SHOP/RESIDENCE FOR
CUSTOM FURNITURE
MAKING FOR
OWNER-BUILDER
BY
HANS HAUMBERGER

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SHOP/RESIDENCE FOR CUSTOM FURNITURE MAKING FOR OWNER-BUILDER

UNDERGRADUATE THESIS IN ARCHITECTURAL DESIGN

by

HANS HAUMBERGER, JR.

Submitted to the School of Architecture as
partial fulfillment of the requirements
for the degree of Bachelor of Architecture

at

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THESIS BOOK

(Submitted as partial fulfillment of credit for Arch. 556, Thesis II)

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School of Architecture,
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March 11, 1977

James Gough, advisor
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Credit should be given to the following people for their contribution to this Thesis:

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My Father

THESIS STATEMENT

The demand of diminishing fossil fuels can be reduced by implementing alternative sources of energy to supplement means of environmental controls required of regional climate conditions.

PROJECT DESCRIPTION

A shop for custom furniture making and related woodworking crafts; also, a residence for the owner-builder and his family.

PERSONAL STATEMENT

My value judgements are more important to me in this thesis, than is finding some expression to substitute for them.

I choose to beleive that architecture is the result of a process that provides a place for things to happen. Although my particular process is intuitive, and difficult to describe, I attempt to communicate it by interpreting Geoffrey Broadbent's three systems of design interrelations in the manner of the thesis following. In short, the process of providing a building system that reconciles the human system with the environment system, will result in an architecture that is completely my own.

CONTENTS

page

INTRODUCTION..... 1

PART I : Program (the Human System)..... 5

PART II: Site (the Environment System)..... 16
- Cultural Influances
- Physical Influances
- Site Plan

PART III: Workshop (the Building System)..... 33
- South Elevation
- Plan
- Environmental Control System
- Systems & Equipment Description

PART IV: Residence (the Building System)..... 40
- South Elevation
- Plans
- Environmental Control Systems
- Systems & Equipment Description

PART V : Comparative Analysis..... 53
- Heat Loss Calculations
  - Workshop
  - Residence
  - Tract House
- Solar Heat Gain
  - Insolation on Collectors
  - Insolation on South Elevation
- Space Heating Needs
  - Data
  - Graphs
  - Sun Chart
  - Radiation Calculators
  - Storage Tank Capacity
- Daily Temperature Study

CONCLUSION..... 77

AFTERWARD..... 78

READINGS..... 79

BIBLIOGRAPHY..... 80

INTRODUCTION

"An intellectual is a man who says a simple thing in a difficult way; an artist is a man who says a difficult thing in a simple way."

(Bukowski)

Before an architect can begin the creative decision-making process of his preference, he must know the various requirements, limitations and objectives of the problem. Preceding the solution of any particular problem, is developement of some sort of program. The program guides decisions that will affect the resulting design solution, regardless of whatever revered information is made available. Along these guidelines, information is then considered to the degree of its applicability. The roots from which programmed information is obtained comes from the initiator of the project. In the thesis project following, the initiator (the person with the goals) is a hypothetical owner/builder. In this particular case, the owner/builder looks to the ability of the architect to interpret his needs, assuming that the latter has a better understanding of the necessary design interrelations. On a level of building design, interrelations are conceptualized by G. H. Broadbent into the form of three major systems: an Environment System, a Building System, and a Human System.

I have interpreted these systems into three areas of considerations. In the environment system, there are eight factors to consider in cultural context. An attempt will be made to illustrate visually and verbally, one chosen example of each of these factors, as they relate to the project. In physical context, there are considerations of climate, geology, topography, and land use. These are in essence, all natural existing factors of the physical environment affecting the chosen site, and in turn, the final design. They are communicated in the form of site analysis.

The building system is designed to reconcile the environment system with the human system, whenever the former is incompatable with desired activities of the latter. Considerations in this system include:
1) building technology; described as modifications of the external environment to provide suitable ambience for specified activities,
2) internal ambience; described as provisions of physical conditions for performance of activities.
I have added another category to this, concerning energy sources — those that are existing and those that are potential. It is my belief that careful value judgement in this category will be helpful toward successful reconciliation of the other two systems. My values placed upon the choice and use of energy sources will attempt to extend beyond methods of climate control that is presently employed. Iddo this because I feel that the most common modificatmons of the external environment are produced for the benifit of corporate economics rather than for regional environment patterns.

When considering the human system, there are certain factors, needs, of the user that cannot be ignored. They are listed as organic, spatial, locational, sensory, and social needs. Values given to these needs toward the design will relate directly to the objectives or needs of the owner/builder. To provide myself with a program direction, the hypothetical owner/builder is chosen from a list of buyer groups recommended by the Solar Dwelling Design Student Competition. In this way, I begin the programming procedure of the project.

These three consideration systems provide me with the lexicon by which this thesis procedure is based. Following is an outline of the three systems as I have adapted them. It must be noted that the order of the outline doesn't order the body of the work in any way, it is primarily a study guide.

ENVIRONMENT SYSTEM CONSIDERATIONS

A. Cultural Context:
1) social
2) political
3) economic
4) scientific
5) technological
6) historical
7(aesthetic
8) religious

B. Physical Context:
1) climate (sun orientation, temperature, wind, precipitation)
2) geology (water, soils, vegetation)
3) topography (landscape)
4) land use (traffic patterns, existing forms, boundaries)

BUILDING SYSTEM CONSIDERATIONS

A. Building Technology (modifications of external environment):
1) resources (cash, materials, labor & equipment)
2) structural/space-separating systems (mass, planar, frame)
3) services (environmental, information/communication, transportation)
4) fittings (furnishings, equipment)

B. Internal Ambience: (atmosphere, feeling, etc.)
1) sesory (lighting, heating/cooling/ventilation, noise, odor)
2) structural mass (visible surfaces, spaces enclosed)

C. Energy Sources:
1) existing
2) potential

HUMAN SYSTEM COSIDERATIONS

A. User Requirements:
1)organic (hunger, thirst, respiration, waste elimination, activity, rest)
2) spatial (functional, territorial)
3) locational (static dynamic)
4) sensory (sight, hearing, heat & cold, smell, kinaesthetic; equilibrium)
5) social (privacy, contact)

B. User Objectives: (goals of user in terms of security, prestige, profit and sentiment)
Assumptions about user given in part I.

PART ONE

"Paradoxically, the most frightening aspect of human life is that man can become adapted to almost anything, even to conditions that will inevitably destroy the very values that have given mankind its uniqueness."

(Rene' Dubos, So human an animal)

Selection of goals is the place to begin. Goals are the focal points of communication around which a designer and his client set up a program. Success in reaching these goals in the case of this thesis depends upon how accurately one can answer Rudyard Kipling's six questions: what, where, when, how, why, and who. In other words, this success is preceded by proper identification of the goals.

"Lets say that a man wants to build a good house for his wife. The most important step toward success will have been to select the right wife." (Rex Roberts, Your Engineered House) The following article illustrates goals of various craftsmen that are similar to those I have chosen to work with.

PROS and CONS
(Crafts, May/June 1976)

Is it worth trying to set up as a furniture maker? We asked a group of them about their reactions to the life and set out thier replies, often contradictory, in the piece below:

RICHARD LA TROBE BATEMAN
Works in London, making very distinctive, personal furniture. Would encourage those who really love the work, but not if they're after the money. Doesn't think it essential to be a good business man, "quality will sell itself in the end."

SETTING UP
"No bank manager in his right mind would lend a would be furniture maker money." Private income not necessary but you do need some kind of starter. He himself has a freehold workshop, a teaching job and a woking wife.

SITE OF WORKSHOP
Thinks it has been essential to his work that he has been in London. "It is more than enough work to make the stuff let alone selling it." Heaven knows what would have happened if he'd beem hidden away in the country. Must have room to store timber. More room for that in the country.

EXHIBITIONS
Essential to exhibit because then you get the response to yoyr work.

TRAINING
He went to art college and then on to the RCA. "The latter was useless in terms of how to do it. You have to find your own way into that and there are as many ways as there are people. Each one needs his own kind of training, depending on the kind of furniture he wants to make." He learnt through art college and then read two books which greatly influenced his technique (both by Charles Hayward).

IN GENERAL
"Furniture makers are thin on the ground because there isn't the talent there and people are too greedy - they want too much back for too little work."

ALAN PETERS

of Kentisbeare, Devon. Makes a wide range of furnitur e. Wouldn't discourage a young furniture maker but feels itis essential tobe either a good businessman or to have someone who can advise.

SETTING UP

Believes it is possible to manage wwithout large amounts of capital, he himself didn't have any but he does have a wife who was working and he did get bank loans. Believes it's necessary to limit one's sights and not to get too ambitious, at first. It may be necessary to take in contract work and only gradually develope into commissions. Reckons it takes at least five years to get underway.

TRAINING

Thinks it essential to have both an apprenticeship and an art school training, though not sure which is the best order. He did a cabinet-making apprenticeship with Edward Barnsley and then went to college. "College gives the freedom to develop design ideas; apprenticeship gives the essential technical grounding."

SITE OF WOKSHOP

Geographical situation of workshop is important when you set out because you have to be easily accessible to people who have the money and the interest to commission. You have to show the work to them when you are still an unknown and so it helps to be within reach of a large town.

Once established it is less important- people will come to you. He has a workshop in Devon but this is for personal rather than purely professional reasons. Actually began 40 miles out of London. Now 99% of his work is commissioned.

IN GENERAL

Thinks furniture is one of the most difficult crafts - needs a lot of storage and equipment.

SANDY MACKILLIGIN

Works in a converted hop kiln in Puttenham, near Guildford. Makes all kinds of furniture - uses plywood and veneer but gets most pleasure from solid hardwoods. Also makes a few small boxes. Would only encourage someone to take up furniture if he was already determined to do so. Thinks it depends entirely on the person. " "First, you must be a good furniture maker but you must also be a good businessman. You can borrow a lot of acumen from accountants but you can't borrow the ability to purchase timber and persuade customers to pay the right price for what they want." Thinks you have to be flexible. Nearly everyone does some other job to begin with (he himself pulled beer). It probably takes five years to get established as asfurniture maker.

SETTING UP

SANDY MACKILLIGIN (Cont.)

SETTING UP
Doesn't think it's very important where you set up. Wherever you live, much of your standard work is done for the local community. Easier in fact to build up a local reputation outside one of the main cities. The more interesting and unusual commission will come your way once you're on your feet.

TRAINING
Couldn't really recommend any of the present courses to anyone wanting to come out and make a design for themselves. "What's needed is a place that is to furniture what Harrow was to pottery." Need to combine art school training with apprenticeship in workshop. Workshop can teach you how to make but can't open your eyes to design ideas.

EXHIBITIONS
Important to exhibit annually. Worth investing money in pieces to have ready for exhibition.

IN GENERAL
"There are too many prima donnas around who come out of art school not realising that to be a success you have to compromise." Not a bad thing to do to begin with, as long as you know you're doing it and know where to draw the line. Thinks the main stumbling block for furniture makers is lack of commissions from public bodies.

MAURICE LEACH
Works in Somerset. Uses the woods of Elizabethan England to make turned country furniture in his own interpretation of a traditional style.

Difficult to advise anyone to go into furnituremaking, because unless they are good businessmen they will fail. There are good people being trained but few with the ruthlessness and business acumen necessary for total comm itment to the craft. Few have any idea of the cost of setting up, eg the cost even of the machinery necessary. The initial expense has increased with the new Public Safety and Health Act - the space required for machinery is now greater and many will have to extend their workshops.

"There is certainly a market for handmade furniture and an increasing one, but the craftsman must do his homework thoroghly."

SETTING UP
To set up he borrowed money from the bank and has also had a grant from the CAC. Has had a workshop for five years now and it is still virtually a twenty-four hour day. Has just begun to pay off overdraft, instead of adding to it each year. Total commitment the first essential. He also has a wife who handles all the secretarial work and is absolutely invaluable.

SITE OF WORKSHOP
Doesn't think it matters where the workshop is - his is rather remote. Eighty per cent of his stuff sold from the workshop, and the rest from exhibitions.

MAURICE LEACH (Cont.)

EXHIBITIONS
Feels it important to exhibit as much as possible.

TRAINING
Worked fourteen years in commercial set up after building/carpentry apprenticeship. Most important thing is to get thorough technical background so that you know the machinery and what it can do. "If you want to influence furniture design in the future the best thing is to serve a long apprenticeship." He could be making the same chair in thirty years time but in terms of finish and workmanship it would be different in 1,000 ways.

IN GENERAL
Don't compromise. He has trade inquiries coming in, asking him to do production lines for large firms, reproduction, etc. But you can't do other peoples work and your own.

PETER NICZEWSKI
Works at 40½ workshops in London, doing marquetry, mainly on tables. Thinks there is a chance for young people setting up in furniture. They need not necessarily be good at business, he's useless. Has realised now that commissions are building up and that sooner or later he'll have to get an accountant. Thinks his graphic work a good stimulus to his other work. "The more you work, the more ideas you get."

SITE OF WORKSHOP
Site of workshop is important, he thinks. He has always lived in London and as he is not a good businessman it was very important forhim to be at the hub of things in order to get off the ground. Luckily for him he does not have to store wood as he works in veneers. He hopes eventually to move to the country, more for personal than for work reasons.

TRAINING
Training depends completely on the individual, and the kind of work they want to produce. Graphics a good training for him because two-dimentional design is what primarily interests him about furniture. Taught himself. But actually building furniture not his main concern.

IN GENERAL
"Furniture should be light-hearted and jokey."

A helpful key to identifying the client "type" of this thesis (if such a "type" indeed exists) is to refer to statistics given by Les Scher & Corol Wilcox from their article in Energy Primer (p. 170), where they describe an owner/builder.

"An owner/builder is defined as a person who either acts as his own general contractor or provides all of his own labor for the construction of his own dwelling. Official Bureau of Census figures show that 20% of all the single family homes built in the U.S. each year are owner-built and 40% of these owner -built homes are in rural areas. These statistics are actually under estimated, since thousands of new rural residents have been building there homes without government recognition.

There are several reasons why there are not more owner builders today, including a lack of access to land; descriminatory lending policies, especially by the federal government; the growth of mass produced housing packages, such as the mobile home; and last and foremost, restrictive building codes and standards. "

The reasons given in the last paragraph of the above passage are hurdles that are to be overcome by the owner/builder. I find nothing wrong with the words "pioneer spirit" when describing my choice of a representative owner/builder. The meaning that I would attach to these words can be felt during the course of any adventurous undertaking. The construction of one's own home certainly needs somewhat of a destination or bust philosophy. The adventure intensifies with each compromise, whenever sacrifices are made to achieve that destination.

The family is the client. The man is an inventor, something of a "jack-of-all-trades", but master at woodworking. He had been a cabinetmaker by trade before this decision to begin a custom woodworking shop. The wife is an avid reader of literature as well as an active gardener and nutritionist. They are a growing family; two sons, aged 12 and 10 years, and a daughter, aged 7 years.

The man wants the business to remain small, so that he can manage it without paid help. He would enjoy tutoring up to three interested individuals under old world apprenticing tradition if it were possible. He would like the house to be separate from the shop and the entire sit e to incorporate autonomous living - someday.

The woman desires an organic household, patterned after somewhat agricultural living routines. She would like the household to provide an example of independance for future development of the area.

The children enjoy the freedom of chasing around the site at full speed.

If I were to interpret the program as a problem, here is the problem I would choose to develope. This Student Design Competition Problem provides a carefully thought out criteria for testing the thesis statement.

problem definition

"SUPPOSE YOU WERE GIVEN THE CHARIOT OF THE SUN: WHAT WOULD YOU DO?"*

The AIA Research Corporation is looking for innovative solutions to the complex problem of "Solar Dwelling Design." The student is to consider how the sun as an inexhaustible source of energy inspires designers to rethink the relationship between energy and architecture. AIA/RC is seeking creative prototype designs for houses that respond to the following issues:

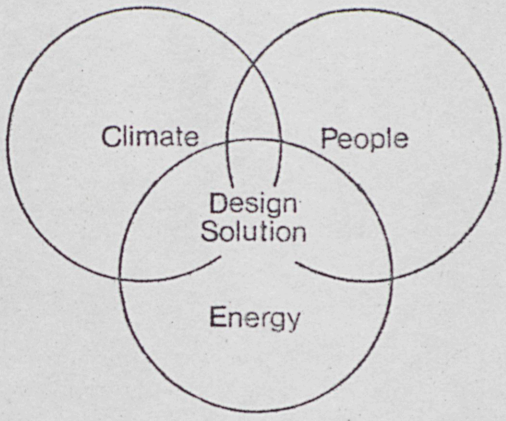
1. Solar energy, along with indigenous energy resources, has significant implications for the design of houses.

2. A characteristic which distinguishes solar energy from conventional energy sources is that it is "weather dependent."

3. The weather dependent nature of solar energy requires two types of design response: (a) designs that are sensitive to the daily and seasonal changes which affect both the supply of solar radiation and the energy demands made on that supply; and, (b) designs that minimize energy demand and therefore supply and that respond to the user's specific comfort and energy needs.

The essence of Solar Dwelling Design is to simultaneously solve these three considerations: (a) the implications of using the sun as an energy source; (b) climate conditions and variations; and (c) the activity patterns and energy needs of the users.

*Ovid, Metamorphoses, Book 2, line 74.



Implications of Using the Sun as an Alternative Source of Energy. This package contains a series of reprints which introduce solar energy and its use for domestic heating, cooling and power needs. The specific manner in which solar energy is to be used has been left optional. The student is not confined to using any one "system" of solar equipment or even to using "equipment" at all. There are many ways to use the sun's energy that do not require mechanical intervention.

Mechanical solar systems should be used only to supply energy needs which cannot be met through direct use of the sun's energy and should be thoughtfully woven into the architectural form of the house. In fact, it is critical to integrate such a consciousness about the energy capabilities of the sun into all aspects of the design process.

Characteristics of the Climate and the Effects of Its Variations. The art of designing with the climate, of using the weather to advantage instead of expending mechanical energy to block it out, is not a new concept. Before mechanical equipment was available, some houses were finely tuned to the regional climate as a matter of necessity.

In addition to the comfort this afforded the users, the sensitive use of regional climatic conditions also led to the evolution of regional architectural forms. Now that mechanical equipment allows us to ignore regional climatic conditions, the vitality of our regional architecture has diminished.

The AIA Research Corporation would like to see that vitality reinstated. Why expend energy resources, whether they are fossil fuel or solar, to do a job that could be done by sensitive design? Our interest in the resurgence of architecture which responds sensitively and elegantly to regional climates is the reason that the Solar Dwelling Design Competition requires designing for a local site.

AIA/RC wants the student to investigate the local climatic conditions and take into account such things as the types of vegetation and the direction of the wind.* The student should become familiar with the many fluctuations that occur during the daily and seasonal cycles and should design for these variations. A "static condition" should not be assumed.

Activity Patterns and Energy Needs of Users. Although we sometimes use the phrase "houses consume x amount of energy," it is not really the houses which consume energy: it is people who consume energy in the process of providing a comfortable environment for themselves. The house is the filter we set up between ourselves inside and the climate outside.

