Design Criteria for Native Housing in Canada

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ABSTRACT

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Factors governing the design of housing for natives in Canada are discussed with reference to their impact on building layout and orientation, and on the selection of building materials and construction systems. Basic determinants, which are analyzed and compiled in a design brief, include the lifestyle of the inhabitants, site location, access and conditions, climate, available materials, services and local resources, and applicable codes and regulatory standards. Performance criteria are assessed for foundations, walls, roofs, windows and doors, interior and exterior finishes, and mechanical and electrical services. Materials and assemblies available for these building elements are compiled and evaluated in the light of design criteria developed above. The report is supported by the experience of government agencies involved in native programs and the writer's experience in housing design and community energy audits for Indian and Innuit villages in Quebec.

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Major contributors to this report are the Cree and Innuit who benefited or suffered from housing designs and building decisions based on assessments now formalized in this document. Their forbearance, co-operation and unfailing cheerfulness during the research, design, construction and follow-up phases of the various projects made the work a pleasure as well as a challenge. The writer hopes that the report contributes to increased awareness of the special needs of these communities.

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PART 1.0 INTRODUCTION

SECTION 1.1 PREFACE

This study is intended as a guide for designers of housing of native populations in the hinterlands of Canada. It establishes criteria for siting of buildings, and for determining their configurations, materials, assemblies and services. Practical alternatives are listed, and their characteristics are discussed in the light of anticipated usage and environment.

The writer's background includes over 20 years programming and designing for a variety of projects in Africa, Asia and South America, where distance, accessibility and cultural differences present problems akin to our Canadian experience. This report is based largely on his work in Indian and Innuit villages between the 48th and 73rd parallels in Baffin Island and in Quebec. Housing design is supported by experience in the design and construction of Chisasibi, a town built for the 2,000 Cree inhabitants of Fort George (which fell victim to the La Grande River hydro electric development), and by the ongoing new and rehabilitation housing programs for Fort Rupert, Eastmain, Waswanipi, Mistassini, Grande Baleine, Wemindji and Nemaska involving over 1,500 families[1]. The sections in energy use benefit from community energy audits and evaluations the writer has carried out at Weymontachie and Obedjiwan. The projects were designed to optimize costs for retrofit programs, and to study alternative energy sources on a village scale. The program will be offered as a model for similarly sized and located centres. Arctic construction practices are derived from details and specifications developed for housing constructed on permafrost at Salluit, Akulivik, Kangirsujuak and Payne Bay, all located along the Hudson Strait. Additional data was available from the design of projected townsites at Milne inlet on Baffin Island, and for Asbestos Hill in Nouveau Quebec. These experiences are supplemented and amplified by the many excellent publications referenced in the foot notes.

The conclusions and recommendations are the writer's own, based on his successes and failures, and on the reactions of his buildings' users. Not burdened by an anthropological education or by exposure to social studies, the writer has felt free to generalize about characteristics of native village life which affect building design and construction.

For the most part, designers of housing for remote locations are white, of European origin, and are trained in the 'modern' idiom. Because their 'clients' are natives whose history, culture, lifestyle, and emotional responses are only dimly understood by those responsible for determining their physical environment, a few introductory words are in order.

Native peoples, whose ancestors inhabited the continent before the arrival of European settlers, include the various nations of the Indians and the Innuit[2]. They live in reservations or in villages often remote from large urban centres, and engage largely in hunting, trapping, fishing, or in maintaining equipment for these activities. The climate, especially in the north, is often harsh. Access may be difficult and means of communication limited. Skilled tradesmen and mechanized equipment are not readily available. There are differences in culture, educational levels and living standards. Villages are often without sanitary services, proper roads, or even electricity. Generally, there is a lack of money to implement programs necessary to up-grade existing housing stock and build infrastructure and new dwellings.

These conditions are changing. There is an emerging political activism and a growing native national consciousness. Construction of pipelines, expanded exploration for oils, minerals and metals in remote areas as well as the construction of hydro-electric developments are encroaching on native lands. These are resulting in financial settlements giving local populations the means to re-build their communities and construct new villages in accordance with their needs, instead of accepting programs imposed, often without consultation, by different government departments.

Architects and engineers are now more often retained directly by native organizations to implement housing and rehabilitation programs. PART 2.0 of this report is intended to provide these designers with exposition of basic criteria required to establish the housing program, which is summarized in a Design Brief (APPENDIX 1). This should ensure a common perception by the designers and the native authorities of requirements and constraints which will govern the design. PART 3.0 developes criteria required to evaluate commonly used building materials, components, assemblies and equipment. PART 4.0 lists alternatives from which the above may be chosen based on the designers' appreciation of the relative importance of the selection criteria.

Although this paper deals with the Canadian native housing problems, the approach should be valid for housing designed for other cultural or ethnic groups, with different economic and logistic constraints, living in remote locations subject to varieties of climatic conditions.

It should be noted that this paper does not:

- furnish designs, details or models for native housing;
- establish priorities for the selection of criteria, or for available alternatives;
- use actual capital costs, life cycle calculations, or other quantitative data to compare housing options;
- deal with rehabilitation of existing houses.

This report will demonstrate that essential criteria for native housing are:

- simplicity; details should be easy to build, with no extraneous work; needlessly complex assemblies take time, require skilled labor, and are a rich source of error;
- use of common materials; familiar, readily available simply constructed components in standard sizes facilitate future renovations and promote proper maintenance;

- attention to logistics and scheduling; assemblies using materials that are cheaply and easily transported and stored under adverse conditions, and consistent with skills of locally available labor, are necessary for timely completion of remote projects;
- constant consultation with the users and their representatives; user satisfaction with completed housing is promoted by developing alternatives during the design phase reflecting native lifestyle, and presenting them to the community, using models freely, with explanations of advantages and drawbacks of each alternative; during the procurement and construction phases constant monitoring of progress and costs with consideration to better suiting the design to local site and labor conditions, and occupancy checks after completion with users and native officials, will provide data to guide design of future projects;
- familiarity with applicable codes; delays and costly drawing changes result from an incomplete understanding of codes and regulations;
- clear, adequately detailed drawings; poorly drafted details drawn to inconsistent or too small scale, or incomplete documents, in conjunction with inadequate supervision and limited communications, invite disaster;
- respect for the climate; past experience has sadly shown that many housing designs conceived in the comfort of 'the south' are unsuited for extreme cold, precipitation and wind.

These are requirements for any architectural project, but have added meaning for remote housing, as will be shown. Natives in villages have, in general, one chance for a proper home, and proper application of appropriate criteria will greatly assist in achieving a happy solution for the occupant and the designer.

PART 2.0 BASIC DESIGN CRITERIA

PART 2.0 establishes basic criteria required for the building program; information needed for selection of materials and assemblies is outlined in PART 3.0.

It should be noted that the criteria given are not listed in any particular order of importance or signifigance; the priorities assigned will rest entirely on the judgment of the designer.

Section 2.1 ESTABLISHING THE PROGRAM

Section 2.1.1 BUILDING PROGRAM CONSIDERATIONS

The internal politics of native societies, and their relationships with federal and provincial governments are outside the scope of this paper. Suffice to say that it is an essential pre-requisite to identify the persons or bodies responsible for setting out the building program, and for approving its scope and the designs which follow.

A word about the writer's experience in negotiating programs and designs with native authorities may be of use.

Native decisions are largely by popular concensus, following long and detailed discussions, with all members participating. Chiefs and other officials represent the group, but do not dictate policy. These highly democratic societies, related by family ties, shared interests, and by common threats to their traditional existence, suffer from conflicts imposed by values from white society. Advanced education of the youth requires sending students to the south, inevitably introducing a degree of alienation from tribal traditions, and from life patterns in outlying settlements. This dichotomy may be reflected in physical and aesthetic standards and perceptions of housing, and is an important subject for discussion between designer and user.

The traditional conflicts between requirements and budgets are complicated by the need to obtain general approval from the population at large, and by cultural disparities between native lifestyle and building practices in 'the south' (i.e. apartment dwellings vs individual houses, 2 storey vs single storey houses). Frequently new housing programs are accompanied by renovations of existing dwellings in order to minimize disparities between family accomodations. Winning general approval is truly a lengthy and arduous task.

Information essential for the design program includes:

- number of 'families' (as defined in 2.1.2) to be housed;
- prefered groupings of dwellings for their accomodation;
- total available budget, including mortgages, loans, subsidies and other resources to be dedicated to the project;
- respective responsibilities of the local native authority, the municipal government, relevant provincial or federal departments and the house owner and/or the occupant, for re-paying any loans, or for paying operating and maintenance costs;
- list of standards, regulations and by-laws governing the design and construction of the project;
- available and projected infrastructure, including capacities of sewer system, water supply, and electrical or communication services.

Criteria for establishing the scope of the program are discussed below.

2.1.2 Number of Dwellings

The housing program is intended to provide shelter for a number of 'families', in accordance with priorities established by the community. The 'family' includes individuals, members of common occupations or professions, or others requiring shared domiciles. The design criteria discussed in this paper pertain to buildings meeting the requirements of Canada Mortgage & Housing Corporation

(CMHC) for housing one or more of these "families", each in a suite operated as a housekeeping unit as described in APPENDIX 1.

The number of dwellings required is one of the basic determinants of the scope of the work. The magnitude of the project will affect construction decisions, such as:

- use of repetitive elements;
- extent of off-site assembly of components;
- type and capacity of field equipment;
- volume purchases of materials;
- mobilization and maintenance on the site of skilled and unskilled labor;
- exploitation of local resources.

2.1.3 Grouping of Dwellings

Dwellings may be detached, or may be grouped in a variety of ways described in 4.1.1.

A prime determinant of building groupings is their acceptability by their users. In the writer's experience, natives have been greatly averse to apartment type dwelling, and their distaste is in direct proportion to their neighbor's proximity. Row type dwellings are not popular, and superimposed housing units are even less favored.

Indians have lived since time immemorial in individual tepees, and the Innuit in summer caves and winter igloos. Their lifestyle, unfettered by lock-step timetables, allows families and their individuals to come, go, eat and work, on purely personal schedules without consideration to their impact on their neighbors. Because natives frequently work in their houses on heavy carcasses or cumbersome snow vehicles, stairways constitute impediments. Noise, a by-product of these activities, becomes a major factor in units above or adjacent to each other. Wood burning stoves, a feature of Indian life, are often unsafe, and difficult to incorporate into apartments.

The spectre of fire sweeping a remote community is frightening. Fire fighting equipment, usually manned by volunteers, is frequently rudimentary. Hydrants, where available, are often widely spaced. Water pressures are usually low, and quantities, especially in Innuit villages, are limited. Strong, shifting winds, a constant feature of remote regions, exacerbate any fire. Wood or oil stoves are sometimes carelessly installed, improperly protected or left untended. Once a fire takes hold it is difficult to contain. The writer was witness to a house burnt to the ground as fire trucks stood by with hoses attached to a frozen hydrant. The instinctive native reaction is to build separate dwellings to localize the effect of a conflagration. Concentrations of families in one building, no matter how fire-resistant, are looked on askance.

Cost is a large factor in the selection of housing grouping. Usually multi-family dwellings are more economical because less wall, roof and foundation construction is required to enclose grouped housing. In remote regions these advantages are partially, or wholly, offset by the increased costs of sound and fire resistant construction demanded by current codes. Heavier and more perishable materials are required, such as gypsumboard and cement, and skilled personnel are needed for the more complex workmanship. Although heating is cheaper due to reduced wall and roof exposure per dwelling unit, the breakdown of a central system serving many families is more serious in a remote location.

Many villages are located on muskeg, clay or similarly unsuitable material. These soils are barely sufficient to support single family dwellings, and should not be allowed to underlay multi-storey construction without piling or other expensive foundations. Extended structures, such as row houses, are prone to differential settlement in these areas, and should be avoided.

Concentrated housing has the advantage of economical utilization of streets, and sewer, water and electrical services, and of providing mutual shelter against wind and precipitation. Fermont, in northern Quebec, has made ingenious use of extended strips of multi-storey, multi-family buildings to shelter single family houses.

Topography plays a role in the choice of building configuration. Uneven terrain is not conducive to extended buildings, but is more adaptable to small, detached dwellings. At high, exposed elevations, buildings are best kept low.

The designer will evaluate all these criteria and present viable alternatives describing the feasibility of each option. The final decision is usually made by the local native organization in concert with the financing agency.

2.1.4 Future Considerations

Although the design and construction of the dwellings may satisfy present needs, future use under changed circumstances should be considered. Requirements may change by reason of growth or shrinkage of the total population (or by age groups within the community), or by technological advances, or by different occupancy factors.

Future needs may be served by:

- modifying dwellings by dividing (or combining) units for different sized occupancy groupings, or for different uses;
- extending dwelling units for an increased number of occupants;
- altering houses because of changes of available services: this may entail switching from septic tanks to municipal sewers, or

installing domestic water supply where only wells were previously available, or changing to electrical heating from wood stoves, or by otherwise upgrading the performance of the dwelling, or improving its amenities;

- re-locating dwellings to other sites; these situations occur when hydro-electric developments flood extensive areas, or when townsites are moved to locations with more suitable soil conditions, or with better access to transport, or more viable hunting and fishing areas.

2.1.5 Forms of Ownership

Dwellings may be owned by:

- their occupants, with all the rights and obligations relating thereto; rights include the power to create or repay mortgages, to sell or rent, and to make physical changes in or to the building, subject to local zoning and construction bylaws;
- the municipality, or by the local native organization, and allocated to the occupant, usually on the basis of subsidized rental;
- Canada Mortgage & Housing Corporation (CMHC), or by some federal or provincial agency, and leased to the occupant, either directly, or through a local organization;

- their occupants, in the form of a co-operative, whereby each owns an undivided share of the buildings, and all financial obligations are the joint and several responsibility of the co-owners; internal arrangements and allocation of space are by private agreement between the co-owners;
- their occupants, in the form of a condominium arrangement, whereby each owner is the proprietor of a dwelling unit precisely described in a registered deed; common areas are owned and maintained jointly; each dwelling unit may be financed individually, and becomes the sole responsibility of the particular owner; the rights and obligations of the proprietors relating to maintenance, energy costs, care of common areas, etc., are governed by a condominium agreement.

The designer, aware of the ownership mode, will take care to make decisions based on the ocupancy needs, resources, and patterns consistent with any of the above alternatives.

Design factors affected by the form of ownership are:

- use of areas held in common by home owners;
- sharing of electrical, plumbing and heating services;
- access to dwelling units;
- locations of wall openings with respect to lot lines;
- parking and recreation areas.

SECTION 2.2 FAMILY CHARACTERISTICS

2.2.1 Family Considerations

Successful housing design requires an intimate understanding of the occupants' characteristics and lifestyle.

For the purposes of this paper, the term 'family' denotes the group occupying the dwelling. 'Family' characteristics are used to determine the size of the house[1], and the nature, disposition and relationship of the facilities needed to satisfy the needs of its occupants. The following data is required:

- total number and gender of persons forming the group;
- relationship of persons within the group;
- age distribution of all occupants, both male and female;
- primary occupation, and all subsidiary occupations;
- traditions, activities, hobbies, social life and pastimes to be practised within the dwelling;
- anticipated number of visitors for whom temporary accomodation may be required;
- occupancy patterns of families who are subject to temporary absence due to work requirements, hunting seasons, school terms, or other seasonal factors;

- existing housing conditions, including average area per occupant, types of storage and work spaces, available services, and other features related to the present lifestyle.

The above information is analysed and transformed into requirements for sleeping accomodations, as listed in APPENDIX 1.

It can reasonably be assumed that one properly sized and equipped food preparation facility and a common eating area are acceptable per dwelling. The size and number of sleeping rooms are determined on the basis of:

- the number of occupants, and their privacy and segregation needs;
- storage and furnishing requirements.

Final design criteria should be established in consultation with the natives, using existing living conditions as a basis for reference[2]. Proposals should be consistent with community resources for initial capital expenditure, as well as for future maintenance and operating costs. Native needs are similar to housing requirements in other communities: accomodation is required for the newly married, for the growing family, for the older inhabitants, and for specialized groups, such as teachers, nurses and other non-permanent residents, either married or single. As the proportions of these groups within the village are not constant, and as resources are limited, priorities and policies must be established by the local government.

2.2.3 Lifestyle

This section admittedly generalizes about lifestyles of Indian populations, and of the Inuit. There are considerable differences in living patterns across Canada owing to diverse cultural development, the relative isolation of bands, and the differing challenges of the environment. The climate may be harsh or benign.

The local population may be well subsidized due to favorable financial settlements, or may have no resources. Natives may benefit from employment from nearby industry, or may be isolated. Their handicrafts may provide an income source, or be unmarketable outside of the village. Contact with the white man and his social milieu may be close and intimate, or remote and non-interactive. Generalizations are further blurred because native lifestyles and perceptions are evolving rapidly due to better educational opportunities, as more schools are opened in the villages, and as more students are trained in white institutions. With the advent of satellite communications, with electronic document transmission facilities, and with better transport, some aspects of the primordial remoteness are over come. Dish antennae of the villages are tuned to the CBC Northern Service, and, as the writer has observed, not infrequently to the more sleazy, if less educational, emissions of the American television industry. This report avoids speculation as to the future effects of these developments and deals with major characteristics which affect design of native dwellings.

Basic differences in house design arise from:

- activities required for the livelihood and maintenance of the family;
- facilities necessitated by the remoteness of the dwelling;
- home occupancy patterns derived from hunting, fishing and trapping;
- social and living habits of many native families;
- high occupancy rates of dwellings.

Household activities not usually associated with living in the south include:

- storage and repair of motorized equipment, such as ski-mobiles, powered tricycles and outboard motors;
- repair and construction of canoes or boats;
- repair or construction of snowshoes, footwear and gloves;
- preparation of ointments and medicines from plants and animals;
- cleaning of fish, fowl, or other game and butchering of animals ranging from beaver and hare to walrus and bear;
- preservation of game;
- removal, cleaning and treatment of skins and hides;
- cleaning and repair of guns, traps and hunting equipment, and manufacture of decoys;
- knitting, sewing, weaving and carving.

The long cold winters and the lack of recreational and shopping facilities common in cities accentuate the importance of the home as the centre of family activities. Traditionally the warm stove was the focus, for obvious reasons. Today the kitchen-dining area, open and inviting, with a pot always steaming on the range, serves the same clientele. There is usually a television set in operation, with English or French intruding in a uni-lingual Cree or Inuktitut environment, the sophisticated dramas of the south playing to the bemused audience. A radio and stereo often complete the home entertainment scene.

Natives in the hinterland have no job market in the conventional sense. While a few are employed as teachers, administrators, workers at accessible resource industries, or at the local store or co-op, the majority are involved in seasonal occupations of hunting, fishing and trapping, in the preparation of the necessary gear, or the dressing of the resulting catch. At Fort George, according to game diaries, the meat, fowl and fish taken averaged in excess of half a kilo per person per day, or about 330 tonnes per year. Except for furs of beaver, otter or fox which are auctioned or sold to the Hudson Bay Company, the balance of the game, about 35 kg for each household, is cleaned and butchered, then smoked (in separate tepees), or frozen, or cooked and eaten. Extensive storage and preparation areas are necessary for these activities.

Hunting, fishing and trapping do not function by the clock, and native activities are neither regular nor predictable. During bird migrations natives will sit concealed in blinds along the waterways from before dawn; fishing depends on ice conditions and seasonal movement of the various schools of fish; hunting bear, caribou, seal and walrus requires an understanding of their migration or hibernation, and is best practised by those depending on the accumulated experience of the centuries.

Trapping will engage families in maintaining traplines for extended periods, often leaving their houses empty. The irregular schedules do not encourage fixed times for meals. The pot continuously cooking in the stove keeps hot food available on demand. Food preparation is virtually a family pastime and the kitchen should not be secluded, but form an integral part of a comfortable eating and living space. These essential activities require areas adequately sized and located in close proximity to the house entrance. Finishes of impervious materials promote sanitation, and generous storage, not necessarily enclosed, provides easy access for tools and parts.

Facilities located in a basements should be entered through an outside door aligned with the stairway to facilitate man-handling of carcasses and heavy equipment. A separate outside shelter is recommended for storage of gasoline, paints, solvents, or other flammables. Food preparation areas need running water with a drain, and space for a freezer; canning and preserving facilities requires a stove or oven. Home produced medicines seem to be highly variable, as the writer discovered when confronted with beavers' testicles drying on the clothesline, awaiting conversion to a healing paste.

In many communities shopping facilities are either non-existent or primitive, and do not offer the wide choice and instant availability of food and goods of urban centres. Natives must buy when supplies are available, and often in quantity. This necessitates ample storage areas, space reserved for freezers, and other provisions for maintaining adequate supplies under proper conditions. At least 4 m^3 of food and dry goods storage space per person is needed to store necessities imported by sealift. An estimated 7 1/2% of the floor area of a one storey house is recommended for dead storage required for indoor work, repair and recreational activities[1].

Native social attitudes have evolved from centuries of nomadic existence under harsh conditions, sheltering in tepees, and subsisting on game and fish. They lived, travelled and hunted in small family groups. Villages, often established in response to trade with the colonizer, are agglomerates of these families. The communities are small, and are, in effect, extended families, with distinctive feelings about property rights, land division, reception of visitors, and eating and sleeping schedules. Indian villages visited by the writer are marked by the total absence of fences or planting denoting property separation, or inhibiting free movement; indeed, there is little distinction between the road and private property.

Families are often extended by grandparents, cousins, nephews, and live-in students from other villages. The average number of occupants per dwelling is high; the writer's visits to 10 villages of Cree and Atapi bands in north Quebec confirm 8-10 per house, with a maximum of 18. The usual house area is 50-85 m^2 (not including the basement), leading to barely tolerable crowding, lack of privacy, and inadequate storage space. Often houses are without indoor plumbing, and water for cooking or washing must be carried from neighborhood wells.

