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ABSTRACT

Designed for secondary and postsecondary vocational teachers and administrators, this resource package on energy conservation in construction trades contains three sections of information. Section I provides an instructional module (developed by the Wisconsin Vocational Studies Center) on solar energy; the module is organized into seven units: using solar energy, locating the sun, solar energy systems, collection, storage, distribution, and representative solar energy systems for heating homes. Each unit generally includes objectives, information sheets, a student assignment sheet, and a unit test with answer key. Section II provides a list of instructional resource materials and organizations and agencies related to solar energy. Section III provides bibliographies related to employment impact on solar energy, marketing potential on the growth of solar energy, and solar energy system design. (JH)

ED174796

ENERGY CONSERVATION IN
CONSTRUCTION TRADES

Special Packages

Instructional Resources for
Vocational Education

The National Center for
Research in Vocational
Education
The Ohio State University
1960 Kenny Road
Columbus, Ohio 43210

This project was developed pursuant to Contract No. 300-78-0032 with the U.S. Office of Education. However, the opinions expressed herein do not necessarily reflect the position or policy of the U.S. Office of Education and no official endorsement by the U.S. Office of Education should be inferred.

OCT 2 1979

Special Package Number IV

SPECIAL PACKAGES-USER FEEDBACK FORM (INSTRUCTIONAL RESOURCES FOR VOCATIONAL EDUCATION)

To assist the National Center for Research in Vocational Education in continuing to serve effectively the needs of vocational and technical educators, would the USER of the Special Packages resources(s) please respond to the following questions. Your responses will help us to determine the kinds of resources you find most useful.

1. Please indicate your job title (e.g. teacher, administrator, counselor, coordinator, local director)

____

2. How was the Special Package used?

- ☐ Planning an instructional program
- ☐ Developing of an instructional program
- ☐ Operating of an instructional program
- ☐ Evaluating of an instructional program
- ☐ Other (please specify, e.g. student services)

____

____

3. Rate Special Packages on the following dimensions: (Please circle the response which most accurately describes the publication.)

	Excellent	Very Good	Good	Fair	Poor
A. Relevance to the occupation (current and representative of occupational needs)	E	VG	G	F	P
B. Ease of Adaptation (Resources work in any instructional setting)	E	VG	G	F	P
C. Availability (Resources were easy to acquire and affordable)	E	VG	G	F	P
D. Reproduction quality	E	VG	G	F	P

Additional Comments ______________________________

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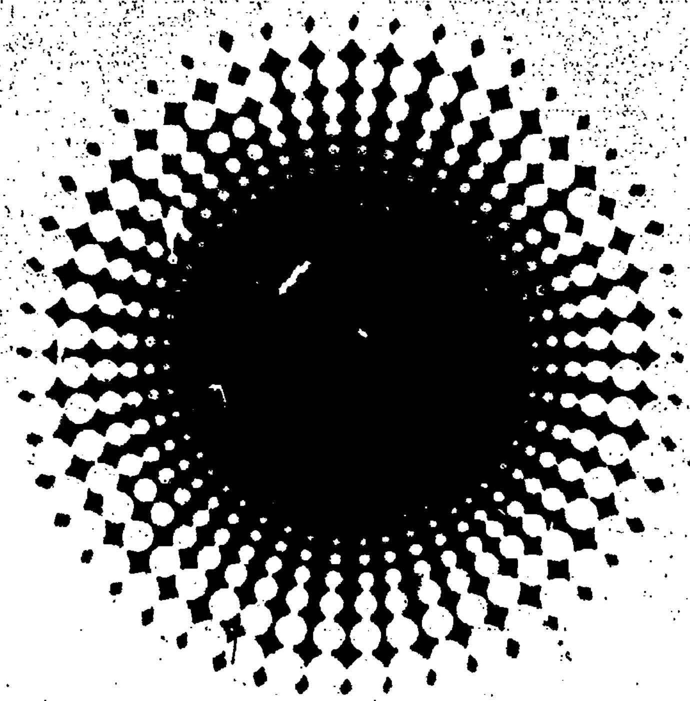

THIS PACKAGE CONTAINS:

- "Solar Energy Instructional Module, Understanding Solar Energy Systems," developed by Educational Research Center, New Mexico State University, Las Cruces, New Mexico.

- MINI-LIST related to existing instructional resources and materials in solar energy systems, developed by The Resource and Referral Service, Research and Development Exchange.

- Bibliographies developed by National Solar Heating and Cooling Information Center related to:

  1. employment impact of solar energy.
  2. marketing potential on the growth of solar energy.
  3. solar energy system design.

A primary objective of the Special Packages Project is to assist vocational educators in developing skills to evaluate and adapt instructional resources.

The Solar Energy Instructional Module "Understanding Solar Energy Systems" may be purchased from The Wisconsin Vocational Studies Center, University of Wisconsin, Madison, 321 Education Building, Box 49, Madison, Wisconsin 53706

FOR MORE INFORMATION CONTACT:

Program Information Office
National Center for Research in
Vocational Education
1960 Kenny Road
Columbus, Ohio 43210
(614) 486-3655, ext. 63

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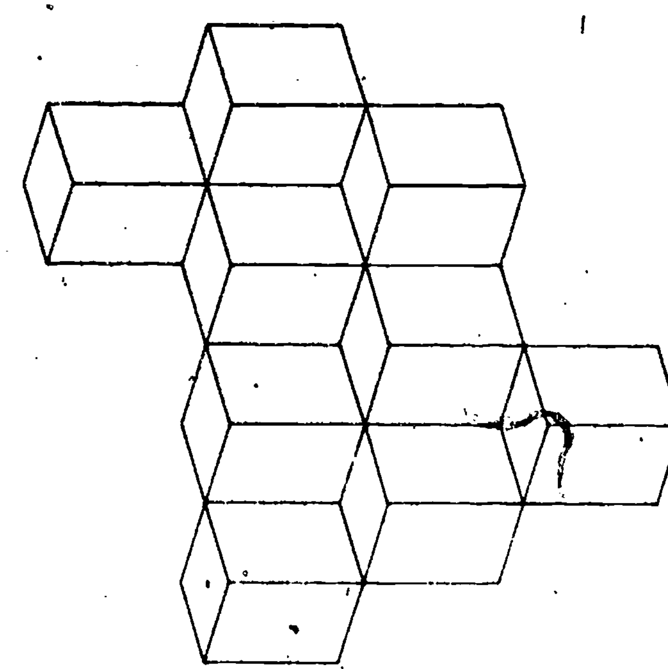
THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY
1960 KENNY ROAD · COLUMBUS OHIO 43210

SPECIAL PACKAGES

Instructional Resources for Vocational Education

ENERGY CONSERVATION IN CONSTRUCTION TRADES



WHAT ARE "SPECIAL PACKAGES"?

- Instructional Resources related to growing and developing occupations.
- Included are Instructional Program Components, Resources Lists, Occupational Information, Program Development Guides, Curriculum Materials, and Special Studies.

WHICH GROWING AND DEVELOPING OCCUPATIONS AND SPECIAL AREAS ARE RECEIVING EMPHASIS IN 1978?

- Biomedical Instrumentation Technology
- Entrepreneurship
- Energy Conservation in Construction Trades
- Business and Office with Emphasis in Interpersonal Skills
- Occupational Survival Skills
- Skills for Developing and Evaluating Curriculum and for Adapting Instructional Resources to Existing Curriculum

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WHO CAN USE THESE PACKAGES?

Secondary and Post-secondary Teachers and Vocational Education Administrators

WHAT IS THE ROLE OF THE NATIONAL CENTER REGARDING SPECIAL PACKAGES?

The three objectives of the Special Packages Project are:

- To identify and select resources to meet the needs of vocational educators in growing and developing occupations.
- To disseminate selected resources.
- To assist vocational educators in developing skills in evaluating and adapting instructional resources.

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THE NATIONAL CENTER
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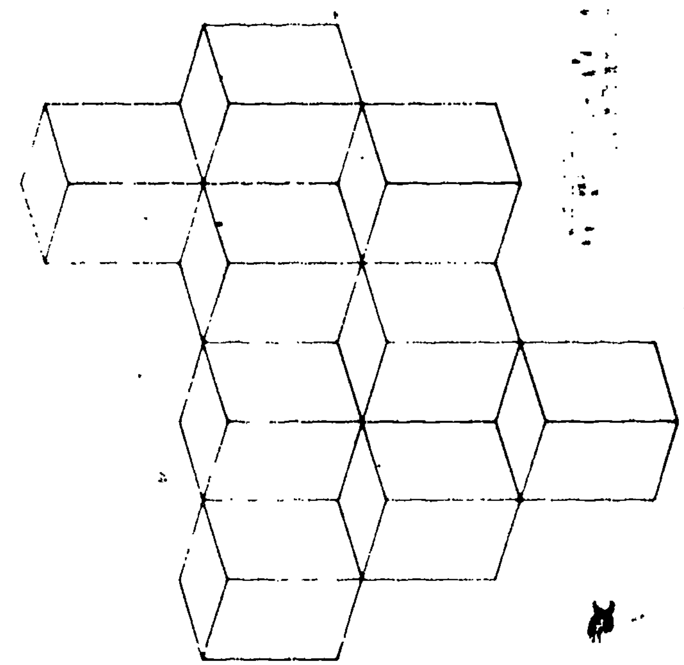
SPECIAL PACKAGES

Instructional Resources for Vocational Education



FOREWORD

Vocational Education must respond to growing and developing occupations. Therefore, there is a need for special packages containing practical and easily-adapted models, materials, and information in the occupations so that secondary and post-secondary school administrators and teachers can respond to these occupational needs. The National Center for Research in Vocational Education has identified, selected, and is disseminating instructional resources in five special packages during 1978. In addition, the National Center is giving assistance to vocational educators in using these resources.

Energy conservation legislation has created a need for up-dating instructional materials for the building trades. These materials reflect changes in the traditional techniques related to insulation, heating and cooling, as well as introducing alternative sources of energy. Recognition is due Laurie Keaton and Everett D. Edington, New Mexico State University and the Resource and Referral Service, a part of the Research and Development Exchange, the National Center for Research in Vocational Education, for their contributions to this energy-related special package.

The National Center is indebted to Robert S. Peterson, Texas Education Agency; Roger Haskell, University of Tennessee; Mary Elizabeth Milliken, University of Georgia; James Burrow, University of Northern Iowa; and Mar[illegible] Charles, Pinellas County School System, who served as consultants for the direction and validati[illegible] of occupational selection criteria. David D. L'Angelle supervised the Special Packages development assisted by Jo-Ann Cherry and Janice T. Adkins.

Robert E. Taylor
Executive Director
The National Center for Research
in Vocational Education

SPECIAL PACKAGES FOR OCCUPATIONAL SERVICE AREAS

Introduction

Secondary and post-secondary vocational education teachers and administrators must respond to the emphases and needs of growing and developing occupations. Resource materials which can be used in shaping and implementing programs to meet some of these emphases and needs have been identified, selected, and packaged by the Special Packages Project staff of the National Center for Research in Vocational Education. Five copies of each Special Package are being distributed to each state and territory.

For 1978 emphasis was given to the following growing and developing occupations and special areas:

- Biomedical Instrumentation Technology
- Entrepreneurship
- Occupational Survival Skills
- Energy Conservation in Construction Trades
- Business and Office with Emphasis in Interpersonal Skills
- Skills for Developing, Evaluating, and Adapting Instructional Resources to Existing Curriculum

Selection criteria for resource materials included in the 1978 Special Packages were:

- Relevance to Occupational Area
- Target Audiences
- Instructional Program Design (Competency based, Modularized)
- Validation/Evaluation Data
- Reproducability
- Cost of Implementation/Adaptation
- Sensitivity to the Special Needs of Groups
- Flexibility
- Innovativeness
- Marketability
- Sex and Ethnic Fairness
- Availability of the Materials

The modular format is a common characteristic of all resources being disseminated. This concept is evident in packaging as well as content. Three ring binders allow for a flexible packaging arrangement and organization of instructional resources. Materials may be added, deleted, repackaged, or modified in accordance with the needs of the user. The content arrangement promotes an individualized approach in that students can proceed through the necessary modules that meet their own training needs. At the same time, on-site training using specific modules can be provided without disrupting the continuity of the instructional program. For example, if training on a specific kind of equipment is necessary that is not available at the school; the teacher could provide that training in an actual work environment. Finally, curriculum updating and revision can be accomplished with minimum disruption to the instructional program. As the occupational area grows, the changes to the technology can be inserted into the curriculum.

SOLAR ENERGY INSTRUCTIONAL PROGRAM

SECTION I. "UNDERSTANDING SOLAR ENERGY SYSTEMS"
Educational Research Center, New Mexico State University
- A modular program directed to vocational educators in the construction trade with basic information about solar energy systems.

SECTION II. MINILISTS COMPILED BY THE RESOURCE AND REFERRAL SERVICE, RESEARCH AND DEVELOPMENT EXCHANGE
— Related to resources for school energy needs.

SECTION III. OTHER RESOURCES

A. Bibliography on Employment Impact of Solar Energy
National Solar Heating and Cooling Information Center

B. Bibliography on Market Potential and Projections of Growth of Solar Energy
National Solar Heating and Cooling Information Center

C. Bibliography on Passive Solar Energy Designs and Systems
National Solar Heating and Cooling Information Center

D. Brochure—Films and Slides, Solar Energy for Heating and Cooling of Buildings
National Solar Heating and Cooling Information Center

E. Energy Conservation in Buildings
National Solar Heating and Cooling Information Center

F. Energy Education Materials
National Solar Heating and Cooling Information Center

G. List of Published Standards, Codes and Performance Criteria Relating to Solar Heating and Cooling Applications
National Solar Heating and Cooling Information Center

H. Solar Energy Publications Available from The Government Printing Office
National Solar Heating and Cooling Information Center

I. Solar Retrofit Bibliography
National Solar Heating and Cooling Information Center

J. Solar Standards Organizations
National Solar Heating and Cooling Information Center

K. Sources of Information on Alternative Energies
National Solar Heating and Cooling Information Center

L. Colleges and Universities - United States
National Solar Heating and Cooling Information Center

M. Vocational/Technical Schools/Courses Solar-Related
National Solar Heating and Cooling Information Center

Understanding Solar Energy Systems

Laurie Keaton   Everett Edington

NEW MEXICO STATE UNIVERSITY

Merle Stephey

WISCONSIN VOCATIONAL STUDIES CENTER

Wisconsin Vocational Studies Center

University of Wisconsin-Madison

Understanding Solar Energy Systems

Laurie Keaton Everett Edington

NEW MEXICO STATE UNIVERSITY

Revised and Edited by:

Merle Stephey

WISCONSIN VOCATIONAL STUDIES CENTER

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FIRST EDITION 1978

Published by: Wisconsin Vocational Studies Center University of Wisconsin-Madison

Table of Contents

Note: The underlined terms in each unit can be found in the Terms and Definitions section of that unit and are compiled in the Glossary as well.

Preface to
Solar Energy Instructional Module
"Understanding Solar Energy Systems"

In 1977 a research project was undertaken to determine manpower needs in emerging energy fields in Arizona and New Mexico. It was found that one of the fields with the greatest growth potential was in solar energy. While there is not a need for "new occupations" in the solar energy industry, there is a real need for those persons in existing skill areas to be trained to have a basic understanding of solar energy systems. This need cuts across all types of occupations from sales to assembly to installation.

This instructional package is to help meet this need. It is designed for programs of post high school technical education and adult education programs. It could be used in both pre-service and in-service installation of solar energy systems but to provide a basic understanding of such systems.

Laurie Keaton
Everett D. Edington

Acknowledgments

Special appreciation is extended to Bill Jackson of the New Mexico State Department of Education and to Roger Lambert of the Wisconsin Vocational Studies Center for their evaluations of the instructional module.

It would also have been impossible to complete the project without the assistance of Dr. Larry Bickle of L. W. Bickle and Associates and the members of the advisory council for their continued support of the project.

UNIT I

USING SOLAR ENERGY

UNIT OBJECTIVE

After completion of this unit, the student should be able to explain why solar energy should be developed as an energy source and describe some characteristics of solar radiation. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

Upon completion of this unit the student will learn to

1. Associate correct definitions with the common terms relating to solar energy.
2. Distinguish between renewable and nonrenewable energy sources.
3. Name some uses of solar energy.
4. Identify correct statements about solar radiation.
5. Identify accurate statements about problems associated with using solar energy.

1. Terms and Definitions

Btu - British thermal unit, a measure of heat

Biomass conversion - energy from the sun is stored through the process of photosynthesis in plants, i.e., in organic material. Chemical processes can be used to change the organic material to simpler forms with an accompanying release of energy.

Diffuse radiation - the solar radiation striking the surface of the earth after its direction has been changed by reflection and scattered by particles in the atmosphere--nondirectional rays.

Direct radiation - direct or parallel rays from the sun.

Energy - the ability to do work.

Insolation - the amount of solar radiation actually striking the surface of the earth.

Nonrenewable energy source - a substance found in nature which cannot be replenished and which can be used to obtain energy in some form. Coal, gas, uranium are examples of nonrenewable energy sources.

Photovoltaic - direct conversion of the sun's energy to electricity.

Radiation - any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Renewable energy source - a substance which occurs in nature and the supply of which cannot be depleted by use.

Solar constant - the amount of solar energy striking the outer atmosphere of the earth varies only slightly and can be treated as a constant.

Thermal pollution - the discharge of heated waste into the natural environment at a temperature detrimental to existing ecosystems.

Watts - a measure of power in the metric system (e.g., a 25-watt lightbulb)

Information Sheet

2. Importance of Solar Energy

The oil embargo of 1973 brought to the attention of the American people how dependent the United States has become on imported oil. Since that time, efforts have been made to assess the nation's energy needs and supplies. With this focus on the question of the availability of energy resources in this country has come an increased interest in solar energy.

Those energy sources now used--coal, gas, and uranium--are available only in fixed quantities. When that quantity is used up, there will be no more. For this reason, these are called nonrenewable energy sources. These energy sources present problems not only because they are nonrenewable energy sources, but also because they create problems. The burning of fossil fuels pollutes the atmosphere. The waste from nuclear-fired power plants presents hazards. All contribute to the thermal pollution of our environment. Thermal pollution can result from high temperature exhaust gases (e.g., air pollution from smokestacks) or from high temperature water effluent (e.g., water pollution from nuclear coolants).

On the other hand, solar energy is a renewable resource. In using the sun's energy, man will not exhaust the supply. Not only is solar energy plentiful, but also its use does not create pollution problems. The sun is the original source of almost all of the earth's energy.

3. Applications of Solar Energy

Man has made use of energy obtained from the sun for thousands of years, especially to heat water and to dry food materials. Wind energy and geothermal energy are forms of solar energy. Both are used today for a number of purposes (e.g., pumping and heating water). Other applications of energy obtained directly from the sun include the generation of electricity through solar-thermal applications or photovoltaic cells. Also, synthetic fuels can be obtained from solar energy in bio-mass conversions to methanol or indirect combustion of cellulose.

The application of solar energy considered here will be for heating and cooling buildings, heating of domestic hot water, and heating of water for swimming pools.

4. Solar Radiation

Energy is transmitted from the sun to the earth by radiation. Solar radiation is transmitted from the sun in wavelengths, of which visible light represents only a small portion. The intensity of the radiation reaching the upper surface of the earth varies slightly because the sun's output varies. Also, the distance between the sun and earth varies because of the elliptical nature of the earth's orbit about the sun.

These variations are considered to be so minor that the amount of solar radiation reaching the outer atmosphere is treated as a constant. The solar constant equals very nearly 429.2 Btu's per square foot per hour, or 1,353 watts per square meter. It is the intensity of solar radiation striking a plane that is perpendicular to the sun's rays at a distance equalling the average distance of the surface of the earth's outer atmosphere from the sun (see Transparency 1.1).

Although the amount of solar radiation striking the earth's outer atmosphere is relatively constant, not all of that energy actually arrives at the surface of the earth. Almost one-half of the energy either is reflected by particles in the atmosphere back into space or is absorbed by material in the earth's atmosphere (see Transparency 1.2).

Insolation is the amount of solar radiation which actually strikes the earth. Insolation, the solar radiation actually reaching the earth, is of three types: direct radiation or parallel rays, diffuse radiation or non-directional rays, and rays reflected from the ground or from building surfaces (see Transparency 1.3).

The amount of insolation available at any given point on the earth's surface is affected by: 1) the purity of the earth's atmosphere, 2) by the distance the radiation must travel through the atmosphere, and 3) by the angle at which solar radiation strikes the earth's surface. As the radiation travels through the earth's atmosphere, energy is absorbed by particles in the atmosphere. How much is absorbed depends on the amount of water vapor, dust particles, or other matter present in the atmosphere.

Not only do the water vapor and dust particles absorb energy but also, these particles will reflect or deflect some of the sun's rays.

Thus some of the solar radiation is lost when the solar rays are reflected back into space. Other rays become diffuse, or nondirectional. How many rays become diffuse or are reflected depends upon the purity of the atmosphere (Transparency 1.3).

The distance the solar radiation must travel through the earth's atmosphere affects the amount of insolation available. The distance traveled affects how much radiation will be lost through absorption and reflection. It also affects how much diffusion of the solar rays will occur.

How far the rays must travel through the atmosphere is determined by the season of year and time of day. If the sun is low in the sky (close to the horizon), the radiation must travel a greater distance through the atmosphere before striking the surface of the earth (Transparency 1.4).

Also, radiation is most effective if the rays strike a surface perpendicular to the direction the rays are traveling. The energy available decreases the more that the sun's rays vary from the perpendicular (as measured by the cosine of the angle). Therefore, direct or parallel rays are of greater energy value than are diffuse or nondirectional rays. Transparencies 1.5 and 1.6 give a visual representation of the importance of the tilt of the receiving surface.

The length of time radiation strikes a surface must also be considered when discussing the amount of insolation available at any given point on the surface of the earth. This fact again indicates that the angle at which radiation is striking the earth and the season of year are of great importance. These factors affect how much insolation is available for use as an energy source and will be discussed in Unit 2.

5. <u>Problems in Using Solar Energy</u>

Solar radiation is sufficiently diffuse that large surfaces are needed to collect the available energy. For example, in Albuquerque, New Mexico, one square meter (approximately 3' x 3') will supply only two percent of the heating needs for an average house. On the other hand, the total solar energy striking the roof and south wall of the house is five to ten times more energy than is used in an average house for all purposes!

Solar energy is intermittent. Energy arrives only during the daylight hours and during periods of cloudy weather or winter storms, more energy may be lost than gained. For this reason, storage or auxiliary heating systems are essential.

At present, solar energy systems are best suited for low temperature operation. Some work is being done to develop solar furnaces which concentrate solar radiation to obtain extreme high temperatures. For use in dwellings, however, a low temperature technology is most suitable at present.

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ASSIGNMENT SHEET

1. Why should we develop the sun's energy as an energy resource?
2. Explain why we can talk about the "solar constant."
3. Tell why only about one-half of the solar radiation which strikes the earth's atmosphere actually arrives at the surface of the earth.
4. Explain why the distance the radiation must travel through the earth's atmosphere affects the amount of solar energy available at a particular spot on the earth.
5. Name two problems involved in utilizing solar energy.

UNIT TEST--USING SOLAR ENERGY

1. Match definitions to terms

____a. Energy

____b. Nonrenewable energy source

____c. Photovoltaic

____d. Radiation

____e. Direct radiation

____f. Diffuse radiation

____g. Insolation

____h. Solar Constant

____i. Renewable energy source

____j. Biomass conversion

1. Direct conversion of solar radiation to electricity.
2. Solar energy striking the outer atmosphere of the earth varies only slightly.
3. Solar energy stored in organic materials is released through chemical processes.
4. Ability to do work.
5. Transmission of heat waves from a warmer to a cooler surface.
6. The solar energy reaching the surface of the earth.
7. Use of the resource to obtain energy will lead to depletion of the resource.
8. Sun's rays are reflected and scattered by particles in the atmosphere.
9. Naturally occurring source of energy which cannot be depleted.
10. Parallel rays from the sun.

2. Indicate with an N those energy sources listed below which are nonrenewable. Mark with an R any renewable energy sources included in the list.

____a. Coal

____b. Uranium

____c. Wind

____d. Gas

____e. Sun

3. Name three applications of solar energy.

1. ________________________________

2. ________________________________

3. ________________________________

4. Mark with a "T" the following statements about solar radiation which are true. Mark false statements with an "F".

____1. All solar radiation which strikes the surface of the earth is direct radiation.

____2. The intensity of the radiation reaching the upper surface of the earth's atmosphere does not vary.

____3. The intensity of the radiation reaching the upper surface of the earth's atmosphere varies slightly because the sun's output varies and because of the elliptical nature of the earth's orbit around the sun.

____4. The solar constant is computed as an average.

____5. Very little of the solar radiation striking the surface of the earth's atmosphere is lost by reflection or absorption.

____6. As solar radiation travels through the earth's atmosphere the rays become more direct.

____7. Radiation is most effective if the rays strike a parallel surface.

____8. The greater the distance the solar radiation must travel through the atmosphere, the greater will be the loss of energy through absorption and reflection.

5. Mark the following statements with a "T" if the statement is true, or with an "F" if the statement is false.

____1. The amount of solar energy available can be calculated.

____2. Large surfaces are needed to collect the available solar energy.

____3. The amount of solar energy striking the roof and south wall of an average house is less than the amount of energy normally used by the average household.

____4. Storage or auxiliary heating systems are needed because solar energy is not always available for collection.

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ANSWERS TO ASSIGNMENT SHEETS AND UNIT I TEST

Answers to Assignment 1

The sun's energy is a renewable resource. Man will not exhaust the supply.

Answers to Assignment 2

The solar energy, which is transmitted to the earth, strikes the surface of the earth's atmosphere at a relatively constant rate. There is a slight variation only as the sun's output of energy varies. There is also some variation in the amount of energy received because the distance between the sun and earth varies owing to the elliptical nature of the earth's orbit. However, these variations are considered so minor that the amount of radiation striking the earth's outer atmosphere can be thought of as a constant and is called the "solar constant".

Answers to Assignment 3

The amount of solar radiation actually striking the surface of the earth is far less than the amount striking the surface of the earth's outer atmosphere because large amounts of the solar radiation are absorbed by particles in the atmosphere. Also, large amounts of radiation are reflected back into space by clouds or materials in the atmosphere.

Answers to Assignment 4

As solar radiation travels through the earth's atmosphere, more radiation is absorbed and more rays become diffuse.

Answers to Assignment 5

Problems associated with the use of solar energy are (1) that solar energy is a diffuse source of energy, thus requiring large surface areas to collect the energy and (2) that solar energy is intermittent, thus requiring storage and even auxiliary heating systems.

Answers To Unit Test 1

a. 4
b. 7
c. 1
d. 5
e. 10
f. 8
g. 6
h. 2
i. 9
j. 3

Answers To Unit Test 2

a. N
b. N
c. R
d. N
e. R

Answers to Unit Test 3 (name three)

1. To dry food
2. To heat water
3. To heat buildings
4. Generation of electricity
5. To obtain synthetic fuels through biomass conversions
6. To cool buildings

Answers To Unit Test 4

1. F
2. F
3. T
4. T
5. F
6. F
7. T
8. T

Answers to Unit Test 5

1. T
2. T
3. F
4. T

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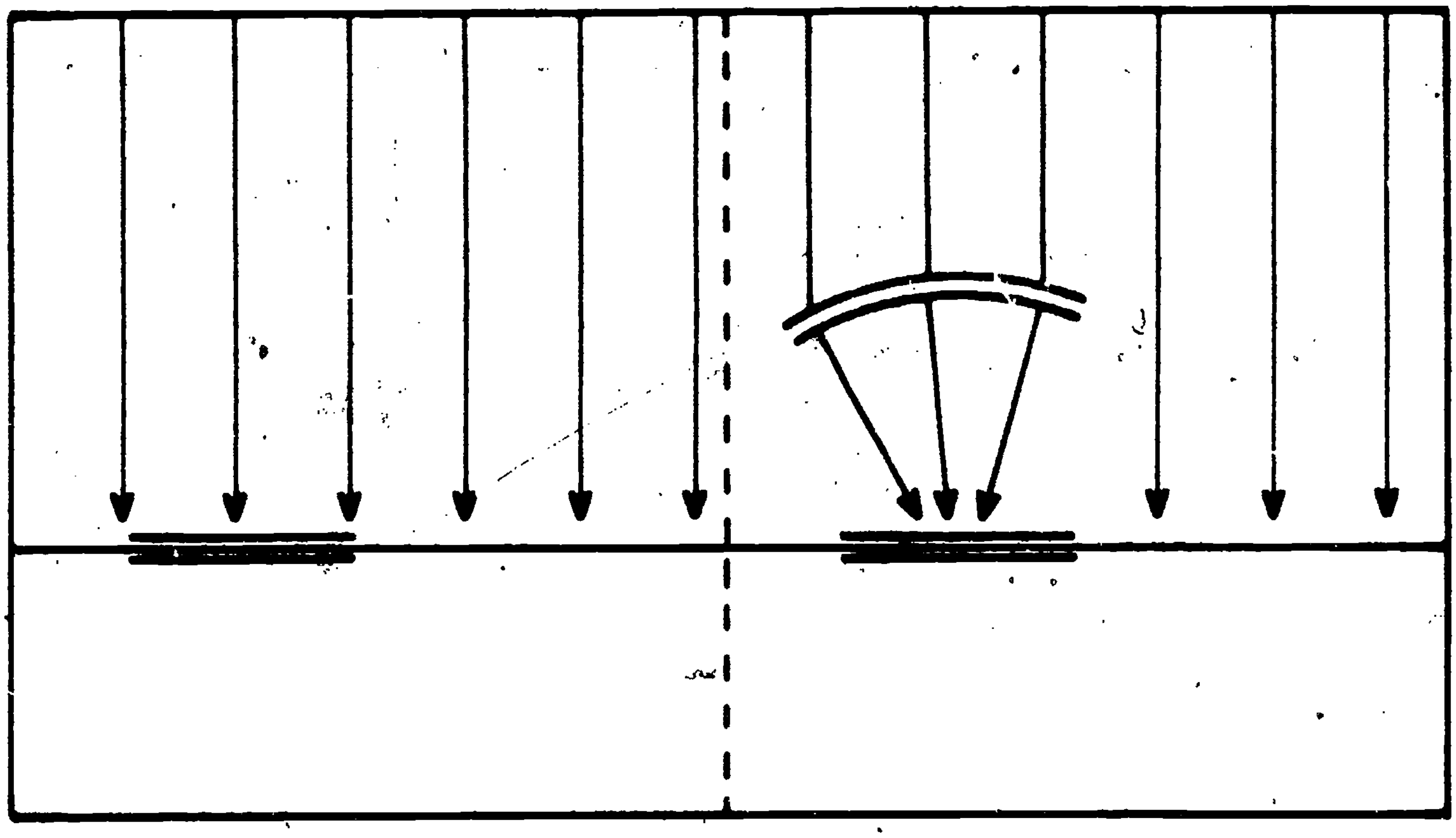
References

AIA Resource Corporation. May 1976. Solar Dwelling Design Concepts. Prepared for the United States Department of Housing and Urban Development, Office of Policy Development and Research. Washington, D.C.: U.S. Government Printing Office.

Solar Energy Utilization for Heating and Cooling. 1974. Compiled by John I. Yellott for the American Society of Heating, Refrigerating and Air Conditioning Engineers. Washington, D.C.: U.S. Government Printing Office. Reprinted from Chapter 59 of the 1974 Edition, Applications Volume, of the ASHRAE Guide and Data Book series.



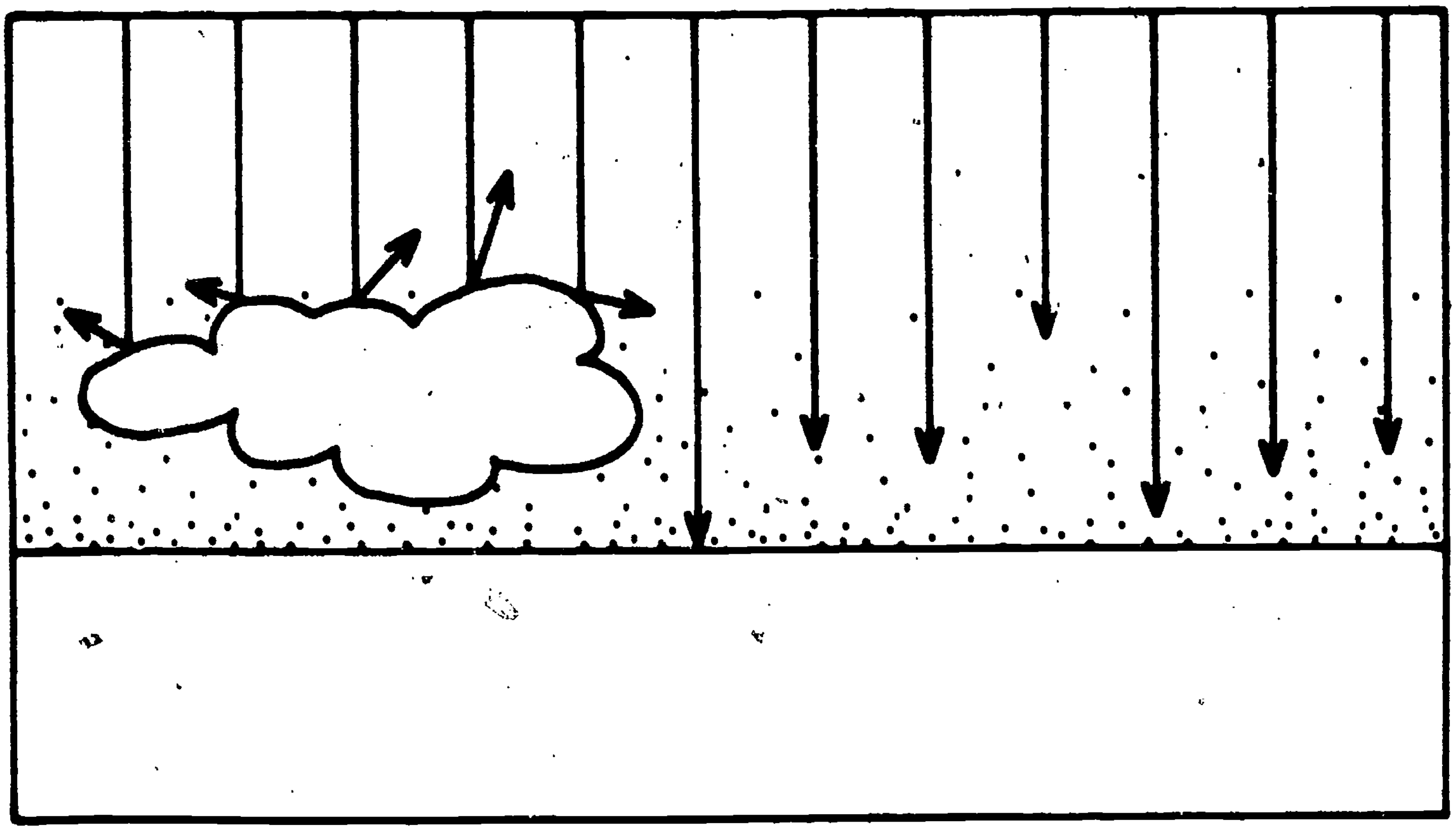
1. SOLAR CONSTANT

THERE IS A NEARLY CONSTANT AMOUNT OF SOLAR ENERGY STRIKING THE OUTER ATMOSPHERE — 429 BTU PER S F PER HOUR — AND THIS QUANTITY IS KNOWN AS THE SOLAR CONSTANT

NOTE

You cannot increase the amount of solar energy striking a collector of a given size by focusing You may increase the collector's efficiency or the temperature of the working fluid

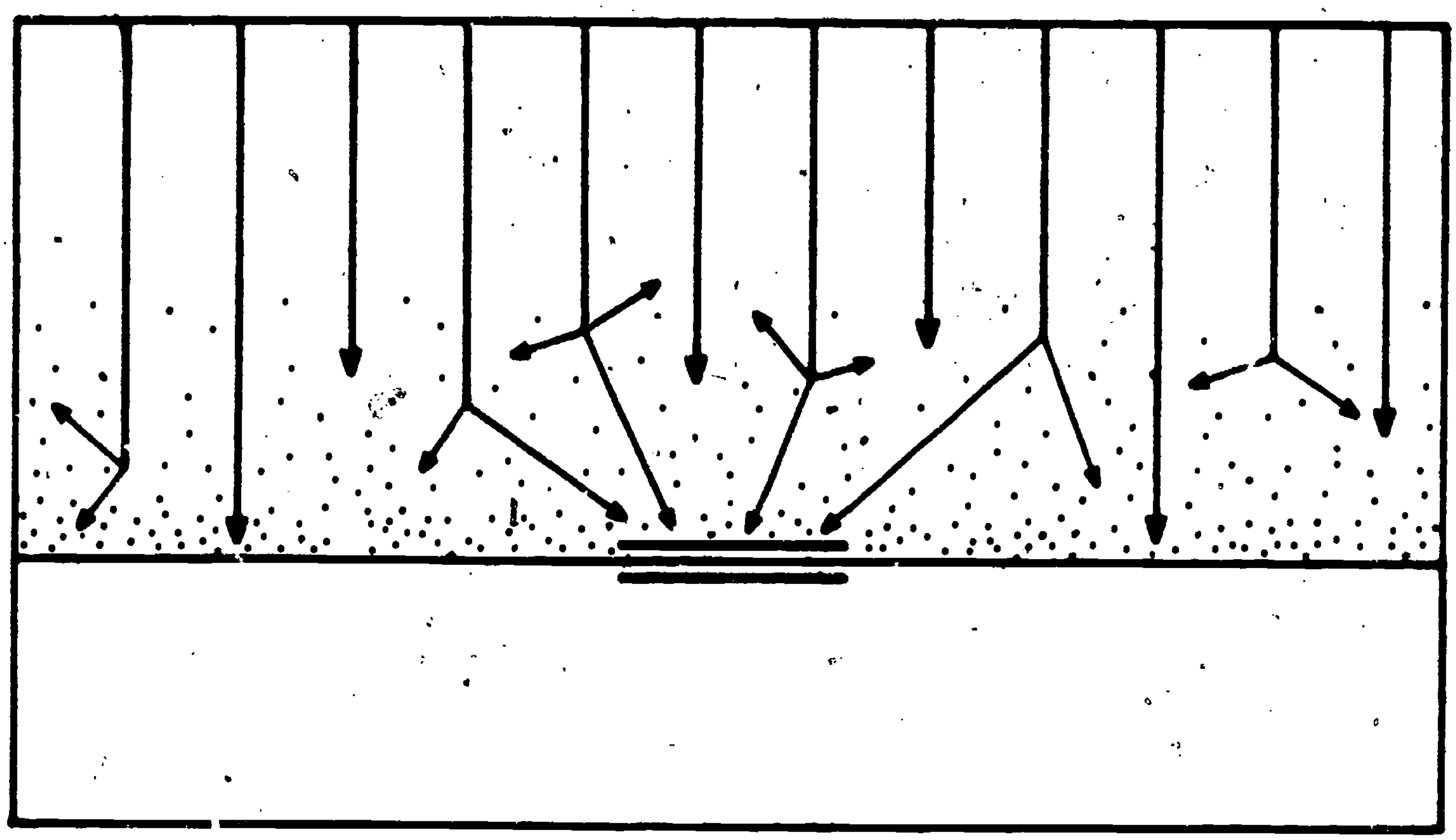
From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



4. ABSORPTION AND REFLECTION.

NEARLY HALF THE SOLAR RADIATION ENTERING THE EARTH'S ATMOSPHERE IS LOST THROUGH ABSORPTION BY MATERIAL IN THE ATMOSPHERE, OR BY REFLECTION FROM CLOUDS.

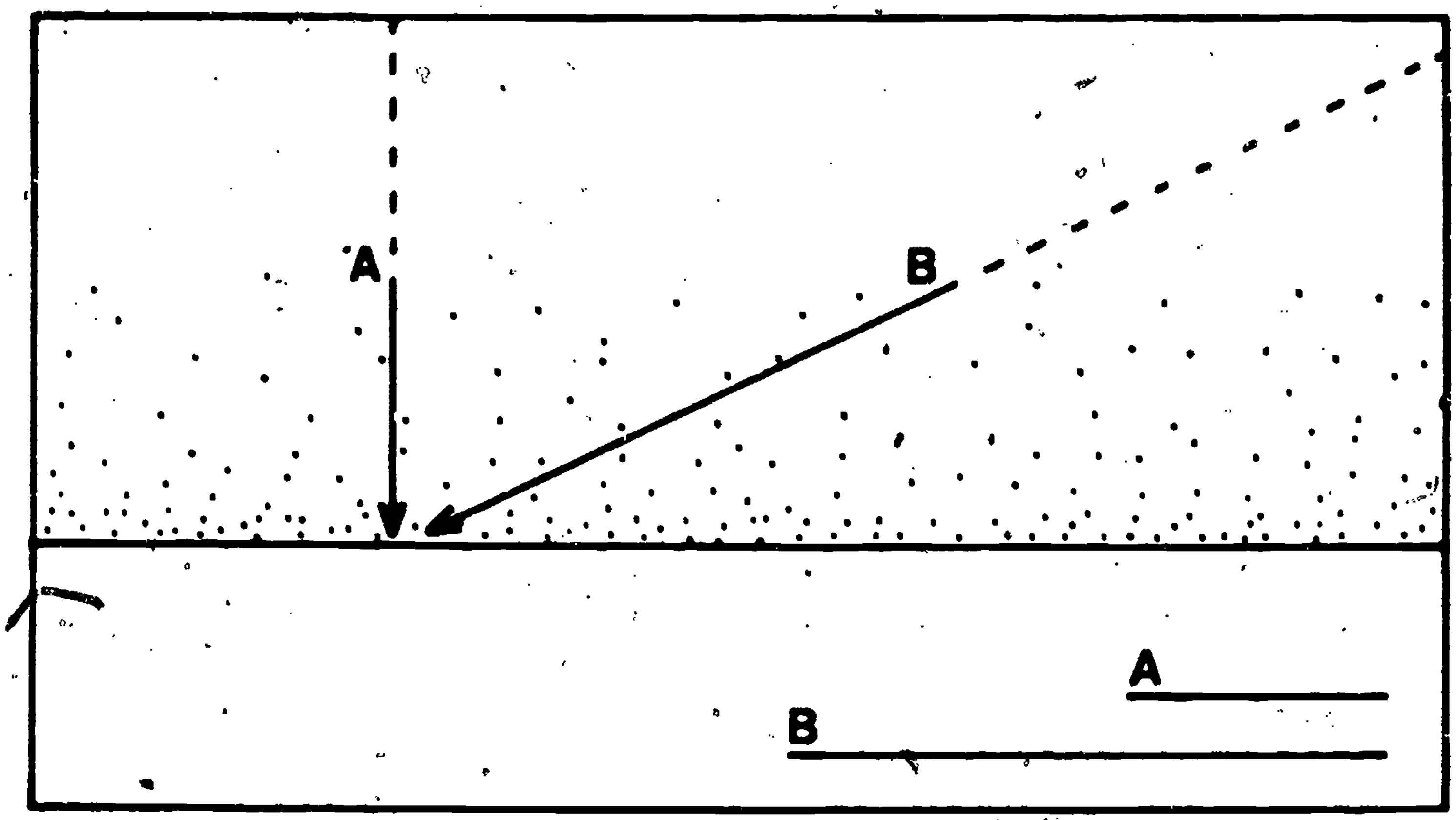
From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



6. DIFFUSE RADIATION

CLOUDS AND PARTICLES IN THE ATMOSPHERE NOT ONLY REFLECT AND ABSORB SOLAR ENERGY, BUT SCATTER IT IN ALL DIRECTIONS. BECAUSE OF THIS, SOLAR ENERGY IS RECEIVED FROM *ALL PARTS* OF THE SKY — MORE SO ON HAZY DAYS THAN ON CLEAR DAYS. SUCH RADIATION IS CALLED *DIFFUSE*, AS OPPOSED TO THE NORMAL *DIRECT* RADIATION.

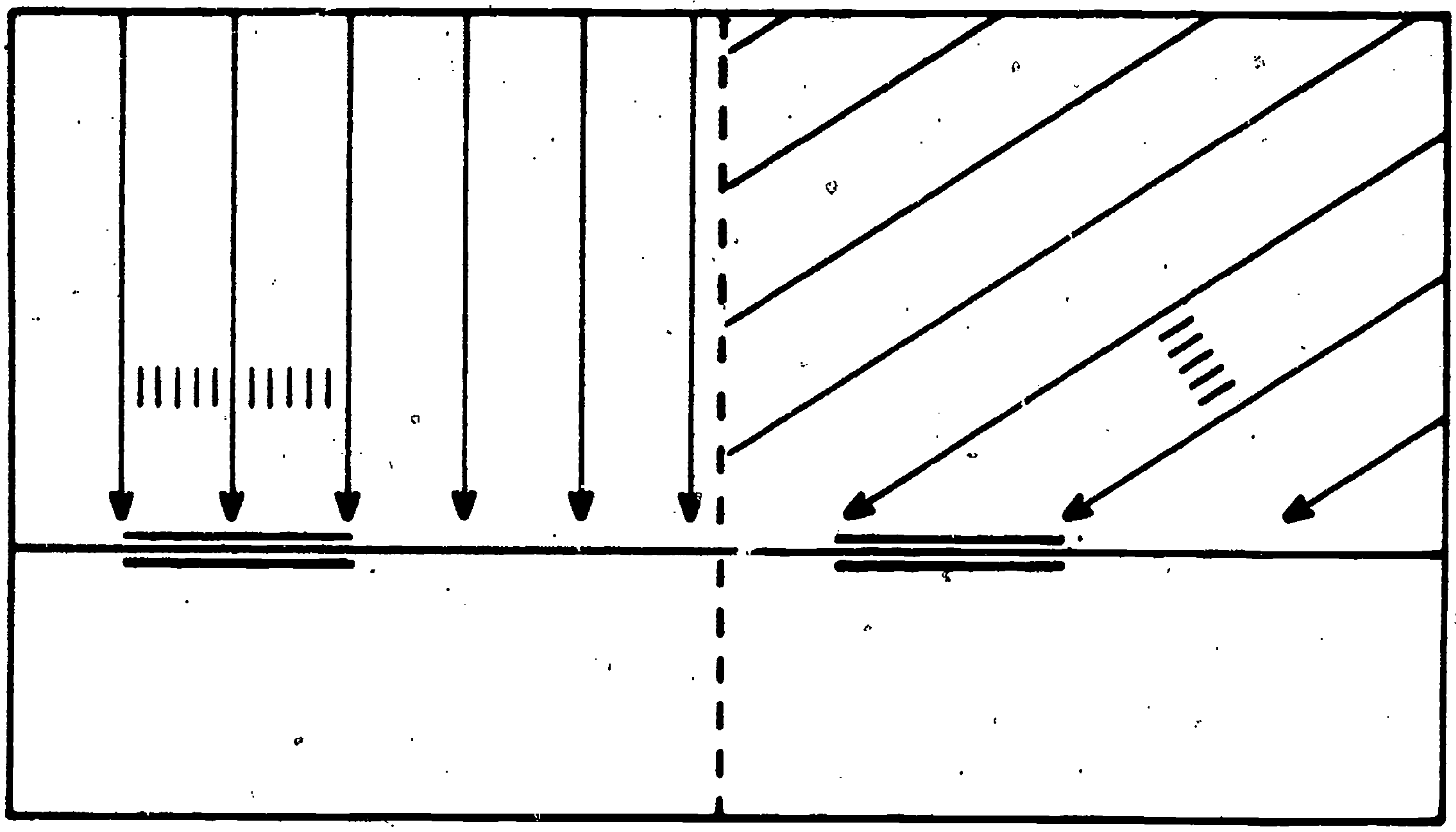
From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



5. LENGTH OF TRAVEL THROUGH THE ATMOSPHERE

MORE SOLAR RADIATION IS LOST BY ABSORPTION AT LOW SUN ANGLES BECAUSE THE LENGTH OF TRAVEL THROUGH THE ATMOSPHERE IS GREATLY INCREASED (THAT IS WHY YOU CAN LOOK DIRECTLY AT THE SUN AT SUNSET.) HIGH ALTITUDES HAVE MORE SOLAR RADIATION FOR THE SAME REASON

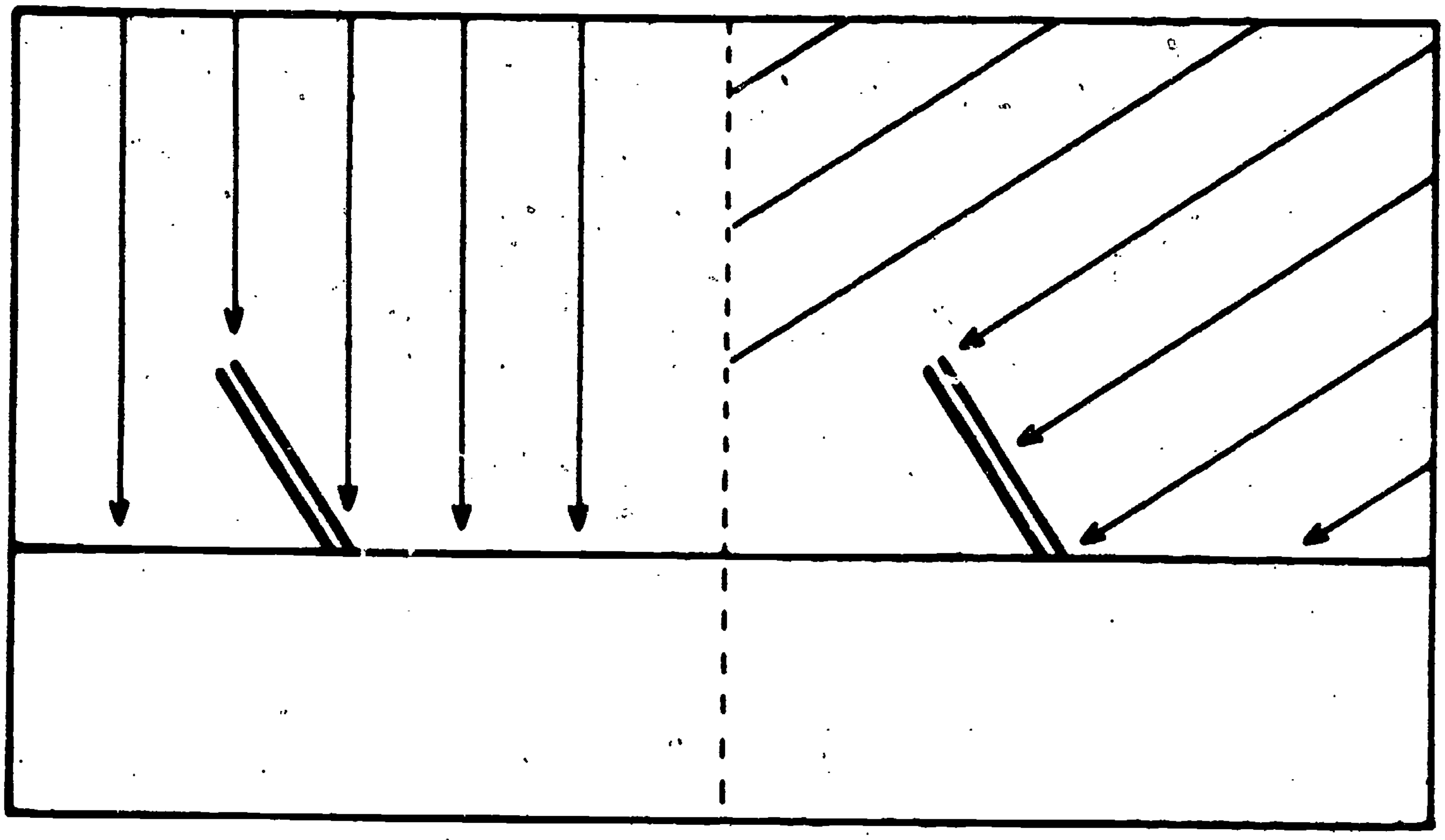
From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



2. COSINE LAW — HORIZONTAL SURFACE

LESS SOLAR RADIATION STRIKES A GIVEN HORIZONTAL AREA AS THE SUN GETS LOWER IN THE SKY THE AMOUNT CHANGES BY THE COSINE OF THE ANGLE, MEASURED FROM DIRECTLY OVERHEAD

From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



3. COSINE LAW — TILTED SURFACE

THE SAME LAW APPLIES TO A TILTED SURFACE, SUCH AS A SOLAR COLLECTOR. BY TILTING THE COLLECTOR SO THAT IT IS MORE NEARLY PERPENDICULAR TO THE SUN, MORE ENERGY STRIKES ITS SURFACE.

