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ABSTRACT

Compiled in this guide are 23 previously published documents for use by secondary school industrial arts teachers who want to incorporate energy studies into their curricula. Over half of the entries describe energy-related projects such as fireplaces, solar water heaters, and solar ovens. Other materials presented address the place of energy in the industrial arts curriculum. Photographs, charts, and diagrams illustrate many of the articles. (WB)

ENERGY

PENNSYLVANIA'S ENERGY CURRICULUM FOR THE SECONDARY GRADES

Industrial Arts

Pennsylvania Department of Education 1980

Funds Provided by Governor's Energy Council

Commonwealth of Pennsylvania
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INDUSTRIAL ARTS

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Articles on Industrial Arts and Energy

Power Technology: Prime Movers and Energy Sources as Subject Matter for Industrial Arts, John J. Geil, NECEP Journal, October 1976.

"Arts" John J. Beil, *NECEP Journal*, October 1976.

"Energy Alternatives and the Role of Industrial Arts", Frank C. Owens and Thomas E. Pinelli, *Man/Society/Technology*, November 1977.

"A Curriculum Guideline for Energy and Power," Vahan V. Basmajian, *NECEP Journal*, March 1977.

"Curriculum Guidelines for Energy Sources and Conversion Devices," Dr. Leonard Sterry and NECEP Curriculum Committee Members, *NECEP Journal*, April 1976.

"Translating Energy Into Power," C. David Gierke, *NECEP Journal*, October 1977.

"Is Solar Power a Practical Solution?", Dr. Charles Alexander, Terrance R. Caster, Dr. Harry Thomason, Malcom Wells, *Popular Science*, Building Manual, Spring-Summer 1976.

Activities

"Electric Truck is Wind-Powered, Too," Edward Moran, *Popular Science* Adventures in Alternate Energy, April 1977.

"Turn Your Fireplace into a Furnace," *Popular Science*, October 1977.

"Solar Assisted Heat Pump," Edward Moran, *Popular Science* Adventures in Alternate Energy.

"Windmill on a Boom," Edward Moran, *Popular Science* Adventures in Alternate Energy, February 1977.

Solar Heating Design and Construction, M. Filepas, J. Chlebowski, E. Hine, Central Dauphin School District, Harrisburg, PA

"Five Solar Water Heaters You Can Build", Edward Moran, *Popular Science Adventures in Alternate Energy*, May 1976.

"Solar Window", Edward Moran, *Popular Science* Adventures in Alternate Energy.

"Sun Power for Space Heating," Edward Moran, *Popular Science* Adventures in Alternate Energy.

"Solar Plus Woodstove Heats His Water," Edward Moran, *Popular Science* Adventures in Alternate Energy, May 1977.

"PS Update, the Newest Solar Heating Equipment," Richard Stepler, *Popular Science*, August 1977.

"Solar Homesteading in a Biosphere," E. F. Lindsley, *Popular Science* Adventures in Alternate Energy.

"Solar Oven", *The Spokesman*, June-July 1978.

"Focusing Collectors Heat a Northern Home," Edward Moran, *Popular Science* Adventures in Alternate Energy, December 1976.

"Solar Pool Heater on a Pedestal," E. F. Lindsley, *Popular Science* Adventures in Alternate Energy.

"Solar Bubble Keeps His Water Warm," Edward Moran, *Popular Science* Adventures in Alternate Energy, September 1976.

"S" Rotor Demonstrates Wind Power, Martin Greenwald, *School Shop*, May 1978.

INTENDED USE OF PUBLICATION

The material published here is for the use of industrial arts teachers and should be a part of their ongoing classes. Much of the material fits naturally into a Power Technology class; however, with a little work it can be incorporated into other areas of industrial arts instruction.

This publication is a part of a larger publication that encompasses all subject areas in education. It is intended to be used in the upper grades and is to emphasize the importance of conserving energy for our society. All students must be made aware of its importance and the industrial arts teacher can play a major role in this effort.

Consider the information provided here as suggested material for building a program for the conservation of energy. Try to make use of the suggested projects as they appear, and build on these ideas as students gain knowledge of energy.

INDUSTRIAL ARTS IN PENNSYLVANIA

Description

Industrial arts has educational value for all pupils in the elementary and secondary school, providing experiences that are progressively intensive in accordance with pupil maturity. The industrial arts program is a sequence of exploratory experiences to assist in the development of insights into technology, and the attainment of occupational literacy. Industrial arts provides vocational orientation experiences through its laboratory skills and also has the unique ability to acquaint students with a variety of career options and possibilities.

In Pennsylvania the industrial arts program is a broad based area of study in industry and technology.

As an integral part of the total educational program, industrial arts will aid students in acquiring a comprehension of industrial technology, career potential and proper use of materials. Through manipulative actions and research experiences with a variety of tools, materials, processes and products of industry, students have the opportunity to develop a self-concept in relation to the changing requirements for participation in an industrial and technological culture.

Industrial arts has a special contribution to make to the total educational program. While industrial arts utilizes and contributes to the goals of education in preparation for life, its interrelationships with other disciplines provides substance to vocational education as well as career education concepts. Furthermore, industrial arts provides unique opportunities for students to participate in realistic experiences in the production of goods, or the rendering of services, through the effective use of people, methods, machines, money, management, and marketing. Students study the effects of industrial technology upon all elements of society. Industrial arts must stand upon the demonstrated values for which it is especially adapted, and should be integrated with the other subject areas in the development of the total educational process.

Purposes

The purposes of industrial arts in Pennsylvania are consistent with the goals of quality education in the Commonwealth of Pennsylvania.

To provide a sound program of industrial arts, clear and realistic objectives are essential. The following statements of purpose are unique to industrial arts programs in Pennsylvania. A properly planned and coordinated Industrial Arts Program should:

1. *Develop technological literacy* - in a technological society one must be able to communicate in the language of industry, technology and science.

2. *Develop an understanding of the place of industry in our society* - Industry is a constructive, dynamic force in the world today. It is the responsibility of the school to provide opportunities for each student to understand this force. Industrial arts provides learning activities by which students acquire knowledge and performance skills.

3. *Discover and develop student talents related to technologies* - the industrial arts pro-

gram should assist students in discovering and developing their talents. Industrial arts helps students identify special abilities through manipulative and research experiences.

4. *Develop problem solving abilities related to the use of tools, materials, processes and products* - the problem solving approach in industrial arts involves creative thinking and gives students opportunities to apply principles of planning and design. Constructive techniques, industrial processes, scientific principles and mathematical computations are applied to achieve solutions to problems.

5. *Develop skill in the safe use of hand and power tools* -Industrial arts provides planning, construction and production activities which enable students to acquire industrial and technical skills. These activities offer opportunities to develop hand and power tool skills commensurate with the mental and physical maturity of the student.

Content

Industrial arts is a multi-disciplinary presentation of knowledge, skills, and attitudes acquired by students. Three common areas required for a minimal program would be designated as industrial materials, power technology, and visual communications.

Industrial Materials - is a study of physical materials as they exist in their natural environment and how these materials are transformed through extraction, fabrication, manufacturing and construction into consumable products. Activities of this group provide experiences fundamental to proper conservation, experimentation, testing, use and analysis of materials.

Power Technology - is the study of energy and its application to such fields as communications, transportation and manufacturing.

Visual Communications - is the process of communicating through sight. Visual communications includes studies in graphic arts, photography and drafting.

These areas are to be taught as general laboratory experiences with multiple teaching methods being used in an effort to individualize instruction. Wide use of instructional media and methods, appropriate in laboratory experiences, are encouraged. Students should be taught in small groups or as individuals; therefore teaching materials must be developed and available to students according to need. A personnel/management system should be used in all laboratories for the development of the human relations aspects of the program. Mini-courses should be available for students who desire specific experiences, and scheduling should be flexible enough to permit courses of varying duration.

Summary

Industrial Arts Education is a phase of education that has the unique responsibility to provide students with the capability to understand and manipulate modern day industrial technology. It is the subject area in the school that deals with the industrial technological society and the problems and benefits of these technologies. The fundamental goal of industrial arts is to provide each individual with the capability to make relevant judgments, to think effectively, to make value choices, to communicate ideas, and to be able to efficiently use technology for the individual's benefit in a variety of life roles (family, occupational, recreational, etc.) and to use these knowledges and skills about industrial technology.

This paper was developed in cooperation with the Industrial Arts Association of Pennsylvania and the Pennsylvania Department of Education.

John T. Feckk, President - Industrial Arts Association of Pennsylvania

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Revised
October 19, 1978

POWER TECHNOLOGY

PRIME MOVERS AND ENERGY SOURCES

AS SUBJECT MATTER FOR INDUSTRIAL ARTS

by John J. Geil

The following article is excerpted from an unpublished master's thesis of the same title, done at Kent State University, Ohio, June, 1967. Original sources are hereby gratefully acknowledged. Readers desiring further information may contact the KSU Library or the author. Portions of this work previously appeared in the NECEP JOURNAL, October, 1976, and the conceptual approach is reflected in ENERGY AND TRANSPORTATION: POWER (Modular Exploration of Technology Series) Prentice-Hall, Englewood Cliffs, NJ 1976.

Dwindling resources and a new role for industrial arts emphasize a need for comprehensive courses dealing with energy and power. While the conversion of vast quantities of energy into usable forms of power constitutes a branch of technology that is fundamental to the American way of life, only a small percentage of students enrolled in industrial arts courses have opportunities to study complex energy/power relationships. Many so-called power technology courses are in reality only automotives or small engines coures, but American youth needs programs dealing with the entire energy-power picture. Research to identify a comprehensive body of subject matter for use in the study of power is long overdue. Comprehensive courses must be concerned with tracing the sources of energy and with the role of prime movers which transform energy into useful power.

The study from which this article was taken was a broad inquiry to determine past, current, and future sources of energy and to trace the historical development of prime movers. Rather than being only theoretical-scientific in nature, the study was technical-cultural. No attempt was made to assign energy and power subject matter to school grade level. The study was a starting point—a *big picture* upon which to build comprehensive programs.

Energy sources and prime movers are fundamental bases for construction power technology courses. In addition to teaching the technology of power, there are possibilities for learning experiences in the history of technology, the concept of *technological flow*, in the events of humankind, the manifestations of human creative spirit rising to the conviction that there must be a *better way*, and the impact of many personalities rarely found in our school history books.

INTRODUCTION

The story of energy and power is the story of the industrial might of America. A hundred years ago, only 5 percent of the total power being consumed was produced by mechanical means; 95 percent was supplied by human and animal power. Today, approximately 98 percent of our power comes from mechanical sources. If industrial arts education is to reflect technology and industry, then studies of power generation and utilization must be included in the curriculum.

The use of vast quantities of energy is basic to the functioning of the American economy. The United States has six percent of the world's population, but consumes 35 percent of the global production of energy and materials. The per capita consumption of energy was about six times the world average.

The use of energy is characteristic of any highly industrialized nation. Industry in the United States accounts for two-fifths of the total energy consumption. In 1975 automobiles, trucks, buses, and other automotive transport consumed about one-fifth of the total energy, or about one-half of that consumed in industry. Modern households consume another one-fifth for heating, cooking, and for operating appliances. Industry, transportation, and households together consume about four-fifths of all energy used, with the remaining fifth used by commercial concerns, the government, and agriculture. Converting these vast quantities of energy to usable forms of power constitutes a branch of technology that is fundamental to the American way of life.

But while power and energy are basic to the American economy and the American way of life, the industrial arts profession has not responded adequately to the need for comprehensive power technology programs. The USOE Schmitt/Pelley study of the mid-sixties revealed that only 2.7 percent of the students enrolled in industrial arts programs received instruction in power mechanics. The true picture of power technology instruction was probably even more bleak since many (if not most) programs consisted of narrowly-conceived small engines or automotives courses.

Prime Movers

Joseph W. Duffey in **Power: Prime Mover of Technology** defined prime movers as ". . . *devices that convert the power of human and animal muscle, running water, wind, heat, or electricity into a more usable form of energy.*" By subscribing to a definition such as this, it immediately becomes apparent that courses with limited scope such as *small gasoline engines* will fall short of the mark in providing the education and experiences needed by today's youth. It is also apparent that basic thermodynamics must be a part of the program and that studying the historical development of prime movers will aid in seeing where we are and where we might be going.

The complete study from which this material was taken is summarized in the accompanying chart, Figure 1. It included external combustion engines, kinetic energy prime movers, direct energy conversion, electricity, and the so-called *exotic* sources. The following excerpt deals only with internal combustion devices and is, of necessity, shortened.

