PASSIVE SOLAR ENERGY APPLICATION IN TOWNHOUSE DESIGN --A CASE STUDY

by

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Chapter 1

INTRODUCTION

The single-family home has been the dream of most American families since the end of World War II. After the 70's, due to the high construction costs and high interest rates the price of a single-family home lies beyond the reach of most families. Even though it is becoming clear that most families can not afford to have this type of home, its form remains to be the preferred one of housing. Because of economic reason, there is a trade- off between preference and ability to pay. This is the reason why condominiums, townhouses, and apartments become more and more common.

The destruction of natural resources has been a problem concerns ecologists for years. In October, 1973, it has become a public concern when the Arab Oil Embargo cut off crude oil to the United States from the Middle East and most people began to realize that the days of inexpensive energy was over.

This study is based on the belief that building designers must play a major role in solving the problem of energy conservation. Although one may debate this problem, one must recognize that the current increasing rate of energy consumption, in light of the decreasing supplies of energy, will eventually put us in the position where we can neither afford to construct new buildings nor to operate those already have. People rely on buildings not only for protection from the natural environment, but also, for the conditioning the immediate environment in which they cook, eat, sleep and play. In the United States, 20% of the total energy consumed was spent in the above activities[1] Therefore, the designer has the moral obligation to help reduce unnecessary energy consumption.

In general, the architectural profession is aware of its responsibility of energy conservation. The question: " What can the architect do ? " has been raised often, and many answers have been offered and discussed.

For the architect to conserve the energy use in the building, he must recognize the energy requirements early in the design stage and incorporate solutions throughout the design process. In this matter, energy becomes not just a problem to be overcome but instead, a creative medium for design development.

This study represents an attempt to demonstrate how the designer who has little or no experience with solar energy application can begin to deal with the problems of energy

[1] NSF/NASA, Solar Energy Panel, An Assessment of Solar Energy as a National Resource, College Park, University of Maryland, 1972, pp. 7-22

conservation by using energy as a design element rather than as a design constraint. Based on two earlier works which have been published[2] in the solar application in townhouse design, the author tries to apply these principles in a practical case.

A site in Blacksburg, Virginia has been selected for this application. It offers the convenience for data collection, site analysis and design evaluation for this study.

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[2] Robert N. S. Chiang, Charles William Fotis Jr., and Leland Sangone Chen, 1. An Energy Conscious Design Methodology for Townhouses, 2. Solar Townhouse Analysis and Design, College of Architectural and Urban Studies, Virginia Tech, Blacksburg, Virginia, 1981.

Chapter 2

ANALYSIS OF ENERGY EFFICIENT SOLAR TOWNHOUSE

As mentioned, the townhouse has great potential for solar energy application. However, there are certain principles and guidelines for this application. Two papers published by Prof. Chiang, Mr. Fotis and Mr. Chen: 1. An Energy Conscious Design Methodology for Townhouses, 2. Solar Townhouse Analysis and Design have provided the fundamental research. The following two sections are summarized from these two papers.

2.1 ENERGY CONSCIOUS TOWNHOUSE DESIGN

In general, a townhouse is defined as a living unit which has approximately 1,200 to 1,600 square feet of area and contains two to three floors with a series of units as small as three and as large as twelve in a group.

The townhouse, as a form of residential housing, if designed properly, could be very efficient in energy conservation. Since a townhouse offers low operating and maintenance cost and saves energy as well as being economical to own, it is very attractive to a lot of families. A townhouse could save energy due to the decrease of square footage, less surface area exposed to the climatic impact and it requires less labor and material to construct.

In order to design an energy efficient townhouse, the following elements have to be studied:

1. Building Orientation:

   a) Solar exposure: this is the most important and critical element that must be considered because the sun affects all the facets of the design. In order to maximize winter heat gain and prevent summer overheating, the control of solar radiation is critical. In general, the first priority is that the townhouse should be oriented due south with a variation of 15 degrees. The second priority is how the sunlight is to be controlled or collected. A proper design of shading could be used to prevent summer heat gain as well as winter overheating problem.

   b) Wind exposure: wind will increase infiltration and thermal conductance over the townhouse exterior and thus will increase the building heating and cooling load. Therefore, windward side walls should be designed with a minimum of openings for winter.

2. Macro Climate Modification: Landscaping could be used to control or improve the impact of natural factors on the site. It can be used to protect the win-

ter wind as well as to maximize summer cooling and shading. Large and small trees and shrubs can be used as well as man-made architectural elements such as fences, paving, decks etc.

3. Shape and Volume: there are two alternatives to consider in the question of exposed surface area. If the first consideration of the design is energy conservation, then the cubic shape is the optimum form because it has the least exposed surface area. If the first consideration of the design is to maximize heat gain, then the rectangular shape with the long section oriented to the south is the optimum form. In general, the most efficient shape of a building is a cube with as many floors as possible and with the smallest enclosure to floor area ratio because the real useful space of the building is its net floor area.

4. Principles of Efficient Townhouse Design:

   a) Minimum space per user: an efficient townhouse should minimize the space for each occupant. Based on the existing practice of apartment design, it could be designed for 400 square feet maximum per user.

b) Multi-purpose and integrated space use: the space should be integrated to a large space to serve multi-purpose room such as living, dining room could be integrated with the kitchen.

c) No waste space: all spaces in the building should be designed for specific task. Unnecessary elements or spaces should be minimized.

5. Energy Conservation Techniques:

a) Heat transmission control: the building has to be designed so as to reduce the heat transfer. Ceiling should have a minimum value of R-30; floor R-19; R-19 for concrete slab floor perimeters; three inches external of one and a half inches internal insulation liner for non-conditioned space duct work; half an inch duct liner for conditioned space duct work; two inches external insulation for water heater; half an inch insulation for hot water pipes in non-conditioned space.

b) Air infiltration control: walls, ceiling and floors should have positive vapor barrier covering entire surface. Concrete slabs must be designed to rest on a complete vapor barrier. Crawl spaces should be covered with a vapor barrier of at least six mil thickness, and windows and doors should not exceed 10% of total floor area, be double glazed and/or storm sashed and must be weather stripped and calked.

As shown in Figure 1, the basic design process is the identification of the potential elements which are explain as follows:

1. Design Objective: it includes historical perspective, cultural influence, social limitation and future changes.
2. Building Programming: it includes the user and user activities, requirements and restrictions.
3. Design Program Analysis: it includes philosophy, occupancy characteristics, organization, spatial relationship, functional relationship and program summary.
4. Site Analysis: it includes macro-environmental factors, social and historical determinants as well as micro-environmental factors.
5. Development of Preliminary Schemes: it includes masssing, geometry, color and texture, orientation, organization, circulation and visual requirements.
6. Schemes Analysis: it includes design criteria and energy utilization criteria.

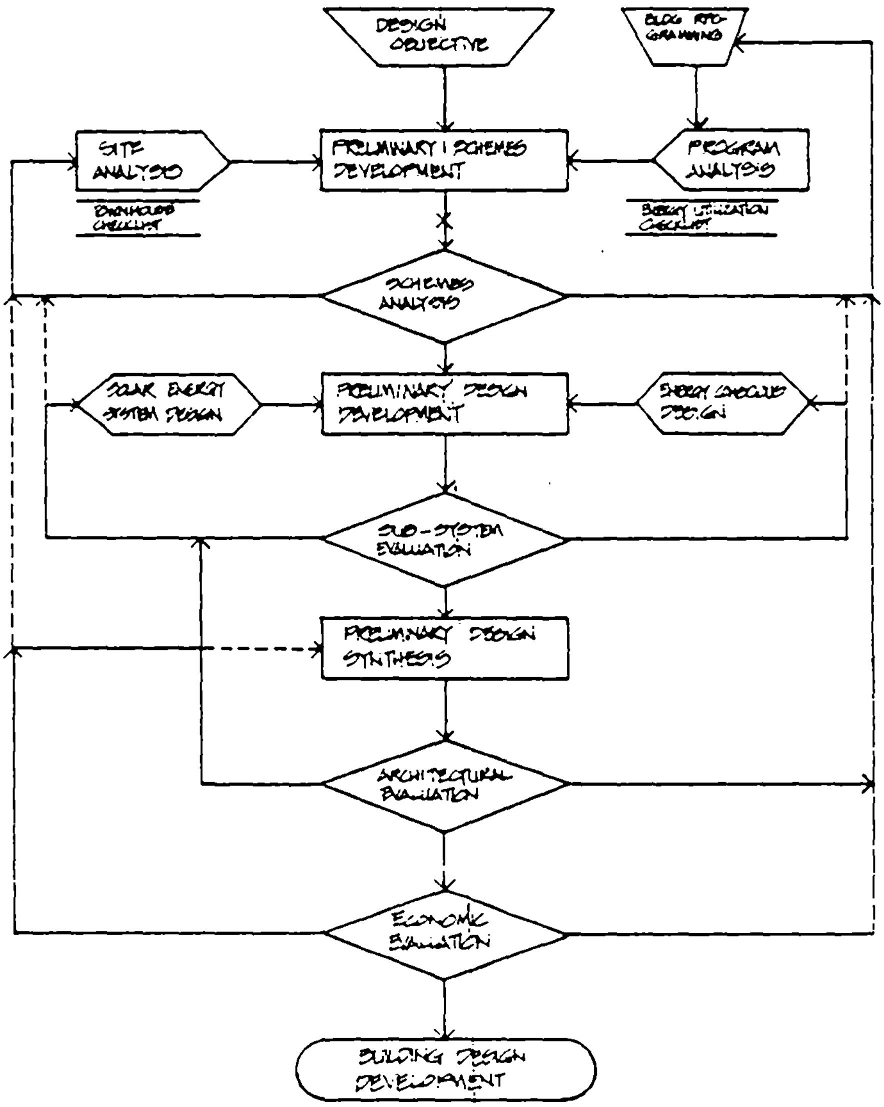

FIG 1 BASIC DESIGN PROCESS

7. Preliminary Design Development: it includes site orientation, climate control, space use and spatial organization, environmental and energy demands as well as circulation controls.
8. Sub-system Evaluation: it includes integration of macro and micro environmental, environmental comfort, health and safety, and energy system allocation.
9. Architectural Evaluation and Design Synthesis: it includes the effects of natural resources, the effects of human perception, optimization of energy supply and demand, and optimization of building subsystem planning.
10. Economic Analysis: it includes building cost estimation, energy conservation cost and benefit, and solar energy utilization cost and benefit.
11. Building Design Development: this is the final stage of the design process. Building documentation will be proceeded in this stage.

2.2 FUNDAMENTALS OF SOLAR TOWNHOUSE DESIGN

the paper "Fundamentals of Energy Conscious Townhouse Design" which was conducted by William Fotis Jr., strongly indicates that passive solar application to townhouse design could reduce approximately 50% of the energy demand. In order to provide the designer an understanding of solar energy townhouse design, the following basic analysis of solar energy systems is presented:

1. Direct Gain Solar System: it is defined as solar radiation entering the living space and providing direct heating of the space as well as heating of the storage mass which is exposed. Figure 2 shows the different designs of this system.
2. Indirect Gain Solar System: it is defined as the solar radiation collected by thermal wall or roof by day and provides heat to the living space day and night. Figure 2 shows the different designs of this system.
3. Isolated Gain Solar System: it is defined as solar energy that enters directly to the sunspace and provides heat to warm the air, as well as thermal storage mass in the sunspace. The air and thermal mass then will provide radian heat to the living space day and night. This system is also known as solarium or

greenhouse. The designs of this system are shown in Figure 2.

Robert N.S. Chiang 1980 (8/1)4 FIG. SPM - 1C

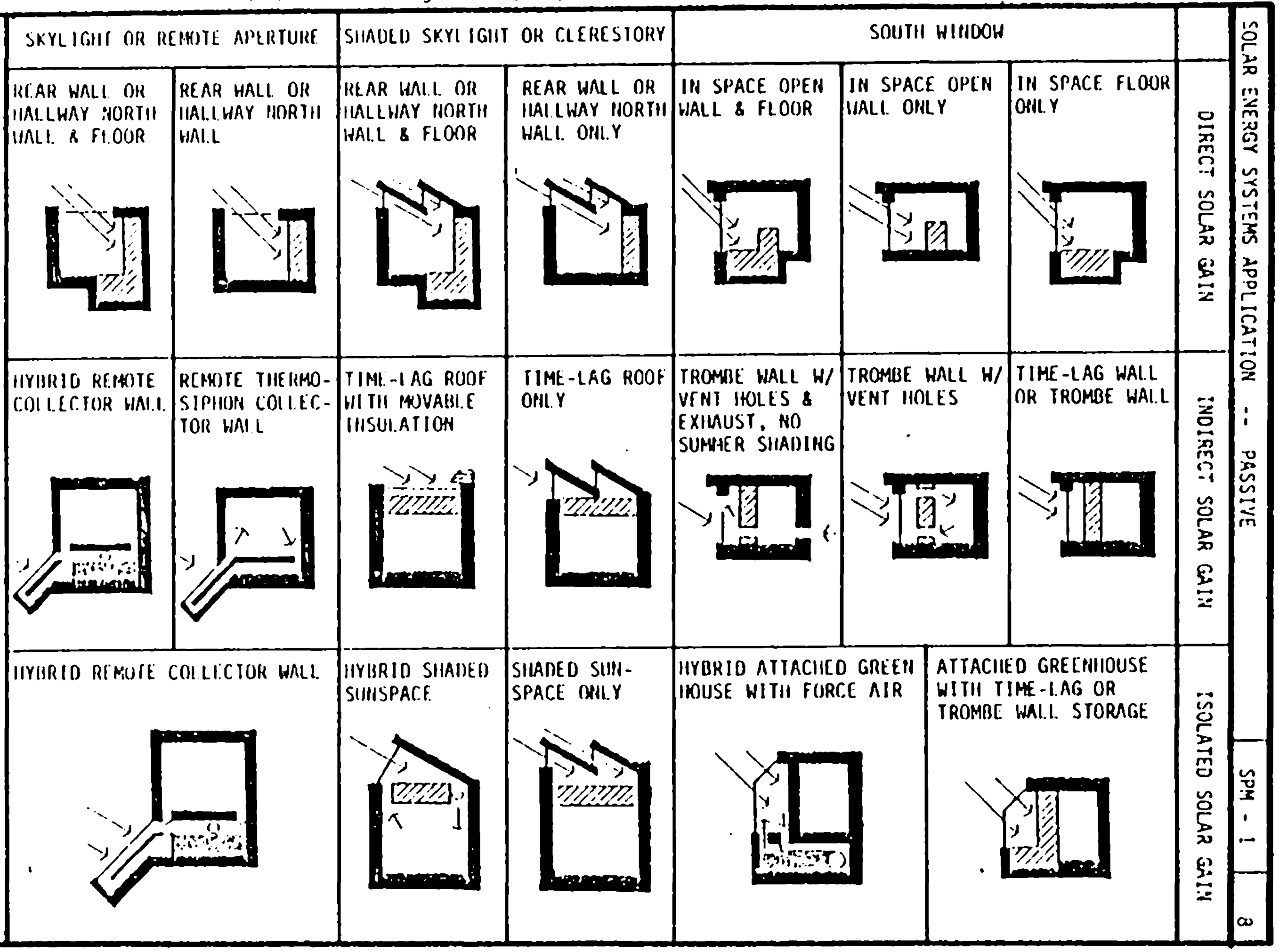

FIG. 2 PASSIVE SOLAR ENERGY SYSTEMS

Chapter 3

PROGRAM ANALYSIS

3.1 HOUSING CONDITIONS IN BLACKSBURG

Because of the energy crises of the past and potential crises in the future, present high interest rate, high housing cost, housing development in Blacksburg trends towards higher densities. Multi-family development, townhouses and condominiums will dominate instead of detached single-family residences, and the single-family residences will be smaller in size on a smaller lot.

For the same reason, the pattern of growth in Blacksburg takes the path of least resistance and private cost by following existing roads and proposed utility lines, and by avoiding those natural barriers that could add significantly to development cost.[3]

According to the Blacksburg Comprehensive Plan[4] by the year 1985, the population will expend from 30,000 (1976) to 45,000. Therefore, additional dwelling units will be needed by that time. Shortage of dwelling units already exist. By the year of 1985, there will be a substantial

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[3] Blacksburg Planning Department, Blacksburg 1985, B.P.D.,1974, pp. 16-21

[4] Blacksburg City Council, Blacksburg Comprehensive Plan, 1978.

shortage of units, especially for the staff, faculties of Virginia Polytechnic Institute and State University (VPI and SU) and others.

In 1974, Blacksburg had 10,716 dwelling units including 4,278 dormitory rooms on the VPI and SU campus, 2,151 single-family homes and 4,287 multi-family units. In 1970, there was an average of 2.66 persons per dwelling unit in Blacksburg. Approximately 5,640 new dwelling units will need to be constructed to accomodate the additional 15,000 newcomers in order to maintain the same density in 1985. According to the university policy against building additional campus housing, most of these units will need to be provided by off campus construction, eventhough limited married student housing is under planning.

Vacancy rate is practically nonexistent in Blacksburg because rapid local growth and the inflationary national economy have already caused a tight housing market. These conditions are not likely to change until the rate of growth levels off in the near future. It is possible that even fewer than 5,640 dwelling units will be provided if there are more persons per dwelling unit.

Because of the significant difference in the amount of land used by single-family homes as opposed to multi-family homes, it is necessary to estimate the additional units that will be contributed between these two categories. Multi-family housing is now primarily associated with students of VPI and SU (approximately 80% of all apartments are occupied by students). At present, 57% of Blacksburg's population not housed by the university are students. The proportion of multi-family to single-family dwellings (67%) is likely to remain constant. Therefore, of the 5,640 dwelling units needed, 3,800 will be constructed as multi-family units and 1,850 as single-family units.[5]

Blacksburg has recently started a multi-million dollar program to extend both its sanitary sewer and public water facilities throughout the entire community. Moreever, Blacksburg has encouraged the development of cluster housing and townhouses in its municipal zoning ordinance. These changes have reduced the average lot size per single-family home. New single-family homes constructed in 1973 had an average lot-size of 1/3 acre as compare to 1/2 acre before 1973. If the trend continues, Blacksburg will only use 645 acres for single-family homes, instead of 890 acres at the larger average lot-size (1/2 acre). Residential land use for Blacksburg in the future is shown in Figure 3.