The more and greater climatic modifications we require our filter to make, the more energy it consumes. This includes energy used for heating in winter, cooling in summer, domestic hot water heating, lighting and other energy needs throughout the year.

*See the page entitled "Climatic Considerations"

But just as there are ways to design with the climate, so there are ways to design with users' needs. These begin with sensitivity to people, their needs, their comforts, and how they use and respond to different environments. If you think carefully about key aspects of human "comfort," and about which human activities require what type of "comfort" for how long, then you can begin to create sensitive architecture that mediates between users' energy needs and their "comfort" needs.

To emphasize the relationship between energy needs and comfort needs, choose as a user a family which is representative of one of these "buyer groups:" single adults, young couples, growing families, extended families, older couples, cooperatives. If the student designs a group of houses for a mixed-market development, choose a representative family for each buyer group to be housed. AIA/RC is not concerned that the student know the representative family (or families) personally; the only concern is that the student has a clear understanding of their activity patterns, energy needs, and the ways in which they use and respond to different types of environments.

The AIA Research Corporation wants the student to be specifically concerned with the family's economic situation. AIA/RC is looking for prototype houses which low- and middle-income households can afford. In order to reinforce this concern, AIA/RC has listed below a maximum interior house volume and range of floor areas for each buyer category.

THE SPECIFIC PROBLEM

Design a solar dwelling according to the following:

1. Limit the project to single-family housing. The scale, however, is optional, and the student can work with any number of dwellings. They may be attached or detached, and may be arranged in any manner (townhouse, cluster, etc.) within the designation "single-family housing."

2. Use local climatic conditions and local site, preferably one that students can easily visit.

3. Design an affordable home for a representative household.

4. Work with a representative family from one or more of the following buyer groups:

BUYER GROUP	SQ.FT.	MAX.VOL.
Single adults	1000-1200	12000
Young couples	1000-1300	13000
Growing families	1200-1800	18000
Extended families	1200-1800	18000
Older couples	1000-1300	13000
Cooperatives	2200-3000	25000

Associated with each group is a recommended range of dwelling sizes intended to reinforce the emphasis on affordable homes for typical people and to discourage upper-middle and high-income house designs. Entries with dwelling units outside of the recommended ranges must indicate why this is so, especially if reasons are energy-related.

5. Solar energy should be a substantial source of the energy supplied. Student designs are to meet the following performance requirements:

a. Minimize the total energy required to provide for users' needs.
b. Of the total energy consumed for heating, hot water, air conditioning and cooling, and electricity, minimize the proportion supplied by depletable fuels.
c. Integrate energy related technology into the architectural form.
d. Tailor the amount and form of supplied energy to fit the various human activities carried out in the dwelling.
e. Satisfy energy needs regardless of the availability of solar energy; make solar and other energy systems complementary.
f. Use site-climate conditions to maximum advantage.

Situations may arise wherein several performance requirements may conflict. Students should point out and explain any major trade-offs they have made.

6. Students must demonstrate how they have designed with solar energy to meet users' needs. They must show how they have designed for annual and diurnal changes in solar availability, how their scheme can work effectively on a monthly basis throughout the year, and the percentage of total energy needs that is met by the sun, where applicable.

Students must also describe how they have made use of the site climate and how it differs from regional climate. They should indicate the assumptions they have made about their users and how, if at all, their dwellings will affect user life-styles.

They should assess the desirability of such effects and answer the question -- "Will your buyer group purchase the homes you have designed for them?"

EVALUATION CRITERIA

Students should keep in mind that the National Review Board will be looking for:

- Innovative design
- Application of the principle that people--not houses--use energy
- Sensitive response to local climatic conditions
- Integration of energy concepts and technology into an architectural solution
- Reasonable value and its justification for the buyer group

The following program outline is derived from information provided in the preceding assumptions about owner/builder and the specific problems defined by the student competition. It is used as the list of client objectives for this thesis project.

PROGRAM OUTLINE

1. RESIDENCE UNIT (Under 2,000 sq.ft.)
   Ground Level:
   A. Social Functions (open space, approx. 850 sq.ft.)
      1) cooking/eating/food prep. and preservation
      2) recreation (conversation/entertainment)
   B. Private Functions (closed space, approx. 450 sq.ft.)
      1) sleeping (parents)
      2) study/relaxation/reading
   Upper Level:
   C. Private Functions (closed space, approx. 450 sq.ft.)
      1) sleeping (children)
      2) recreation (same as A.2) above)
   D. Other Functions
      1) storage (all kinds)
      2) cultivation (outside garden)
      3) garage (two vehicles)
      4) 1½ bath
2. WORKSHOP UNIT (Approx. 1500 sq.ft.)
   A. Social Functions (open plan)
      1) woodworking (approx. 800 sq.ft.)
         (a) equipment
            (1) heating stove
            (2) workbenches (2)
            (3) drill press
            (4) jointer
            (5) thickness planer
            (6) bench (table) saw
            (7) band saw
            (8) jig saw
            (9) stationary belt sander
            (10) wood lathe
         (b) tools (cabinet space for conventional and power tools, nails, glue, paint, etc.)
         (c) vented painting and varnishing area
      2) display area
   B. Private Functions (approx. 400 sq.ft.)
      1) studio/office (approx. 150 sq.ft.)
      2) washroom/lav.
   C. Other Functions
      1) stock lumber storage (indoor- 250 sq.ft., outdoor- 250 sq.ft.)
      2) flammables storage (turpentine, laquer thinner, etc.)

The information given so far will undoubtedly pattern the design solution. The solutions chosen, however, are to relate in strategy to an understood goal. To give a direction to the client objectives which lead to the program outline, I will conclude these goals:

1. Decreased energy dependance (minimum, if any, fossil fuel use)
2. Increased energy potential
3. Self-construction

To these goals, I will attempt to apply the following strategy-methods, respectfully:

1. Energy conservative, climate control techniques
2. Utilization of alternate energy forms
3. Finishing touches provided by owner

With these goals and objectives in mind, I turn now to PART II, where factors exist beyond control by the owner/builder. They are the factors of the environment, which must be analyzed and synthesized into workable criterion for a place to design.

PART II

This complex system refers to the cultural context of environment as well as the physical context. Since this system includes the entire planet, I will first limit the scope to the Gallatin Valley, then to the Belgrade area, then further to the Clark Ranch site. The cultural context deals with various factors known as: social, political, economic, scientific, technological, historical, aesthetic, and religious. The physical context deals with factors that can be interpreted in the form of maps, charts, and various other recorded data, and is analyzed directly from these forms. When synthesized in interrelation to the program, this information limits and influences decisions made in a building system.

According to the Belgrade Planning Report, the Belgrade area is favorable to development. Many factors such as climate, geology, physiography, and hydrology of the entire Gallatin Valley region have been presented to me during the course of my education. I have long ago concluded that development in the Belgrade area would be far less harmful to the environment than development presently practised in the Bozeman area. Thus I chose the location of the Clark Ranch on the outskirts of Belgrade itself as the specific site. The site choice also conforms to the criteria given in the Solar Dwelling Design Competition problem definition (PART I).

In working with the cultural context, I find that explanation is not simple, and an order is difficult to establish. Research in depth into any factor mentioned here requires accuracy for which I have neither the skills or the time. I have chosen, instead, to present

a pictoral illustration of each of these cultural factors relative to the site.

The images of the existing cultural influences, represented by these illustrations, of the Belgrade area, reflect the interpretation of that particular cultural factor as I have observed it. The selections are my own.

To begin with, below is the site as it exists, viewed from a point between the Railroad and Highway 10, just south of the site.

CLARK RANCH SITE

SOCIAL INFLUENCES:

The schools of Belgrade are probably the focus of social activity, for the most part, of the young people.

GRADE SCHOOL IN BELGRADE

Although many people commute to Bozeman for social leisure functons, there are accommodations as such that also exist in Belgrade.

BEAUMONT CLUB-LOUNGE

POLITICAL INFLUENCES:

The presence of the law-enforcement agency is a constant reminder to the people of Belgrade that they have political identity.

BELGRADE POLICE DEPT. OFFICE

The Post Office functions as an ever present communication to one's congressman, when law-making matters arise.

BELGRADE POST OFFICE

ECONOMIC INFLUENCES:

At first, agriculture was the primary economic baes for Belgrade and vicinity.

GRAIN ELEVATORS, NOW SURROUNDED BY THE CLUTTERED SIGNS OF "MODERN PROGRESS"

Other industry has since moved into the area, however, most of the population still commute to Bozeman for a living.

GALLATIN HOMES INC., MOBILE HOME FACTORY

SCIENTIFIC INFLUENCE:

The most apparent scientific influence in the area is the veterinary hospital.

BELGRADE VETERINARY HOSPITAL

TECHNOLOGICAL INFLUENCES:

The obvious technological influence for years has been transportation modes. The once magnonimous railroads still dominate parts of Belgrade and vicinity.

BURLINGTON NORTHERN RAILROAD

A favorable location for an airport brought a new image to the area--as a stopping place within a new technological era.

BELGRADE AIRPORT

HISTORICAL INFLUENCE:

Atypical "main street" development characterises Belgrade within the growth patterns of small towns across the entire western U.S. As in many others, the major traffic bypasses the town along the interstate highway.

MAIN STREET, BELGRADE

AESTHETIC INFLUENCES:

The natural aesthetic dominance in the area is the magnificence of the Bridger Range.

BRIDGER RANGE, BELGRADE OUTSKIRTS IN FORGROUND

Sadly enough, thuogh, there is also a "false aesthetic" imagery that is spreading like spilled children's toys on the landscape.

NEW HOUSING DEVELOPMENT

RELIGIOUS INFLUENCES:

With the coming of new homes and people, there arises also the imagery of there religious beliefs.

NEW CHURCH, BEING COMPLETED

The spirit of the earlier religious foundings is maintained by the show of traditional permanence.

OLDER CHURCH IN BELGRADE

FACTORS WITHIN PHYSICAL CONTEXT

The elevation of Belgrade is 4450' or 1335m

The average length of freeze-free season is 110 - 120 days, although it can be cut to as short as 90 days.

Test drilling indicates that below a depth of 20ft., the alluvium consists predominately of cobbles and pebbles.

In the vicinity, the alluvium is at least 400ft. thick.

The depth of the water table in the vicinity can be as much as 40 to 50 feet below the land surface, even at its highest position during the year.

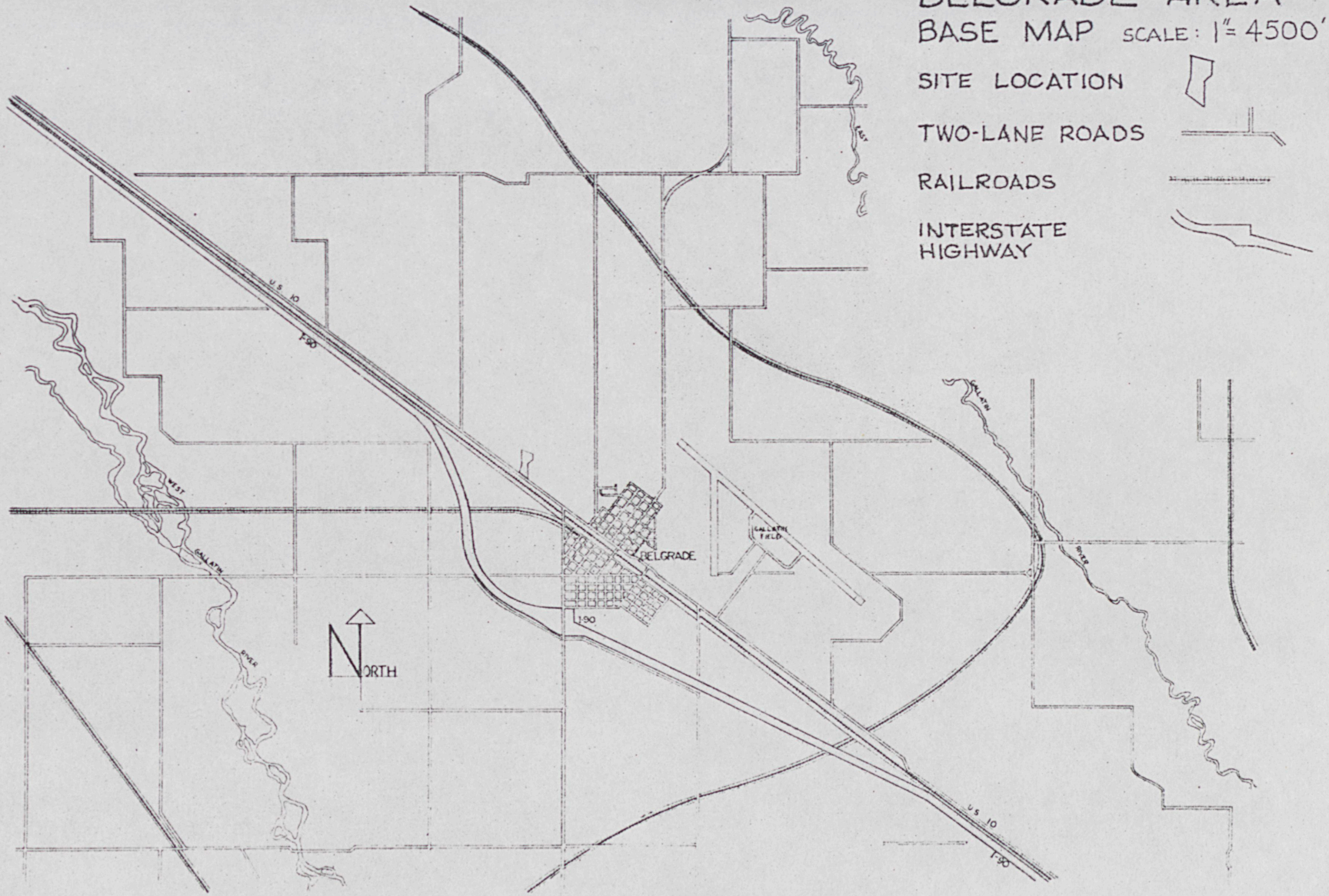
Near the margins of the Belgrade subarea most of the wells are 20 to 60 feet deep, whereas in the vicinity of Belgrade, wells are 60 to 200 feet deep.

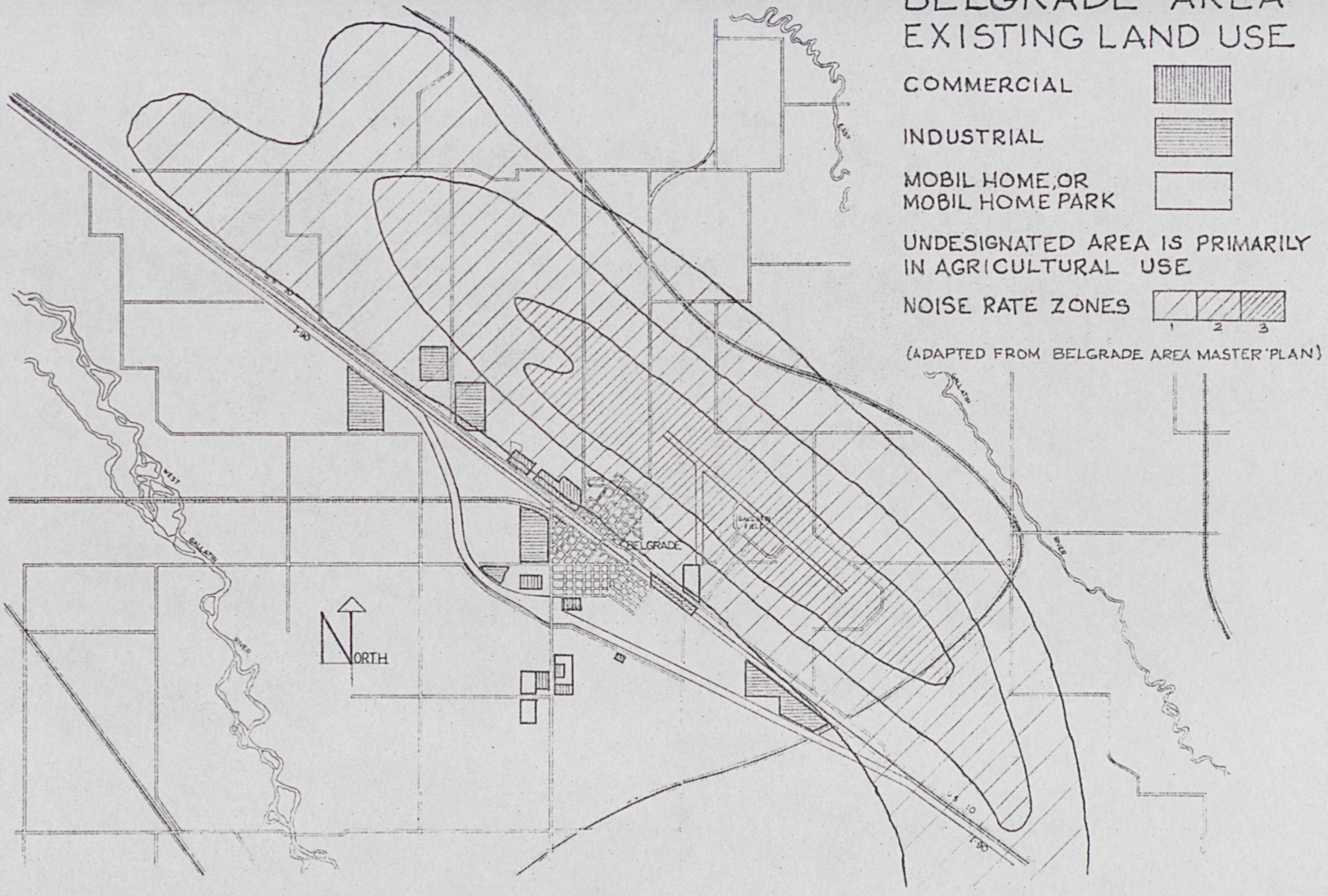
BELGRADE AREA MAPS

The physical environmental factors of the site are shown.