INTERNAL COMBUSTION ENGINES

Internal combustion engines form, in terms of quantity at least, the backbone of our power needs. Steam power is used to generate the tremendous quantities of electricity we need, but the internal combustion engine is the basic source of power for nearly all our transportation and other requirements.

Internal combustion engines are not efficient. They are generally noisy and plagued with vibration. They emit noxious and offensive fumes and are often short-lived. But the versatility and adaptability of these engines, especially in the reciprocating form, has literally transformed our way of life. So common is the "gas" engine that we take it very much for granted until, for some reason, it fails to perform its job.

Internal combustion engines are now made in many forms; reciprocating, rotary, turbine, reaction, and rocket. They may be very small or very large, with various methods of accomplishing ignition, cooling, and lubrication. But they are all heat engines characterized by the fuel being burned rapidly inside the engine.

Reciprocating Engines

The reciprocating internal combustion engine is perhaps the most familiar form of power. Throughout the world, automobiles, trucks and other engine-driven conveyances transport people and goods, perform as regulatory and emergency vehicles and provide a freedom of movement undreamed of a century ago. The auto industry is one of the largest employers in the United States. Almost every family has a car, and the trend is to two or even three. Even with the increasing complexity of automobiles, the average American feels he is something of an expert on cars. The popular "scientific" literature abounds with articles on the subject. High schoolers by the thousands repair, rebuild, and modify everything from jalopies to racing cars.

The automobile is indeed one of the most remarkable developments of all time, but it is also one of the most wasteful and has been called "... a superlative example of short life and low efficiency in use." Many maintain that over powered automobiles will do more to hasten the end of the fossil-fuel era than any other factor.

Development

The the [illegible] Carnot in the mid 1800's [illegible] when [illegible] engines [illegible] engineers using a heat exchanger similar to a boiler. But the heat exchangers burned out at high temperatures because there was no protection against overheated metal surfaces. Carnot suggested that this difficulty could be overcome by heating the air by combustion within the engine, thus eliminating the necessity of transferring heat through an exchanger wall.

The first engine utilizing [illegible] internal [illegible] engine [illegible] pressure from the burning fuel charge acted [illegible] piston [illegible] [illegible]. Five years later, William Barnett worked out a method of compressing the air-fuel mixture before combustion so that the subsequent expansion would release more [illegible] energy, another idea that had been suggested by Carnot. Wright's and Barnett's machines were not practical engines but crude experimental models.

[illegible] the [illegible] a two-stroke cycle. Although [illegible] method of [illegible] several hundred were sold.

[illegible] his [illegible] ideas into reality.

[illegible] The [illegible] was unable to [illegible] with [illegible] he called with Eugene Langen to produce a successful two-cycle engine. This engine operated on atmospheric pressure and was similar in operation to Newcomen's original steam engine. While the engine was heavy and noisy, its efficiency was twice that of the Lenoir engine. Approximately 5,000 units were produced starting in 1872.

Otto was not satisfied, however, and returned to the pursuit of the four-cycle idea. His efforts this time, due to his experience in the field, were successful, and in 1876 he marketed an engine producing three horsepower which ran at 180 revolutions per minute. It was so quiet in contrast to the earlier engines that it became known as the "Otto Silent."

Otto's new engine was so superior to all other existing models that it quickly dominated the industry. By the time he died, over 30,000 engines bearing his name were in operation, some being of multicylinder design and capable of producing 100 horsepower. His basic designs still predominate although many improvements have, of course, been made in ignition, valve design, lubrication, metallurgy, and so forth.

In 1892, Rudolph Diesel patented a compression-ignition engine. High compression generated sufficient temperature to cause vaporization and ignition when the oil was introduced. Because of the high compression ratio, the engine proved more efficient than gasoline fueled models even though it had to be more heavily built. Diesel engines immediately became very popular for stationary and heavy duty applications.

Types of Reciprocating Engines

Internal combustion engine [illegible]
[illegible] classifications are two-cycle or four-cycle [illegible]
In the two-cycle engine, commonly used in outboard [illegible] a power stroke occurs each time the piston reaches the top of its stroke. A power pulse is thus obtained for each revolution of the crankshaft in a one-cylinder engine. Four-cycle engines go through four strokes, intake, compression, power, and exhaust, during one complete series of events and a power pulse is obtained for each two revolutions of the crankshaft in a one-cylinder engine. Both types may be air cooled or liquid cooled.

A [illegible]
[illegible] gasoline, although propane and natural gas [illegible] (usually called Diesel engines) use the heat generated by high compression to ignite the [illegible] light oil.

[illegible]

[illegible] Two-cycle engines always have [illegible] vibration problems. Two-cycle engines [illegible] In this respect it may be noted that a three-cylinder [illegible] four-cycle engine [illegible] power pulses per [illegible] the crankshaft. [illegible] configurations are [illegible] in line [illegible]

[illegible]

[illegible]

1. the mechanical system; to capture the energy of the burning fuel and transform it first to reciprocating motion and finally to rotary action.

2. the fuel system; to supply and vaporize or atomize fuel at the correct point, mixed with the proper quantity of air for most efficient combustion.

3. the combustion system; to cause burning of the fuel at the proper point in the cycle.

4. the lubrication system, to control friction and cool, seal and clean the engine parts

5. the cooling system, to carry off excess heat and maintain the most advantageous operating temperature

6. [illegible]

Applications

[illegible] to be made in a [illegible] range of sizes and configurations [illegible] a model [illegible] engine weighing a few ounces to giant marine and stationary engines weighing several tons and generating as much as [illegible],000 h[illegible] power. They have been put to almost every conceivable use from portable power tools to power shovels, from motorboats to [illegible] ships, from toy airplanes to huge aircraft, and from rudimentary go-carts to the most elegant land transport. Yet, as stated previously, they are one of the least efficient users of fossil fuels. Despite all [illegible] claims, the total energy system efficiency of automobiles [illegible] is something less than 5 percent.

[illegible]

[illegible]

Thermodynamically, rotary engines are similar to other internal combustion engines--the differences lie in the ways of achieving engine action. In the Wankel engine, three chambers are formed by the sides of the rotor and the wall of the housing. The usual four-stroke cycle occurs with the simplicity and power stroke frequency of the two-stroke cycle.

In any one chamber, the cycle begins as an intake port is uncovered and fuel and air is drawn in by the action of the rotor in its housing. As the rotor continues, the intake port is covered and compression begins, followed by ignition, combustion and expansion for the power stroke. Continued motion of the rotor uncovers the exhaust port and the rotor is in position to repeat the sequence. The three chambers experience in order the same series of events, thus there are three power pulses for each revolution of the rotor.

[illegible]

A gas [illegible] steady flow of the working medium which is an [illegible] hot gas. The general principles of operation and construction are similar to steam turbines.

[illegible] The first patent on a gas turbine was awarded in [illegible] John [illegible] design included all the necessary elements of a modern turbine except that it employed a reciprocating compressor. In 1868 John Gumbel was granted a patent which described a turbine with rotating blades but no stationary elements, thus missing the advantage of multistaging. W. S. [illegible] although designed in 1850 a turbine for steam or gas. None of these designs were developed because of the success of the steam engine.

[illegible] power [illegible] In 1904 the [illegible] turbine into a gas turbine. [illegible] about 4% The efficiency [illegible] about half [illegible] engine.

[illegible] It was [illegible] that gas turbine [illegible] 1920 [illegible] 3000 horsepower turbine [illegible] locomotive [illegible] World War II [illegible]

The closed-cycle turbine is the other major type. Air does not come into contact with the burning fuel but is heated in a heat exchanger, passed through the turbine, cooled, and then recompressed and reheated in a closed system. Almost any type of fuel can be used, including the heat generated by nuclear reactors. Sometimes, both open- and closed-cycle principles are used.

Aircraft jet engines and turbo-prop engines are forms of gas turbines, but due to their highly specialized nature, they are usually considered separately from general types for stationary, marine or vehicluar use.

Systems

Turbines are generally in two sections, the gasifier section which includes the compressor and the combustion chamber, and the power turbine which converts the latent energy of the exhaust gases into mechanical energy.

In the first section the compressor [illegible] turned directly by the power turbine. In the second section the power turbine itself the hot gases are made to expand against blades in a manner very similar to that in a steam turbine and heat energy is transformed into mechanical energy. The output shaft may be coupled directly to a generator or other device or a gear train may be used to reduce the speed of rotation.

[illegible] common to reciprocating internal combustion engines [illegible] these systems employ standard techniques with special attention given to the problems of speed and temperature encountered. The cooling system operates on a principle of excess air. Since the metal surfaces within the turbine could not withstand the full heat developed by combustion, the burned gases are immediately diluted with excess air from the compressor.

[illegible]
[illegible] limits preclude their treatment [illegible]

ENERGY ALTERNATIVES AND THE ROLE OF INDUSTRIAL ARTS

by

Frank C. Owens & Thomas E. Pinelli

The Arab oil embargo and the hardship and suffering experienced during the wake of the country's coldest winter of the twentieth century provide additional evidence and credibility to the belief that this nation's traditional sources of energy will one day prove inadequate for meeting U.S. energy needs. These recent experiences, which are symptomatic of America's steadily deteriorating energy situation, necessitate the development of an affirmative plan of action against conditions which threaten national security, continued U.S. economic growth and development, and the active participatory role of the U.S. in world affairs. Solving America's energy problems presents an enormous challenge which requires the joint efforts of government, business and industry, the academic community, and most importantly the American people working together to help develop a diversified, environmentally acceptable energy economy so that future energy requirements can be met. The alternative is economic stagnation, unemployment, and considerable change in American life style.

[illegible] are required to re-educate people's attitudes about energy and energy conservation. [illegible] and accurate information will be needed to reshape values and attitudes and to face the energy conditions and environment as they will exist tomorrow. What is needed is an energy literate society. With the establishment of energy education programs this goal can become a reality. Industrial arts, as that part of the school curriculum which draws its content from industry and technology, can make a major contribution toward the creation of an energy literate society. Offering instruction in a broad range of energy topics, including energy conservation and the development of alternative energy sources, industrial arts is well suited to take the lead in energy education.

[illegible]

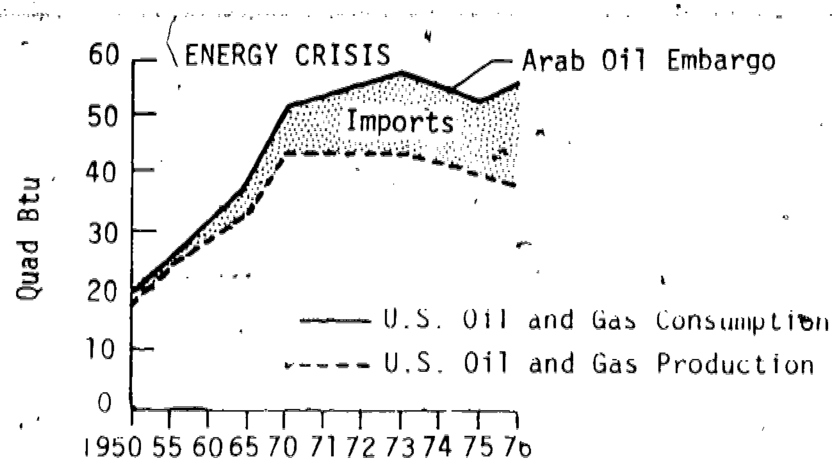


Figure 1 US Consumption and Produc[illegible]

difference [illegible] MBPD was obtained through the importation of [illegible] The importation of this energy cost approximately $30 billion in 1973 and had a sharp and dramatic impact on America's balance of payments If appropriate and timely action can be taken, domestic production could be increased to about 49 MBPD in 1985

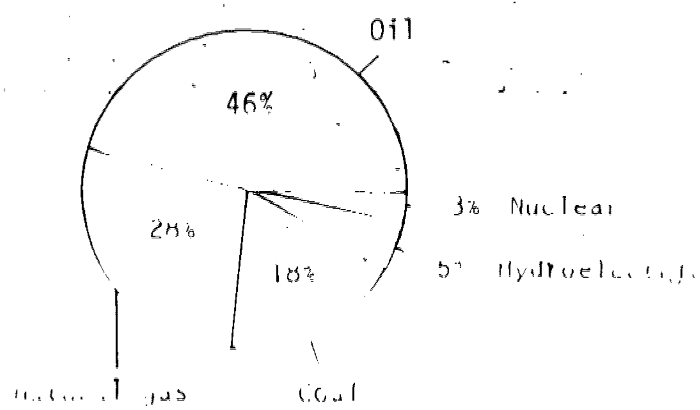
Past Present and Future

The United States [illegible] one third of its energy supplies [illegible] is about six times the average world level It is important to note [illegible] rapid changes in the sources of energy supply have been the norm in U S energy consumption and radical and rapid changes will be required for the move from a petroleum to a diversified energy economy

Since [illegible] U S energy consumption [illegible] the United States consumed 71 5 quadrillion British thermal units (QBTU) of energy [illegible] current average annual rate of increase the estimated or projected energy consumption was placed at 7[illegible] QBTU for 1976 The Federal Energy Administration has predicted (see Figure 2) that the amount of American energy consumption will continue to rise although the annual rate of increased consumption, currently 4 5 percent, will diminish

Changing values and reshaping attitudes toward energy will require timely and accurate information Integrating a study of wind energy into existing power and energy course can contribute toward achieving this change *Photo by George Herbert VPI&SU*

Share of All Energy Used in U.S.
Today



The Solution

Energy [illegible] percent in the U.S. Based upon known domestic fossil fuel recoverable [illegible] constant or fixed rate of energy demand, there is ample time to change from a fossil fuel to a limited fossil fuel economy. However, such a course of action is going to be difficult and will require decisive action on the part of government and the American public. Consider the following: (1) the Earth contains a finite amount of oil and natural gas; (2) domestic production of oil and gas has sharply decreased and foreign oil and natural gas has been imported to keep [illegible] of U.S. consumption which is not increasing at a fixed or constant demand; (3) world wide energy consumption is on the rise with the largest increase expected to come from the Third World nations who, desirous of western world affluence, will increase their rate of energy consumption; (4) there is a well-known relationship between Gross National Product (GNP) per capita and energy consumption which clearly shows that [illegible] standard of living is directly related to energy consumption; and (5) a change in the rate of U.S. energy consumption would [illegible] affect continued U.S. economic growth and development. The requirement then must be to develop a low [illegible] and environmentally acceptable level of energy consumption per unit of GNP economy.