Notwithstanding, native hospitality is automatic, and that of the Innuit is legendary, based on a fully communal history. Spending a few days at a stranger's home is casually accepted. The writer has inspected and measured hundreds of native houses; not one has had a door bell. With the slow increase of conventional occupations, and the acquisition of hitherto unavailable 'luxuries' it is said that these characteristics are changing; they are certainly in transition.

Due to increased expectations, greater financial capability and more sophisticated political awareness, natives are often able to obtain unprecedented features in their houses. Current housing projects routinely include most, if not all, of the following:

- full plumbing services, and provision of an indoor year round water supply, either by municipal services, or by tank truck;
- central heating systems, with distribution of each room;
- laundry facilities, including tubs, washers and dryers;
- full food preparation and storage facilities, including freezers;
- television receivers, radios and modern tape/record players;
- vehicle shelters.

Introduction of some (or all) of the above imposes responsibilities and design decisions, such as:

- provision of controlled heating systems capable of automatically maintaining above freezing interior temperatures, or of protecting plumbing fixtures and piping against freeze-up during winter periods when the inhabitants of the houses may be absent for prolonged periods;
- provision of exhaust systems to remove water vapor produced in bathrooms, kitchens and dryers to minimize deterioration due to hidden or apparent condensation;

- protection of footings against seasonal movement, occasioned by sub-grade freeze-thaw cycles, by their location below the frost line, or by fitting with equivalent perimeter insulation;
- provision of controlled air intake systems for human respiration, for combustion of natural fuels, and for introduction of dry air during cold periods; modern, tightly sealed homes require ventilation which was not necessary for loosely built housing of the past;
- provision of fire alarms and extinguishers to diminish the risk of fire;
- formulation of maintenance and fire prevention instructions for use by the occupant.

The shortage of housing units remains the most serious problem of the villages. It imposes a responsibility on the designer to comfortably accomodate as many as possible within budgetary constraints.

Design features which adapt the dwelling for larger, or extended families, include [2]:

- making the basement into an attractive, comfortable integral living space; this may be accomplished by raising the house to permit larger basement windows, and by using an intermediate landing at the entrance ('split-level entry'); sub-grade perimeter walls should be waterproofed and well insulated; in this way, up to 8 bedrooms may be comfortably included within 100m2 (for each of 2 living levels);

- building in bunk beds;
- obtaining approval for reduction of minimum bedroom sizes now permitted by Building Standards (CMHC);
- planning cupboards to store specialized apparel, such as hunting or fishing clothing, in locations outside bedrooms.

SECTION 2.3 SITE CONSIDERATIONS

2.3.1 Site Considerations

Proper appreciation of site conditions may be decisive in determining the success or failure of the project.

The major considerations are:

- accessibility;
- soil conditions;
- ecological factors;
- topography, including drainage, vegetation and ground levels.

These considerations will affect the selection of:

- foundations;
- construction equipment and techniques;
- building size and configuration;
- site drainage and roadways;
- septic tank disposal beds, where applicable;
- building location, orientation and landscaping.

Site considerations impose important constraints upon types of housing units, and upon their configuration and orientation. As most native housing is in remote locations, the importance of considering site conditions is magnified by difficulties in modifying grades of drainage patterns, or by problems of preparing special foundations for structures resting on sub-standard or on permanently frozen soil. Heavy equipment in these areas is expensive, difficult to transport, costly to maintain, and requires specialized, hence high-cost, operators. Expense related to using heavy graders, pile drivers, de-watering equipment, rock crushers, excavators and loaders often renders their use prohibitive. Accurate information as to site conditions allows the designer to plan and locate buildings for maximum economy and utility, and with optimum use of the topography for access, orientation, view, and shelter from wind or snow. Poor soils are avoided, where possible, and drainage patterns respected to avoid flooding of roads or buildings. Forestation and vegetation can be integrated into the design. Levels and grades may be studied to minimize cutting and filling, to simplify construction of access roads, and to facilitate surface drainage.

2.3.2 Soil Conditions

Historically Indians and Innuit were nomads following the migrations of game and fur clad animals. With the advent of the Europeans, villages were located to facilitate the fur trade, and to provide fishing, hunting and trapping areas for native groups. The housing was primitive, services were rudimentary or non-existent, and access was by rudimentary roads or water transport. Soil conditions were never a priority in the selection of the site, or in its development. With the advent of central sewage and water systems, and the design of houses requiring stable foundations, the problems resulting from poor soils and bad drainage became all too manifest. Much hinterland terrain is in a permafrost zone, or is covered by muskeg, or is underlain by unstable clays. As most villages are adjacent to waterways, high water tables are common. Because of remoteness, negligence and cost, comprehensive soil tests were (and are) seldom found. In many communities the results of these conditions are:

- leaking basements, and basement slab uplift due to hydrostatic pressure;
- unstable foundations, resulting from settlement and from volumetric instability of soils under footings and grade slabs;
- lack of adequate supplies of gravel for construction purposes, restricting use of concrete and precluding proper backfilling under grade slabs and against foundation walls;
- roadways of inadequate capacity which are difficult to maintain.

These are discussed in more detail below.

Soil conditions are evaluated by the following techniques:

- airphoto studies taken in summer and winter to various scales;

- test pits to depths consistent with type of structure to be built, and with nature of soils encountered;
- core drilling, to recover undisturbed samples;
- percussion testing, to determine soil bearing values;
- measurement of soil temperatures[1] at different levels during the cold season. Information listed in APPENDIX 1 is essential for the proper design of buildings, roadways and services.

In regions of soils of questionable value[2], which may include permafrost, muskeg or sensitive or unstable clays or silts, more sophisticated analysis may be required. As sources of fill are a frequent necessity, soil tests are needed to evaluate the characteristics, location and capacity of borrow pits to ensure a reliable supply of sound, granular material. Fill should be gravel and/or coarse sand, free of deleterious amounts of clay or silt, and capable of draining freely. All soil considered for backfill should be evaluated for compaction characteristics at optimum moisture content.

Types of soil at the footing bearing level, and the stratum above to ground level, will affect the performance of the house. At the bearing level, decisive characteristics are:

- <u>resistance to superimposed loads</u>; soil with bearing values below $24\ kN/m^2$ is considered unstable, and is not recommended for support of permanent structures; in building on such ground, pilings or caissons should be used to transfer loads to deeper, more resistant strata;

- susceptibility to freezing; well-drained, granular material will not readily hold water, and, in event of freezing, will be less subject to expansion because of the high proportion of voids; lack of capillarity action will minimize formation of ice lens below the footings;
- volumetric stability; certain clays will undergo changes in volume if their water content is reduced or increased, and induce settlement or lifting of slabs or footings placed thereon.

At strata above the bearing level, important characteristics are:

- presence of rock; excavation difficulties in remote areas, where equipment and skilled operators are scarce or non-existent, often place limitations on work in solid rock, or in extremely hard or boulder-filled soil;
- water table elevations ; high water tables create problems related to footing and foundation formwork erection, concrete placement, foundation waterproofing and hydrostatic pressure under grade slabs; water penetration into sub-grade areas of buildings is common; as de-watering techniques and proper subsurface waterproofing is expensive and often ineffective, these locations should be avoided, or the houses built without basements;

- permeability of the soil; it is advisable to have freely draining material in contact with foundation walls to enable water to percolate down to the sub-grade drainage system; frozen fine grained backfill will adhere to foundations walls and damage the building by uplift, as described in 2.5.5.

In areas free of permafrost, foundations should be established at levels below frost penetration, or the ground should be insulated to contain the natural heat from below to prevent freezing under footings.

Where these techniques are not feasible, care should be taken to found structures well above the water table, and on non-frost susceptible soil, such as sand or gravel, which does not encourage capillarity-incuded formation of frost lens which may distort the structure above by uplift. Where differential settlement is anticipated, provision for jacking or wedging the superstructure should be made.

In areas underlain by permafrost, the danger of movement due to thawing of the permanently frozen layer imposes special disciplines on the designer. As the supports for the building are set into the permanently frozen subsoil, and their stability depends on their remaining frozen solidly for the life of the structure, it is crucial that heat produced in the building (as well as radiation from the sun's rays reflected from the exterior walls) be prevented from raising subsoil temperatures above the freezing point.

Techniques for achieving permanent, stable foundations under extreme conditions are discussed under SECTION 4.3.

2.3.3 Surface Drainage

Native housing is not generally constructed in urban settings, but is more often located in remote regions, exposed to climatological extremes. The village itself, often isolated and with limited resources, is vulnerable to extremes of precipitation. Flooding can occur if the construction site is imprudently located with respect to rivers or lakes which overflow their banks, or by surface run-off which has not been properly anticipated and channelled. Suitable surveys, airphotos, and inspection of the past behavior of neighboring waterways, in conjunction with weather records, as discussed later, will guide the planner in avoiding errors. Attention should be paid to the danger of flash flooding caused by rapid melting of snow, or intense rain, over frozen ground. It is axiomatic that dwellings should be set higher than their immediate surroundings, and adjacent ground sloped to drain away from the buildings, roadways and walkways. Suitably sized, graded and stabilized ditching is necessary to lead run-off into natural formations ample capacity to store or conduct waterwithout danger of back-up. Well designed culverts are required to carry water under roads or elevations; undersizing can result in local ponding.

2.3.4. Site Topography

Surveys of the construction site should include:

- contours at 600 mm intervals in the building area, and at 1525 mm intervals elsewhere, with reference to mean sea level;
- location, nature and elevation of watercourses and ditching of the surface drainage network;
- north point, latitude and longitude, and bench mark locations;
- natural boundary lines of all adjoining or included rivers or lakes, with high and low water levels, and tidelevels at sea front locations;
- property limits, boundary measurements, and angles;
- nature and location of all servitudes and encroachments;
- location and extent of all roads, air strips and rights-of-way;
- location and elevations of glide parths at air strip approaches;
- location of all power lines, fences, buildings, and above or below ground services on or adjacent to the property;
- location of underbrush, swamps and tree stands.

This information is required to:

- site buildings with a minimum of cutting and filling;
- locate buildings with optimum sun orientation required for passive or active solar heating, and to suitably size overhangs controlling sun radiation through windows;
- take advantage of landscape features which offer protection from the wind, and enhance the local environment;
- suitably integrate roadways with regard to their slopes and susceptibility to flooding and snow accumulation;
- design grades which ensure adequate surface drainage;
- provide information to engineers for the design of services;
- avoid locations subject to flooding from lakes, rivers or tides.

Accurate information has, in the writer's experience, been notoriously lacking. Elevations, datum points, roads, etc., are often hopelessly confused, usually because well intentioned surveyors lack the competence required to fix starting points accurately, and because of the less disciplined requirements of village life.

2.3.5 Latitude

The latitude of the site is necessary determine the position and angle of the sun at any given time. This data enables the designer to develope fenestration and protective overhangs for passive solar heating, or to orientate heat receptors for active solar heating.

2.3.6 Vegetation & Forestation

Vegetation and forestation are indicative of the nature of the underlying soil and of drainage conditions.

Trees and shrubs can be used to enhance the appearance of buildings, prevent erosion of the soil, and give a measure of protection against snow and wind. In temperate areas, where agricultural land use is a planning consideration, more detailed and specific evaluation of the soil is required. Information gathered should include:

- number, location, type and size of trees;
- location and type of vegetation;
- identification of soil relevant to planting possibilities;
- measurement of levels and natural features needed to realize landscaping op[illegible]ities.

2.3.7 Seismic Risk

Seismic risk factors noted in APPENDIX 1 establish criteria needed to design the structure to withstand anticipated ground acceleration.

2.3.8 Accessibility

The delivery of building materials, the transportation, feeding and lodging of outside labor, and the use of imported construction equipment, are all governed by the accessibility of the construction site. Distances are often great, and the means of transport are limited and expensive. In the writer's experience the cost penalty is a factor in the range of 1.5-2.5, depending on the relative isolation of the project. Any possible savings in this regard could well be devoted to improving the quality of the dwellings.

As shown in 2.4.9 and 2.4.10 most projects depend largely on equipment and supplies brought in from the nearest large towns. Transportation is by:

- trucks, using all-weather highways, or seasonal roads;
- barges or ships servicing coastal villages, or serving as a link in the delivery chain;
- commercial or chartered fixed wing aircraft, or helicopter;
- railway.

Delivery capacities and related costs are highly variable, as can be seen from APPENDIX 2, showing approximate transportation charges from Montreal to a variety of destinations. The great disparities underline the necessity of designing and scheduling the work to suit the particular site circumstances.

Trucks, with their economy, flexibility and availability, are the prefered means of transport. Unfortunately roads to remote villages may not exist, or may be unimproved, improperly maintained logging trails, with permanent or seasonal restrictions on load size or capacity. In some areas vehicular access is only possible by building winter roads over terrain which is impassable unless frozen, and by constructing ice bridges over rivers and lakes. Their continued use depends on local temperature conditions, and the shipping season ends when the first truck sinks from sight. These roads are expensive to build and maintain; the Eastmain winter road costs $500,000. ($5,000 per km), an annual cost which must be written off over the construction season.

Available transport vehicles should be suitable for distances and road conditions involved. Some transport requires materials handling gear, especially for heavy loads such as concrete block, cement, or gypsumboard. Adequate fuel and repair/maintenance depots are required at appropriate intervals, and standby transport and other equipment reserved to maintain delivery schedules.

Many communities are dependent on water transport to support any significant construction program. In these situations work must be scheduled to ensure that all materials are at dockside in time for shipment; properly crated to the approval of the carrier. The cargo must be consistent with the load and configuration requirements of the vessel. Loading and unloading facilities at harbors must be known, as well as sailing schedules, trip durations and seasonal restrictions. Comprehensive insurance is required for the entire route. Specialized components, such as structural steel, cabinet work, ducts, and pre-fabricated items require additional lead time for shop drawing preparation and approval, and for fabrication. Wharves, docks and crane-equipped off-loading facilities are luxuries seldom found in small coastal villages. Cargo is transfered to barges or light vessels, dumped on beaches and man-handled or trucked to the site. In arctic regions, because of the short shipping season, only one trip per year is possible. Much planning may be negated by inadequate packaging, or by improperly supervised handling. The writer vividly recalls the cancellation of a years's work due to a diesel generator sinking to the ocean bottom 100 yards from the Baffinland coast.

Air transport, by plane or helicopter, may provide sole or supplementary access to the site. In evaluating the capacity of the air transport system the designer must determine the configuration and load limitations of the plane, the loading, unloading and runway characteristics at all flight terminals, and the availability of servicing equipment. Flight schedules must be studied, or aircraft chartered. Allowance should always be made for anticipated weather and airport restrictions described below.

For the fortunate projects which are favored by rail access, similar studies are required as for air and water transport, with the additional evaluation of the condition of the railbed.

Whether by road, water, air or rail, it must be emphasized that the capacity, availability and scheduling of vehicles and craft must be thoroughly investigated. Access limitations may arise from:

- roadways which are subject to thaw, washout, blockage by snow, mud or avalanche, or have undersized bridges, low overpasses, or unduly narrow or steep sections, or have legal or practical load limitations;
- weather conditions which limit air traffic, such as high crosswinds, or periods of low visibility at airstrips which lack radio or navigation aids; many native villages are only accessible by visual flying; poorly constructed runways which

are water and frost susceptible often limit or eliminate traffic for extended periods;

- inadequate loading/unloading equipment, either for air or water craft;
- limitations of vehicle or craft payloads, by restrictions of either weight or size due to poor roads, inadequate air strips, or docking facilities;
- restrictions on shipping by water due to ice conditions.

Much of the foregoing is beyond the designer's control. However consideration of the following principles will assist in reducing transport-related costs:

- use materials that are light, and readily nested, compactly stacked or knocked down; shipping totally prefabricated house modules is considerably more expensive than an equivalent version with the walls folded down; do not ship 'air';
- use materials that are not unduly fragile, or which can readily be protected during transit; glass and asbestos cement sheets are examples of fragile components;
- select materials not readily deteriorated by moisture or by freezing; proper storage facilities may be lacking; often shipping crates double as warehouses, or even temporary residences; gypsmboard and cement are affected by water;

emulsions and certain paints and adhesives should not be exposed to freezing temperatures;

- standardize materials and assemblies where possible, and avoid specialized components whose damage or loss will cripple job progress; standardization will simplify construction and subsequent maintenance; wall components (i.e. siding, framing), windows, doors, hardware, finishes and fasteners are suitable candidates;
- use locally available materials, facilities and skills; these factors are discussed in 2.4.9 and 2.4.10;
- ship generous amounts of stock items, such as plywood, gypsumboard, fasteners, cement, etc., to offset possible losses by deterioration, wastage or pilferage; the lack of critical items may prove costly if they cannot be readily replaced; in any case, excess material generally finds a ready local market in an isolated community with a healthy tradition of improvisation and ingenuity;
- avoid construction techniques which require heavy equipment (i.e. high-capacity, cranes, pile drivers, heavy compactors) as their transport, maintenance and operation are costly; if their use is unavoidable, select equipment which may be leased to the municipality, or to other contractors.

2.3.9 Ecological Factors

Housing sites should be located with an awareness of environmental hazards; these include:

- mercury-contaminated waterways;
- acid rain, or lakes which are affected by industrial fall-out;
- rivers poisoned by untreated effluent from upstream communities, or by waste products from paper or chemical industries, or from nuclear plants;
- chemically contaminated fish or game;
- radioactive soils;
- forests contaminated by chemicals used to spray insects.

Not all deleterious conditions are man-produced. Available water may have high mineral content, affecting its taste, or the piping used for its circulation. Soils, or aggregate sources, may have a high sulphate content, requiring special cements. The writer designed a project in Abu Dhabi on ground about 1.5 m above sea level; the sand was so contaminated by salts that imported aggregate was required.

Government agencies are generally aware of the various hazards, and are equipped to carry out the necessary tests and evaluations.

SECTION 2.4 COMMUNITY SERVICES, FACILITIES AND RESOURCES

2.4.1 Community Considerations

Services, facilities and resources available within the community impose conditions on the project. Design and construction decisions are affected by:

- internal roads;
- building services and community infrastructure listed in APPENDIX 1;
- fire protection.

2.4.2 Roads

Roads discussed in this section refer to internal circulation ways within the townsite; access roads to the settlement from other communities are discussed in 2.3.8.

In developed communities, with suitable internal circulation, the inhabitants will own cars, small trucks, vehicles for passage over snow, etc. Storage for these vehicles will be required on the properties of their owners, with, perhaps, provision for their repair and maintenance. Site planning should anticipate these needs, and evaluate the use of open parking, covered storage or heated or unheated garages.

The design of the dwelling units will be oriented toward vehicular access; driveways will be required, and consideration given to crossing drainage ditches which usually parallel the road system.

In new communities it is expected that the road network will be designed integrally with the services, the town plan, and with all infrastructural considerations. The timing of the installation of these new roads, and the services which they incorporate, with respect to the construction of the houses, will affect the logistics of the construction, including:

- access of heavy equipment or building materials;
- temporary services required during the construction period;
- connections of house services, or septic tanks, as applicable;
- grading and ditching around housing.

In existing communities, roadways affect the:

- size and weight of construction equipment to be used, and of materials and building components, especially pre-built sections, to be erected during construction;
- potential re-location of existing houses;
- ability of fire fighting vehicles to deploy effectively;
- truck delivery of water or garbage pick-up, where applicable.

To evaluate existing roadways, the designer should determine:

- roadway width;
- bearing capacity of road, or of bridges or overpasses;
- restrictions of vehicle size due to road layout, grades, or bridges, overpasses, or underpasses;
- susceptibility of roads to flooding, washout, precipitation, thaw, snow build-up or avalanches;
- seasonal restrictions due to any of the foregoing;
- availability and capacity of snow clearing and other maintenance equipment;
- availability of suitable fill or other material required for road repair;
- road surface conditions;
- condition of ditching or culverts;
- adequacy of safety barriers, signage or signals.

An evaluation of those factors will determine the transport vehicle characteristics listed in APPENDIX 1.

2.4.3 Sewage

Sanitary sewage will usually be disposed of by any of the methods listed in APPENDIX 1.

Factors dictating the selection of the sewage system are beyond the scope of this paper. The designer, after determining the characteristics and limitations of the available services, will make the necessary allowances in orientating and siting the buildings, and in allocating building lots consistent with legal and functional requirements. If storm sewers are available, flat roofs and paved areas may be sloped to drains, and the run-off directed into the appropriate drainage network.

In many northern communities sanitary wastes are collected in plastic bags and picked up by truck. Appropriate storage is required pending their collection. Where individual holding tanks are used, the design must allow for their incorporation into the structure, with provision for their accessibility and maintenance.

Accurate information is required as to:

- depth of sanitary and storm sewers, manholes and catch basins, to ensure that house connections are possible with the required piping slopes;
- characteristics of soil destined to receive septic tank disposal beds, to obtain necessary approvals from the authorities having jurisdiction, and to permit the proper sizing of the beds;
- any special features or limitations of sewage disposal systems.

2.4.4 Water Supply

Water may be available by any of the systems listed in APPENDIX 1.

Planning of the dwelling unit should provide facilities to receive, store, and, if necessary, treat water introduced into the supply system. Treatment may include chlorination, filtration, de-ionization or de-mineralization, depending on the chemical content and purity of the available water. If storage and pressurizing is necessary, the building will require tanks and pumps.

2.4.5 Electrical Power Supply

Most communities have an electrical supply, either by connection to a central grid, or generated within the community. The characteristics of the system will determine the extent of electrical equipment to be installed in the houses. This subject is dealt with in greater detail under 3.H.

Information required by the designer is listed in APPENDIX 1.

2.4.6 Garbage Collection

Frequency of garbage collection affects the design of storage space for waste containers. These should conveniently located, adequately sized for anticipated requirements, protected from animals, and sealed to prevent attracting wildlife and rodents, and to eliminate odors and infestation; cold locations will retard decomposition and reduce health hazards.

2.4.7 Fire Protection

The remoteness of many native communities, their extensive use of combustible construction materials, fossil fuel heat sources, including stoves in living areas, and their frequent lack of ample water supply and fire fighting equipment, combine to create high risk occupancies. Fire hazard can be reduced by:

- suitable design and selection of all heat sources, and electrical components;
- educational programs for use of materials creating or contributing to fire hazards;
- provision of ample, protected storage facilities for hazardous substances;
- provision of home extinguishing equipment and alarm systems.