BELGRADE AREA

BASE MAP SCALE: 1" = 4500'




BELGRADE AREA
EXISTING LAND USE
COMMERCIAL
INDUSTRIAL
MOBIL HOME, OR
MOBIL HOME PARK
UNDESIGNATED AREA IS PRIMARILY
IN AGRICULTURAL USE
NOISE RATE ZONES
1
2
3
(ADAPTED FROM BELGRADE AREA MASTER PLAN)
US 10
MT 53
GALLATIN
RIVER
BELGRADE
NORTH

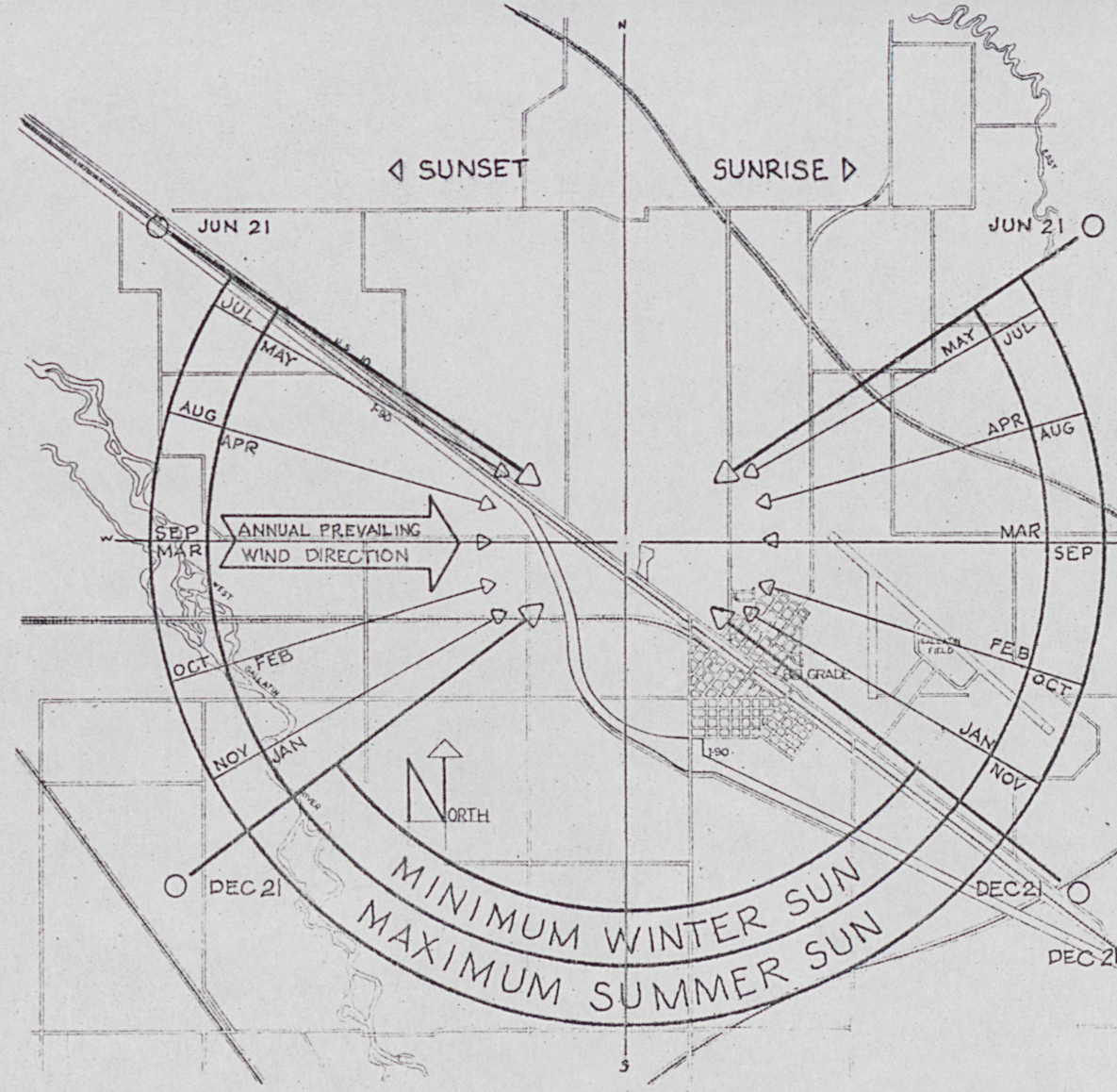
BELGRADE AREA
SUN ANGLE & WIND DIRECTION

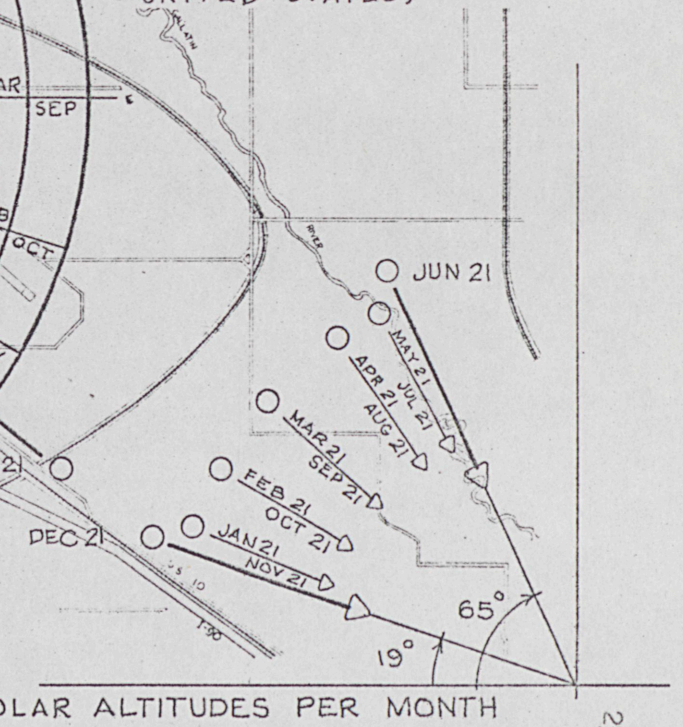
MEAN POSSIBLE ANNUAL SUNSHINE = 60% OF TOTAL.

MEAN ANNUAL SKY COVER = BETWEEN 6/10 & 7/10 OF SKY.

MEAN ANNUAL WIND SPEED = 8 M.P.H.

(INTERPOLATED FROM THE CLIMATIC ATLAS OF THE UNITED STATES)





SOLAR ALTITUDES PER MONTH

MONTHLY MEAN TEMPERATURES, HEATING DEGREE-DAYS, & PRECIPITATION NORMALS FOR BOZEMAN & TRIDENT, MONTANA FOR THE PERIOD FROM 1941 TO 1970.

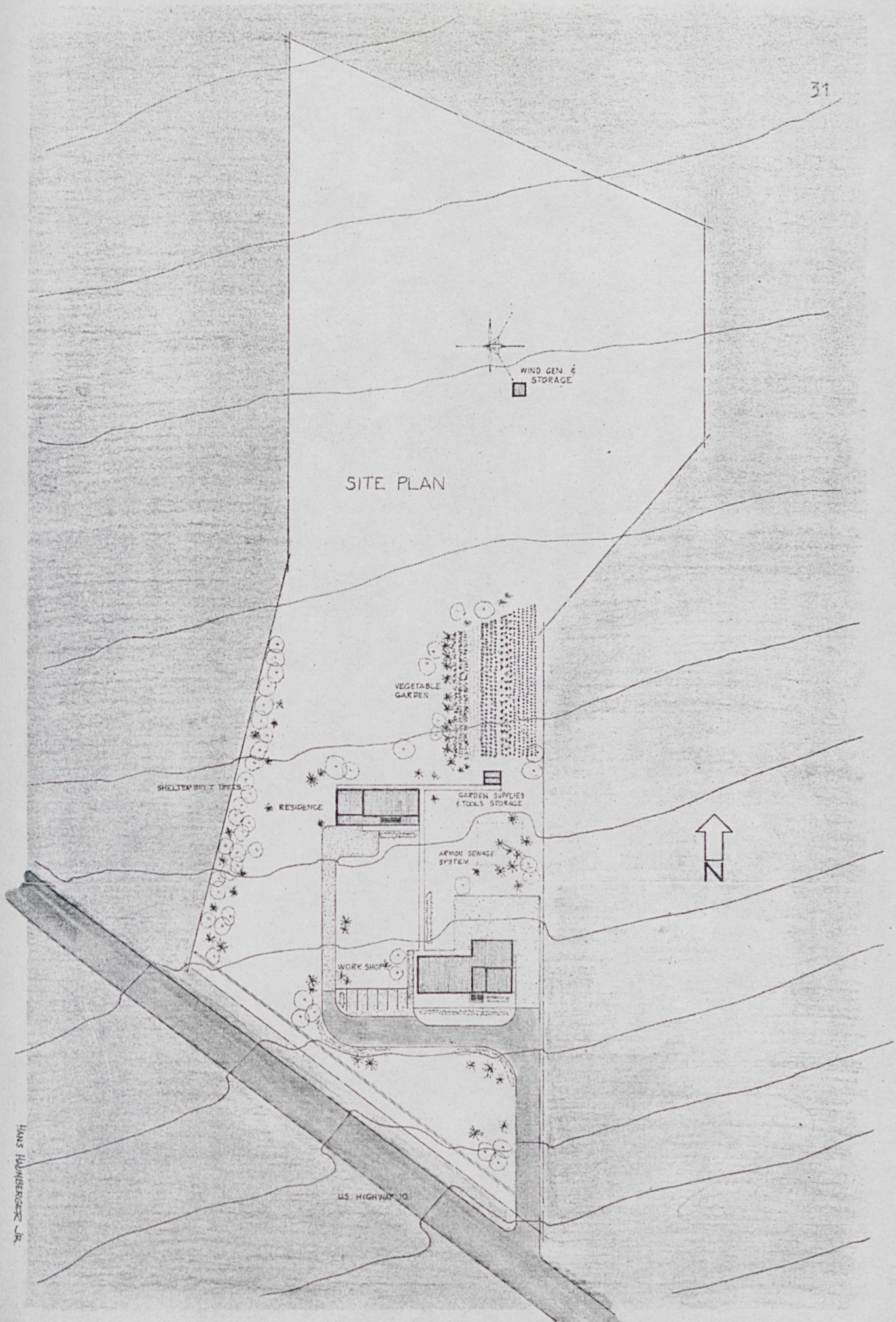
MONTH	MEAN TEMPERATURE		HEATING DEGREE-DAYS		PRECIPITATION NORMALS	
	BOZEMAN	TRIDENT	BOZEMAN	TRIDENT	BOZEMAN	TRIDENT
JAN	20.8	21.3	1370	1355	0.92	0.38
FEB	26.2	28.6	1086	1019	0.65	0.26
MAR	29.9	33.3	1088	983	1.44	0.60
APR	41.9	45.0	693	600	1.78	1.04
MAY	50.8	54.1	440	343	2.67	1.95
JUN	57.6	61.2	239	147	3.22	2.58
JUL	66.4	69.4	53	15	1.30	1.05
AUG	65.0	67.6	80	28	1.37	1.16
SEP	55.3	57.4	312	255	1.76	1.25
OCT	45.9	47.7	592	536	1.46	0.70
NOV	32.5	34.6	975	912	1.26	0.49
DEC	25.1	26.3	1237	1200	0.83	0.33
ANNUAL	43.1	45.5	8165	7393	18.66	11.79

(COOLING DEGREE-DAYS FOR TRIDENT = 320 ANNUALLY FROM JUN-SEP ONLY. COOLING DEGREE-DAYS FOR BOZEMAN WEREN'T LISTED)

IT IS ASSUMED THAT BELGRADE IS A CLIMATIC MIDPOINT BETWEEN THE LOCATIONS OF BOZEMAN & TRIDENT. CLIMATOLOGICAL DATA FOR BELGRADE IS THUS INTERPOLATED FROM THE ABOVE DATA & SHOWN BELOW.

MONTH	MEAN TEMPERATURE	HEATING DEGREE-DAYS	PRECIPITATION NORMALS	% CLOUD COVER (ESTIMATED)
JAN	21.05	1362.5	0.650	52
FEB	27.40	1052.5	0.455	50
MAR	31.60	1035.5	1.020	56
APR	43.45	646.5	1.410	63
MAY	52.45	391.5	2.310	72
JUN	59.40	193.0	2.900	80
JUL	67.90	34.0	1.175	58
AUG	66.30	54.0	1.265	60
SEP	56.35	283.5	1.505	64
OCT	46.80	564.0	1.080	57
NOV	33.55	943.5	0.875	54
DEC	25.70	1218.5	0.580	51
ANNUAL	44.30	7779.0	15.225	60

(PERCENTAGE OF CLOUD COVER IS ESTIMATED BY CALCULATING THE AVERAGE MONTHLY PRECIPITATION NORMAL, WHICH EQUALS 1.269. THE MONTH OF AUGUST MOST NEARLY CORRESPONDS TO THIS FIGURE. SINCE ANNUAL MEAN SKY COVER IS 6/10, OR 60% OF THE SKY, CLOUD COVERAGE FOR AUGUST IS ASSUMED TO BE 60%. THE OTHER MONTHS ARE ESTIMATED PROPORTIONAL TO THEIR PRECIPITATION, USING AUGUST AS A BASE FIGURE.)



HANS HAUNBERGER JR.

I determined the parameters of the site by choosing existing fence lines, and surveying them myself. I also determined the general slope of the site, recorded in one-foot contour intervals, which decrease in elevation toward the north.

A row of shelterbelt trees are planned near the existing roadway to the ranch house. The workshop is planned near to the Highway for short access. The residence, 100ft. to the north of the shop, will be 200ft. nearer the Highway than the existing house.

The entire north half of the site is to remain free of any obstructions that would interfere with the option of a wind generator.

Adefinition of site frontage is provided by a wooden fence, running the length of the site that fronts to the Highway.

A fence around both the unloading area and the parking area, provide a partial visual barrier between the residence and the shop, plus there is the distance that separates them.

The size and form of the vegetable garden will vary.

PART III

There are basicly four ways in which buildings can utilize solar energy:

1) Sun to Space

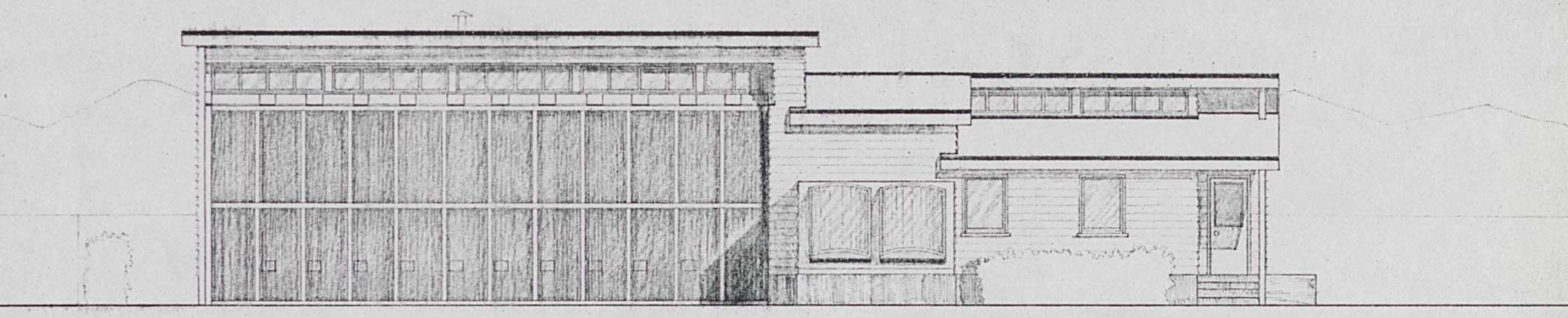
2) Sun to Mass

3) Sun to Collector to Storage to Space

4) Sun to Solar Cell to Use or Storage, to Mechanical equipment to Space

I have chosen forms of the first three ways, the fourth being too expensive for this thesis program.

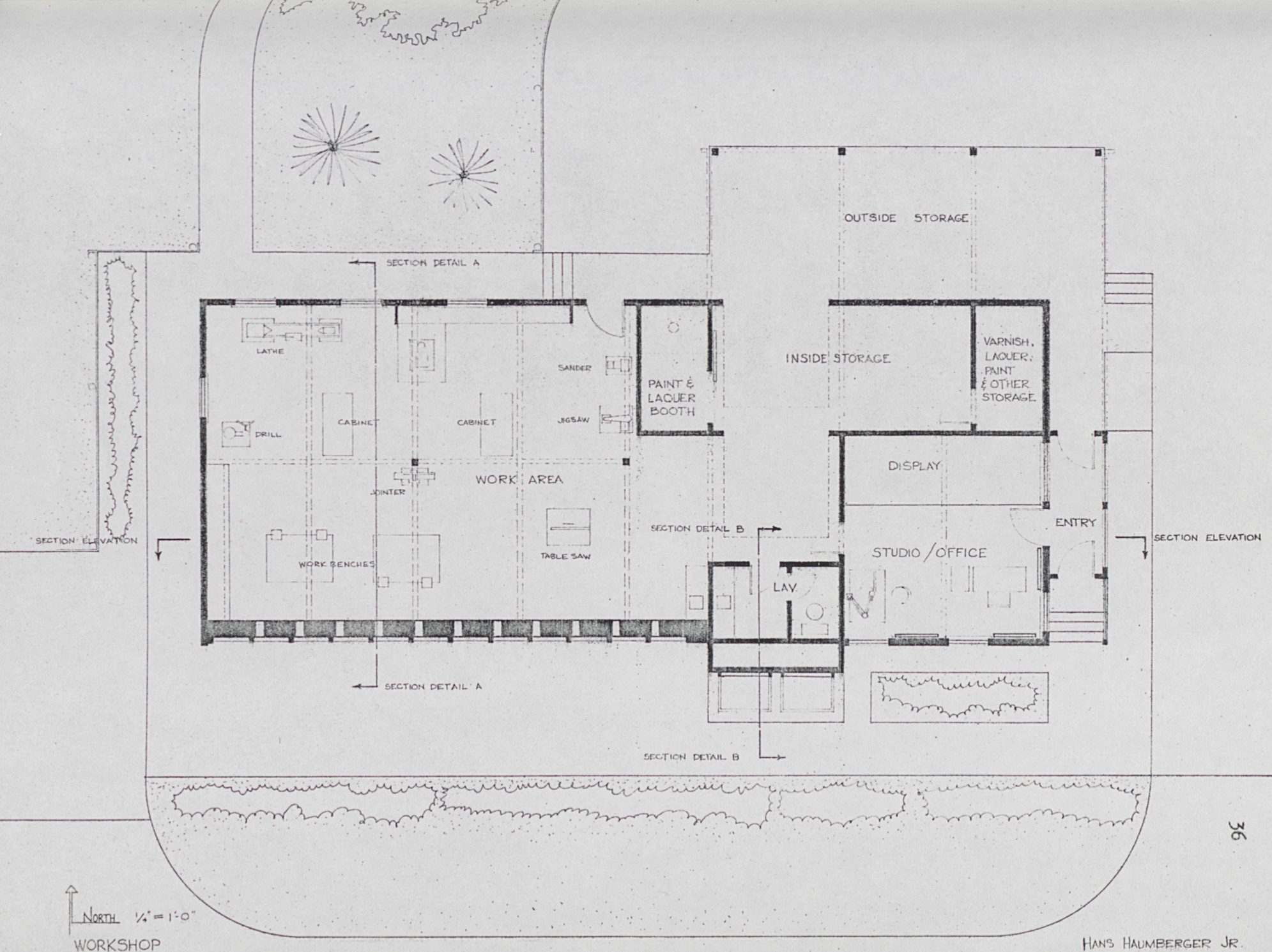
The interrelations from parts I & II are synthesized in the design process into the final building forms shown on the following pages. The character of these buildings are influenced considerably by an effort to draw energy from the sun, in helping to provide for a compatable interior environment.