[illegible]

which is less than 100 percent. The secret, then, is to obtain from each energy system the highest rate of efficiency which is possible for that system. According to Ross and Williams, *second-law efficiency* is critical and imperative to any projections for energy conservation. In other words, potential energy conservation should be based upon the performance of a system relative to that which is possible for a given task.

Any discussion of energy use and conservation would have to include the consumption of energy for electrical generation, a function which cuts across the three end use sectors previously mentioned. Because of the peaks and valleys caused by daily and seasonal demand, the industry uses an average of 51 percent of its generating capacity. Losses in the generation and transmission of electricity are such that only 30 percent of the energy consumed at the utility reaches the end user. The conservation opportunities in the utilities sector include:

Reducing overall energy usage for electricity through [illegible]

Leveling utility peak loads thereby increasing [illegible] and enabling use of more efficient equipment

[illegible] generation and transmission [illegible]

[illegible]

[illegible] Energy [illegible] fivation are applied to end uses of energy [illegible] as [illegible] percent

[illegible]

[illegible] geographic regions throughout the U.S. [illegible] future industrial [illegible] awareness. (2) The need for direction in developing energy education [illegible] that energy [illegible] can be more effective when taught [illegible] Utilizing the study and the information presented [illegible] develop an understanding [illegible] energy [illegible] work. (3) [illegible] of alternate energy [illegible] system design.

[illegible]

Collecting temperature and atmospheric data on two different collector panel designs (left is a serpentine layout, right is a circular pattern) tank capacities with approximately four gallons. Note that tanks are constructed of 5 gallon plastic pails that provide insulation for the internally mounted tanks. Type of data collected were initial water temperature in the morning, ambient temperature, sky condition and heated water temperature at various times during the day. *Photo by Dr. Walter Deal, Old Dominion University*

[illegible]

[illegible]

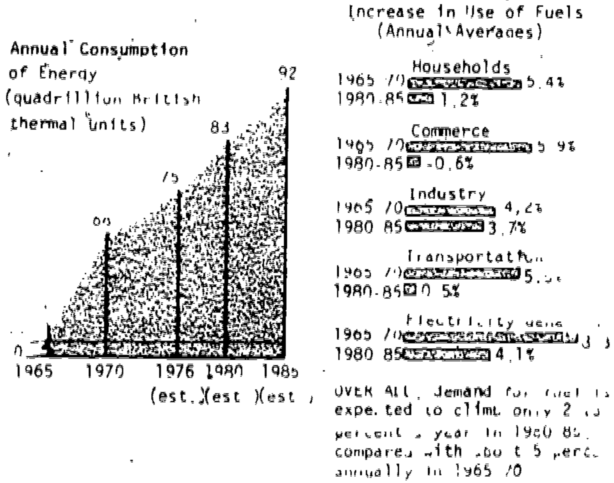
[illegible]

[illegible]

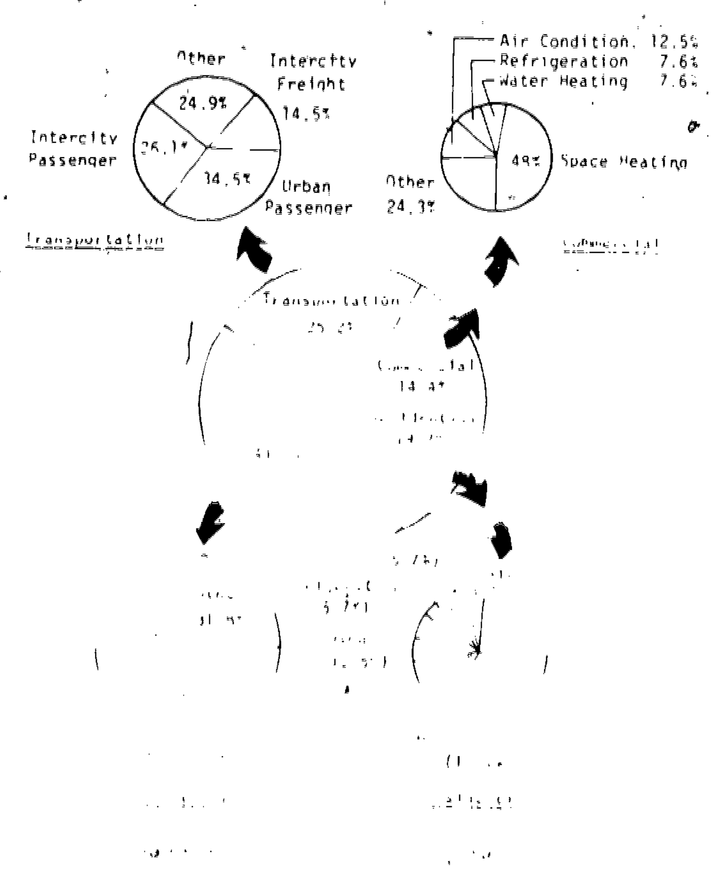
Looking Ahead:

Americans Will Use

More Energy. . . . . . But Growth Rates Will Slow



2366.


Other
Intercity Freight
14.5%
24.9%
Intercity Passenger
26.1%
34.5%
Urban Passenger
Transportation
Air Condition. 12.5%
Refrigeration 7.6%
Water Heating 7.6%
49%
Space Heating
Other
24.3%

The Occupational Aspect

Industrial arts as defined in Public Law 94-482 has the responsibility of assisting individuals in making informed and meaningful occupational choices. Occupations in energy, particularly in the electric power industry, are expected to increase about as fast as the average for all industries through the mid 1980's. However, many new occupations and openings in the field of energy are expected to occur with the expansion and development of alternate sources of energy. Students need occupational information and orientation to the broad spectrum of occupations which exist in this most important aspect of society.

Conclusions

[illegible] ... successfully meet the challenge, current values and attitudes must change. Accurate information delivered as part of an energy education program can help prepare for the future. Industrial arts can play a key role and assume a position of leadership in energy education. How will the challenge be met?

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[illegible]

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A CURRICULUM GUIDELINE FOR ENERGY AND POWER

by
Vahan V. Basmajian

The author is a curriculum committee member of the National Educational Council on Energy and Power (NECEP), whose members are engaged in the development of a national curriculum model. Mr. Basmajian has been conducting similar activities with Virginia Polytechnic Institute and has been writing a course program on Energy and Power.

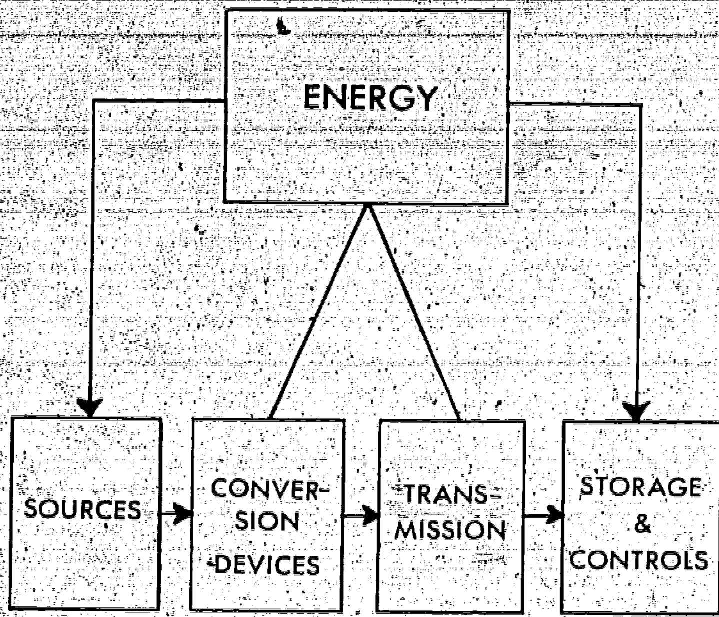
This article represents a course outline derived from the flow charts as published in the April, 1976 issue of Energy & Power Journal, Page 25. It is hoped that this article will give further details and guidelines to school administrators and educators as to the scope and magnitude of an Energy and Power program.

The energy related social, economic and political upheavals in the U.S. and world wide have added a new dimension and new responsibilities for educators. Certainly, the most important concern is preparing the students of today for the energy conditions that will exist tomorrow.

The Nation's energy demand for the future and the declining supply of fossil fuels indicate clearly a need for a new emphasis on alternate energy systems. Federal, Industrial or Research Agencies conducting an energy analysis all agree on one matter ... the ultimate solution of U.S. energy shortages depends on the development of alternate energy sources. For this reason, education has to play an important role in the transition from traditional *power technology programs that are essentially small engine programs into those inclusive of alternate energy sources.*

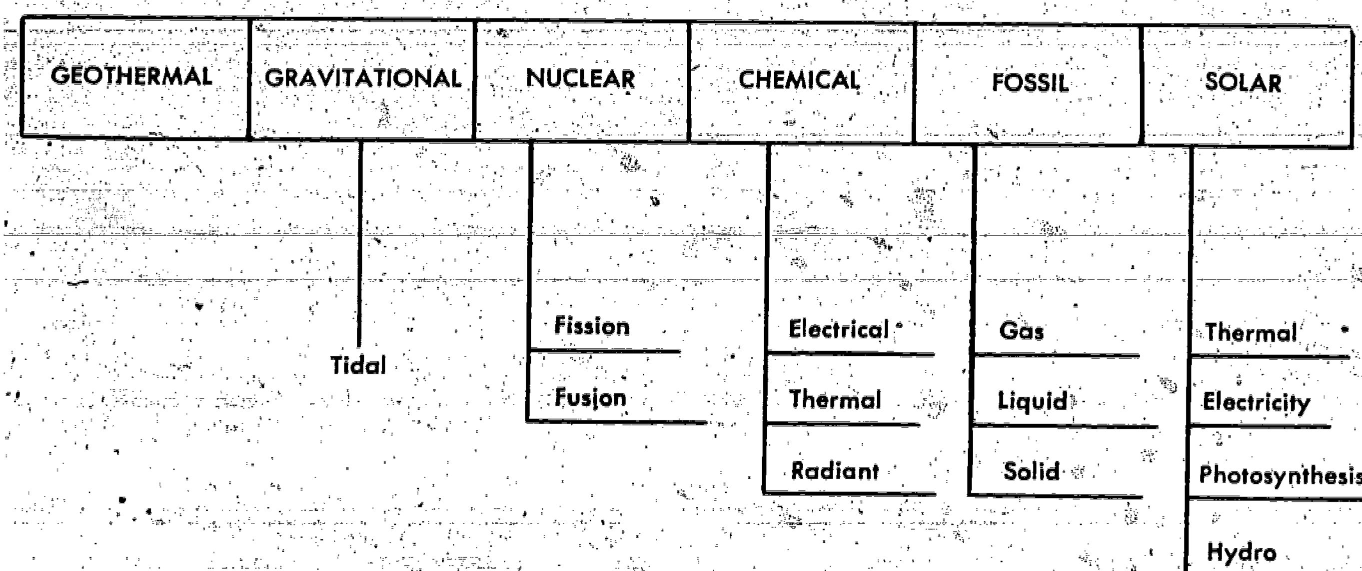
The student needs to be able to relate new energy sources to devices that can produce power. Additionally, he must develop an awareness of the emerging occupations in this field. A well planned curriculum with the proper hardward and software will be the beginning of a transitional period of growth as the student develops new career awareness. It is imperative that a curriculum be structured modularly and with continuity. He must be able to follow the program through various levels and achieve the prescribed competency levels. No doubt an Energy and Power Curriculum model must offer the student an awareness, orientation, exploration and preparation sequence.