The effectiveness of the fire protection facilities for the village depends on:

- type and condition of mobile fire-fighting equipment;
- training and availability of fire fighting personnel;
- village alarm and communication system;
- condition of roadways during all seasons;
- availability and accessibility of water supply, and relevant water pressure and quantity;
- alarm and extinguisher systems in buildings.

2.4.8 Future Development

Services available in communities evolve and expand, and their future development should be considered in the design of the dwelling to minimize costly up-grading later. This considerations particularly apply to sewer, water and electrical supply. Examples are:

- where septic tanks are necessary, piping may be installed to facilitate future connection to a central system;
- where 'honey buckets' are used, holding tanks may be provided for future collection by pump-equipped trucks;
- where electrical supply is minimal, entries and distribution may be installed to anticipate any augmented future capacity.

2.4.9 Use of Local Materials

Where possible the designer should make use of local materials. These are generally more economical, are familiar to the local population and workmen, and assist the village economy. Usual available materials are:

- stone, which may be crushed, and used as aggregate or fill, or split and used as masonry;
- trees, which can be transformed into lumber, or into firewood (see 3.9.2);
- gravel, which can be used as concrete or asphalt aggregate, or as fill material, or as flat roof topping.

Where extensive processing equipment is specified, its use must be justified by the volume of usable material produced.

2.4.10 Use of Local Labor and Facilities

An inventory of local resources will guide the designer in selecting materials and construction techniques most responsive to overall efficiency and economy.

These resources may include:

- heavy equipment and garaging/repair facilities, including excavators, graders, drills, trucks, compactors, pile drivers, quarrying and crushing equipment and cranes; the high cost of importing and maintaining these items in the field may affect design decisions, and their local availability should be investigated;
- shops and equipment for production of building components; these may include sawmills, wood prefabrication shops and concrete masonry plants; the presence of one or several of these facilities may be decisive in the selection of materials;
- skilled and unskilled labor; import of labor, and consequent problems of housing, feeding, care, entertainment and transport, makes employment of equivalent local counterparts more attractive; it will be necessary to ensure that the level of skill and experience, as well as local union regulations and jurisdictions, are compatible with job requirements;
- heated or unheated storage space; when transport facilities are limited, or weather conditions impose seasonal restrictions, it becomes necessary to stockpile materials beyond the requirements of more accessible projects; availability of already erected, heated and secure shelters will save time and expense;
- housing, eating and other facilities for imported labor; the high cost of building staffing, servicing, and maintaining cafeterias, dormitories, hospitals, and recreational halls in

remote locations may be eased by boarding imported labor with local townpeople, or using or converting already constructed facilities;

- fuel availability; delivery, storage and distribution facilities for oil, natural gas, propane, coal or wood may be determinants in the selection of heating systems for the dwelling units, in conjunction with cost and adequate capacity.

2.4.11 Communications

Because good communications are important between the construction site and the usually distant operational offices of the designer, builder, materials suppliers, and various governing authorities, the availability, cost, reliability, and speed of the following communication modes must be verified:

- postal service, including special delivery, parcel and registered mail;
- telephone or equivalent radio service;
- electronic document transmission equipment;
- private courrier, or via air transport;
- telex communications.

SECTION 2.5 CLIMATE

2.5.1 Climate Considerations

The Canadian climate is highly variable. The winter design temperature in southern British Columbia is $-5\,^{o}C$, while the Northwest Territories contend with $-45\,^{o}C$. The corresponding degree day indices are 3,000 and 13,000. Annual total precipitation in these areas diminishes from 2,000 mm on the rainy west coast to about 250 mm in the desert-like Arctic. Ground snow loads are 0.9 kN/m^2 at Calgary, Alberta, and 5.9 kN/m^2 at Seven Islands, Quebec. Permafrost, either continuous or discontinuous, underlies about 2/3 of the country.

These extremes of precipitation and temperature, combined with wind, must be successfully dealt with for the:

- efficient use of energy;
- maintenance of a weather-resistant, draft-free interior environment, with comfortable levels of temperature and humidity;
- maintenance of building structural integrity in the face of snow and wind loads;
- minimization of open and hidden condensation;
- minimization of interior odor build-up, and provision of healthy levels of fresh air.

Data required for design are listed in APPENDIX 1.

2.5.2 Design Factors Relevant to Energy Consumption

In the far north, where temperatures drop to below -40°C for extended periods, the annual degree day calculation reaches twice that of Montreal. To maintain comfort inside dwellings takes about 90% of the total energy consumed within the community. Although wood is used to heat many houses, the prime fuel for remote communities is oil. Oil-fired generators supply electricity for villages which are not linked to power networks, and oil is the most common source of heat for automatically controlled individual furnaces. The cost of oil has risen by a factor of 6 over the past 10 years. This increase in the base price is augmented by the cost of transportation and distribution to remote regions. Diesel oil for electrical generation and furnace heating, worth $.25/L in Montreal, costs $.70/L in Chimo. A typical house of 80 m^2 at Obedjiwan, Quebec (lat. 49°) built before the energy crisis uses about 7,500 L/yr. of oil for a total annual outlay of $3,000 (based on $.40/L). A similar house at Chimo (lat. 58°) burns 9,000 L/yr., at a cost of $6,300. These amounts are high by any standard and beyond the reach of a population with limited earning power. They may be reduced by about 1/2 to 2/3 by proper design of new dwellings and appropriate retrofitting of existing buildings. Dwellings built before the rapid escalation of energy costs often have minimally insulated log walls or wood framing with 50-75 mm of fibre or sawdust, or the equivalent, with an R value of about 1.75. Roofs may be doubly efficient, due to extra depth available between the ceiling joists. Resistance to air infiltration is pitiful, resulting in 3-4 air changes per hour of uncontrolled movement through window crackage and wall joints. Floors are often over poorly constructed crawl spaces, with little or no insulation. Frost formation on interior surfaces of living areas, especially at corners and at wall-floor joints, is usual. Drafts sweeping across floors are so common as to not merit mention. Centrally placed stoves, ovens or furnaces are especially inefficient, not to say dangerous, and heat only within their effective zone of radiation. Hopefully, these conditions will never be repeated in new designs. Under the impetus of energy costs, applied building science has made great strides, and has been reinforced by appropriate legislation. Revisions to Residential Standards (Canada Mortgage & Housing Corporation)[1] legislate the minimum R (m^2.C/W) requirement for the building envelope as a function of its location. For houses in regions of 8,000 degree days, roofs, superstructure walls, basement walls, and floors over unheated spaces are to be 7.1, 3.7, 1.5, and 4.7 respectively.

More efficient products and practices relating to air/vapor barriers and insulation, design improvements to the construction of the building envelope, and improved ventilation techniques, have made realization of these norms possible. Implementation of these regulations may reduce heat losses by 50-75%.

Determinants of energy efficiency are:

- suitable type and thickness of envelope insulation, and detailing to avoid thermal bridging;
- control of air infiltration;
- efficient design and construction of windows and doors, and use of insulating screens;
- building orientation for solar heat gain;
- fuel utilization efficiency;
- recuperation of heat from air exhausted from the building;
- positioning of building for wind protection;
- provision of protected building entrances;
- use of color, texture and thermal mass for heat absorption and retention.

The selection of the envelope insulation and its thickness must be made in conjunction with constructional features of the walls and roofs. Insulation can be applied on the outside surface of the walls, on the inside surface, or within the wall, or in combinations thereof. 'Outside' insulation has the advantage of full continuity and no thickness restrictions; 'inside' insulation is at the expense of living area, and necessitates penetration of structural members at floor-wall and roof-wall junctions. 'In-wall' insulation necessitates increased sizes of wall framing members, or double wall construction, the former increasing the effects of thermal bridging, and the latter reducing livable floor space. These alternatives are discussed in 4.2.2. and illustrated in APPENDIX 3.

Roof insulation presents fewer complications, as the common construction systems allow unrestricted thickness between suitably modified roof trusses; or between joists.

Thermal requirements for windows necessitate triple glazing in regions where degree days exceed 6,500, and double glazing elsewhere, with air infiltration limits of .775 $dm^3/s/m$ of sash perimeter. Window frames and sash should be of wood, as no other material is as effective in minimizing frost formation over the inside surfaces. Exterior doors should have insulated cores; foamed urethane sandwich-type bonded to metal facings and hung in wood frames provide high insulation efficiency and good resistance to warping and bowing.

When light wood framing is used, consideration should be given to the following:

- use of studs at 600 mm oc (instead of 400 mm oc), where structural requirements permit, results in labor and materials savings, and reduces heat loss due to thermal bridging; over the outside framing, a layer of continuous rigid insulation, or insulation type sheathing, maximizes this effect;
- the weakest part of the building envelope, thermally, is the discontinuity of the stud-insulation joint; it is susceptible to careless application and impossible to seal properly using rigid insulation, due to the inevitable irregularities and distortion of the framing members; it is recommended that fibrous insulation be fully compressed into place, and set against solid backing to preclude displacement;
- where rigid polystyrene board is used on inner surfaces, it should be the extruded type with a permeability of hg/Pa.s.m^2; joints should be sealed with permanently flexible mastic; over outer walls, in conjunction with other insulation towards the warmer side where trapped water vapor may condense, beaded polystyrene or glass fibre should be installed;
- care should be taken to fit fibrous insulation between exterior double studs occuring at inner partitions, between studs which form exterior corners, and between joists where they form a platform for succeeding stud assemblies;
- roof trusses should be fabricated with end posts at the eave bearings to ensure clearance for the specified insulation thickness, with ample volume for ventilation of the roof space;

- rigid board insulations which are intended to reduce wall permeability should have their joints sealed with a permanently vapor resistant, flexible mastic, as the butted junctions can never be acceptably fitted;
- fibrous insulation should completely fill joist cavities over unheated crawl spaces;
- sub-grade spaces are more habitable when fitted with full height floor-ceiling insulation, preferably applied on the outside to include the thermal mass of concrete or concrete masonry within the heated zone, retaining the heat and re-introducing it into the living areas;
- when concrete masonry basement walls are used in conjunction with non-full height insulation, core cavities should be blocked to preclude heat loss by convection currents within the foundation wall;
- when using thick applications of low density fibrous insulation, consider building up the total thickness using thinner layers separated by permeable paper; this technique restricts the creation of convection currents within the insulation which reduce its thermal efficiency;
- when using low density fibrous insulation between ceiling members, or similar applications of granular insulations such as cellulose or vermiculite, verify that air currents within the roof space do not displace the insulation causing significant differences in thickness, or blocking of air vents;

- for through-wall components, such as door and window frames, use low conductivity materials, such as wood; fit other materials with thermal breaks detailed to avoid thermal bridging and installed within the plane of the wall insulation.

Conductivity losses of the envelope have been reduced by up to 2/3 over the last 15 years because of more stringent building regulations, more efficient insulation systems, better application techniques, and, above all, by a greater awareness of the financial and comfort implications of energy-efficient housing.

Air filtration[2] accounts for 30-60% of the total energy losses. As mentioned, many older dwellings experience 3-4 air changes per hour due to poor construction and badly fitted, unweatherstripped windows and doors. Respiration requirements are 4.72 L/s per person, about 60 L/s for a dryer, and 40-200 L/s to support natural combustion. Using a typical housing model of 80 m^2, occupied by 8-10 persons, not more than .75 air changes per hour are necessary. The writer's study at Weymontachie (Quebec) showed that 18,000 kWhr/yr., representing 30% of the total heat loss, was attributable to air change for the unimproved dwelling built in 1970, and 7,300 kWhr/yr., or 40% of the total loss, would occur if upgraded to present standards. The dramatic energy saving equivalent to 1,400 L of oil, indicates the importance of controlling air entry. This objective is attainable by:

- weatherstripping metal doors with magnetic gaskets and wood doors with compressible gaskets selected for long service life; an outer door to an unheated vestibule will prevent frost build-up on the frame by condensing vapor; where use of glazed panels is unavoidable, use sealed double glazed lights; as doors opening into heated spaces tend to warp due to temperature and humidity conditions, double doors are advisable; seal the air barrier to the door frames and tightly pack the door frame perimeter with fibrous insulation;
- minimizing window areas; on operating sash, use long service replaceable weatherstripping; in regions of prolonged extreme low temperatures and high winds, moveable sash tends to freeze in partially open position; use fixed triple glazed sash, and admit air through protected snow-proof ports, or through intakes into the heating system; seal the air barrier to the window frames, and tightly pack the window perimeter with fibrous insulation;
- providing a continuous air barrier (usually combined with a vapor barrier), fully supported against a backing, with all joints lapped and sealed as described in 2.5.3;
- avoiding installation of wiring or of electrical outlets in the outside walls and in ceilings under unheated roof spaces; these form pathways extremely prone to air passage, and are almost impossible to seal; if absolutely necessary, consider the use of surface wiring and boxes;

- providing exhaust fans in the kitchens and bathrooms which operate in increments up to 300 L/s; at least one fan should be controlled by a humidistat; through-wall kitchen fans are a prime source of air leakage, and bathroom fans ducted through the ceiling are difficult to seal properly, thus allowing moisture to escape into the roof space; best results are attained by exhausting air through ducts below the ground floor and out through the wall; exhaust dampers in exterior walls at first floor ceiling heights blow high humidity air up through the eave vents into the roof spaces; air-to-air heat exchangers that the writer has evaluated do not provide an economic payback;
- providing a controlled fresh air supply into the basement or directly into the return air plenum of a hot air system; this will replace stale air, reduce interior humidity levels, and eliminate negative air pressure induced by exhaust fans which will promote uncontrolled infiltration.

Conductivity losses through windows, and doors which total about 15% of the floor area, account for about 60-70% of total heat loss. Important savings may be achieved by using:

- triple glazed sash (R.50 $m^2 \cdot {}^oC/W$) instead of doubled glazed (R.30 $m^2 \cdot {}^oC/W$) units;
- interior insulating screens tightly fitted at the perimeter to minimize frost build-up on the frame and glass;

- minimum window sizes permitted, and designing for maximum southern orientation;
- wood frames and sash for windows, and wood frames and insulated panels for doors.

A feature of northern construction is the unheated porch. Construction of an amply sized enclosure provides:

- protection of the entrance from wind and precipitation;
- an insulation value, calculated at R.16 $m^2 \cdot {}^oC/W$;
- space for storage of equipment and provisions;
- a reduction of condensation at the protected doorway.

Suitable orientation of the house and proper selection of window sizes and locations results in a passive heat gain of 20-50%[3-4]. By facing about 75% of the windows to the south (about 6% of the gross floor area), and by installing insulating shutters to reduce heat loss during sunless hours, solar energy is absorbed within the house.

Window overhangs provide protection in the summer from excessive heat build up. The heat gain depends on the latitude, number of sunless hours, construction of the house, and the efficiency of the insulating shutters.

Comparison of annual heat loss between identical small houses, differing only in color, indicates that the darker requires about 6.7% less heating energy than the lighter.[5] This factor should be considered, as well as the positive psychological implications of strong colors in an environment often characterized by a bleak and neutral ambience throughout much of the year.

The house may be advantageously sited to:

- admit solar heat through windows, as described above;
- protect the building from north winds by utilizing natural relief features or trees or shrubs;
- use prevailing breezes to cool the building by cross-ventilation.

The energy conservation measures which have been discussed will be partially or wholly incorporated into the house design if justified by the resultant savings, and if the overall budget permits.

Common methods of analysis are:

- the payback period, defined as the incremental investment cost divided by the first year savings; calculations are made for each feature considered and for the sum of the measures which are adopted; the resulting analyses are simple to understand and compare, and utilizes the present, known costs of energy and of the proposed design features; however, the increased value of the property is not accounted for, and projections of fuel prices are not considered;

- the life cycle analysis which discounts future energy costs over the hypothetical building life using a rate based on an assumed differential between the fuel cost escalations and a mortgage interest rate; this analysis is more complex, and depends on a number of assumptions which only future conditions can justify.

2.5.3 Design Factors Relevant to Condensation

Condensation hidden in the structure or appearing on interior surfaces is a universal feature of dwellings in northern regions. Its pervasiveness stems from prolonged and extreme cold spells, and from interior humidities often in excess of 50% coupled with inadequate ventilation.* Conditions in the hinterland tending to excessive interior humidities are :

- high occupancy rates of dewellings; an eight person family contributes about 15 L/day of water vapor through respiration and normal living activities;
- extended cooking periods necessitated by native lifestyle; food preparation is often in open pots steaming freely without containment by hoods;

- drying of stored firewood, which introduces 130 L/cord for each 10% drop in moisture content;
- open drying of laundry for large families, which contributes upwards of 25 litres per washday[1];
- evaporation from exposed soil surfaces in crawl spaces, adding up to 45L/day; open pools of water may triple this amount;
- use of kerosene or propane heaters, resulting in 1 L/kg of fuel consumed;
- diffusion of water from the concrete in contact with soil is 1-2L/day;
- lack of, or inoperable, mechanical ventilation; windows are usually left shut in winter to ensure freedom from drafts and because escaping moist air tends to flash-freeze on the frame and prevent proper closing of the sash;
- evaporation from wood used in the construction of the house (about 3,000 kg with a MC variation of 9-19%) contributes 300L.

Moisture produced in the dwelling in winter can be rapidly transferred into the roof spaces by air infiltration powered by the stack effect ('chimney' action), which may sustain a pressure differential of .25 kg/m^2 (.01'' of water) in a 2 storey house over several weeks[2]. Attics and joist spaces are vulnerable because it is difficult to remove the water vapor before it condenses and freezes, sometimes filling the entire free roof space volume.

In some cases roof spaces have been successfully pressurized with fans to negate stack pressure, or have been mechanically ventilated to remove water vapor. These techniques should be treated with great caution, as they may be counter productive.

The effects of the high humidity are striking. The writer has viewed houses in late winter with attics clogged with frost, their surfaces covered with ice stalagmites and stalactites. The high interior humidities are sensed immediately as one opens the door and is enveloped in a rolling cloud of escaping condensate. Spring brings rivulets through ceiling light outlets, chimney and pipe penetrations, and joints between finishing panels. In severe cases ceilings collapse; in milder situations a patchwork of ceiling stains provides its mute evidence. Aside from discomfort and unsightliness, condensation promotes:

- decay of wood;
- warping and swelling of wood doors, windows and framing;
- oxidation of steel components, including fasteners and structural supports;
- deterioration of dissimilar metals through electrolytic reaction; this is especially evident in electrical boxes;
- diminished thermal efficiency of insulation susceptible to moisture absorption;

- proliferation of fungi on and in wetted components and creation of a hospitable climate for wood-eating insects[2];
- displacement of envelope components by continuous ice formation.

The high humidity of many older dwellings is alleviated by the high rate of uncontrolled air infiltration, often reaching 4 air changes/hr in poorly sealed log houses. The inconveniences of condensation are replaced by the discomfort of cold drafts. Air at 21°C can sustain 150 times as much moisture as at − 40°C, and introduction of up to 20 L/s of cold outside air has an immediate and drastic dessicating effect on the interior environment.

New houses, with well sealed air barriers, tight windows, and often with electric heating systems devoid of draft-inducing chimneys, may reduce infiltration to .1 air change/hr. Moisture, produced at 50-100 L/day by a large family, creates a vapor pressure during the cold, dry months, that cannot practically be contained by a barrier. The writer has seen cones of frost formed in insulation by vapor passing through thumbnail sized cuts in .15 mm polyethylene sheet fitted in the ceiling. The perfection of detailing, materials and installation required for a hermetic seal is beyond the capabilities of the most skilled work crews, let alone the type of workmanship often encountered in hinterland construction. The variable work quality is exacerbated by wind, cold and other site conditions[3] frequently encountered.

4

The greatest proportion of water vapor introduced into wall and roof spaces from living areas in carried by air movement through openings in the vapor barrier. These openings result from careless design or poor workmanship, and usually occur at:

- poorly sealed junctions of vapor barrier material;
- exterior wall- and ceiling-mounted electrical boxes, and along the connecting wiring;
- penetrations through insulated ceilings of ductwork, piping, chimneys and access panels;
- discontinuities of the vapor barrier at floor-exterior wall construction;
- poorly sealed junctions of the vapor barrier and exterior door and window frames;
- torn vapor barrier sheeting.

Without the slightest doubt the most effective method of minimizing condensation is by maintaining interior relative humidity at 20-25%, the threshold of discomfort, static sparking, and vapor filming on windows. This can be accomplished by:

- avoiding introduction of any unecessary moisture by humidifiers, and by venting dryers to the outside with the outlet located and directed to preclude vapor entry into the roof space through soffit openings;

- providing exhaust fans with humidistat controls in high humidity areas such as the bathrooms and kitchens, sized to provide at least [illegible] change [per] hour, [illegible] for an average small dwelling;
- introducing fresh outside air to replace the exhausted air; if feasible, warm the incoming air with the outgoing exhaust, taking care to drain the resulting condensate; the writers' attempts in this direction were not noticeably successful; air exchanges evaluated have a payback period of 10-15 years.