WORKSHOP
SOUTH ELEVATION 1/4"=1'-0"

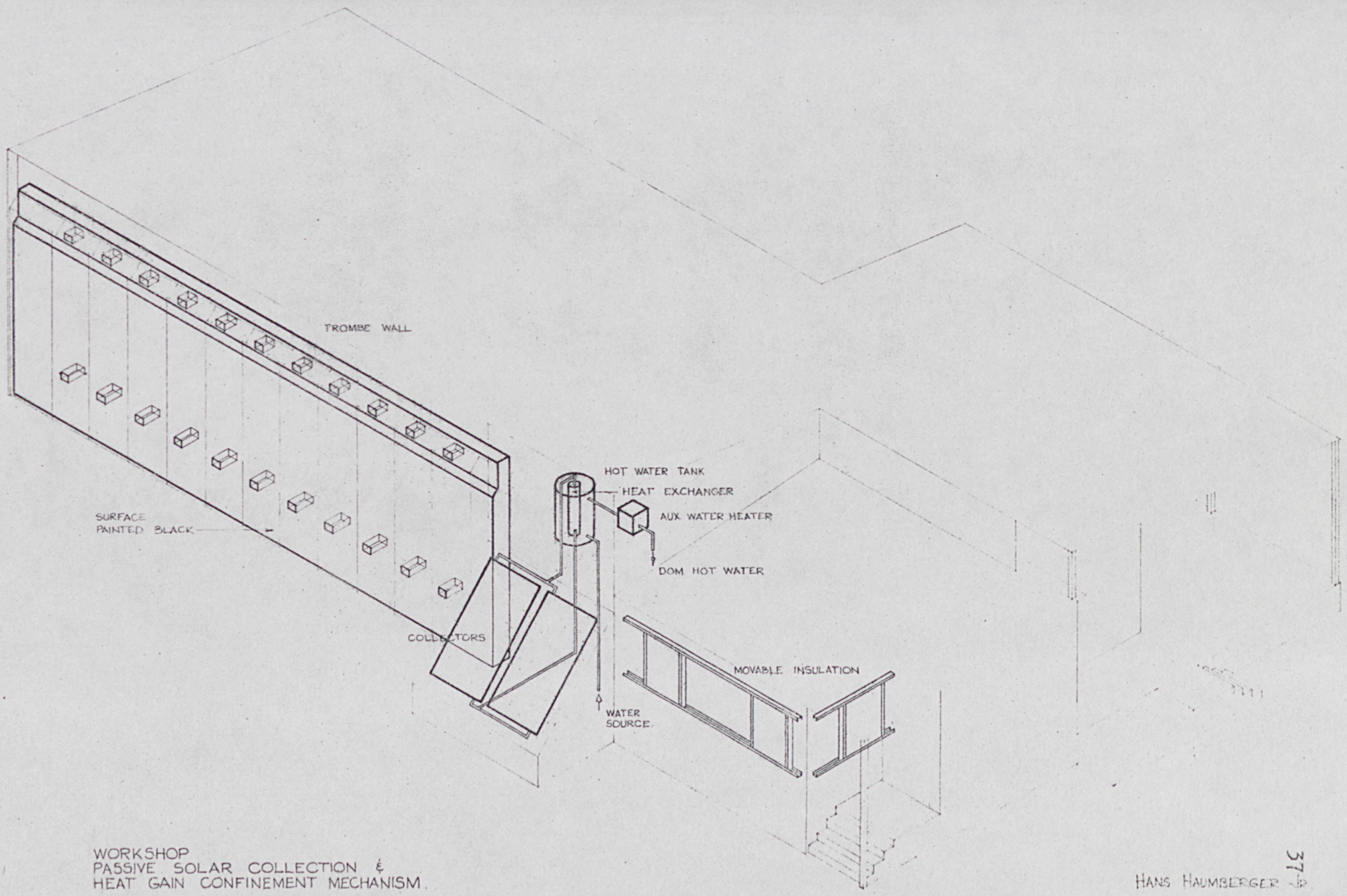
HANS HAUMBERGER JR.

35



WORKSHOP

HANS HAUMBERGER JR.



WORKSHOP
PASSIVE SOLAR COLLECTION &
HEAT GAIN CONFINEMENT MECHANISM.

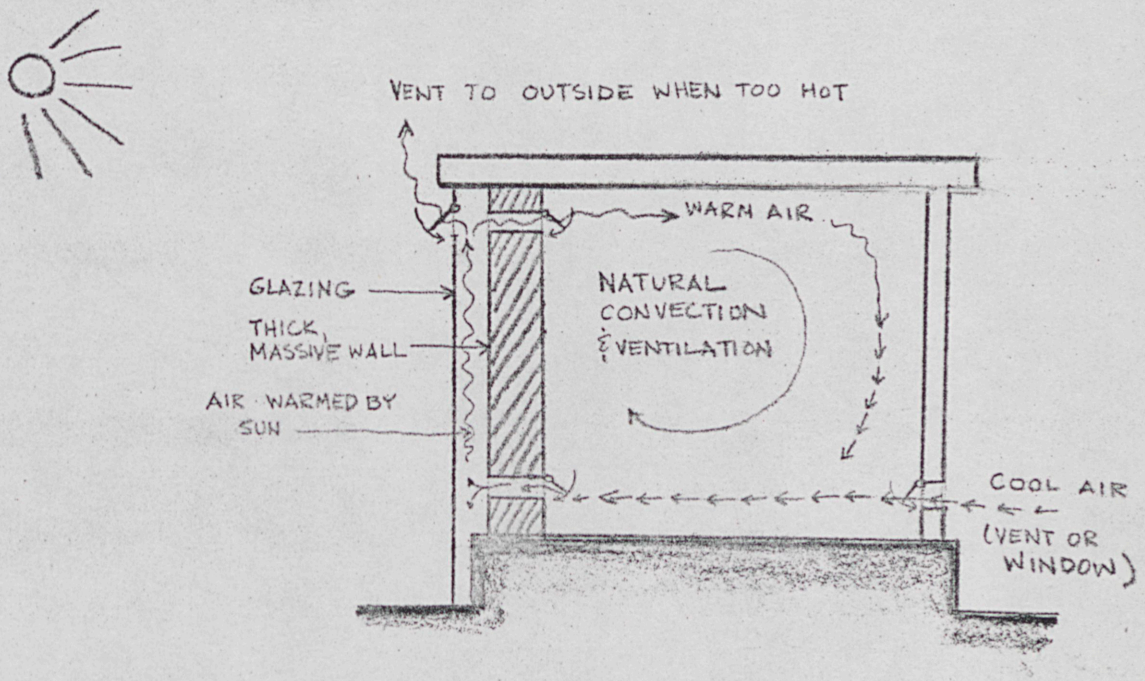
HANS HAUMBERGER

The workshop maintains an interior climate through passive use of the sun's energy by a Trombe Wall south elevation, supplemented with a wood heating stove. (Sun to Mass)

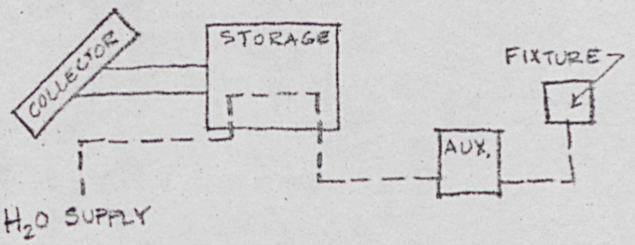
The office/studio space is regulated by opening and closing of insulated panels over the windows, thus controlling the amount of insolation into the space. (Sun to Space)

Water for the washroom is heated with the aid of flat plate solar collectors and auxillary heating elements. (Sun to Collector to Storage to Water Tank)

TROMBE WALL PRINCIPLE



SOLAR DOMESTIC HOT WATER SYSTEM (Process Diagram)



The domestic water supply would pass through heat storage enroute to the conventional water heater, thus preheating the hot water supply.

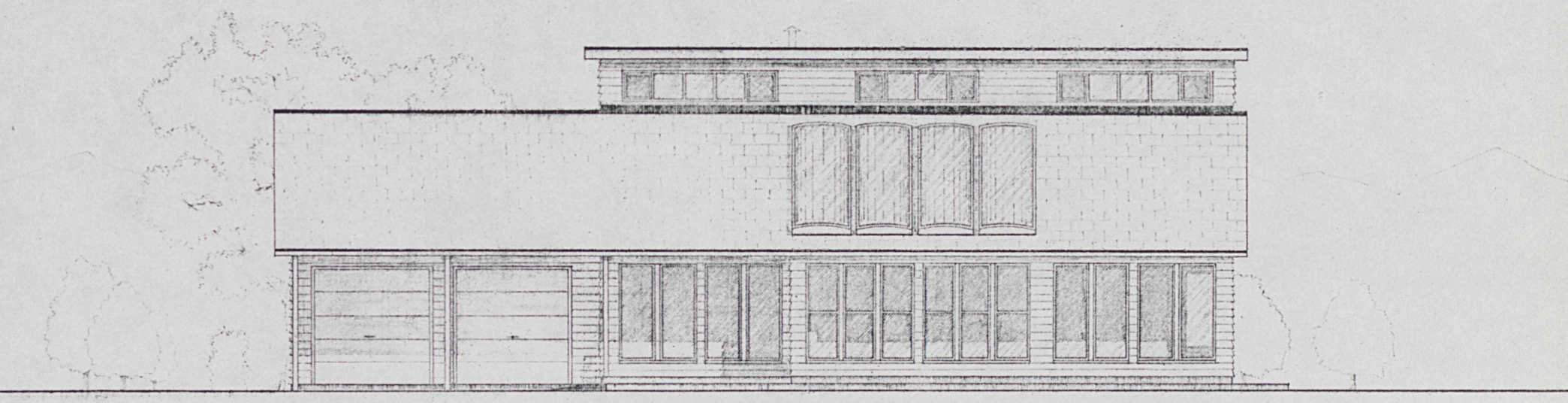
SOLAR WATER HEATERS CURRENTLY ON THE MARKET

Sunworks' SOLECTOR

Ken Herrington's Solar Water Heater

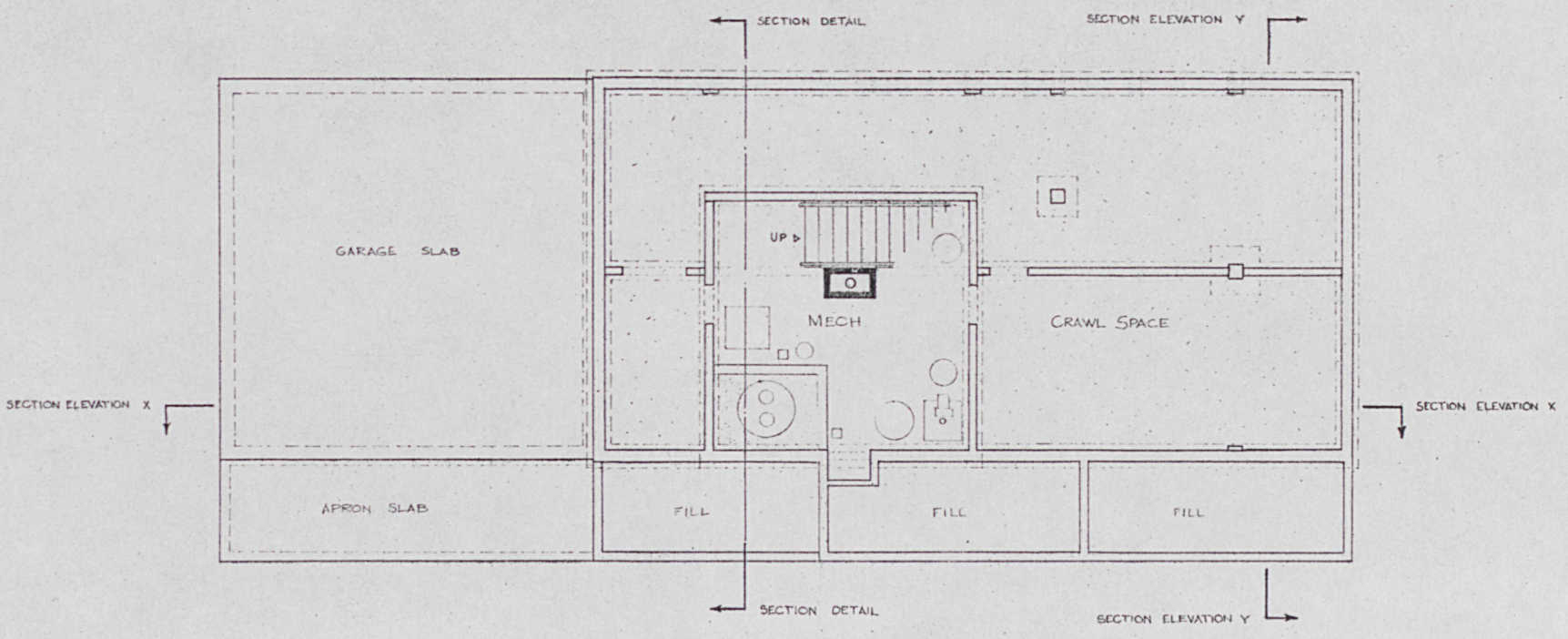
J. Don Field's "Trickle Collector"

PART IV



RESIDENCE
SOUTH ELEVATION 1/4" = 1'-0"

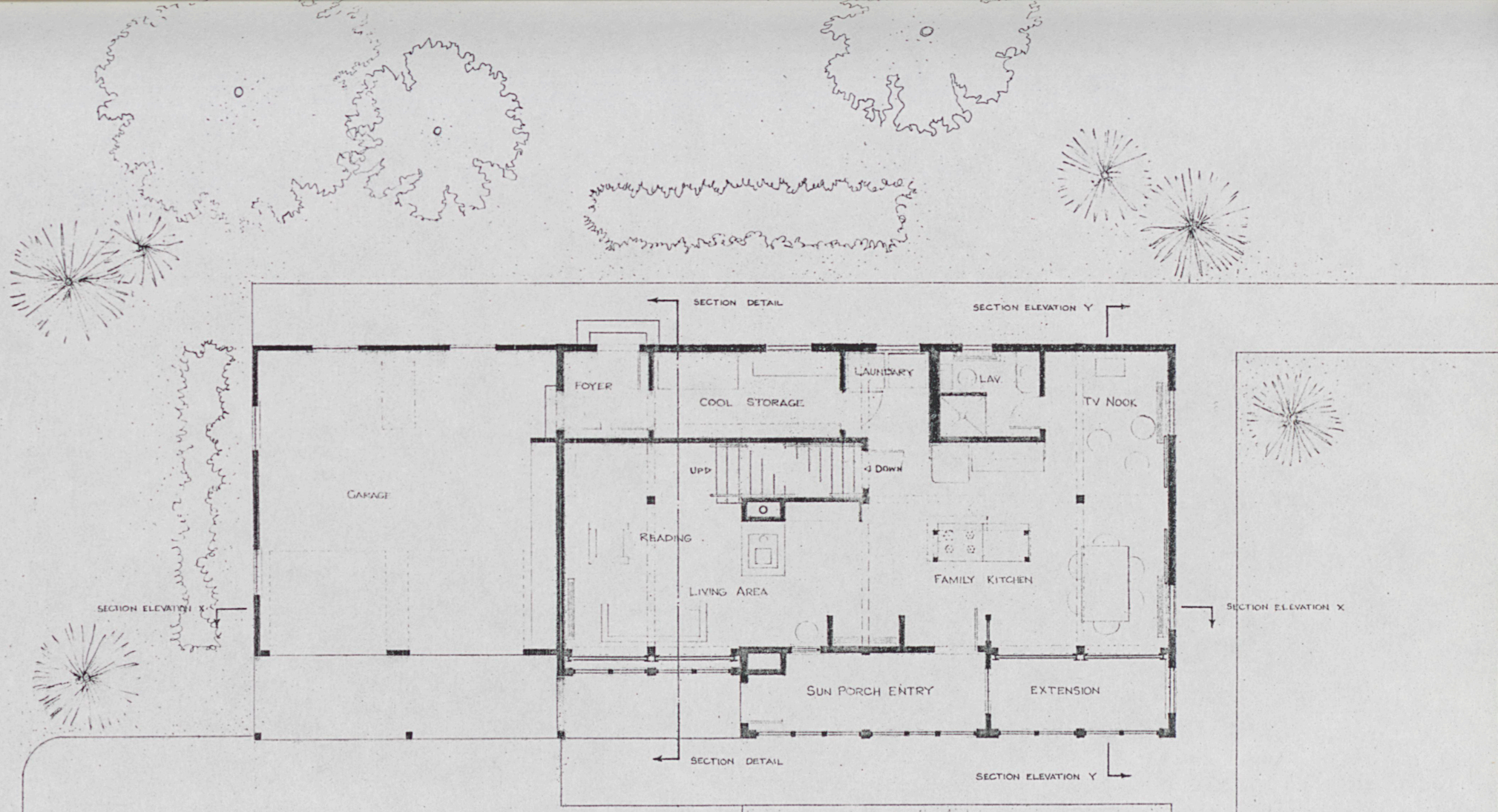
HANS HAUMBERGER JR.



NORTH 1/4" = 1'-0"

RESIDENCE
BASEMENT / FOUNDATION

HANS HAUMBERGER JR.

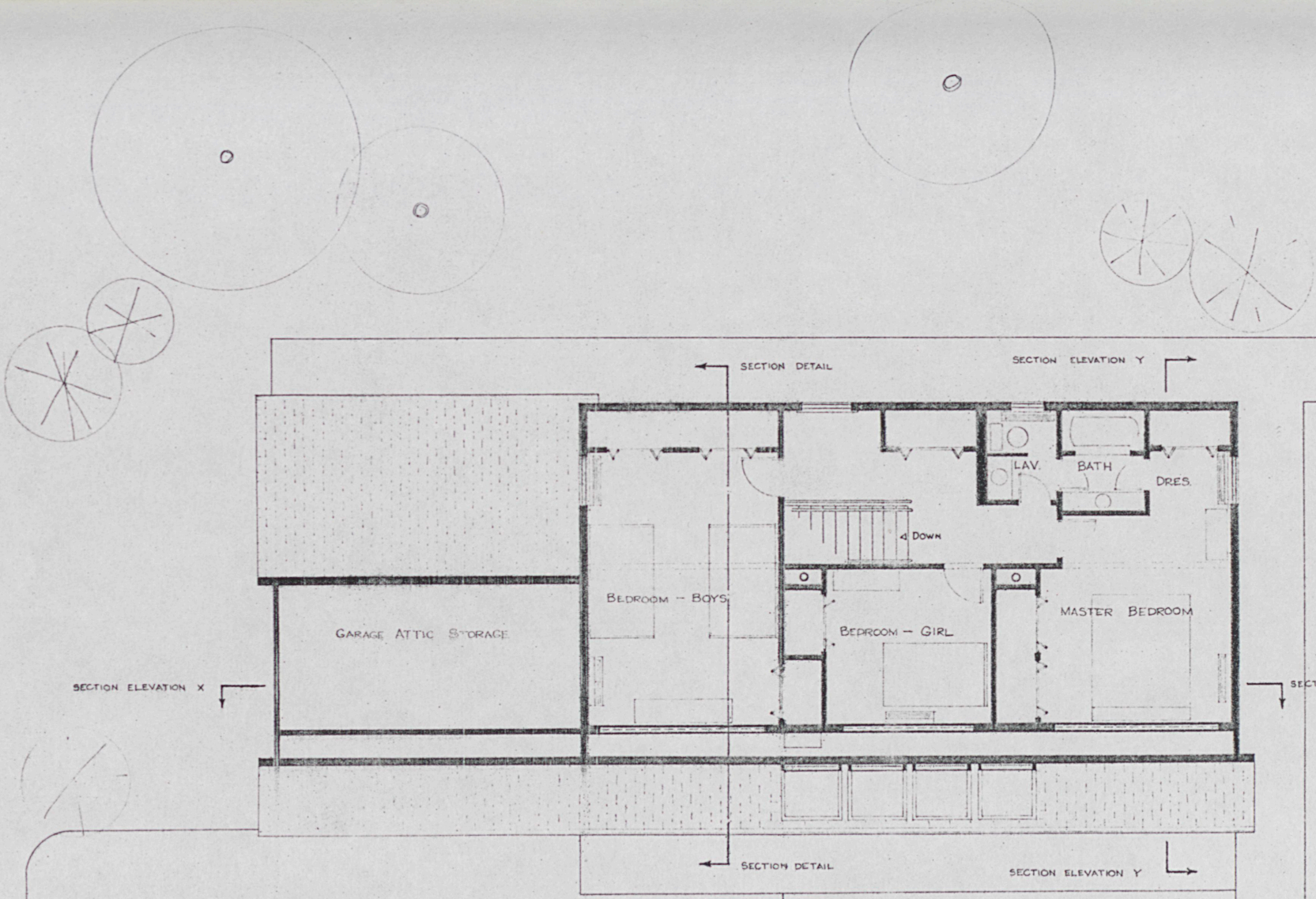


NORTH 1/4" = 1'-0"

RESIDENCE
GROUND LEVEL

HANS HAUMBERGER JR.