It is hoped that the following model can serve as a basis for the above objectives and assist educators and administrators in making their decisions as how best to serve the needs of the students and the nation.



ENERGY FLOW CHART

The above energy flow chart indicates the interrelationship which exists between energy sources, conversion devices, transmission, storage and controls. In order for the student to develop total energy awareness for energy and power, in a given area of a laboratory he must be able to explore the various sources of energy and the corresponding conversion systems. Upon producing power, the student certainly must be aware of the various methods by which power is transmitted and stored.



ENERGY SOURCES

PRIMARY ENERGY SOURCES

The above chart indicates the primary energy sources which have the greatest potential in the development of U.S. alternate energy supplies. There are secondary sources which are dependent on the primary sources. These are not listed since the major emphasis during the next twenty five years will be placed on the above listed energy sources. The student's awareness and exploration must be directed towards the primary sources of energy. New emerging occupations and careers that are a direct result of the development of these energy sources must be brought to the student's attention.

ENERGY SOURCES

A. The Nature of Energy and Power

1. Concept of Energy
2. Definition of energy, work and power
3. Relationship between different forms of energy

B. Fossil Fuels

1. History of fossil fuels utilization
2. Formation of fossil fuels
3. The availability of fossil fuels in the U.S. and the world
4. Consumption of fossil fuels for transportation, commercial, industrial and residential purposes
5. Production of power from fossil fuels
6. Advantages and disadvantages of fossil fuels
7. Fossil Fuels as chemical raw materials
8. Environmental Impact
9. Career opportunities

C. Radioactive Materials

1. Nature of the atom
2. Explanation of nuclear reactions (fission and fusion)
3. How a nuclear reaction can be used to produce power
4. Uranium mining
5. Availability of uranium in the U.S.
6. The advantages and disadvantages of nuclear energy
7. The role of nuclear fuels in the utility industry
8. Environmental Impact
9. Career opportunities

D. Hydro

1. Hydro Power, its history and origin
2. Availability
3. How it can be used to produce power
4. Applications for industrial use
5. Advantages and disadvantages of its use
6. The role of hydro power stations for the generation of electricity
7. Environmental Impact
8. Career Opportunities

E. Solar

1. Explanation of Solar Power
2. Historical utilization
3. Its applications for heating and air conditioning
4. Its advantages and disadvantages as an alternate source of energy
5. The role of solar power in the future
6. Environmental Impact
7. Career Opportunities

F. Wind

1. Explanation of how the winds are produced
2. History of their use
3. Power generation from wind
4. Advantages and disadvantages
5. The role of wind power for the nation's future energy needs
6. Environmental Impact
7. Career Opportunities

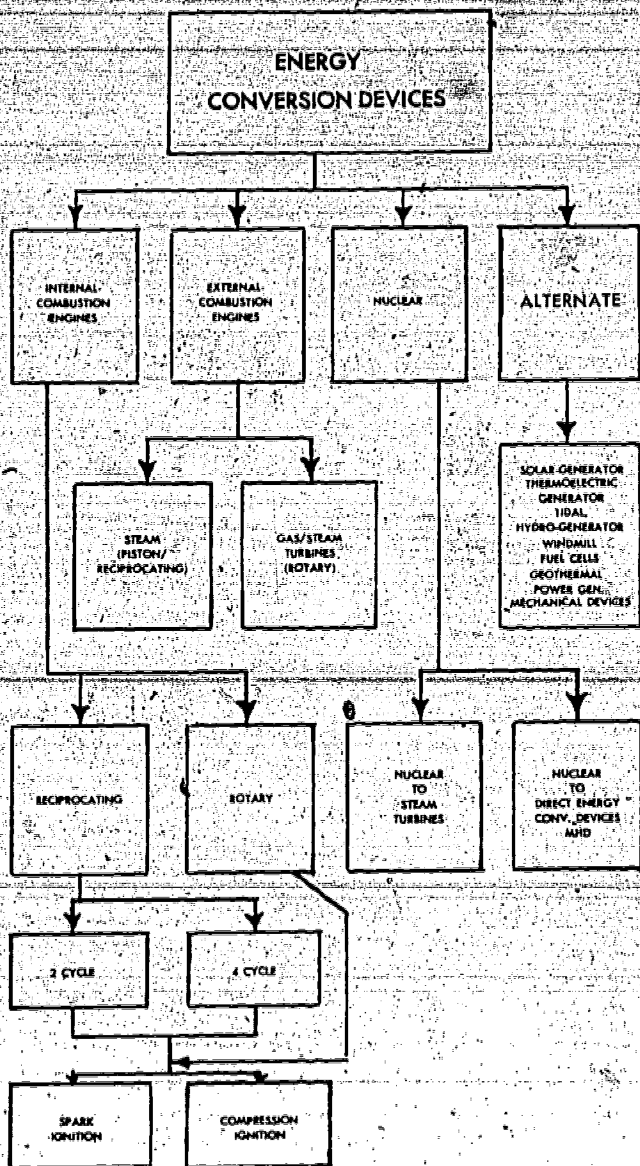
G. Geothermal

1. Description of geothermal energy source
2. Location of geothermal energy sources
3. Power production of geothermal sources
4. Advantages and disadvantages
5. The role of geothermal power for the nation's future energy needs
6. Environmental Impact
7. Career Opportunities

ENERGY CONVERSION DEVICES

INTERNAL COMBUSTION ENGINES

Traditionally the internal combustion engine has been the prime mover of the transportation industry and this sector consumes approximately 25% of the oil in the United States. The nation is 92% dependent on fossil fuels; yet these are the very sources that are depleting rapidly. Greater awareness and emphasis should be placed on alternate energy sources and conversion devices which could reduce the dependence on fossil fuels. The student must develop an awareness and explore various methods of power conversion systems. New career opportunities must be sighted where these industries are growing rapidly.



I. RECIPROCATING 2 & 4 CYCLE SPARK IGNITION ENGINES

A. *HISTORICAL DEVELOPMENT OF INTERNAL COMBUSTION ENGINES*

B. *SAFETY IN THE LABORATORY*

C. *TWO AND FOUR STROKE (CYCLE) ENGINES*

1. Fundamental Mechanics of 2 & 4 Cycle Engines

2. Learning the Components and Subsystems of 2 and 4 Cycle Engines
   (a) Piston & Rings
   (b) Carburetor and Power Control
   (c) Connecting Rod

(d) Wrist Pin and Journals
(e) Crankshaft and Crank Gear
(f) Camshaft and Cam Gear
(g) Engine Main Bearings
(h) Cylinder Heads
(i) Valves
(j) Rocket Arms and Lifters
(k) Spark Plug
(l) Points and Condenser
(m) High Voltage Coil
(n) Ignition Power Source
(o) Flywheel
(p) Engine Block

D. OPERATION OF 2 & 4 CYCLE ENGINES

1. Starting Systems
   (a) Rope Start
   (b) Recoil Start
   (c) Starter Motors

2. Operation
   (a) Start up Procedures
   (b) Operating Controls

E. POWER CONTROL

1. Function of a Carburetor
2. Principles of operation of Venturi type Carburetors
3. Air/Fuel Mixture Ratio
4. Various types of Carburetors
   (a) Float
   (b) Diaphram
   (c) Overflow
5. Filters

F. IGNITION

1. Types of ignition systems
   (a) Battery-Coil
   (b) Magneto
2. Definition of ignition timing
3. How to Read Ignition Timing
4. How to Vary Ignition Timing
5. Relationship of Piston position to spark plug firing
6. Effect of Ignition Timing on Engine Power

G. COMPRESSION

1. Definition of Compression Ratio

2. How to Vary Compression Ratio
3. Effect of Compression Ratio on Engine Power
4. Effect of Compression Ratio on Engine Exhaust

H. COOLING SYSTEM

1. Need for Engine Cooling
2. Types of Cooling
   (a) Air Cooling
   (b) Water Cooling

I. LUBRICATION

1. Need for Lubrication
2. Types of Lubrication Systems
   (a) Splash
   (b) Spray
   (c) Pressure

J. Dynamometers

1. Connecting Engines to Dynamometers
2. Definition of Torque and Horsepower
3. Operating Principles of Electric Dynamometers
4. Operating Principles of Hydraulic Dynamometers
5. Operating Principles of Prony Brank Dynamometers
6. Operation of Electric Dynamometer/Generators
   (a) Starting Mode
   (b) Loading the Engine
   (c) Electric Power Generation

K. Performance of 4 Cycle Engines

1. Measuring Horsepower Output
2. Factors affecting Power Output

L. Performance of 2 Cycle Engines

1. Measuring Horsepower Output
2. Comparisons of 2 & 4 Cycle Engines

M. Applications

1. Single Cylinder
2. Multi-Cylinder

N. Environmental Aspects

1. Emissions of 4 Cycle Engines
2. Emissions of 2 Cycle Engines

P. Career Opportunities

II RECIPROCATING 2 & 4 CYCLE COMPRESSION IGNITION ENGINES

A. Historical Development of Diesel Engines

B. Safety in the Laboratory

C. Operating Principles of 4 Cycle Diesel Engines

D. Operating Principles of 2 Cycle Diesel Engines

E. Fuel Injection systems of Diesel Engines

1. Common Rail System
2. Jerk Pump System

F. Fuel Injectors

1. Variable Piston Stop Type
2. Variable Lifter Type
3. Bosch Type

G. Diesel Fuel

H. Combustion Process in a Diesel Engine

I. Operation of a Diesel Engine

1. Cold Start
2. Warm Start
3. Power Control

J. Loading and Power Measurement

1. Connecting Engine to Dynamometer
2. Torque
   (a) Definition
   (b) How it is Measured
3. Horsepower
   (a) Definition
   (b) How it is Calculated
4. Efficiency

K. Performance

1. How Throttling is Achieved
2. Relationship of Air/Fuel Ratio and Load
3. Relationship of Injector Timing and Power Output

L. Diesel Engine Maintenance

1. Fuel System
   (a) Injector
   (b) Injection Pump
2. Cylinder and Head

M. Comparison of Diesel and Spark Ignition Engines

N. Applications

1. Single Cylinder
2. Multi-Cylinder

O. Environmental Aspects

1. Emissions of Diesels
2. Comparison with Spark Ignition Engines and its Effect on Environment

P. Career Opportunities

III ROTARY ENGINES

A. Historical Background of Rotary Engines and Comparison to Reciprocating Engines

B. Safety in the Laboratory

C. The Wankel Engine

1. Fundamental Principles of Operation
2. Identifying the Components and Subsystems
   (a) Rotor and Seals
   (b) Carburetor and Power Control
   (c) Mainshaft and Eccentric
   (d) Housing
   (e) Side Plates
   (f) Flywheel
   (g) Spark Plug
   (h) Magneto

D. Power Control in Rotary Engines

1. Function of Carburetor
2. Principles of Carburetor Operation
3. Air/Fuel Mixture Ratio
4. Types of Carburetors
   (a) Float
   (b) Diaphram
   (c) Overflow

35

E. Operation Under Load

1. Connecting Engine to Dynamometer
2. Operation of Engine
   (a) Cold Start
   (b) Warm Start
   (c) Throttle Control
3. Operation of Electric Dynamometer/Generator
   (a) Principles of Operation
   (b) Starting Mode
   (c) Loading the Engine
   (d) Electric Power Generation
4. Operation of a Hydraulic Dynamometer

F. Power Measurements

1. Torque
   (a) Definition
   (b) How it is measured
2. Horsepower
   (a) Definition
   (b) How it is Calculated
3. Efficiency

G. Fuels and Mixtures

1. Connecting flow meters
2. Definition of Air/Fuel Mixtures
3. Effect of Mixtures on Engine Power
4. Effect of Various Fuels on Engine Power
5. Efficiency