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[5] same as Footnote 3

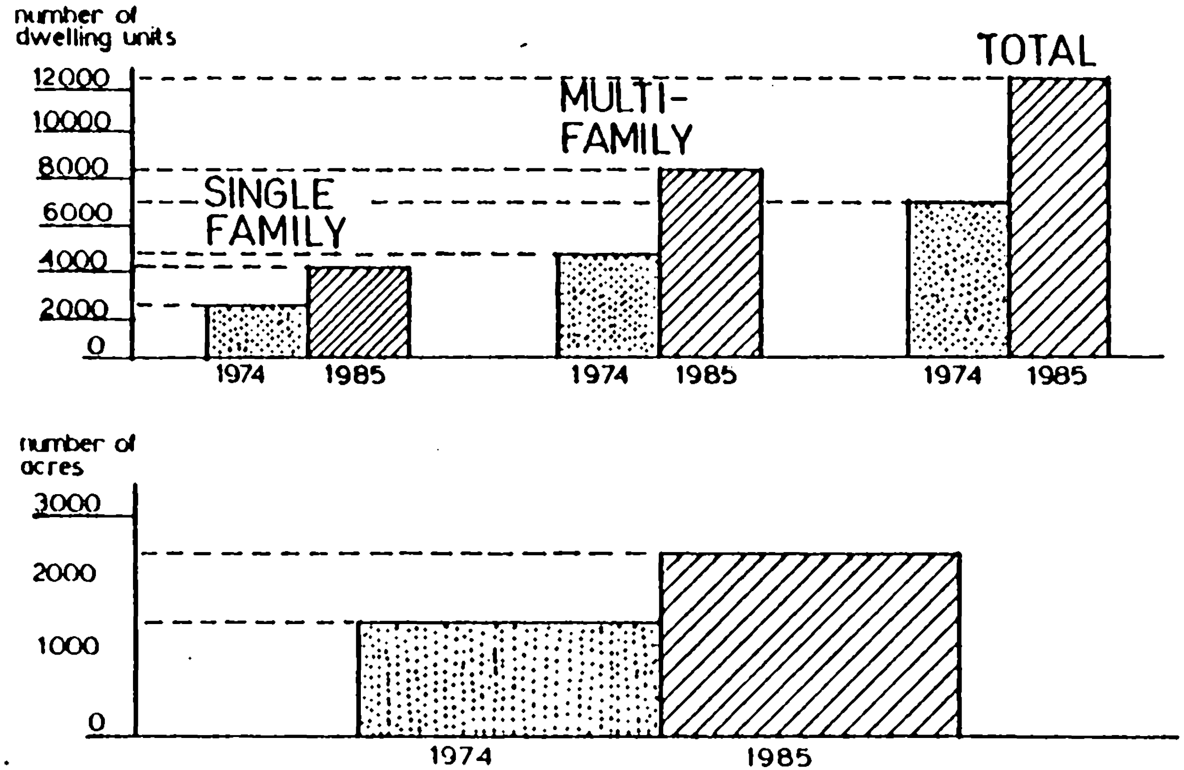


FIG. 3 PREDICTED FUTURE RESIDENTIAL LAND USE IN BLACKSBURG

SOURCE: BLACKSBURG 1985, BLACKSBURG PLANNING DEPARTMENT, 1974

3.2 DESIGN GOALS/OBJECTIVES

1. To apply solar energy application principles to the design of townhouses for Blacksburg. The following principles have been specially studied:
   a) maximizing solar exposure.
   b) utilizing the " mass " of the structure for passively storing solar heat and internal heat gains.
   c) utilizing night insulation and/or solar shading devices.
   d) minimizing all non-south windows.
   e) wind screen during winter, but allowing for summer breezes.
2. To provide living amenities such as view, pricary and individuality generally associated with single-family houses but normally lacking in multi-family dwellings.
   a) view:
      i) units should be planned to take advantage of the view of the surrounding areas.
      ii) units should be planned to avoid visual penetration of adjacent units.
   b) privacy/individuality:
      i) it should be maximized to provide the greatest sense of privacy and individual owenership.

ii) courtyards shoulds be provided for all units.

iii) sufficient variety should be provided to allow individual preferences.

3. To change the stereotype images associated with condominium living in hopes of creating living situations more competitive with the single-family dwelling units.

4. To create a living place which is in harmony with the surrounding environment.

5. To create a distinctive image of high quality and pride.

6. To establish a " sense of place " that gives each occupant a feeling of individuality while at the same time, as being a community.

7. To help meet the increasing demand for housing in Blacksburg.

8. To offer the occupant an alternative to single-family houses.

3.3 SPATIAL REQUIREMENTS

The following program was developed to meet the general needs of generalized occupant and is therefore less specific in nature and detail than would be expected for a specific occupant. The program was developed around the concept of providing guidelines for fulfilling these general needs. Specific solutions for specific amenities were left undefined and open for consideration as the problems became evident within a particular design context.

Spatial Module:

1. Entry: transition zone form public into private (interior) space. Large (exterior) enough to accommodate small group of people. Should provide good access to unit zones and have designated space for guest coats, etc..
2. Living room: planned for ease of entertaining, relaxing and appreciation of outward view. Interior fireplace or wood stove is desirable as backup unit for the solar system.
3. Dining space: flexible for formal and informal living; direct relationship with the kitchen.
4. Kitchen: planned for ease of food preparation, clean up, access to entry and service to dining. Should be

with maximum amount of counterspace. Built-in utility area and storage should be incorporated in the kitchen area.

5. Bedroom/bath: guest or child bedroom should be located away from living areas. Adequate storage provisions and bathroom should be provided.
6. Master bedroom: planned for ' luxury ' both size and spatially; good view and sunshine and storage should be provided.
7. Storage: specific storage space should be considered and should be an integrated part of all storage space in the housing as well as outside the unit.
8. Miscellaneous circulation: circulation corridors and space should be kept to a minimum.
9. Family room: a separate family room should be provided as much as possible.
10. Open plan where possible: integration of kitchen, dining and family rooms; combined living, family and dining room; or study, guest and family room.

Figures 4, 5, 6 and 7 are provided to illustrate the relationships among the major components of the projected townhouse as described above. Figure 8 is a proposed list of design priority among the major elements within a single housing unit to demonstrate solar applicability to these elements.

3.4 USER IDENTIFICATION

As shown in Figure 9, the major multi-family dwelling shortage falls in the category of staff, faculty of VPI and SU and others by year 2000. In addition, this shortage is mostly caused by young couples with one to two children. Therefore, this project is aimed to satisfy this need and is composed of two-bedroom and a limited amount of three-bedroom units.

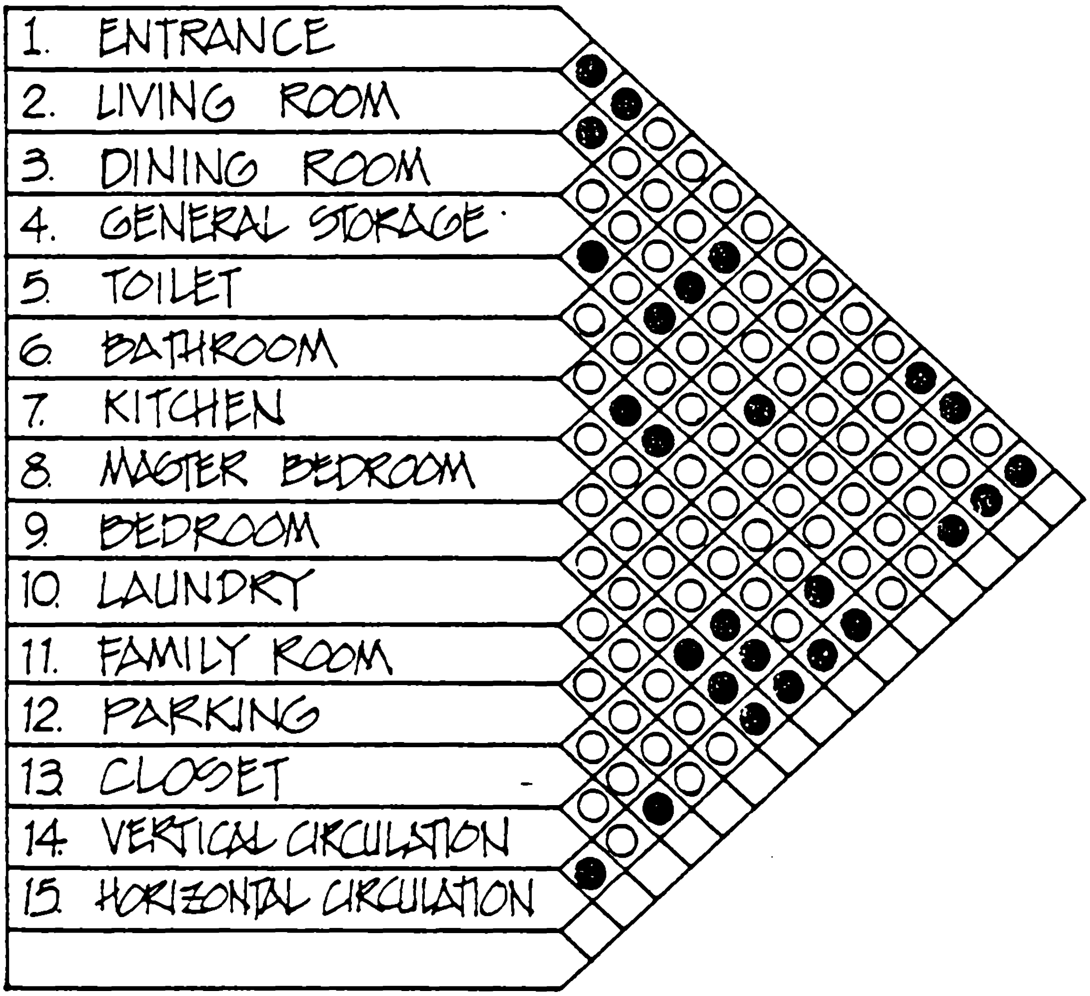


FIG. 4 FUNCTIONAL RELATIONSHIP OF THE PROTOTYPICAL TOWNHOUSE UNIT

○ = INDIRECT RELATIONSHIP

● = DIRECT RELATIONSHIP

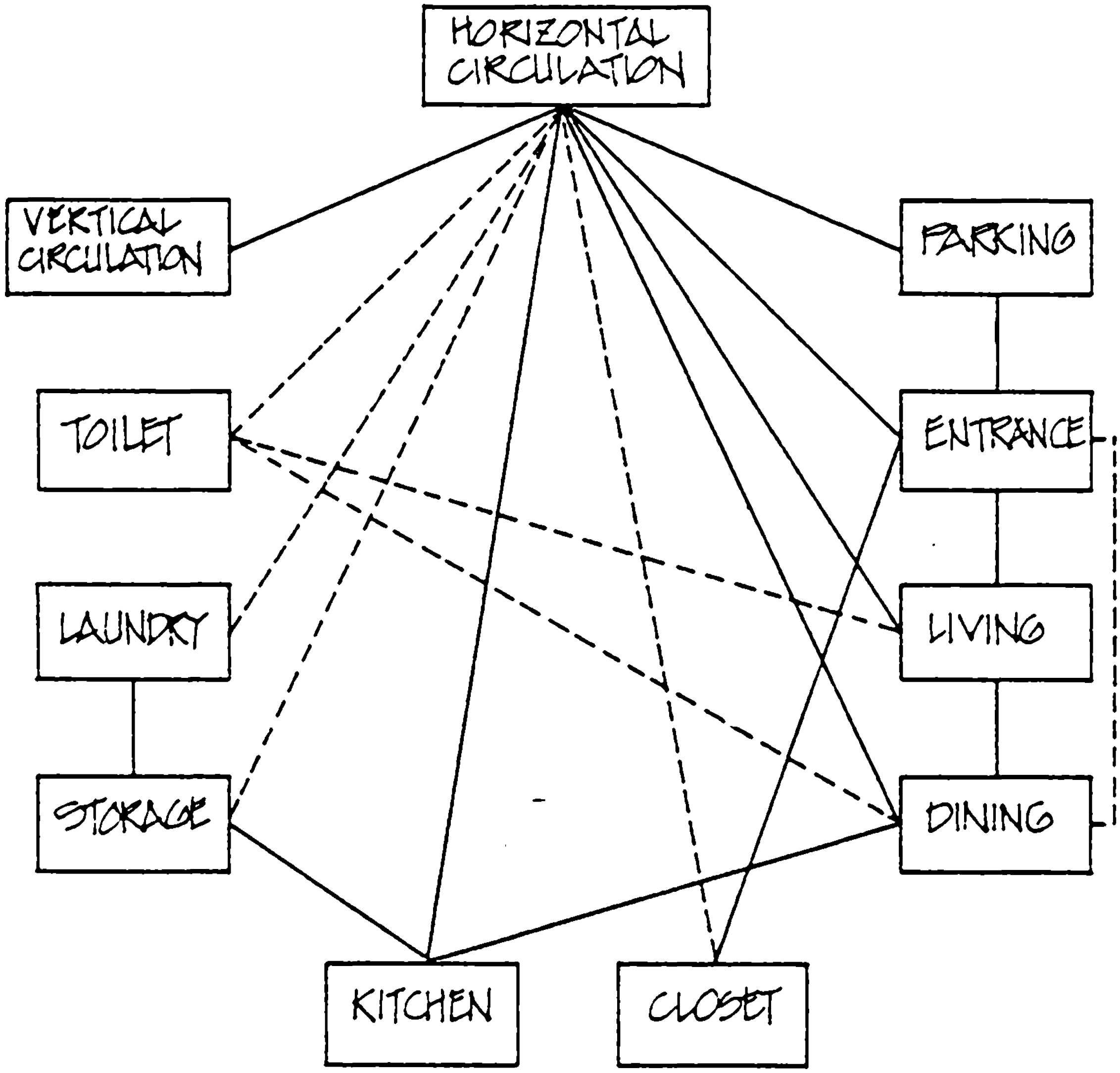


FIG. 5 ILLUSTRATION OF FUNCTIONAL RELATIONSHIPS OF THE PROTOTYPICAL TOWNHOUSE UNIT — FIRST FLOOR

DIRECT RELATIONSHIP = ————————

INDIRECT RELATIONSHIP = – – – – – – –

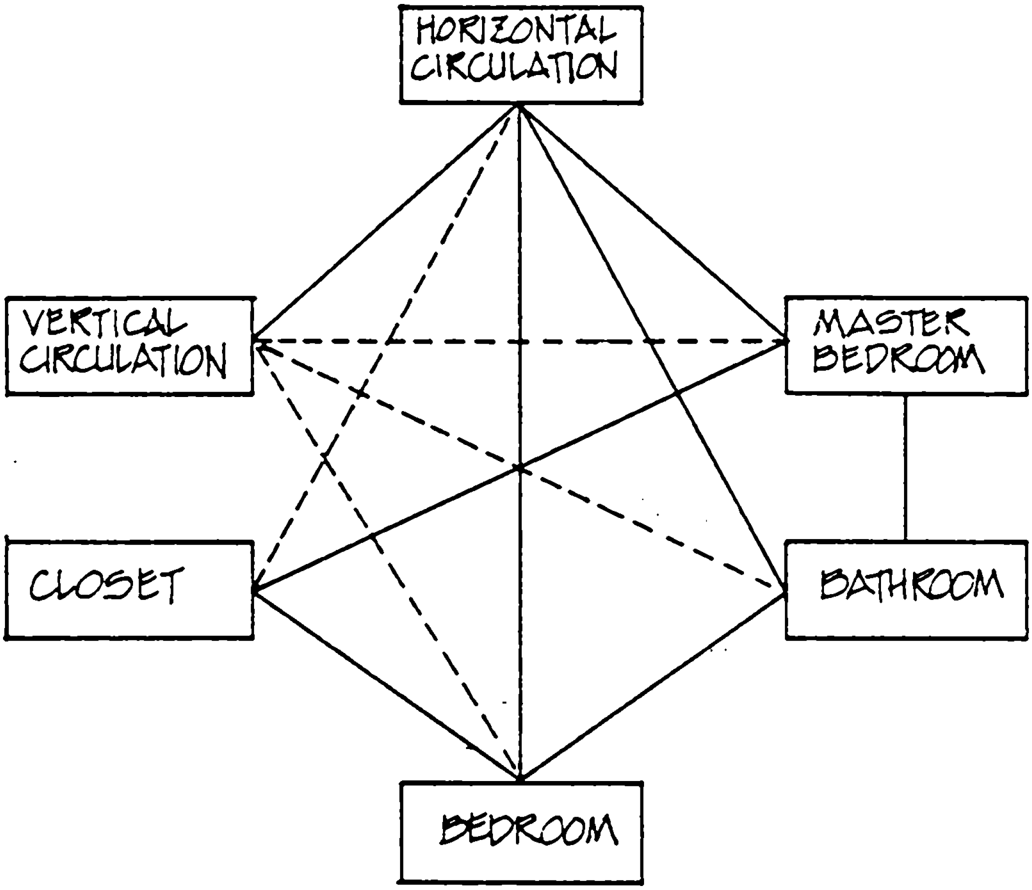


FIG. 6 ILLUSTRATION OF FUNCTIONAL RELATIONSHIPS OF THE PROTOTYPICAL TOWNHOUSE UNIT — SECOND FLOOR

DIRECT RELATIONSHIP = ————

INDIRECT RELATIONSHIP = - - - -

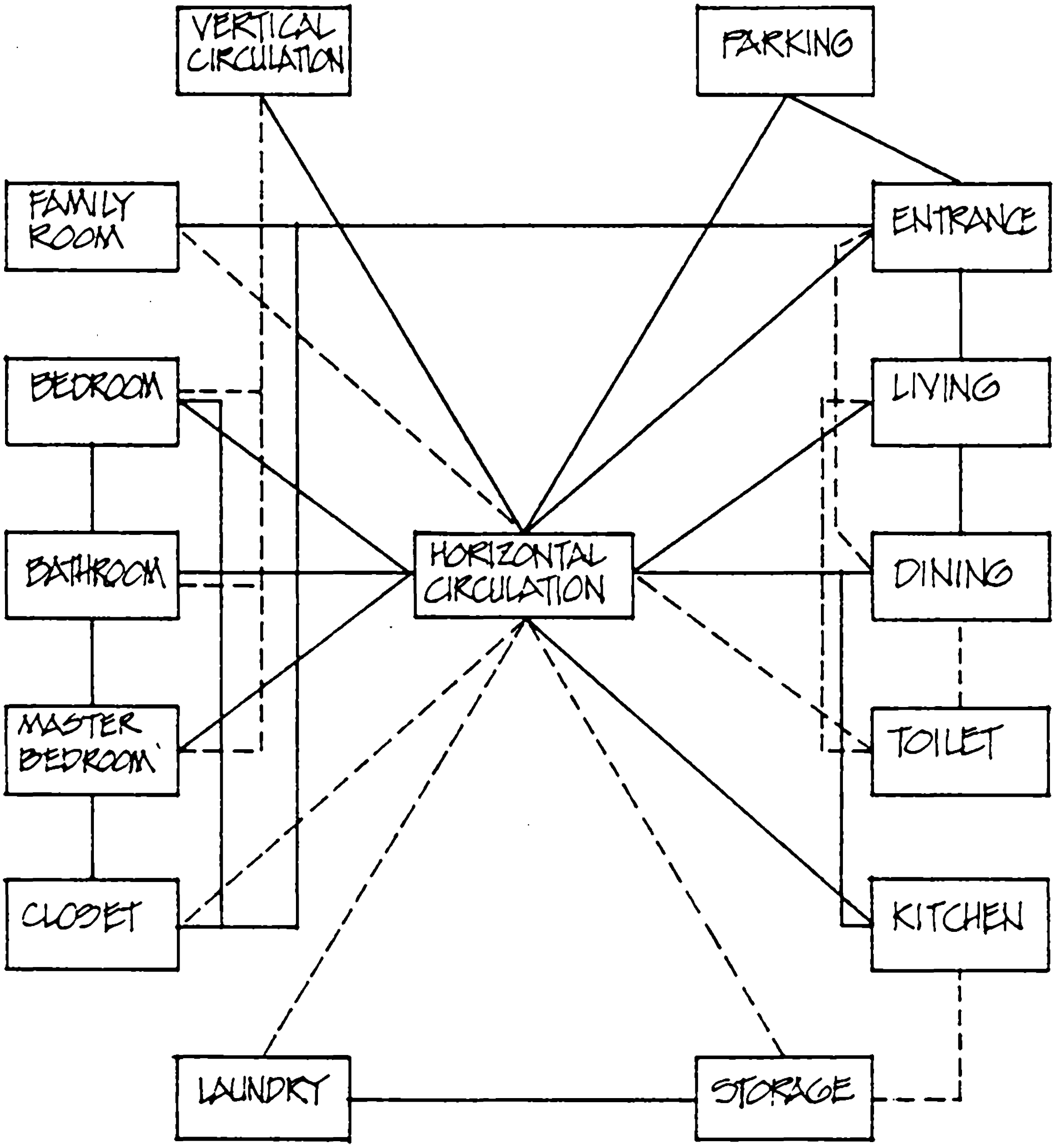


FIG 7. COMPOSITE FUNCTIONAL RELATIONSHIPS

DIRECT RELATIONSHIP = ————

INDIRECT RELATIONSHIP = - - - - - -

		1 DIRECT GAIN	2 INDIRECT GAIN	3 SHADING CONTROL	4 NATURAL VENTILATION	5 WIND SCREEN	6 SUPER INSULATION	
1	ENTRANCE	C	C	B	B	A	A	
2	LIVING ROOM	A	B	A	A	A	A	
3	DINING ROOM	A	B	A	A	A	A	
4	GENERAL STORAGE	C	C	C	C	C	C	
5	TOILET	C	C	C	C	C	C	
6	BATHROOM	C	C	C	C	C	C	
7	KITCHEN	B	B	A	B	B	A	
8	MASTER BEDROOM	A	A	A	A	A	A	
9	BEDROOM	A	A	A	A	A	A	
10	LAUNDRY	C	C	C	C	C	C	
11	FAMILY ROOM	B	B	B	B	B	B	
12	PARKING	C	C	C	C	C	C	
13	CLOSET	C	C	C	C	C	C	
14	VERTICAL CIRCULATION	C	C	C	C	C	C	
15	HORIZONTAL CIRCULATION	C	C	C	C	C	C	

FIG. 8 SOLAR APPLICABILITY CHART

A = IMPORTANT
B = LESS IMPORTANT
C = LEAST IMPORTANT

	SINGLE FAMILY	MULTI FAMILY	TOTAL NEED
CURRENT SHORTAGE	40	313*	353
VPI & SU. STUDENTS AND FAMILY		533	533
STAFF, FACULTY AND OTHERS	2,907	1,666	4,573
TOTAL	2,947	2,512	5,459

* INCLUDES DORMITORY AND MOBILE HOME SHORTAGES

FIG. 9 PREDICTED HOUSING DEMAND BY YEAR 2000

SOURCE: BLACKSBURG COMPREHENSIVE PLAN, BLACKSBURG CITY COUNCIL, 1978

Chapter 4

A CASE STUDY

4.1 DESIGN PROCESS AND SUMMARY

The townhouse analysis and design, and solar townhouse application are based on the studies of Prof. Chiang, Mr. Fotis and Mr. Chen.[6] The design process this project deploys can divided into four major components--PROJECT PROGRAMMING, DESIGN ANALYSIS, PRELIMINARY DESIGN DEVELOPMENT AND FINAL DESIGN DEVELOPMENT, (see Figure 10). Based on the discussion in the previous chapters, the task of the first stage is to define the goals and objectives of the project, to developed its design program, to select a site and collect pertinent data for analysis.

