Northern Regions

Yoshihiro Hiraoka

One century has passed since modern development began in Hokkaido. Our ancestors lived in houses built according to technologies inherited from Honshu. They patiently endured the bitterly cold weather, using inventions that protected their houses against freezing and other difficulties caused by snow and the cold climate. However, conventional galvanized sheet iron roofs, which let snow fall naturally, have been the cause of many difficulties; they require heating, a slope to let snow fall, and they have overhangs.

Heating in the house warms the roof and changes the snow into water. Because water or melting snow is slippery, snow can fall off the roof, resulting in accidents. In addition, the design of houses with such roofs does not allow efficient use of the land. Therefore, sloped roofs are not appropriate to the contemporary lifestyle of a densely populated northern community. Further, the overhangs have clearances that cause capillarity, resulting in water leakage, which cause deterioration of the houses. Some kinds of snowfall-free galvanized sheet iron roofs are horizontal or sloped inward, but their waterproof capability is not complete. As a result, leakage is more severe than with conventional galvanized sheet iron roofs because they retain more water or melting snow. In addition, it has already been proved that conventional roofs cannot be used safely in Hokkaido.

These problems have now been solved. We have been working on research and development of roof structures, materials, and installation techniques for years, and have finally succeeded in developing a new type of galvanized sheet iron roof uniquely suited to Hokkaido. The product is perfectly waterproof and snowfall-free. It has been named the HO-type, after Hokkaido. Because this roof is produced in one piece, it has no overhang but is fixed in place in one piece. In addition, special seals are applied between the parts which make it completely waterproof, and fill in any clearances between parts perfectly. Therefore, there is no clearance to cause leaks. It slopes inward to eliminate the danger of snowfall. The HO-type roof is safe and incomparably effective.

We will continue to work on the development of a roof for the regions of Honshu and other northern areas which experience heavy snowfalls. Sales and installation with the HO-type construction method started in 1976 for general consumers, and reached 500 M yen in 1991. A further expansion due to product demand is anticipated in the future. These results prove that the actual installations and research and development efforts over long years have been well received by consumers. We will continue to develop new products; especially for an ideal roof not only for Japan, but also for all northern regions, to overcome difficulties due to snow, ice, and cold.

Yoshihiro Hiraoka founded the Hiraoka Bankin Kogyo Co. Ltd. in 1966, and remains the President. In 1986 he received the Hokkaido Governor's Prize for development of a roof structure for northern houses.

SESSION E
CONSTRUCTION, ENERGY AND PLANNING

ROOMS 17 AND 18, EDMONTON CONVENTION CENTRE

Monday, June 17

10:20 - 12:00 Materials I
14:00 - 16:00 Materials II

Tuesday, June 18

08:40 - 10:00 Pipelines I
10:20 - 12:00 Pipelines II

Wednesday, June 19

08:40 - 10:00 Regional Planning
10:20 - 12:00 Urban Studies: Japan
14:00 - 16:20 Urban Studies: Canada and Finland

Thursday, June 20

08:40 - 11:40 Alternate Energy

Session E
Schedule of Speakers

- **Materials I**

  T.G. Brown, F.G. Bercha, P. Olsen and P. Hofseth
  H. Saeki, N. Oritani, T. Yamashita, K. Goto and Y. Muraki
  R.H. Boon and L.B. Smith
  Yoneo Terada
  Naoki Nakazawa, Fumihiro Hara, Kunio Enoki, Toshiyuki Ono and Hiroshi Saeki

- **Materials II**

  Piyush K. Dutta
  Makoto Kagaya, Hiroshi Tokuda and Makoto Kawakami
  Yuzo Mizuno, Yoshiaki Sugimoto, Masashi Takahashi and Shinji Kuwabara
  Y. Kariyazono, H. Katoh, K. Sato, F. Ohtsuki, K.Goto and H. Saeki
  Takashi Terashima, Naoki Nakazawa, Shigeki Sakai, Toshihiko Yamashita and Hiroshi Saeki
  Liang Zhaochun, Wang Luyi, Wei Wenchun, Chen Yinglie, Wue Jie and Yang Lina

- **Pipelines I**

  Graeme King
  R. Bruce Partington
  Hayat Ahmad
  Wang Demin

- **Pipelines II**

  V. Kharionovsky
  Rezo Gabelaya
  Shen Zhongbao and Sun Weimin
  J.G. Nygren
  W.J. Vornbrock

- **Regional Planning**

  Archie Grover
  Takashi Terashima, Harukuni Tachibana and Hiroshi Saeki
  Masaya Uozumi, Takashi Kawabata, Nobuaki Sakai and Teruo Sugawara
  Zhang Quan

- **Urban Studies: Japan**

  Shoichiro Asakawa
  Hiromasa Chiba and Kimio Taniguti
  Hidetsugu Kobayashi and Taku Machida
  Shuichi Katoh
  Hidetsugu Kobayashi

- **Urban Studies: Canada and Finland**

  Craig Curtis
  Wm. (Bill) Ashton
  K.R. Johnson and J. Cucheran
  Colin J. Williams and Bill F. Waechter
  Raymond Vaivada and David Kinnaird
  Eero Vaananen
  Fumihiro Hara, Takashi Kawabata, Nobuaki Sasaki and Hidetsugu Kobayashi

- **Alternate Energy**

  R. LaPlace, D.G. Howell and A.M. Robinson
  Clint (Jito) Coleman
  Cui Wei and Sui Tieling
  Tetsuro Ise
  Jack Dueck
  P.A. (Pete) Poohkay and B.M. (Blain) Smetaniuk
  W.D. Kalkreuth and R.J.H. Richardson
  I.Z. Goldstrach, M.I. Sleptsova and N.I. Fiodorov

ICECRETE: A Construction Material for Arctic Applications

T.G. Brown, F.G. Bercha, P. Olson and P. Hofseth

The use of ice as a construction material provides a logical construction engineering solution to many problems, particularly in polar and high latitude regions. Ice is plentiful, easily available and inexpensive, environmentally benign, and relatively strong and stable. Its primary shortcoming, in terms of mechanical properties, is its low tensile strength and hence, certain additives must be used to enhance its mechanical properties. The possibility of using ice reinforced with some form of fibrous material has been considered since World War II. Although many attempts have been fraught with difficulties regarding composite materials construction, a Norwegian development called ICECRETE has partly solved these problems. The composite material exhibits mechanical properties which are considerably better than those of pure ice, particularly as they relate to tensile properties and fracture toughness.

ICECRETE is a structural material consisting of ice with certain fibrous additives which make it particularly desirable as a bulk structural material in cold regions. Construction is based on a set of processes involving continuous pour and flood techniques to make the fibre reinforced ice material. A mixture of crushed ice with the appropriate reinforcing additives is poured, spread, and frozen in layers in formwork which may be designed to virtually any structural shape in accordance with the specific requirements. The formwork is insulated and has a simple refrigeration system located just within the insulation in order to maintain the ICECRETE at temperatures below freezing.

The ice may be obtained by harvesting from natural ice or produced artificially using techniques similar to those currently used in the fishing industry. The wood pulp additive material is added in concentrations between 5 and 10% by volume, mixed with the ice during the crushing process, and the temperature of the mixture reduced to -20°C. In a continuous production process, the material is conveyed directly to the structure where it is spread in thin layers, ~7 cm thick. About 7 to 10% by volume of water is then added to the layer as it is being vibrated and the saturated layer is then allowed to freeze before the construction sequence is repeated.

The ICECRETE development program has entailed two principal phases; namely, small sample static and dynamic material testing, and a small prototype test program.

A series of >1000 material tests measuring static and dynamic mechanical properties has been conducted since 1981. The optimal proportion of fibrous material and the resulting mechanical properties have been derived from these tests. The table illustrates some of the results obtained indicating, in particular, the significant increase in tensile strength derived from the addition of wood pulp.

	ICECRETE (no wood pulp)	ICECRETE (with wood pulp)	ICECRETE Prototype Core Samples
Compressive strength (MPa)	6.11	7.65	5.97
Tensile strength (MPa)	0.788	4.83	--
Shear strength (MPa)	1.035	--	--

Following the small-scale testing, a small prototype was constructed in Oslo harbour in 1986 and evaluated for constructability and operating performance. The prototype was a 5-m cube constructed with 6% fibrous additives according to the process described earlier. The system performed satisfactorily in a depth of 3 m of water over a period of 5 months.

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P. Olson and P. Hofseth are with ICECRETE Contracting and Engineering A.S. (Oslo, Norway).

Determination of Compressive Strength and Static Elastic Modulus of Sea Ice by a Vibration Method

H. Saeki, N. Oritani, T. Yamashita, K. Goto and Y. Muraki

Offshore structures for petroleum extraction in Arctic regions are subject to great stresses from sheet ice. These stresses are influenced by the properties of the ice. There are few laboratory data for such properties and they are of limited value for accurately estimating these stresses; collection of data in the field is presently difficult, because equipment for directly testing the properties of interest is heavy and bulky. Tentative results are presented for the relations between those properties which can be conveniently measured in the field and the dynamic elastic modulus of ice.

The vibration test using a dynamic elastic modulus meter has been established as the best non-destructive testing method for predicting the strength and static elastic modulus of concrete from its dynamic elastic modulus. In the present experiments, a dynamic elastic modulus meter was used to induce vibration in an ice specimen and to detect its resonance frequency. From this, the dynamic elastic modulus of the ice specimen was calculated from the theoretical relation. The shape of the ice specimen was cylindrical (10 cm diameter and 20 cm height), and comprised sea ice produced from artificial seawater, with 2.1 to 11.4% salinity, and a temperature of -3°C to -10°C. After the vibration test, the uniaxial compressive test (using the conventional method) was carried out on the same ice specimen to measure the compressive strength and the static elastic modulus at a strain rate $\dot{\epsilon}$=0.001/s. Thus, the existence of relations between the dynamic elastic modulus and the uniaxial compressive strength and static elastic modulus were established.

Generally, the main factors influencing the strength and elastic modulus of sea ice are grain size, ice quality (whether it is granular or mosaic), brine volume (salinity), air content, ice temperature and loading direction in relation to the direction of ice growth. However, as noted by the senior author, the strength and elastic modulus of sea ice are most greatly influenced by the temperature, salinity and density of ice. The following relations were observed upon analysis of the results of the vibration tests described above.

1. The dynamic elastic modulus E_D decreased as the salinity (S) increased and the ice temperature (T) decreased.
2. The uniaxial compressive strength σ_c and the static elastic modulus (E_S) decreased as the salinity (S) increased and the ice temperature (T) decreased.
3. At this time the data are too few to draw more than a rough conclusion about the relations between the dynamic elastic modulus (E_D) as found by the vibration test and the uniaxial strength(σ_c) and static elastic modulus (E_S), but there appears to be a consistent relation of non-linear character.

From the above results it was concluded that the uniaxial compressive strength and the static elastic modulus may be determined from only the dynamic elastic modulus, though further studies must be made to elucidate the exact relation. There is no dependence on the temperature, salinity, or ice growth direction. Finally, the total weight of the equipment used for the test, namely the electric ice drill, ice cutter, dynamic elastic modulus meter, electric generator, and hand tools, was ~170 kg. Because of the low weight of the testing equipment, this method to measure the uniaxial compressive strength and the static elastic modulus of sea ice is recommended for its convenience for work in ice fields under severe climatic conditions.

Hiroshi Saeki is a Professor at the Engineering Department of the Hokkaido University (Nishi 8-chome, Kita 13-jo, Kita-ku, Sapporo 060, Japan). He is a specialist of ice engineering, coastal engineering, and port and harbor engineering. He has published five books and more than 500 papers.

Design and Construction of Permafrost Dikes, Pond Inlet, Northwest Territories

R.H. Boon and L.B. Smith

The hamlet of Pond Inlet is located at the north end of Baffin Island in the Northwest Territories, and is ~700 km N of the Arctic Circle. The area is underlain by permafrost. In order to provide a long term, year round water supply for the hamlet, it was decided to raise the level of the existing water supply lake. This required the construction of earthwork dikes ranging up to 4 m in height along one side of the existing lake.

In conventional construction practice, the dikes would be constructed of silty clay or other impervious material, compacted at or near optimum water content. In this case, however, the most suitable material available was a silty sand till which contained significant excess ice and which was extremely wet and unstable when thawed. It was not possible to drain and dry this material during the short cool summers. It was therefore proposed to create a saturated, frozen core within the dikes in order to make them virtually water tight. The core was constructed using thawed, wet silty sand which was keyed into saturated frozen soil below the dike centerline. The silty sand was permitted to freeze during one winter and then it was capped with extruded polystyrene insulation and granular material.

Past experience at a number of northern locations has indicated that in order to maintain the watertightness of such dikes in the long term, it is essential to prevent seepage water from flowing through the silty sand core. Seepage water which flows through or over the top of the frozen core during the thaw season usually concentrates at a particular location. The flow of water results in thermal erosion and the creation of a deep thaw-channel within the dike. This channel may or may not refreeze during the following winter. In any event, the seepage channel will be subject to cyclical freezing and thawing, which frequently leads to a significant increase in permeability and increased seepage losses over a period of years. In order to ensure that the dike would remain watertight, a membrane liner was incorporated into the core of the dike to prevent seepage water from flowing over the top or through the frozen core.

The soils in many other areas of the Northwest Territories are similar to those found at Pond Inlet. It would, therefore, be possible to use a similar design for the construction of sewage lagoons and water reservoirs in other Arctic communities.

Bob Boon is a principal of Reid Crowther and Partners Ltd. (PO Box 1259, Yellowknife, NWT X1A 2N9, Canada). Over the past 14 years he has designed a wide variety of facilities in permafrost regions, including subdivisions, water treatment plants, water distribution systems, and sewage treatment facilities for projects located throughout the Northwest Territories.

Bruce Smith is a geotechnical engineer and principal of Thurber Engineering Ltd. (Suite 110, 7710 - 5th Street SE, Calgary, Alberta T2H 2L9, Canada). He has more than 20 years of geotechnical consulting experience in permafrost, and has completed projects in virtually every community in the Northwest Territories. Past projects include water reservoirs, sewage lagoons, pipelines, building foundations, airports and offshore structures.

Effect of Two New Non-Freezing Agents on Concrete Properties

Yoneo Terada

Traditional freeze preventives like NaCl are very detrimental to the higher early strength but lower long-term strength of concrete, corrosion of steel bars, and considerable drying shrinkage of concrete. For these reasons, these agents have been eliminated from the standard specifications of the Institute of Civil Engineering and the Architectural Institute of Japan and are no longer in use. Because concrete making in cold weather requires protection from freezing and an increase in early age curing, a lower ratio of water to cement, air-entraining agents, and air-entraining water-reducing agents have been used to provide the strength necessary to prevent early age freezing due to insulated curing or heat curing.

In rapid succession, recently, two admixture manufacturers have marketed new low-alkali and non-chloride non-freezing agents. These two non-freezing agents reportedly offer important benefits -- lower freezing temperature for concrete, prevention of early age freezing after concrete placement, increased hydration of cement at low temperature -- all without any detrimental effect on long-term concrete durability.

The purpose of the present study was to verify experimentally whether the new non-freezing agents can be used in the same way as the regular air-entraining agents and air-entraining water reducing agent, and if so, to what temperature the freezing temperature can be depressed, and whether concrete durability can be retained. The reported benefits of these two agents would help greatly using concrete in cold weather. Concrete with the two new non-freezing agents and the regular air-entraining agents was tested at low and standard curing temperatures, and the quality of fresh concrete tested. The experimental procedures are as follows:

Materials

Cement: Normal portland cement and high early strength portland cement.

Aggregates: Gravel and sand.

Admixture: Non-freezing agent A and B and air-entraining agent.

Mix proportion

Required slump: 18 cm; Required air content: 4%; Unit cement content: 350 kg/m^3, 400 kg/m^3, 450 kg/m^3, water cement ratio: 37% to 50%.

Curing method

Laboratory tests: ambient temperature of first day was 5°C, and over 2 to 28 d averaged -2.5°C (1 cycle per day was -10°C to +5°C) while concrete test pieces were cured in air. Field tests: concrete test pieces and cores were covered with single layer vinyl sheet for 91 d and cured at average 0°C.

The following conclusions were reached:

1. Concrete made with the non-freezing agents requires less water per unit volume of concrete than that made with the regular air-entraining agents.
2. The non-freezing agents provide normal air entrainment and workable concrete.
3. The compressive strength at every age of the concrete made with non-freezing agents under conditions of standard curing is greater than that of concrete made without the non-freezing agents.
4. The compressive strength of concrete made with the non-freezing agents is greater than that of concrete made without the non-freezing agents at low temperature curing. However, in addition, the compressive strength of most concrete made with the non-freezing agents at low curing is close at every age to that of the concrete made without the non-freezing agents at standard curing temperature.
5. Despite the 28-d daily freezing and thawing cycle (from -10 to +5°C) there was no frost damage at an early age.
6. Under the above curing conditions the non-freezing agents allow the concrete to acquire the compressive strength (50 kg/cm^2) necessary to prevent frost damage at early age in far fewer days.
7. The drying shrinkage of concrete decreases the water content per unit volume of concrete. There was little difference in Young's Modulus between concrete made with the non-freezing agents and that made without these agents.
8. The results of the experiments demonstrate that the non-freezing agents allow the making of concrete in cold weather in far fewer days than otherwise possible.

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Adfreeze Bond Strength and Coefficients of Friction Between Sea Ice and Various Construction Materials

Naoki Nakazawa, Fumihiro Hara, Kunio Enoki, Toshiyuki Ono and Hiroshi Saeki

When sea ice adheres to structures, vertical ice forces are exerted on the structures when water level changes occur. Generally, the vertical forces are assumed to induce only a shear force on the structure-ice interface, but adfreeze bond failure occurs when the shear force exceeds the adfreeze bond strength.