From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

UNIT II

LOCATING THE SUN

UNIT OBJECTIVE

After completion of this unit, the student will be able to explain the importance of the position of the sun in relation to the earth for making use of the sun's energy. This knowledge will be evidenced through demonstration and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

Upon completion of this unit, the student will learn to

1. Associate correct definitions with the new terms in the unit.
2. Identify correct statements about solar radiation and the importance of the earth's location with respect to the sun.
3. Complete sentences referring to the sun's location in the sky.
4. Identify true statements explaining why it is important to know the location of the sun.

Editor's note: An introductory astronomy textbook can be a valuable source for further explanations and additional examples of the material in this unit.

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1. Terms and Definitions

Declination angle - the angle between the plane of the earth's rotation around the sun and the earth's equatorial plane in a direction facing the sun.

Earth-sun line - an imaginary line between the center of the sun and the center of the earth.

Equatorial plane - an imaginary plane through the earth's equator and perpendicular to the north-south axis.

Irradiation - exposure to radiant energy.

Latitude - the angular distance north or south from the earth's equator measured through 90°.

Solar altitude - the angle of elevation of the sun above the horizon.

Solar azimuth - the angle on a horizontal surface which measures the difference between the direction of a fixed point (e.g. true south) and the direction of the sun.

Solar noon - that time of day when the azimuth angle is 0°, when the sun is due south of an observer.

2. The Earth's Tilt

As the earth follows its elliptical path around the sun, it also rotates around its own axis. This axis can be defined as a line drawn through the north and south poles. The earth rotates once around its own axis every 24 hours (one day) and once around the sun every 365.25 days (one year).

The axis of the earth's rotation is tilted at an angle of 23.5°. This angle is calculated relative to the plane of the earth's orbit around the sun. The direction of tilt of the axis is constant, even as the earth rotates about its own axis and as it travels around the sun (see Transparency 2.1). The constant angle of tilt means that the point on the earth's surface receiving the greatest amount of solar radiation varies. The greatest amount of radiation is received at the point on the surface most perpendicular to the sun's rays (see Transparencies 1.5 and 1.6 in Unit I). Relative to the equator, the point moves north and south between the Tropic of Cancer (latitude 23.5° north) and the Tropic of Capricorn (latitude 23.5° south). What the sun "sees" is diagrammed in Transparency 2.2.

As the earth orbits about the sun, the tilt of the earth's axis causes the angle between the direct earth-sun line and the equatorial plane to change. This angle, called the angle of declination (Transparency 2.3), changes according to the date of the year. The change in declination determines how much sunlight will strike a surface. Thus, the change in declination explains variations in the intensity of solar radiation at different places on the earth's surface. It explains variations of the temperature at differenr times of year.

3. The Sun's Position In The Sky

The solar azimuth (see transparency 2.4) is an angle on a horizontal surface obtained by measuring the difference between true south and the sun's direction at that moment. The azimuth is defined to be 0° at solar noon. The solar altitude is the sun's angle of elevation above the horizon. By knowing the solar azimuth and the solar altitude, one can state the position of the sun for any latitude at various times of the day. With this information, insolation values (see Unit I) for a given latitude can be obtained. Tables giving the altitude and azimuth angles at different latitudes and for different hours of the day are available in the ASHRAE Handbook of Fundamentals (1972).

4. The Importance of Locating the Sun

Knowledge of the solar azimuth angle and the solar altitude angle, i.e., knowing where the sun will be at a specific time on a particular day, can help in planning a solar dwelling. By knowing the location of the sun at critical times, one can determine at what times house surfaces will be shaded during each season and the intensity of solar radiation available.

For example, during the summer months, the sun may spend a substantial portion of the day to the north of an observer in the northern hemisphere (see Transparency 2.5). Because the sun moves farther north in the summer, south-facing windows can be shaded by an overhang during the heat of the summer day. In this way, solar radiation is prevented from adding to the heat of the interior during the summer months. Yet during the winter months, because the sun has moved farther south, a properly designed overhang will not shade the south-facing windows. This means the direct rays of the sun can be used as a source of energy for warming a dwelling in winter, and yet not add to summer cooling problems.

The position of the sun is important in determining how to place collectors to absorb a maximum amount of solar energy. A surface placed perpendicular to the direct rays of the sun will absorb the greatest amount of energy from the sun. Thus, depending upon the intended use of the energy collected, one may wish to tilt a solar collector so that it receives direct rays from the sun at one time of year and not at another.

In Sunspots (1975), Steve Baer suggests a simple method for illustrating how much surface will be exposed to the sunlight at a specific time. Simply place a rod so that it extends perpendicularly from the flat surface of a board. Keeping the rod perpendicular, tilt the board toward the sun until there is no shadow. This will be the maximum amount of sunlight for that season and time of day. In this way one can visualize what orientation of a surface will affect the amount of exposure to the sun. Orientation depends on the amount of <u>irradiation</u> desired on a specific surface.

ACTIVITIES--LOCATION OF SUN

Activity 1

A. Materials Needed

1. Protractor
2. Paper
3. Pencil
4. Model of house, showing overhang, drawn to scale.
5. Window cutouts, to scale: 3', 4', 5', 6' high.
6. Table showing solar position for your Latitude on June 21 and on December 21.

B. Procedure

1. Set protractor so that side of house is at center (90°) of protractor and so that bottom of protractor is at ground level.
2. Reading from table, mark altitude angle at 8:00 a.m. on June 21.
3. Using broken line for angle at 8:00 a.m., draw parallel lines to side of house, maintaining the same altitude angle. Observe where the overhang stops the line, see example in Transparency 2.6.
4. Repeat "2" and "3" for altitude angles at 10:00 a.m. and solar noon on June 21. Use a dotted line for 10:00 a.m. and a solid line for solar noon.
5. Using a second model, follow the same steps for December 21.
6. Place window cutouts on side of house to determine placement for optimum shading.

C. What Has Been Learned?

1. What is the effect of the overhang in shading a south-facing window?
2. What could be done in summer to avoid overheating?
3. What can be achieved by a smaller window, placed higher in the wall? Would this interfere with collection of solar radiation in winter? Why?
4. Where will the sun be at 2:00 p.m. on each day?
5. This activity takes only solar altitude into consideration. How does the azimuth angle effect where the sun will be?
6. How could the optimum angle for a flat-plate collector situated on the roof of your building be determined? See Transparency 2.7.

Activity 2

A. Materials Needed

1. Protractor
2. Paper
3. Pencil
4. Table showing solar position for your latitude on June 21 and on December 21.

B. Procedure

1. Establish north-south and east-west lines on a piece of paper.
2. With the protractor, mark off the azimuth angles, using due south as 0° and counting the degrees east or west from that point, for various times of day. Use a table for the latitude at which you live (see Transparency 2.8).
3. Mark off the azimuth angles for June 21, March 21, and December 21.

C. What Has Been Learned?

1. How does the angle at which direct solar radiation strikes a surface affect the amount of radiation available?
2. How does the above question bear upon the solar azimuth?
3. If the altitude and azimuth points for a given date could be plotted on a three-dimensional graph, the resulting line would represent the sun's path across the sky on that date. Transparency 2.9 represents the sun's path on December 21, March and September 21, and June 21. How do these drawings relate to the angles you have plotted for altitude and azimuth?

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ASSIGNMENT SHEET: LOCATING THE SUN

1. a. List two ways in which the constant tilt of the earth's axis affects human beings.

   b. Explain the importance of the Tropic of Cancer and the Tropic of Capricorn.

2. What information is needed to state the position of the sun in the sky at a specific time of any day of the year.

UNIT TEST: LOCATING THE SUN

1. Match definitions to terms.

____a. Declination Angle

____b. Azimuth

____c. Solar Noon

____d. Latitude

____e. Solar Altitude

____f. Irradiation

____g. Insolation

1. Angle indicating distance north or south from the earth's equator.

2. Exposure to radiant energy.

3. Angle between the plane of the earth's rotation around the sun and the earth's equatorial plane in a direction facing the sun.

4. The amount of solar radiation actually striking the surface of the earth.

5. Angle of sun's elevation above the horizon.

6. An angle obtained by measuring from due south and rotating until facing the sun.

7. The time of day when the sun is due south of an observer.

2. Mark with a "T" the following statements about solar radiation which are true, and mark with an "F" those statements which are false.

____a. The earth rotates once around its own axis every 365.25 days.

____b. The axis of the earth's rotation is tilted 23.5°.

____c. The greatest amount of solar radiation is received at the point on the surface of the earth which is most perpendicular to the direct rays of the sun.

____d. The tilt of the earth's axis causes the constant change in the angle of declination.

____e. The spot on the earth most perpendicular to the direct rays of the sun moves from latitude 23.5°N to latitude 15.5°S.

____f. Variations in hours of daylight and in seasonal temperature differences are explained by the constant change in the angle of declination.

3. Complete the blanks in the following sentences using the words listed below:

1. Solar Azimuth
2. Insolation
3. Solar Altitude
4. Solar Noon

____a. The solar azimuth is defined to be 0^{o} at ____________________.

____b. If one knows the (i) ______________ and (ii) ____________________ for a given latitude, (iii) ____ __________ values can be obtained.

____c. Tables are available which give _________________ and _____________ angles at different latitudes and for different hours of the day.

4. Place an "x" in front of the statements below which are true.

____a. It is impossible to know when house surfaces will be shaded.

____b. South-facing windows can be of value in a solar-heated house and still not cause cooling problems in the summer.

____c. In the northern hemisphere, during the summer, the sun can actually be north of an observer at certain times of the day.

____d. Roof overhangs are of no value in solar design.

____e. Flat surfaces which are perpendicular to the direct rays of the sun will collect solar energy efficiently.

ANSWERS TO ASSIGNMENT SHEET AND UNIT TEST: LOCATING THE SUN

Answer to Assignment 1

a. The constant tilt of the earth's axis causes season changes and the length of the day.

b. The Tropic of Cancer is at latitude 23.5° North, and the Tropic of Capricorn is at 23.5° South. During the year, the length of time required for the earth to move around the sun, the latitudinal spot on the earth nearest the sun moves between these two latitudes. The latitudinal angle is equal to the constant degree of tilt of the earth's axis.

Answer to Assignment 2

a. Solar azimuth, solar altitude, and latitude.

Answers to Unit Test 1

a. 3
b. 6
c. 7
d. 1
e. 5
f. 2
g. 4

Answers to Unit Test 2

a. F
b. T
c. T
d. T
e. F
f. T

Answers to Unit Test 3

a. 4
b. i. 1 Interchangeable
 ii. 3
 iii. 2
c. 1,3

Answers to Unit Test 4

b,c,e

References

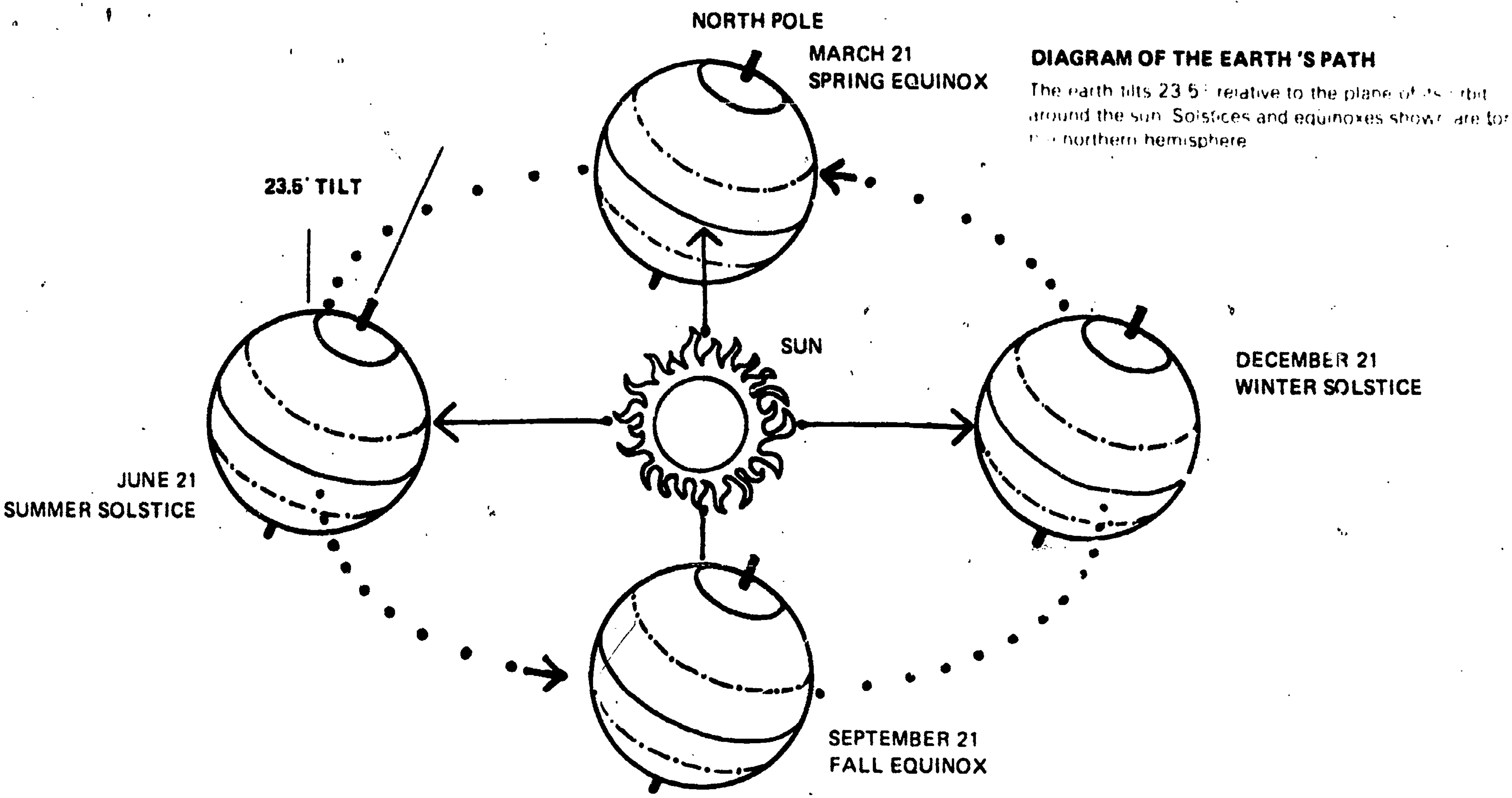
AIA Research Corporation. May 1976. Solar Dwelling Design Concepts. Prepared for the U.S. Department of Housing and Urban Development, Office of Policy Development, Office of Policy Development and Research. Washington, D.C.: U.S. Government Printing Office.

Baer, Steve. 1975. Sunspots, Collected Facts and Solar Fiction. Albuquerque, New Mexico: Zomeworks Corporation.

Balcomb, J. Douglas, James C. Hedstrom, and Hugh S. Murray. November 1976. Pacific Regional Solar Heating Handbook. Prepared for United States Energy Research and Development Administration. Los Alamos, New Mexico: Los Alamos Scientific Laboratory. Available from Superintendent of Documents, U.S. Government Printing Office.

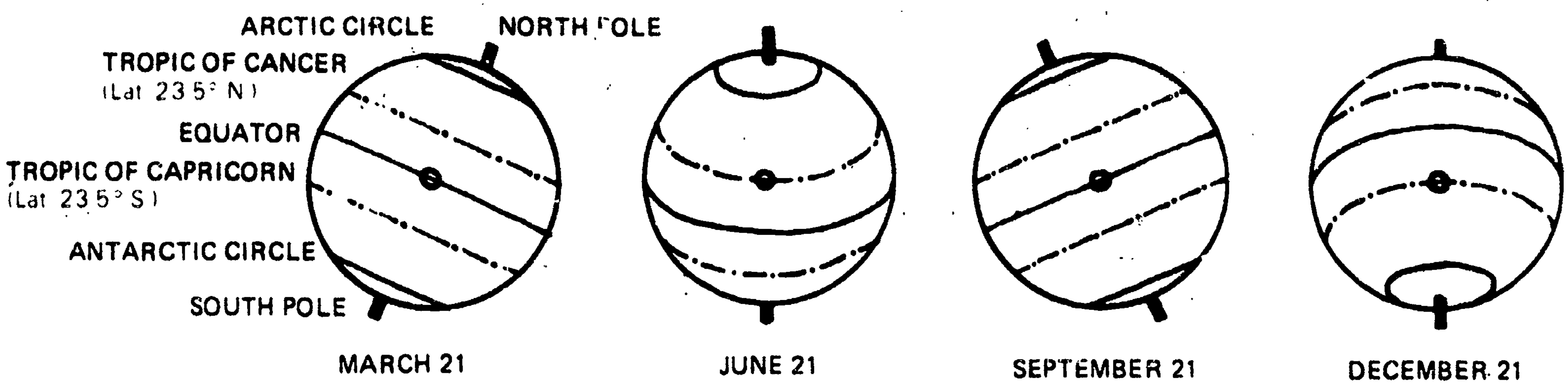
Solar Energy Utilization for Heating and Cooling. 1974. Compiled by John I. Yellott for the American Society of Heating, Refrigerating and Air Conditioning Engineers. Washington, D.C.: U.S. Government Printing Office. Reprinted from Chapter 59 of the 1974 Edition, Applications Volume, of the ASHRAE Guide and Data Book series.

Transparency 2.1



From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

Transparency 2.2



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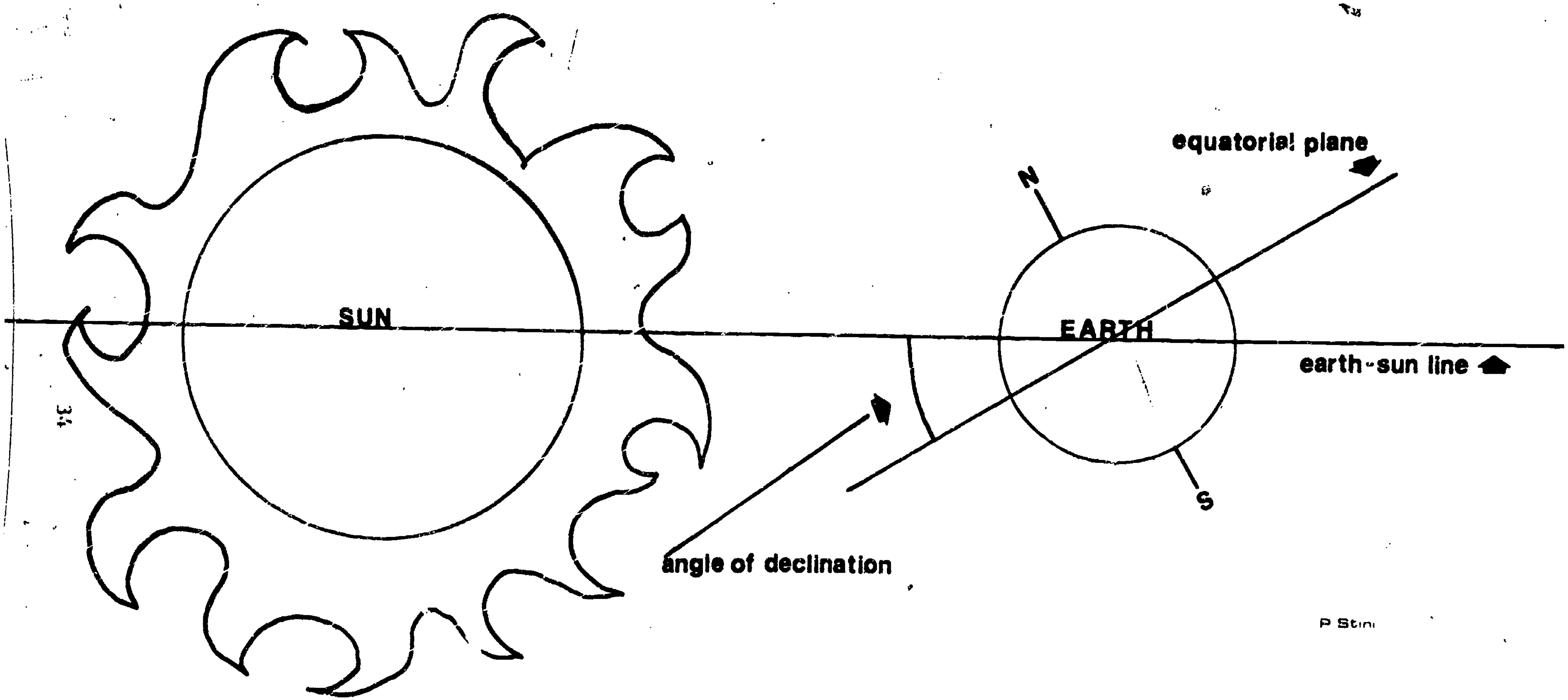
From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

Transparency 2.3



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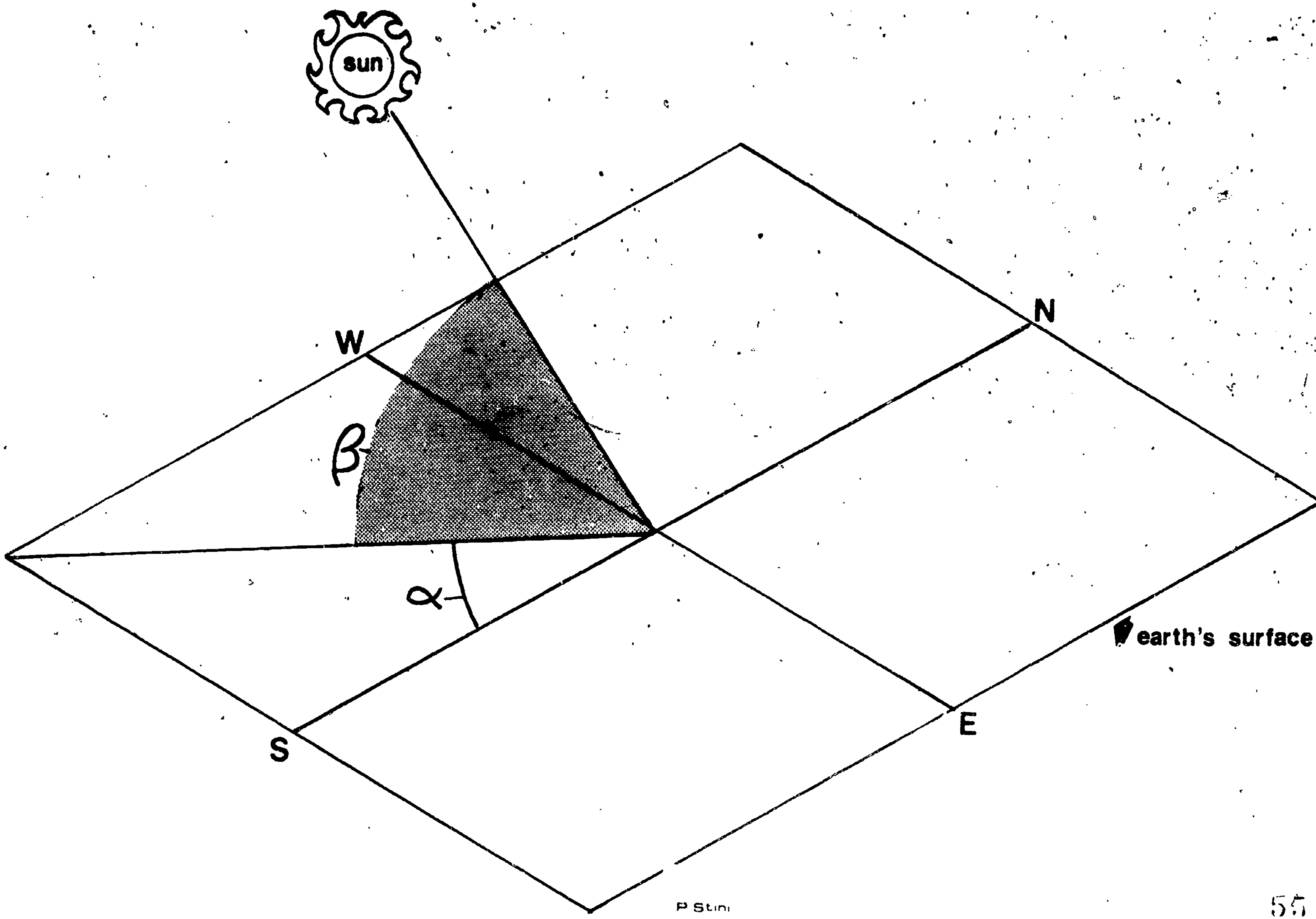
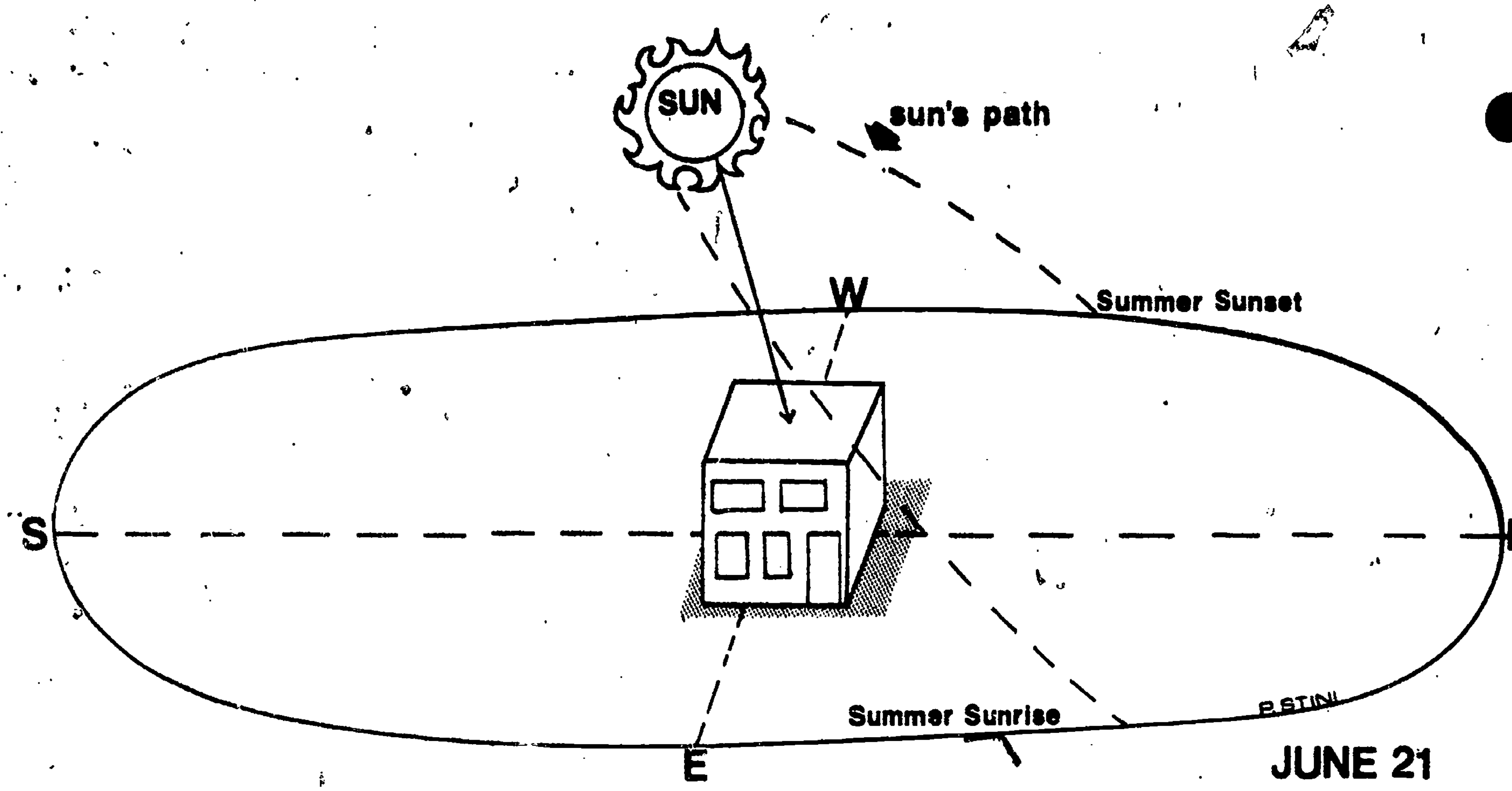
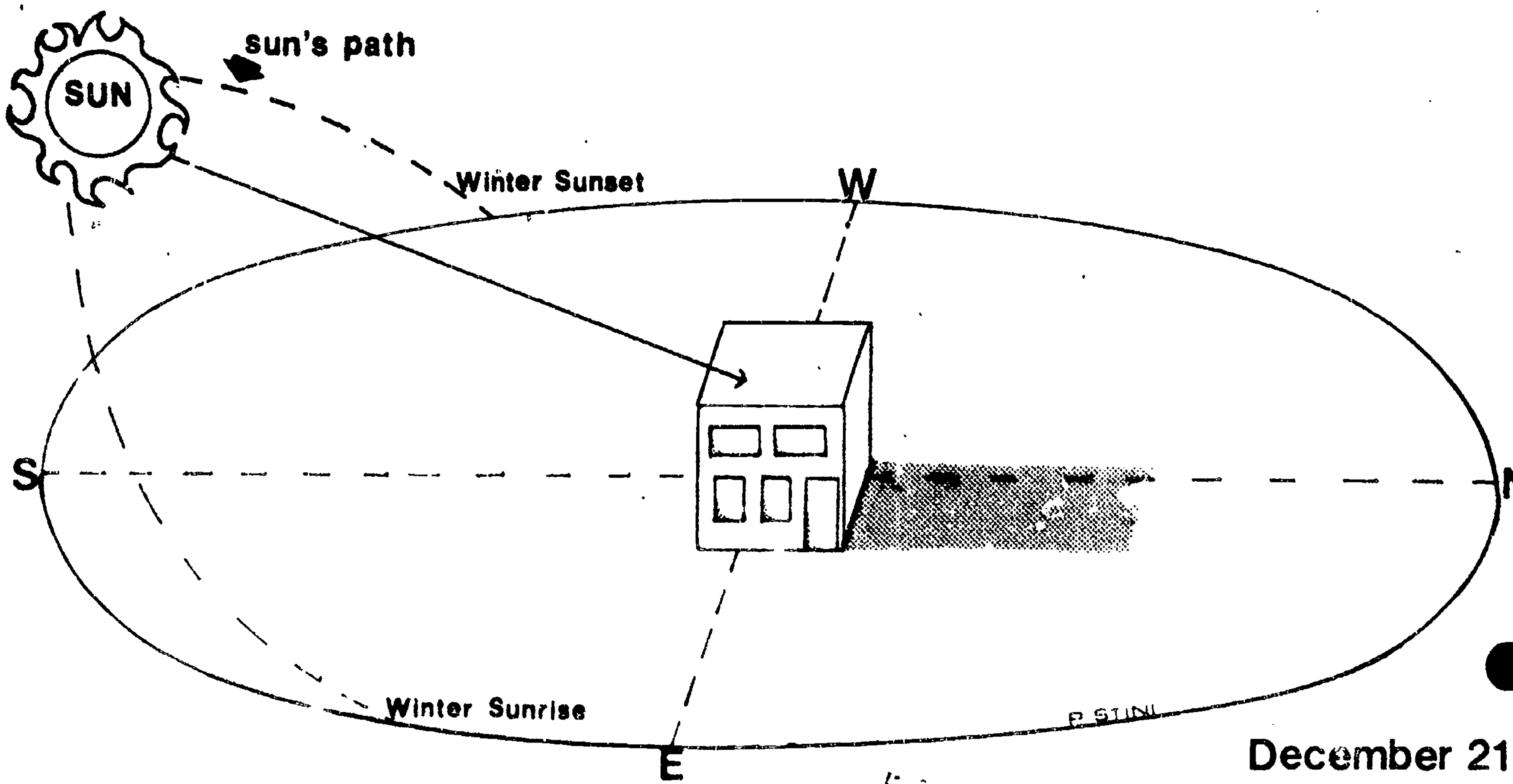
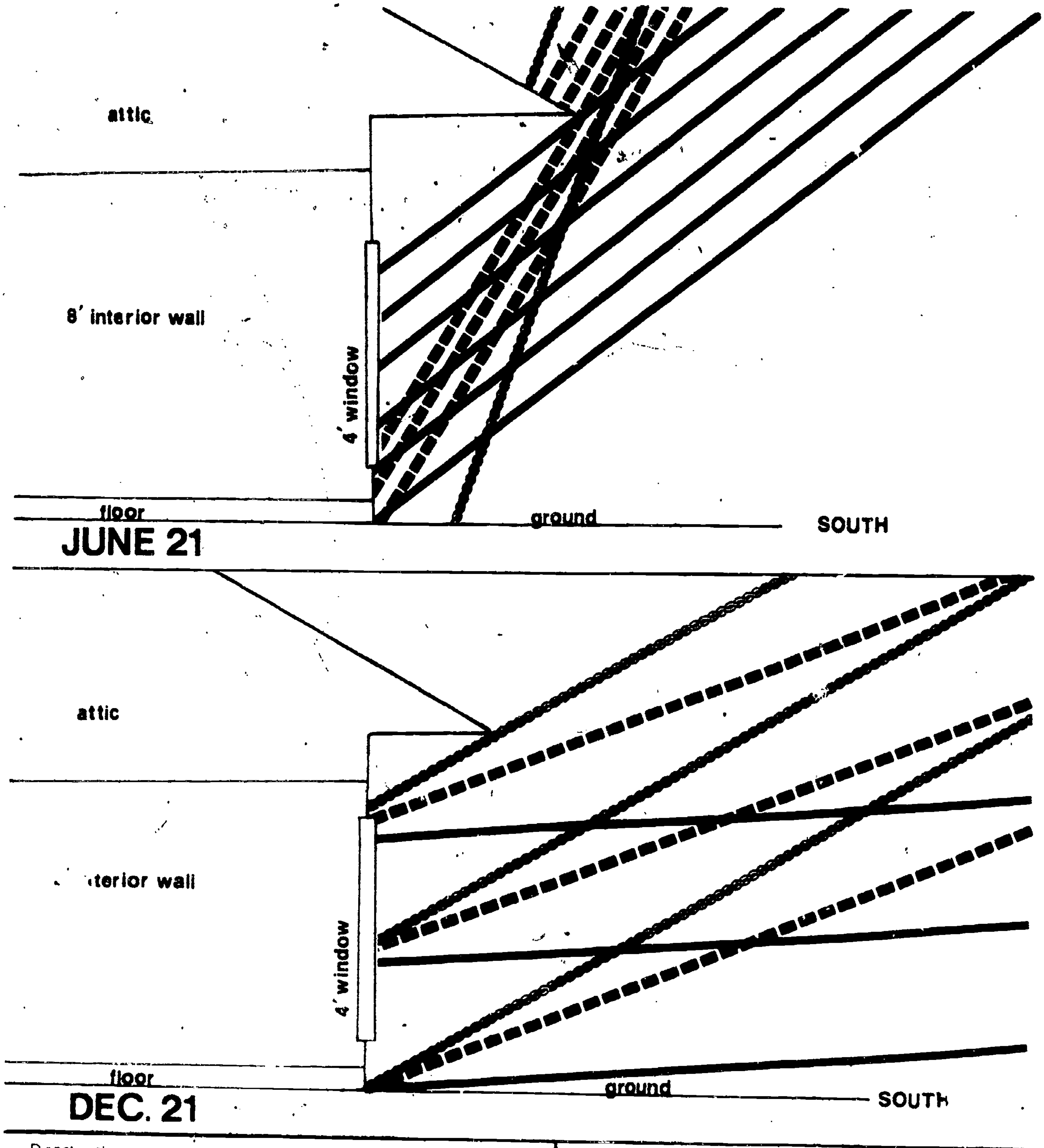

sun
W
N
β
α
S
E
earth's surface
P Stini

Transparency 2.5







Direct solar rays on south window of house

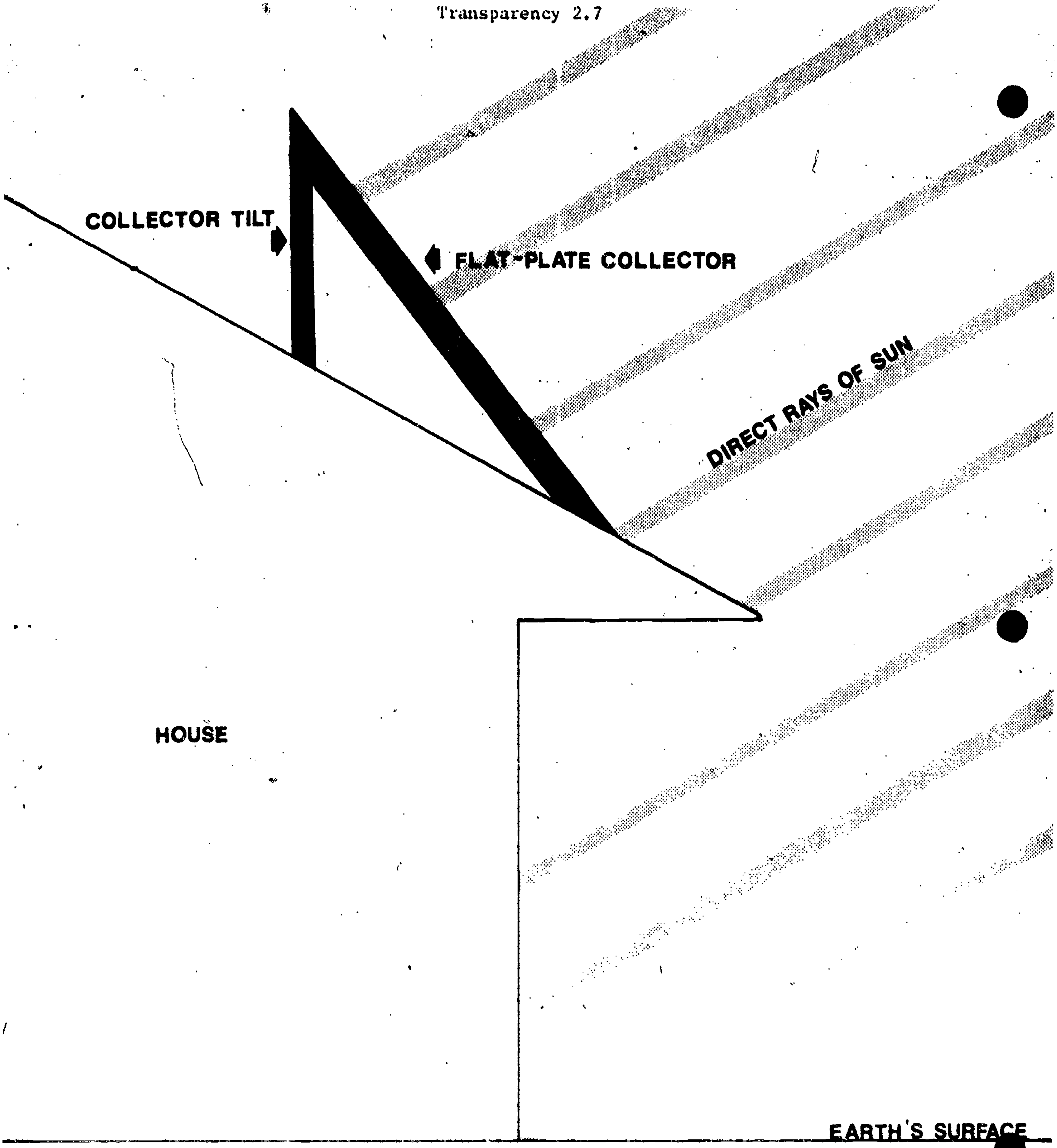
P Stin

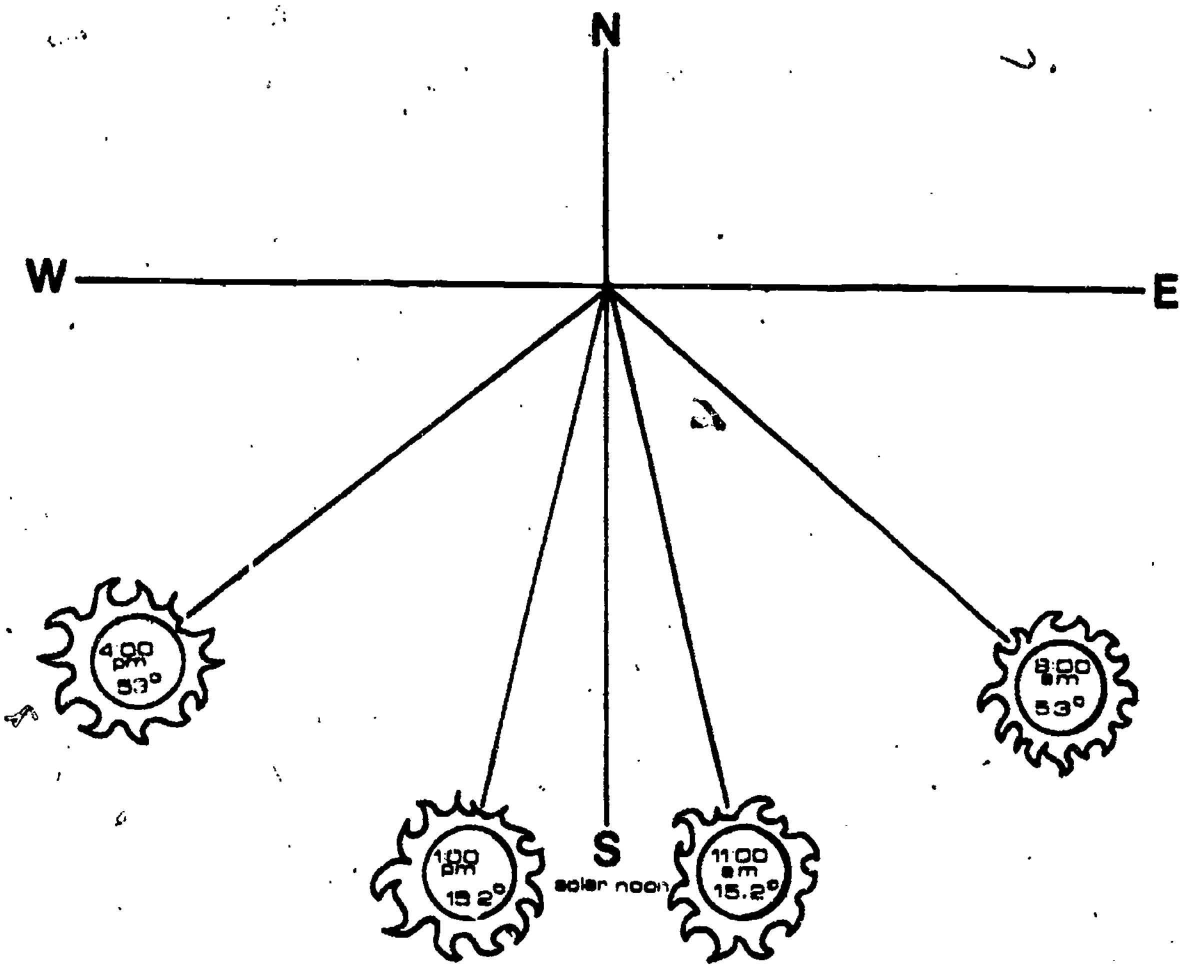
SOLAR NOON

10:00 A.M.

8:00 A.M.