It is then followed by two interrelated stages which are essentially carried out in a cyclic fashion. In the design analysis stage, data collected are analyzed, summarized and developed into design elements and/or design criteria for design development and evaluation into large stage. The site, the nature and characteristics of townhouse, its opportunities and constraints for passive solar applications are specially studied.

[6] same as Footnote 2

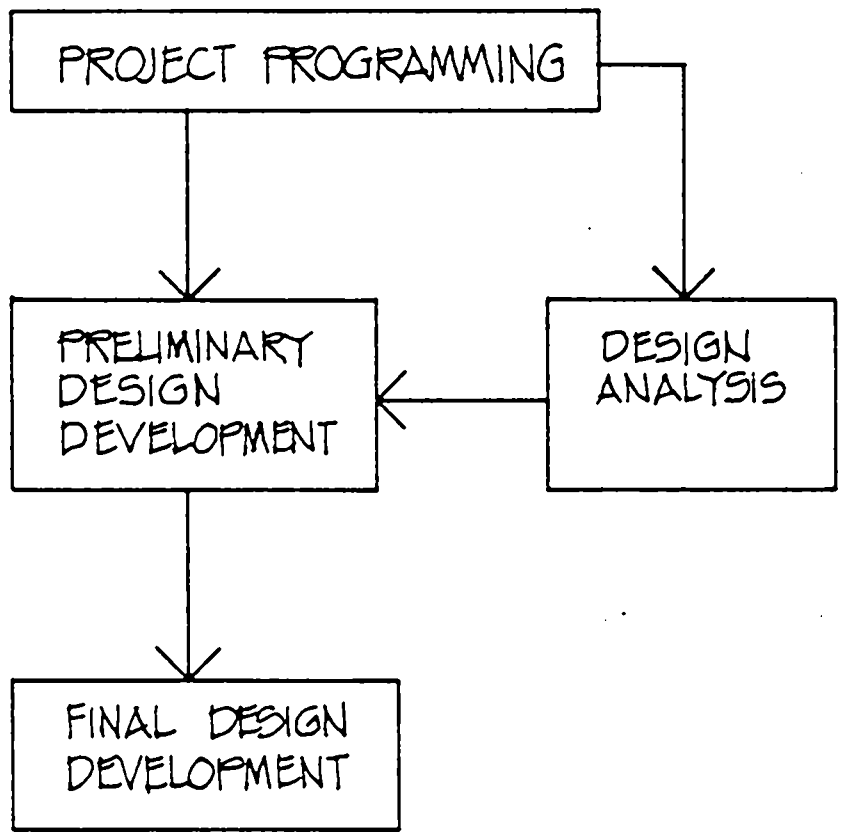


FIG. 10 SIMPLIFIED DESIGN FLOW CHART

At the same time, a preliminary design scheme is developed upon the design elements and conditions established. At its completion, it then goes through two evaluation processes-- solar application and architectural evaluation--based on the developed criteria in the design analysis stage. The preliminary scheme will be recycled and modified within the second and the third stages until it satisfies the evaluation criteria in both processes.

Once preliminary design scheme or schemes are established, a final design optimization will be carried out to produce the best solution for the project in the final design development stage. The final task of this stage is to document the total process and the result of the design (see Figure 11).

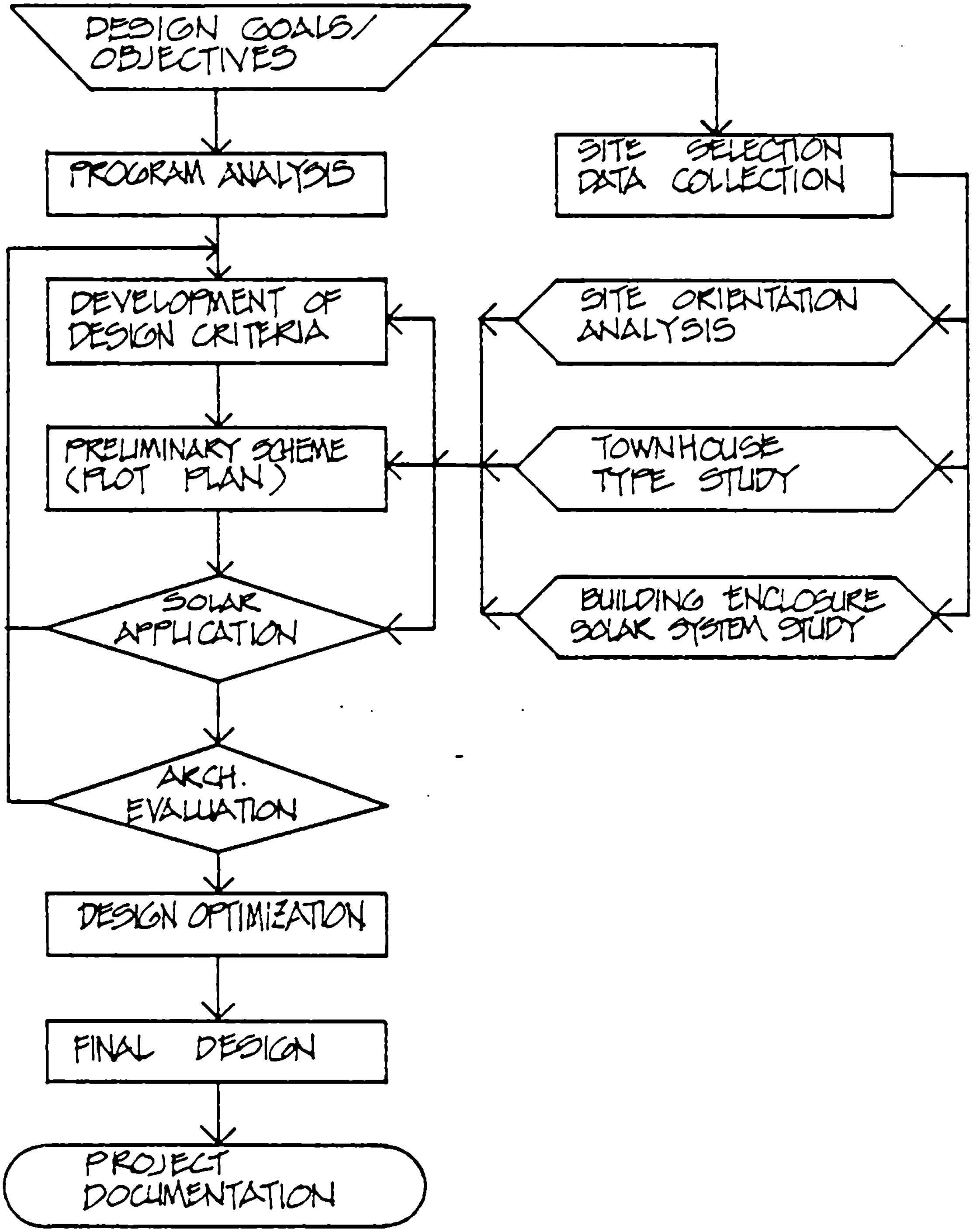


FIG. 11 DESIGN PROCESS FLOWCHART

4.2 BASIC DESIGN

4.2.1 SCOPE OF DESIGN:

This project consists of the following elements:

1. 45 units of prototypical townhouses applying passive solar technologies on the selected site.
   a) townhouse units: 45
   b) three-bedroom units: six, approximately 1,500 square feet per unit.
   c) number of floors: three
   d) two-bedroom units: 39, approximately 900 square feet per unit.
   e) number of floors: three
2. Passive solar system: direct gain
   a) solar saving fraction (annually): 65-80%
   b) collector area: 11-23% of total floor area
   c) collector: double glazing
   d) clerestories: double glazing
3. Public facilities:
   a) children playground: two, approximately 4,500 square feet each
   b) clubhouse: consists of spaces for ping pong table, pool table, with an office and a meeting hall, approximately 4,000 square feet.
   c) outdoor swimming poor

4.2.2 PLOT PLAN:

Based on the site analysis, approximately five and a half acres of the land is suitable for applying solar technologies as indicated in Figure 13.

Major circulation loops through the site connecting the two entrances, leading to Faculty and Wilson Streets respectively, and organizing the three proposed townhouse groupings. Elements and the area taken within these groupings is shown in Figures 12 and 13.

The remaining three and a half arces will be essentially occupied by a park with a clubhouse and a swimming pool. This open area also has the potential to be developed in the future for expansion of this community.

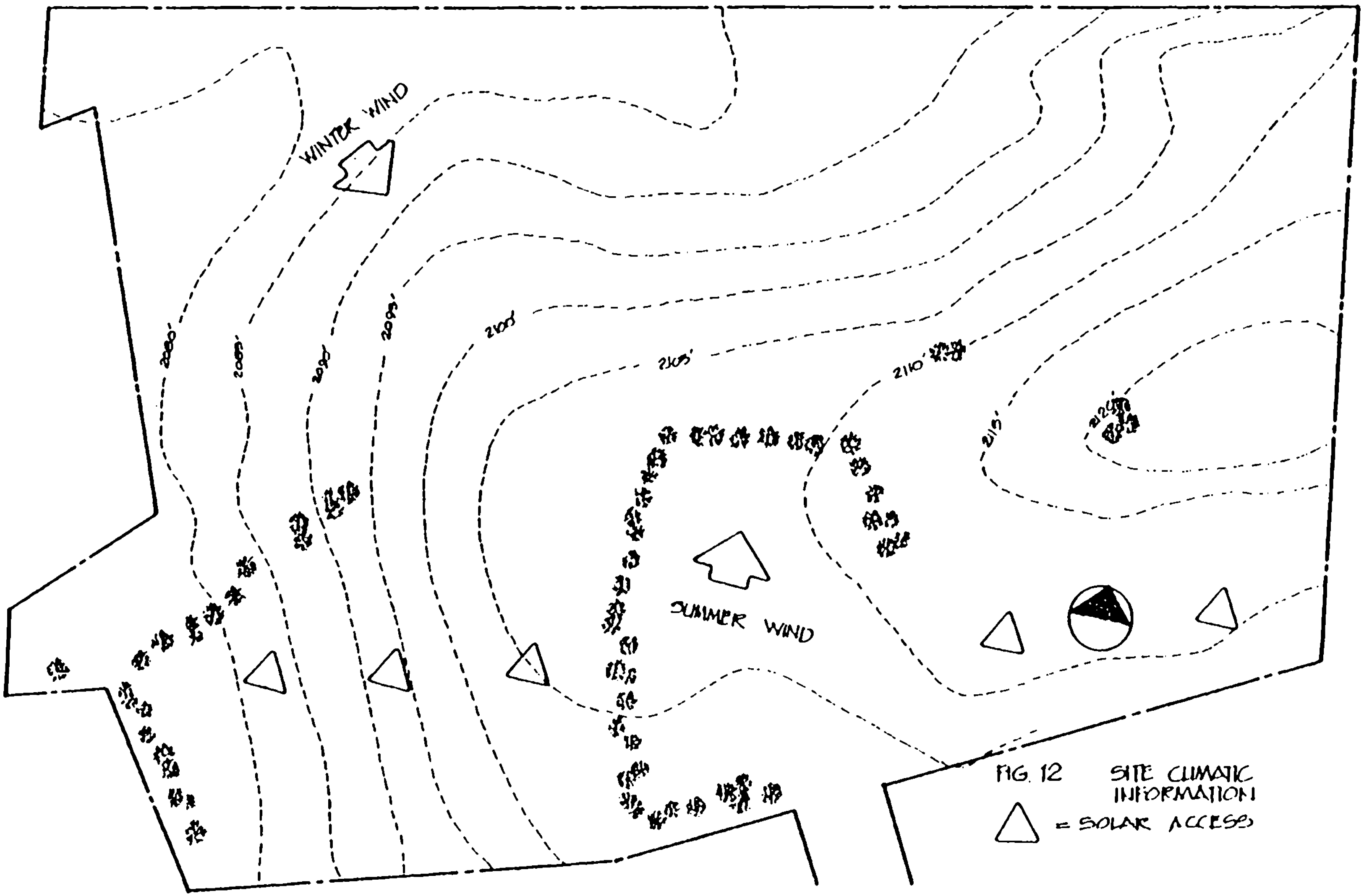


FIG. 12 SITE CLIMATIC INFORMATION

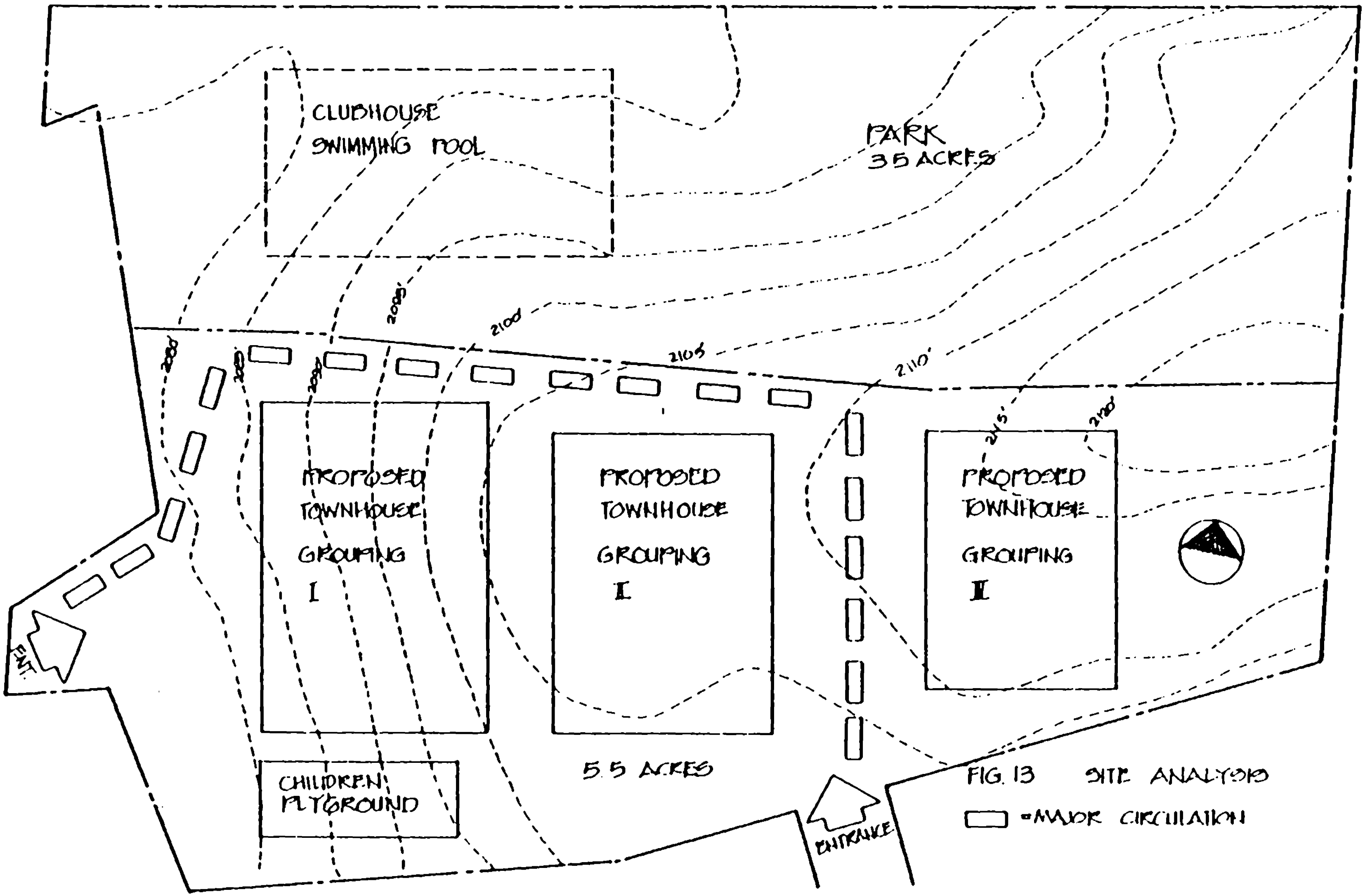


FIG. 13 SITE ANALYSIS

4.2.3 HOUSING TYPE ANALYSIS

1. Solar exposure: as shown in Figure 14, the direction to get maximum solar exposure is due south.
2. Regular form: under a given climatic condition, regular forms minimize heat loss from the units. As indicated in Figure 15, building A has less exposure to the air and thus has less heat loss.
3. Continuous units: due to the fact that continuous units share building walls and also reduce heat loss. From the comparison of alternative layouts of continuous units, type A is the most suitable for minimizing heat loss due to its minimum exposure to the air (see Figure 16).

Based on above study, the design of the project townhouse will be characterized by the following features:

1. due south.
2. continuous straight line units with five to seven units in a row.
3. rectangular unit form.

