THE UNIVERSITY OF MANITOBA

ENERGY EFFICIENT HOUSING DESIGN

BY

AJMAL MOHAMED

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF CITY PLANNING

For my two sons, Kirk and Tod and their friends, wishing them a future without "scare-city".

With special appreciation to my readers and advisors on this thesis

Professor Mario Carvalho
Professor Basil. Rotoff
Professor Demitrios Styliaras
Professor Ozdemir Erginsav

And to CMHC for having awarded me a scholarship to complete my studies toward a Master of City Planning Degree

And most of all to my wife, Lynda, for her continued devotion, patience and assistance in making this study possible.

ABSTRACT

This thesis examines ways of conserving energy through a rational approach to housing design. It seeks to answer the following questions:

1. Can energy be conserved through appropriate housing design, and if so, by what rational principles of design?
2. Can these design principles be used as a basis for directing public policy and incentives programs toward encouraging the design and construction of energy efficient housing, and if so, how can this be done?

Within the scope of housing, however, this thesis concentrates on the single family, detached house because of its inherent challenge to energy efficiency. An examination is first made of the conventional house to determine ways in which its design may be made inherently more energy efficient. Two alternate, potentially energy efficient forms of construction are also examined. These are the "double shelled" house and the "earth sheltered" house.

By examining the role of the public sector in encouraging the design of energy efficient housing, this study discusses various existing and proposed incentive programs.

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PREFACE

The news media reminds us daily that the "energy crisis" is increasingly real and that it's full implications will be felt in almost all aspects of our lives. Energy, in fact, has become a dominant factor in issues ranging from national defence and security; national economic stability; to the individual citizen's ability to cope with the ever increasing energy costs in maintaining a home and automobile.

This is indeed a serious and complex situation calling for the combined efforts of many. Government and industry are continually working on new ways of increasing the production of energy supplies in Canada. On the demand side of the equation, some conservation efforts have been initiated by governments and the private sector. However, on both sides of the equation, it is recognized that much more work is needed if Canada is to achieve its nationally stated objective of being self-sufficient in her energy needs by 1990.

> "In April 1976, the Government of Canada, in support of the objective of energy self reliance, within ten years, proposed nine major policy thrusts. These policy elements provide a co-ordinated framework for the development of specific programs and measures. They include: (1) appropriate pricing; (2) energy conservation; (3) increased exploration and development; (4) increased resource information; (5) inter-fuel substitution; (6) new delivery systems; (7) emergency preparedness; (8) increased research and development; and (9) greater Canadian content and participation in resource development."[1]

1 Workshop on Alternate Energy Strategies (WAES) Energy Demand Studies: Major Consuming Countries, M.I.T. Press, 1976, page 52.

We should indeed be striving for more than just self-reliance, we should strive for the elimination of all waste, especially in our use of our non-renewable resources.

It has been stated that when viewed as a balanced equation between supply and demand, the cost of saving energy (reducing demand through conservation) is far less than the cost of producing the same unit of energy - especially at today's costs. As energy costs increase, this fact will become even more relevant.

> "The cheapest "source" of energy is conservation - energy efficiency - so that vehicles, equipment, buildings and appliances do their work with a minimum of waste".[1]

As planners and architects, we have a very significant role to play in addressing our efforts to the task of conserving energy. This role can be played by directing our focus on two broad areas of concern.

1. In designing buildings so that they are more energy efficient.
2. In designing cities and towns so that their inhabitants may conserve transportation energy (gasoline consumed by the private automobile) without sacrificing the convenience and enjoyment of living in cities, or without destroying the opportunity for the efficient movement of people, goods and service

1 "The Energy Crisis - A Program for the '80's" Special Report in Newsweek, New York, July 16, 1979 p.26

These two broad areas of focus are relevant because they strike at the two sources of energy in which both Canada and the U.S.A. have become increasingly vulnerable - namely "heating fuels and gasoline". Therefore, the need to conserve these fuels is of paramount importance.

However, in spite of this recognized vulnerability emphasized almost daily by the news media; despite the ever increasing price of fuels; despite the stated government objective of attaining self sufficiency by 1990; despite the fact that it has now been 7 years since the first Arab oil embargo on North America, it is almost inconceivable that builders and planners go on building the energy wasteful, sprawling suburbia filled with "conventionally designed houses" today. One has only to look at most Canadian cities, especially Edmonton and Calgary, Alberta, for proof of this continued wasteful practice with little regard for conserving non-renewable resources. No doubt, if this situation is allowed to persist, Canada will indeed be faced with very painful energy shortages in years to come.

We, as Canadians, cannot allow ourselves to fall into the trap of complacency by thinking that, because of our comparatively good supplies of natural resources, (when compared with the U.S.A.), we need not be concerned about the future. In fact, because of the extreme dependence on energy created by our harsh winters and a very large and sparsely populated country, our very survival as human beings and as a federate union depends heavily on adequate energy supplies. Also, Canada is heavily dependent on the U.S.A. as our trading partner as well as our "big brother" in our defence needs. Both our economic and national defence depend on the survival and strength of the U.S.A. Consequently, when viewed in this way, it must be recognized that the energy problems facing the U.S.A. are indirectly our own as well.

It is against this background of far reaching implications, that the importance of conserving energy and the proposals of this thesis should be viewed.

APRIL 1980

INTRODUCTION

The primary purpose of this thesis is to determine whether or not energy can be conserved through a rational approach to the design of buildings and towns and if so, by what principles of design. These principles of design may then be used by planners, architects and builders in the future. This is discussed in PART A.

The second objective of this study is to illustrate to the public sector ways in which it may become involved and instrumental in encouraging the design and construction of energy efficient buildings and cities. By so doing, this thesis may be instrumental in guiding the way for co-ordinated and effective ACTIONS between the public and private sectors in attaining the national objective of energy self-sufficiency. This is discussed in PART B.

To concentrate the scope of this thesis, however, these discussions are approached from the perspective of housing design, and, more specifically, the single family detached house.

While it is recognized by the author that other forms of housing have a greater inherent potential for being energy efficient by virtue of party wall construction, shared roofs and floors (i.e. apartment blocks, townhouses, rowhouses, maisonettes, etc.), the single family house represents the most challenging conditions for designing an energy efficient building unit.

The lessons learned from this exercise can be extrapolated and applied (within threshold limits) to the design of other building units as well - be they multiple housing "blocks" or commercial or industrial buildings. Also, while this study concentrates on methods of designing new housing units, there is no reason why lessons learned here could not equally well be used as a basis for up-grading or "retrofitting" existing houses.

As well, it should be noted that the single family house is a very popular choice among Canadians in many cities.

> "At April 1975, single detached dwelling units were by far the most common form of housing, comprising 3,987,000 units or 60% of the total housing stock..."[1]

For most, it is a dream or major goal in life to own a house. If we are successful in designing an energy efficient house, this dream could become a reality for more Canadians who are increasingly being excluded from the market because of increasing energy costs. Also, the energy savings on a national scale would be obviously very significant if all housing units were to be made more energy efficient.

There is, therefore, "great mileage" to be gained by concentrating on the single family deatched house.

1 Central Mortgage and Housing Corporation: <u>The Conservation of Energy in Housing</u> CMHC, Ottawa 1977 p.13

Before proceeding with the central discussion, certain qualifications must be made to focus the perspective of this thesis.

The fundamental and primary role of a building is to provide shelter and protection to its inhabitants as they perform their activities. This protection is primarily directed at the ill effects of natural phenomenon such as the climatic elements. While the house may be required to serve many other important roles such as providing security, privacy, prestige, identity, etc., by far its most important purpose is that of providing a basic level of physiological comfort by sheltering its occupants and contents, (against the detrimental effects of the climatic environment). This is especially true in a climate as harsh as the North American prairie region.

In view of the growing energy crisis, this fundamental requirement of shelter is of even greater importance. Building design in North America has been less than optimum when viewed from an energy efficiency standpoint. From the author's observation, the modern building's architectural design has not been conceived of as playing a fundamental role in maximizing energy conservation. Instead, and because of an abundance of cheap fuels, the building's mechanical and electrical systems have been designed to provide the internal climate control requirements of heating, cooling, lighting and ventilation.

> ".....man and other creatures have always turned to the earth for protection from the elements and extremes of climate. It is only in the historically brief era of plentiful and cheap fossil fuel supplies that we have been able to design a house without regard to the climate and then to supply whatever equipment and energy may be necessary to keep us comfortable."[1]

Architectural design has been given to priorities of "higher" values. For example, the three "Master Builders" of our century have had a profound influence on the design and planning of buildings and cities in North America (and, in fact, much of the industrialized world). These are Frank Lloyd Wright, Le Corbusier and Mies Van Der Rohe. Students of architecture will quickly recognize that their priorities were definitely not with energy efficiency. Mies designed buildings to "express their structural integrity" in steel and glass - the two most inefficient materials when viewed from the standpoint of energy efficiency. Mr. Wright was more concerned with the design of "broadacres" (the original ancestor of suburbia) for living close to nature in "natural houses", which artfully manipulated the relationships of spaces and material in harmony with their surroundings - visually. However, Mr. Wright's houses often leaked, a fact which indicates his lack of concern for the building's fundamental function of providing shelter against the elements.

While the "higher" objectives of modern architecture are important and worthy of the pursuit of a society, these objectives can no longer

1 The Underground Space Centre: Earth Sheltered Housing Design
Van Nostrand Reinhold Company
New York 1979 p.4

be sought after at the expense of energy efficiency and with a heavy dependence on mechanical and electrical systems. For the purposes of this study, these priorities have been reversed so that the planning and architectural design are required to play a major role in providing these comfort requirements, while mechanical and electrical devices are used as back-up systems (to support the building's inherent ability to respond to nature in providing these comfort requirements). Because climate sensitive design will vary from region to region (and, infact, from one site to another,) it is necessary to limit the specific geographic context of this study. In addition, the following design parameters are to be noted:

1. Geographic and Climatic Context

Under consideration is the Canadian prairie region. This region encompasses such cities as Winnipeg, Regina, Saskatoon and Edmonton. (It should also be noted that the prairie region also extends into the U.S.A. as far south as Kansas City, so many topics discussed would also apply to the U.S. situation). Because this region is characterized by hot, dry sunny summers and long, very cold but sunny winters, use of the sun's energy is considered a major design determinant. See Figures 1 to 7 for climatic data on this region. Also, because this region is at the interface or meeting place of two major air masses (cold masses from the North and tropical air from the South), it is also characterized by strong winds, occasional tornadoes and thunderstorms in the warmer months. Winter months are characterized by cold north and northwesterly prevailing winds. Therefore, designing for maximum shelter from the winter winds is considered a major design determinant.

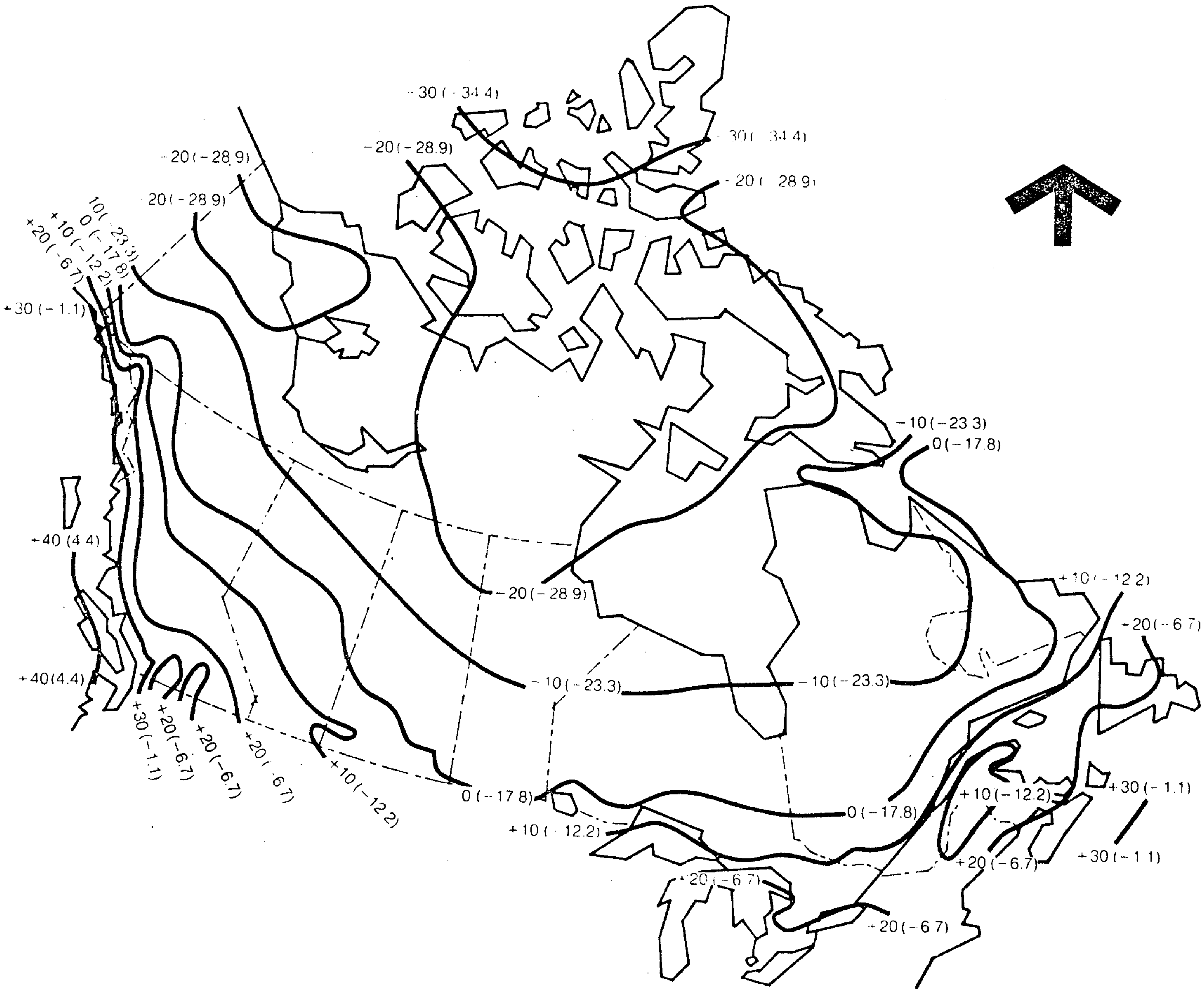
2. Technological Context

The technology under consideration is essentially as we know it today, or as we can realistically achieve within the next decade, without first requiring wholesale transformation of social values and customs or political revolution.

Because of the great number of sunshine hours experienced in this geographic region, the use of (natural) passive solar heat gain principles are under consideration (See "Definitions" for a comparison with active solar gain).

Conventional heating systems using oil, natural gas, electricity or wood as fuel may be used as back-up systems unless otherwise stated. This does not rule out the use of active systems as back-up in any of the designs discussed.

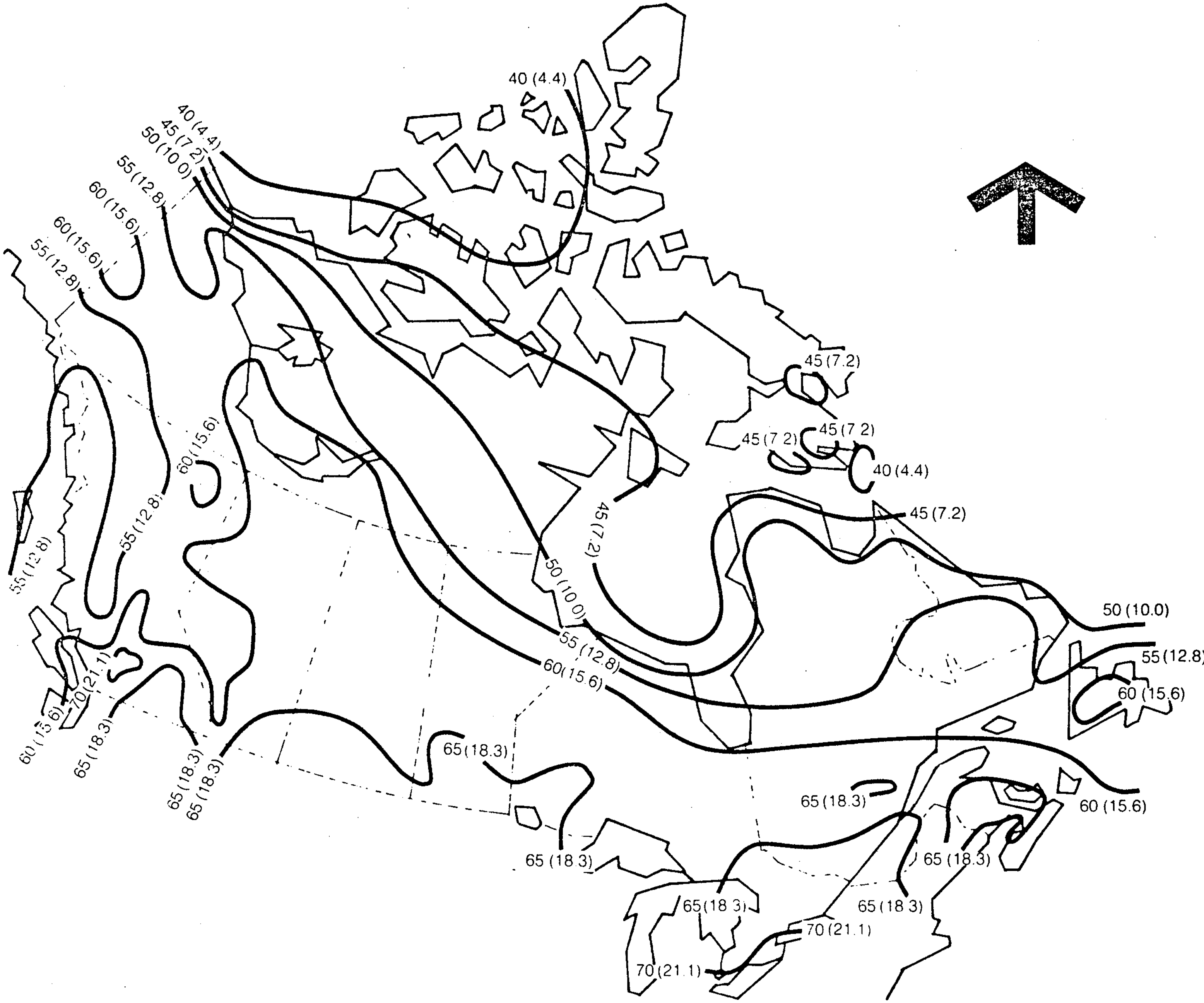
Cooling, ventilating and lighting by natural "means" is given a high design priority as well. Artifical or mechanical means of achieving these ends is considered necessary as back-up. It is also recognized



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953)

Fig. 1

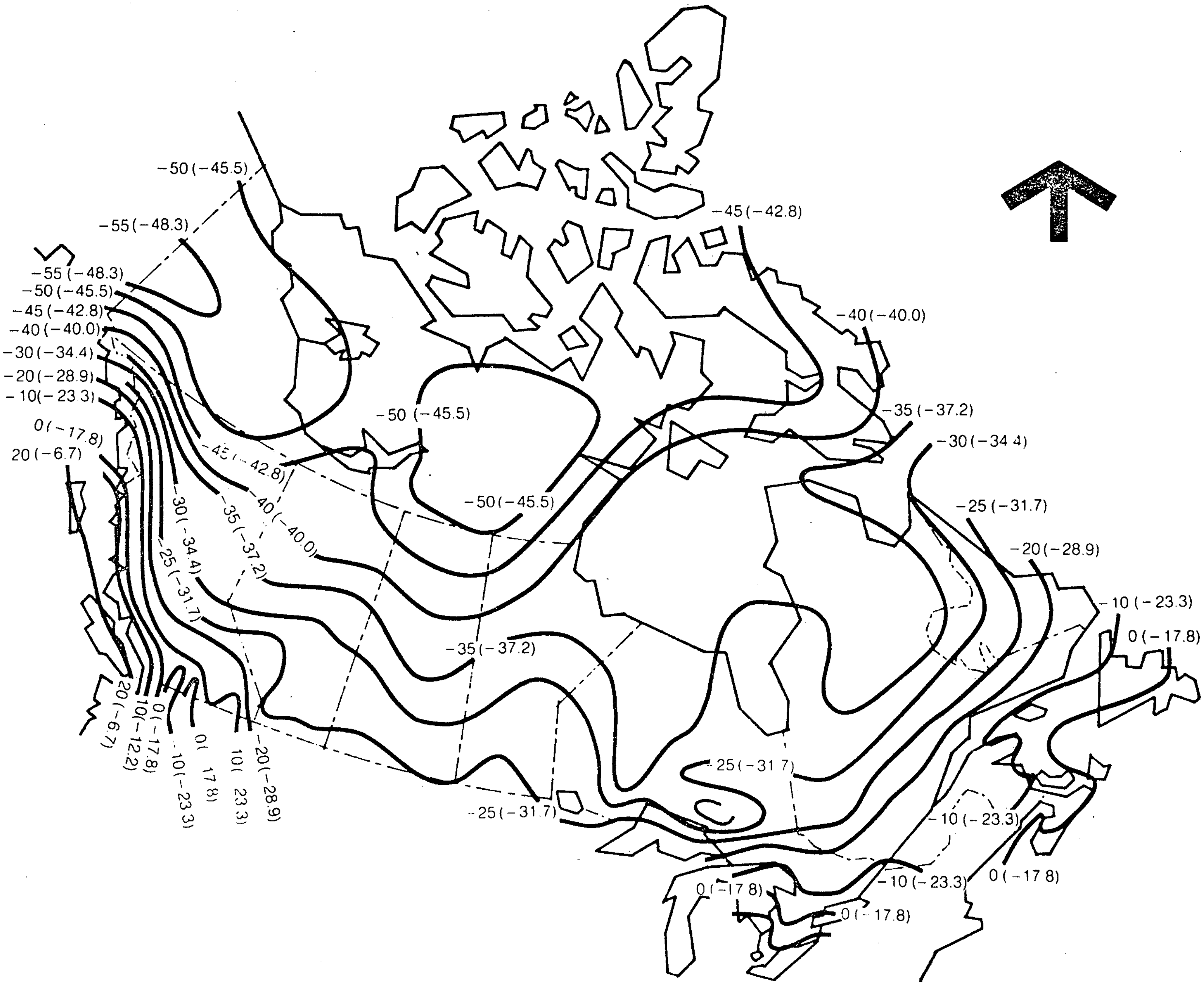
Mean January temperatures in Canada in Fahrenheit (with Celsius in parentheses)



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953).

Mean July temperatures in Canada in Fahrenheit (with Celsius in parentheses)

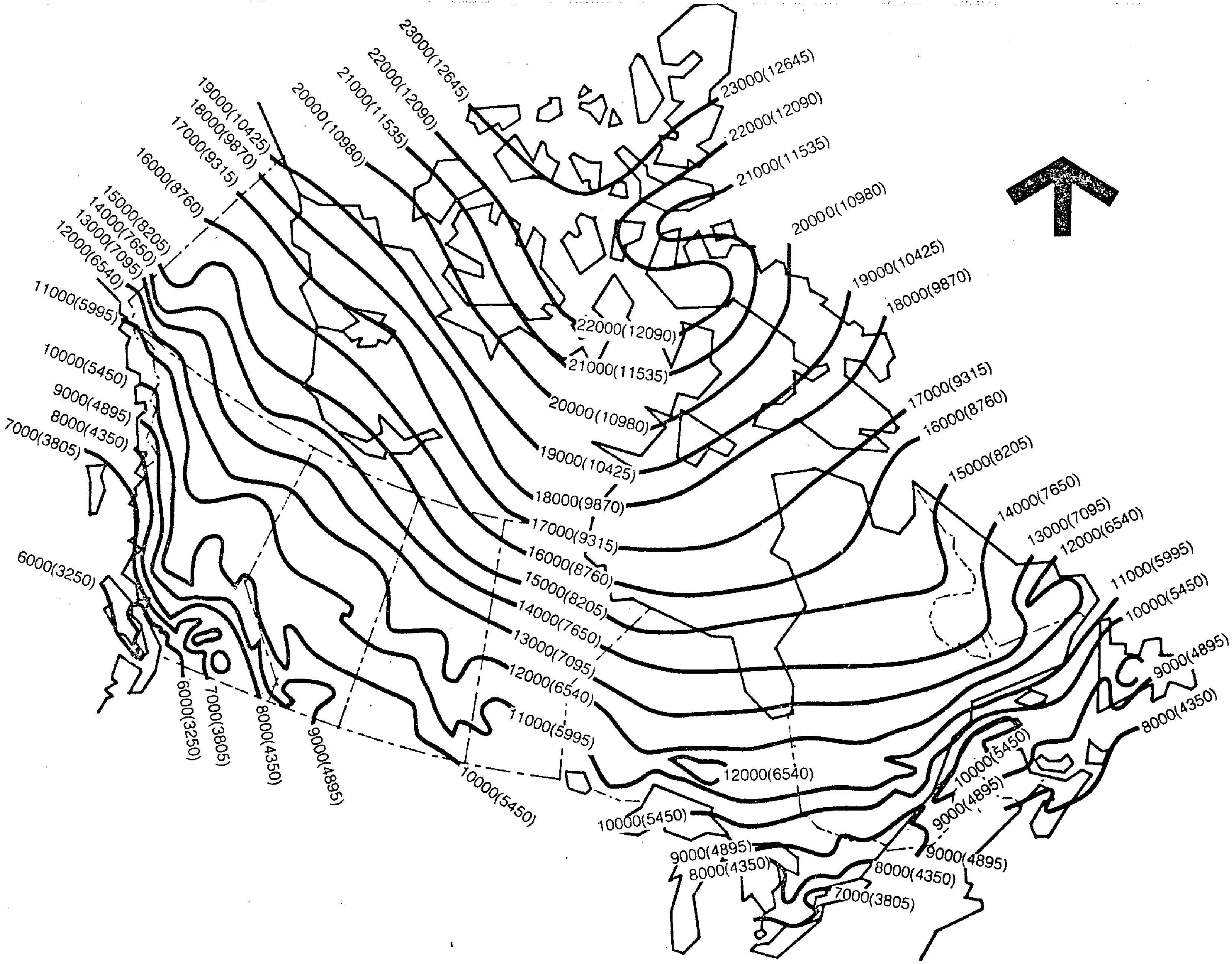
Fig. 2



Source: *Climatic Information for Building Designs in Canada*, 1975 Supplement to the National Building Code of Canada, 1970 (Ottawa National Research Council of Canada)

January design temperatures for dwellings in Canada — In Fahrenheit (with Celsius in parentheses)

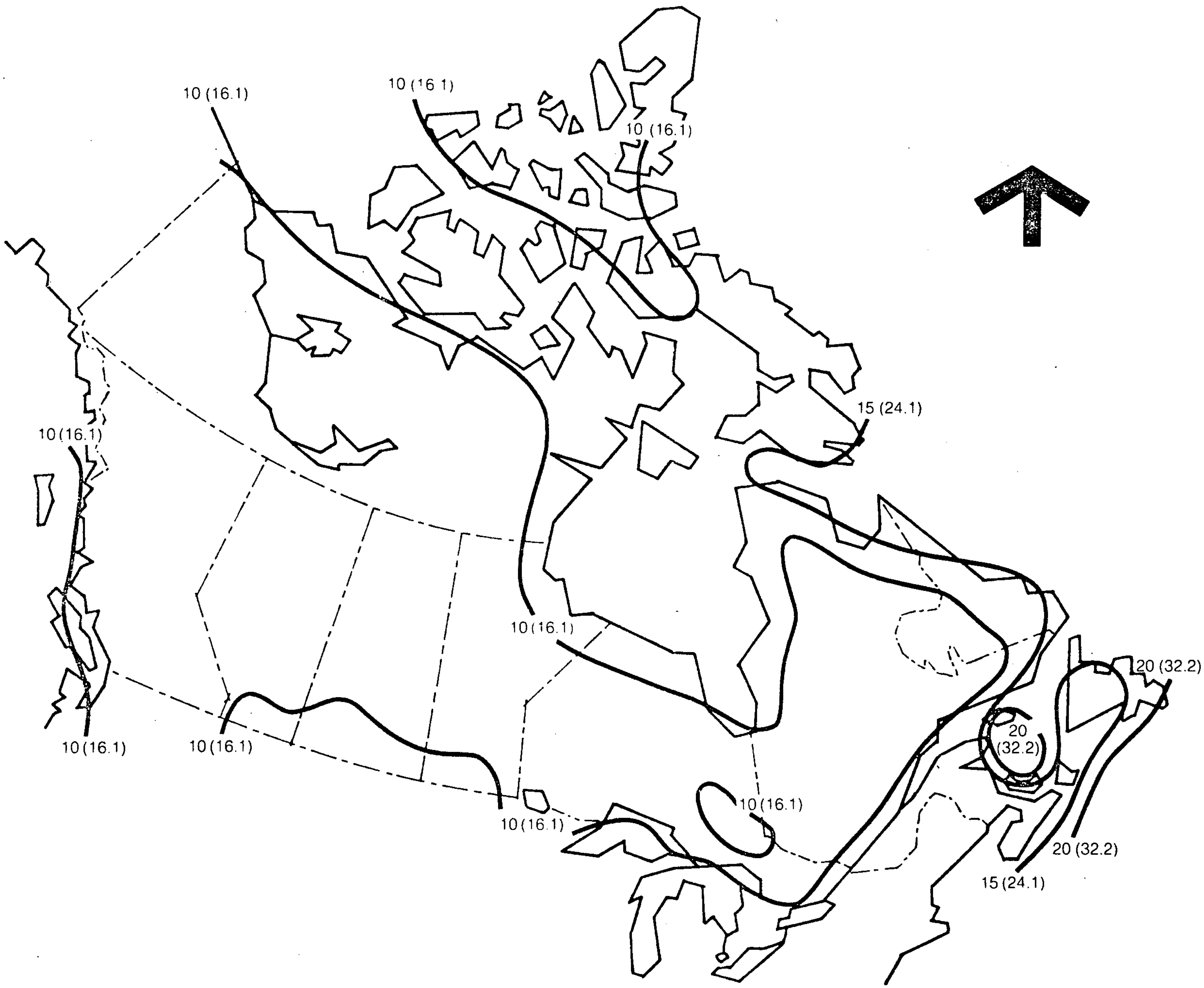
Fig. 3



Source: *Climatic Information for Building Designs in Canada, 1975.* Supplement to the National Building Code of Canada, 1970 (Ottawa: National Research Council of Canada).

Annual degree days in Canada in Fahrenheit (with Celsius in parentheses)

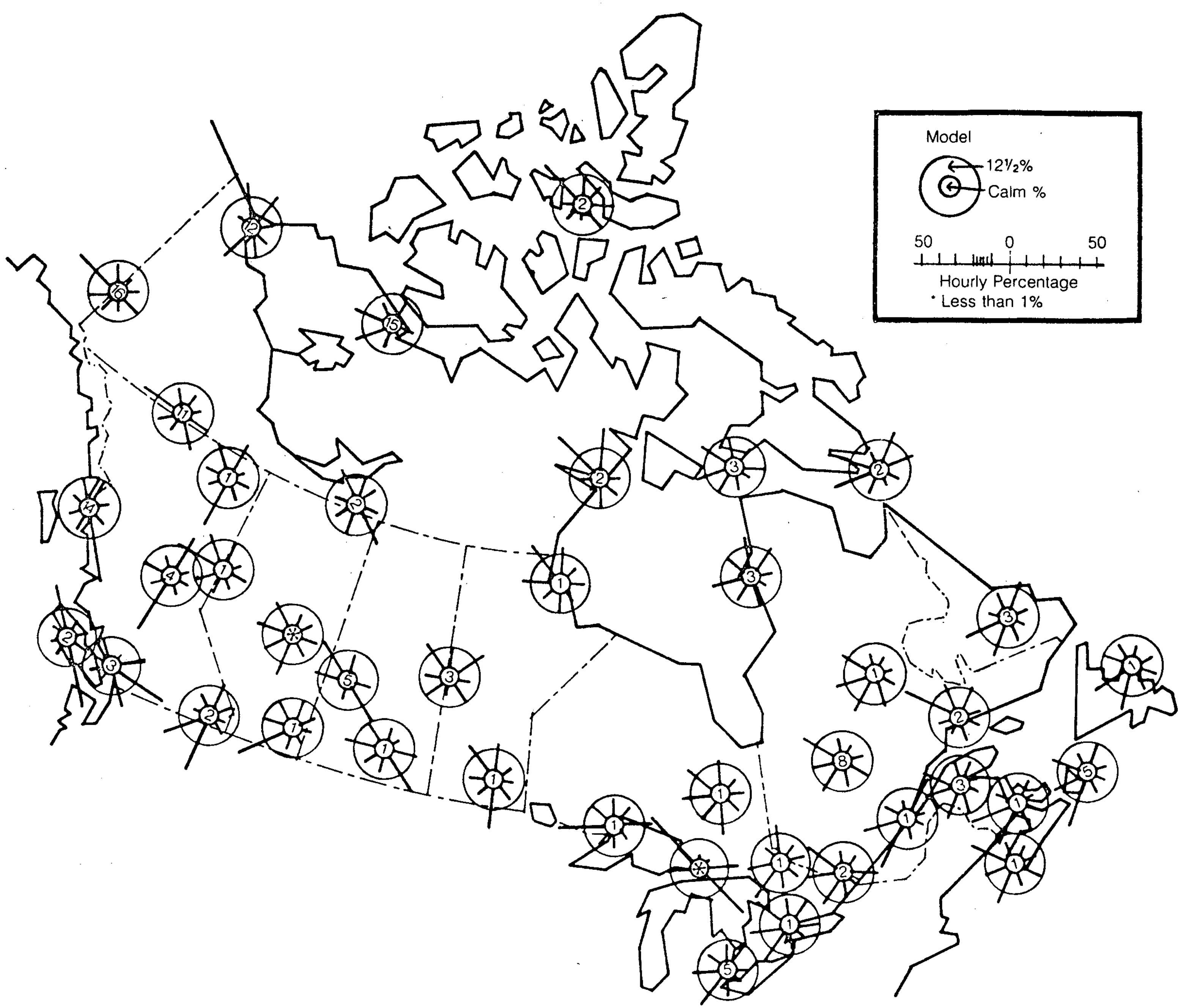
Fig. 4.



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953).

Mean winter wind speeds in Canada — In miles/hours (with km/h in parentheses)

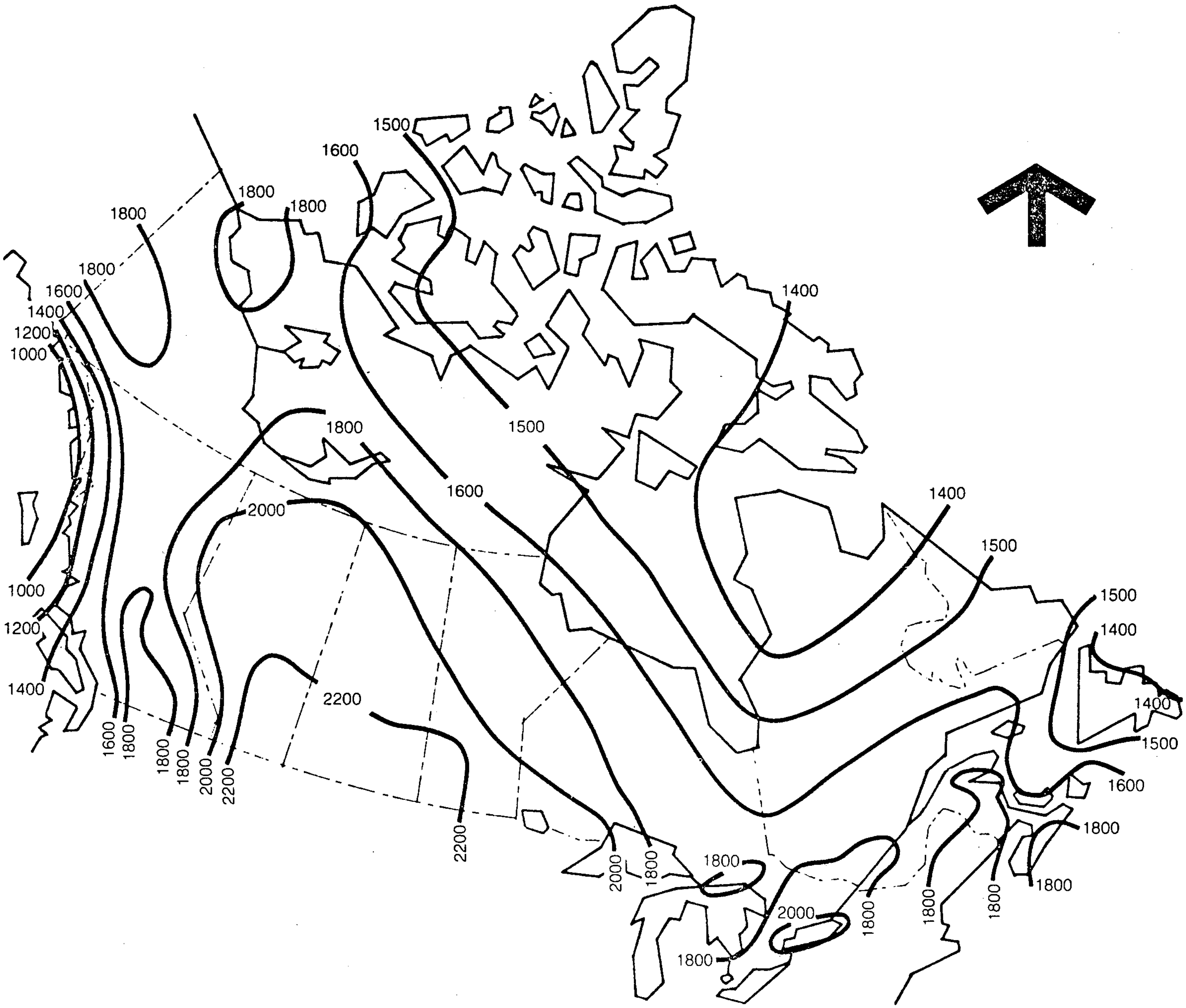
Fig. 5



Source *Climatological Atlas of Canada* (Ottawa National Research Council of Canada and Department of Transport 1953)

Direction of annual winds in Canada

Fig. 6



Source: *Climatological Atlas of Canada* (Ottawa: National Research Council of Canada and Department of Transport, 1953).

Mean annual hours of sunshine in Canada

Fig. 7

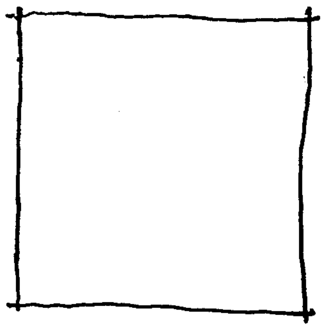
that electricity could be generated by wind, to provide power for these mechanical devices in order to conserve energy. Such mechanical devices, even though they may be energy conserving, and operating on "alternate" sources of energy, are considered as back-up systems for purposes of this study.

3. <u>Building Design Parameters</u>

All acceptable standards of good housing design (i.e. providing inhabitants with adequate sunlight, fresh air, opportunities for pleasant views, appropriate outdoor spaces, privacy, etc.) are to be recognized as fundamental requirements.

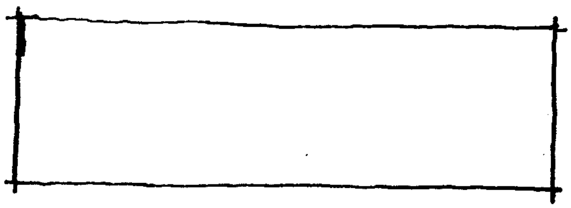
While it is recognized that the multiple storey house may be more economical to build (less surface area of enclosing walls and roof for the amount of floor area enclosed - See Figure 8 for a comparison), and may, in fact, be more energy efficient than a single storey house, the decision to build a two storey house usually is based not on economics or energy efficiency, but on many other considerations. They may include site conditions, lot size, size of family, number of bedrooms, preferred location of bedrooms, occupant's disabilities, etc. For this reason, this study assumes that the single or multiple storey houses are equally appropriate energy efficient designs. This can reasonably be assumed because measures can be taken to make one equally as energy efficient as the other.

PLAN A



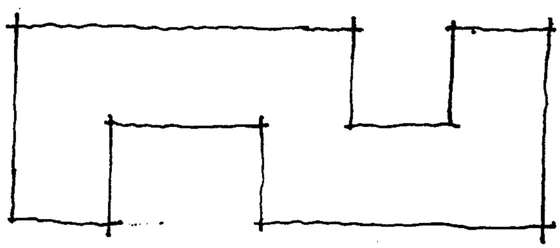
PLAN A

FLOOR AREA : 1296 S.F.
WALL AREA : 1152 S.F.



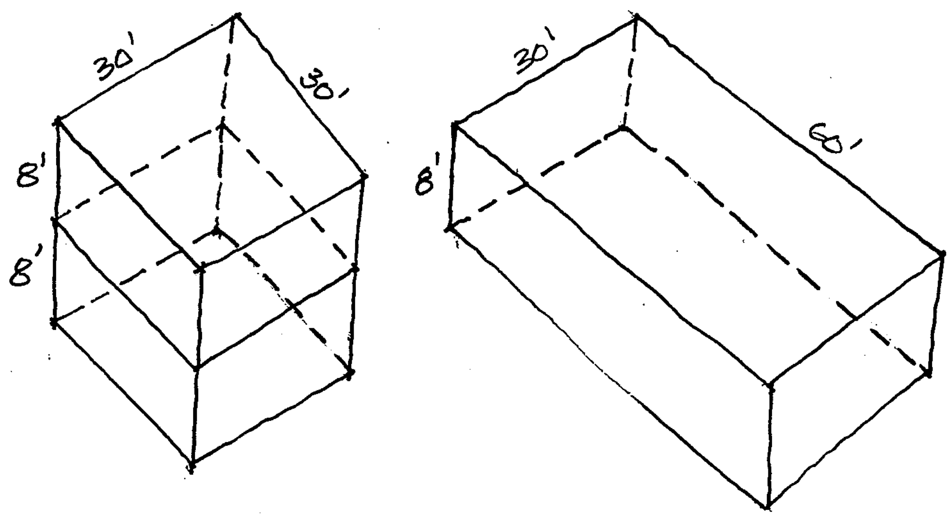
PLAN B

FLOOR AREA : 1296 S.F.
WALL AREA : 1440 S.F.



PLAN C

FLOOR AREA : 1296 S.F.
WALL AREA : 1920 S.F.



FLOOR AREA : 1800 S.F.
TOT. SURFACE AREA 3720 S.F.

FLOOR AREA 1800 S.F.
TOT. SURFACE AREA 5040 S.F.

FLOOR AREA vs. SURFACE AREA

SOURCE: EARTH SHELTERED HOUSING DESIGN
THE UNIVERSITY OF MINNESOTA, UNDERGROUND SPACE CENTER
VAN NOSTRAND REINHOLD CO. 1979 P. 35

FIG 8

A high priority is given to measures which are conducive to inhibiting the flow of heat through the shell of the building. Insulation is one of the many important techniques discussed.

4. Non-Architectural and Non-Mechanical Considerations

Many considerations which are neither architectural, urban planning or technological in nature, but affect the energy efficient design of buildings, are discussed.

5. Occupants' Life Style

The design principles discussed herein should not call for a significant alteration of the occupants' life style. It is recognized however, that many of our present habits are definitely energy wasteful. Where changes in these habits do not require a change in our life style, they are discussed.

METHODOLOGY

As a logical sequence to this discussion, the following methodology should be noted:

The thesis is divided into two major parts, PART A deals with the design characteristics of energy efficient housing, while PART B focuses on the public policy incentives that can be provided to encourage energy efficient housing design.

PART A, Chapter I, first examines the conventional house to determine where the energy is being consumed. Sources of heat loss, heat gain and non-architectural sources of energy consumption are discussed. An estimated energy budget is established for the conventional house, which will later be used as a comparison with an energy efficient house.

Chapter II then discusses in detail, various principles of energy efficient housing design; methods of implementing these design principles; and a discussion of the cost implications of these methods.

The final discussion of this chapter aims at evaluating the design principles by establishing a general energy budget for a conservation house and comparing it with that of a conventional house.

Chapter III examines alternate or non-conventional concepts of design which inherently enhance a building's ability to use the sun's energy and to retain it.

Two specific concepts are discussed in detail. These are the double-shelled house and the earth sheltered house. Their design characteristics are evaluated against the design principles outlined in Chapter II.

In PART B, Chapter I first examines the role and programs of the public sector (the Federal Government of Canada) to determine to what extent it has been involved in or is willing to become involved in providing incentives for the contruction of energy efficient housing.

Chapter II focuses on making suggestions for incentive programs for energy conservation in housing design. The discussion consistently cites precedent examples of programs used in the past (with other objectives) as a basis of establishing workable programs for the energy conservation initiative and thrust.

DEFINITIONS

For purposes of this study, the following definitions are to be noted:

Passive Solar Heat Gain

Heat gained from the sun through natural or non-mechanical means of collecting and storing this heat. This fundamentally involves the proper placement of south facing windows to admit the direct sunshine and a method of absorbing and storing the sun's excess heat for use during sunless hours. (See illustrations in Chapter III of Part A).

Active Solar Heat Gain

Heat gained from the sun through the use of mechanical means of collecting and storing this heat. This usually involves the use of solar collectors (quite often of a highly technical construction) containing materials (liquids or gases) used to transfer heat via systems of pipes and conduits to a heat storage facility. Heat is then extracted from the storage facility and conducted to the space which needs heating (See Figure in Chapter III of Part A).

Source of Energy Loss (SEL)

Anything causing the loss of energy or contributing to the consumption of energy. Throughout this report, the abbreviation "SEL" is used to designate "Source of Energy Loss".

Source of Energy Gain (SEG)

Anything which contributes to a reduction in the consumption of energy. This may, in fact, be a source of energy itself, i.e. the sun's radiant heat. Throughout this report the abbreviation "SEG" is used to designate "Source of Energy Gain".

"The Winnipeg Study"

In order to differentiate it from many other studies referred to in this thesis, the author has given the name "The Winnipeg Study" to a study done by Unies Ltd., a Winnipeg mechanical engineering consulting firm. This study consisted of comparing the heat loss of a conventionally designed house (Baseline House I), and the same house with an R-6 insulated basement (Baseline House II). A final heat loss comparison was made after taking the same house plan and making energy efficient improvements to it. This final house is referred to as Conservation House A in this thesis. A complete set of drawings are shown under Appendix A of this thesis.

"The Winnipeg Study" was presented by Unies Ltd at a conference entitled "Low Energy Solar Housing Workshop" sponsore by the Manitoba Chapter of the Solar Enerc Society of Canada Incorporated (SESCI), held at the University of Manitoba, February 15th and 16 th, 1980.

PART A

ENERGY EFFICIENT HOUSING DESIGN

CHAPTER I

WHERE THE ENERGY IS BEING CONSUMED

Before embarking on a study of the design of energy efficient housing, it is first useful to determine where our present or past practices are failing. First, an examination is made of the conventional house in its climatic environment, to determine factors which affect heat loss and heat gain. Based on this examination, an estimated energy budget is determined. In addition, there are many non-architectural considerations which affect energy efficiency in buildings. These are discussed as well.

A) THE BUILDING IN ITS CLIMATIC ENVIRONMENT

Two basic laws of physics are fundamental to a building's heat loss or gain (performance) within its climatic environment. These are as follows:

1. The first is that heat travels (by conduction) through a material in the direction from the warmer side to the colder side. The greater the difference in temperature between the two sides, the greater will be the flow of heat through the material (all things being equal). The implications of this fundamental law are great.

For example:

a) Heat loss is potentially greater through the attic or upper portions of wall, simply because of the fact that the air at the upper layers of an enclosed space will be warmer than lower layers, close to the floor.

b) During winter months, heat loss is potentially greater on the windward side of a building than on the leeward side, simply because the windchill factor on the exterior surface of the building will be greater on the windward side during periods of blowing winds. These facts are known from experience.

c) The practice of supplying warm air at outlets just beneath windows is theoretically very wasteful, simply because the warmest air comes into contact with the window before entering the room. Because the window is a poor insulator and the air is hottest when by-passing the window, the greatest heat loss occurs through the window before the room is warmed. This is a very important point because it would imply that heat should be supplied to the room at a point away from the window. However, in dealing with the problem of moisture condensation at windows, <u>some</u> warm air should be circulated through a supply air register close to the window.

2. The second fundamental law of physics to be noted, concerns vapour pressure.

> "Water vapour has its own pressure and this pressure always pushes it towards lower pressure areas.
>
> Under pressure, vapour diffuses through any materials that are permeable to it. Because warm, indoor air contains water vapour at a high pressure and the moisture in cold, outdoor air is at a lower pressure, in winter all water vapour diffusion is outward - from the interior of the building to the exterior."[1]

Because water vapour is carried by air, arresting the flow of air from inside to outside, or into any space which is colder will achieve two results:

a) stop the flow of heat to colder areas.

b) stop the flow of water vapour to a point which is cold enough to cause condensation (the dew point).

These two fundamental principles of physics are central to the proper design of energy efficient housing.

1 Op cit., Central Mortgage and Housing Corporation P. 35

I SOURCES OF ENERGY LOSS (SEL)[1]

In general, energy conservation experts agree that with residential buildings, the greatest source of energy loss are by:

a) the infiltration of air

b) the conduction of heat through walls and attics

c) the improper design and construction of the house.

According to a study done in the United States by the Federal housing agency, Housing and Urban Development (HUD), with support by the National Science Foundation, detailed theoretical quantitative thermal analyses were done on typical single family residences in the Baltimore-Washington area.[2] The results of this study are shown on Table I.

It is shown that heat loss and cooling loads caused by air infiltration through windows and doors account for about 50% of the total transfer of heat.

1 "SEL" is an abbreviation used in this thesis to mean "Source of Energy Loss".

2 Report #HUD-HAI-2: "Residential Energy Consumption, Single Family House". prepared by Hittman Associates, Inc., Columbia, Maryland March 1973

TABLE 1 ENERGY LOSS IN THE CONVENTIONAL HOUSE

SOURCE OF ENERGY LOSS (SEL)[1]		HOUSE USED IN H.U.D. STUDY		HOUSE USED IN WINNIPEG STUDY (BASELINE HOUSE II)	
		% HEATING LOAD	% COOLING LOAD	% HEATING LOAD	% COOLING LOAD
SEL I	AIR INFILTRATION	52.2	41.5	38.0	—
SEL II	THRU WALLS	23.9	14.2	22.0	—
SEL III	THRU BASEMENT WALLS	2.2 (FLOOR)	2.4 (FLOOR)	18.0	—
SEL IV	THRU WINDOWS	13.6	4.1	13.0	—
SEL V	THRU CEILING	3.7	2.3	8.0	—
SEL VI	THRU DOORS	1.4	0.4	1.0	—
(INTERNAL LOAD)		—	(35.1)	—	(30.0) APPROXIMATE
TOTAL		100%	100%	100%	

1. "SEL" IS AN ABBREVIATION USED IN THIS THESIS TO MEAN "SOURCE [illegible]"

The second source of energy loss as defined by the HUD study, is through walls (attics must be included here because in the HUD study, attics were disproportionately insulated, compared to the walls). This accounted for about one-quarter of the total heating and one-seventh of the cooling load.