Latitude 240° NORTH


COLLECTOR TILT
FLAT-PLATE COLLECTOR
DIRECT RAYS OF SUN
HOUSE
EARTH'S SURFACE


N
W
E
4:00
pm
53°
8:00
am
53°
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S
solar noon
11:00
am
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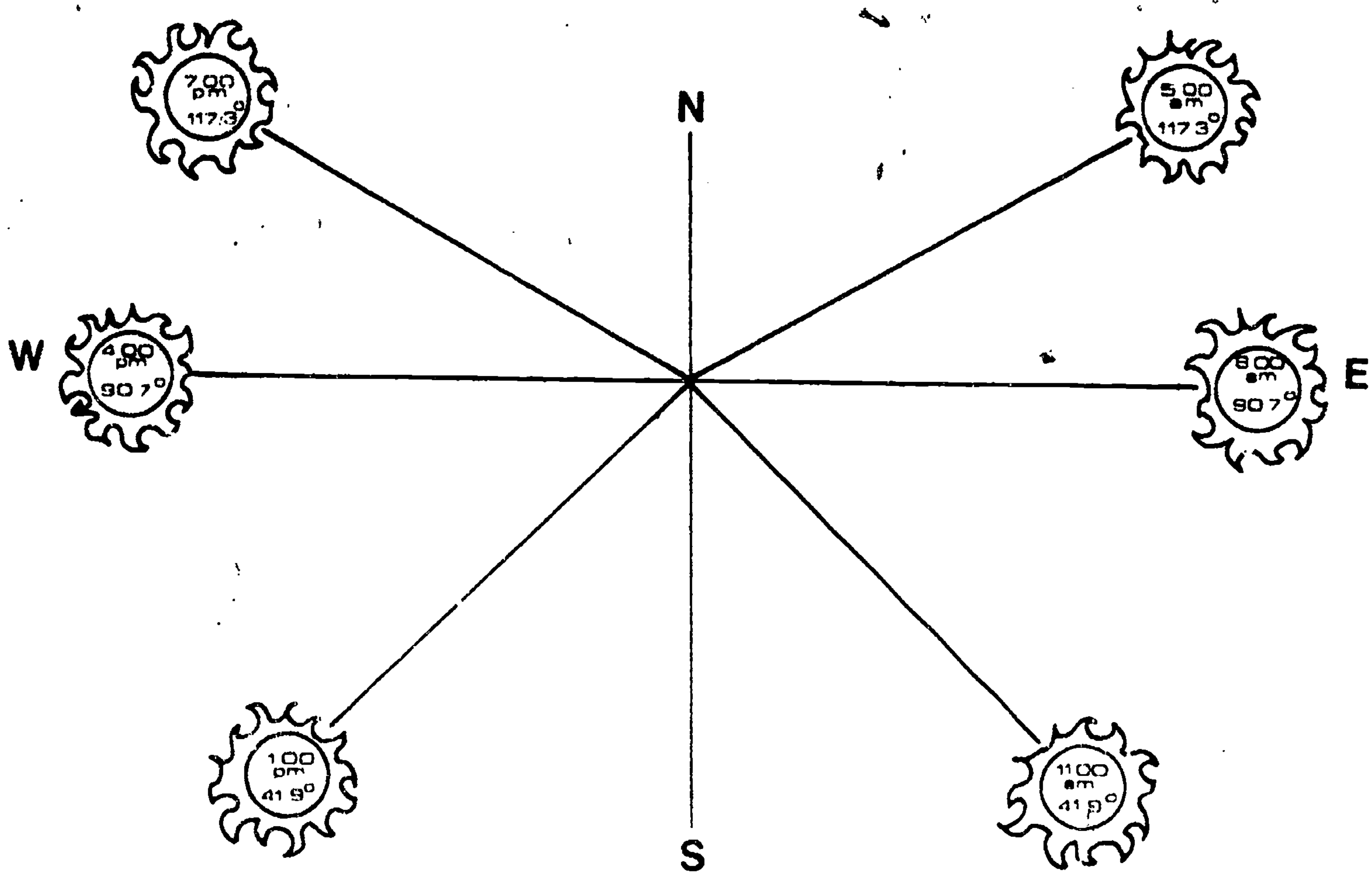
7:00
pm
117.3°
N
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W
4:00
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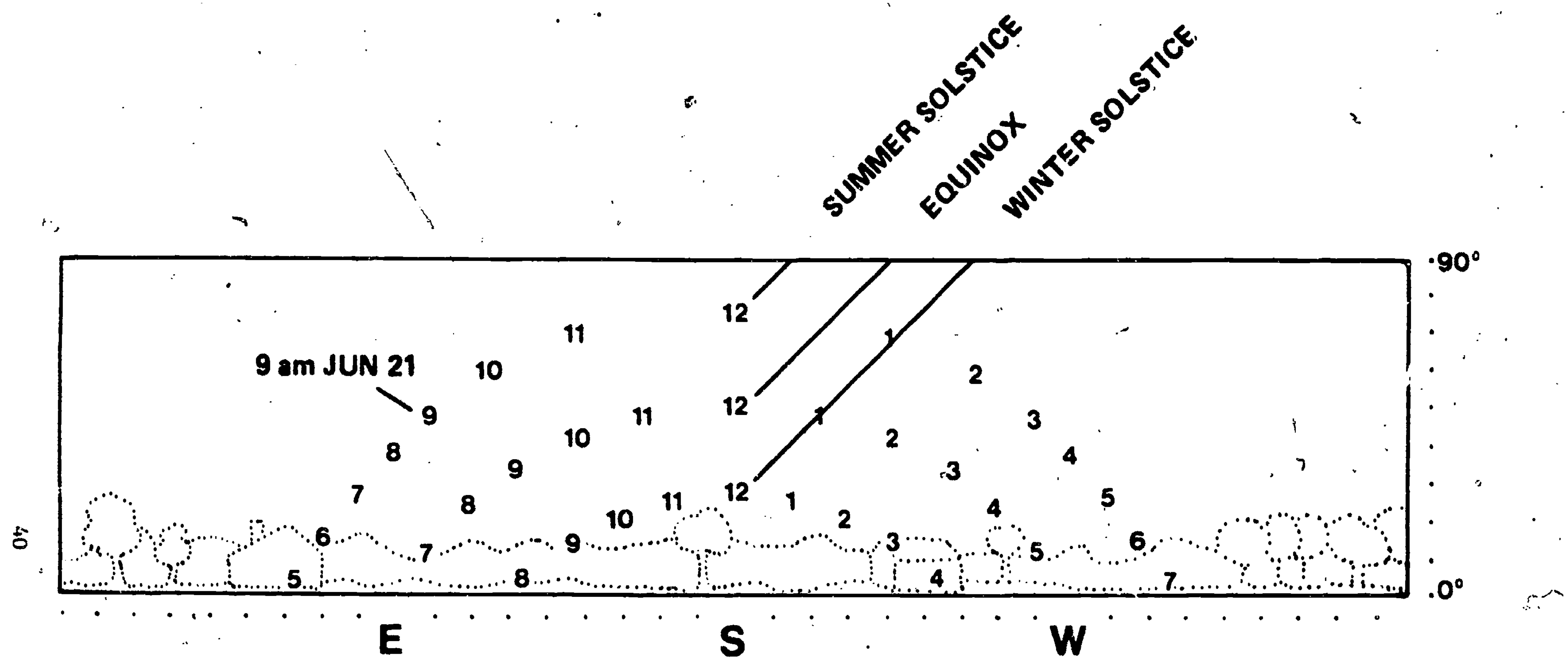
Transparency 2.9



From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

UNIT III

SOLAR ENERGY SYSTEMS

UNIT OBJECTIVE

After completion of this unit, the student will be able to explain the principles governing the operation and name the component parts of solar energy systems. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will learn to

1. Associate correct definitions with the new terms in the unit.
2. Identify true statements referring to solar energy systems.

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1. Terms and Definitions

Active Solar Energy System - thermal energy is transported from the collectors to storage and then to the distribution system in a regulated way, using mechanical pumps and thermal controls.

Collector - a device for receiving solar radiation and converting it to heat in a fluid.

Conduction - heat flows through different materials at varying rates. Copper is an excellent conductor of heat; insulating materials are poor conductors. Heat transfer by conduction occurs only when two surfaces are in direct physical contact because heat transfer is caused by molecular scale vibration.

Convection - when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

Distribution - the component in a solar energy system whereby the thermal energy in storage is made available at the point of use.

Passive Solar Energy System - heat is transported by natural means, and the components are typically integrated into the basic design of the dwelling, so that few, if any, mechanical devices are needed in the system.

Radiation - any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Storage - the component in a solar energy system which retains the solar energy which has been collected for later use, either at night or on cloudy days.

System - a regularly interacting (or interdependent) group of components forming a unified whole.

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Information Sheet: Solar Energy Systems

2. Systems

A system is a regularly interacting (or interdependent) group of components forming a unified whole. We observe systems in nature, e.g., the human body (a biological system), or the pond (an ecological system). In addition, we design systems out of physical parts. An automobile is a physical system made of parts which must work together if the system is to fulfill its design purpose (e.g., if it is to provide transportation from one place to another). To understand a system, it is necessary to understand the parts and how they function. However, it is important to understand not only how the parts function individually, but also, how they function as a unified whole to accomplish the desired end. Very often, individual components may function very well separately and yet not function well at all when joined with the other components in the system. The parts of a system are interdependent. How one component functions will affect how other components function.

A solar energy system is a system designed to use solar radiation as an energy source. The system can be used to heat or cool dwellings, to heat domestic hot water, to heat a pool, and so on. The parts or components of a solar energy system are the collector(Unit IV), storage(Unit V), and distribution (Unit VI). Transparency 3.1 represents schematically a typical solar energy system. Solar radiation is absorbed by the collector, placed in storage, with or without the assistance of a transport medium (e.g., water or forced air) and distributed to the point of use.

Solar energy systems are usually classified as being either active or passive. In an active solar energy system, thermal (heat) energy is transported from the collectors to storage and then to the distribution system in a regulated way using thermal controls. It is necessary to use mechanical devices to pump the gas or liquid transport medium from the collectors to storage and/or to the interior of the dwelling.

In a passive solar energy system, heat is transported by natural means, by radiation, convection, or conduction. The components are typically integrated into the basic design of the dwelling--the windows, walls, floor or ceiling.

ASSIGNMENT SHEET

1. Name three "systems", and explain why you think they are systems. Include a statement of the design purpose, list the components, and describe very briefly what might happen if one of the components failed or was changed in some way.

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UNIT TEST: SYSTEMS

1. Match terms with definitions

_____a. System

_____b. Collector

_____c. Storage

_____d. Distribution

_____e. Active Solar Energy System

_____f. Passive Solar Energy System

_____g. Radiation

_____h. Convection

_____i. Conduction

1. Heat is collected, then transported by natural means. The components are integrated into the basic structure of the building.

2. Heat transfer caused by molecular scale vibration.

3. The component of a solar energy system which carries heat to the point of use.

4. Components designed to form a unified whole.

5. Component designed to retain heat for long periods of time.

6. Moving air currents carry heat from a hot to a cold surface.

7. Heat waves transmit energy from a warmer surface to cooler surroundings.

8. Collected heat is transported through system by pumps regulated by thermal controls.

9. Receives solar radiation and converts it to heat.

2. Check the statements which are correct concerning systems generally or solar energy systems specifically.

____a. A system is designed to fulfill a specific purpose.

____b. Not only must the components in a system function well individually, but also they must function effectively within the unified whole.

____c. If a component functions well individually, it follows necessarily that it will function well within a specific system.

____d. Heat is transported by natural means in an active solar energy system.

____e. Convection and radiation are the only natural means of heat transfer.

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ANSWERS TO ASSIGNMENT SHEET AND UNIT III TEST: SYSTEMS

Answer to Assignment 1

Three systems might be (A) the circulatory system of the human body; (B) an ecological system, such as can be seen in the life balances in small, naturally occurring pond; and (C) a motorcycle or an automobile. All are systems because they are made up of components which must function together if the entire system is to function.

A. The components of the circulatory system are the heart and the arteries, vessels, and veins. The purpose of the system is to distribute oxygen and needed nutrients to the cells in the body. If the heart stops beating, distribution ceases. If a valve in the heart fails to close, the blood will not be pumped; if a vein or artery were to open or close, circulation of the blood could not continue.

B. In a small pond, vegetation, insect life, and animal life function together to support life in the pond. Biological balances between these components can be very delicate. Wastes from insects and animals provide nutrients for the vegetation. The vegetation converts carbon dioxide into oxygen for the insects and small vertebrates and invertebrates. A food chain exists among these creatures and if one link of the chain is destroyed all those creatures above it may die.

C. A motorcycle has a motor, a drive assembly, and a steering mechanism. Each of these components is also a subsystem made up of smaller components. The total mechanism is designed to transport a person from point "A" to point "B". If the motor is not functioning or if the gears do not shift out of neutral, transportation will not occur.

Answers to Unit Test 1

a. 4

b. 9

c. 5

d. 3

e. 8

f. 1

g. 7

h. 6

i. 2

Answers to Unit Test 2

a,b

References

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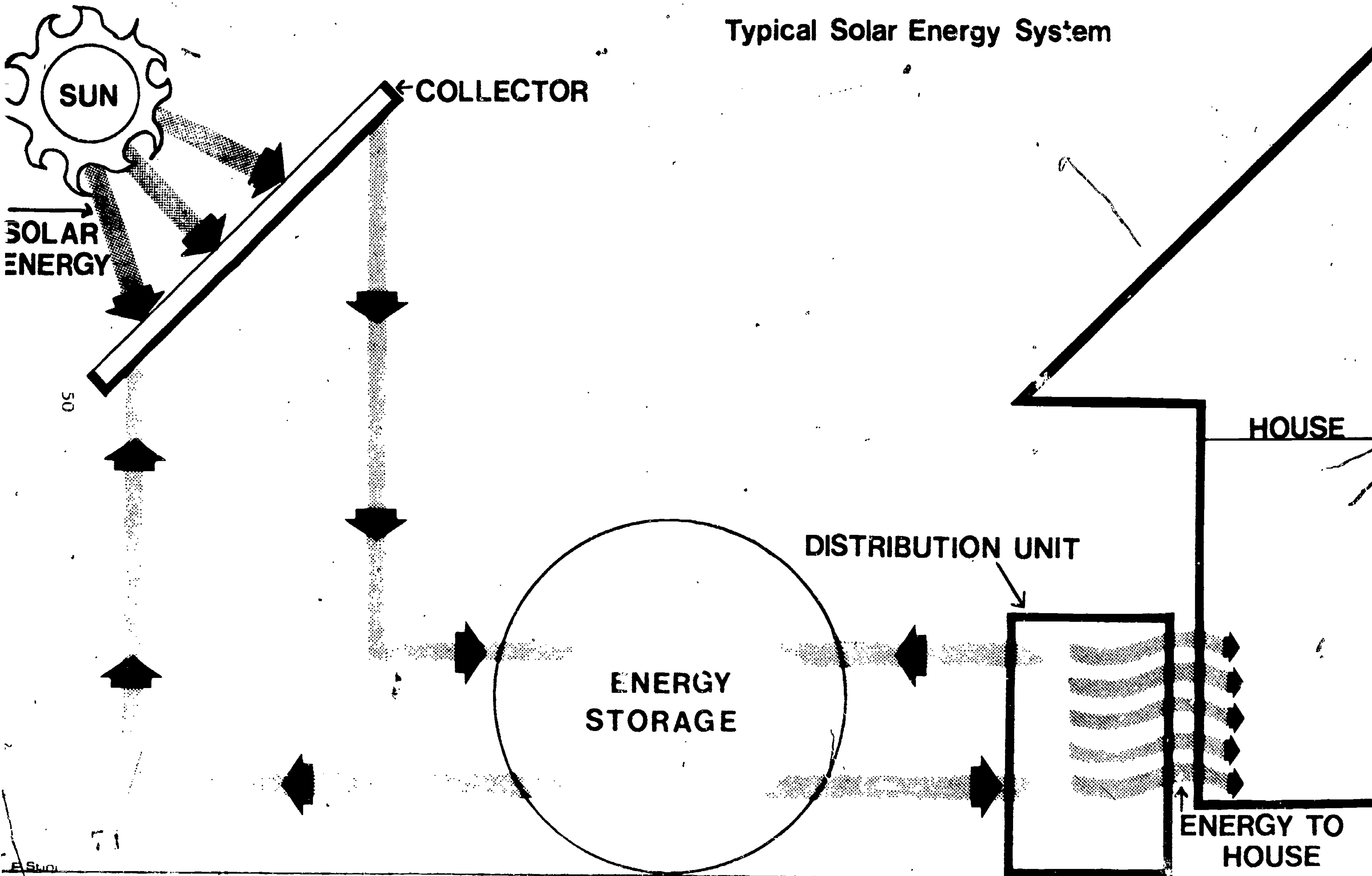
Forrester, Jay W. 1968. Principles of Systems. Cambridge, Mass.: Wright-Allen Press, Inc.

Typical Solar Energy System



UNIT IV

COLLECTORS

UNIT OBJECTIVES

After completion of this unit, the student will be able to name the types of and function of the collector as a component in a solar energy system. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

Upon completion of this unit, the student will learn to

1. Associate correct definitions with the new terms in the unit.
2. Select from given statements those that accurately describe general concepts about collectors.
3. A. Identify the different types of flat-plate collectors.

   B. Select from a list the correct advantages and disadvantages associated with each type of flat-plate collector.
4. A. Match terms with descriptions of concentrating collectors.

   B. Select from a list the correct advantages and disadvantages associated with each type of concentrating collector.
5. Identify correct statements about passive collectors.

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1. Terms and Definitions

Beadwall - a patented insulated window in which polystyrene beads are blown into or pulled out of a space between two sheets of glass or plastic by a vacuum-driven system.

Clerestory window - a south-facing window in the wall of a room which rises above an adjoining roof; the window can be used to admit solar radiation.

Collector - a device for receiving solar radiation and converting it to heat in a fluid.

Concentrating collector - a class of collectors which use reflectors to focus solar radiation on a small area.

Fenestration - the placement, size, and design of windows and doors in a building.

Flat-plate collector - a class of collectors so named because of the large surface area exposed to the sun.

Heat-transfer medium - a liquid or gas which absorbs heat efficiently and moves the heat away from the collector to storage or to point of use.

Thermosyphoning - the principle that heated gasses and liquids rise naturally has been applied as a means of heat transport in passive solar energy systems. Heat built up within a wall or roof structure can be drawn off to heat interior spaces.

Trombewall - a type of passive collector which makes use of a massive masonry wall, painted black and placed behind a south-facing wall of glass. Air trapped between the wall and the glass is heated, moves up over the wall and into the interior space.

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Information Sheet: Collectors *

2. <u>Introduction to Collectors</u>

The <u>collector</u> can be any suitable surface which will absorb the solar radiation striking the surface (insolation), and convert it to usable thermal energy. (Note: In a photovoltaic collector, insolation is converted directly to electricity). The thermal energy captured by the collector is transferred to a fluid within the collector. This fluid, a heat-transfer medium, is usually a gas or liquid which transports the thermal energy to storage or point of use.

Specific types of collectors to be discussed are listed below. Some collectors can be organized and operated independent of the unit they serve (i.e., the building). Collectors can be classified according to whether they are used in active or passive solar energy systems. The following are usually associated with active systems:

A. Flat-Plate Collectors
   - i. Open-Water Collector
   - ii. Air-Cooled Collector
   - iii. Liquid-Cooled Collector

B. Concentrating Collectors
   - i. Linear Concentrating Collector
   - ii. Circular Concentrating Collector

A second class of collectors can be referred to as passive collectors. Passive collectors serve as integral parts of the building unit. If a passive collector is modified, the entire design of the building would have to be modified. Some typical collectors used in passive solar systems are south-facing windows, greenhouses, skylights or clerestory windows, thermosyphoning roof or walls, and ponds (especially roof ponds).

Certain characteristics are common to all collectors. In general, a transparent sheet or plate is used to cover the absorbing surface of the collector. The absorbing surface, or absorber, is coated with a dark substance to increase absorption. Most of the solar radiation transmitted through the glass is absorbed and converted to heat. However, once heated,

*Adapted from AIA Research Corporation, <u>Solar Dwelling Design Concepts</u>, Washington, D.C., Government Printing Office, May 1976.

Percent of Possible Sunshine Intercepted by a Plane Misaligned x Degrees

Degrees	Percent
0	100.0
5	99.6
10	98.5
15	96.5
20	94.0
25	90.6
30	86.6
35	81.9
40	76.6
45	70.7
50	64.3
55	57.4
60	50.0
65	42.3
70	34.2
75	25.8
80	17.4
85	8.7
90	0.0

Table 4.1

Evidently, when orienting planes to receive sunlight, pretty close is close enough. If your angle is off as much as 25 degrees, you still are intercepting over 90% of the possible sunlight.

Source: Steve Baer, Sunspots (Albuquerque, New Mexico: Zomeworks, Inc., 1975) p. 7. Reprinted by permission of the author.

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the absorber will radiate heat away from it. The purpose of the cover plate is to reduce heat loss back to the atmosphere by convection or radiation. The cover plate, usually made of glass or plastic, will trap heat radiated by the absorbing surface. While the solar radiation reaching the collector is generally in the form of ultraviolet (short-wavelength radiation), the heat radiated from the absorbing surface is characteristically long-wavelength radiation. Glass and some plastics will transmit short-wavelength radiation but absorb long-wavelength radiation. These characteristics of the materials explain why the heat is trapped in the collector.

3. Active Collectors

A. Flat-Plate Collectors

When talking about solar collectors, most people automatically think of a flat-plate collector. The flat-plate collector is simple and is widely used. It absorbs both diffuse and direct radiation. The collector can be oriented to catch the optimum insolation at a desired time and temperatures to 250°F can be obtained. There temperatures are well within the range needed for heating interior spaces or domestic hot water.

The flat-plate collector works best when the collector surface is perpendicular to the direct rays of the sun. The tilt should be determined by the season of year when the most solar radiation is needed for the solar energy system; however, the tilt need not be exact. The amount of sunshine intercepted by a misaligned collector has been calculated (see Table 4.1).

A flat-plate collector usually consists of the following: one or two cover plates; a dark-colored absorbing surface insulated on the back to reduce heat loss; and a transporting fluid, either air or gas, which absorbs the heat and carries it to storage or to points of use (see Transparency 4.1). The type of fluid used in the flat-plate collector further defines the type of flat-plate collector. Often the type of fluid used is determined by other components in the system.

i. Open-Water Collectors. Water makes a good heat transport fluid for use in a flat-plate collector. It requires a smaller space for piping, and it absorbs heat readily. In an open-collector, such as Harry Thomason has developed, the water is trickled over the absorber surface. The absorber surface is usually corrugated roofing material which is painted black. The water is distributed across the top of the collectors and trickled down the grooves where the water absorbs heat from the absorbing surface, and and is then caught in a trough at the bottom and piped to storage. Without a cover, there will be heat losses by evaporation. If a glass cover is used, to prevent evaporation, water condensation on the surface can reduce the efficiency of the collector. A second cover sheet minimizes this problem.

Another possibility is to place a second sheet of the corrugated roofing over the first, leaving only a small passage for the water so that the water will be in contact with both surfaces. Open-water collectors have been operated successfully in the Washington, D.C. area. In cold climates with hard freezes, these collectors should be evaluated carefully before installation.

This type of collector can be constructed at the building site. A collector which can be constructed at the building site from easily obtained materials will be less expensive than a factory-produced collector which must be shipped intact to the site. If there comes a time when demand is sufficient to justify mass production of a standard collector type, this saving may be reduced.

ii. Hot-Liquid Collectors. Most collectors using a liquid as the heat transport medium pipe the liquid through the collector box. The pipes usually are attached to the absorber plate, and the heat transfer is by conduction. To increase heat transfer by conduction, greater absorber surface area must be in direct contact with the heat transfer medium. Rectangular pipe is used rather than round tubing, thus increasing the amount of surface contact and effecting better heat transfer. The heated liquid is transported to storage, where the heat is transferred to the storage medium.

There are problems involved in using a liquid transport medium. If water is used, freezing is a real danger: and repairs can be costly. Controls can be added to the system to prevent freezing, but the controls themselves can be costly. Also, leaks may occur. If solutions such as antifreeze are used, corrosion can decrease the efficiency of the collector. However, liquid collectors are efficient in collecting and transporting heat. The liquids used absorb heat readily and require relatively smaller space for piping than does air.

iii. Hot-Air Collectors. Air can be used as the transport medium. By using air, problems associated with freezing, leaks, and corrosion are overcome. Also, the heated air can be pumped directly into the interior space to be heated or it can be pumped to storage.

There are problems associated with using air as the transport medium. A much larger volume of air is needed to transport heat than is needed if a liquid is used as the transport medium. The transfer of heat from the absorber to air presents some problems in efficiency. Often, a finned apparatus, screenwire, or some other method is needed to increase contact of the heated surface with the air (Environmental Research Laboratory, Reprint No. 43, Tucson, Arizona: Tucson International Airport).

B. Concentrating Collectors

Concentrating collectors use reflectors to increase the amount of radiation striking a small area. The target area may be either a tube or a point which absorbs the thermal heat. A major problem with concentrating collectors is that they require direct radiation. Thus they will not absorb heat on a cloudy day. Also, concentrating collectors require tracking devices to follow the sun. Another problem is that the reflecting surface must be kept clean. To date, concentrating collectors have not been used extensively in systems designed for interior heating of dwellings. A major advantage of concentrating collectors is that less surface area is needed to collect solar energy in an amount equal to that collected by a flat-plate collector.

i. Linear Concentrating Collectors. Linear concentrating collectors reflect radiation onto a pipe or tube, which is the absorber. The heat-transport medium circulates through the absorber and is then moved to the point of use or to storage. Fairly accurate orientation to the sun must be maintained, both in an east-west and north-south direction. A linear concentrating collector is illustrated on Transparency 4.2.

ii. Circular Concentrating Collectors. Circular concentrating collectors are dish-shaped to focus radiation on a single point. An absorber is located on the point. The heat absorbed is carried to point of use or storage by a transport fluid. Circular concentrating collectors must track the sun to collect direct rays. However, high temperatures can be achieved which may make their use highly desirable (see Transparency 4.3).

4. Passive Collectors

A passive solar energy system is designed to make the greatest possible use of natural heat transfer processes--conduction, convection, and radiation. Usually, the heat collector and the storage areas are an integral part of the living space, and it is impossible to entirely divorce the two components in a passive system. However, homes are now being built with one or several combinations of the individual components. The emphasis here will be on the collector component.

A. Fenestration

Windows admit into a room solar radiation which can then be absorbed by surfaces within the building. South-facing windows are used to increase heat gain The major drawback of south-facing windows is the enormous amount of heat which is collected. To reduce over-heating, however, massive walls and floors can be used to absorb and store the heat. How massive the walls and floors must be can be calculated so that the mass does not become a drawback. If the mass is too great, it may take up too much of the heat acquired or it may take too long to warm up after periods of low temperature.

B. Greenhouses

Greenhouses, on the south side of a house, are also used to collect heat. However, to avoid heat loss, some kind of insulation must be available. Beadwalls are one possibility. A Beadwall is a patented system involving a space between two sheets of glass or plastic. Polystyrene beads are blown into or pulled out of the space by a vacuum-driven system. Panels of insulating material can also be used for insulating the greenhouse to avoid heat loss at night or on cloudy days. A massive floor of rock or masonry or a masonry wall between the greenhouse and dwelling may be needed to avoid over-heating.

C. Skylights and Clerestory Windows

Skylights and clerestory windows can also be used to collect heat from the sun. It is important to note that both may need to be insulated at night or on cloudy days. Insulated shutters are available for this purpose. Windows placed in the ceiling or high in a wall can be a problem because the heat could be trapped near the ceiling. The heat admitted through skylights and clerestory windows will enter at a high point in the building. A return air register can be placed at a point high in the room. The heat gained from solar radiation and trapped at the ceiling can thus be circulated to floor level. A fan placed in the duct will facilitate the circulating process.

D. The Thermosyphoning Concept

The thermosyphoning concept, using the walls and roof, can also collect solar energy for use in heating interior spaces. The fact that hot gases or liquids rise can be used to employ a natural heat transport system. If solar-heated air, trapped in an air space within a wall or roof, is warmer than the air in the interior of the building, the solar-heated air can be drawn off through vents. If the exterior wall or roof is made of glass or plastic, much higher temperatures can be obtained and the thermosyphoning technique will be more efficient.

A special application of the thermosyphoning technique is the Trombe Wall. Placed behind a south-facing wall of glass is a massive masonry wall, painted black. An air space between the window and the wall traps the heated air, which moves up and over the wall into the room. Vents at the bottom of the wall allow colder air from the interior to enter the space, and as the air is heated it moves up and finally re-enters the interior of the house.

E. Roof Ponds

Roof ponds can provide both heating and cooling of buildings. The pond is usually placed on the roof. However, the pond can be put in the interior of the building with the liquid, usually water, circulated to the roof. Presently, designers are experimenting with using pools completely separated from the building to collect and store heat. Controls are needed if roof ponds are used as collectors to maintain the most comfortable temperature level within the building. ' using insulated panels to either cover or uncover the pond or by filling or emptying the pond, heating and cooling needs can be satisfied.

When the ponds are on the roof, the water is usually contained in black plastic bags. Some arrangements do not use a transparent roof covering because then during the night evaporation can be used, as well as conduction and radiation, to help cool the water.

Solar ponds are most effective in warm, dry areas with cool or cold nights. In warm climates, the ponds would be covered during the day. Cooling is thus accomplished by allowing natural radiation to the sky at night. If the water is cooled at night, then during the day time, the heat from the building can be absorbed by the ponds for radiation at night. If heat is needed, the insulating panels covering the pond are removed during the day so the water can absorb heat and then placed over the pond at night to retain the solar heat collected during the day. Solar ponds are not effective in areas of the country with high humidity. High humidity interferes with night radiation during times when cooling is desired.

There are real advantages to placing the solar ponds on a flat roof. In southern climates, if the roof is flat, there is no problem about how the building is oriented with regard to the sun. In northern climates, the ponds should be covered, tilted, and placed under a transparent cover for best results. The insulation panels can be moved with the aid of fairly simple machinery and stored, perhaps over the garage or a patio covering. If the pond is in direct contact with the interior space and spread over the entire roof area of the dwelling space, heat is radiated evenly throughout the living area.

ASSIGNMENT SHEET: COLLECTORS

1. List the advantages and disadvantages of an open-water collector.

   Advantages   Disadvantages

2. List the advantages and disadvantages of a hot-liquid collector.

   Advantages   Disadvantages

3. List the advantages and disadvantages of a hot-air collector.

   Advantages   Disadvantages

4. List the advantages and disadvantages of a linear concentrating collector.

   Advantages   Disadvantages

5. List the advantages and disadvantages of a circular concentrating collector.

   Advantages   Disadvantages

ACTIVITIES--MAKING A COLLECTOR

Activity 1

A. Materials Needed

1. Two cans with covers
2. Black paint
3. Four glass jars. Size is important. Each can must fit inside one jar which will in turn fit inside the second jar.
4. Thermometer

B. Procedure

1. Paint one can black and allow paint to dry.
2. Fill both cans with water and seal.
3. Place a can inside each of the smaller jars.
4. Lay the jars on their side where the direct rays of the sun will strike the jars.
5. After approximately 20 minutes (depending on the size of the containers) read and record the water temperature in each can.
6. Repeat the activity, but this time, place each can and jar inside the second glass container and wait for approximately 20 minutes before reading the temperature of the water.
7. Leave these "collectors" where the direct rays from the sun will strike the containers for about one hour. Read and record the temperatures again.

C. What Has Been Learned?

1. What temperature differences were observed?
2. How could higher temperatures have been obtained (consider using insulation and reflectors)?
3. Can you explain why a difference in temperature was observed when two glass containers were used instead of one?

Activity 2

A. Materials Needed

1. A 2' x 4' rectangular box with sides approximately 4" high.
2. Insulation
3. Black paint
4. Transparent glass or plastic cover
5. A large quantity of cans of the same size; beer cans or vegetable cans would be excellent.
6. Hole cutter
7. Can opener
8. Epoxy glue or caulking material
9. Thermometers

B. Procedure

1. Make two 4 1/2 feet tubes by cutting off can lids and bottoms and gluing the cans together.
2. Remove one-half the lid and the bottom of each can. In this way, the movement of air through the tube will be impeded and more heat will be absorbed. Leave the lids at each end of the tube intact.
3. Paint the one tube black.
4. Place insulation in the bottom of the box.
5. Paint the surface of the insulation black.
6. Cut holes in either end of the box. Place cans in box o that the cans will protrude slightly at each end. Caulk around pening.
7. Cut 2-inch openings in each end of tube.
8. Place transparent cover over collector.
9. Tilt collector so that the flat, transparent surface is normal (perpendicular) to the direct rays of the sun. Be sure the holes in the tubes are not blocked.
10. After approximately 30 minutes, check the temperature of the air entering the collector at the bottom and the air escaping at the top. Be careful to shade the thermometer when taking temperature readings.

C. What Has Been Learned?

1. Is there any difference in temperature between the air rising in the tubes which were painted black and those left unpainted?
2. Materials can be a serious problem in building collectors because the materials must withstand high temperatures and prolonged exposure to solar radiation. Plastics, caulks, adhesives, and paints are of especial importance. Where might one obtain information about materials?

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UNIT TEST: COLLECTORS

I. Match definitions with the correct terms.

____a. Collector

____b. Heat-transfer medium

____c. Flat-plate collector

____d. Concentrating collector

____e. Clerestory window

____f. Fenestration

____g. Thermosyphoning

____h. Beadwall

____i. Trombe Wall

1. Placement, size, and design of windows and doors in a building.

2. A means of heat transport making use of the principle that heated gasses and liquids rise naturally.

3. A type of passive collector which uses a black masonry wall and a glass wall with an air space in between.

4. A component in a solar energy system which receives solar radiation and converts it to heat.

5. A class of collectors which expose a large surface area to the sun.

6. A south-facing window in the wall of a room which rises above an adjoining roof.

7. Polystyrene beads are blown into or pulled out of a space between two sheets of glass or plastic by a vacuum-driven system.

8. A liquid or gas which absorbs heat and moves it from the collector to storage or to point of use.

9. A class of collector which reflects radiation and focusses it on a small area.

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2. Select from the statements written below those which accurately describe general concepts about collectors and mark them with an "x".

____A. Any surface which will absorb soalr radiation and convert it to heat can be called a collector.

____B. If a surface is coated with a dark substance, it will increase the rate of absorption of radiation.

____C. Open-water collectors are a type of concentrating collector.

____D. The transparent sheet which covers the absorbing surface of the collector serves mainly to keep the absorbing surface clean.

____E. After radiant energy is converted to heat, it is transported away to storage or point of use in a solar energy system.

____F. Heat is trapped in the collector by the transparent covering.

____G. Once the absorbing surface of the collector has absorbed the radiant energy, there is no danger of heat loss.

____H. A south-facing window can serve as a solar collector.

3A. Flat-Plate Collectors

I. Identify the different types of flat-plate collectors by filling in the blanks with the proper term.

a. Open-water collectors

b. Hot-liquid collectors

c. Hot-air collectors

____1. The liquid which serves as the heat-transport medium is piped through the collector box.

____2. Air is pumped through the collector box.

____3. The heat-transport medium, water, is trickled over the absorber surface, which is usually made of a corrugated roofing material.

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II. Select from the following list, the advantages and disadvantages associated with the three types of flat-plate collectors. Place letters from the list on the appropriate lines for each type of collector. Each letter may be used more than once.

a. Freezing

b. Corrosion

c. Heat losses through evaporation if cover is not used.

d. Leaking

e. Heat-transfer medium can be pumped directly to point of use.

f. Usually less expensive

g. Water or other liquid is an efficient heat-transport fluid.

h. If cover is used condensation may interfere with rate of absorption.

i. Because heat transfer is a problem, greater direct contact of heat-transfer medium with absorber surface is needed.

j. A larger volume of the heat transfer medium must be used.

k. No problems with freezing.

l. No problems with corrosion.

m. No problems with leakage.

n. A smaller piping ysstem is needed to carry the heat-transfer medium.

o. A larger piping system is needed to carry the heat-transfer medium.

i. Open-water collector

Advantages ______________________________

____

Disadvantages ______________________________

____

ii. Hot-liquid collectors

Advantages ______________________________

____

Disadvantages ______________________________

____

iii. Hot-air collectors

Advantages ______________________________

____

Disadvantages ______________________________

____

3B. Concentrating Collectors

I. Match terms with the appropriate description.

____a. Not a collector

____b. Linear concentrating collector

____c. Circular concentrating collector

1. Radiation is reflected onto a pipe or tube through which the heat transport medium is circulated.
2. The radiation is focussed and reflected onto a sin point.
3. Radiation is reflected onto a single spot on the moon.

II. Select from the following list the advantar :s and disadvantages associated with the two types of concentrating collectors. Place letters from the list on the appropriate lines for each type of collector. Each letter may be used more than once.

a. Only a small area is needed to collect a large amount of energy.
b. The collector must be oriented exactly with the sun.
c. Orientation with the sun must be fairly accurate.
d. Absorbs only direct radiation.
e. High temperatures may be obtair d.
f. The reflecting surface must be ker clean.

1. Linear Concentrating Col ector

Advantages ______________________________

____

Disadvantages ______________________________

____

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2. Circular Concentrating Collector

Advantages ____

____

Disadvantages ____

____

4. Passive Collectors

Identify and mark with a "T" the statements below which accurately describe passive collectors. Mark false statements with an "F".

____a. South-facing windows collect only small amounts of heat.

____b. There are no drawbacks to using greenhouses as passive collectors.

____c. Because of the natural movements of heated air, air can be used as the heat-transport medium in passively heated dwellings.

____d. Massive walls and floors of rock or masonry have no effect on the amount of heat which must be collected.

____e. The heat admitted through skylights and clerestory windows enters at a high point in the room and is trapped there.

____f. In a Trombe Wall, vents are placed at the top and bottom of the wall.

____g. The purpose of the vents in the Trombe Walls is to allow warm air to enter the interior of the dwelling as it rises and to allow cooler air to be moved from the interior of the dwelling to be reheated.

____h. Roof ponds are a type of passive solar collector.

____i. The heat collector and the heat storage components can be entirely separated in all passive solar energy systems.

____j. If windows are used for thermal gain, the windows must be insulated at night.

____k. Roof ponds can only cool buildings.

____l. Roof ponds work best in areas with high humidity.

____m. Solar ponds may be completely separated from the building.

____n. If a greenhouse is used to collect heat, the windows will need to be insulated at night and a massive floor or wall will be needed to to absorb the heat.

ANSWERS TO ASSIGNMENT SHEETS AND UNIT IV TEST: COLLECTORS

Answers to Assignment 1

Advantages

Water is a good heat transport medium

Collector is inexpensive

Smaller piping system is needed to carry the heat-transport medium

Disadvantages

Without transparent cover heat is lost to evaporation.

With transparent cover, condensation can be a problem.

Freezing

Corrosion

Leakage

Answers to Assignment 2

Advantages

Water is a good heat transport medium

Smaller piping system is needed to carry the heat transport medium

Disadvantages

Freezing

Leaking

Corrosion

Heat transfer is by conduction, meaning that contact of heat transfer medium with absorber must be maximized.

Answers to Assignment 3

Advantages

Does not freeze or corrode

Leakage is not a problem

Air can be pumped directly to point of use.

Disadvantages

Larger volume of heat transport medium is needed.

Requires large duct work.

Heat transfer from absorber to air is not efficient.

Answers to Assignment 4

Advantages

Small area is needed to collect large amounts of energy

High temperatures may be obtained.

Disadvantages

Orientation with sun must be fairly accurate

Absorbs only direct radiation

The reflecting surface must be kept clean

Answers to Assignment 5

Advantages

Small area collects large amounts of energy

High temperatures may be obtained

Disadvantages

Collector must be oriented exactly with sun

Absorbs only direct radiation

Reflecting surface must be kept clean

Answers to Unit Test 1

A. 4

B. 8

C. 5

D. 9

E. 6

F. 1

G. 2

H. 7

I. 3

Answers to Unit Test 2

A, B, E, F, H

Answer to Unit Test 3A

I. 1. b

2. c

3. a

II. i. Advantages f,g,n

Disadvantages a,b,c,d,h

ii. Advantages g,n

Disadvantages a,b,d,i

iii. Advantages e,k,l,m

Disadvantages i,j,o

Answers to Unit Test 3B

I. 1. b

2. c

3. a

II. i. Advantages a,e

Disadvantages c,d,f

ii. Advantages a,e

Disadvantages b,d,f

Answers to Unit Test 4

a.	F	f.	T	k.	F
b.	F	g.	T	l.	F
c.	T	h.	T	m.	T
d.	F	i.	F	n.	T
e.	T	j.	T		

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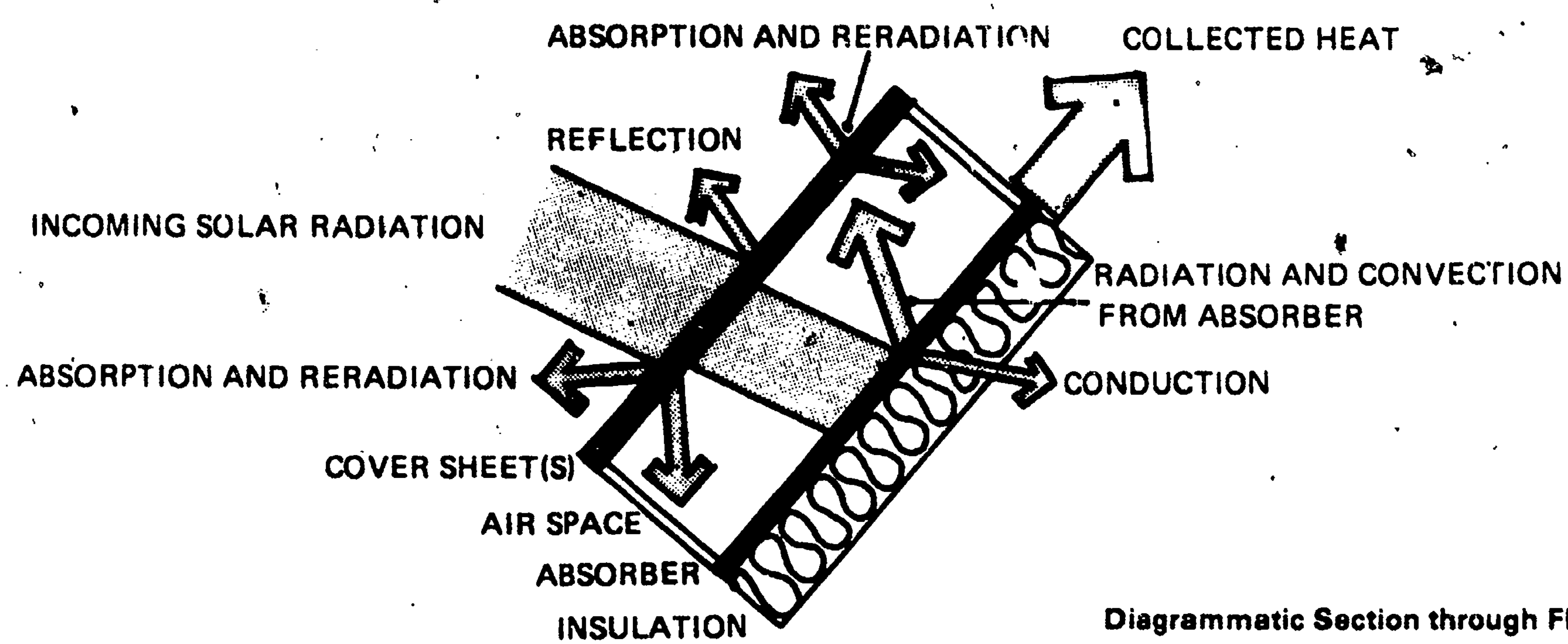
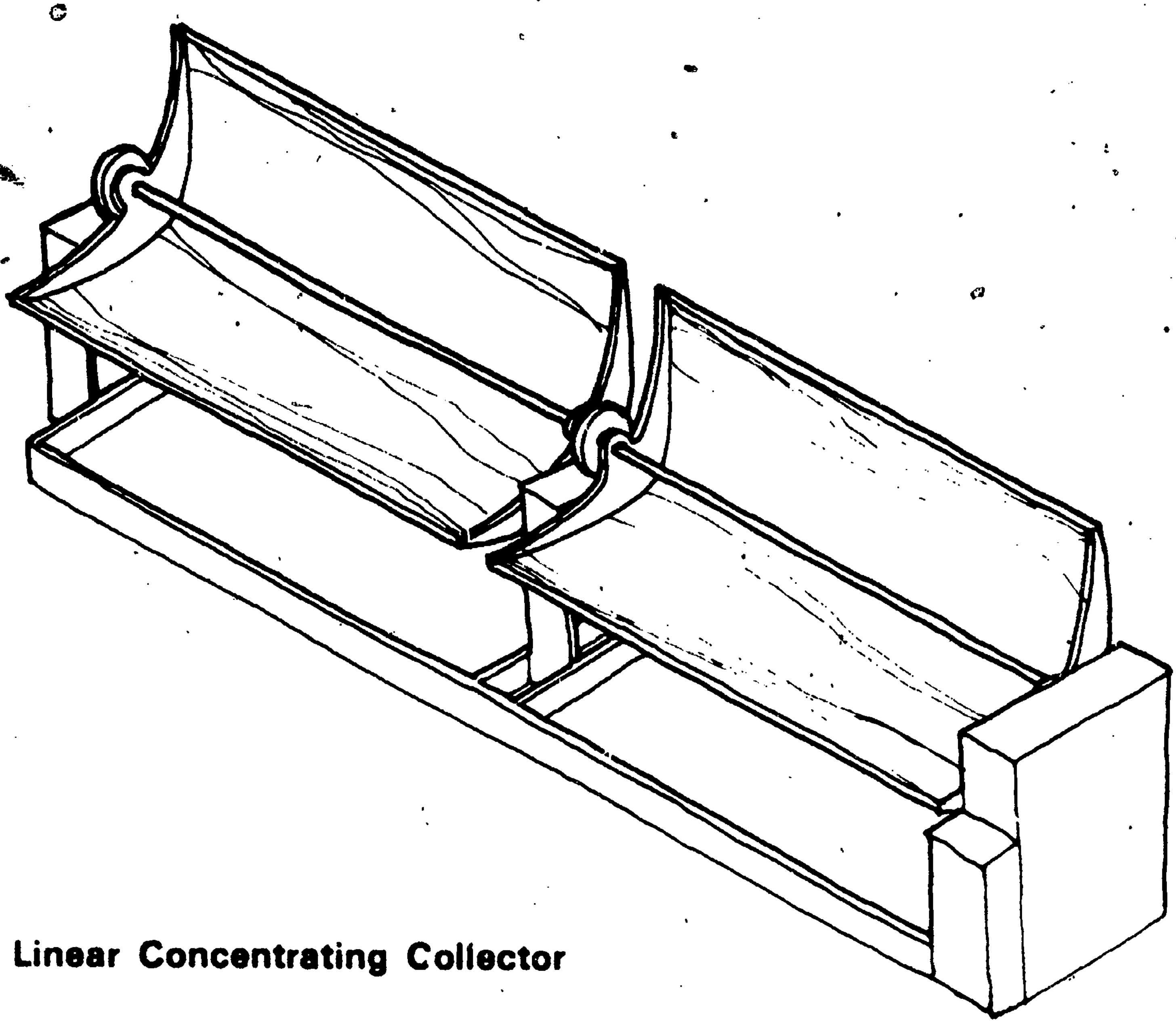


Diagrammatic Section through Flat-Plate Collector

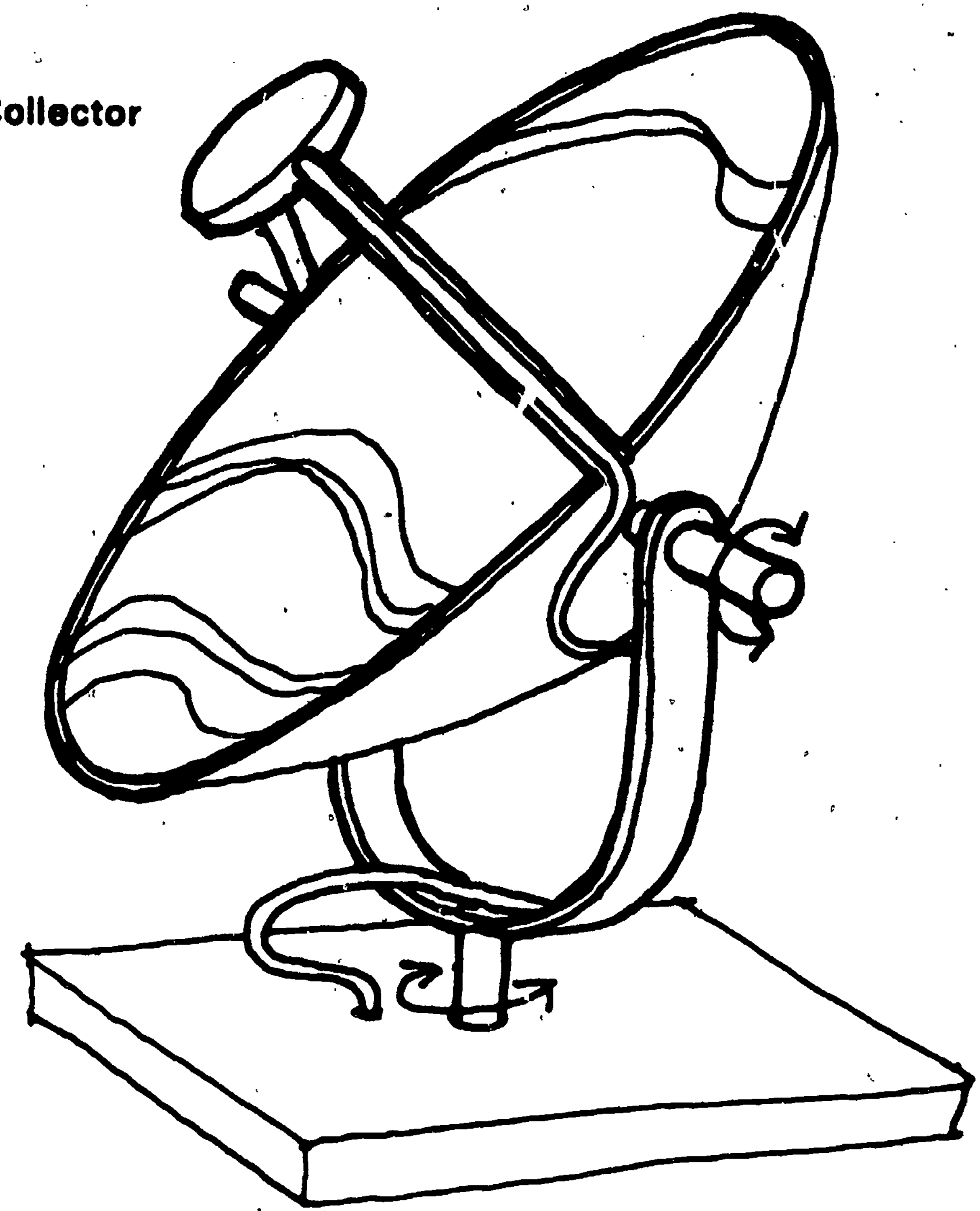
From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



Linear Concentrating Collector

From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

Circular Concentrating Collector



Transparency 4.3

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From AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

UNIT V

STORAGE

UNIT OBJECTIVE

After completion of this unit, the student will be able to name the types of and function of the storage component of a solar energy system. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will learn to

1. Recognize correct statements referring to the storage component.
2. Identify which statements about passive storage are true and which are false.
3. Select from a list the correct advantages and disadvantages associated with each of three types of active storage systems.