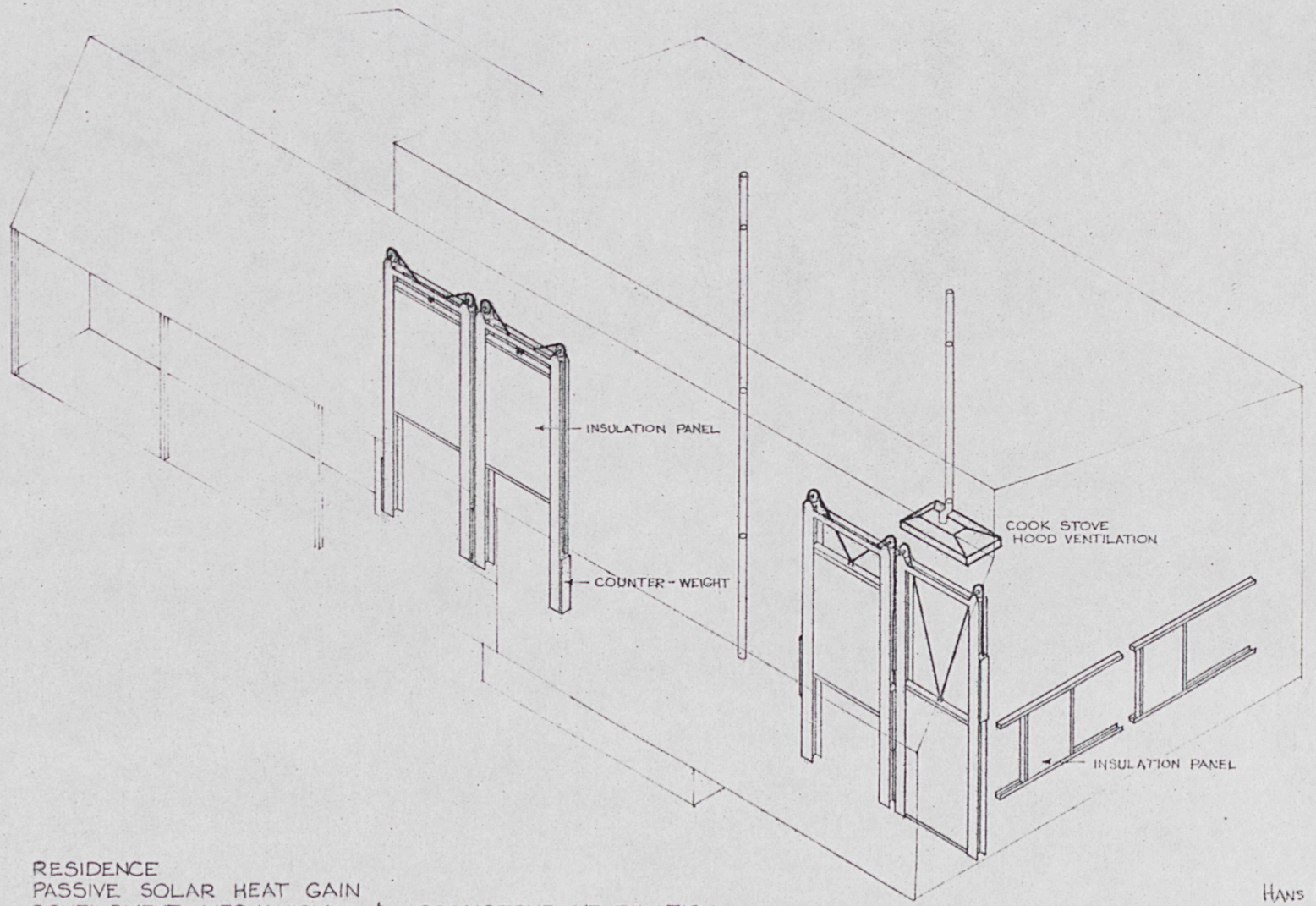
43



NORTH 1/4" = 1'-0"

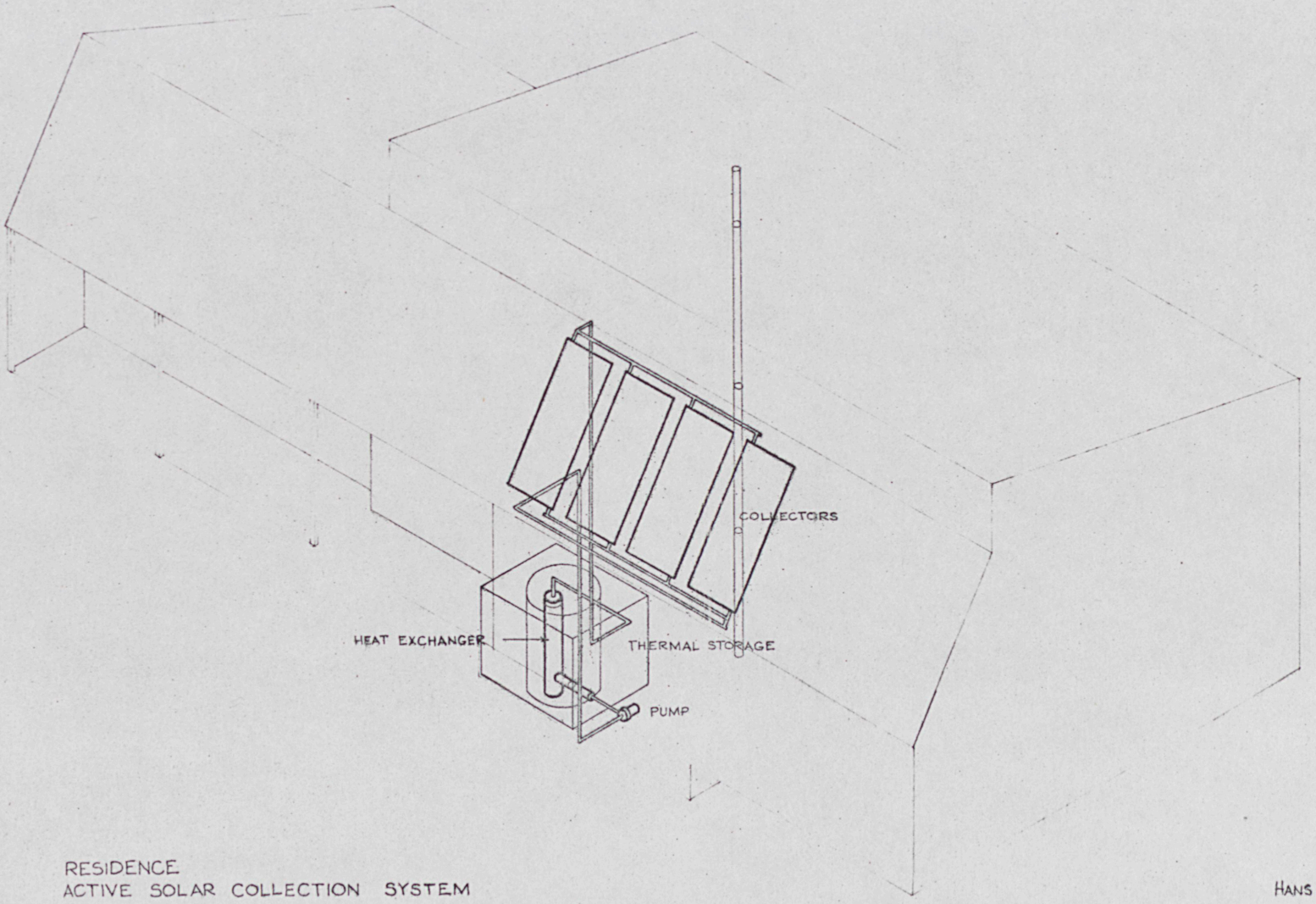
RESIDENCE
SECOND LEVEL

HANS HAUMBERGER JR.



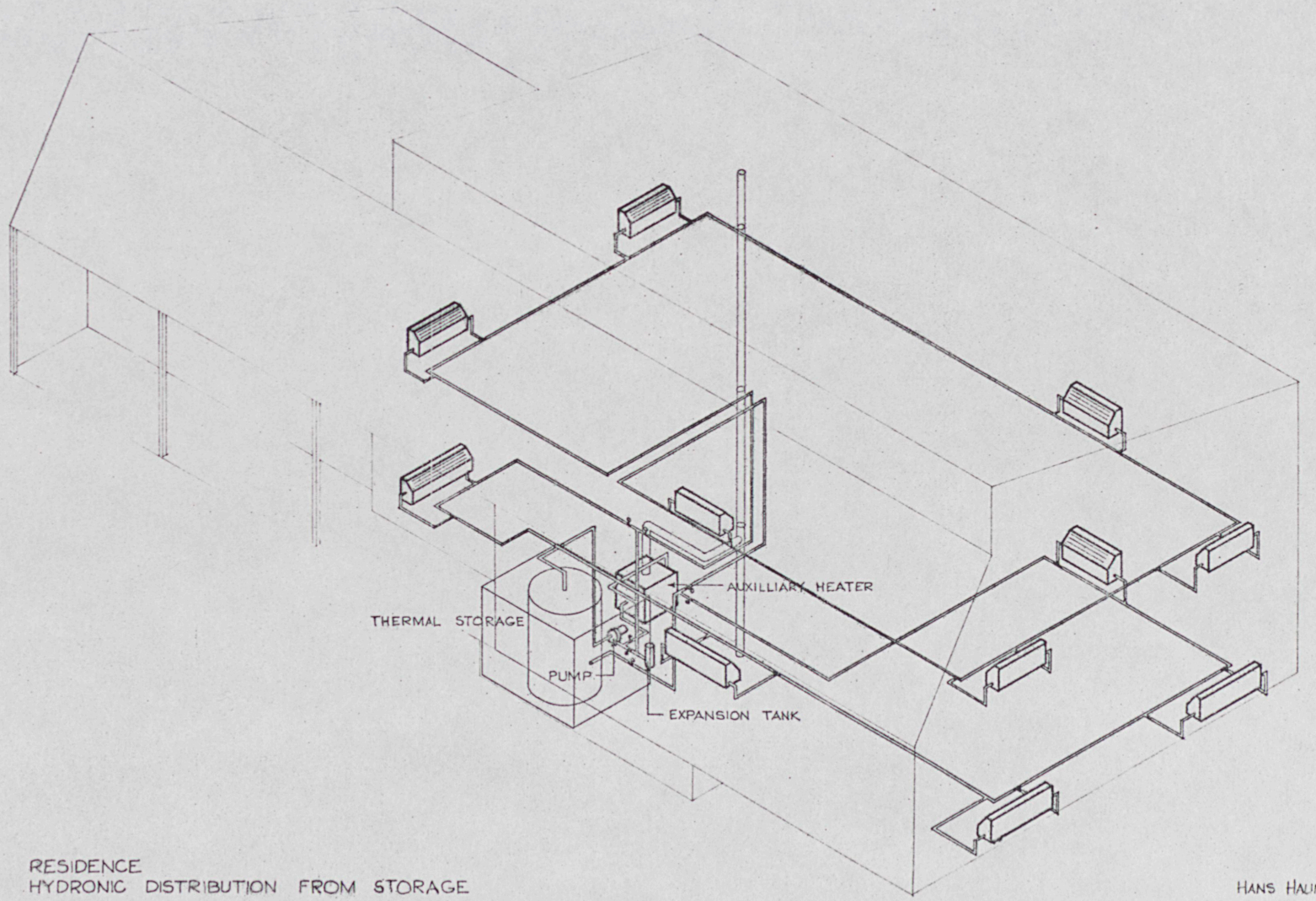
RESIDENCE
PASSIVE SOLAR HEAT GAIN
CONFINEMENT MECHANISM & COOKSTOVE VENTILATION

HANS HAUMBERGER JR.



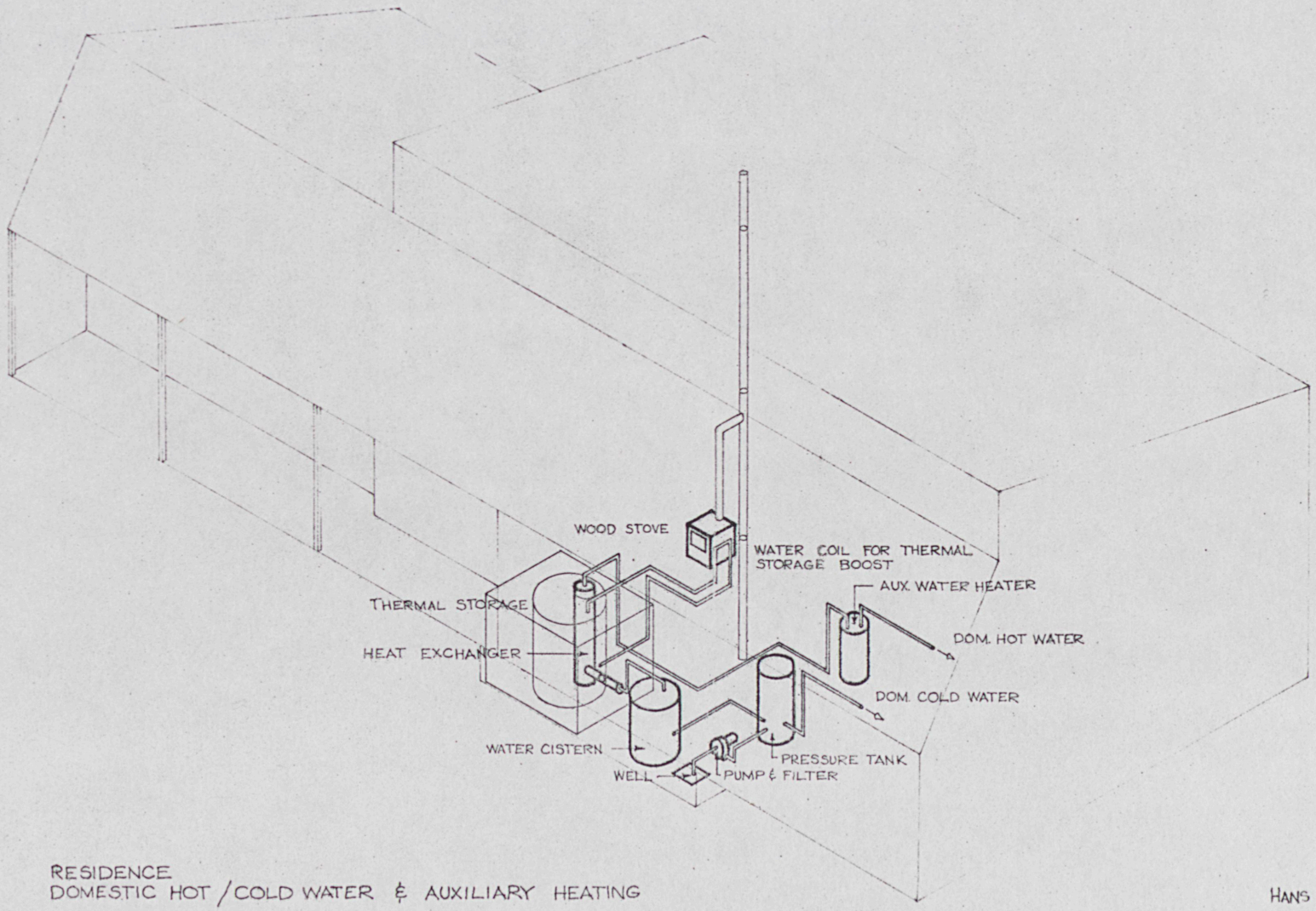
RESIDENCE
ACTIVE SOLAR COLLECTION SYSTEM

HANS HAUMBERGER JR.



RESIDENCE
HYDRONIC DISTRIBUTION FROM STORAGE

HANS HAUMBERGER JR.



RESIDENCE
DOMESTIC HOT / COLD WATER & AUXILIARY HEATING

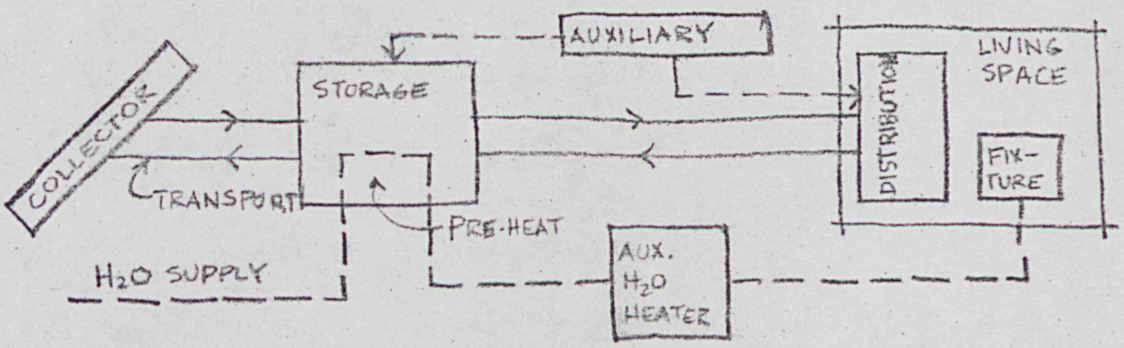
HANS HAUMBERGER JR.

The residence maintains an interior climate with the aid of direct solar radiation, regulated by opening or closing insulated window panels. (Sun to Space)

In addition to the above, there is an active solar collection system, combined with a hydronic distribution system. This equipment is to be installed in two to four phases, as initial cost could be prohibitive. (Sun to Collector to Storage to Space)

A Riteway wood burning stove supplements space heating as well as contributing to thermal storage by means of water coils that run through the stove, and circulate directly to the thermal storage tank.