It should be noted, however, that while the HUD study dealt with cooling loads, this is not considered a significant energy consuming factor in the Prairie region of Canada because under most circumstances, air conditioning is not usually required.[1]

Several studies have been done reflecting Canadian conditions. For example, the Federal Department of Energy, Mines and Resources identifies these two major sources of heat loss for Canadian houses built between 1951 to 1975. (See Figure 9)

Prairie conditions of construction and climate are more specifically reflected in studies performed by several private sector parties. The results of one such study were presented at a conference in Winnipeg in February 1980.[2] In this study, two baseline houses were established, each using the identical standard house plan. (See Figure 10.)

1 For a further discussion on this point, please see subtitle "Cooling Energy Budget" contained in this chapter.

2 Referred to as "The Winnipeg Study" in this thesis. See Definitions for a description of this study.

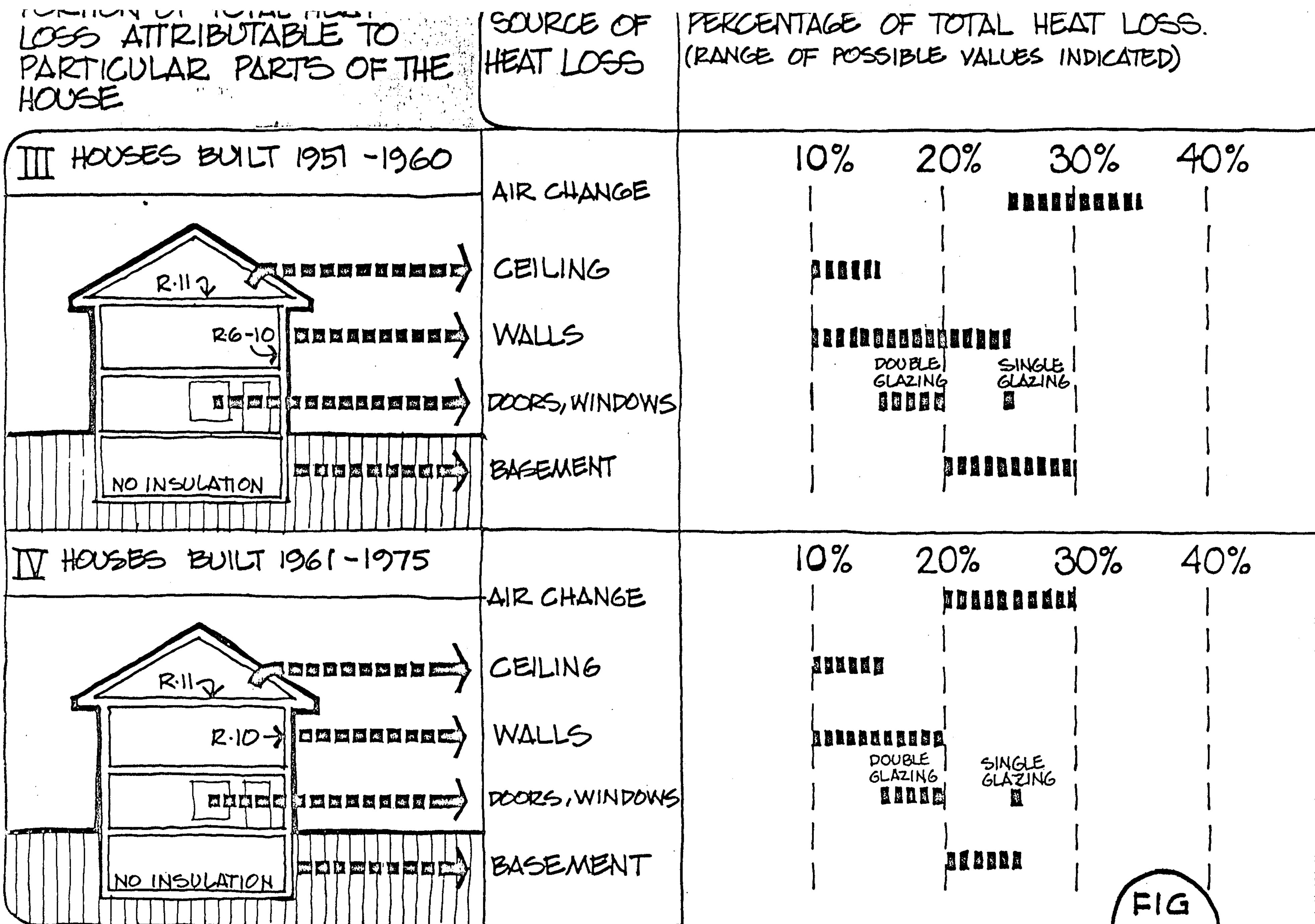
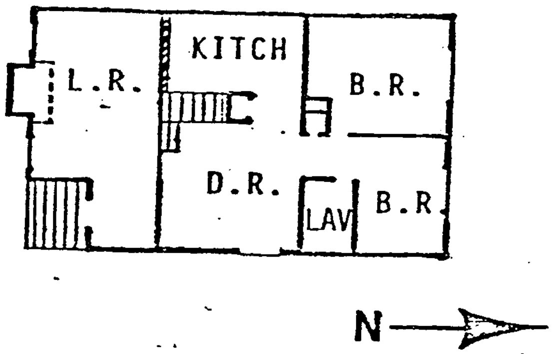


FIG 9

SOURCE: KEEPING THE HEAT IN. ENERGY, MINES AND RESOURCES CANADA
AUGUST 1976 PAGE 36

BASELINE HOUSE I



DIMENSIONS: 42' x 24'

AREA: 968 ft²

WALL INSULATION:

R-12 $\frac{\text{hr-ft}^2\text{-F}}{\text{Btu}}$

CEILING INSULATION:

Cathedral R-26 "

Vertical R-16 "

Flat R-38 "

BASEMENT INSULATION:

none

GLAZING: Double Glazing

HEATING SYSTEM:

Forced air with gas furnace and DHW tank; wood fireplace

OCCUPANCY:

2 adults & 2 children

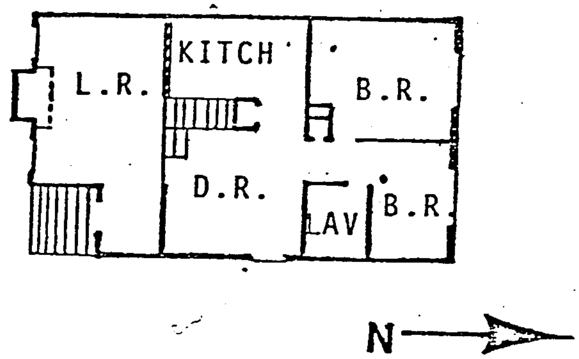
ELECTRICAL ENERGY CONSUMPTION:

1020 kW-hr/month

GAS HEATING BILL:

$504 per year

BASELINE HOUSE II



DIMENSIONS: 42' x 24'

AREA: 968 ft²

WALL INSULATION:

R-12 $\frac{\text{hr-ft}^2\text{-F}}{\text{Btu}}$

CEILING INSULATION:

Cathedral R-26 "

Vertical R-16 "

Flat R-38 "

BASEMENT INSULATION:

R-6

GLAZING: Double Glazing

HEATING SYSTEM:

Forced air with gas furnace and DHW tank; wood fireplace

OCCUPANCY:

2 adults & 2 children

ELECTRICAL ENERGY CONSUMPTION:

1020 kW-hr/month

GAS HEATING BILL:

$299 per year

SOURCE: UNIES LTD.
PRESENTED AT A CONFERENCE
"LOW ENERGY SOLAR HOUSE WORKSHOP"
IN WINNIPEG.
SPONSORED BY THE MANITOBA CHAPTER
OF S.E.S.C.I
FEBRUARY 1980

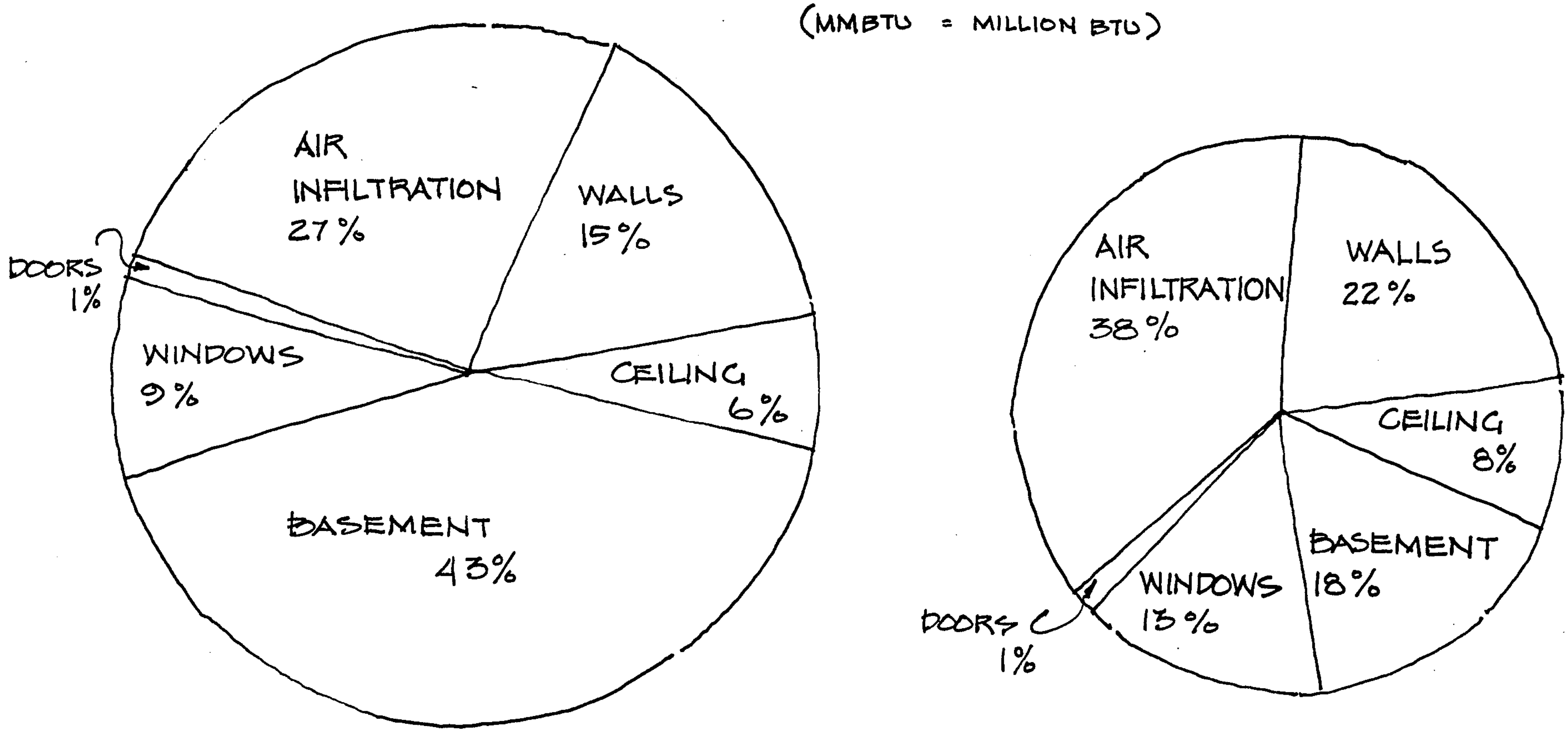
FIG 10

Baseline House I has an uninsulated basement and Baseline House II has an insulated basement (R-6). All other characteristics of the houses were identical. Baseline House II will be used as the principal "benchmark" of a conventional house throughout this thesis, because an insulated basement (R-6) can be considered to be a standard practice in prairie houses even before the energy crisis.[1]

Figure 11 illustrates the percentage of energy losses incurred in Baseline Houses I and II.

Studies done by the Department of Mechanical Engineering, University of Saskatchewan, with assistance from the National Research Council of Canada, with the Department of Mineral Resources, Province of Saskatchewan, outline the principal sources of air leakage as follows:

1 The 'R' factor denotes the amount of thermal resistance a material offers. Therefore, an insulating material having an 'R' value of 20 (R-20) is a better insulation than one with an 'R' value of 6 (R-6).



BASELINE HOUSE I

128 MMBTU/YEAR

BASELINE HOUSE II

76 MMBTU/YEAR

COMPARISON OF DESIGN HEAT LOSSES

SOURCE: UNIES LTD
PRESENTED AT A CONFERENCE IN WINNIPEG ENTITLED "LOW ENERGY SOLAR HOUSE WORKSHOP" SPONSORED BY MANITOBA CHAPTER SESCI.
FEBRUARY 1980

FIG 11

"Exterior walls and basement 60%
(electrical and plumbing, penetrations, connections between foundation and floor.)

Windows and Doors 20%

Ceiling . . . . 20%"[1]

The central focus of Chapter II and III of PART A is directed at finding solutions to these sources of energy loss, as described above, and outlining principles of design by which these solutions are governed.

II SOURCES OF ENERGY GAIN (SEG)[2]

Energy gains are achieved through several sources. In the case of heating energy requirements, these are:

1 Low Energy Passive Solar Housing Handbook
University of Saskatchewan. Saskatoon, Saskatchewan
October 1979 P. 3

2 "SEG" is an abbreviation used in this thesis to mean "Sources of Energy Gain".

Heat Gain Sources

a) Service sources (SEG-I)

- the furnace

b) Internal sources (SEG-II)

- the occupants
- stoves and other appliances
- refrigerator exhaust.
- electrical and lighting fixtures.

c) passive solar gain (SEG-III)

- the sun's radiant energy absorbed through south facing windows.
- the sun's radiant energy absorbed through the walls of the building.

It is known from experience that the major source of heat gain (in winter) in the conventional Canadian prairie house, is the furnace. According to "The Winnipeg Study" if 30% of the heat gain is from internal sources, then approximately 70% of the heat requirements of the house must be provided by the furnace. This, of course, assumes that solar heat gain (not measured in The Winnipeg Study) is negligible.

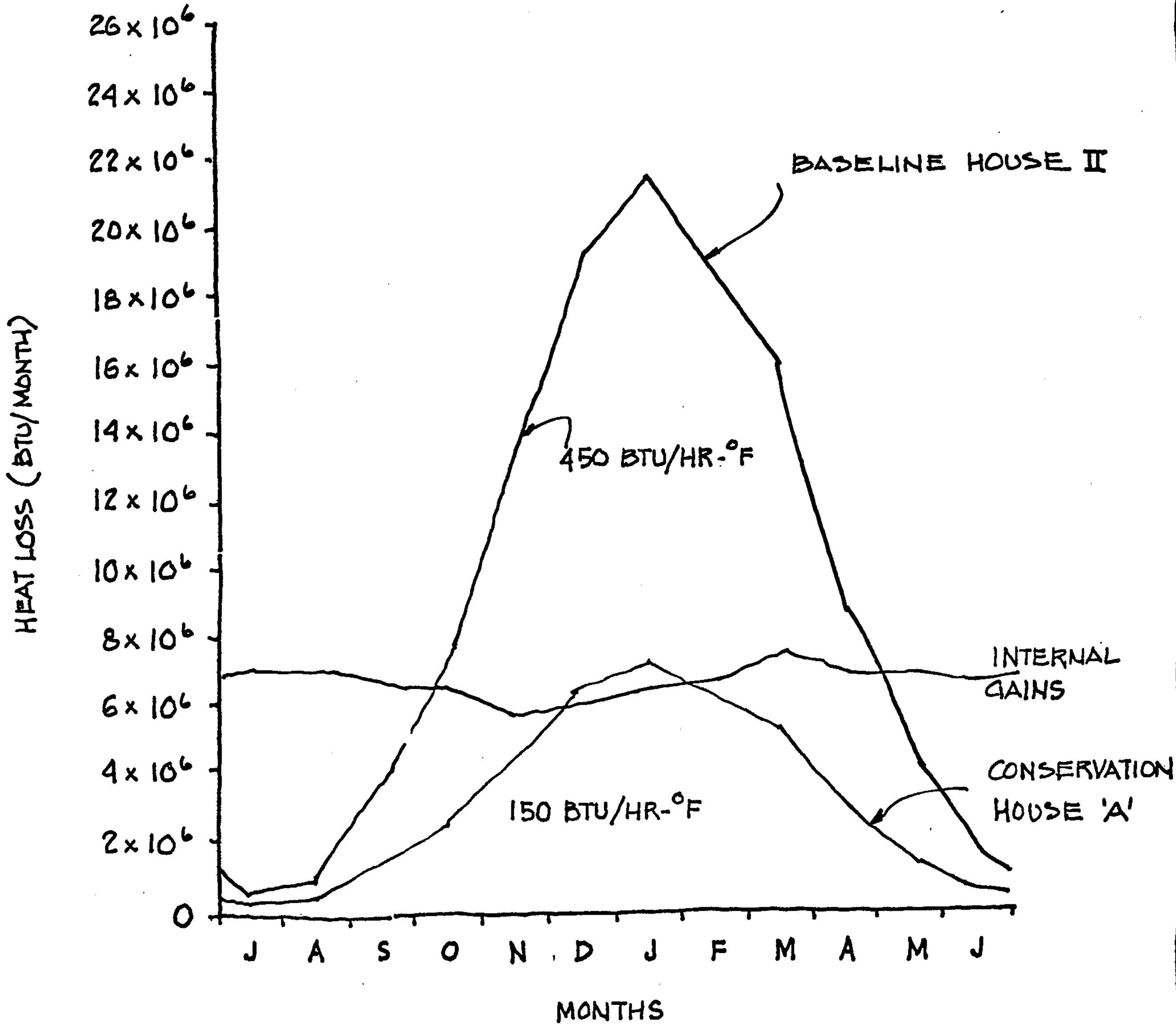
However, it should be noted that a major source of energy gain not usually recognized in previous design practices (Baseline House II) is the effect of passive solar heat gain. This, in fact, is a source of energy gain (SEG) which can be significant in reducing the building's total energy requirements and, as such, is considered an important design determinant of an energy efficient house in the prairie region.

An internal load or internal heat gain of 30% is assumed as being constant all year (This assumption is based on the HUD study which calculates 35.1% for its internal gains and The Winnipeg Study which shows (See Figure 12) an almost constant internal gain of 6×10^6 BTU/month, compared with a peak energy need of 21×10^6 BTU/month - or approximately 30% of the peak winter energy requirements).

III HEATING ENERGY BUDGET

An energy budget for the conventional house (Baseline House II) may be summarized as shown on Table 2.

In this thesis, the balanced energy budget is determined by simply establishing the amount of heat loss on one side of the equation (SEL's) and balancing this with the internal gains and other sources



HEAT LOSS $= (UA) \times (\text{TEMP. DIFF.})$
$= (450) \times (100) = 45000$ BTU/HR.

ANNUAL HEAT LOSS PROFILES FOR BASELINE HOUSE II & CONSERVATION HOUSE 'A'

SOURCE: UNIES LTD

PRESENTED AT A CONFERENCE "LOW ENERGY SOLAR HOUSE WORKSHOP" IN WINNIPEG.
SPONSORED BY: MANITOBA CHAPTER OF S.E.S.C.I. FEB.80

FIG 12

of energy gains (SEG's).

IV COOLING ENERGY BUDGET

According to the HUD study there is no internal source of energy which reduces the cooling load. In fact, the internal heat gains add to the cooling load. This, of course, is logical. What should be noted, however, is that despite the implied 100% requirement for cooling energy in summer, there is sufficient reason to assume that with the minimum amount of care, few houses need to be cooled artifically in the prairie region (unlike houses in hot, humid or hot, dry climates in the southern USA).

The fact that temperatures may vary from 50°F at night to 80° F, 90° F or even 100°F in the afternoon, means that considerable moderating effects are gained from day to night. Nominal operations such as keeping windows open at night, drapes drawn during the day, installing awnings on sun-receiving windows, are usually enough to keep houses at 65°F to 75°F maintained day and night.

While it is recognized that there may be situations which are intolerable (bedrooms facing south or west, no shade whatsoever either on the house, or over the windows), it is assumed for purposes of this thesis that cooling is not a critical energy need in the prairie region and that a minimal amount of care in design and operation of a house is enough to satisfy cooling needs.

However, because the sun's energy is considered to be an important source of winter heat in the context of passive solar design, this thesis also recognizes that measures must be taken to protect the building from gaining solar heat in the summer. Consequently, consistent references are made to design principles which also protect the building from taking on heat in summer.

B) NON-ARCHITECTURAL CONSIDERATIONS

It should be noted that there are many other factors which will have a bearing on the energy efficiency of a house or any building for that matter.

> "Metered tests on energy conservation for heating have shown that the amount of energy used for heating a house is not necessarily related to the design heat loss of the house. The biggest single influence on heating energy consumption is the occupants themselves. Identically built adjacent houses can easily have heating energy consumption variations of 50% due to occupant life style. Consumer operating procedure, is therefore, another important area of potential energy saving."[1]

In addition, there are many non-architectural considerations which affect energy efficiency of buildings. If we view buildings as components within our man-made environment, which are designed to facilitate your comfort and convenience, we begin to realize that there is a two-way feedback relationship that exists between building and occupant. A building is not just an accumulation of hardware, mechanical devices and building materials, it's an extension of our clothing, designed to protect us from the elements and give us comfort and convenience while we perform our various activities.

1 The Builder's Guide to Energy Conservation, National Association of Home Builders of the U.S.A. 1974 P. 8

Many non-architectural or even non-mechanical considerations can enter into the picture when viewed this way. For example:

a) The materials with which our skin comes into contact will determine our level of comfort in that environment. If furniture is furnished in materials having a high co-efficiency of heat transmission (metals, chrome, vinyl) we immediately feel cold, when our skin comes into contact with these materials, even at room temperature. Therefore, simply placing low heat conductive materials on surfaces coming into contact with the skin will improve the comfort level of occupants without any change in actual room temperature. The interior of a car is a perfect example of this, on hot as well as cool days.

b) The physical fitness of the occupant will affect his comfort level in a building. For example, a person who is in good health, or who has just returned from a 2 mile job, will feel more comfortable in a room temperature which is low, than a person who has been sitting idly, watching television. Consequently, the "idle" or unfit person is likely to use more fuel energy for home heating.

c) The physical condition of the building (like the physical fitness of the occupant) affects the building's ability to retain heat. This is obvious and needs no further comment. Generating heat, too, is a matter of physical conditioning. For example, it has been claimed that simply regulating the nozzle in an oil burning furnace can improve the oil consumption by 20 to 40%.[1] (We all know that an automobile which is badly tuned or in poor condition can consume far greater amounts of gasoline than if all system are in proper condition).

Several books have now been published by Federal and Provincial Departments of Energy, Mines and Resources, outlining ways of conserving energy in the home, through the proper operation of appliances and user habits. Several other well known scientific and "consumer guide" magazines have published special. issues dealing with these non-architectural considerations.

d) A room which is painted in light or bright colours will reflect more light than one finished in dark colours. The result is that less energy is required to artifically illuminate the high light reflective room to a level of illumination deemed to be comfortable for the activity taking place in that room. In fact, if the activity in that room may be scheduled to take place during daylight

1 These claims are presently being made by various furnace manufacturers and disputed by fuel oil suppliers. While the exact savings are debatable, it is known that some energy savings do occur.

hours, (if there is a need for a high level of lighting) and proper exposure to natural light is possible, no energy may be required to provide a comfortable degree of lighting. Simply scheduling that activity to the night time will increase the lighting energy requirement. A good example of this is a student's study schedule and his need for artifical lighting.

In all of the above examples no insulation needs to be added, nor any expensive retrofit capital investments made, to reduce energy consumption. These variables make it very difficult to measure the exact effect of any specific design or construction idea. However, it should be understood that the total energy performance of a building (town or city) has many variables and it is only with an awareness of all or most of the variables, will there be meaningful strides made toward energy saving.

CHAPTER II

PRINCIPLES OF ENERGY EFFICIENT HOUSING DESIGN

While the major focus of this thesis is on improving the energy efficiency of "the house", (for reasons discussed earlier), the author is mindful of the fact that the house itself is only one-half of the energy consumption problem associated with housing. The other is transportation.

Based on present and past planning practices, the single family house and suburbia are perceived as being synonymous. Suburbia has been a notoriously energy wasteful form of planning because it encourages extensive use of the private automobile for making connections with virtually any activity which takes place beyond the residential lot lives. In fact, without the automobile, suburbia would not have been possible in its present form.

Therefore, while it is recognized that "the house" itself needs to be designed in a more energy efficient manner, its location within the city and methods of planning for single family housing so as to reduce the heavy consumption of transportation energy, also should be included in this discussion.

This chapter will therefore discuss energy efficient housing design within the context of the following headings:

A. Location of housing within the urban structure.

B. Location of the house on its lot.

C. The shape and orientation of the building

D. The internal organization of the building

E. The building shell.

The prime objective of this discussion is to formulate and evaluate design principles and design methods which are energy conserving.

A) LOCATION OF HOUSING WITHIN THE URBAN STRUCTURE

It is hasty to conclude that, in view of the "energy crisis", we should no longer build in suburbia because suburbanites are faced with the additional energy cost of commuting.

An option open to cities that have no alternative but to expand outwardly, is to plan suburban subdivisions in a more energy efficient manner. As well, there are many developments which may in fact aid in the reduction of transportation energy consumed by "suburbanites". Within this context, the following points should be noted:

1. Transportation energy costs and consumption must be viewed in a total lifestyle context. For example, it is very conceivable that as the four day work week increases in popularity (20% reduction in commuter time and energy cost over the five day week), the consequent increase in leisure time for more people may encourage many families to consider increasing leisure and recreational facilities at home instead of commuting hundreds of miles on weekends to a lakeside cottage. Already there is evidence that many people are, in fact, making that choice, as seen in the increasing number of backyard swimming pools, (which may be solar heated), increased use of community recreational facilities, such as tennis courts, biking trails, ski trails, etc.

While the "downtown" dweller may be exempt from commuting costs, he does not have the "backyard" facility for outdoor recreation in relative privacy. His recreational facilities may well be accesible at a much larger scale of travel (inter-city, inter-provincial or event international); therefore there is a trade off in terms of transportation energy costs which must be considered.

2. Many other developments may tend to reduce the transportation cost of living in suburbia. These include:

a) more energy efficient automobiles.

b) greater use of car pools or neighbourhood "bus pools".

c) flexible working hours for commuters so that energy wasteful peak hour traffic jams are avoided.

d) greater use of telecommunications media, so that office workers may "stay at home" and perform many "office" duties via closed circuit T.V., telex, microfilm filing systems, conference call telephones, etc.

3. Planning methods may be improved in the following ways:

a) zoning to permit a greater mix of non-residential functions to be incorporated appropriately into the otherwise homogeneously residential subdivisions. These facilities should be placed within walking distance from groups of houses.

For example, schools are the only facility presently planned into suburban subdivisions on the basis of walking distances. Many other facilities such as drug stores and other convenience community use facilities, multi-purpose indoor spaces and recreational facilities could also be incorporated into small community centres within walking distance from houses, perhaps planned in conjunction with school facilities.[1]

Davis, California, a town which has been planned and developed with the view to conserve on energy, recognizes new methods of planning lot layouts to minimize the need for automobile travel. These principles are illustrated in Figure 13

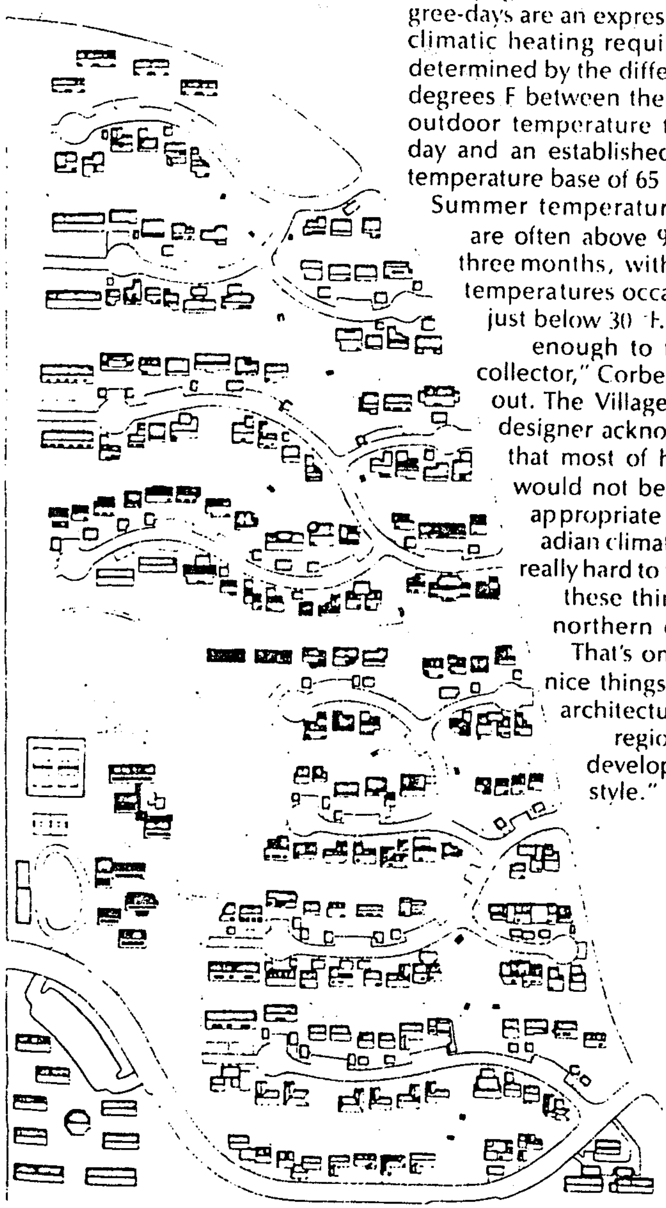
b) the layout of lots within a subdivision should be planned to incorporate and integrate linear parks and playgrounds which are landscaped to shelter pedestrians from the hot summer sun and cold winter winds to encourage people to walk to the community facilities.

4. Within the context of reducing energy consumption in suburban buildings, the following points should be noted as ways of improving planning methods:

1 It is recognized that there are many jurisdictional and administrative problems associated with this idea. However, they are not insurmountable. Elaboration on these points are beyond the scope of this thesis.

square-mile town, you're within a mile of anything."

Such a community would grow much of its own food,



Cul-de-sacs minimize use of automobiles in this development.

than most of Canada's. Davis has 2,800 heating degree days, compared with Ottawa's 8,740 or Winnipeg's 10,658. (Heating degree-days are an expression of a climatic heating requirement, determined by the difference in degrees F between the average outdoor temperature for each day and an established indoor temperature base of 65 °F.)

Summer temperatures here are often above 90 °F for three months, with winter temperatures occasionally just below 30 °F. "That's enough to freeze a collector," Corbett points out. The Village Homes' designer acknowledges that most of his units would not be directly appropriate for Canadian climates. "It's really hard to translate these things into northern climates. That's one of the nice things of solar architecture. Each region has to develop its own style."

gardens.

This pattern is altered in Village Homes by first reducing lot sizes from the traditional 70 by 100 feet to 50 by 85 feet. It makes front yards much smaller, turning them into useable private spaces rather than a showcase of lawn to be maintained at considerable expense. Back yards are also reduced, but a common greenbelt is provided for each group of eight houses, which gives the desired feeling of space.

Running down these greenbelts is a path for bikes and pedestrians, eliminating the need for sidewalks on the streets, which are subsequently reduced in width from 32 feet to between 20 and 25 feet. All the roads end in cul-de-sacs, a deliberate attempt to make it easier and faster to walk or bicycle within the village than to drive.

Elimination of the automobile from housing developments is essential, Corbett says. The car is "one of the biggest intrusions into our life. It's dangerous. It's noisy. It has a very, very big, but subtle impact on our lives." It also accounts for 50 per cent of the energy consumed by a typical Davis resident.

The net effect of this compact design is that 32 per cent of the Village Homes' development is used as common or agricultural land. Residents have set up a 15-acre mini-farm with orchards, vineyards and vegetable fields. Gardens are also tended in the common areas among the houses.

A more subtle though much intended impact of the Village Homes plan is the creation of a sense of community.

Brian Toller

Village Homes developer Mike Corbett shares his sunny living-room with a visitor.

Penn.)

"Village Homes has made getting together easy and essential," they write, "by setting up greenbelts, which are controlled by eight families, who were in most cases involved from design through to construction. After completion, most of the maintenance is also done by cluster members. This has not always been easy for those of us not used to shared responsibility, but it has been very effective in establishing community."

The development is not a co-operative, but a condominium, with a profit-making subsidiary which in time will own and rent out commercial property within the project, thus providing a source of income for the community. Residents pay a $22 per month homeowners' maintenance fee to the condominium.

The authors also point to group work projects (i.e. wall building, construction of play areas and a community centre with its solar swimming pool), and the availability of local jobs—through gardening or in a

cause they had no children and did not like living in the development.

With Village Homes nearing completion, Mike Corbett is taking some time out to write a book on "appropriate planning" while consulting on two other solar subdivisions—one in Rosemount, Calif., 70 miles northeast of Los Angeles and one in West Sacramento, 85 miles west of San Francisco.

"I'm hoping to develop within four or five years a whole town of 15,000 or 20,000 people," Corbett says, but notes that such a project could take 20 years to complete.

Meanwhile, Village Homes is leaving its mark on visitors, residents and developers alike. But North America's largest solar subdivision is only a drop in the bucket compared to the thousands of energy-wasteful subdivisions still being built on this continent every year.

"We're going to have to retrofit everything anyway," Corbett laments. "In the meantime we've got to stop pouring in the bad stuff."

SUBDIVISION PLANNING IN DAVIS, CALIFORNIA

SOURCE: RENEWABLE ENERGY NEWS

FIG 13

a) permit the construction of multi-use facilities in conjunction with suburban schools so that a more varied range of activities may be performed within the neighbourhood.

b) encourage a more intensive use of existing and new facilities so that buildings (which must be heated 24 hours a day) are used on a 24 hours a day basis. For example, schools could be used for their usual function between 9 a.m. and 4 p.m. After hours, classroomscould be used for community activities such as hobby workshops, librairies, studyrooms for university students, decentralized university or college classrooms with T.V. instructors, etc. This would conserve on energy in two ways:

1) by reducing the need to travel to distand locations in in the city to specialized buildings.

2) by reducing the need to build (and heat) many new buildings since these multi-use buildings would make specialized buildings redundant.

A second option open to city planners in dealing with the location of low density housing within the urban structure is to incorporate residential zoning closer to the centre of the city.

There are many examples of high rise, high density housing developments in or near the "down town" area of many cities, with the obvious advantage of reducing commuter energy consumption or, in fact, the need for owning an automobile. While in most cases it is not practical to locate single family housing downtown, many options exist for incorporating low density housing (townhouses, row houses), close to downtown or other centres of major concentrated development.

Within this context the following suggestions should be noted:

a) Low density housing may be located downtown if rooftops of commercial buildings are utilized. Place Bonaventure in Montreal is an example in which low density housing (a hotel in row house configuration) was successfully incorporated on the roof of a multipurpose building in the downtown area. A full range of possibilities exist for very rich and varied residential environments at a very low density, using this concept.

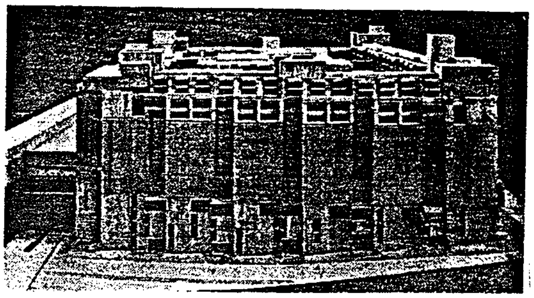
b) Considerable savings in transportation energy would be realized if housing were to be incorporated into the total range of functions contained in multipurpose complexes. These multi-use centres may contain facilities for shopping, leisure, work (offices, etc.)

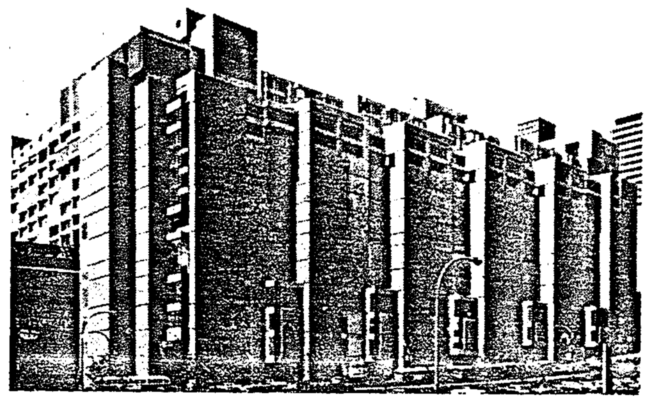
cultural developments, health care, education, etc., as well as major stops for various forms of mass transit modes.

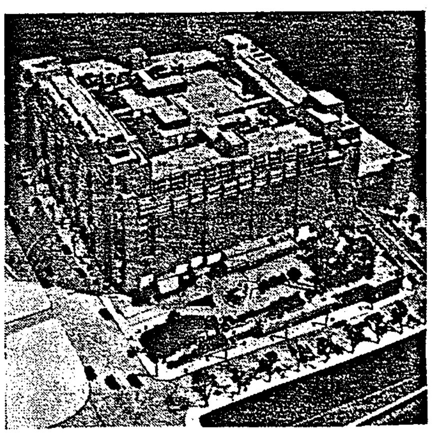
These centres may contain bike paths, moving sidewalks, elevators and escalators (in the nodal high density centre) as alternatives to moving people, goods and services almost exclusively by motor vehicle as is done in today's suburban subdivisions. Several alternatives exist for the design and planning of such nodal developments.

Place Bonaventure is an example of a multi-use complex housed in one building (a megastructure). A full spectrum of activities ranging from housing (on roof top), offices, displays, stores, theatres, restaurants, recreational facilities, are located within walking distance from each other, and are connected by escalators, elevators and walkways (See Figure 14). In addition, the complex is connected to the rest of the city by containing terminal and stop facilities for rail, subway, bus, truck and automobiles.

It is interesting to note that the design of Place Bonaventure (while not a perfect design), was not predicated by thoughts of energy efficiency in response to the "energy crisis". Of greater concern to the designers, was the desire to create a vibrant







PLACE BONAVENTURE

FIG 14

and vital human activity environment on a pedestrian scale. However, in so doing, another very desirable design quality has resulted - that is, the elimination of the dependence on the private automobile and, with it, a very costly energy demand.

For decades planners have realized that the human urban environment is greatly abused by planning for the private automobile. They have frequently sought after the design of centres, villages and towns on a pedestrian scale, because this offers a greater opportunity for a more pleasant human experience. The qualities of many European villages and squares have been sought after in the downtown areas of many North American cities, where streets have been closed off to automobile traffic and given over to the pedestrian. While this has been done only on a very limited scale, the examples that do exist, by and large, are successful. Calgary, Alberta and Minneapolis, Minnesota, are two cities which display such facilities in downtown locations.

While pedestrian oriented planning has been looked upon as somewhat of a romantic and nostalgic idea in North America, perhaps because of our extreme dependence on the automobile, the author is of the opinion that the energy shortage is just the crisis situation that will bring about a shift in values, away from extensive automobile use in city planning in North America.

In his book City 2000+, Dr. Demitrios N. Styliaras illustrates and proposes many examples of pedestrian oriented urban planning which capture all of the desirable qualities of totally integrated multi-use complexes in creating human environments which are vital, pleasant, interesting and convenient places for living, meeting, working, playing, shopping and learning. While these centres are connected to the rest of the city by a full range of transportation modes, including the automobile, it is possible to live within these multi-use complexes for long periods of time without ever having to use the automobile. His examples illustrate that such environments are not only possible in megastructures in downtown locations (as is the case of Place Bonaventure, described earlier), as shown in Figure 15 ; but also that it is possible to incorporate housing at much lower densities in multiple building, multi-use planned unit development complexes as well (shown in Figures 16,17). Low density and single family housing may be located on the periphery of such nodal developments and connected to the centres by bike paths, pedestrian peomenades (See Figure 18). Once within the higher density centre, elevators and escalators may move the pedestrian vertically.

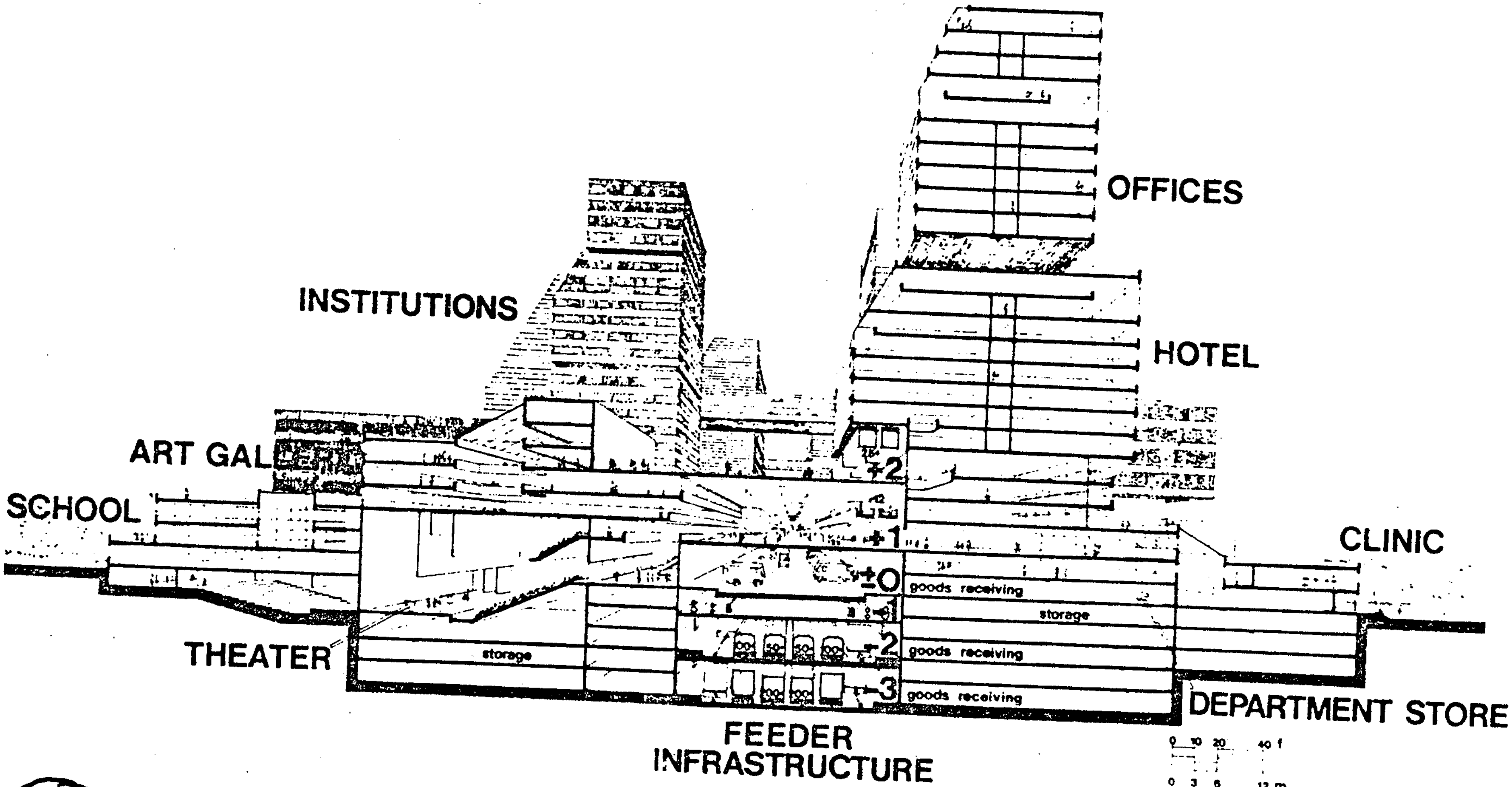
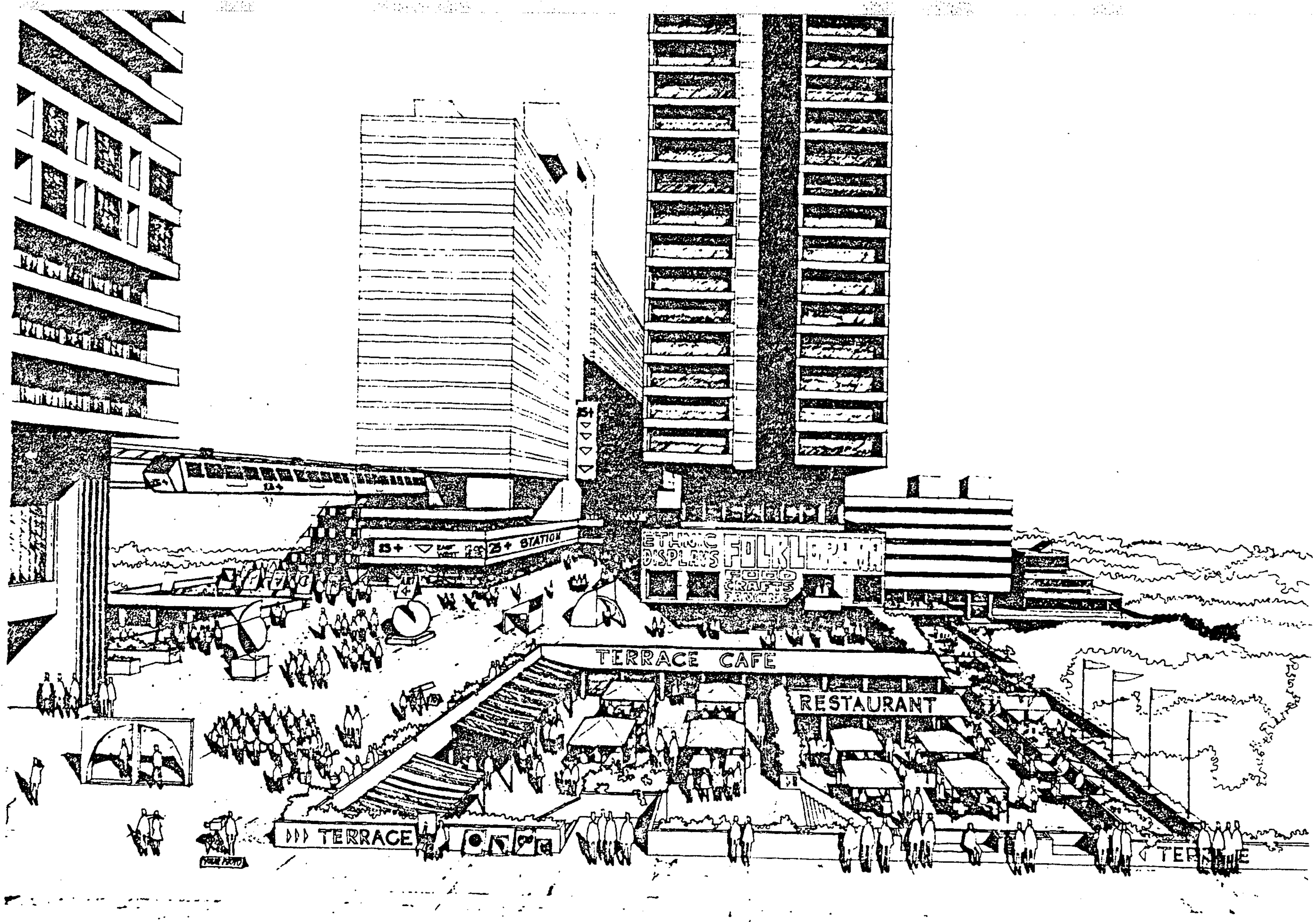


FIG 15

A MULTI-FUNCTION MEGASTRUCTURE

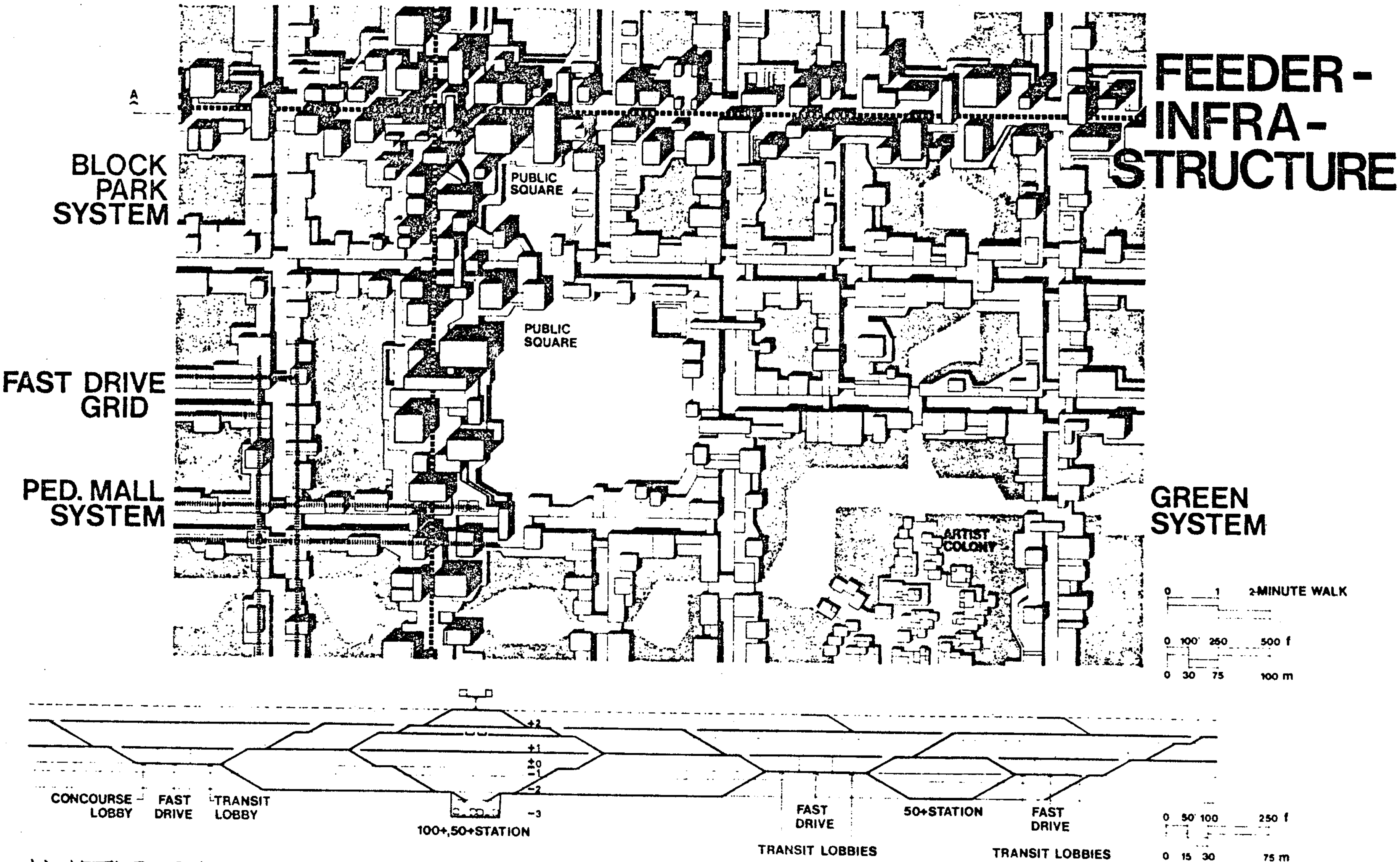
SOURCE: STYLIARAS, DR. D.N. CITY 2000+ UNIVERSITY OF MANITOBA PRINTING AND PUBLICATION SERVICES. WINNIPEG 1977 P.125



MULTIPLE BUILDING MULTI-USE PLANNED UNIT DEVELOPMENT

SOURCE: Ibid., STYLIARAS, DR. D.N. p. 135

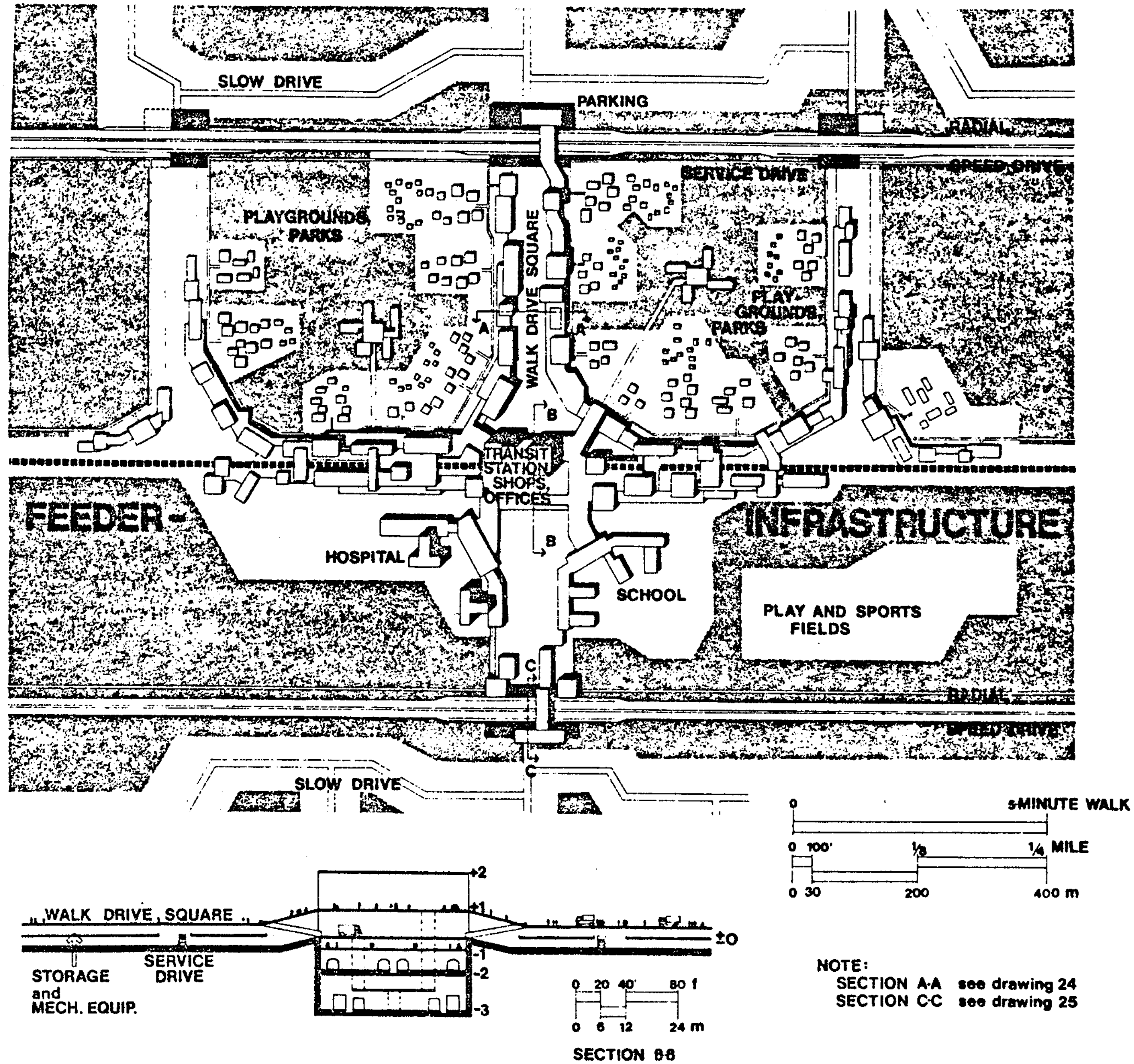
FIG 16



INTEGRATION OF URBAN SYSTEMS

SOURCE: Ibid., STYLIARAS, DR. D.N.
P. 143

FIG 17



PROXIMITY OF LOW DENSITY HOUSING TO NODAL DEVELOPMENT

FIG 18

SOURCE: Ibid., STYLIARAS DR. D.N. p. 149

It is clear then, that a sprawling suburban subdivision is not the only choice available to planners in locating low density housing in the city. The single family house may, in fact, be located within an activity framework at a scale which reduces its inhabitants' dependence on energy wasteful travel by the private automobile.