Because fracturing of ice is more easily induced by bending rather than compression, structures having sloping surfaces are usually considered more efficient. The expectation is that the load causing failure in bending will be less than the load associated with crushing failure. The interaction force has two components: a force normal to the surface of the structure and, because the ice is moving relative to the surface, a frictional force. Even for structures with very shallow angles, high friction can increase loads significantly.

Therefore, calculation of ice forces on structures requires the relations between the adfreeze bond strength and the coefficients of friction between ice in various conditions and construction materials.

The following parameters were used in characterizing the experimental methods and in determining adfreeze bond strength: 1. stress rate; 2. diameter of test piles; 3. ice thickness; 4. relative velocity between the ice sheet and test pile at failure; 5. ice temperature; and 6. surface roughness of the materials.

Experiments were conducted using various construction materials in order to evaluate the effects of the following: 1. contact area; 2. normal stress; 3. growth direction of sea ice; 4. relative velocity (i.e. velocity of test specimen relative to the sea ice); 5. water in the sea ice and construction material interface; 6. sea ice temperature; and 7. surface roughness of construction material.

Of the commonly used construction materials for coastal and offshore structures, the following were chosen for both experiments: 1. steel pile-uncoated (uncorroded); 2. steel pile-uncoated (corroded); 3. steel pile-coated with marine paint (INERTA 160); 4. old concrete; and 5. new concrete.

Through six years of experimental studies, the following conclusions have been drawn:

Adfreeze bond strength: In order to establish the experimental method for the adfreeze bond strength of ice, push out, pull out and twist methods were developed during the initial stage of this study. The following results were obtained mainly from the push out method: 1. the three testing methods gave no great differences for adfreeze bond strength; 2. under certain conditions, the adfreeze bond strength of sea ice greatly depends on the surface roughness of construction materials; 3. adfreeze bond strength increases with decreasing sea ice temperature; 4. adfreeze bond strength decreases, approaching a constant ($\pi\Phi$/Dgr>80), with increasing structure diameter; 5. adfreeze bond strength increases, approaching a constant, with increasing ice thickness; 6. adfreeze bond strength is not greatly affected by push out velocity and stress rate.

The coefficients of friction: These were affected by: 1. relative velocity (i.e. velocity of construction material relative to sea ice); 2. sea ice temperature; and 3. surface roughness of construction material. They were relatively unaffected by the contact area, normal stress, growth direction of sea ice, and water at the sea ice-material interface.

Both test results emphasize that the adfreeze bond strengths and the coefficients of friction not only vary with the materials but also depend on the condition of the surface of the material. Thus these two parameters are greatly affected by surface irregularities. Therefore, when similar experiments are conducted in the future, the surface of the test material must be analyzed. Also, it is important to compare results with other studies in order to facilitate the standardization of future tests.

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Low Temperature Fracture Strength of Glass Fiber Reinforced Polymer Composites

Piyush K. Dutta

Glass fiber reinforced polyester resin (GFRP), a thermoset composite, is increasingly used as beams and rods in structural construction. It is manufactured by the process of pultrusion in which the composite is pulled through a metal die. The total glass content varies from 45 to 50% by weight. Its application in cold regions is attractive because of its excellent corrosion resistance; however, its mechanical behaviour at low temperatures is not well understood. This paper discusses the influence of cold region low temperatures on the behaviour of GFRP under compressive loads.

Compression tests were performed on three batches of 38.1 mm diameter cylindrical specimens. One batch was tested at room temperature (24°C), the second at -48°C, and the third was subjected to 100 thermal cycles from +60 to -60°C before testing at room temperature. The test load was applied by a servohydraulic testing machine at a strain rate of 1.6×10^{-4} strains per second in the fiber direction. The results show that on cooling the composite to -48°C, the yield strength increased 28.1% and the ultimate strength 17.1%. The elastic modulus increased only slightly (0.6%).

To provide a relative and quantitative assessment of the brittle behaviour of this material under the three thermally controlled environments an index was defined as the difference between the strain at yield and the strain at ultimate failure. A small difference indicates higher brittleness. On cooling to -48°C, the strain difference between the yield and the ultimate failure decreased 28.2%, indicating, as expected, a more brittle behaviour at the lower temperature.

Following thermal cycling, the yield strength increased 4.1%, the ultimate strength 2.4% and the elastic modulus 6.2%. The strain differential between the yield and the failure points increased 34.6%, showing that the thermal cycling had caused a significant reduction of brittleness.

The compressive load produced major deformation of the matrix in extension in the direction perpendicular to the fiber. Initiation of fiber buckling at the yield point could be observed visually, and was recorded by strain gauges mounted on the specimens. The longitudinal clumps of fibers first split and then burst open, disintegrating the specimen. The violence was greater at low temperature.

Analysis of the results shows that two factors controlled the change of its mechanical properties on cooling: one, the induced residual stresses within the composite as a result of thermal expansion mismatch between its constituents (glass and polyester) and two, the stiffening of the polyester matrix at low temperature. Past experimental data have shown that, on cooling, the elastic modulus of polyester resin increases at a rate of ~12.23 MPa/°C. By superimposing the effect of residual stress on the critical fiber stress derived from Rosen's model of failure by extensional buckling, and assuming monotonic stiffening of the matrix with cooling, the theoretically predicted yield strength at -48°C was 530 MPa. This value agreed within 11.5% of the measured value (475 MPa). The elastic modulus in compression, from the Tsai and Hahn method of computation, was estimated to increase by 0.96%, but the experimental results showed only a 0.6% increase. Considering that the polyester matrix varies considerably in its properties depending on the manufacturing process, the variation of measured data from the theory is within reasonable limits.

Reduction of brittleness following the thermal cycling is expected because of microcrack coalescing. This process removed local stress concentrations and, as a result, reduced brittleness, which is clearly evident from the large (34.6%) increase in the yield to failure strain differential.

Both theoretical prediction and experimental results show that low temperature has beneficial effects for the structural application of glass fiber reinforced polyester composites. At low temperature not only do the mechanical properties improve (for example, compressive strength and stiffness increase) but also progressive thermal cycling reduces brittleness and improves impact durability.

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Rationalization of RCD Construction by Determining Compaction in Fresh Concrete

Makoto Kagaya, Hiroshi Tokuda and Makoto Kawakami

Big concrete dams are commonly built in mountainous regions. In northern Japan, it is very cold with much snow in the winter, resulting in shutting down of concrete placement; the construction cannot be extended. Further, high construction costs and time are spent on materials, formwork, concrete placement, and cooling pipes of conventional concrete dams. So big concrete gravity dams in the cold regions of Japan use the proposed roller compacted dam construction (RCD) method. In this method the concrete is a lean mix with extremely stiff consistency, and is transported by dump truck, spread by bulldozer, and compacted by vibratory rollers. Savings over conventional concrete are considerable.

The major problem in using this method is that there is no simple and precise method to judge, quickly, whether all parts of the concrete lift in the vertical direction are satisfactorily compacted. As a result, trial concrete placements are supposed to be carried out in a test yard and the compaction method decided from these placement results. Big savings could be realized by developing appropriate compaction techniques.

In this study, the concrete used coarse aggregate (80 mm maximum size) which was screened to 40 mm sieve. The VC value and water:cement ratio were 20+/-5 s and 80%, respectively, following practical considerations. Specimens were 75 x 75 cm in cross section and 30 cm high. The pore water pressure gauge (ϕ40x62 mm, maximum capacity 2kgf/cm^2) was attached to the end of a steel pipe (ϕ4x100 cm) and was located ~1 cm above the centre of the bottom of the cross section. The pore pressure (cement paste pressure) was measured as a function of vibrating time. The pipe could be pulled out easily after compaction and reused.

The specimen was compacted in one layer by a surface vibrator and the vibrator was moved systematically. The characteristics of the vibrator were: frequency 50 Hz; amplitude 0.2 cm; weight 38 kg; size of compaction plate 14.5x14.5 cm. The frequency and amplitude correspond to the characteristics of vibratory rollers used in the RCD construction method.

In order to measure the compressive strength and density in the upper and lower parts of the specimen, two specimens were prepared for a given compaction level and 10 cm diameter cores cut at right angles to the placement direction. After a 28-d curing period, the density was measured and a strength test carried out.

The cement paste pressure at the bottom of the concrete increased only a little during the early compaction stage, but subsequently increased rapidly and attained a maximum value, before finally decreasing.

The compressive strength in the upper part was higher than that in the lower part during the early compaction stage. Both values increased with vibrating time and then reached a maximum value almost equal to the standard value. After this stage, only the value in the upper part started to decrease, eventually becoming lower than that in the lower part. The density in both parts exceeded the standard value when the compressive strength reached the maximum, and then increased gradually.

The vibrating time required to reach the maximum pressure was nearly equal to the time needed to reach maximum strength. Therefore, the compaction state under the amount of compaction applied was judged unsatisfactory.

It is concluded that more research is needed to determine the degree of compaction for RCD concrete using a pore water pressure gauge and practical compaction effort, the method of setting the gauge and its simple installation. By using this method, however, further rationalization of RCD construction and shortening of the construction period are expected.

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Durability of Asphalt-Mats Used for Increasing The Coefficients of Friction between Offshore Concrete Structures and Rock Mound

Yuzo Mizuno, Yoshiaki Sugimoto, Masashi Takahashi and Shinji Kuwabara

Concrete caissons for breakwaters and offshore structures are usually mounted directly on rock mound, but if an asphalt-mat is laid between the concrete caissons and the rock mound, the coefficients of friction can be increased. As a result, more economical structures are possible. Asphalt-mats are a valuable design feature for gravity-type maritime structures, constructed in cold regions where the presence of floating ice and severe wave conditions present a hazard. For the past ten years the authors have been conducting experiments on the coefficients of friction (static and kinetic) between asphalt-mats and concrete plates; tests on the mechanical properties of the asphalt-mats (i.e. compression, bending, shear and tension tests); and tests on the physical properties of the asphalt absorbed from the asphalt-mat (i.e. softening point test, ring and bail test).

The investigations included changes of the above characteristics between the time of the manufacture of the asphalt-mats and the time of the test on the asphalt-mats after they had been mounted on the seabed for a certain time:

1. The coefficients of friction between the asphalt-mats and the concrete plates.
2. The mechanical properties of the asphalt-mats.
3. The physical properties of the asphalt absorbed from mats.

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Durability of Coated Steel in Sea Ice Regions

Y. Kariyazono, H. Katoh, K. Sato, F. Ohtsuki, K. Goto and H. Saeki

Polyethylene and polyurethane coatings are now widely applied to steel piles. In sea ice regions, these coatings are subject to ice attack and experience ice forces, abrasion and adfreezing. However, these actions on coatings have yet to be clarified. Adhesion strength of these coatings by sea ice was found to be the smallest among concrete, uncoated steel and other coatings systematic experiments were carried out with the following results.

The test specimen was coated and the steel plate uncoated. Sliding abrasion tests were conducted for specimens with a reciprocating abrasion type wear tester. The sea ice plate was set on the reciprocating bed and the specimen placed on the sea ice plate at a relative abrasion velocity of 5 cm/s under a vertical stress of 0.98 MPa at -20°C and -10°C. From the result of observations of sand in sea ice from the Okhotsk Sea, the maximum concentration of sand was 0.4% with maximum grain diameter 0.15 mm. Hence sea ice containing 0.4% fine sand of 0.14 mm in average diameter was used, and the results compared with a sample without sand.

The results show that wear behaviour using sea ice without sand had two stages. At the first stage, at 1 km, the wear increased according to the sliding distance. However, the second stage from 1 to 2 km was steady state and wear increased less than that of the first stage and the wear rate depended on surface roughness. After sliding 2 km, the wear of low density polyethylene (LDPE) and polyurethane (PU) coatings was ~0.08 mm, which was the smallest among the specimens tested. The larger the ice pressure the larger the wear of the LDPE coating. At -20°C, wear under ice pressure of 0.98, 1.96 and 2.94 MPa were 0.0029, 0.0069 and 0.0162 mm, respectively. Wear behaviour using ice with sand also had two stages. Rapid wear occurred at the first stage, at the end of which the wear of the LDPE was 0.0058 mm, the smallest among the various materials studied. Wear of high density polyethylene (HDPE) and PU coatings, uncoated steel and Zebron coating were 0.010, 0.024, 0.010 and 0.080 mm, respectively. At the second steady state stage, the wear rate of uncoated steel was ~0.014 mm/km which was the smallest among the various materials tested. Uncoated steel cannot be employed because it corrodes too easily in sea water. The wear rate of PU and Zebron coatings was 0.016 mm/km which was the smallest among various coatings and concrete. From the results of a further experiment, the wear rate depended on concentration and diameter of sand in the sea ice. The larger the amount of sand or the greater its diameter, the larger the wear rate of concrete, LDPE and HDPE coatings, at steady state.

In conclusion, PU and LDPE coatings were suitable for use in sea ice regions. However, as the wear rate of these coatings depends on the concentration and diameter of sand, further observation of sand in offshore sea ice is necessary.

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Design Methods for Intake Pipes in Culture Fisheries in Cold Regions

Takashi Terashima, Naoki Nakazawa, Shigeki Sakai, Toshihiko Yamashita and Hiroshi Saeki

Recently, the needs of culture fisheries are increasing in the northern part of Japan because of the restrictions on open-sea fishery areas. For the design of the facilities for fish culture in cold regions, the influence of waves, water temperature and sea ice all have to be considered. In order to design an intake pipe especially, the following information is required:

1. the depth of air bubbles in the incoming sea water as the result of breaking waves;
2. the effects of low sea water temperature; and
3. the ice force on the intake pipe.

Air bubbles coming into an intake pipe sometimes cause damage to the intake pump. Experiments were conducted to estimate the underwater depth of the incoming air bubbles so as to determine the best location of the intake pipe. The sea ice regime in the coast of Hokkaido was also examined. From experimental results and the observation of sea ice, the underwater depth of the intake can be determined so as to avoid the effects of both air bubbles and sea ice. Recommendations concerning ice forces for the design of the intake are also presented.

A two-dimensional waterway was used in the experiments: depth 0.8 m; width 0.4 m; length 24 m. The slopes of the bottom of the waterway were 1/30 and 1/50. The depth of the air bubbles were measured by a video camera and by visual observation. It was determined that the depth of air bubbles depends on the forms of the breaking waves, on wave height, and on the structure of vortexes. The relations between the depth of the air bubbles and the forms of breaking waves, the slope of the sea floor, and the slope of offshore wave shapes were all determined. Using this data it is possible to predict the depth of air bubbles.

Experiments were also conducted using the waterway and boards (width 39 cm; thickness 1.5 cm) to observe the movements of ice floes caused by wave motion. The length of the boards, the periods of the waves, and the wave height were all changed to clarify the effects they had on ice movement.

Further, equations were proposed and compared, and the ice forces on the intake calculated.

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Mathematical Models for Forecasting Mechanical Failure in Forest, Mining, Road and Railway Vehicles Working in Cold Regions, Heilongjiang, People's Republic of China

Liang Zhaochun, Wang Luyi, Wei Wenchun, Chen Yingjie, Wu Jie and Yang Lina

This paper reports a 12-a statistical research program on the low-temperature mechanical failure of forest, mining, road and railway vehicles in Heilongjiang Province. The purpose of the research was to find a way to predict low temperature failure in this cold region. Previous studies on typical cases of low-temperature failure concluded that most of the failure occurred without obvious prefailure signs. To estimate the probability of failure, statistical methods were used. The analysis on accumulated data discovered a regularity of the failure in relation to the time of service and the average working temperature.

This made it possible to establish mathematical models that may help predict possible failure. To assure that the models are practical, an analog test was made to determine the difference between the calculated results and field-reported data. The check showed a maximum error level of +/-8.12%, which is acceptable for practical purposes.

These models may also be an aid in manufacturing, in storage control and in maintenance planning. The models may be run on computers, and some of them are listed below:

1. R-AT
   R(AT)forest=0.5194 + 0.0166at
   R(AT)road=0.6527 + 0.0130at
   R(AT)mine=0.5293 + 0.0164at
   R(AT)rail=0.9731 + 0.0009at
2. R-T
   $R(T)forest=1-0.39894exp[-0.5(T-49.2136)^2/13052.424]$
   $R(T)road=1-0.39894exp[-0.5(T-93.1663)^2/1032.882]$
   $R(T)mine=1-0.39894exp[-0.5(T-50.4111)^2/3101.366]$
   $R(T)rail=0.39894exp[-0.5(T-1779.29)^2/1677478]$
3. F-AT
   F(AT)forest=244.0416 + 13.9758at
   F(AT)road=132.6385 + 6.4165at
   F(AT)mine=245.8772 + 13.5856at
   F(AT)rail=7.3515 + 0.2445at
4. F-T
   $F(T)forest=58.25 + (T-263.57)^2/132.95$
   $F(T)road=35.19 + (T-438.80)^2/709.19$
   $F(T)mine=65.11 + (T-232.24)^2/93.44$
   $F(T)rail=3.980 + (T-3778.12)^2/790129$
5. F-T
   R(T)forest=0.7961 + 0.0011F
   R(T)road=0.9199 + 0.0020F
   R(T)mine=0.8069 + 0.0011F
   R(T)rail=0.9932 + 0.0024F

where:
   R = reliability (0-1)
   AT = average temperature (°C)
   F = times of failure (n)
   T = length of intervals (MTBF,h)

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Ultra-High Pressure Arctic Natural Gas Pipelines, Canada

Graeme King

Ultra-high pressure pipelines are defined in this paper as operating at pressures >15 MPa, which is almost twice the pressure normally used for the long-distance transport of natural gas. The concept has been developed in an attempt to satisfy environmental, engineering and economic constraints of Arctic regions. It arose out of earlier work on the dense phase transmission of natural gas at temperatures in the vicinity of -80°C and at conventional pressures (Katz and King, 1973). Dense phase transmission is achieved by operating at ultra-high pressures rather than very low temperatures, and the advantages of carrying richer gases is explored in greater depth.