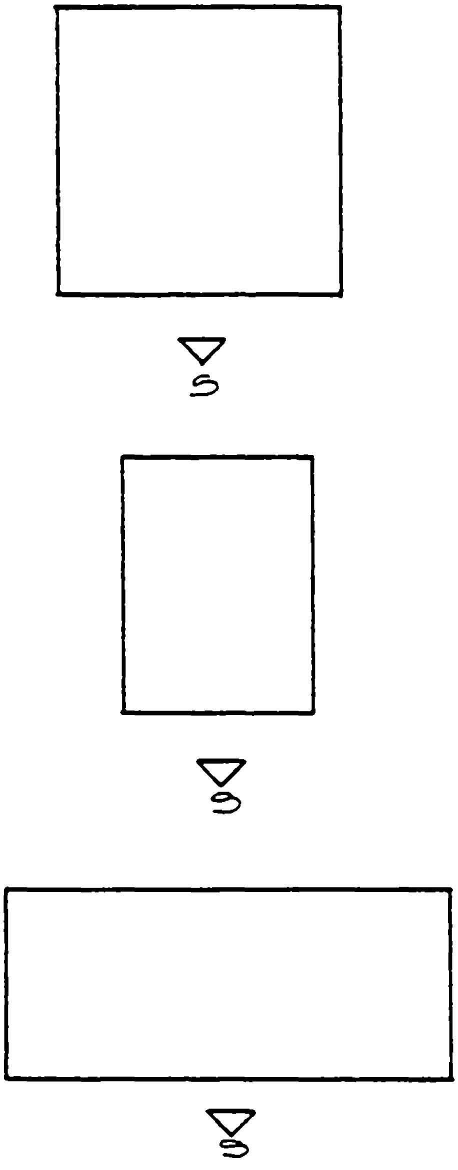


FIG 14. SITE SOLAR EXPOSURE

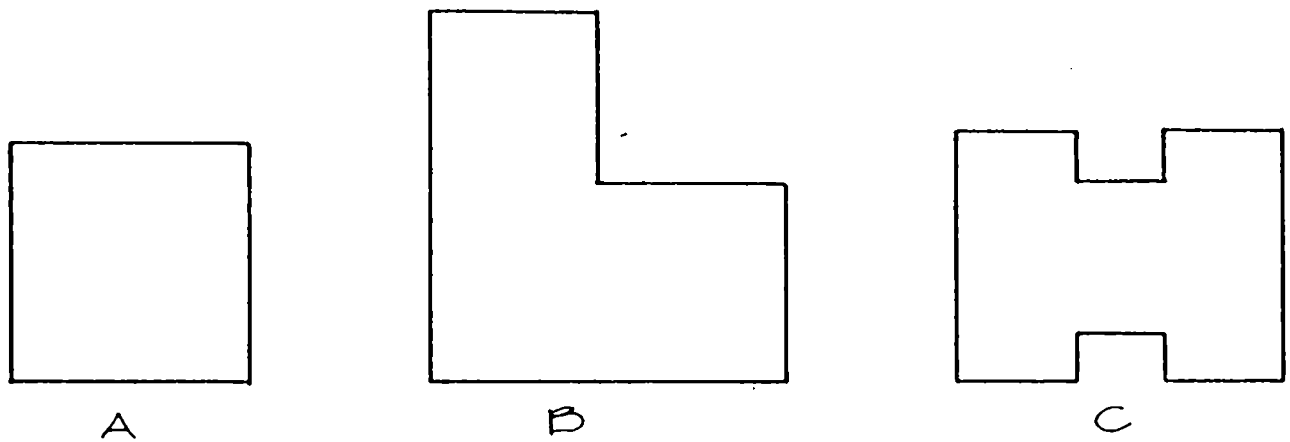


FIG. 15 THE SHAPE OF THE SOLAR TOWNHOUSE

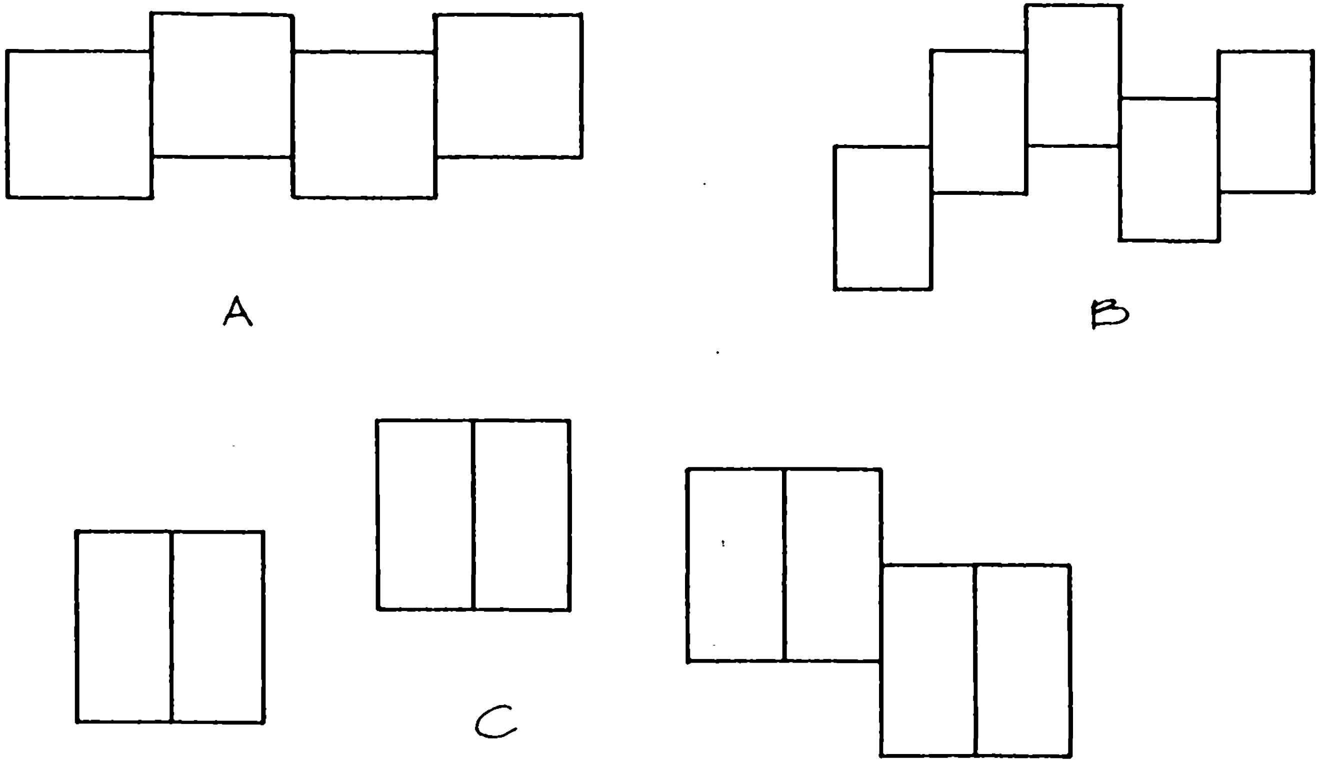
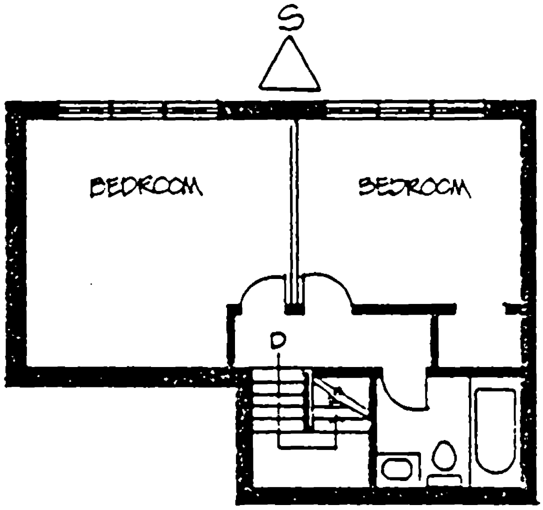


FIG. 16 THE GROUPING OF THE SOLAR TOWNHOUSE

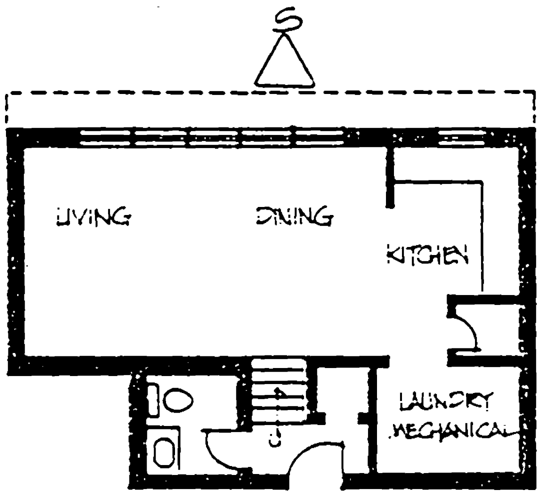
4.3 SAMPLE DESIGN

Based on the established program, three alternative units are developed as the ptototype of the townhouse project. (see Figure 17, 18 and 19).

Type A and type B both have two floors. While the former has a wider south-facing frontage and a smaller floor area, the latter has a narrower south-facing frontage and a slightly larger floor area. Type C is the smallest alternative unit with three floors. Its proportion and orientation are similar as type A. The collector areas of all three alternatives are kept very close--156 square feet for type A, 144 square feet for type B and type C.

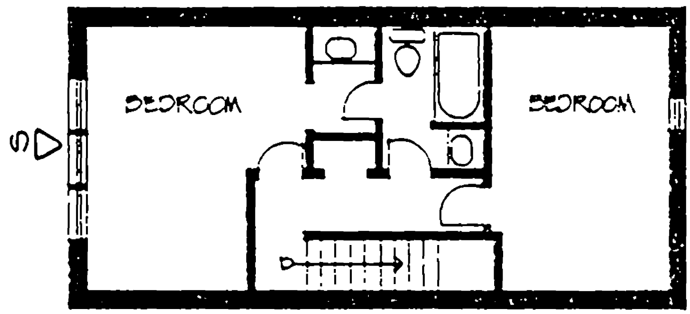


2ND FLOOR PLAN

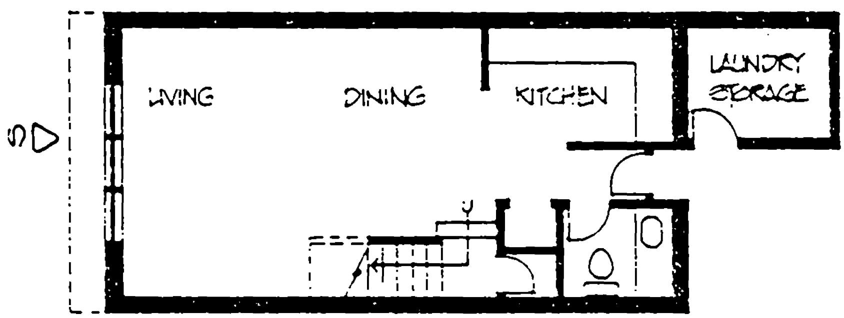


1ST FLOOR PLAN

FIG. 17 ALTERNATIVE SOLAR TOWNHOUSE UNIT TYPE A



2ND FLOOR PLAN



1ST FLOOR PLAN

FIG. 18 ALTERNATIVE SOLAR TOWNHOUSE UNIT TYPE B

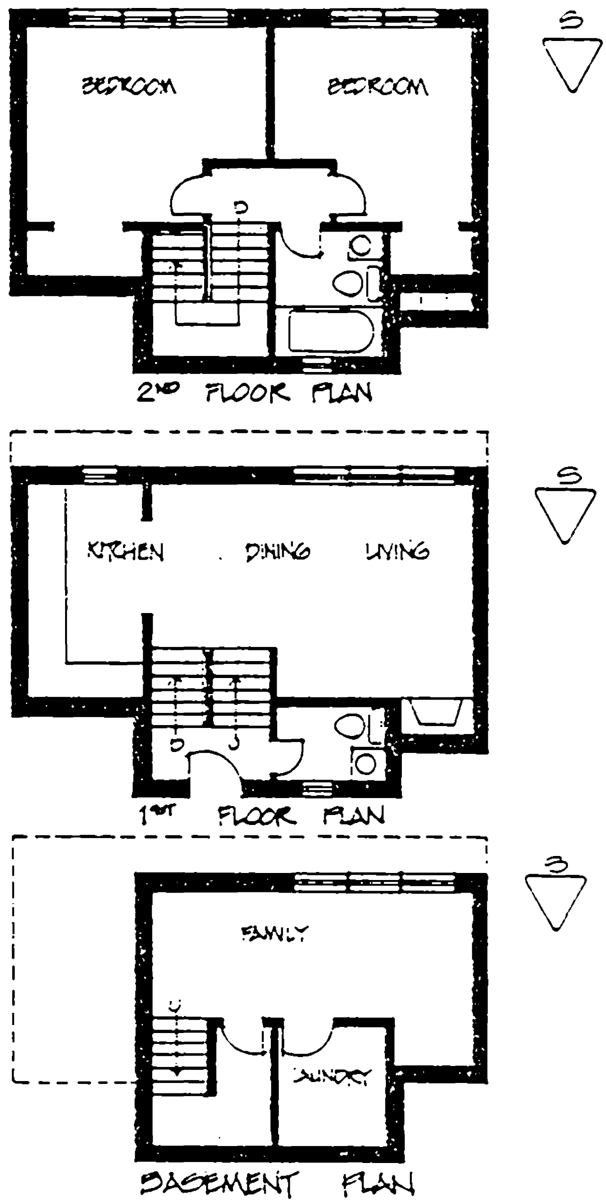


FIG. 19 ALTERNATIVE SOLAR TOWNHOUSE UNIT TYPE C

4.4 COMPARATIVE ANALYSIS

The purpose of this section is to determine the best spatial layout as the prototype for single townhouse unit in this project for further development.

Based on Balcomb Method A (see Appendix A), the solar performance of the three prototypes--type A, B and C (see Figures 17, 18 and 19)--are calculated as shown in Figure 20 and 21.

For the yield to close solar saving fractions, EUI's, and rates of return type B and type C require less collector area then type A. However, type C has a more efficient spatial layout and an essential family room. Therefore, type C is the best prototype for this project and is then going through Balcomb Method B (see Appendix B) for detailed solar performance study.

TYPE	AREA (FT²)	COLLECTOR AREA (FT²)	S.S.F.	E.U.I.	RATE OF RETURN	SYSTEM
A	908	156	27%	4.5×10^6	7.5 YRS	DIRECT GAIN
B	960	144	28%	4.15×10^6	7 YRS	WITHOUT NIGHT
C	880	144	27%	4.2×10^6	7 YRS	INSULATION

FIG. 20 COMPARATIVE SOLAR PERFORMANCE ANALYSIS I

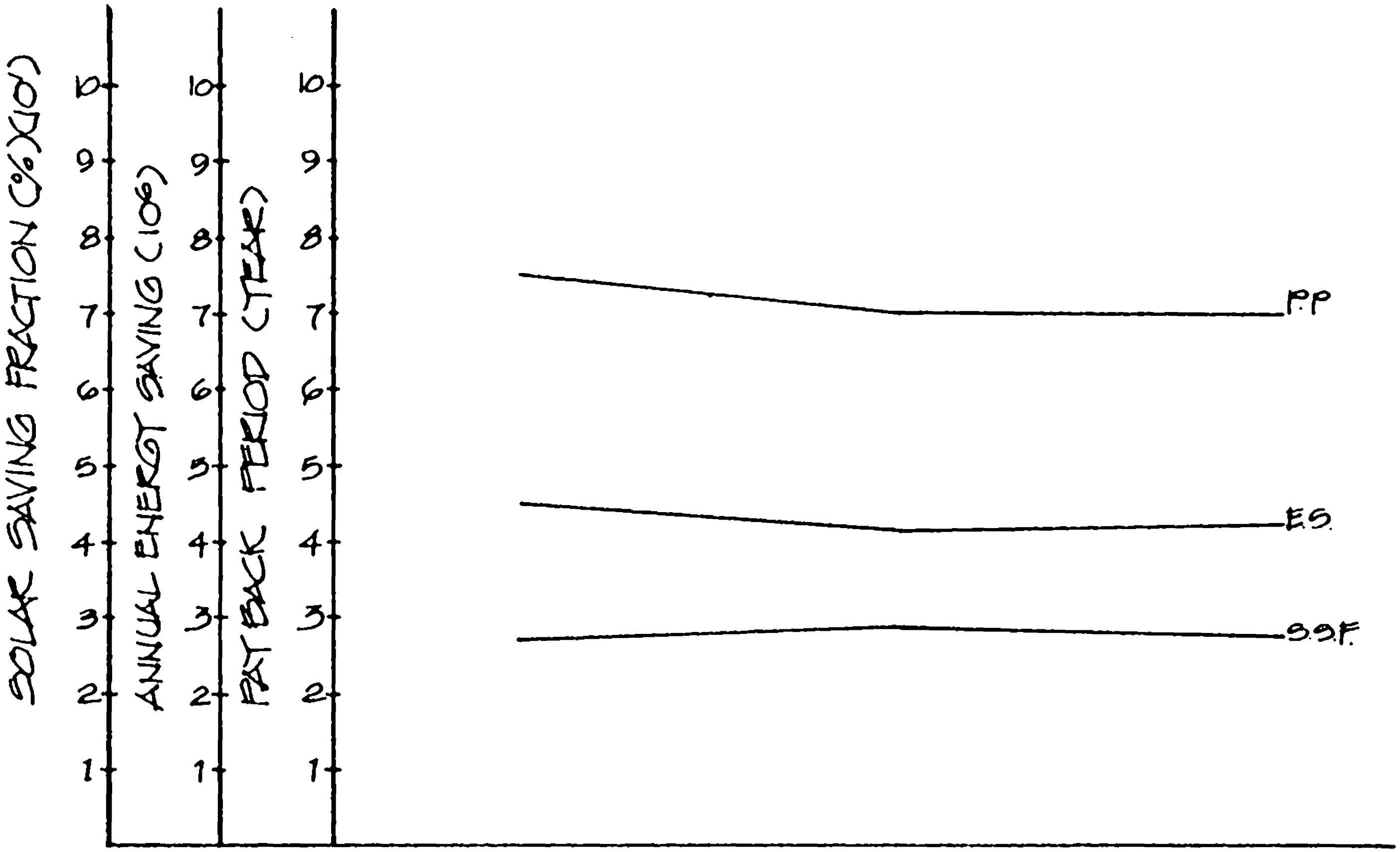


FIG. 21 COMPARATIVE SOLAR PERFORMANCE ANALYSIS II

4.5 SOLAR DESIGN DEVELOPMENT AND ANALYSIS

From the calculation of Balcomn Method B, the solar performance of unit type C is reasonably satisfactory with 69% of solar saving fraction and 22F temperature swing (see Appendix B).

A townhouse design and site planning are then developed based on unit type C and the plot plan mentioned previously.