B) LOCATION OF THE BUILDING ON ITS LOT

One of the most significant decisions about the building, is its location on the site.

DESIGN PRINCIPLE I

Place the building in a favourable micro-climate:

- sheltered from north and northwest prevailing winds in winter.
- exposed to sunshine in winter, spring and fall, and shaded in the summer months.
- located appropriately, relative to the cardinal points.

Explanation and Discussion

Positioning the building so that it is shielded from cold winter winds and is exposed to the direct sunlight in winter, greatly increases the amount of radiant heat it may absorb from the sun, as well as decreases the effect of wind chill factors on the building. (Proof of the two-fold advantage this has in winter is that snow melts fastest on the wind sheltered, sunny side of a cluster of trees or the sunny side of a building). The building is therefore less susceptible to the harsh extremes of the winter.

In summer months, shading the building from the sun has the obvious effect of keeping the building cooler, therefore decreasing the cooling load on the building's energy requirements.

Problems Being Resolved

The combined effect of sheltering and exposing the building, as described above, greatly reduces energy loss in the following ways:

a) reduces air infiltration through windows and doors on the windward side of the building (SEL I & IV)

b) reduces heat loss through walls by sheltering them against cold winds (SEL II)

c) increases the building's ability to absorb heat in winter and reflect it in summer (SEG II).

See Figure 19 for an illustration of the effects of winds on the conventionally designed house.

Methods of Achieving Solutions

The simplest and most common method of achieving these ends are:

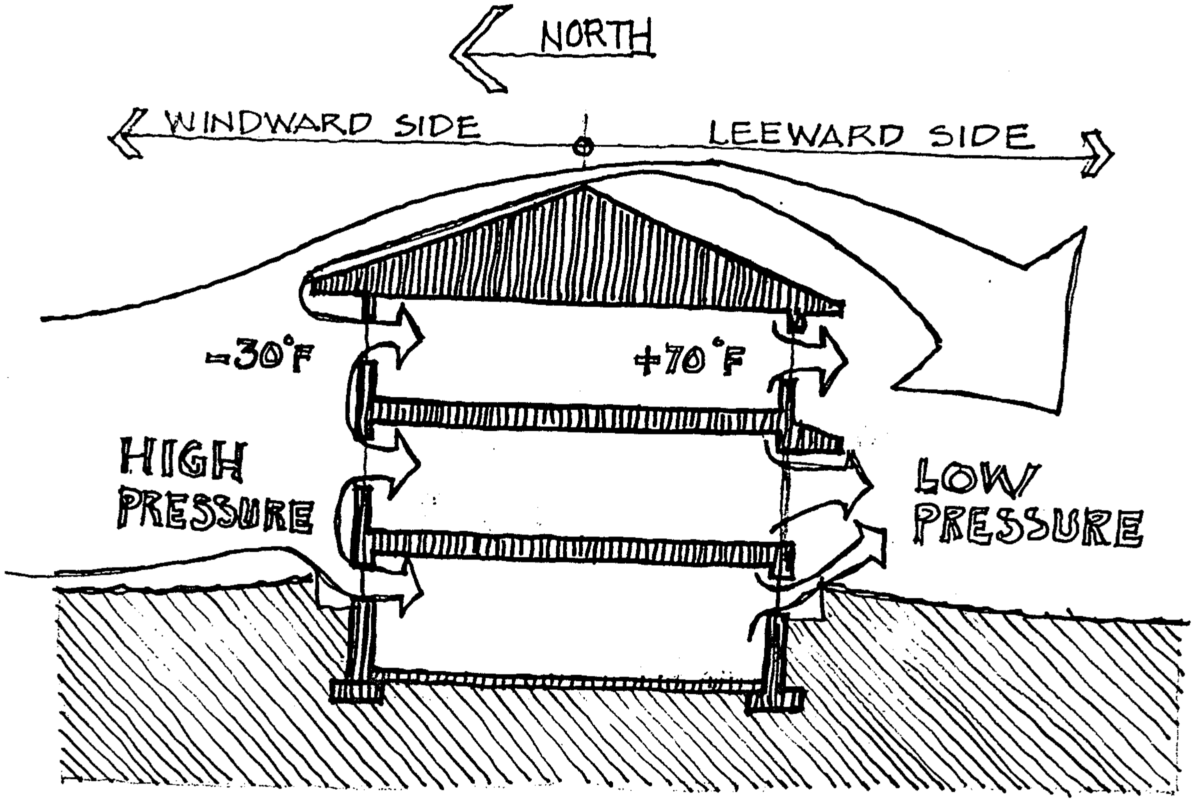
a) by placing deciduous trees on the south side of the building.

b) by placing coniferous trees on the north and west sides of the building.

c) by placing the building on the northern-most position of the site (still allowing space for buffer landscape elements on the north), greatly reduces the possibility that the building itself will be shaded by another building located to the south.

d) It should , however, be recognized that during winter months, the sun's heating benefit is significant only between the hours of 9 a.m. and 3 p.m., so that permitting maximum exposure to the sun at this time is of prime importance. (See Figure 20).

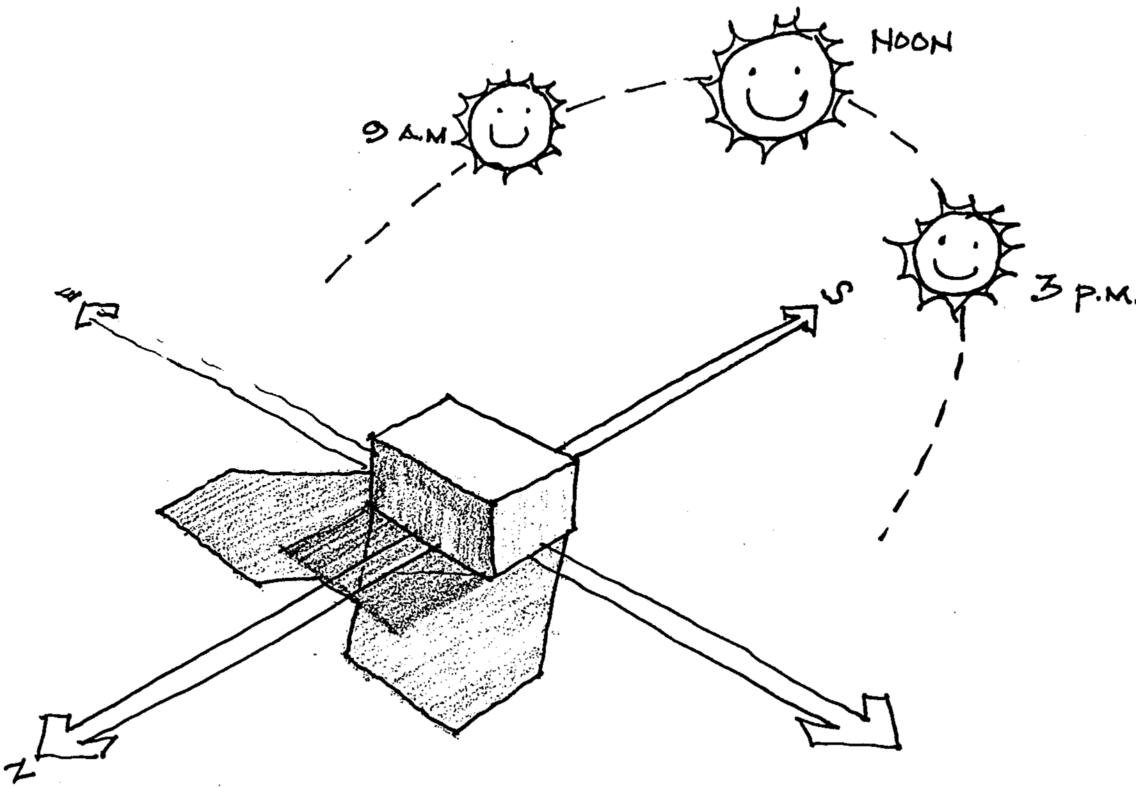
> "During the winter months, approximately 90% of sun's energy output occurs between the hours of 9 a.m. and 3 p.m. sun time ...... For example, in New York City (40° NL) on a square foot of south facing surface on a clear day in the month of December, 1610 BTU's out of a daily total of



EFFECTS OF WIND ON CONVENTIONAL HOUSE IN WINTER

- COLD AIR INFILTRATION ON WINDWARD SIDE OF BUILDING
- WARM INSIDE AIR IS DRAWN OUT OF THE BUILDING ON THE LOW PRESSURE LEEWARD SIDE.
- VERY LOW TEMPERATURES (HIGH WINDCHILL FACTORS) ARE EXPERIENCED ON THE WINDWARD SIDE OF THE BUILDING

FIG 19



LONG SHADOW ON NORTH SIDE OF BUILDING WITH A HIGH NORTH WALL

FIG 20

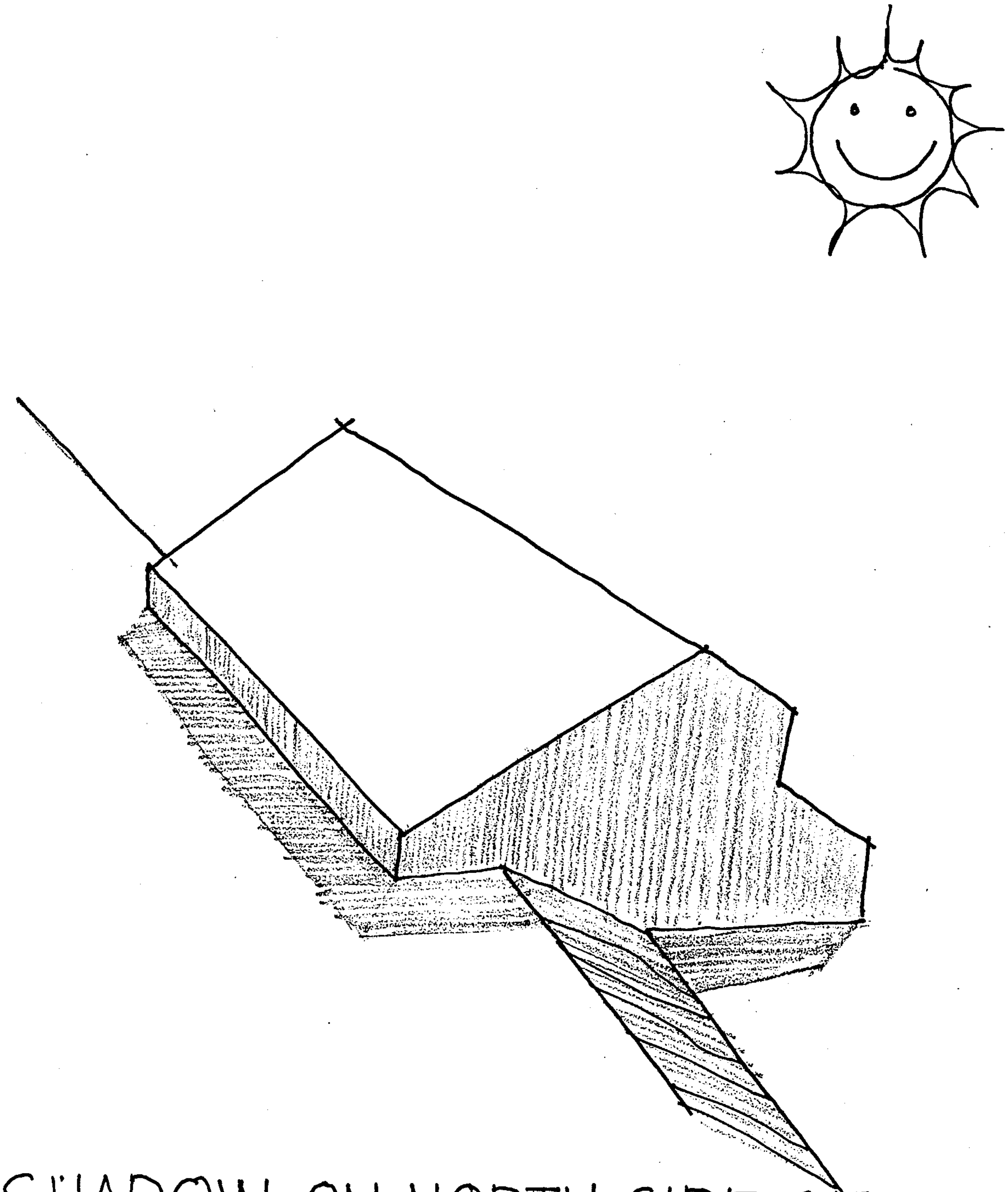
1,724 BTU's (or 93% of the total) are intercepted between the hours of 9 a.m. and 3 p.m. "[1]

e) Another consideration worth noting about the north sides of a building is that because this area is almost always in shade and may be exposed to cold winds, this side of the building is often not useful as an outdoor space. As well, snow and ice tend to linger on this side, further reducing its use as an outdoor space (See Figure 20). The shadows created by the tall walls of the north side could be greatly reduced by sloping the roof of the building to the north, thereby achieving two things:

1) reduced shadow length
2) less wind resistance to northern winds. These north and northwest winds would tend to be deflected by the sloping roof, thereby reducing the "stack pressure" on the building. As well, the sloping roof effectively reduces the amount of of wall surface exposed to the north.

Another method of achieving the same effect is to berm on the north side, thereby reducing shadow angles, as well as the amount of wall surface exposed to the wind (See Figure 21).

1 Mazria, Edward, The Passive Solar Energy Book
Rodale Press, Emmans Pa.
1979 P.73



SHADOW ON NORTH SIDE OF BUILDING SHORTENED BY USE OF EARTH BERM AND SLOPING ROOF

FIG 21

Cost Implications

Because the design guideline can be achieved simply by selecting and locating landscape elements (trees and shrubs) or locating the building in a favourable position relative to the existing buildings on adjacent sites, the capital costs for these items need not be greater than for a "conventionally" landscaped lot. The recommendation here is that landscape elements may serve the added purpose of sheltering the house (or building) appropriately, Depending on specific site conditions and the prevalence of existing natural landscape elements, however, the provision of these landscape features could become a costly item and its value must be assessed in each specific context.

The use of architectural elements such as louvers and and shades is not considered significant in cost and may easily be traded off against the use of such purely ornamental elements as mock Georgian shutters, fake swans and other extraneous nonsense decorations seen on many suburban houses.

C) BUILDING SHAPE AND ORIENTATION

The building's shape and orientation have a significant effect on its ability to absorb the sun's radiant heat.

DESIGN PRINCIPLE 2

The building should have a rectangular shape (in PLAN) positioned so that it is elongated (moderately) in an east-west axis.

Explanation and Discussion

When solar radiation is considered as a source of heat, and it should, the shape of the building and its attitude to southern exposure is of considerable importance.

> "When deciding on the rough shape of a building, it is necessary to think about admitting sunlight into the building. A building elongated along the east-west axis will expose more surface area to the south during winter for the collection of solar radiation. This is also the most efficient shape, in all climates, for MINIMIZING heating requirements in the winter and cooling in the summer."[1]

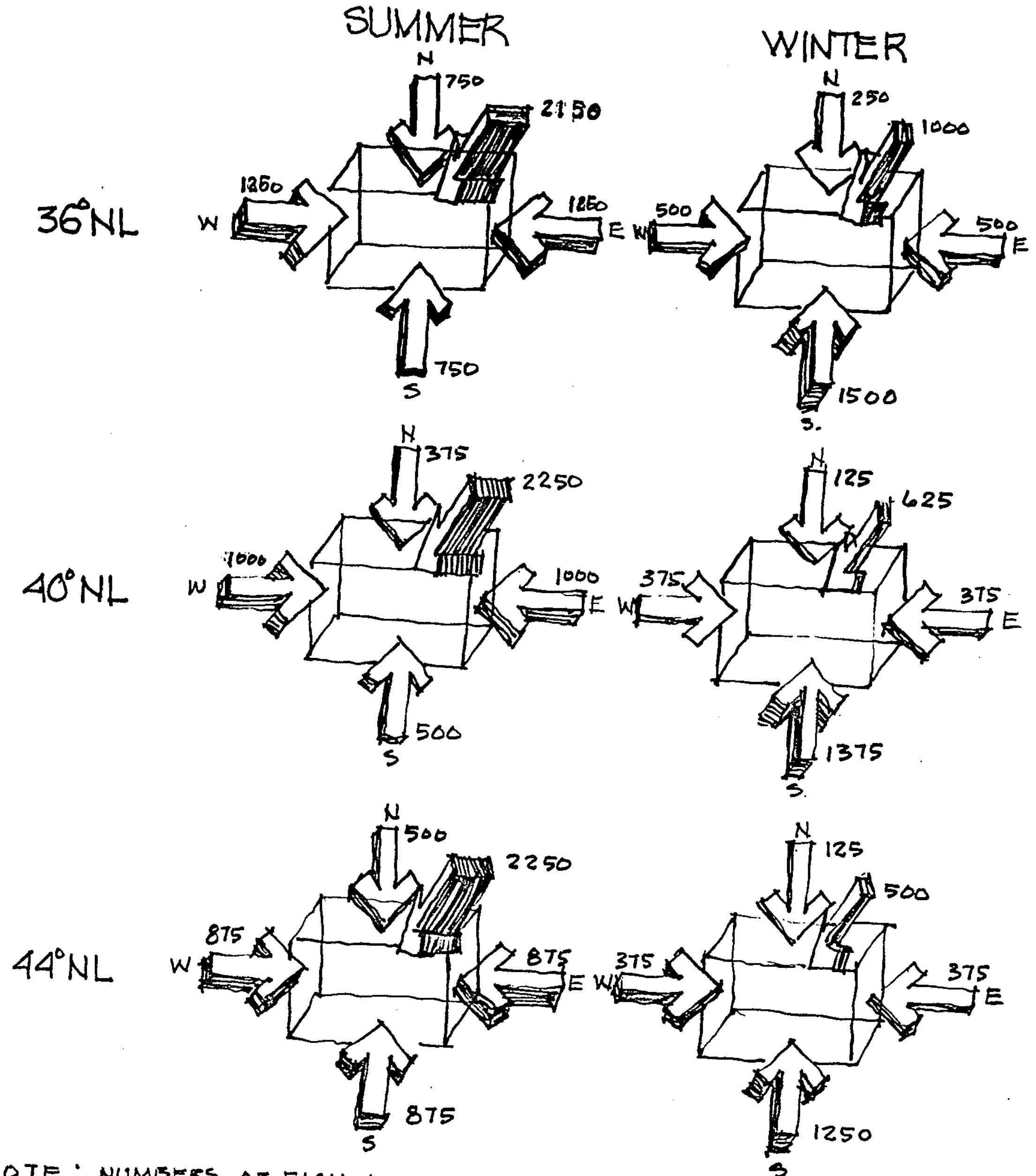
1 Ibid, P.79

In studies done by Victor Olgyay (. in his book Design with Climate) on the effects of thermal impacts (sun and air temperature) on building shapes for different climates in the USA, the following conclusions may be reached: (See Figure 22).

" 1) The square house is not the optimum form in any location.
2) All shapes elongated on the north-south axis work both in winter and summer with less efficiency than the square one.
3) The optimum shape lies in every case (all climates) in a form elongated somewhere along the east-west direction."[1]

It should be noted, however, that there are limits within which a rectangular building may be "elongated" in any direction. For example, the square building is the most economical because it encloses the most floor area with the least perimeter length. (See Figure 8). Therefore, a balance must be achieved between the floor area and the perimeter length when designing a rectangular house with conservation in mind. For this reason, it is suggested as a general rule of thumb, that the building be elongated moderately.

1 Ibid., P.82



NOTE: NUMBERS AT EACH ARROW REPRESENT BTU/DAY. (IE. 750 = 750 BTU/DAY)

SOLAR RADIATION IMPACTS AT DIFFERENT LATITUDES

SOURCE: EDWARD MAZRIA: THE PASSIVE SOLAR ENERGY BOOK EMMAUS Pa.
RODALE PRESS
1979 P. 81

FIG 22

Shaping the building in this fashion accomplishes two things:

a) increases heat intake from the sun in winter (SEG II).

b) reduces the exposure to the building to the low angled morning and afternoon summer sun, and therefore provides a measure of shelter from the sun in summer (SEG II).

Cost Implications

Shaping the building with the priority for energy efficiency, should not add to the capital or maintenance costs of the structure. By minimizing the amount of exterior surface area relative to the enclosed floor area, capital cost economics can actually be realized. Every square foot of wall or roof surface eliminated translates into lower construction costs (materials mainly), as well as surfaces to be maintained. Simplifying the building configuration usually reduces costs as well.

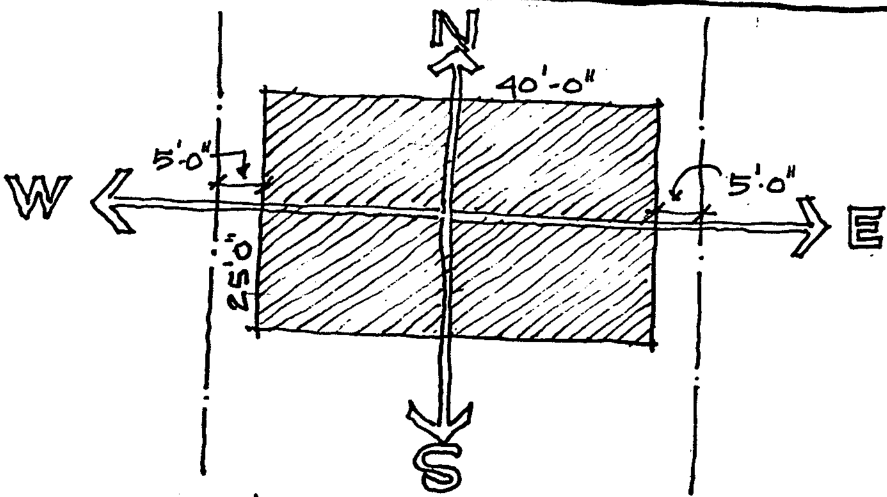
By implication of design principles I and 2, the orientation of lots within a subdivision is worthy of consideration.

DESIGN PRINCIPLE 3

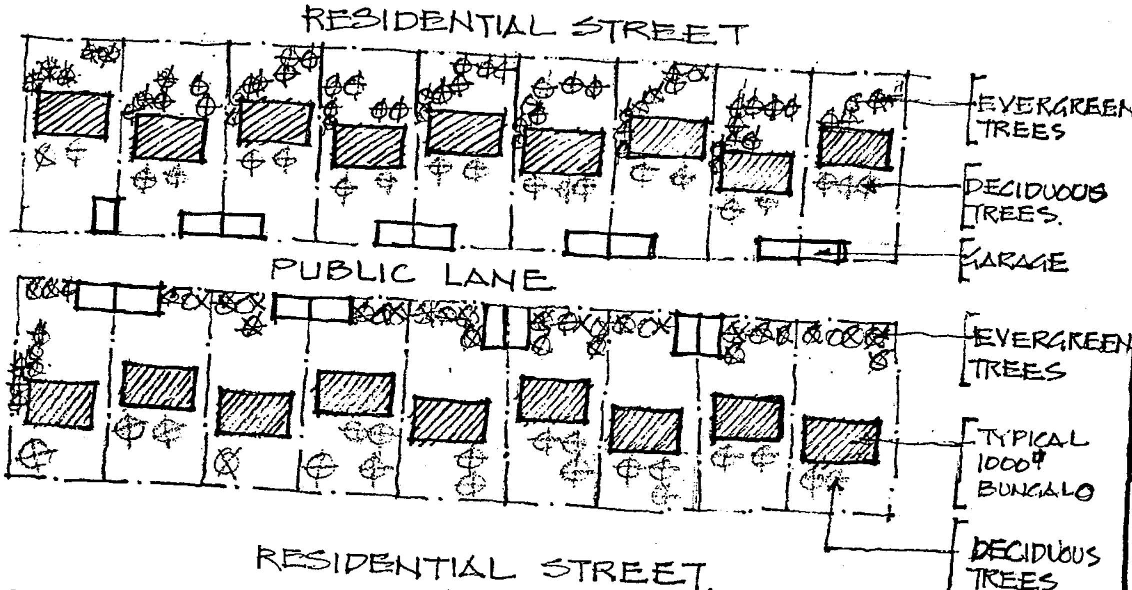
Lot orientation within a subdivision should be laid out to permit houses to be properly oriented to the sun, sheltered from winter winds and shaded from the summer sun. As much as possible, orient streets in an east-west fashion, permitting houses to face the street in a north-south orientation. Collector streets could the run north-south, having no houses fronting on them, or, alternatively, placing houses in a staggered formation so that shadows of one house do not fall on another.

We know, by observation, that this is not reflected in our conventional methods of site planning subdivisions for single family houses. This practice can be changed to conform to the recommendations being made here without any sacrifice to the economics of subdivision planning (See Figure 23).

Davis, California, is a town which has demonstrated how southern exposures for houses can be accomplished in a curved street pattern (See Figure 13).



1000# HOUSE ON 50' LOT



CONVENTIONAL 50' × 100' LOTS PROVIDING:

- EACH HOUSE WITH MAXIMUM SUN EXPOSURE
- VARIATIONS IN FRONT YARD - BACKYARD CONFIGURATIONS, MORE VARIETY IN STREETSCAPE.
- STREETS COULD ALSO BE SLIGHTLY CURVED
- SETBACKS COULD ALSO BE VARIED TO MORE THAN TWO BASIC SETBACKS
- LOT SIZES COULD BE VARIED (WIDTH) T TO BETTER ACCOMMODATE ATTACHED GARAGES.

SUBDIVISON PLANNING ECONOMICS EQUAL TO STANDARD PRACTICE

FIG 23

D) ORGANIZATION OF INTERNAL SPACES

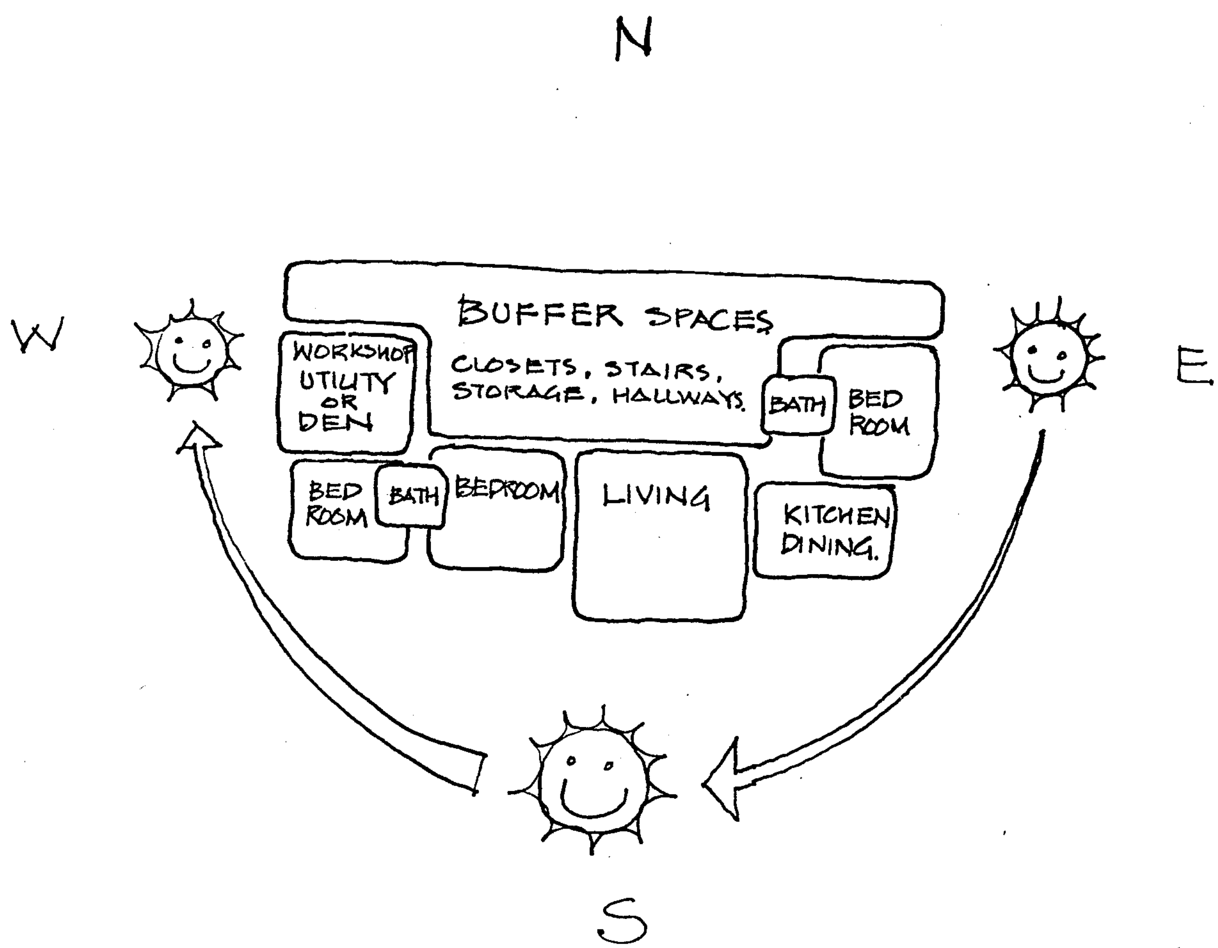
Once an appropriate site has been selected, with the possibility of achieving most, if not all, of the site conditions regarding the building shape and orientation resolved as mentioned above, the designer still has many more design options and tools at his disposal in making the "house" function energy efficiently.

DESIGN PRINCIPLE 4

Place low heat and low cooling requirement spaces (i.e. garages, outdoor storage rooms) on the north and west sides of the buildings, wherever possible, to act as a thermal buffer for internal, higher heat and cooling requirement spaces.

Explanation and Discussion

For example, an automobile garage does not have to be heated (or, at any rate, it does not require heating above 50°F). As such, this space can easily be located on the north side of the house, to act as a wind and temperature buffer. As well, such facilities as the storage of articles not requiring high heat, or any heat, could also be placed on the north side (See Figure 24).



SYNCHRONIZING THE LOCATION OF INDOOR SPACES WITH THE PATH OF THE SUN

FIG 24

The net result of such a design practice greatly reduces the potential heat loss from the north side of the house since this side is now "buffered" by low heat spaces (against extremes of temperature of outside air resulting in windchill and low air temperature).

Problem Being Resolved

These buffer spaces serve to reduce the transmission of heat along the north and northwest walls, by reducing the temperature differential on either side of the exterior wall (SEL II). A similar advantage is gained in summer months by keeping heat out.

Methods of Achieving Solutions

The placement of garages, outdoor storage spaces, "cold rooms" for the storage of chilled foods, wine cellars, and the like, serve as good buffering elements. Clothes closets should not be placed along these walls unless they are adequately ventilated, otherwise condensation can be a problem in winter months.

Cost Implications

No additional capital cost should be incurred simply because this principle suggests better ways of locating functions that would ordinarily be included in the program but simply located in a more energy conscious manner.

DESIGN PRINCIPLE 5

Locate functions or activities in the building so that their need for sunlight and heat may be synchronized with the position of the sun at various times of the day.

Explanation and Discussion

The underlying principle of arranging internal functions or spaces in such a manner that each space is furnished with adequate, natural light, ventilation, heat and cooling, is a basic design consideration. However, when analyzed more closely, it is observed that varying requirements of each space gives it (the space), the potential for actually increasing the energy efficiency of the entire building. The designer can formulate an "energy program" consisting of the (internal) environmental requirements of all interior functions and use these requirements as a basis of locating interior spaces.

For example, by locating functions based on the time of day that they are normally in use, and related to their need for heat and light, their optimum operating conditions can be met at low cost. The best example of this is the location of bedrooms on the east side of the house where they get sunlight early in the morning, the time of day when these rooms are still in use and lighting and heat is required. During the day, in most homes, bedrooms are not in use and as such do not need sunlight and heating to 70°F. However, between 9 a.m. and 5 p.m. the kitchen, dining room and living room do receive some use. Locating the living room on the southwest corner of the house, where it can trap the sun's heat during the day and evening (therefore keeping warm during the day and evening when it is to be used), can therefore decrease the mechanical heating load of the room. In the summer time, deciduous trees and overhangs appropriately located with respect to these south and west windows, would provide shade to reduce the radiant heat gain through these windows.

The net result in such a house is that bedrooms (if separately heated) can be reduced to 65°F during the day and increased to

68°F at night. It is possible that under such conditions, there would be no mechanical heating required during the daytime, since these spaces can be buffered by other spaces on 3 sides. (See Figure 24).

Cost Implications

No additional capital cost should be incurred simply because this design principle merely suggests alternate ways of locating spaces which would ordinarily be required.

DESIGN PRINCIPLE 6

Provide a vestibule at the entrance to the building.

Explanation and Discussion

This is a common practice in Canadian architecture, however, in the design of single family and other low density housing, this principle seems to have been forgotten.

Problem Being Resolved

Vestibules reduce energy consjmption by:

a) reducing the amount of air allowed to infiltrate at doorways(SEL I

b) reducing the heat transfer through the outside door itself, by acting as buffer (SEL VI).

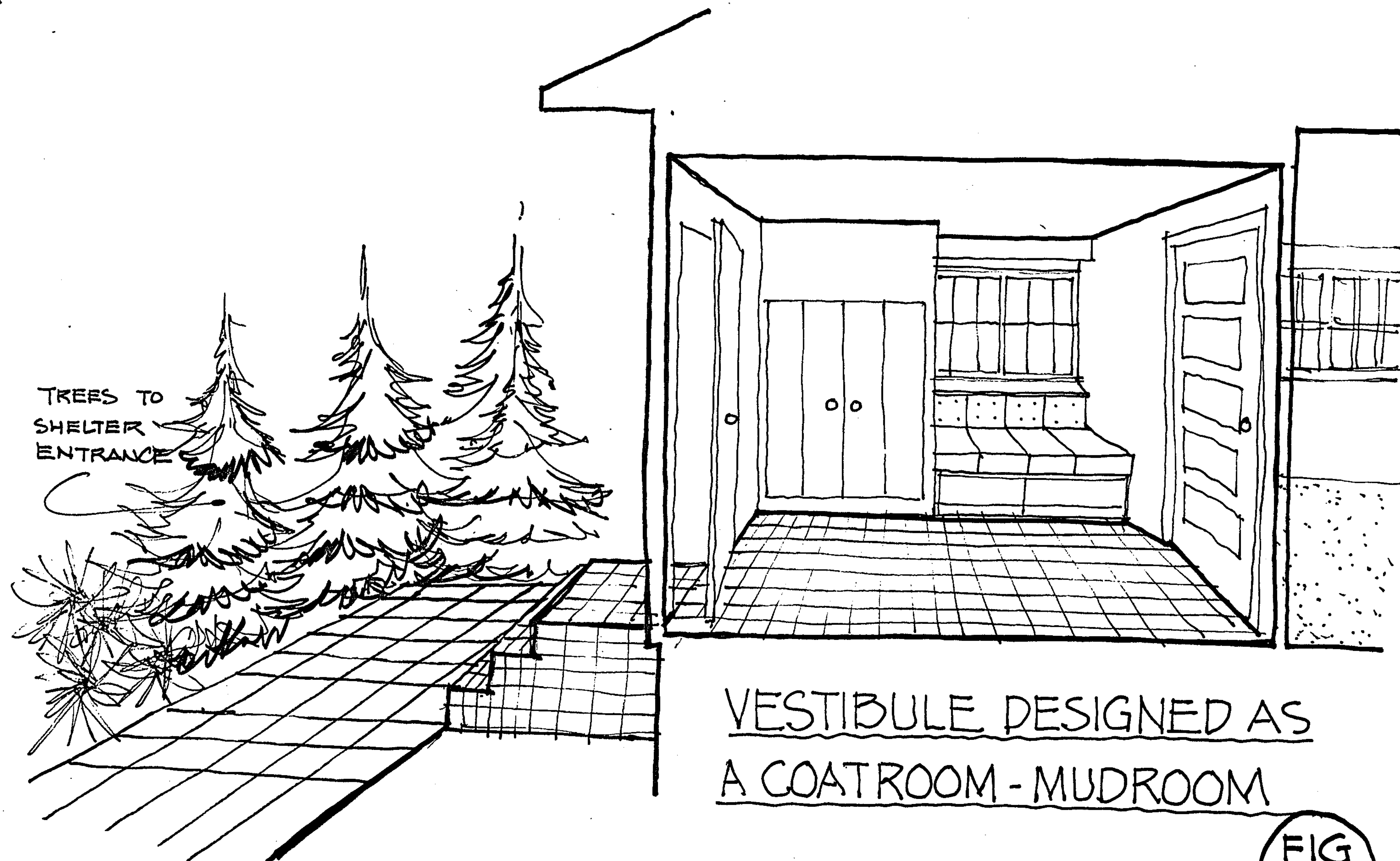
Methods of Achieving Solutions

Create an enclosed space (vestibule), which may also serve as a coatroom and mudroom at the entrance of the building.

The entrance should also be sheltered (by landscaping) or recessed to achieve additional protection from winter winds. (See Figure 25).

Cost Implications

This provision need not involved more than placing a second door in a strategic location around the space ordinarily used as an entrance hallway. As such, an additional capital cost of $100.00 per doorway would be considered adequate.



VESTIBULE DESIGNED AS
A COATROOM - MUDROOM

FIG 25

E) THE BUILDING'S SHELL

As the envelope of interior spaces, the building's shell is an interface between inside and outside climatic conditions. Through its proper design, the building can achieve a substantial degree of energy efficiency. In concept, a significant lesson can be gained by comparing the function of the human skin to that of a building's. For the human being, the skin serves the purpose of protecting the inner organs against excessive moisutre intake (it is essentially water proof), or loss. It protects against heat gain, from the sun, by becoming darker (tanning during hot season) and regulates internal body temperature by perspiring to "cool off" the body (by heat absorption process), if it is too hot. If the body becomes too cool, veins will recede or decrease in size to restrict the flow of heat to the skin, and pores will constrict (goose bumps) to limit heat loss through these openings. The exact process takes place in reverse when the body becomes too hot, pores open and veins swell and rise to the surface to expell as much heat as possible.

Though an oversimplified description of physiological processes, it is interesting to note how the body's skin responds to varying climatic conditions. There is no reason why, in concept, the building's skin should not be designed to do the same, to respond to varying climatic or weather changes.

Perhaps not to the same flexible extent that the living body can, but the building's skin can be viewed as living, breathing membrane, which can respond to changes in sunlight, temperature differentials between inside and outside, etc. There are sophisticated technology, materials and processes available and developed to serve such industries as aerospace and medicine. These technologies could be used and applied with equal zeal and budgeting toward developing an advanced technology for building envelope systems. However, it is not the intent of this study to explore technologies not available today, but instead to outline objectives and principles of good design, which can lead to energy efficient buildings using known building technologies.

For purposes of this study, the building shell is examined relative to the following categories:

1) the wall and attic

2) the window and door.

DESIGN PRINCIPLE 7

The building's exterior walls, attic and basement foundation walls should be insulated to at least the minimum standards recommended using insulation values of R-40 (attic); R-20 (exterior walls) and R-12 (basement walls). (The Conservation

House "A" discussed later uses R values of 50, 40 and 27, respectively). Wall construction should be according to accepted building practices in their use of vapour varriers, moisture barriers and necessary damp-proofing, etc.[1]

CMHC today recommends the following minimum levels of insulation in new housing in the Winnipeg area:

Total attic construction R-34.8 (9 1/2" batt insulation = R-32)

Total wall construction R-14 (3 1/2" batt insulation = R-12)

Total basement wall construction R-8 (2 1/2" batt insulation = R-7)

Manitoba Hydro recommends the following insulation values be used in new house construction using electric heat:

Attic R-40 or 12" of batt insulation

Walls R-20 or 6" of batt insulation

Basement R-12 or 3 1/2" of batt insulation.

1 Where windows and walls are properly sealed and insulated, and particularly if "super insulation" is practised (i.e. some walls have been designed to insulation values of R-40, 12" of batt insulation!), care must be taken to ensure that adequate fresh air is allowed to enter the house through other sources. This is particularly important where wood-burning stoves and fireplaces are used as a back-up heat source. The use of heat exchangers are useful in this event, to preheat fresh air intake!

Explanation and Discussion

The subject of insulation, how much, what kinds, methods of application, construction details, etc., have become very controversial (as the differences in recommendations above begin to indicate). Because this is a topic which has, and will continue, to receive a great deal of attention, and in fact, can be the subject of an entire thesis, to be thoroughly discussed, detailed discussion is considered beyond the scope of this thesis. Figures 26,27,28,29 show alternative methods of insulating walls, attics and foundation walls for both new and existing buildings.

Problem Being Resolved

The obvious function of insulation is to reduce the heat transfer through exterior walls and attics, in both summer and winter. (SEL II, III, V). It's usefulness is, therefore, fundamentally important in the design of energy efficient buildings of all kinds.