Oil and gas reservoirs in the Canadian Arctic contain intermediate weight hydrocarbons such as ethane, propane and butane which are difficult to carry in conventional oil and gas pipelines. At normal pressures they cause vapour problems if they are included in the oil stream and they cause liquid problems if they are left in the gas stream. But at ultra-high pressures they can be commingled and transported successfully as a single dense phase. This eliminates the need for a separate gas liquids pipeline or for re-injection facilities.

Ultra-high pressure gas pipelines have several other features which make them well suited for Arctic service. For example, they require smaller diameters than conventional gas pipelines carrying an equivalent amount of gas. This makes them more flexible and better able to conform elastically to differential movements caused by thaw settlement and frost heave (King, 1990). They also have thicker walls which make them more robust and better able to resist ovalling and buckling under extreme bending stresses.

More important, however, at ultra-high pressures natural gas flows at a constant temperature and does not exhibit the marked Joule-Thomson cooling effect characteristic of conventional gas pipelines. Ultra-high pressure gas pipelines, therefore, can be designed to flow at or near ground temperature like the Norman Wells (Northwest Territories) oil pipeline and advantage can be taken of the experience gained from its successful operation in permafrost terrain.

Physical comparisons between a wide variety of ultra-high pressure and conventional pipelines were made using consistent and accurate thermodynamic properties calculated from the BWRS equation of state, which is one of the most reliable techniques for predicting gas and liquid densities with the accuracy needed to make fair comparisons between the different systems.

Results show an ultra-high pressure pipeline would use a similar amount of pipe steel and station power as an equivalent conventional gas pipeline with a separate gas liquids line. It is therefore concluded that ultra-high pressure pipelines deserve serious consideration for transporting natural gas from the Arctic because of their better environmental acceptability and durability.

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Rural Gasification in Alberta, Canada

R. Bruce Partington

Eighteen years after its 1973 initiation, the Alberta Rural Gas Program has expanded to service 130,000 domestic, commercial, industrial and farm consumers who use gas for their homes and business and for such specialized farm applications as irrigation and grain drying. It comprises of a gas pipeline network of >90,000 km spread over 250,000 km^2, the populated rural area of Alberta. Recent surveys indicate that this program, which has now made natural gas service available to all rural Albertans, is unique on a world-wide scale.

One of the main reasons for the program was the need to provide a reliable energy supply to residents in one of the coldest regions in the world.

Natural Gas Cooperatives

Based on their success during the 1960s, the government initiated the program by facilitating the formation of additional farmer-owned Rural Gas Cooperative Associations to install and operate gas distribution systems. Under this type of organization whole communities of energetic individuals pulled together to volunteer thousands of hours of time to make this dream a reality. At present >70 cooperatives operate gas distribution systems within large franchise areas.

The success of the program was due in part to many innovative techniques and materials that were developed or utilized in the construction of these rural gas systems. Without the imagination and innovations of many inspired individuals, the size and effectiveness of the program would have been less significant.

Crawler tractors with a specially designed hollow plow (ripper tooth) that could install coiled lengths of pipe at depths of ~1 m was one example of new equipment that was important to the success of the program. This plow-in technique was used to install ~90% of the pipeline system.

The arced lead rod on water-crossing push equipment was another. This equipment enabled contractors to economically thread pipelines under creeks and canals with minimal soil disturbance.

The Alcan Aluminum Corp. developed an aluminum pipe product suitable for high-pressure natural gas applications. This new cost-effective product could be coiled for plowing in continuous lengths of up to 1.8 km, depending on diameter.

Several other factors have contributed to Alberta's ability to develop its rural gas system. One was the availability of plentiful and reliable supplies of natural gas in most regions of the province via a province-wide gas gathering and transmission grid that currently totals 120,000 km of pipeline. Because supplies under the program are intended for domestic consumption, rural gas coops have relied primarily on the NOVA Corporation, Alberta's major gas transmission company and transportation grid, and on transmission pipelines owned by Northwestern Utilities and Canadian Western Natural Gas, Alberta's two largest gas utilities, for their gas supplies.

The need to acquire easements at virtually no cost was seen as critical to the success of the cooperatives, because the addition of land costs would have raised system costs well beyond the threshold the government was willing to support. The coops were successful in convincing land owners to grant easements for the nominal sum of $1 and to date have acquired ~190,000 easements on this basis.

A government agency was also set up as a natural gas broker to negotiate the purchase of secure gas supplies for the rural gas distributors. This agency, referred to as Gas Alberta, pools the purchase costs of this energy supply and in turn sells gas to all distributors at a common price.

Currently, Gas Alberta acts as a purchasing agent for 88 gas coops, municipal gas utilities and Indian bands. This represents an annual supply pool of ~450 M $m^3 x 10^3 m^3$ delivered through 725 meter stations located throughout Alberta.

By 1983, just ten years into the program, energy cost savings by the participants in the program had offset the capital cost of the systems. As these substantial savings (currently $150 M/a) will remain in effect, the participants of this program will continue to reap the benefits of an infrastructure built by an innovative group of Albertans. This success story is one of which rural Albertans can be proud of.

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Gas Pipeline Renewal by Insertion in Cold Climates

Hayat Ahmad

In 1986, Northwestern Utilities Limited (NUL) decided to replace its ageing low-pressure, steel pipe system comprising ~200 km of main, and was faced with the challenge to minimize inconvenience to its customers given the need for continuity of gas supply in this cold region of the continent.

It was particularly essential that gas service not be disrupted in cold weather. NUL developed suitable work schedules to accomplish this, which meant that the construction period fell between May and November. Related activities were analyzed by a Critical Path Method. It was estimated that most customers could tolerate 8 h as the maximum length of gas disruption because this period was not sufficient to freeze the houses. Heat loss calculations were done. Field temperature measurements showed that typically the house temperatures remained between 10°C and 15°C after 8 h of gas shut off in November, the coolest month in the construction period. To reduce discomfort to the customers, shorter work days were planned by cutting the daily job size to half a block instead of the usual full block. This ensured that gas disruption was <5 h in the worst case. With falling temperatures, polyethylene pipe becomes harder to work with due to loss of pliability; it is recommended that when temperatures dip to 0°C, the polyethylene pipe be heated to 20°C before being fused together. NUL is currently replacing pipe by a new technique, termed dead insertion (Ahmed, 1990). Insertion can save up to 40% of construction costs, even though the old steel pipe (casing) is abandoned in place in the ground; indeed, it serves as a shield against future construction damage to the plastic pipe. In cold climates there is a special problem encountered in replacing pipe by insertion. Surface water or groundwater in high water-table areas finds its way into the casing pipe through corrosion holes, cut points or through the fittings on the casing. This water becomes trapped in the cavity between the plastic pipe and the steel casing. As the ground starts to freeze in winter, water becomes ice. The specific volume of ice is ~10% higher than that of water. The modulus of elasticity of steel pipe is ~207 x 10^3 MPa, whereas that of PE 2406 pipe is ~620 MPa (flexural modulus of medium-density polyethylene pipe is ~861 MPa). As a result of expansion of water by freezing, the plastic pipe yields to accommodate the ice, whereas the steel pipe expands by only a negligible amount. NUL determined that if the ratio of cross-sectional area of the plastic pipe to the internal cross-sectional area of the casing pipe is 30%, deformation of plastic pipe is in some cases negligible and in others severe. It was further observed that if this ratio is 40%, there is no collapse of the plastic pipe.

As a result, NUL developed the concept of double insertion. Working with the plastic pipe manufacturers, NUL designed low-cost, special size plastic sleeves that can be used in conjunction with the carrier (plastic) pipe. Sleeving provides not only freeze protection, but also protection against gouging of the carrier pipe during pushing.

By using the sleeve as a complement to the insertion technique, NUL will save ~$10.5 M on its expected expenditure of >$100 M on the Edmonton project alone.

Reference:

Ahmad H. (1990) Gas Pipeline Renewal - Insertion Technology. Gulf Publishing Company, Houston, Texas, pp. 68-78.

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Gathering of Oil and Gas in Winter: Daqing Oilfield, People's Republic of China

Wang Demin

The paraffin content (~27%) of Daqing crude oil and its pour point (28°) are high, and the paraffin precipitation temperature is also high (~37°C, which is higher than the highest ambient temperature in summer). The ambient temperature in winter can reach a low of -40°C, and so the difference between the pour point of the crude oil and the lowest ambient temperature is >60°C. Therefore, it is difficult to gather the produced fluids from the wellhead to the metering station economically (i.e. with a low consumption of energy) and in safety. Daqing Oilfield has adopted several methods to gather the produced fluids, with quite good results. On condition that the water cut is <60% and the production rate low (200 t/d), the main methods were to heat the produced fluids to >45°C. For this method water jacket heaters to heat individual wells were developed and adopted, but the consumption of energy was high and it was hard to service so many units. Therefore, methods were developed and adopted to centralize the management and to control the heating at the metering station, including dual water-mixing and oil-mixing systems and a three-pipe heat-tracing system. The capital cost of the former was lower but was more difficult to manage and the measured water cut of the produced fluid was not accurate; the latter has the opposite characteristics. When using the above centralized heating for the gathering systems, the consumption of gas burnt to heat the fluid was 20 to 25 m^3/t of crude oil produced. In order to lower the consumption, from 1980 on, wells with produced fluids with high water content (>60%) and high production rate (>100 t/d of fluid) were left unheated or heated only periodically. Now, in Daqing, >70% of the produced fluid is unheated throughout the gathering system. In addition, after developing and adopting several methods to lower the fluid temperature when removing water from the crude, the consumption of gas burnt during heating was lowered to 10 to 12 m^3/t of crude oil produced. The results are very good.

Laboratory experiments showed that before the water cut reaches 60-65%, the state of the produced fluid is a water-in-oil emulsion, and the viscosity of the fluid increases with higher water cut; once the water cut is >60-65%, the produced field is an oil-in-water emulsion and its viscosity decreases rapidly with the increase in water cut. Laboratory experiments and field tests proved that a strong magnetic field lowers the viscosity and the amount of paraffin that is precipitated, and the lower the water cut of the produced fluid the better the results. For a produced fluid with a water cut <30%, the resistivity of the fluid flowing in the pipeline can be changed from 30% to 80%. Field tests showed that if a gathering line is plugged, use of an alternating current is a good method to heat up the fluid and restart the well. To heat up each meter of gathering and transmission line requires 70 W of electricity, and if the voltage capacity of the transformer is 600 V, it can heat up to 1000 m of gathering and transmission line.

These measures showed very good results in the Daqing Oilfield, and are also of value to the gathering and transmission of high pour point crude in oil fields situated in frigid zones.

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Polar Gas Pipeline Systems, Norilsk Industrial Region, Siberia, U.S.S.R.

V. Kharionovsky

In the polar regions, natural gas is the most reasonable and ecologically significant fuel. Therefore, the problems of its transportation to end users, including construction decisions and operating conditions, are of particular importance. To maintain continuity of power supply in the Norilsk Industrial Region, the region is supplied by the Soleninsk-Messoykh-Norilsk gas pipeline system, incorporating several gas fields, a multistring gas main that crosses large rivers, gas-condensate conditioning units, and gas-distribution stations. The system is constructed and operated in harsh climate conditions, with an 8-9 month winter and absolute minimum temperatures of -57°C. The main pipeline route includes regions of permafrost with extensive ice inclusions, and is considered to be highly susceptible to heaving.

Due to these conditions the industrial structures and gas pipelines are built on pile supports so as to protect the natural conditions of the tundra. As for the gas main, of particular importance for the span between supports is the use of rectilinear layers with slightly bent compensators. Practical experience during construction of the first string of the gas main and full-scale tests have allowed optimization of the length of the span. The reliability of independent gas pipelines is estimated on the basis of the 'pipeline-pile support-permafrost' system. For this purpose the following studies have been carried out:

1. the development of the initial requirements for pipes and welds;
2. metal analysis of pieces cut out from the gas pipelines with different service lives;
3. the analysis of the stability of pile supports for gas pipelines, tanks and industrial buildings; and
4. the development of piles resistant to soil heaving, and supports with low friction. For buried pipelines laid in flood plains, protection from heaving requires several technical decisions including antiheave soil cuts, heating the gas during the seasonal soil freezing, and changing the flow over to the reserve.

During pipeline operation it is necessary to monitor both the critical points of the gas pipeline and of individual installations using telemetry. This enables the operators to control frost soil effects (temperature condition, heaving forces), and check supports and the level of stressed state of individual installations. Special attention is paid to monitoring underwater pipeline sections with respect to controlling their position (with the help of datum marks), the use of design decisions for strengthening pipelines near river banks, and the use of special transducers for controlling the freezing of the pipeline surface when the temperature of the transported gas is below freezing.

Other matters of concern include evaluations of the reliability of the gas complex as a whole, the description of optimal operating conditions under failure, and the grounding arrangements for pipe connections between strings. Based on the promising development of polar gas strings already constructed, preliminary results are given of the full-scale tests being conducted on a 1.42 m diameter gas pipeline several kilometers in length. The test pipeline was constructed using different methods including above-ground, semiburied and buried pile supports.

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Technology and Organization of Oil and Gas Pipeline Construction, Western Siberia, U.S.S.R.

Rezo Gabelaya

Western Siberia (Tyumen and Tomsk provinces) is the main oil and gas producing region of the USSR. The region is characterized by a severe environment, extremely unfavorable construction and geological conditions, and low population density, leading to complications for construction and building. The Western Siberia lowland is ~2500 km from north to south and ~1500 km from west to east, and the region can be conditionally divided into three climatic zones: polar, taiga and the south.

The development of the oil and gas producing region occurs in the polar and taiga zones, with 70% of construction taking place in the taiga. In winter the temperature drops to -40°C, the depth of frozen soil is 1.5 m, and the maximum depth of snow is 100 cm.

Most construction (up to 70%) takes place in winter while the soil is frozen, thus allowing heavy equipment to move on bogs and lakes without specially constructed roads. Moreover, winter time is more preferable than summer from the ecological point of view. During the summer it is necessary to bring soil for the construction of temporary roads. Trenching for pipelines is made by backhoe. Preliminary ripping of the soil is done by explosives or mechanical units. Bucket-wheel trenching machines are only used while digging dry soil. Pipeline backfilling is commonly made using frozen soil, hence the necessity to rip the soil beforehand.

Coating of large diameter pipes is done in the field using polymer tapes. In contrast, small diameter pipe coating is done in the factory using tar polymer material. When it is necessary to apply coating under field conditions, pipes are first dried and then heated. Trench-bottom padding by soil protects the coating from damage. Nowadays foam material is generally used as a padding.

Reinforced concrete "set-on-weights" or screw-in and expanding anchors are used for fixing pipelines to the bottom of trenches in rivers and lakes. For anchor installation the soil is thawed using specialized equipment. In the polar tundra zone with permafrost, pipeline construction can be carried out only in winter.

To minimize the scope of works along pipeline routes, industrial methods of pipeline construction are in wide use in Western Siberia, especially in the polar zone. For example, in order to avoid machinery starting in the morning at the lowest temperature and to keep up a high rate of construction, it is necessary to work 24 h/d. There are two shifts of 12 h each.

Because such a construction pace under extreme conditions causes rapid tiredness of personnel an "expedition" method is used, whereby the working staff are replaced every two weeks by a new crew, following a two-week rest. To ensure complete rest, working staff are flown home.

The experience gained shows that long spells in changing climate conditions have an unfavorable influence, and so extension of shift time is under consideration.

To reduce the tiredness of the staff during the working day, breaks for lunch, rest and listening to music are recommended. The schedule of breaks depends upon the profession of the worker.

A 24 h operating day results in more wear of machinery and shut-down of equipment. To avoid idle time in case of shut-down, the method of spare machinery and equipment and running repairs are widely used.

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Optimization Research on the Insulation and Burial Depth of Pipelines in Seasonal Frozen Soil Areas, People's Republic of China

Shen Zhongbao and Sun Weimin

At present, pipelines are the chief means of transporting oil by land. Owing to the effects of low temperatures and frozen soil, there are serious losses of the oil in gathering and transporting pipelines. As a result, there is frequent solidification of the oil and transportation ceases. However, increasing oil temperature by setting up heating stations along the pipelines results in a waste of both energy and capital investment.

Starting systematically, the study analyzes gathering and transportation pipelines buried in frozen soil areas and points out that the heat resistance is a reasonable parameter when considering the insulation condition of the system on the basis of heat conduction theory. The pipeline insulation system consists of pipes, thermal insulation and surrounding soil (including the thawed and frozen zones). The heat loss of oil in the pipelines is inversely proportional to the heat resistance, that is, the bigger the resistance the less the heat loss.

The paper presents a nonlinear programmed mathematical model of the pipeline insulation system using the system optimization method. The key for getting the best insulation results is to allocate the limited investment optimally to the pipelines, the thermal insulation and earthworks, that is, increasing the heat resistance to reduce the energy loss, thus achieving the best investment benefit available.

The insulation optimization model of the pipeline insulation system is as follows:

$$S_{min} = \left(\frac{1}{2\pi\lambda_s} - \frac{1}{2\pi\lambda}\right)\ln K + \frac{1}{2\pi\lambda}\ln\frac{X_2}{X_1} + \frac{1}{2\pi\lambda_s}\left[\arccos h\left(\frac{X_3 + \frac{\lambda_s}{\alpha}}{X_2}\right) - \arccos h\left(\frac{H'}{r'}\right)\right] + \frac{1}{2\pi\lambda_f}\left[\arccos h\left(\frac{H'}{r'}\right)\right]$$

$$S.t\begin{cases}\pi[K_2(m_1 - m_2) - m_1]X_1^2 + (\pi m_2 + 2m_3)X_3^2 + 2m_3X_1X_3 \leqslant G \\ X_1 + B_1 \leqslant X_3 \leqslant X_1 + B_2\end{cases}$$

Where

- x_1 = the inner radius of the pipelines
- x_2 = the outer radius with thermal insulation
- x_3 = the depth of the centre axis of the pipeline
- E_1 = the upper limit of the depth of the pipeline
- E_2 = the lower limit of the depth of the pipeline
- S = high heat resistance of the system
- G = the investment cost of pipe/m

According to the series of parameters, a polyhedron method was used to solve the nonlinear programming problem. After simplifying the system optimization model, the results were obtained by computer and compared with that of the real pipes.