Vapor barriers, required at the warm side of the envelope, must be integrated into the overall envelope design. The following recommendations have proven useful:

- avoid the use of materials beyond the vapor barrier which may restrict vapor flow; these include plywood, with low permeability caused by its layers of glue between the plies, and extruded polystyrene or other vapor resistant plastic insulation;
- provide maximum roof space between ceiling insulation and the underside of the roof structure, and ventilate well in excess of the legally mandated norms (1/300th of the insulated ceiling area); ventilate this space with snow resistant grilles located at the high and low points of the roof space to promote continuous air movement; at low temperatures flash formation of ice occurs, and the continuous cold prevents its disappearance

and leads to its ongoing buildup; consider the use of filled and sealed insulated roof panels, or a roof design free of attics or other unheated volumes which must be vented;

- use more efficient vapor barriers, with better resistance to mechanical damage; double layers of polyethylene have been used successfully on ceilings; lap and tape all joints; install stripping over bearing walls to facilitate film continuity over partitions which are installed before ceiling framing; seal at floor-wall installations where structural members interfere with the normal placement of the vapor barrier;
- ensure that a sequence of work is followed which will allow the vapor barrier to be fully protected until job completion; the writer has witnessed the use of unprotected, unbraced vapor barriers secured to the studs as temporary protection; they did not survive the construction period intact;
- tightly seal vapor barriers at perimeters of all envelope penetrations, such as windows, doors, chimneys, piping or ductwork;
- provide storage space for wood in unheated areas;
- avoid all unnecessary openings in insulated ceilings; by relocating the usual trap door access to a gable wall, the ceiling will be spared potential air leakage and use of the roof space as storage will be eliminated, thereby avoiding disturbance to the insulation; by installing the chimney outside

the exterior wall, and by running exhaust ducts horizontally or downward through the basement, the ceiling vapor barrier will gain in continuity;

- educate the house occupants in the theory and practice of condensation control, and in proper use of heating and ventilating systems;
- avoid use of 'cathedral' roofs, or other systems which have potential for trapping and condensing water vapor;
- provide crawl spaces and basement floor slabs with a continuous, sealed, moisture barrier to eliminate evaporation or migration of water past the top surface of the ground.

2.5.4 Design Factors Relevant to Snow, Rain and Wind

Snowfall across Canada is highly variable, depending on location, elevation, and the particular year. The annual snowfall is less important than its accumulation. In coastal areas frequent thaws result in relatively small build-up; the Rocky Mountains, because of their elevations, and the central and northern regions with their extended periods of low temperature, maintain greater snow cover over longer time periods. The Arctic, with very little precipitation, but with virtually no thaws throughout winter, accumulates considerable snow cover which is wind driven to fill low areas and the lee sides of obstructions. Montreal, with a total annual precipitation of about 1,000 mm, has a ground snow load of 2.7 kN/m^2, the same as Rankin Inlet, Northwest Territories, with its precipitation of 2[illegible] mm. The ground snow load, reduced by a factor appropriate to the type of roof, is used to calculate roof live loads. Roof areas adjacent to projections or raised portions may require triple the design snow load, due to the possible build-up of snow deposited by wind. Snow on roofs may be evenly distributed, or may be asymetrical, and result in unbalanced loads, depending on the roof configuration, the direction of the prevailing wind, and the proximity of protective natural features. Wind-driven snow creates problems by:

- filling around the lee side of buildings, thereby blocking exits and accessways; depressed roads are virtually impossible to clear in winter;
- infiltrating into buildings, sometimes through openings little larger than an unprotected keyhole, and filling roof spaces through improperly baffled vents;
- creating impenetrable whiteouts, and greatly hampering movement between buildings.

Rain, in conjunction with wind, can adversely affect buildings by:

- being blown through even microscopic apertures in the building envelope; common points of entry are the interface of masonry and poorly bonded mortar, through joints of wall and roof prefabricated panels, between siding panels or boards, between roof shingles, and through sash and door perimeter joints;
- constant wetting and subsequent deterioration of exposed finishes, such as masonry products or untreated wood, or of concealed water-susceptible products, such as gypsumboard or fibreboard sheathing, or insulations, and even interior finishes; the effects are exacerbated by salt sprays from adjacent oceans;

Wind, without precipitation, is capable of potent effects, including:

- exerting pressures[3] of up to 1.6 kN/m^2 on building walls; turbulence and suction multiply this effect, creating pockets of negative and positive pressure capable of blowing out glass, curling shingles, stripping flashings or even removing entire roofs, and distorting structures, or rocking, or overturning buildings;
- abrading exterior finishes by the continuing action of wind-blown granular material;
- increase fire risk by fanning flames, or by carrying burning embers to neighboring buildings.

To minimize the above risks, it is recommended that:

- the structural design of the roof anticipates show loading patterns, with careful attention to potential build-up on the lee side of raised portions;
- walls are braced against racking by using plywood or other rigid sheathing, or by diagonal braces if plastic or glass fibre sheathing is used; temporary braces are required for the construction period before structural sheathing is applied;
- building superstructures are bolted to foundations; where buildings are erected free of the ground on piers or isolated footings, the superstructure should be anchored to rock, or to buried sleepers;
- exteriors finishes are highly abrasion resistant;
- siding and roofing are tightly secured with extra fasteners at edges, corners and perimeters of assemblies; where possible, bolts and screws are prefered; nails should be protected against corrosion, and of the spiral or ringed variety for increased resistance to withdrawl;
- vents and wall opening perimeters are protected by baffles and by caulking and/or weatherstripping respectively; in the case of raised buildings, air may introduced into roof spaces ~~from below~~ the building;

- walls are detailed as rain screens, with a 19 mm pressure equalization gap behind the facing;
- exterior doors are located to preclude blocking by snow drifts, or are fitted with snow porches which provide open space in front of the egress;
- roads are built above the surrounding grades to allow clearing by wind scouring, and collector, deflector or blower fences or snow embankments are erected to direct or trap blowing snow when clear access is necessary ;
- buildings are faced with non-combustible cladding, such as metal, and are spaced to reduce fire risk;
- buildings are sited to take advantage of any protection afforded by the terrain, and, where possible, trees or hedges are planted for shelter.

In remote areas the consequences of improper design are not readily remedied, and under extreme conditions may prove uncomfortable, expensive, or even dangerous.

2.5.5 Design Factors Relevant to Temperature

The relationship of temperature to heating and condensation has been discussed in 2.5.2 and 2.5.3. However, other important temperature effects may be anticipated.

Where below $0^{o}C$ temperatures occur over any lengthy period, the ground moisture freezes. The depth of this frost penetration depends on the:

- duration and severity of ambient temperatures;
- composition and water content of the soil;
- soil cover by vegetation, or by shading from adjacent natural or man-made structures.

The depth of frost penetration is difficult to determine theoretically, and should be obtained by reference to local experience or by field testing, with the addition of an ample safety factor.

Freezing of the soil moisture may, in fine grained soils, result in the formation of expanding frost lenses capable of displacing a building founded above them[4]. Consequently footings must be set below the level of frost penetration, or the level must be artificially raised by adding a horizontal layer of insulation in the soil around the building perimeter[5], as illustrated in APPENDIX 3, Fig. 5.

Where winters are so intense or prolonged as to result in a permafrost condition, techniques described in 4.3.1 are employed.

Freezing soil tends to adhere to foundation walls, piles and piers [6]. Any upward movement of the freezing ground is transmitted to the structure, and tends to raise the building. As most remote construction is light, there is a very real possibility of vertical displacement. The writer has witnessed the superstructure of several houses lifted about 100 mm through the action of frozen soil adhering to subgrade plywood protection sheathing situated directly below a wood sill plate which was subsequently torn free of its tie-down bolts.

Other temperature effects are:

- damage to the building through expansion (or contraction) of restrained components exposed to gross temperature changes, or which are secured to materials of substantially varying expansion coefficients; problems may occur with aluminum sections, (which expand 13 mm/10 m over a 60 °C range), or through differential expansions of steel flashings embedded in asphalt (as occurs in certain fascia designs); as most housing units are comparatively small, the problem has not been serious;
- progressive destruction of materials which have absorbed water, and are subject to continuing freeze-thaw cycles; hard components are most usually affected, such as masonry units, mortars and concretes;

- brittleness of some building materials, such as plastic sheet, when exposed to extreme cold.

Temperature effects deleterious to buildings are buffered by:

- setting footings at depths below anticipated frost penetration,
- recognizing discontinuous or continuous permafrost, and by providing special foundations as described later;
- backfilling with granular soils against foundations to minimize adhesion and consequent uplift, and wrapping buried portions of piers or piles with polyethylene sheet and/or insulation to prevent adhesion between the foundation element and the soil;
- providing control joints or space for expansion for components subject to large temperature swings;
- guarding against excessive wetting of walls by use of protective coatings, and by detailing to avoid roof and sill or other run-off over walls; use of air-entrained concrete is helpful where freeze-thaw cycles are common;
- selecting building materials which are not excessively brittle at low temperatures.

SECTION 2.6 REGULATIONS & STANDARDS

2.6.1 Regulatory Considerations

Housing design and construction are subject to restrictions, regulations and constraints imposed by:

- building codes;
- plumbing, heating and electrical codes;
- zoning regulations;
- energy conservation codes;
- building materials standards;
- fire protection standards;
- union restrictions;
- provincial decrees and regulations;
- institutions or government bodies providing or guaranteeing financing of the project.

Applicable building codes and regulations should be listed in the APPENDIX I.

2.6.2 Building Codes

Building codes are as old as civilization; with the growth of cities and congestion-related hazards, authorities instituted regulations to control:

- spacing and construction of buildings to minimize risk of fire, control its spread, and to protect the occupants;
- disposal of sewage and garbage to reduce disease, and to promote a wholesome environment;

- disposition and widths of streets to direct the development of the town, and to facilitate transportation of people and goods;
- regulate the occupancies of buildings to minimize nuisances to the inhabitants.

The authority to regulate design and construction of buildings rests primarily with provincial governments, who have delegated some of these functions to the municipalities. In Quebec and Ontario, the provincial departments ensure conformity of public buildings, and of buildings exceeding a certain size, with safety precautions. Most other requirements are administered by the municipalities.

Building regulations include:

- limits of number of floors and areas of buildings with respect to their occupancy, type of construction, and fire resistive features.
- separations between floors, between different occupancies, and around exits, access to exits and service spaces;
- type, capacity and location of exits and access thereto;
- fire resistivity of exterior walls and their openings, all with respect to the proximity of neighbouring properties;

- safety requirements of highrise buildings;
- fire extinguishing equipment required for different occupancies and types of construction.

The National Building Code (NBC) is a comprehensive document produced by the National Research Council of Canada. As a federal instrument, it is not legally enforcable; however the provinces have adopted this code, or have used it as a basis for their regulations. Part 9 of the NBC governs small buildings, and is used to control dwelling construction for the CMHC.

Zoning by-laws are usually written and enforced by the municipality, and impose restrictions which vary with the location of the building. These include:

- types of occupancies permitted;
- building heights and land coverage;
- front, side and rear setbacks from the property lines;
- parking requirements.

Sanitary codes are administered by the provinces, and are drafted and enforced to safeguard health. These legislate requirements of disposal of human wastes, and for provision of a safe water supply. These regulations govern:

- number and type of sanitary fixures with respect to their occupancy;
- water supply system adequate for hot and cold water requirements of these fixtures;
- types and sizes of drains, vents and other components of the sanitary waste disposal system;
- holding, treatment, and disposal of noxious or environmentally undesirable waste products;
- ventilation and natural light requirements, including clearances for windows in courtyards and sideyards, and their proximity to property limits.

Electrical codes, also under provincial jurisdiction, govern all aspects of design and installation of electrical systems, including types and capacities of wiring, switchgear, generation and transformer equipment, and all related components.

All plumbing and electrical work must be carried out by licensed constructors employing accredited mechanics. Systems require prior design approval and inspection during installation and after completion.

All native housing of which this writer is aware is funded by grants, loans or loan guarantees from the Canada Mortgage and

Housing Corporation (CMHC), a federal crown corporation, and must conform to Part 9 HOUSING AND SMALL BUILDINGS, of the National Building Code. As a practical matter the designer must be fully aware of the applicable provisions, and of procedures for approval of plot plans, working drawings, and materials. Where other municipal or provincial regulations also apply, the more rigorous will be mandatory. In the absence of municipal or provincial regulations governing building services, these are governed as follows:

- electrical installations, by the Canadian Electrical Code;
- plumbing installations, by the Canadian Plumbing Code;
- heating, ventilation and air conditioning, by ASHRAE Guide and Data Books.

2.6.3 Material Standards

Most building materials conform to norms set either by industry or by government, or by a combination of the two. Characteristics and performance are measured and tested in accordance with standardized methods, permitting the designer to readily assess, evaluate, and select from available materials. Industry and trade associations formed by member companies provide criteria for performance, units of measurements, and cost, supply and installation data. Characteristics of building materials are important to the designer because they:

- permit a degree of predictability of the performance of the component, either singly or as part of an assembly;
- inform the designer of conformity (or lack thereof) of the material with respect to the applicable codes;
- allow an assessment of different materials, based on comparable performance data, and cost;
- permit ready evaluation of new products, or improvements to existing products.

Properties of materials of interest to the designer are:

- strength: compressive, tensile, shear, or penetration resistance or modulus of rupture, as applicable;
- water absorption;
- water vapor transmission;
- fire resistance; fuel contributed, smoke produced or flame spread rating, as applicable;
- melting, flash or decomposition temperatures;
- density;
- dimensional stability;
- hardness or abrasion resistance;
- color fastness or fading; surface reflectivity and absorption characteristics;
- coefficient of thermal or moisture expansion;
- thermal conductivity, present and future;

- susceptibility to deterioration from oxidation, radiation or chemical attack;
- resistance to deterioration from moisture, or from fungal or insect attack.

Nationally recognized standards are formulated by:

- The Canadian Standards Association (CSA); this organization is composed of representatives of major supply companies, professional consultants, and government delegates;
- their work includes setting design and installation standards for a great variety of materials and systems, including steel and concrete construction, electrical equipment and installations, grading of lumber, plywood and properties of reconstituted wood products;
- The Canadian Government Specifications Board (CGSB); under this jurisdiction the Department of Supply & Services has established committees to which representatives of government, industry and research organizations contribute time and expertise on a voluntary basis; the CGSB formulates qualitative specifications for many materials within and outside the construction milieu which are used as standards for government purchases; CGSB specifications are in the process of being unified within a comprehensive CSA framework;
- The American Society for Testing and Materials (ASTM); the ASTM, based in the United States, has developed norms of acceptability

for building materials, and a series of standardized test methods to ensure that these properties can be assessed on a uniform basis; these tests which have been accepted by the CSA, CGSB, and most materials manufacturers, readily permit the designer to compare characteristics required for building components and assemblies, and ensure a degree of predictability of their performance;

- The National Research Research Council of Canada (NRC); The NRC is a Canadian government facility whose Division of Building Research provides the technical support for producing and up-dating the National Building Code, for testing materials and assemblies, and for carrying out research on all aspects of building design and construction.

2.6.4 Fire Protection Standards

Various agencies are involved in issuing standards and codes designed to reduce fire risk to buildings and their occupants. These include the:

- National Research Council of Canada (NRC), through the Division of Building Research, which collaborates with experts in fire prevention and fire protection industries and services to produce the National Fire Code and auxilliary documents;
- Underwriters' Laboratories of Canada (ULC); the ULC maintains and operates facilities to examine, classify and certify

materials, assemblies and components with regard to their use in prevention or fire spread;

- Factory Mutual System (FMS) and the "Insurers' Advisory Association of Canada (IAOC); the FMS and the IAOC each serve groups of insuring companies by establishing standards of fire protection required for risks to be assumed by the insurers;
- National Fire Protection Association (NFPA); the NFPA, based in the United States, serves as a clearinghouse for information related to fire prevention and protection; its Fire Protection Handbook is the standard reference for the industry.

The above agencies produce recommendations which include materials, methods and procedures for:

- design and installation of standpipes, extinguishers, sprinklers and other euqipment for combatting fires;
- design and installation of protection for structural elements of buildings which require resistance to fire;
- storage of materials and housing of equipment, processes or occupancies which impose fire hazards;
- establishing standards for doors, windows or other components which protect openings in fire resistive construction;
- establishing standards for the design and construction of floors, ceilings, walls and other assemblies intended to limit the spread of fire.

2.6.5 **Energy Conservations Standards**

As the costs of oil and electricity escalated, the Canadian government formulated recommendations to encourage design of more energy efficient buildings. These measures relate to standards for insulating walls and roofs, for exterior door and window construction, for heating, cooling and ventilating design, and for lighting and power regulation. Though not mandatory they serve as an excellent guide.

In 1983 CMHC issued 'Technical Builders' Bulletin T-5', incorporating into their standards a complete energy code governing all housing built under its jurisdiction. In the same year Quebec adopted 'Regulation Respecting Energy Conservation in New Buildings', which applied similar restrictions to all buildings to be erected in the province. The efficiencies required for building envelopes relates to their location with respect to climatic conditions.

SECTION 2.7 FINANCIAL CONSIDERATIONS

2.7.1 Financial Considerations

Building projects are limited by available financial resources; to mobilize and utilize adequate funding requires a determination of:

- capital construction cost estimates;
- operating and replacement cost estimates;
- availability of loans, and repayment conditions;
- availability of capital and operating grants, and subsidies, and related conditions;
- cash flows and carrying charges.

2.7.2 Financial Needs

To determine funds required to implement the housing program, capital cost projections for the various alternatives are required, based on:

- preliminary estimates[1], based on unit prices per square metre (or square foot) to 20% accuracy;
- working estimates, based on labor and material to 5% accuracy.

It is important that all capital costs be calculated, including costs of:

- municipal services, electrification, roads, and other infrastructure (which are beyond the scope of this paper);
- soil tests, surveys, and land division;
- architectural and engineering fees;
- transport and storage of materials;
- subsistence and lodging of imported workers;

- communication and travel;
- interest on cash flow during the construction period.

To maintain these houses, either by individuals, government agencies, co-operatives, or municipalities, it is necessary to estimate the operating costs, including applicable costs of:

- financing, comprising interest and capital payback of loans;
- heating;
- telephone;
- power;
- municipal taxes, fire protection, garbage collection, water distribution, amortization of cost, and maintenance of services and roadways, and special assessments;
- insurance for fire liability and other risks;
- house maintenance and repair;
- eventual replacement of major components such as roofs or furnaces.

2.7.3 Evaluation

Evaluation of alternative aspects of the building program, or between various program proposals, can be made by life cycle cost analysis techniques which calculate the present worth of the proposal taking into account:

- capital cost, as described above;

- operating cost, including an anticipated inflationary factor;
- costs of items requiring replacement during the period of the study;
- discount rate based on anticipated cost of money;
- an anticipated investment horizon.

2.7.4 Sources of Funds

Sources of funds vary depending on current financial conditions, government policy, and the financial status of the villages and their inhabitants. Traditional sources are one or a combination of:

- the municipality, based on its borrowing power, which is a function of the tax base, and its current indebtedness; most native communities are not self-supporting, and do not self-finance in this traditional fashion;
- the provincial governments, by loans or by direct subsidies;
- by the federal government, by loans or by direct subsidies; these are often administered by the Indian & Northern Affairs Canada and financed through Canada Mortgage & Housing Corporation;
- by native organizations funded by financial settlements made for use of traditional hunting and fishing territories, taken over by governments or industries for hydro electric projects, or for exploitation of oil or mineral resources;

- private or government lending corporations; privately sourced loans are usually guaranteed by a government agency or crown corporations; private sources are generally insurance companies, banks, pension funds or trust companies.

Administrators of the housing program must decide, based on the foregoing determination of capital and operating costs, and on the resources available through the aforementioned agencies, the short and long term fiscal viability of the venture. If necessary the houses may be modified, or the mix varied, or the schedule altered, all in accordance with priorities established by community and consistent with available resources.

2.7.5 Standards

Governments and mortgagors wish to assure themselves of the quality of the buildings which they finance, and usually require that they conform with the minimum requirements of 'Residential Standards 1980' (NRCC No. 17304). This publication is based on standards established by the National Research Council (NRC). The designer must be aware that all materials and equipment permitted to be incorporated into houses must be approved and identified by number by the agency.

PART 3 BUILDING DESIGN CRITERIA

SECTION 3.1 GENERAL CRITERIA

In addition to criteria which pertain to the selection of specific building components, all materials and assemblies should be:

- acceptable and familiar to the occupants, and consistent with their lifestyle and aesthetic preferences; these obvious truisms have often been ignored; extensive consultation and reliance on local decision-making procedures avoid later discontent;
- in conformity with applicable codes; notwithstanding, where local conditions or materials give rise to alternative, equally viable solutions, every effort should be made to press for their acceptance;
- available, and capable of being economically transported to the site; 'availability' should be considered in the context of maintenance and future replacement; components should be of standard shapes, sizes, finishes and colors and should be widely procurable; pay special attention to doors, windows, hardware, and interior and exterior finishing materials in this regard; avoid items produced by a single manufacturer serving a narrow market, and be wary of highly customized, prefabricated components requiring special manufacturing processes;

- capable of being stored under adverse conditions without deterioration by heat, sunlight, insect infestation or freezing, and relatively tolerant of moisture and humidity; bagged cement sets, gypsum products dissolve, wood fibre and particle board materials twist, warp or delaminate, beetles and ants eat wood and even some foamed plastics, ultraviolet rays deteriorate polyethylenes and polystyrenes, and some paints and adhesives are made useless if frozen;
- within cost constraints established by the budget; costs must be calculated for transport, storage, insurance and protection required for remote site situations;
- capable of being installed rapidly with available labor operating under anticipated site and climatic conditions; anticipate inexperienced labor, inadequate supervision, a lack of understanding of basic building science, a tendency to improvisation, and absenteeism due to the appearance of fowl, fish or game;
- resistant to hard use; in a harsh environment repairs and alterations are often of the rough variety, maintenance is lacking, and the lifestyle places great demands of the durability of finishes, stairs, storage and work areas;

- selected with a view to renovations, improvements and maintenance which will often be carried out by the occupant, or by relatively unspecialized labor as may be available in the village.

It should be again noted that criteria are not listed in any particular order of importance or signifigance.

SECTION 3.2 FOUNDATIONS

3.2.1 Foundation Criteria

Evaluation criteria for footings are:

- capability of distributing building loads to suit soil bearing capacity;
- contribution to the dead load of the building; building sites underlain by very weak material often cannot sustain concrete pads;
- anchorage required to resist building movement due to wind loads; strong gusts will rock or overturn light structures characteristic of remote villages;

- resistance to decay, insect attack, or deterioration from deleterious chemical content of the soil; wood should be pressure-treated to a 50 year life expectancy, and concrete in contact with sulphate bearing soil requires appropriate cement;
- ease of alignment or positioning; as surveying is often practised in rudimentary fashion, buildings should have simple configurations and easily determined levels;
- installation with minimum of special equipment; imported machinery is expensive, requires operators from the outside, and often presents maintenance problems;
- capability of re-levelling superimposed structural elements in event of movement.