Methods of Achieving Solutions

It should be noted that, in all systems (presently in practice), of insulating walls and roofs, insulation is effective against heat transfer by conduction and convection principally. There is little

W ENERGY HOUSING
PRESSURE TREATED WOOD FOUNDATION

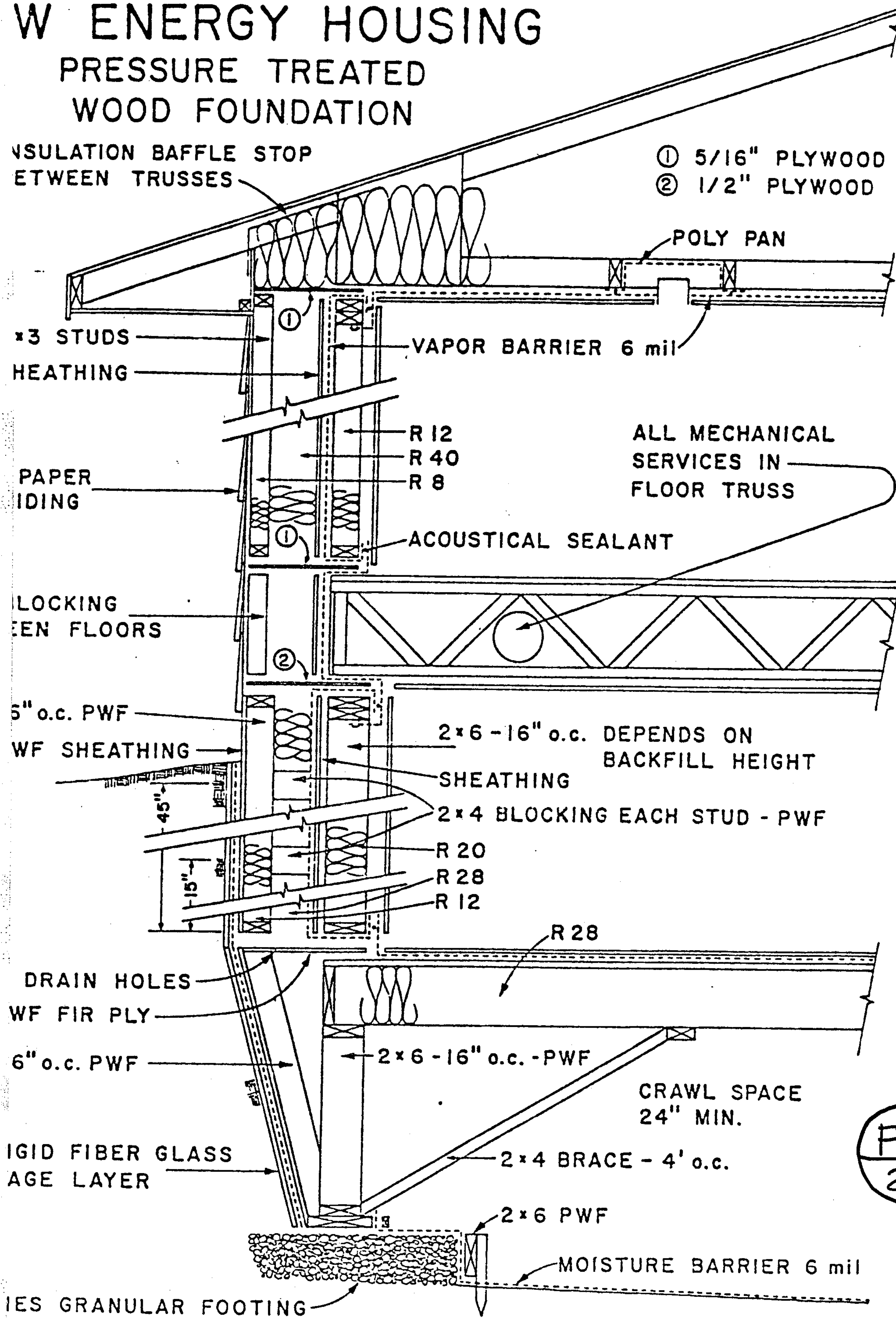


FIG 26

GRADE BEAM AND PILING FOUNDATION

GRADE BEAM & PILING FOUNDATION

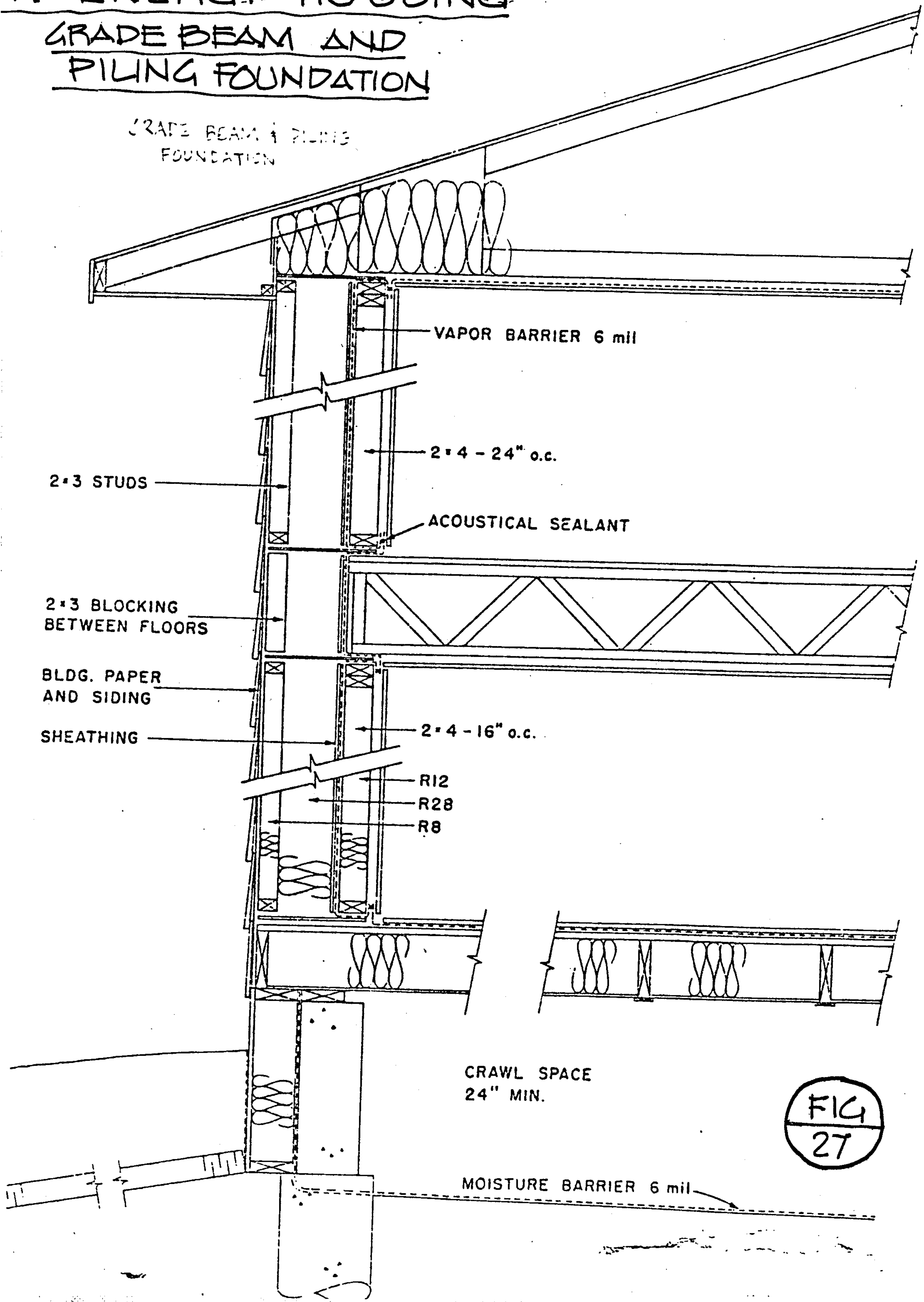
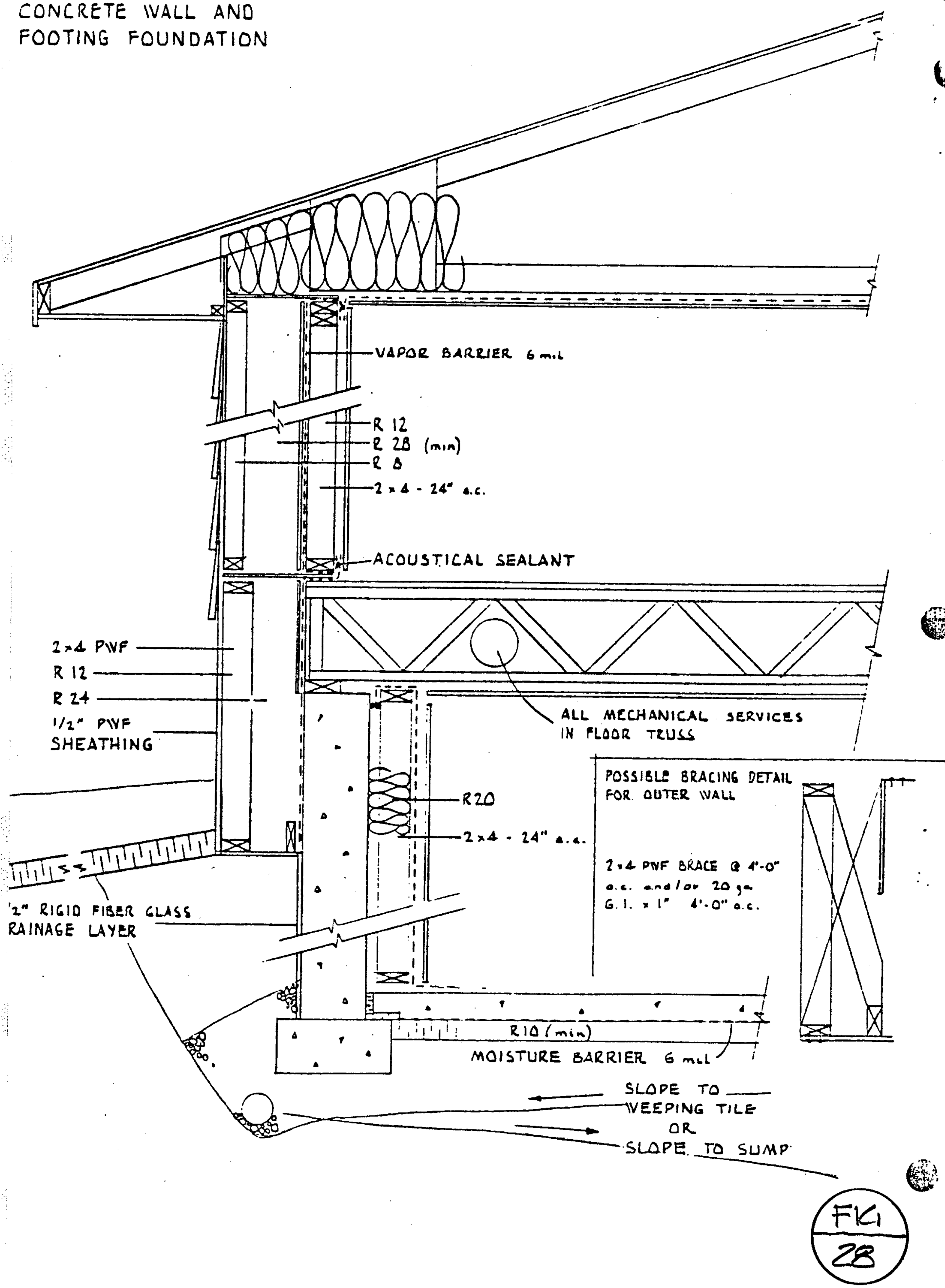
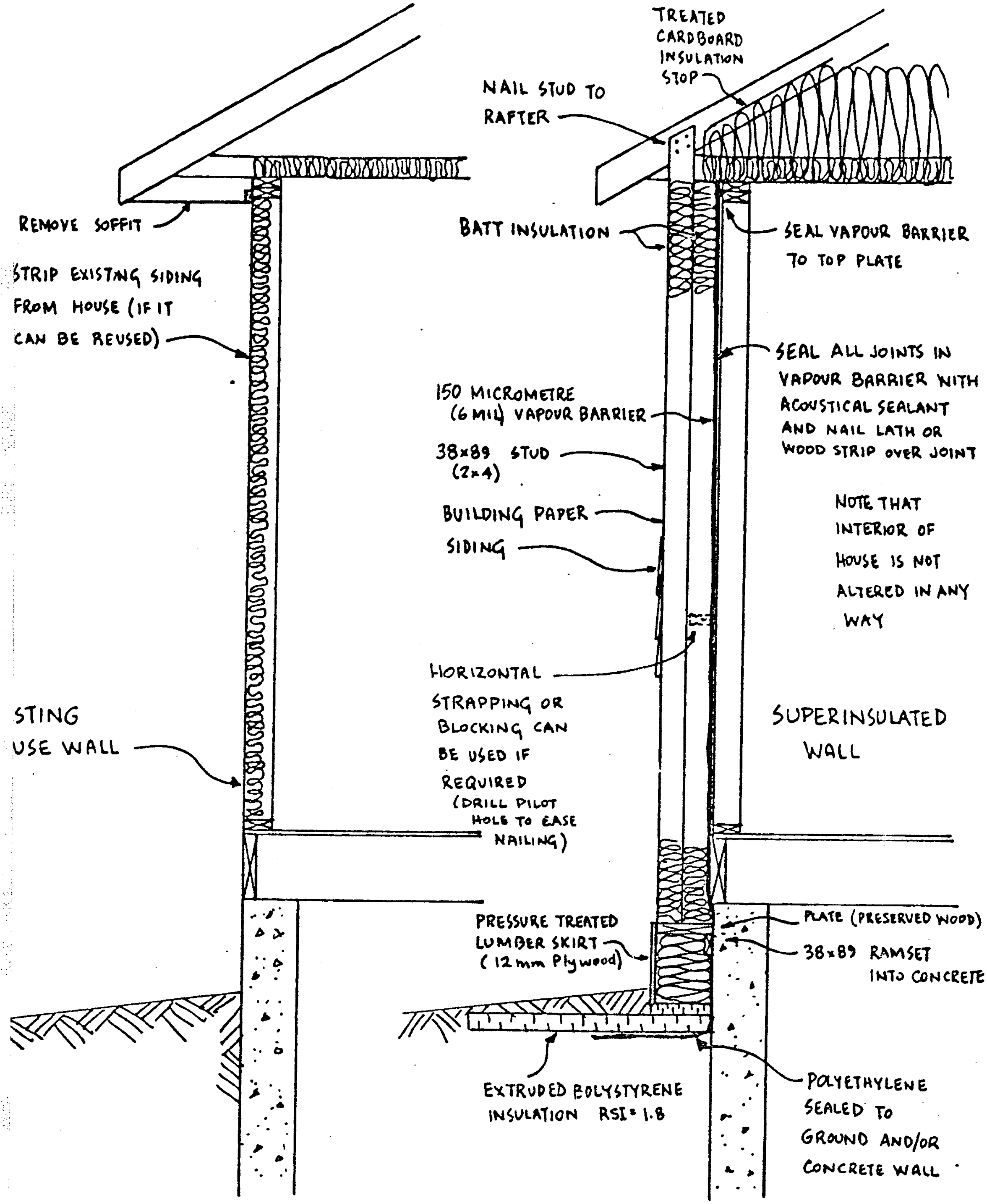


FIG 27

CONCRETE WALL AND FOOTING FOUNDATION





TECHNIQUE FOR SUPER INSULATING THE EXTERIOR WALLS OF AN EXISTING HOUSE

FIG 29

or no insulation against heat transmission by radiation through walls and roofs. In an unofficial and preliminary study done by the author and in conjunction with Dr. Hasan, P. Eng. Professor at the University of Manitoba, Faculty of Engineering, it was calculated that if radiant heat loss through a conventional 3 1/2" stud wall (3 1/2" batt insulation) could be arrested, the effective R-value of that wall would be increased by R-20 (total value (R-32). This would be possible by providing a 1/2" vacuum space lined by a highly reflective surface within the wall. Though no known method is presently available to accomplish this in an economical manner, this is one area in which a minor technological advancement could yield significant energy savings. For example, with the introduction of a wafer vacuum panel made of sheet metal or other highly reflective foil surface, this could be accomplished.

DESIGN PRINCIPLE 8 (Windows and Doors)

Use windows in location and design to maximize the intake of the sun's radiant heat in winter; minimize the intake of the sun's heat in summer.

> "One of the largest single factors affecting building energy consumption is the location and size of windows. Windows placed without consideration for the amount of sunlight they admit will usually be an energy drain on the building.
>
> The heat lost through a window in winter is very large when compared to the heat loss through a well-insulated wall. For example, a square foot of standard wood frame wall with 3 1/2" of insulation will lose approximately 2 BTU's each hour when the temperature is 30°F. outside and 68° F. in side.
>
> A square foot of single pane glass, with the same outside temperature will lose approximately 43 BTU's each hour or 20 times as much heat as the wall. The heat loss through the window is basically the same regardless of which direction it faces. It is important then, to place windows so that their heat gain (from sunlight) is greater than their heat loss during the winter. During the summer, windows need to be shaded from direct sunlight so that heat gains are kept to a minimum."[1]

It should also be noted that when windchill factors are to be considered, the potential temperature differential between the outside and inside of the building surface is logically greater at the windward sides of the building (north and west). As a result, the potential heat loss is greater on the windward sides (through windows and walls) during periods of strong winds. Also, on the wardward side of the building, because of the

1 Op. cit., Mazria , P.101

wind velocity, air infiltration through windows may be increased. These are additional reasons to limit the use of windows on the north, and to some extent, the west sides of the house.

Based on information contained in Figures 30, 31, it is clear that maximizing the area of windows on the South side of the building is a prime priority for the intake of the sun's radiant heat in winter.

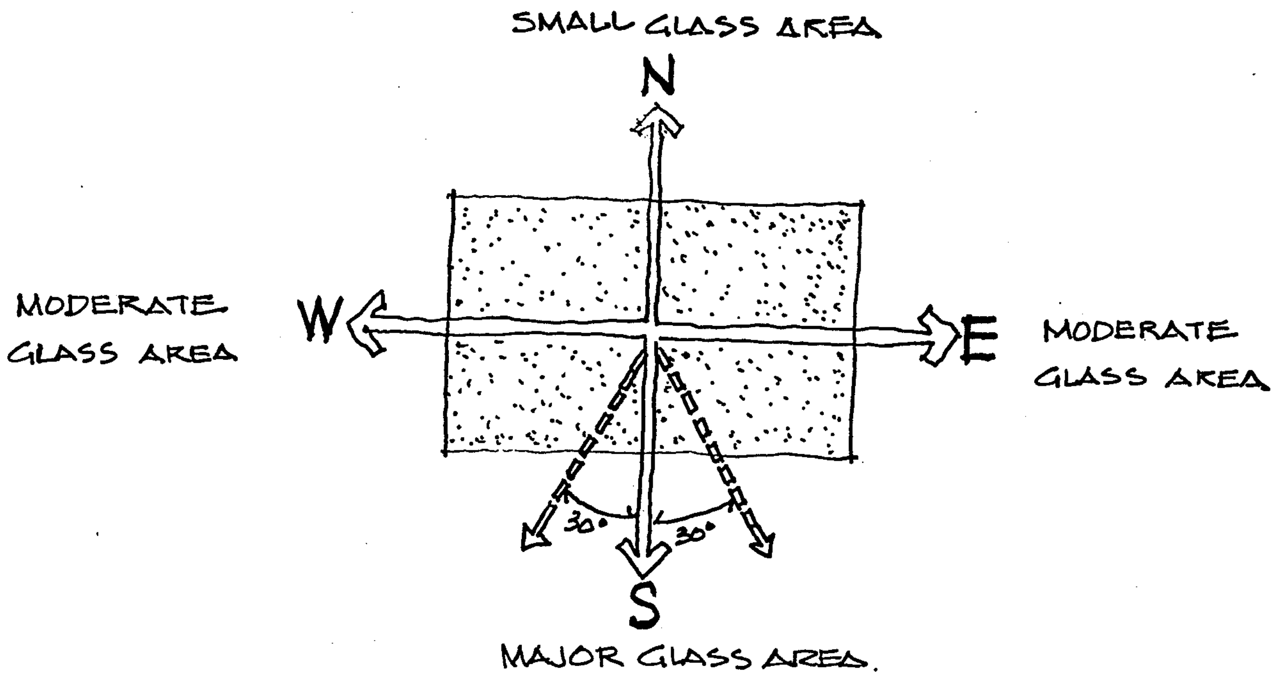
> "According to a recent study on passive solar energy, a double glazed window facing south will produce a net energy gain even without the use of drapes or shutters at night."[1]

Reflective glass should be used on the east and west windows if it is necessary to place windows here. This reduces the radiant heat intake during summer mornings and afternoons. However, in all cases, proper sun shading devices must be provided (overhangs, deciduous trees, etc.) to reduce heat build-up in the summer months.

Cost Implications

The total capital cost for windows need not be different from a "conventional" house. The locations of these windows is all that is changed by this design principle. In fact, by concentrating all window openings into one or two walls, labour costs are greatly reduced for the house since two walls are uninterrupted by window openings (reduces the time spent framing openings in these walls).

1 Op. cit., The Underground Space Centre, P.20

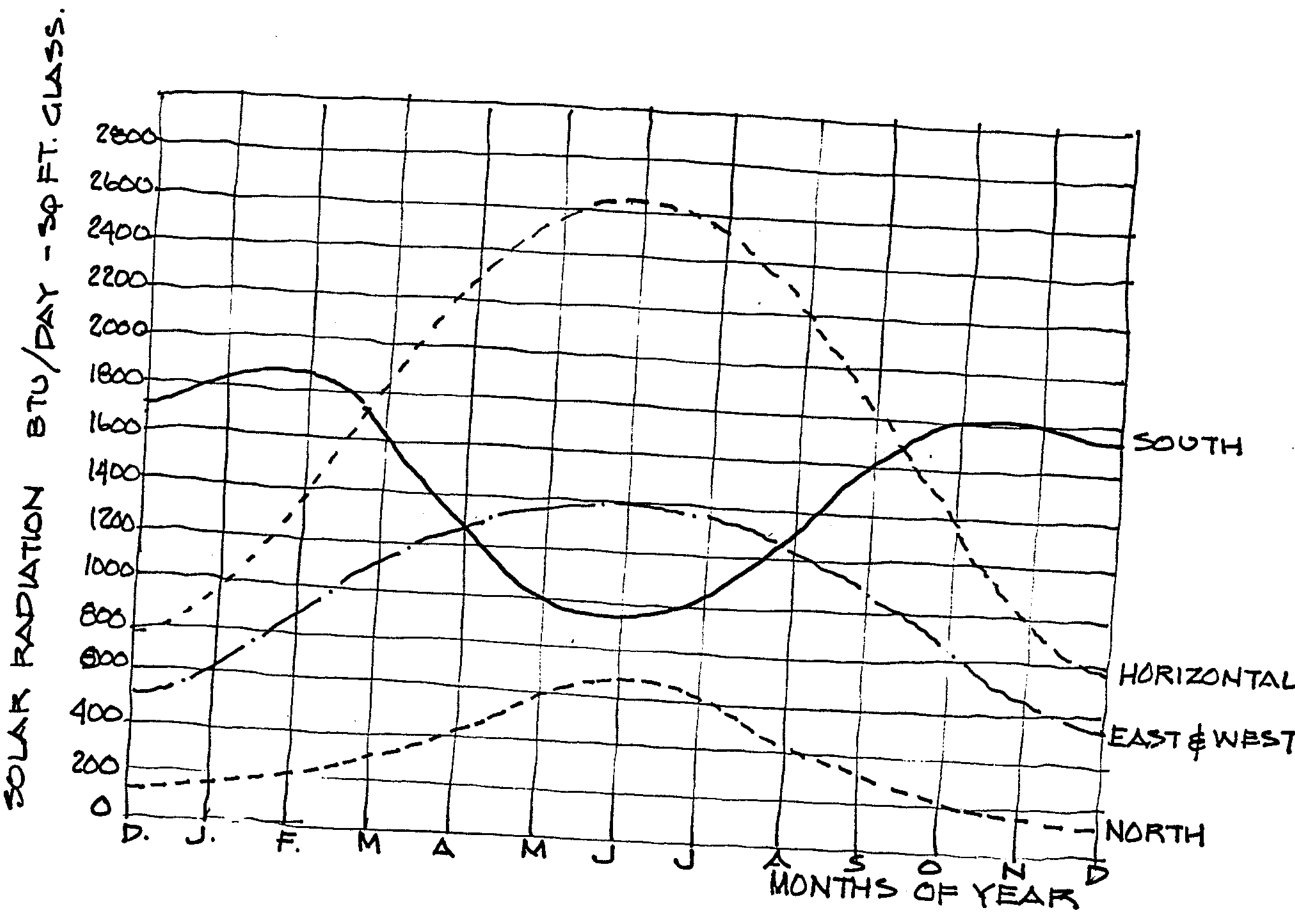


WINDOW LOCATION PRIORITY

SOURCE: EDWARD MAZRIA, THE PASSIVE SOLAR ENERGY BOOK, EMMAUS Pa RODALE PRESS. 1979 P. 102

NOTE: IN ADDITION TO THE PRIORITIES FOR WINDOW LOCATION RECCOMMENDED ABOVE, THE AUTHOR OF THIS THESIS RECCOMMENDS THAT WINDOWS ON THE EAST AND WEST SIDES BE REFLECTING GLASS TO KEEP OUT LOW ANGLED SUMMER SUN (MORNING AND AFTERNOON).

FIG 30



COMPARISON OF WIDOW ORIENTATION

NOTE: THIS GRAPH REPRESENTS CLEAR-DAY SOLAR RADIATION VALUES, ON SURFACES INDICATED FOR 40° N.L.

SOURCE: EDWARD MAZRIA: THE PASSIVE SOLAR ENERGY BOOK. EMMAUS, Pa.
RODALE PRESS
1979 P. 103

FIG 31

By concentrating the required windows for the entire house in the other two walls and placing them in the thoughtfully grouped "banks" of windows, further labour costs reductions could be realized since the actual number of window openings is reduced even though the sizes and total square footage of window space remains the same for the total house.

As well, these windows, if standardized in shape and size, according to manufacturerer's stock sizes, using as large a glass size as is appropriately possible, reduces the cost per square foot of window area (providing, of course, that the glass areas are not too large as to require the use of expensive tempered glass.) The skillful designer may actually save on capital costs when applying these design recommendations.

DESIGN PRINCIPLE 9

Provide the maximum possible insulation value for windows during summer days and during sunless hours of the winter months.

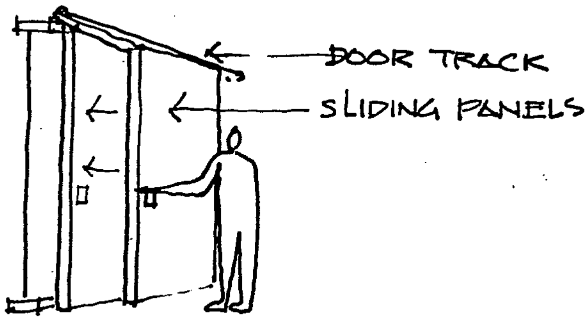
Explanation and Discussion

Perhaps the most obvious component of the building's skin which affects heat loss and gain is the window. This loss occurs by air infiltration (SEL I) and by radiation and conduction (SEL IV). Added to that it has been estimated that a single pane window is 20 times less effective in retaining heat than a typical 3 1/4" wall.[1]

Methods of Achieving Solutions

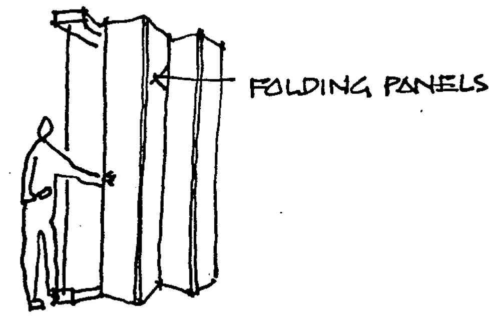
A simple way of dealing with the problem of heat loss is to equip all windows with insulating drapes or shutters. See Figure 32 for examples of various types of window insulating devices. These devices permit the windows to be "thermally open" to allow in radiant heat during daylight hours and to "thermally" close during the night time, restricting the loss of heat. During summer months, the "open and closed" sequence could be reversed thereby keeping daytime heat out and permitting heat to escape to the outside at night. It should be noted that when insulated drapes or shutters are place on the inside, or heated side, of windows, there should be no possibility of warm air coming into contact with the windows as this will cause condensation and "sweating" on the windows. As an alternative to shutters and

1 Op. cit., Mazria, P. 101



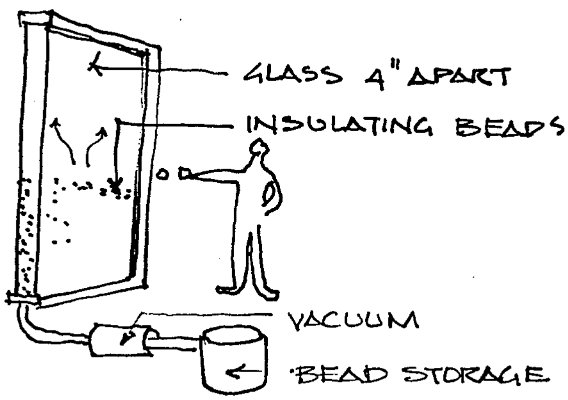
HORIZONTAL SLIDING

SLIDING DOOR TRACK
STACKS RIGID PANELS
TO SIDES



HORIZONTAL FOLDING

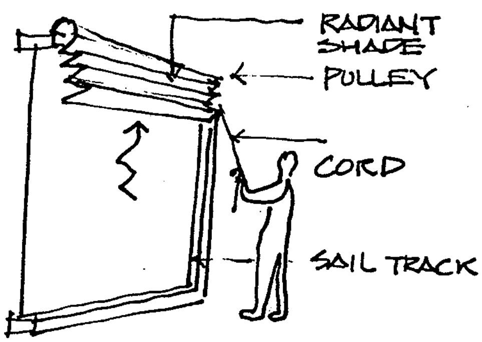
BIFOLD DOOR ACTION FOLDS
PANELS TO SIDE.



BEADWALL *

FOAM BEADS ARE
BLOWN TO FILL GLASS
AT NIGHT & EMPTIED
DURING THE DAY

* TRADE NAME.



ROMAN SHADES

PULL UP DURING THE DAY
SAIL TRACK MAINTAINS
EDGE PLACEMENT.

EXAMPLES OF WINDOW INSULATING DEVICES

SOURCE: DAVID WRIGHT. NATURAL SOLAR ARCHITECTURE: A PASSIVE PRIMER NEW YORK.
VAN NOSTRAND REINHOLD CO.
1978 P. 98, 100.

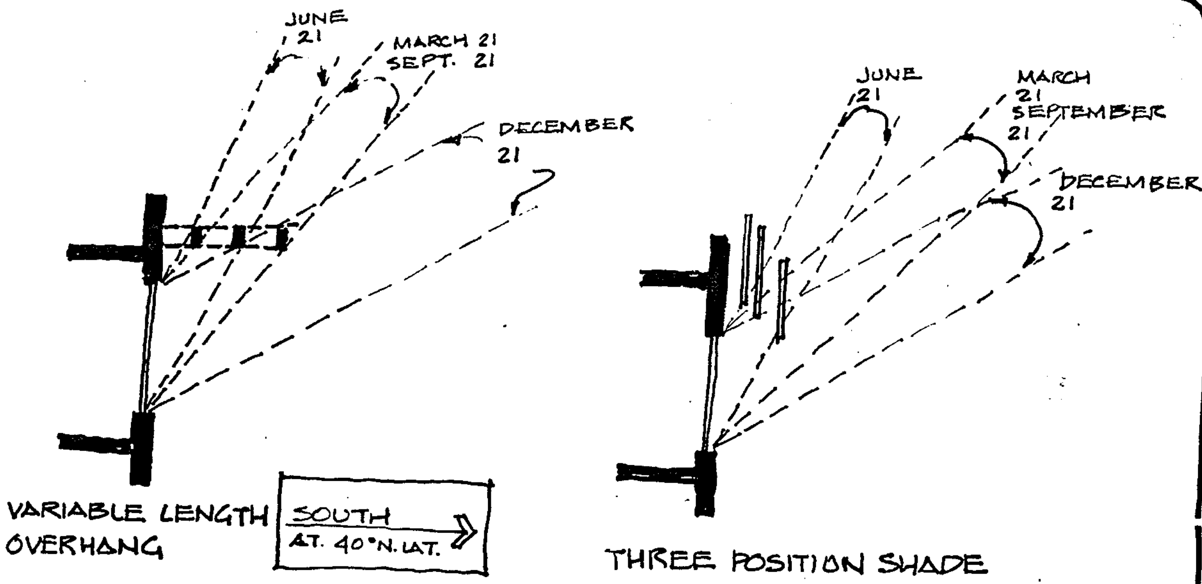
FIG 32

drapes, blown in insulation can be used to fill the space between windows at night.

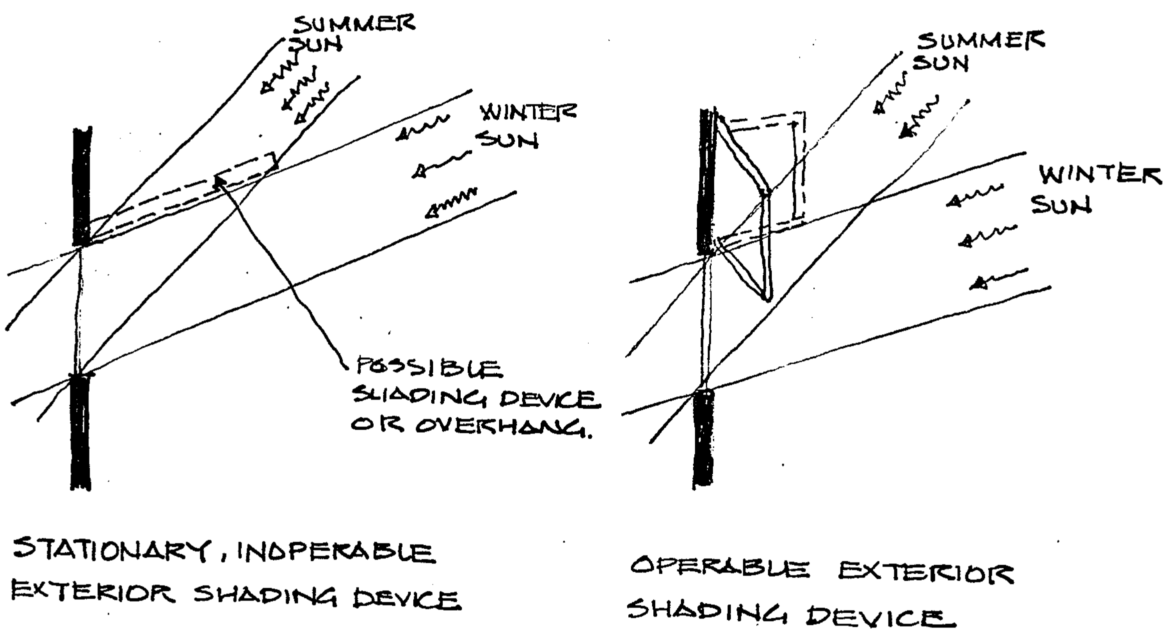
It is apparent that this type of flexibility in window use and design can begin to emulate the flexible functioning of the human skin. In fact, given a computer designed for domestic use (already available) and programmed to regulate and operate these windows and shutters, these operations can become as automatic a reflex as any living organism. The energy savings incurred under such computer operated homes could be enormous if programmed accurately.

A more "static" way of achieving a measure of protection from the sun's radiant heat in summer months is through the use of overhangs, designed to admit the low angled winter sun and screen out the high angled summer sun (See Figure 33).

Another more static and conventional method of "insulating" and shading windows is simply through the use of awnings (for shade) and mutliple paned windows. While the conventional window is designed to be double paned hermetically sealed units, many builders use triple paned windows on north walls (to reduce condensation) or even two double paned hermetically sealed units for insulation value.



VARIATIONS IN LENGTHS OF OVERHANGS



TWO DIFFERENT EXTERIOR SHADING DEVICES

SOURCE: BRUCE ANDERSON: SOLAR ENERGY, FUNDAMENTALS OF BUILDING DESIGN
MCGRAW-HILL BOOK COMPANY
1977 P. 48, 49.

FIG 33

However, the R values do not increase substantially with each added pane of glass simply because the radiant heat loss through these windows remains high regardless of the number of panes. Heat loss by conduction, however, is significantly reduced with each added pane.

Cost Implications

The cost of providing insulated shutters or drapes is significant if computerized. Assuming that shutters are operated manually, the cost may be offset at least in part, by the fact that other drapes and curtains that would ordinarily be used for decoration and shading of the sun can now be substituted for insulated shutters and drapes. Cost would then depend, in the final analysis, on the quality of drapes that would ordinarily have been used and the style of insulated shutter or drapes selected.

Consider for example, a house in which glazing is equal to 15% of the gross floor area. Assume floor area of 1000 square feet, and glazed area of 150 square feet. Assume an average square foot cost of R-12 rigid insulated drapes, installed at $3.00 per square foot = total $450.00.

This price would easily be budgeted for ordinary drapes in the average household. The benefit is substantial, however, when one considers that a 3 1/2" insulated wall (R-12) is approximately 20 times more efficient in keeping in the heat than a double pane window. Stated another way, having 150 square feet of glazed area insulated to R-12 would have the same effect as insulating 3000 square feet of wall space to R-12. This is about 50% more than the total surface area (roof and walls) of the 1000 square foot house (assuming dimensions of 30' x 33').

In other words, the heat loss through 150 square feet of uninsulated glazed area would be about the same as the total heat loss through the walls and attic (assuming R-12 as well), of a house approximately 1500 square feet (assume dimensions of 40' x 36') in floor area, but having insulated windows.

That is significant and illustrates a very great degree of benefit relative to cost.

DESIGN PRINCIPLE 10

Windows should be properly sealed. Reduce the number of operable windows to the minimum required for cross ventilation purposes (and emergency exits).

Discussion and Explanation

Operable windows are expensive and they present opportunities for air infiltration if they do not close properly. Fixed windows are normally less expensive and are more reliable as a shield against air infiltration.

Cost Implications

Minimizing the use of operable windows (substituting where possible for fixed units), should provide a capital cost saving simply because fixed windows are less expensive than operable windows, all things being equal. Wood frame windows are generally more expensive than aluminum windows, however, so there is a trade off here, that may be marginally more expensive depending on specific design prices.

DESIGN PRINCIPLE 11

Reduce air infiltration through the building's shell by the installation of an air-vapour barrier.

Explanation and Discussion

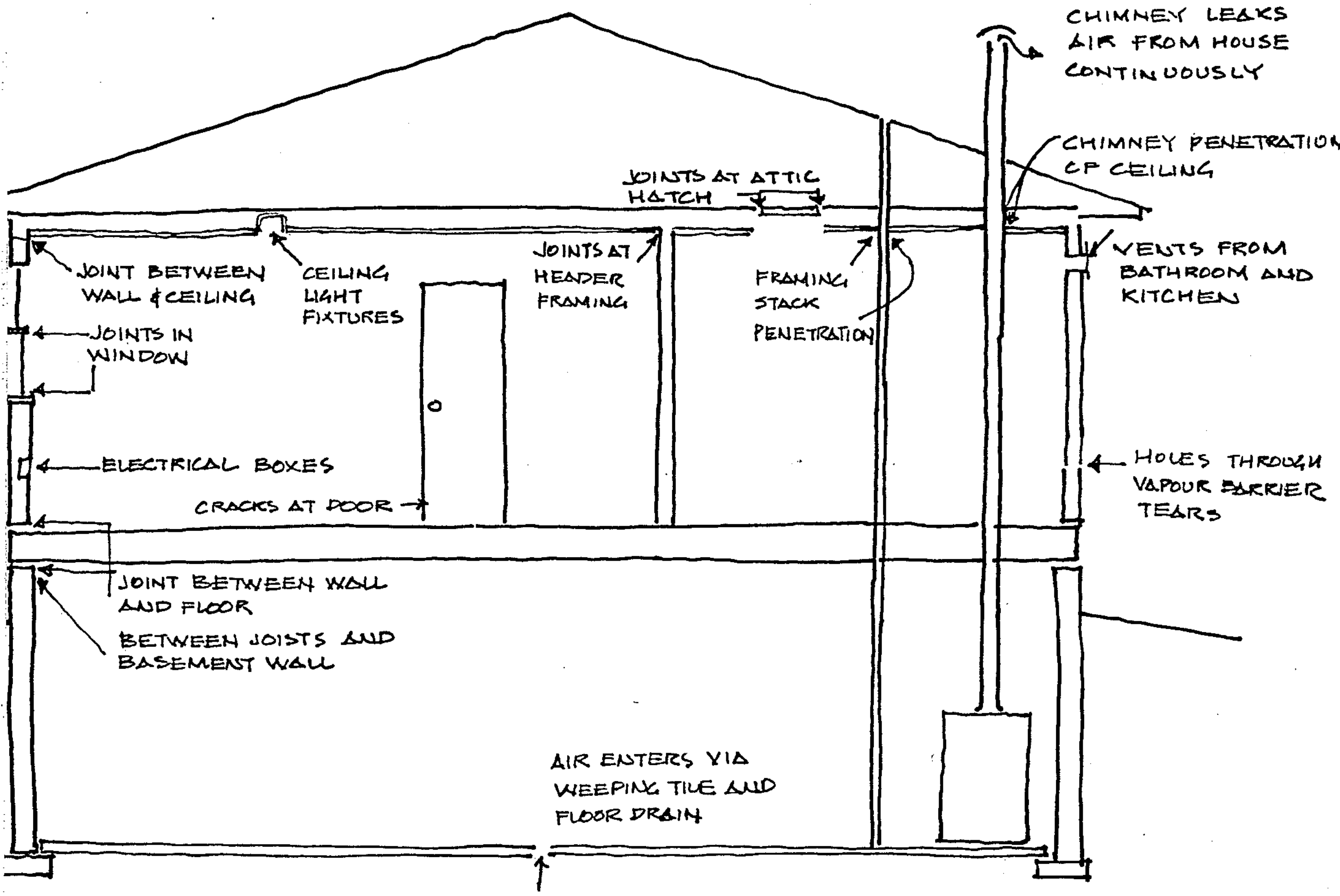
Air infiltration has been identified previously in this study, as a major source of heat loss. Air infiltration occurs not only around doors and windows, but also through a variety of locations in the building shell as well. Figure 34 , illustrates many of the vulnerable locations common to conventional housing. Associated with this movement of air, is the flow of water vapour as well as heat. When the moisture laden air cools down, moisture condenses creating even more problems which may further contribute to heat loss. This is caused when moisture enters the insultaion thereby reducing its ability to retard heat flow by conduction. (Dry rot of the building's structure is also associated with excessive condensation accompanied by poor ventillation).

Air infiltration, then, is associated with three major problems:

1. Heat loss by convection.
2. Vapour pressure and condensation.
3. Heat loss by conduction through moisture laden insulation.

> "In average, present day homes, this air leakage is responsible for about 1/3 of the heating load, or about 6 KW (20,000 BTU/hr.) when the outside temperature is -35°C. In a conservation house, this amount of air leakage would be unacceptable. Ideally, a conservation house should be sealed as tightly as a hot air balloon .. no leaks tolerated. To provide fresh air and to remove moisture from the house, some other ventilation schemes are required......"[1]

1 Op. cit., The University of Saskatchewan, P.3



AIR LEAKAGE LOCATIONS IN THE CONVENTIONAL HOUSE

SOURCE: UNIES LTD
PRESENTED AT A CONFERENCE "LOW ENERGY SOLAR HOUSE WORKSHOP" IN WINNIPEG. SPONSORED BY MANITOBA CHAPTER SESCI
FEBRUARY 1980

FIG 34

Fresh air intake and the expulsion of foul air can be accomplished by heat exchangers which also remove the moisture from the air. A variety of such devices are available on the market, at prices ranging from $300.00 and up (January 1980 prices).

It should be noted, however, that while air leakage may be responsible for approximately 1/3 of the building's heat loss, this does not include the heat loss through the building's insulation when air leakage and condensation in the insulation occur. In other words, air leakage may be indirectly and directly responsible for greater than 1/3 of the building's heat loss.

Methods of Achieving Solutions

Many systems have been proposed for the "super insulation" and placement of air-vapour barriers within the building's shell. Such systems, as presented by the University of Saskatchewan in its handbook, Low Energy Passive Solar Housing, are illustrated in Figures 26, 27, 28 & 29.

In general, the rule of thumb is to fully seal the building by the placement of an air tight air-vapour barrier on the warm side of the insulation. In "super-insulated" walls, the insulation may be placed as much as 1/3 of the total insulation thickness into the wall. This practice is beneficial in that it permits the installation of an air vapour barrier without penetration by nails, electrical wiring and fixtures.

Cost Implications

The material most recommended for vapour barriers is a 5 mil polyethylene sheathing. This is not an expensive item. However, its proper installation is critical and requires a great deal of care and expertise. The labour component of cost, therefore, may be considerable if an inexperienced contractor is used. However, as more houses are built and workmen become more acquainted and experienced with "super-sealing", this component of cost should be greatly reduced.

DESIGN PRINCIPLE 12

Use insulated doors at all exterior doorways.

Explanation and Discussion

Metal insulated doors, when properly designed with thermal breaks to prevent warping and the transfer of heat through the metal, can greatly reduce heat loss by conduction.

When used as part of a vestibule entrance design, the single metal insulated door is appropriate as an exterior door.

Cost Implications

While these doors are individually more expensive than solid core wood slab doors, the metal insulated door can be used by itself, therefore comparing favourably with a double wooden door system.

F) EVALUATION OF DESIGN PRINCIPLES

While it is recognized that no single building may ever incorporate all of the design guidelines outlined above in their entirety, each has its value in reducing energy consumption. Each guideline, in fact, may have varying degrees of effectiveness, depending on each specific design and set of contextual conditions. As well, each guideline may be overdesigned or underdesigned in any one house. For these reasons, it is very difficult to state in exact terms, the effectiveness of any one design feature.

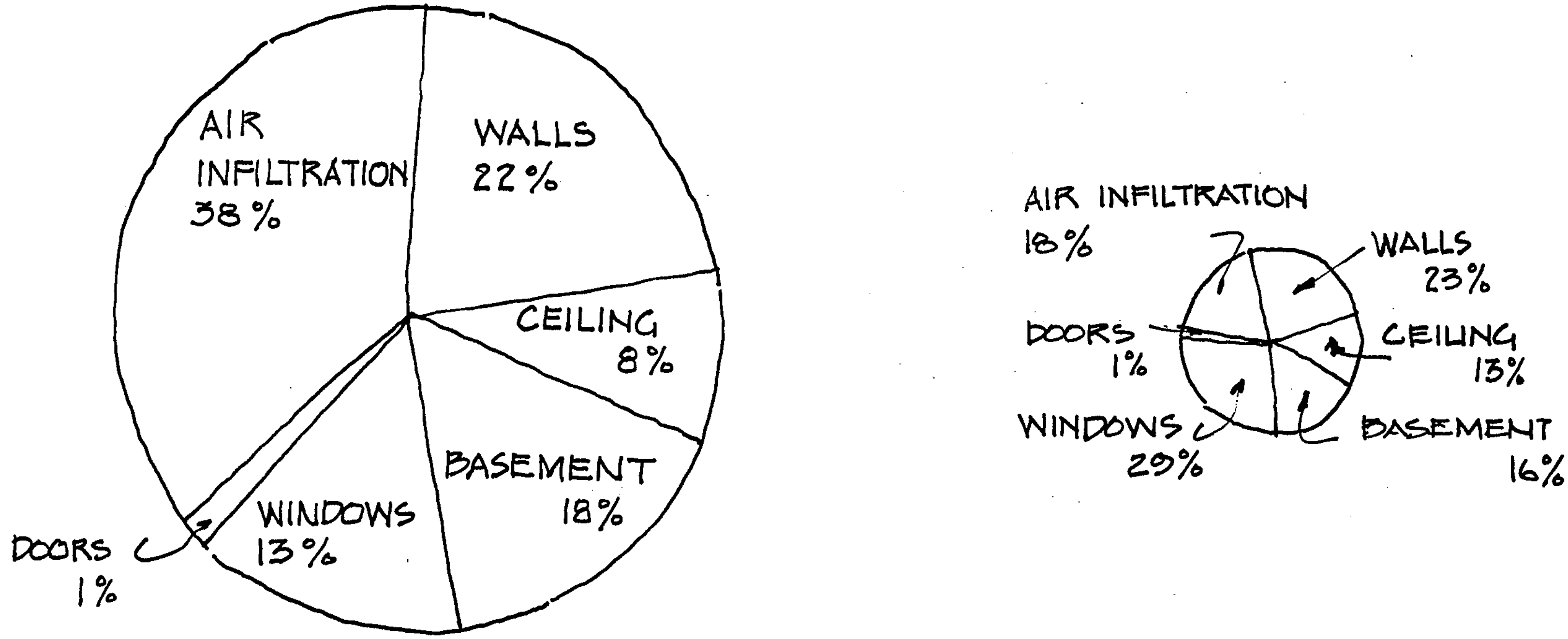
However, as an approximate measure of the energy conserving value of these guidelines, the following analysis is noteworthy. A comparison is made between Baseline House II and Conservation House A, which employs some of the design guidelines discussed above.[1] From this, we may approximate the value of the respective guidelines in so far as they have been applied to the Conservation House. See Table 2 for a comparison of energy consumption and Table 3 for a detailed checklist of energy conservation design principles used in Conservation House A. (Also see Figure 35).

1 Conservation House A is based on the identical plan of Baseline House II, however, it includes energy conservation design features as shown on Table 3. Studies and analysis of Conservation House A were done by Unies Ltd. of Winnipeg, as part of "The Winnipeg Study" referred to earlier in this thesis.

TABLE 2 HEAT ENERGY CONSUMPTION COMPARISON

BASELINE HOUSE II AND CONSERVATION HOUSE "A"

SOURCE OF ENERGY LOSS (SEL) BY COMPONENTS.	BASELINE HOUSE II		CONSERVATION HOUSE 'A'	
	% HEATING LOAD	CONSUMPTION *	% HEATING LOAD	CONSUMPTION
SEL I AIR INFILTRATION	38.00	28.88	18.00	1.08
SEL II THRU WALLS	22.00	16.72	23.00	1.38
SEL III THRU BASEMENT	18.00	13.68	16.00	.96
SEL IV THRU WINDOWS	13.00	9.88	29.00	1.74
SEL V THRU CEILINGS	8.00	6.08	13.00	.78
SEL VI THRU DOORS	1.00	.76	1.00	.06
TOTAL	100.%	76 mm BTU/YEAR	100 %	6 mm BTU/YEAR
SOURCE OF ENERGY GAIN (SEG) BY COMPONENTS.				
SEG I INTERNAL GAIN	30 (APPROX)	22.8	30 (APPROX.)	1.8
SEG II FURNACE	70	53.2	70	4.2
SEG III SOLAR GAIN	NOT MEASURED	NOT MEASURED	NOT MEASURED	NOT MEASURED
TOTAL	100 %	76 mm BTU/YR.	100 %	6.0 mm BTU/YEAR



BASELINE HOUSE II

76 MMBTU/YEAR

CONSERVATION HOUSE 'A'

6 MMBTU/YEAR

(MMBTU = MILLION BTU)

COMPARISON OF DESIGN HEAT LOSSES

FIG 35

SOURCE: UNIES LTD.
PRESENTED AT A CONFERENCE IN WINNIPEG ENTITLED "LOW ENERGY SOLAR HOUSE WORKSHOP." SPONSORED BY: MANITOBA CHAPTER OF SESCI. FEB. 80.

TABLE 3A CONSERVATION HOUSE 'A' – EVALUATION

DESIGN FEATURES REQUIRING LITTLE OR NO CAPITAL EXPENDITURE IN ADDITION TO THAT REQUIRED FOR A CONVENTIONAL HOUSE OF EQUAL SIZE

DESIGN PRINCIPLES [ARRANGED IN ORDER OF INCREASING CAPITAL COST FROM TOP TO BOTTOM]			EFFECTIVE IN COUNTERACTING SOURCE OF ENERGY LOSS (SEL)						SOURCE OF ENERGY GAIN		DESIGN FEATURES OF CONSERVATION HOUSE 'A'									ENERGY SAVINGS OVER BASELINE HOUSE II
			SEL I AIR INFILTRATION	SEL II THRU WALLS	SEL III THRU BASEMENT	SEL IV THRU WINDOWS	SEL V THRU CEILINGS	SEL VI THRU DOORS	SOLAR HEAT GAIN	REDUCED COOLING LOAD	WALLS R-40	BASEMENT R-20	ATTIC R-50	TRIPPLE GLAZE	AIR TIGHT	WINDOW LOCATION	ROOM LOCATION	INSULATE DOOR	WINDOW SEAL/FIXED	
1	ORIENT LOT FOR MAX. WINTER SUN.: SUM. SHADE	WINTER	□	□		□			■											
		SUMMER	□	□		□				■										
2	BUILDING SHAPE RECT. IN EAST-WEST AXIS	WINTER							■											
		SUMMER								■										
3	ORGANIZE SPACES FOR BUFFER EFFECT.	WINTER	□	□		□			■											
		SUMMER	□	□		□				■										
4	SYNCHRONIZE LOCATION OF SPACES WITH PATH OF SUN	WINTER							■							X	X			
		SUMMER								■						X	X			NOT MEASURED
5	LOCATE WINDOWS ON SOUTH AND SHADE (SUM)	WINTER							■							X				
		SUMMER								■						X				NOT MEASURED
6	SEAL WINDOWS AND USE FIXED SASH IF POSSIBLE.	WINTER	□			□													X	
		SUMMER	□			□				■									X	NOT MEASURED

TABLE 3[b] CONSERVATION HOUSE "A" – EVALUATION

DESIGN FEATURES REQUIRING CAPITAL EXPENDITURE IN ADDITION TO THAT REQUIRE FOR A CONVENTIONAL HOUSE OF EQUAL SIZE

DESIGN PRINCIPLES [ARRANGED IN ORDER OF INCREASING CAPITAL COST FROM TOP TO BOTTOM]		EFFECTIVE IN COUNTERACTING SOURCE OF ENERGY LOSS (SEL): SEL I AIR INFILTRATION	SEL II THRU WALLS	SEL III THRU BASEMENT	SEL IV THRU WINDOWS	SEL V THRU CEILING	SEL VI THRU DOORS	SOURCE OF ENERGY GAIN (SEG): SOLAR HEAT GAIN	REDUCED COOLING LOAD	DESIGN FEATURES OF CONSERVATION HOUSE 'A': WALLS R-40	BASEMENT R-20	ATTIC R-50	TRIPPLE GLAZE	AIR TIGHT	WINDOW LOCATION	ROOM LOCATION	INSULATED DOOR	WINDOW SEALED/FIX	ENERGY SAVINGS OVER BASELINE HOUSE II MM BTU/YEAR
7 PROVIDE VESTIBULE AT ENTRANCE	WINTER	☐					☐												
	SUMMER	☐					☐		■								X		
8 USE INSULATED DOOR AT EXTERIOR DOORWAYS	WINTER						☐										X		SEL VI ·70
	SUMMER						☐		■								X		
9 INSULATE WINDOWS DURING SUNLESS HOURS (SHADE IN SUM)	WINTER	☐			☐								X						SEL IV 8·14
	SUMMER	☐			☐				■				X						
10 SHELTER BUILDING FROM WINTER WIND AND EXPOSE TO SUN.	WINTER	☐	☐		☐		☐	■											
	SUMMER	☐	☐		☐				■					X					
11 INSTALL HEAT EXCHANGER AND VAPOUR BARRIER	W.	☐	☐	☐		☐								X					SEL I 27·80
	SUM.	☐	☐	☐		☐			■					X					
12 INSULATE WALLS R-40, ATTIC R-50, BASE. R-12	WINTER	☐	☐	☐		☐				X	X	X							SEL II 15·34; SEL III 12·72
	SUMMER	☐	☐	☐		☐			■	X	X	X							SEL V 5·30

Specific design features of Conservation House A are as follows. See Appendix A for a complete set of drawings of this house.