Information Sheet *

1. The Storage Component

Energy in the form of direct or diffuse solar radiation will not be available for collection and use at night or on cloudy days. If the solar energy system is to be of value, the energy must be collected when it is available and stored for later use. The heat can be stored by raising the temperature of such substances as rocks, water, concrete, or other masonry. Another method now being investigated is to use the energy to cause changes of state, such as changing a solid to a liquid or a gas.

The type of storage used in a particular system may depend upon the type of collector used for a specific building. However, considerations about storage materials--their cost, operation, and size--must be taken into account in planning the entire solar energy system.

2. Heat Storage in Passive Systems

The solar radiation received from south-facing windows or transparent panels increases the temperature of room air and surfaces exposed to the sun's rays. As such, the room's air and exposed surfaces (walls, floors, furniture) are the solar storage components for a window wall, greenhouse, or transparent panel which collects the radiation. For most situations, the storage capacity of the air and surfaces will not be sufficient for long periods of heating demand. Additionally, in the process of "charging" the storage, the space may become overheated and possibly extremely uncomfortable for the occupants.

In order to reduce the overheating effect, masonry surfaces such as concrete, brick, tile, or stone on the floor or on the walls can be used for their heat storage capacity, absorbing the heat during the day and radiating it later for several hours or more. The storage effect of a particular floor or wall can be calculated as a function of the specific heat of the masonry, its volume and weight, and the expected temperature differences it will experience throughout the day. Too great a storage effect in the exposed room surfaces can have a negative effect on occupant comfort or fuel consumption if the morning "reheat" time of the materials is too

*Adapted from AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

long. However, properly designed, the thermal mass of constru materials can play a significant role in an integrated solar dwelling design.

To use the radiation stored in the air and room surfaces effectively, careful attention must be given to minimizing the loss of heat at night or when collection is not occurring. Insulated drapes, shutters, and other such devices are necessary to reduce heat loss and increase the use of trapped heat through windows. The room size; the window placement; the material composition, volume, and weight; and the expected temperature difference will also determine the performance of the solar storage. The exterior side of masonry walls used for thermal storage should be insulated to prevent heat loss from the walls.

A more direct application of this storage concept involves the placement of a glass or transparent wall over an exposed masonry surface, such as in the Trombe Wall. The exposed surface serves as the collector and as the heat store. The collecting surface is painted a dark color and is located directly behind the transparent surface. The heat transfer and specific heat of the wall material and the expected temperature range will determine the volume of the wall. The radiation time-lag must be accurately calculated to assure proper heating of the space. It is sometimes necessary to place insulation on the room side of the storage wall to avoid overheating the space. The exposed masonry storage method is frequently used in conjunction with interior and exterior vents to control the heat distribution to the space or to another storage system.

A variation of exposing a masonry surface to solar radiatin is to expose containers filled with water. The exposed water containers may be placed just inside a glass south-facing wall. The sides of the containers facing the transparent wall are painted black and serve as collecting surfaces. To retain heat collected in this manner, moveable insulation should be used to cover the south-facing wall at night. Roof ponds function in much the same manner, collecting and storing heat during the daytime. Likewise, the water-filled containers will reradiate heat to the sky at night during the summer and thus can be used for cooling the building as well. Careful calculations are required to properly size the storage capacity. Also, thermal controls such as interior and exterior vents may be necessary to assure a proper lag-time and to avoid overheating.

3. Heat Storage in Active Systems

Rock Storage

Rock storage is most often associated with flat-plate collectors using air as the transport medium. Pebble beds or rock piles contained in an insulated storage unit have sufficient heat capacity to provide heat for extended sunless periods. The rock storage is heated as air from the collector is forced through the rock container by a blower. Rock storage will require approximately 2 1/2 time the volume of water storage, assuming the same temperature range. For example, a rock pile with a void space of one-third the total volume can store approximately 23 Btu/cubic feet/degree F. However, rocks can be used to store heat at temperatures above 212°F.

A convenient rock size for storing solar heat is about two inches in diameter. A decrease in pebble size increases the air flow resistance through the storage and may affect blower and duct size and distribution efficiency. Rock storage does not have to be in close proximity to the collector. However, as the distance increases, the heat transfer losses between the heated air and the rocks also increases and larger air ducts and more electrical power are generally required for moving air between the collector, storage, and heated spaces.

Rock beds, while bulky, require little or no maintenance, and rock is cheap. Hot air gives up its heat quickly to the rocks, and elaborate heat exchangers such as are needed for liquid systems are not needed with air and rock.

Water Storage

Water has the highest heat capacity per pound of any ordinary material. It is also very inexpensive and therefore is an attractive storage and heat-transfer medium. However, it does require a large storage tank which may be expensive. It is sometimes practical to compartmentalize the storage tank to control temperature gradients (different temperatures within the storage tank) and to maintain an efficient heat transfer. Potential disadvantages of water storage include freezing, corrosion, and leakage.

Water storage tanks must be protected from freezing if located outside the dwelling. Also, the tank must be heavily insulated to prevent loss of the stored heat. Steel tanks are subject to corrosion unless rust and corrosion inhibitors are added, but then the water cannot be used for most household purposes. A plastic liner would solve the rust and corrosion problems, but the types of plastic needed to store large quantities of water at high temperatures are expensive. Concrete is safe, durable, and relatively inexpensive; but if a leak does occur, it is difficult to repair.

Heat is generally transferred to and from storage by a working fluid circulated by an electric pump. The heated working fluid itself may be placed in storage or its heat transferred to the storage tank by a heat exchanger. The process of heat transfer to water is more efficient than to rock, and, therefore, less surface for the heat exchanger is required. However, care must be taken to guard against contamination of water intended for household use by the heated working fluid. This warning applies mainly when antifreeze or a rust inhibitor are used in the heat transport medium, for these substances may be toxic.

Systems using a liquid transport and transfer medium are better suited for use with domestic hot water heaters. Thus if the solar energy system is planned to include the use of solar energy for heating water for domestic use, a liquid system may be preferred. Also, the availability of liquid system components makes liquid systems more attractive for the time being. Although air systems were developed earlier than were the liquid systems, the latter have been used more frequently in recent years, which accounts for the availability of components for liquid systems.

<u>Change-of-State Storage</u>

Processes which induce a change of state from a solid to a liquid when heated can be used to store energy. The change in state permits the storage of more heat per pound than if the material did not change composition. When a material such as Glauber's salt is cooled and goes from a liquid to solid state, it gives off this extra heat. This method, however, is still in the experimental state.

The great advantage of change-of-state storage is that it can contain a great amount of heat in a limited space and at limited weight. Let's say that the objective of a storage system is to hold 200,000 Btu's at 100-160° F. Water systems would need 53 cubic feet at 3,300 pounds, rocks would need 175 cubic feet at 17,500 pounds, while Glauber's salt would require only 19 cubic feet at 1,740 pounds. In addition, such salts are obtainable at relatively reasonable prices.

Salt storage, however, has a number of major limitations. The salts can only go through so many cycles before their natural state is altered to the point whereby they lose their capacity to successfully store heat. There are some chemical additions which act to prolong the number of cycles considerably, and there are some interesting experiments which, if successful, may dynamically prolong the life span.

Although salts are economical, present costs for containerization and transportation are fairly expensive. Mass production could bring these costs down dramatically.

ASSIGNMENT SHEET: STORAGE

1. A basement which is below ground and has concrete walls and floor is almost always cold. Large industrial buildings are frequently built with cement walls and concrete floors. The interior space is often very cool or even cold. Does any of the material in this unit offer an explanation as to why? If so, explain.

2. Why would it take large amounts of energy to heat the interior spaces described above?

3. List the advantages and disadvantages of using rock storage.

4. List the advantages and disadvantages of using water storage.

ACTIVITIES--STORAGE

A. Materials Needed

1. A large, well-insulated ice chest (lid off)
2. A clear cover
3. Two thermometers
4. Props for supporting the chest at the latitude angle
5. Five-gallon can painted black, with rubber gasket in screw-top lid
6. Wire
7. Graph paper

B. Procedure

1. Place the chest on the standards with the long axis of the chest pointing east-west and the open top facing south.
2. Using the standards to support the box, tilt the box south at an angle equal to the latitude.
3. Fill the 5-gallon can with water. Be sure the rubber gasket, which can be cut from an inner tube, is flat and in place. Slip the thermometer into a wire holder attached at the back of the 5-gallon can, and place the can in the chest with the thermometer at the top back of the can, i.e., out of the sun. Orient the thermometer so that readings can be taken without uncovering the box.
4. Slip the vinyl cover over the chest--some wire or string or tape should be wrapped around the cover to keep it from blowing off.
5. Hang the air thermometer from a wire at the back of the case, again, out of the sun--in the shadow of the chest.

6a. Read the thermometers every 2 hours throughout a 24-hour period, and record the readings for each thermometer.

b. Read the thermometers at 8:00 a.m. and 8:00 p.m. for 7 consecutive days.

7. Plot the temperature readings for both thermometers over the 24-hour period.

C. <u>What Has Been Learned?</u>

The sun heats the water, but the water loses heat to the surroundings. The water temperature rises on sunny days. The temperature falls during the night or during cloudy weather. On some cloudy days when the clouds are thin and and the sky is bright, the temperature may stay even or rise slightly.

The box does not measure the sunshine or the cold very accurately but it does show the difference and this is what is important to a solar-heated house.

The box is not a model of a solar-heated house. The temperature fluctuates much more in the box than in a house.

1. What differences are there in the temperature readings for the two thermometers?
2. Does the temperature inside the box fluctuate more or less than the temperature outside the box?
3. How do the fluctuations in the two temperature readings relate to each other?

UNIT TEST: STORAGE

1. Check correct statements referring to the storage component with an X.

_____a. If a solar energy system is to be of value, the energy which is collected must be available for later use.

_____b. Heat can be stored in water, rocks, and concrete, among other possible materials.

_____c. Changing a solid to a liquid does not involve the use of energy.

_____d. The type of collector used has no effect on storage.

2. Mark with a "T" those statements about passive storage which are true, and identify with "F" those statements which are false.

_____a. When south-facing windows are used as the collectors, the best storage is the air itself and the furniture and walls.

_____b. To reduce overheating, masonry and concrete walls and floors can be used to store heat.

_____c. Overheating is not a problem in a passive system using south-facing windows to collect heat.

_____d. If the mass of concrete and masonry is too great, fuel consumption from an auxiliary heating system may go up.

_____e. The performance of solar storage in passive systems can be optimized by proper calculation of the storage mass needed.

_____f. It's impossible to calculate the storage effect of exposed room surfaces in passive storage.

_____g. Passive solar energy systems require that there be no windows in the dwelling.

_____h. If exterior masonry walls are used for their heat storage capacity, the internal surface must be well insulated.

_____i. Water can be used as the storage component in a passive energy system.

_____j. Water storage is effective for heating and cooling a dwelling.

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3. Select from the following list the advantages and disadvantages associated with the three types of active storage. Place numbers from the list on the appropriate lines for each type of storage arrangement. Each number may be used more than once.

1. Contains a great amount of heat in a limited space and at a limited weight.
2. Since it is most frequently used, components are readily available.
3. After extended use, the storage capacity is lost.
4. Freezing is a problem.
5. Freezing is not a problem.
6. Corrosion is a problem.
7. Corrosion is not a problem.
8. Leakage is a problem.
9. Leakage is not a problem.
10. Finding an effective storage container is a problem.
11. Container is not a problem.
12. It can store heat at high temperatures.
13. The storage medium is bulky.
14. It has a high heat capacity per pound.
15. Weight is a problem.
16. Maintenance is high.
17. Maintenance is low.
18. It is still in the experimental stages.
19. The medium is inexpensive.
20. Heating of domestic water is easily integrated into the system.

A. Rock Storage

Advantages ______________________________

____

Disadvantages ______________________________

____

B. Water Storage

Advantages ______________________________

____

Disadvantages ____

____

C. Change-of-State Storage

Advantages ____

____

Disadvantages ____

____

11?

ANSWERS TO ASSIGNMENT SHEET AND UNIT TEST V: STORAGE

Answer to Assignment 1

Masonry surfaces and concrete absorb whatever heat is available. In a basement there is no insulation between the wall and the ground, and the heat will move out into the surrounding dirt and thus not be available to reheat the interior space. The mass of the concrete and masonry in an industrial building may be so great that heat cannot be supplied in a sufficient quantity. The heat provided, rather than heating the air, is absorbed by the masonry and concrete.

Answer to Assignment 2

It would take large amounts of energy to heat the interior spaces which are enclosed by cement and masonry because the available heat will be absorbed by these surfaces.

Answer to Assignment 3

Rock Storage

Advantages	Disadvantages
Large heat capacity	Bulkiness of the rocks
Can store heat at high temperatures	Heaviness of the rocks
Low maintenance	Require large space
No leakage	
Inexpensive	
Used with air, exchange is simple	

Answer to Assignment 4

Water

Advantages	Disadvantages
Highest heat capacity per pound	Storage tanks are expensive
Water is inexpensive	Freezing
Heat transfer to water is more efficient than to rock	Corrosion
Heating of domestic water is easily integrated	Leakage

Answers to Unit Test 1

a,b

Answers to Unit Test 2

a. F

b. T

c. F

d. T

e. T

f. F

g. F

h. F

i. T

j. T

Answers to Unit Test 3

A. Advantages 5, 7, 9, 11, 12, 17, 19

Disadvantages 13, 15

B. Advantages 2, 14, 19, 20

Disadvantages 4, 6, 8, 10, 15, 16

C. Advantages 1, 5*

Disadvantages 3, 6*, 8*, 10, 18

* Answer may be omitted.

11j

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UNIT VI

DISTRIBUTION

UNIT OBJECTIVE

After completion of this unit, the student will be able to explain the methods available for transporting the thermal energy to the point of use. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will learn to

1. Recognize correct statements referring to the distribution component.
2. Identify correct statements about distribution processes which make use of the flow of gasses.
3. Identify correct statements about distribution processes which make use of radiation.

Information Sheet*

1. The Distribution Component

Generally speaking, methods by which thermal energy from storage or collector can be distributed to point of use are gas flow and radiation. Within each category there are several techniques by which the distribution of energy to occupied spaces can be accomplished. Some involve mechanical and electrical equipment and processes while others utilize natural convection and radiation. The manner in which solar radiation is collected and stored will usually determine the means of distribution. For example, in a flat-plate collector which employs air as the heat-transport medium and a rock pile to store the heat, distribution is usually accomplished by air.

2. Gas Flow Distribution

Natural Convection

Natural convection is the circulatory motion of air caused by thermal gradients without the assistance of mechanical devices. An example of convection is the motion of smoke towards room lamps--the hot air generated by the lamp rises because it is less dense, and cooler air moves in to replace it.

Natural convection is a useful means of distributing solar thermal energy because it requires no mechanical or electrical input. However, for this same reason, careful attention to design is required to maintain proper control of convective distribution methods. The placement of solar collectors, storage, interior and exterior walls and openings is extremely important for the successful operation of convective distribution.

The operation cycle of natural convective distribution is quite simple. Heat from the collector or storage is supplied to the living space. This process is controlled by the collector or storage design or by wall or floor vents. As the hot air rises to displace cooler air, convection currents similar to those causing winds occur, and the air is distributed through the

*Adapted from AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C.: Government Printing Office, May 1976, pp. 30-31.

space. The air is cooled, becomes dense, and falls toward the floor, where it is captured by cool air return vents, passed through the collector and storage and once again distributed. The cycle will continue as long as there is a temperature difference between the collector/storage components and the room air. When the convection heating cycle is not desired, in the summer for instance, the warmer air may be vented to the exterior.

Forced Air

A forced air system relies on mechanical equipment and electrical energy for the distribution of thermal energy. Design for solar systems is much the same as for conventional forced air systems. However, because solar-produced temperatures in storage are often relatively low, distribution ducts and vents must be larger than those used in conventional heating/cooling systems. Therefore, to achieve maximum efficiency in a solar system, careful attention to the design of air distribution throughout a dwelling is required.

Forced air distribution for solar systems is similar to conventional air distribution. Air from either the collector or storage is blown through ducts to the occupied spaces. The type of solar collector or storage is not the determining factor for selection of a forced air ducted system: the system is adaptable to rock, water, or change-of-state storage components. For rock and containerized change-of-state storage, air is simply blown through the storage to ducts which supply the dwelling spaces. In the case of water storage, a heat exchanger is required to transfer heat from the liquid to air, which is distributed to dwelling spaces.

3. Radiation

Natural Radiation

Radiation occurs as a natural phenomenon. It is the direct emission of energy by a radiation source, and occurs without the need for any intervening substance such as air or water. All of the energy from the sun reaches the earth by radiation through space. Thus, radiation can take place without the assistance of mechanical devices. The radiation properties of the emitting and absorbing surfaces, which are influenced by their temperature, will determine the rate of heat flow between the two surfaces.

Unlike natural convection, which is dependent on differential air temperatures for distribution, natural radiation is dependent on differential surface temperatures. An example of natural radiation is the sun warming a greenhouse on a cold day. The radiant energy is transferred directly to the greenhouse surfaces and is not significantly affected by the cool temperature of the surrounding air. Natural radiation is particularly useful for collector or storage systems which are directly exposed to the occupied spaces. The captured energy can be emitted by natural radiation directly to the room's surface. The walls, floors, and ceiling of a dwelling are used to collect and/or store thermal radiation. The energy will radiate directly to a room's other cooler surfaces.

Forced Radiation

Forced radiant distribution relies on the transfer of heat to air in the occupied spaces by radiation and convection from circulating hot water liquid flow through tubes. For cooling, the forced radiant system is generally used in conjunction with a refrigeration unit which passes chilled water through a fan coil unit located at the point of distribution. A blower is used to force air through the cooled fan coil unit and into occupied spaces.

The piping for the radiant system may be located in the ceiling, floor, or along the wall in fin tube baseboard units. The only significant alteration required of conventional radiant systems for use by solar systems is the enlargement of the radiations surfaces--larger fin tubes or closer spaced ceiling or floor coils--because of lower temperatures from storage.

UNIT TEST: DISTRIBUTION

1. Mark with a "T" those statements which are true, and identify with "F" those statements which are not true.

____A. There are four general methods used for distributing the thermal energy from storage or the collecting surface to the point of use.

____B. Pumps must always be used to force a heated liquid or air through the distribution system in solar heating systems.

____C. The heat transfer medium may determine the type of distribution system used.

____D. The way in which solar radiation is collected and stored may determine how the thermal energy is distributed.

____E. Radiation is the only method for distributing thermal energy.

____F. Natural methods for distributing thermal energy are convection and radiation.

____G. The distribution component of a solar energy system can be accomplished by using mechanical equipment and processes.

____H. Natural heat transfer principles cannot be applied in distributing thermal energy to a house.

2. Indicate which of the following statements apply to natural convection and which apply to forced air. Not all statements may apply.

A. Natural Convection ____________________

B. Forced Air ____________________

1. The two surfaces must be in direct physical contact for heat transfer to occur.

2. When the heating cycle is not desired, the warm air can be vented to the exterior of the building.

3. Distribution is similar to that used in conventional heating systems.

4. No mechanical or electrical input is required if the distribution system is designed carefully.

5. Distribution is controlled by the collector or storage design or by wall or floor vents.

6. Vents and ducts must be much larger than in conventional systems because temperatures are relatively low.

7. The system is adaptable to any kind of storage component.

8. Distribution will occur only if the sun is not shining directly on the surface.

9. Distrib[illegible]on will continue as long as there is a difference in temperature between the collector/storage components and the room air.

3. Indicate which statements below refer to Forced Radiation (FR) and which refer to Natural Radiation (NR). Some statements may refer to both; some may refer to neither method of distribution.

____A. Radiating surfaces, such as fin tubes or ceiling or floor coils, must be larger than in conventional systems.

____B. The walls, floors, and ceiling may be used not only to collect and store the energy but also in the distribution of the energy.

____C. Heat flow is determined by differences in temperature of two surfaces.

____D. Hot water is circulated through tubes in the floor or ceiling.

____E. Heat flow is partially aided by air temperature differentials.

ANSWERS TO UNIT TEST VI: DISTRIBUTION

Answers to Unit Test 1

A. F

B. F

C. T

D. T

E. F

F. T

G. T

H. F

Answers to Unit Test 2

A. Natural Convection 2, 4, 5, 9

B. Forced Air 3, 6, 7

Answers to Unit Test 3

A. FR

B. NR

C. FR, NR

D. FR

E. FR

1̲2

UNIT VII

REPRESENTATIVE SOLAR ENERGY SYSTEMS FOR HEATING HOMES

UNIT OBJECTIVE

After completion of this unit, the student will be able to describe some representative solar energy systems. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student will learn to

1. Associate correct definitions with the new terms in the unit.
2. A. Name and describe the components of a warm-air flat-plate system.
   B. Identify advantages and disadvantages of the system.
3. A. Name and describe the components of a warm-air flat-plate system.
   B. Identify advantages and disadvantages of the system.
4. A. Name and describe the components of a warm-water concentrating system.
   B. Identify advantages and disadvantages of the system.
5. A. Name and describe the components of a warm-air passive system.
   B. Identify advantages and disadvantages of the system.

1. Terms and Definitions

Auxiliary energy system - in addition to the solar energy system, an additional heating system may be installed. These additional systems can range in complexity from an air-tight, woodburning stove to a gas-fired furnace.

Heat transfer medium, or heat transport fluid - a liquid or gas which absorbs heat efficiently and moves the heat away from the collector to storage or to point of use.

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Information Sheet*

2. <u>Warm-Water Flat-Plate System</u>

Solar heating using water as the heat transfer and storage medium is a system which is in common use today. The basic components of a typical water system consist of a collector; storage; a system of piping, pumps, and controls for circulating water from storage through the collector; and a distribution network for transferring stored heat to the dwelling space. The relationship of the various components of a warm-water solar system is diagrammed in Transparency 7.1.

Component Description and Operation

A. Collector. The liquid-cooled flat-plate collector has a flat absorbing surface integrated with transfer fluid piping which collects both direct and diffuse radiation. Energy is removed from the collector by a liquid flowing through conduits in the absorber plate. The transport fluid is pumped to storage, where the heat is transferred to the storage medium (water in this case) and then returned to the collector to absorb more heat. Generally, the transfer fluid is circulated through the collector only when the absorbing surface is hotter than storage (except in instances when snow has covered the collector surface and the heated transport fluid is circulated through the collector to melt it).

B. Storage. Storage consists of either a concrete or a steel tank located near or beneath the building (access should be provided). The tank should be insulated to minimize heat loss. A concrete tank should be lined with a leak-proof material capable of withstanding high storage temperatures for extended periods without deterioration. Heat from the collector is transferred to storage by a heat exchange coil passing through the storage tank. Coil length and size is dependent on expected collector operating temperatures.

*Excerpt from AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976, pp. 32-38.

C. <u>Distribution</u>. The distribution system consists of a pump and pipes which deliver heated water to the occupied spaces. A thermostat controls the operation of water flow or fan coil unit use in each room or dwelling. Baseboard heaters (convectors) require careful evaluation when not used in conjunction with a fan coil unit. Liquid-cooled flat-plate collectors seldom deliver water above 150°F in winter operation without auxiliary energy or reflected surface focusing. For this reason most warm water distribution systems use fan coil units or enlarged convectors.

Energy is transported away from the collector to storage by water or a water-antifreeze solution. Liquid transport fluids should be carefully evaluated before selection. The liquid must absorb heat readily at various collector temperatures and easily give up heat to the storage medium. Additionally, the liquid should not be corrosive to the system components, toxic, or susceptible to freezing or boiling.

A gas-fired conventional boiler is integrated with the solar system to provide an <u>auxiliary energy</u> supply should the solar system fail to function or not meet the dwelling's heating requirement. The distribution piping is run through the boiler where an energy boost may be supplied when temperatures from storage are not sufficient to heat the dwelling adequately.

Domestic hot water piping is run through the central storage tank prior to passing through a conventional water heater. Storage heat is transferred to the hot water piping, thereby either eliminating the need for additional heating or substantially reducing the energy required to raise the water to the needed distribution temperature. The domestic water heating system may operate independent of the space heating system. This is very useful for summer months when space heating is not required.

<u>Advantages of Warm-Water Flat-Plate Systems</u>

1. They have repeatedly been proved to work well.
2. Water is a cheap and efficient heat transfer and storage medium.
3. Piping, as opposed to ductwork, uses little floor space, is easily interconnected, and can be routed easily to remote places and around corners.

4. The circulation of water uses less energy than the circulation of air with corresponding heat content.
5. Much less heat exchanger area is required than with an air system.

Disadvantages of Warm-Water Flat-Plate Systems

1. High initial cost, particularly when expensive prefabricated collectors are employed. With the use of large areas of lower-efficiency collectors, the total system cost may be lowered considerably.
2. Care must be taken to prevent the occurrence of corrosion, scale, or freeze-up capable of causing damage or blockage.
3. Leakage anywhere in the system can cause a considerable amount of damage to the system and to the dwelling.
4. Contamination to the domestic hot water supply is possible if a leak allows treated water storage to enter the domestic water system.

3. Warm-Air Flat-Plate System

Warm-air systems differ from warm-water systems in that air is used to transfer heat from collector to storage. The storage medium can be water, but typically rock piles are used for warm-air systems. Heat, stored in the rock pile, can easily be distributed to the dwelling space by a forced air system. One possible arrangement of a warm-air system is diagrammed in Transparency 7.2.

Component Description and Operation

A. Collector. The-air cooled flat plate collector has a solid absorbing surface and collects both direct and diffuse radiation. Energy is removed from the collector by air flowing in ducts beneath the absorber plate. As shown in the diagram, the system may be operated in four different modes:

1. heating storage form collector
2. heating house from collector
3. heating house from storage
4. heating house from auxiliary energy system

The four modes of operation are regulated by several sets of dampers. One set of dampers will direct air flow from the collector into storage or directly into the occupied spaces while another set will regulate air flow from storage to the occupied spaces. The dampers may be adjusted by manual or automatic controls. During modes two and three, an energy boost may by supplied to the warm air by the auxiliary energy system before the air is distributed to the occupied space. The amount of the energy boost is determined by the temperature of the air passing through the auxiliary heater and the amount of heat required at the point of use.

B. Storage. Storage consists of rocks about two inches in diameter, contained in a concrete bin in a basement area or underground beneath the building. The container is insulated on the earth sides to reduce heat loss. The storage capactiy should be sufficient to provide several days of winter heating.

Because the temperatures in rock storage are typically highly stratified from inlet to outlet, the air flow providing heat to storage should be from top to bottom. This insures that the temperature of air returning to the collector from the storage is as low as possible, thereby increasing collector efficiency. The air flow, when removing heat from storage, should be in the opposite direction to insure that air returning to the rooms is as warm as possible.

C. Distribution. The hot air distributed to the rooms comes either directly from the collectors or from storage. The ducting required to conduct the air from the collectors to storage is extensive when compared to analogous piping requirements for liquid-cooled collectors. Two blowers are required to distribute air throughout the system.

Almost any type of auxiliary energy system can be used in conjunction with a solar system. The auxiliary system may be completely separate or fully integrated with the solar heating/cooling system. However, in most cases it makes economic sense to integrate the back-up system with the solar system. This may mean running the distribution component from heat storage to the occupied space through the auxiliary system where an energy boost may be supplied when storage temperatures are low. Heat from storage may be used in conjunction with a heat pump. The heat pump, a device which transfers heat from one temperature level to another by means of an electrically driven compressor, utilizes the solar heat available from storage to supply necessary heat to the occupied space. The advantage of the heat pump/solar system integration is the reduction of electrical energy required by the heat pump because of heat supplied by solar storage. Also, the heat pump is the most efficient device presently available for extracting and transferring electricity into heat.

Piping for the domestic hot water is run through the rock pile storage bin. As a result the domestic hot water is preheated before passing through a conventional water heater, thus reducing the water heater's energy requirement.

Advantages of Warm-Air Flat-Plate Systems

1. Capital cost tends to be lower than a water system of the same capacity.
2. There is no problem with corrosion, rust, clogging or freezing.
3. Air leakage does not have the severe consequences of water leakage.
4. Domestic hot water supply is not subject to contamination by leakage from heat storage, as in the water system.

Disadvantages of Warm-Air Flat-Plate Systems

1. Ductwork risers occupy usable floor space and must be aligned from floor to floor.
2. Air, having a lower thermal storage capacity than water, requires correspondingly more energy to transfer a given amount of heat from collector to storage, and from storage to occupied spaces.
3. Air collectors and storage may need frequent cleaning to remove deposits of dust (filters may solve this problem).
4. Air systems require a much larger heat exchange surface than liquid systems.

4. Warm-Water Concentrating System

Solar systems with concentrating collectors have not been extensively used for the provision of space heating or cooling. The absence of such equipment from the market is one major reason. In addition the high cost and uncertain reliability of tracking or concentrating equipment in adverse weather conditions has been another primary reason for the limited use of concentrating systems. However, they do offer advantages over flat-plate collectors--primarily the generation of high temperatures to operate heat driven cooling systems.

Representative solar system three utilizes a linear concentrating collector. The system is diagrammed in Transparency 7.3.

Component Description and Operation

A. Collector. The collector is a linear concentrator with a glass-enclosed pipe absorber. The collector captures only direct radiation and is, therefore, limited to climatic regions with considerable sunshine and direct radiation in winter. However, where applicable the linear concentrating collector offers considerable economies over flat-plate collectors since the necessary absorber area is reduced and the assembly is often simpler to construct.

The absorber pipe is a black metal tube within a glass enclosure under vacuum to reduce convection and radiation losses. Radiation is focused on the absorber by a trough-shaped reflector surrounding the pipe.

B. Storage. Storage consists of a steel tank or a lined concrete block enclosure filled with water. Again, the storage unit should be insulated to minimize heat loss. As with most all solar storage techniques, special structural support will be required if the storage tank is to be located in the dwelling.

C. Distribution. The distribution system is by heated water to baseboard convectors. Heat is removed from storage by liquid-to-liquid heat exchanger. The heated water is pumped to baseboard convectors located throughout the building. If storage is below a preset minimum temperature, the pump continues to operate with a conventional oil or gas-fired furnace assist in the liquid distribution.

As shown in the system diagram, collector fluid transport is by means of a pump which causes the fluid to flow through the absorber and into the

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storage heat exchanger, from which energy is removed and transferred to storage. The working fluid should be a heat transfer medium which has excellent transport properties and a boiling point above the expected operating temperature of the collector.

Domestic hot water piping is run through a heat exchanger in storage, thus preheating the water, before it proceeds to a conventional water heater which also provides storage. The water heater may or may not supply a boost to the water depending on its temperature.

Advantages of Warm-Water Concentrating Systems

1. Potential for more than double the temperatures of either air or water flat-plate collectors (particularly useful for solar cooling).
2. Total absorber area needed is substantially smaller than flat-plate collectors.
3. Collector forms lend themselves to mass production techniques.
4. Water requires less piping and storage space than air.
5. Water is a cheap and efficient heat transfer and storage medium.

Disadvantages of Warm-Water Concentrating Systems

1. Capital cost of collectors at present is greater than either air or water flat-plate collectors.
2. Concentrating collectors may present problems of operation, reflecting surface durability, and structural mounting.
3. Leakage at flexible absorber connections may present possible problems.
4. Climatic applicability for winter space heating is limited because only direct radiation can be collected.

5. Warm-Air Passive System

The passive system described here is one possible concept among many. It makes use of extensive south-facing glazing with an intermediate collection/storage wall between the glazing and the occupied space. It relies in part on thermosyphoning. Diagrammatically, the passive system can be represented as illustrated in Transparency 7.4.

Component Description and Operation

A. Collector. The passive collector, made up of a massive south-facing wall of either concrete or masonry separated by an air space from an outer wall of glass, captures direct, diffuse, and reflected solar radiation. With the use of automatic or manually operated dampers and vents, the system may operate in four modes.

1. natural ventilation--no collection
2. house heating from collector
3. storage heating from collector
4. house heating from collector and storage

When no collection or heat distribution is required, the vents and dampers may be opened to provide natural ventilation and removal of heat striking the collector. The space may be heated directly from the collector by closing the storage vent duct, thus forcing the heated air into the occupied space. Once sufficient heat has been transferred to the space, the storage vent may be opened and heated air from the collector transmitted to storage. If heat is required at a later time, the storage vent may be opened to allow stored heat to enter the occupied space.

B. Storage. The system employs several storage concepts. The exposed masonry wall which the radiation strikes acts as a storage element. The warmed masonry surface transmits collected heat to the occupied space by radiation. The second storage element is a rock pile located beneath the occupied space. Insulation is placed between the rock pile and floor surface to avoid overheating the space. Water or containerized salts (change-of-state storage) could also have been used as the storage medium.

C. Distribution. Heat is distributed to the occupied spaces from the collector or storage component. Ducting is required to transport the heated air from the collector to storage, and a small fan may be necessary to circulate this air. Heat is distributed to the space by convection from the collector and/or storage, by radiation from the collector and surrounding surfaces, and to a small degree, by conduction from the collector and surrounding surfaces.

Domestic water heating is not directly integrated in the solar space heating system. However, a storage tank or the domestic hot water piping may be placed in the rock pile storage to preheat the water before it passes through a conventional electric or gas water heater.

Advantages of Warm-Air Passive Systems

1. A system with electrical controls can be designed to operate manually in a power failure.
2. Cost should be reduced through simpler technology and elimination of a separate collector.
3. Collector serves multiple functions (i.e., can be a wall or roof).

Disadvantages of Warm-Air Passive Systems

1. May not be cost effective relative to warm air or water flat-plate collector systems.
2. In many cases, require automatic or manual insulating devices which are expensive and may require life style modification.
3. Larger unobstructed area needed to the south of the house for a vertical passive collector than for a roof collector.
4. In some climates and for some passive systems, low winter sun angles may be disturbing to the occupants.
5. Potential problems of occupant-privacy for passive systems with large expanses of south-facing glass.
6. Potentially large nighttime thermal losses from collector if not properly insulated.

ACTIVITIES--REPRESENTATIVE SOLAR ENERGY SYSTEMS FOR HEATING HOMES

Activity 1

A. From the matrix below, choose components and a heat transport fluid for a hypothetical active solar energy system. Anticipate possible advantages or disadvantages which might be associated with the system. Consider some systems which were not discussed in the information section of this unit.

		Heat Transfer Fluid	
	Components	Air	Liquid
Collectors	Flat-Plate: Air, Open H_2O, Liquid Concentrating: Linear, Circular		
Storage	Water Rock Change-of-State		
Distribution	Forced Liquid (Radiation) Forced Air		

B. A system is defined as a group of components forming a unified whole. In performing step A, above, did you find that choosing one component restricted your choice of the other components? In your own words, explain why your choice might become more restricted as each component is added.

Activity 2

A similar matrix for components of a passive system are shown below.

	Components	Heat Transfer Medium: Air	Fluid
Collector	South-facing Windows Clerestory Windows Trombe Wall Water Ponds Greenhouse		
Storage	Floor Walls Water Ponds		
Distribution	Convection Radiation Conduction		

Why cannot this matrix be used in a manner similar to the matrix in Activity 1?

UNIT TEST: REPRESENTATIVE SOLAR ENERGY SYSTEMS

1. Match terms with the correct definitions

____a. Heat transfer medium

____b. Auxiliary energy system

1. Supplementary heat source other than solar.

2. A liquid or gas which absorbs heat readily--is used to move heat away from the collector.

2. A. Name and describe briefly the components of a warm-water flat-plate system.

1. ____

____

2. ____

____

3. ____

____

B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-water, flat-plate system. Not all statements will be applicable (NA).

____1. Leakage could be a problem.

____2. Corrosion could be a problem.

____3. Can use only direct radiation.

____4. Circulation of water uses less energy than the circulation of air with the same amount of heat content.

____5. Freezing is a potential problem.

____6. Initial cost is high.

____7. Less heat exchanger area is required than with an air system.

____8. Piping takes up less space than does duct work.

____9. The reflector surface must be kept clean.

____10. Water is a cheap and efficient heat transfer and storage medium.

3.A. Name and describe briefly the components of a warm-air flat-plate system.

1. ______________________________

____

2. ______________________________

____

3. ______________________________

____

B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-air flat-plate system. Not all statements will be applicable (NA).

____1. Leakage is not a problem.

____2. Corrosion is not a problem.

____3. Only direct radiation can be used.

____4. The collectors and storage may need frequent cleaning.

____5. Cost of equipment tends to be lower than with a water system of the same capacity.

____6. More energy is required to transfer heat if air is used as the heat transport medium.

____7. Ductwork requires a greater amount of space than does piping for fluids

____8. The reflector surface must be kept clean.

____9. A larger heat exchange surface is needed for air than is needed for liquids.

____10. The system does not require complicated controls.

4.A. Name and describe briefly the components of a warm-water concentrating system.

1. ______________________________

____

2. ____

____

3. ____

____

B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-water concentrating collector. Not all statements will be applicable (NA).

____1. Leakage may present problems.

____2. The reflector surface must be kept clean.

____3. Water is a cheap and efficient heat transfer and storage medium.

____4. Only direct radiation can be collected.

____5. Higher temperatures can be obtained than can be obtained with flat-plate collectors.

____6. The absorber area needed is smaller than that needed with flat-plate collectors.

____7. Ductwork must be large.

____8. Costs could be lower because the collector forms lend themselves to mass production techniques.

____9. At present, concentrating collectors are more expensive.

____10. In climates with many sunless days, the system may not be applicable.

5.A. Name and describe the components of a warm-air passive system.

1. ____

____

2. ____

____

3. ____

____

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B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-air passive system. Not all statements will be applicable (NA).

____1. Automatic or manual insulating devices are expensive.

____2. Life style may need to be modified.

____3. Cost should be reduced through simpler technology.

____4. Elimination of separate collector should reduce cost.

____5. A vertical passive collector will require a larger unobstructed area for access to the sun.

____6. Ductwork is expensive and takes up a large amount of space.

____7. Leakage may be a problem.

____8. May not be cost-effective relative to air- or liquid-cooled collectors.

____9. Collector serves multiple functions.

____10. Large expanses of south-facing glass may cause problems about occupant-privacy.

ANSWERS TO UNIT TEST: REPRESENTATIVE SOLAR ENERGY SYSTEMS

Answers to Unit Test 1

A. 3
B. 8
C. 7
D. 5
E. 1
F. 2
G. 4
H. 6

Answers to Unit Test 2

A. 1. Liquid-cooled flat-plate collectors have a flat absorbing surface to absorb both direct and diffuse radiation. The heat transfer fluid is piped across the absorbing surface.

2. Hot water is stored in an insulated concrete or steel tank. Heat from the collector is transferred to storage by means of a heat exchange coil.

3. Distribution is accomplished by pumping the hot water from storage through pipes to baseboard heaters.

B. 1. D
2. D
3. NA
4. A
5. D
6. D
7. A
8. A
9. NA
10. A

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Answers to Unit Test 3

A. 1. The air-cooled flat-plate collector has a solid absorbing surface to collect direct and diffuse radiation. Air is pumped through the collector.

2. The hot air is blown into the rock storage. The rocks are about 2 inches in diameter and the container is insulated.

3. The hot air is pumped through ducts to the rooms.

B. 1. A

2. A

3. NA

4. D

5. A

6. D

7. D

8. NA

9. D

10. NA

Answers to Unit Test 4

A. 1. The linear collector captures only direct radiation, which the reflecting surface concentrates on a glass-enclosed pipe. The pipe, usually painted black, is the absorber. The heat transfer medium circulates through the pipe.

2. The storage unit is a well-insulated, leak proof tank for storing hot water.

3. Distribution is accomplished by pumping the heated water to baseboard heaters located throughout the building.

B. 1. D

2. D

3. A

4. D

5. A

6. A

7. NA

8. A

9. D

10. D

Answers to Unit Test 5

A. 1. The collector is a massive south-facing wall of masonry or concrete separated by an air space from an outer wall of glass. It will capture reflected, direct, and diffuse radiation (a Trombe Wall).

2. Storage is the exposed wall, a rock pile under the floor, and other internal surfaces which absorb heat radiated from the south wall.

3. Distribution is by convection, radiation, and conduction. Also heated air is transported through ducts to storage and from storage to the living space. A small fan may be needed to assist natural means of heat transfer.

B. 1. D

2. D

3. A

4. A

5. D

6. NA

7. NA

8. D

9. A

10. D

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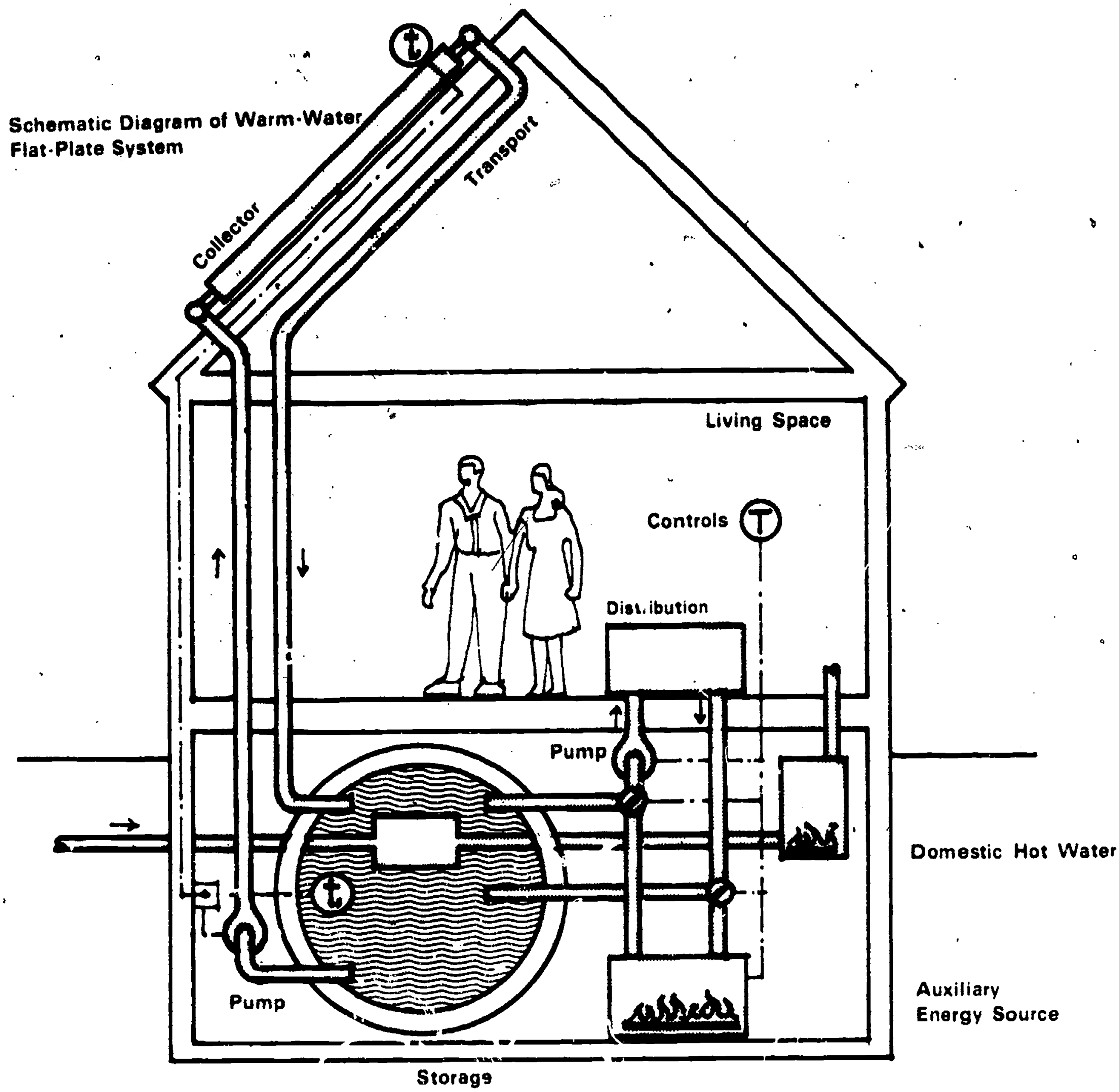

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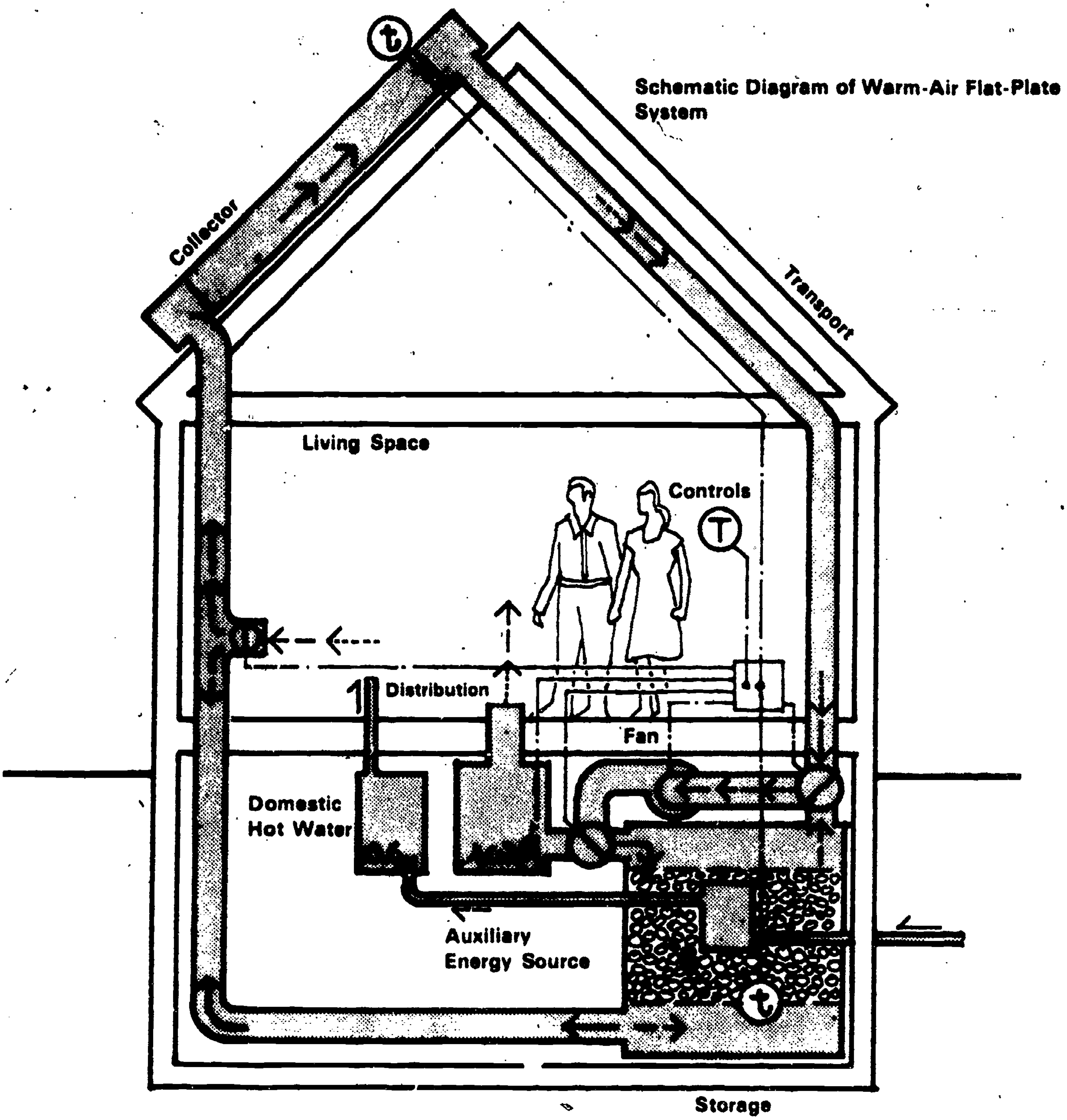
Transparency 7.2



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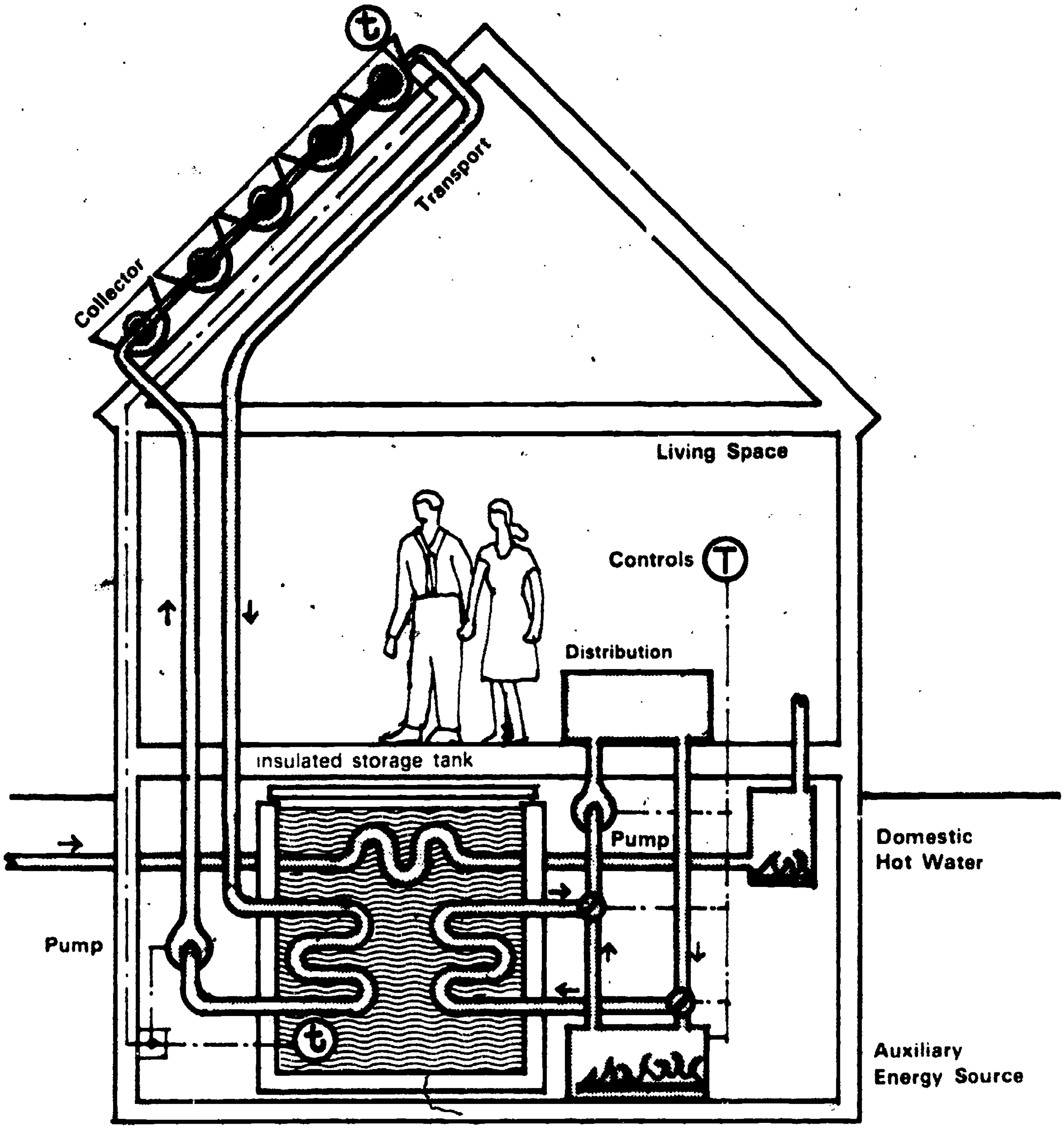
Transparency 7.3

Schematic Diagram of Warm-Water Concentrating System



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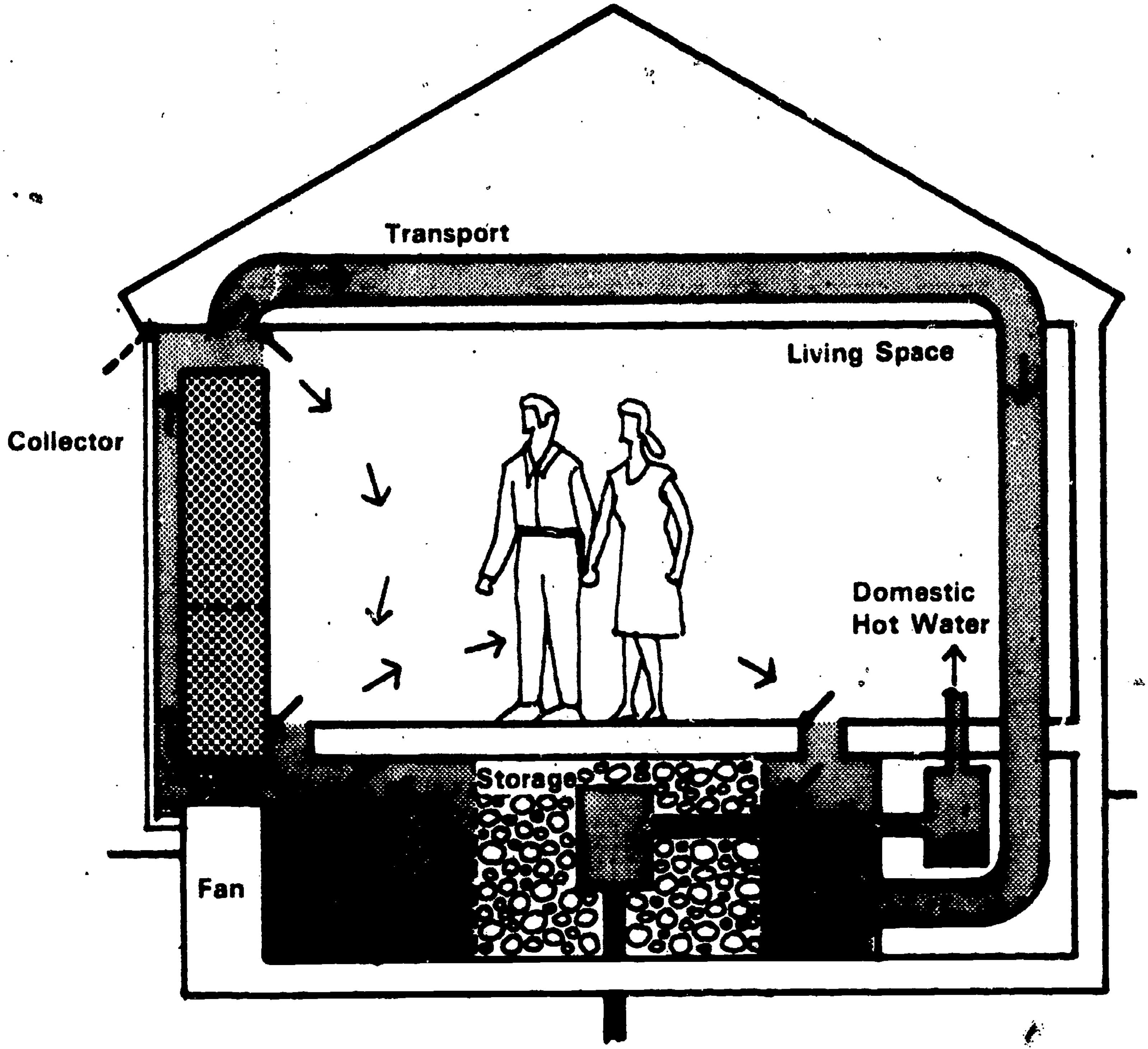
Warm Air Passive System



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GLOSSARY

Active Solar Energy System - thermal energy is transported from the collectors to storage and then to the distribution system in a regulated way, using mechanical pumps and thermal controls.