Evaluation criteria for foundation walls are:

- compatibility with the footings and the superstructure;
- contribution to building dead load;
- watertightness, or compatibility with water-resistant systems; jointed systems, such as concrete masonry or wood panels, are difficult to treat successfully under severe conditions;
- structural capability with regard to superimposed loads, lateral earth pressure, and hydrostatic pressure, where applicable;
- availability of formwork and related skilled labor, and concrete ingredients;

- compatibility with insulation and related protection;
- durability and appearance of the exterior finish of exposed portions of walls, or its compatibility with anticipated finishes.

SECTION 3.3 EXTERIOR WALLS

3.3.1 Exterior Wall Criteria

Evaluation criteria for exterior walls are:

- structural capability with respect to wind loads and floor and roof support, as applicable;
- contribution to the dead load of the building;
- resistance to distortion, joint opening or separation of any materials in the assembly;
- thermal efficiency over the life of the building;
- minimal thermal bridging at structural supports, at wall-floor, or wall-roof junctions;
- maximum resistance to air passage;
- low permeability of the vapor barrier and efficacy of joint seals;
- location of dew point, on the outside of the vapor barrier, based on an acceptable interior humidity level;

- compatibility with a variety of interior and exterior finishes;
- weather resistance capability of exterior cladding, and adaptability to rain screen design;
- surface resistance to abrasion and scouring by wind-blown sand or snow;
- maximum vapor permeability of the assembly between the vapor barrier and the exterior;
- ability to incorporate light fixtures, electrical outlets, ducts, and other mechanical and electrical components without adversely affecting the performance of the air and vapour barriers, and the thermal efficiency of the assembly;
- maximum resistance to fire spread, smoke propagation, or development of noxious fumes;
- adaptability to total or partial offsite assembly, depending on local facilities, available labor, and work volume;
- compatibility with future construction by local labor; rooms, porches, sheds and vehicle are often built on by the occupant, sometimes on a highly informal basis.

3.3.2 Insulation Criteria

Evaluation criteria for wall and roof insulation are:

- maximum thermal efficiency (R) over the life of the building; some plastics suffer from diminished R value with time; low density fibre insulations allow internal convection currents, and granular insulations tend to settle;
- dimensional stability; some plastics shrink on curing;
- minimum amount of fuel and smoke contributed to a fire;
- minimum flame spread rating;
- minimum production of noxious fumes in case of fire; certain plastics require special protection to separate the insulation from the living space;
- compatibility with wall and roof construction; requisite thicknesses should readily fit into available clearances; fastening methods should be simple and secure;
- resistance to decay, deterioration and insect attack; organic materials may be attacked by fungi and ants, beetles or termites;
- minimal water absorption characteristics; insulation wetted by rain penetration or by condensation will have greatly reduced thermal efficiency;
- vapor transmission characteristics; insulation placed on the outside of the vapor barrier should be permeable;

- ability to form and maintain tight joints between the insulation panels, and between the panels and the wall structure;
- density;
- flexibility and compressibility; transportation is cheaper for compressed insulation such as fibrous butts;
- ease of application and minimal necessity for specialized application equipment;
- absence of application restrictions due to temperature or wind.

3.3.3 Exterior Wall Sheathing Criteria

Evaluation criteria for exterior wall sheathing are:

- resistance to racking or distortion of the structure;
- maximum thermal efficiency over the building life;
- compatibility with and structural backing for outside finish;
- minimum water absorption and resistance to deterioration, decay, insect attack, or loss of thermal efficiency;
- integrity of the joints under design conditions;
- dimensional stability; plastics may shrink while curing;
- ease of fastening to structural elements.

SECTION 3.4 ROOFS

3.4.1 Roof Criteria

Evaluation criteria for roofs are:

- maximum resistance to penetration by precipitation and wind under design conditions; jointed materials should be sealed;
- maximum resistance to degredation by ultra-violet radiation;
- maximum surface resistance to scouring or abrasion by wind-blown sand or snow;
- expansion coefficient consistent with size of undivided roof areas under design temperature conditions; shrinkage of membranes should be within job tolerances and tensile resistance capabilities of the components;
- maximum resistance to distortion, uplift or damage by high winds;
- resistance to deterioration by chemical attack from precipitation or deposit originating from metals refining or paper manufacturing, or other industries often located in remote areas;
- capability of emergency repair, in all seasons and under all conditions;
- maximum capability of positive and rapid drainage, with minimum of ice-damming or icicle formation;

- compatibility with properly secured flashings, drains and other building components;
- contribution to dead loads; inverted roofs add considerable ballast weight to the roof structure;
- compatibility with common roof decking;
- minimum predisposition to condensation through ready adaptability to integration of vapor barriers, and to provision of adequate ventilation of spaces susceptible to vapor entrapment;
- maximum resistance to fire spread;
- minimum amount of fuel, smoke and noxious fumes contributed to a fire;
- conformity with standards of the applicable insuring authority;
- minimum infiltration of precipitation into roof spaces through eave or gable vents.

3.4.2 Effects of Roof Configuration

Different roof profiles affect their performance as follows:

- single level nearly flat roofs are readily scoured clean of snow by wind action; more steeply sloped roofs, or adjoining roofs at different levels, accumulate snow on the lee side, which will necessitate supplementary reinforcement of the affected roof structure; roof areas depressed below and surrounded by other roofs will fill completely with snow, and should be avoided;

- nearly flat roofs may be designed to drain internally or externally; internally drained roofs require insulated drains and a run-off collection and a storm disposal system not often found in villages; externally drained roofs may be fitted with maintenance prone gutters and leaders, or may simply be allowed to drain over the eaves, which leads to icicle formation and wetting of walls;

- sloped roofs are pre-disposed to the formation of ice dams at the eaves during warming trends which occur towards the end of winter; as snow and ice adhering to the roof start to melt from heat produced within the building, the resulting moisture runs down the roof slope; when no longer over the heated area, i.e. at the overhanging eaves, the moisture will re-freeze ; as moisture continues to flow, a dam will form which will prevent water from draining of the roof; in extreme cases, the backed up water will flood into the building through the joints between the shingles; this condition can countered by minimizing overhangs at eaves, providing electric resistance heating cable along eaves to melt any ice dams, and installing suitable membranes under the shingles at the eaves.

SECTION 3.5 WINDOWS AND DOORS

3.5.1 Window and Door Criteria

Evaluation criteria for windows are:

- maximum thermal efficiency based on number and spacing of glazing panels, and of the thermal resistance of frame and sash;
- minimum air infiltration through sash-frame joints under design wind loads;
- durability of frames and sash and resistance to warping or distortion;
- suitability, durability, maintenance and replaceability of weatherstrips;
- durability of screening and ease of replacement;
- adaptability for use as an emergency exit; sash should be sufficiently large, and not be glazed with unbreakable glass or plastic;
- easy functioning of all movable components and resistance to frost formation on the sash or frame rebates as would prevent full operation;
- resistance to thermal bridging, to condensation formation, and provision for condensation disposal;

- standardization of units to simplify stockpiling of spare glass and hardware components in the villages, allowing for better maintenance practices.
- simplicity, durability and ready availability of hardware;
- ease of replacement of glazing panels and/or sash, and use of standard or replaceable glazing stops;
- ease of cleaning from the interior;
- permanence of frame and sash finishes and minimum maintenance of all components;
- compatibility of window frames with wall construction;
- ability of sash to maintain partially open positions under design wind conditions;

Doors should generally be evaluated on those characteristics listed above which pertain to their particular function, and specifically on:

- resistance of frames and leaves to warping or distortion;
- suitability, security and durability of weatherstrips, butts, locksets and stops with respect to design conditions; door pulls should be consistent with operation by heavy gloves and mittens;
- glazed panels should be evaluated on the same basis as windows.

SECTION 3.6 INTERIOR PARTITION STRUCTURE

3.6.1 Interior Partition Criteria

Evaluation criteria for structures of interior partitions are:

- structural suitability for imposed loads and ability to receive and support cabinets and shelving;
- weight imposed on the floor systems;
- minimum fuel contribution to a fire or smoke generation;
- compatibility with different finishes;
- flexibility of accomodation of built-in electrical and mechanical components;
- maximum sound resistance, or accomodation for sound reducing materials;
- erection restrictions due to temperature or humidity;
- responsiveness to design change and adaptability to future alterations.

SECTION 3.7 INTERIOR FLOOR, CEILING AND PARTITION FINISHES

3.7.1 Interior Finish Criteria

Evaluation criteria for interior floor, ceiling and partition finishes are:

- minimum amount of fuel contributed to a fire and smoke generation;
- minimum flame spread rating;
- minimum production of noxious fumes in case of fire;
- maximum resistance to abrasion and abuse;
- ease of cleaning using household materials which can be purchased in the village;
- ease of replacement by unskilled labor using standard tools;
- compatibility with floor, partition and ceiling construction;
- performance of adhesives required to secure the finishes, including storage requirements, water resistivity, use restrictions due to temperatue or ventilation limitations and compatibility with contact surfaces;
- sound absorption or reflection characteristics, where applicable;
- resistance to warping, distortion, shrinkage or swelling under design conditions;
- resistance to staining or deterioration on exposure to water;
- easily and neatly finished internal and external corners, joints, and perimeters;
- availability in a variety of colors, textures or designs;
- degree of on-site labor required for installation, finishing and protection;
- suitability of partition finishes for installation of shelving, hanging rods and similar items.

SECTION 3.8 MILLWORK

3.8.1 Millwork Criteria

Evaluation criteria for millwork, including interior and exterior stairs, kitchen cabinets, moldings, shelving, and hanging rods are:

- standardization of components;
- resistance to abrasion and abuse; freedom from maintenance;
- compatibility with pre-fabrication or pre-cutting techniques;
- delivery capability to the site in 'knocked-down' components, if pre-fabricated elsewhere;
- minimum on-site labor requirement for installation, finishing and protection;
- resistance to warping, distortion, shrinkage or swelling under design conditions;
- structural integrity of stairs and kitchen cabinets after their assembly;
- compatibility of interior and exterior stair structural and anchorage systems with related adjoining construction; safety aspects of stair and railing design, and freedom from vibration;
- capability of adjustment to job tolerances, and ease of trimming in place;
- adaptability of exterior stairs to possible ground movement;
- suitability, durability, and standardization of cabinet hardware.

SECTION 3.9 HEATING SYSTEMS

3.9.1 Heating System Criteria

Evaluation criteria for heating systems are:

- type, availability, cost, and dependability of supply of fuel, or energy source;
- expense to the community of fuel storage and distribution facilities, generators, or other capital costs;
- occupancy patterns of the building occupants;
- efficiency of fuel utilization;
- building features and space requirements needed to accomodate the heating system, including chimneys, fire resistive construction, and framing and space required for ductwork;
- available skills and supplies required for cleaning and repair of the system;
- simplicity of starting, operating, controlling and cleaning the system;
- acceptable fire risk;
- convertibility to other fuel or energy sources, or capability of operating on 2 fuels, such oil and wood;
- life cycle cost of the entire heating system, including fuel consumption and utilization efficiency, capital cost of

installation, incorporating comparative costs of building features, present and projected energy costs, operating and replacement costs, and anticipated discount and inflation rates, all projected over an extended investment horizon.

3.9.2 Energy Sources

Energy sources usable for heating are:

- oil;
- wood;
- electricity;
- propane;
- kerosene;
- natural gas;
- peat.

No. 1 fuel oil (Arctic diesel), with low wax content, is widely used for houses heated on a continuous basis, and is compatible with a great variety of space heaters and furnaces. Powered oil burners can be readily controlled thermostatically with minimum maintenance during the occupants' absence, an important feature for houses left empty during the winter trapping season. Oil is relatively safe to transport and store; at about -45 °C it will require preheating to diminish its viscosity. Cost varies, depending on location and taxes; 1984 prices range from $.30/L in Montreal to about $.70/L in Innuit communities on Hudson Strait. Costs used for energy studies must include oil purchase and transport charges, and allow for amortization and maintenance costs of village storage facilities, and local distribution by truck.

Wood, where available, is a 'free' resource, and is widely used for stoves and furnaces; it may be employed in combination with some oil fired systems, ensuring low cost when the house is occupied, and automatic control during absences. Where trees are undersized, or where much scrubwood, slash or mill waste is available, powered grinders can produce wood chips suitable for combustion with specially fitted systems. Wood collection, preparation and storage is favored as one of the few native employment possibilities based on local resources. Its disadvantages include the constant fueling and cleaning of the fireboxes, fire risk from high temperatures of the stove shells and from creosote deposits in the flues which are infrequently cleaned. Wood requires over $10\ m^3$ for a heating season, liberates large amounts of moisture (see 2.5.3), and introduces insects into living space.

Electricity may be supplied from outside the settlement. Unless subsidized by the utility or the government its cost may be high. In Quebec the domestic rate for remote villages connected to the provincial grid is set at the 'southern' rate, i.e. 3.06¢/kWh. Where isolation precludes an outside power source, local diesel fired generators will supply basic needs; available village demand may reach 1,000 kW. and cost up to 35¢/kWh. Electrical heating is clearly not a viable option for locally oil-generated power. Electricity may be produced by 'mini' hydro dams. These installations may cost $6-10,000,000, and require ample runoff and topography capable of water storage with the necessary head. Wind power is not yet reliable or efficient on a long term basis, although promising trials are in progress.

Natural gas is almost never available to villages; propane and kersone are not commonly used due to transportation costs.

Peat deposits are not uncommon in many remote locations. With suitable processing equipment these present potential fuel sources which could be exploited where the scale of operation and the logistics justify the investment[1].

3.9.3 Occupancy Patterns

New houses designed for natives have features previously lacking. These include inside plumbing, finishes susceptible to moisture, tight construction joints to control air infiltration, and doors and windows which are sealed and weatherstripped. These features are emperilled if interior temperatures drop below freezing, or, if frost-susceptible soil causes building movement.

Families who leave their houses for lengthy periods during the cold season require heating systems controlled and fueled to provide above freezing temperature without supervision, unless the function is carried out by a caretaker, or unless extensive precautions are taken to minimize potential damage, such as draining fixtures and pipes.

3.9.4 Acceptable Fire Risk

Fire may be a devastating occurence in remote locations, especially during periods of low temperature. Villages often have insufficient water or inadequate fire-fighting equipment, and their inhabitants must give special consideration to design and protection of heat-producing appliances. Criteria should include:

- installations in conformity with NBC and NFPA recommendations;
- use of CSA approved apparatus and fittings;
- use of equipment designed and insulated to preclude high temperatures of exposed surfaces;
- use of readily cleaned and maintained burners, chimneys and other components;
- installation of extinguishers and alarm systems.

3.9.5 Building Features Required for Heating Systems

To properly integrate heating systems, buildings should provide:

- accomodation for ducts, with consideration to appearance and headroom;
- adequate air intakes for fuel-burning equipment;
- access panels for controls and cleanouts;
- clearances, flashings and insulation for chimneys;
- protection for combustible sections adjoining high temperature elements of the system;
- safe storage for fuels.
- fire resistive enclosures for furnaces.

SECTION 3.10 PLUMBING SYSTEMS

3.10.1 Plumbing System Criteria

Evaluation criteria for plumbing systems are:

- nature and capacity of available community sanitary services;
- community preferences for fixture and fitting types;
- laundry facilities required by the occupants;
- special drainage needs which require connections to the house system;
- elevations of floors requiring drainage with respect to levels of municipal services;
- subgrade drainage requirements;
- available skills and materials required for the maintenance of the system;
- compatibility of subgrade piping with anticipated subgrade conditions;
- house humidification requirements.

3.10.2 Community Services

The type of plumbing accessories provided will depend on the:

- source of water supply; if water is not available by pipe, either underground, or enclosed in insulated above grade structures ('utilidors'), then holding tanks, or individual wells with pumps and pressure tanks may be required;

- pressure and volume of centrally supplied water; an insufficiency may necessitate pumps, or supplementary storage tanks;
- levels of municipal drainage system in the right-of-way; if drains are set too high, pumps may be required to raise the effluent into the drains;
- nature and capacity of the municipal drainage system; if a central system is not available, a holding tank, or a septic disposal system may be required; in permafrost or other regions where septic tanks are not possible, and where a pump truck is not available, toilets which utilize disposable bags ('honey buckets'), or which dispose of waste internally, are required;
- if storm drains are not available, and the sanitary sewers have limited capacity, methods suitable to the area will be required to connect to service basins, perimeter subgrade systems, internally drained flat roofs, depressed driveways, or other surface run-off;
- quality of available water; if pollution is present, sterilization facilities may be required.

SECTION 3.11 ELECTRICAL SERVICES

3.11.1 Electrical System Criteria

Evaluation criteria electrical systems are:

- characteristics of power available from the local utility;
- capacity and demand requirements of house fixtures, appliances, and heating elements, where applicable;
- emergency power requirements;
- house construction characteristics;
- availability of telephone or radio services;
- availability of television;
- availability of central monitoring for fire alarm or security systems.

3.11.2 Electrical Considerations

Electrical equipment, fixtures and appliances in the building must be consistent with the characteristics of power available from the utility, taking into account:

- phase;
- voltage;
- power supply limitations, due to load, dependability of the generating source, or seasonal conditions.

Power supply limitations will determine the feasibility of providing electrical house heating, resistance type hot water heaters ovens, dryers and other high energy appliances. Dependability of electrical power raises considerations of emergency supply by oil or gasoline powered generators or battery-operated systems to service minimum security needs.

Due to danger of air infiltration through penetrations in exterior wall and ceiling vapor barriers by wiring or boxes, consideration should be given to:

- minimizing plugs, switches and other components on insulated walls;
- using special sealed electric box enclosures;
- providing furred spaces between the vapor barriers and the living areas to accomodate electrical components; or
- using surface wiring and boxes.

3.11.3 Communications Systems

House planning should make provision for the accomodation of television sets, even if not yet available.

PART 4.0 DESIGN OPTIONS

This paper is not intended to provide design solutions for building problems posed by remote sites, poor soils, limited resources, severe climatic conditions, and the gamut of native preferences, but furnishes a 'menu' of alternatives, with comments, from which selections (or variations thereto) may be made, in response to evaluations using criteria described in PART 2.0 and PART 3.0.

The order in which the design options are listed is not intended to establish any priority or preferential rating.

APPENDIX 4 provides a commentary on the options listed in PART 4.0, as noted in the following sections

SECTION 4.1 BUILDING DESIGN OPTIONS

4.1.1 Building Grouping and Configuration

Dwelling units may be grouped as follows:

.1 detached one storey single family dwelling units ('bungalow' type) [1a];

.2 detached two storey building single family dwelling units ('cottage' type) with full or partial upper storey [2a];

.3 detached two storey buildings, consisting of two superimposed single family dwelling units ('duplex' type);

.4 detached two or three storey buildings, consisting of three superimposed single family dwelling units ('triplex' type);

.5 any combination of the above, attached on one or both sides with common walls[5a];

.6 multi-storey buildings, consisting of a number of dwelling units both superimposed and adjoining each other, having access through common entrances and corridors ('apartment type')[6a].

Depending on soil conditions, grades, drainage, and cost of below grade construction, buildings may be built with basements (except in permafrost regions). These areas can readily accomodate work and storage rooms, mechanical equipment, and additional living space.

Entrance to single family dwellings may be at the first floor (max. 2m above grade), or may be at a stair landing between the basement and this floor (split level entry); the latter option has the advantage of providing access through an exterior door very near to ground level, while integrating the basement with the ground floor. Uniting the two levels encourages incorporation of upper floor activities with the lower level space, and effectively increases the house size. Most village houses with basements access from the ground floor through relatively steep and narrow stairs, which tends to isolate and under-utilize this area. By properly heating and insulating the basement, by providing suitable electric outlets and lights, and by incorporating adequate fenestration, the split entry can effectively provide two storey accomodation in one storey construction.

Another configuration involves grouping certain rooms on levels separated by less than a full flight of stairs (split-level mode). This plan is intended to more intimately relate certain activities, but often increases the cost without proportionate benefit.

Other considerations being equal, for any given living area, a detached house is most economically constructed with approximately equal length and width dimensions. A house with a square plan has 5-10% less wall area than a house of equivalent area, but whose dimensions are in 2:1 ratio. Additional savings accrue from decreased heating and maintenance costs, and from shorter municipal services and roadways needed for houses with smaller frontages. Further economies may be possible by building the two storey option, thus halving the roof area and the foundation structure.

SECTION 4.2 CONSTRUCTION CATEGORY OPTIONS

4.2.1 Construction Categories

Residential buildings must be of non combustible construction if they exceed 3 storeys in height, or are greater than certain area limitations per floor, the areas depending in the number of contiguous streets, and on the installation of an automatic sprinkler system.

In non combustible construction, combustible elements are limited to minor components of the building, such as roofing, finishes and related furring, and protected wood studs for interior partitions. Because of restrictions of cost, transport, material, labor and equipment availability, and because native lifestyle has not favored large, multi-family buildings, almost all housing constructed to date falls within the combustible category. These are subject to requirements of Residential Standards (1980), which applies to buildings not exceeding 3 storeys, with an area not greater than 600 m^2 (6458 ft^2) per floor.

These standards are is essentially derived from PART 9 of the National Building Code of Canada, 1980, and contains requirements for all housing funded directly or indirectly by the Canadian government, including Canada Mortgage & Housing Corporation. This report will not deal in depth with techniques and assemblies of non combustible construction, as they are, to date, virtually non-existent for native housing, or for any housing outside of Canada's cities or towns.