1. Designed for the Canadian Prairie region (Manitoba) and analysed against those climatic conditions.
2. The identical plan used for Baseline House II is used for the Conservation House A. However, some changes are made to conform to the energy efficient design principles.
   - window locations are altered.
   - window design changed, so that all fixed windows are triple glazed and operable windows are double glazed.
3. Insulation values have been increased.
   - Walls - R-39
   - Attic - R-50
   - Basement - R-27 1/2 (including rigid insulation outside of basement walls).
4. Building is designed to be "air tight" through the use of air vapour barriers. Fresh air is supplied via the use of a heat exchanger.
5. A metal insulated door is ued instead of the conventional double door system (wood doors).
6. Total additional capital cost of providing these design features is $4,000.[1]

1 Estimated in "The Winnipeg Study"

Conservation House A has demonstrated that very substantial savings are possible by the application of several of the design principles outlined in this chapter. See Table 3^B,. for specific principles and the estimated energy savings associated with each.

While Design Principles 1, 2 and 3 are not specifically incorporated into the design or analysis of Conservation House A, it is logical to assume that these site planning guidelines, if incorporated, will decrease the harsh effects of the climatic conditions on the house. The result would be a further saving in energy. Since these planning guidelines are not associated with additional costs, the implementation of these recommended design practices would logically be desirable, if not mandatory.

Again Design Principles 4 (organization of internal spaces) and 6 (vestibule), while not associated with substantial additional costs, were not incorporated into the Conservation House A. They can also have an energy saving value for reasons discussed earlier.

While only 7 of the 12 design principles were used in Conservation House A a very substantial saving of 12/13 of the energy consumption of Baseline House II was realized. The application of all 12 of the design principles outlined could only lead to greater savings at about the same capital cost increase ($4000.00) as the Conservation House A.

G) SUMMARY AND CONCLUSIONS

It has been shown in Chapter II that a rational approach to design can result in substantial energy savings. This is possible without great capital cost.

In the case of Conservation House A, a total additional capital cost of $4,235.00 was estimated for all energy efficient design features incorporated. This would correspond to approximately a 10% increase in the cost of the house for a total reduction in energy cost per year of 92%. Since Conservation House A used only 7 of the 12 design principles, it is possible that the use of all of the design principles outlined in Chapter II would result in even greater energy saving at very little additional cost.

It is reasonable to conclude then, that a rational approach to architectural and planning design, can result in significant energy savings by adhering to the design principles outlined in this thesis.

CHAPTER III

ALTERNATE DESIGN CONCEPTS

The design principles discussed in Chapter II have been outlined with specific reference to modifying conventional housing design and construction practices. It is significant to note that in the case of Conservation House A, the outward and internal appearance of the house have not been altered significantly. It would be indeed very difficult to differentiate Conservation House A from Baseline House II except if one were to measure wall thickness, etc. By and large, the design principles outlined in Chapter II would not substantially change the appearance of housing as we in North America have come to accept it.

However, this is not to suggest that this is as far as we can go toward designing more energy efficient structures. The author has outlined design principles which serve to shelter the conventional house agains the harsh effects of the climate (Design Principles 1 to 5 inclusively) as well as to take advantage of the sun's radiant heat in winter (Design principles 1,2,4,5). However, these design principles were totally lacking in Conservation House A, except to a minimal degree in the case of Design Principles 4 and 5 (See Table 3A). What this suggests is that the conventional house can be made reasonably energy efficient through the practice of "super insulating" and "air tightness" in its design. However, at least in the example outlined, the modified conventional house has not taken advantage of the full potential for using the sun's radiant energy as a source of heat, nor has it used landscape features to any advantage for sheltering (or keeping the weather out).

There are, however, three variations on the treatment of the building's shell which are radical departures from the more conventional measures outlined in Chapter II. They represent design approaches which inherently permit the building to use the sun's energy or to be sheltered from the elements. These are:

- Concept I - The building incorporating heat gain systems.
- Concept II - The building designed as a double-shelled structure for protection from the elements.
- Concept III - The building designed to be earth sheltered against the elements.

Each of these systems can be an exhaustive study in itself (beyond the scope of this thesis), since they each have profound implications for the design opportunities and limitations in building design. However, within the scope of this thesis, a description of each system is warranted here, as new dimensions in which energy efficient building design may evolve.

A) CONCEPT I - The Building Incorporating Heat Gain Systems

There are three basic systems of passive solar heat gain. These are:

1. The direct gain system.
2. The indirect gain system.
3. The isolated gain system.

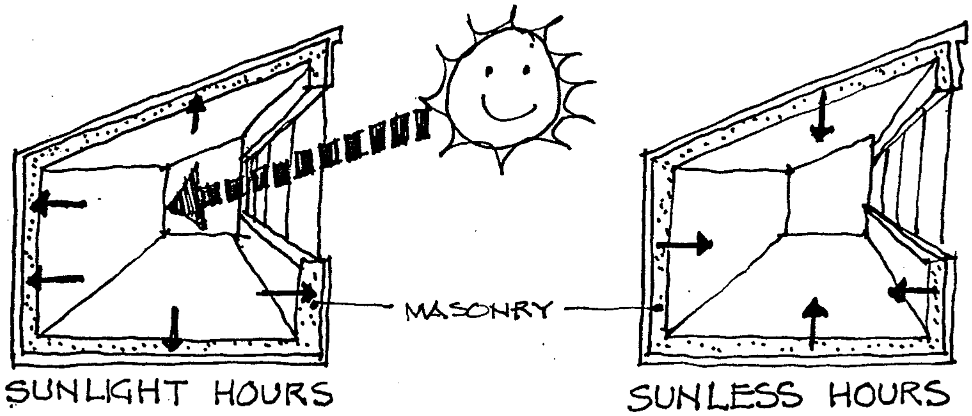
Each system is described in turn.

1. The Direct Gain System

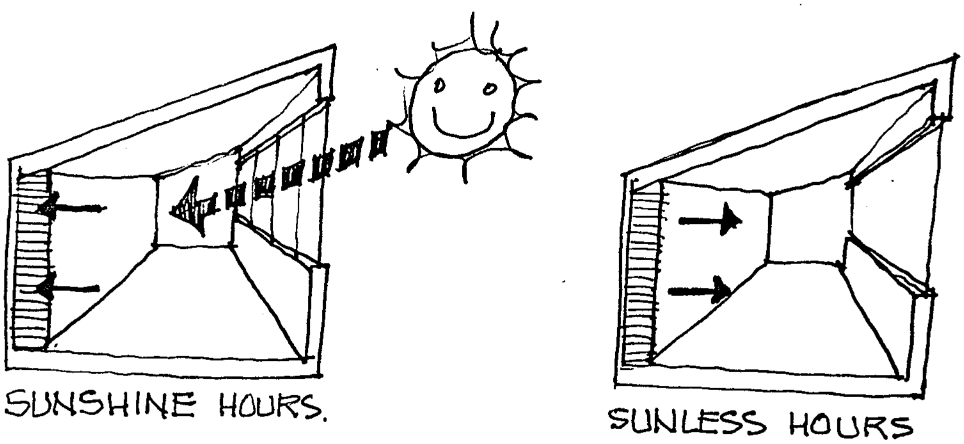
This can best be described as a system which uses southern exposed solar gain windows to heat the building space directly. In short, the living space itself is used as a solar collector and must be able to store its daytime heat gain for use at night (or sunless hours). The most common methods of storing heat are in masonry walls or in water tanks or water filled walls surrounding the space to be heated. Over-heating of living spaces can become a problem with this system. However, if properly design, this type of heat gain system has been known to provide up to 50% of a building's heating needs on the west coast of England at 53°NL. (See Figure 36).

2. Indirect Gain System

"Windows" in this system also face south, however, their purpose is not to provide views or admit sunlight to the living space. The



MASONRY HEAT STORAGE.



WATER WALL HEATSTORAGE

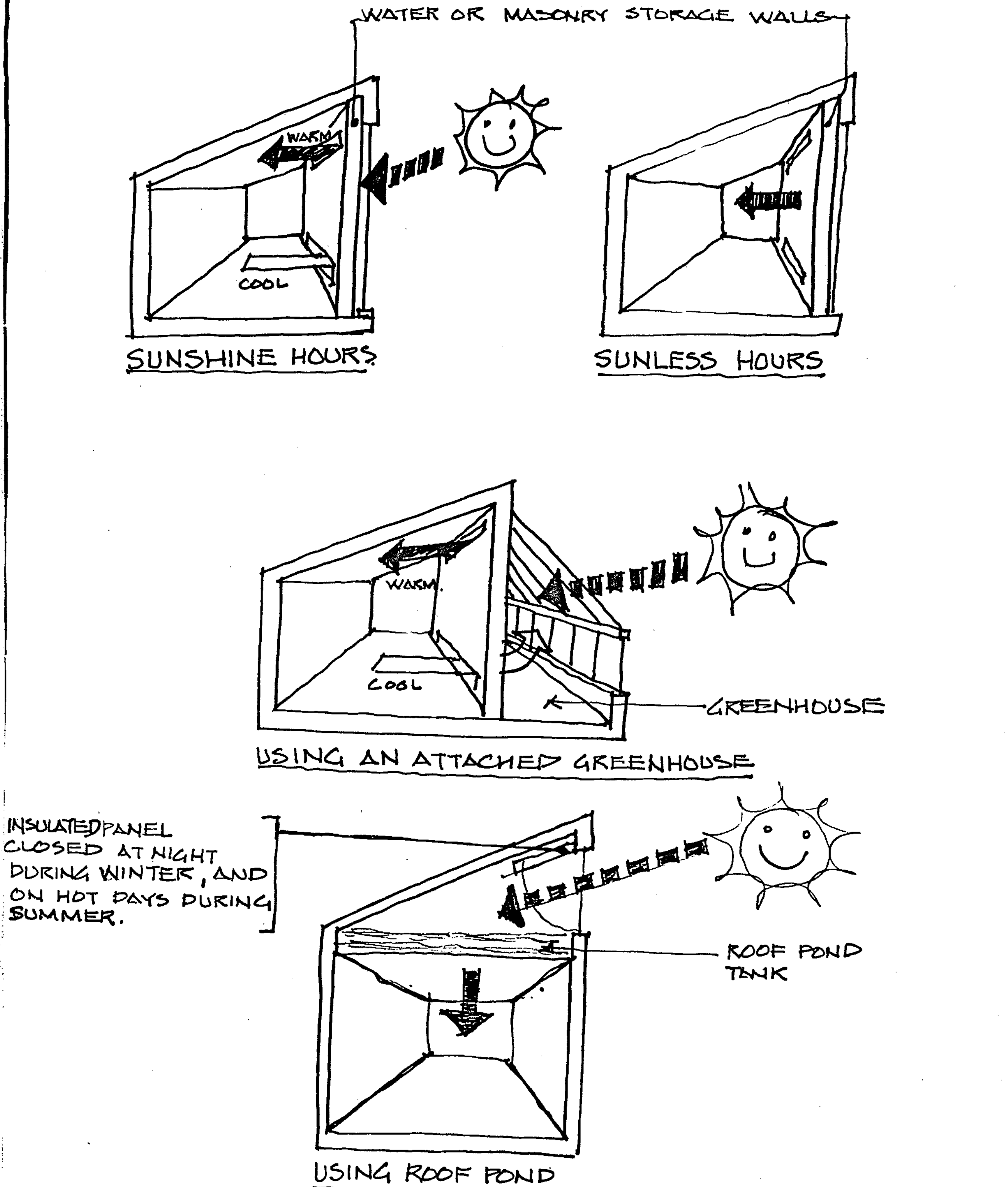
DIRECT GAIN SYSTEMS

FIG 36

"window" glass is designed to admit sunlight into a narrow air space cavity formed between the extensive glazed area and a heat absorbent storage wall. The living space is located behind this wall and is heated by thermal energy which is stored in the wall. Storage walls may be made of masonry or a wall filled with water, (water thermal storage wall). This latter storage system has been known to provide a constant temperature between 63° and 70°F. through most of the winter, while the masonry wall system has been recorded to have reduced heating costs by up to 76%.[1] One of the major advantages of this system is its ability to provide relatively constant space temperatures day and night without the disadvantages of overheating the space, as is problematic of the direct heat gain system. (See Figure 37).

The attached greenhouse which has become a popular method of heating spaces within houses, really is a combination of a direct gain system and an indirect gain system. The greenhouse itself is the direct gain portion, while a heat storage wall is used to separate it from the adjacent space. This storage wall transfers thermal energy (heat) to the adjoining space (inside the house) indirectly.

1 Op. cit., Macria, P.50



INDIRECT HEAT GAIN SYSTEMS

FIG 37

A roof pond system is also practical for heat storage. In this case, heat is stored in a water pond located on the roof of the building (See Figure 37).

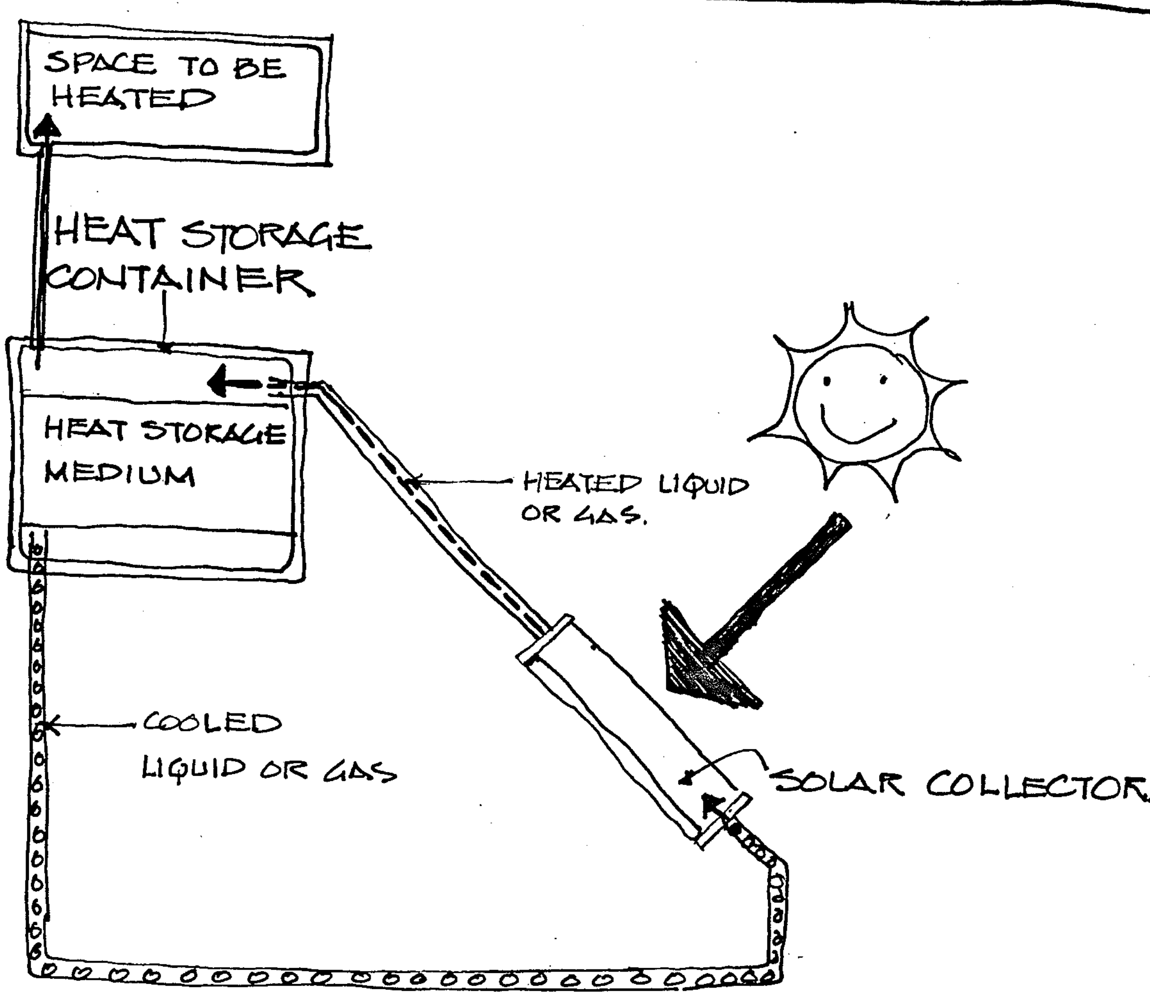
3. The Isolated Gain System

In essence, this sytem consists of the two components; the building's skin (glass) being used as a method of admitting the entry of the sun's radiant heat and secondly, a method of storing this heat. However, in this system, the methods of collecting and storing may be quite separate from the living space. In this sense, the isolated gain system does not necessarily have to be a part of the building at all, it can be isolated from the building. However, using the system's components as part of the building's skin is a less redundant and more direct way of accomplishing the same thing. The principal reasonfor having the isolated gain system separate from the building is to achieve the best orientation for the system if it is not possible to achieve this with the building's orientation. Also, when the system is isolated from the living space, it becomes a very convenient process to draw heat from the system only when it is needed, since the system can function independently of any living space.

Typically, this system consists of a flat plate collector and a heat storage tank. The most common form of heat storage mediums used are water and air with a rock storage bed. Both water and air systems use a natural convection current formed while the sun is shining on the collector plate (See Figure 38). The indirect gain system is similar to the "active" solar gain system in principle. However, active systems are different in that they normally use a high degree of mechanical components.

There are numerous ways in which these three basic systems may be applied and used in various house designs. In fact, all three systems may be used collectively and in combination with each other to produce a workable and appropriate system for heating various parts of an entire building. During summer months, the systems may be "shut off" simply by allowing heat to be expelled to the outside through ventilation dampers located at the highest point in the convection path. Also, shading devices may be used to restrict the sun's rays from shining on the "window" component of the system. As well, the natural convection which is established in these systems could be used to draw cool air out of basements, etc., to cool the buildings.

Depending on the severity of the climate within which a building is located, these passive systems may require back-up heating and cooling mechanical devices. However, as a natural way of augmenting the building's heating and cooling needs, these systems can be a significant design consideration.



CONVECTION LOOP

ISOLATED HEAT GAIN SYSTEM

NOTE: THE CONVECTION LOOP IS THE BASIC PRINCIPLE OF HEAT CIRCULATION USED IN THE ISOLATED HEAT GAIN SYSTEM. IT SIMPLY INVOLVES THE MOVEMENT OF THE HEATED AIR OR LIQUID TO A HIGHER LOCATION WHERE HEAT IS DRAWN OFF AND STORED. THE COOLED AIR OR LIQUID THEN FALLS TO A LOWER LOCATION AND IS THEN DRAWN BACK INTO THE SOLAR COLLECTOR FOR RE-HEATING. THE 'CONVECTION LOOP' IS THEREFORE COMPLETED.
THE ACTIVE SOLAR SYSTEM USES THIS BASIC PRINCIPLE BUT RELIES ON MECHANICAL MEANS OF MOVING THE LIQUID OR GAS. MOST OFTEN

FIG 38

Walls and Roof

The glazing components of these systems most often serve as the south facing wall or south sloping roof skin of the building. The non-glazed components of the building's skin, the wall and other portion of the roof, generally should serve their traditional functions of sheltering against the elements.

B) CONCEPT II - The Double-Shelled Structure [1]

The building's skin is an integral part of the three passive solar systems described above. There are as many variations on the use of these systems as there are designs for specific houses. However, they all fall into one of the three categories or combinations of them.

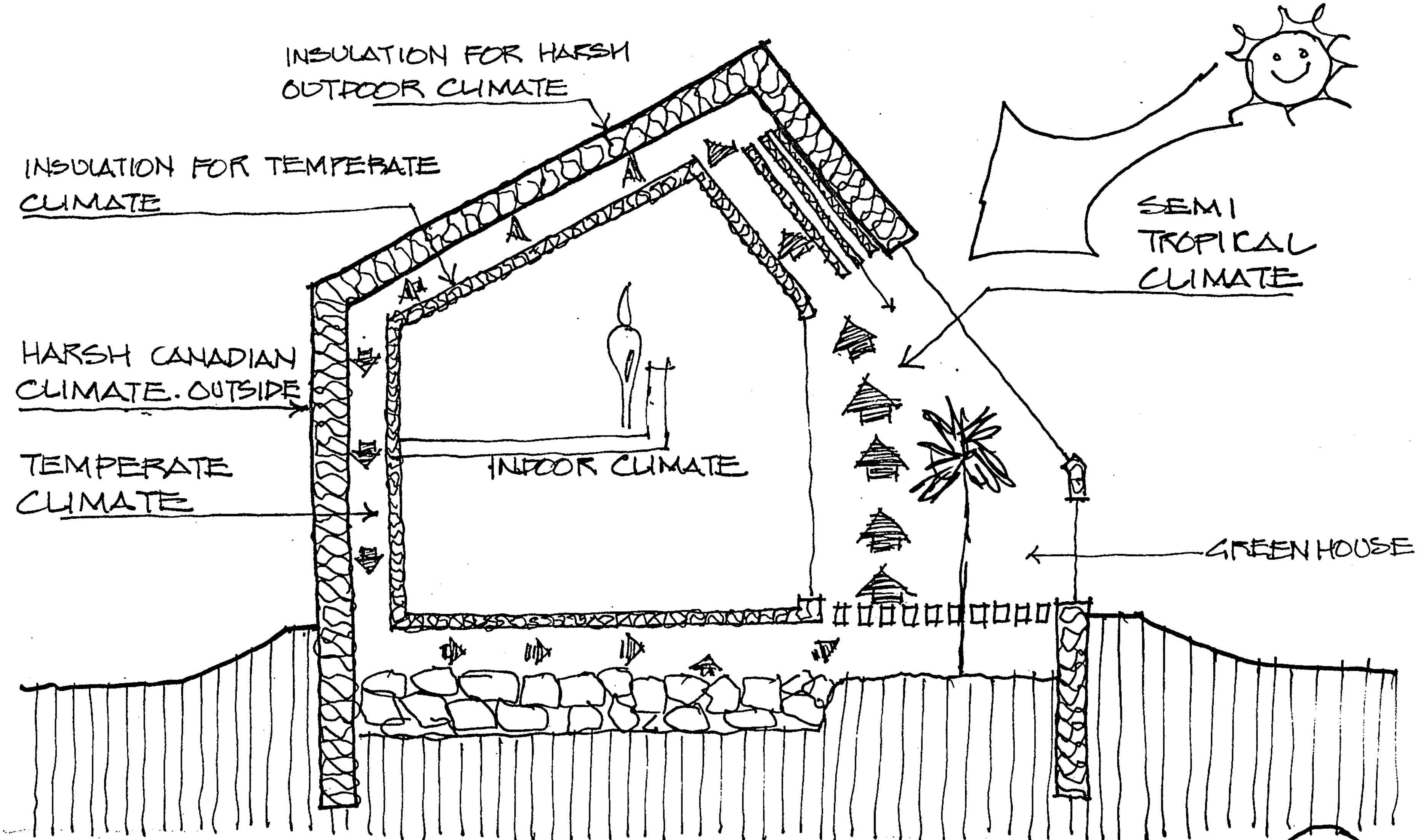
There is, however, one variation which is worthy of note since it exemplifies the use of all three systems, not as part of the building's skin, but in fact, making up the entire shell of the building. As well, this system represents an inherent way of protecting the building against the elements.

This concept can be called a "double-shell" passive solar system (See Appendix B for further information on this concept). As the

1 For purposes of comparison with other energy efficient house design concepts presented in this thesis, the double-shelled house is referred to as "Conservation House B" throughout this study.

title implies, the entire shell or skin of the building is composed of an outside and inside layer separated by an air space or "a house within a house". Within this air space, a convection air current is induced by allowing the south side of the house to take on heat by direct gain (See Figure 39). The south side of the house, therefore, becomes the solar collector (direct gain greenhouse) which then "fires up" a "convection loop" which surrounds the habitable spaces as an envelope. Heat is stored in the "crawl space" area of the loop in the earth or rocks which form the base of the crawlspace. Individual spaces may be heated "indirectly" by drawing air from the warm side of the convection loop directly into the living space through controlled dampers or simply by being indirectly heated or cooled by the passage of warm or cool air (respectively, depending on whether the loop is operating in winter or summer) in the convection loop system.

Though in theory this double shell system does work and there are examples already built, there has not been enough data collected to prove conclusively to what extent the system is cost effective. The major drawback of the system is that it requires a high capital cost to literally build two separate envelopes for the living space. However, these costs can be offset by reduced cost of mechanical heating and air circulating devices. Also, the "greenhouse" can be used as living space. There are numerous claims being made for this system, which are worthy of note, even though to a great extent these claims are not conclusively proven.



THE DOUBLE-SHELL HOUSE

FIG 39

In some climates, the buildings designed with a double-shell can operate with a minimum amount of back-up systems. Where wood-burning stoves or fireplaces provide the back-up heating, these houses have been observed to be very quiet due to the lack of ducts, vents registers, fans and also because the double shell itself acts as a very good insulator of noise originating from the exterior.

> "In the Smith house located in Lake Tahoe (See Appendix B). the designer claims that this double shell design achieves an 80% reduction on fuel cost over conventional homes ....this includes an 80% reduction on cooling costs over conventional homes."[1]

Bruce Maeda, a solar consultant at Davis (California) Alternative Technology Associates, has made the following observations on the double-shell design:

> "...an extremely cost effective way of achieving high R values and a unique way of distributing the insulating value around the house....... windows are typically the worst heat leaks, and the double shell allows sizeable window area without excessive heat loss."[2]

The Popular Science Magazine goes on to say:

> "Conventional double-panewindows have only 1/4 to 1/2" of insulating air, while the double shell puts at least 12" of relatively warm air in contact with the inner windows. Maeda contends that the effective R value of the north windows in the Smith house is R-6, versus R-1.5 for a conventional double-glazed window."[3]

1 "Double-Shell Solar House" in Popular Science Magazine Times Mirror Magazines Inc., New York December 1979 P.55

2. Ibid., P.56

3. Ibid., P.57

It is clear that there is a raging controversy over the exact thermal performance and heat circulation characteristics of the double-shell design. Ralph Jones, an architect and solar engineer at Brookhaven National Laboratory, who has monitored several homes for the Department of Energy, has concluded that:

> "Every house I've monitored has turned out to operate for very different reasons from the ones the owner believed.
>
> ... these mechanisms can only be understood by making a large number of rather detailed measurements.
>
> ... with more than 30 double-shell houses ready to be occupied by this winter, however, this aspect of the controversy should be resolved in practice, if not in theory."[1]

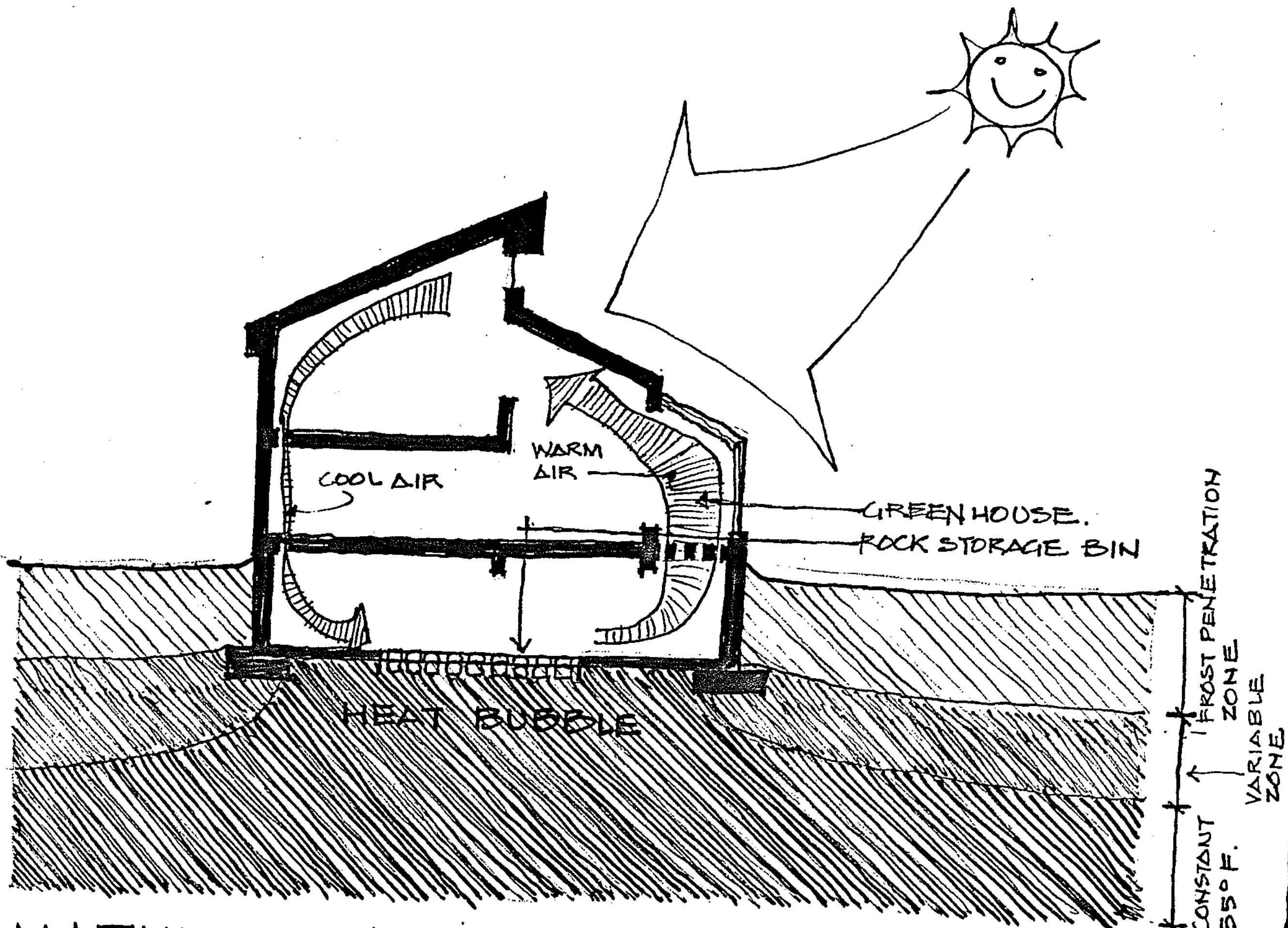
However, it appears clear that even though the exact thermal and heat circulation characteristics of the house cannot be fully described and explained at this time, there are legitimate claims to be made for the design. The design has proven to be substantially more energy efficient, more quiet and having good cooling ability and perhaps more comfortable (by virtue of limited "drafts" in interior spaces and a low rate of air infiltration), than the conventional home. In addition, it would appear that there is substantial control of temperature fluctuations from day and night (on interior spaces). As well, there is a considerable advantage gained by being able to insulate the house from exterior heat in the summer by circulating cool air around the inner envelope.

1 Ibid., P.57

In essence, the three passive solar heat gain methods can be seen to be design concepts of treating the building's shell so that the shell itself becomes a source of collecting heat or providing cooling.[1] Before the energy crisis, the shell of a house was perceived to have the functions of providing enclosure, moisture protection, ornamentation or design style, ventilation and light. It has now become clear that the shell can effectively serve the functions of collecting and holding heat, as well as restricting heat flow through it, like a blanket, in addition to all of its other functions.

Other modifications to the building's shell are possible as no doubt the search will go on. Among many experiments being done, is one which attempts to use the building's skin as a <u>source</u> of heat, simply by extracting heat from the exterior surface through a heat absorption process involving a complex array of pipes and tubes. Another heat absorption process attempts to cool the building by making it "perspire", by continually wetting the south side of the structure during hot weather. As the water evaporates, it cools the building's skin. Several other systems of heat pumps, etc. are being used. However, these are all considered to be mechanical solutions which are beyond the scope of this study.

1 As a passive solar house, the double-shelled house as well as any of the houses using passive solar heat gain principles and storing heat in its basement, also derives heat from the earth in the form of a "heat bubble" (See Figure 40).



NATURAL HEAT SOURCE FOR THE PASSIVE SOLAR HOUSE

THE PASSIVE SOLAR HOUSE GAINS HEAT FROM THE SUNS RADIATION. THIS HEAT CAN THEN BE CONVEYED BY A NATURAL CONVECTION LOOP TO A ROCK STORAGE BIN LOCATED IN THE BASEMENT FLOOR.

BECAUSE THE SOIL UNDER THE BASEMENT FLOOR IS COVERED BY THE HOUSE, THIS SOIL NEVER COOLS DOWN. IN WINTER. AS A RESULT A "HEAT BUBBLE" IS FORMED UNDER THE HOUSE. THIS "HEAT BUBBLE" IS AN EXTENSION OF THE EARTH'S CRUST LAYER WHICH MAINTAINS A CONSTANT TEMPERATURE OF ABOOT 55° F. AS A RESULT THE HOUSE IS ALSO HEATED BY THIS "HEAT BUBBLE" [1]

[1] SOURCE: THIS THEORY WAS ADVANCED BY ARCHITECT ARNIE FULLERTON IN A SEMINAR GIVEN AT THE UNIVERSITY OF MANITOBA, MARCH 1980.

FIG 40

C) CONCEPT III - The Earth Sheltered Structure

This study has so far been concerned with the design of housing using modified conventional methods of construction while incorporating principles of design which recognize the influence of passive solar considerations in making the building more energy efficient.

It has been shown that building orientation, shape, internal organization and shell characteristics can all be designed so as to conserve energy. All of these principles hold true whether a building is located entirely above grade and exposed to the elements, or whether it is partly submerged and sheltered by the earth.

However, earth sheltering a building proves to be a method of construction which inherently gives the building an added measure of protection (from the elements) and thermal insulation which conventional methods do not.

In fact, in one simple step it is possible to design the building in such a way that problems of noise, air infiltration, windchill factors and direct heat loss are greatly diminished. This is simply done by pulling earth over the building like a blanket, so as to provide maximum shelter from the elements. These are, in fact, the very objectives which most designers of energy efficient buildings are seeking; it is, in essence, the objective of the designers of the double-shell buildings (discussed previously), to give the building shell an added layer of protection. In the earth sheltered example, the earth provides that added layer of protection - inherently.

A personal note is relevant at this time. The author has long felt that the mode of housing design (in fact, many other uses as well) should be underground in a climate as harsh as the Canadian Prairies. That observation was made in 1959, when, as a high school student, the author moved to Winnipeg from the tropical climate of the West Indies. At various stages of his university and practical career as an architect, the author has attempted to test this idea in a practical way - however, the psychological resistance to this idea was too great and clients were not inclined to live "underground". The first such design was for a school addition in Dauphin,Manitoba, in 1971.[1] Here the school board was not comfortable with the idea and rejected it as being too radical. In 1973, during the time of the Arab Oil Embargo, the author again attempted to get this idea off the drawing boards (this time for his principle residence), but was unable to find financial institutions interested in "burying their money".

1 This project was designed by the author for architects, Moody, Moore and Partners of Winnipeg, Manitoba.

Today the idea has been tried in several locations in the U.S. and (ironically a school has now been built undergound in Manitoba) Canada. Though this form of construction is still in its infant stage in housing, the author believes even more so today that this type of design offers the greatest opportunity to deal with the climate of this region and with many other aspects of housing design and city planning as well.

Because earth sheltering of the building's shell represents a significant point of departure from the "norm", several unique or special design considerations are necessary to render such buildings acceptable to "normal living standards". What is of great importance, however, is that, while this design concept is able to benefit by all, if not most, of the design principles discussed earlier, as applying to more conventional above grade designs, the earth sheltered house can achieve even greater harmony with its natural surroundings; can have a high degree of energy self-sufficiency; and be made to psychologically and physiologically acceptable for human habitation.

The remainder of this chapter is devoted to a discussion of design ideas and guidelines as they apply to the earth sheltered house in accomplishing these goals.

I DESIGN CONSIDERATIONS

a) Orientation to the Sun

As with the conventional above grade design, orientation of the building elongated on the east-west axis, so that extensive southern exposure can be achieved along the south-facing wall (exposed to sunlight) is a design principle which produces a net heat gain through these windows.

> "The use of passive solar collection techniques in an energy efficient residence is a very desirable concept since it does not involve the capital expense that an active solar collector does and can provide a substantial amount of energy. According to a recent study on passive solar energy, a double glazed window facing south will produce a net energy gain even without the use of drapes or shutters at night."[1]

> "Passive solar collection is diminished considerably with east and west facing windows and eliminated completely on the north side."[2]

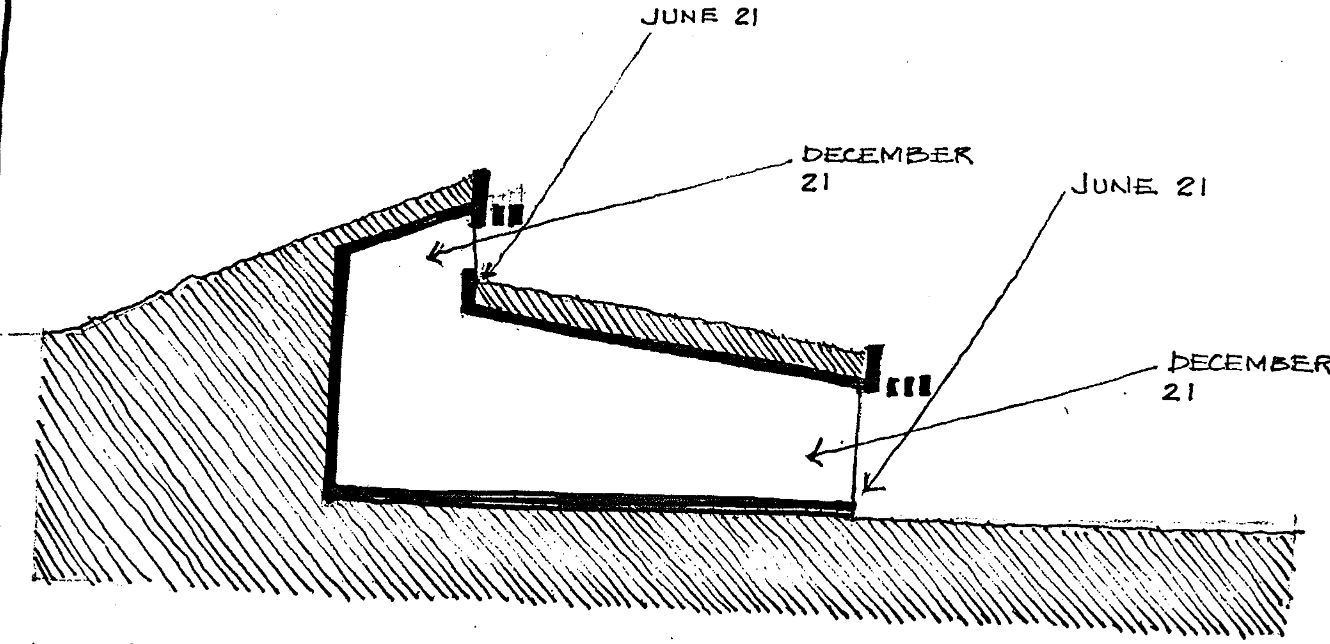
The earth sheltered house lends itself inherently and optimally to this type of orientation. The entire north, east, and west walls and roof could be earth covered, leaving the only net heating gaining wall, the south wall, exposed to the south, and glazed.

1 Op. cit., The Underground Space Centre, University of Manitoba P.20

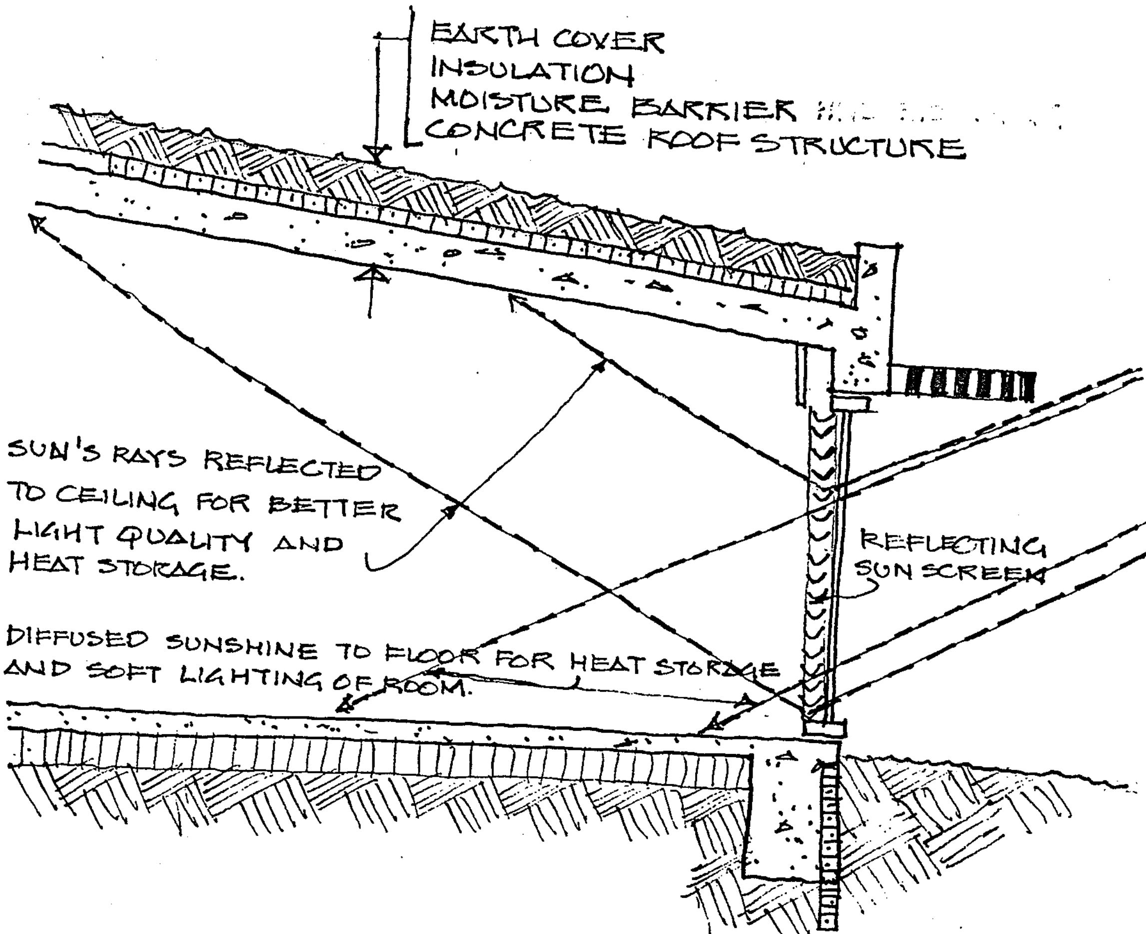
2. Ibid., P.20

Where it is not possible to have all windows facing south, it is possible to use the other design techniques or methods of trapping the sun's heat. This may be accomplished through the use of skylights, which themselves face south and are earth sheltered. (See Figure 41).

Because of the possibility of too much direct heat gain on sunny winter days (a problem with all direct heat gain methods, as discussed earlier), the earth sheltered house has the inherent advantage of being able to store this heat for later use, at night or on cloudy days. For example, a reflective screen may be placed along the inside of the south wall (glazed) so that the sun's rays are deflected upward to the ceiling. Because the roof of the earth sheltered house must be constructed of concrete, this inherent heat storage mass acts as a device to absorb heat during overheating sunlight hours and to release this heat during "cool" hours. (See Figure 41). This handling of the south facing wall does not need to obstruct views to the outside, but instead, permits a better quality of natural light to enter the house. Instead of having a direct, bright and glary light entering a wide expanse of the house, the reflective screen deflects the light to the ceiling, thereby giving an indirect, softer and more uniform light quality to the room. As well,



NATURAL LIGHTING IN EARTH SHELTERED HOUSE



SUNLIGHT CONTROL

FIG 41

because the light so reflected penetrates deeper into the room, the entire room may have a more uniform and pleasant light quality. (See Figure 41).

During summer months, these south facing windows, skylights or courtyards may be screened from the high angled summer sun in a similar way to the "above grade" design, i.e. through the use of eaves, shutters, louvers or deciduous trees and shrubs.

b) <u>Shelter from the Wind</u>

As mentioned, earlier, the earth sheltered house has the advantage of being buffered from the direct effects of wind chill.

It is recognized that the earth (depending on the type of soil) usually has quite a low insulation value. In fact, it takes about 3 meters of most soils to give the equivalent insulation value as 10 cm. of styrofoam insulation. However, with respect to the heat loss characteristics of the earth sheltered house, the following points are very important to note:

1. One of the major contributors to heat loss is the differential temperature between outside air and inside air (this applies to all structures). In the case of the earth sheltered structure, this differential temperature is greatly buffered by the earth. The result is that a fairly constant "outside" temperature is maintained, thereby greatly reducing the heating and cooling load in the house.

2. A further very significant buffering is achieved when wind chill factors are taken into account.

Therefore, while a desirable room temperature of 70°F (about 20°C) may be maintained in both above grade and earth sheltered structures, the temperature on the outside skin of the earth sheltered structure in winter may be relatively stable at 32°F (0°C) (temperature of the soil at frost line), while the above grade structure would be subject to wind chill factors far below 0°F. Consider the workload created on the heating system of an above grade structure under such circumstances! Similar moderating effects (of the relatively stable temperature earth covering) help keep the house cool in summer.

The effect of wind on the orientation of the earth sheltered house is therefore a serious energy efficiency determinant. Since further heat loss is incurred due to cold air infiltration through windows , doors and walls in the above grade structure, the earth sheltered structure (if properly covered and oriented), derives considerable advantage in respect to air infiltration. This is also an advantage in the summer, in keeping heat out. In fact, if properly designed and landscaped, the earth berming around earth sheltered structures may themselves provide deflectors to the wind and direct the wind and snow away from windows and doors.

Ventilation becomes a critical consideration for earth sheltered housing since this may not be as easily achieved as in the above grade structure. For this reason, special care is needed in the location of windows. It may be necessary to locate special "roof" outlets or wall outlets specifically for the purpose of allowing cross ventilation during the warm summer months. Mechanical devices such as exhaust fans can also be used (not a heavy energy load since these are very small motors) in hard to ventilate spaces such as washrooms, kitchens, storage rooms, as is quite often done in the standard house. Heat exchangers may be used on these fans so that in winter months, the heat is not expelled with exhausted air.

c) Designing for Site Considerations

1. View

One of the considerations in designing earth sheltered houses which must be carefully accounted for, is the concern for views to the outside. The consequence of not providing proper access to views would be to create a basement or "bunker-like" feeling inside the house. Therefore, when siting the earth sheltered house with windows facing southern exposure, the site must also be conducive and suitable so as to cultivate the potential for pleasing views on the south side of the house. Obvious concerns for privacy on the south side of the house is likewise to be noted. Proximity to higher structures in the neighborhood therefore, is a serious consideration when privacy is accounted for.

2. Topography

Because an earth sheltered house may be placed totally or partly below the prevailing grade line, water drainage must be a carefully considered site planning determinant. The type of soil, too, must be carefully considered for its ability to drain water.

From a topographic viewpoint, several alternatives can be considered:

i) Flat site, fully recessed

ii) Flat site, semi-recessed.

iii) Sloping site - one level.

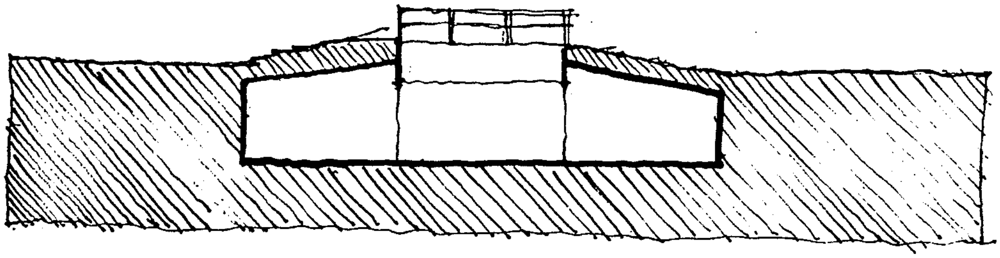
See Figure 42 for illustrations of the effects of these various site considerations.

> "Since earth sheltered housing usually requires a heavier structure and may be placed more deeply into the earth than a conventional house, considerations of soil type and ground water conditions are particularly important to site selection. Determination of the soil type is mainly important for proper structure design of footings and walls. Certain types of soil can be unsuitable due to their poor bearing capacity or their tendency to expand when wet. Ground water conditions are important to determine because of their impact on water proofing, as well as structural design. A high water table may require more costly structural and water proofing techniques and make a site unsuitable."[1]

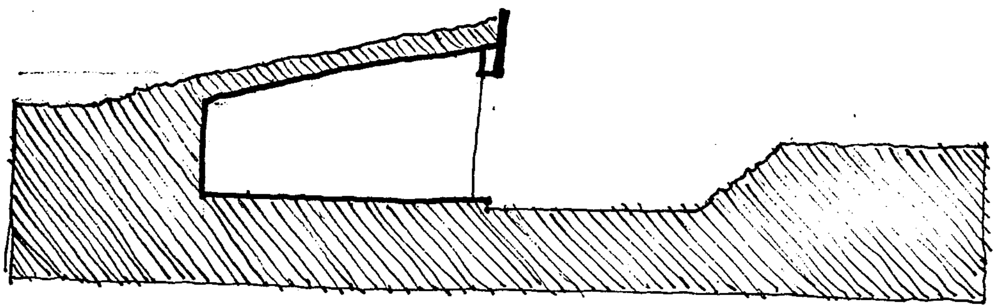
d) Designing the Plan

As stated earlier, one of the principal reasons for designing earth sheltered housing is the great benefit derived in terms of energy conservation. However, to effectively conserve energy, several factors must be considered in terms of the building's overall configuration.

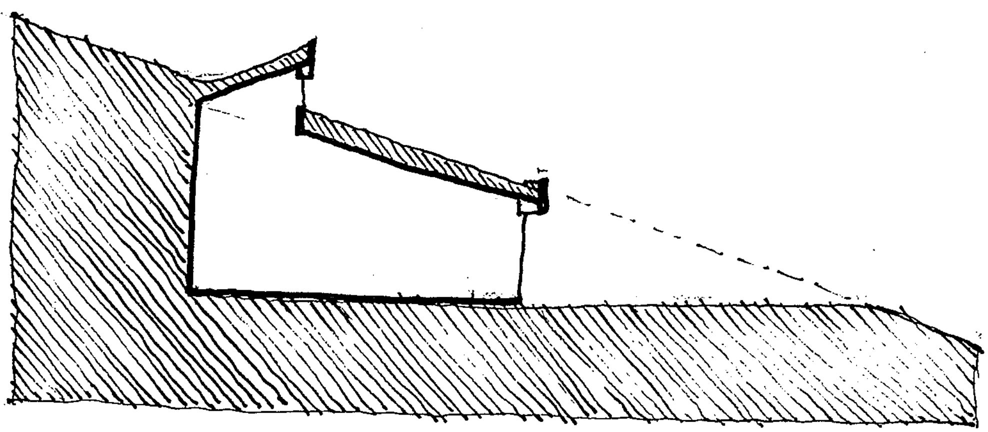
1 Ibid., P.26



FLAT SITE - FULLY RECESSED



FLAT SITE - SEMI-RECESSED



SLOPING SITE

EFFECTS OF SITE CONDITIONS

FIG 42

> "There are two ways in which energy conservation directly affects the overall configuration of an earth sheltered house. These are the development of a compact plan geometry and the maximization of the earth mass around the structure."[1]

The reasons for these two points are essentially very simple. The more compact the plan and therefore the less amount of area of enclosing surface will be exposed to the elements; the less will be the opportunity for heat loss. (See Figure 8).