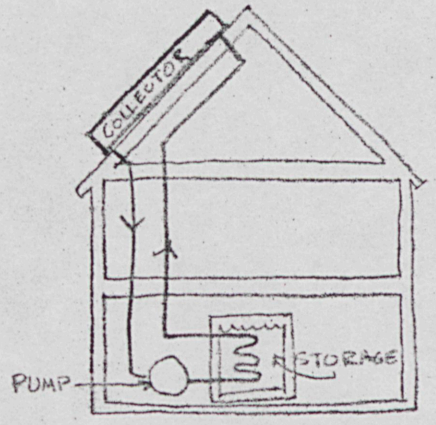
SOLAR HEATING & DOMESTIC HOT WATER SYSTEMS (Process Diagram)



Solar radiation is absorbed by a collector and removed by a heat transfer (transport) medium to storage. Heat is removed from storage and distributed to the living spaces by a heat transfer medium (may or may not be same medium flowing through collector). Circulation throughout the system is by pumps, blowers, or other heat transfer medium moving devices. An auxiliary energy system is available both to supplement the output supplied by the solar system and to provide for the total energy demand should the solar system become inoperable. Manual or automatic controls maintain and monitor the system oper-

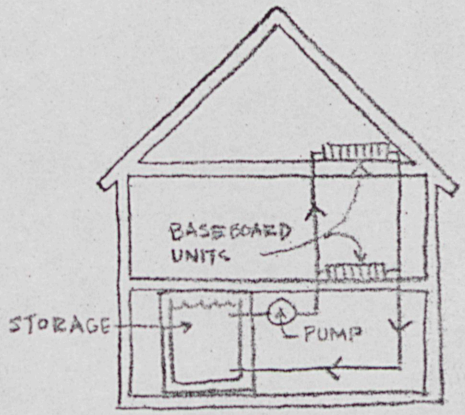
ation. Domestic hot water is preheated by passing the water supply through heat storage prior to passage through a conventional water heater.

CLOSED CIRCUIT LIQUID COLLECTOR



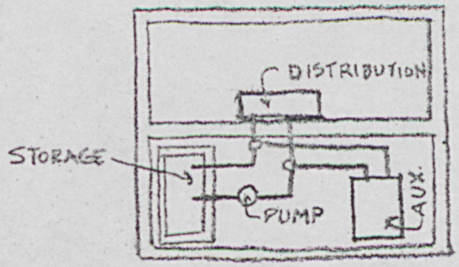
A heat transfer liquid - treated water, anti-freeze solution or other liquid - is pumped through the collector and then through a heat exchange in storage and back to the collector, in a closed loop. The loop is always filled with fluid, and therefore must be protected from freezing.

HYDRONIC DISTRIBUTION



Liquid from storage is pumped directly through standard baseboard convector units, despite relatively low temperatures that usually occur in solar systems during winter. The size of baseboard units, and the circuiting may change from ordinary hydronic systems.

AUXILIARY HEATING, STORAGE TRANSPORT LOOP TO DISTRIBUTION

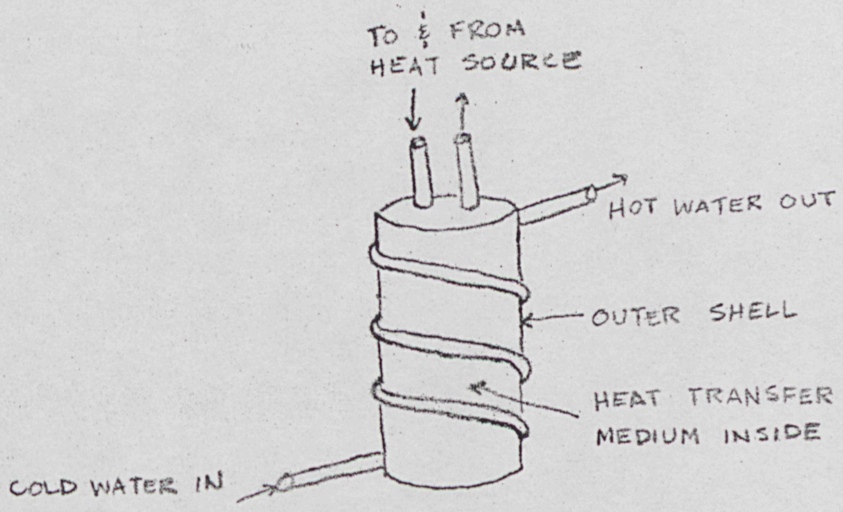


The auxiliary energy system is located between the storage and distribution component to permit a full or partial operation. The auxiliary system uses the same distribution network as the solar system. Valves at the connection between systems regulates auxiliary energy supply and prevents auxiliary from heating storage. Solar and auxiliary system operation is maintained and monitored by an integral control component.

HEAT EXCHANGERS

A heat exchanger is a device for transferring thermal energy from one fluid to another. In some systems, a heat exchanger may be required between the transfer medium circulated through the collector and the storage medium or between storage and the distribution component.

DOUBLE WALL CONSTRUCTION OF HEAT EXCHANGER



A method of providing a double separation between the transfer medium and the potable water supply consists of tubing or a plate coil wrapped around and bonded to a tank. The potable water is heated as it circulates through the coil. When this method is used the tubing or coil must be adequately insulated to reduce heat losses.

SEWAGE SYSTEM

The Armon System, model Mark II, is a 1008gal. unit, 7ft. high Upper Section has 556gal. capacity, providing extremely long average retention time for raw sewage.

Excavation area requirements for private residences:
For average sized houses of 3 or 4 bedrooms, two adults and three chidren, as an example.

Field Test Report:
A functional result is production of clear, clean effluent from Armon System,, filtered by passage through rock and sand areas, and distilled by evaporation. Engineers reported laboratory tests of unit's contents proved that double compartment system principle achieved solids removal in excess of 90% of discharge.

PART V

(Comparative Analysis)

HEAT LOSS OF WORKSHOP

DESCRIPTION OF SECTIONS

□ ROOF SECTION

SECTION	R-FACTOR
15 M.P.H. WIND	0.170
BUILT-UP ROOFING	0.330
15 LB FELT	0.120
1/2" PLYWOOD	0.625
3/4" PINE DECKING	0.980
9 1/2" FIBERGLASS INSULATION	49.970
5/8" GYPSUM BOARD	0.500
STILL AIR	0.610
TOTAL R	53.305

$U = 1/R = 1/53.305 = 0.019$

□ WALL SECTION

▲ MASONRY WALL

SECTION	R-FACTOR
15 M.P.H. WIND	0.170
SINGLE GLAZING	0.880
3 1/2" AIR SPACE	2.000
12" CONCRETE BLOCK, FILLE W/EXPANDED MINERAL WOOL	5.820
USED COMMON BRICK	0.700
3/4" PLASTER	0.200
STILL AIR	0.610
TOTAL R	11.260

$U = 1/R = 1/11.260 = 0.090$

□ WALL SECTION (CONT.)

▲ FRAME WALL

SECTION	R-FACTOR
15 M.P.H. WIND	0.170
HORIZONTAL BOARD SIDING	0.810
15 LB. FELT	0.120
3/4" PINE SHEATHING	0.980
5 1/2" FIBERGLASS INSULATION	28.930
5/8" GYPSUM BOARD	0.500
STILL AIR	0.610
TOTAL R	32.120

$U = 1/R = 1/32.120 = \underline{0.030}$

□ FLOOR SECTION

BTU LOSS / HR. / FOOT OF EXPOSED SLAB EDGE = 67 BTU/HR.

EXPOSED SLAB EDGE = $68.5(2) + 26(2) = 242$ FT.

BTU LOSS/HR THROUGH FLOOR = $(67)(242) = 16,214$ BTU/HR.

□ GLASS SECTION (WINDOWS)

$U = \underline{0.580}$ (FOR DOUBLE GLAZING)

□ DOOR SECTIONS

$U = \underline{1.220}$ FOR SINGLE GLASS IN DOORS

$U = \underline{0.430}$ FOR 2" SOLID WOOD DOOR

CALCULATIONS HEAT LOSS = $FT.^2(U)(\Delta T)$

☐ ROOF ($U = 0.0190$)

AREA = $(67)(25) = 1675\ FT.^2$

TOTAL HEAT LOSS = $1675(0.0190)(100) =$ **3182.5 BTU/HR**

☐ NORTH WALL

Δ FRAME SECTION ($U = 0.030$)

AREA = $(67)(12.6) - [(3)(4)(12) + (3)(6.5) + (8)(8)]$

$= 844.2 - (144 + 19.5 + 64)$

$= 844.2 - 227.5$

$= 616.7\ FT.^2$

HEAT LOSS = $616.7\ (0.030)(100) =$ 1850.1 BTU/HR

Δ WINDOW SECTION ($U = 0.580$) AREA = $144\ FT.^2$

HEAT LOSS = $144\ (0.030)(100) =$ 8352.0 BTU/HR

Δ DOOR SECTION ($U_{glass} = 1.220$, $U_{wood} = 0.430$)

$AREA_{glass} = 6\ FT.^2$ $AREA_{wood} = 13.5\ FT.^2$

HEAT LOSS = $6(1.220)(100) + 13.5(0.430)(100) =$ 1312.5 BTU/HR

TOTAL HEAT LOSS = $1850.1 + 8352.0 + 1312.5 =$ **11,514.6 BTU/HR**

☐ EAST WALL

Δ FRAME SECTION ($U = 0.090$) AREA = $288\ FT.^2$

HEAT LOSS = $288\ (0.090)(100) =$ 2592.0 BTU/HR

Δ WINDOW SECTION ($U = 0.580$) AREA = $30\ FT.^2$

HEAT LOSS = $30\ (0.580)(100) =$ 1740.0 BTU/HR

Δ DOOR SECTION (SAME AS ABOVE)

HEAT LOSS = 1312.5 BTU/HR.

TOTAL HEAT LOSS = $2592.0 + 1740.0 + 1312.5 =$ **5644.5 BTU/HR**

□ SOUTH WALL

Δ MASONRY SECTION (U = 0.090) AREA = 456 FT.²
HEAT LOSS = 456 (0.090)(100) = 4104.0 BTU/HR

Δ FRAME SECTION (U = 0,030) AREA = 244 − 62.25 = 181.75 FT.²
HEAT LOSS = 181.75 (0,030)(100) = 545.3 BTU/HR

Δ WINDOW SECTION (U = 0,580) AREA = 62.25 FT.²
HEAT LOSS = 62.25 (0,580)(100) = 3610.5 BTU/HR

TOTAL LOSS = 4104,0 + 545,3 + 3610.5 = **8259.8 BTU/HR**

□ WEST WALL

Δ FRAME SECTION (U = 0.030) AREA = 325,5 FT.²
HEAT LOSS = 325,5 (0.030)(100) = 976.5 BTU/HR.

Δ WINDOW SECTION (U = 0.580) AREA = 12 FT.²
HEAT LOSS = 12 (0,580)(100) = 696.0 BTU/HR

TOTAL HEAT LOSS = 976.5 + 696.0 = **1672.5 BTU/HR**

□ FLOOR (FROM PRECEDING PAGE)
HEAT LOSS = **16,214.0 BTU/HR**

SUM OF TOTALS = 3182.5 + 11,514.6 + 5644.5 + 8259.8 + 1672.5 + 16,214.0
" = 46487.9 BTU/HR

SUM TOTAL HEAT LOSS = TOTAL LOSS + LOSS DUE TO AIR CHANGE

LOSS DUE TO ONE AIR CHANGE/HR = (1)(46487.9) = 46487.9

→ SUM TOTAL HEAT LOSS = 46487.9 + 46487.9 = **92975.8 BTU/HR**

BTU/HR LOSS/FT.² = $\frac{92975.8}{1675}$ = 55.5 BTU/HR/FT.²

HEAT LOSS OF RESIDENCE

DESCRIPTION OF SECTIONS

☐ ROOF SECTION

SECTION	R-FACTOR
15 M.P.H. WIND	0.170
ASPHAULT SHINGLES	0.440
15 LB. FELT	0.120
1/2" PLYWOOD	0.625
11 1/2" FIBERGLASS INSULATION	60.490
5/8 GYPSUM BOARD	0.500
STILL AIR	0.610
TOTAL R	63.935

$U = 1/R = 1/63.935 = 0.016$

☐ WALL SECTION

SECTION	R-FACTOR
15 M.P.H. WIND	0.170
HORIZONTAL BOARD SIDING	0.810
15 LB FELT	0.120
3/4" SHEATHING	0.980
5 1/2" FIBERGLASS INSULATION	28.930
5/8" GYPSUM BOARD	0.500
TOTAL R	31.510

$U = 1/R = 1/31.510 = 0.032$

□ WINDOW SECTION (GLASS AREAS)

▲ WITHOUT PANEL COVER

- INSULATING PLATE GLASS
- 1/2" AIR SPACE
- DOUBLED, WELL CAULKED

$U = \underline{0.580}$ $R = 1/U = 1.724$

▲ WITH PANEL COVER

SECTION	R-FACTOR
ABOVE WINDOW SECTION	1.724
2 - 1/2" PLYWOOD LAYERS	1.250
2 1/2" FIBERGLASS INSULATION	13.150
STILL AIR	0.680
TOTAL R	16.804

$U = 1/R = 1/16.804 = \underline{0.059}$

□ DOOR SECTION

- 2" SOLID WOOD DOOR
- WOOD STORM DOOR

U-COEFFICIENT GIVEN FOR WINTER CONDITION = $\underline{0.240}$

CALCULATIONS

HEAT LOSS = $FT.^2(U)(\Delta T)$

☐ BASEMENT (ASSUME: DENSITY OF CONCRETE = 60 LBS./$FT.^3$
GROUND H_2O TEMPERATURE = 40°F)

WALL HEAT LOSS = 6.0 BTU/HR/$FT.^2$ SQ. FOOTAGE = 672 $FT.^2$
HEAT LOSS = 672(6) = 4032 BTU/HR

FLOOR HEAT LOSS = 3.0 BTU/HR/$FT.^2$ SQ. FOOTAGE = 800 $FT.^2$
HEAT LOSS = 800 (3) = 2400 BTU/HR

TOTAL HEAT LOSS = 4032 + 2400 = **6432 BTU/HR**

☐ FLOOR (NEGLECTED DUE TO BASEMENT HEAT LOSS CALCULATION)

☐ ROOF (U = 0.016) AREA = (20)(39.5) = 790 $FT.^2$
HEAT LOSS = 790 (0.016)(100) = 1264 BTU/HR

☐ NORTH WALL

△ FRAME SECTION (U = 0.032) AREA = 560.5 $FT.^2$
HEAT LOSS = 560.5 (0.032)(100) = 1792 BTU/HR

△ WINDOW SECTION (U = 0.580) AREA = 52 $FT.^2$
HEAT LOSS = 52 (0.580)(100) = 3016 BTU/HR

△ DOOR SECTION (U = 0.240) AREA = 19.5 $FT.^2$
HEAT LOSS = 19.5 (0.240)(100) = 468 BTU/HR

TOTAL HEAT LOSS = 1792 + 3016 + 468 = **5275 BTU/HR**

☐ WEST WALL

△ FRAME SECTION (U = 0.032) AREA = 339 $FT.^2$
HEAT LOSS = 339 (0.032)(100) = 1084.8 BTU/HR

△ WINDOW SECTION (U = 0.580) AREA = 12 $FT.^2$
HEAT LOSS = 12 (0.580)(100) = 696 BTU/HR

TOTAL HEAT LOSS = 1084.8 + 696 = **1781 BTU/HR**

□ EAST WALL (PANELS OPEN)

Δ FRAME SECTION (u = 0.032) AREA = 333 FT.²
HEAT LOSS = 333 (0.032)(100) = 1066 BTU/HR

Δ WINDOW SECTION (u = 0.580) AREA = 48 FT.²
HEAT LOSS = 48 (0.580)(100) = 2784 BTU/HR

TOTAL HEAT LOSS = 1066 + 2784 = **3850 BTU/HR**

□ EAST WALL (PANELS CLOSED)

Δ FRAME SECTION (u = 0.032) AREA = 303 FT.²
HEAT LOSS = 303 (0.032)(100) = 970 BTU/FT.²

Δ CLOSED PANEL WINDOW SECTION (u = 0.059) AREA = 24 FT.²
HEAT LOSS = 24 (0.059)(100) = 142 BTU/FT.²

Δ WINDOW SECTION WITHOUT PANEL (u = 0.580) AREA = 12 FT.²
HEAT LOSS = 12 (0.580)(100) = 696 BTU/FT.²

TOTAL HEAT LOSS = 970 + 142 + 696 = **1808 BTU/FT.²**

□ SOUTH WALL (PANELS OPEN)

Δ FRAME SECTION (u = 0.032) AREA = 600FT.²
HEAT LOSS = 600 (0.032)(100) = 1920 BTU/HR

Δ WINDOW SECTION (u = 0.580) AREA = 204 FT.²
HEAT LOSS = 204 (0.580)(100) = 11,832 BTU/HR

Δ DOOR SECTION (u = 0.240) AREA = 19.5 FT.²
HEAT LOSS = 19.5 (0.240)(100) = 468 BTU/HR

TOTAL HEAT LOSS = 1920 + 11,832 + 468 = **14,220 BTU/HR**

□ SOUTH WALL (PANELS CLOSED)

△ FRAME SECTION ($u = 0.032$) AREA 582 FT.^{2}
HEAT LOSS = $582 (0.032)(100) =$ 1862.4 BTU/HR

△ CLOSED PANEL WINDOW SECTION ($u = 0.059$) AREA = 108 FT.^{2}
HEAT LOSS = $108 (0.059)(100) =$ 637.2 BTU/HR

△ WINDOW SECTION WITHOUT PANEL ($u = 0.580$) AREA = 64 FT.^{2}
HEAT LOSS = $64 (0.580)(100) =$ 3712.0 BTU/HR

△ DOOR SECTION ($u = 0.240$) AREA = 19.5 FT^2
HEAT LOSS = $19.5 (0.240)(100) =$ 468.0 BTU/HR

TOTAL HEAT LOSS = $1862.4 + 637.2 + 3712.0 + 468.0 =$ **6680 BTU/HR**

SUM OF TOTALS:

- OPEN PANEL SITUATION -
  HEAT LOSS = $6432 + 1264 + 5275 + 3650 + 14220 + 1781$
  " = 32,822 BTU/HR

- CLOSED PANEL SITUATION -
  HEAT LOSS = $6432 + 1264 + 5275 + 1808 + 6680 + 1781$
  " = 23,240 BTU/HR

SUM TOTAL HEAT LOSS = TOTAL LOSS + LOSS DUE TO AIR CHANGE.