H. Comparison of Rotary and Reciprocating Engines

I. Applications

1. Single Rotor
2. Multi-rotor

J. Environmental Aspects

1. Emissions of Rotary Engines
2. Comparison with Reciprocating Engines and its Effect One the Environment

K. Career Opportunities

EXTERNAL COMBUSTION ENGINES

I STEAM TURBINE GENERATOR

A. *Fundamental Principles of Open Cycle Steam Turbines*

B. *Safety in the Laboratory*

C. *Components and Subsystems of Steam Turbine Generators*

1. Steam Generating System
   - (a) Heat Source and Controls
   - (b) Boiler
   - (c) Preheater Coal
   - (d) Superheater
   - (e) Steam Exhaust
2. Energy Conversion Systems
   - (a) Turbine Wheel
   - (b) Electrical Generator
3. System Loads
   - (a) Fixed Resistors
   - (b) Variable Resistors

D. *Power Output*

1. How to Measure Power Output
2. How to Vary Power Output
3. Relationship of Output Power and Load
4. Relationship of Output Power and Input Steam Pressure

E. *Applications*

F. *Environmental Aspects*

G. *Career Opportunities*

II RECIPROCATING STEAM ENGINES

A. *Fundamental Principles of Open Cycle Reciprocating Steam Engines*

B. *Safety in the Laboratory*

C. *Components and Subsystems of Reciprocating Steam Engines*

1. Steam Generating System
2. Energy Conversion System
   - (a) Piston-Cylinder
   - (b) Valve Train
   - (c) Connecting Rod
   - (d) Crankshaft
   - (e) Flywheel

D. Applications

E. Environmental Aspects

F. Career Opportunities

NUCLEAR POWER GENERATION

I NUCLEAR REACTION AS HEAT SOURCE

II SAFETY IN THE LABORATORY

III NUCLEAR POWER GENERATORS

A. Fundamental Principles of a Closed Loop Steam Cycle

B. Components and Subsystems of a Nuclear Power Generation System

1. Steam Generating System
   - (a) Reactor and Control Rods
   - (b) Superheat and Its Control
   - (c) Condenser
   - (d) Reheater System
   - (e) Water Pumps and Controls
2. Energy Conversion Systems
   - (a) Turbine Wheel
   - (b) Electrical Generator
3. System Loads
   - (a) Fixed Resistors
   - (b) Variable Resistors

C. Power Output

1. How to Measure Output Power
2. How to Vary Output Power
3. Relationship of Output Power and Load
4. Relationship of Output Power and Input Steam Pressure

D. Applications

E. Environmental Aspects

F. Career Opportunities

ALTERNATE ENERGY SOURCES

I SOLAR ENERGY

A. *Introduction to Solar Radiation as a Direct Source of Energy*

1. Geographic Distribution of Solar Energy Input
2. Solar Flux at Various Parts of the Day and Night Cycle

B. *Safety in the Laboratory*

C. *Solar-Electric Generator*

1. Fundamental principles of operation of Silicon Solar Cells
2. Components and Subsystems of a Solar-Electric Generator
   a. Sources of Energy
      1. Natural - Sun
      2. Artificial - High Density Lamp
   b. Energy Conversion Systems
      1. Silicon Solar Cell Array
      2. Other, Crystals
   c. System Loads
      1. Resistors
      2. Batteries
      3. Electro-Mechanical
3. Power Output, Solar Electric Generators
   a. How to Measure the Output Power
   b. How to Vary the Output Power
   c. Relationship of Output Power and Load
   d. Relationship of Output Power and Light Density
   e. Relationship of Output Power and Distance from Light Source
4. Applications
5. Environmental Aspects
6. Career Opportunities

D. *Solar-Thermal System*

1. Fundamental principles of operation of solar thermal systems
2. Components and Subsystems of a solar-thermal system
   a. Energy Conversion
      1. Solar Collector
         (a) Types of Collectors
         (b) Insulation
         (c) Paint Selection
         (d) Glass Covering
      2. Plumbing System
         (a) Pumps
         (b) Tubing-Fittings

3. Operation and Controls
4. Applications
5. Environmental Aspects
6. Career Opportunities

II WIND POWER

A. Introduction to Wind as a Source of Energy

B. Safety in the Laboratory

C. Wind Power Generation

1. Fundamental principles of operation of a wind power generator
2. Components and subsystems of a wind power generator
   a. Energy Conversion System
      1. Windmill types
      2. Mechanical Drives
      3. Electric Generator
   b. System Loads
      1. Resistors
      2. Batteries
      3. Output Power
         (a) How to Measure the Output Power
         (b) How to Vary the Output Power
         (c) Relationship of Output Power and Load
         (d) Relationship of Output Power and Wind Velocity

D. Applications

E. Environmental Aspects

F. Career Opportunities

III HYDRO POWER

A. Introduction to Flowing Water as a Source of Energy

B. Safety in the Laboratory

C. Hydro Electric Power Generation

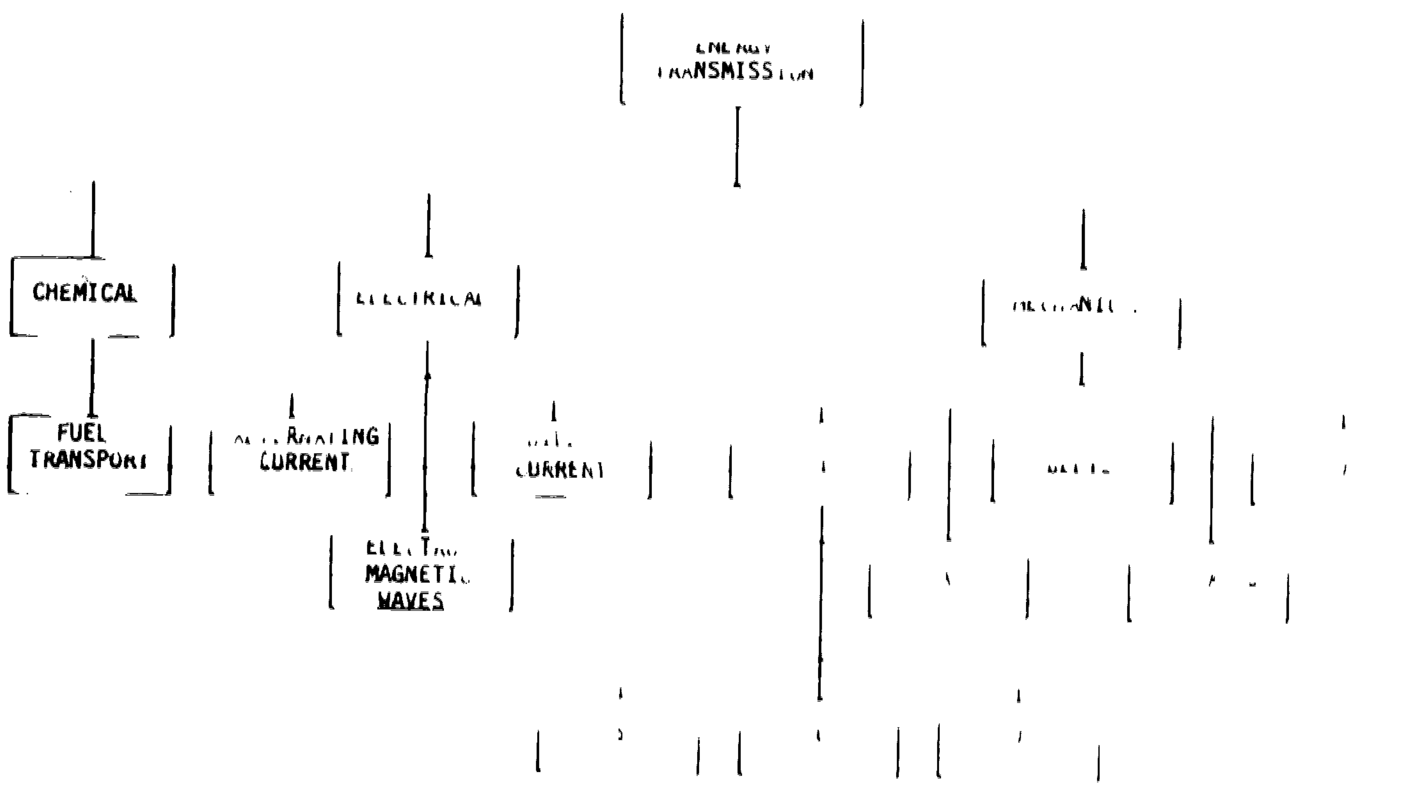
1. Fundamental principles of operation of a Hydro-Electric Generator
2. Components and subsystems of a Hydro-Electric Generator
   a. Water System
      1. Supply and controls
      2. Discharge

    b. Energy Conversion Systems
        1. Types of nozzles
        2. Types of turbine wheels
        3. Electric generator
    c. System Loads
        1. Resistors
        2. Electro-mechanical
3. Output Power
    a. How to Measure the Output Power
    b. How to Vary the Output Power
    c. Relationship of Output Power and Load
    d. Relationship of Output Power and Input Water Pressure

D. *Applications*

E. *Environmental Aspects*

F. *Career Opportunities*



VARIOUS METHODS OF ENERGY & POWER TRANSMISSION

The power transmission industry has long been concerned with the cost of power distribution especially when the primary supply of energy is at long distances from the point of distribution. The primary method of transmitting power has been through solid conductors through alternating current.

Solar energy transmission from outer space has seriously been considered as a means of uninterrupted power through microwave beams. The industrial applications of microwaves and lasers have been established and are the most rapidly growing areas. Student awareness and exploration in the laboratory must highlight new emerging technologies and careers

I. MECHANICAL ENERGY TRANSMISSION

A. *Historical Development of Basic Machines*

B. *Safety in the Laboratory*

C. *Basic Units*

1. Force
2. Torque
3. Work
4. Speed
   (a) [illegible]
   (b) Rotary
5. Pow[illegible]

D. *Devices for T[illegible]*

1. Shafts
2. Gears
3. Belts
   (a) [illegible]
   (b) Flat
   (c) Vee
   (d) Poly[illegible]
   (e) Gear
   Ch[illegible]

4. [illegible]

II ELECTRICAL ENERGY TRANSMISSION

A. *Historical Background of Electricity and Its Use*

B. *Safety in the Laboratory*

C. *Fundaments of Electricity*

1. Origin of Electric Current
    - (a) Matter
    - (b) Atomic Structure
    - (c) Electron flow
    - (d) Conductors and Insulators
2. Circuits
    - (a) Definitions
    - (b) Laws
    - (c) Power Measurements
    - (d) Power Controls
    - (e) Method of Transmission
    - (f) Energy Storage

D. [illegible]

E. [illegible]

1. [illegible]
2. High Voltage Power Transmission

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

(b) [illegible]

[illegible]

[illegible]

4 Flow Measurement

(a) Rate

(b) [illegible]

[illegible]

D. Hydraulic Pumps–Tramsmission of Fluid Energy

1. Basic Types
2. Components and their functions
3. Flow rates

E. Basic Hydraulic System Components

1. Pipes
2. Connectors
3. Filters
4. Control Valves
5. Actuators
   (a) Linear
   (b) Rotary
6. Seals
7. Type of Circuits
   (a) Series
   (b) Parallel

F. Applications

G. [illegible]

H. [illegible]

III. [illegible] ENERGY IN [illegible]

A. [illegible]

B. Safety in the Laboratory

C. [illegible]

1. [illegible]
   (a) Units
   (b) Symbols
2. Flow meters
3. Compressibility
   (a) Heat of [illegible]
   (b) Condensation

1. [illegible]
2. C[illegible]
3. Flow rates

1. Pipes
2. Connectors
3. Filters
4. Control Valves
5. Actuators
   (a) Linear
   (b) Rotary
6. Water Separators

F. *Comparison to Hydraulic Systems*

1. Response time
2. Power - Density
3. Tank energy storage

G. *Applications*

H. *Environmental Aspects*

I. *Career Opportunities*

V ACOUSTIC ENERGY TRANSMISSION

A. *Introduction to Acoustics and [illegible]*

B. *Safety in the Laboratory*

C. *Acoustic Transmission System*

1 Fundamental principles [illegible]
2 Components and subsystems [illegible] system
   (a) Energy transmission system
      (1) Power Supply
      (2) Sonic Transm[illegible]
   (b) Energy Reception system
   (c) System Loads

[illegible]
   (a) Measurement [illegible]
   (b) Measurement of received
   (c) Relationship of transmitted [illegible]
   (d) Relationship of received power [illegible] transmitter and receiver
   Relationship of received power [illegible] transmitter and receiver
   (f) The effect of various ob[illegible] in t[illegible]
   (g) Transmission losses