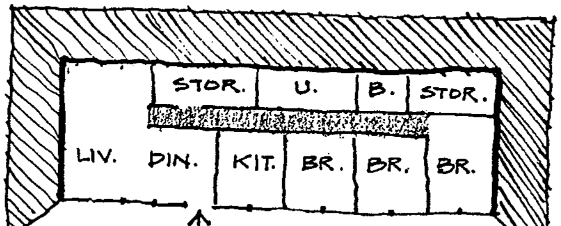
Maximizing the earth mass around the structure, gives the greatest opportunity to shelter the building's skin from exterior climatic elements.

> "From an energy conservation point of view alone, the ideal design would be a totally enclosed chamber well below the surface."[2]

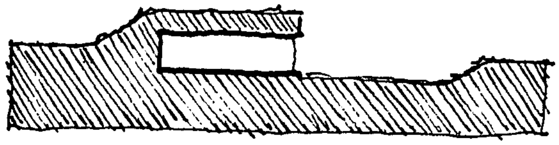
However, it is obvious that such a design would be totally unacceptable as a place to live because of considerations of sunlight, views, ventilation and psychological effects. In order to create a desirable and acceptable balance between all of these considerations, as well as create an energy efficient design, several "typical plans" are worthy of note. (See Figure 43). for illustrations of each.

1 Ibid., P.35

2. Ibid., P. 36

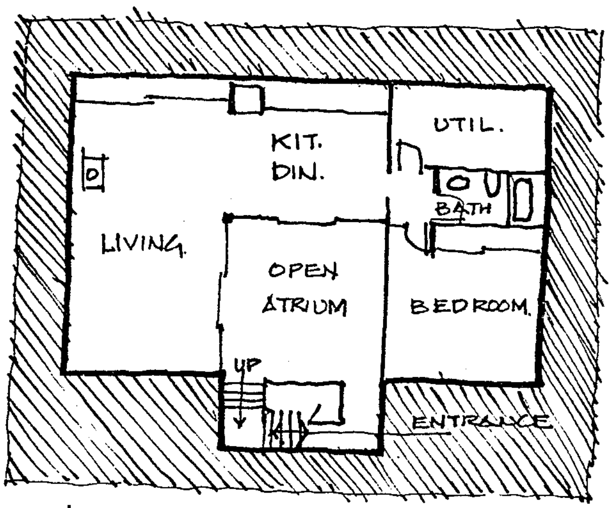


PLAN



SECTION

ELEVATIONAL PLAN



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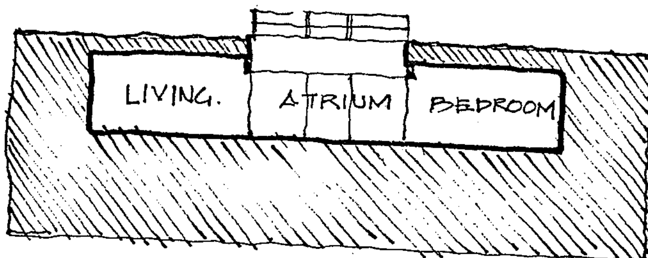
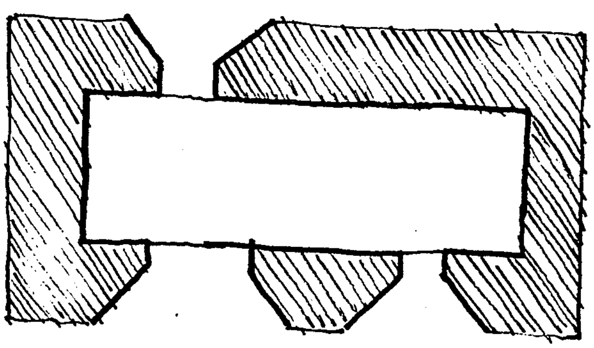
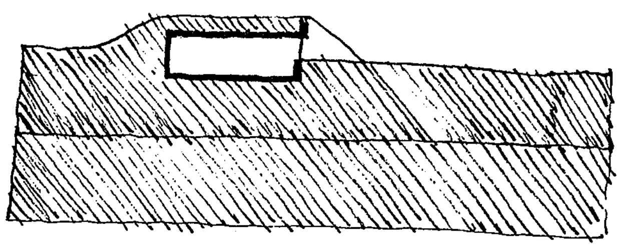


SECTION

ATRIUM PLAN



PLAN



SECTION

PENETRATIONAL PLAN

FIG 43

SOURCE: EARTH SHELTERED HOUSING DESIGN
THE UNIVERSITY OF MINNESOTA, UNDERGROUND SPACE CENTER
VAN NOSTRAND REINHOLD CO
1979

II TYPES OF PLANS

1) The Elevational Plan

This plan maximizes the effect of southern exposure by concentrating all windows to the south wall and completely sheltering the other 3 sides and top of the house. It should be noticed that this plan adheres to the ideas discussed earlier with respect to the internal organization of spaces by locating them in relation to their need for sunlight, view and ventilation, as well as for their buffering potential in heat transmission. This plan is not unlike the typical apartment block suite in that 3 walls are completely without windows and all windows are on an exterior wall, so that its internal "feeling" should be similar to a typical apartment suite (often found in apartment blocks with double loaded corridors) which faces south.

2) The Atrium Plan

The concept of the atrium plan is simply to locate all spaces around an internal courtyard or atrium so that all rooms face into this opening to obtain sunlight, views, ventilation and access. In warmer climates, such a courtyard can serve as an internal circulation space, giving access and interconnections to all spaces.

However, in colder climates, such as the Canadian Prairies, circulation must be gained through a corridor around the courtyard or, alternatively, by enclosing and "heating" the courtyard itself. The latter solution also overcomes the problem of snow building up in the courtyard cavity, were it to be left open.

One of the main problems of this type of plan is in resolving the circulation problem in cold climates (where there must be an internal corridor) if the courtyard is not heated and sheltered.

> "The circulation must now, however, pass between the spaces and the courtyard. It is acceptable to pass through open spaces such as a living, dining or even kitchen area in this manner, but private spaces such as bedrooms cannot be used as corridors nor can they be cut off from windows without adjusting present building codes.
>
> This problem of internal circulation in an atrium type of plan is basically a factor of size and building code requirements for windows .... Some alternatives are to use two or more atriums, additional window openings through the earth berms or a two-level design."[1]

On the other hand, the courtyard can become a very desirable focal point, giving access, privacy and controlled views and, because of its sheltered location, greatly diminishing heat loss, a fact which compensates for the fact that not all windows face south.

1 Ibid., P.41

3) The Penetrational Plan

The penetrational plan is one in which windows are allowed to be placed on any side of the house. In this respect, this plan is quite similar to a conventional house plan with a central hall or corridor and rooms located off this corridor. The earth berm is "penetrated" wherever windows occur or entrance doorways are located. However, as with the principles of design discussed for a conventional house (using passive solar gain), windows should be limited on east and west sides, eliminated along the north side and concentrated on the south. Likewise, this would affect the manner in which internal functions are ordered. This gives the advantage of grouping windows so that the earth cover can be maximized for the rest of the building without creating frequent and costly retaining walls in numerous locations.

The penetrational plan illustrates that a very conventional plan may be used in earth sheltered houses. However, this is not the most efficient plan from a n energy standpoint. The plan which maximizes the amount of earth cover while still maximizing the amount of southern exposure (and sheltering north, east and west exposures) is the most efficient. Its efficiency is further enhanced if the plan is designed as compactly as possible. This is the elevational plan.

III ADVANTAGES OF EARTH SHELTERED HOUSING

In the author's opinion, the internal "feeling" of the earth sheltered house, particularly the elevational and the penetrational plans, should not be significantly different from conventional house or suite plans. Thus, there should be no real psychological effect of living "underground".. There are, however, considerable advantages to be gained by sheltering houses with earth.

a) The structure receives an inherent layer of skin or cover which shields it from extremes in temperature, wind chill factors, air infiltration, hail damage, or any other type of potential damage resulting from extremes in weather conditions, i.e. tornadoes, hurricanes, etc.

b) Exterior capital cost and maintenance cost should be greatly reduced since expensive finishing materials (brick, wood trim, panelling and their up-keep), are eliminated or greatly reduced.

c) Because, for structural reasons, the house must be made of concrete, (i.e. basement construction), it is virtually fireproof, longer lasting, less vulnerable to vibration from exterior noise sources and can be very quickly constructed (very low labour costs).

d) Noise from exterior sources is virtually eliminated.

e) Heating and cooling earth sheltered houses can be done in much the same manner as conventional above grade houses. A combination of passive solar gain systems and mechanical back-up systems can be provided.

f) "Problems" of ventilation, structural loading, ground moisture and surface drainage have been cited as the major disadvantages and drawbacks of earth sheltered housing. However, the technology and practical expertise for dealing with these "problems" are in constant practice in dealing with them in other building types which have floors below grade. In the author's opinion, dealing with these matters is no more a problem than dealing with the "problem" of windloading, cladding of exterior surfaces, providing drainage off the building, etc., in conventional above grade buildings. The fact is that the expertise is available to deal with both situations very adequately. It simply means that one set of building practices is used for above grade structures, and another for below grade structures, in coping with the particular construction performance requirements of each.

g) Lifecycle costing should be lower for the earth sheltered than the conventional house, due to lower maintenance cost, and reduced energy costs. If it were possible to mass produce earth sheltered dwellings (if sufficient demand were available), the unit cost would drop substantially. Because of the large structural concrete components used in the earth sheltered house, labour costs are substantially below the conventional wood frame house.

h) "Active" solar collection systems can be used with this type of building and still achieve optimum orientation with its collectors since the collectors can be remote from the house and not be dependent on the house design, as is often the case with conventional above grade structures.

i) Visual pollution could be greatly alleviated: i.e. consider a subdivision built entirely of earth sheltered houses of the atrium plan. Garages too, could be earth sheltered and partially depressed into the ground. It could be like a park, with no houses or buildings above grade for acres (See Figure).

j) There are considerable benefits for greater land utilization and implications for urban planning. When structures are earth sheltered there is:

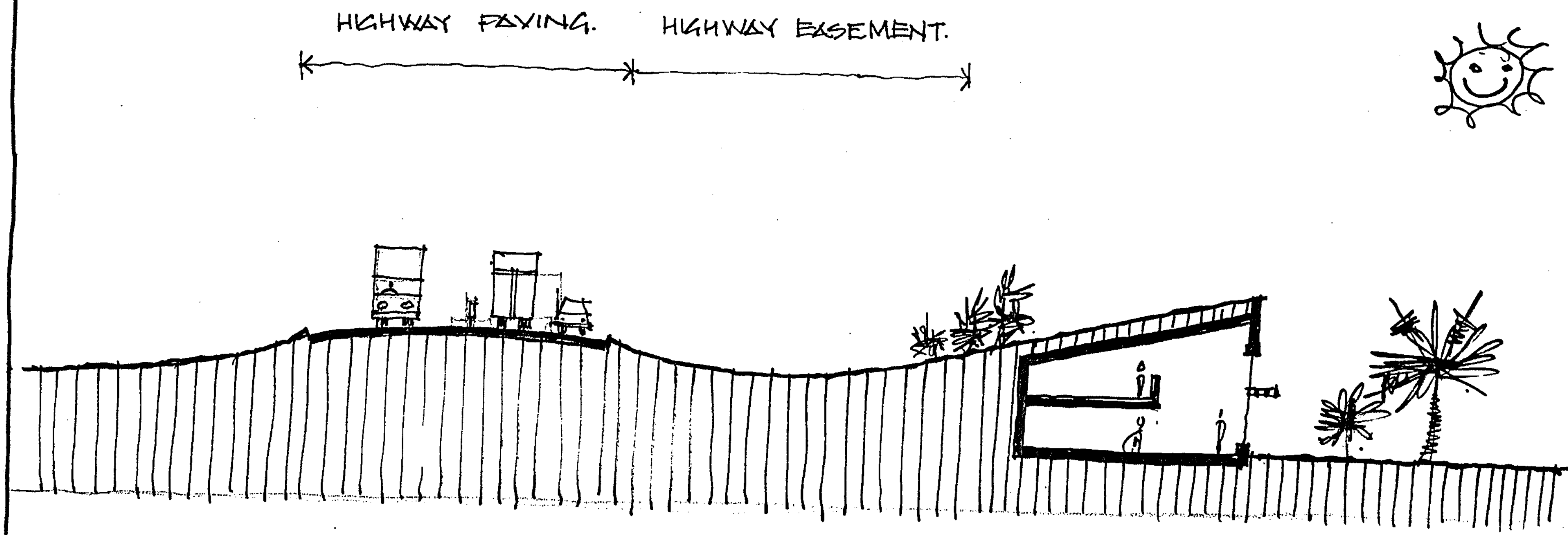
1. Greater use of the land on each individual lot since the house can occupy very little ground space. The space above the

Leaf blank to correct numbering

house can be used for gardens, lawn, etc. This also allows for city planners to increase the density of housing without reducing recreational and open space requirements; i.e. lots may be smaller and still afford the occupants an adequate area for outdoor living. Consequently, the number of units per acre may be increased.

2. Because of this advantage, lots may be made narrower, since no substantial space is required between structures on adjacent lots (i.e. for access and separation). If each lot is reduced in width by 5', this could amount to a 10% increase in the number of houses or reduction in street length - thereby conserving on transportation energy and other resources (building of roads, land, etc.).

3. Because of the great accoustical value of building underground, sites which were previously not suitable for housing (near freeways railroads, tracks, airports, etc.) could now be used for these purposes with little or no detrimental impact on the quality of housing. Greater densities could result with housing being located very close to arterial or collector routes. Both of these situations would result in possible savings in transportation energy. (See Figure 44).



EARTH SHELTERED HOUSING ON DIFFICULT SITE FOR HOUSING

FIG 44

The city would derive a greater intensity of land use and stand to gain substantially from increased property tax revenue, a more intensive use of services (without having to provide these services to locations which are increasingly remote from the city, as with suburbia).

4. Where an entire subdivision or multi-family residential complex has been placed "underground", the result can be a very desirable park-like environment. The proper integration of recreational facilities into such an environment would obviously be a very desirable place to live and play. As well, convenience stores and other facilities could be located in the midst of the neighbourhood (underground) without creating an eyesore, but still providing a very needed additional function at close proximity to housing.

IV DISADVANTAGES OF EARTH SHELTERED HOUSING

a) The psychological factor of living "underground" may be totally unacceptable to some. However, as discussed earlier, when viewed in an objective way, the "underground" house really need not be very differnt from some conventional houses and apartment suites (from the inside).

b) Structural loading of the roof can be substantial, depending on individual design. This would create excessive costs for roof, walls and foundation.

c) Where high water tables exist, this type of dwelling should not be built, unless budgets are generous enough to deal with the design for adequate drainage, pressure values in plumbing systems and drainage allowances to reduce hydrostatic pressure against walls.

d) Humidity can become a problem in some types of soil and climates. However, mechanical dehumidifiers can be used to overcome this problem.

e) Snow or rain can create flooding and plugging problems in the atrium plan. However, the elevational and penetrational plans are usually free of these problems, depending on the manner in which the berms and retaining walls are designed. Also, covering the atrium will serve to remedy this problem.

In conclusion, a quotation from an article written by William Morgan entitled "Up to Earth" in the April 1979 edition of Progressive Architecutre is appropriate:

"As more examples of earth-related architecture become available, to the public, and as fresh approaches to such design emerge, we may expect earth related structures to gain wider acceptance.

This is not to suggest that earth architecture is an appropriate solution to every problem - nor that the future of earth as a building material is solely a function of energy awareness. But man's almost forgotten tradition of earth architecture may now be on the verge of re-evaluation."

CHAPTER IV

SUMMARY AND CONCLUSIONS

In Part A, this thesis has focused on the physical aspects of planning and design for energy efficiency in housing. It has been shown that our past construction and planning practices have been energy wasteful and that through a rational approach to design, this waste can be greatly reduced.

This rational design approach can begin at the urban planning scale in dealing with the location of housing within the city. As a fundamental guideline, planners may greatly reduce the total energy consumption associated with housing, by reducing the need for travel by the private automobile. To this end, it has been shown that many technological developments in the transportation and telecommunications media may be combined with multi-purpose, multi-use planning to create environments designed for the pedestrian. These "villages" may encompass most, if not all, of the day to day activities of the inhabitans, thereby reducing the amount of intercity travel necessary.

As well, twelve design guidelines have been formulated and evaluated as energy efficient design solutions, relating to location of the house on its lot, the building's shape and orientation, internal organization of spaces and the building's shell itself. By comparing a traditionally designed house (Baseline House II) with one designed with greater energy economy in mind (Conservation House A), it was shown that a 92% saving in energy consumption could be realized by the application of seven of these design principles. Because of the low capital cost involved in the applica ion of the other five design principles, their application would also be desirable and effective in reducing energy consumption still further.

In addition to these twelve design guidelines, (which essentially are directed at ways of modifying the design of the conventional house), it has been shown that there are radical new approaches to design which are inherently effective in conserving energy. Two of these, the double-shelled house (Conservation House B), and the earth sheltered house (Conservation House C), are particularly useful and effective ways of sheltering the building against the climatic elements, or "keeping the heat in". In summary, Table 4 evaluates in general terms, the extent to which Conservation Houses B and C are able to comply with the twelve design principles outlined in Chapter II.

In addition there are natural heat gain systems which may be applied to the design of each of these houses, as well as the more conventional house, to give the buildings a greater ability to use the sun's energy for heating needs.

While these three (the double-shell, earth sheltering and passive solar gain systems) new approaches are still in their formative stages of

TABLE 4 CONSERVATION HOUSES "B" & "C" EVALUATION

DESIGN PRINCIPLES			DESIGN FEATURES CONSERVATION HOUSE 'B' - DOUBLE SHELLED								DESIGN FEATURES CONSERVATION HOUSE 'C' - EARTH SHELTERED							
			BUILDING ORIENTATION AND SHAPE	SUN CONTROL ON WINDOW AND WINDOW LOCATION	DOUBLE SHELL (INSULATION)	AIR AND VAPOUR BARRIER	SPACES ORGANIZED TO BUFFER AND SYNCHRON.	VESTIBULE	SOLAR HEAT GAIN SYSTM	HEAT STORAGE SYSTEM	BUILDING ORIENT. & SHAPE	SUN CONTROL ON WINDOW AND WINDOW LOCATION	EARTH SHELTERED (INSULATION)	AIR & VAPOUR BARRIER	SPACES ORGANIZED TO BUFFER & SYNCHRONIZE	VESTIBULE	SOLAR HEAT GAIN SYST.M	HEAT STORAGE SYSTEM
1	ORIENT LOT FOR MAX. WINTER SUN : SUMM. SHADE	WINTER	P						I		P						I	
		SUM.	P						I		P						I	
2	BUILDING SHAPE RECT. IN E-W AXIS	WINTER	I		I				P		P		P				P	
		SUMMER	I		I				P		P		P				P	
3	ORGANIZE SPACES FOR BUFFER EFFECT	WINTER			P		I						P		I			
		SUMMER			P		I						P		I			
4	SYNCHRONIZE LOCATION OF SPACE WITH PATH OF SUN	WINTER			I		I		I				I		I		I	
		SUMMER			I		I		I				I		I		I	
5	LOCATE WINDOWS ON SOUTH WITH SUN CONTROL	WINTER		I	I				I			I	I				I	
		SUMMER		I	I				I			I	I				I	
6	SEAL WINDOWS AND USE FIXED SASH IF POSSIBLE.	WINTER			P	I							P	I				
		SUMMER			P	I							P	I				
7	PROVIDE VESTIBULE AT ALL ENTRANCES	WINTER			I			I					P			I		
		SUMMER			I			I					P			I		
8	USE EXTERIOR INSULATED DOORS	WINTER			P			P					P			P		
		SUMMER			P			P					P			P		
9	INSULATE WINDOWS DURING SUNLESS HOURS, SHADE IN SUMMER	WINTER		P	P							P	P					
		SUMMER		P	P							P	P					
10	SHELTER BUILDING FROM WINTER WIND AND EXPOSE TO SUN IN WINTER.	WINTER			I				I				I				I	
		SUMMER			I				I				I				I	
11	INSTALL HEAT EXCHANGER AND VAPOUR BARRIER	WINTER			P	I							P	I				
		SUMMER			P	I							P	I				
12	INSULATE WALLS R-40 ATTIC R-50 BASE R-12	WINTER			I								IP					
		SUMMER			I								IP					
13	PROVIDE A NATURAL SOLAR HEAT GAIN SYSTEM.	WINTER		I	I				I			I	P				I	
		SUMMER		I	I				I			I	P				I	
14	PROVIDE A HEAT STORAGE SYSTEM.	WINTER			I					I			I					IP
		SUMMER			I					I			I					IP

I = INHERENT IN THE DESIGN CONCEPT (OR DESIGN FEATURE)

P = POSSIBLE TO INCORPORATE IN THE BUILDING DESIGN development, they represent ideas with great potential for the design of future energy efficient buildings. At this time, there is insufficient conclusive data on the exact design performance of these systems, though it is known in general terms that their application has been effective in reducing energy consumption.

It may then be concluded that energy conservation is possible through a rational approach to building design. Our dependence on machines and energy consuming mechanical equipment can be greatly reduced by better planning of our cities, better utilization of our communications media and better design of our buildings.

PART B

PUBLIC POLICY AND PROGRAMS

INTRODUCTION

In arriving at a list of basic design principles, a prime objective of Part A has been to determine a list of criteria which planners, architects and builders may use as a basis of rational design for housing. It is also recognized that these principles of design may be applied to housing (the single family house in particular) but also have a spin-off application to other forms of housing and in fact, other building types as well. (The reader should be conscious of the fact that while Part B again focuses on the single family house as a demonstration vehicle, ideas discussed herein have implications for many other types of buildings as well. However, elaboration on the full range of implications is considered well beyond the scope of this study).

The prime objective of Part B is in suggesting ways in which the public sector (in particular, the Federal Government of Canada for purposes of this study), may use these design principles as a basis for directing programs at encouraging the design and construction of energy efficient housing.

Implicit in such an investigation are answers to the following questions:

1. Is the Federal Government interested in becoming involved in programs designed to encourage energy conservation? If so, within what context?

2. Is there a willingness to address programs to any of the design principles outlined in Part A of this study? If so, give examples.

3. Suggest ways in which programs may be structured to encourage the use of these design principles. Are there precedent examples of programs which are being used to encourage the construction of certain types of buildings (and having specific design qualities) in the past? If so, can these programs and others be used to encourage the design of energy efficient housing?

CHAPTER I

CAN PUBLIC POLICY ENCOURAGE ENERGY EFFICIENT DESIGN?

It is an expressed objective of the Federal Government of Canada to encourage energy conservation in all sectors. In fact, the Federal Government has already embarked on several programs designed to encourage energy conservation in buildings, equipment, transportation and industry.

> "In February 1976, the Government of Canada announced a number of new federal government initiatives directed at strengthening the energy conservation program introduced one year earlier. The new initiatives are briefly summarized below.
>
> Automobiles:
>
> New mileage standards were introduced for automobiles sold in Canada.......
>
> Buildings:
>
> The Government of Canada has announced new guidelines for the design, construction and operation of energy efficient buildings of all sizes in Canada which will be completed before the end of 1976. These guidelines will either be adopted as part of the National Building Code or be embodied in new federal standards. In addition, encouragement and assistance, through the revision of existing loan and grant programs to emphasize the purchase of insulation material and energy saving equipment.

Appliances:

Minimum energy efficiency standards are being reviewed for furnaces and prepared for major home appliances and office equipment.

Industry:

Existing industrial assistance programs are now being administered in a manner that supports energy conservation, including the recovery of "waste heat"...

Federal Government:

Specific elements of the Government's in-house conservation program were announced in early 1975..... Beginning in the 1976-77 fiscal year, all government departments and agencies have been asked to decrease their energy consumption by 10% and target to hold energy use at that level for the next 10 years."[1]

From this list it is evident that the Federal Government intends to act on a broad range of areas using several programs to achieve its objectives. With specific reference to "energy conservation" in buildings, several things have already been accomplished:

1. The book entitled "Measures for Energy Conservation in New Buildings, published by the National Research Council in 1978, contains the design and performance standards referred to above.

2. Several publications have already been made by the Department of Mines and Natural Resources designed to illustrate to the homeowner

1 Op. cit., Workshop on Alternate Energy Strategies (WAES) P. 53

ways and means of "keeping the heat in" and otherwise saving the energy around the house (and car).

3. CMHC has published the book entitled "The Conservation of Enery in Housing".

4. The Federal Government building projects are required to meet energy standards as set out in "energy briefs" applicable to each building program. The author has had occasion to work with one of these briefs while working as designer and project architect on the $34 million Government of Canada Building, Calgary, in 1975 and 1976.

There are numerous other specific examples that may be cited, however, the above give a good cross section of the types of work and effort currently being done by the Federal Government. It is therefore, clear that the Federal Government, through its administrative entities, has fostered a number of studies and publications designed to advance the cause of energy conservation in buildings.

However, in most cases, this has taken the form of stipulating design performance and standards for various building components viewed in a piecemeal fashion (windows, walls, roofs, mechanical equipment, lighting and electrical equipment, etc.) in the form of codes and performance briefs. This is predominantly the case of the Items # 1 and #4, mentioned above. Item #2 mentioned above, consists essentially of "household tips" to the homeowner designed to recommend ways of conserving energy on a day-to-day basis. This is a very valuable input into the total energy conservation drive since it has been estimated (as stated earlier in this study), that 50% of every consumption can be due to occupant lifestyle.

The CMHC handbook (Item #3 above), "The Conservation of Energy in Housing" deals specifically with housing and deals quite extensively with the up-grading or retrofit potential of existing single family housing in Canada. This includes a look at mechanical equipment as well. Though the book takes a look at basic guidelines for the design of housing and makes recommendations on that basis, its focus is on the conventional house design and does not deal with the house as a passive solar collector, nor does it deal with alternate (energy efficient) design concepts possible for Canadian housing.

It is with the intent of adding a new dimension to this on-going work that the author has selected the specific topic and subject matter of this study. In taking the approach of passive solar design, this study forms a compatible new dimension to the work already done by CMHC, even though there are minor areas of overlap necessary when presenting a comprehensive look at this topic!

In addition to the writing of regulations and guidelines, the Federal Government has also sponsored building design competitions to attract novel and innovative design solutions. The LEBDA (Low Energy Building Design Awards) is one example. CMHC has been instrumental in sponsoring housing design competitions.

As well, various programs have been designed and run by various levels of government to assist homeowners with energy efficiency up-grading. CHIP (Canadian Home Insulation Program) is one such example.

However, simply publishing volumes of material on energy conservation guidelines does not necessarily have its desired effect in encouraging the implementation of these guidelines in construction. Where they are written into codes and regulations they serve to enforce implementation; and that is one way of accomplishing this end. From the author's experience, however, very often code regulations tend to take a very localized, limited and piecemeal approach to enforcing standards. Very often, complying with these regulations proves to be very limiting to the design concepts that may otherwise be possible in achieving the same end results. For that reason, it is almost dangerous to embark on a program of code writing before first investigating several broad approaches to the design of energy efficient buildings. However, faced with the immediate and urgent problem which energy conservation is to this nation, it is logical that retrofit solutions be found first, in an attempt to up-grade existing buildings and, it is inevitable that many code regulations and new building standards will be determined from knowledge gained by the piecemeal up-grading of building components. The approach taken on this thesis is one of determining design principles by which housing may be designed on a conceptual level in order to conserve energy. These principles can then form a basis of writing codes and regulations which recognize the importance of the broader approach to solving the problem. The writing of codes and regulations can be a spin-off benefit of this study, therefore.

It is recognized that no single building will be able to incorporate all of the design principles outlined in this thesis. Each situation will warrant its own special solution, based on many, if not most, of the basic principles. What is important at this stage is that designers and builders are encouraged to build according to these principles by developing programs which give incentives to do so. The following chapter focuses on recommending ways in which this may be done.

CHAPTER II

SUGGESTIONS FOR INCENTIVE PROGRAMS

The Federal Government has already indicated a willingness and a need to embark on incentive programs designed to encourage energy efficiency in housing. So far, this has been done in retrofit programs.

SAMPLE:

Established Precedent Using: GRANTS AND SUBSIDIES

Design Principle:

A very basic design principle is to adequately insulate walls, attics and basement foundation walls in existing buildings.

Recommended Standards:

Walls: R-20

Attic: R-40

Basement Walls: R-12 (min.)

These are desired levels of insulation realizing that many existing houses will not be able to be upgraded to the full extent recommended because of existing design limitations. In many cases, insulation levels above these are attainable and being practised.

Incentive Program:

The Canadian Home Insulation Program (CHIP) gives grant subsidies to homeowners, tenants and corporations to pay for a portion of the insulation and labour (maximum grant $500.00) providing the home was built before 1962.

This may be an acceptable way of providing incentives to comply with a retrofit task as simple as upgrading insulation standards. However, it does illustrate an example of the manner in which public policy objectives may be achieved through an incentive program. It may be possible to use the same vehicle of grant subsidies in encouraging homeowners of new or existing housing to implement other design principles as well.

For example, the installation of insulated shutters and drapes on windows could easily be accomplished through a grant program. Since it has been estimated that single glazed windows lose approximately 20 times as much heat as a standard 3 1/2" insulated wall, of equal area, it stands to reason that the energy savings in many houses would be greatly improved by installing such shutters and drapes. The cost benefit, assuming a reasonable square footage cost of these devices, when mass produced, would be substantial as well.

An even more cost effective way of achieving the same end (from the government's point of view) would be for the Federal Government to subsidize the interest (assume 12%) on loans made by homeowners for the installation of such devices. This would mean that instead of putting out actual cash for these improvements, only 12% of the capital cost would be invested (over a period of one year) to achieve the same ends.

The Federal Government would derive benefits in other ways as well. It is conceivable that such a program would create employment in the construction industry. This would decrease unemployment payments in sectors of the economy that are plagued with high unemployment. Also, a new industry, which will pay income tax, will be created. These benefits may be enough to offset the costs to the Federal Government.

Many other vehicles are available to the Federal Government in providing incentives to builders and designers of new housing, so that they are encouraged to comply with the design principles outlined.

For example, the Federal Income Tax Act has been used to provide incentives for the use of energy efficient mechanical equipment.

SAMPLE:

Established Precedent Using: THE INCOME TAX ACT

Design Principle:

Use energy efficient mechanical equipment in the design of mechanical systems:

Recommended Standards:

Variable, depending on specific industry and use of the component. Generally, those falling under Class 34 of the regulations to the Income Tax Act.

Incentive Program:

The Federal Income Tax Act provides for rapid write-off capital cost allowances, C.C.A. (otherwise termed "depreciation") for capital equipment falling under Class 34 of the Income Tax Act.

> "4224: Energy Conservation Equipment Fast write-off provisions apply to equipment that contributes to the conservation of energy (Class 34). Such equipment may be depreciated at a rate of up to 50% in the year of registration. The unclaimed balance may be claimed in any subsequent year."[1]

1 Canadian Master Tax Guide
C.C.H. Canadian Ltd. Publishers 1977 P.235

This type of incentive program is of particular effectiveness in encouraging the use of energy efficient capital investment in new buildings. Similarly, it may be possible for the Federal Government to provide incentives to homebuilders to use passive solar gain design components.

For example, the design and use of south facing greenhouses, designed to comply with predetermined standards, may be itemized in cost of materials and this component of the building written off for tax advantages to the homeowner. The same could apply to the use of designated energy efficient back-up systems in a house. For example, exhaust fans, wood burning stoves, computer controlled window shutters, etc. could be given tax advantages and therefore would become preferred choices for use by builders and owners.

The exact extent of the write-off priviledge (percentage) could be determined after a cost benefit study has been done for the use of the particular devices designated together with total cost and spin-off advantages to the Federal Government. The fact of the matter is that, at present, there are no tax write-off advantages given to homeowners for the use of any devices in the home so that any move in this direction would be an advantage to the homeowner. Several industrial commercial use buildings already qualify for such tax advantages when using specific designated components.

The "Tax Incentive":

The "tax incentive" program approach is not a new one. It has been used for different policies with different objectives in many countries. The United States, for example, is presently proposing to draft new legislation and regulations to its federal income tax act with the specific policy objective of encouraging energy efficient housing design, and Canadians could learn from the United States' example:

> "Sunshine may be free, but the equipment to harness it is costly. Thus, the National Energy Act contains various provisions designed to stimulate the manufacture of solar equipment, help to lower its cost and thereby make solar energy systems more attractive for widespread use......'
>
> It specifies that 30% of the first $2000.00 and 20% of the next $8000 spent on solar equipment (for a total of $2200) can be whacked right off the top of your income tax bill.
>
> ....The only question is how to cut cost so that solar power can be used more widely."1

Design principles on a much broader scale may be encouraged through incentives in the Tax Act as well. For example, in Canada, the "MURB" program (Multi-Unit Residential Building) was implemented on November 18th, 1974 with a specific purpose. This was to encourage private investors to channel their money into the construction of rental housing (multiple unit residential buildings). The incentive for doing so was that high income earners could once again (this provision in the Act was allowed for any rental building before 1972), depreciate their buildings at an annual rate (5% or 10%) to generate "rent losses" which could be tax deductible from the owner's personal income. This "tax shelter"

1 Smay, E. "Solar Tax Incentives", Solar Energy Handbook 1979 published by Popular Science and Times Mirror Magazines, New York 1979 P.7

provision had the desired effect of suddenly fostering the construction of thousands of new residential rental accommodations in almost every city in Canada. Subsequent to the success of the program, regulations within the Income Tax Act have been changed, thereby altering the C.C.A. annual amount to 5%. On several occasions, since 1976, the regulations have been changed, in stipulating the type of construction, starting date and amount of C.C.A. allowed under that phase of the program.

The interesting thing to note is that the regulations to the Act could be changed from time to time and thereby encourage the use of certain types of building materials, with important implications for the design of buildings.

SAMPLE:

Established Precedent Using: THE INCOME TAX ACT

Design Principle: (in this case, policy objective)

Canada requires more capital from the private sector to be channeled into the construction of new residential rental accommodation.

The Incentive Program:

1975 Provision:

"For purpose of the Income Tax Act, property which qualified fall into two classifications, Class 31, being a masonry or steel and concrete building and as such eligible for depreciation rates of 5% per annum on declining balance, or Class 32, being a wood frame or frame and stucco or metal siding building which is eligible for depreciation rate of 10% per annum on a declining balance."[1]

1978 Provision:

"The tax shelter provision in the capital cost allowance regulations, designed to stimulate the contruction of multi-unit buildings (Class 31 and 32) is to be extended for a further year to include buildings commenced before 1979. It permits the offset against other income."[2]

Similarly, it would be possible for the Federal Government to use the Income Tax Act as a vehicle through which housing design could be made more energy efficient.

Separate building classifications could be given to rental housing which are earth sheltered; passive solar heated buildings, having only wood burning stoves as a back-up; or double shell construction. Each of these types of rental accommodations (assume townhouse or row house applications) could then qualify for similar "MURB" allowances and have an equally successful response in terms of the number of units being built as a result.

1 Topical Law Report, Tax Topic Report
C.C.H. Canadian Ltd. Publishers 1977 P.3

2 Wright, J.Harvey, Multiple Unit Residential Building (MURB) and Individual Tax Shelters
A.E. LaPage, Investment & Professional Services Co. Newsletter P.1

As another alternative to this "building classification approach", buildings could be accessed according to the number of energy efficiency design principles they follow. Each design principle could be assessed for its particular effectiveness in conserving on energy and the total points accumulated will qualify it for certain types of financing.

For example, CMHC standard for residential buildings could be up-dated to include these design principles. Based on the "point score" of a building, that design may qualify for CMHC approved "energy loans" which may have preferred interest rates, subsidized by the Federal Government.

<u>SAMPLE</u>:

<u>Established Precedent Using: PREFERRED INTEREST RATES</u>

<u>Policy Objective</u>:

To provide new accommodation at low rents for low income earners.

<u>Incentive Program</u>:

Limited Dividend (L.D.) mortgage loans giving apartment block builders and owners low interest rates in return for keeping rents low on rental units.

A similar model could be used for "point scoring" of projects on an "energy efficiency rating scale" as described above, so that preferred interest rates could be attained. This model could apply to single family housing as well as multiple unit rental accommodations.

In order to encourage "energy wise" living habits, renters in these subsidized energy efficient buildings could qualify for low rents as long as their energy consumption is below certain predetermined quantities. Above those quantities (being adjusted on a month to month basis to compensate for weather conditions) renters could be penalized. Similarly, homeowners could lose their preferred interest rate status or pay a penalty if their energy consumption exceeds certain seasonally or annually adjusted quantities.

One final area which is mandatory for attention by the public sector at all levels, is the issue concerning the "right to light". Solar heat, whether gained through active or passive systems, requires one principal ingredient - sunshine. When it becomes a matter of deriving energy from the sun, the individual citizen's right to uninterrupted access to the direct sunlight becomes a matter of paramount importance - a right which must be protected by law.

It is clear from the points raised in this chapter, there are many possible programs upon which the public sector may embark in order to encourage the construction of energy efficient buildings. While energy conservation in buildings has been a stated objective of the Federal Government, this policy objective must be put into action through the use of various tools available to it.

CHAPTER III

CONCLUSION

The author has focused this thesis on a discussion of the issues involved in rationalizing the design of energy efficient buildings (housing in particular) and in recommending ways in which the public sector may use this rationale toward the design of programs which encourage the construction of energy efficient buildings.

The design principles outlined in this thesis provide a comprehensive base or bench mark from which architects and planners may approach the design of buildings in the future. These principles give us a new attitude, a shift in perception, a new rationale, in our way of viewing the building within its climatic and urban context.

Almost every guideline outlined in this study can provide the framework for further intensive study, experimentation and investigation in a specific area. Such localized and concentrated efforts can lead to the establishment of specific quantities, standards, measurements and relationships for the design of Canadian buildings. A spin-off benefit of this could be the writing of building codes and other energy efficiency regulations. In this way, precise measurable criteria may be attainable which reinforce the basic design principle. All too often, it is the opposite process which takes place, where design concepts and principles become limited by piecemeal code and building regulations too hastily conceived. For this reason, this study has focused on a discussion of issues and relationships rather than specific quantities.

Energy conservation (in buildings) has been stated as a national objective. If we, as planners and architects, can state the principles by which we propose to design energy efficient buildings and cities, and isolate possible directions in which the public sector may take in encouraging the design of these facilities, then we have gone a long way in advancing the cause of energy efficiency and conservation in architecture and town planning.

This has been the purpose and objective of this study.

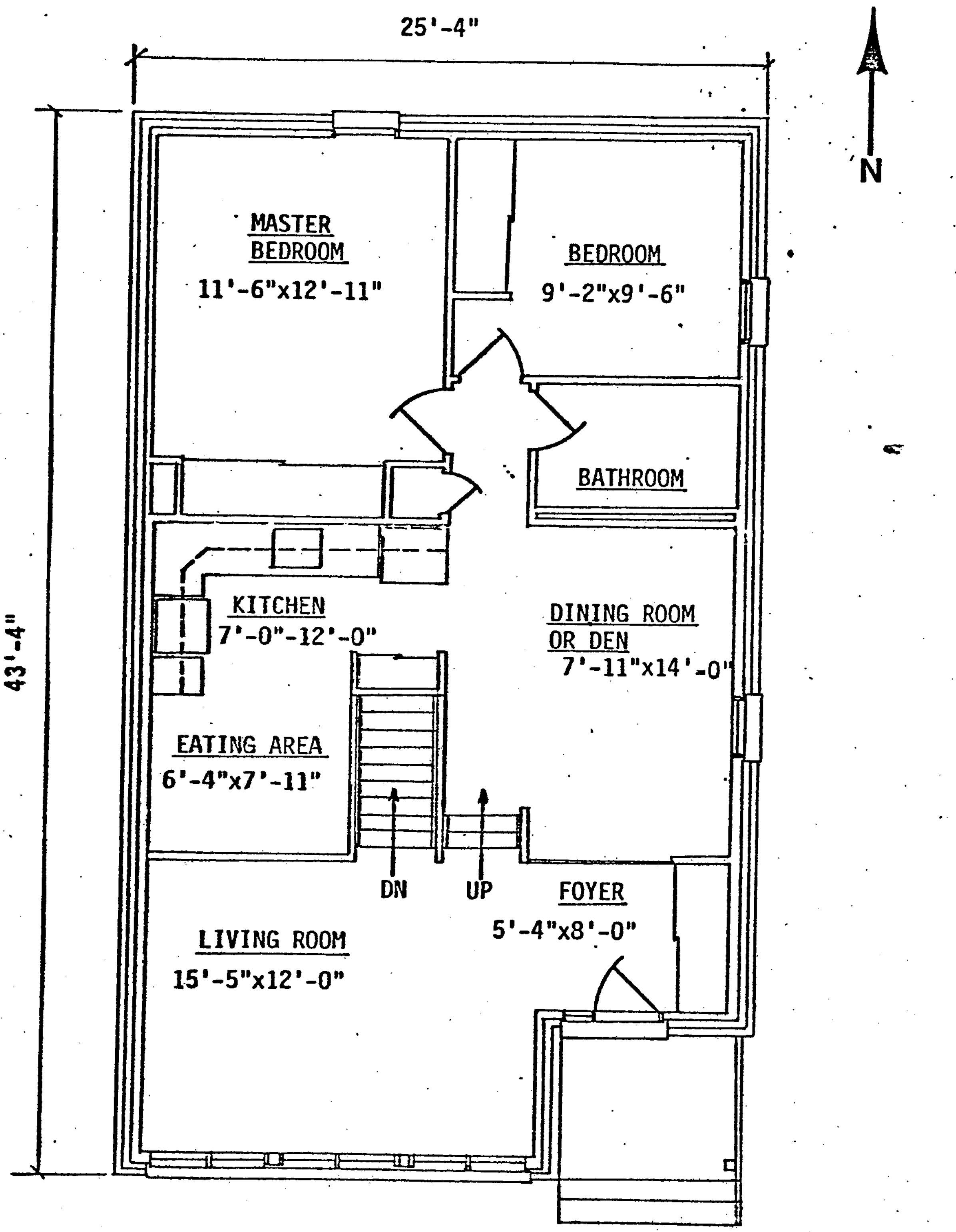
APPENDIX

APPENDIX A

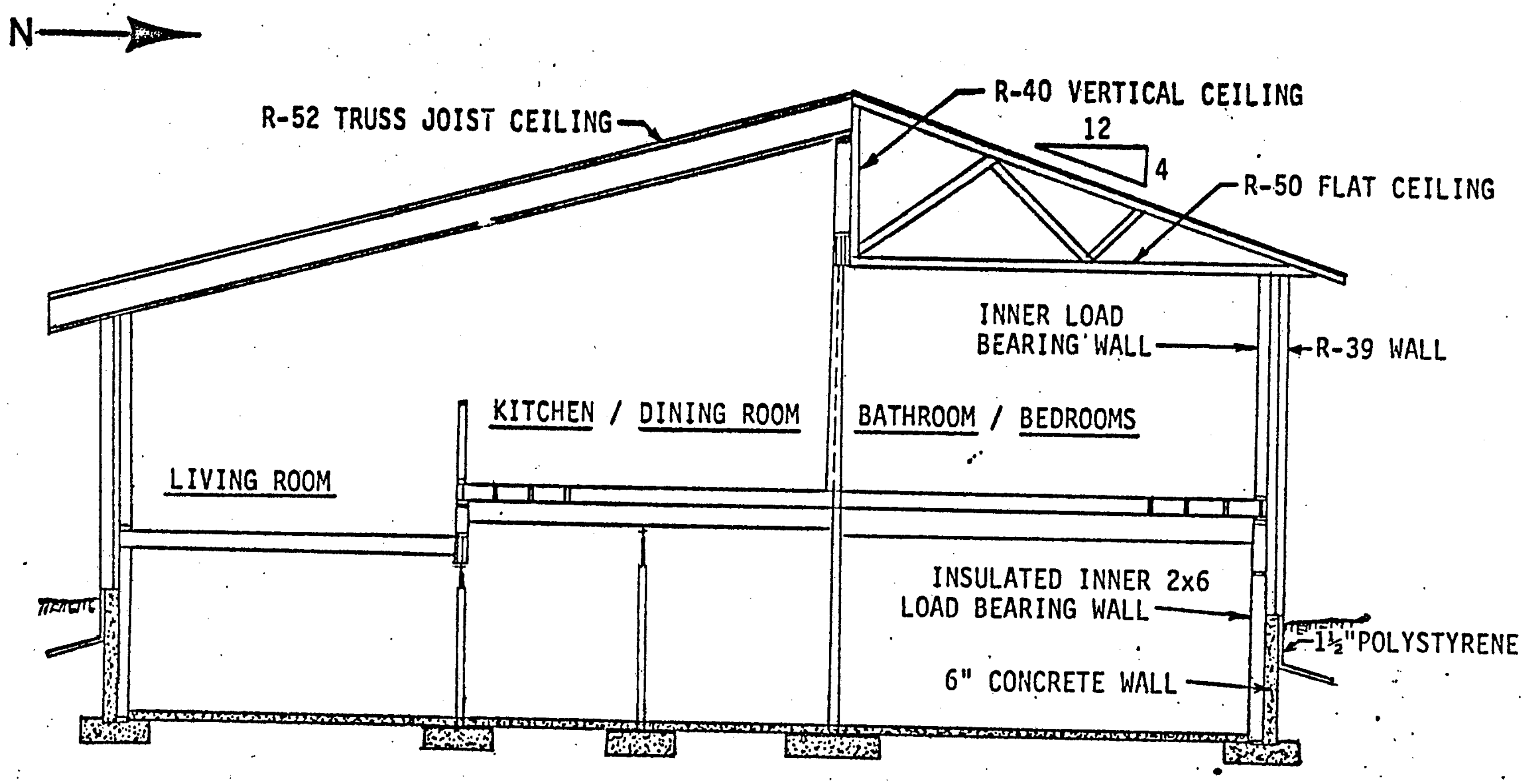
CONSERVATION HOUSE "A"

Source: Drawings taken from a study prepared by UNIES LTD. of Winnipeg, Manitoba.

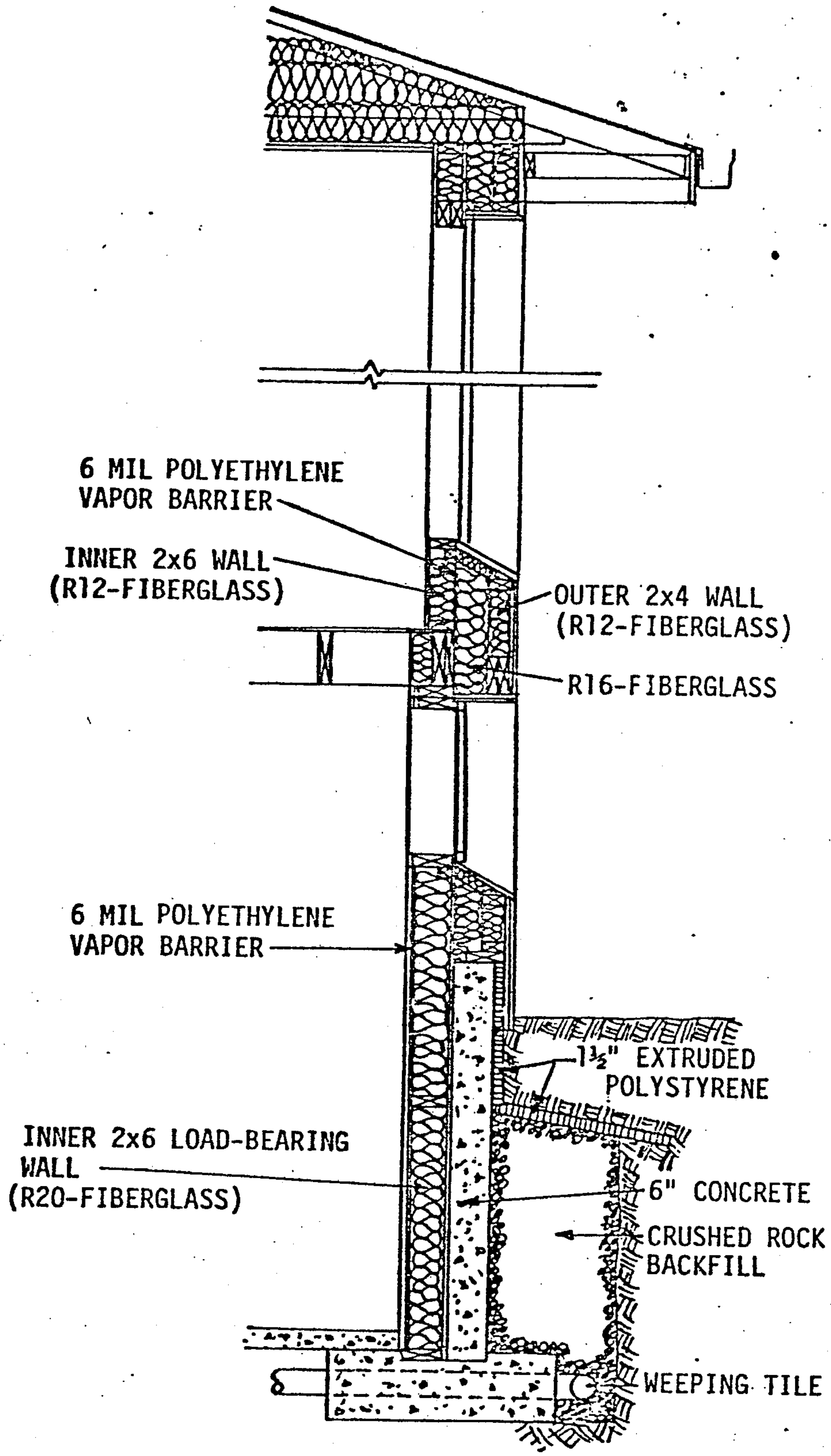
Drawings were presented at a conference: "Low Energy Solar Housing Workshop" sponsored by the Manitoba Chapter of the Solar Energy Society of Canada Inc. at the University of Manitoba, 15 Feb 80.