Air-Cooled Collector - a type of flat-plate collector in which air is used as the heat transport medium..

Angle of Declination - see Declination angle.

Angle of Incidence - see Incidence angle.

Beadwall - a patented insulated window in which polystyrene beads are blown into or pulled out of a space between two sheets of glass or plastic by a vacuum-driven system.

Biomass conversion - energy from the sun is stored through the process of photosynthesis in plants, i.e., in organic material. Chemical processes can be used to change the organic material to simpler forms with an accompanying release of energy.

Btu - British thermal unit, a measure of heat.

Change-of-state - the physical form of matter changes from solid to liquid to gas. For example, water can be changed to a solid (ice) or a gas (steam). When changes of state occur, energy is either used or released in the process.

Circular Concentrating Collector - a type of concentrating collector which is circular in shape so that the affected solar radiation is focused on an absorbing surface.

Clerestory Window - a south facing window in the wall of a room which rises above an adjoining roof; the window can be used to admit solar radiation.

Collector - the component in a solar energy system which receives solar radiation and converts it to heat.

Collector-tilt - the angle measured from the horizontal at which a solar collector is tilted to face the sun for better performance.

Concentrating Collector - a class of collectors which use reflectors to focus solar radiation on a small area.

Conduction - Heat flows through different materials at varying rates. Copper is an excellent conductor of heat; insulating materials are poor conductors. Heat transfer by conduction occurs only when two surfaces are in direct physical contact because heat transfer is caused by molecular scale vibration.

Convection - when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

Convection - when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

Declination angle - the angle between the plane of the earth's rotation around the sun and the earth's equatorial plane in a direction facing the sun.

Diffuse radiation - the solar radiation striking the surface of the earth after its direction has been changed by reflection and scattered by particles in the atmosphere--nondirectional rays.

Direct radiation - direct or parallel rays from the sun.

Distribution - the component in a solar energy system whereby the thermal energy in storage is made available at the point of use.

Earth-Sunline - an imaginary line between the center of the sun and the center of the earth.

Energy - the ability to do work.

Equatorial plane - an imaginary plane through the earth's equator and perpendicular to the north-south axis.

Fenestration - the placement, size, and design of windows and doors in a building.

Flat-Plate Collector - a class of collectors so named because of the large surface area exposed to the sun.

Heat-transport fluid - a liquid or gas which absorbs heat efficiently and moves the heat away from the collector to storage or to point of use. Also called heat transfer medium.

Incidence Angle - the angle between the line for direct rays and a line perpendicular to the irradiated surface.

Insolation - the amount of solar radiation actually striking the surface of the earth.

Irradiation - exposure to radiant energy.

Latitude - the angular distance north or south from the earth's equator measured through 90°.

Linear Concentrating Collector - a type of concentrating collector, oblong in shape, which focuses the reflected radiation onto a tube through which the transport medium is circulated.

Liquid-Cooled Collector - a type of flat-plate collector in which the liquid used as the heat transport medium, is piped through the collector box.

Nonrenewable energy source - a substance found in nature which cannot be replenished and which can be used to obtain energy in some form. Coal, gas, uranium are examples of nonrenewable energy sources.

Open-water collector - a type of flat-plate collector in which the heat transport medium, usually water, is trickled down grooves rather than piped through the collector.

Passive Solar Energy System - heat is transported by natural means, and the components are typically integrated into the basic design of the dwelling, so that few, if any, mechanical devices are needed in the system.

Photovoltaic - direct conversion of the sun's energy to electricity.

Radiation - any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Renewable energy source - a substance which occurs in nature and the supply of which cannot be depleted by use.

Solar Altitude - the angle of elevation of the sun above the horizon.

Solar Azimuth - the angle on a horizontal surface which measures the difference between the direction of a fixed point (e.g., true south) and the direction of the sun.

Solar Constant - the amount of solar energy striking the outer atmosphere of the earth varies only slightly and can be treated as a constant.

Solar Energy System - a grouping of parts designed to use energy from the sun. The parts, or components, are the collector, storage, and distribution. One or several components may themselves by sub-systems, i.e., systems within the system.

Solar Noon - that time of day when the azimuth angle is 0^{o}, when the sun is due south of an observer.

Storage - the component in a solar energy system whihc retains th solar energy which has been collected for later use either at night or on cloudy days.

System - a regularly interacting (or interdependent) group of components forming a unified whole.

Thermal pollution - the discharge of heated waste into the natural environment at a temperature detrimental to existing ecosystems.

Thermosyphoning - the principle that heated gasses and liquids rise naturally has been applied as a means of heat transport in passive solar energy systems. Heat built up within a wall or roof structure can be drawn off to heat interior spaces.

Transmittance - the fraction of solar radiation which having entered a layer of absorbing material, flows to its further boundary.

Trombe Wall - a type of passive collector which makes use of a massive masonry wall, painted black and placed behind a south-facing wall of glass. Air trapped between the wall and the glass is heated, moves up over the wall and into the interior space.

Watts - a measure of power in the metric system (e.g., a 25-watt light bulb).

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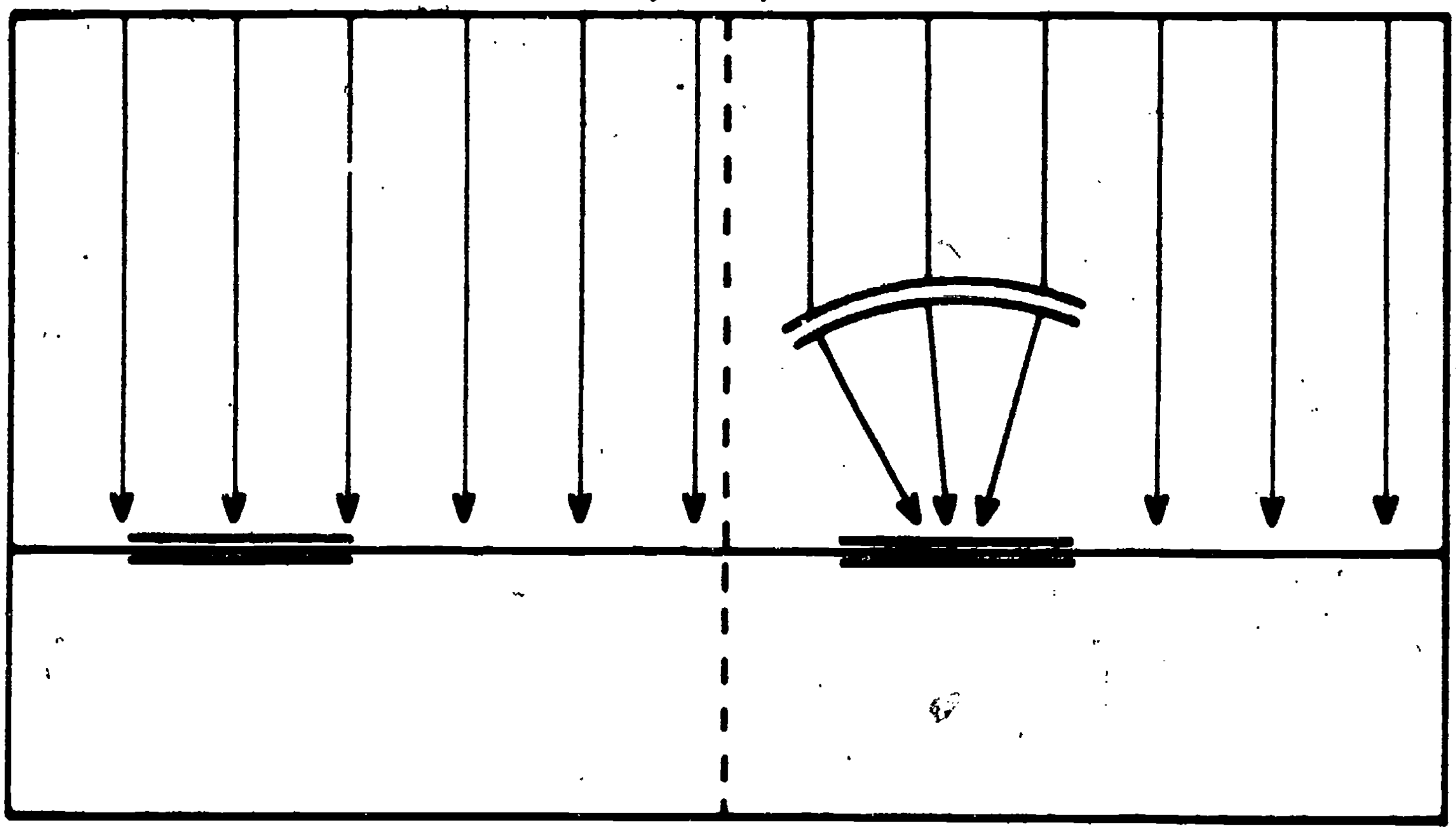
Transparency 1.1



1. SOLAR CONSTANT

THERE IS A NEARLY CONSTANT AMOUNT OF SOLAR ENERGY STRIKING THE OUTER ATMOSPHERE — 429 BTU PER S.F PER HOUR — AND THIS QUANTITY IS KNOWN AS THE SOLAR CONSTANT

NOTE

You cannot increase the amount of solar energy striking a collector of a given size by focusing You may increase the collector's efficiency or the temperature of the working fluid

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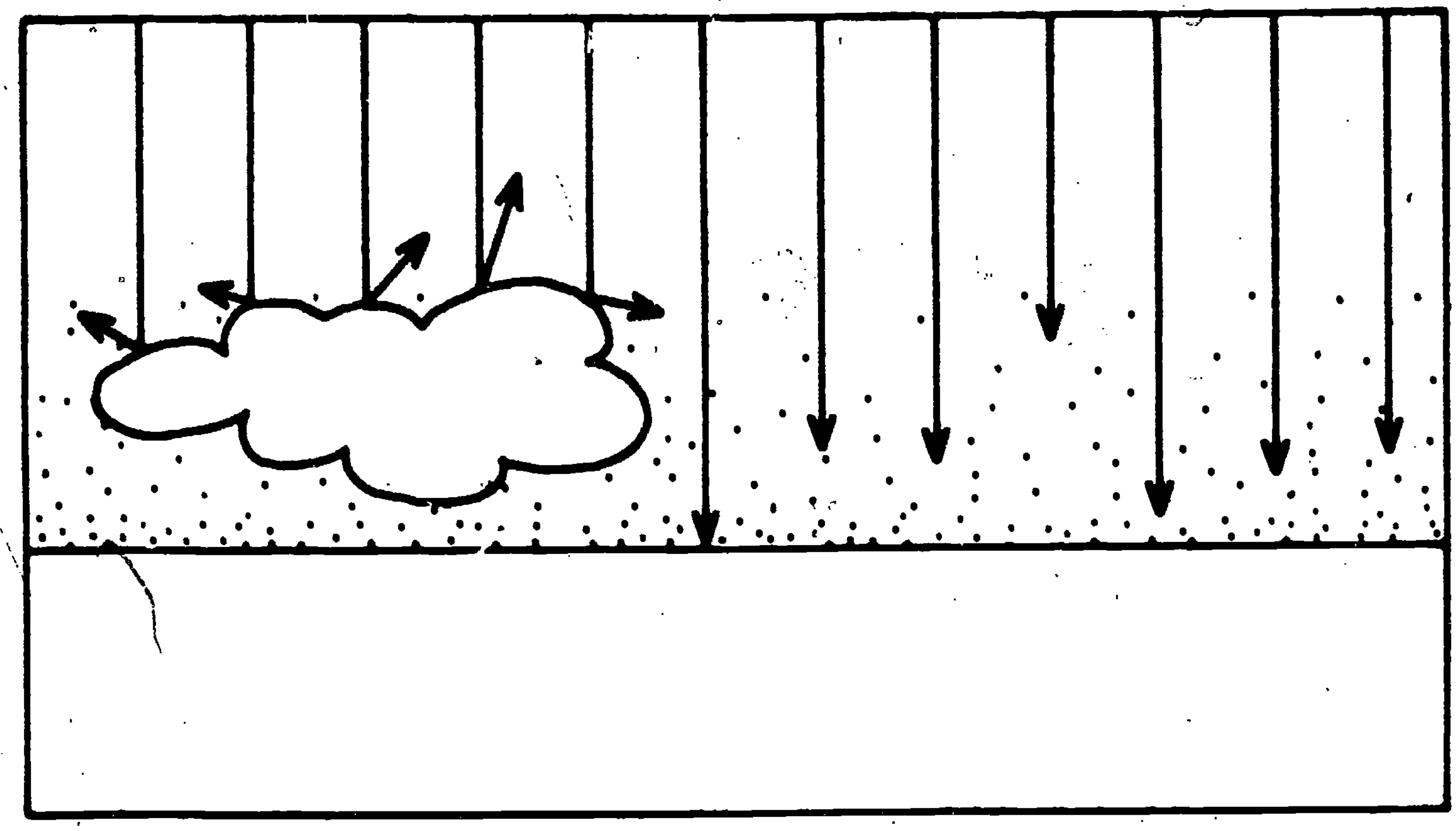

4. ABSORPTION AND REFLECTION

NEARLY HALF THE SOLAR RADIATION ENTERING THE EARTH'S ATMOSPHERE IS LOST THROUGH ABSORPTION BY MATERIAL IN THE ATMOSPHERE OR BY REFLECTION FROM CLOUDS.

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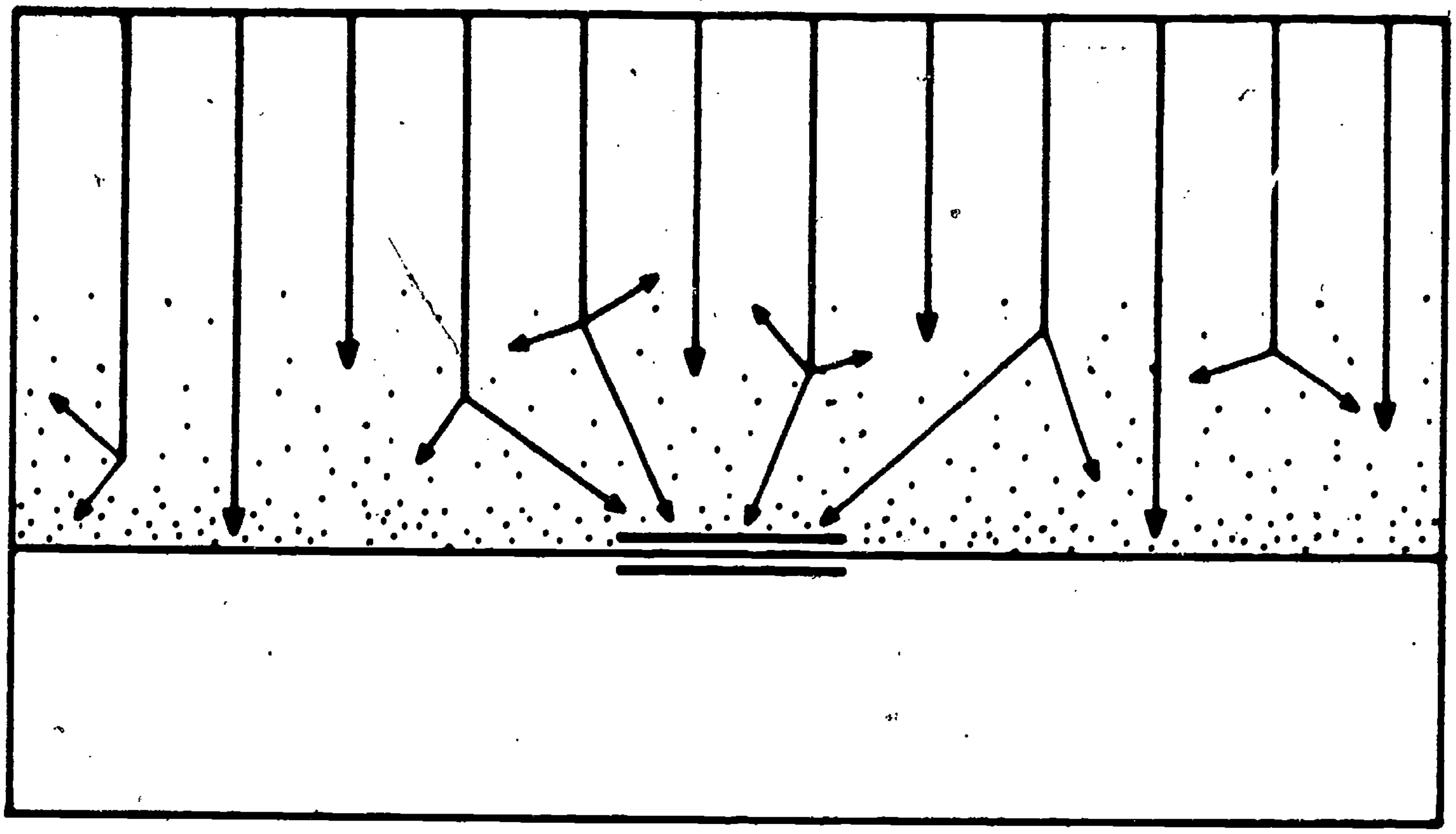
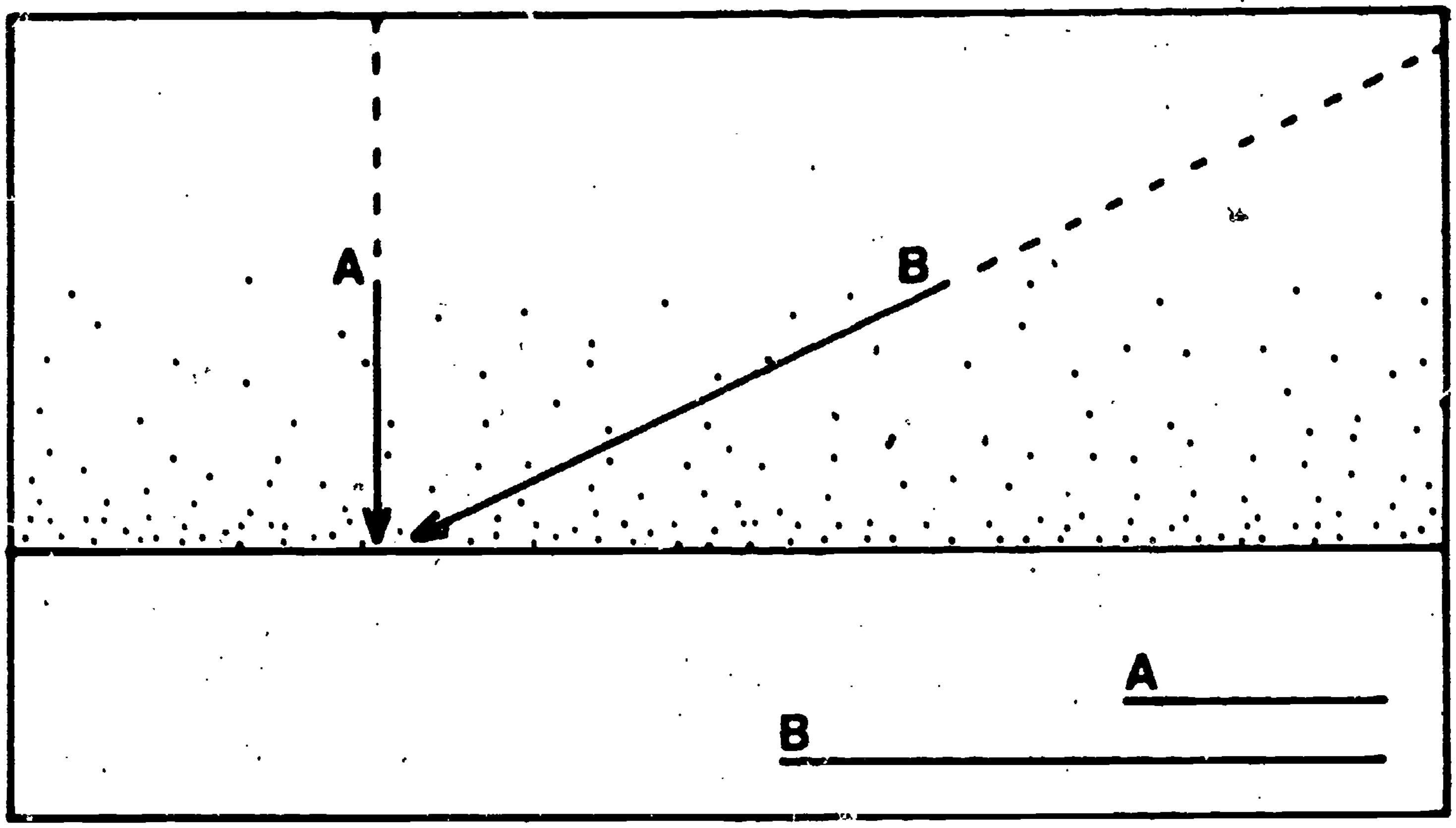


6. DIFFUSE RADIATION

CLOUDS AND PARTICLES IN THE ATMOSPHERE NOT ONLY REFLECT AND ABSORB SOLAR ENERGY, BUT SCATTER IT IN ALL DIRECTIONS BECAUSE OF THIS, SOLAR ENERGY IS RECEIVED FROM *ALL PARTS* OF THE SKY — MORE SO ON HAZY DAYS THAN ON CLEAR DAYS SUCH RADIATION IS CALLED *DIFFUSE*, AS OPPOSED TO THE NORMAL *DIRECT* RADIATION

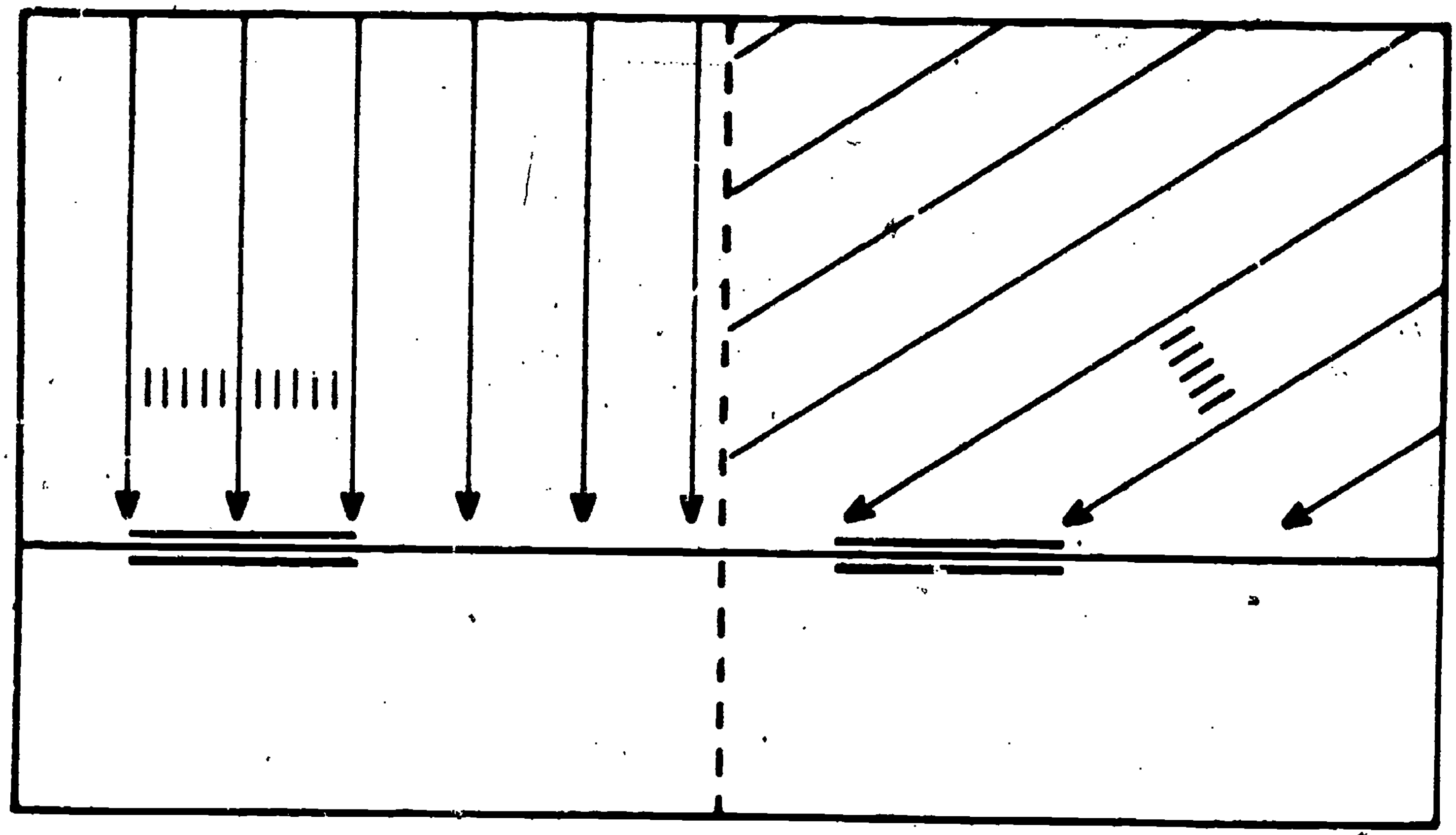
AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



5. LENGTH OF TRAVEL THROUGH THE ATMOSPHERE

MORE SOLAR RADIATION IS LOST BY ABSORPTION AT LOW SUN ANGLES BECAUSE THE LENGTH OF TRAVEL THROUGH THE ATMOSPHERE IS GREATLY INCREASED (THAT IS WHY YOU CAN LOOK DIRECTLY AT THE SUN AT SUNSET.) HIGH ALTITUDES HAVE MORE SOLAR RADIATION FOR THE SAME REASON.

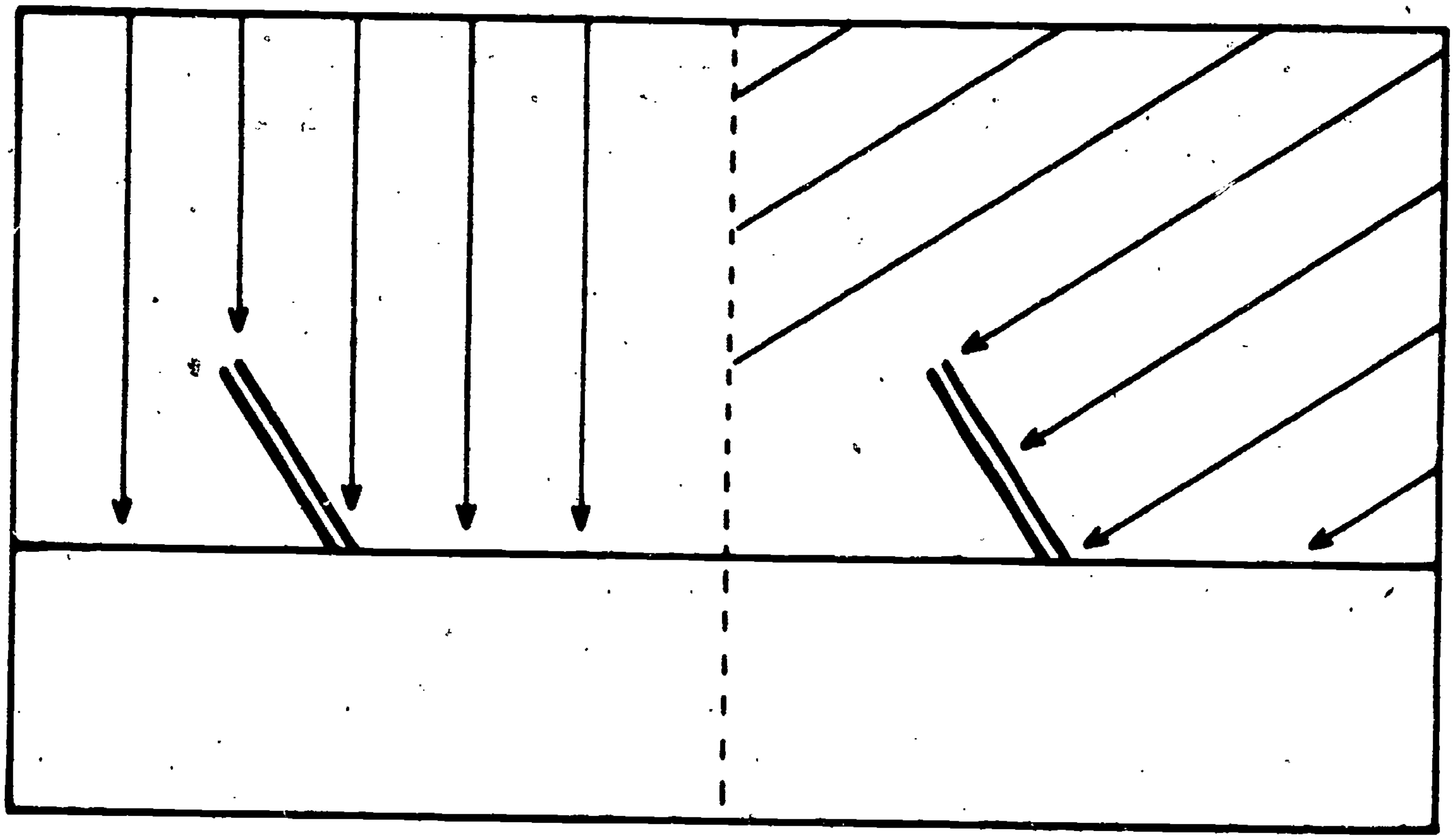
AIA Res ›rch Corporation, Solar Dwelling Design Concepts, Washington, D.C., .vernment Printing Office, May 1976.



2. COSINE LAW — HORIZONTAL SURFACE

LESS SOLAR RADIATION STRIKES A GIVEN HORIZONTAL AREA AS THE SUN GETS LOWER IN THE SKY THE AMOUNT CHANGES BY THE COSINE OF THE ANGLE, MEASURED FROM DIRECTLY OVERHEAD

AIA Research Corporation, Solar Dwelling Design Concepts, Washi ...on, D.C., Government Printing Office, May 1976.



3. COSINE LAW — TILTED SURFACE

THE SAME LAW APPLIES TO A TILTED SURFACE, SUCH AS A SOLAR COLLECTOR. BY TILTING THE COLLECTOR SO THAT IT IS MORE NEARLY PERPENDICULAR TO THE SUN, MORE ENERGY STRIKES ITS SURFACE.

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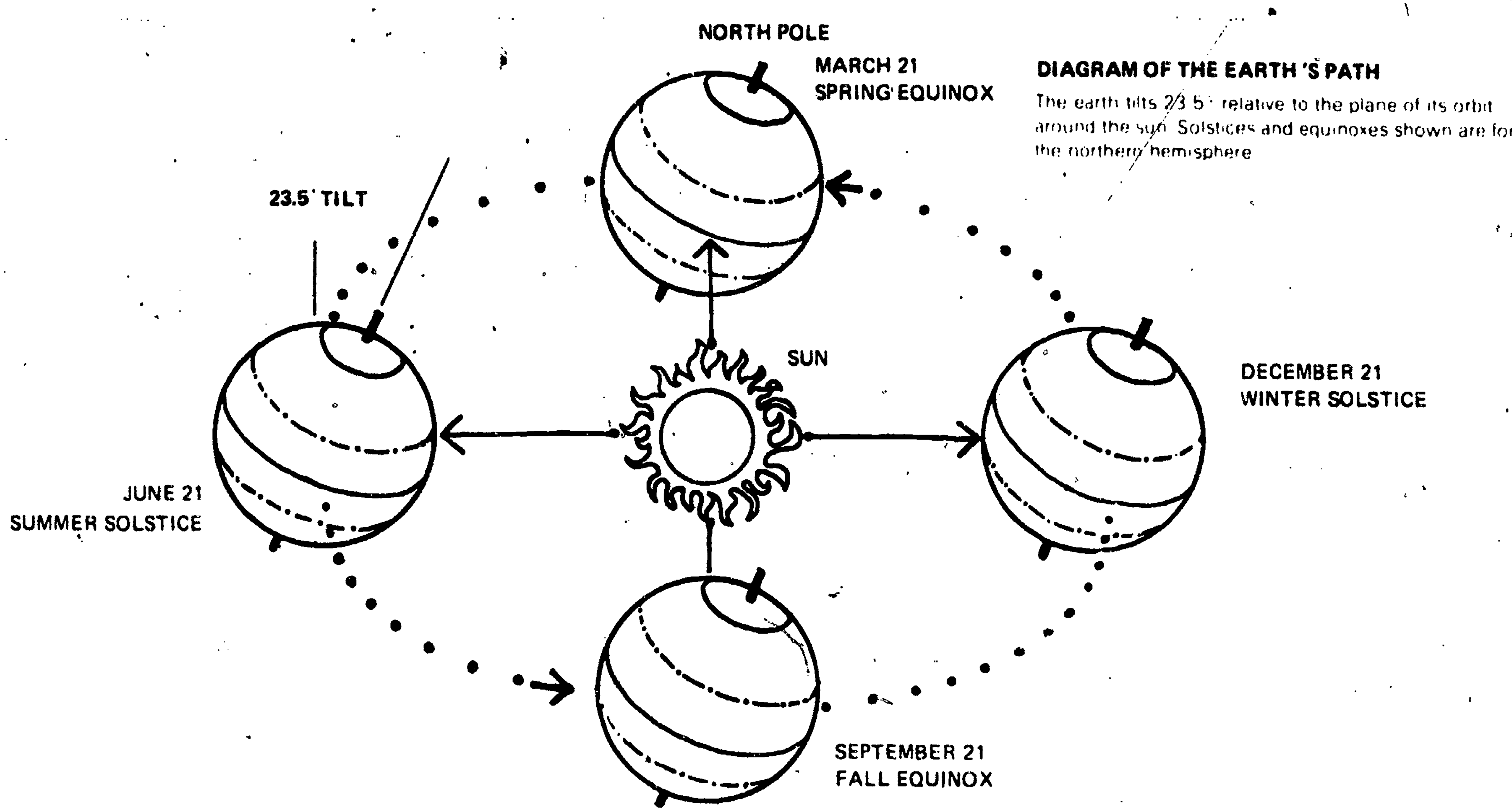
Transparency 2.1



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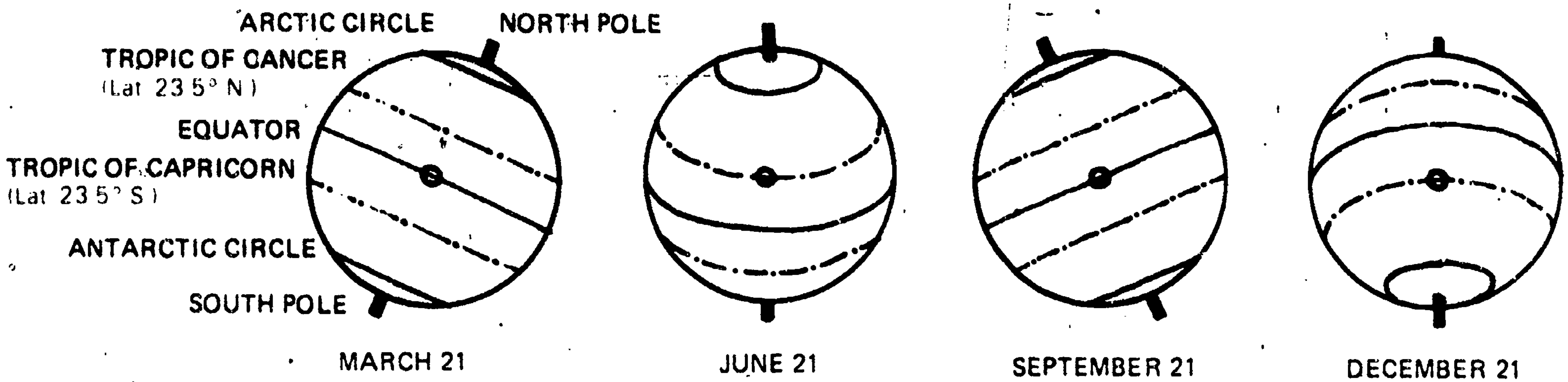