4.2.2 Prefabrication and Prebuilding

Because of the expense of maintaining labor and equipment at remote sites, techniques for off-site assembly of components of buildings present viable options, and have been used with varying degrees of success. These include:

.1 standardized, modular stressed skin panels, constructed of exterior grade plywood or waferboard sheathing glued and stapled or nailed over both sides of wood framing; units intended for use in exterior walls and roofs have vapor barriers on the interior of the warm side, and are filled with mineral or glass fibre insulation; as the cavities are completely filled, and the perimeters of the panels are closed, although not hermetically sealed, no significant condensation problems have been evidenced; the panels are assembled and locked together with edge-mounted hardware to form a completely floored, roofed and walled house; roof covering and wall and floor finishes are added as required; electrical and heating components may be partially incorporated into the panels, or added after assembly[.1a-.1f];

.2 pre-construction of the entire house, usually in 2 sections, which are shipped to the site either pre-built, or knocked down; these buildings are fitted together and anchored to foundations which are constructed on the site[.2a-.2b];

.3 standardized, modular glass fibre reinforced plastic-faced panels completely filled with foamed urethane insulation; these panels may be manufactured off-site, or prepared from molds on location .3a-.3b;

.4 pre-building at or near the site of selected sections of walls, floors and roof of houses in protected shops. .4a-.4c

SECTION 4.3 FOUNDATION OPTIONS

4.3.1 Footing Options

Foundation options for soils free of permafrost are:

.1 concrete strip footings set below level of frost penetration, or protected with insulation sized and positioned to provide equivalent protection, or cast on well-drained gravel compacted over non-frost susceptible soil, or set on sound rock .1a;

.2 concrete spread footings set on a gravel pads which are compacted over a substrate of well-drained, non-frost susceptible soil .2a;

.3 concrete piers set directly on sound rock, and anchored with steel bars grouted into the substrate;

.4 timbers, pressure-impregnated with preservative, secured in layers, each with timber layer laid crosswise to the timbers below[.4a,.4b];

.5 piles made of treated wood, steel H or tubular members, or precast concrete, or concrete cast into previously driven tubular steel sections[.5a];

.6 caissons of concrete poured into a drilled holes, with or without forms;

.7 reinforced concrete mats, with insulated perimeter grade beams, floated atop compacted, drained granular fill on non-frost susceptible soil; heating ducts are built into the slab perimeter.[.7a]

In areas underlain by permafrost, the danger of movement due to thawing of the permanently frozen layer imposes special disciplines on the designer. Common foundation techniques for these conditions are:

.8 use of concrete piers set directly on sound rock, where possible, and anchored with steel bars grouted into the substrate[.8a];

.9 use of a well-drained, compacted, coarse gravel pad of sufficient thickness to insulate the active layer from heat generated within the house, to spread the building load over a greater area, and to prevent any rise in the water table through capillary action; spread footings of concrete or wood timber, anchored to the ground by angled drift pins, are placed on the fill; if the soil comprising the active layer is not adequate for footings, wood, metal or precast concrete piles are frozen into pre-drilled holes in the permafrost at depths sufficient to preclude displacement by freeze-thaw cycles in the active layer; the section of the pile in the active layer[.9a,.9b];

.10 buildings on permafrost are supported well clear of the ground to ensure continuous ventilation below, minimizing heat transfer from the building to the ground below; beams span across the footings, or piles, to support the superstructure[.10a].

4.3.2 Foundation Wall Options

Foundation walls which enclose basements or crawl spaces for buildings on soils free of permafrost are:

.1 poured concrete, with walls suitably reinforced to function as grade beams, and as retaining walls against earth pressures; walls may be full height and restrained by the floor structure, or knee walls cantilevered from the footings; sections of walls below grade must be damproofed with bituminous material, or waterproofed with plies of cotton or glass fibre fabric embedded in bitumen, depending on water table levels .1a;

.2 concrete blocks, with subgrade areas parged with cement mortar, and damproofed or waterproofed as described for concrete walls .2a-.2d;

.3 preserved wood studs faced with treated plywood; the exterior faces are waterproofed using polyethylene film with joints taped, or with the membranes described above .3a.

Where piers, pads or other isolated supports are used, buildings may be supported on grade beams designed and anchored as specified for construction suspended over permafrost; use of fewer, more widely spaced supports will minimize distortion of the superstructure.

4.3.3 Subgrade Insulation Options

Insulation applied over the exterior face of the foundation walls extending from the superstructure insulation envelope to a minimum of 600 mm below finished grade is highly effective in reducing heat loss; this insulation may be:

.1 extruded polystyrene panels [.1a];

.2 glass fibre batts.

As protection against backfill and incidental damage to the exposed sections of the wall, the insulation may be covered with:

.3 pressure-impregnated exterior grade plywood [.3a];

.4 asbestos-cement panels;

.5 cement mortar, or other water-resistant parging [.5a].

Aside from the permafrost regions, the ground may freeze to depth in excess of 4 m. An alternative technique to setting foundations at these levels is to install extruded polystyrene insulation boards in an approximately horizontal plane extending out from the foundation wall (see APPENDIX 3, Fig. 5). The insulation thickness and extension width is calculated to provide an equivalent thermal resistance of soil cover, allowing the building footings to be set at a correspondingly higher elevation.

4.4. BUILDING ENVELOPE OPTIONS

4.4.1 Non-combustible Construction

For reasons listed in 4.2.1 non-combustible houses for natives are seldom built, and are not treated here in great detail. The most common categories are:

.1 masonry bearing walls supporting cast or precast concrete slabs, with or without structural steel framing[.1a];

.2 steel framed structures with cast or precast concrete floors and roofs[.2a];

.3 cast concrete framed structures, with cast concrete floors and roofs poured integrally, with supporting monolithic concrete beams or joists, or as flat slabs[.3a];

.4 precast concrete framed structures, with precast (and usually prestressed) concrete floor and roof slabs, and similar exterior wall facing[.4a].

Exterior walls for steel or concrete framed buildings are supported on or tied to the structure, and may be:

.5 brick, concrete block or stone, or any combination of these materials, laid in mortar; the masonry may be exposed, or may be erected in conjunction with the cladding systems listed below; exterior walls may have insulation applied over their exterior face, and be protected with suitable cladding described later, or have insulation applied over the interior face, and covered with an appropriate finish, or have insulation placed between the inner and other wythes; the vapor barrier is applied at or near the warm side of the assembly[.5a];

.6 precast concrete panels; insulation is secured to the back face, and covered with a vapor barrier and interior finish[.6a];

.7 non-load bearing steel studs clad with sheathing, and designed to anchor masonry, sheet steel or other veneers; insulation is applied over the sheathing face, or between the studs[.7a];

.8 curtain walls of formed sheet steel, aluminum, or asbestos-cement panels, field assembled or pre-fabricated, with an insulated core, and a vapor barrier or metal liner; the cladding may be secured to the structural frame, to steel studs, or over masonry backing; an alternative system consists of modular extruded aluminum curtain wall framing, with appropriate insulated infill panels and windows[.8a];

Interior partitions may be:

.9 steel studs covered with plaster or sheet material with acceptable fire characteristics[.9a];

.10 masonry, either exposed or covered with plaster or sheet material on furrings[.10a];

.11 prefabricated metal or composite systems[.11a].

4.4.2 Combustible Construction

Combustible construction generally refers to the wood frame, consisting of an assembly of wood studs, joists and/or trusses either stick-built, or pre-assembled in any of the systems described in 4.2.2. Wood is often locally available, is light and compact to transport, can readily be framed in different ways to receive vapor/air barriers, insulation, integrate mechanical and electrical services, and receive a variety of inside and outside finishes. Its appearance and use are familiar to the native population, and local carpentry skills are usually available. Buildings so constructed are subject to well known and understood building codes. They can be easily extended or altered with standard, readily available tools and materials. It must be recognized that wood is combustible, and is subject to warping, decay and insect attack. Wood framing techniques, and the various combinations of sheathing, cladding, interior finishes, insulation, and related vapor barriers are constantly evolving with experience, with the development of new materials, and with new recommendations by government and industry.

Wood framing methods in use are the:

.1 conventional platform or balloon frame construction (see Appendix 3, Fig. 1), consisting of wood stud exterior and interior walls supporting wood joist or wood truss floors and roofs; insulation batts are set between the exterior wall studs and upper ceiling or roof framing members, and covered with a vapor barrier; the outer face of the exterior studs is protected with sheathing, paper, and an exterior finish; interior finishes are applied directly to the framing members, or to furring members used to more accurately align the wall and ceiling surfaces, or to provide space for mechanical or electrical components within the vapor barrier .1a-.1d;

.2 double wall system (see APPENDIX 3, Fig. 4), built as conventional platform construction, with an additional wood framed exterior wall independently supported and braced clear of the inside wall, and tied to the structure by plywood connectors at each floor level; the entire cavity is filled with batt insulation; the vapor barrier and sheathing cover the outside face of the inner wall; supplementary insulation batts are set between the inner studs; other components of this system are similar to the conventional construction .2a-.2c;

.3 thermal enclosure system (see APPENDIX 3, Figs 2 and 3), built as conventional platform construction, with the exterior wall studs covered on the outside face with sheathing, a vapor barrier, and batt or board insulation as appropriate, full height from the roof to the footings; supplementary insulation batts are set between the studs; the outer cladding is secured to wood or metal furrings through the insulation to the studs; an alternative to this system uses wood blocking and horizontal wood 'girts' on the outside of the sheathing to increase the insulation thickness;
all other components of this system are similar to conventional construction .3a, .3b;

.4 thermal envelope system, consisting of conventional stud platform construction at the east and west walls, and a double shell of insulated wood frame construction on the north and south exterior walls, with a continuous cavity between built completely around, over and under the living space; each wall is independently insulated and fitted with vapor barriers; the space between the south walls is enlarged to usable size;

portions of the south wall and/or roof are glazed to trap solar heat; the air will circulate in the cavity around the living space in convective currents, heating in the winter, and cooling in the summer by releasing warmed air through vent at the roof[.4a, .4b];

.5 timber post and beam construction, consisting of wood posts supporting beams made of solid, built-up, glue-laminated wood, or plywood web beams; roof or floor decking consist of lumber laid flat or on edge; walls are non-bearing, and are usually of wood studs; exterior walls are insulated sheathed and clad as in any of the above systems;

.6 plank frame construction, consisting of exterior bearing walls built from plank vertical and horizontal members, with matching infill; insulation is usually on the inside of the plank frame, and is covered with a vapor barrier and wall finish secured to furrings; floors and roofs are wood joists or truses, and other components correspond to those of conventional platform frame house[.6a];

.7 log construction, an ancient technique with different variations, consists of exterior walls built of round, square or flatted logs laid horizontally with corners notched and interlocked; joints between logs are sealed with compressible insulation and caulked; for flat log contact surfaces splines or dowels may be used for stability; round logs may be angle cut longitudinally on the bottom to ensure a better bedded and weathertight joint; insulation, interior partitions and finishes are consistent with other wood framed housing .7a, .7b.

Sheathing options which contribute to the rigidity of stud framed buildings are:

.8 exterior grade plywood .8a;

.9 fibreboard;

.10 wood boards;

.11 gypsumboard .11a;

.12 waferboard.

Sheathing options with superior insulating qualities, but limited structural capabilities are:

.13 glass fibre panels .13a;

.14 polystyrene boards.

Insulation options are:

.15 glass or mineral fibre batts [.15a];

.16 extruded or beaded polystyrene boards [.16a];

.17 urethane boards;

.18 vermiculite, cellulose or polystyrene loose fill [.18a];

.19 urethane foam [.19a];

.20 fibreboard [.20a].

Vapor barriers options are:

.21 sheet polyethylene [.21a];

.22 kraft paper facings over an asphalt core;

.23 aluminum or copper coated paper.

Exterior wall finish options are:

.24 Wood board siding, plywood, or other sheet material with field-applied coatings [.24a];

.25 hard-pressed fibreboard or other wood-based sheet material with factory-applied finishes [.25a];

.26 wood shingles or shades [.26a];

.27 asbestos-cement shingles [.27a];

.28 pre-finished aluminum or steel sidings [.28a];

.29 extruded plastic sidings [.29a];

.30 granule-coated asphalt felt sheeting or shingles [.30a];

.31 stucco [.31a];

.32 clay or concrete brick, or concrete block, or stone [.32a].

4.4.3 Roof Membrane Options

Roof membranes options for near-flat decks are:

.1 hot or cold-applied bitumen fully mopped between bitumen impregnated or asbestos felts, and topped with aggregate or a finish bitumen coat ('smooth surface' type) [.1a];

.2 synthetic single ply membrane systems .2a ;

Roof membrane options for sloped decks are:

.3 asphalt shingles .3a ;

.4 asbestos cement shingles;

.5 wood shingles or shakes .5a ;

.6 slate shingles .6a ;

.7 corrugated asbestos cement panels .7a ;

.8 bitumen-impregnated mineral granule surfaced felts, with bitumen sealed joints ('selvage' type) .8a ;

.9 galvanized cold-rolled steel sheet, or cold-rolled aluminum, with an optional paint pre-finish .9a .

4.4.4 Roof Deck Options

Roof decks, which serve as a substrate for near flat roofs intended to be protected by built-up or single ply membranes, include:

.1 cast or precast concrete slabs .1a ;

.2 asbestos-cement panels .2a ;

.3 fluted metal decking, covered with gypsum board, plywood, and/or rigid insulation .3a ;

.4 pre-formed glass fibre, phenolic boards, polystyrene boards, fibreboard or glass foam boards laid over any of the aforementioned decks, over a vapor barrier.

Roof decks which serve as a substrate for sloped nailable roofing include:

.5 exterior grade plywood;

.6 waterboard;

.7 wood boards or planking.

4.4.5 Window and Door Options

Window operation options are:

.1 double horizontally sliding sash .1a ;

.2 vertically sliding sash ('double hung' type) .2a ;

.3 side-hinged sash, inswinging or outswinging ('casement' type) .3a, .3b;

.4 top hinged sash, outswinging ('hopper' type);

.5 bottom hinged, inswinging sash ('awning' type);

.6 fixed sash;

Glazing options are:

.7 single, double or triple glazed fixed or operable sash;

.8 glass: tinted, heat absorbing, reflective, textured, or tempered .8a;

.9 plastic: acrylic or polycarbonate sheet .9a.

Options for materials for frames and sash are:

.10 wood, exposed or covered with aluminum sheet or extruded vinyl .10a;

.11 extruded aluminum .11a;

.12 extruded vinyl .12a;

.13 combinations of the above.

Exterior door options are:

.14 exterior grade plywood facing secured both sides over a solid wood or insulating core[.14a];

.15 pre-finished sheet steel panels filled with an insulating core;

Exterior door frame options are:

.16 wood;

.17 pressed steel, either 'knock-down' or unitized[.17a].

4.5 INTERIOR FINISH OPTIONS

4.5.1 Interior Partition Options

.1 concrete block or brick, either exposed, or to be finished as hereinafter noted[.1a];

.2 cold-rolled galvanized steel studs[.2a];

.3 wood studs[.3a];

.4 wood planking;

.5 pre-fabricated wood or metal panels[.5a];

.6 built-up gypsumboard[.6a].

4.5.2 <u>Interior Finish Options</u>

Interior partition finish options over studs or furred surfaces are:

.1 wood boards, either paint ready, natural or pre-finished;

.2 gypsumboard, either paint ready, or vinyl covered, or textured[.2a];

.3 plywood, either paint or stain ready, or pre-finished[.3a];

.4 hardboard, particleboard or waferboard, either natural, paint ready, or pre-finished;

.5 gypsum-lime plaster over gypsum or metal lath, or cement plaster over metal lath, on concrete block[.5a];

.6 fibreboard, either natural, or paint ready.

Interior finishes over the foregoing materials except where pre-finished, are:

.7 paints, stains or varnishes;

.8 sheet vinyl .8a ;

.9 ceramic tile;

.10 thermo-setting plastic sheet .10a .

Interior ceiling finish options over framing or furrings are the same as for partition finishes listed above, or:

.11 fibreboard pre-finished tiles.

Interior floor finish options over floor decking are:

.12 resilient tile, either vinyl asbestos, vinyl, rubber, cork, or linoleum .12a ;

.13 resilient sheet, either vinyl, rubber or linoleum;

.14 broadloom carpet .14a ;

.15 hardwood tongued and grooved boards or parquetry;

.16 seamless trowelled or sprayed surfaces, either polyurethane or epoxy.[16a]

4.6 SERVICE OPTIONS

4.6.1 Heating System Options

Heating system options are:

.1 hot air furnaces, with fans and supply/return ductwork, and outlet grilles, using oil, or electricity, or wood (or a combination thereof)[.1a];

.2 hot water furnaces, with pumps, piping and convectors, using oil or electricity[.2a];

.3 centrally located space heaters or stoves, using oil or wood[.3a];

.4 electrical resistance convectors[.4a].

Control options are:

.5 air temperature thermostats connected to burners for oil fired units; air systems have fans activated by furnace air temperature, and water systems have circulating pumps activated by return water temperature;

.6 interior air temperature thermostats mounted in the room wall, or on the heating unit, for electric convectors.

PART 5.0 SUMMARY

The intent of this paper is to serve the housing industry by identifying and evaluating factors contributing to decisions critical to the design of native residential projects. These will determine materials and assemblies used in their construction, and the amenities provided within the dwelling. A list of options is provided, with appropriate commentaries. Criteria discussed include:

- impact of house design resulting from remoteness of many project sites from urban centres, and relate to problems of access, communications, and the support of construction operations;
- lifestyles of the inhabitants, taking into account livelihood, social and family interaction, economic levels usually encountered, anticipated numbers of occupants per housing unit, and recreational and home craft needs;
- climatic conditions, including effects of low temperatures, wind, and precipitation;
- site conditions often characteristic of remote locations, including poor soils, susceptibility to flooding, and permafrost;
- applicable codes, standards and regulations of government and industry.

Relevant factors are collected into a Design Brief (see APPENDIX 1) which will serve as a basis for the definition of the housing unit and its components. The report has been accepted by Housing Design Services (Canada and Mortgage Housing Corporation) as a reference document and will be made available to the public through the Canadian Housing Information Centre. The writer intends to continue his relationship with the appropriate officials to ensure that the content of the report reflects the state-of-the-art of native housing programs, and reflects the ongoing experience of its builders.

APPENDIX 1

DESIGN BRIEF

The Design Brief is an information system containing basic data needed to determine the scope of the project, and the materials and assemblies required for its construction. Care in the compilation of the brief is rewarded by an authoritative document setting out criteria for:

- number, capacity and occupancy patterns of housing units;
- site conditions required for logistical considerations, including location-access, transport availability, local resources and facilities;
- climatic conditions, including temperature and precipitation data;
- structural considerations, including soils evaluation, seismic risk, snow and wind loads;
- available services including sewer, water, electricity garbage disposal, and fire protection;
- applicable codes and standards;
- sound and fire resistivity of building components;
- available fuels and related costs;
- energy efficiency of the building envelope;
- environmental conditions.

2.8.1 Scope of Building Program

A. Scope

A.1 No. of persons to be housed [ ]

A.2 No. of families to be housed [ ]

A.3 No. and types of dwellings (to determined in conjunction with client representatives): [ ]

A.3 Definitions:

Dwelling: a suite operated as a housekeeping, usually containing cooking, eating, living, sleeping and sanitary facilities;

	Detached	Semi-Detached	Row (Attached)
Bungalows	☐	☐	☐
No. bedr'ms	☐	☐	☐
Cottages	☐	☐	☐
No. bedr'ms	☐	☐	☐
Duplexes	☐	☐	☐
No. bedr'ms/unit	☐	☐	☐
Triplexes	☐	☐	☐
No. bedr'ms unit	☐	☐	☐
Apartments	☐	☐	☐
No. bedr'ms/unit	☐	☐	☐
Total no. of dwellings	☐	☐	☐

Bungalows: single family, 1 storey

Cottage: single family, 1 1/2 or 2 storeys;
Duplex: 2 families, superimposed;
Triplex: 3 families, superimposed;
Apartment: 4 (or more) families in 1 building;
Detached: independent building, no common walls;
Semi-detached: 2 adjacent dwellings, 1 common wall;
Row (attached): 3 or more adjacent dwellings separated by common walls.

B. Occupancy classification, per dwelling

B.1 Male adults ☐
B.2 Female adults ☐
B.3 Children ☐
B.4 Total ☐

B. Use when scope includes dwellings for specialized groups of non-related adults, such as teachers, nurses, or temporary residents.

C. Occupancy pattern

J	F	M	A	M	J	J	A	S	O	N	D
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

C. Residents may be absent from dwellings for extended periods during hunting, fishing and trapping seasons, necessitating special design features for protection from frost.

2.8.2 Site Data

A. Location

A.1 Municipality [ ]

County [ ]

Province [ ]

Territory [ ]

A.2 Latitude [ ]

A.3 Longitude [ ]

A.4 Distances:

- by air, to [ ] [ ] km
- by road, to [ ] [ ] km
- by water, to [ ] [ ] km

A.5 Elevation above MSL [ ] m

B. Site Access

B.1 Summer

	Vehicle or Craft	Max. Payload (kg)	Max. Load Size (mXmXm)
Road	[ ]	[ ]	[ ]
Air	[ ]	[ ]	[ ]
Water	[ ]	[ ]	[ ]

B.2 Winter

	Vehicle or Craft	Max. Payload (kg)	Max. Load Size (mXmXm)
Road	[ ]	[ ]	[ ]
Air	[ ]	[ ]	[ ]
Water	[ ]	[ ]	[ ]

C. Site Information

C.1 Max tree ht. ☐ m; max tree diam ☐ mm.

C.2 Distance of gravel borrow pit to construction site ☐ km.

C.3 Distance of airstrip to construction site ☐ km.

C.4 Distance of harbor to construction site ☐ km.

C.5 Storage facilities available

- heated ☐ m^2
- unheated ☐ m^2

C.6 Rooms available for workers ☐

2.8.3 Climate

A. Temperature

A.1 Design temperature ☐ °C

A.2 Annual degree days ☐

A.3 Annual freezing index ☐

B. Precipitation/Wind

B.1 Rainfall

- max 15 min, 5 yr period ☐ mm
- max 1 day, 5 yr period ☐ mm
- annual total precip ☐ mm

B.2 Direction of prevailing wind ☐

B.3 Driving rain index ☐

Climatological statistics can be obtained from 'The Supplement to the National Building Code of Canada, 1980' (NRCC No. 17724).