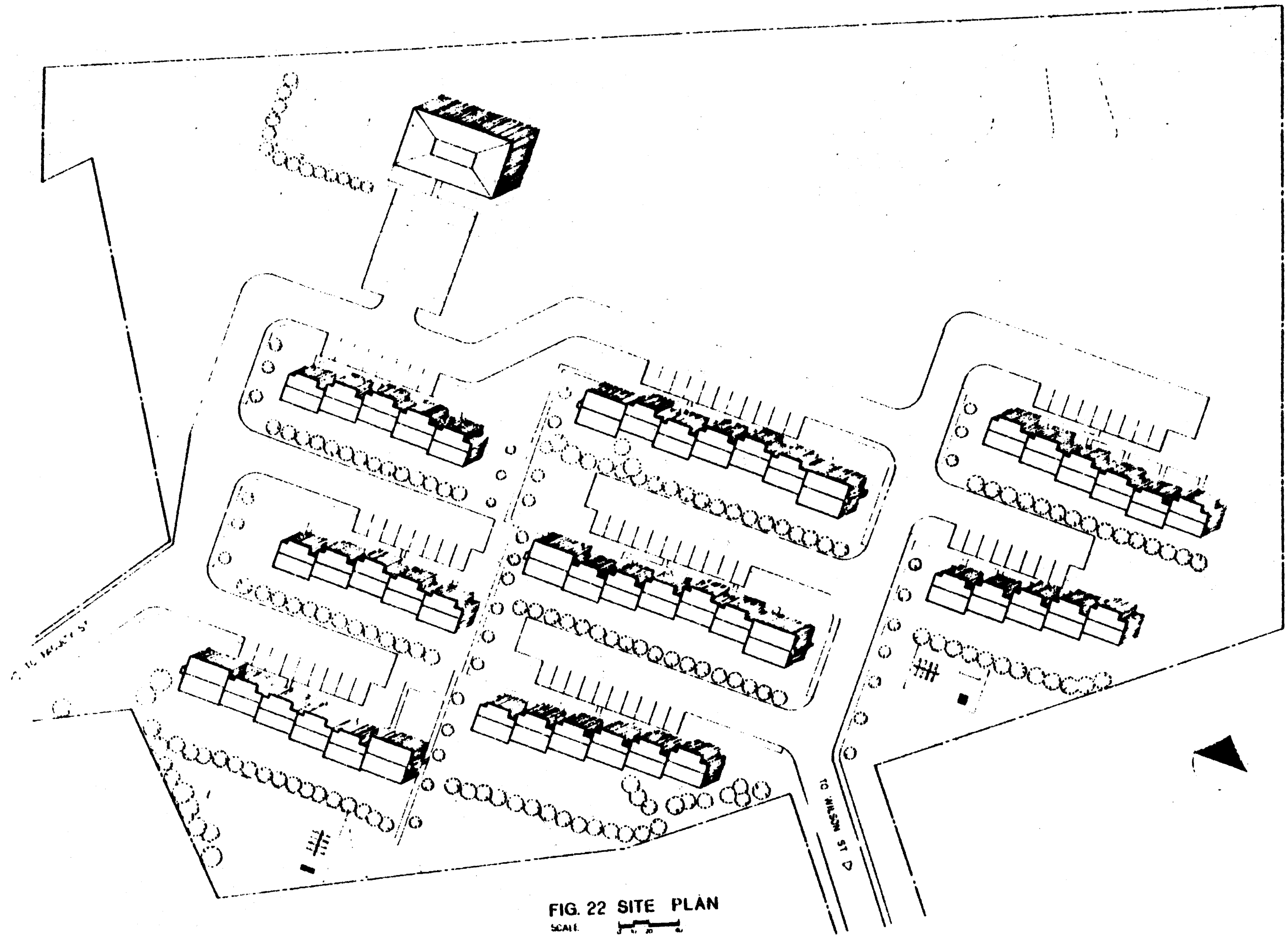
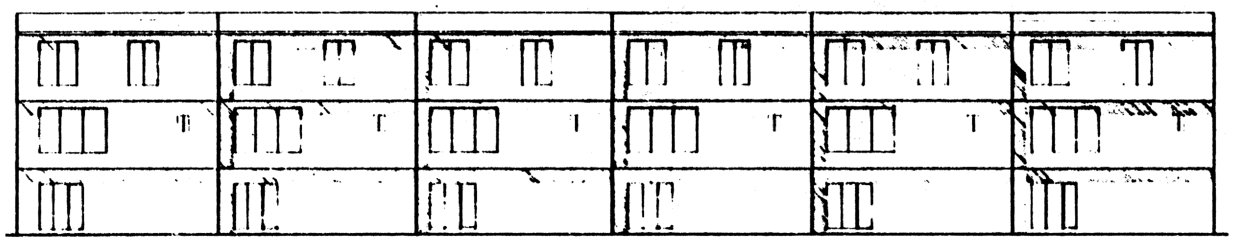


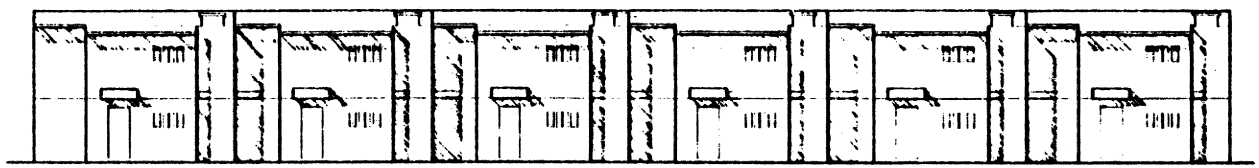
FIG. 22 SITE PLAN

SCALE

FIG. 23 FLOOR PLANS
SCALE



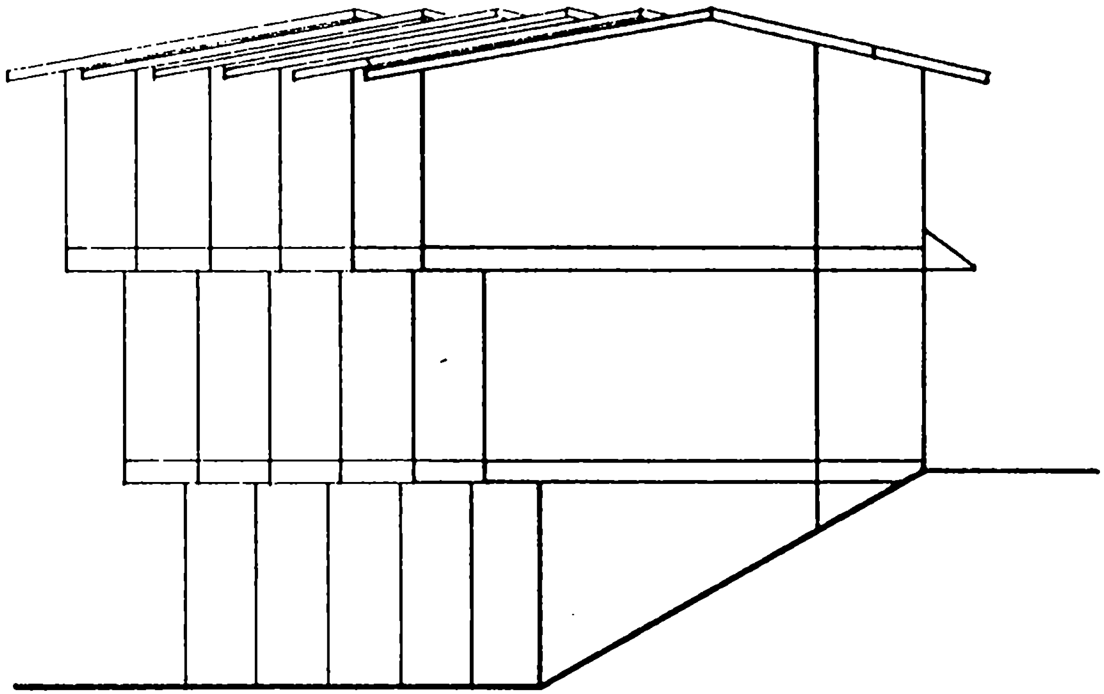
SOUTH ELEVATION



NORTH ELEVATION

FIG. 24 ELEVATION I

SCALE



WEST ELEVATION

FIG. 25 ELEVATION II

SCALE : 0' 2' 4' 10'

Chapter 5

CONCLUSION

5.1 EFFIENCY OF THE DESIGN PROCESS

Aimed as a design guide of solar energy application, this design process is simple and easy to follow because the analytical process is substantially reduced by the application of Balcomb Method A for preliminary design study. Selected alternatives are than evaluated by Balcomh Method B for detailed solar effeciency and effectiveness. This process is especially useful for architects and developers alkie to come up with the most potential preliminary design solutions for further study in a relatively short of time. Its advantages and effectiveness have been proven by this study.

In the case of this project, only direct gain system is applied for the townhouse design without any combination of other systems. This adds to the simplicity of the process. However, it can be easily modified for more complicated applications.

5.2 DESIGN EVALUATION

To summarize the advantages and disadvantages of the design solutions, it is divided into two major sections:

5.2.1 FUNCTIONAL AND SPATIAL EFICIENCY

Some 40% of the site is not suitable for solar energy application due to the northward orientation. However, they are appropriate for a park for recreation and protection of winter wind of the community. The remaining 60% yields appropriate building site for solar exposure.

As a result of regular south facing layouts to maximize solar exposure, exterior space has less room for variety. However, sufficient distance between groups of rowhouses compensate for this problem.

Major rooms in a single unit are arranged on southern side and service spaces--bathroom, storage, stairways-- on the northern side as buffer zone of the unit. This arrangement resulted in a more energy efficient building envelop but puts a limitation on building layout since the major rooms are competing for solar exposure.

5.2.2 ENERGY EFFICIENCY

As mentioned previously, regular form and layout, buffer zone and good insulation combine to reduce the heat loss of the units to the minimum.

Carefully calculated solar windows and clerestory openings have maximized the most desirable collected solar energy.

The direct gain system this project applies offers the advantage of simplicity and less expansive investment while maintains a relatively comfortable living environment for residents.

As shown in Figure 26, the upper curve represents the annual utilities consumed of a unit of townhouse located at Yorkshire Court, Blacksburg. The lower curve represents the energy would be consumed should the system of this study is applied. The area between these two curves indicates the amount of energy saved.

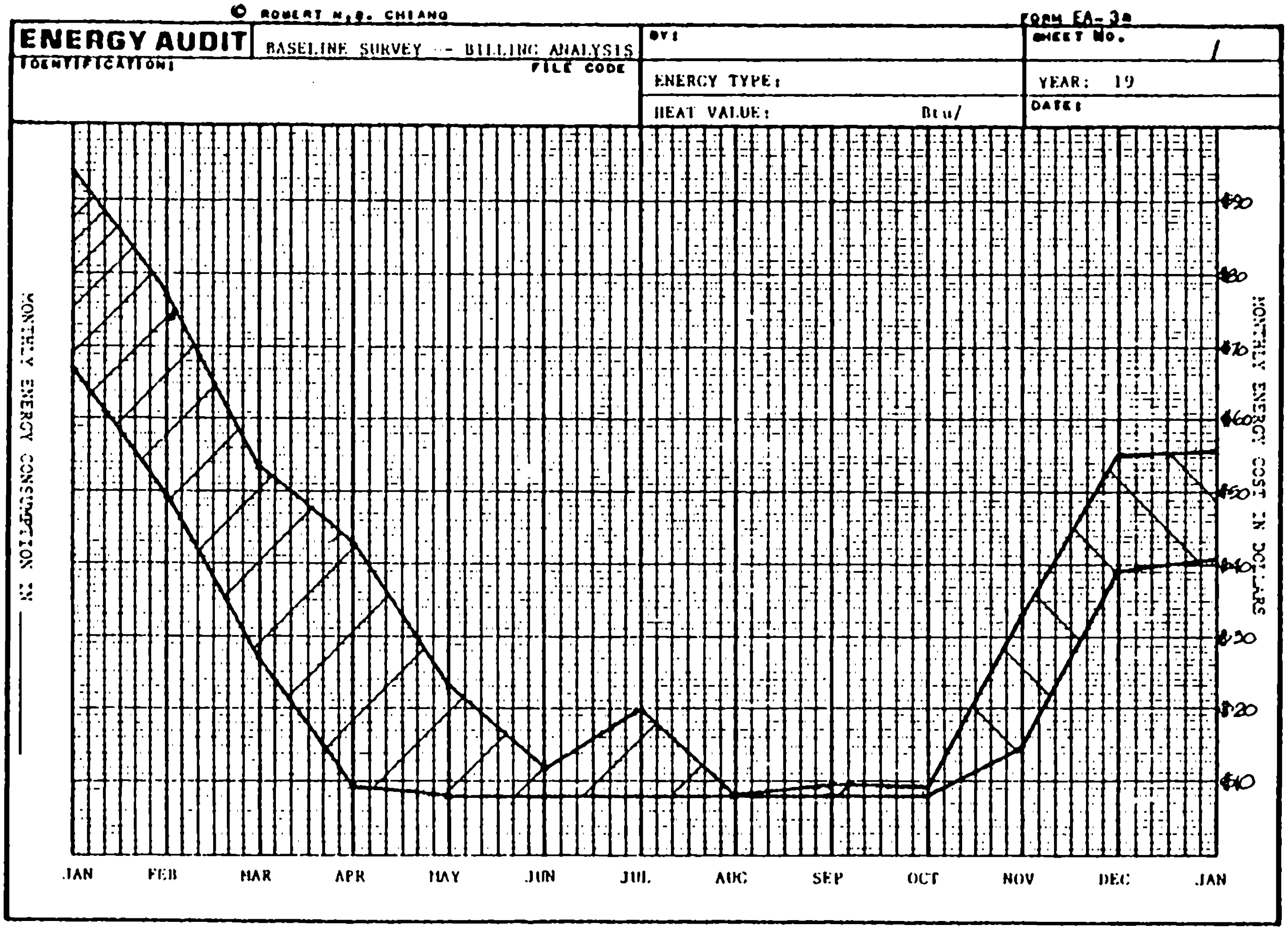


FIG. 26 ENERGY SAVING EVALUATION

5.3 PROPOSED CHANGES

On the whole, this project suggests an easy and quick way to apply passive solar energy to townhouse design efficiently in a moderate temperature zone. As indicated by this study, the most efficient solar system may not be the best architectural solution, and there are a lot of environmental and human factors to be taken into account if a desirable solution is to be generated.

Inspite of these advantage, this process is subjected to future modifications due to the crudeness of the state of the art and rapid improvement of solar energy design. More sophisticated solar systems and design processes are expected to be available for application in the near future. The systems and processes suggested by this study should be adjusted accordingly.

Appendix A

Balcomb Method A is a very useful method for passive solar energy design. It is used for preliminary sizing and evaluation. The procedures of this method is as follow:

A. Decide the area of the building and the areas of of the walls, floor, window, roof, door, etc.

B. Determine the building R values so as to decide the U values.

C. Calculate the building loss coefficient (BLC) for heat-transfer loss. (BTU/F-DAY)

D. Calculate BLC for air infiltration.

E. By adding up all the BLC, then compute the building load collector ratio (LCR):

$$LCR = \frac{BLC}{Ag \times Rg} = BTU/FT^2\text{-}DD$$

Ag= gross area of collector (ft^2)

Rg= rate of glazing in the collector essembly (%)

F. From the calculated LCR, check the solar saving fraction (SSF in %) from Appendix F of Passive Solar Design Handbook Vol. II by Balcomb from U.S. Department of Energy. Then fill the number into the following column:

A	B	C
D	E	F

A and C are the SSF from Appendix F. The value of A is smaller then C.

B is the actual SSF to be calculated.

E = LCR calculated from step (E).

D and F are the LCR values read under A and C.

B = A + 0.1 x (D-E)/(D-F).

G. Compute the annual energy savings from solar energy (ES) by:

ES = SSF x BLC x HDD = BTU/YEAR

HDD = F-day or DD (heating degree day)

H. Compute the annual auxiliary energy required (AE) by:

AE = (1-SSF) x BLC x HDD = BTU/YEAR

I. Estimating the January average inside clear-day temperatures (JAICT):

From Appendix F, check the site's latitude and its mean temperature in January, then from Figure E-4 of Balcomb's book, check the average outside temperature (ΔT solar).

JAICT = ΔT(Jan) + ΔT(solar) + ΔT(internal heat)

ΔT(Jan) is from Appendix F

ΔT(solar) is from Figure E-4 of Balcomb's book

ΔT(internal heat) = 5F constant

J. Estimating temperature swings: based on the thermal mass = 45 BTU/F per ft^2 of glazing, the value of temperature swing is:

ΔT(swing) = 0.74 x T(solar)--direct gain

ΔT(swing) = 0.65 x T(solar)--Trome wall with 3% vents

ΔT(swing) = 0.39 x T(solar)--water wall

ΔT(swing) = 0.13 x T(solar)--unvented Trome wall

Then the maximum and minimum temperatures of clear January days could be decided by:

T(max.) = January average inside clear-day temperature + ΔT(swing)/2

T(min.) = JAICDT - ΔT(swing)/2

The different between maximum and minimum temperatures should not exceed 25F.

K. Add on cost calculation (AOC):

AOC = Ag x (CSFC - CSFE)

AOC(NI) = Ag x (CSFC - CSFE + CSEI)

AOC(NI) = add on cost with night insulation

CSFC = estimated cost of square feet of collector area

CSFI = estimated square feet cost of night insulation

CSFE = estimated cost of square feet displaced enclosure area

L. Payback period:

Annual saving index = AOC/SS

SS = annual dollar saved

= (fuel unit save) x ($ per unit of fuel)

From payback graph of Appendix D (author's study), based on the annual interest rate and annual fuel inflation rate, check the graph and find the payback period.

SOLAR ENERGY SYSTEMS DESIGN -- BLC & SSF (Method A)					TN - 400	:
STEPS	A	B	C	D	E	
	DESCRIPTION	24 X Fx	AREA FT²	U-Factor	BLC STU/°F-Day	
1	WALL	24	872.5	0.0432	904.6	
	ROOF	24	482	0.023	266.1	
	WINDOW	24	4	0.49	47	
F	DOOR	24	42	0.24	241.9	
	SLAB ON GRADE	24x1/4	426	0.117	299.1	
	EXCLUDE THERMAL STORAGE WALL					
G	BUILDING LOSS COEFFICIENT (BLC) FOR HEAT-TRANSFER LOSS: (sum of Lines Fs in Column E) Rht =				1758.7	
H	BLC FOR AIR INFILTRATION: Q = V X AC 7262 x 0.6 = 4358.4 24 X 0.018 X Q = Riv =				1882.8	
K	TOTAL BUILDING LOSS COEFFICIENT OR AU-FACTOR: Line K = G + H BLC, BTU/°F-Day =				3641.5	

2 L COMPUTE THE BUILDING LOAD COLLECTOR RATIO (LCR):

$$LCR = \frac{BLC}{Ag \times Rg} = \frac{(\ 3641.5\ )}{(\ 156\ ) \times (0.90)} = 25.93$$

3 M INTERPOLATE THE SOLAR SAVING FRACTION (SSF):

	A	A/At	WITHOUT	NI	WITH	NI
WW						
TW						
DG	156			0.28		0.58
At = 156			SSF = 0.28		SSF = 0.58	

4 N COMPUTE THE ANNUAL ENERGY SAVINGS FROM SOLAR ENERGY (ES):

	SSF	BLC	HDD	ES
DG NI	0.58	3641.5	4152	8.77x10⁶
DG	0.28			4.23x10⁶

5 P COMPUTE THE ANNUAL AUXILIARY ENERGY REQUIRED (AE):

	SSF	1 - SSF	BLC	HDD	AE
DG NI	0.58	0.42	3641.5	4152	6.35x10⁶
DG	0.28	0.74			11.19x10⁶

PROJECT: TYPE A	BY:	DATE:	

FORM BS-11

Robert H.S. Chiang 1981 (1/19/1) R1980(3/7)

ES WORK SHEETS

ENERGY CONSERVATION -- INFILTRATION | PAGE

DETERMINATION OF INFILTRATION LOSS -- AIR CHANGES

	GOOD, ONE AIR CHANGE	AVERAGE, TWO AIR CHANGES	POOR, THREE AIR CHANGES
WINDOWS	Fitted, caulked, and weatherstripped in good condition with storm sash properly fitted. /	No storm sash, but caulking and weatherstripping in good condition with good fitting.	No storm sash and poorly fitted, caulking and weatherstripping is missing or in disrepair.
DOORS	Fitted, caulked, and weatherstripped in good condition with storm door properly fitted. /	No storm door, or storm door poorly fitted, door closure inoperatable, but caulking and weatherstripping relatively good.	No storm door and door is poorly fitted, caulking and weatherstripping is missing or in disrepair.
ROOF/CEILING	Ceiling insulation with vapor barrier, interior joints are taped or molding with caulking, no access or access with fitted cover or door. /	Interior joints cover with molding, access door properly fitted, ceiling light and junction boxes are covered or sealed.	No vapor barrier, visible cracks on interior joints and access doors, ceiling light and junction boxes are not covered or sealed
FLOOR	On grade construction, base caulked, no visible cracks, and all joints are sealed. /	Wooden floor over unheated space, insulated with vapor barrier, base with molding, and access door fitted.	Wooden floor over unheated space with cracks unsealed, no vapor barrier, access door poorly fitted and caulking and weatherstripping missing or in disrepair.
WALLS	Masonry exterior finishing with joints caulked in good condition, insulation with vapor barrier, plaster finishing interior, no power outlets and connections, or outlets and connections /	Siding with good fitting, no vapor barrier, all joints are caulked, power outlets and connections are properly sealed, and exhaust back draft cover in operatable condition.	Siding with cracks unsealed, no vapor barrier, power outlets and connections are unsealed, and caulking is missing or in disrepair.
	SUB-TOTAL = 5	SUB-TOTAL =	SUB-TOTAL =