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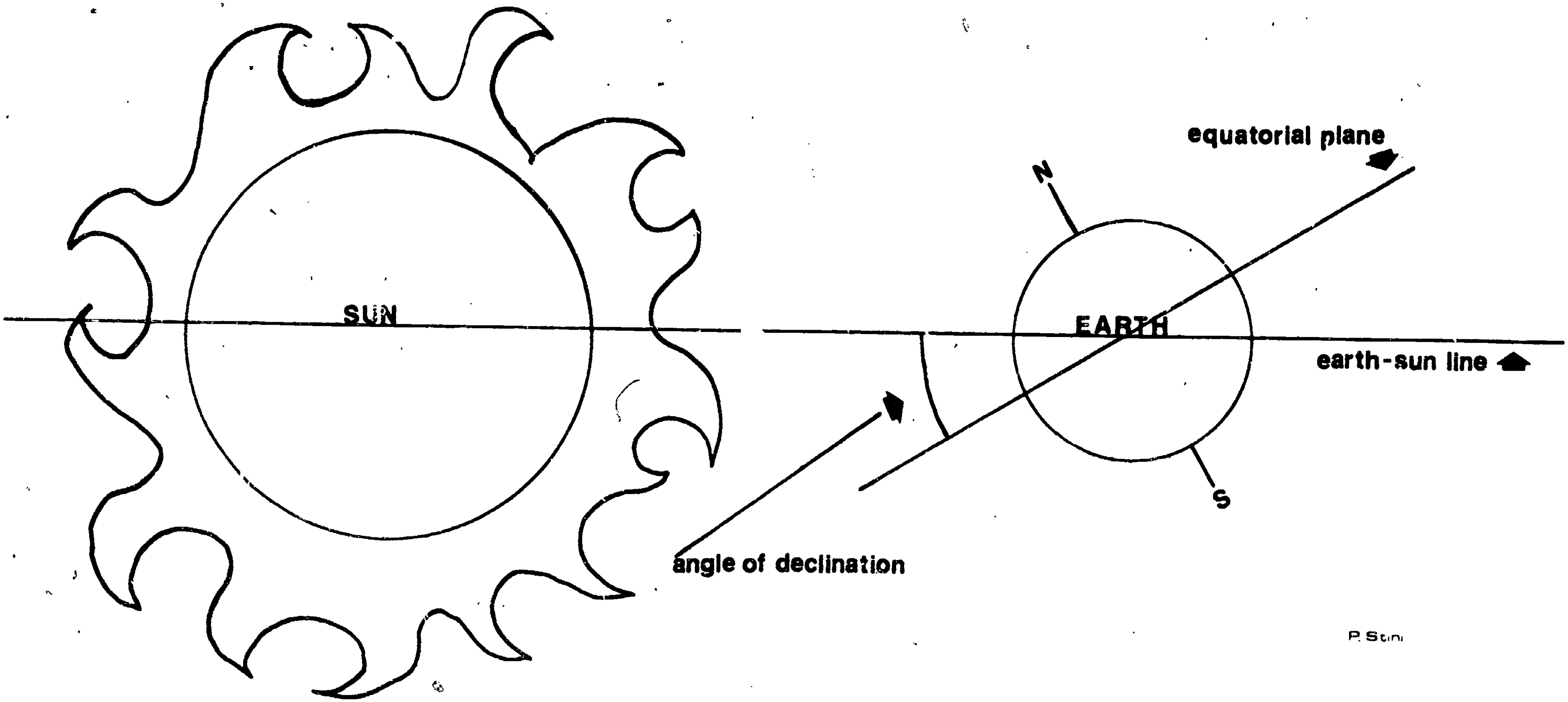
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EARTH
N
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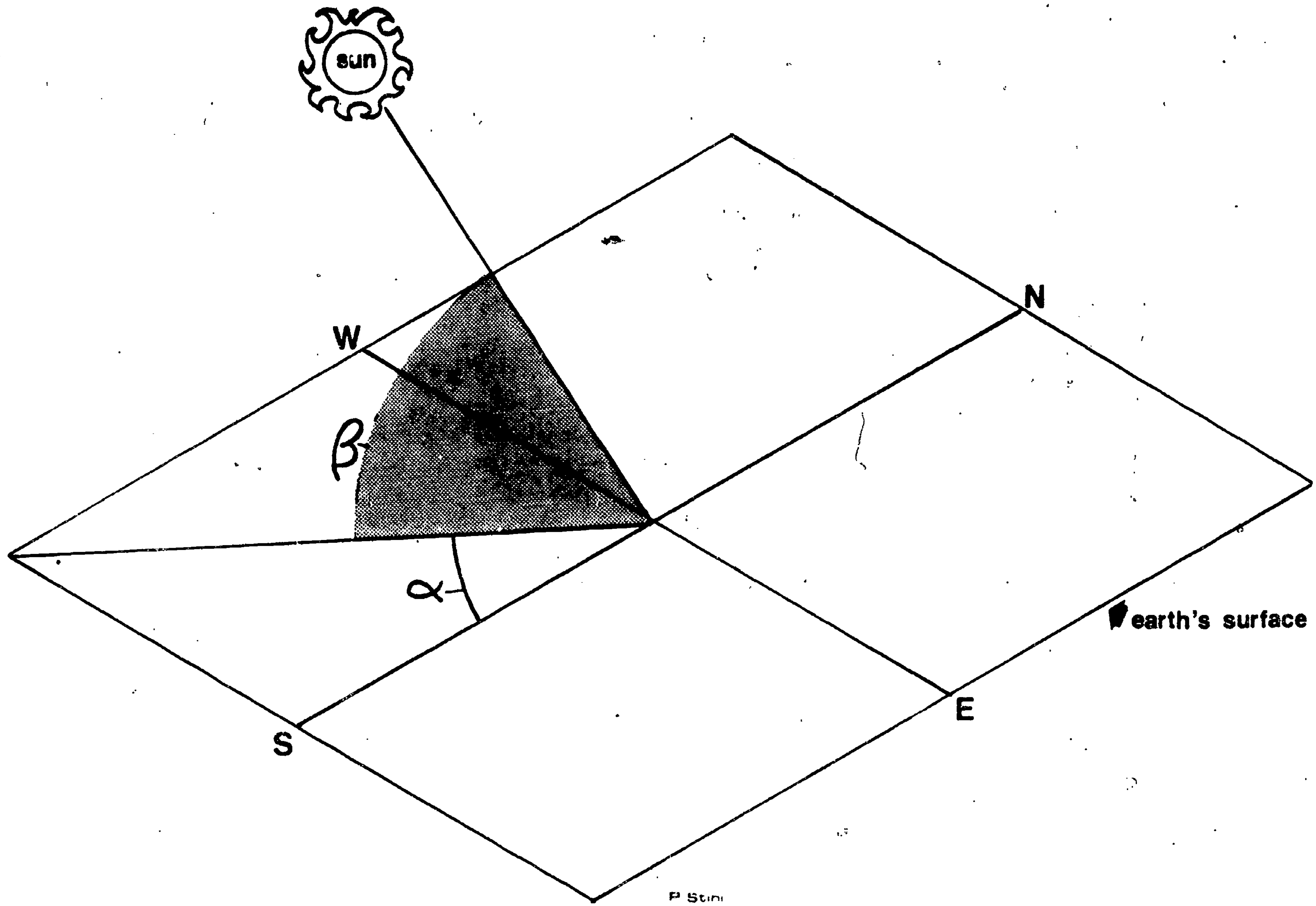
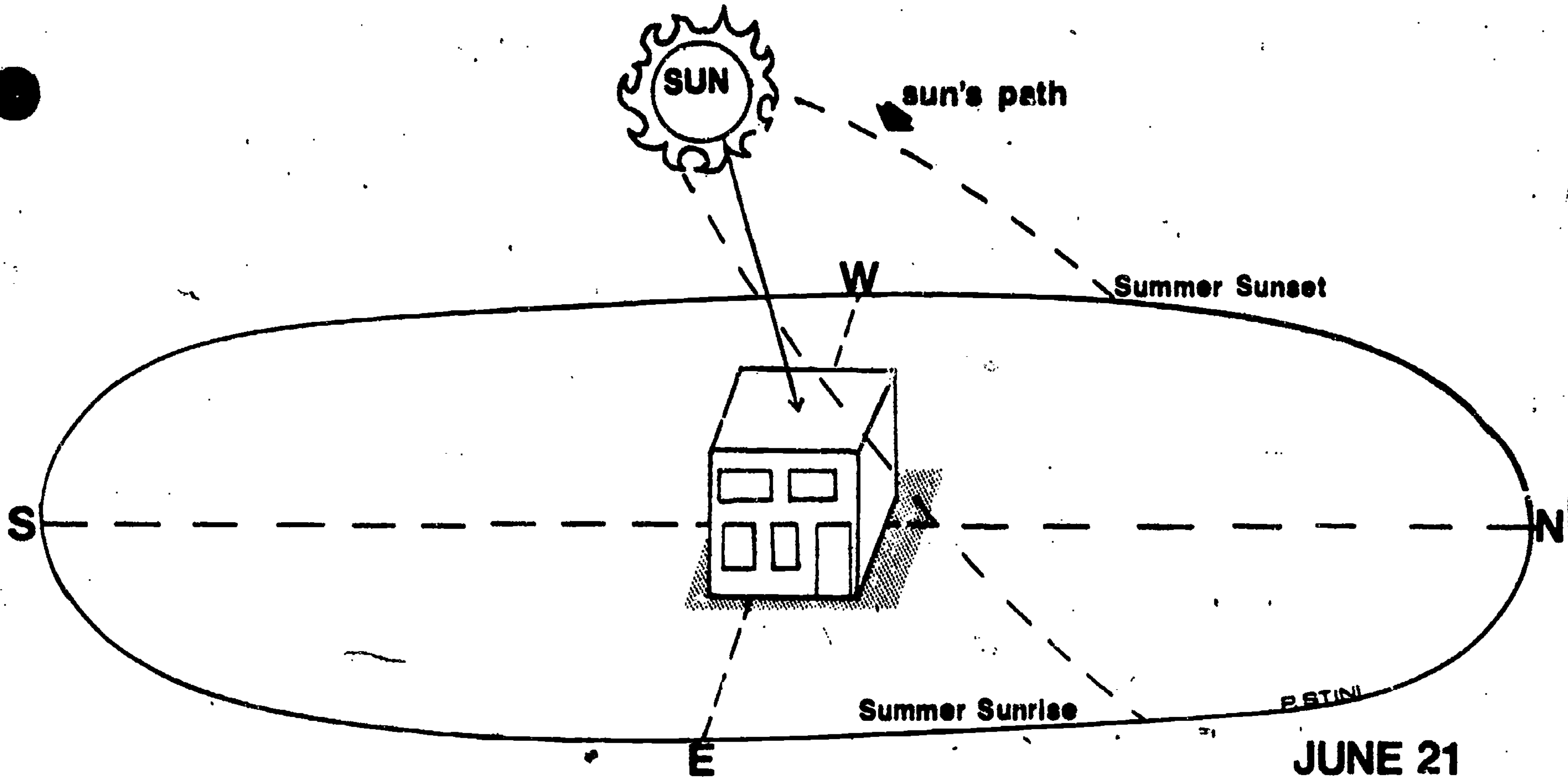
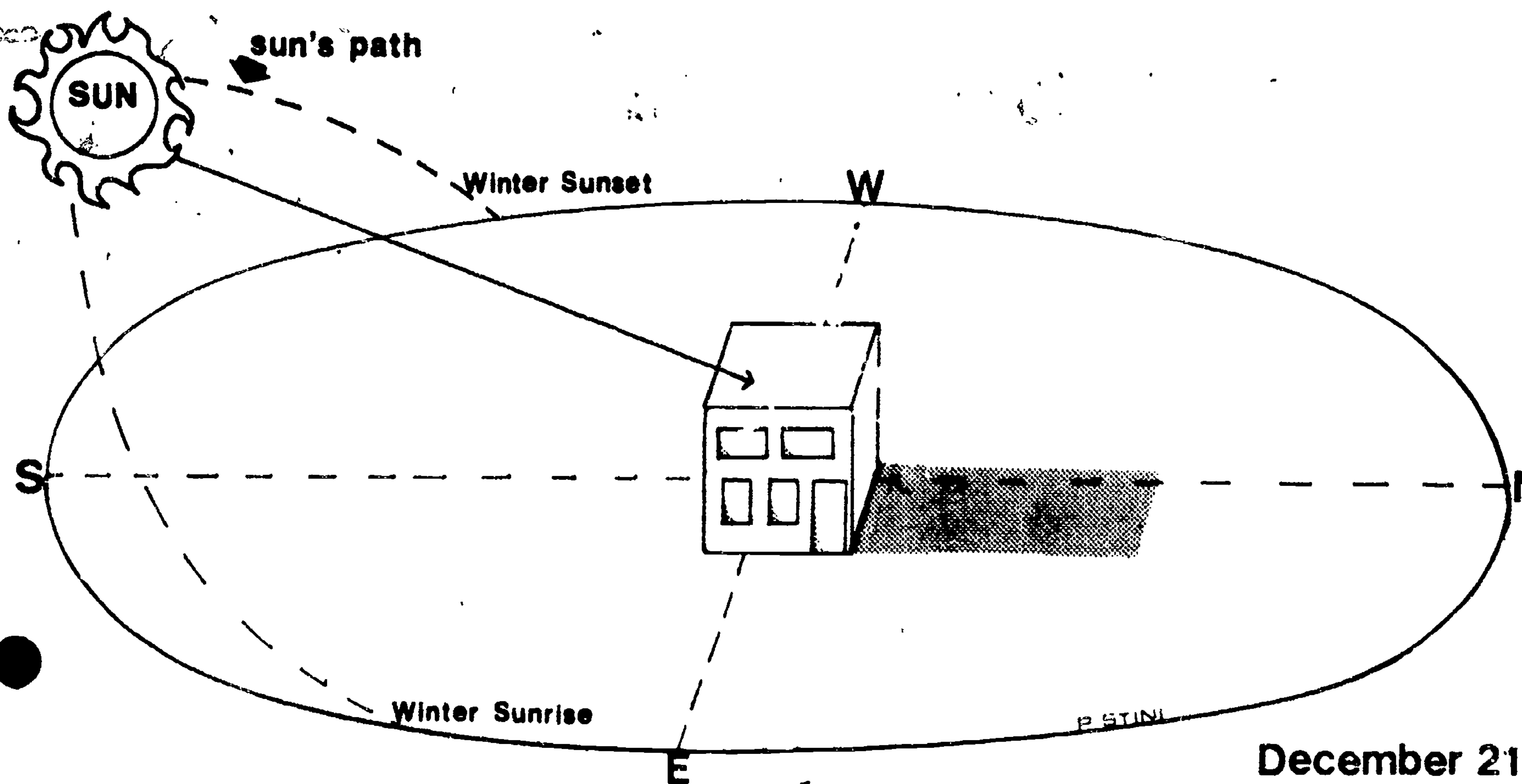
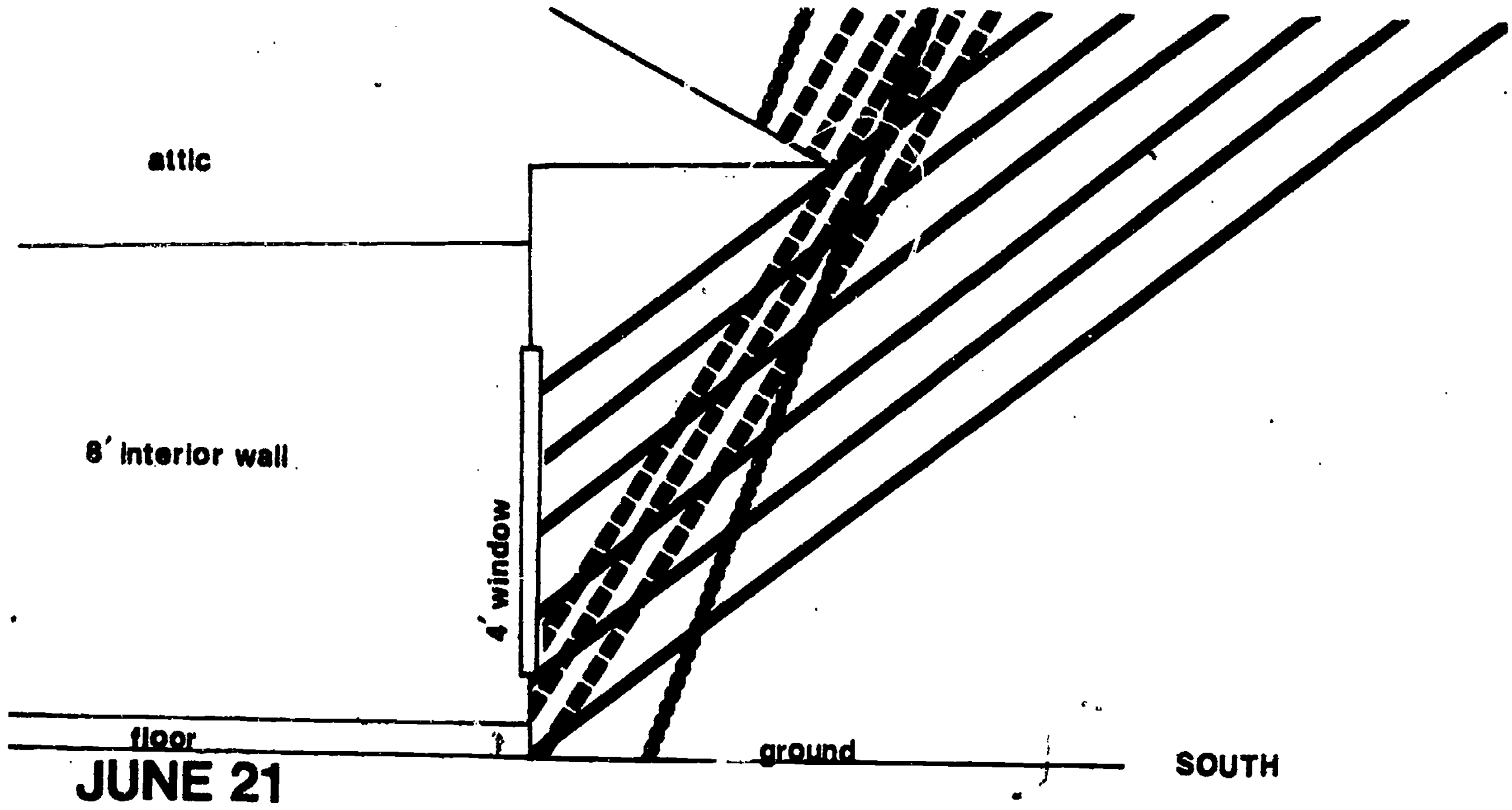
equatorial plane
earth-sun line
angle of declination
P. Stini

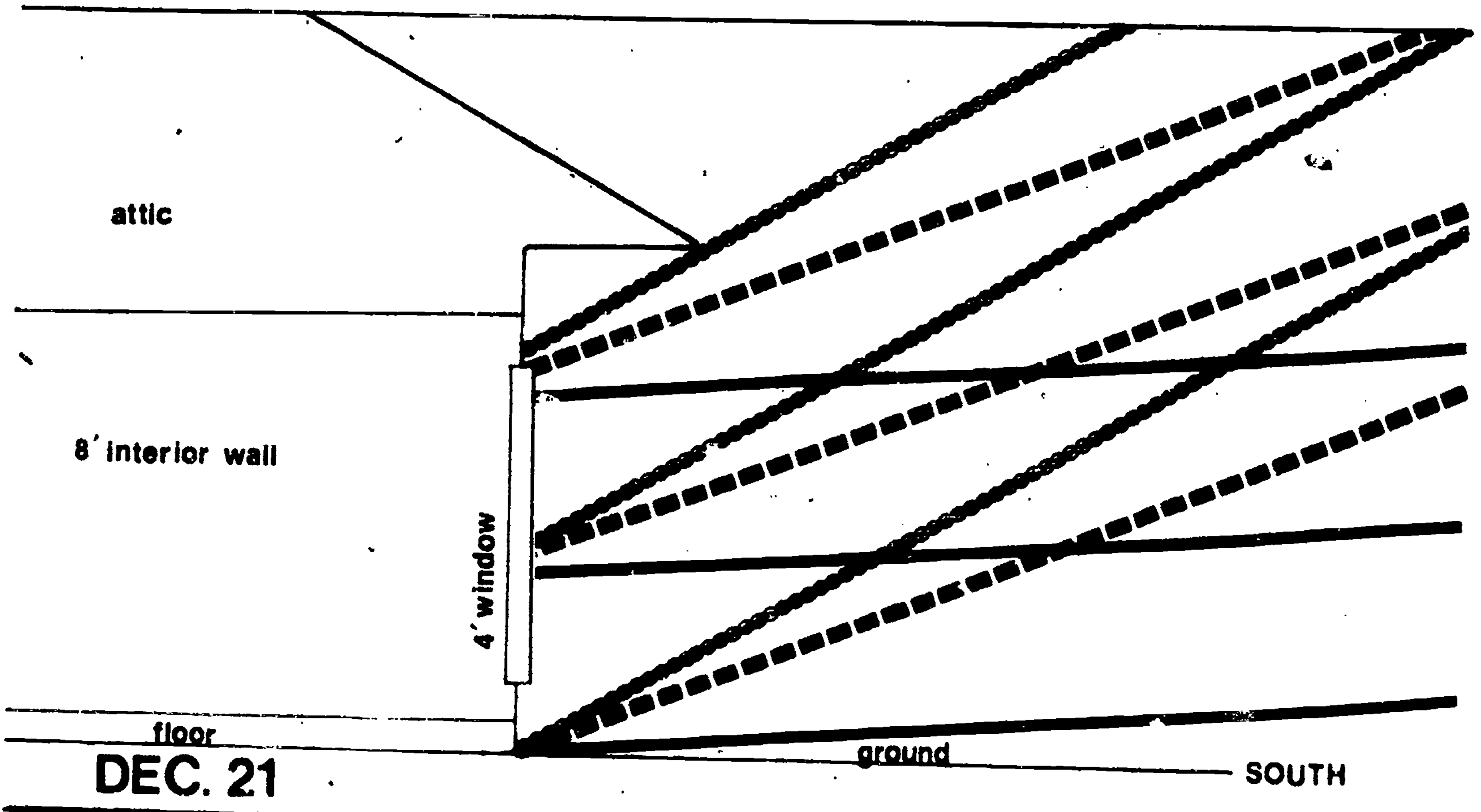

sun
W
N
β
α
earth's surface
E
S
P Stini

Transparency 2.5









Direct solar rays on south window of house

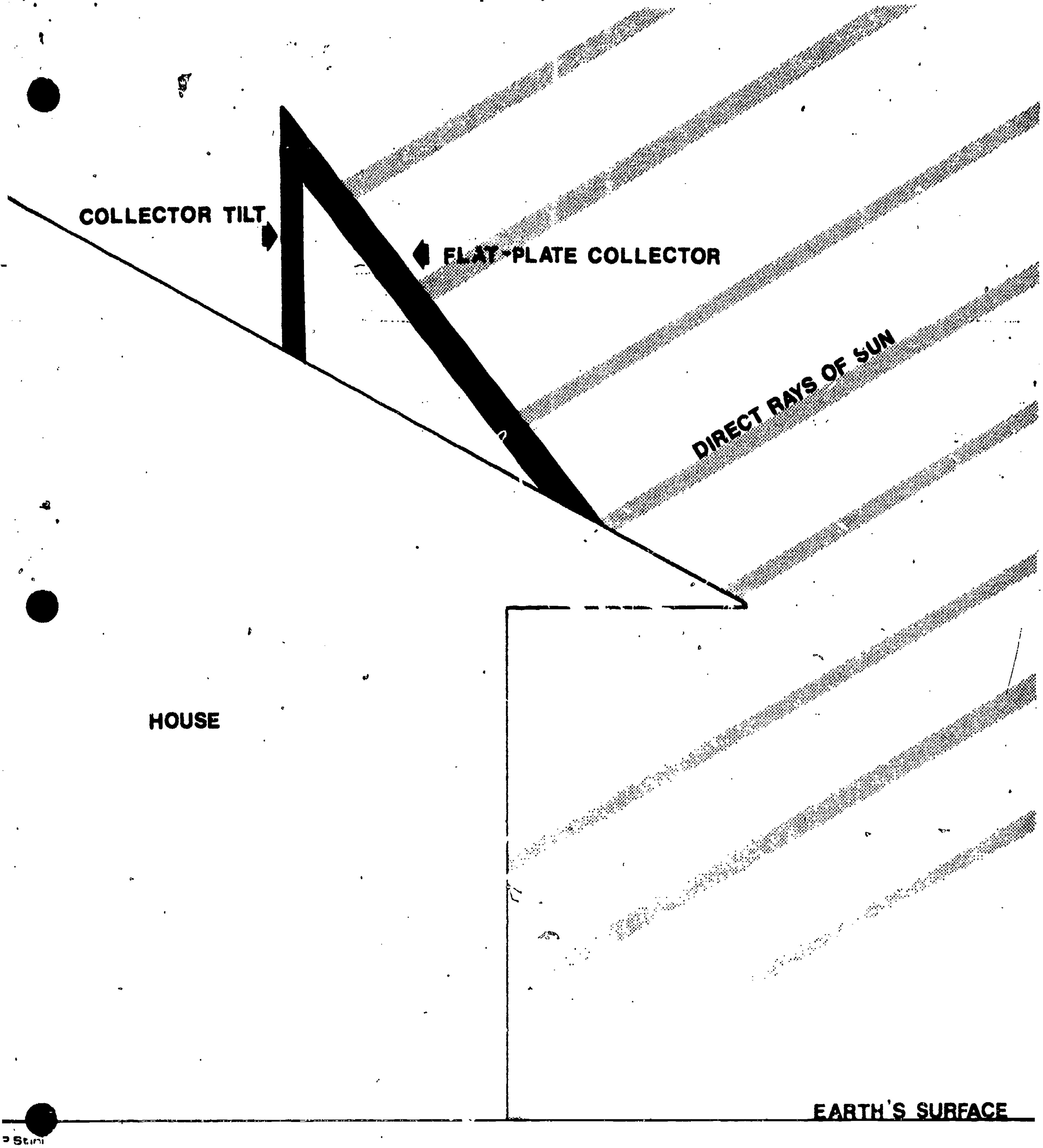
P. St...

SOLAR NOON

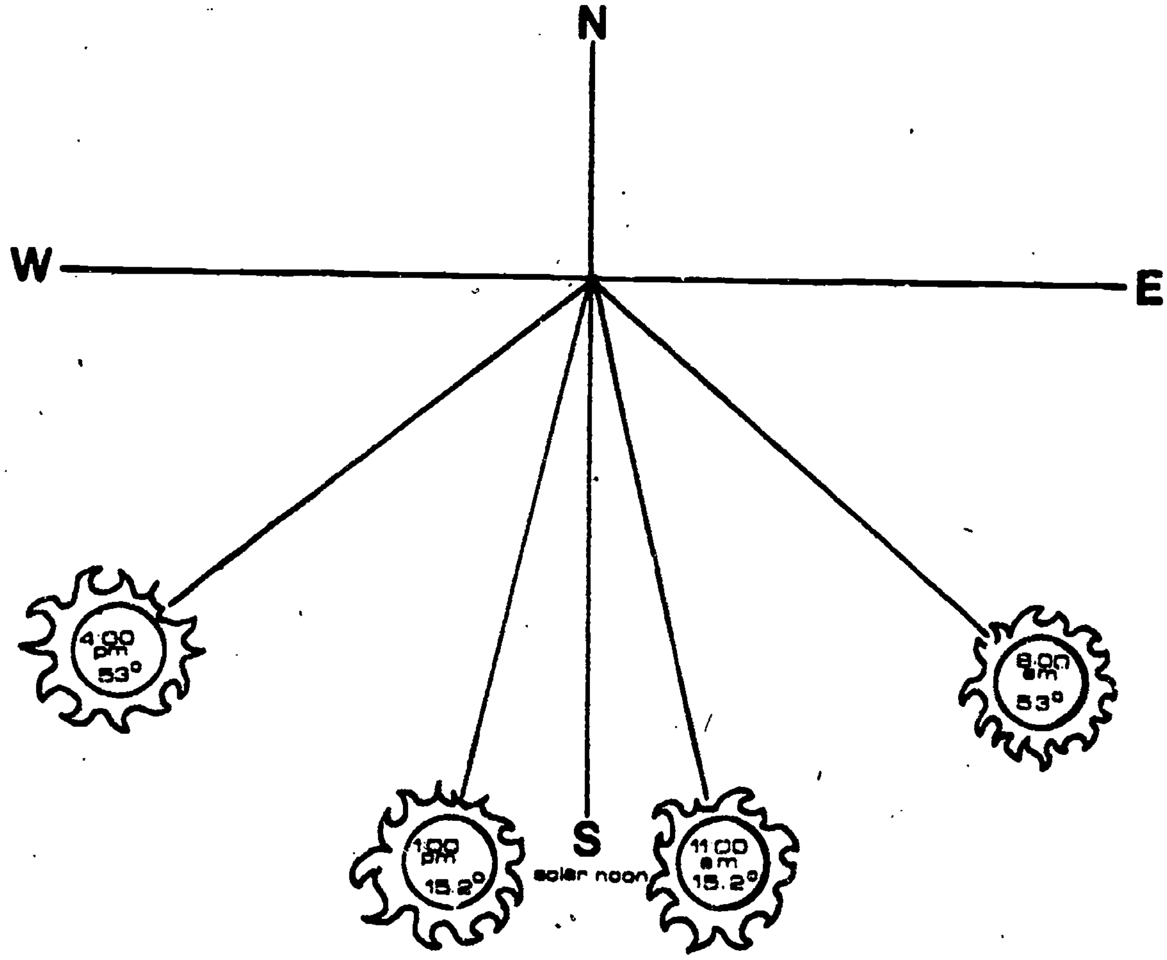
10 00 A M

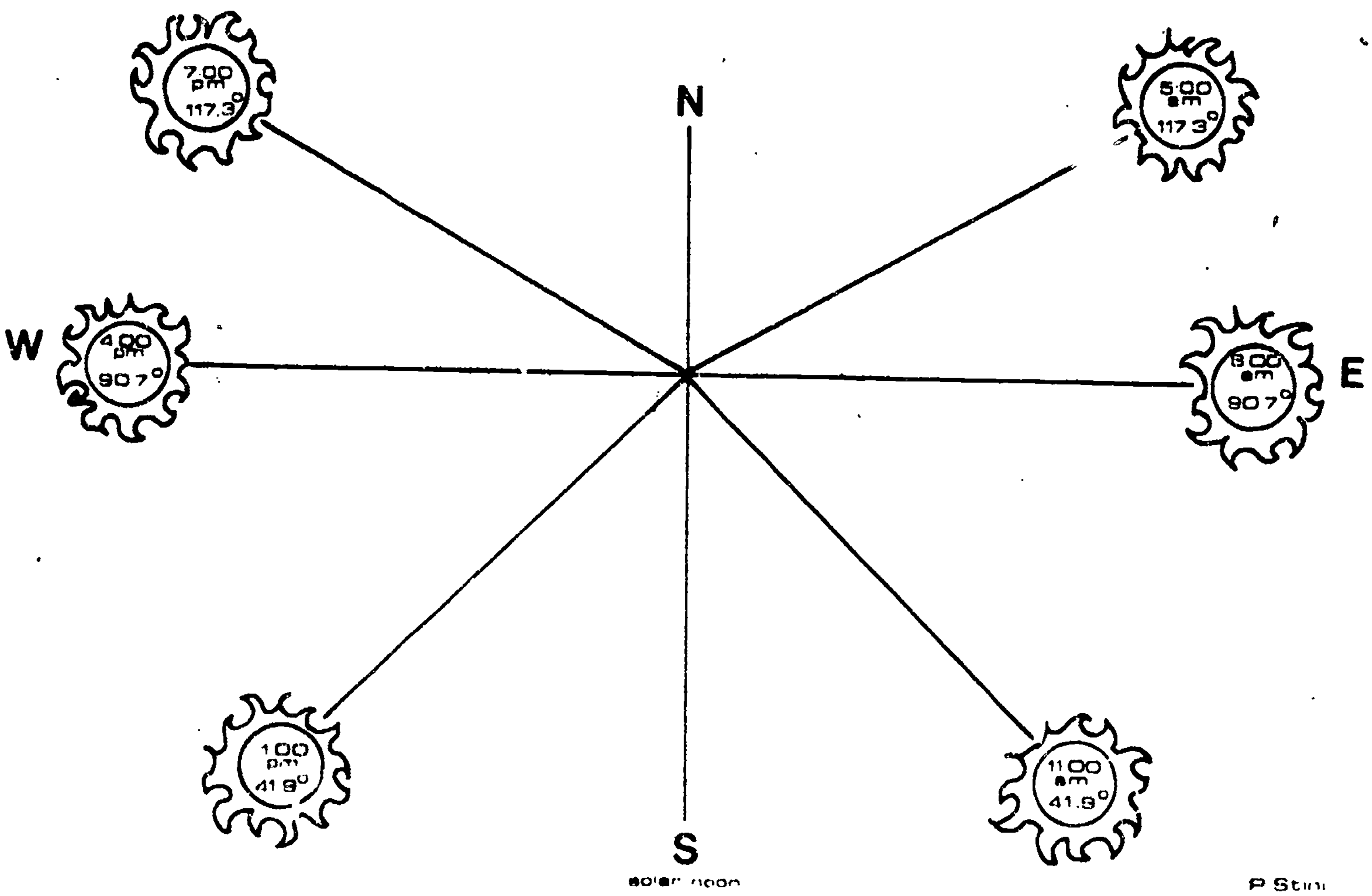
8 00 A M

Latitude 240° NORTH


COLLECTOR TILT
FLAT-PLATE COLLECTOR
DIRECT RAYS OF SUN
HOUSE
EARTH'S SURFACE

Transparency 2.8





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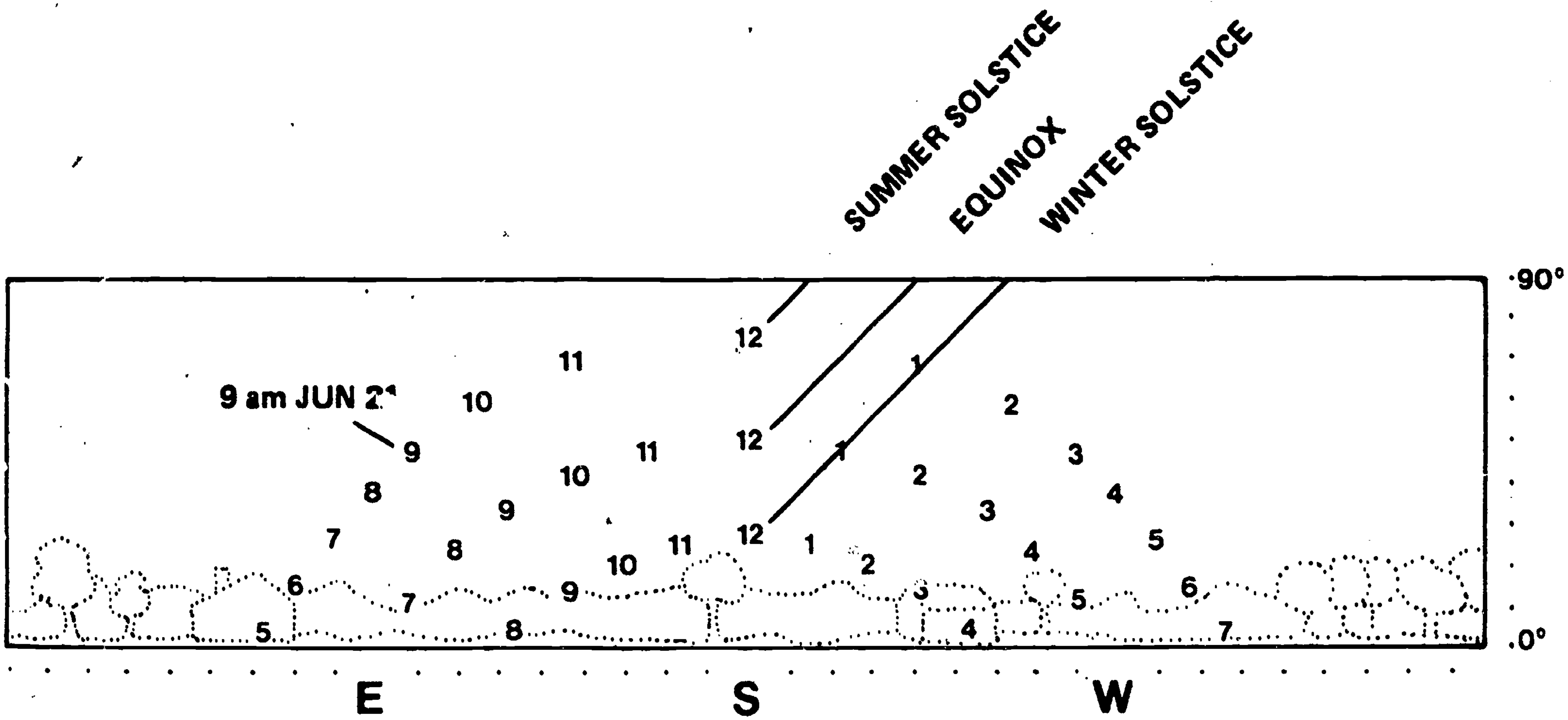

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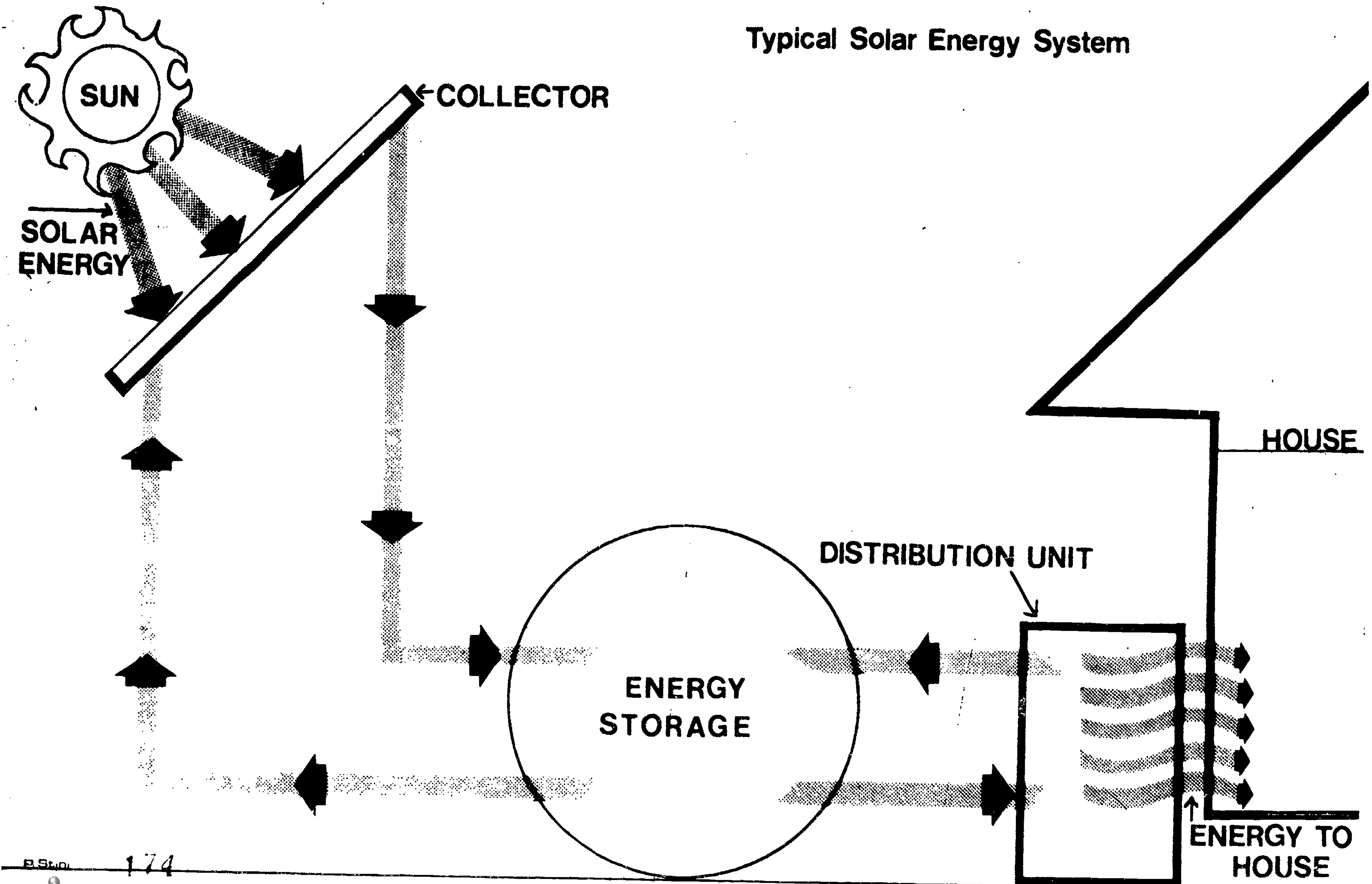
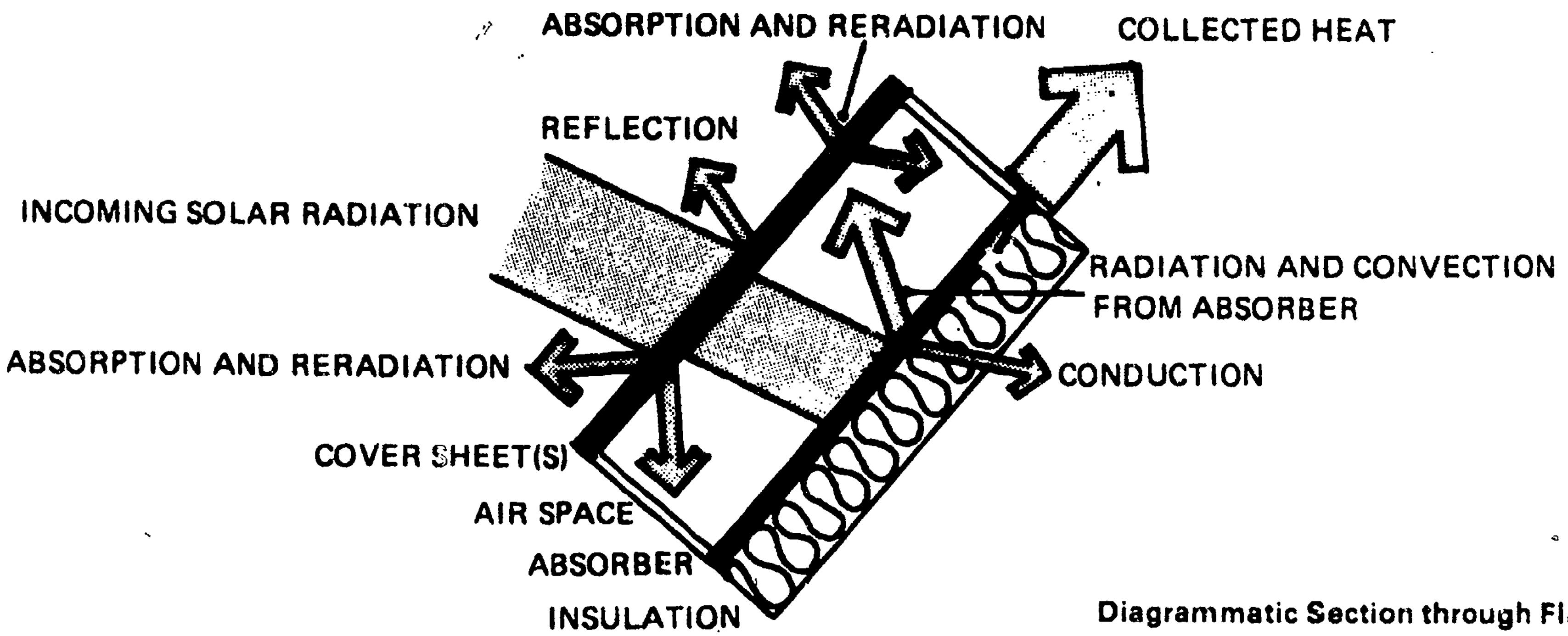
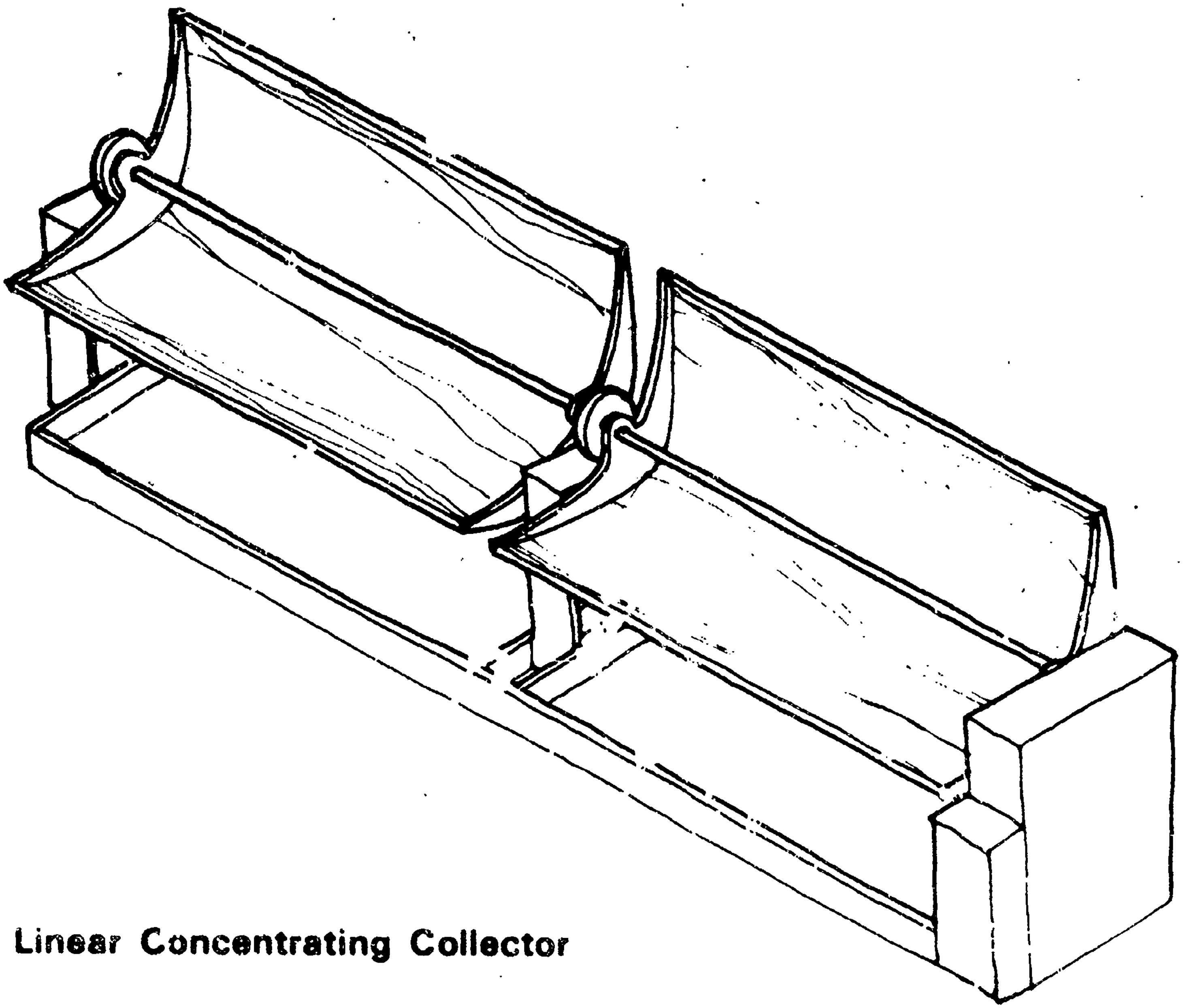
Typical Solar Energy System





Diagrammatic Section through Flat-Plate Collector

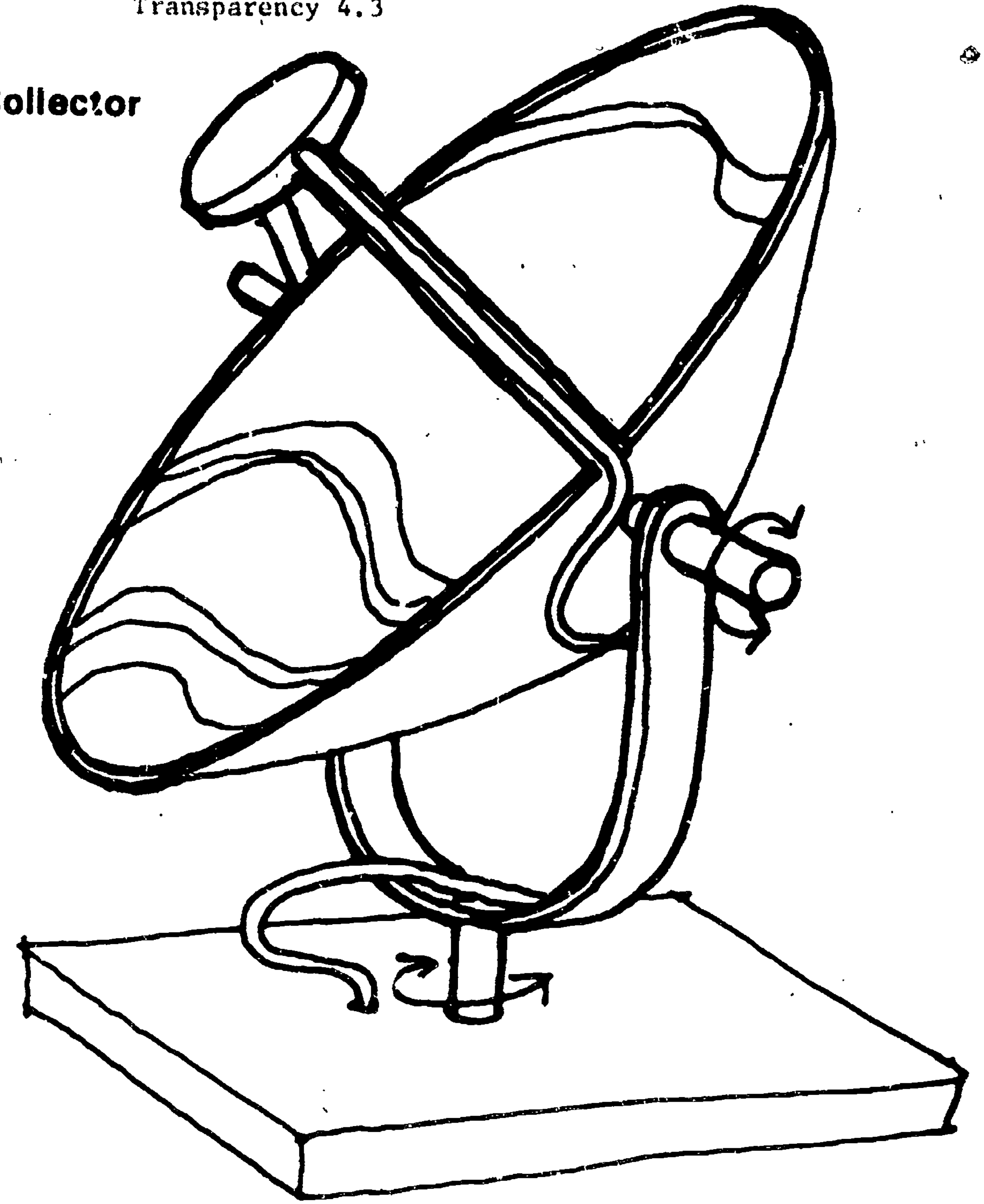
AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.