D. *Applications*

E. *Environmental Aspects*

F. *Career Opportunities*

VI. LASER ENERGY TRANSMISSION

A. *Introduction to Lasers and Their Uses*

B. *Safety in the Laboratory*

C. *Laser Transmission Systems*

1. Fundamental principles of operation of laser energy transmission systems
2. Components and subsystems of the laser transmission system
   - (a) Power Source
   - (b) Energy transmission system
     1. Power Supply
     2. Laser
   - (c) Energy reception system
   - (d) System Loads
3. Energy Transmission
   - (a) Measurement of transmitted [illegible]
   - (b) Measurement of received power
   - (c) Relating the input power to output
   - (d) Relating power received and distance [illegible] and receiver
   - (e) Relating power received and angle between [illegible] and receiver
   - (f) The effect of various obstacles in the beam
   - (g) Transmission losses

[illegible]

[illegible]

[illegible]

[illegible] WAVE ENERGY [illegible]

[illegible]

[illegible]

[illegible]

[illegible] system

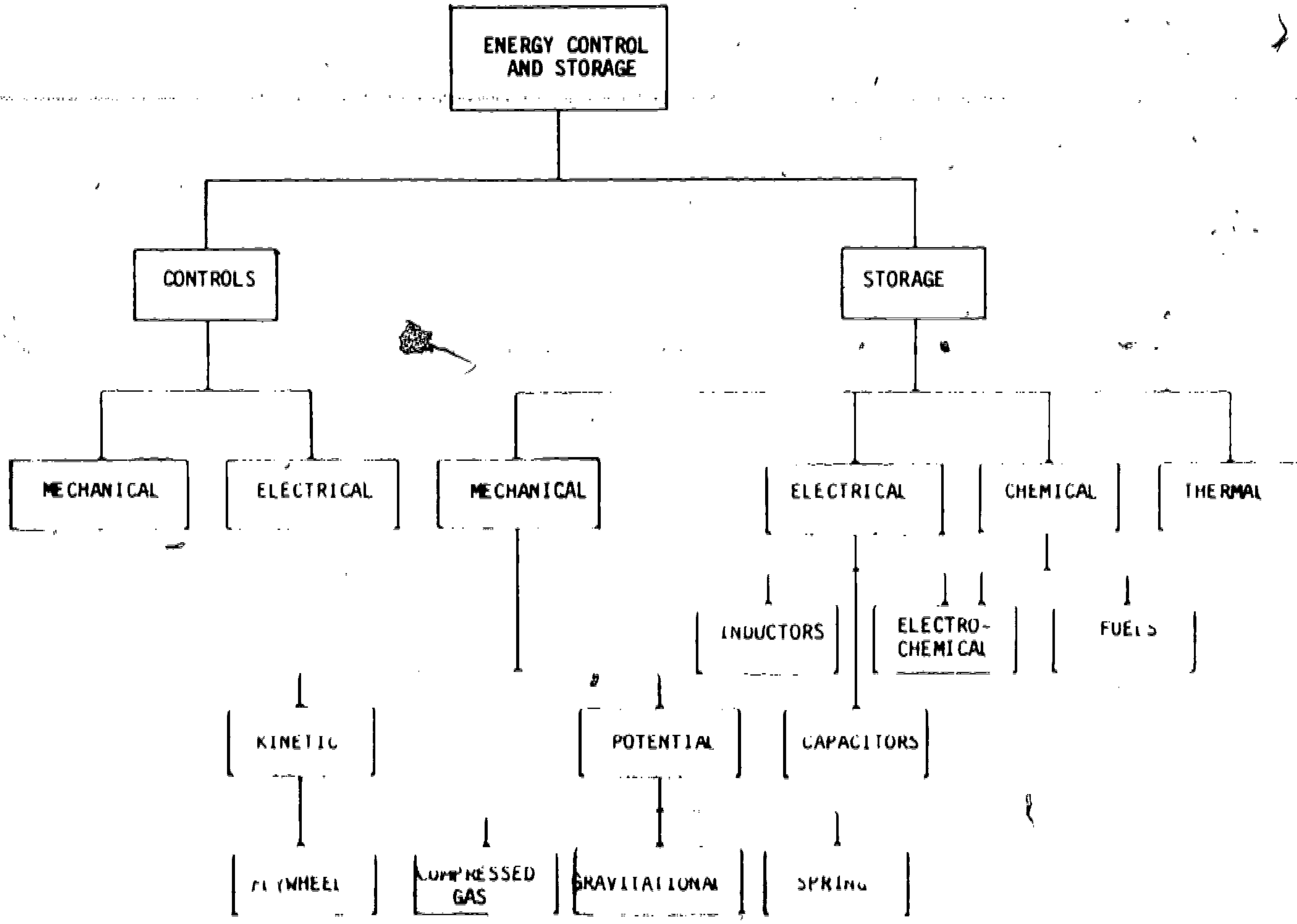
2. Components and subsystems of a microwave transmission system
   - (a) Energy transmission
     1. power supply
     2. microwave transmitter
   - (b) Energy reception system
   - (c) System Loads

3. Energy transmission
   - (a) Measurement of transmitted power
   - (b) How to vary transmission power
   - (c) Measurement of received power
   - (d) Relationship of power transmitted and power received
   - (e) Power variation due to angle between transmitter and receiver
   - (f) Power variation due to distance between transmitter and receiver
   - (g) The effect of various obstacles in the beam
   - (h) Transmission losses

D. *Applications*

E. *Environmental Aspects*

F. *Career Opportunities*



ENERGY CONTROL AND STORAGE

[illegible] energy applications depends on [illegible] of [illegible] systems which can store energy for long periods of time without [illegible] and degradation. Similarly the success of an electric powered vehicle depends on the development of new types of energy storage systems. The student must be able to develop such awareness and explore various techniques of energy storage in a laboratory. New emerging occupations and careers must be highlighted and brought to the student's attention.

[illegible]

4 [illegible]

[illegible]

[illegible]

1 [illegible]

(a) Capacitors

(b) Inductors

2. Mechanical Energy
   (a) Flywheels
   (b) Position - gravitational
   (c) Spring tension - compression
   (d) Compressed gasses
3. Thermal
   (a) Hot Mass
   (b) Evaporation - condensation
   (c) Fusion - solidification
4. Chemical
   (a) Fuels
   (b) Batteries

D *Applications*

E *Environmental Aspects*

F *Career Opportunities*

II ENERGY CONTROL

A *Introduction to Energy [illegible]*

B *[illegible] in the Laboratory*

C *[illegible]*

[illegible]
   (a) Ele[illegible]
      1 [illegible]
      2 Electrostat[illegible]
   [illegible] Electromechanical
      1 Solenoids
      2 Relays
   [illegible]
   [illegible]
   (b) Brak[illegible]
   [illegible] Transm[illegible]

[illegible]

[illegible]

(b) [illegible]

CURRICULUM GUIDELINE FOR ENERGY SOURCES AND CONVERSION DEVICES

Part I

By
Dr. Leonard Sterry and
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The Scope of the Problem

The NECEP Curriculum Committee Members [illegible] the past [illegible] information pertaining to the development of Energy and Power programs. Since the subject is of broad scope and depth, it will be divided into two parts.

In Part I, as published in this issue, the following [illegible] presented:

a. An awareness on the part of students that we live in a world of finite resources

b. How these limited resources [illegible] and efficiently by relating to energy conversion devices

[illegible] will include information [illegible] Programs 2. Engineering Educational Programs 3. Social and [illegible]

A World of Finite Resources

The energy crisis of [illegible] served in some respect [illegible] an awareness that energy is not abundant and without it [illegible] and living habits are disturbed causing extreme discomfort.

The lessons learned [illegible] have accomplished it any faster.

[illegible] attempt will [illegible] the relationships are between [illegible]

[illegible] earth and the earth [illegible] with limited supplies of food [illegible] energy [illegible] very [illegible] Any misuse of the [illegible] supply [illegible]

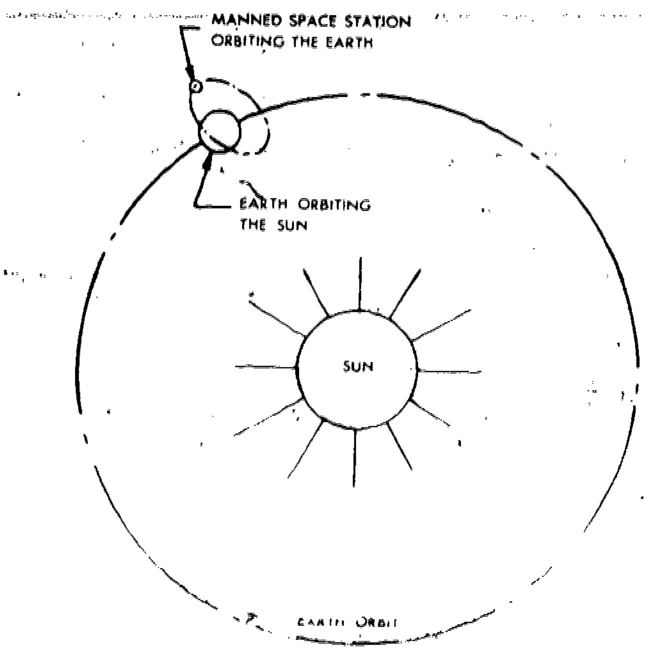


FIGURE 1. SPACESHIP EARTH

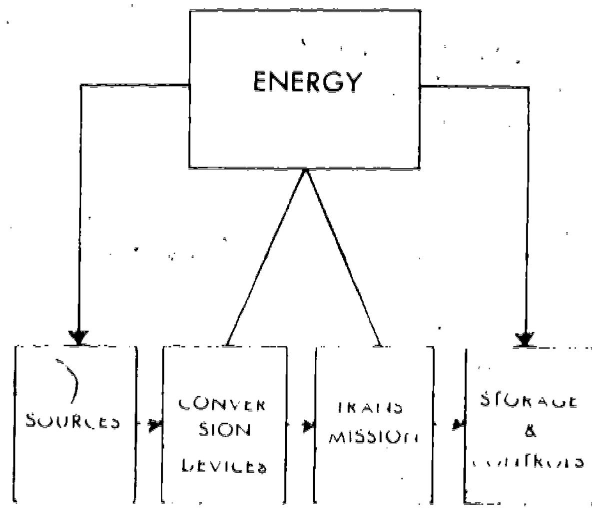


FIGURE 2. ENERGY FLOW CHART

[illegible] of energy [illegible] air and food [illegible] of using energy [illegible] consideration of emissions, merely leads to a poisoned atmosphere. This is not acceptable, since it will certainly alter the physiobiological conditions both in human beings and animals. Plant life will also be affected from such conditions thereby decreasing the amount and quality of food.

From Energy to Power Generation

An Energy and Power [illegible] energy, energy conversion devices [illegible] events. The student must be exposed and obtain the knowledge [illegible] its types and forms as they are found on earth to types of energy conversion devices, to transmission methods and how energy can be stored and controlled.

[illegible] form and [illegible] such energy sources [illegible] a list [illegible] properties for each type of energy. Additional information [illegible] originate in What quantities they are available and what are the [illegible] type.

[illegible] produce electrical power [illegible] element is to select the [illegible] energy conversion device.

Another important element is to classify the energy conversion devices so that the student can point out the basic differences for each classification. For example, internal combustion engines operate on a different principle if compared to external combustion engines. The following parameters characterize the energy conversion devices:

1. Operating Principle
2. Performance
3. Efficiency
4. Emissions
5. Uses and Applications
6. Cost of Operation
7. Availability
8. Adaptability to the environment

It is obvious that energy conversion should take place with as high efficiency as possible and with a minimum amount of emissions.

Energy and power transmission including storage and control of energy [illegible] presented in a sequence and with proper perspective. Energy loss occurs during transmission and several important parameters must be considered such as:

1. Energy Loss
2. Cost
3. [illegible]
4. Adaptability to the Surroundings

[illegible] Sources

[illegible] sources which are earth [illegible] and those [illegible] energy can be obtained directly and converted to useful electrical energy [illegible] solar energy causes cloud formations, rain, waterfalls and therefore power hydroplants.

The lunar gravitational pull on our oceans is another source of energy [illegible] *tidal energy* which permits hydroplants to operate and produce electricity.