- OPEN PANEL SITUATION -
  LOSS DUE TO ½ AIR CHANGE/HR = $(\frac{1}{2})(32822) = 16,411$

→ SUM TOTAL HEAT LOSS = $32822 + 16.411 =$ **49233 BTU/HR**

BTU/HR LOSS/FT.^{2} = $\frac{49,233}{1800} =$ 36.5 BTU/HR/FT.^{2}

- CLOSED PANEL SITUATION -
  LOSS DUE TO ½ AIR CHANGE/HR = $(\frac{1}{2})(23,240) = 11,620$

→ SUM TOTAL HEAT LOSS = $23,240 + 11,620 =$ **34860 BTU/HR**

BTU/HR LOSS/FT.^{2} = $\frac{34860}{1800} =$ 19.4 BTU/HR/FT.^{2}

HEAT LOSS OF TRACT HOUSE

DESCRIPTION OF SECTIONS

☐ ROOF SECTION

SECTION	R-FACTOR
CEDAR SHINGLES	0.790
15 LB. FELT	0.120
1/2" PLYWOOD	0.625
4" BLOWN WOOL INSULATION	12.480
6" FIBERGLASS INSULATION	31.560
1/2" GYPSUM BOARD	0.450
TOTAL R	46.025

$U = 1/R = 1/46.025 = 0.020$

☐ WALL SECTION

SECTION	R-FACTOR
CEDAR SIDING	0.790
15 LB FELT	0.120
1/2" PLYWOOD	0.625
3 1/2" FIBERGLASS INSULATION	18.410
1/2" GYPSUM BOARD	0.450
TOTAL R	20.395

$U = 1/R = 1/20.395 = 0.050$

☐ WINDOW SECTION : $U = 0.580$ (ASSUME DOUBLE PANES)

☐ GLASS SLIDING DOORS : $U = 1.130$

☐ GARAGE DOORS : ASSUME $U = 0.625$

☐ METAL DOORS : $U = 0.060$

CALCULATIONS

☐ BASEMENT (ASSUME: DENSITY OF CONCRETE = 60 LBS/FT.^{3}
GROUND H_2O TEMPERATURE = 40°F.)

WALL HEAT LOSS = 6.0 BTU/HR/FT.^{2} SQ. FOOTAGE = 290 FT.^{2}
HEAT LOSS = 290 (6.0) = 1740 BTU/HR

FLOOR HEAT LOSS = 3.0 BTU/HR/FT.^{2} SQ. FOOTAGE = 1404 FT.^{2}
HEAT LOSS = 1404 (3.0) = 4212 BTU/HR

☐ FLOOR (NEGLECTED DUE TO BASEMENT CALCULATIONS)

☐ ROOF ($u = 0.020$) AREA = 1404 FT.^{2}
HEAT LOSS = 1404 (0.020)(100) = 3089 BTU/HR

☐ WALLS ($u = 0.050$) AREA = 1777 FT.^{2}
HEAT LOSS = 1777 (0.050)(100) = 8885 BTU/HR

☐ WINDOWS ($u = 0.580$) AREA = 285.5 FT.^{2}
HEAT LOSS = 285.5 (0.580)(100) = 16,559 BTU/HR

☐ GLASS SLIDING DOORS ($u = 1.130$) AREA = 78 FT.^{2}
HEAT LOSS = 78 (1.130)(100) = 8814 BTU/HR

☐ GARAGE DOORS ($u = 0.625$) AREA = 117 FT.^{2}
HEAT LOSS = 117 (0.625)(100) = 7312.5 BTU/HR

☐ METAL DOORS ($u = 0.060$) AREA = 32.5 FT.^{2}
HEAT LOSS = 32.5 (0.060)(100) = 214.5 BTU/HR

TOTAL HEAT LOSS = 1740 + 4212 + 3089 + 8885 + 16559 + 8814 + 7312.5 + 214.5
" = 50,826 BTU/HR

SUM TOTAL HEAT LOSS = TOTAL LOSS + LOSS DUE TO AIR CHANGE
LOSS DUE TO ONE AIR CHANGE/HR = (1)(50826) = 50826

SUM TOTAL HEAT LOSS = 50826 + 50826 = 101,652 BTU/HR
BTU/HR LOSS/FT.^{2} = $\frac{101,652}{2754}$ = 37 BTU/HR/FT.^{2}

THERMAL STORAGE TANK HEAT LOSS

☐ TOP COVER SECTION

SECTION	R-FACTOR	U-COEFF.	AREA
½" PLYWOOD	0.625	0.082	16.88 FT.²
2½" FIBERGLASS INSULATION	10.900		
½" PLYWOOD	0.625		
TOTAL R	12.170		

HEAT LOSS = 16.88 (0.082)(100) = 138.42 BTU/HR

☐ INTERIOR WALL SECTION

SECTION	R-FACTOR	U-COEFF.	AREA
6" CONCRETE BLOCK, FILLED	2.990	0.334	37.13 FT.²

HEAT LOSS = 37.13 (0.334)(100) = 1240.14 BTU/HR

☐ EXTERIOR WALL SECTION

SECTION	R-FACTOR	U-COEFF.	AREA
8" REINF. CONC.	0.640	0.084	37.13 FT.²
2" GLASS FIBER RIDGID INS.	10.520		
½" PLYWOOD	0.625		
TOTAL R	11.785		

HEAT LOSS = 37.13 (0.084)(100) = 311.89 BTU/HR

☐ FLOOR

SECTION	R-FACTOR	U-COEFF.	AREA
3.5" PINE	0.875	0.837	16.88
4" CONC. SLAB	0.320		
TOTAL R	1.195		

HEAT LOSS = 16.88 (0.837)(100) = 1412.85 BTU/HR

TOTAL HEAT LOSS = 138.42 + 1240.14 + 311.89 + 1412.85

" = **3103.30 BTU/HR**

MONTH ↓	TOTAL INSOLATION BTU/DAY/FT.²			CLOUD COVER REDUCTION		BTU/DAY COLLECTED		COLLECTOR INEFFICIENCY OF 30%	ULTIMATE BTU/DAY COLLECTED	
	40° N	48° N	INTERP. FOR 44° N	% COVER	RESULTING BTU/DAY PER FT.²	PHASE I COLLECTOR AREA = 124 FT.²	PHASE II COLLECTOR AREA = 310 FT.²	BTU/DAY PER FT.² REDUCTION	PHASE I COLLECTOR AREA = 124 FT.²	PHASE II COLLECTOR AREA = 310 FT.²
JAN	1778	1448	1613	52	774	95976	239940	232	28768	71920
FEB	2060	1860	1960	50	980	121520	303800	294	36456	91140
MAR	2228	2118	2173	56	956	118544	296360	287	35588	88970
APR	2258	2200	2229	63	825	102300	255750	246	30504	76260
MAY	2230	2200	2215	72	620	76880	192200	186	23064	57660
JUN	2224	2204	2214	80	443	54932	137330	133	16492	41230
JUL	2230	2200	2215	58	930	115320	288300	279	34596	86490
AUG	2258	2200	2229	60	892	110608	276520	268	33232	83080
SEP	2228	2118	2173	64	782	96968	242420	235	29140	72850
OCT	2060	1860	1960	57	843	104532	261330	253	31372	78430
NOV	1778	1448	1613	54	742	92008	230020	223	27652	69130
DEC	1634	1250	1442	51	707	87668	219170	212	26288	65720

TOTAL DAILY INSOLATION FOR SOUTH FACING SURFACES, TILTED UPWARD AT ANGLE ϕ = x° N. LAT. , FOR THE 21ST DAY OF EACH MONTH.

VALUES FOR 44° N. LAT. ARE INTERPOLATED FROM TABULATED VALUES FOR 40° N. LAT. & 48° N. LAT. TABULATED VALUES ARE FROM ENERGY PRIMER.

PASSIVE SOLAR HEAT GAIN THROUGH SOUTH ELEVATION (INSOLATION)

MONTH	% CLOUD COVER	INSOLATION THROUGH TRANSPARENT SURFACE		INSOLATION THROUGH OPAQUE SURFACE		RESIDENCE (OPEN PANELS)			WORK SHOP			TRACT HOUSE		
		BTU/FT.²	REDUCED BTU/FT.²	BTU/FT.²	REDUCED BTU/FT.²	TRANS. SURFACE FT.² = 204 BTU/TOTAL FT.²	OPAQUE SURFACE FT.² = 600 BTU/TOTAL FT.²	TOTAL INSOLATION BTU	TRANS. SURFACE FT.² = 518 BTU/TOTAL FT.²	OPAQUE SURFACE FT.² = 182 BTU/TOTAL FT.²	TOTAL INSOLATION BTU	TRANS. SURFACE FT.² = 96 BTU/TOTAL FT.²	OPAQUE SURFACE FT.² = 606 BTU/TOTAL FT.²	TOTAL INSOLATION BTU
JAN	52	1226	588.5	1380	662.4	120054	397440	517494	304843	120557	425400	56496	401475	457971
FEB	50	1384	692.0	1580	790.0	141168	474000	615168	558456	143780	502236	66432	478740	545172
MAR	56	1294	569.4	1536	675.8	116158	405404	521562	294919	122996	417945	54662	409535	518859
APR	63	1002	371.0	1236	445.0	75684	267000	342684	192178	80990	273168	35616	269670	305286
MAY	72	693	194.0	895	250.6	39576	150360	189936	100492	45609	146101	18624	151864	170488
JUN	80	606	120.0	776	155.2	24480	93120	117600	62160	28246	90406	11520	94051	105571
JUL	58	693	291.0	895	375.9	59364	225540	284904	150738	68414	309558	27936	227795	255731
AUG	60	1002	401.0	1236	494.4	81804	296640	378444	207718	89981	297699	38495	299606	338101
SEP	64	1294	465.8	1536	553.0	95023	331800	426823	241284	10065	251349	44717	335118	379835
OCT	57	1384	650.5	1580	679.4	132702	407640	540342	336959	123650	460609	62448	411716	474164
NOV	54	1226	564.0	1380	634.8	115056	380880	495936	292152	115534	407686	54144	384689	438833
DEC	51	1125	551.0	1274	624.3	112404	374580	486984	285418	113623	399041	52896	378326	431222

THE BTU/FT.² FIGURES ARE TAKEN FROM OLGYAY'S TOTAL RADIATION CALCULATORS, OVERLAYED ON A 44° N. LAT. SUN CHART, FOR THE 21 ST DAY OF EACH MONTH.

SPACE HEATING NEEDS PER DAY

MONTH	AVERAGE DEGREE-DAYS INTERPOLATED FOR BELGRADE		RESIDENCE					TRACT HOUSE			WORKSHOP		
			OPEN PANEL SITUATION		CLOSED PANEL SITUATION		OPEN PANEL SITUATION MINUS INSOLATION ON SOUTH SIDE			TOTAL MINUS INSOLATION ON SOUTH SIDE			TOTAL MINUS INSOLATION ON SOUTH SIDE
	PER MONTH	PER DAY	BTU/FT.²	BTU/TOTAL FT.²	BTU/FT.²	BTU/TOTAL FT.²	BTU/TOTAL FT.²	BTU/FT.²	BTU/TOTAL FT.²	BTU/TOTAL FT.²	BTU/FT.²	BTU/TOTAL FT.²	BTU/TOTAL FT.²
JAN	1362.5	44	528	950400	264	475200	432906	528	1454112	996141	792	1326600	901200
FEB	1052.5	37	444	799200	222	399600	184032	444	1222776	677604	666	1115550	613314
MAR	1035.5	33	396	712800	198	356400	191238	396	1090584	571725	594	994950	577005
APR	646.5	22	264	475200	132	237600	132516	264	727056	421770	396	663300	390182
MAY	391.5	13	156	280800	78	104400	90864	156	429624	259136	234	391950	245849
JUN	193.0	6	72	129600	36	64800	12000	72	198288	92717	108	180900	90494
JUL	34.0	1	12	21600	6	10800	-263304	12	33048	-222683	18	30150	-279408
AUG	54.0	2	24	43200	12	21600	-355244	24	66096	-272005	36	60300	-237399
SEP	283.5	9	108	194400	54	97200	-232423	108	297432	-82403	162	271350	20001
OCT	564.0	18	216	388800	108	194400	-151542	216	594864	120700	324	542700	82091
NOV	943.5	31	372	669600	186	334800	173664	372	1024488	585655	558	934650	526964
DEC	1218.5	39	468	842400	234	421200	355416	468	1288872	857650	702	1175850	776809

$$\text{DAILY BTU/FT.}^2\text{ NEEDS} = \frac{\text{HEAT LOSS/DEGREE-DAY} \times \text{DEGREE-DAYS/MONTH}}{\text{DAYS/MONTH}}$$

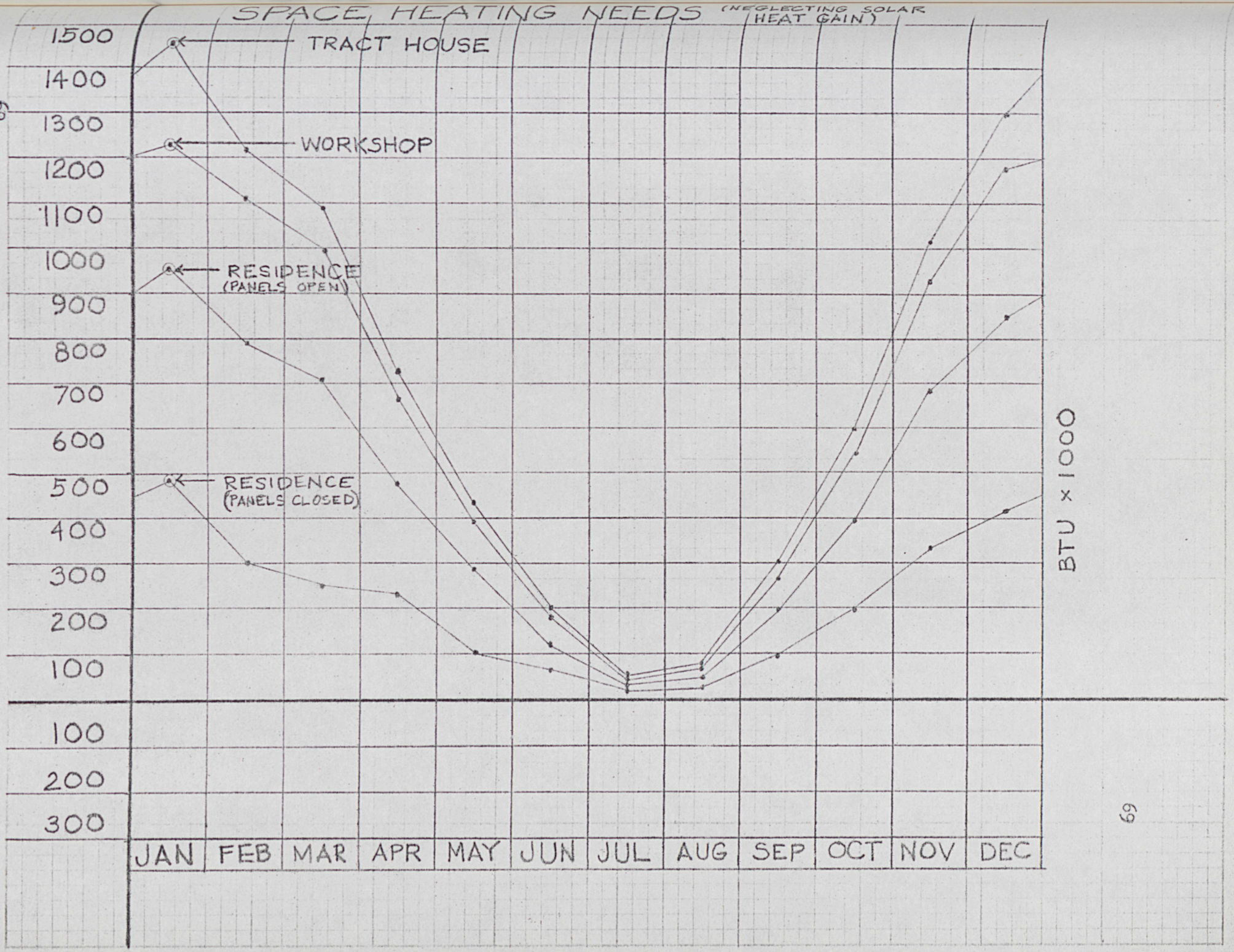
$$\text{HEAT LOSS/DEGREE-DAY} = \frac{\text{BUILDING HEAT LOSS (BTU/HR.)} \times 24\text{ HRS.}}{75^\circ\text{F TEMP. DIFFERENCE}}$$

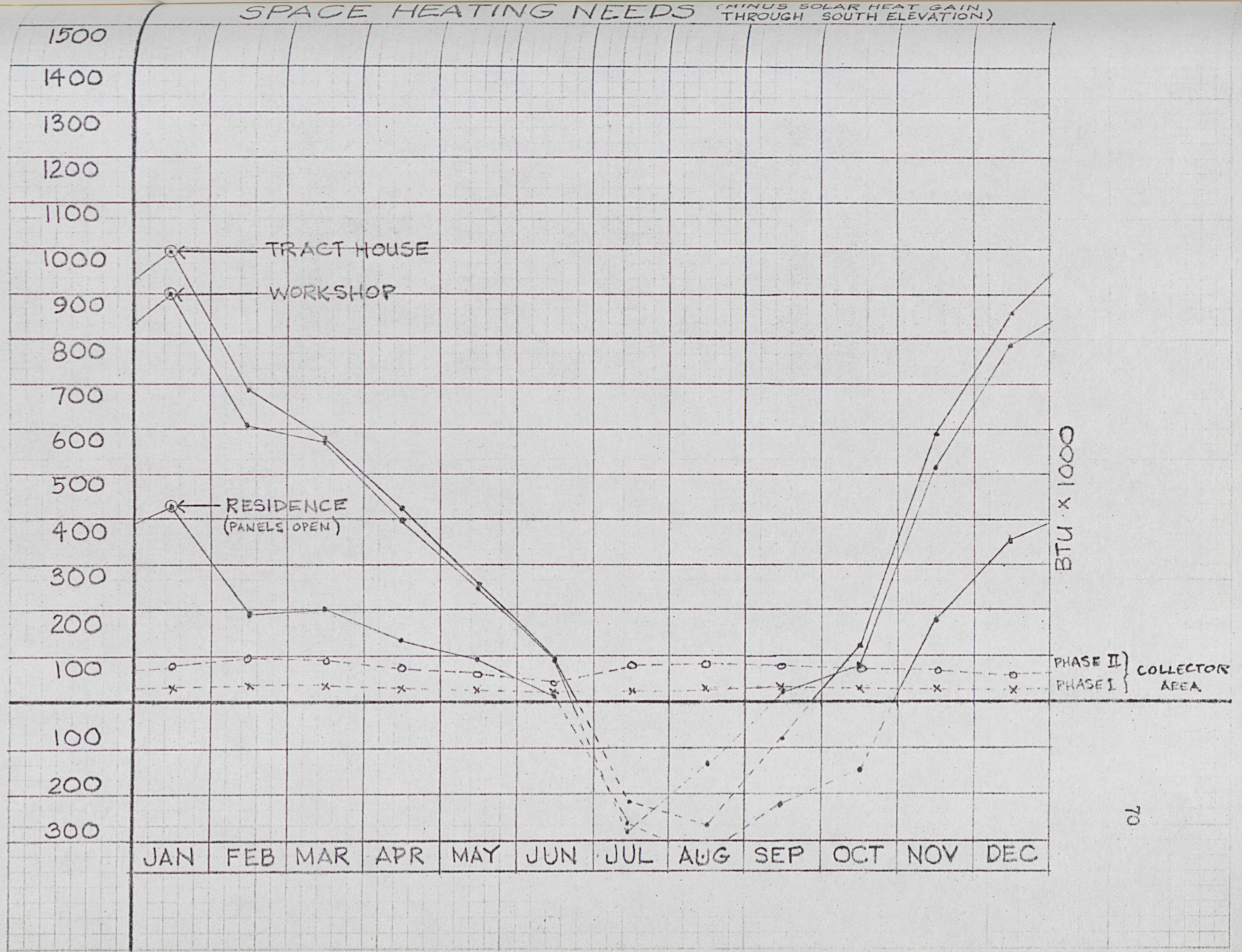
$$= 12 \quad \text{(RESIDENCE; PANELS OPEN)}$$