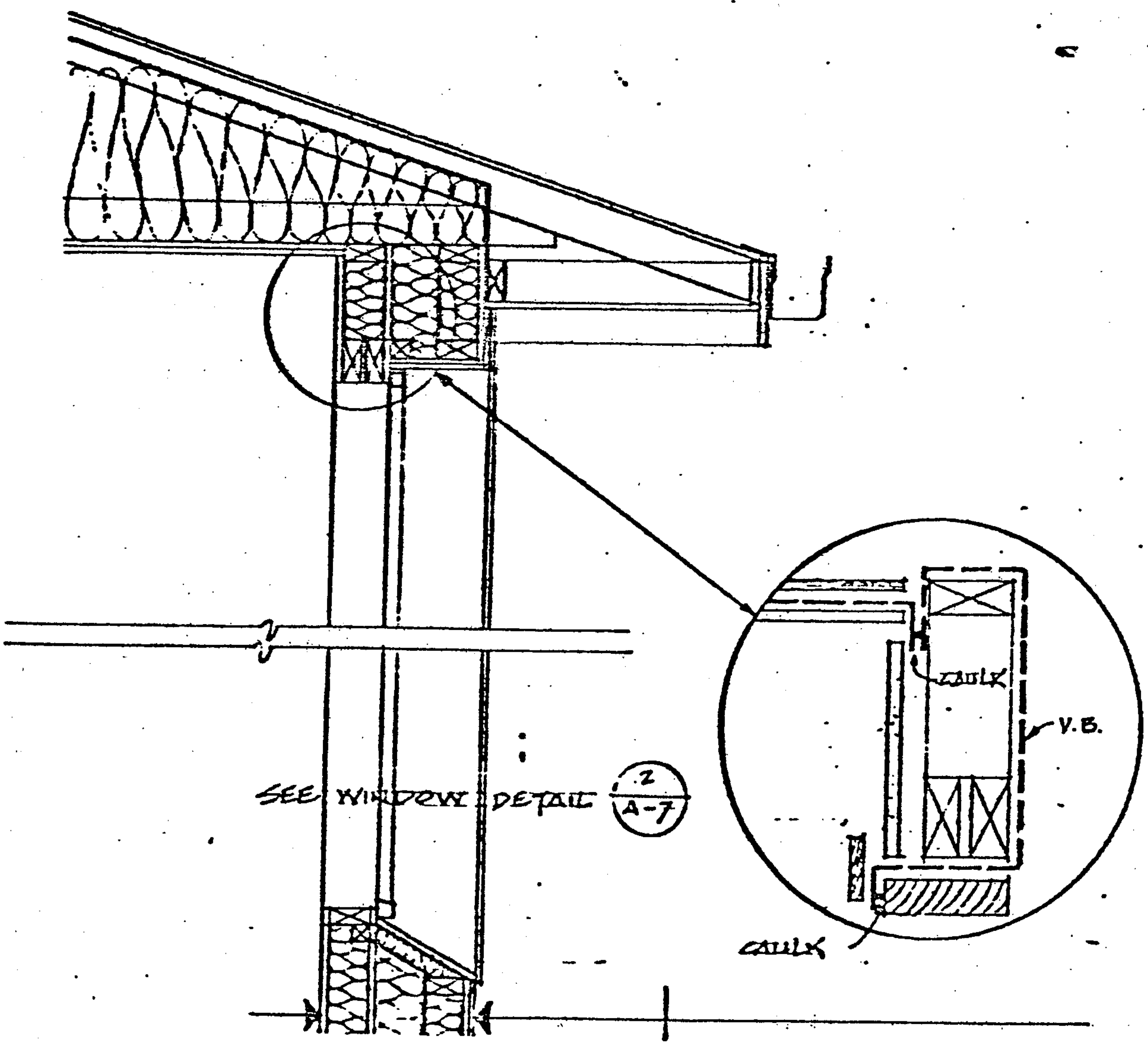
FLOOR PLAN OF
FINAL DESIGN

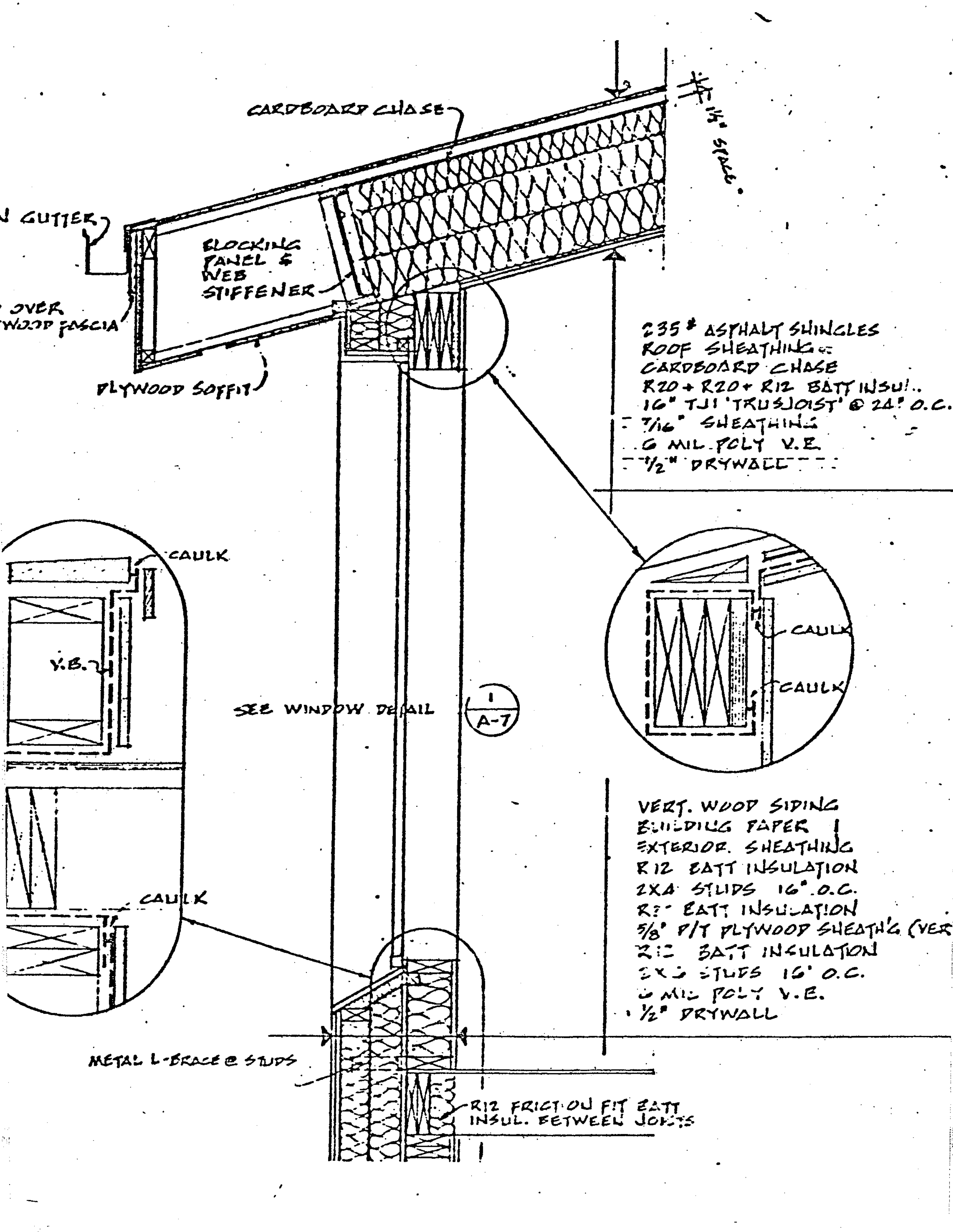


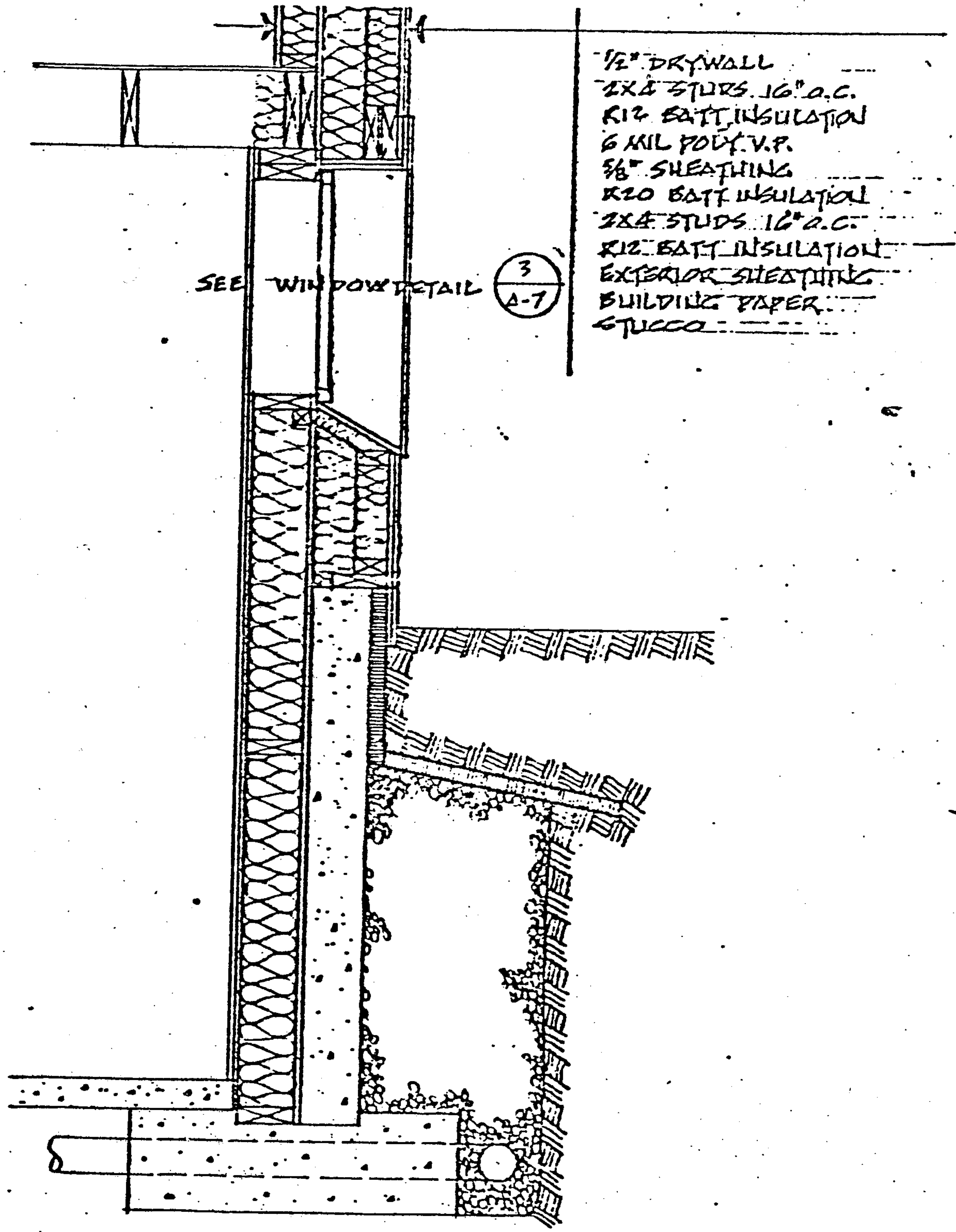
CROSS SECTION OF
FINAL DESIGN



CROSS-SECTION OF HOUSE

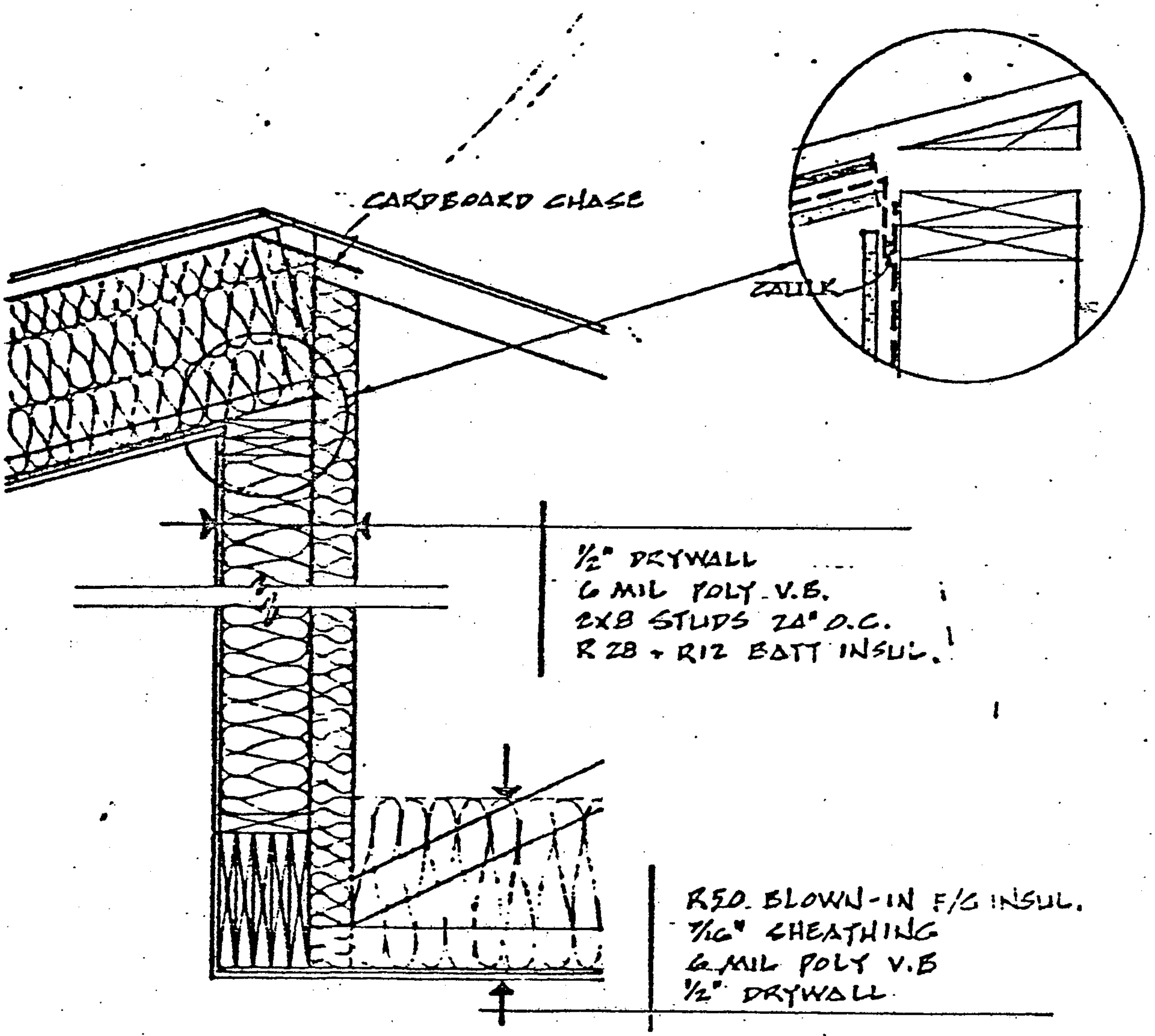

SEE WINDOW DETAIL
2
A-7
CAULK
V.B.
CAULK


CARDBOARD CHASE
1½" SPACE
GUTTER
BLOCKING PANEL & WEB STIFFENER
OVER WOOD FASCIA
PLYWOOD SOFFIT
235 # ASPHALT SHINGLES
ROOF SHEATHING
CARDBOARD CHASE
R20 + R20 + R12 BATT INSUL.
16" TJI 'TRUSJOIST' @ 24" O.C.
7/16" SHEATHING
6 MIL POLY V.B.
1/2" DRYWALL
CAULK
V.B.
SEE WINDOW DETAIL
1
A-7
CAULK
CAULK
CAULK
VERT. WOOD SIDING
BUILDING PAPER
EXTERIOR SHEATHING
R12 BATT INSULATION
2X4 STUDS 16" O.C.
BATT INSULATION
5/8" P/T PLYWOOD SHEATH'G (VER
BATT INSULATION
STUDS 16' O.C.
MIL POLY V.B.
1/2" DRYWALL
METAL L-BRACE @ STUDS
R12 FRICTION FIT BATT INSUL. BETWEEN JOISTS

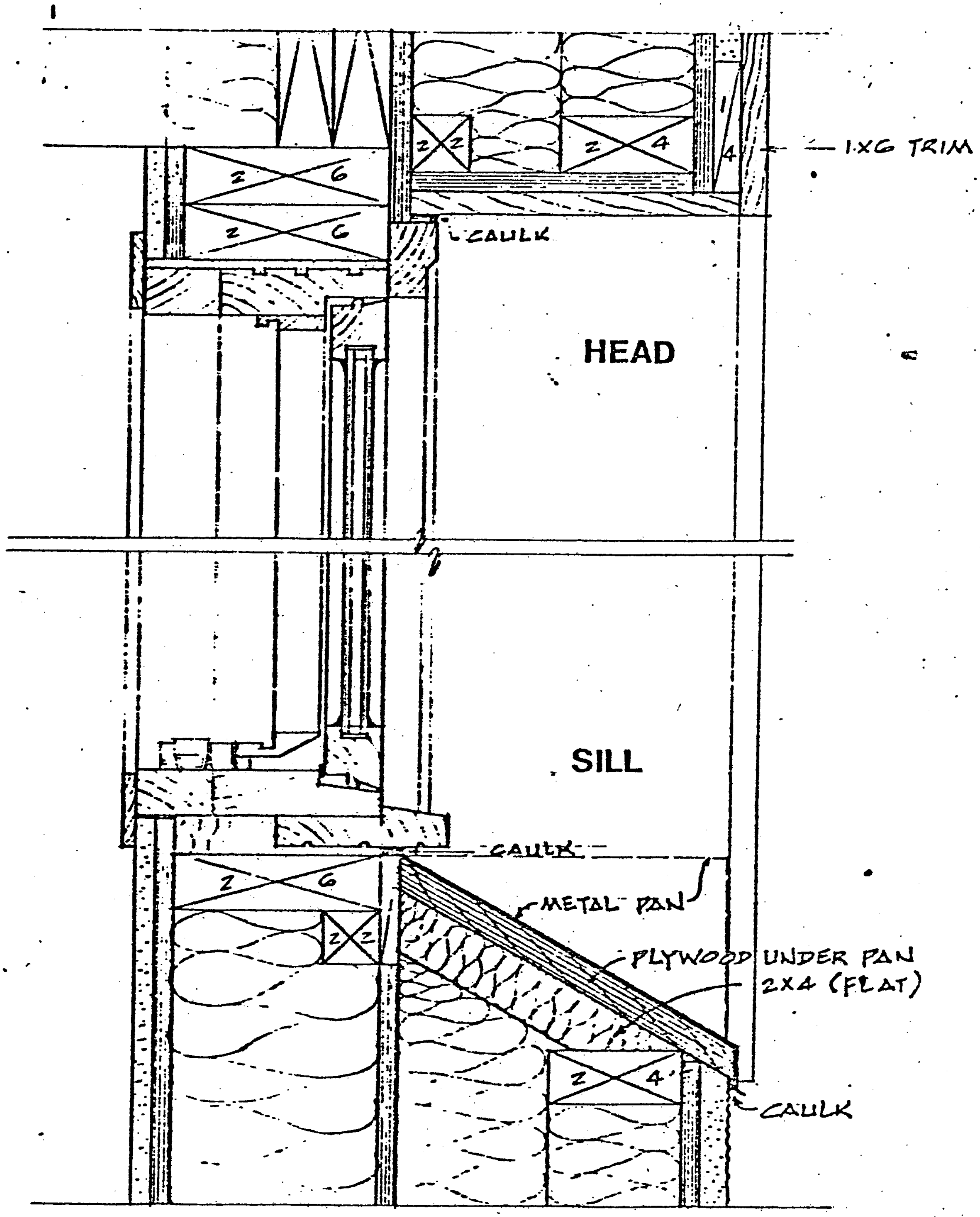


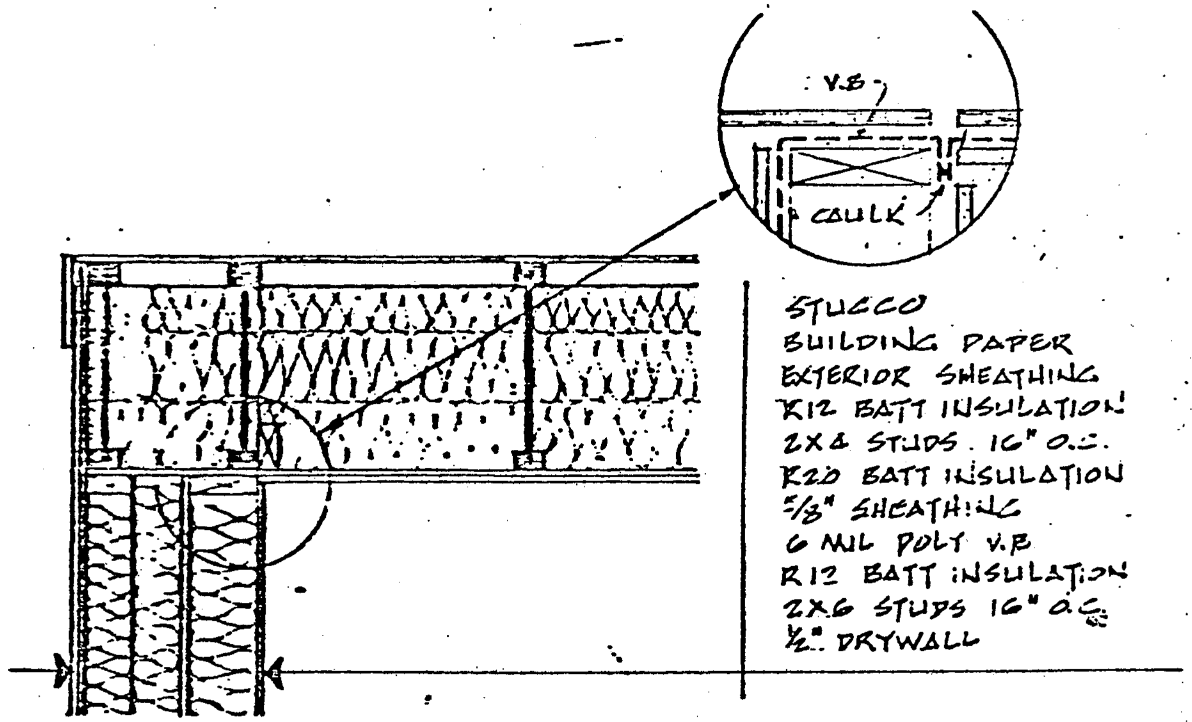
SECTION THROUGH REAR WALL

SC 3/4" = 1' - 0"

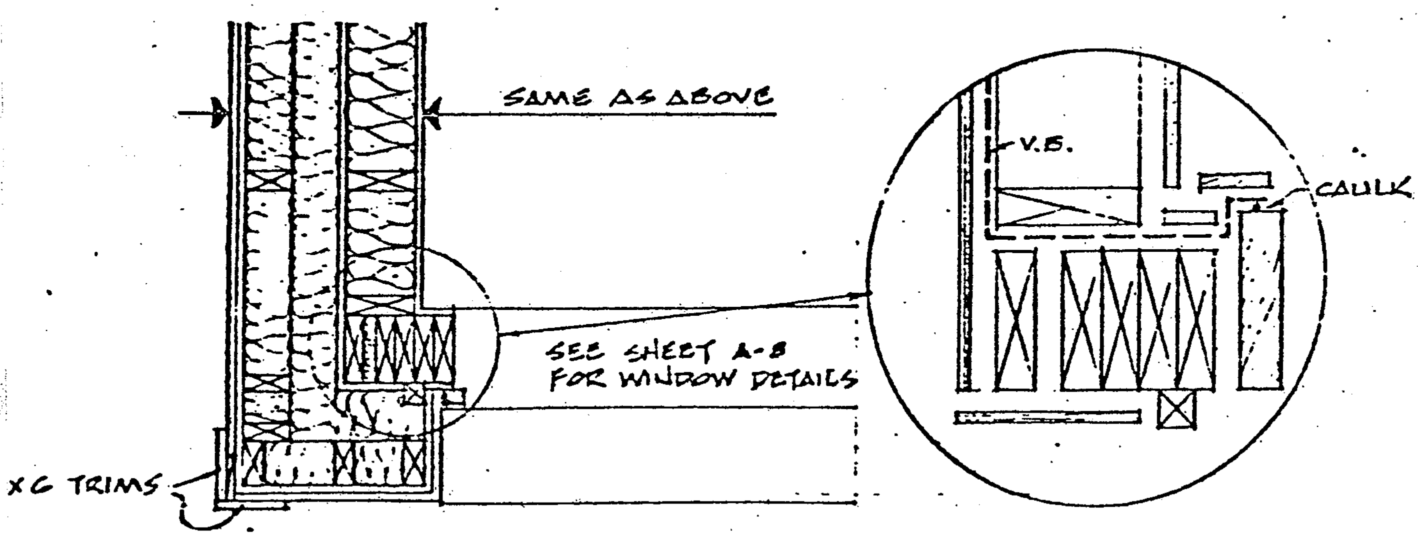


2 SECTION AT RIDGE
SC 3/4" = 1' - 0"

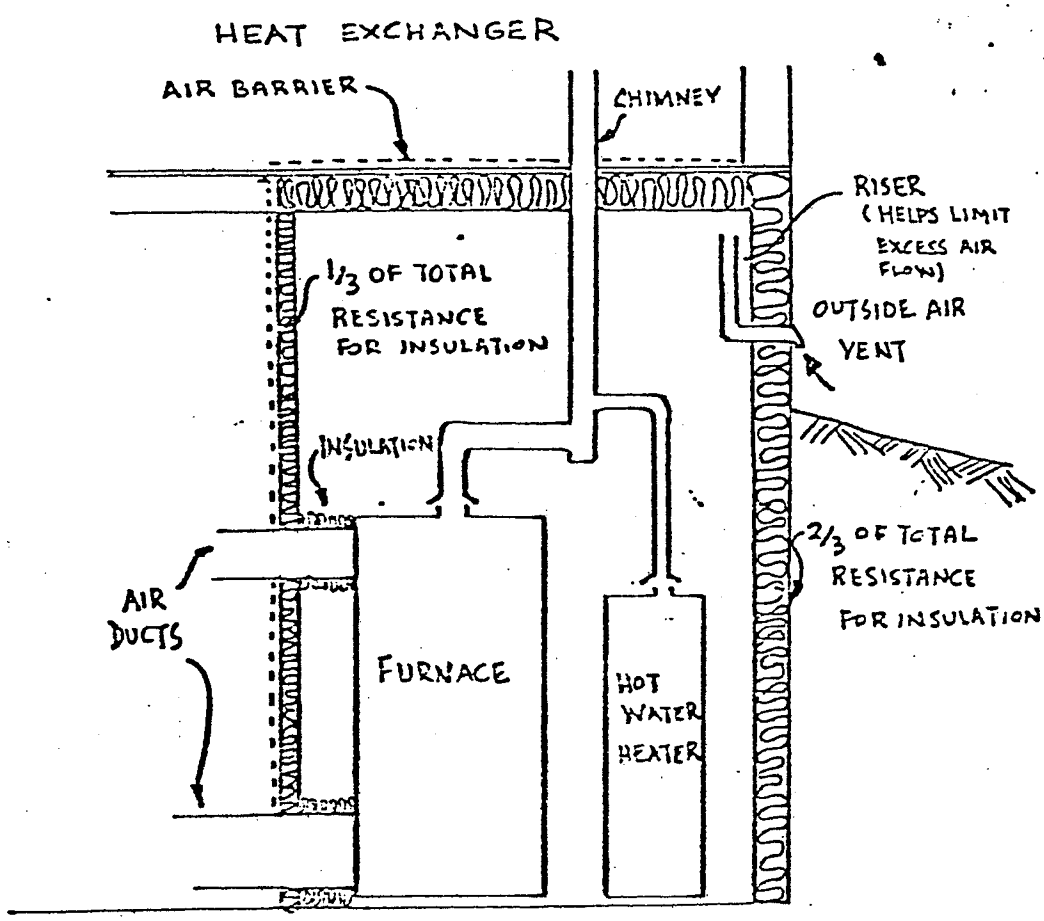

1X6 TRIM
CAULK
HEAD
SILL
CAULK
METAL PAN
PLYWOOD UNDER PAN
2X4 (FLAT)
CAULK



3 ROOF EDGE AT SLOPED CEILING
SC 3/4" = 1'-0"

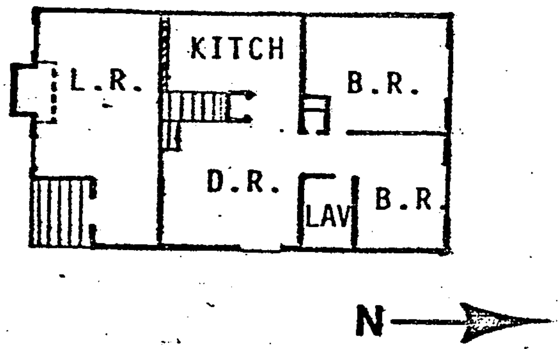


4 PLAN DETAIL AT FRONT CORNER
SC 3/4" = 1'-0"



USE OF A FURNACE ROOM
TO ISOLATE FUEL BURNING
EQUIPMENT FROM REST OF HOUSE

BASELINE HOUSE I



DIMENSIONS: 42' x 24'

AREA: 968 ft^2

WALL INSULATION:

R-12 $\frac{hr\text{-}ft^2\text{-}F}{Btu}$

CEILING INSULATION:

Cathedral	R-26	"
Vertical	R-16	"
Flat	R-38	"

BASEMENT INSULATION:

none

GLAZING: Double Glazing

HEATING SYSTEM:

Forced air with gas furnace and DHW tank; wood fireplace

OCCUPANCY:

2 adults & 2 children

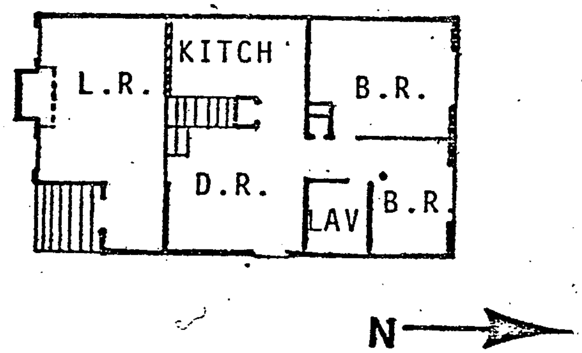
ELECTRICAL ENERGY CONSUMPTION:

1020 kW-hr/month

GAS HEATING BILL:

$504 per year

BASELINE HOUSE II



DIMENSIONS: 42' x 24'

AREA: 968 ft^2

WALL INSULATION:

R-12 $\frac{hr\text{-}ft^2\text{-}F}{Btu}$

CEILING INSULATION:

Cathedral	R-26	"
Vertical	R-16	"
Flat	R-38	"

BASEMENT INSULATION:

R-6

GLAZING: Double Glazing

HEATING SYSTEM:

Forced air with gas furnace and DHW tank; wood fireplace

OCCUPANCY:

2 adults & 2 children

ELECTRICAL ENERGY CONSUMPTION:

1020 kW-hr/month

GAS HEATING BILL:

$299 per year

DESCRIPTION OF
BASELINE HOUSES I & II

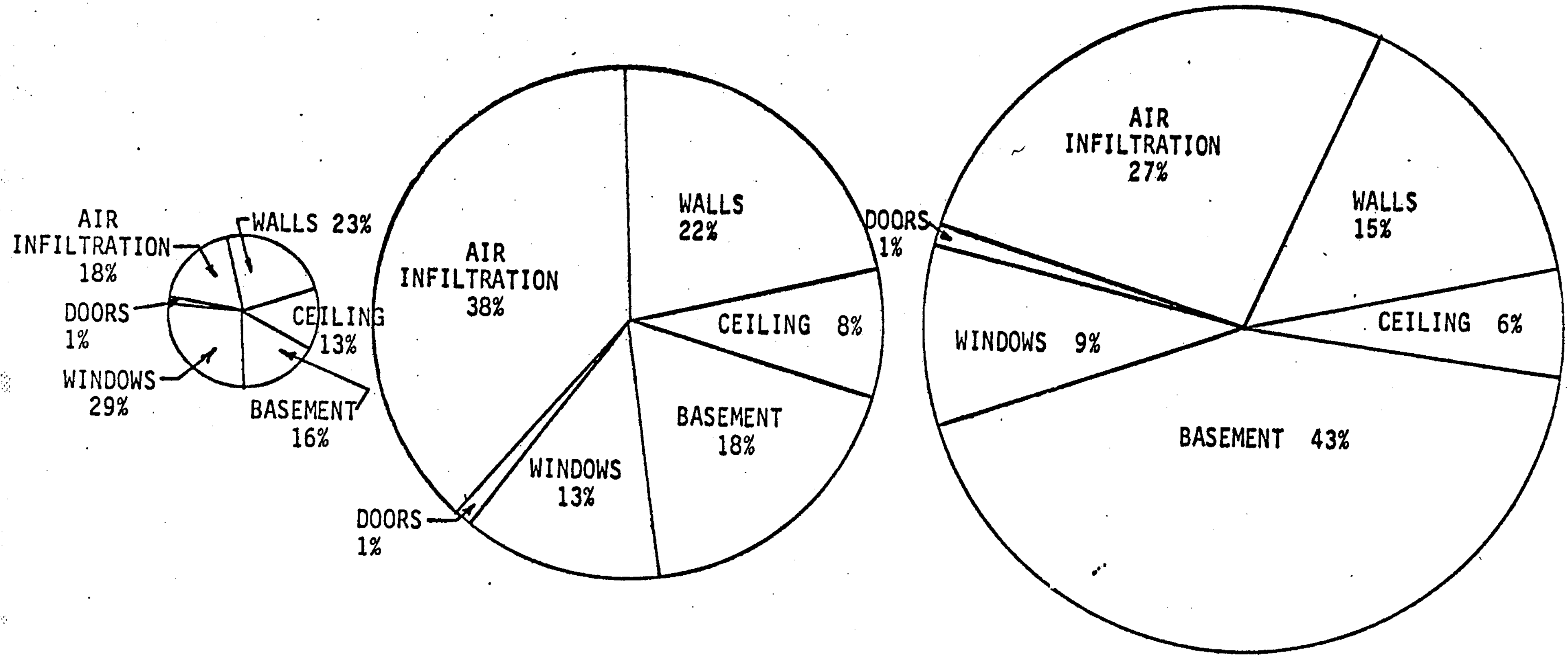
SUMMARY OF COSTS AND PERFORMANCE OF CONSERVATION FEATURES

ITEM	COST	$\Delta R^{(1)}$	ΔUA	$\frac{\Delta UA}{COST}$
Airtight Vapor Barrier With Heat Recovery	$ 800		80	0.100
Double Wall	$ 1,550	27	69	0.045
Extra Ceiling Insulation: Cathedral	$ 825	26	11	0.013
Vertical	65	15	4	0.055
Flat	165	12	2	0.015
Window Relocation	$ 0			
Basement Insulation	$ 500	17	24	0.048
Partial Triple Glazing	$ 225		8	0.035
Insulated Door	$ 0	5	2	
Heating System	$ 195			
TOTAL	$ 4,325			

Credit for deletion of fireplace - $850

∴ Total Cost of Conservation Package - $3,475

(1) *Change in thermal resistance, hr-ft²-F/Btu*



FINAL DESIGN
6 MMBTU/YEAR

BASELINE HOUSE II
76 MMBTU/YEAR

BASELINE HOUSE I
128 MMBTU/YEAR

* MMBTU - MILLION BTU

COMPARISON OF DESIGN HEAT LOSSES FROM FINAL DESIGN AND BASELINE HOUSES I AND II

APPENDIX B

DOUBLE-SHELL HOUSES

CONSERVATION HOUSE "B"

Source: Dans, Ron. "Double-Shell Solar House - High Performance in a Controversial Package." Popular Science. Volume 215, Number 6 (December 1979) : 59

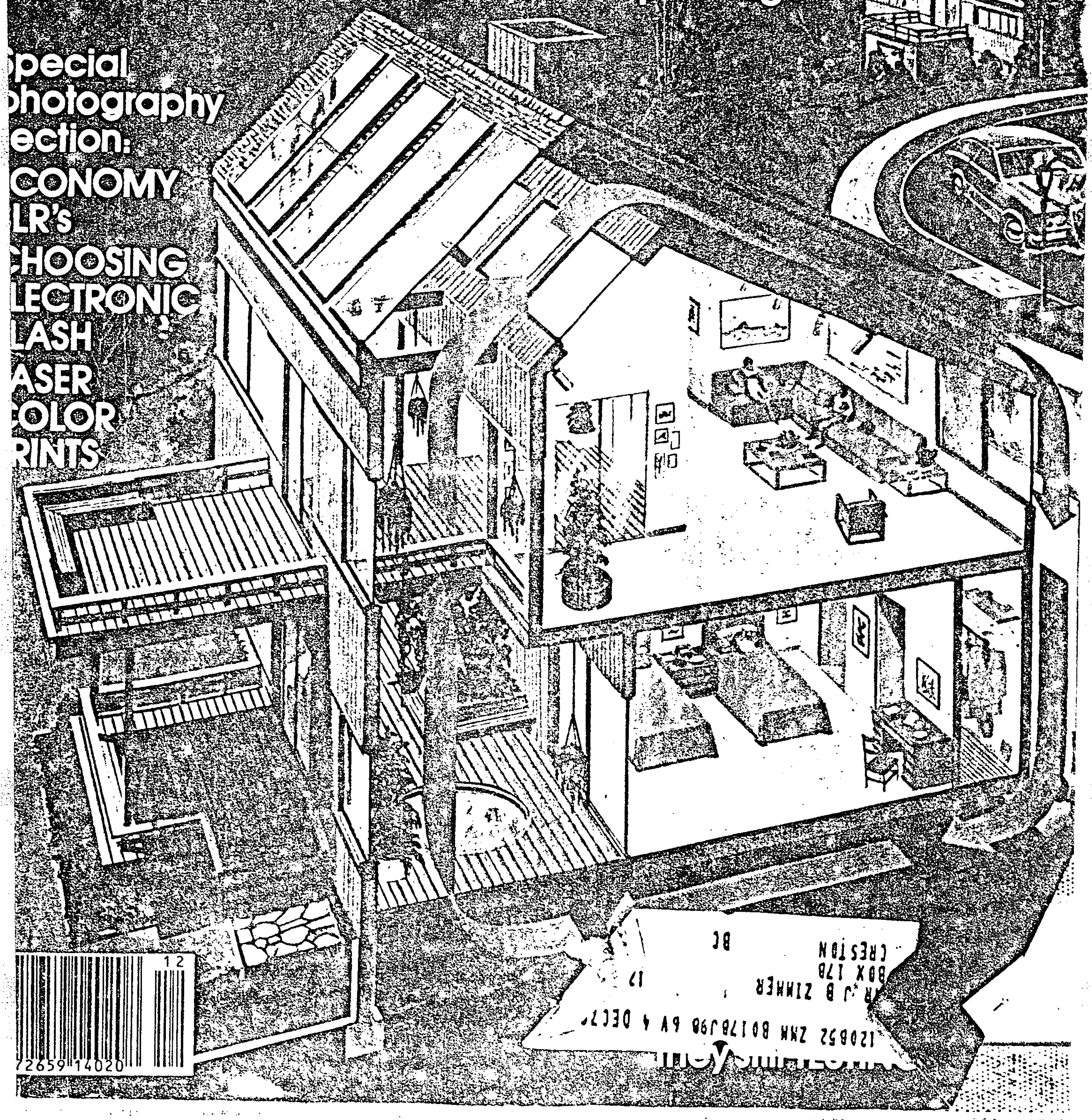
Popular Science

The What's New magazine

HEAVY CRUDE
Best answer to the oil shortage?

Double-shell solar house
High performance in a controversial package

Special photography section:
ECONOMY SLR's
CHOOSING ELECTRONIC FLASH
LASER COLOR PRINTS



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72659 14020

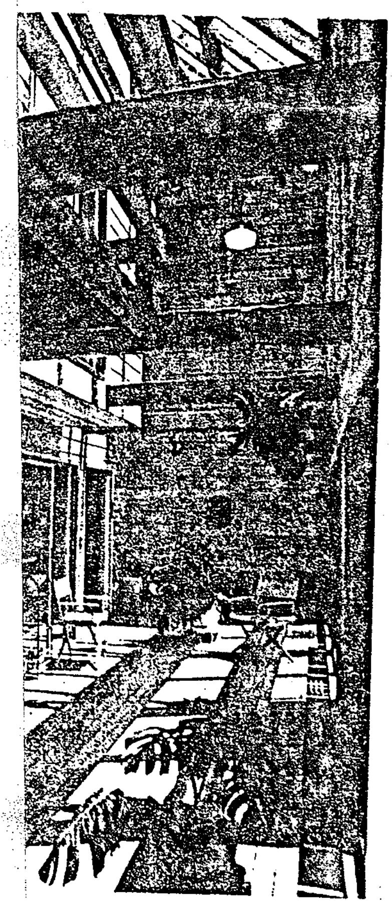
Double-shell solar house

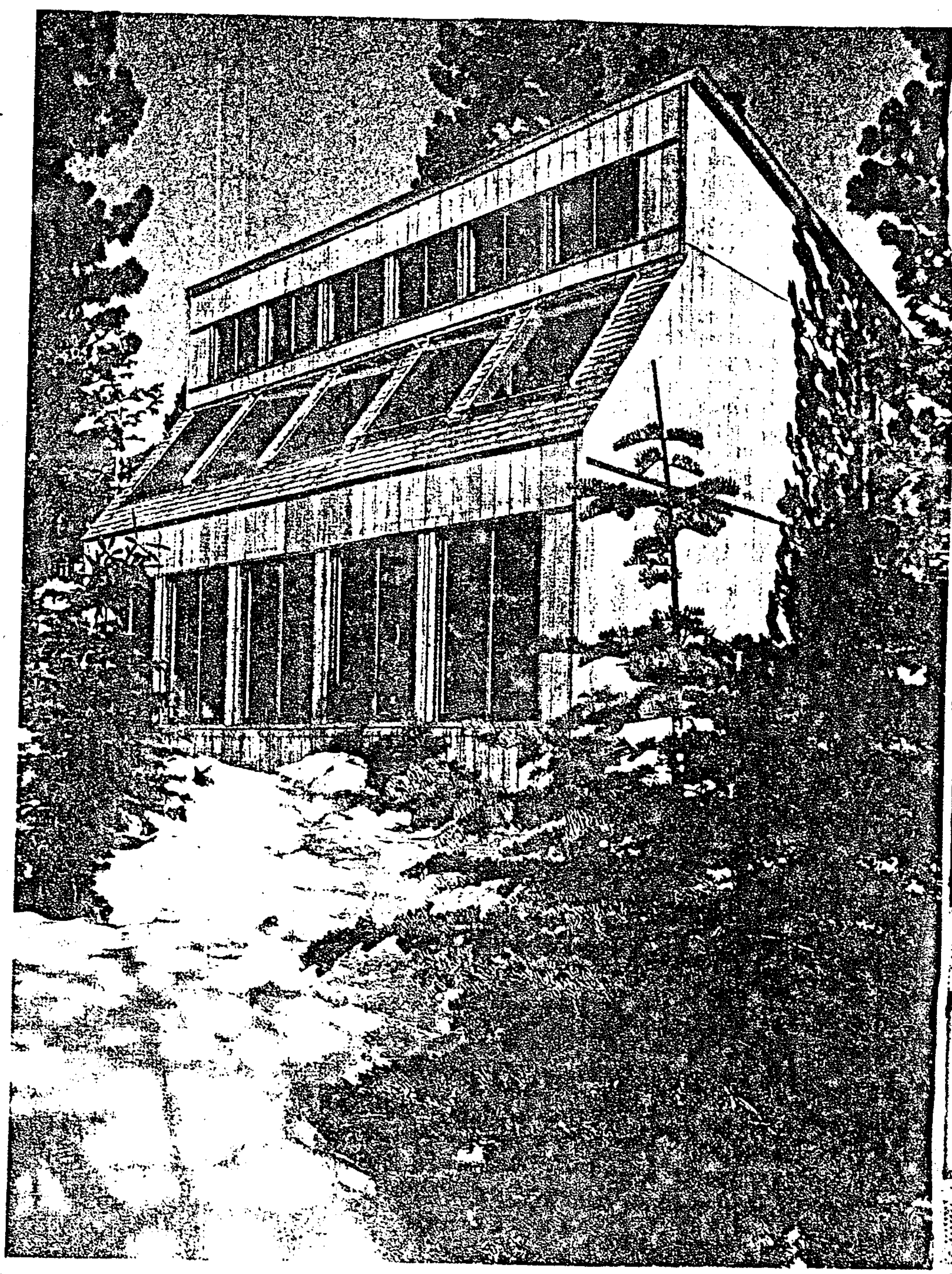
—high performance in a controversial package

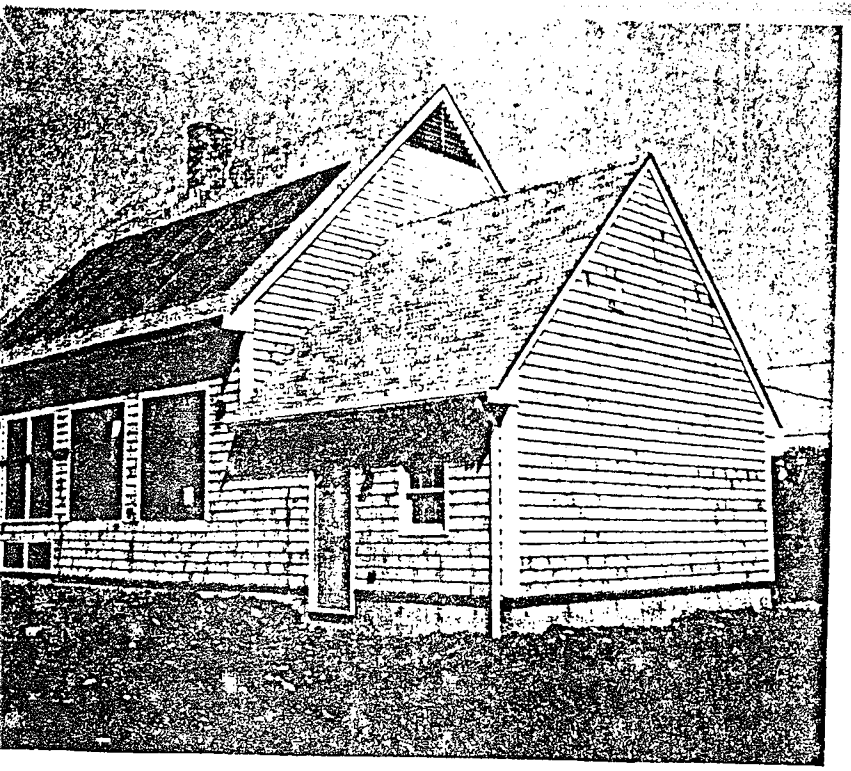
ese "naturally driven," ssive-solar designs 'stify the experts

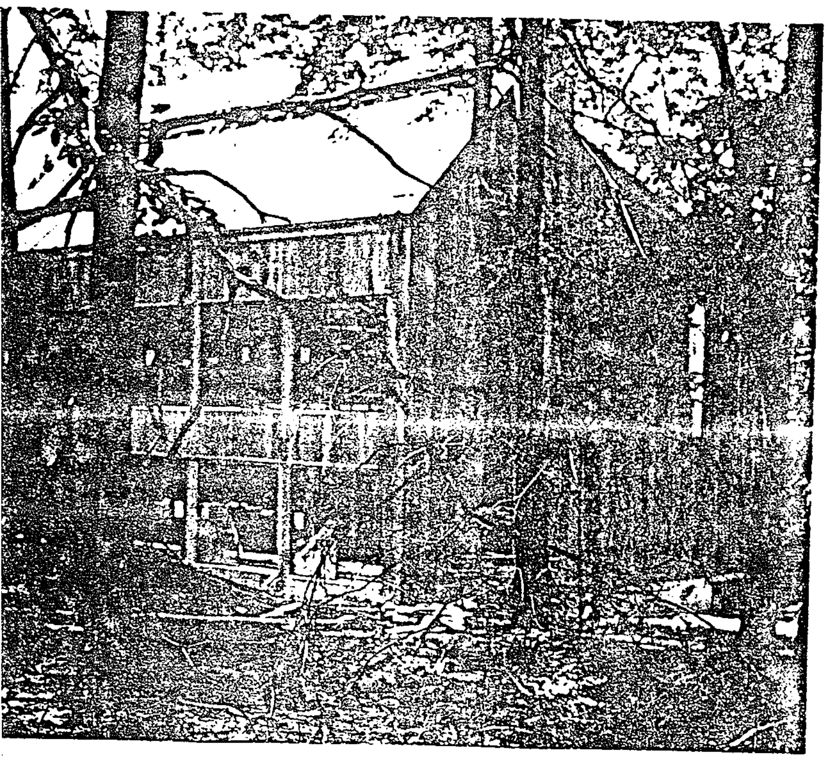
RON DANS

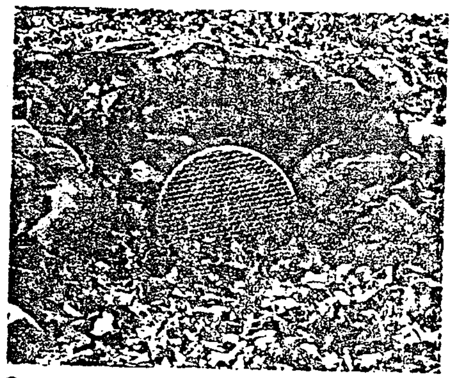
n the outside, I saw nothing un-l about the striking contempo-house. Once I was inside, the only to the home's true nature was the e of complete quiet, unbroken by ds of rumbling ductwork, circu-











Several versions of double-shell solar homes have been built in different parts of the country. Saltbox-style home (top left photo, this page) fits well in Newport, R.I. Contemporary shown below it is sited in woods near Raleigh, N.C. Another contemporary is Tom Smith's, located high in snow country in Tahoe, Calif. (facing page). Greenhouse of an Ekose'a home in Cincinnati, Ohio, boasts a hot tub (top right). Two-story greenhouse in Atlanta home has dramatic overhanging deck (facing page). This house also features cooling tubes; screened opening of one is above.