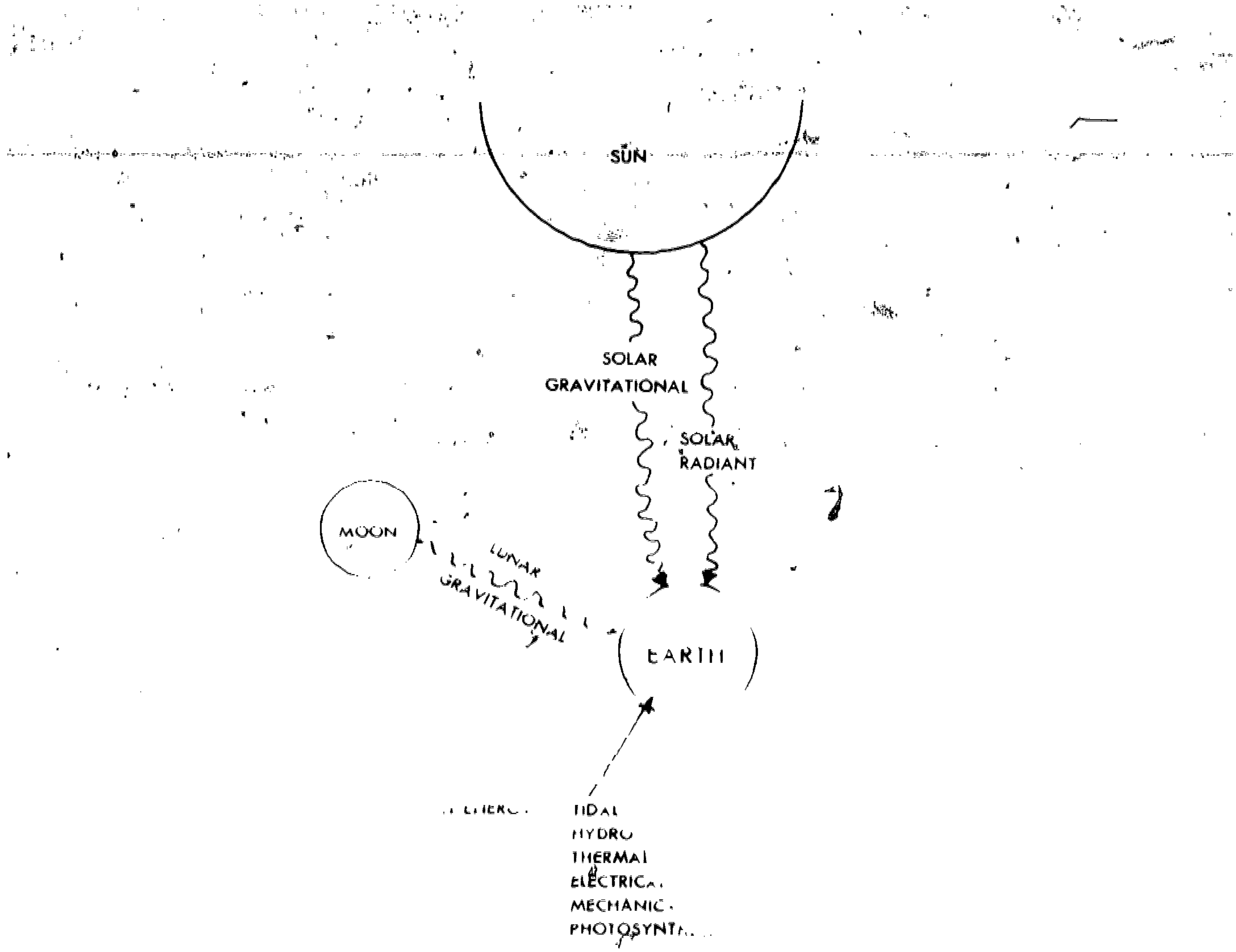
[illegible] earth [illegible] neighbors, the sun and the moon.

In the United States [illegible] energy comes from the sun causing the plant life [illegible] of wood to alcohol which has the equivalent of 200 gallons of gasoline [illegible] and [illegible] within [illegible] technology to produce in large quantities.

[illegible]

[illegible] energy sources [illegible]

[illegible] energy sources [illegible]



[illegible] FROM SUN & [illegible]

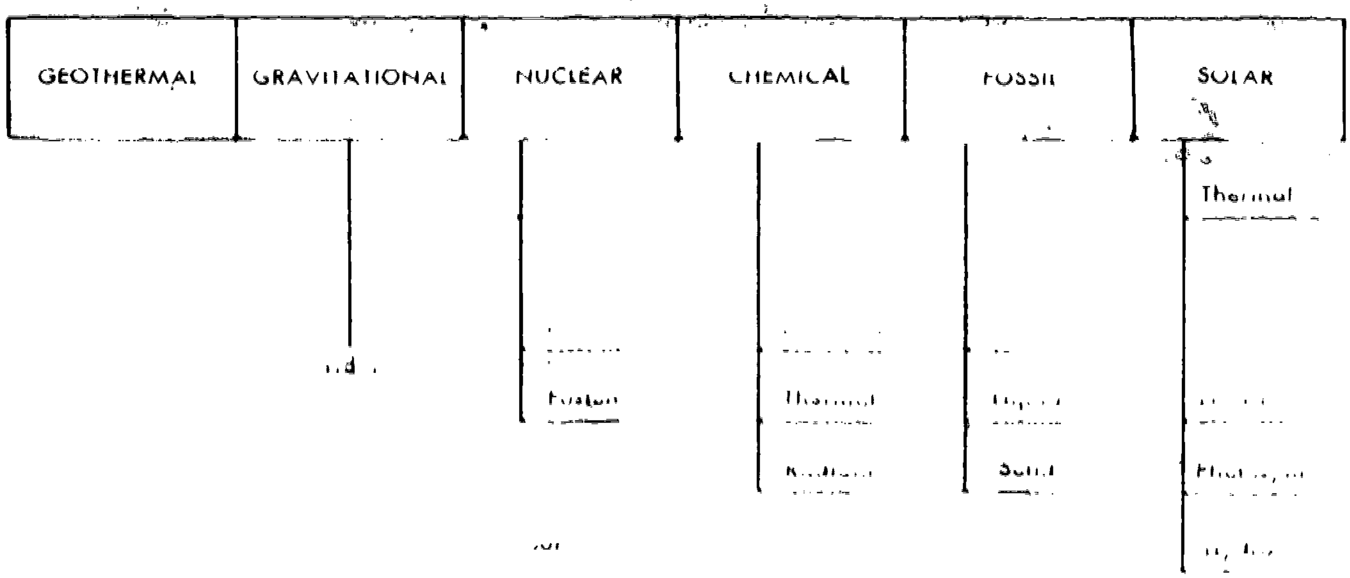
[illegible] combustion engines [illegible] There are two basic types [illegible] reciprocating engines have been operated at higher efficiencies because of [illegible] *ratios*. Compression ignition engines are found under the hoods of all large trucks and [illegible] Rotary piston engines have not been able to produce comparable [illegible] compression as has been the case with reciprocating engines

[illegible] engines have become [illegible] in operation

[illegible] generate high pressure [illegible]

[illegible] be achieved [illegible]

There are many other varieties of energy converters. Excepting the hydro-turbines, the rest are in experimental stages. Fuel cells, thermionic, solar and others presently produce a small fraction of the needed power. However, the future development of alternate sources of energy is directed towards the exotic types. Solar, Geothermal, Hydro and MHD generators show the greatest potential in power generation.



[illegible]