A.1 Dry and wet bulb temperatures which are not exceeded at the high and low ranges for more than 2 1/2% of the time.

A.2 Total of the difference between 18°C and the mean temperature for every day of the year that the temperature is below 18°C.

A.3 Total of the difference between 0°C and the mean temperature for every day of the year that the temperature is below 0°C.

B.3 Mean annual windspeed multiplied by mean annual rainfall.

2.8.4 Structural Considerations

A. Soils

A.1 Description [ ]

A.2 Bearing capacity at footing depth [ ] kN/m²

A.3 Refusal depth [ ] m

A.4 Depth of water table [ ] m

A.5 Permafrost

- continuous y/n [ ]
- discontinuous y/n [ ]

A.6 Frost penetration (in non permafrost regions) [ ] mm

A.1 Information required:

- depth of organic or filled overburden;
- composition and characteristics of subsoil strata;
- permeability absorption and drainage characteristics;
- susceptibility to expansion shrinkage;
- susceptibility to displacement or slide action;
- reaction to moisture and frost.

B. Seismic zone

C. Wind:

Annual max-hourly wind & gust speeds

Risk	Wind Speed (Km/hr)	Wind Pressure (kN/m²)
1/10	[ ]	[ ]
1/30	[ ]	[ ]
1/100	[ ]	[ ]

2.8.5 Available Services

A. Sewage disposal:

A.1 Septic tanks: y/n [ ]

A.2 Central collection:

sanitary waste: y/n [ ] diam [ ] mm

storm: y/n [ ] diam [ ] mm

A.3 Collection of sanitary waste from holding tank: y/n [ ]

A.4 Collection of bagged sanitary waste: y/n [ ]

B. Water Supply

B.1 Central supply piped to house:
y/n ☐
Pressure ☐ kPa waterpipe ☐
drain ☐ mm

B.2 Individual walls to each
house: y/n ☐
well capacity ☐ L/min. over 1hr

B.3 From outside source & carried
to each house: y/n ☐

B.4 From outside source & delivered
to each house by tank truck:
y/n ☐

B.5 Water characteristics: ☐

C. Electrical Supply

C.1 Connected to utility grid: y/n ☐

C.2 Generated in municipality:
y/n ☐

C.3 Electrical characteristics
phase ☐ distribution max.
rating ☐ A voltage ☐ V

C.4 Chargeable rate ☐ ¢/kWhr

D. Garbage Collection y/n ☐

E. Heating

E.1 Available fuels
oil: y/n ☐ @ ☐ $/L
electricity: y/n ☐ @ ☐ ¢/kWhr
propane: y/n ☐ @ ☐ $/kg
natural gas: y/n ☐ @ ☐ $/m³
wood: y/n ☐ @ ☐ $/m³

F Fire Protection Services

F.1 Hydrants y/n ☐

Characteristics pressure ☐ kPa;

flow ☐ L/s, available water ☐ L

F.2 Central alarm system y/n ☐

Description ☐

F.3 Other resources ☐

2.8.6 Regulations

A. Applicable Codes

A.1 Building ☐

A.2 Plumbing ☐

A.3 Electrical ☐

A.4 Safety ☐

A.5 Energy ☐

A.6 Fire ☐

A.7 Zoning ☐

A.8 Other ☐

2.8.7 Environmental Considerations

A. Soil Pollutants

A.1 Radioactive emissions. y/n ☐

A.2 Contaminated subsoils & aquifers. y/n ☐

A.3 Soil borne chemicals harmful to building materials: y/n ☐

A.1 Soil based radon.

A.2 Insecticides and chemical wastes.

A.3 Sulphates and other chemicals attacking concrete.

B. Aggressive Atmospheres

B.1 Direct proximity to industrial fumes: y/n ☐

B.2 Subject to acid emissions: y/n ☐

B.3 Air borne salt. y/n ☐

B.1, B.2 Emissions from paper mills and metal refineries.

B.3 Proximity to ocean.

C. Water-borne Pollutants

C.1 Lakes & rivers contaminated with water-borne chemicals harmful to humans: y/n ☐

C.1 Mercury, insecticides, phenols and other poisonous substances.

2.8.8 Communications

A. Within the village:
- telephone: y/n ☐

B. Between the village & outside communities:
- telephone y/n ☐
- television y/n ☐
- facsimile y/n ☐

2.8.8, 2.8.9 Sound and fire protection is required between dwellings occupying the same building, and for construction separating exits and public spaces from dwellings.

2.8.9 Fire Resistance

A. Fire resistivity ratings (hrs) of:

A.1 Firewalls between buildings ☐
A.2 Floors between dwellings ☐
A.3 Walls between dwellings ☐
A.4 Walls around public corridors ☐
A.5 Walls around stair wells ☐
A.6 Exterior walls ☐

A.6 Fire resistivity of exterior walls depends on their proximity to lot lines, or to other buildings.

2.8.10 Sound Control

A. Sound transmission class ratings for:

A.1 Walls between dwellings ☐
A.2 Floors between dwellings ☐

A. Sound ratings for construction elements are listed in 'Residential Standards 1980' (NRCC 17304), Section 11.

2.8.11 **Energy Efficiency**

A. Thermal efficiency (Rm^2 °C/W) of:

A.1 Walls above grade ☐

A.2 Walls below grade ☐

A.3 Roofs ☐

A.4 Floors over unheated spaces ☐

A.5 Windows ☐

A.6 Exterior doors ☐

APPENDIX 2

TRANSPORT FACTORS

Distances between villages and major population centres are often great, and the different transportation modes involve significant costs in moving personnel, materials and equipment. The following examples convey a general appreciation of conditions typically encountered.

1. Fort Chimo (Kuujjuaq), on Ungava Bay, is an important centre serving many Innuit villages. It is 1,000 km north of Montreal by air, and 3,000 km distant by sea, with an ice-free shipping season of 2-4 weeks. Boat cargo rates are about $250/tonne, or per 2.5 m^3, whichever is greater. Air freight is about $2,000/tonne, with transhipment to coastal villages by light aircraft an additional $550-2,000/tonne (depending on distance). Air fare is about $500 per round trip. These factors result in a construction cost penalty of about 100%. Oil delivery by ship adds $.08/L to fuelcosts; local delivery is a further $.06/L.

2. Fort Rupert is a small Cree village on the Baie James coast, about 750 km north of Montreal. Access is by air, barge, and winter road. A truckload delivery over the frozen terrain costs about $2,600. Air freight is about $2,500/tonne, but with size and weight of the delivery considerably limited by the primitive runway. Aircraft may be chartered at rates ranging from $175/hr. (Cessna 185) to $600/hr (Twin Otter). Houses built in Fort Rupert cost 60-70% more than comparable dwellings in Montreal.