In addition to solving this problem, the converse question can be raised, namely, what is the minimum investment while satisfying the system heat resistance requirements.

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Sun Weimin is an engineer at the Design and Research Institute of Daqing Oilfield. He works on railway engineering and civil engineering designs and permafrost of the Qing-Zong railway, frozen soil in the Daqing area and temperature field of pipeline research.

Peak Day Analysis for Natural Gas Consumption, Alberta, Canada

J.G. Nygren

Peak day analysis is a process whereby peak day load demands are forecast, and pipeline facilities are then analyzed to determine their capacity to deliver the necessary supplies to match the demands. In addition, the sources of supply are reviewed to ensure there are adequate supplies to meet the demands.

Demands are forecast through the use of a computerized "peak demand" program for temperature sensitive customers, and contractual requirements for non-temperature sensitive customers. Supplies are set at levels based on historical experience or contractual obligations. Pipeline facilities are then analyzed using computer simulations to determine their adequacy.

Peak day analysis was conducted for a 6-a period into the future to identify deficiencies, thereby allowing adequate time to plan and implement the necessary improvements.

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Measurement and Regulation of Natural Gas in Cold Climates

W.J. Vornbrock

Celsius or fahrenheit? It does not make any difference at -40°. Humans can be exposed to this environment for only minutes before severe medical problems are apparent, and similarly measurement and regulation devices are extremely vulnerable at these conditions. Add to this wind chill and almost unbearable situations exist for men and machines.

This scenario necessitates critical examination of how measuring and regulating equipment is used in cold climates. Extensive research is needed to evaluate gas line indirect heaters or other antifreeze devices in the gas stream itself; metering accuracy and cold climate capabilities of all associated mechanical and electronic gear is another critical matter; minimum temperature specifications on all equipment is required. Further, the operating and maintenance factors are closely examined to allow reasonable daily operation of these facilities. Finally, at the customer's outside metering, although economical and desirable for many reasons, is not conducive to good measurement.

Many facets of design, construction operating and maintenance must be carefully considered for developing metering and regulating facilities in cold climates. This paper, using real life experiences, will attempt to basically cover many of these facets.

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Local Government Development in Alberta

Archie R. Grover

No abstract available.

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A New Storage System for Agricultural Products, Hokkaido, Japan

Takashi Terashima, Harukuni Tachibana and Hiroshi Saeki

Japan has four main islands: Hokkaido, Honshu, Shikoku and Kyushu, stretching over 3000 km, and through climatic zones ranging from subarctic in the north to subtropical in the south. The climate in Hokkaido, the northernmost island, is influenced by the oceans, i.e. Japan Sea, Pacific Ocean and Okhotsk Sea. In the northern part of Hokkaido, pack ice drifting south from the coastal areas of the USSR can force harbors to close from January until April. The accumulated degree days reaches almost 800 to 1100 degree days on the Okhotsk Sea side during winter. The low temperature and the sea ice close to the harbors causes considerable disadvantages to agriculture and fisheries which are the main industries in this region. This paper presents the results of studies to improve these conditions by considering a new storage system using cold region technology.

The main agricultural products of Hokkaido are potatoes, onions and beets, which account for >30% of the agricultural products of the Island. Agricultural problems awaiting solution are as follows:

1. to overcome the influence of international free trade;
2. to keep the quality of products fresh throughout the winter; and
3. to develop a transportation and distribution system for the wintertime.

In order to retain the quality of agricultural products during the winter, new storage systems are being developed using cold air, snow and ice. The latent heat energy of snow or ice results in suitable low temperatures and appropriate humidity conditions in storage rooms. Experiments using this storage system were conducted with 20 containers and 100 tons of potatoes in the Tomakomai industrial yard. Sea water, frozen in winter by the ambient air temperature, was used as the latent heat energy in summer. The temperature and humidity in the container are kept between 2° and 4°C and 95%, respectively. These conditions in the storage area were expected to retain the good quality of agricultural products.

For the development of Hokkaido investment has to be made in new policies and new technology. In addition to the above new storage system, a new navigation route for the distribution of agricultural products from Hokkaido to the southern market in Honshu has also to be developed.

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Snow Sapporo 21st Century Plan

Masaya Uozumi, Takashi Kawabata, Nobuaki Sakai and Teruo Sugawara

The city of Sapporo is home to 1.67 million citizens who live an active life despite the cold temperatures and 5 m of snow every winter.

Only a little over 120 years ago, Sapporo was an undeveloped wilderness. It has grown, however, into the center of Hokkaido's development. Along with rapid urbanization, came various problems such as population increase, traffic congestion, and lack of urban space. During the four-month winter season, these problems are even more serious. Therefore, in order to facilitate urban functions and to improve the living environment, the "Snow Sapporo 21st Century Plan" was implemented for a ten-year period from 1991 to 2000. There are three main aspects, as follows:

1. Improvement of snow clearing and removing.

   Approximately 50 M m^3 of snow falls on city-managed roads. In order for winter traffic to flow efficiently, it is necessary to remove 30 M m^3, or 60% of the total snowfall. However, considering financial aspects and land available for dumping the snow, step-by-step improvements will have to be carried out throughout the decade. The goal of the plan is to remove 10 M m^3, three times as much as in 1990.

2. Establishment of snow treatment facilities.

   Construction of melting tanks, snow-flowing gutters, and dumping sites is planned. By establishing nine snow melting tanks utilizing sewage treatment water and waste heat from incineration plants, ~3.5 M m^3 of snow will be treated. Snow-flowing gutters, constructed at 11 locations, will cover a total road distance of 45 km. This facility, utilizing treated sewage and river water, is expected to dispose of up to 1 M m^3 of snow. In addition, five multipurpose sites equipped with water quality treatment facilities will be designated on the green belt where urbanization is restricted. They are expected to treat 2.5 M m^3 of snow.

These facilities will make it possible to treat an additional 7 M m^3 of snow, the quantity arising from the improved snow removal standard. In order to safeguard the environment, the city has a policy of treating highly polluted snow at these sites.

3. Partnership between city and citizens

   Improvement in the quality for snow clearing and removal, and construction of snow treatment facilities in the Snow Sapporo 21st Century Plan will be carried out from fiscal year 1991 as far as they are financially and technically feasible.

However, it is also necessary to have the citizens understand how much it costs to maintain the same conditions in winter as in summer, and the limits of the city's budget.

In the areas where demand is high, citizens should be able to choose, for example, whether to pay part of the costs or to provide manpower. They might be charged for snow removal from neighbourhood roads or they could be requested to participate in throwing snow into flowing gutters. In this way, a partnership between the city and the citizens should be established.

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A Proposed Model for Combining Science and Technology with Economy

Zhang Quan

The ultimate aim of undertaking scientific and technological studies is to promote the development of both the national economy and society. In other words, science and technology are the precursors of national economy and societal development. Therefore, it is very important to study the relation between science and technology and the national economy and to find an approach for combining science and technology with economic and societal development.

This paper describes a model for combining science and technology with the economy and society. The model is a closed-loop system composed of research, development, and production, with multi-feedback cost-benefit paths.

Many research institutes of the Heilongjiang Academy of Sciences have been operating in accordance with the principle of this proposed system in recent years. In practice, the system - with its multiphases and multifunctions - works quite well.

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Analysis of the Demand for Winter Outdoor Recreation, Sapporo, Japan

Shoichiro Asakawa

It is very important to participate in outdoor recreational activities to enjoy winter life in northern regions. This study attempts to analyze the demand for winter recreational activities and some of the factors which affect these activities, to enable further planning to be undertaken in Sapporo.

Groups of college students in Sapporo and Obihiro completed questionnaires about their preferences for seasons and their images of the winter season. The year was divided into eight separate seasons, and the students were asked to rate each season according to their preferences. The results showed that the favourite season is early summer and the most disliked season is early winter. The survey also showed that the time of the beginning of each season varies according to season and between Sapporo and Obihiro. When we examined the percentage of respondents who liked the winter season, many more students who enjoy winter outdoor recreational activities and do not mind cold temperature prefer winter. A relatively large number of students from Honshu, mainland Japan like winter because of their active attitude toward winter. With the image of winter by word associations, the survey showed that, although many respondents have a bad image of traffic problems, they have a positive image concerning winter activities, festivals and the winter landscape.

Results of a questionnaire survey of randomly sampled citizens in Sapporo showed that people who participated in outdoor recreational activities (e.g. skiing) were more satisfied than those who did not participate in such activities, just like the students. Using multiple discriminant analysis, the different effects of the classified recreational activities on satisfaction are shown as follows:

$$S=0.1885X_1+0.0546X_2+0.0753X_3+0.0161X_4+0.0143X_5-0.7361$$

Where: S=satisfaction
X_1=Frequency of outdoor sports
X_2=Frequency of indoor sports
X_3=Frequency of other outdoor recreation
X_4=Frequency of other indoor recreation
X_5=Frequency of leisure travel

An analysis by quantification theory 1 showed the relative importance of some variables which influence the five classified activities and skiing. Effects of factors such as the season, day, holiday and weather, on the number of users of lifts in ski areas were also shown.

Based on the questionnaire survey, future demand of main outdoor recreation activities were estimated and the results will be useful not only for planning the outdoor recreation facilities but also for the conservation of natural areas in and around Sapporo.

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Influence of Snowstorms on Regional Economic Activity: Example from Sapporo City, Japan

Hiromasa Chiba and Kimio Taniguti

Snowstorms cause considerable trouble to regional transportation and economic activity during the snow season in areas of high snowfall. For example, snowstorms result in temporary stagnant regional economic activity and increased traffic accidents, whereby the regional economy and social life are damaged. This paper identifies, specifically, how regional economic activity is damaged by the interruption of transportation caused by snowstorms, as well as the loss to the regional economy caused by traffic interruption, using various statistical data and reports on economic activity.

The additional cost of snow to the industrial activity of Sapporo City is estimated to be in the range 15.8 billion yen to 65.1 billion yen per winter, as shown in the following table:

	(billion yen).
Fuel expense	2
Snow removal from parking lots	4.5 - 25.0
Damage from traffic interruption	9.3 - 37.1
Total	15.8 - 65.1

Note: The frequency of snowstorms causing traffic interruptions is estimated at 1-4.
Note: Increased personal expenses as a result of slower delivery times are ignored.

The loss caused by traffic congestion in different industries is as follows: Wholesale and retail businesses 8.8 to 35.2 billion yen; Manufacturing industry 270 million to 1.1 billion yen; Construction industry 30 to 130 million yen; Transportation industry 170 to 660 million yen. The loss due to traffic congestion is the largest factor being ~60% of the entire loss.

The loss in the wholesale and retail businesses is the largest, being almost half the total loss. Also, the industrial profit per day of the transportation industry is smaller than that of manufacturing industry; however, the loss in the transportation industry due to traffic congestion is large compared with the loss in the manufacturing industry.

Analysis of the transportation cost due to snow fall is as follows:

1. Transportation time increases in the winter by ~35%, compared with the summer.

2. About 54% of industries contract the job of removing snow from parking lots. On average, each industry makes snow removal requests 7.6 times per winter, and the cost of each snow removal is ~617,000 yen.

3. The loss suffered by each industry due to traffic congestion is ~28.4% of sales and the monthly loss averages 3.64 million yen.

4. The transportation industry suffers the biggest loss, being ~34% of the daily sales. This is followed by the wholesale and retail industries, with a daily loss of 32%. The manufacturing industry suffers daily losses of 15%, and the construction industry suffers a daily loss of 12%.

Types of losses caused by snowfall and industrial awareness:

1. About 52% of industries are affected indirectly by traffic congestion, ~32% of industries are affected by short term effects on the same day, with ~12% of industries affected in the long term. The transportation industry has a short term effect on the same day of ~44%, which is the highest among all industries. The wholesale and retail industries are most strongly affected indirectly, with 21% of industries being affected in the long term.

2. On average, ~72% of industries are acutely aware of loss due to traffic congestion caused by snowfall, out of which 80% of the transportation industries are aware of the loss due to snow because they receive the strongest direct effect.

3. Regarding snow removal during day time, about half the industries in the center of the city do not prefer it, while ~76% of all industries in the suburbs prefer snow removal during day time.

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Present State of Utilization of Public Open Spaces and Their Future Development, Sapporo, Japan

Hidetsugu Kobayashi and Taku Machida

This research sought to answer how effective public open spaces are, how they influence activities of people in the city centre, and what determines the design and planning of public open spaces in city centres in cold and snowy regions. The following aspects were considered: 1. composition of the space; 2. how it was used; 3. evaluation and awareness of the value of space; and 4. the way it was managed.

The objective of the study was to gather information in order to develop guidelines for future planning of open spaces or space for public use in cities in cold and snowy regions.

Public open space means space in front of a building or between two buildings, that is, space produced by legal setbacks. Hence, public open space is based on building law and urban redevelopment law, and is decided by planning and permits. These aim to make urban space beautiful, to prevent site subdivision, to utilize space in a crowded area, and to use the site rationally.

The research was carried out on ten public open spaces in downtown Sapporo. Information gathering included: surveying the site; observation of the activities of people; and questioning the people using the space. The data was then analyzed according to the three different concepts of space: districts, blocks and sites.

As a result, public open spaces are classified, according to their street-relation in the block, into four typical patterns, as follows: A-type opens on to a single street; B-type opens on to a cross-street, effectively a corner space; C-type is open on two opposite sides in the middle of the block. The C-type is divided into a C(1)-type and a C(2)-type by the proportion of width and length of the public open space. The C(1)-type passes, or seems to pass, through a block. The C(2)-type is a plaza-type, and takes up space in a crowded area. The D-type opens on to three streets, and is the so called edge-type.

Usage of the various types differs: for example, the C(1)-type is mainly to pass through a block whereas the C(2)-type is used both for passing through and resting. There is also ~80% less usage of the latter in the winter, compared to the summer.

The catchment area of the C(1)-type is determined by the pedestrian's origin-destination survey, and is smaller than that of the C(2)-type. If there are major facilities (e.g. subway stations, department stores, entrance to underground mall, landmarks, public facilities) available around the catchment area of a public open space, then the number of people who come is large and the frequency of use high.

Public open spaces include various elements within them. In the C(1)-type, which has a clear, central space, people easily recognize the surrounding buildings and axial space, especially in winter. In the C(2)-type, which has no dominant axis, it is rather difficult for people to perceive the space, especially in winter.

It is concluded that not only vertical views, but also eye-level views (e.g. bird's eye view, unbroken vista) are effective in achieving openness of public spaces. Therefore, the position of the sidewalk is also effective for creating an open function. Thus, the elements felt by people are affected by axis, focus, and orientation. If there are existing major facilities in the catchment area of a public open space, we have to recognize their function and local activity. In winter, it is not possible to avail ourselves of them to rest; one only passes through the block and enters the building directly.

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Riverside Improvement Toward a High Quality of Life in Hokkaido, Japan: - An Approach to Measuring the Benefit

Shuichi Katoh

It has been said that Japan is very successful economically but that the living conditions of the people, notably health and welfare, do not reflect such affluence. Therefore, the government has recently begun to formulate policies toward a high quality society where the living standard of the people will be commensurate with the great economic success of the nation. In the circumstances, the prefectural government and the municipalities of Hokkaido have also initiated attempts to restructure the society through new strategic development planning toward the 21st century. It is particularly essential to note that people in Hokkaido endure a long winter. This makes it absolutely essential that the short summer is beneficially and efficiently utilized toward a high quality of life. Many policies have already been executed. Among them, however, riverside improvement policy has recently changed significantly. Objectives of traditional riverside projects were mainly to prevent floods and to utilize the water for varied purposes. The new trend appreciates utilization of the riverside for the people and consequently new policies and measures have been executed from the viewpoint of a high quality of life, such as maximizing access to the riverside for recreation, even in winter. The riverside improvement considered in this study has features such as embankments with a gentle slope, grass areas, play areas, and cycling and ski courses, and has been applied to the utilization of the riversides of rivers in urban areas in northern Hokkaido. After clarifying the issue of river utilization for the people, an attempt was made to measure and evaluate the benefit arising from the improvement, using multiattribute function ($U=UO + \sum Wi.Xi$) which consists of six living conditions including access to the city centre, convenience of shopping, access to public facilities, and so forth, through a household survey at the Toyohira riverside. From the analysis a unique result has been obtained as shown in the Table, which gave proof of the benefit from riverside improvement toward a high quality of life for the people. The result indicates that the amount of the benefit reaches ~1 billion yen per year in Toyohira River basin. And it is known from the economic and quantitative points of view that the improvement contributes toward promoting attractiveness of the riverside area. This result is also available as a benefit stream in a cost-benefit analysis.

Table 1. Weight of attribute

1.	Access to city centre	1.74
2.	Convenience of shopping	2.60
3.	Public facilities	1.14
4.	Accessibility to riverside	0.79
5.	Sunshine time of living room	1.10
6.	House floor space	0.84

Shuichi Katoh is an associate professor at Otaru University of Commerce (5-21, 3-chome, Midori, Otaru 047, Hokkaido, Japan). He worked for five years as assistant director of the Takugin Research Institute attached to the Hokkaido Takushoku Bank, where he was involved in many research activities concerning regional planning, especially measurement and evaluation of development impact.

A Comparative Study on the Types of Public Space Utilization in Residential Areas, Hokkaido, Japan

Hidetsugu Kobayashi

The research reported here was concerned with common spaces in planned residential estates with detached houses. The analysis and study was conducted from the following viewpoints:

1. the use and typical daily outdoor activities;
2. the contribution to the organization of the local community and an evaluation of its effectiveness;
3. the influence on the local/neighbouring environment;
4. the influences and affects the awareness of the inhabitants had on the living environment.