ADJUSTMENT		
	TOTAL	= 5
Glass missing or broken	(+1)	
Glass area more than 50% of the wall area	(+2)	
Building underground 40% or more	(-1)	
Building with air-lock entrance or swinging door	(-2)	-2
Inoperable back draft cover	(+1)	
	GRAND TOTAL =	3
	AIR CHANGES (÷ 5) =	0.6

PROJECT:	BY:	DATE:

FORM BS-10A

Robert N.S. Chiang 1981 (10/20)

A. 1. Ceiling area = 482 ft^2

2. Exposed window = 4 ft^2

3. Exposed door = 42 ft^2

4. Exposed floor on grade = 426 ft^2

5. Total floor area = 908 ft^2

6. Exposed wall area = 872.5 ft^2

7. Collector area = 156 ft^2

8. Volume of building = 7,264 ft^3

B. LCR calculation

1. Direct gain with night insulation:

$X = 0.5 + 0.1(33-25.93)/(33-24) = 0.58$

2. Direct gain without night insulation:

$X = 0.2 + 0.1(46-25.93)/(46-21) = 0.28$

C. January average inside clear-day temperatures:

$\Delta T(\text{Jan}) = 36F$

$\Delta T(\text{solar}) = 29F$

$\Delta T(\text{internal heat}) = 5F$

$JAICT = 36 + 29 + 5 = 70F$

D. Temperature swing calculation:

$\Delta T(\text{swing}) = 0.74 \times T(\text{solar})$--direct gain

$0.74 \times 29F = 22F$

$\Delta T(swing)max = 70F + 22/2 = 81F$

$\Delta T(swing)min = 70F - 22/2 = 59F$

E. Add on cost calculation:

$AOC = Ag \times (CSFC - CSFE)$

$= 156 \times (\$8 - \$4.5) = \$546$

F. Payback period:

Annual saving index = AOC/SS

SS = \$20.51 x 4.23 = \$86.76

546/86.76 = 6.3

Based on 13% of annual interest rate and 10% annual fuel inflation rate, from graph, payback period = 7.5 years

SOLAR ENERGY SYSTEMS DESIGN -- BLC & SSF (Method A)				TN - 40D	1
STEPS	A	B	C	D	E
	DESCRIPTION	24 X Fx	AREA FT²	U-Factor	BLC BTU/°F-Day
1	WALL	24	366	0.0432	379.5
	ROOF	24	495	0.023	272.2
	WINDOW	24	12	0.49	141.1
F	DOOR	24	42	0.24	241.9
	SLAB IN GRADE	24x1/4	465	0.117	326.4
	EXCLUDE THERMAL STORAGE WALL				
G	BUILDING LOSS COEFFICIENT (BLC) FOR HEAT-TRANSFER LOSS: (sum of Lines Fs in Column E) Rht =				1361
H	BLC FOR AIR INFILTRATION: Q = V X AC 8040x0.6 = 4824 24 X 0.018 X Q = Riv =				2084
K	TOTAL BUILDING LOSS COEFFICIENT OR AU-FACTOR: Line K = G + H BLC, BTU/°F-Day =				3445

2 L COMPUTE THE BUILDING LOAD COLLECTOR RATIO (LCR):

$$LCR = \frac{BLC}{Ag \times Rg} = \frac{(3445)}{(144) \times (0.90)} = 26.58$$

3 M INTERPOLATE THE SOLAR SAVING FRACTION (SSF):

	A	A/At	WITHOUT	NI	WITH	NI
WW						
TW						
DG	144			0.28		0.57
At = 144			SSF =	0.28	SSF =	0.57

4 N COMPUTE THE ANNUAL ENERGY SAVINGS FROM SOLAR ENERGY (ES):

	SSF	BLC	HDD	ES
DG NI	0.57	3445	4152	8.15x10⁶
DG	0.28			4.01x10⁶

5 P COMPUTE THE ANNUAL AUXILIARY ENERGY REQUIRED (AE):

	SSF	1 - SSF	BLC	HDD	AE
DGNI	0.57	0.43	3445	4152	6.15x10⁶
DG	0.28	0.72			10.30x10⁶

PROJECT: TYPE B	BY:	DATE:	

FORM BS-11 Robert H.S. Chiang 1981 (1/19/1) R1980(3/7)

ES WORK SHEETS	ENERGY CONSERVATION -- INFILTRATION DETERMINATION OF INFILTRATION LOSS -- AIR CHANGES		PAGE

	GOOD, ONE AIR CHANGE	AVERAGE, TWO AIR CHANGES	POOR, THREE AIR CHANGES
WINDOWS	Fitted, caulked, and weatherstripped in good condition with storm sash properly fitted. [/]	No storm sash, but caulking and weatherstripping in good condition with good fitting. [ ]	No storm sash and poorly fitted, caulking and weatherstripping is missing or in disrepair. [ ]
DOORS	Fitted, caulked, and weatherstripped in good condition with storm door properly fitted. [/]	No storm door, or storm door poorly fitted, door closure inoperatable, but caulking and weatherstripping relatively good. [ ]	No storm door and door is poorly fitted, caulking and weatherstripping is missing or in disrepair. [ ]
ROOF/CEILING	Ceiling insulation with vapor barrier, interior joints are taped or molding with caulking, no access or access with fitted cover or door. [/]	Interior joints cover with molding, access door properly fitted, ceiling light and junction boxes are covered or sealed. [ ]	No vapor barrier, visible cracks on interior joints and access doors, ceiling light and junction boxes are not covered or sealed [ ]
FLOOR	On grade construction, base caulked, no visible cracks, and all joints are sealed. [/]	Wooden floor over unheated space, insulated with vapor barrier, base with molding, and access door fitted. [ ]	Wooden floor over unheated space with cracks unsealed, no vapor barrier, access door poorly fitted and caulking and weatherstripping missing or in disrepair. [ ]
WALLS	Masonry exterior finishing with joints caulked in good condition, insulation with vapor barrier, plaster finishing interior, no power outlets and connections, or outlets and connections [/]	Siding with good fitting, no vapor barrier, all joints are caulked, power outlets and connections are properly sealed, and exhaust back draft cover in operatable condition. [ ]	Siding with cracks unsealed, no vapor barrier, power outlets and connections are unsealed, and caulking is missing or in disrepair. [ ]
	SUB-TOTAL = 5	SUB-TOTAL =	SUB-TOTAL =

ADJUSTMENT			
		TOTAL =	5
	Glass missing or broken	(+1)	
	Glass area more than 50% of the wall area	(+2)	
	Building underground 40% or more	(-1)	
	Building with air-lock entrance or swinging door	(-2)	-2
	Inoperable back draft cover	(+1)	
		GRAND TOTAL =	3
		AIR CHANGES (÷ 5)=	0.60

PROJECT:	BY:	DATE:

FORM BS-10A

Robert H.S. Chiang 1981 (10/20)

A. 1. Ceiling area = 495 ft^2

2. Exposed window = 12 ft^2

3. Exposed door = 42 ft^2

4. Exposed floor on grade = 465 ft^2

5. Total floor area = 960 ft^2

6. Exposed wall area = 366 ft^2

7. Collector area = 144 ft^2

8. Volume of building = 8,040 ft^3

B. LCR calculation:

Direct gain with night insulation

X = 0.5 + 0.1(33-26.58)/(33-24) = 0.57

Direct gain without night insulation

X = 0.5 + 0.1(46-26.58)/(46-21) = 0.28

C. January average inside clear-day temperatures:

36F + 29F + 5F = 70F

D. Temperature swing calculation:

ΔT(swing)max = 70F + 22/2 =81F

ΔT(swing)min = 70F - 22/2 = 59F

E. Add on cost calculation:

AOC = 144 x (\$8 - \$4.5) = \$504

F. Payback period:

SS = $20.51 x 4.01 = $82.25

504/82.25 = 6.13

Payback period = 7 years

SOLAR ENERGY SYSTEMS DESIGN -- BLC & SSF (Method A)					TN - 40D	1
STEPS	A DESCRIPTION	B 24 X Fx	C AREA FT^2	D U-Factor	E BLC BTU/^{o}F-Day	
1	WALL	24	919	0.0432	965.2	
	ROOF	24	350	0.023	193.2	
F	WINDOW	24	7	0.49	82.3	
	DOOR	24	42	0.24	241.9	
	SLAB UNDER GRADE	24 x 1/4	204	0.117	143.2	
	WALL UNDER GRADE	24 x 1/4	296	0.073	129.6	
	EXCLUDE THERMAL STORAGE WALL					
G	BUILDING LOSS COEFFICIENT (BLC) FOR HEAT-TRANSFER LOSS: (sum of Lines Fs in Column E) Rht =				1755.4	
H	BLC FOR AIR INFILTRATION: Q = V X AC 7032 x 0.6 = 4219.2 24 X 0.018 X Q = Riv =				1822.7	
K	TOTAL BUILDING LOSS COEFFICIENT OR AU-FACTOR: Line K = G + H BLC, BTU/^{o}F-Day =				3578.1	

2 L COMPUTE THE BUILDING LOAD COLLECTOR RATIO (LCR):

$$LCR = \frac{BLC}{Ag \times Rg} = \frac{(3578.1)}{(144) \times (0.90)} = 27.6$$

3 M INTERPOLATE THE SOLAR SAVING FRACTION (SSF):

	A	A/At	WITHOUT NI		WITH NI	
WW						
TW						
DG	144			0.27		0.56
At =	144		SSF =	0.27	SSF =	0.56

4 N COMPUTE THE ANNUAL ENERGY SAVINGS FROM SOLAR ENERGY (ES):

	SSF	BLC	HDD	ES
DG NI	0.56	3578.1	4152	8.32 x 10^6
DG	0.27			4.01 x 10^6

5 P COMPUTE THE ANNUAL AUXILIARY ENERGY REQUIRED (AE):

	SSF	1 - SSF	BLC	HDD	AE
DG NI	0.56	0.44	3578.1	4152	6.54 x 10^6
DG	0.27	0.73			10.85 x 10^6

PROJECT: TYPE C.	BY:	DATE:	

FORM BS-11

Robert N.S. Chiang 1981 (1/19/1) R1980(3/7)

ES WORK SHEETS	ENERGY CONSERVATION -- INFILTRATION	PAGE
	DETERMINATION OF INFILTRATION LOSS -- AIR CHANGES	

	GOOD, ONE AIR CHANGE	AVERAGE, TWO AIR CHANGES	POOR, THREE AIR CHANGES
WINDOWS	Fitted, caulked, and weatherstripped in good condition with storm sash properly fitted. [/]	No storm sash, but caulking and weatherstripping in good condition with good fitting. [ ]	No storm sash and poorly fitted, caulking and weatherstripping is missing or in disrepair. [ ]
DOORS	Fitted, caulked, and weatherstripped in good condition with storm door properly fitted. [/]	No storm door, or storm door poorly fitted, door closure inoperatable, but caulking and weatherstripping relatively good. [ ]	No storm door and door is poorly fitted, caulking and weatherstripping is missing or in disrepair. [ ]
ROOF/CEILING	Ceiling insulation with vapor barrier, interior joints are taped or molding with caulking, no access or access with fitted cover or door. [/]	Interior joints cover with molding, access door properly fitted, ceiling light and junction boxes are covered or sealed. [ ]	No vapor barrier, visible cracks on interior joints and access doors, ceiling light and junction boxes are not covered or sealed [ ]
FLOOR	On grade construction, base caulked, no visible cracks, and all joints are sealed. [/]	Wooden floor over unheated space, insulated with vapor barrier, base with molding, and access door fitted. [ ]	Wooden floor over unheated space with cracks unsealed, no vapor barrier, access door poorly fitted and caulking and weatherstripping missing or in disrepair. [ ]
WALLS	Masonry exterior finishing with joints caulked in good condition, insulation with vapor barrier, plaster finishing interior, no power outlets and connections, or outlets anc connections [/]	Siding with good fitting, no vapor barrier, all joints are caulked, power outlets and connections are properly sealed, and exhaust back draft cover in operatable condition. [ ]	Siding with cracks unsealed, no vapor barrier, power outlets and connections are unsealed, and caulking is missing or in disrepair. [ ]
	SUB-TOTAL = 5	SUB-TOTAL =	SUB-TOTAL =

ADJUSTMENT			
		TOTAL =	5
	Glass missing or broken	(+1)	
	Glass area more than 50% of the wall area	(+2)	
	Building underground 40% or more	(-1)	
	Building with air-lock entrance or swinging door	(-2)	-2
	Inoperable back draft cover	(+1)	
		GRAND TOTAL =	3
		AIR CHANGES (÷ 5)=	0.6

PROJECT:	BY:	DATE:

Robert N.S. Chiang 1981 (10/20) FORM DS-10A

A. 1. Ceiling area = 350 ft^2

2. Exposed window = 7 ft^2

3. Exposed door = 42 ft^2

4. Exposed floor below grade = 204 ft^2

5. Basement area = 204 ft^2

6. Total floor area = 880 ft^2

7. Exposed wall area = 919 ft^2

8. Collector area = 144 ft^2

9. Volume of building = 7,032 ft^3

10. Wall under grade = 296 ft^2

B. Fx calculation for basement:

$\Delta T(\text{wall}) = T(\text{indoor}) - T(\text{outdoor}) = Ti - To$

$\Delta T(\text{basement}) = T(\text{indoor}) - T(\text{ground}) = Ti - Tg$

$Fx = (Ti - Tg)/(Ti - To)$

$= (68 - 55)/(68 - 16) = 0.25$

C. LCR calculation:

1. Direct gain with night insulation

$X = 0.5 + 0.1(33-27.6)/(33-24) = 0.56$

2. Direct gain without night insulation

$X = 0.2 + 0.1(44-27.6)/(44-21) = 0.27$

D. January average inside clear-day temperatures:

36F + 29F + 5F = 70F

E. Temperature swing calculation:

T(swing) = 0.74 x T(solar)--direct gain

T(swing)max = 70F + 22/2 = 81F

T(swing)min = 70F - 22/2 = 59F

F. Add on cost calculation:

AOC = 144 x ($8 - $4.5) = $504

G. Payback period:

SS = $20.51 x 4.01 = $82.25

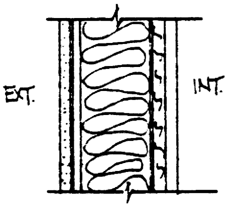
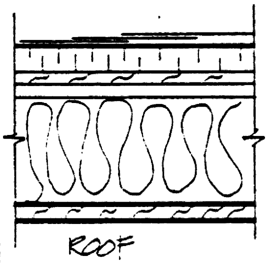
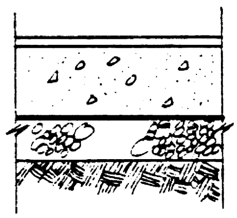
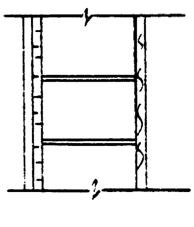
504/82.25 = 6.13

Payback period = 7 years

Appendix B

Balcomb Method is a more complex and more precise techniques for solar system sizing and evaluation than Method A. It provides sophisticated quantitative model which enables the architect or designer to size the solar glazing, thermal storage and other elements of the building with accuracy to achieve a comfortable living environment and a satisfactory solar heating performance.

For more informations and details of the calculation procedures, please read Passive Solar Design Handbook Volume II prepared by J. Douglas Balcomb. This book could be purchased by writing to the U. S. Department of Energy, Assistant Secretary for Conservation and Solar Energy, Office of Solar Application, Passive and Hybrid Solar Building Program, Washington D. C., 20585.

SOLAR ENERGY SYSTEMS DESIGN -- BASELINE SURVEY - U-Factors			TN - 40A	4		
IDENT	SECTION	DESCRIPTION	WINTER		SUMMER	
			x/k,..	R	x/k,..	R
	 EXT. INT. WALL	(A) 1" STUCCO (EXTERIOR)	0.20			
		(B) BLDG PAPER	0.06			
		(C) 1/2" WOOD SHEATHING W/V.B.	1.32			
		(D) 6" INSULATION	19.00			
		(E) 6 MIL POLYETHYLENE				
		(F) 1" PLYWOOD	1.25			
		(G) 1" DRYWALL (INT.)	0.47			
		(H) EXT., INT. AIR FILM	0.68, 0.17			
		Rt =	23.15			
		U =	0.0432			
	 ROOF	(A) ASPHALT SHINGLE	0.44			
		(B) ASPHALT ROLL ROOFING	0.15			
		(C) 2" RIGID INSULATION	9.10			
		(D) 1" PLYWOOD	1.25			
		(E) 1" AIR SPACE	1.01			
		(F) 9" INSULATION	30.00			
		(G) 6 MILL POLYETHYLENE				
		(H) 1" PLYWOOD	1.25 ; 0.32			
		(I) PLASTER Rt =	43.52			
		U =	0.023			
	 FLOOR ON GRADE	(A) INSIDE AIRFILM	0.92			
		(B) CARPET	2.08			
		(C) 6" CONCRETE	0.50			
		(D) VAPOR BARRIER				
		(E) 6" GRAVEL	0.67			
		(F) 24" EARTH	4.364			
		Rt =	8.54			
		U =	0.117			
	 BASEMENT WALL	(A) 1" STUCCO	0.20			
		(B) 1" STYROFOAM	11.00			
		(C) 6" POLYETHYLENE				
		(D) 8" CONCRETE BLOCK	2.00			
		(E) 1" DRYWALL	0.47			
		Rt =	13.67			
		U =	0.073			
PROJECT:		BY:		DATE:		

SOLAR ENERGY SYSTEMS DESIGN -- BASELINE SURVEY - U-Factors | TN - 40A | 4

IDENT	SECTION	DESCRIPTION	WINTER x/k,..	WINTER R	SUMMER x/k,..	SUMMER R
	DOOR	2" SOLID WOOD WITH STORM DOOR 50% GLASS (WOOD)				
		Rt =				
		U =	0.24			
	WINDOW	DOUBLE GLASS (0.25") WITH 1/2" AIRSPACE				
		Rt =				
		U =	0.49			
		Rt =				
		U =				
		Rt =				
		U =				

PROJECT:	BY:	DATE:	

FORM SP-2 (BS-2)

ES WORK SHEETS | ENERGY CONSERVATION -- INFILTRATION | PAGE
DETERMINATION OF INFILTRATION LOSS -- AIR CHANGES

	GOOD, ONE AIR CHANGE	AVERAGE, TWO AIR CHANGES	POOR, THREE AIR CHANGES
WINDOWS	Fitted, caulked, and weatherstripped in good condition with storm sash properly fitted. [/]	No storm sash, but caulking and weatherstripping in good condition with good fitting. [ ]	No storm sash and poorly fitted, caulking and weatherstripping is missing or in disrepair. [ ]
DOORS	Fitted, caulked, and weatherstripped in good condition with storm door properly fitted. [/]	No storm door, or storm door poorly fitted, door closure inoperatable, but caulking and weatherstripping relatively good. [ ]	No storm door and door is poorly fitted, caulking and weatherstripping is missing or in disrepair. [ ]
ROOF/CEILING	Ceiling insulation with vapor barrier, interior joints are taped or molding with caulking, no access or access with fitted cover or door. [/]	Interior joints cover with molding, access door properly fitted, ceiling light and junction boxes are covered or sealed. [ ]	No vapor barrier, visible cracks on interior joints and access doors, ceiling light and junction boxes are not covered or sealed [ ]
FLOOR	On grade construction, base caulked, no visible cracks, and all joints are sealed. [/]	Wooden floor over unheated space, insulated with vapor barrier, base with molding, and access door fitted. [ ]	Wooden floor over unheated space with cracks unsealed, no vapor barrier, access door poorly fitted and caulking and weatherstripping missing or in disrepair. [ ]
WALLS	Masonry exterior finishing with joints caulked in good condition, insulation with vapor barrier, plaster finishing interior, no power outlets and connections, or outlets and connections [/]	Siding with good fitting, no vapor barrier, all joints are caulked, power outlets and connections are properly sealed, and exhaust back draft cover in operatable condition. [ ]	Siding with cracks unsealed, no vapor barrier, power outlets and connections are unsealed, and caulking is missing or in disrepair. [ ]
	SUB-TOTAL = 5	SUB-TOTAL =	SUB-TOTAL =