APPENDIX 3

CONVENTIONAL PLATFORM CONSTRUCTION

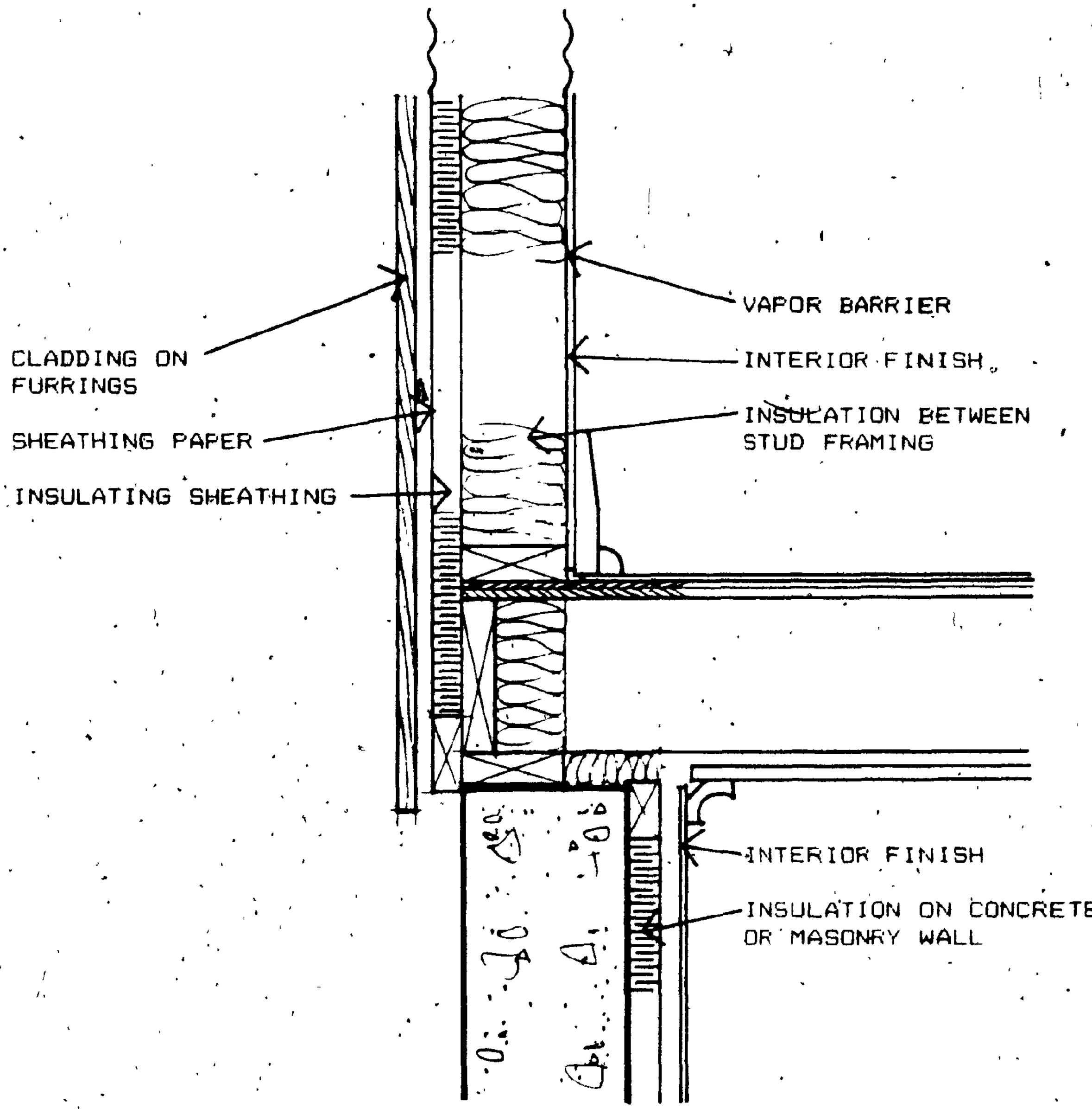

Fig. 1

APPENDIX 2

THERMAL ENCLOSURE SYSTEM

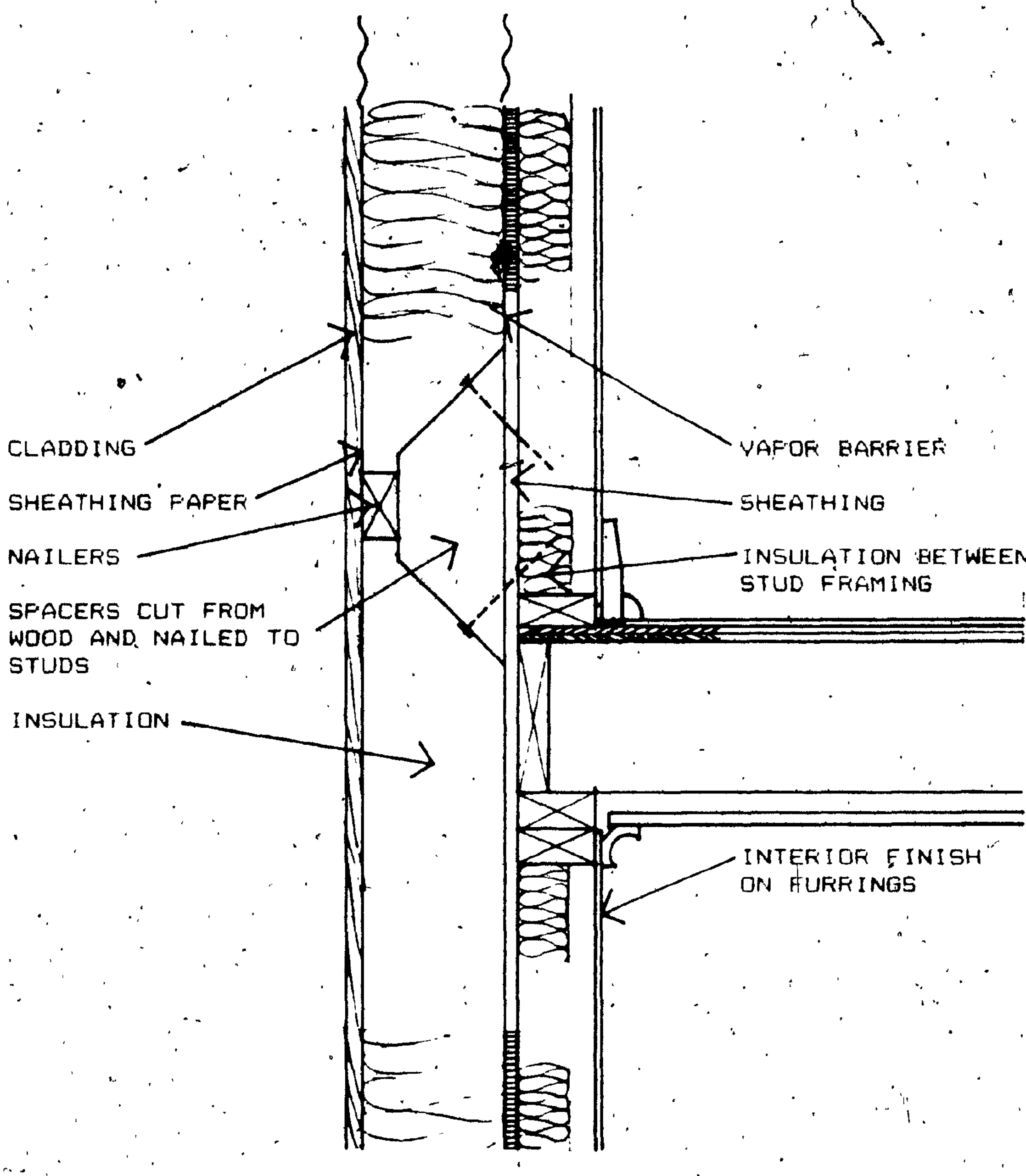

Fig. 2

APPENDIX 3

THERMAL ENCLOSURE SYSTEM

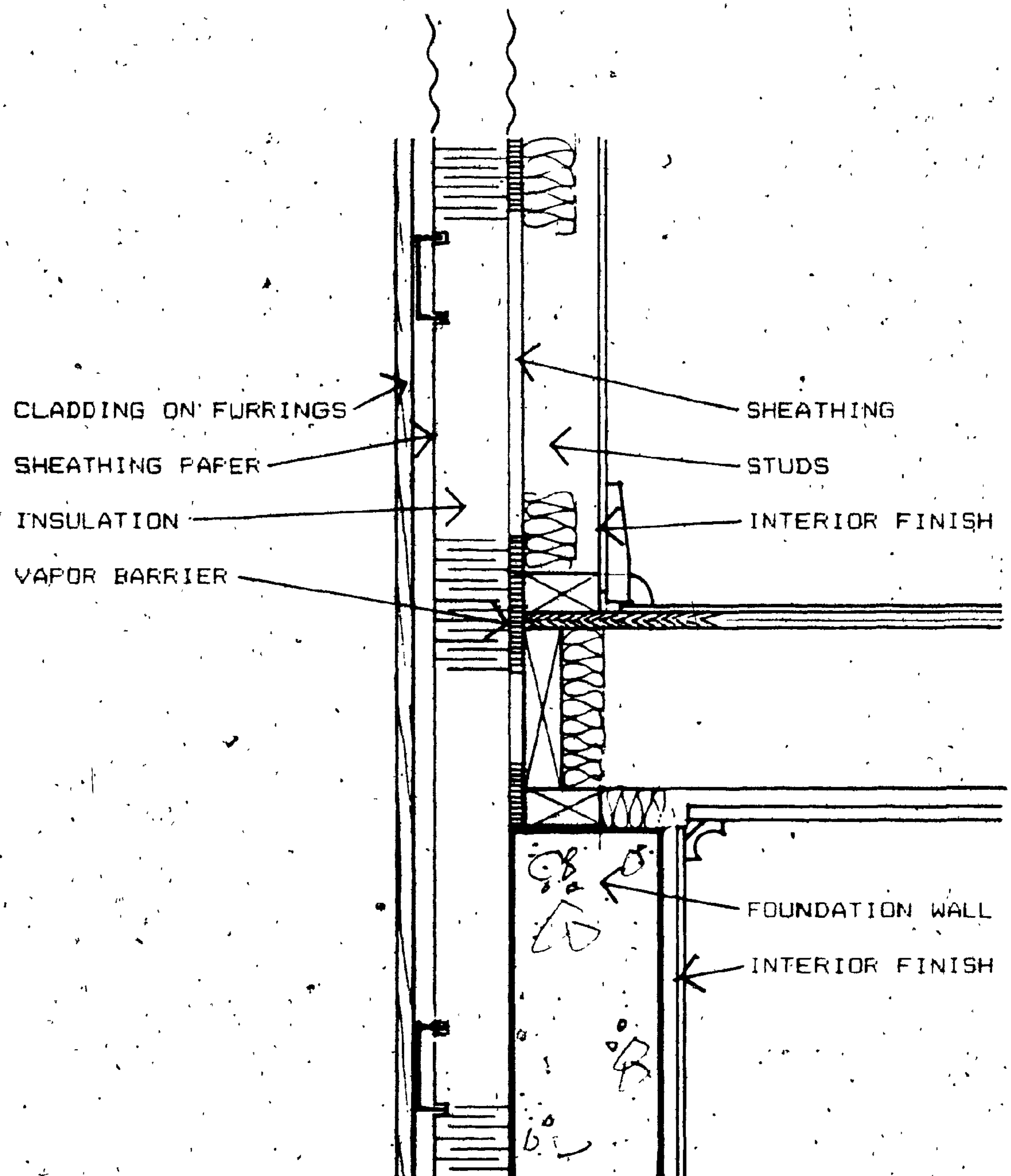

Fig. 3

APPENDIX 3

DOUBLE WALL SYSTEM

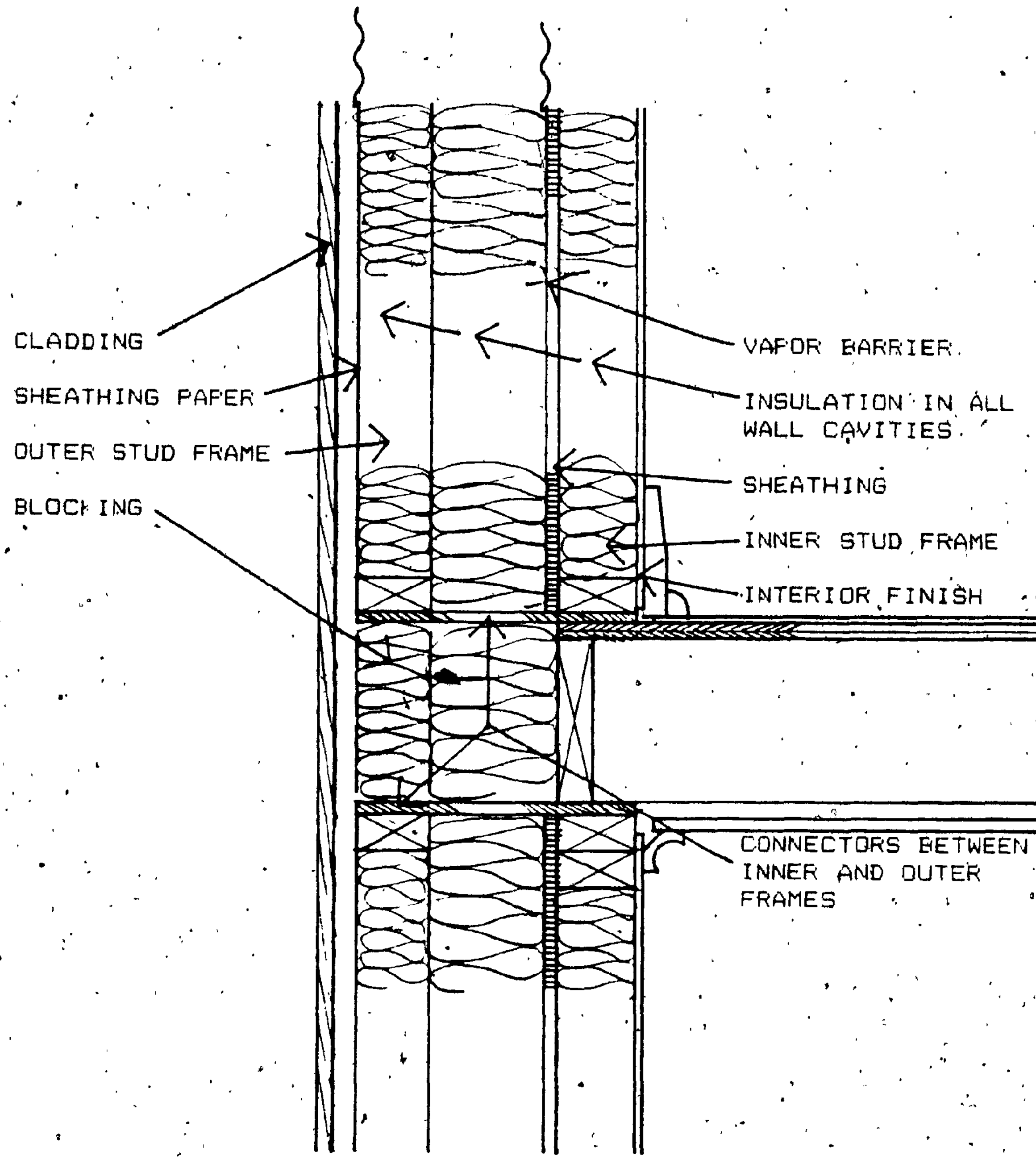

Fig. 4

APPENDIX 3

FOUNDATION INSULATION

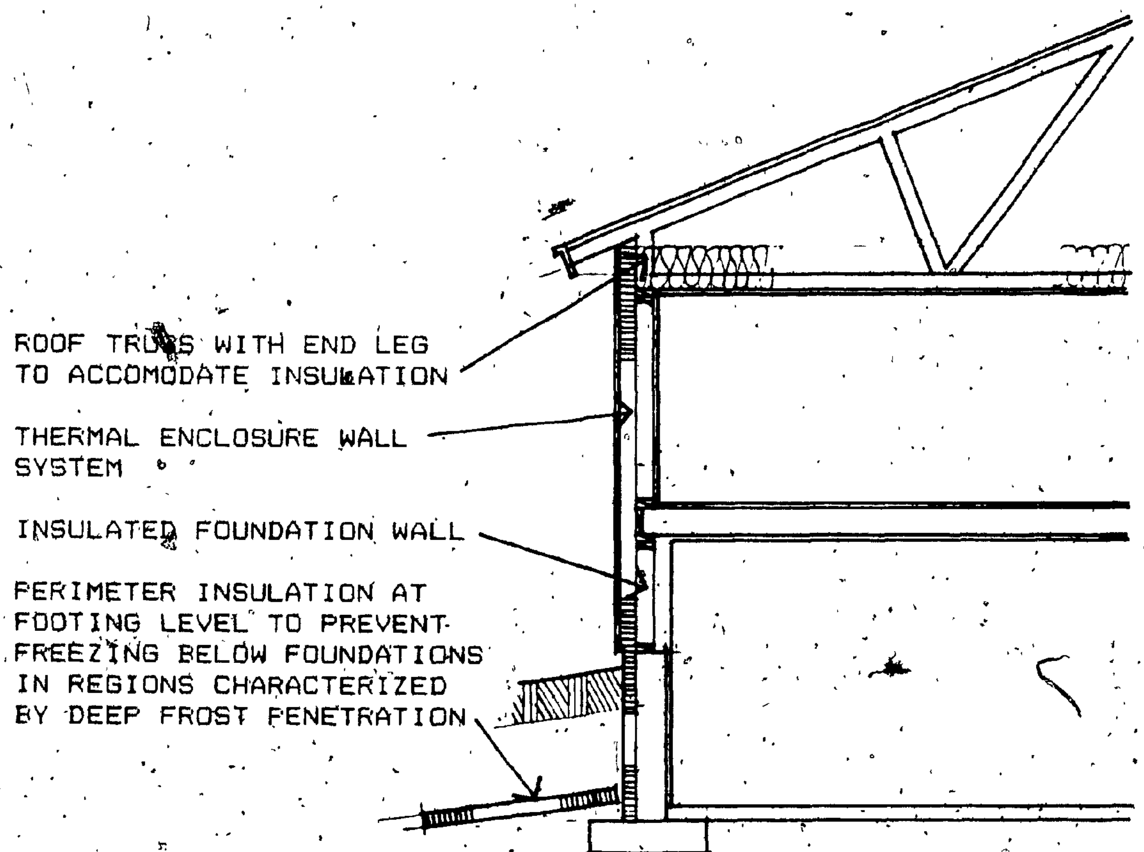

Fig: 5

APPENDIX 4

COMMENTARY ON OPTIONS LISTED IN PART 4.0 DESIGN OPTIONS

4.1.1 Building Grouping and Configuration

.1a Bungalows are the most common, and the prefered housing type and are the most expensive to build per m^2 of living space.

.2a Cottages have 70% of the foundation walls and 50% of the roof of bungalows with the same area.

.5a Because of the high ratio of frontage to depth foundations of row houses should be carefully studied to minimize differential settlement along the length of the building due to poor soils or to frost-actuated movement common in areas of high frost penetration.

.6a Multiple dwellings in multi-storey buildings may offer important savings in capital and operating costs because of reduced areas of exterior walls, roofs and services required for each housing unit; the lower construction cost is partially offset by additional requirements for sound isolation and fireproofing; grouped dwellings are not generally accepted because they are not in keeping with native tradition, and because the consequences of a fire are potentially more far-reaching; these factors are discussed in 2.1.3.

4.2.2 Prefabrication and Prebuilding

.1a Panels require minimum on-site labor for erection;

.1b many models have no additional inner or outer finishes over the panels and the integrity of the dwelling depends entirely on the efficacy of the seal between the prefabricated sections;

.1c heat loss due to thermal bridging is a greater factor in this construction type;

.1d variety of interior and outer finishes is limited;

.1e insulation thickness is limited by the size of the panel framing members; more stringent thermal requirements are difficult to attain within an economical panel thicknesses;

.1f integration of mechanical and electrical components is more difficult; often surface wiring and outlets are used; ductwork and piping are not readily concealed.

.2a Crating, shipping and handling large components presents problems;

.2b limitations of road sizes and conditions leading to the site, and lack of heavy transport and lifting equipment require consideration.

.3a While satisfactory for schools and government buildings, this construction is not yet economical for housing;

.3b plastic panels are not conducive to future repair, alteration or extension by local labor.

.4a with proper planning, prebuilding some of the house under cover, close to the construction site can advance the schedule by utilizing the off-season and taking advantage of inclement weather for production,

.4b selection of components to be pre-built is flexible, and can readily be varied for different house types, and suited to local facilities, equipment, manpower and transport,

.4c local labor may be employed on a year round basis, with accompanying social and economic benefits, and increased identification with community housing.

References:

Platts, R.E., "The Angirraq: Low Cost Prefabrication in Arctic Houses", NRC 4281.

Platts, R.E., "Prefabrication in Northern Housing", NRC 6059.

Platts, R.E., "Prefabrication in Canadian Housing", NRC 7856.

Platts, R.E., "Structural Sandwich Panels in Housing", NRC 5761.

Dickens, H.B., and Platts, R.E., "Housing in Northern Canada: Some Recent Developments", NRC 5902.

4.3.1 <u>Footing Options</u>

.1a Reinforcement [illegible] footings is recommended to bridge possible pockets of poor soil.

.2a Footings should be adequately sized to stabilize the structure against wind loads.

.4a Cut ends of timbers should be thoroughly sealed with preservative;

.4b timber pads should be anchored by driving steel pins at angles into the subgrade, or by tying down to buried preservative treated 'deadman' timbers.

.5a Piles and caissons are generally too expensive for small residences.

.7a Careful evaluation of the site and of local drainage patterns is essential because the floor is close to ground level and susceptible to flooding; because the level of frost penetration is below the mat, the nature of the soil/backfill must not encourage moisture migration through capillarity, or creation of frost lenses which will lift the structure above.

.8a Rock should not be underlain by frost susceptible material, or by fissures infiltrated by water.

4.3.1 Footing Options (cont'd)

.9a Spread footings should be anchored by any of the methods described above;

.9b sections of piles in the active layer should be wrapped to avoid uplift through friction.

.10a To minimize building movement resulting from footing displacement beams should be continuous across the supports and of maximum depth; prefered assemblies are laminated wood, plywood box beams, or steel; these should be secured by wedges to the supports using slotted connectors capable of subsequent adjustment, and have their ends anchored to pressure-treated timber 'deadmen' buried at least 1 m; narrow, deep beams should be cross braced to resist wind-induced forces.

References:

Chili, R., "Design Guidelines & Technology for Northern Housing Construction", Indian & Northern Affairs Canada (DRM 10-7/82.2.4).

"Foundation Design for Buildings in Permafrost Regions", Indian & Northern Affairs Canada (DRM 10-7/84.5).

Pihlainen, J., "Pile Construction in Permafrost", NRC 5515.

4.3.2 Foundation Wall Options

.1a Poured concrete [illegible], most resistant to displacement, most readily waterproofed, but most expensive foundation walls.

.2a Concrete masonry is very susceptible to cracking if footings are displaced,

.2b concrete masonry joints are difficult to treat against water penetration,

.2c cavities of concrete block readily transfer heat from the basement by convection unless sealed at the insulation line;

.2d masonry foundations require sub-grade parging, with the disadvantages discussed for stucco finishes in 4.4.2.

.3a Preserved wood foundations are difficult to waterproof as the polyethylene film covering over the subgrade portion is often damaged during backfilling.

Reference:

Hansen, A.T., "Wood Frame Foundations", CBD 234.

4.3.3 Subgrade Insulation Options

.1a Expanded ('beaded') polystyrene is highly water-absorbent and will deteriorate in direct contact with soil.

4.3.3 **Subgrade Insulation Options (cont'd)**

[illegible] Use of gravel for backfill against foundation walls will avoid damage caused by adhesion and lifting by ice forming at the building perimeter (see 2.5.5).

[illegible] Mortars, stuccos and plasters are [illegible]y seldom used in the north due to lack of skilled labor, perishability of the basic materials, and uncertain working conditions.

References:

Tao, S.S., Bomberg, M., and Hamilton, J.J., "Glass Fibre as Insulation & Drainage Layer on Exterior of Basement Walls".

Kubalsky, E.I., and Besprlug, K.E., "Design of Insulated Foundations", Journal of Soil Mechanics & Foundations Division, September, 1973.

4.4.1 **Non-Combustible Construction**

All these structural systems are characteristic of areas with ready access to heavy, specialized equipment, availability of concrete, masonry and structural steel, and the skilled labor required for their construction.

4.4.1 Non-Combustible Construction (cont'd)

.1a Masonry possesses advantages of fire resistance and thermal capacity, but requires highly stable building foundations, protected working conditions, specialized tradesmen, and heavy duty transport; as all of these conditions are rarely present at remote sites, few houses incorporate masonry, except for foundation walls; for large scale work, where logistics are favorable, it may be practical to manufacture concrete blocks near the site, to the advantage of the local economy.

.2a The manufacture, transport and erection of precast panels all require sophisticated equipment and techniques; as panels are heavy, subject to close tolerances, and do not adapt well to structural movement, the expense and characteristics of precast concrete construction render it impractical for remote construction.

.3a Cast concrete construction is heavy and requires skilled labor and specialized equipment to erect formwork, place rebars, pour concrete, and finish exposed work; in extreme climates, with short building seasons, concrete requires protection and temporary heat.

.4a Precast concrete, in addition to the disadvantages listed above, requires protected areas with specialized equipment for fabrication of components; components imported from established, remote plants, require improved roads and good site access; high capacity cranes and welding equipment, with attendant skilled labor, are need for erection.

.5a See above for comments on the use of masonry facing systems.

.6a See above for comments on the use of precast concrete components.

.7a Steel studs in outside walls are pre-disposed to excessive thermal bridging.

.8a Curtain walls are light, durable, and have great design flexibility, but are subject to thermal bridging, are easily damaged, difficult to repair, require specialized erection equipment and skilled labor, are not readily adapted to extensions or renovations, and are expensive; they are seldom used for housing.

.9a Steel studs are light, quickly erected, and readily receive electrical wiring, but are not load-bearing and depend on wall finishes for rigidity; local labor is more familiar with wood studs.

.10a Masonry partitions because of their weight, cost and equipment and labor requirements, are seldom used.

4.4.1 Non-Combustible Construction (cont'd)

.11a Prefabricated metal partition systems are not practical in the hinterlands as they are costly, require close tolerances for proper fitting, are not readily re-finished, are not load-bearing, and require special care for transport and storage.

4.4.2 Combustible Construction

.1a Standard platform light wood framing, stick-built or prefabricated, is the most common, least expensive and readily accepted housing system;

.1b familiarity with light wood framing by natives encourages their employment in the construction of their own houses, and facilitates future renovations and maintenance;

.1c augmented thermal efficiency is achieved by increasing the stud depth and by using insulating sheathing; roof members should be designed to receive thicke ceiling insulation without impeding attic ventilation;

.1d where non-rigid sheathing, such as glass fibre or polystyrene is used, additional bracing should be incorporated as resistance against racking.

4.4.2 Combustible Construction

.2a The efficiency of the double wall system depends on the clearance selected between the two exterior walls to be filled with insulation;

.2b the thickness of the double walls is at the expense of available living space;

.2c fitting of the vapor barrier to be fully continuous is somewhat complex; the position of the vapor barrier ensures its protection from damage during mechanical and electrical roughing operations.

.3a The efficiency of the thermal enclosure system depends on the thickness of insulation selected for application over the sheathing; as insulation is on the outside of the framing, living area is not penalized;

.3b the vapor barrier, set over the outside of the sheathing, is readily applied, and the joints easily sealed; its position ensures protection from damage during mechanical and electrical roughing operations.

.4a the thermal envelope, in effect a partial double house, is the most expensive of the models described;

.4b the thermal envelope system is currently under test and evaluation, and any conclusions regarding its cost effectiveness would be premature.

.6i Plank houses, as constructed in the hinterland, suffer from air infiltration through open joints occasioned by wood shrinkage.

.7a Inspections of older houses have disclosed widespread failure of the joints between the logs due to shrinkage and warping, with resulting air infiltration and high conductivity heat loss,

.7b the tendency of the horizontal joints between the logs to trap water leads to wood decay.

.8a Plywood acts as a vapor barrier and may contribute to condensation formation.

.11a Gypsumboard is an excellent fire retardant, but is highly susceptible to damage by water.

.13a Resistance to racking in houses sheathed with glass fibre or polystyrene is greatly augmented by securing plywood panels over the studs at each external corner.

.15a Internal convection currents may develope in low density fibre insulations.

.16a Plastic insulations decompose into highly poisonous fumes at relatively low temperatures, and should be protected; plastic insulations with low permeability should not be positioned so as to entrap water vapor in walls or roofs where condensation may occur.

.18a Granular insulation tends to settle in walls, leaving unprotected areas; in ceilings it is readily displaced by air currents in the roof spaces.

.19a Foamed insulations, despite their high thermal efficiency are costly, need specialized installation equipment and careful supervision, and can only be applied within a restricted temperature range.

.20a Fibreboard, as an insulation, is generally used over decking as a substrate for built up roofing.

.21a As most vapor penetration is by infiltration through badly sealed joints or damaged material, great care is required in detailing and installing barriers (see 2.5.3).

.24a Wood boards and wood-based sheet materials are the most commonly used sidings due to their low cost, ease of installation, adaptability, and wide variety; their durability depends largely on the quality of the field-applied paints or stains, and on their maintenance.

.25a Factory-finished wood-sheet products are durable and attractive, but are subject to damage under severe conditions.

.26a Wood shingling may be expensive, and is highly susceptible to fire spread.

.27a Asbestos-cement shingles are not commonly used as they are brittle and costly.

.28a Metal sidings are resistant to fire spread, but require special tools and skills to install, are subject to mechanical damage and maintenance problems; steel sidings tend to rust where finishes are deteriorated and aluminum may deteriorate in contact with other metals, or with concrete.

.29a Plastic sidings may be brittle in extreme cold, are susceptible to mechanical damage and difficult to maintain.

.30a Coated asphalt felt materials are inexpensive, are easily and quickly applied, but are susceptible to fire spread.

.31a Plaster materials are susceptible to moisture and finishes are difficult to apply during cold months, require skilled labor, need a solid, continuous base, and do not tolerate building movement; they are seldom used.

4.4.2 Combustible Construction (cont'd)

.32a Masonry is heavy, expensive to transport and build, requires solid foundations, can only be constructed in cold months using temporary protection and heat, and does not tolerate building movement; it is seldom used.

References:

Orr, H.W., "Design & Construction of Low Energy Houses in Saskatchewan", BPN No. 30.

Chown, G.A., "Thermal Envelope Houses", BPN No. 31.

"Log House Construction Requirements", CMHC (NHA 5370).

4.4.3 Roof Membrane Options

.1a Built-up roofs are seldom used in the hinterland because of cost, and need for specialized equipment and skilled applicators;

.2a There is inadequate experience with single ply membranes to justify any recommendations; many require specialized installation techniques, and may be difficult to repair.

.3a Asphalt shingles are almost universally used due to ease of application, repair and replacement, and low cost; self-sealing tabs are recommended; in high wind locales supplementary cementing is necessary.

4.4.3 Roof Membrane Options

.5a Wood shakes are expensive, and highly susceptible to fire spread.

.6a Slate shingling is widely used in the Norwegian hinterland, due to its local availability; paradoxically, thatched roofs are de rigeur for expensive housing; the Canadian experience has no such parallels.

.7a Asbestos-cement panels are not commonly used as then are brittle to transport and to cut and fit.

.8a Asphalt-saturated felt roofs are more difficult to apply than shingles, but are inexpensive and effective.

.9a Metal roofing, properly applied and flashed, is more costly than shingles; light guage sheet may work loose due to wind 'flutter'; with suitable raised joints metal sheeting is particularly effective for low slope roofs.

4.4.4 Roof Deck Options

Near flat roofs are more common in dwellings using panelized systems often found in the high Arctic; conventional flat roof decks used with concrete or steel systems seldom are economical for hinterland construction.

.1a Concrete construction is not practical for housing in remote regions.

4.4.4 **Roof Deck Options**

.2a Asbestos-cement roof panels are brittle, difficult to work, and are not often used for dwellings.

.3a Metal decking roof systems are prone to thermal bridging and air infiltration at the perimeters.

Underlays and starter strips are required over all decks.

4.4.5 **Window and Door Options**

.1a Sash operate horizontally entirely within the window frame and, when open, can be positioned to avoid direct drafts; pile weatherstripping is locked into recesses in the sash; sash can readily be removed from the interior for cleaning.

.2a Double hung sash operate vertically entirely within the window frame; weatherstripping is interlocking type recessed into the sash; counterbalancing is required to maintain the 'open' position.

.3a Inswinging sash interfere with living arrangements and are hazardous; outswinging sash are difficult to maintain in an 'open' position, and require special hardware to operate through an inside mounted screen; flexible pressure type weatherstripping is very effective; condensation on window frame rebates interferes with sash operation;

.3b fixed sash are most economical and efficient, but necessitate alternative ventilation methods for the house.

.3a Broken glass panes are very common, due to vandalism and repair difficulties; the use of tempered glass, or polycarbonate sheet, impedes use of the window as an emergency exit.

.9a Plastics scratch, abrade, and tend to turn yellow.

.10a Exposed wood requires paint and ongoing maintenance.

.11a Metal frames or sash constitute thermal bridges and develope condensation, even with thermal breaks; as hardware for aluminum windows is specialized, manufacturers should be selected who can give assurance of continued availability of components.

.12a Some plastics become fragile in extreme cold.

.14a Wood doors swell and shrink with seasonal flunctuations of humidity, and may warp to the extent that weatherstripping and even hardware do not operate efficiently.

.17a Metal frames act as thermal bridges and build up condensation.

4.5.1 Interior Partition Options

.1a Concrete masonry is fire resistant and durable, but is heavy, expensive and requires skilled labor.

.2a Metal studs are non-load bearing, and require special skill to erect.

.3a Conventional wood framing is light, readily erected by unspecialized labor in any configuration, adaptable to most finishes, and uses readily available materials.

.5a Modular panels lack design flexibility, and may present problems with door construction and location, incorporation of mechanical and electrical components, and with future renovations.

.6a Solid gypsumboard partitions are seldom, if ever, used in native housing because of their expense, weight, specialized labor requirements and lack of adaptability to mechanical and electrical components.

4.5.2 Interior Finish Options

.2a Gypsumboard is heavy to transport, requires heated, dry site storage, is relatively fragile, and requires skilled labor to install and finish; it is an excellent fire-resistive material; pre-finished gypsumboard cannot readily be repaired, an important requirement in houses with many children, and where heavy work takes place.

.3a Pre-finished panels, though highly flammable, are easy to install and replace, have a large variety of finishes, are light, inexpensive, and require little maintenance.

.5a 'Wet' finishes are seldom used because of cost and application problems in remote areas.

.8a Sheet materials cannot readily be repaired, or matched in subsequent work, and require skilled application.

.10a Sheets are difficult to repair, require skilled application, are susceptible to humidity, require great care in detailing, and are best left for covering cabinet work.

.12a Cork and linoleum are susceptible to moisture, and require on-going maintenance.

.14a Carpet requires on-going maintenance with specialized equipment, is difficult to repair, and is not compatible with many native activities and tasks.

.16a Seamless flooring requires a solid, continuous, sub-strate, skilled application labor, and is expensive.

4.6.1 **Heating System Options**

.1a Hot air systems are common, as they are relatively inexpensive, and provide possibilities of air treatment, and of introduction of fresh air; ducts must be incorporated into the building design; the system is adaptable to all energy sources.

.2a The high initial cost, susceptibility to freezing, and the shortage of qualified repairmen for maintenance have limited hot water systems to larger buildings.

.3a Stoves, though inexpensive, are inefficient, encourage drafts, provide limited, uneven heat, require constant care, and are often dangerous because of high surface temperatures and fire risk.

.4a Convectors are individually controlled and combine low installation cost with optimum control and eliminate the need for a central system.

APPENDIX 5

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2.5.1 Climate Considerations

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2.5.2 Design Factors Relevant to Energy Consumption

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APPENDIX 6

ABBREVIATIONS

ASTM	American Society for Testing Materials
BN	Building Note
BPN	Building Practice Note
^{o}C	degree Celsius
CBD	Canadian Building Digest
CGSB	Canadian Government Specifications Board
CMHC	Canada Mortgage & Housing Corporation
CSA	Canadian Standards Association
dm^3	cubic decimetre
FMS	Factory Mutual System
IAOC	Insurers' Advisory Association of Canada
kg	kilogram
km	kilometre
kPa	kilopascal
kN	kilonewton
kWhr	kilowatt hour
L	litres

ABBREVIATIONS (cont'd)

m	metres
m^2	square metres
m^3	cubic metres
MC	moisture content
mm	millimeter
NBC	National Building Code
ng	nanogram
NFPA	National Fire Protection Association
NRC	National Research Council
oc	centre to centre
Pa	Pascal
R	resistance
s	second
ULC	Underwriters' Laboratories of Canada
W	watt
yr.	year