Also considered was what future space structure of residential areas in cold and snowy regions should be undertaken and how.

The research sites were the O-asa housing estate, Ebetsu City, Bannaguro, suburb of Sapporo City, and Midorigaoka, Asahikawa City. At each site, the common space was evaluated with respect to its value at eliminating through traffic, and segregating vehicles and pedestrians. The research was conducted through observation and questionnaires, and the results were as follows:

Management: The common spaces studied were managed by separate independent bodies: however, summer cleaning and other responsibilities were entrusted to volunteer residents. O-asa depends on an independent body, and the other two (Bannaguro and Midorigaoka) on residential management for snow removal and disposal. This difference affects the usage of the common spaces.

Snow Removal and Disposal: In O-asa, snow is removed by machines to a cul-de-sac, and is accumulated at its end, causing difficulties in accessing pedestrian paths and houses. In Midorigaoka, residents remove snow and accumulate it at hedges. In Bannaguro, the common space is used for snow disposal, and hence no snow removal is carried out.

Some general results are:

1. In the common spaces of O-asa, a few spontaneous activities such as playing and exercising are conducted, although the spaces are mainly used as passages to houses. In the common spaces of Bannaguro, games, exercises, and walks take place during the summer, but the space is used for snow disposal during winter. The common spaces of Midorigaoka are used for parking and as passages to houses, and playing, exercising, walking, conversing and other social activities are enjoyed even in winter.
2. The residents understand that common spaces are effective in forming neighbourhood relationships. Square-type spaces are especially valued because they provide many opportunities to meet people: this type of space allows and encourages a greater variety of activities, even in winter. Also, in the course of their voluntary management of the spaces, the residents engage in communal activities, such as caring for hedges and flower beds, which are effective means of forming neighbourhood relationships.
3. Although all common spaces studied were on government-owned land there was a strong sense of belonging felt among the residents. Square-type spaces, particularly, are considered 'spaces to be shared by neighbouring houses', and they are cared for almost in the same manner as the private land adjoining the houses. Even in a residential area where public and private spaces were distinguished, the square-type common spaces were considered by the residents as having semi-private status.
4. Common spaces from which through traffic has been banned are safe, have a less public atmosphere than streets, and residents around the spaces have a strong sense of belonging. They may be considered medium spaces of creating richer community lives.

The main conclusions of the study were:

1. Residential common spaces were found to be suitable for daily outdoor activities not only in summer but also in winter. However, some problems remain concerning management of the spaces.
2. The common spaces studied may be classified as 'approach type', 'through type', and 'square type' from their shapes. There were differences in the activities held in the spaces, and the evaluation and sense of belonging of the residents varied according to the type of space.
3. The 'square type' proved the most flexible for activities and produced the strongest sense of belonging among the residents. The spaces may absorb and accommodate the various irregularities of adjoining houses, because they stimulate and secure the creation of a neighbourhood living environment.
4. It should prove effective to have a 'flexible agreement' among residents adjoining common spaces concerning the design of houses and the best uses for public spaces, so that they serve to create and enhance neighbourhood social environments.

Hidetsugu Kobayashi is an associate professor at the Department of Architecture at Hokkaido University (N-13, W-8, Sapporo, Japan). His major research is in urban design and planning.

Waskasoo Park, Red Deer, Alberta, Canada: The Conservation of a Unique Natural Resource

Craig Curtis

Waskasoo Park is a unique natural resource within the City of Red Deer, Alberta. The Master Plan was completed and unanimously approved by the City and County Council in 1982. Implementation began immediately and, today, the completed park closely resembles the blueprint outlined in the original planning report.

Waskasoo Park stretches 12 km along the Red Deer River through the city, and comprises >1000 ha of land. It is linked by a comprehensive bicycle/pedestrian trail system which is used for cross-country skiing in winter. This system includes two major pedestrian bridges across the Red Deer River which tie the park together as a total open-space system. Low-key hiking trails have been developed in areas with physical and environmental restrictions. The trail system focuses on historical and environmental features within the areas, and identifies and interprets them wherever possible.

Bower Ponds is the major family recreation facility within the park system. It includes a large, manmade trout pond used for fishing, canoeing and paddleboating during summer, and skating and ice-fishing during winter. A new pavilion has been developed along the water's edge, which includes a concession for food and equipment rental. The historic Cronquist House Multicultural Centre is a unique feature on the site, and a focus of the annual Canada Day celebrations.

The Gaetz Lakes Sanctuary is the major conservation area within the park. This wildlife sanctuary has been retained, enhanced and protected within the city boundaries. Development includes the award-winning Kerry Wood Nature Centre, as well as limited-access interpretive trails and boardwalks within the sanctuary boundaries. Park naturalists operate a wide range of summer and winter programs from this site.

Waskasoo Park is a rare example of a conceptual plan which was implemented with minimum change, over a short timeframe of 5 a. It has preserved the unique natural heritage of Red Deer and, as such, was an appropriate use for funds from the Alberta Heritage Savings Trust Fund.

Craig Curtis is Director of Community Services for the City of Red Deer (PO Box 5008, Red Deer, Alberta T4N 3T4, Canada) and is directly responsible for the coordination and management of the city's Recreation and Culture, Parks and Social Planning Departments. He is a qualified architect and urban designer, and was author of the Master Plan for Red Deer's Waskasoo Park.

Building a Resource Town Community (Swan Hills, Alberta, Canada): Thinking Strategically, Integrating Collaboration

Wm. (Bill) Ashton

Presented by Barry Clark

Swan Hills, a resource town of 2400 people, is a former new town in Alberta. In 1988 the municipal council dealt with significant community development issues that were said to be calling into question the town's future viability. Recognizing that a large number of local and provincial agencies and industries influence their future and recognizing that these agencies needed to be part of the solution, the town requested Alberta Municipal Affairs to assist with a process that could bring all parties together to examine the issues and assess the solutions. The response was a colloquium process, a planning tool for public sector organizations. It was both strategic and interactive to assist in coordinating collaborative actions of the stakeholders to achieve a shared vision for the town's future.

The colloquium approach was a process in stark contrast to how the town was established and generally thought of in 1960. Swan Hills, like many of Alberta's new towns and their counterparts across Canada after WWII, was constructed with the state-of-the-art technology, following proven engineering practices, which reflected a military exercise. This paralleled the setting up of the oil and gas industries surrounding the town in terms of using the most advanced technologies. Just as the oil around the town was thought to run out one day, so would the usefulness of Swan Hills come to a similar end. In many ways, this former new town was struggling with becoming a community that wanted to have a future, but uncertain what it would be or how to define its destiny. Paradoxically, local control of the town's future seemed to be in the hands of others and at the same time in none. The town council struggled with this macabre challenge, as did others.

The colloquium process used in Swan Hills offered a unique, interactive and self-help approach to what would later be regarded as community development. Initially, a process not a product was decided upon. A four month process involved interviews of all the stakeholders (>40 people), an issues discussion paper, a 1.5 d workshop in October 1988, and an action plan document. The entire process was seen as a special type of social interaction that resulted in accommodation of others, shifts in positions on issues, shared image of reality, agreement on goals, willingness to work together and would be ongoing. These characteristics are fundamental of a self-help process to enable individuals to collaborate and to generate solutions to community development concerns.

The application and relevance of the colloquium process for the stakeholders (many of whom were policy decision makers) was assessed immediately after the workshop and again six months later. Positive and noticeable results were evident on issues of delivery of government human services, housing ownership and talks on tax-base sharing. An update, some two years later, also contributed to understanding how this town has been growing, building and moving toward a sense of community. Since then, such a process has been applied elsewhere, and thought appropriate for a wide variety of development, planning and conflict circumstances.

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Community Infrastructure Planning and Management, Iqaluit, Northwest Territories, Canada

K.R. Johnson and J. Cucheran

Iqaluit is a community of 3100 people, located on the south end of Baffin Island, in the southeastern section of the Northwest Territories, Canada. The infrastructure services of the community include water supply, sewage disposal, solid waste disposal, roads and municipal buildings, which constitute an annual operating budget of ~$7 M. The infrastructure development plan over the next 5-a has identified $30 M in capital expenditures.

Iqaluit presently services ~2/3 of the community with piped water and sewage, while the remainder of the community is serviced by trucked water and sewage. Trucked water and sewage services will remain an important service to the community because of the economics of providing piped services to low density housing.

The recent development of a new subdivision in the southeast portion of the community has produced development costs >$65/m^2 for piped services, and $23/m^2 for trucked services. This variation in development cost has created a demand for single-family trucked serviced lots, and has prompted planning of high density development for piped service lots.

The community is currently developing and implementing a management system for the operation and maintenance of the $42.5 M infrastructure in the town. The town has also undertaken a comprehensive review of the operation and maintenance costs to determine an appropriate rate to recover costs, and to establish a reserve fund for future maintenance, upgrading and capital expansion.

The funding for infrastructure management comes from a variety of sources. As a tax-based municipality, property tax and grant in lieu of taxes constitute the majority of the general revenue. Other sources come from sales of services, tariffs, subsidies, grants and debentures.

Funds for operating and maintaining the water, sewer and solid waste systems are received through the application of tariffs. The water tariff is based on the expense of annual delivery of the service divided by the billable metered consumption. The government of the NWT in some instances subsidizes the water tariff for selected groups of consumers. The garbage tariff if based on the cost of providing service divided by the number of annual pick-ups; presently garbage tariffs are not subsidized and that service is strictly a user pay system.

Capital funding is also available from the government of the NWT under its water and sanitation capital program for major new facilities and trunk mains. The town is planning to fund the replacement of its distribution infrastructure through an infrastructure replacement reserve which is a component of the water tariff.

Infrastructure needs of the community have had to be assessed and priorized in conjunction with the priorities of both the town council and the various governmental agencies which have jurisdiction over capital funding. Short-term and long-term needs must then be assessed and priorized.

The town developed a 20-a capital needs plan in 1989, which has benefited both the town and the capital funding agencies. The information from the 20-a needs plan is now carried forward into the framework of the various capital funding agencies through which the capital funding is apportioned.

In many ways Iqaluit has fallen behind in its infrastructure planning due to the cautious transfer of responsibility from the territorial government. Coupled with this has been the high turnover of personnel that the town has experienced during the current growth period. This has resulted in recent projects which have been undertaken on fast track scheduling. However, over the next 5-a the town will move toward establishing phased infrastructure development that will see the projects spread out over a longer time period. Although infrastructure planning and management in the northern regions is especially difficult, given the high costs and limited resources, the difficulties may be reduced if an adequate timetable is established and there is maximum consultation between concerned parties.

K.R. Johnson is a project engineer in the Arctic Engineering Division of UMA Engineering Ltd. (17007 - 107 Avenue, Edmonton, Alberta T5S 1G3, Canada) and is an environmental engineer with 10 years experience on a variety of municipal and environmental projects. He has been involved in projects in northern Canada since 1987.

J. Cucheran is the Director of Public Works for the town of Iqaluit (Box 460, Iqaluit, NWT X0A 0H0, Canada) and has 10 years experience in northern infrastructure planning and project management.

Planning for Sun, Wind and Snow Effects from Urban Highrises to Arctic Communities

Colin J. Williams and Bill F. Waechter

A good understanding of the seasonal prevailing winds is essential when designing buildings or site plans to consider wind effects. Knowledge of the wind directions associated with average and high-speed winds is needed for wind comfort planning. When designing roads, buildings and site plans for snow effects, detailed wind data, which correlate wind direction with occurrences of snowfall and blowing snow, are necessary. Seasonal sun path data are used in site planning to design for solar exposure during the cold months.

When wind strikes a tall building it flows down the building face and accelerates around the windward corners of the building, making these locations undesirable for doors or sidewalks. A low building situated in close proximity and upwind of the same tall building would further increase wind speeds at the pedestrian level. Canopies, colonnades or podiums added to the base of a tall building deflect wind away from sensitive areas near the building. Where significant wind shelter is required at the street level for nearly one city block, wind gates can be used in urban centres. Wind gates (i.e. a tall porous screen mounted on a canopy) span the full width of a street.

To reduce wind activity around tall buildings, the long axis of the building should be oriented with the dominant wind. This 'streamlines' the building shape to the wind, as also would chamfering the windward corners or stepping upper floors, on the windward face, back from the wind.

The exposure of the site to the prevailing winds must also be considered. Open fields upwind of a site offer no wind shelter and retain snow which can be relocated by the wind. Severe snowdrifting conditions could occur downwind of this type of site exposure. Forested areas, rugged terrain, or subdivisions upwind of a site partially reduce wind speeds and retain snow, thereby reducing snowdrift impacts downwind.

Severe snowdrifting conditions are inherent to most arctic communities, where 50 to 150 m long snowdrifts form downwind of buildings. These harsh snowdrift conditions warrant their consideration in community planning, snow management and building design programs. One-storey-high arctic snowfences have been used for community wide reduction of snowdrifts, which can actually bury houses. Snowdrifts which form against a downwind building face can completely block doors. One solution is to raise arctic buildings to provide an open air space beneath, where wind flows through and forms a leeward snowdrift away from the building face. Mounting a wind deflector above the leeward door is an alternative solution.

Snowdrifting in roof steps blocks clerestory windows, skylights or fresh air intake louvers. Roof steps can be oriented to allow wind to remove the snow and minimize snow loads. Parapet walls and canopies reduce ground level snowdrifting due to roof scoured snow. Sloped roofs can create hazardous sliding ice and snow conditions; therefore, pedestrian use of the area below should be discouraged. Warm roof overhangs, heat tracing and snow retention clips are possible control methods.

Roads on exposed terrain and hillsides often experience snowdrifting problems that can be resolved with snow management, regrading, snowfencing or landscaping. Information reviewed here can serve as a basic guide for planning and design; however, microclimate specialists should be consulted where these simple guidelines cannot be applied.

Colin Williams (principal) and Bill Waechter (project manager) of Rowan Williams Davies and Irwin Inc., (RWDI) (650 Woodlawn Road West, Guelph, Ontario N1K 1B8, Canada), collectively have 30 years of experience conducting field investigations and scale model studies of sun, wind and snowdrift effects around buildings and roads.

Aspects of Operations and Maintenance Costs of School Buildings in Alberta

Raymond Vaivada and David Kinnaird

An empirical examination of operations and maintenance costs of school buildings throughout Alberta, a western province of Canada, was conducted by the consulting firm of Kinnaird Planning and Research Ltd. on behalf of Indian and Northern Affairs Canada during 1989-1990. Data were collected for the period of one school year, 1988-09-01 to 1989-08-31. Of interest to the analysts were the expenditures for heating and electrical energy per unit area of school buildings. School building construction and operating practices throughout Alberta have allowed school jurisdictions to include energy management systems and energy conservation programs on a voluntary basis. In fact, the provincial Department of Education had actively encouraged energy conservation in schools in the late 1970s and early 1980s. This paper examines whether the expenditures made to heat and light schools vary, depending on the existence of energy management systems and/or energy conservation programs. The comparison was based upon schools in several climate zones, of which there are five across Alberta.

As expected, those schools with energy management systems tended to have lower expenditures per unit area for heating, and those schools with energy conservation programs tended to have lower expenditures per unit area for electrical energy usage. The researchers found:

1. a significant lack of energy conservation programs throughout the sampled schools;

2. that smaller schools tended to have higher costs per unit area for both heating and electrical energy; and

3. that the significant variations in expenditures could be attributed to several schools within a few, but mostly one, school jurisdiction.

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David Kinnaird is President of Kinnaird Planning and Research Ltd. (540 Sun Life Place, 10123 - 99 Street, Edmonton, Alberta T5J 3H1, Canada). He is a registered Alberta Community Planner whose education embraces the disciplines of planning and geography.

Architectural Competition on Rural Building in the North: Kevajarvi Village, Finland

Eero Vaananen

In 1990, the National Board of Agriculture in Finland, in collaboration with the Housing Exhibition of Finland and the commune Inari, arranged a planning competition, the aim of which was to find good solutions for planning functional, well constructed and architecturally satisfying buildings in country-side areas of the Nordic countries.

Invitees included inhabitants of Finland, Iceland, Norway, Sweden and the USSR, all countries which have a similar cold climate as Canada. The competition ended 1990-10-01.

Forty-four entries were received; in view of the extent and nature of the competition and the location of the competition area, this can be considered a good response. The top entries were about equal in quality, and no one entry was clearly superior. However, the final ranking of the top entries was easily and unanimously achieved.

In terms of entry content and quality, the competition fulfilled its set aims. The entries contained numerous concepts and ideas which can be applied in developing construction in northern areas. From the point of view of community planning and the environment, the best entries offered plenty of guidelines for the future construction of Kevajarvi village. The planning concepts can also be applied more generally in the design of northern housing areas, in which case Kevajarvi village would serve as an excellent example.

In building design, the competition produced some feasible new housing types, adaptable both to different terrains and to different layouts. The competition also produced some interesting and worthwhile ideas on the integration of home and work and on facilities shared by the inhabitants. Many entries reflect serious concern for the northern landscape and fragile countryside in the exterior shape and character of the buildings. The architecture varied from the traditional to the ultra modern. Thus, the competition shed valuable light on this current and emotionally loaded question.

The best entries based their design on the existing landscape, that is, the form of the terrain and the climate. In most entries, the new construction was placed on the hill to the north of Lake Kutujarvi, where foundation work is easiest and the view the best. In the most successful entries, the construction was placed on the south and west slopes of the hill, leaving the north slope, the marshy areas and the lakeshore in their natural state.

The National Board of Agriculture and Inari commune have already started to produce the final building plans and the site planning through financing the planning work of the first and second prize winners. It is hoped that the Kevajarvi village will be almost completed in 1994 when the next ISCORD symposium takes place in Finland. We are sure that Kevajarvi will be a good example of housing and building in our cold regions.