ADJUSTMENT		
	TOTAL =	5
Glass missing or broken	(+1)	
Glass area more than 50% of the wall area	(+2)	
Building underground 40% or more	(-1)	
Building with air-lock entrance or swinging door	(-2)	-2
Inoperable back draft cover	(+1)	
	GRAND TOTAL =	3
	AIR CHANGES (÷ 5)=	0.60

PROJECT: | BY: | DATE:

FORM BS-10A

Robert H.S. Chiang 1981 (10/20)

EC -- ENERGY AUDIT | TN - 40A | 6

FORM BS-4

	A	B	C	D	E	F
	DESCRIPTION	24 X Fx	AREA ft^2	U	AU-FACTORS	AU-FACTORS
G	EXPOSED CEILING/ROOF	24	350	0.023	193.2	
	EXPOSED WALLS (NET)	24	919	0.0432	965.2	
	EXPOSED WINDOWS	24	7	0.49	82.3	
	EXPOSED DOORS	24	42	0.24	241.9	
	EXPOSED FLOORS on grade below grade unheated space	24x1/4	204	0.117	143.2	
	WALLS UNDER GRADE	24x1/4	296	0.073	129.6	
H	BLC FOR HEAT-TRANSMISSION LOSS: BLCHT =				2368.5	
J	BLC FOR AIR-INFILTRATION LOSS: Q = V X AC = 7032x0.6= 4219.2 0.432 X Q = BLCAI =				1882.7	
K	BUILDING LOSS COEFFICIENT OR AU-FACTOR: BLC = BLCHT + BLCAI, Btu/°F-Day BLC =				4191.2	

	M	N	P	R
	MONTH	BLC	°F-Day DD	MONTHLY HEATING DEMANDS MBtu/M
S	AUG	4191.2	0	0
	SEP		50	0.21
	OCT		233	0.977
	NOV		543	2.276
	DEC		806	3.378
	JAN		840	3.521
	FEB		722	3.026
	MAR		588	2.464
	APR		289	1.211
	MAY		81	0.339
	JUN		0	0
	JUL		0	0
T	ANNUAL TOTAL =		4152	17.4×10^6

ENERGY UTILIZATION INDEX (EUI):

$$EUI = \frac{BLC}{Agf} = \frac{4191.2}{880} = 4.76$$

ENERGY BUDGET (EB, HEATING):

EB = EUI X $DD/10^3$ $MBtu/ft^2$-Yr

=

ANNUAL HEATING ENERGY DEMAND:

HD = BLC X $DD/10^6$ MMBtu/Yr

$= 4191.2 \times 4152/10^6$

$= 17.4 \times 10^6$

PROJECT: | BY: | DATE:

Robert N.S. Chiang 1981 (6/12)2

ES COMPUTATION SHEETS | PASSIVE SOLAR ENERGY SYSTEMS DESIGN | PAGE
SOLAR GLAZING AREA -- ROT Method

EUIR = 7   Rg = 90 %   Af = 880 SF

From TABLE D-1

R1 = 11 %   R2 = 23 %

S1 = 21 %   S2 = 34 %

S3 = 37 %   S4 = 61 %

Agl = Af X R2 (EUI/EUIR)

= 880 X 23 % (4.76 / 7) = 138 SF

Ags = Af X R1 (EUI/EUIR)

= 880 X 11 % (4.76 / 7) = 66 SF

Select the Glazing Size (compute the net glazing area):

Ag = WIDTH ' X HEIGHT ' (Rg)

= 144 ' X ____ ' X 90 % = 130 SF

$$SSF = S1 + \frac{S2 - S1}{Agl - Ags}(Ag - Ags)$$

$$= 21\% + \frac{34\% - 21\%}{138 - 66}(130 - 66)$$

= 32.5 %

$$SSF_{NI} = S3 + \frac{S4 - S3}{Agl - Ags}(Ag - Ags)$$

$$= 37\% + \frac{61\% - 37\%}{138 - 66}(130 - 66)$$

= 58 %

PROJECT: | BY: | DATE:

PASSIVE SOLAR ENERGY SYSTEMS DESIGN -- DATA WORKSHEET	TN - 40E	3

PROJECT LOCATION: BLACKSBURG, VIRGINIA.

LATITUDE: 37.3 °N

PASSIVE SYSTEM TYPE	GLAZING AREA, SF	%	NI VALUE	Rc	Uc
DG.	144	100		5.6	0.1774

TOTAL GLAZING AREA, Ac = 144 100

THERMOSTAT SETTING, Tset = 68 °F

INTERNAL HEAT RATE, FORM 7B-1e, Qint = ______ Btu/Day

or Qint = 20,000 Btu/Day per person, PR

= 20,000 X 3 PR = 60,000 Btu/Day

BUILDING LOAD COEFFICIENT, from PART III, BLC = 4191.2 Btu/DD

LOAD COLLECTOR RATIO, LCR = $\frac{BLC}{Ac} = \frac{(4191.2)}{(144)}$ = 29.1 Btu/DD

Degree-Day Base Temperature for Non-solar Building, Tbns = ______ °F

OR Tbns = Tset - $\frac{Qint}{BLC}$ = 68 - $\frac{(60,000)}{(4191.2)}$ = 54 °F

Degree-Day for Non-solar Building, Appendix A, DDns = ______ DD/yr

Degree-Day Base Temperature for Solar Building, Tbs = ______ °F

OR Tbs = Tset - $\frac{\Sigma Qint}{BLC + (24 \times Ac \times Uc)}$

$= 68 - \frac{60,000}{4191.2 + (24 \times 144 \times 0.1774)}$

= 55.5 °F

(DDs from WORKSHEET W2)

PROJECT:	BY:	DATE:	

WORKSHEET NO.

Robert N.S. Chiang 1981 (2/26)

PROJECT:

BY:

DATE:

Robert N.S. Chiang 1981(2/16)

TABLE A (Method B)

SOLAR ENERGY SYSTEMS DESIGN -- PASSIVE (BALCOMB METHOD B)

TN - 40E

7

M	(1)				(L - D)			(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	VSM				L-D			FØ	FT	FGR	RCF	ØSF	TRF	FSS	CF	S
MONTH	DAYS OF THE MONTH, D	VS or HS (Appendix A)	CONVERTION FOR HS (FIG. XC-1)	D·X VS, Btu/Sq.ft.-Mon	L, LATITUDE, Degree	D, Degree SOLAR DECLINATION,	Degree L-D	ORIENTATION (FIG. XC-2)	TILT (FIGS. XC-3 to 6)	GROUND REFLECTANCE (FIG. XC-7)	REFLECTOR CORRECTION (FIGS. XC-8 to 10)	OVERHANG SHADOWING (FIGS. XC-11 to 14)	TRANSMITTANCE (FIGS. XC-15 to 19)	SITE SHADOWING (Appendix B)	PRODUCT OF (2) to (8)	EFFECTIVE SOLAR ENERGY INCIDENT, MONTHLY 10^3 Btu/Sq.ft.-Mon.
SEP	30	1124	1	33720	LATITUDE = 37.3	2.8	34.5	1	1	1.1	1	0.82	0.62	1	0.56	18.88
OCT	31	1256	1	38936		- 9.1	46.4	1	1	1.08	1	0.86	0.67	1	0.62	24.14
NOV	30	1155	1	34650		-18.6	55.9	1	1	1.07	1	1.0	0.704	1	0.75	25.99
DEC	31	1002	1	31062		-23.1	60.4	1	1	1.06	1	1.0	0.71	1	0.75	23.30
JAN	31	1059	1	32829		-21.4	58.7	1	1	1.06	1	0.99	0.709	1	0.74	24.29
FEB	28	1158	1	32424		-14.0	51.3	1	1	1.07	1	0.98	0.69	1	0.72	23.35
MAR	31	1185	1	36735		- 2.8	40.1	1	1	1.075	1	0.88	0.648	1	0.61	22.41
APR	30	1051	1	31530		9.1	28.2	1	1	1.12	1	0.74	0.60	1	0.50	15.77
MAY	31	885	1	27435		18.6	18.7	1	1	1.16	1	0.68	0.57	1	0.45	12.35
JUN	30	840	1	25200		23.1	14.2	1	1	1.18	1	0.72	0.562	1	0.48	12.10
JUL	31	838	1	25978		21.4	15.9	1	1	1.15	1	0.70	0.564	1	0.45	11.69
AUG	31	941	1	29171		14.0	23.3	1	1	1.13	1	0.69	0.58	1	0.45	13.13

WORKSHEET W2/W3

PROJECT:

BY:

DATE:

W2	(1)	(2)	(3)	W3	S/DD	(1)	(2)	(3)
DD BASE TEMPERATURE	T1 55	T2 60	Tbs 55.5	SYSTEM NI R-VALUE		RO=	R9=	R
$F1 = \frac{T_2 - T_{bs}}{T_2 - T_1}$ $F2 = \frac{T_{bs} - T_1}{T_2 - T_1}$	F1= 0.90	F2= 0.10	DD = F1 X DD1 + F2 X DD2	$F1 = \frac{Ro(9-R)}{9(Ro-R)}$	$F2 = \frac{R(9+Ro)}{9(Ro+R)}$	F1=	F2=	SSF = F1 X SSFRO + F2 X SSFR9
MONTH	APPENDIX A DD1	APPENDIX A DD2	DD	MONTH	$\frac{S}{DD}$	F-1,3,or 5 SSFRO	F-2,4 or 6 SSFR9	% SSF
SEP	2	9	2.7	SEP				
OCT	43	119	50.6	OCT				
NOV	257	401	271.4	NOV				
DEC	546	701	561.5	DEC				
JAN	577	732	592.5	JAN				
FEB	474	613	487.9	FEB				
MAR	306	457	321.1	MAR				
APR	67	152	75.5	APR				
MAY	6	28	8.2	MAY				
JUN	0	0	0	JNU				
JUL	0	0	0	JUL				
AUG	0	0	0	AUG				
		TOTAL DD =	2371.4	TOTAL SOLAR SAVING FRICTION, % =				

PASSIVE SOLAR ENERGY SYSTEMS DESIGN -- DD & NI INTERPOLATION

TN - 40E

10

PROJECT:

BY:

DATE:

M MONTH	(1) FROM TABLE A COL. (10) or W1 10^3 Btu/Sq.ft.-Mon S	(2) FROM APPENDIX A or W2 ^oF-Day/Mon DD_s	(3) (1)/(2) Btu/Sq.ft.-Mon-^oF Day S/DD_s	(4) FROM FIGS. F-1 to 6, Equation, W3 or W4 % MONTHLY SSF	(5) (1 - SSF) X DD X BLC 10^6 Btu/Mon Qaux
SEP	18.88	2.7	6992.6	1.0	—
OCT	24.14	50.6	477	1.0	—
NOV	25.99	271.4	95.8	0.74	0.2957
DEC	23.30	561.5	41.5	0.32	1.6003
JAN	24.29	592.5	41	0.31	1.7335
FEB	23.35	487.4	47.9	0.40	1.2269
MAR	22.41	321.1	69.8	0.58	0.5652
APR	15.77	75.5	208.9	0.96	0.0127
MAY	12.35	8.2	1506.1	1.0	—
JUN	12.10	0	—	—	—
JUL	11.69	0	—	—	—
AUG	13.13	0	—	—	—
				TOTAL ANNUAL AUXILIARY HEAT-	5.4143

(6)

BLC = 4191.2 Btu/^oF-Day

DDns = 4152 oF-Day, DD

LCR = 29.1 Btu/Ft^2-DD

$$SSF = 1 - \frac{\Sigma Qaux}{BLC \times DDns}$$

$$= 1 - \frac{5.4143 \times 10^6}{4191.2 \times 4152}$$

$$= 1 - 0.31$$

$$= 69\%$$

Storage mass calculation: based on Balcomb Method A: " 3 x SSF pounds of masonry is recommended for each square foot of south glazing..........."

From calculation:

SSF = 69%

Collector area = 144 ft^2

3 x 69 = 207

207 x 144 = 29,808 lbs

Assume: floor density = 130 lbs/ft^3 and 6 inches thick

solar absorptance = 0.85 (brown concrete)

Therefore, area needs for storage:

$$\frac{29{,}808}{130 \times 0.5 \times 0.85} = 547\ ft^2$$

Solar feasibility:

From calculation:

Annual heating demands: 18.5 x 10^6 BTU/YEAR

SSF = 69%

Therefore, annual energy saving from solar energy:

18.5 x 68% = 12.95 x 10^6

Compare with other sources of energy:

Electricity : 7¢/KWH

293 KWH = 10^6 BTU

293 x 0.07 = $20.51/MBTU

Annual saving:

$20.51 x 12.95 = $265.4

Natural gas: $438/1000 cu. ft.

16.67 CCF = 10^6 BTU

0.438 x 16.67 = $94.55 (annual saving)

Oil: $1.15/gallon

11.9 gal = 10^6 BTU

11.9 x 1.15 = 13.685

Annual saving:

13.685 x 12.95 = $177.22

Appendix C

SITE ANALYSIS

The following is an analysis of the proposed site:

A. Zoning/orientation: according to the Blacksburg Land Use Plan adopted by the Blacksburg Town Council on Feburary 14, 1978, the proposed site belongs to the medium density residential zone (4-10 units/acre). (see Figure 27)

The site is bordered on the north by Owens St., on the south by Progress St., on the east by Wilson St., and on the west by Turner St.. The area is 9.2075 acres which is equal to 401,484 square feet.

B. Topography/slope: The topography within the county is, in general, gently rolling. Figure 28 shows the detail of the site's topography as well as its slope. The site is 2,080 feet above sea level with a gradually increase of elevation from west to east to 2,120 feet above sea level as shown in Figure 28.

C. Existing land use: referring to the Blacksburg Neighborhood Action Plan, July, 1978, the area is defined as the transition area between the Central

LEGEND:

R1 = MEDIUM DENSITY RESIDENTIAL (4-10 UNITS/ACRE)

R2 = HIGH DENSITY RESIDENTIAL (11-40 UNITS/ACRE)

R3 = COMMERCIAL DEVELOPMENT

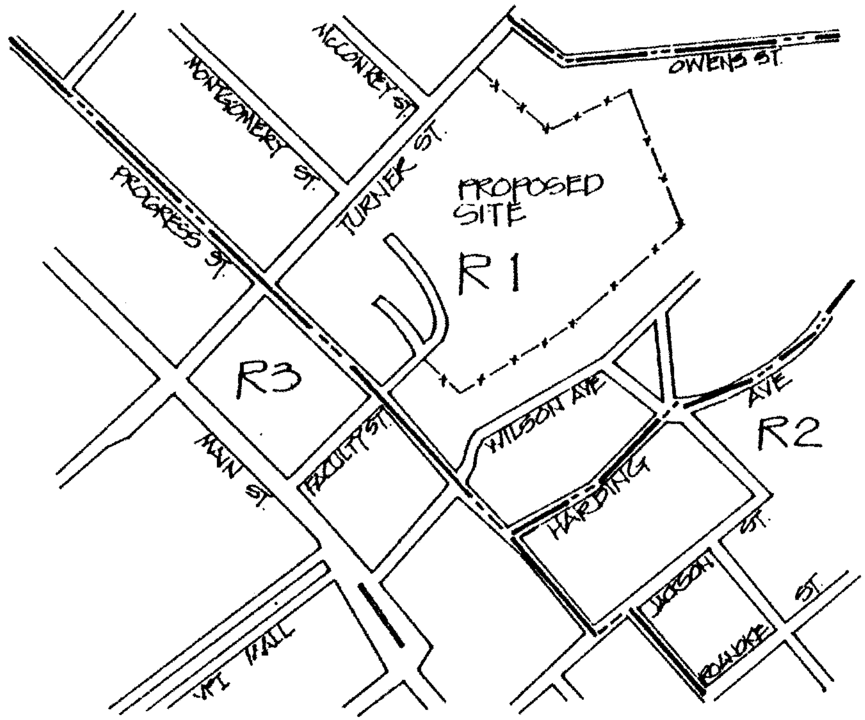
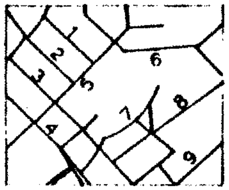


FIG. 27 ZONING OF THE STUDY AREA



1. McCONKEY ST.
2. MONTGOMERY ST.
3. PROGRESS ST.
4. MAIN ST.
5. TURNER ST.
6. OWENS ST.
7. WILSON ST.
8. HARDING AVE.
9. ROANOKE ST.

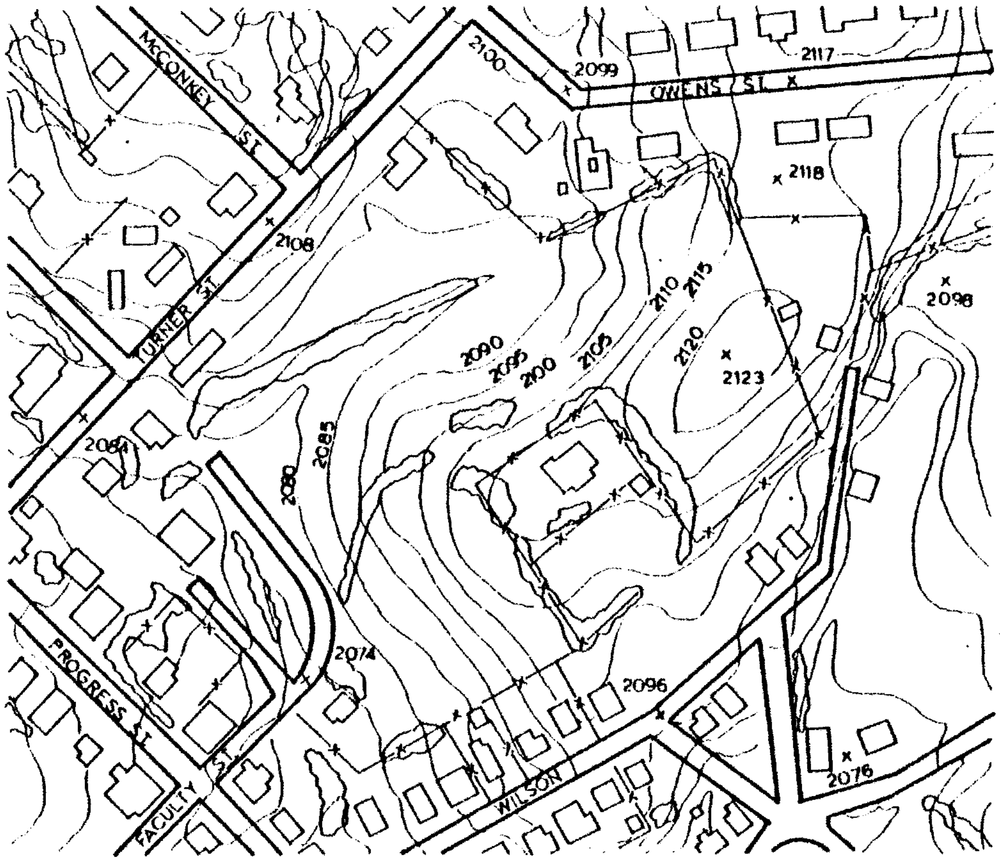


FIG. 28 TOPOGRAPHIC MAP OF STUDY SITE

SOURCE: BLACKSBURG PLANNING DEPARTMENT

Business District and the purely residential neighborhood. Already, a mixed land use pattern can be identified in the adjacent land as professional offices located in converted houses. Adjacent to the downtown and slightly lower priced property apparently are attracting the non-residential land use into the area. Besides professional offices, there are fraternities, churches and a few small business.