$$= 6 \quad \text{(" : " CLOSED)}$$

$$= 12 \quad \text{(TRACT HOUSE)}$$

$$= 18 \quad \text{(WORKSHOP)}$$

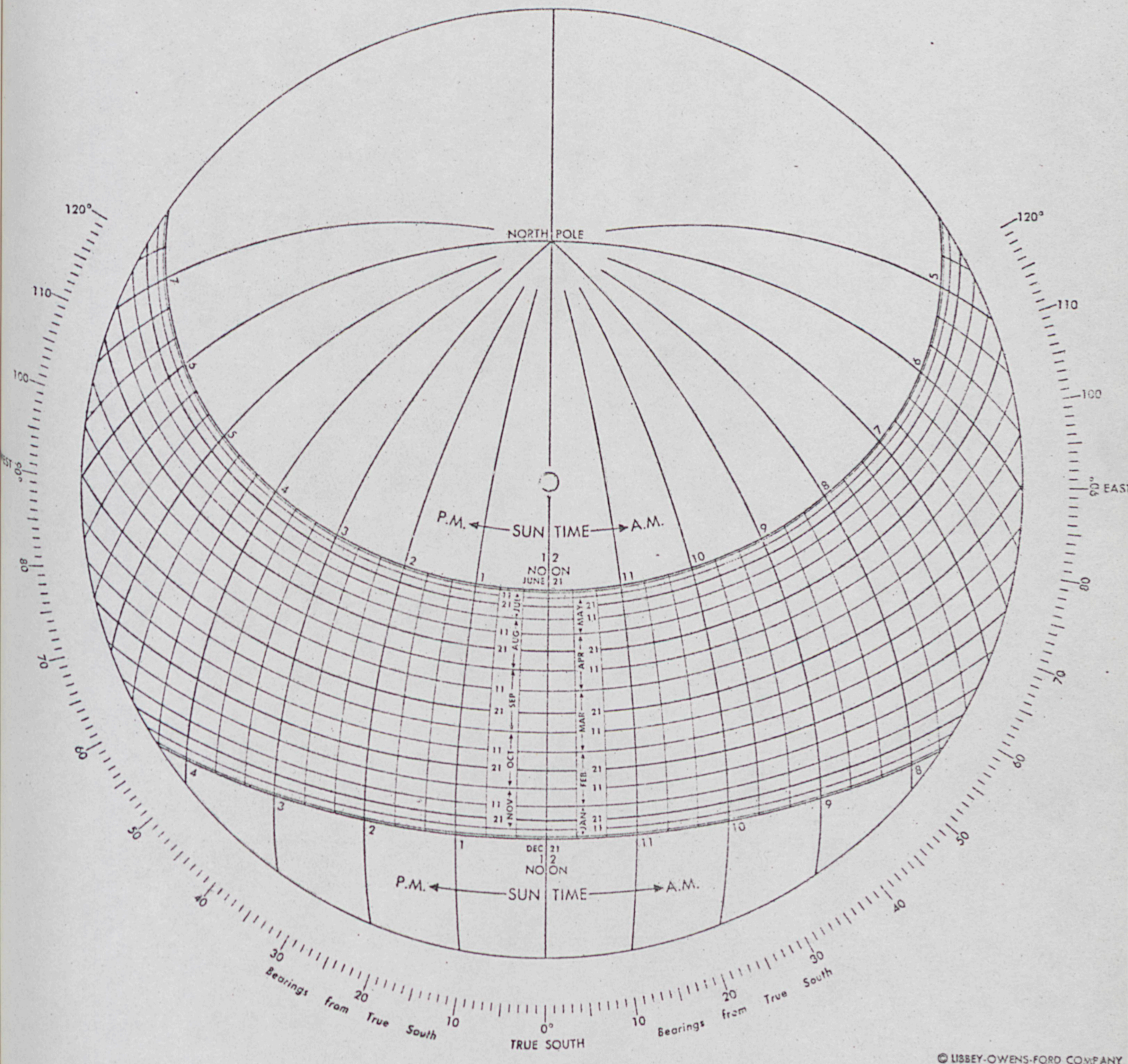

SPACE HEATING NEEDS (NEGLECTING SOLAR HEAT GAIN)
TRACT HOUSE
WORKSHOP
RESIDENCE (PANELS OPEN)
RESIDENCE (PANELS CLOSED)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
100
200
300
BTU x 1000
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
69
69



CITADEL® No. 803
CROSS SECTION - 8 SQUARES TO INCH

44° SUN CHART

(44° N. Lat.)



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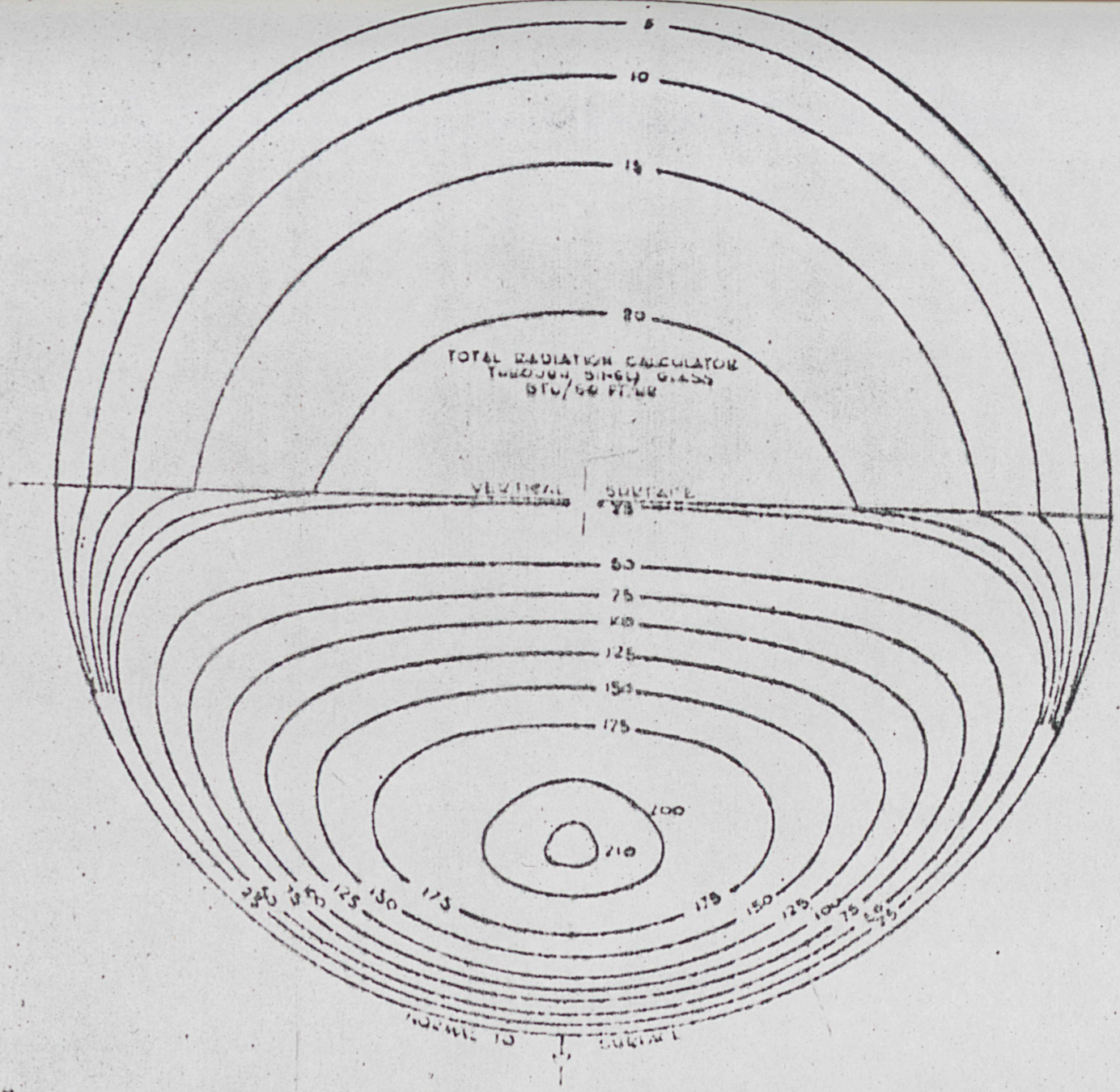
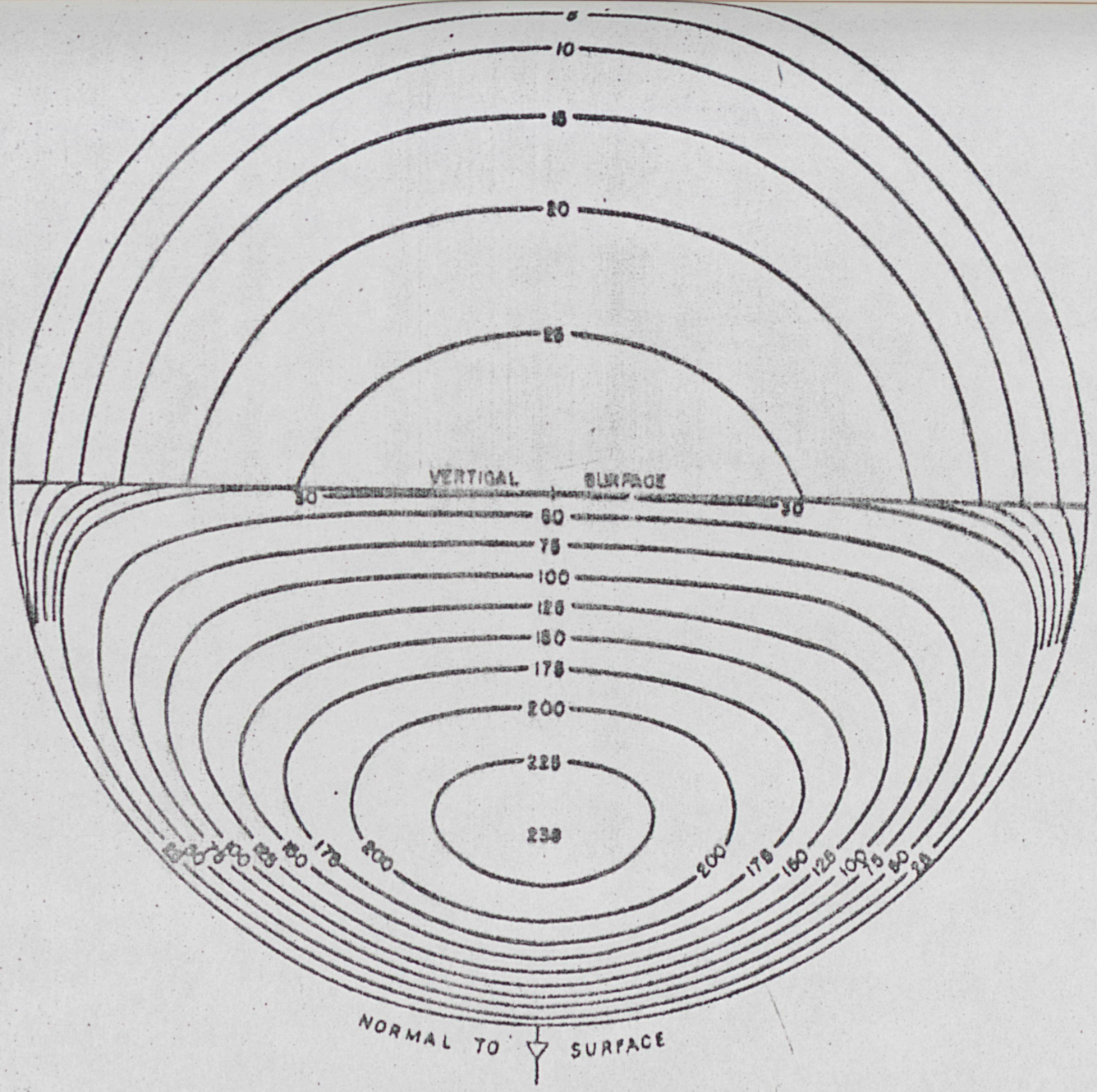


71. Total Radiation Calculator.



68. Total Radiation Calculator.

THERMAL STORAGE CAPACITY

(Assume that hydronic distribution system begins to heat space with water temperature at 95°F.& water in thermal storage = 150°F.)

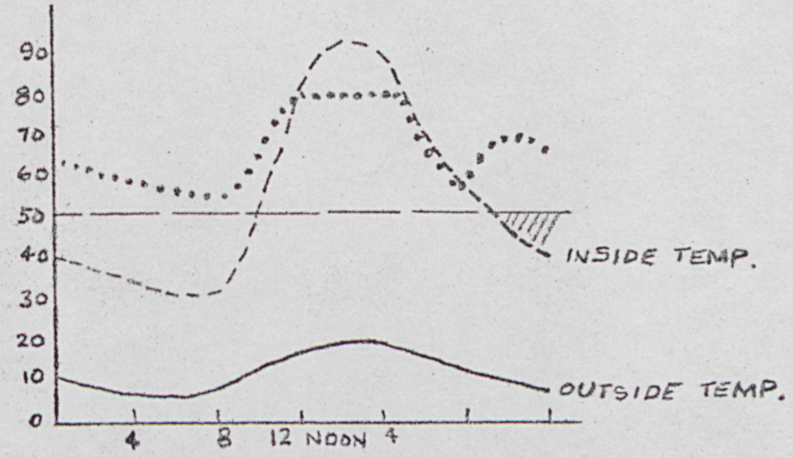
8.34lb./gal. x (150°F. - 95°F.) = 458BTU/gal.

Tank capacity = 150gals.

150 x 458 = 68,700BTU thermal storage capacity.

WITH A HEAT LOSS OF 3103.3BTU/hr., (p. 65) it will take approximately 22hrs. to lose all of the stored thermal energy, if there are no BTU's of energy restored to the tank.

The following passage discusses a daily temperature study--a step further in analyzing the effects of the climatic variables on a building.



My house does not have central heating, nor does it have a thermostat in every room. It has built-in climatic variability. The illustration shows the temperatures outside and inside my passive solar house. A passive solar house is one having large amounts of glass on the south side and small amounts ofglass, or none at all, on the north. My house has 600sq.ft. of glass on the south, southeast, and southwest, and only 8sq.ft. on the north.

In the graph the outside temperature (solid line) reaches a daily high of 20°F at around 2 P.M. and a low of 5°F at 6 A.M. The dashed line represents the temperature curve this passive solar house has followed without any human intervention (including no source of heat). Starting from a low temperature near freezing, the house warms rapidly upon sunrise. The maximum inside temperature occurs at about the same time as the outside maximum, but the ΔT (temperature inside minus the temperature outside) is 70°F. As the sun falls so does the temperature, with a rapid rate of fall starting at sunset. Through the night the rate of fall decreases, being proportional to ΔT. The inside temperature never reaches the minimum outside temperature during the 16 hour dark period. Notice that the average inside temperature is considerably higher than the average outside temperature. This is due to the greenhouse effect.

Clearly, however, this inside temperature range exceeds anyone's comfort zone. The normal temperature curve the house follows with my intervention is shown as the dotted line: As soon as the temperature inside reaches my upper limit of 80°F, I open a ventilator, allowing the excess heat to escape. When the temperature begins to fall noticeably (around 4P.M. during winter) the ventilator is closed. At sunset a fire is started in the Jøtul 118 woodstove. A quick burst of heat (producing lots of red-hot coals) quickly brings the temperature up to 70°F for the evening social hours. At bedtime the stove is restoked and the damper set proportionally to the expected overnight low temperature. This causes a constant rate of heat production

and the house slowly cools down toward a morning minimum of 50° - 60° F, following the outside temperature. The Jotul 118 is capable of burning 10 to 12 hours at a low setting, and so in the morning we have a choice of letting it burn out (sunny day) or restoking it for another 10 to 12 hours (cloudy day). We operate this way, using about 4 cords of wood per heating season (7700 degree-days) to heat 1700sq.ft. of house.

If I found wood hard to come by, I could install reflective window shades or install insulating shutters and reduce the fuel consumption to two and a half cords.

The temperatures in the illustration are typical of the main living area of the house -- the "social house". Not only does temperature change with time, but with space also. The adult house has two spaces -- a full-sized loft that, without ventilation, is always 10°F warmer than the social house, and a downstairs workspace, 10°F cooler than the social house. In the early morning the cat and I are found in this loft. By late morning we find each other in the social house, and at 2P.M. on a sunny day we work (Iwork, she dozes) in the cool workspace.

We,as a culture, have achieved, in spite of the Walt Disney hour viewed electronically as a series of TV lines and dots in "living color", an all time low sensitivity to nature as a dynamic environment. Man created shelter as a buffer against the extremes of weather. It is not until recent times that we have completely isolated ourselves from climate.

However much we try to ignore it, weather is in our blood. Talk about weather cannot be entirely dismissed as an avoidance of intimacy. It is important to us. I used to work in a windowless basement office. All visitors from the outside world were greated by, "What's the weather outside?"

I have been reborn. With the exit of the thermostat came a rebirth of awareness. I no longer call the weatherman; I don't need to. Like the farmer, I hve developed an early warning system for subtle changes that fortell the future. I don't need to consult the almanac for the times of sunrise and sunset; I am there. Sunrise is when the benificient rays begin to warm me; sunset is when the fire is lit. I don't need a clock; I am a sundial. I don't need a thermometer; the outside temperature is obvious. I don't need a calender with the date etched by the angle of the noon rays against the wall. I know when the maple sap flows; it is when I should stop cutting firewood because the wood is at its greenest. I accept and exult in my nature.

It can be concluded from the analysis that space heating needs are substantially reduced by merely closing the insulating panels over the windows at night. Insulating heavily, reducing infiltration losses and decreasing total square footage also lower the space heating needs.

It should be noted that the sources and methods that determined the data is based to relate to monthly averages, and is by no means exact.

I have learned much about the application of solar energy and other alternative energy sources such as wood and wind, and also energy from people. I would say that the most effective method of calculation should be supported by experiment and test results. There is so much information being made available now, to aid in setting up procedures for calculations and experiments that arrive at test results, that I feel this thesis is only a scratch on the surface. I therefore personally conclude that basis for success in "thesis" is that it scratches the proper surface.

AFTERWARD

Upon observation of the space heating needs graph that accounts for insolation on the buildings, it seems that there may be too much solar heat gain. The ventilation stage of the Trombe Wall, to my estimation, would handle this excess haet gain, in the case of the workshop. With the residence, however, there is a probable need for ventilation thruogh the ceiling near the south wall, into the volume of space under the roof where the flat-plate collectors are fastened. This space, in turn, would be vented to the outside via cross-flow ventilation through ducts by the prevailing winds from the west. On still days, there may be the need for an attic vent fan. The drawings don't indicate any of this, so I should at least account for this awareness in print.

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