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Safety of Pedestrian Walking Areas in Winter, Sapporo, Japan

Fumihiro Hara, Takashi Kawabata, Nobuaki Sakai and Hidetsugu Kobayashi

Research has been conducted in Sapporo, Japan on pedestrian accidents following slipping and falling on icy winter streets and the data have been analyzed. The data comprises records of the ambulance service of the Sapporo Fire Bureau regarding people injured in accidents following a slip and fall with subsequent hospitalization during the winter (December-February) from 1984 to 1989.

Number of people injured by a slip and fall in each month

	Dec	Jan	Feb	Total
Jan-Feb 1984		17	23	40
Dec 1984-Feb 1985	28	43	49	120
Dec 1985-Feb 1986	38	78	51	167
Dec 1986-Feb 1987	95	47	67	209
Dec 1987-Feb 1988	111	52	51	214
Dec 1988-Feb 1989	82	47	68	197
Total				947

The total number (947) of injured people comprised 501 males and 446 females. The average number of injured persons per day, calculated by dividing the total number of hospital patients by the total number of days, was 1.9 patients/d.

When the data were grouped by age, they showed that 30% of the injuries occurred to people older than 65 years. Further, males suffered more accidents until their fifties, but their incidence of accidents decreased after their sixties. On the other hand, accidents to females were comparatively low until their forties, but increased drastically in their fifties, and the over-70 age group had the largest number of accidents. As a result, it can be said that elderly people are more likely to be injured by an accident following a slip and fall, especially females.

Relation between age groups and the number of injuries following a slip and fall

Age Group	-9	10-19	20-29	30-39	40-49	50-59	60-69	70-
Total	23	36	80	110	128	211	162	197
Female	7	15	37	37	37	94	91	128
Male	16	21	43	73	91	117	71	69

When the data were classified by which part of the body was injured, the head and legs accounted for ~67% of the injuries, with head injuries being the most important. Among injured males 50.2% suffered head injuries, 15.3% higher compared to females (34.9%). However, females had more injuries to their arms or lower back than males (arms: 3.7% for males; 10.1% for females; lower back: 8.0% for males; 14.6% for females). Thus, the type of injury following a slip and fall on winter street differs according to sex.

Part of the body injured by a slip and fall (%)

	Head	Shoulder	Back	Lower Back	Legs	Foot	Arms	Hands	Others	Total
Total	42.9	3.6	3.4	11.1	24.0	5.1	6.7	3.0	0.2	100
Female	34.9	3.9	4.1	14.6	24.8	3.4	10.1	3.9	0.3	100
Male	50.2	3.3	2.7	8.0	23.2	6.6	3.7	2.1	0.2	100

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Takashi Kawabata is a Sub-chief of the Snow Sapporo 21st Century Plan, Road Maintenance Department, Construction Bureau, City of Sapporo (North-1, West-2, Chuo-ku, Sapporo 060, Japan). He is a specialist in the study of comprehensive snow measurement.

Nobuaki Sakai is a staff member, Snow Sapporo 21st Century Plan, Road Maintenance Department, Construction Bureau of Sapporo. His research area is the study of snow measurement.

Hidetsugu Kobayashi is an Assistant Professor in the Department of Architecture, Hokkaido University (Nishi 8-chome, Kita 13-jo, Kita-ku, Sapporo 060, Japan). He is a specialist in urban planning.

Photovoltaic/Diesel Generator Hybrid Power Systems for the Canadian North

R. LaPlace, D.G. Howell and A.M. Robinson

The generation of electric power at remote locations has been primarily through the use of diesel generators. However, the rising cost of petroleum-based fuels as well as environmental concerns have required consideration of alternate power systems in areas, especially the arctic regions of Canada.

An important configuration for generating electrical power in remote locations is the photovoltaic (PV)/diesel generator hybrid system with battery storage. Such systems use the battery as the main source of power, while the PV array and generator maintain the proper battery state-of-charge. This configuration removes the requirement for continuous generator operation. The resulting advantages include: significantly reduced fuel and maintenance costs; increased generator lifespan; improved fuel efficiency; and decreased noise and air pollution. The disadvantages of this hybrid system are the increased capital and installation costs.

A study of five sites in the Canadian arctic was undertaken comparing three types of electrical power systems: a continuously-running diesel generator, or genset; a diesel generator with battery storage, or Gencharger™; and a PV/diesel hybrid generator with battery storage or Photogenset™. The genset was used as the basic system for operational and economic comparison.

The five sites in the study were: Sheep Creek Warden Station, YT (69°N); Stokes Point Warden Station, YT (69°N); Snare Lake, NWT (64°N); Trout Lake, NWT (60°N); and Arctic Red River, NWT (67°N). The sites represent northern locations with a wide variety of factors, such as geographic location, weather population, power load requirements, seasonal use and degree of remoteness. The Sheep Creek and Stokes Point sites have seasonal occupation of only 4-10 persons and low power requirements of <25 kWh/d when occupied; because of the remoteness of these sites, fuel costs are high (~$2.30/l). The other three sites are less remote, with 60-120 people, requiring higher power, which varied from 200-1200 kWh/d; fuel costs are significantly lower ($0.41/l).

The power systems were simulated using the electrical power system design and economic analysis program SYSTEM-SPEC™. This is a program designed by Photron Canada Ltd. for complete system sizing and cost analysis of PV, generator and hybrid systems. A number of factors were considered in the simulation process, the more important being battery type and capacity, PV array size, diesel generator capacity, and control strategy. System optimization was obtained for both the Gencharger and Photogenset systems at each site, relative to genstet system operation.

The study indicated that Gencharger and Photogenset systems operating at high fuel cost and low power requirement sites, such as Sheep Creek and Stokes Point, are economically advantageous compared to the genset system. The Gencharger systems have shorter payback periods, ~1.7-a, while Photogenset systems result in a higher return on investment. The sites with lower fuel costs and higher power needs are more economical using genset systems, due to fuel costs, efficient power loading, and high costs for PV. The Gencharger system becomes economically attractive at larger sites where fuel costs are as high as $1.00/l.

The Sheep Creek site was selected for detailed monitoring of a Photogenset power system, installed in May, 1990. Comparison of operation with design predictions will be made and component performance assessed. The installation consists of a 15 kW diesel generator, 48 PV modules with a total rated power of 3 kW and a 48 V battery system of 48 kWh total capacity. A battery charger and four inverters complete the system.

The monitoring system was installed in August, 1990. It comprises a PV-powered computer and a commercial data acquisition unit. The software for making measurements, performing calculations and storing data is COPILOT™, developed by Howell-Mayhew Engineering.

Fourteen environmental and system parameters are being measured, including solar radiation, PV cell temperatures, and input and output power levels of all units. Parameters such as PV output power and efficiency, genset operating time and fuel efficiency, battery charger power and efficiency, battery current and power, and inverter power and efficiency are calculated in real time for data storage and subsequent analysis.

Monitoring at the site will begin in spring, 1991, and extend over the summer operating season.

R. LaPlace is President of Photron Canada Ltd. (PO Box 136, Colinton, Alberta T0G 0R0, Canada) and has more than 12 years experience in the remote power generation field.

D.G. Howell is a consulting electrical engineer with Howell-Mayhew Engineering (10005 - 103 Avenue, Edmonton, Alberta T5P 0N8, Canada) in the area of energy conservation and renewable energy systems, and data acquisition and analysis software. He is presently monitoring and analyzing 14 renewable energy systems across Canada.

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Wind Power in Antarctica: Case Histories of the North Wind HR3 Wind Turbine

Clint (Jito) Coleman

Presented by Woody Stevens

Since 1985 wind systems of Northern Power Systems have provided power to remote sites in the harsh polar environment of Antarctica. The overall perspective provided by this experience is that wind power can effectively provide reliable electrical power and heat to the variety of loads needed to support the manned and unmanned stations on the Antarctic continent.

A hybrid power system incorporating an HR3 wind generator with a Closed Cycle Vapor Turbine (CCVT) was installed on Black Island, Antarctica in 1985. These power sources provided power for a satellite link between Black Island and the US McMurdo Base. Because the McMurdo Base does not maintain a year round line-of-sight with the INMARSAT satellite, a ground link between Black Island and the McMurdo Base was established to provide uninterrupted communications for the base. The unmanned Black Island site is 33 km from the McMurdo Base and is accessible only by helicopter or a dangerous overland traverse.

The unattended station requires up to 1200 W of power at 24 V(DC). In normal operation, power for the radio link is provided by the HR3 wind energy system and stored in the batteries to provide for windless periods. The NPS SC-374 controller provides overall system monitoring and control functions. During extended calm periods, or whenever the batteries reach 40% state of charge, the CCVT is started and powers the load. At 80% state of charge the CCVT is turned off and remains in a standby mode.

The performance of the wind turbine at this site has been remarkable. Over the entire 5-a history of operation the unit has never failed, nor has it needed an unscheduled maintenance visit. Twice annual regular maintenance visits have been performed by the customer.

The severity of the weather at Black Island is typical of coastal Antarctica; however, the wind regime is more extreme than at other nearby locations because of the air flow patterns driven by adjacent land and ice masses. Over the first three years peak winter winds were commonly recorded at 45 m/s (100 mph) with one prolonged storm where the peak reached 56 m/s (126 mph) after which the anemometer blew away. Under these conditions the early anemometers were destroyed although no damage was incurred by the wind turbine.

Recently, the site has been refitted with special high wind anemometery to record the actual wind speed. During the winter of 1989 the highest ever one hour average was 78 m/s (175 mph). Again, the wind turbine survived intake, relying solely on its passive mechanical control system to provide shut down protection for the turbine. The reliability of this system continues to prove itself.

The temperature extremes are equally daunting. Average winter temperatures are -30°C (-22°F) with normal minimums during the winter months of -54°C (-65°F).

At Greenpeace Base, World Park, Antarctica, an HR3 wind generator was installed in February 1988 to supply resistance heating and battery charging for this permanently staffed facility. The Greenpeace mission to Antarctica is to conduct research and to act as an environmental watchdog for the fragile continent. The World Park complex is located on McMurdo Sound ~30 km from the US McMurdo Base. While the site is staffed year round, thereby facilitating maintenance of the wind turbine, reliability is still critical because a resupply vessel only visits the site once per year. Auxiliary power for the base is supplied by a diesel generator. The installation of the wind generator has offset the consumption of significant amounts of diesel fuel estimated to have a delivered cost of $10-$12/gal ($38-$45/l).

In conclusion, wind power has significant inherent advantages in solving the electrical energy problem for sites in Antarctica. The combination of a readily available wind resource over much of the continent coupled with the remoteness of all the installations, the logistic difficulties associated with the delivery of fossil fuels, and the environmental problems associated with burning fossil fuels, all support a more aggressive use of wind power on the Antarctic continent.

Clint Coleman is Vice-President of Engineering at Northern Power Systems (One North Wind Road, Moretown, Vermont 05660, USA). He is a sole or co-inventor on several US patents for wind turbine rotors, controls and blade manufacturing techniques.

Experiment and Research for Using an Air Duct to Store Cold Energy

Cui Wei and Sui Tieling

As with solar and tidal energy, cold energy in winter is also usable natural energy. An air duct system has been developed in the USA for utilized cold energy.

In the present experimental installation, beside an air duct system, a cold transfer system and a cold storage system were also set up. This combined storage of cold energy without energy consumption in the winter and released the cold energy in the summer. Initial research results showed that the tentative plan was successful and was worth developing.

According to thermodynamic principles, air density decreases when it is heated and hot air rises. The characteristic of the air duct is to transfer cold irreversibly and passively by placing the air duct under the ground which needs to be frozen. When the atmospheric temperature is lower than the underground temperature, the air in the duct under the ground becomes lighter and rises, then cold air comes into the duct and air convection commences. During the warm season, when the outside air temperature is higher than the ground temperature, convention ceases because of the greater density of the air inside.

Experimental installation of stored cold energy with an air duct consists of four parts, as follows:

1. the air duct system
2. the cold transfer system
3. the cold storage system
4. the applied system

The air duct is used to hasten the heat exchange between the cold air outside and the cold storage system under the ground. The cold transfer system is used to transfer the cold from the storage system to the applied system expeditiously.

The cold storage system should be thermally large enough to accommodate the cold energy to be stored. The materials in the storage system usually are water or saturated soil and sand. The applied system consists of a refrigerator, air conditioner, and pump.

On the basis of test data taken during the winter of 1989-1990, the whole storage was frozen by January 16, 1990. The frozen depth of the cold storage was twice as deep as the maximum natural frozen depth and the freezing time was 35-d less than the time when it was needed when saturated soil was used as the storage material. These results showed that the air duct system can result in greater frozen depths and faster rates of freezing, hence more cold energy can be stored. During the experiments the temperature in the refrigerator (292 l) was 3-10°C and the air temperature of the air conditioner in the room (102 m^3) was ~10°C.

In summary, in seasonally frozen regions, frozen depth can be increased efficiently using the air duct. As a result of installing a cold transfer system the release of the cold energy is very easy to handle. Therefore, the installation of stored cold energy using the air duct is a new method to utilize natural cold resources. After further research and improvement it might substitute for an electric refrigeration system and so could save electric power and be beneficial to the environment.

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Research and Development of a System for the Effective Use of Thermal Energy in Northern Regions of Japan

Tetsuro Ise

Restrictions of energy resources and environmental protection are now global concerns. Regional industrial promotion and urban problems, including disposal of waste matter and unused low-calorie coal, must take these considerations into account. The establishment of systems for the effective use of resources and energy recycling are urgently required. Research and development of alternative energy to replace oil must also be promoted.

Central Hokkaido is situated at latitude 43°N, but the temperature rises beyond 30°C in summer and falls below -20°C in winter, a difference of 60°C. The effective use of energy for heating in winter and environmental protection are inevitable problems in this northern region.

In Furano City (population ~30,000) located near Asahikawa, waste matter is collected by type. For example, biodegradable waste is recycled as compost for agriculture, and combustible waste is used as solid fuel.

Our company has developed an automatic solid fuel combustion apparatus for recycling combustible waste and low-calorie coal which emits no smoke and little pollution (see Table below) and currently supplies 50% of the energy required to heat schools and public facilities. Hot water boilers operate at all these facilities.

Comparison of Pollution Constituents

	Dust Density (g/m3)	SO_x (m^3/h)	NO_x (cm^3/m^3)	HCl (mg/m^3)
Waste matter solid	0.14	0.01	80	70
Coal	0.17	0.21	130	-

There are three combustion methods for the boilers. The following are two typical methods.

Chain Stoker Method (Output 1.05M to 16.75M kJ/h)

A conveyer belt carries the fuel from the storage area to the hopper of the combustion machine, and then the chain stoker automatically carries it into the combustion furnace. Air is supplied by a primary fan and a secondary fan, which have different blow-off outlets. The temperature in the combustion furnace is kept constant at 1200°K, and radiation heat allows complete combustion, thus preventing smoke generation. Ash falls downward and is discharged automatically by a screw conveyor belt.

Reactor Burner Method (Output 84k to 335 k kJ/h)

Two cylinders are set horizontally in concentric circles to form the structure of the reactor burner. Air for combustion is forced into the space between these two cylinders. Fuel is supplied by a screw conveyor belt to the inner cylinder where it mixes with the air. The fuel is burned completely in three stages: carbonization, primary combustion, and secondary combustion. The temperature in the combustion furnace is kept constant at 1200° K.

Features of the devices are as follows:

1. The cost is low because inexpensive local materials are the energy source;
2. Little work force is required because of the complete automation;
3. The complete combustion lowers the amount of pollutants;
4. An electric or bag filter dust collector is not necessary.

Tetsuro Ise is President of Ise Kogyosho Co. Ltd. (8-chome, 4-jo, Nagayama, Asahikawa, Hokkaido, Japan), a company manufacturing energy-related machinery. The company's goal is to find alternative energy sources for oil. Current research and development includes: a rapid carbonization apparatus with which anyone can produce charcoal in only 3-4 days from waste material or lumber obtained from thinning; prototype of a mobile co-generation system using coal combustion (for export).

APSCO Wood-waste Fired Boiler

Jack Dueck

The APSCO wood-waste fired boiler produces thermal energy by burning wood by-products in the form of wood chips, cord wood, wood pellets, sawdust, shavings and lumber offcuts. Fossil-fuel-burners can be installed to provide secondary or standby functions should wood-waste fuels not be available.

The boiler is a vertical, three-pass, fire-tube design, utilizing a large vertical hearth to allow the complete development of the wood burning process. Hearth temperatures as high as 1425°C ensure complete and virtually smoke-free combustion. The hearth is fully water jacketed and partially refractory lined. Thermal efficiencies of 80% are commonplace with dry fuels.

Granular fuels (wood chips, pellets, sawdust and shavings) are fed to the boiler furnace by an automatic underhearth stoker. Offcuts and controlled sizes of cordwood can be fed automatically by an inclined conveyor or manually through large loading doors.

The granular fuel supply is stored in a bunker or silo under or near the boiler building. From here it is transferred to the boiler building by auger or by a pneumatic conveying system and fed through a rotary-air-lock into the boiler stoker. A 'live bottom' in the bunker or silo ensures that the fuel is consistently metered to the feed system.

Offcuts and sized cordwood are stored in a large moving floor conveyor which in turn feeds an inclined conveyor discharging into the boiler hearth.

Fuel feed systems are automatically controlled on demand by the water temperature or steam pressure controllers.

Combustion air is fed into the furnace at two levels; the primary level from under the hearth through openings in the refractory, and the secondary level above the fuel peak through the loading doors and secondary air supply ports. The primary air provides partial combustion for gasification of the wood wastes that then burn at the secondary air level.

By burning at very high furnace temperatures, virtually all C is combusted, and only ash remains as a pollutant.

High efficiency cyclones or multiclones used in conjunction with the APSCO boiler will satisfy pollution control requirements. Independent tests commissioned by the Yukon Government at a northern installation gave total emissions during hot burn trials ranging from 123 mg/m^3 to 167 mg/m^3.

The boiler is designed to ASME Code Section IV, "Heating Boilers" and CSA B-51 "Code for the Construction and Inspection of Boilers and Pressure Vessels". Operation of these boilers falls under the ASME Code Section VI, "Recommended Rules for Care and Operation of Heating Boilers".