Linear Concentrating Collector

AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

Circular Concentrating Collector



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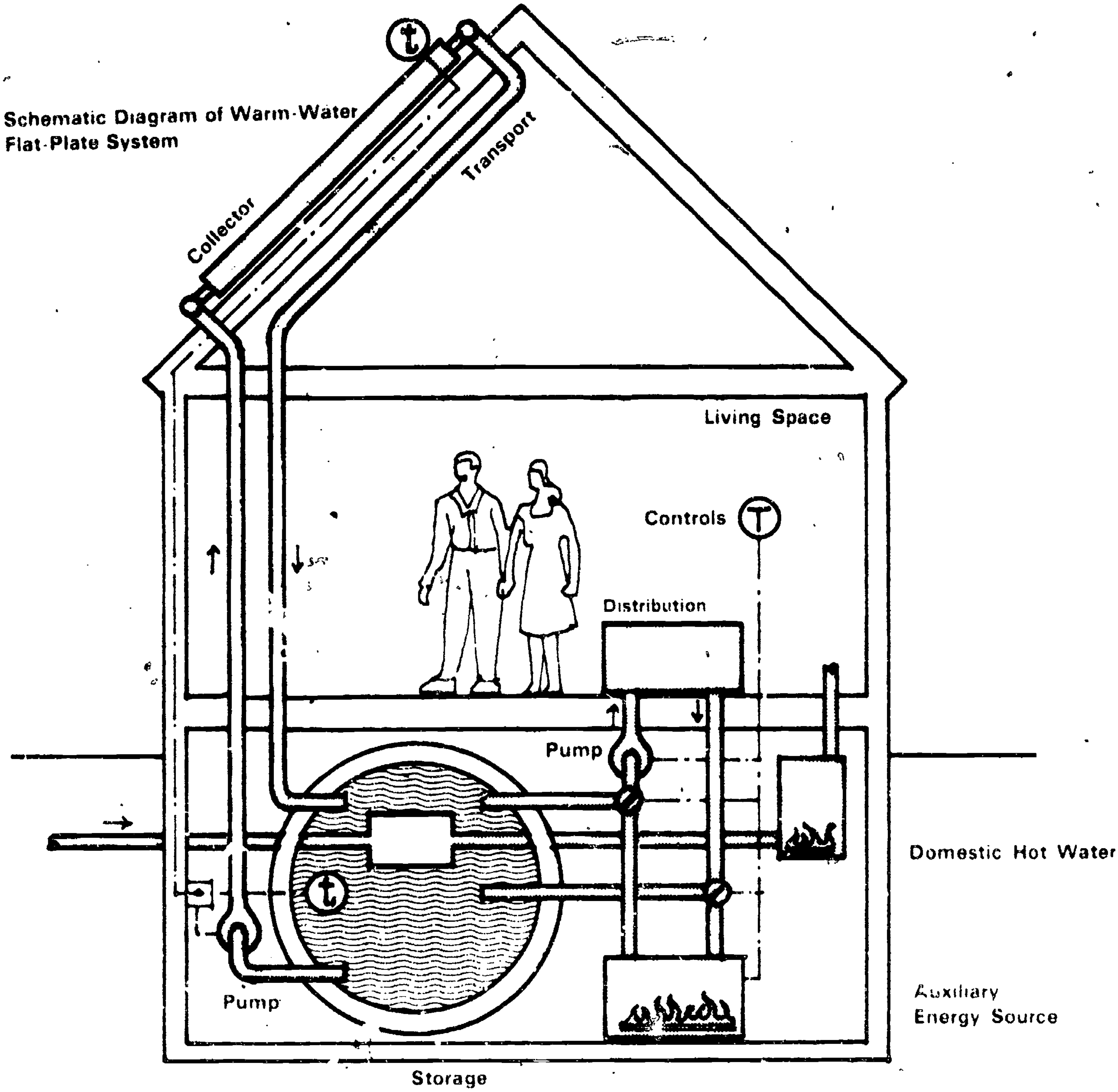
Transparency 7.1



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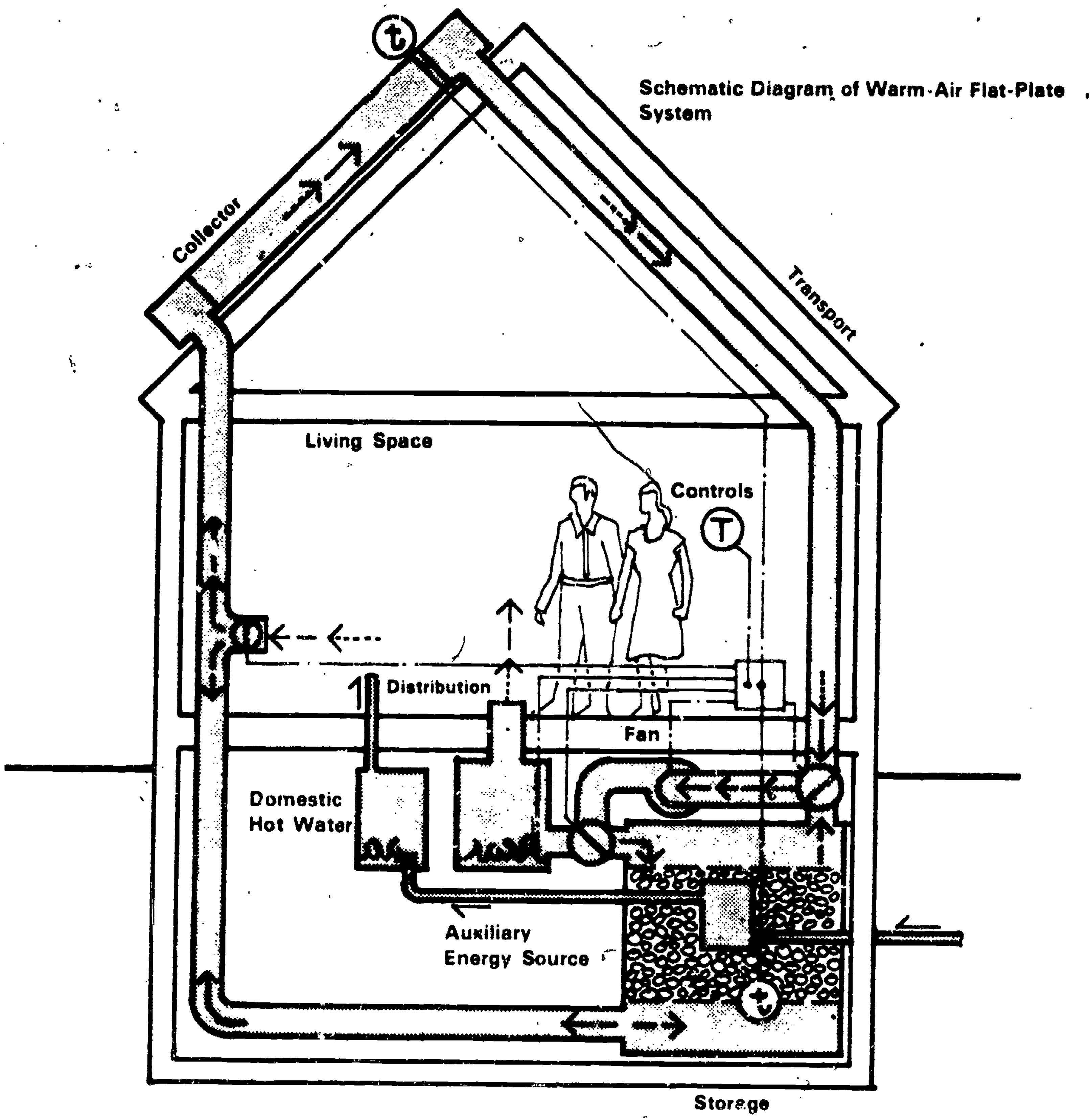
Transparency 7.2



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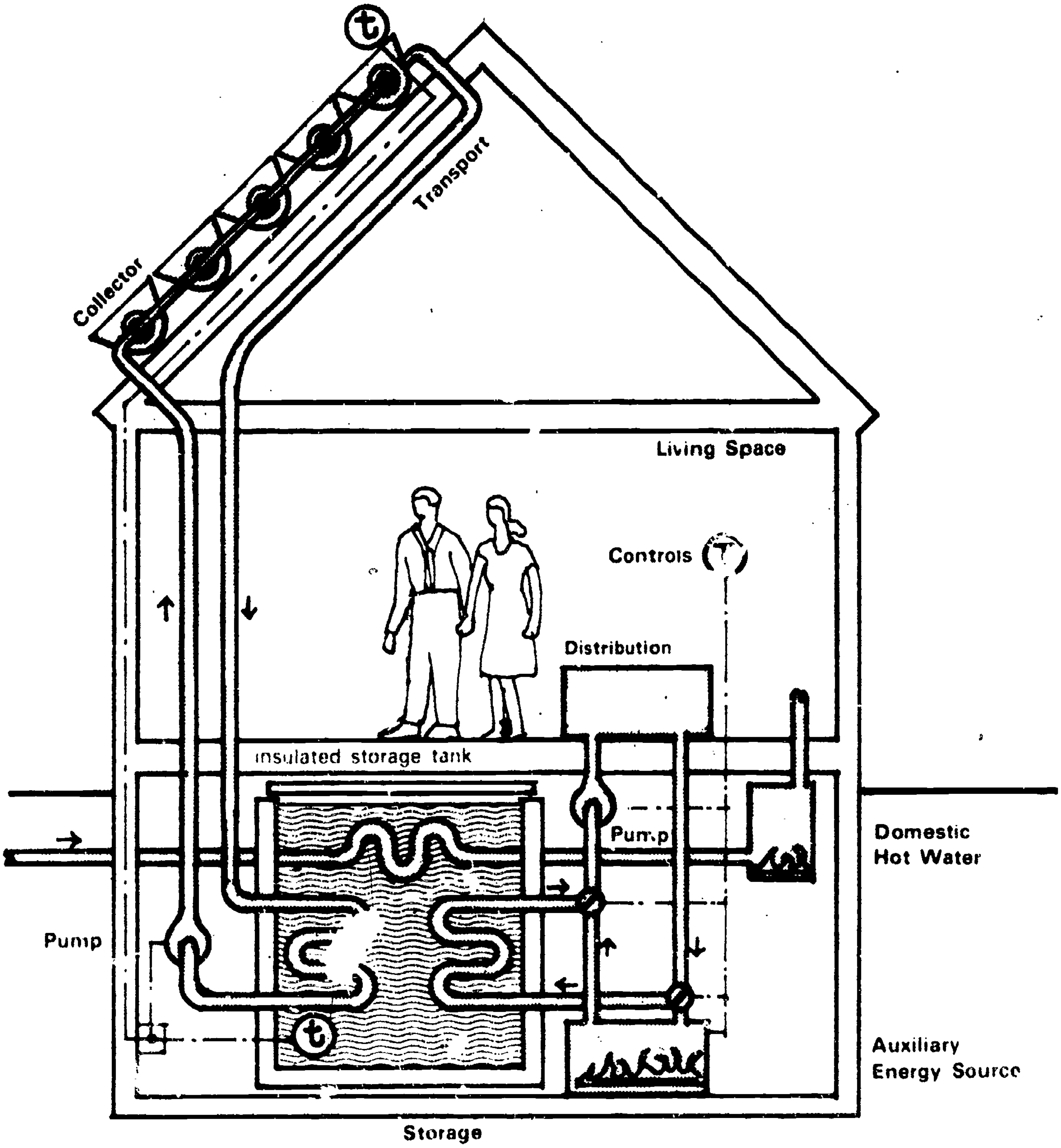
Transparency 7.3

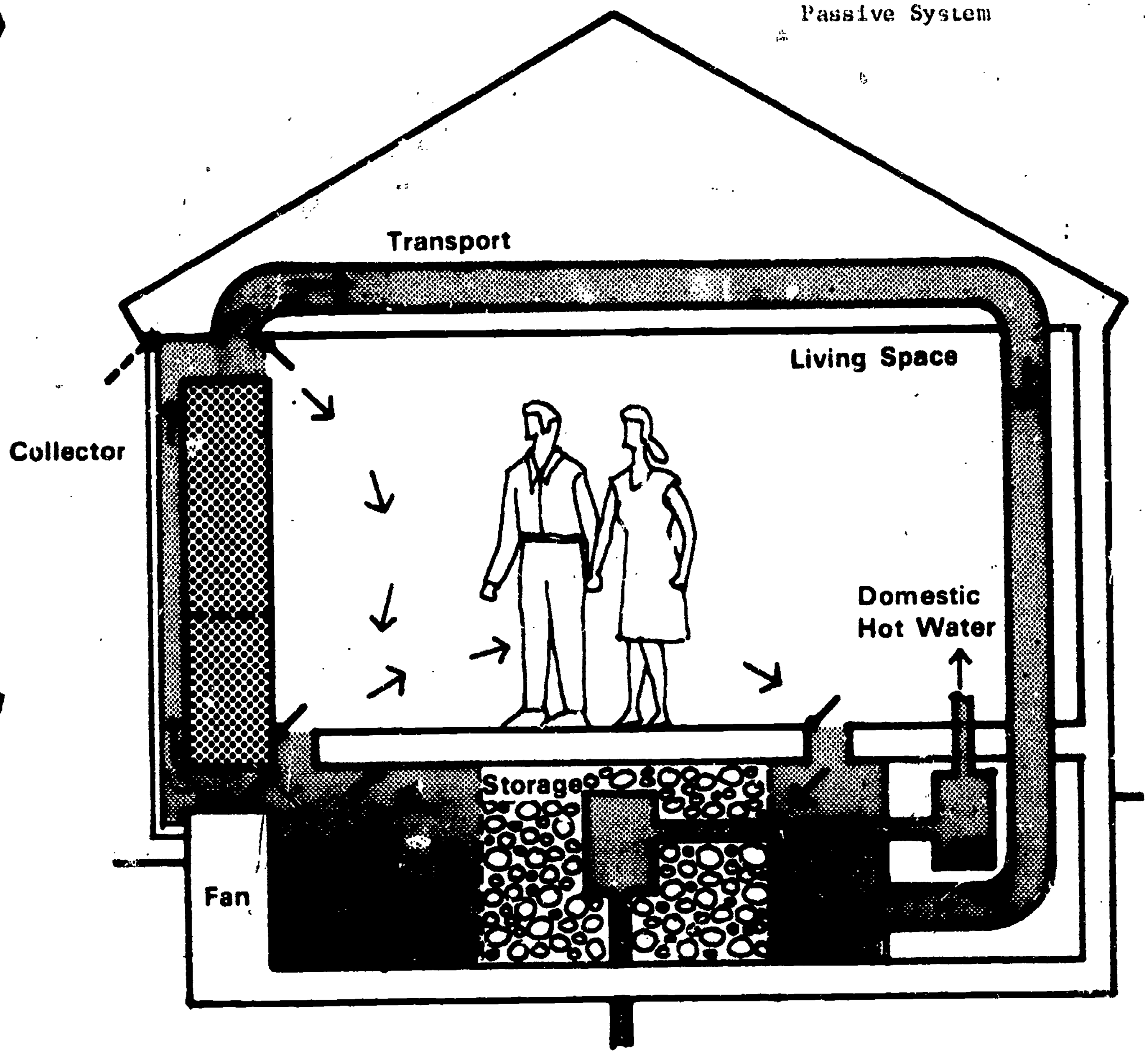
Schematic Diagram of Warm-Water Concentrating System



AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976.

Transparency 7.4

Schematic Diagram of Warm-Water Passive System



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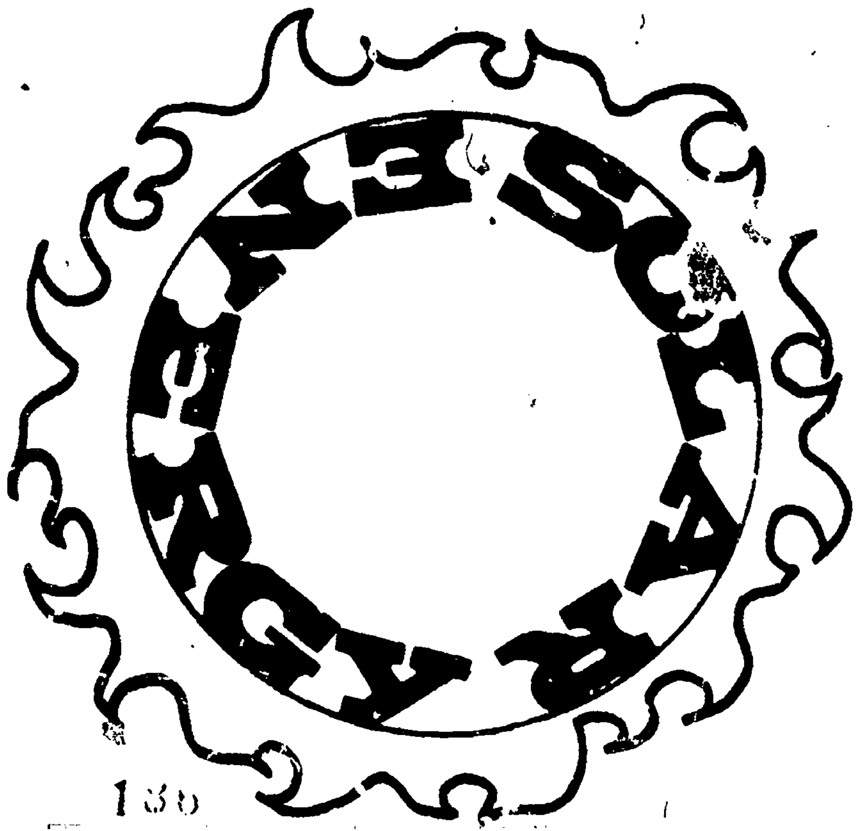

schools. AIA publications include the 156 page *Energy Conservation in Building Design* (Cat. No. 4RC201, $5.00) which describes opportunities for conserving energy through building design; the 183 page *Energy Conservation in Buildings* (Cat. No. 3M184, $20.00) which approaches the subject of energy consumption in economic as well as technical terms, citing financial, political and tax obstacles; and the 124 page *New Design Concepts for Energy Conserving Buildings* (Cat. No. 4RC210, $9.95) which features 12 entries of distinction from the Energy Conscious Design student competition held in 1976.

NATIONAL SCIENCE TEACHERS ASSOCIATION (NSTA)
1742 Connecticut Ave., N.W.
Washington, DC 20009
Telephone: (202) 265-4150
Contact: John M. Fowler

NSTA has many helpful energy-related materials for the classroom. Many of these could be used to generate energy saving ideas for schools. A new bimonthly newsletter, *Energy and Education*, was begun in October 1977. This newsletter is concerned with the process through which energy related political, social, economic, and environmental issues are translated into classroom activities. Subscription requests for this free newsletter should be sent to Mary T. McGuire at the NSTA address. Also available from NSTA are the *Energy-Environment Source Book* ($4.00) which provides background information for teachers; *Energy-Environment Materials Guide* ($2.00), an annotated bibliography of materials for teachers and graded student reading lists; and *Energy-Environment Mini-Unit Guide* ($3.00), a collection of sample student activities for grades K-12. The publications are available from the NSTA office.

The publication *Award Winning Energy Education Activities* contains brief descriptions of the winning entries to the NSTA Teachers Participation Contest in Spring 1976. Nineteen NSTA *Fact Sheets on Alternative Energy Sources* and a series of *Interdisciplinary Student/Teacher Materials in Energy, the Environment, and the Economy* are also available from ERDA Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830.

Other resources on this topic may be obtained by contacting RRS at The Center for Vocational Education. Telephone: (614)486-3655

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292 Madison Avenue
New York, NY 10017
Telephone: (212) 949-9482
Contact: David Smith, Director, Information Services

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EDUCATIONAL FACILITIES LABORATORIES (EFL)
850 Third Avenue
New York, NY 10022
Telephone: (212) 751-6214
Contact: Alan Green, President

3000 Sand Hill Road
Building 1, Suite 120
Menlo Park, CA 94025
Telephone: (415) 854-2300
Contact: EFL California Office

EFL has one major publication on energy available, *The Economy of Energy Conservation in Educational Facilities* (1973, $2.00) from the New York address. In addition, several reports and newsletters

RESOURCE & REFERRAL SERVICE

dealing with planning for energy and energy conservation are available, including *Energy and Educational Facilities: Costs and Conservation* and *Energy Conservation and the Building Shell*. *Schoolhouse* is a free newsletter on financing, planning, designing, and renovating school facilities.

EFL's California office offers the Public Schools Energy Conservation Service (PSECS). The PSECS will provide a summary report on energy consumption for each school, a self-help audit, and a capital audit that identifies capital modifications and cost/benefits of these modifications. All reports are based on information submitted to PSECS by an enrolling school district on forms provided by PSECS. The fee is $30 per elementary school and $50 per secondary school.

United States Office of Education
ENERGY AND EDUCATION ACTION CENTER (E & EAC)
Suite 514, Reporter's Building
300 Seventh Street, S.W.
Washington, DC 20202
Telephone: (202) 472-7777
Contact: Wilton Anderson

The Energy and Education Action Center will coordinate all energy-related education activities among Federal agencies. The Center will serve as a clearinghouse on energy and education; give schools technical assistance on energy standards, projects and funding sources; train energy, environmental and related personnel at all educational levels; and support education projects through state and local agencies, higher education institutions and school systems.

PLUMBING—HEATING—COOLING INFORMATION BUREAU (PHCIB)
35 East Wacker Drive
Chicago, IL 60601
Telephone: (312) 372-7331
Contact: James E. Purnell

An organization of over 1200 manufacturers and their representatives, wholesalers, contractors, and labor personnel in the plumbing-heating-cooling industry. It maintains a clearinghouse for consumer inquiries, and publishes educational materials on the industry for consumers, school builders, architects, and engineers. PHCIB can respond to inquiries on energy and water conservation.

COUNCIL OF EDUCATIONAL FACILITIES PLANNERS, INTERNATIONAL
29 W. Woodruff Avenue
Columbus, OH 43210
Telephone: (614) 422-1521
Contact: Edmond LeBlanc, Energy Director

One of this organization's major publications on energy is the *Energy Sourcebook for Educational Facilities*. Chapters include "Conservation Guidelines," "Energy Conscious Design," "Cost/Benefits of Conservation," "Programming Energy Management," and "Auditing Energy Management." The Council also publishes a series called the *Educational Facilities Digest*. Each digest, 4-8 pages, includes a brief review of a topic, followed by an extensive annotated bibliography. Two appropriate titles are *Energy Conservation* (ED 126 553) and *Building Renovation and Modernization* (ED 131 522). Copies are available for $1.50 each from the Council or on microfiche from ERIC Document Reproduction Service, P.O. Box 190, Arlington, VA 22210.

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR-CONDITIONING ENGINEERS, INC. (ASHRAE)
United Engineering Center
345 East 47th Street
New York, NY 10017
Telephone: (212) 644-7946
Contact: Nicholas A. LaCourte, Manager of Standards

• ASHRAE is currently working on a series of publications on Energy Conservation in Existing Buildings. *ASHRAE Standard 100.5P: Energy Conservation in Existing Buildings—Institutional* is currently undergoing a revision of the first draft. The second draft will be available in January 1978. *ASHRAE Standard 100.6P: Energy Conservation for Existing Buildings—Public Assembly* might also be appropriate since it includes standards for large assembly halls (gyms, auditoriums, etc.). Appropriate articles appear in the *ASHRAE Journal*.

AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS (AASA)
1801 North Moore Street
Arlington, VA 22209
Telephone: (703) 528-0700
Contact: Sharon Ford, Publications

AASA has four publications in this area. *School Energy Crisis: Problems and Solutions* ($8.95) published in 1977, is a comprehensive special AASA Critical Issues Report on the impact of America's energy crisis on schools and school budgets. It includes tips from the field on what practitioners are doing to cope with declining resources, spiraling costs, and alternative sources. *Energy Conservation and the Schools*, ERIC Abstract Series No. 35, a 1976 publication ($2.00), cites 24 sources in its 10 pages. *To Re-Create a School Building* ($10.00), is a 123 page document published in 1976 which explores the when's, why's, and how's of refitting obsolete or surplus facilities to meet new enrollments, energy, and space needs. *Saving Schoolhouse Energy* contains a year-long comprehensive engineering analysis of 10 "representative" elementary schools located in various parts of the country. It also contains some specific suggestions for school administrators on how to make cost-effective building modifications to save energy.

AMERICAN INSTITUTE OF ARCHITECTS (AIA)
1735 New York Ave., N.W.
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Contact: David Bullen, Executive Director for Energy Programs

A professional society of architects which sponsors several educational programs with schools of architecture, graduate students, and elementary and secondary

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ADOBE: DESIGNING FOR PASSIVE SOLAR HEAT IN THE SOUTHWEST...D. Wright; Solar Age 1(7):10-15, July 1976.

ARCHITECTURE AS ENERGY...M. Villecco; Design Quarterly (103):1-36, 1977 (Complete issue).

CLIMATE BASED SOLAR HOUSE DESIGN: HOT AND HUMID, Charleston SC...D. V. Scully; Sharing the Sun: Solar Technology in the Seventies, Vol. 4, pp. 23-26. (See List of Sources).

CONCRETE WALLS TO COLLECT AND HOLD HEAT...F. Trombe et al.; Solar Age 2(8): 13-19, 1977.

DESIGNING, BUILDING A TROMBE WALL...B. Anderson; Solar Age 2(8):25-28, 1977.

DIRECT SOLAR HEATING: WHY NOT JUST LET THE WINTER SUN IN THE WINDOWS?..R. W. Bliss; Preprint, Consumer Conference on Solar Energy Development, Albuquerque NM, Oct. 2-5, 1976, Donovan & Bliss, Chocorua NH 03817, 58 pp, Sept. 20, 1976.

HEATING WATER IN A BREADBOX...A. Von Vleet; Alternative Sources of Energy (25):21-25, April 1977.

HERE'S A ~~PASSIVE~~LY HEATED AND COOLED HOUSE THAT YOU CAN AFFORD,...AND WILL WANT ...Anon.; Mother Earth News (48):117-119, September 1977.

THE ILLINOIS HOUSE...W. S. Harris et al; Sharing the Sun: Solar Technology in the Seventies, Vol. 4, pp. 30-35. (See List of Sources).

INDIGENOUS WOOD AND SOUTH-FACING GLASS FOR PASSIVE SOLAR GAIN TYPIFY HOMES BUILT TO SHELTER INSTITUTE SPECS...E. TOZER; Popular Science 211(3): 114-117, September 1977.

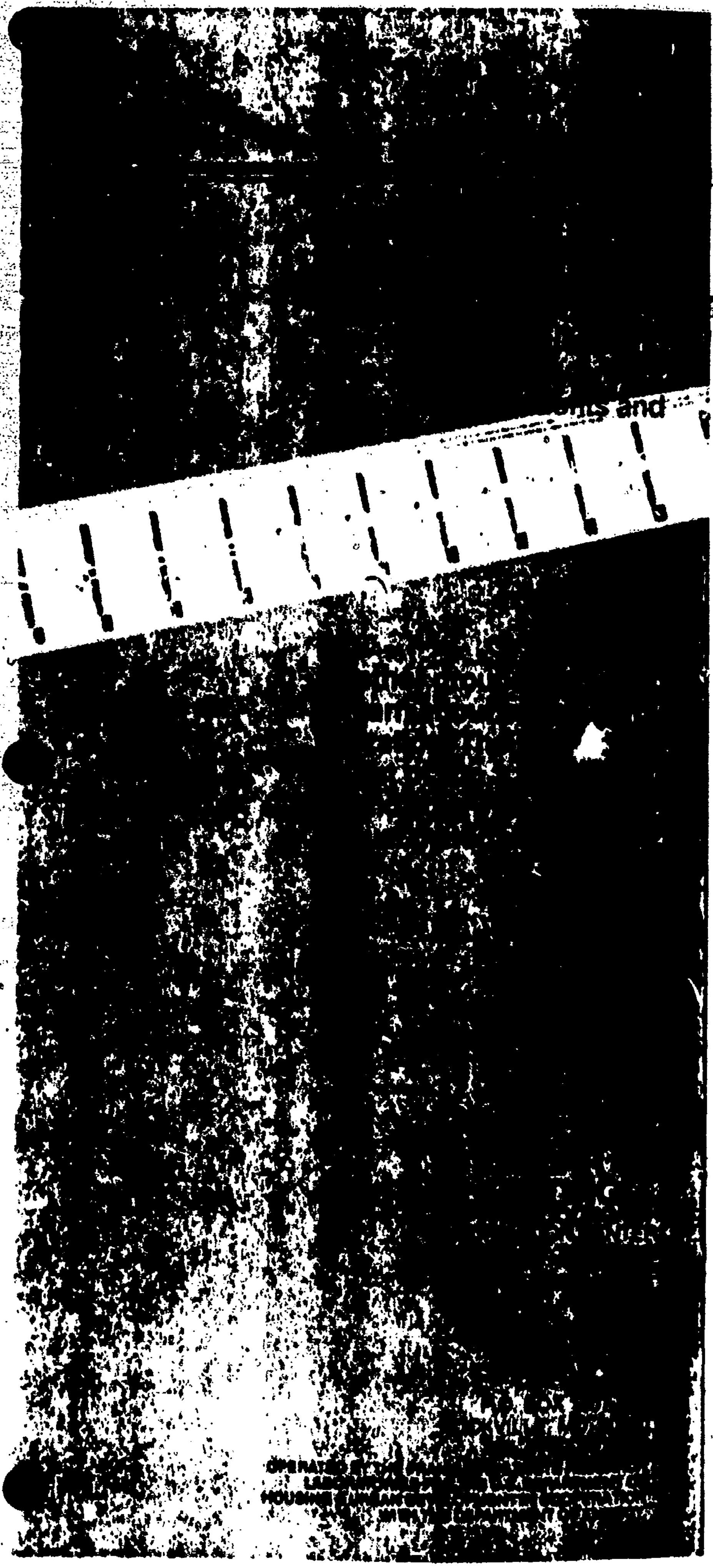
THE KELBAUGH HOUSE...D. Kelbaugh; Solar Age 1(7):19-23, July 1976.

THE LIVE-IN SOLAR COLLECTOR...B. Anderson; Solar Age 1(6):19-23, June 1976.

LOW TECHNOLOGY SOLAR HOMES THAT WORK WITH NATURE...T. Price; Popular Science 209(6):94-95, Dec. 1976.

A NON-TECHNICAL EVALUATION OF FOUR DIFFERENT CONCRETE WALL SOLAR COLLECTOR CONFIGURATIONS...B. Anderson et al; Sharing the Sun: Solar Technology in the Seventies, Vol. 4, pp. 15-22. (See List of Sources).

A PASSIVE SOLAR HEATED HOUSE: DESIGN AND CONSTRUCTION...J. Cook and H. Wade; Sharing the Sun: Solar Technology in the Seventies, Vol. 4, pp. 8-14. (See List of Sources).



FILMS

HERE COMES THE SUN: 1974, 15 minutes, color, for junior & senior high school
In Massachusetts, Maryland, Virginia & Minnesota solar energy "goes to school" as students, teachers & their communities find solar heating an important asset in helping relieve the energy shortage, and in the process learn how the systems work. Shows collectors, control centers, a solar experimental van, etc.

PUTTING THE SUN TO WORK: 1974, 5 minutes, color, for junior & senior high school, college & technicians
Film explains some of the research being done in the solar field to reduce costs, improve efficiency, etc. Covers collectors for home heating, power farms, and solar thermal power plants.

ENERGY: THE AMERICAN EXPERIENCE: 28½ minutes, color
ERDA's tribute to the Bicentennial produced by Sid L. Schwartz. Covers oil, solar and geothermal as energy sources briefly but thoroughly.

PROJECT SAGE: 8½ minutes, 16mm, color, order #0511
Documents installation of solar collectors and appropriate piping to supply hot water to 40 apartment units at a small complex south of Los Angeles. Shows that, contrary to popular belief, the process is very simple and a great deal of fossil fuel can be saved by such projects.
(Also for sale, from: Madison Films, Inc., 215 E. 49th St., New York, NY 10017)

CHALLENGE OF THE FUTURE: 1975, 29 minutes, color
Discusses the energy situation. Shows that we are running out of fossil fuels, and need to develop new sources of energy. Shows some of the research being done by ERDA in developing new sources. Emphasis on energy conservation.

These films are available from:
Department of Energy Film Library (free rental)
P.O. Box 62
Oak Ridge, TN 37830

SOLAR WATER HEATING: 1964, 13 minutes, 16mm, color
Film explains the design of a standard collector for solar water heating and outlines the principles involved.

DESIGN FOR CLIMATE: 1967, 21 minutes, 16mm, color
Discusses how architects & engineers can control a number of natural elements, including solar heat, sun and sky glare, wind, rain and noise in designing buildings with comfortable indoor climates.

The foregoing films are available from:
Office of Counsellor (Scientific) (free rental)
Embassy of Australia
1601 Massachusetts Avenue
Washington, DC 20036

THE AGE OF THE SUN: 1974, 21 minutes, 16mm, color
Film on use of solar energy in the U.S. Introduces various methods of solar energy utilization and explains the advantages, disadvantages and potentials of solar energy today and in the future.
(Also available from: Glen/Kaye Films, 100 E. 21st St., Brooklyn, NY 11226, (212) 287-2929. Purchase—$280, Rental—$35 and up.)

ENERGY: NEW SOURCES: film 3 of 4 part series, 20 minutes, 16mm, color, junior/senior high school, college, adult
Film covers possible uses of solar cells, solar panels for hot water and temperature control in buildings, and solar heat for generation of electricity. Also deals with geothermal energy and briefly covers energy from wind, tides, burning trash, methane and thermal gradients.
(Also available from: Churchill Films, 662 N. Robertson Blvd., Los Angeles, CA 90069. Purchase—$250, Rental—$21.)

The foregoing films are available from:
Environmental Action of Colorado (rental—$21)
2239 E. Colfax
Denver, CO 80206 (303) 320-6537

ENERGY: HARNESSING THE SUN: 19 minutes, 16mm, color, junior/senior high
Introductory film on the many forms of solar energy utilization: collectors for heating & cooling buildings; two basic types of solar energy collection—natural and technological. Covers advantages and problems associated with solar utilization. Reviews current energy situation for fossil fuels, showing need for solar.
(Also available from: Sterling Educational Films, 241 E. 34th St., New York, NY 10016, purchase—$255)

SUNBEAM SOLUTIONS: 38 minutes, 16mm, color, high school, college, adult produced by BBC-TV
Looks at the efforts of the past which have become insufficient in fulfilling present energy needs. Explains how we are faced with the problem of survival, finding and using new forms of energy as conventional sources run out. Points to possibilities of solar.
(Also available from: Time/Life Multimedia, Time & Life Building, New York, NY 10020, order no: F1620 (film), V1341 (video), purchase—$425 (film), $300 (video), rental—$40)

The foregoing are available from:
University of California
Media Extension Center
Berkeley, CA 94720

ENERGY FOR THE FUTURE: 17 minutes, 16mm, color, senior high/junior college
Features alternative energy utilization, including geothermal facility in California, coal gasification plant in Chicago. Chief emphasis on solar technologies.
(Also available from: P.R.L., 1822 Pickwick Avenue, Glenview, IL 60025, rental—$21)

Available from:
Britanica Educational Corporation
(Purchase—$220)
1925 North Lynn St.
Arlington, VA 22209

ENERGY FROM THE SUN: 11 minutes, 16mm, black & white
Illustrates importance of the sun as the earth's major source of energy. Explains photosynthesis as well as discussing present & future uses of solar energy.

Available from:
Encyclopedia Britanica Educational Corp.
(Purchase—$70)
425 N. Michigan Ave
Chicago, IL 60611

HOW TO MAKE A SOLAR HEATER: 20 minutes, 16mm, color
Explains principle of solar energy applications, especially first generation of solar heaters. Shows step-by-step construction of a functional solar heater at a cost of less than $100. Do-it-yourself approach suggests a classroom project.

Available from:
Handel Film Corporation (Purchase—$290)
8730 Sunset Blvd.
West Hollywood, CA 90060
(213) 657-8990

SOLAR ENERGY: 13½ minutes, 16mm, color
Covers solar power in the past, present & future with emphasis on solar architecture, high & low temperature conversion, ocean thermal, solar cells and biomass.

Available from:
Montage Educational Films
PO. Box 38128
Hollywood, CA 90038

ENERGY FOR TOMORROW: package—3 films, 8mm, 14 minutes each, sound on individual cassettes, comes with study guides
FILMS:
Energy Alternatives—overview of alternate energy resources
Solar Energy—overall coverage of various uses of solar energy
Nuclear Energy—uses of nuclear energy for power, problems involved.

Available from:
Educational Materials & Equipment Co.
(Purchase—$58, sold as package, must buy all 3)
Attn: Dept. B
46 Lafayette Avenue
New Rochelle, NY 10801

GIFT FROM THE SUN: 13 minutes, 16mm, color, sound
About community built solar heated and cooled center for environmental education in Somerset County, NJ.

Available from:
UNITL Film Producers (Rental—$15)
423 W. 118th St.
New York, NY 10027 (212) 865-6201

SOLAR T.E.A. HOME: 8 minutes, 16mm, color, sound
Covers how to build a solar home, using home built in New Hampshire by the Total Environment Action group as an example. Home was built as part of the U.S. Department of Housing & Urban Development Solar Heating & Cooling Residential Demonstration Program.

SOLAR DESIGN: 30 minutes, 16mm, color, sound
Several architects who have designed solar homes are interviewed about their problems and experiences in building solar homes. The homes they designed are shown and the solar systems explained.

THE SOLAR BUILDERS: 27 minutes, 16mm, color, sound
A New Jersey builder, a builder from Dallas, TX, and a Colorado builder are interviewed about their experiences in building solar homes. The homes they built, which were funded under the U.S. Department of Housing & Urban Development Solar Residential Demonstration Program, are shown and their solar systems explained

THE DAWN OF TIME: 6 minutes, 16mm, color, sound
General overview of the utilization of solar energy from the beginning to now.

The foregoing are available from:
National Solar Heating & Cooling Information Center
(Loan only—free)
PO Box 1607
Rockville, MD 20850
Attn: Carolyn Trimarchi

INDUSTRIAL/LARGE SCALE ENERGY SYSTEMS: 32 minutes, black & white
Sandia Corp. (NM) talks about project to use 600°F sun heat to provide heating, cooling & electricity to living or work space using parabolic collector; National Research Council of Canada outlines experimental research in energy efficient house design, methane recovery on farms, and electricity from large, remote vertical axis wind turbine; Graduate Asst. at New Mexico State Univ. explains two solar projects—solar lab and solar demonstration house; Marelco Inc. engineering & design company discusses looking to vegetable matter for a renewable energy resource.

The foregoing are available from:
Dennis Karlstad
2330 Burano
Sacramento, CA 95825
(415) 524-7353

Instructional television news features for lecture supplement & library reference (½" reel to reel or ¾" cassette)
RESIDENTIAL ENERGY-CYCLE SYSTEMS: 33 minutes, black & white
"Sky-Therm" solar systems, the design & operation, are described; "Sundance Solar Systems" equipment is described particularly their domestic heat storage projects; "Solar Research" ready to install domestic water heating kits are described along with Annual Cycle Energy System components; an architect with "Sun-Structures, Inc." describes integrated alternate energy systems designed for homes in Michigan

PROJECT OUROBOROS: 25 minutes, black & white
Lecture of Prof Dennis Holloway, University of Minnesota School of Architecture on results of work done by 300 design students in the areas of solar heating, sanitation, windmill electricity & gardening as expressed in two houses: Ouroboros South—a new house utilizing energy conservation & solar system, Ouroboros East—solar retrofit of home in Minnesota

SOLAR ENERGY TODAY: 55 minutes, color, television program; available in broadcast format for TV airing and in ¾" video cassette for viewing by educational, professional & governmental organizations—no fee
Covers present day solar energy applications & related energy-conserving building design. Interview with Fred S. Dubin, nationally recognized expert in application of solar energy & design of energy-conserving buildings & operating systems. Shows solar homes & other installations, related materials on design, effectiveness, aesthetics of practical solar energy systems.

Available from:
Center for Energy Policy & Research
New York Institute of Technology
Old Westbury, NY 115[illegible]8
(516) 686-7578

FILM LIBRARY: library of films on conservation, environment & ecology. Available for loan. For information write:
National Association of Conservation Districts
1025 Clark Street
Stevens Point, WI 54481 (715) 341-1022

SLIDES

SOLAR HOMES: 50 35mm color slides with printed narration (price--$50), 50-frame 35mm color filmstrip with 30-minute tape cassette (price—$25). Shows examples of houses & buildings with: liquid flat-plate solar collectors, "rollbond" copper & aluminum absorber panels, extruded plastic & rubber solar collectors, reinforced concrete solar collector, trickling water solar collectors, energy storage systems, hot-air collectors, various types of solar air-conditioning systems.

Available from:
James L. Ruhle & Associates
P.O. Box 4301
Fullerton, CA 92631
(714) 526-6120

BASIC SOLAR SLIDE KIT (V01): 19 slides, 35mm, color (Purchase—$19)
Illustrates basic solar principles solar heat gain through windows, flat-plate collectors, and photovoltaics as well as views of famous solar homes by Harry Thomason, Zomeworks, Harold Hay and the University of Delaware.

SOLAR COLLECTORS SLIDE KIT (V02). 19 slides, 35mm, color (Purchase—$19)
Slides depict flat-plate collectors from inventors and manufacturers. Copper, aluminum and steel products included, as well as Delaware U's air collector and the solar sun roof sandwich by the editor of Solar Energy Digest

SOLAR BUILDINGS SLIDE KIT (V03): 19 slides, 35mm, color (Purchase—$19)
Shows solar heated buildings both built & planned around the country. Duplicates many of the pioneer projects included in Basic Slide Kit, and adds projects like the Decade 80's Solar Home, Grassy Brook Village and the Science Museum of Virginia

The foregoing are available from:
Solar Bookshop
TEA Inc
Church Hill
Harrisville, NH 03450

SOLAR SLIDE KIT: 1974, 21 slides, 35mm, color (Purchase—$12)
Describes beadwall construction, drum heat storage & skylid operation for a passive solar design.

Available from:
Zomeworks Corporation
P.O. Box 712
Albuquerque, NM 87103

SOLAR ENERGY: READY WHEN YOU ARE: 1977, 140 slides, 35mm, color, audio cassette (Purchase—$28)
Explores variety of solar technologies readily available for homes, apartments, office buildings, schools & factories. Focuses on residential & commercial applications in different parts of the U.S.

Available from:
National Audio-Visual Center
General Services Administration
Washington, DC 20409

SOLAR HOMES IN THE LOW COUNTRIES: 1976, 75 slides, 35mm, color, narration on cassette
Shows construction of two homes with solar heating & hot water systems. Both were built by Solar Development Associates with HUD grants for the solar systems. Homes are located in South Carolina. Covers architecture, engineering & cost benefits.

Available from:
Solar Sources Corp.
Bankers Trust Office Park
Hilton Head, SC 29928
Attn: Ren Frutkin (803) 785-8818
(Rental—$50/day, $25/day if rented 3 or 4 times)

SOLAR SLIDES, PICTURES, VIEW-GRAPHS: variety of solar slides solar heating & cooling applications, instrumentation, systems analysis, etc. (10 categories), pictures & view-graphs Available for duplication costs.

Available from.
Dave L Christensen
University of Alabama in Huntsville
P.O Box 1247
Huntsville, AL 35807

SHOWCASE OF SOLAR HOMES: 40 slides, 35mm, audio cassette (Purchase—$40)
Shows solar houses & test installations open to the public in various parts of the U S. Houses vary in price range, type of architecture & system. Set includes both private & government funded projects, demonstration & test houses & universities

RETROFIT OF A SUBURBAN HOME: 20 slides, 35mm, audio cassette (Purchase—$30)
Describe systems & steps involved in the air system designed and installed by engineer Charles Thomsen in his Nebraska home. Script (on cassette) written by Thomsen

COMMERCIAL SOLAR INSTALLATIONS: 40 slides, 35mm, audio cassette (Purchase—$40)
Shows buildings with solar systems, including motels, warehouses, offices, high rise apartments, condominiums, medical complexes, coin-op laundries & car washes Accompanying materials give details on installation costs, collector & storage area, performance & expected payback

A SOLAR GREENHOUSE PROJECT: 19 slides, 35mm, audio cassette (Purchase—$30)
Describes various types of solar greenhouses; details construction of an attached solar greenhouse.

SOLAR SPEC HOMES: 40 slides, 35mm, audio cassette (Purchase—$40)
Shows variety of architectural styles & different solar systems that are used. Shows solar homes in a number of price ranges.

FULL CIRCLE: 40 slides, 35mm, audio cassette (Purchase—$40)
Reviews millennium of solar development in North America. Beginning with Pueblo structures in southwest, slides trace solar systems for heating & cooling to the present. Shows examples of early designs & solar homes from 1930's to present plus view of the future proposed by leading architects. Presentation prepared & written by Donald Watson, a solar architect.

The foregoing are available from:
Solar Engineering Magazine
8435 N. Stemmons Freeway, Suite 880
Dallas, TX 75247

SOLAR-ED LIBRARY: 200 slides, 35mm, color (Purchase—$129.50)
To be used for educational purposes. Covers collector design and performance, thermal storage & solar terminology. Includes calculations, graphs, concept drawings, photos of actual solar components. Comes with manual to assist in classroom presentation.

Available from:
The Cooper Solar Distributing Company
1627 Litchfield Turnpike
Woodbridge, CT 06525

A TOUR THROUGH AMERICA'S FIRST SOLAR ENERGY SUBDIVISION: 18 slides, 35mm, color, script (Purchase—$24, discount to teachers & schools)
Shows solar houses and solar systems—what systems and components look like, some schematic diagrams.

Available from:
Sennergetics
18621 Parthenia Street
Northridge, CA 91324 (213) 885-0323

SOLAR ARCHITECTURE SLIDE SET: 35mm (Purchase—$10)
Slides of eleven solar homes in Colorado, N Mexico, Arizona and Minnesota. Photos by Gregory Franta

Available from:
Roaring Fork Resource Center
PO Box 9950
Aspen, CO 81611 (303) 925-8885

SOLAR SLIDES: 35mm slides on all aspects of solar energy—collectors, swimming pools, photovoltaics, heating & cooling, homes, commercial buildings, schematics, etc (Purchase—$1.00/each for non-members, $.70 for members, $5 minimum order)

Available from:
Solar Energy Institute of America
PO Box 6068
Washington, DC 20005

VIDEOTAPES

ARCHITECTURE, BUILDING & THE SUN—THE KAREN TERRY HOUSE: videotape geared for students, professionals & laymen, 21 minutes, black & white
Documentary account of conception, construction & performance of a sophisticated "passive" project featuring Karen Terry, builder; David Wright, architect; and B. T. (Buck) Rogers.
(Also available from: The Solar Bookshop, TEA, Church Hill, Harrisville, NH 03450, purchase—$175 (½" reel), $200 (¾" cassette)

SOLAR REALITY: A DIALOGUE WITH JOHN I. YELLOTT: videotape geared for students, professionals & laymen
Yellott, a famous solar pioneer, talks about past, present & future of solar.

The foregoing are available from:
Solarvision Inc.
Box A
Hurley, NY 12443

SOLAR HEATING & COOLING OF RESIDENTIAL BUILDINGS: SIZING, INSTALLATION & OPERATION OF SYSTEMS and SOLAR HEATING & COOLING OF RESIDENTIAL BUILDINGS: DESIGN OF SYSTEMS: videotapes (also available as manuals)
Training materials for designers & installers of solar systems. Material developed by Colorado State U under sponsorship of Dept. of Commerce & Nat'l Assn. of Home Builders.

Available from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
or
Colorado State University
Ft Collins, CO 80523

SOLAR TOPICS ON COLOR VIDEO CASSETTE:
3 color video cassettes on solar energy (Purchase $50/each. 3 for $135)

Cassette #1 Sheldon Butt. President, Solar Energy Industries Assn describes potential market for solar heating & air-conditioning (15 minutes).

Cassette #2 Joe Sherman. HUD executive, is interviewed by John Blake. Exec Dir., SEIA Interview covers solar demonstration program of Dept of Housing and Urban Development (15 minutes).

Cassette #3 Bob Schlesinger President of Rho Sigma gives visual demonstration of proper orientation of controls in a solar energy system (9 minutes)

Available from

Solar Engineering Magazine
8435 N Stemmons Freeway, Suite 880
Dallas TX 75247

FLAT PLATE SOLAR COLLECTORS, PART I and PART II: (Part I -58 min). (Part II—58:30 min.) color
Harry McMillan Univ of South Carolina
Description of function of various parts of the flat plate collector and some typical geometries. Mathematical model presented for collector efficiency, and useful gain in terms of pertinent variables Some practical considerations reviewed and several features of current models are listed Notes included

SELECTIVE COATINGS & EVACUATED COLLECTORS. PART I: 46 15 min . color
Harold B[illegible] Southern Methodist University
Thermal resistance network described which shows quantitatively the combined importance of selective coatings and vacuum in controlling useful energy produced in solar collector How vacuum affects losses is considered Post support evacuated model shown Design equations that relate losses to spacing pressure level, and temperature are developed

SELECTIVE COATINGS & EVACUATED COLLECTORS. PART II: 42 45 min . color
Harold Blum & Charles Moore. Southern Methodist University
Selective coatings to enhance solar collection & lessen heat losses by radiation are discussed by considering basic energy equations, the thermal resistance model and mechanisms of selectivity Equipment to measure solar absorptivity & operating temperature emissivity shown and described. Copper on galvanized steel selective coating prepared. and samples of coatings displayed.

SOLAR CONCENTRATORS: 30 min.. color
Kent Reed, Argonne National Laboratory
Optical concentration of incoming solar energy reduces active absorber area required in collector of a given acceptance aperture area. Potential benefits of this reduction in thermal & photovoltaic collectors outlined. Limiting relationship between concentration & angular acceptance presented. and implications in concentrator collector design discussed. Examples of nonfocusing & focusing collectors described.

THERMAL STORAGE SYSTEMS: 59:30 min., color
L. Neuman Connor, University of South Carolina
Introduction to energy storage in solar thermal system. Time dependent relationship between solar input, delivered load, and energy storage depicted. Characteristics of thermal storage media and systems fabricated using these media discussed. Particular attention given to water systems, pebble bed storage, and phase-change systems.

DESIGN & INSTALLATION OF SOLAR HEATING & COOLING SYSTEMS, PART I: 52:25 min., color
George Löf, Susumu Karaki, Byron Winn, Colorado State University
Review of solar energy systems. discussion of simplified design procedures, and discussion of solar system economics and installation procedures.

DESIGN & INSTALLATION OF SOLAR HEATING & COOLING SYSTEMS, PART II: 51:30 min.. color
George Löf. Susumu Karaki, Byron Winn. Colorado State University
Discussion of automated design procedures for solar systems. the design and installation of subsystem components. and solar system economics.

SOLAR ENERGY AND CONSUMER MARKETS:
60 minutes. black & white
S. Lampert. Univ of Southern California. Gilbert Yanow. Caltech JPL
Consumer oriented considerations relative to general acceptance of solar energy as an alternative energy resource Comparative costs of systems. legal aspects and regulations. financing problems. and incentives. Influence of rising costs & availability of oil or natural gas compared with costs associated with installation and use of solar operated systems

INSTITUTIONAL CONSIDERATIONS INVOLVING SOLAR ENERGY SYSTEMS: 55:45 min., black & white
S Lampert, University of Southern California; Gilbert Yanow, Caltech JPL
Panel of experts from industry, government and education discuss ramifications of various institutional, societal & economic measures upon development & growth of a solar energy industry. Issues such as uniform standards & regulations for solar energy systems & their use; governmental responsibilities for planning & zoning; educational programs for acceptance of solar as meaningful alternative resource

SOLAR HOUSE DESIGN: 49:10 min., color
W Shick, S Konzo, R. Jones, W Harris, University of Illinois
House designed as efficient solar collector-storage unit, with super-insulated enclosures and south triple-glazed windows presented. Solar gain of south-facing triple-glazed windows analyzed and sun control by roof overhang described. Costs of super-insulation estimated. Other energy savings options described

SOLAR DEMONSTRATION PROJECTS: 60 min., color
J Williams, Georgia Institute of Technology
Schematic diagrams of typical solar heating and cooling systems presented along with typical hot water heating systems. Several case studies shown ranging from small residential installations to large elementary school and large community center with ice rink. Presents overview of material in other tapes by showing real-world applications

The foregoing are available from
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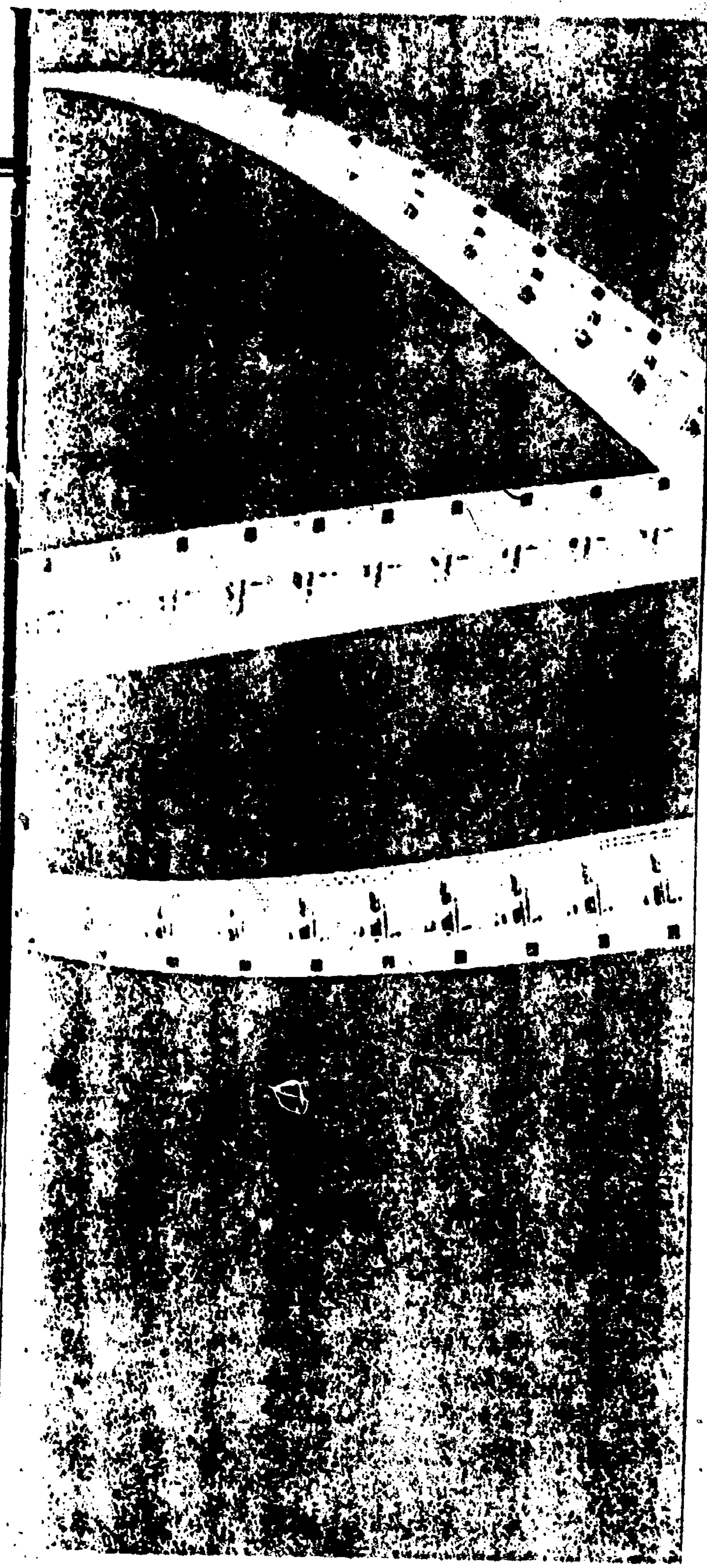
(312) 567-3460
(Purchase—$295/video cassette. ¾" video cassettes, also available for loan)

Also available from
Association for Media-Based Continuing Education for Engineers, Inc
c/o Georgia Tech
Atlanta, GA 30332
(404) 894-3362



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IN PENNSYLVANIA CALL (800) 462 4983

DC 104
2nd edition
Oct. 1977

ENERGY CONSERVATION IN BUILDINGS

Technical

ASHRAE HANDBOOK OF FUNDAMENTALS...ASHRAE Publications, 345 East 47th St., New York NY 10017, 1977, 688 pp, $40.00 + $2.00 handling. Chapter 20, "Design Heat Transmission Coefficients", contains a complete list of the properties, including R-values, of insulation and building materials.