D. Macro circulation: vehicular circulation is handled primarily by Main Street which is on the south side of Progress Street; and secondary by Progress Street for north-south traffic. East-west traffic is handled by Roanoke Street and Turner Street. As shown in Figures 29 and 30, there are three routes which lead to the major vehicular circulation. These are Faculty Street, Wilson Street and Turner Street.

The proposed site is located in the walk zone. The majority of the streets have sidewalks and are in good condition.

E. Macro-micro circulation interface: to create a living environment which includes safety and privacy is one of the goals. Therefore, the less vehicular circulation in the proposed site the better it is. There will be speed limit, designated parking area

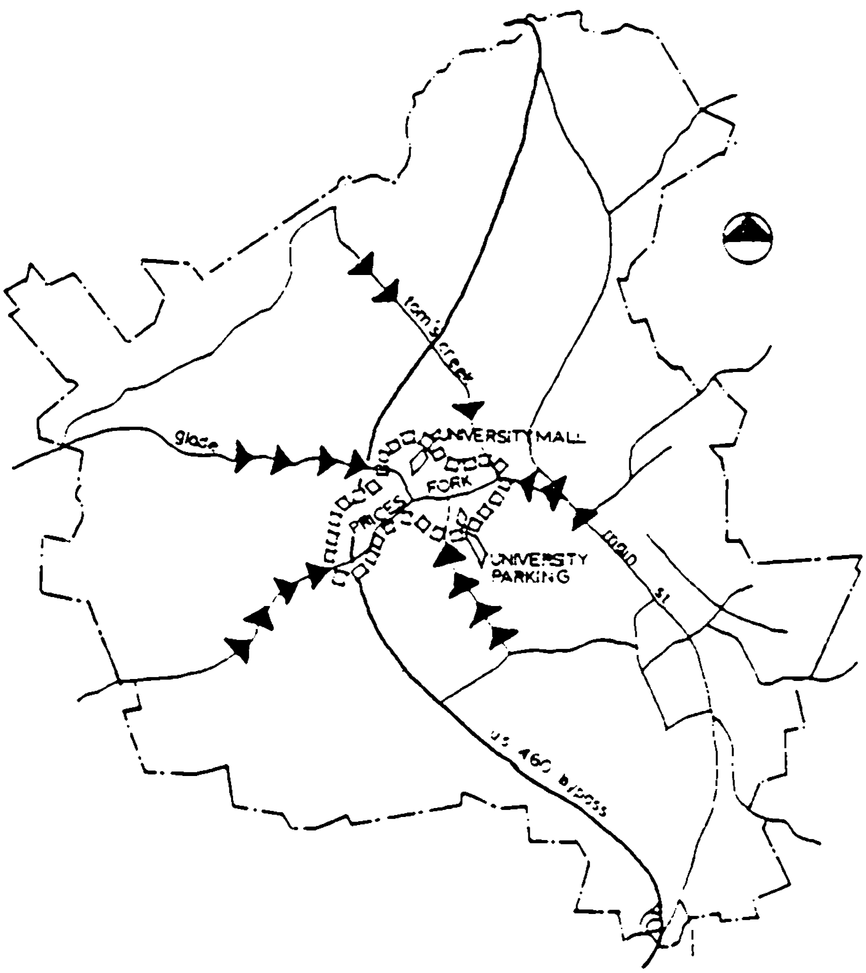


FIG. 29 TRAFFIC FLOW PATTERN IN BLACKSBURG

SOURCE BLACKSBURG 1985. BLACKSBURG PLANNING DEPARTMENT. 1974

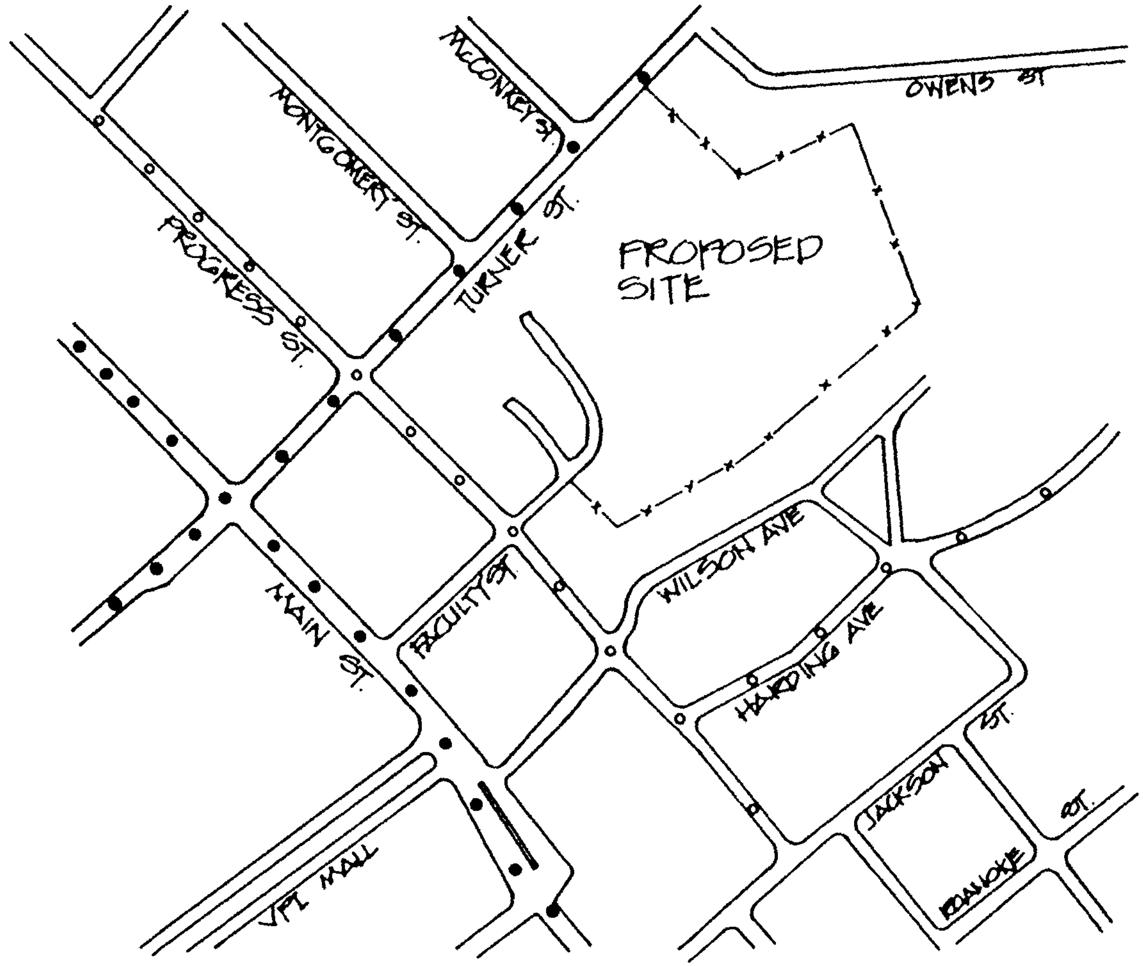


FIG. 30 TRAFFIC CIRCULATION IN THE STUDY AREA

MAJOR TRAFFIC = ● ● ● MINOR TRAFFIC = ○ ○ ○

as well as pedestrian crossing and other measures in order to achieve this goal. Based on the study, major entrance to the site could be either Faculty Street or Wilson Street or both of them.

F. Utilities: Figures 31 and 32 indicate the sewage lines and water lines of the site. Based on the Blacksburg Neighborhood Action Plan, July 1978, drainage is in fairly good condition.

G. Communities facilities: the town of Blacksburg has one high school (on Patrick Henry Drive), one middle school (on Main Street), and three elementary school (on Tom's Creek Road, Harding Avenue and Airport Road). Besides the elementary school on Harding Avenue, which is only a short distance walk, transportation is needed for others. The locations of all schools are shown in Figure 33. All existing schools are located on major streets. Along these roads, there are high density residential and commercial areas.

The proposed site is close to VPI and SU, banks, shops, library, restaurants, service station, theatres and only takes approximately five minutes of driving to two shopping malls.

H. Climate: Blacksburg has a humid "continental

FIG 31 EXISTENT SANITARY SEWER LINES

SOURCE BLACKSBURG PLANNING DEPARTMENT

FIG 32 EXISTENT WATER LINES

SOURCE BLACKSBURG PLANNING DEPARTMENT

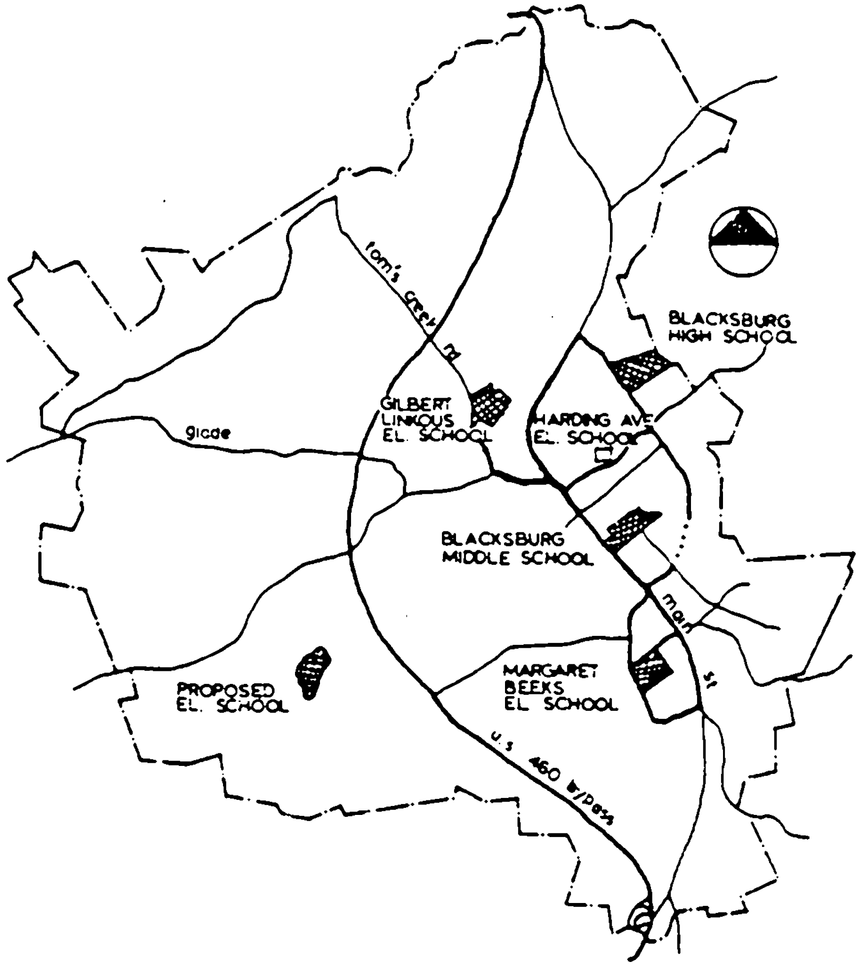


FIG. 33 LOCATION OF SCHOOLS IN BLACKSBURG

SOURCE: BLACKSBURG 1985, BLACKSBURG PLANNING DEPARTMENT, 1974 type" climate which is affected by elevation. Due to the nearby mountains, it is protected from weather extremes of winter and summer. Temperature is approximately five degrees lower than that of Roanoke which is at a lower elevation. The winter is moderately cold and the summer is relatively comfortable.

Mean annual temperature at Blacksburg is about 52F. Eventhough temperatures below freezing have been recorded, May and September are relatively warm. Daytime highs during the cold season are in the middle 40's with nighttime lows in the middle 20's. During the winter season, the maximum and minimum temperatures are in the 70's and teens below respectively. Daytime highs during the summer are usually in the low 80's and night-time lows in the upper 50's. The maximum temperature of 100F and a minimum temperature of 41F are observed during July.

The number of days with temperature higher or equal to 90F has ranged from none in several years to 26 days in 1953. Temperature falls below freezing at an average of 25 days a month during the winter months and below zero at an average of two days in a year.

With maximum in July and the minimum in November, precipitation is well distributed throughout the year. Rainfall in summer is due mainly to thunderstorms and showers, while snow in winter contributes to the precipitation. The average precipitation is 20 inches a year.

Relative humidity is high in the morning and low in the afternoon. Its average during the summer is in the 80's early in the morning and drops to 50's in the afternoon. Partly cloudy days are most frequent in summer.

Heavy rains are brought when hurricanes and other tropical disturbances move far enough inland to affect Blacksburg and the surrounding areas. Tornadoes are quite rare in Montgomery county. Thunderstorms accompanied by serve lighting, high winds and hail are more frequent than the hurricanes and tornadoes.

The prevailing winds in Blacksburg are generally westerly with a more northerly component in winter and a more southerly component in summer. The topography also affects the wind with the air tending to flow parallel to the mountain ridges which are oriented mainly northeast to southwest.

The above climatic summary is excerpted from

Curtis W. Crockett, NOAA Climatologist for Virginia, Agronomy Department, VPI and SU, Blacksburg, Virginia, 24061.

Appendix D

PASSIVE SOLAR ENERGY SYSTEMS DESIGN -- Effect of Overhang

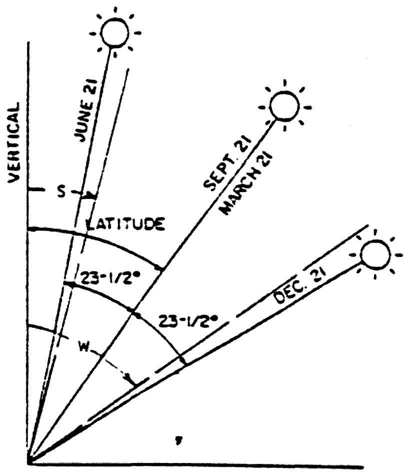


Fig. E-55.
This diagram shows a simple method of calculating noontime sun angles. On March 21 and September 21 the sun angle, measured from the zenith, is identical to the latitude of the site. On December 21 and June 21 this angle is either increased or decreased by 23.5° respectively.

$$S^{o} = Lat^{o} - 23.5^{o} + 5^{o}$$
$$= Lat^{o} - 18.5^{o}$$
$$W^{o} = Lat^{o} + 23.5^{o} - 5^{o}$$
$$= Lat^{o} + 18.5^{o}$$

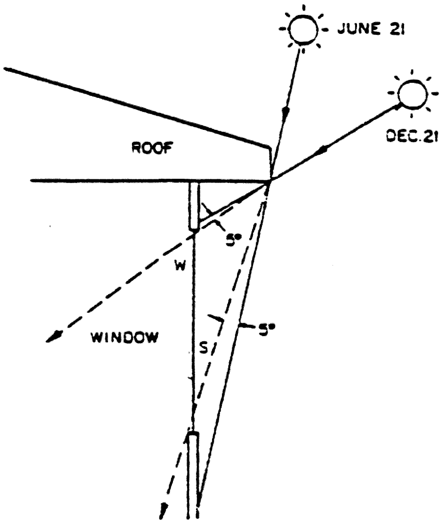
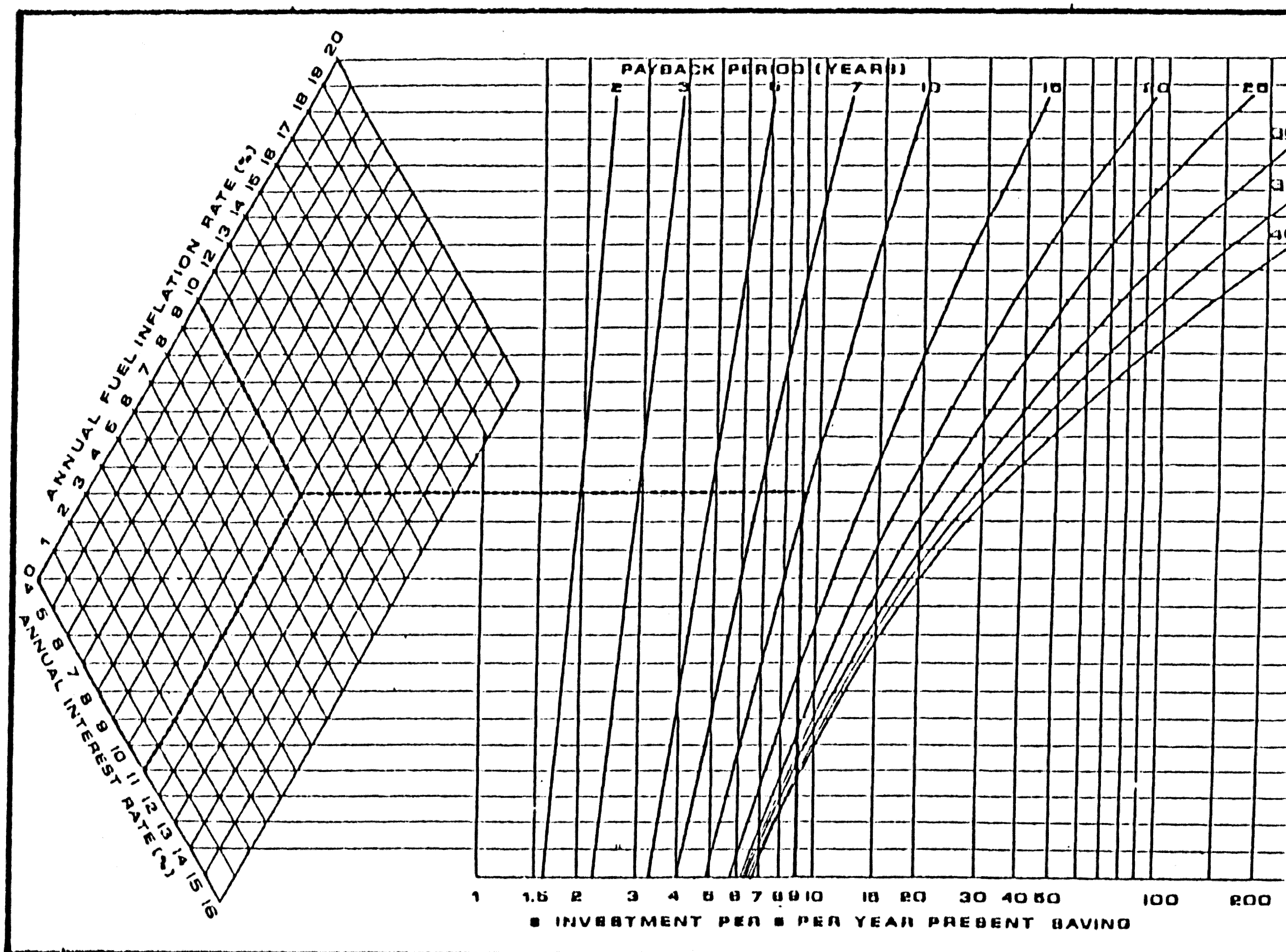


Fig. E-56.
An example showing how roof overhang geometry can be modified to provide desired summer shading and winter solar gain. The 5° allowances shown extend the desired effects over a ten-week season.

Appendix E



SOLAR ENERGY SYSTEMS DESIGN -- PAYBACK

TN - 40B

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PASSIVE SOLAR ENERGY APPLICATION IN TOWNHOUSE DESIGN

--A CASE STUDY

by

Yapp Pow Khin

(ABSTRACT)

The plan and design of a large housing development project by itself was a difficult task in the past, the energy issue make the options very limited, and the planner and/or engineer deal with the solution more often technically intended with or without considering the energy problem. This study is centered on the energy issue as part of the design decision making process.

This study tries to integrate the energy use effects as part of the basic planning process, such as land use and building style dependent on the land contour as well as solar exposure; and the passive solar energy utilization as part of the design process where the solar use is not an add on solar system but an integrate part of the basic design scheme. A development summary of the analysis and process guideline is introduced for medium-low density housing pro-

ject in an unban setting with an actual site as a case study to illustrate the process.