All regulatory controls are wired 'fail-safe' in the CSA Control Panel. In addition, the boiler is fitted with the mandatory self-acting pressure relief valve or valves.

The stoker feed system is protected with a solenoid water supply valve, activated by the fire-danger temperature controller to extinguish any burn-back in the feed system. This solenoid valve is piped in parallel to a self-contained controller to operate in case of a power failure. A standby reservoir supplies water in case of a system water supply outage. In addition to these fire extinguishing devices, the rotary-air-lock serves as a physical separation between boiler furnace and fuel storage.

By placing the air supply fan on the downstream side of the boiler, the boiler hearth is always at a negative pressure condition. Whenever the furnace door is opened, air is drawn into the system, ensuring safety to the operator.

Installations include several applications in northern locations as well as numerous installations in woodwork industries throughout Canada.

ASPCO boilers are produced in the following range of sizes:

Hot water: 125 Kcal/h to 3000 Kcal/h
Low pressure steam: 0.5M BTU/h (15 horsepower) to 12M BTU/h (358 horsepower) [146.5 kW to 3.52 MW]

Jack Dueck is the founder and CEO of APSCO Engineering Ltd. (P.O. Box 270, Cremona, Alberta T0M 0R0, Canada). He is a member of APEGGA and holds an M.B.A. from The University of Calgary.

Steam Thawing of Frozen Ground

P.A. (Pete) Poohkay and B.M. (Blain) Smetaniuk

It has long been accepted for the utility industry in Alberta to open-burn coal during the winter to thaw frozen ground for most excavations. Currently, the Alberta Government imposes virtually no restrictions on open coal burning. However, some municipalities have disallowed this practice because of the fire hazard and environmental impact. To address this situation, Northwestern Utilities Limited (NUL) has evaluated various ground thawing systems.

Several methods presently exist, all operating on the same principle, namely applying heat to the surface of the ground from a fossil fuel burning heater. The evaluation criteria include public safety, environmental impact, depth of thaw per typical application time, economics, and practicability. When using coal or a ground surface heater, a large portion of the heat applied to the ground surface is lost to the atmosphere. As the ground is heated, it drys, forming a layer of dry soil which acts as an insulator impeding heat transfer into the soil. This slows the thawing rate, requiring longer heating times which equates to higher fuel consumption. Coal firing or ground surface heating methods can require up to 4 d of application time. This results in public inconvenience due to smoky coal fires, blocked traffic, and noisy equipment. Public safety is also compromised when open coal fires or hot heating equipment (up to 1300°C) are left unattended.

Field tests using various ground heating techniques provided inconsistent results with regard to required heat application times and depth of thaw. A crucial operation in pipeline construction is "hand exposing" existing energized utilities prior to a crossing or tie-in. Therefore, it is imperative that the ground at the "pipe zone" be completely thawed, or the task becomes a dangerous and arduous one.

Since the winter of 1988-1989, the Construction Department of NUL has been using a steam injection process to thaw ground with excellent results. The system, constructed by NUL, generates steam within a high pressure steam boiler. The boiler, along with an electric power plant and feedwater system, is contained within an insulated freight trailer. Steam is conducted onto the worksite through rubber hoses and is injected into the ground through steel probes. Steam is injected into the ground for 2 to 3 h, depending on soil type. The steam condenses in the soil and heat is then released over a 24 to 48 h period, thawing the soil. The area can then be excavated by hand or by machine, and tends to be only slightly moister than soil excavated in the summer. During the operation an area around the trailer unit and work site is barricaded. Upon completion, the equipment and the barricades are removed and the site is left unaltered. Roadways and worksites are useable after steaming and no hazardous materials are introduced onto the site.

The steaming process developed by NUL is supervised by qualified personnel, the combustion flame is confined to the boiler furnace, the steam is released into the ground in a controlled manner, and with steaming times between 2 to 3 h, the operation imposes little danger to the public, and inconveniences to traffic are minimal.

Steaming a typical worksite produces less pollutants as a result of consuming less fuel than the coal fire or ground surface heating application. The following table provides a comparison of emission quantities for the open coal burning technique and the steam boiler (fired on diesel or natural gas) technique. Typical thawing applications involve the open burning of 135-180 kg (300-400 lb) of coal or the consumption of either 72 l (16 gal) of diesel fuel or 71 m^3 (2500 scf) of natural gas within a boiler burner.

Emission Factors for Typical Thawing Combustion Processes (relative to natural gas)

	Coal	Diesel	Natural Gas
CO_2	2.70	1.4	1
CO	167	1.06	1
SO_x	2715	284	1
NO_x	1.36	1.05	1
nmHC	250	1	1
Methane	175	0.55	1
Particulates	263	4	1

The coal-burning method is more economical due to the lower cost of material and low labour requirements. Ground surface heating systems and the steam injection system both have significant capital investment costs, but one steam injection system working in an 8 h period can steam as many sites as three ground surface heating systems working continuously for 1 to 3 d, or three coal-fired sites burning over a period of several days.

In conclusion, excavation of underground power and gas lines in frozen ground can be a dangerous and costly operation to a utility company without the aid of a practical and economical method of ground thawing. NUL developed their own steam injection system as a proactive step toward finding an alternative to the use of burning coal, and steaming has been field proven to be an effective method of thawing ground and is safe in the course of its application. The process of transferring heat generated by the burning of a boiler fuel, such as natural gas, directly into the frozen ground is an efficient and environmentally friendly use of energy.

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Coal: A Potential Energy Resource in the Canadian Arctic Archipelago

W.D. Kalkreuth and R.J.H. Richardson

Substantial coal resources, estimated at 50 Gt, occur in the Canadian Arctic Archipelago (Smith, 1989; Bustin and Miall, 1991). Coal has been known to occur in the Arctic for a long time; early Arctic explorers noted it over the last 150 years, and recently coal has been reported from ancient archaeological sites. Since the first geological review of coal occurrences in the Arctic islands by MacKay (1946), systematic mapping by the Geological Survey of Canada and specific coal studies by Fortier *et al.* (1963), Caine (1973), Ricketts and Embry (1984) and Ricketts (1989) have established the diverse nature and widespread occurrence of coal in the Arctic Islands.

Most of the resources, in terms of quantity, are found in the Eureka Sound Group of the Sverdrup Basin on Ellesmere Island. The coals range from lignites to high volatile bituminous coals with 80% occurring in the lignite to subbituminous ranks. In general, the coals are low in S, but few coal quality studies have been done and those often in widely separated areas. Ricketts (1989) described a major coal deposit on the shores of Strathcona Fiord, west-central Ellesmere Island, with individual seams ranging up to 12 m in thickness and traceable over a distance of 8 km. 'Speculative' coal resources in the area were estimated at >1 Gt. A few spot samples showed the coals to be of lignitic to subbituminous C ranks and locally rich in resin. Although Ricketts believed the exploitation of the deposit to be far in the future, if ever, it remains one of the best prospects for eventual development in the Arctic Archipelago.

In 1990 the area was visited to obtain a complete suite of samples through all the major seams and to take grab samples from all seams in the area. The major seams were channel sampled at 50 cm intervals for vitrinite, maceral and chemical analysis. More than 100 samples were taken and will result in one of the best databases characterizing the quality of a Canadian Arctic Island coal deposit. Much more sampling, both vertically and along the seams with associated detailed sedimentological studies, will be undertaken before a depositional and coal facies model can be constructed. Deposits of equivalent age and character also need to be examined elsewhere in the basin to test the model.

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Investigation of the Effect of Microwave Field Treatment on Rubber Properties

I.Z. Goldstrach, M.I. Sleptsova and N.I. Fiodorov

This paper reports a study of the effect of partial rubber vulcanization using a microwave electromagnetic field (MW-EMF).

The processing technology represents a combination of traditional rubber vulcanization procedures by means of conventional equipment, followed by treatment in the MW-EMF of a certain intensity. A consumer microwave oven *Electronika* equipped with a coaxial waveguide was used as a microwave field generator.

The vulcanized samples were cylindrical specimens measuring 10x10 mm with collars 50x70 mm in diameter. Previously, it had been established that the optimum time of preliminary vulcanization was from 5 to 7 min, and that of microwave treatment from 2 to 5 min. The rubbers were vulcanized in two stages.

In the first stage, the rubber was vulcanized in molds at 151°C for 5, 7 and 25 min, then treated by the MW-EMF for 2 and 4 min.

After such a vulcanization, cylinders measuring 4x5 mm in diameter were cut out of the collars. They were tested for frost resistance by determining the coefficient of recovery after compression at temperatures of 23, -40, -45, -50, -55 and -60°C.

The test results show that at temperatures above -50°C the recovery coefficient of partially vulcanized rubbers is higher than that of a rubber vulcanized for 25 min, while at temperatures below -50°C it is the reverse, which shows a frost resistant increase.

Thus, the treatment of rubber in MW-EMF reduces the vulcanization time by 2 to 3 times, and the rubber frost-resistance is increased.

EXHIBITION SHOWCASE

INTERNATIONAL SYMPOSIUM ON COLD REGION DEVELOPMENT

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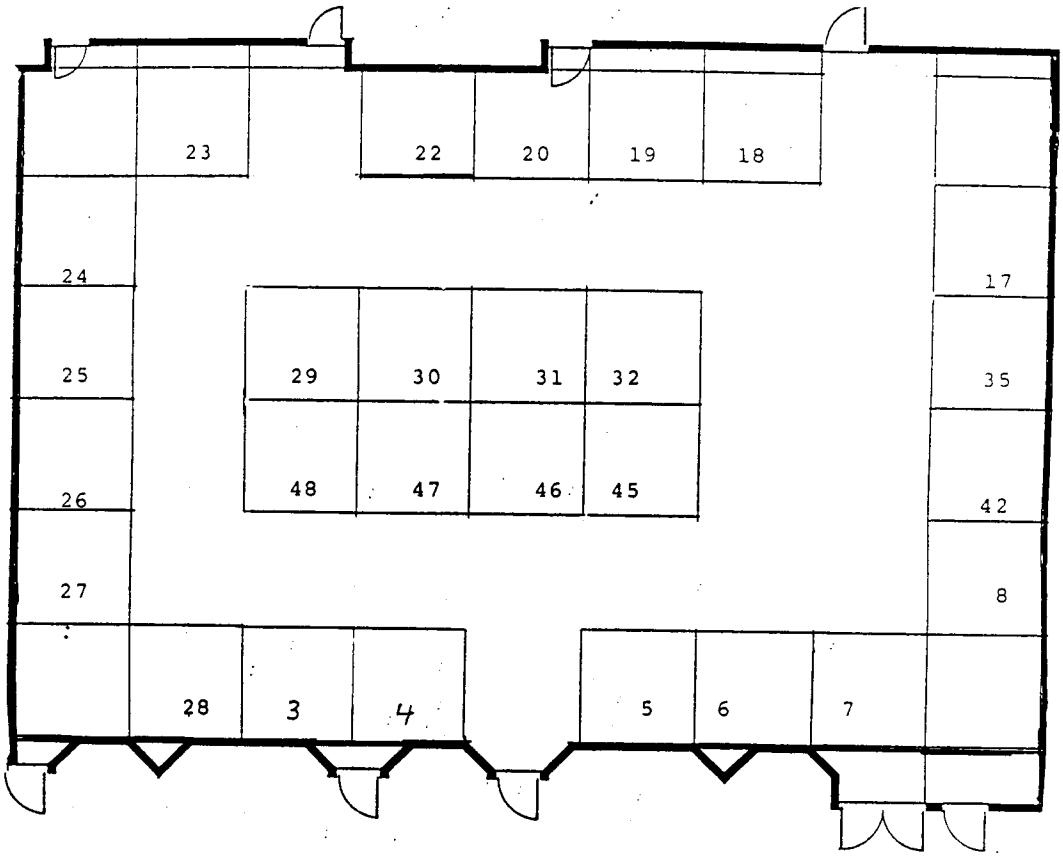
Edmonton Convention Centre
Edmonton, Alberta Canada
June 16 - 21, 1991



EXHIBITOR'S FLOOR PLAN

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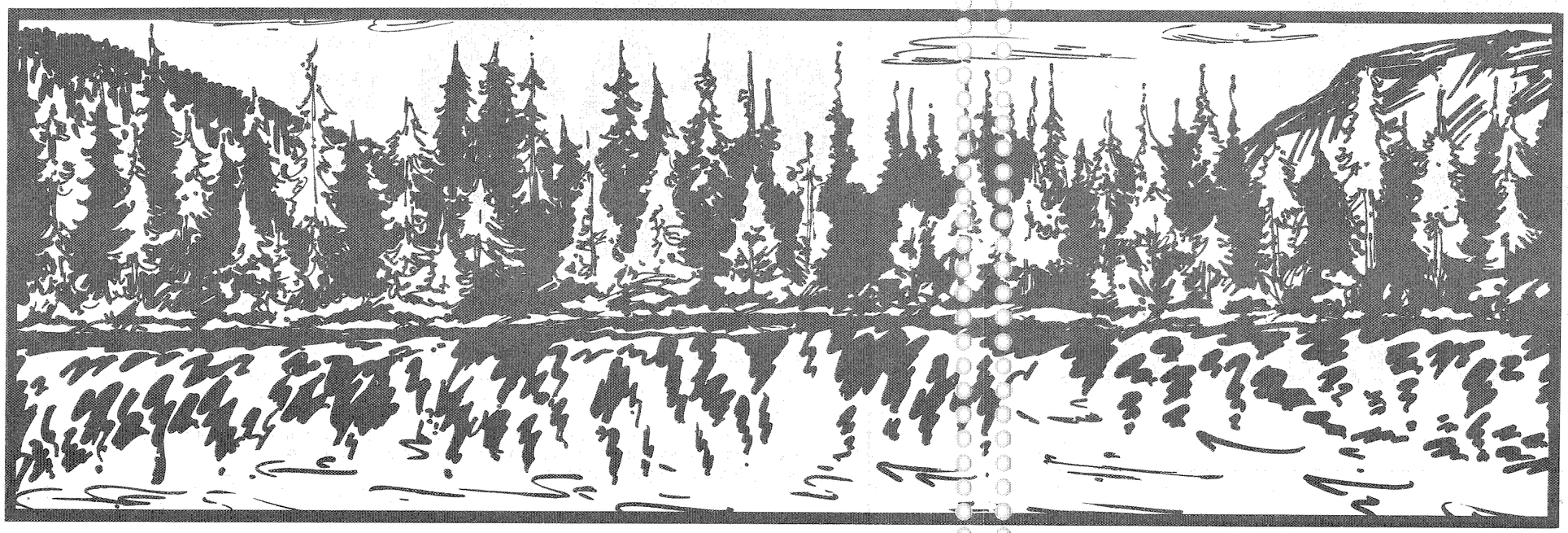

A Northern Experience

Fort McMurray, Alberta. The little fur trading town, north of the 56th parallel, that grew up to be the centre of Canada's impressive Oil Sands industry.

The Oil Sands operation has been called an engineering miracle. Syncrude Canada Limited and Suncor Inc. Oil Sands Group. Two companies, distinct, but using the same technology to mine the oil-laden sands from beneath the muskeg.

In less than twenty-five years, the two companies have built an operation that produces 215,000 barrels of oil daily. That's 15 per cent of Canada's energy supply.

The reserve deposits are mind boggling. Experts estimate there are 300 billion barrels of oil available by current mining and extraction methods. And, a total of two-and-a-half trillion barrels waiting for the technology to meet the challenges of getting at it.

One of those challenges is climate. Fort McMurray temperatures swing from summer highs of 30 degrees celsius (86 degrees fahrenheit) to winter lows of -42 degrees celsius (-44 degrees fahrenheit).

Join the City of Fort McMurray, Syncrude and Suncor at noon, Monday, June 17, for a north country luncheon and a look at the challenge of the Oil Sands.

The City of Fort McMurray and Syncrude and Suncor present A Northern Experience Noon Monday June 17

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Every Time Industry Chooses Natural Gas, The Workers on Pringle's Farm Seem To Hum A Happier Tune.

The labourers on Pringle's Farm love to hum as they work the fields.

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Something is disturbing the workers.

What's happening at the farm is a clear signal that our relationship with the environment needs repair. Nature is reminding us that we must change our old ways of thinking.

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We can recycle, reuse and recover. We can be more mindful of the energy we use to heat our homes and fuel our industries and vehicles.

Part of the solution is the greater use of natural gas.

It's efficient, the cleanest of fossil fuels and a plentiful resource we can count on for a long time to come.

More importantly, natural gas can reduce air pollution, lessen the damage of acid rain and help moderate the greenhouse effect.

Fuel for thought.

Look at the facts.

Industries that use natural gas in the manufacturing process can virtually eliminate their emissions of sulphur dioxide, the primary cause of acid rain.

Industries fueled by natural gas can also reduce harmful emissions of carbon dioxide – the chief culprit of global warming.

And vehicles adapted to natural gas produce fewer hydrocarbons – which means less smog – and therefore cleaner air.

Natural gas is not the complete answer. But it is a better alternative, and it offers us a chance to make a positive contribution to a cleaner environment.

C'mon, let's get busy and get the place humming again.