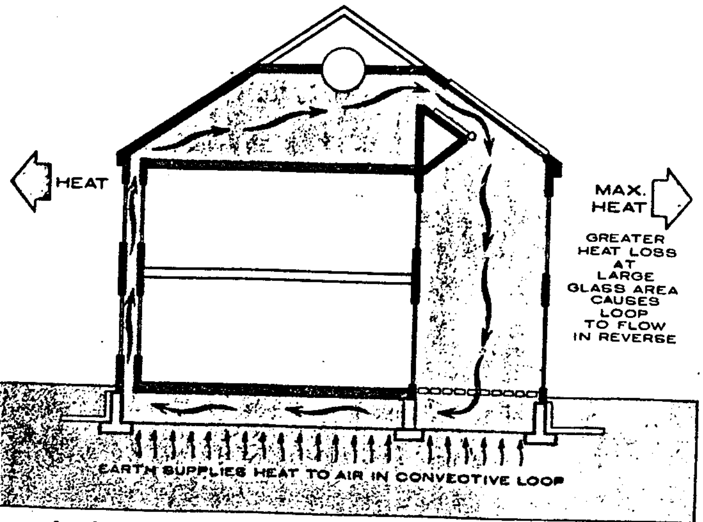
pumps, blowers, automatic or other mechanical devices.
no inkling that my casual visit ne in Lake Tahoe, Calif., would e on the trail of a controversial oout passive-solar technology. he way I spoke with owners larly designed passive-solar well-known solar architects igners, builders, bank officers, ar tinkerers."
g my initial visit, I formed a a about how these houses op- My subsequent investigation ed this idea so many times w wonder if anyone really un- ls how they work.
use I visited in Lake Tahoe is y Tom Smith, who enthusiastically speaks about a coming revolution in housing styles. Smith's home, which was designed in collaboration with San Francisco-based architect Lee Porter Butler, combines the well-known and accepted idea of an attached, south-facing greenhouse for solar collection ["Passive Solar," PS, April '78] with the little-known idea of double-shell construction and a continuous air plenum surrounding the house. It is this double shell and so-called air loop that have raised the most controversy.

Of course, unusual design features alone seldom stir great controversy; the performance claims for the house are also in dispute. Smith used two-thirds of a cord of wood last winter in his wood-burning stove, and says that "while it's not an inconsequential amount of heat for an 1800-sq.-ft. home, you must consider that many of my neighbors with well-insulated homes of the same size used six to eight cords of wood. I think this is doing very well for a home with a great deal of traffic during the winter and one where no special attempts were made to save wood."

A neighboring house of almost identical design was used as a ski lodge last winter and reported nearly the same fuel usage as Smith's house. Smith claims his double-shell design achieves an 80 percent reduction in fuel costs over conventional homes.

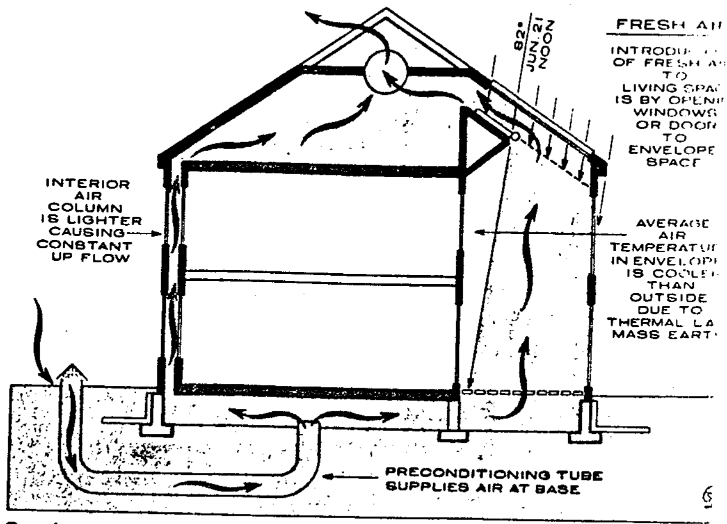
Continued

Winter: heat loss



At night, air loop flows in reverse because greatest heat loss is through glazing in south envelope space, claims architect Lee Porter Butler. Gravity now pulls air down in the greenhouse into the crawl space, where heat from the storage mass replaces heat lost. Constant air circulation during cool-down period distributes heat loss uniformly throughout double-shell structure.

Summer: ventilation and cooling



Overhangs block high summer sun from entering interior living areas; east and west glazing is minimal. Air in greenhouse and attic heats up, but in this mode heated air is vented outside. Hot air is replaced by a constant flow of cooler air entering at lowest point of house, the crawl space. In some climates, underground pipes or preconditioning tubes supply the makeup air.

the earth, and rises back into the envelope. It probably accounts for most of the heat transferred out of storage. This type of natural heat transfer is very hard to understand unless you have done some very careful observations."

Says Smith, who has spent two winters observing how his home works: "I'm still not sure what the exact pattern of air flow is, but there certainly is significant flow both during sunlight hours and cold nights."

I got the clearest explanation of the value of the double shell and air loop from Bruce Maeda, a solar consultant at Davis (California) Alternative Technology Associates. In 1977, Maeda helped Tom Smith with his original calculations, and since then has worked with both Smith and Butler, refining a computer model capable of predicting the performance of a loop house. He is confident enough of his latest model that he has used it to predict the performance of a double-shell house he designed for Homer, Alaska. It will be finished late this year and should be a good test of the model.

Maeda characterizes the loop design as "an extremely cost-effective way of achieving high R-values and a unique way of distributing the insulating value around the house." He says that "windows are typically the worst heat leaks, and the double shell allows sizable window area without excessive heat loss." Conventional double-pane windows have only ¼ to ½ inch of insulating air, while the double shell puts at least 12 inches of relatively warm air in contact with the inner windows. Maeda contends that the effective R-value of the north windows in the Smith house is R-6, versus R-1.5 for a conventional double-glazed window.

Additionally, Maeda says that "the higher temperatures of the interior glass surface improve the comfort level by decreasing the rate at which occupants lose heat by radiation to cold surfaces. Rate of radiant heat loss is recognized as an important, yet often overlooked, factor in rating a home's comfort, and in this respect many passive-solar home designs have suffered from large areas of glass exposed to low outside temperatures."

Maeda's original calculations used to size Smith's house did not include the effects of the thermal storage, and this, says Maeda, may be "why my original calculations did not predict that the house would work as well as it does." His newest model includes the contribution of the storage system, although he admits that "the exact mechanisms for heat storage and release in this situation are far from being well understood. My model assumes a rate of 5000 to 10,000 Btu per hour released when the air in the envelope is 50 degrees F and the storage is 68 degrees F, but this has not been verified experimentally."

Reasons for confusion

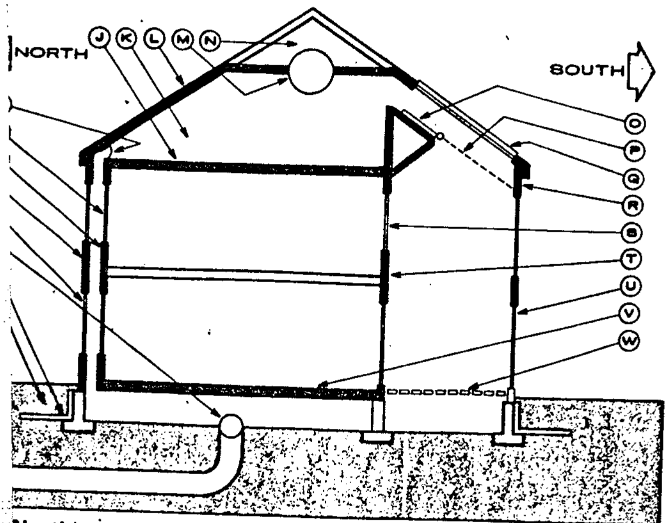
Ralph Jones, an architect and solar engineer at Brookhaven National Laboratory who plans to instrument one of the Ekose'a houses beginning this winter, has monitored other homes for the Department of Energy and expects to examine just such theories. "Every house I've monitored," says Jones, "has turned out to operate for very different reasons from the ones the owner ever believed. People generally have very little idea of the actual mechanisms involved in a passive-solar house, and these mechanisms can only be understood by making a large number of rather detailed measurements."

The lack of a clearly understood massive-storage element and heat-transfer mechanism has caused many passive-solar advocates, such as J. Douglas Balcomb of Los Alamos Scientific Laboratory, to predict that the house would experience uncomfortably wide temperature swings. None of the owners I interviewed has reported this problem, highlighting the difficulty of predicting exact thermal performance of naturally driven systems. With more than 30 double-shell houses ready to be occupied by this winter, however, this aspect of the controversy should be resolved in practice, if not in theory.

The idea of circulating heated air within a few inches of the exterior has also drawn criticism. Wayne Shick, retired professor of architecture at the Small Homes Council of the University of Illinois, commented, "The last place you want to circulate hot air is where you would expect the greatest heat loss. That seems like a perfect waste of energy." He also questioned the rationale that heat would flow easily through the single layer of drywall into the interior of the house.

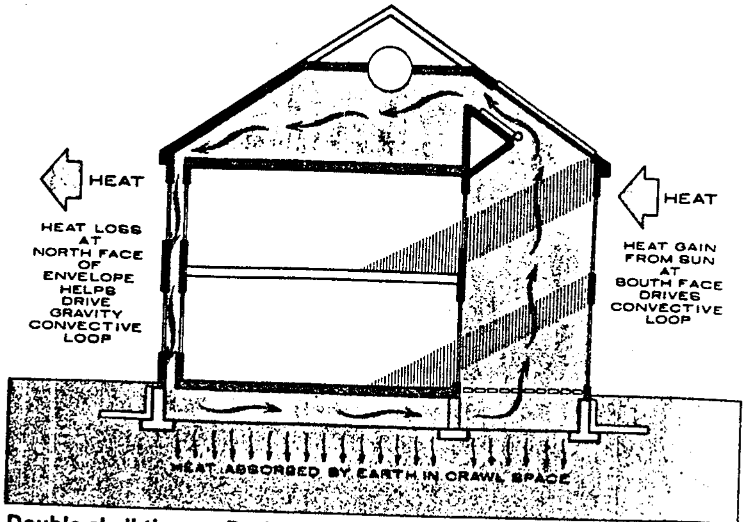
[Continued on page 116]

Double-shell components



North/south cross section (R-values for insulation and glazing vary with climate): fresh-air intake (A); earth (B); foundation insulation (C); cool-air-intake damper (D); glazed openings (E, H, Q, S, U); insulated frame (F, G, J, L, R, T, V); fire damper (I); envelope space (K); hot-air exhaust damper (M); ventilated attic space (N); solar collector (O); sun control (P); deck (W).

Winter: heat gain



Double-shell theory: During the day, the sun heats air in south envelope (greenhouse), making it lighter. As heat is lost by conduction in north envelope, air cools, becoming heavier. Gravity pulls heavier air into crawl space, where heat is stored in foundation and earth. The constant circulation of air distributes the heat gain uniformly throughout the structure.

Architect Butler has designed and upervised construction of six other xisting double-shell houses, and has 8 others in various stages of contruction. He claims even more dranatic results, saying that his homes o not need *any* backup heat. His firm, ¦kose'a (Greek, meaning "from the ssence, willingly, or voluntarily"), uarantees that it will install at no harge a backup heating system in ny home that fails to provide all the eating needs of the occupants.

The cooling properties of the design re also cited by both Smith and Butr: Smith claims an 80 percent reducon in cooling, while Butler claims a 0 percent solution.

These claims have disturbed many ople in the solar community, particarly since there have been no objecve tests run on any of the houses. A pical comment came from Sym Van r Ryn, former California state aritect: "I can't really comment on the rformance of Smith's house because little empirical data are available, d I can say less about the theory of eration for the same reason. More ormation is necessary; I can't unrstand why it isn't available." Most ofessionals I interviewed had a simr wait-and-see attitude.

uble construction

n the Smith house, the double shell ormed by a false north wall, a ceil- air plenum running the full width the house, the greenhouse space, l a fully enclosed crawl space (see wings). The ceiling plenum is ned by leaving a 12-inch air space between the ceiling drywall and the roofing board. Urethane insulation is placed on top of the sheathing. The air passage is continued on the north side by a false 2×4-framed wall built 12 inches inside the exterior wall. The flooring on both the first and second floors is laid only up to the false wall, allowing air to flow into the crawl space. From there, the air moves back up through the slatted greenhouse floor.

This constant circulation of air is intended to eliminate stagnation of hot air under the roof and the resulting high heat-loss rate. The foundation is insulated down to the footings and is backfilled with a combination of lava rocks and earth. This provides a heat-storage mass to absorb excess heat collected during the day. In other loop designs, the air passages may include a full basement or even a true attic space, allowing for variety in architectural design (see color photos).

Butler's original drawings of a double-shell home show a complete circulation of air around the loop, driven by the temperature differential between the north wall and the greenhouse. In making a complete circuit during sunny periods, the air would move heat into the basement or crawl space. At night, or during cold, cloudy days, the greenhouse would cool more quickly than the north wall, causing the circulation to reverse. It's this reverse circulation that's supposed to carry heat from storage into the house.

This theory has been disputed by many solar architects, including Mike Riordan, co-author of *The Solar Home Book*, and Sym Van der Ryn. They both commented that the circulation pattern as described can't work without some type of fan to drive it. There just isn't enough energy available to make air flow all the way around the house, they say. Also, air-flow rates would be very low, and just moving air slowly over the surface of a rock and earth bed would not transfer appreciable amounts of heat into storage.

Revised theory

More recently, Butler has revised his theory and now speaks of "multiple air flows in very thin layers that may encompass only portions of the air space." He goes on to say that "the insulating properties of a large number of very thin films moving quickly over one another have never been measured. My calculations show that there is considerably more insulating value in this situation than we would expect from a 12-inch space."

Some support for this theory comes from solar designer Philip Henshaw, one of the few who has extensively studied air flow in passive-solar buildings. His experiments, using smoke trails and hot-wire anemometers, have led him to the conclusion that "there is not much heat transfer in this situation from the moving air into storage. Most of the heat stored under the house comes from radiation from the floor. During periods of cold weather, a thin film of very cold air is formed on the inside of the exterior wall. It is this thin film that falls rapidly into the crawl space, warmed by

Double-shell solar house

[*Continued from page 57*]

"The last thing you want to do with your precious heated air is to impede the transfer of heat into the house. Why not just circulate heated air into the living area of the house?"

Double-shell benefits

Clearly understood benefits of double-shell construction are noise control, low rate of air infiltration, cooling ability, and moderate costs. The double shell insulates the interior from external sound, and the complete lack of mechanical noise associated with pumps, valves, and fans is quickly noted by visitors.

Dave Leone, owner of a house in Lake Tahoe similar to Smith's, commented, "Since we use the house only on weekends during the ski season, we forget how relaxing it is to just sit in it. When we arrive on Friday night, it's always a pleasant surprise to walk into a house that's at a comfortable temperature but doesn't have a noisy oil burner running."

The double shell completely buffers the interior from air infiltration. Interior windows can be opened to remove odors and temporarily improve circulation without breaking the air seal to the outside. The air plenum also serves as a place to run wiring and plumbing, eliminating those punctures in the vapor barrier that are nearly unavoidable in normal construction.

The loop houses use a natural cooling system consisting of buried air-intake pipes that lead into the basement or crawl space. Capped in the winter, the pipes are opened in summer, and vents at the peak of the air plenum are opened to create a draft through the envelope. This chimney effect, used in other passive-solar designs, could be important in areas where energy used for air conditioning often exceeds that used for heating.

Like fireplace chimneys, however, this technique requires careful analysis of wind patterns and sizing of ducts for optimal draw. At least two of the double-shell homeowners I talked with reported that they needed auxiliary fans to get sufficient air movement on very hot days.

Construction costs for all of the houses I surveyed were under or right at the regional average. The moderate costs can be explained partly by the personal involvement of the owners in the building process, but it's also due to the simplicity of the concept. The additional cost of building a false wall is more than offset by the lack of a central heating system (bank-loan officers I interviewed were willing to waive this requirement, based on the design of the homes), and the greenhouse structure can be counted partially as living space, offsetting its extra expense.

Bob Mastin's house (see color photo) in Newport, R.I., is a good example of the economics when the owner acts as the general contractor. All three floors of this 33-by-30-ft. house are usable, and with the 600-sq.-ft. greenhouse included, there is 2600 sq. ft. of living space. Total cost of construction: $60,000, excluding $5000 for septic tank and well. This gives a cost of $23 a square foot, considerably below the national average. Allowing for an increase of 25 percent, to cover the cost and profit of a contractor, brings the figure to $28.75 per sq. ft. Leone's house was built by the same contractor who built the Smith house and, even including such things as a hot tub in the greenhouse, was finished for $35 a square foot. These houses clearly belie the idea that solar homes are only for the rich.

Judging from the rate of inquiries that Lee Butler, Tom Smith, and other owners have been receiving, there is tremendous popular interest in the double-shell concept. Comments Smith: "There have been so many visitors that I've completely given over my Saturdays to an open house. Frequently I have 50 people visit, and many go off and build these homes with no further contact with me." Bob Mastin reports a similar experience: "Even though we've only been in the house since March 1979, I'm continually amazed at how many people have heard about it and want to visit."

If you're interested in finding out more about double-shell solar homes, or are thinking of building one yourself, my best advice is to read the books listed below, and wait for a follow-up article in POPULAR SCIENCE.

Brookhaven National Laboratory plans to fully instrument an Ekose'a home beginning this winter, but the results won't be available until 1981. Until then, you'll have to accept the statements made by owners of the homes or visit them and see for yourself. Most consider themselves pioneers and are eager to share their experiences with skeptical guests. PS

FOR MORE INFORMATION

The Solar Home Book, by Bruce Anderson and Michael Riordan (Cheshire Books, Harrisville NH. 1976).

"Ekose'a Homes: Preliminary Planning Package," by Lee Porter Butler, costs $24.95 from Ekose'a, 573 Mission St., San Francisco CA 94105.

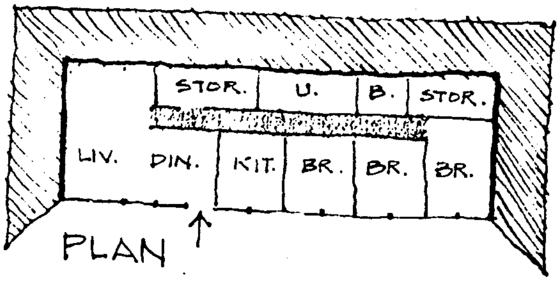
Energy-Producing House: Handbook/Case Study costs $18.95 from Tom Smith (Box 2356, Olympic Valley CA 95730).

APPENDIX C

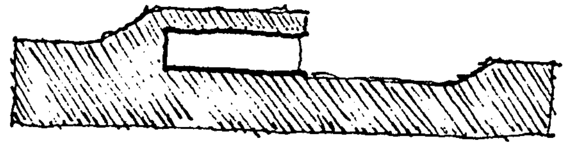
EARTH SHELTERED HOUSES

CONSERVATION HOUSE "C"

Source: The Underground Space Centre, University of Minnesota. Earth Sheltered Housing Design. Van Nostrand Reinhold Company, New York 1979 P.201-227

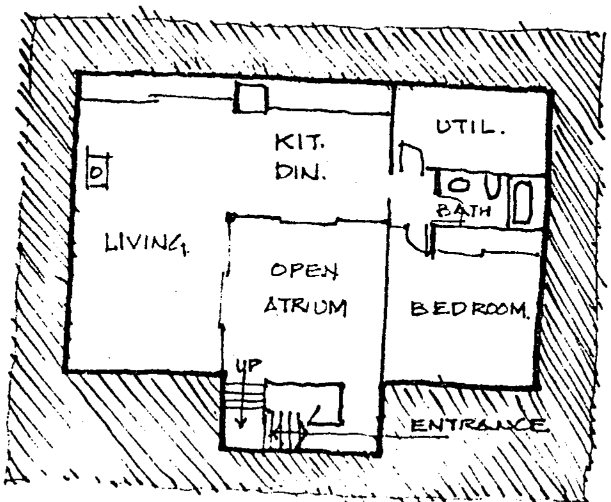


PLAN

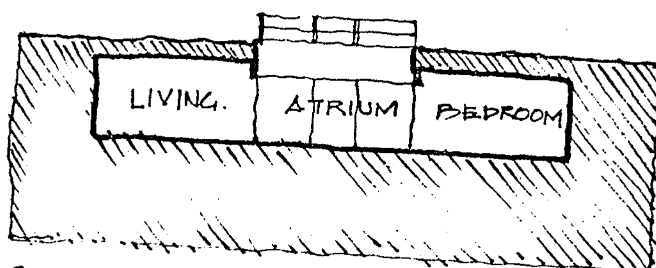


SECTION

ELEVATIONAL PLAN

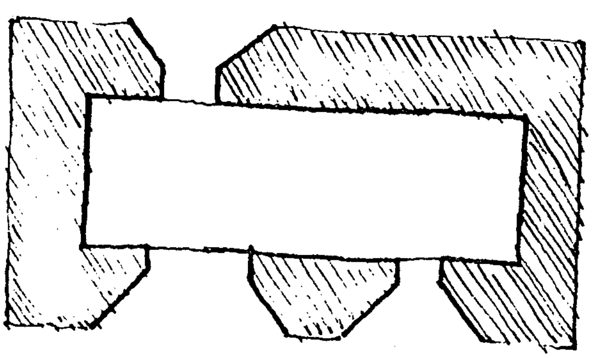


PLAN

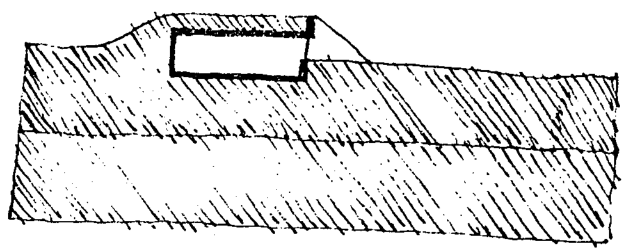


SECTION

ATRIUM PLAN



PLAN

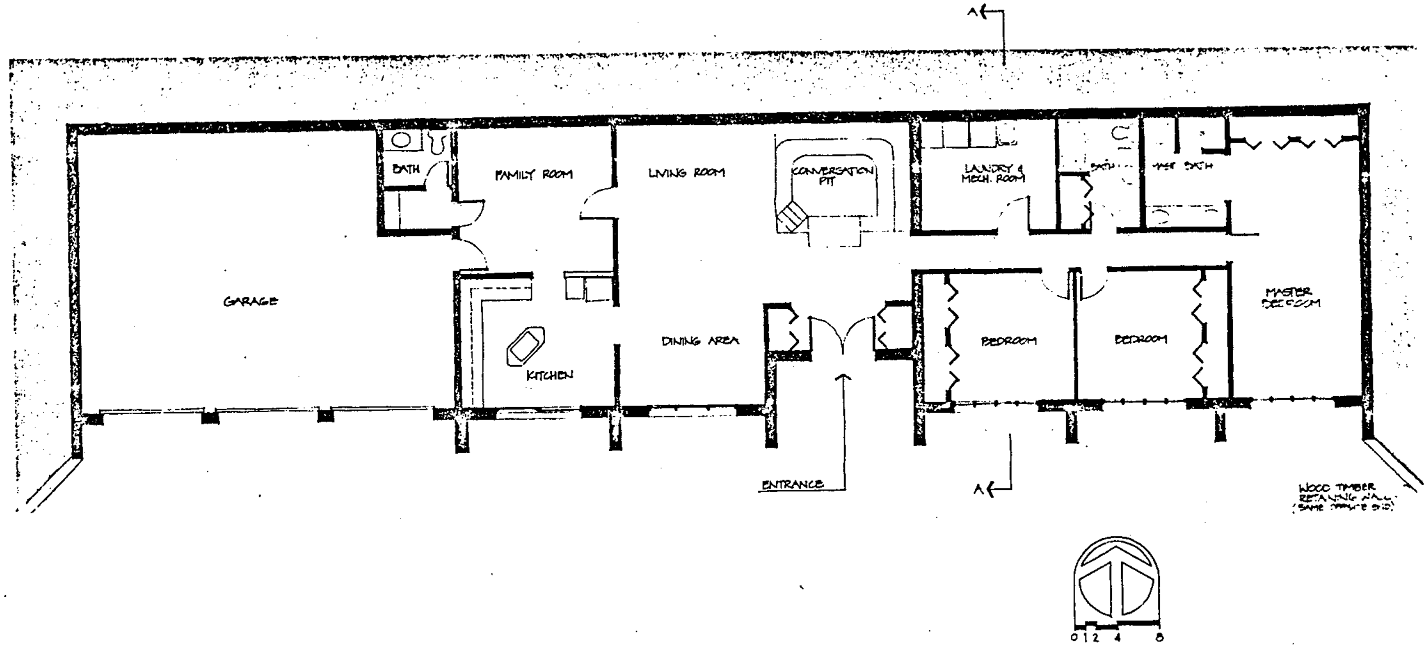


SECTION

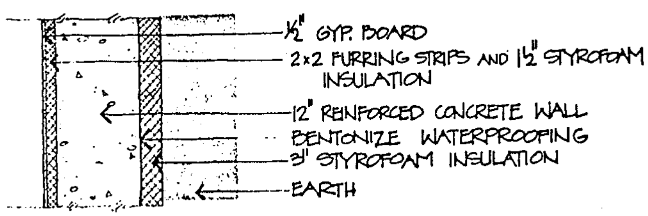
PENETRATIONAL PLAN

FIG

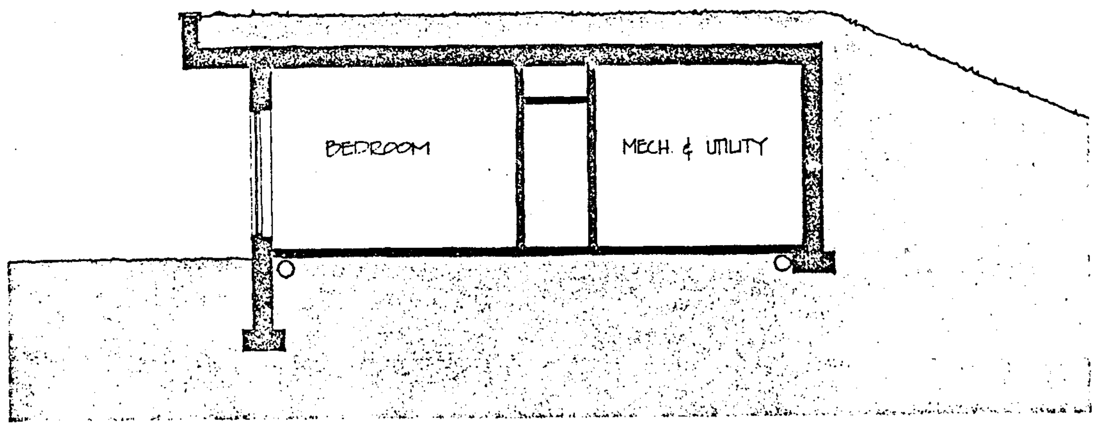
SOURCE: EARTH SHELTERED HOUSING DESIGN
THE UNIVERSITY OF MINNESOTA, UNDERGROUND SPACE CENTER
VAN NOSTRAND REINHOLD CO
1979



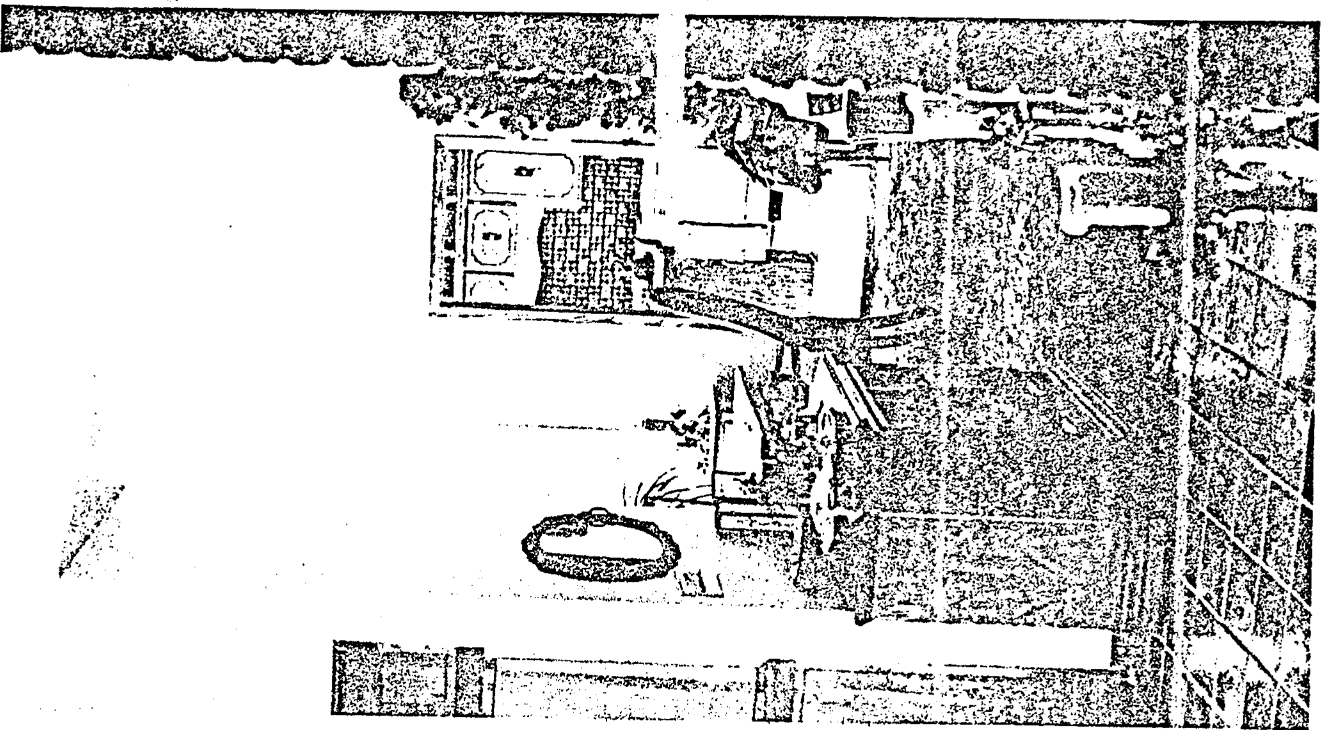
floor plan

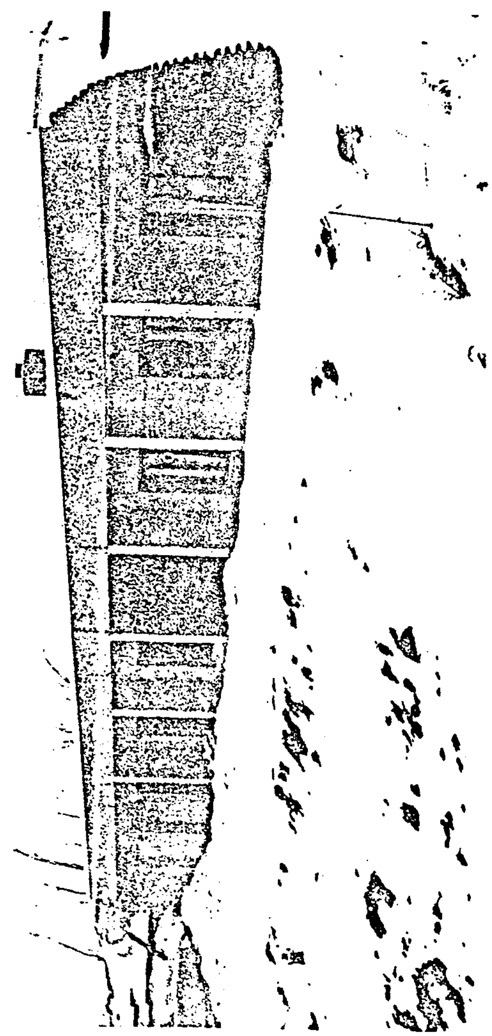


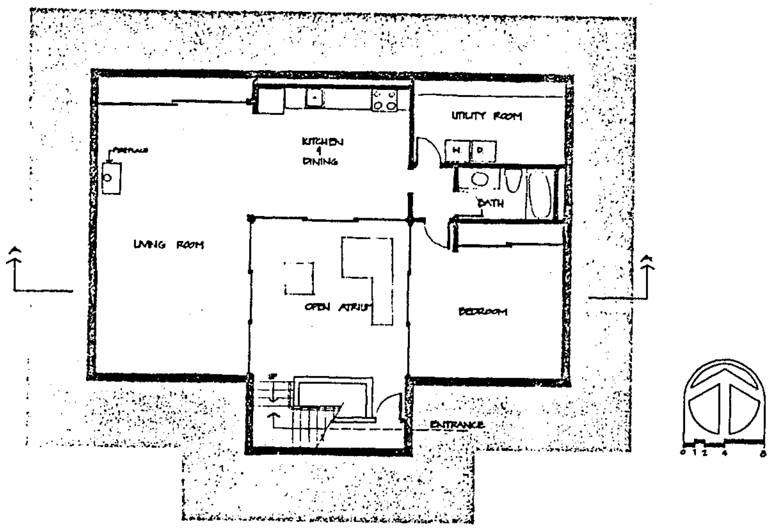
typical wall detail



section a-a

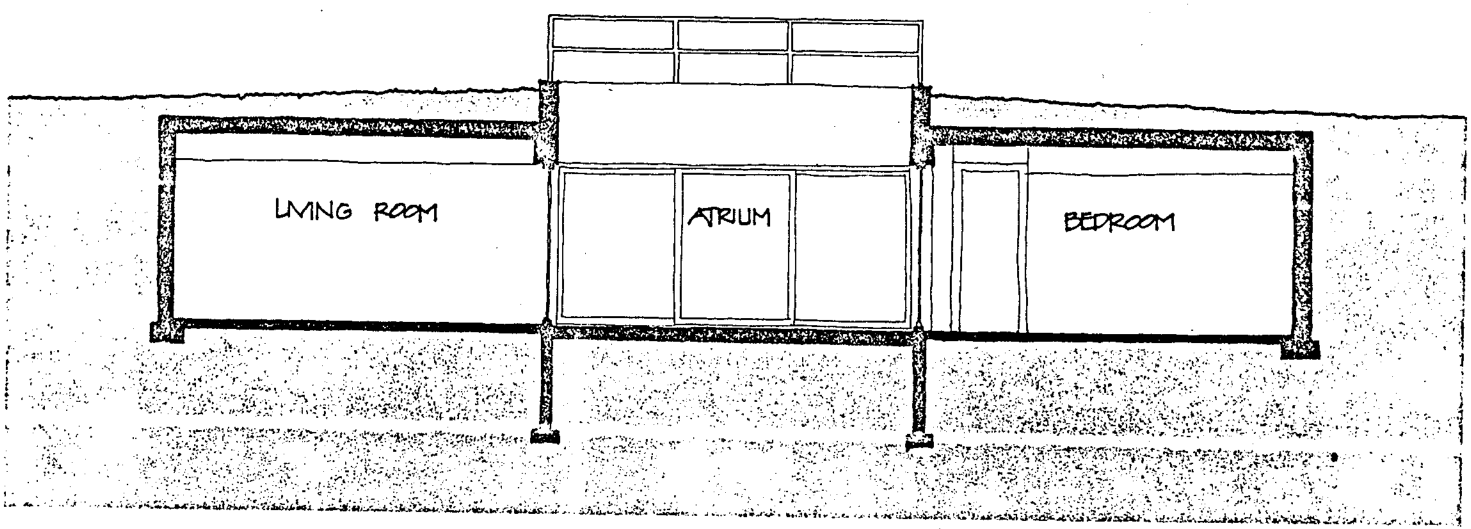




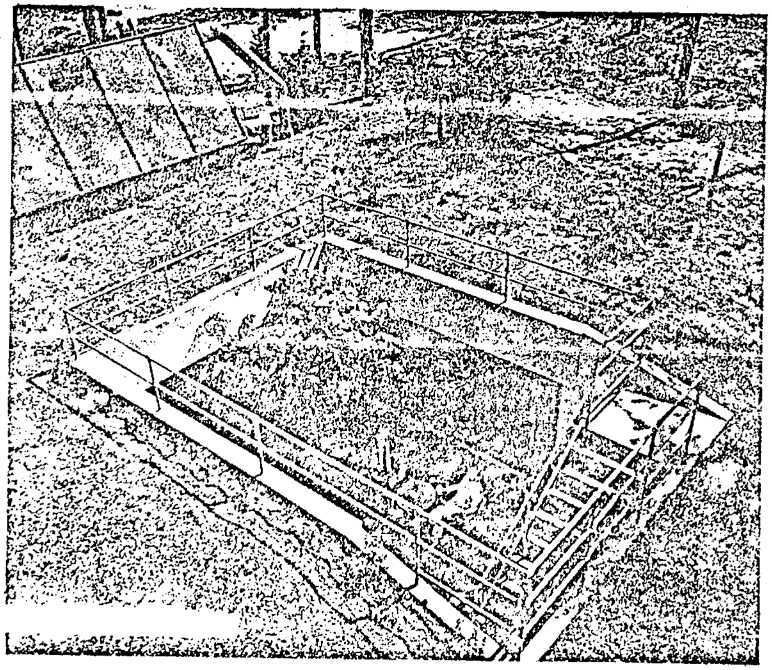


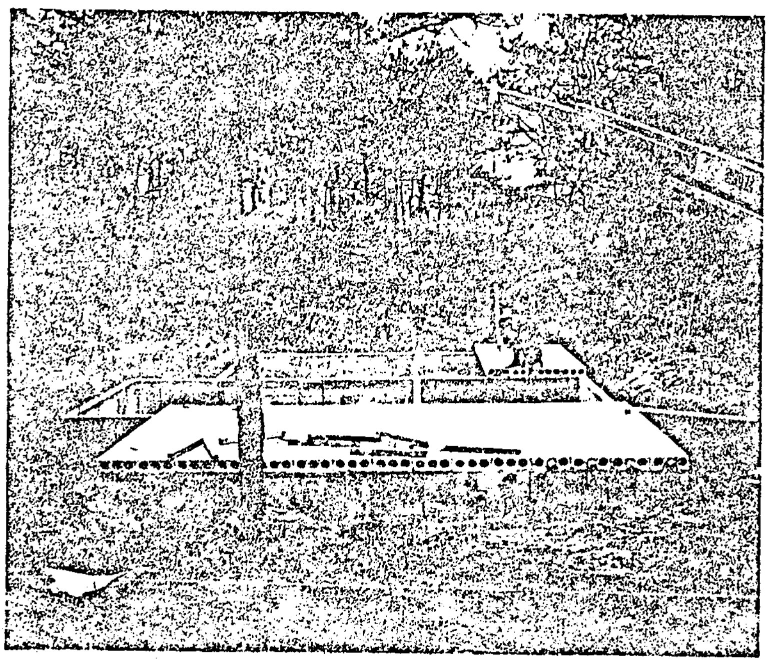
floor plan

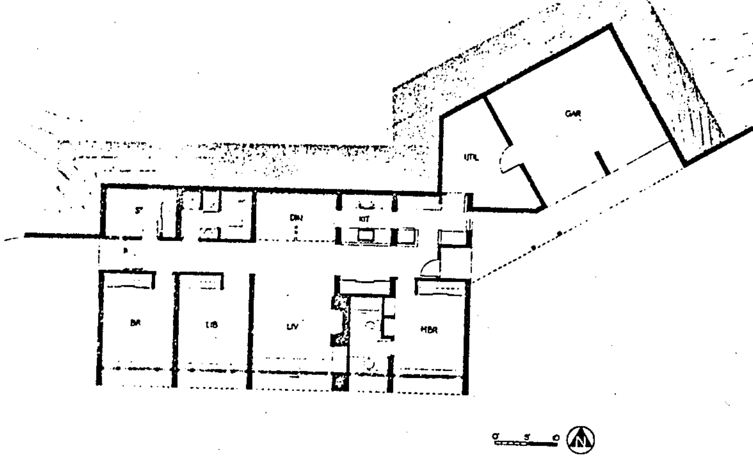
LOCATION:	Osterville, Massachusetts
ARCHITECT:	John Barnard, 872 Main Street, Osterville, MA 02655
COMPLETED:	1973
GROSS AREA:	1,200 sq. ft.
EARTH COVER:	10 in. to 16 in.
STRUCTURE:	Reinforced concrete walls Precast plank roof with steel beams
INSULATION:	2 in. styrofoam on roof & walls
WATERPROOFING:	Roof—3 ply (60 lb.) built up Walls—Hot mopped pitch
HEATING SYSTEM:	Solar collector with forced air furnace
COOLING SYSTEM:	Forced air
ENERGY USE:	25% of normal



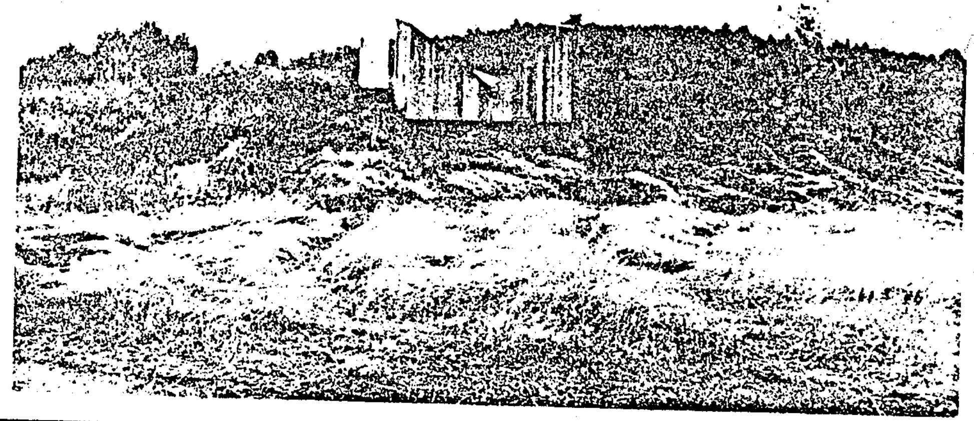
section a-a

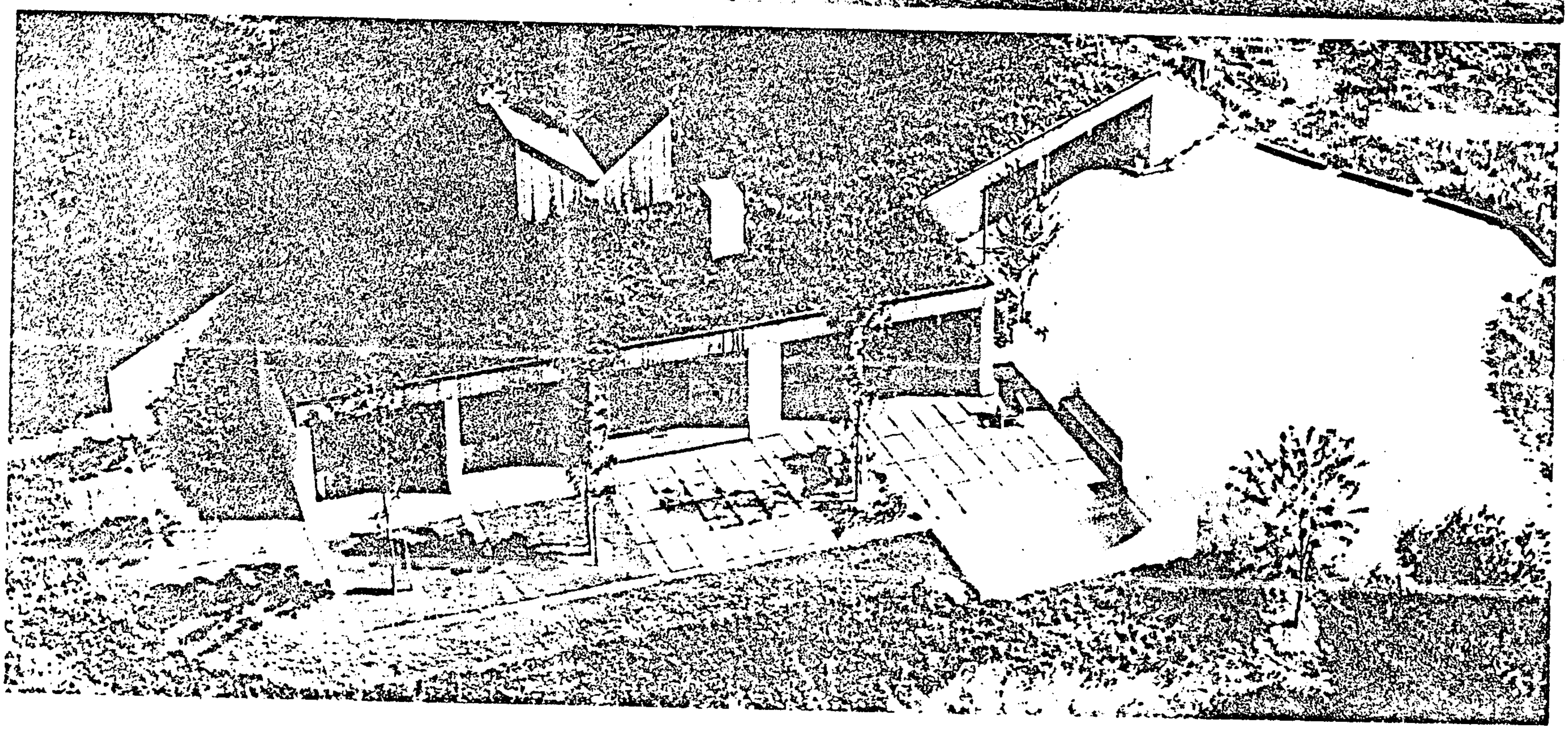


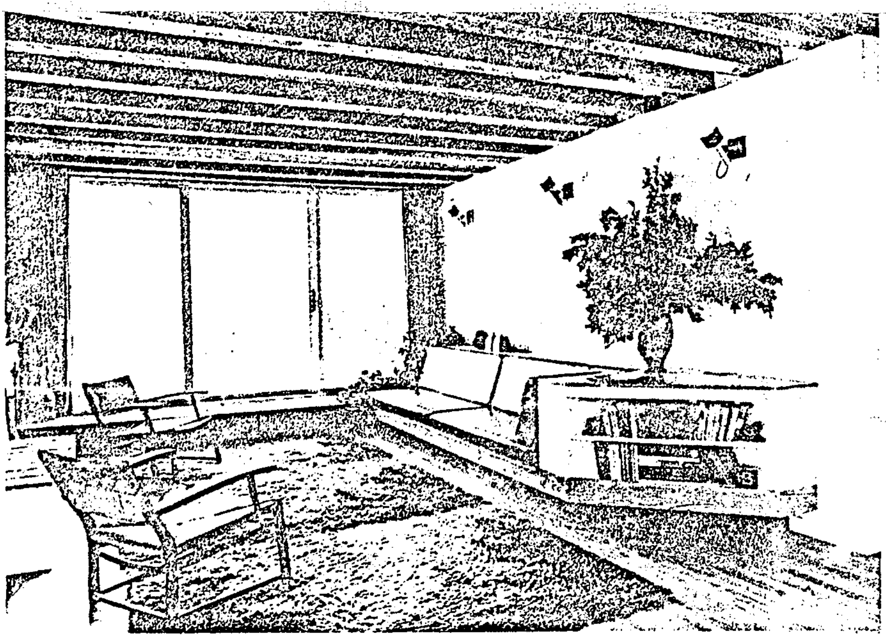


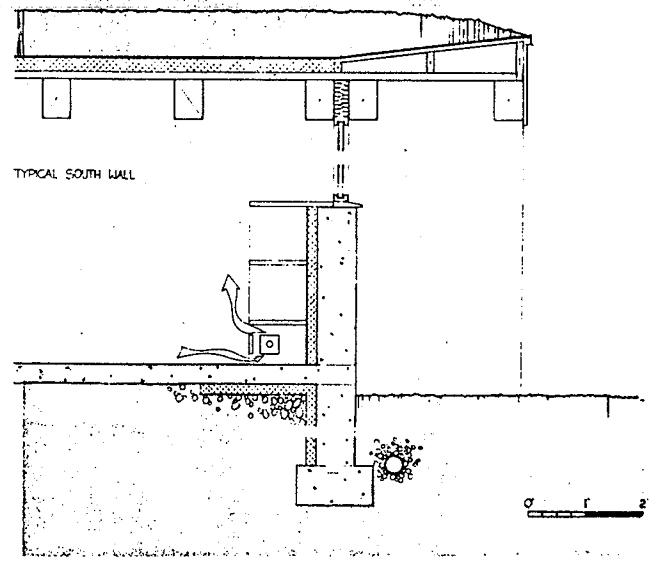


floor plan

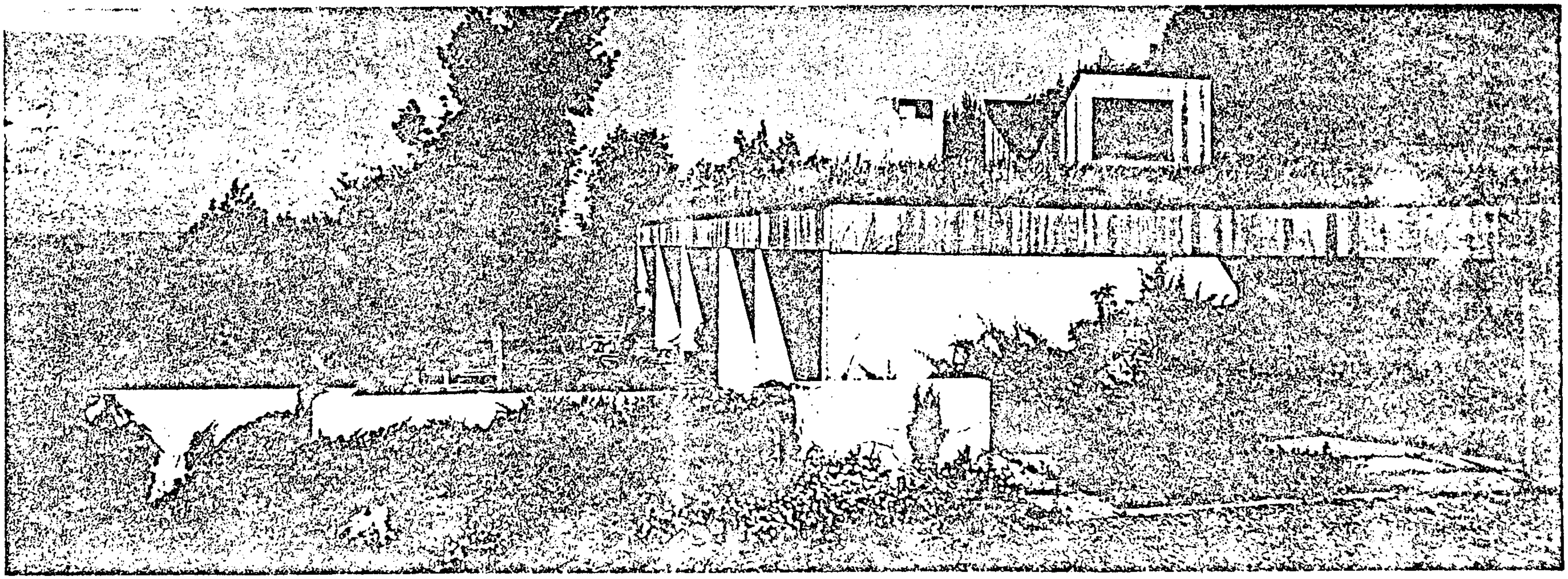








typical south wall section



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1 Because of the importance and wide appeal of "energy" related issues over the past 2 or 3 years, newspapers, magazines, TV news, and other components of the news media have been deluged with reports and articles on this topic. The author has taken note of many of these, but considers it totally impractical to list literally scores of them here. However, only those actually cited in the text of this thesis are noted here.

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1 During the past three years the author has attended scores of lectures, seminars and conferences in addition to conducting personal interviews on "energy" related issues. These sources of information are too numerous to list. However, those interviews which have been directly cited in the text of this thesis are listed here.