GUIDELINES FOR SAVING ENERGY IN EXISTING BUILDINGS...GPO, 1975; Pt. 1 - Stock No. 041-018-00079-8, 304 pp, $5.25; Pt. 2 - Stock No. 041-018-00080-1, 465 pp, $5.05. Two-part manual for building managers and engineers on ways to save energy.

MANUAL J -- LOAD CALCULATION FOR RESIDENTIAL WINTER AND SUMMER AIR CONDITIONING...National Environmental Systems Contractors Association, 1501 Wilson Boulevard, Arlington VA 22209, 4th edition, $7.50 (Non-Members), $4.50 (Members). Technical guide to calculating heat loads.

MINIMUM DESIGN STANDARDS FOR HEAT LOSS CALCULATION...U. S. Dept. of Housing and Urban Development, Washington DC 20410, Order No. 4940-6, 22 pp, March 1973. Guide to calculating the heat transmission coefficients of building sections.

RETROFITTING EXISTING HOUSING FOR ENERGY CONSERVATION - AN ECONOMIC ANALYSIS...S. R. Peterson; GPO, Stock No. 003-003-01360-9, 76 pp, 1974, $1.35. Covers the economic factors of adding insulation to existing housing.

Non-Technical

CITIZEN ACTION GUIDE TO ENERGY CONSERVATION...Citizens' Advisory Committee on Environmental Quality; GPO, Stock No. 040-000-00300-2, 64 pp, 1974, $1.75. Overview of the energy problem and various opportunities for saving energy in industry, transporation and buildings.

CONSUMERS' GUIDE TO EFFICIENT ENERGY USE IN THE HOME...Gas Appliance Manufacturers Assoc., 1901 N. Ft Myer Dr., Arlington VA 22209, 5 pp, 1973, Free.

11 WAYS TO REDUCE ENERGY CONSUMPTION AND INCREASE COMFORT IN HOUSEHOLD COOLING...Office of Consumer Affairs and the National Bureau of Standards; GPO, Stock No. 003-003-00876-1, $.40.

ENERGY CONSERVATION - UNDERSTANDING AND ACTIVITIES FOR YOUNG PEOPLE...GPO, Stock No. 041-018-00091-7, 20 pp, $.85. Designed for junior high school students; contains suggested activities for increasing their awareness of energy conservation.

THE ENERGY MISER'S MANUAL...W. H. Morrell; The Grist Mill, 90 Depot Rd., Eliot ME 03903, 77 pp, 1976, $1.95 + $.30 postage. Compares the insulating values of different materials and different types of walls; covers other ways to save energy through site planning.

ENERGY PRIMER...Portola Institute, 558 Santa Cruz Ave., Menlo Park CA 94025, 200 pp, 1974, $5.50. Section on "Architecture" contains a detailed description of building codes.

THE ENERGY SAVING GUIDEBOOK...G. S. Springer and G. E. Smith; Technomic Publishing Co., Westport CT 06880, 103 pp, 1974, $8.50. Covers the basics of heating and cooling your house; includes short section for mobile home owners.

44 WAYS TO BUILD ENERGY CONSERVATION INTO YOUR HOMES...Owens-Corning Fiberglas Corp., Grandville OH 43023, Pub. No. 5-BL-7055-A, 1975, Free.

THE FUEL SAVERS...D. Scully, D. Prowler and B. Anderson; Northwest New Jersey Community Action Program, Inc., Prospect and Marshall Sts., Phillipsburg NJ 08865, 60 pp, 1976, $3.00. Do-it-yourself guide to winterizing the home; includes some simple solar retrofit ideas.

HOME ENERGY HOW-TO...A. J. Hand; Harper & Row, New York NY 10022, 258 pp, 1977, $9.95. Part I of this book concentrates on ways to conserve energy, including insulation; Part II covers ways to use alternative energies, including solar.

HOME ENERGY SAVER'S WORKBOOK...Federal Energy Administration; GPO, Stock No. 041-018-00116-8, 29 pp, 1976, $.35. Basic measures to make your home more energy efficient.

THE HOMEOWNER'S ENERGY GUIDE: HOW TO BEAT THE HEATING GAME...J. A. Murphy; Thomas Y. Crowell Company, New York NY 10033, 218 pp, $6.95. Contains section on computing the cost of your home's present heat loss versus the cost of improving its heat retention.

HOMEOWNER'S GUIDE TO SAVING ENERGY...B. L. Price and J. T. Price; Tab Books, Blue Ridge Summit, PA 17214, 288 pp, 1976, $5.95. Illustrated simple methods for saving energy and money.

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ED-U-SOL (a scaled down version of a solar collection and water heating system) Contact: Systems Using Nature, Ltd., P. O. Box 230, Ballston Lake, NY 12019.

KWASNOSKI SOLAR ED-KIT (Can be changed into 30 different collector configurations) Contact: The Cooper Solar Distributing Company, 1627 Litchfield Tpke., Woodbridge CT 06525, $395.00.

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UNIFORM SOLAR ENERGY CODE. International Association of Plumbing and Mechanical Officials, 5032 Alhambra Ave., Los Angeles, California 90032. $6.00

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ANSI	American National Standards Institute 1430 Broadway New York, NY 10018 Tel: (212)-354-3300	Coordinates activities of other standards-making organizations.
ARI	Air-Conditioning & Refrigeration Institute 1815 North Fort Myer Drive Arlington, VA 22209 Tel: (703)-524-8800	Formed ARIF (Air-Conditioning & Refrigeration Institute Foundation) for developing procedures for certifying collectors under NBS contract.
SEIA	Solar Energy Industries Association Suite 800 1001 Connecticut Ave., NW Wash. DC 20036 Tel: (202)-293-2981	Formed SEREF (Solar Energy Research and Education Foundation) for administering the above certification program under contract to DOE.
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers 345 East 47th St. New York, NY 10017 Tel: (212)-644-7853	Developed methods of testing solar collectors and thermal storage, ASHRAE 93-77 & 94-77.
ASTM	American Society for Testing & Materials 1916 Race St. Phila., PA 19103 Tel: (215)-299-5476	Developed performance tests for materials and components.
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UL	Underwriters Laboratories, Inc. 207 East Ohio St. Chicago, IL 60611 Tel: (312)-642-6969	Is drafting safety standards for collectors.
ASME	American Society of Mechanical Engineers United Engineering Center 345 East 47th St. New York, NY 10017 Tel: (212)-644-7722	Developing temperature and pressure standards for piping and pressure vessels.
SMACNA	Sheet Metal & Air-Conditioning Contractors National Association, Inc. 8224 Old Courthouse Rd. Tyson's Corner Vienna, VA 22180 Tel: (703)-790-9890	Developed installation standards for air collectors.
IAPMO	International Association of Plumbing & Mechanical Officials 5032 Alhambra Ave. Los Angeles, CA 90032 Tel: (213)-223-1471	Issued Uniform Solar Energy Code which has been adopted by several jurisdictions as a plumbing code for installing liquid collectors.

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SOURCES OF INFORMATION ON ALTERNATIVE ENERGIES

Acorn
Governors State University
Park Forest South, IL 60466
(312) 534-5000
. gives news about energy alternatives, appropriate technology, and people in the Midwest; prints newsletter, $6/yr., for individuals, $10/yr., for institutions.

Alternative Energy Association of American
P.O. Box 26507
Albuquerque, NM 87125
(505) 873-2084
. prints bimonthly newsletter, Alternative Energy News; membership $10/yr.

Alternative Energy Resources
435 Stapleton Building
Billings, MT 59101
(406) 259-1958
. prints newsletter, AERO Sun-Times; membership, $10/yr.

Alternative Technologies Association
P.O. Box 20571
Indianapolis, IN 46220
. prints bi-monthly newsletter, $3/yr.; membership (including newsletter), $10/yr.

American Underground-Space Association
Thomas C. Atchison, Executive Director
Dept. of Civil and Mineral Engineering
University of Minnesota
Minneapolis, MN 55455
(612) 376-5580
. prints journal, Underground Space; membership $30/yr.

American Wind Energy Association
54468 CR 31
Bristol, IN 46507
(219) 848-4360
. prints Wind Power Digest, $6/yr., membership (including newsletter and Wind Power Digest), $25/yr.

Center for Energy and Mineral Resources
Texas A & M University
College Station, TX 77843
(713) 845-8025
. free information on energy conservation and alternative technologies.

Center for Energy Policy and Research
New York Institute of Technology
Old Westbury, NY 11568
(516) 686-7744
. free energy information.

Citizens United for Responsible Energy
1342 30th St.
Des Moines, IA 50311
. membership including newsletter, $10/yr., and up.

Ecotope Group
2332 E. Madison
Seattle, WA 98112
(206) 322-3753
. information on biogas, solar greenhouses and agriculture; please send stamped, self-addressed envelope.

Energy Information Center
215 Freemont, 6th floor
San Francisco, CA 94105
. free D.O.E. literature; includes insulation, wind, photovoltaic, etc., information.

Environmental Action Reprint Service
(EARS)
2239 East Colfax
Denver, CO 80206
. catalog available. 50¢

Geothermal Resources Council
Box 1033
Davis, CA 95616
(916) 758-2360
. free and low cost information on geothermal energy; membership $25/yr.

Lewis Research Center
NASA-MS 49-5
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-4000
. photovoltaic information.

Midwest Energy Alternatives (MEA)
P.O. Box 83202
Lincoln, NE 68501
(402) 477-3101
. membership, $10 and up.

The National Center for Appropriate Technology
P.O. Box 3838
Butte, MT 59701
(406) 723-6533
. information applicable to the needs of people with low incomes.

The National Center for Community Action Network Services: Energy
1711 Connecticut Ave., N.W.
Washington, DC 20009
. information on general energy conservation measures.

National Energy Information Center
Federal Building
12th Street and Pennsylvania Avenue, NW
Washington, DC 20461
(202) 566-9820
. free FEA and ERDA information; includes wind, photovoltaic, etc. information.

Photovoltaic Project
Massachusetts Institute of Technology
Lincoln Laboratory
Box 73
Lexington, MA 02173
. free photovoltaic information.

Photovoltaic Systems Definition Project
Division 5719
Sandia Laboratories
Albuquerque, NM 87115
. free photovoltaic information.

Service for Energy Conservation in Architecture (SECA)
Boston Architectural Center
320 Newbury St.
Boston, MA 02115
(617) 267-7772
. functions as a within-industry clearinghouse of information on insulation, building codes and alternative technologies; membership, $25/yr., and up.

Total Environmental Action (TEA)
Church Hill
Harrisville, NH 03450
(603) 827-3374
. workshops; books.

U.S. Department of Agriculture
Office of Communications
Publications Office
Washington, DC 20250
(202) 447-8611
. prints Solar Grain Drying: Progress and Potential and Solar Heating for Milking Parlors.

U.S. Department of Agriculture
Agricultural Research Service
Northeastern Region
Agricultural Research Center West
Beltsville, MD 20705
. prints Solar Energy Utilization: A Bibliographic Guide.

Wind Energy Society of America
1700 East Walnut Street
Pasadena, CA 91106
(213) 443-1786
. membership (including newsletter), $20/yr.

Wood Energy Institute
Box 1, Fiddlers Green
Waitsfield, VT 05673
(802) 496-2508
. prints newsletter; membership, $15/yr.

Note: Also contact your state's energy office for general energy information.

Periodicals

ALTERNATIVE SOURCES OF ENERGY. Alternative Sources of Energy, Inc., Route 2, Box 90A, Milaca, MN 56353, Quarterly, $10.00/yr. Combination of articles, columns and features on many aspects of energy alternatives; serves as a clearinghouse for exchange of ideas and technologies.

CO-EVOLUTION QUARTERLY. POINT, Box 428, Sausalito, CA 94965, $8.00/yr. Continuation of the Whole Earth Catalogs; contains essays and reviews of publications and services in the field of alternative lifestyles.

THE MOTHER EARTH NEWS. The Mother Earth News, Inc., 105 Stoney Mountain Road, Hendersonville, NC 28739, Bi-monthly, $10.00/yr. Down-to-earth descriptions of peoples' experiences with alternative lifestyles, ecology and energy; source for what is happening in energy at the grass roots level; source for books.

RAIN: Journal of Appropriate Technology, 2270 NW Irving, Portland, OR 97210, 10 issues, $10.00/yr., or less. Information access and reference service for people developing more satisfying living patterns that increase local self-reliance and press less heavily on our limited resources.

WOODBURNING QUARTERLY. Division of Investment Rarities, 8009 34th Avenue S, Minneapolis, MN 55420, $5.00/yr.
Features articles on using wood as fuel and on related sources of energy.

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Auburn, AL 36830
Attn: Prof. R. I. Vachon

Center for Environmental Studies
UNIVERSITY OF ALABAMA
P.O. Box 1247
Huntsville, AL 35807

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College of Architecture
ARIZONA STATE UNIVERSITY
Tempe, AZ 85281

School of Engineering
ARIZONA STATE UNIVERSITY
Tempe, AZ 85281

College of Engineering & Technology
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Flagstaff, AZ 86001
Attn: Dr. B. W. Davis

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Holbrook, AZ 86025

UNIVERSITY OF ARIZONA
Tucson, AZ 85721
Attn: Dr. Robert Carlile
Chmn.-ESE Option Committee
Dept. of Electrical Engineering
College of Engineering
Engineering Building #20

ARKANSAS

Dept. of Engineering Science
UNIVERSITY OF ARKANSAS
209 Engineering Building
Fayetteville, AR 72701

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CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, CA 91103

Department of Physics
CALIFORNIA POLYTECHNIC STATE UNIVERSITY
San Luis Obispo, CA 93407

School of Natural Sciences
CALIFORNIA STATE COLLEGE
5500 State College Parkway
San Bernardino, CA 92407

School of Engineering
CALIFORNIA STATE POLYTECHNIC UNIVERSITY
3801 West Temple Avenue
Pomona, CA 91768

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Chico, CA 95929

Department of Mechanical Engineering
CALIFORNIA STATE UNIVERSITY
Fullerton, CA 92634

Physical Sciences Department
CALIFORNIA STATE COLLEGE, STANISLAUS
Turlock, CA 95380

CALIFORNIA STATE UNIVERSITY
Long Beach, CA
Attn: Dr. Boyd A. Davis
Director of Academic Planning

School of Engineering
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5151 State University Drive
Los Angeles, CA 90032

Department of Engineering
CALIFORNIA STATE UNIVERSITY
18111 Nordoff Street
Northridge, CA 91330

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Industrial-Technical Department
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5885 Haven Avenue
Alta Loma, CA 91701
Attn: Dean of Occupational Services

Civil/Mechanical Engineering Technology
COGSWELL COLLEGE
600 Stockton Street
San Francisco, CA 94108

Dept. of Engineering & Technology
COLLEGE OF THE DESERT
43-500 Monterey Avenue
Palm Desert, CA 92260

COLLEGE OF MARIN
Kentfield, CA 94904

COLLEGE OF THE REDWOODS
Eureka, CA 95501

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COLLEGE OF THE SISKIYOUS
C00 College Avenue
Weed, CA 96094

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CONSUMNES RIVER COLLEGE
8401 Center Parkway
Sacramento, CA 95823

Biological Science Department
DIABLO VALLEY COLLEGE
321 Colf Club Road
Pleasant Hill, CA 94523

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321 E. Chapman Avenue
Fullerton, CA 92635

Physics Department
GROSSMONT COLLEGE
8800 Grossmont College Drive
El Cajon, CA 92020

Department of Engineering
HUMBOLDT STATE UNIVERSITY
Arcata, CA 95521

Physical Science Department
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2659 Lake Tahoe Blvd.
P.O. Box 14445
South Lake Tahoe, CA 95702

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One Barnard Drive
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21400 Highway 79
San Jacinto, CA 92383

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2701 Fairview Road
Costa Mesa, CA 92626

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P.O. Box 1600
Oxnard, CA 93032

Dept. of Engineering & Technology
PASADENA CITY COLLEGE
1570 E. Colorado Blvd.
Pasadena, CA 91106

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Air-Conditioning & Refrigeration Dept.
12th & Russ Streets
San Diego, CA

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7250 Mesa College Drive
San Diego, CA 92111

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1600 Holloway Avenue
San Francisco, CA 94132

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5151 Pacific Avenue
Stockton, CA 95207

Solar Technology Department
SAN JOSE CITY COLLEGE
2100 Moor Park Avenue
San Jose, CA 95128

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Building U
San Jose, CA 95192
Attn: Program Information

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Rocklin, CA 95677
Attn: Dean of Voc/Career Ed.

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Sacramento, CA 95814
Attn: JoAnn Trujillo
Program Coordinator

Solar Heating Technician Skills
Training Program
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1801 East Cotati Avenue
Rohnert Park, CA 94928
Attn: Gayla Mote

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Stanford, CA 94305

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Los Angeles, CA 90024

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Solar Energy Applications Laboratory

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Attn: Dr. Tom Forster

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Attn: Dept. of Energy Sciences

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GEORGIA INSTITUTE OF TECHNOLOGY
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Shepherd Road
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Instructional Services

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225 West Engineering Building
Ann Arbor, MI 48109

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Northfield, MN 55057

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Minneapolis, MN 55455

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Mississippi State, MS 39762

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Springfield, MO 65802

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Rolla, MO 65401

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UNIVERSITY OF NEVADA, LAS VEGAS
4505 Maryland Parkway
Las Vegas, NV 89154

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Reno, NV 89557

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Hanover, NH 03775

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GLASSBORO STATE COLLEGE
Glassboro, NJ 08028

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RUTGERS UNIVERSITY
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Piscataway, NJ 08854
Attn: Prof. Fich, Graduate Director

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Santa Fe, NM 87501

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Las Cruces, NM 88003

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UNIVERSITY OF NEW MEXICO
Albuquerque, NM 81731

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Annandale-on-Hudson, NY 12504

Department of Physics
MOHAWK VALLEY COMMUNITY COLLEGE
1101 Sherman Drive
Utica, NY 13501
Attn: Dr. Francis Dunning

Energy Engineering & Policy Program
POLYTECHNIC INSTITUTE OF NEW YORK
Route 110
Farmingdale, NY 11735

Department of Mechanical Engineering
ROCHESTER INSTITUTE OF TECHNOLOGY
1 Lomb Memorial Drive
Rochester, NY 14623

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Albany, NY 12222

Department of Earth Sciences
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Brockport, NY 14420

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Fargo, ND 58102

School of Engineering & Mines
UNIVERSITY OF NORTH DAKOTA
Grand Forks, ND 58202

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OHIO STATE UNIVERSITY
Columbus, OH 43210

Department of Mechanical Engineering
UNIVERSITY OF DAYTON
Dayton, OH 45469

Electrical Engineering Department
YOUNGSTOWN STATE UNIVERSITY
Youngstown, OH 44555
Attn: Dr. C. K. Alexander, Jr.

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School of MAE
OKLAHOMA STATE UNIVERSITY
Stillwater, OK 74074

School of Aerospace, Mechanical & Nuclear Engineering
UNIVERSITY OF OKLAHOMA
Norman, OK 73019

Department of Mechanical Engineering
UNIVERSITY OF TULSA
Tulsa, OK 74104

OREGON

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Oregon City, OR

UNIVERSITY OF OREGON
Eugene, OR 97403

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Continuing Professional Education
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Philadelphia, PA 19104

LAFAYETTE COLLEGE
Easton, PA 18042
Attn: Department of Engineering

Department of Architectural Engineering
PENNSYLVANIA STATE UNIVERSITY
101 Engineering Building "A"
University Park, PA 16802

Department of Architecture
TEMPLE UNIVERSITY
Philadelphia, PA 19122

Department of Mechanical Engineering
UNIVERSITY OF PENNSYLVANIA
111 Towne Building, D-3
Philadelphia, PA 19174

RHODE ISLAND

Dept. of Engineering & Engineering Technology
RHODE ISLAND JUNIOR COLLEGE
Knight Campus, 400 East Avenue
Warwick, RI 02886

Department of Mechanical Engineering
UNIVERSITY OF RHODE ISLAND
Kingston, RI 02881

TENNESSEE

Department of Mechanical Engineering
MEMPHIS STATE UNIVERSITY
Memphis, TN 38152

Mechanical Engineering Department
TENNESSEE TECHNOLOGICAL UNIVERSITY
Cookeville, TN 38501

Dept. of Mechanical & Aerospace Engineering
UNIVERSITY OF TENNESSEE
Knoxville, TN 37916

TEXAS

Department of Mechanical Engineering
RICE UNIVERSITY
Houston, TX 77501

Dept. of Civil/Mechanical Engineering
SOUTHERN METHODIST UNIVERSITY
Dallas, TX 75275

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Department of Physics
TEXAS A & I UNIVERSITY
Kingsville, TX 78363

Department of Mechanical Engineering
TEXAS A & M UNIVERSITY
College Station, TX 77843

Department of Mechanical Engineering
TEXAS TECHNOLOGICAL UNIVERSITY
Lubbock, TX 79409

Solar Energy Program Graduate Office
TRINITY UNIVERSITY
715 Stadium Drive
San Antonio, TX 78284

UNIVERSITY OF HOUSTON
Houston, TX 77004
Contact: Graduate Advisor
Department of Engineering or Arch.

UNIVERSITY OF TEXAS AT AUSTIN
Austin, TX 78712

UTAH

Chemistry Department
DIXIE COLLEGE
St. George, UT 84770
Attn: C. A. Dean

Department of Mechanical Engineering
UNIVERSITY OF UTAH
Salt Lake City, UT 84112

Physics Department
WEBER STATE COLLEGE
Ogden, UT 84408
Attn: Dr. Robert Capener

VERMONT

Institute for Social Ecology
GODDARD COLLEGE
Plainfield, VT 05667

Electrical Engineering Department
UNIVERSITY OF VERMONT
Burlington, VT 05401

VIRGINIA

Department of Mechanical Engineering
OLD DOMINION UNIVERSITY AT VARC
12070 Jefferson Avenue
Newport News, VA 23606
Attn: Dr. G. L. Goglia

Department of Mechanical Engineering
UNIVERSITY OF VIRGINIA
Charlottesville, VA 22901

College of Architecture & Urban Studies
V.P.I. & STATE UNIVERSITY
Blacksburg, VA 24061

WASHINGTON

JOINT CENTER FOR GRADUATE STUDY
100 Sprout Road
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Program in Social Management of Technology
UNIVERSITY OF WASHINGTON
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Department of Mechanical Engineering
WASHINGTON STATE UNIVERSITY
Pullman, WA 99163

WISCONSIN

College of Engineering
MARQUETTE UNIVERSITY
1515 West Wisconsin Avenue
Milwaukee, WI 53233

College of Environmental Sciences
UNIVERSITY OF WISCONSIN-GREEN BAY
Green Bay, WI 54302

Department of Mechanical Engineering
UNIVERSITY OF WISCONSIN
1343 Engineering Res. Bldg.
Madison, WI 53706

Department of Engineering
UNIVERSITY OF WISCONSIN-EXTENSION
Madison, WI 53706

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Milwaukee, WI 53211

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VOCATIONAL/TECHNICAL SCHOOLS/COURSES
SOLAR-RELATED

April 1978

California

CENTER FOR EMPLOYMENT TRAINING
425 South Market Street
San Jose CA 95113
Attn: Rudolph Rodriguez

Offer two weeks of solar training (build solar collectors & install them) as part of a 6-week course in "Building Maintenance."

Industrial Technical Department
CHAFFEY COMMUNITY COLLEGE
5885 Haven Avenue
Alta Loma CA 91701
Attn: Dean of Occupational Services

Offer "Solar Energy I"-introduction to solar heating & cooling systems; and "Solar Energy II" construction & installation of solar energy devices.

Civil/Mechanical Engineering Technology
COGSWELL COLLEGE
600 Stockton Street
San Francisco CA 94108

Offer "Solar Energy Applications" workshop for designers, builders, etc. on design & contruction of sun & wind-powered systems.

COLLEGE OF THE REDWOODS
Eureka CA 95501
Attn: Industrial Technology Dept.

Offer "Solar Heating Systems" course on design & construction of active solar systems - for vocational/technical majors.

ENERGY SYSTEMS INC.
4570 Alvarado Canyon Road
San Diego CA 92120

Offer solar energy training course - originally developed for their dealers & installers as a hands-on training project; now offered to others. Schedule & locations can be obtained by writing ESI. Fee: $135 (includes "Solar Heating" training notes); notes may be purchased separately for $8.50.

Physical Science Department
LAKE TAHOE COMMUNITY COLLEGE
2659 Lake Tahoe Blvd.
P.O. Box 14445
South Lake Tahoe CA 95702

Offer "Solar Energy" course which covers utilization of solar energy & mechanics of various systems.

Technical, Trade & Industrial Div.
LONG BEACH CITY COLLEGE
1305 E. Pacific Coast Highway
Long Beach CA 90806

Air Conditioning & Refrigeration program includes a segment on Solar Energy.

Engineering Department
MT. SAN JACINTO COLLEGE
21400 Highway 79
San Jacinto CA 92383

Offer "Solar Energy Applications" course - semi-technical on applications & design of collectors.

Technology Division
ORANGE COAST COLLEGE
2701 Fairview Road
Costa Mesa CA 92626

Offer "Solar" course on system design & application of solar heating & cooling equipment. Planning complete program to include designing equipment, construction methods, & fabrication of solar devices.

SAN DIEGO CITY COLLEGE
Air Conditioning & Refrigeration Dept.
12th & Russ Streets
San Diego CA

AIR CONDITIONING & REFRIGERATION DEPT: Offer two courses in "Solar Energy Maintenance & Technology" as part of their A.S. degree program - cover installation, trouble-shooting, efficiency & cost estimating.

SAN DIEGO COUNTY CONSTRUCTION LABORERS BENEFIT FUND
4161 Home Avenue
Suite 260
San Diego CA 92105
Attn: Mr. H. Thurman

Six-week training program for those who want to be construction laborers. One week spent on installation & maintenance of solar equipment. Write for application (must be 18 yrs. old & resident of San Diego County. Four-six month waiting list). For California residents outside San Diego County, write: San Diego County Construction Laborers Benefit Fund, P.O. Box 1307, Boulevard CA 92005.

Construction Technology Dept.
SAN DIEGO MESA COLLEGE
7250 Mesa College Drive
San Diego CA 92111

Offer "Utilization of Solar Energy" - covers types of solar equipment & laboratory.

Physics Department
SAN JOAQUIN DELTA COMMUNITY COLLEGE
5151 Pacific Avenue
Stockton CA 95207

Offer "Energy Conservation & Alternatives" course which includes solar energy. Plan to offer courses on "Solar & Wind Power Technology" and "Construction of Solar Elements" in the future.

SAN JOSE CITY COLLEGE
Air Conditioning & Refr. Dept.
2100 Moor Park Avenue
San Jose CA 95128

Offer 2-year "Solar Technician" program leading to associate degree & certificate under division of air-conditioning & refrigeration. Courses cover residential solar design & industrial solar application. Provides students with knowledge to become solar technicians.

SOLAR HEATING TECHNICIAN TRAINING SKILLS TRAINING PROGRAM
Sonoma State College
1801 East Cotati Avenue
Rohnert Park CA 94928
Attn: Gayla Mote
(707) 664-2577

Training Program sponsored by Sonoma State College & State of California Comprehensive Employment & Training Act (C.E.T.A.) grant. Training: solar technology, climatology, energy conservation techniques, contractor licensing law, uniform mechnaical code, etc. Upon completion individual able to design, size, build & install solar systems. On-the job training included.

SOLAR TECHNICIAN TRAINING PROJECT
1322 "O" Street
Sacramento CA 95814
Attn: JoAnn Trujillo, Proj. Coord.
(916) 322-7190

Six-month course for installation of solar hot water systems. For low-income individuals. Sponsored by California Office of Appropriate Technology.

Colorado

COLORADO TECHNICAL COLLEGE
655 Elkton Drive
Colorado Springs CO 80907
Attn: Dr. Tom Forster
(303) 598-0200

Offer Associate in Applied Science Degree in Solar Engineering Technology. Also offer B.S. in solar engineering technology. Associate Degree (2-years) to prepare students for employment as solar technicians in research labs, test facilities, solar companies & other energy-related organizations. B.S. (4-years) to prepare students to work as solar energy engineering technologist - emphasizes mechanical engineering technology of heating, ventilating & airconditioning systems & energy conservation methods.

Delaware

Energy Conservation & Solar Application Center
NEW CASTLE COUNTY VOCATIONAL-TECH. SCHOOL DISTRICT
1417 Newport Road
Wilmington DE 19804

ADULT EDUCATION PROGRAM: Offer "Solar Heating of Buildings" course for practitioners in construction industry on sizing, design, installation, maintenance & economic feasibility of solar heating systems (60 hours). Fee: $360 (includes educational materials & access to computer program for economic optimization of solar heating systems).

Florida

PINELLAS VO-TECH INSTITUTE
6100 154th Avenue North
Clearwater FL 33520

Two training programs (2 evenings/week - registration every 9 wks): 1) "Solar Energy-Heating & Cooling" (mechanics, theory of building solar hot water heaters design & construction of solar airconditioning units); 2) "Household Energy Conservation/Solar Energy" (how homeowner can conserve energy; information on using solar hot water heating).

Georgia

COOSA VALLEY AREA VOC-TECH SCHOOL
112 Hemlock Avenue
Rome GA 30161

HEATING & AIRCONDITIONING DEPT: In process of developing course on solar collectors, heat storage & controls associated with domestic solar heating as part of heating & airconditioning course.

DE KALB COMMUNITY COLLEGE
495 North Indian Creek Drive
Clarkston GA 30021

In process of developing short term course in Solar Equipment Installation & Maintenance. Long range plans include solar energy as part of Heating, Air-Conditioning & Refrigeration Program. (No courses in solar offered at present - 12/77).

NORTH GEORGIA TECH & VOC SCHOOL
Lake Burton Road, Georgia 197
Clarkesville GA 30523

Planning curriculum to train technicians to install & service solar energy systems. (No courses in solar offered at present - 12/77).

SOLAR ENERGY MAY BE OFFERED AS OPTION AT FOLLOWING SCHOOLS IN GEORGIA:

ALBANY AREA VOC-TECH SCHOOL
1021 Lowe Road
Albany GA 31705

ATHENS AREA VOC-TECH SCHOOL
U.S. Highway 29 North
Athens GA 30601

AUGUSTA AREA VOC-TECH SCHOOL
2025 Lumpkin Road
Augusta GA 30904

CARROLL COUNTY AREA VOC-TECH SCHOOL
P.O. Box 548
Carrollton GA 30117

MACON AREA VOC-TECH SCHOOL
940 Forsyth Street
Macon GA 31201

MARIETTA-COBB AREA VOC-TECH SCHOOL
980 South Cobb Drive
Marietta GA 30060

MOULTRIE AREA VOC-TECH SCHOOL
P.O. Box 520
Moultrie GA 31768

PICKENS COUNTY AREA VOC-TECH SCHOOL
Burnt Mountain Road
Jasper GA 30143

SAVANNAH AREA VOC-TECH SCHOOL
214 West Bay Street
Savannah GA 31401

SWAINSBORO AREA VOC-TECH SCHOOL
201 Kite Road
Swainsboro GA 30401

THOMAS AREA VOC-TECH SCHOOL
P.O. Box 1578
Thomasville GA 31792

UPSON COUNTY AREA VOC-TECH SCHOOL
P.O. Box 1089
Thomaston GA 30286

VALDOSTA AREA VOC-TECH SCHOOL
Route 1, Box 211
Valdosta GA 31601

WALKER COUNTY AREA VOC-TECH SCHOOL
Box 454 Merry Meadow Lane
Rock Spring GA 30739

WAYCROSS-WARE CO. AREA VOC-TECH SCHOOL
1701 Carswell Avenue
Waycross GA 31501

BRUNSWICK JUNIOR COLLEGF
Vocational-Technical Program
Altama at Fourth
Brunswick GA 31520

Iowa

Trade & Industrial Occupations Div.
SCOTT COMMUNITY COLLEGE
Belmont Road
Bettendorf IA 52722

Offer Solar Energetics Technology major - Associate Degree (2 yrs). Prepares student for employment as technician in: research labs, solar energy systems installation, assistants to designers & architects, systems maintenance, other energy-related occupations. Graduate will also be proficient in heating & airconditioning, sheet metal work & all installation of domestic & industrial units.

Kentucky

WESTERN KENTUCKY UNIVERSITY
Dept. of Engineering Technology
Bowling Green KY 42101
Attn: Henry M. Healey, P.E.

Mr. Healey has prepared a 3-hr. seminar "Solar Energy Applications" for hvac contractors. Covers: information & background on sizing solar systems, cost analysis techniques. Will present seminar at afternoon or evening group meetings of contractors.

Maine

PORTLAND VOCATIONAL CENTER
Portland ME 04111

Offer training in solar installation.

Massachusetts

BRISTOL COMMUNITY COLLEGE
777 Elsbree Street
Fall River MA 02720

Has been funded to set up an energy program.

Engineering Science & Industrial Related Technologies Dept.
CAPE COD COMMUNITY COLLEGE
West Barnstable MA 02668

Offer 3 solar courses: "Solar Energy I-Design & Installation Techniques for Residential Buildings" - deals with systems design, sizing & installation of solar heating units; "Solar Energy II-Design & Installation Techniques for Residential Buildings" - deals with installation & operation of solar heating systems (includes retrofit); and "Survey of Alternative Energy Sources" - discussion of various energy resources.

NEW ENGLAND FUEL INSTITUTE
Technical Training Center
390 Commonwealth Avenue
Boston MA 02215

Offer four-week (160 hour) hands-on solar heating technical training course. For those who want to learn to install solar systems. Fee: $450.

Division of Engineering Technology
SPRINGFIELD TECH COMMUNITY COLLEGE
Armory Square
Springfield MA 01105

Offer A.S. degree in Solar Energy. Graduates are qualified to install complete liquid or air solar heating systems, size systems, and evaluate cost effectiveness.

Michigan

LANSING COMMUNITY COLLEGE
Engineering Technology Department
419 North Capitol Ave.
Lansing MI 48914

Courses offered: Solar Housing (AT 200) Solar Site Seminar (AT 208) Principles of Solar Energy Collection (AT 201) Residential Solar Heating System Design (At 203) Alternate Sources of Energy (ATG 150) Building a Solar Furnace (ATG 151) Building a Solar Water Heater (ATG 152) Passive Solar Design (AT 211) Passive Solar II (AT 215)
Solar Energy Technician Program: One year certificate or two year associate degree programs are being planned.

FOLLOWING MICHIGAN SCHOOLS TO OFFER ONE SEMINAR & EIGHT-WEEK SOLAR HEATING/COOLING COURSE:

HENRY FORD COMMUNITY COLLEGE
5101 Evergreen Road
Dearborn MI 48128
Attn: SEMTAP

HIGHLAND PARK COLLEGE
Glendale & Third Streets
Highland Park MI 48203
Attn: SEMTAP

JACKSON COMMUNITY COLLEGE
2111 Emmons Road
Jackson MI 49201
Attn: SEMTAP

MACOMB COUNTY COMMUNITY COLLEGE
Division of Continuing Education
South Campus - Box 948
Warren MI 48093
Attn: SEMTAP

MICHIGAN SCHOOLS (Continued):

MONROE COUNTY COMMUNITY COLLEGE
1555 Raisinville Road
Monroe MI 48161
Attn: SEMTAP

SCHOOLCRAFT COMMUNITY COLLEGE
18600 Haggerty Road
Livonia MI 48152
Attn: SEMTAP

WASHTENAW COMMUNITY COLLEGE
Ypsilanti Center - 214 N. Huron
Ypsilanti MI 48197
Attn: SEMTAP

CHARLES STEWART MOTT COMMUNITY COLLEGE
1401 East Court Street
Flint MI 48503
Attn: SEMTAP

ST. CLAIR COMMUNITY COLLEGE
323 Erie Street
Port Huron MI 48060
Attn: SEMTAP

WAYNE COUNTY COMMUNITY COLLEGE
4612 Woodward Avenue
Detroit MI 48201
Attn: SEMTAP

MID-PLAINS COMMUNITY COLLEGE
Inter. of I-80 & Highway 83
North Platte NE 69101

Incorporate solar heating instruction in Building & Construction Dept. and Refrigeration/Airconditioning Dept. Students given introduction to solar heating as it applies to their particular field - familiarization level.

SOUTHEAST COMMUNITY COLLEGE
Milford Campus
Milford NE 68405

Airconditioning & Arch. Tech. Programs: Offer "Solar Energy"-a 32 hr. 2-quarter credit course as part of these programs. Basic course which includes brief history & basic calculations for sizing solar systems for residential structures.

Nebraska

SOME DEGREE OF SOLAR TECHNICIAN TRAINING OFFERED AT FOLLOWING SCHOOLS:

CENTRAL TECHNICAL COMMUNITY COLLEGE
P.O. Box 1024
Hastings NE 68901

METROPOLITAN TECHNICAL COMMUNITY COLLEGE
30th & Fort Streets
Omaha NE 68111

NORTHEAST TECHNICAL COMMUNITY COLLEGE
801 East Benjamin Avenue
Norfolk NE 68701

New Hampshire

NEW HAMPSHIRE VOCATIONAL-TECHNICAL COLLEGE
1066 Front Street
Manchester NH 03102

Offer Certificate program in solar system installation maintenance and repair.

New Jersey

BROOKDALE COMMUNITY COLLEGE
Lincroft NJ 07738

Solar & Wind Technology course offered.

Heating, Ventilating & Airconditioning Department
ESSEX COUNTY TECHNICAL CAREERS CENTER
91 West Market Street
Newark NJ

Offer a day & evening program in solar heating systems (adult education courses - certificate given) - courses cover domestic water heating & residential & commercial solar space heating & cooling systems; how to install & service systems. Day program (300 hours), evening program (120 hrs). Also planning Solar Heating course for their votech high school to be in operation late Spring '78.

MANASQUAN PUBLIC SCHOOLS
Broad Street
Manasquan NJ 08736

Offer Energy Education/Curriculum Development course.

Plumbing, Heating & Refrigeration
MERCER COUNTY AREA VOCATIONAL TECHNICAL SCHOOLS
1085 Old Trenton Road
Trenton NJ 08690

As part of curriculum have integrated knowledge & skills related to implementation and installation of solar heating and cooling units.

MIDDLESEX COUNTY COLLEGE
Edison NJ 08817

Project WATTE (Workshop Approach to Teacher Training in Energy) - to assist teachers in developing courses & curriculum strategies for integrating energy education into traditional disciplines. (Workshops planned for March-May 1978).

OCEAN COUNTY VOCATIONAL TECHNICAL SCHOOLS
Route 571
Jackson NJ 08527

Offer 3 solar courses: "Solar Energy Theory for Heating, Ventilating & Airconditioning Technicians."(Evening School - open to general public - evening school certificate awarded - start Fall '78 - 15 wks. Course for hvac specialists covering design considerations for solar hot water & space heating systems "Solar Energy Workshop" (Evening School - open to general public) - 21 hour program to assist homeowner in designing & installing solar hot water heating equipment - covers theory of operation, life cycle costing & installation; and "Climate Control" program (high school students only - 2 yr. high school certificate) - program for training in plumbing, heating, airconditioning & refrigeration. Students learn to design, repair & install such systems - includes new unit in design & installation of solar heating equipment.

Continuing Education Program
SALEM COUNTY VOCATIONAL TECHNICAL SCHOOLS
R.D. #2, Box 350
Woodstown NJ 08098

As part of Continuing Education program (nights), offer a 36-hour program - Introduction to Solar Heating - to acquaint student with current trends in use of solar energy for heating & cooling. Plumbing & Heating Trades Program - during 1977-78 school year will introduce a unit on solar energy for secondary & post-secondary students - will build a solar hot water heating systems.

New York

BROOME-DELAWARE-TIOGA BOCES Broome-Tioga Educational Center Upper Glenwood Road Binghamton NY 13905	Offer solar training as part of electronics course.
Department of Physics MOHAWK VALLEY COMMUNITY COLLEGE 1101 Sherman Drive Utica NY 13501 Attn: Dr. Francis Dunning	Offer two courses in solar: "Solar ergy & Energy Conservation" - general introductory course for homeowner on solar energy utilization; and "Solar Energy for the Heating and Airconditioning Technician which covers development of skills for the installation, maintenance & repair of solar heating & cooling systems.
NASSAU COUNTY BOCES Valentines Road & the Plains Road Westbury NY 11590	Offer solar energy technology as part of Heating/Air Conditioning courses.
SARATOGA-WARREN BOCES F. Donald Myers Occupational Center Henning Road Saratoga Springs NY 12866	Offer solar energy technology as part of Heating/Air Conditioning courses.
CAPE FEAR TECHNICAL INSTITUTE Solar Energy Educational Program 411 North Front St. Wilmington NC 28401	Evening extension program: offers Solar Energy Systems Workshop. 33 hour non-credit survey course, including laboratory demonstration of solar water and air heating. Heating, Air Conditioning and Refrigeration program: one solar energy course planned for immediate presentation. General Occupational Technology program: one-three solar energy courses planned. Solar Technology program: full two year planned for Sept., 1979.

Oregon

LINN-BENTON COMMUNITY COLLEGE Mid-Willamette Energy Information Center 6500 SW Pacific Blvd. Albany OR 97321	General Science or Engineering: Offer "Technical Projects-Solar" course - design & build projects related to construction of solar liquid & air heating systems & passive solar heated buildings; "Alternate Energy Sources" course - covers solar & wind systems, etc. Community Education: Offer "Home Energy Alternatives" course which is half on solar, and offer four solar workshops on: solar water heaters, solar air collectors, solar greenhouses & solar food dryers - workshops cover design & construction.

South Carolina

AirConditioning, Refrigeration & Heating
FLORENCE-DARLINGTON TECHNICAL COLLEGE
P.O. Drawer 8000
Florence SC 29501

Offer 2-year (7 quarter) diploma program in airconditioning, refrigeration & heating. "Solar Energy Applications" course offered as part of curriculum - covers theory & practical application of heating & airconditioning through use of solar energy & the design, installation, servicing & trouble shooting of solar heating & cooling units.

AirConditioning, Refrigeration & Heating
YORK TECHNICAL COLLEGE
U.S. 21 By-Pass
Rock Hill SC 29730

Offer 2-year (7 quarter) diploma program in airconditioning, refrigeration & heating. Beginning Spring 1978 will offer "Solar Energy Applications" course as part of curriculum - hands-on course which covers installation, service & control of collection of solar energy.

SOLAR ENERGY MAY BE OFFERED AS PART OF CURRICULA AT FOLLOWING SOUTH CAROLINA SCHOOLS:

Air Conditioning & Refrigeration
BEAUFORT TECHNICAL EDUCATION CENTER
100 S. Ribaut Road
Beaufort SC 29902

Air-Conditioning Technology
DENMARK TECHNICAL EDUCATION CENTER
Denmark SC 29042

Air Conditioning Technology
HORRY-GEORGETOWN TECHNICAL COLLEGE
P.O. Box 710
Highway 501
Conway SC 29526

Air Conditioning Technology
PIEDMONT TECHNICAL COLLEGE
Drawer 1208
Greenwood SC 29646

Air Conditioning Technology
SUMTER AREA TECHNICAL COLLEGE
506 Guignard Drive
Sumter SC 29150

Refrigeration Technology
TRIDENT TECHNICAL COLLEGE
North Campus
7000 Rivers Avenue
North Charleston SC 29406

Climate Control Technology & Refrigeration
CHESTERFIELD-MARLBORO TECHNICAL COLLEGE
Drawer 928
Cheraw SC 29520

Refrigeration Technology
GREENVILLE TECHNICAL COLLEGE
P.O. Box 5616, Station B
Greenville SC 29606

Climate Control Technology & Refrigeration
MIDLANDS TECHNICAL COLLEGE
Beltline Campus, P.O. Drawer Q
316 Beltline Blvd.
Columbia SC 29205

Air Conditioning & Refrigeration
SPARTANBURG TECHNICAL COLLEGE
P.O. Drawer 4386
Spartanburg SC 29301

Refrigeration Technology
TRI-COUNTY TECHNICAL COLLEGE
P.O. Box 87
Pendleton SC 29670

Refrigeration Technology
WILLIAMSBURG TECHNICAL, VOCATIONAL & ADULT ED. CENTER
601 Lane Road
Kingstree SC 29556

Texas

CENTRAL TEXAS COLLEGE
P.O. Box 1416
U.S. Highway 190 West
Killeen TX 76541

Offer "Solar Heating Systems" course - overview of basic components of various solar energy systems; operation, installation, maintenance, trouble-shooting & service procedures.

NAVARRO COLLEGE
Highway 31 West
Corsicana TX 75110
Attn: Charlie G. Orsak, Jr.
Director of Energy Programs

In process of developing 2-year Associate Degree Solar Technician curriculum. Should be ready for initial dissemination & pilot testing by Spring 1979.

TEXAS STATE TECHNICAL INSTITUTE
Rolling Plains Campus
Sweetwater TX 79556

Continuing Education program: 48 hour training course teaches installation, maintenance, repair techniques for residential and commercial water and space heating systems. Course includes both liquid and air type collector sub-systems.
Air Conditioning and Refrigeration Department: Plans Solar Energy Mechanic curriculum covering 16 courses in three quarters. Graduates receive certification as solar energy mechanics.

Virginia

LORD FAIRFAX COMMUNITY COLLEGE
P.O. Drawer E
Middletown VA 22645
Attn: Electronics Technology Dept.

Offer "Solar Heating & Cooling of Residential Buildings" course (ENVR 155) for contractors currently in hvac business. (one night/wk for 11 weeks). Course covers sizing, installation & maintenance of solar systems with emphasis on economics. Anticipate offering similar more advanced course for architects in the future.

Washington

NORTH SEATTLE COMMUNITY COLLEGE
9600 College Way North
Seattle WA 98103

Will offer section on solar heating as part of Environmental Control Technician/Refrigeration & Air Conditioning Design class. (start Fall '78)

Continuing Education Program
PENINSULA COLLEGE
1502 E. Lauridsen Blvd.
Port Angeles WA 98362

Offer "Solar Heating Systems for Homes" course during fall quarter each school year. Evening course for contractors & engineering technology students - to develop practical skills for sizing, installing, operating & maintaining active solar energy systems.

For more information on learning to install solar energy systems, the following reference sources may be of use:

BARRON'S GUIDE TO THE TWO-YEAR COLLEGES - lists more than 150 colleges as having programs in heating & airconditioning (climate control) technology. Courses in solar energy principles & solar thermal conversion system maintenance may be included in some cases.(available at public libraries).

STATE EMPLOYMENT COMMISSIONS - can give information on vocational schools in your state.

HIGH SCHOOL COUNSELORS - can provide information on vocational trades and schools.

JUNIOR OR COMMUNITY COLLEGES - offer courses and certificate programs in the building trades.