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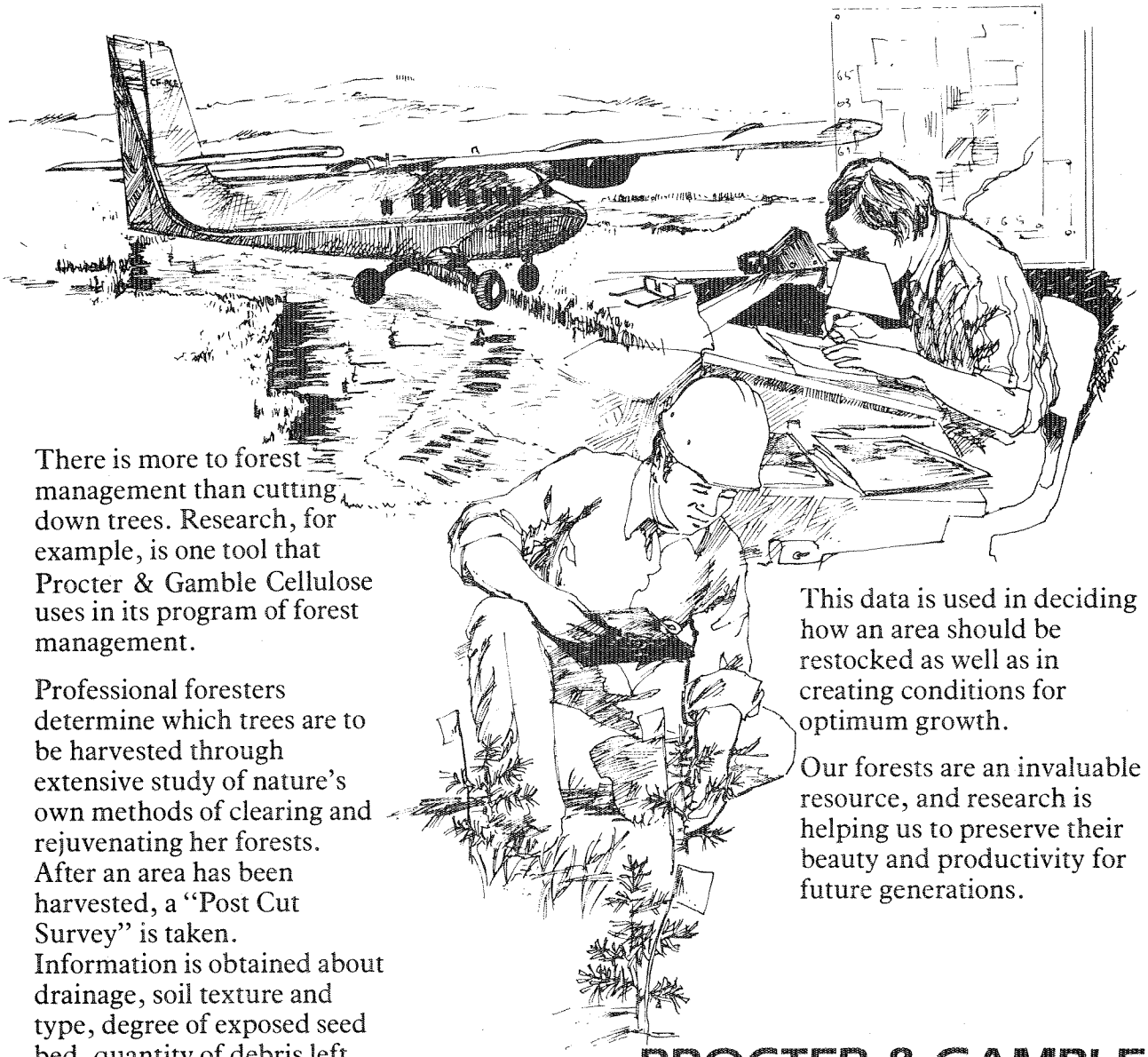

There is more to forest management than cutting down trees. Research, for example, is one tool that Procter & Gamble Cellulose uses in its program of forest management.

Professional foresters determine which trees are to be harvested through extensive study of nature's own methods of clearing and rejuvenating her forests. After an area has been harvested, a "Post Cut Survey" is taken. Information is obtained about drainage, soil texture and type, degree of exposed seed bed, quantity of debris left after harvesting, slope and seed source.

This data is used in deciding how an area should be restocked as well as in creating conditions for optimum growth.

Our forests are an invaluable resource, and research is helping us to preserve their beauty and productivity for future generations.

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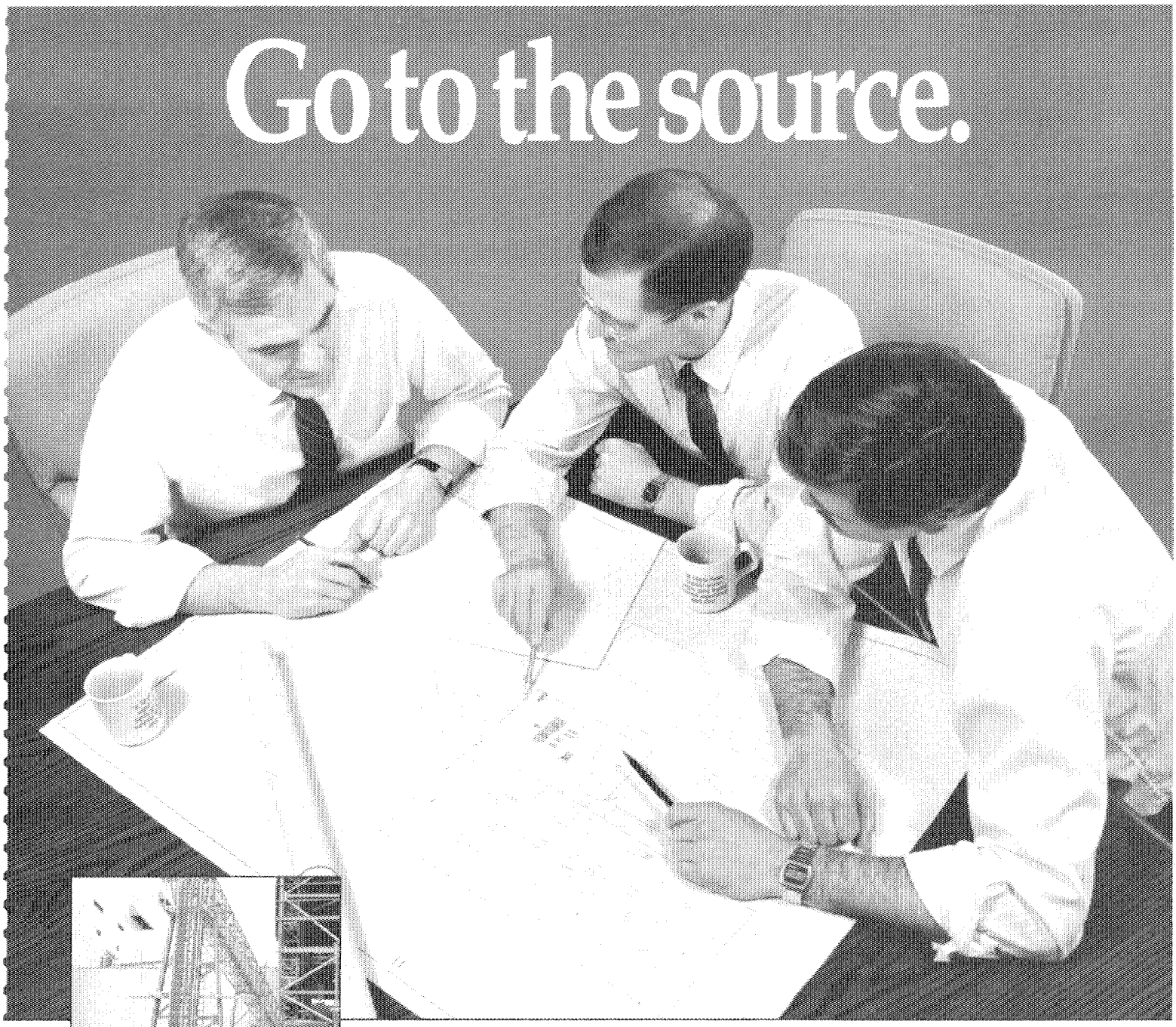

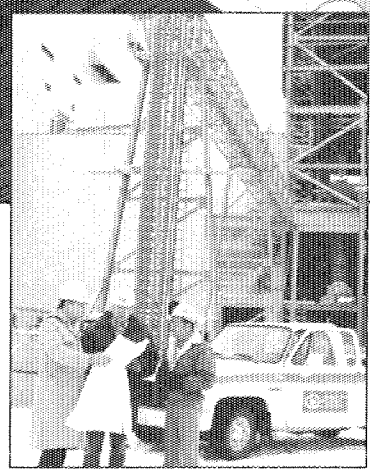

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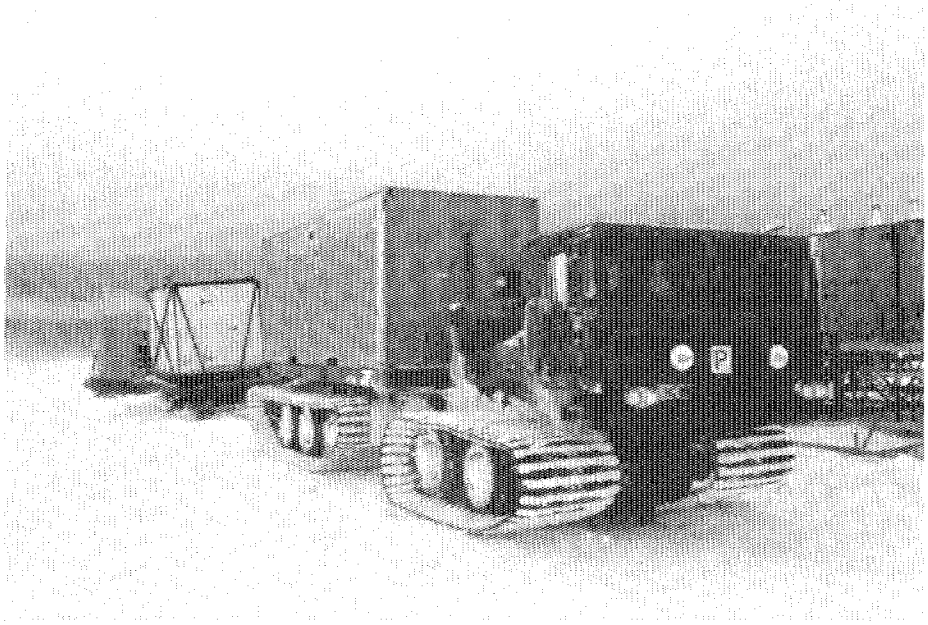

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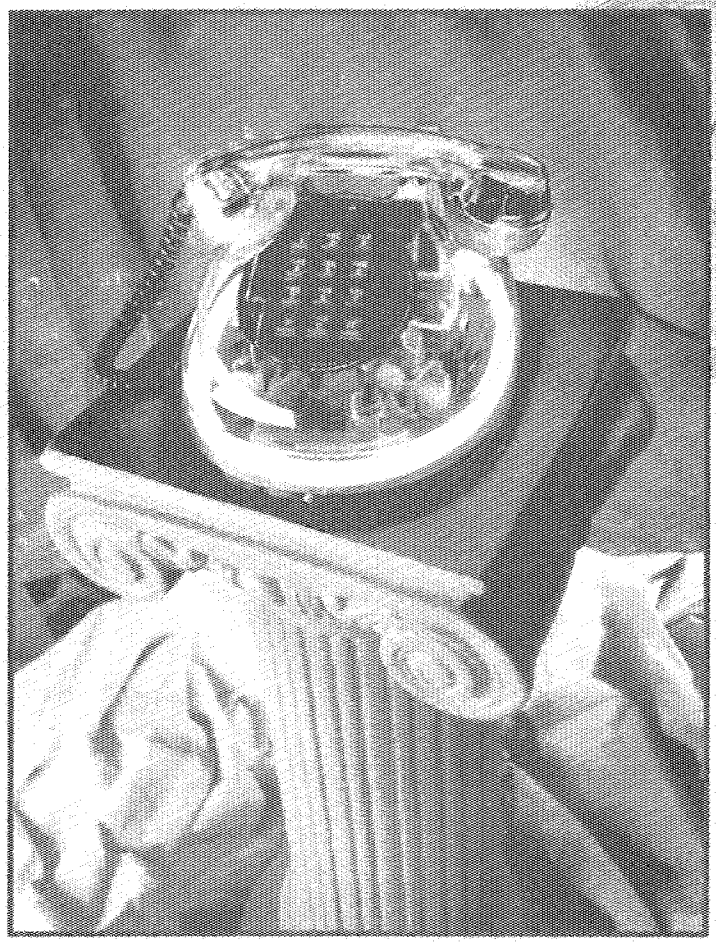

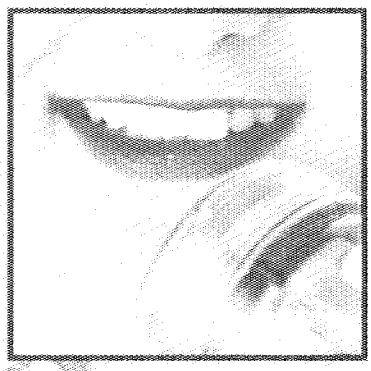

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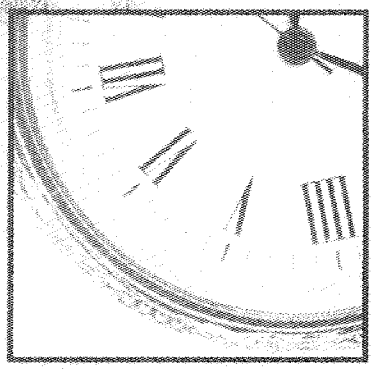

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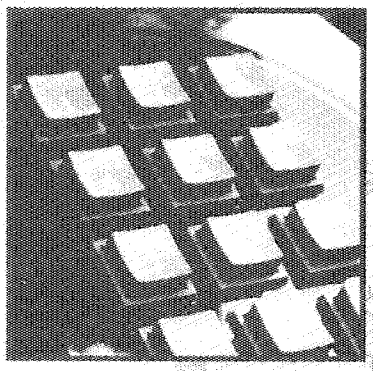

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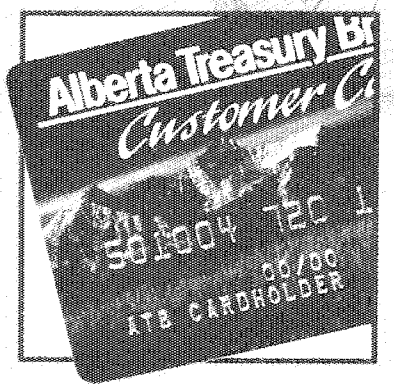

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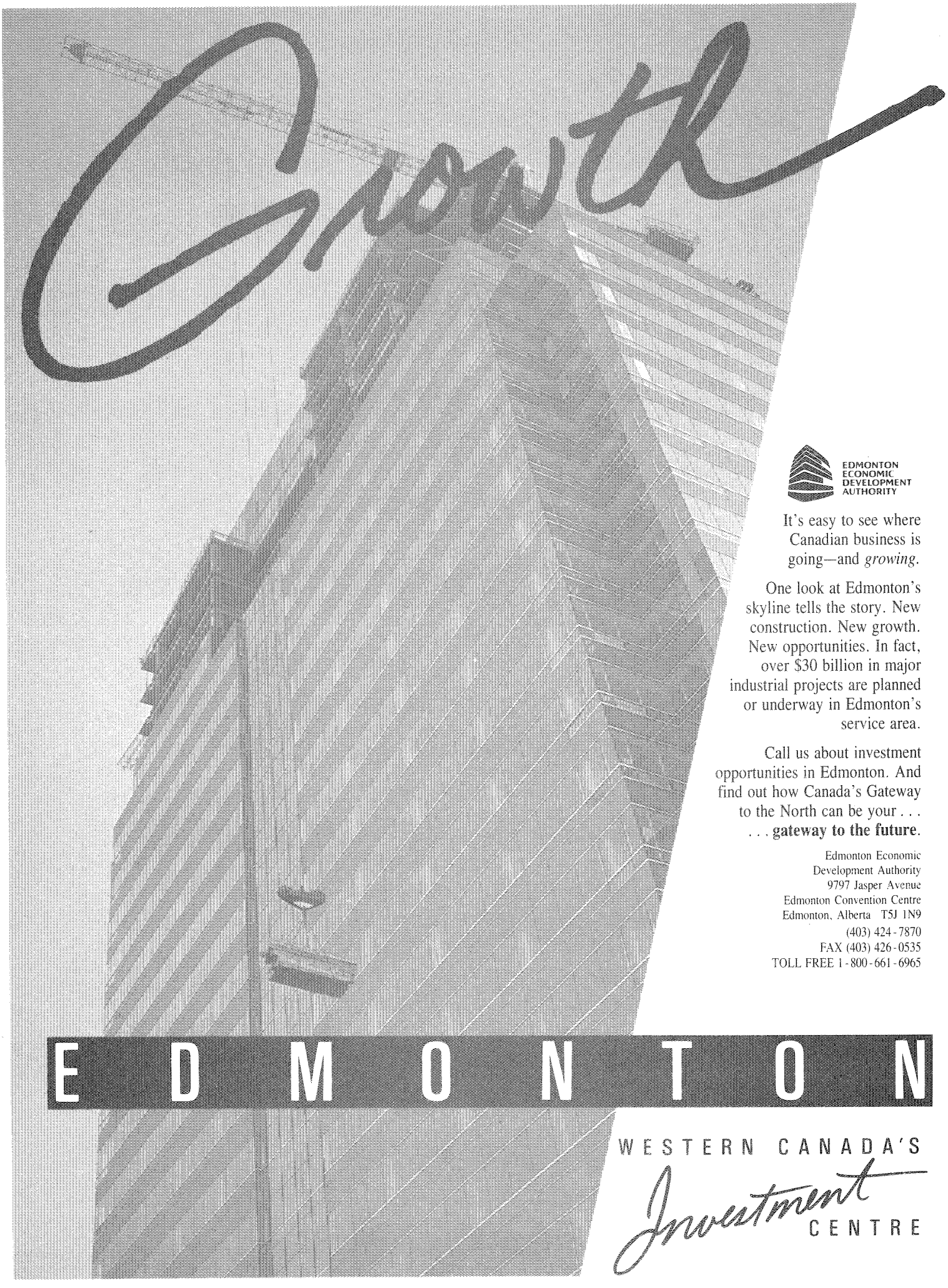

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