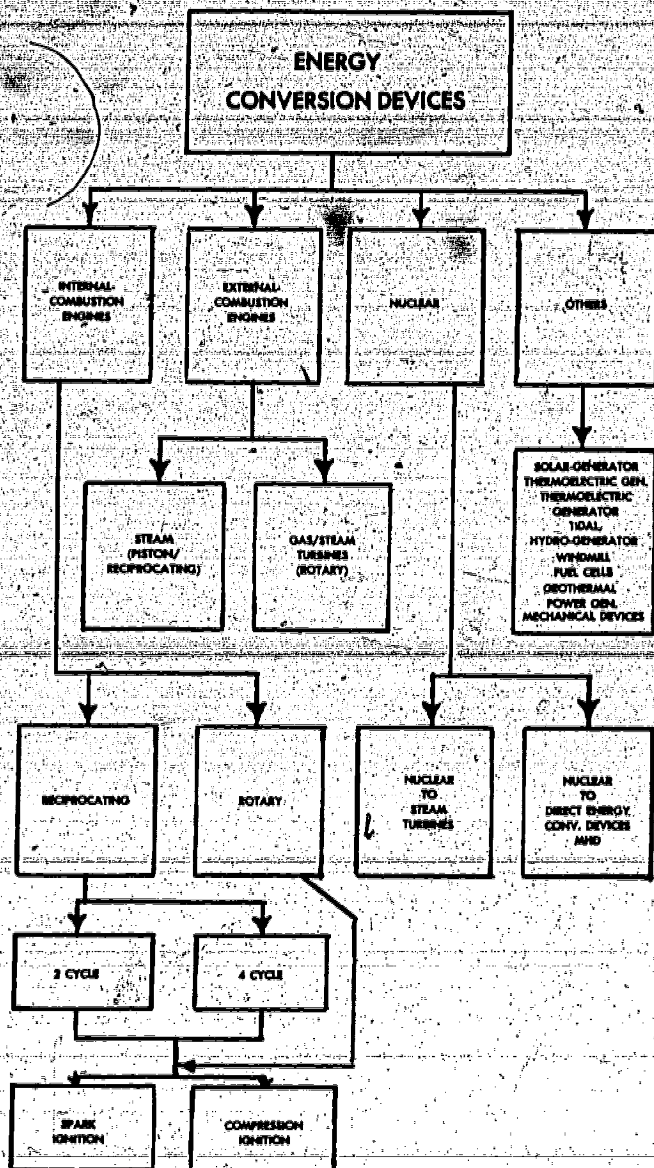


FIGURE 5: ENERGY CONVERSION DEVICES

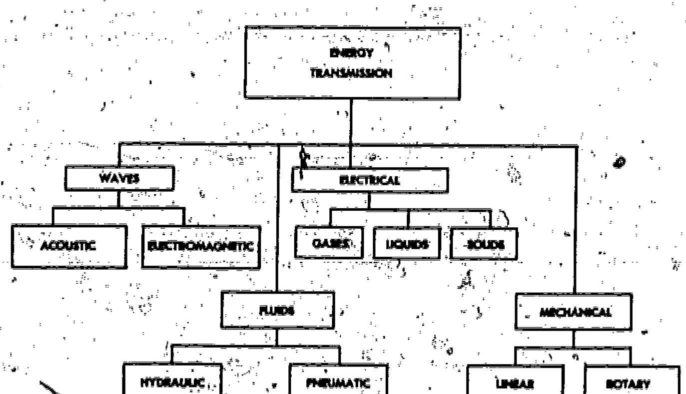


FIGURE 6: CATEGORIZATION OF ENERGY TRANSMISSION METHODS

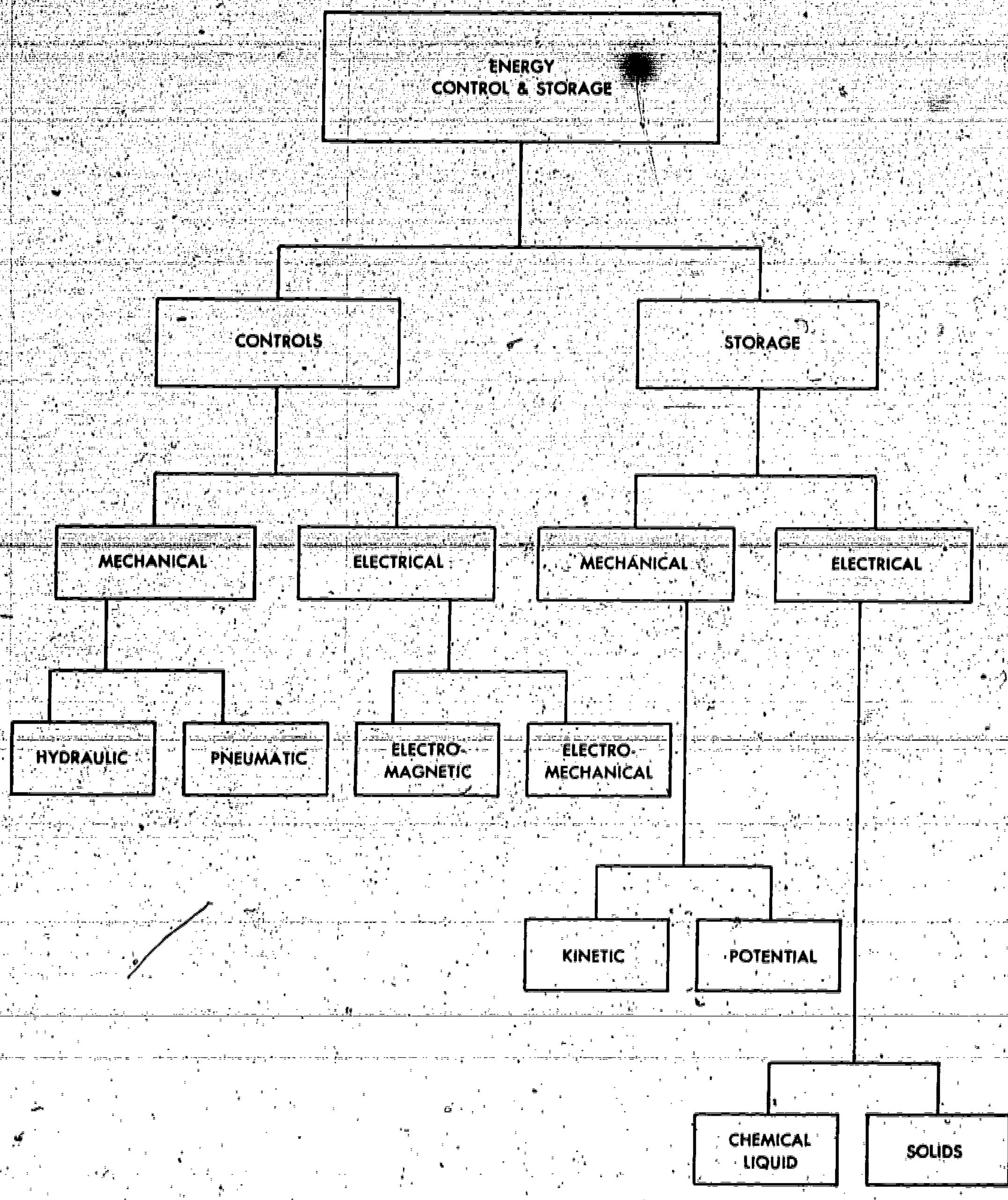
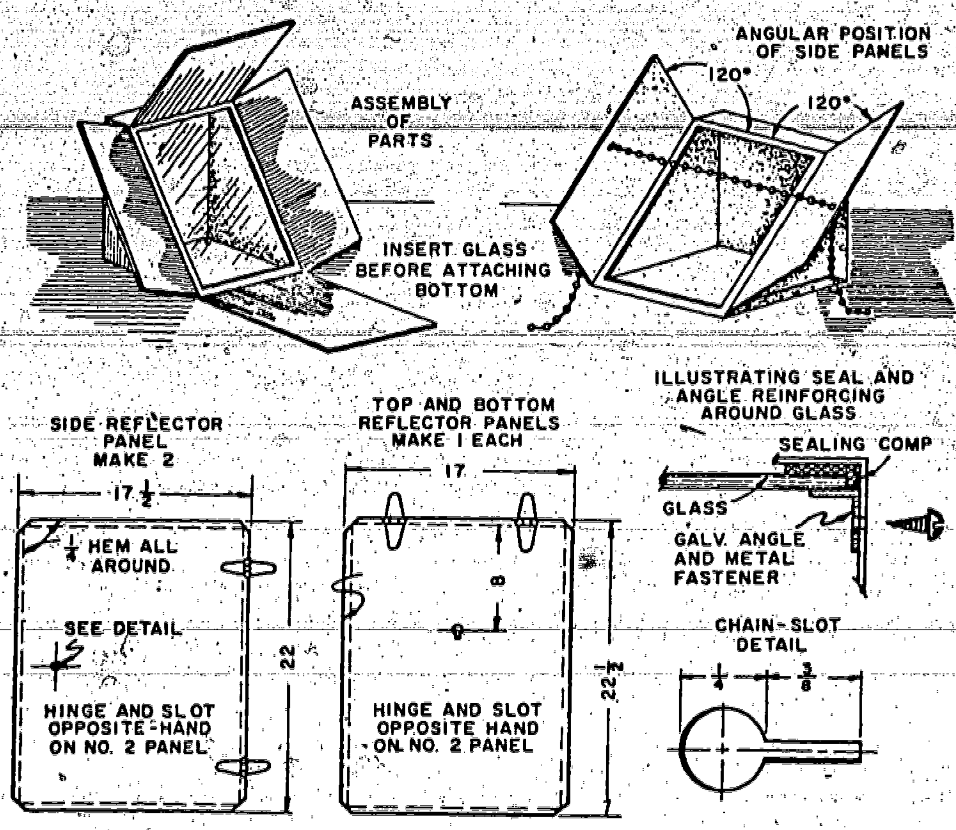


FIGURE 7:
FLOW CHART INDICATING ENERGY CONTROLS & STORAGE

SOLAR OVEN

The sun is a vast reservoir of "free" energy which comes to us as sunlight. A solar oven makes use of this energy and, through scientific principles of heat retention, raises the temperature to a point where food can be baked.

Working Drawing



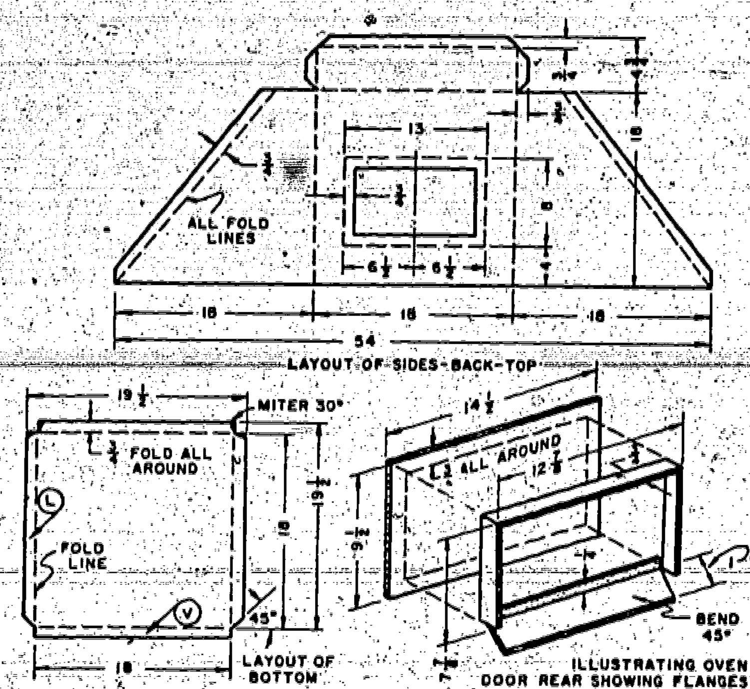
Alternate Design

Instead of using one piece of metal to form back and sides, they may be made separately.

Sheet metal screws may be used instead of machine screws.

Aluminum may be substituted for the galvanized sheet steel and tin plate.

Detail Drawing



Bill of Materials

1 Piece galvanized sheet steel, No. 26 gage x 19½ inches square, base
1 Piece galvanized sheet steel, No. 26 gage x 22¾ inches wide x 54 inches long, back, top, and sides fabrication
1 Piece galvanized sheet steel, No. 26 gage x 13 inches square, false bottom
1 Piece galvanized sheet steel, No. 26 gage x 9½ inches wide x 14½ inches long, door
1 Piece galvanized sheet steel, No. 26 gage x ¾ inches wide x 28¾ inches long, top and sides, door insert strip
1 Piece galvanized sheet steel, No. 26 gage x 1¼ inches wide x 12¾ inches long, bottom, door insert strip
2 Pieces galvanized sheet steel, No. 26 gage x 1¾ inches wide x 18 inches long, glass support
2 Pieces tin plate, No. 25 gage x 17 inches wide x 22½ inches long, top and bottom reflector panels
2 Pieces tin plate, No. 25 gage x 17½ inches wide x 22 inches long, side reflector panels
1 Piece Fiberglas insulation, 1 inch thick x 24 inches wide x 96 inches long
1 Piece glass, double thickness, 17¾ inches wide x 22¼ inches long
2 Pieces band iron, ⅛ inch thick x ¾ inch wide x 2 inches long, door clamps
4 Pair strap hinges, 1 inch x 4 inch
3 Sash pulls
1 Piece steel safety chain, No. 1/0 x 9 feet long
5 Nails, No. 6 penny
2 Sash handles
40 Machine screws, No. 6 x 32 x ½ inch long, round-head, with nuts
1 Machine screws, No. 4 x 48 x ½ inch long, round-head, with nut
16 Tinner's rivets
Duco cement
Flat black paint
Solder
Sealing compound
Heavy white thread

ENERGY CONVERSION TECHNOLOGY

in

Industrial Arts Education:

Evolving a Contemporary Program From a Traditional Base

TRANSLATING ENERGY INTO POWER

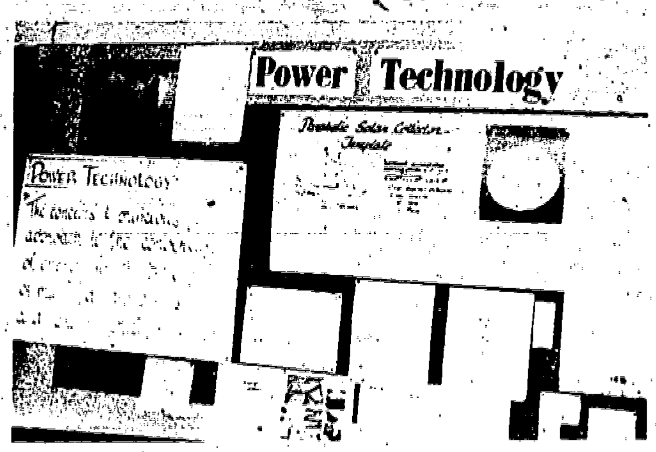
Students in Action

Most of the articles concerning energy education deal with the philosophy of energy education programs, the identification of the scope of the field, and the formultion of goals and objectives. Such articles are not much help to a teacher who is operating in an automotive, small engine or power mechanics program within a school district which is on austerity. The problems of implementing energy education in such cases are many, but can be condensed to money, facilities and equipment. If the teacher and the administration are dedicated, concerned about the future and enthusiastic, a solution may be arrived at within existing conditions.

At West Seneca East Senior High School (West Seneca Central School System, a suburb of Buffalo, N.Y.) an *Energy Conversion Technology* program has been operating for the past seven years. From a very meager beginning, the program has advanced with very little monetary support to the position of excellence as reflected by the performance of the energy education students. Numerous competition victories by the students in local American Society of Mechanical Engineers (A.S.M.E.) sponsored events plus first place finishes in the local Science Congress competitions in lecture-demonstration for the past two years point out this success.

West Seneca East is the *only* high school to be funded by the Federal Energy Research and Development Administration (E.R.D.A.) for work on alternate Energy systems in the forthcoming SCORE ERA II intercollegiate competition. The student group's proposal was ranked 5th from the 80 proposals received for grant request review.

Over the years, many of the energy technology students have gone on to college and specialized in energy-environmental related careers. They have obtained scholarships which have demonstrated their exceptional ability and dedication in the area of energy related matters, including the Westinghouse Science Talent Search scholarship, which is competitive on the national level.

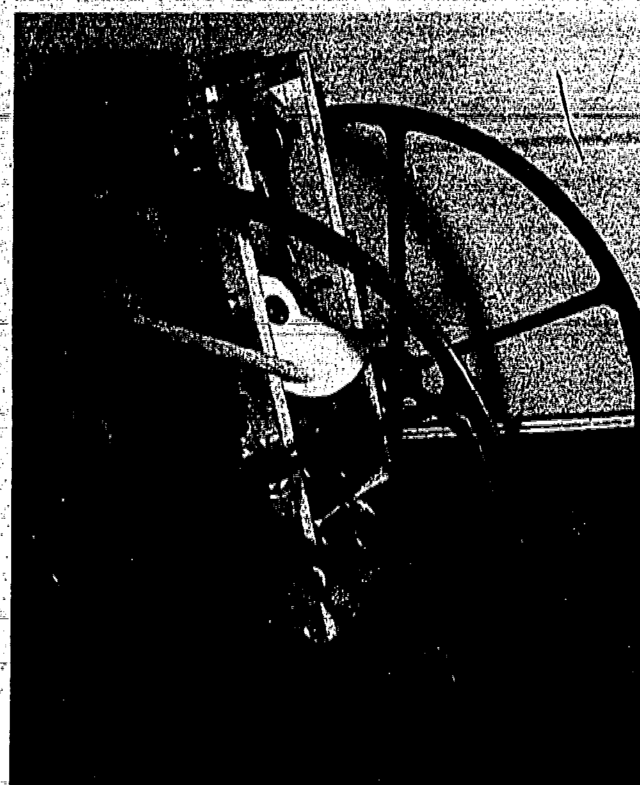


One of several bulletin boards in the Lab. This one describes the meaning of Power Technology.

Three of the students placed in the top 30 percent of the National Materials Handling competition, which was held in Chicago last spring. Who were there competitors? Professors of engineering, practicing engineers and college engineering students.

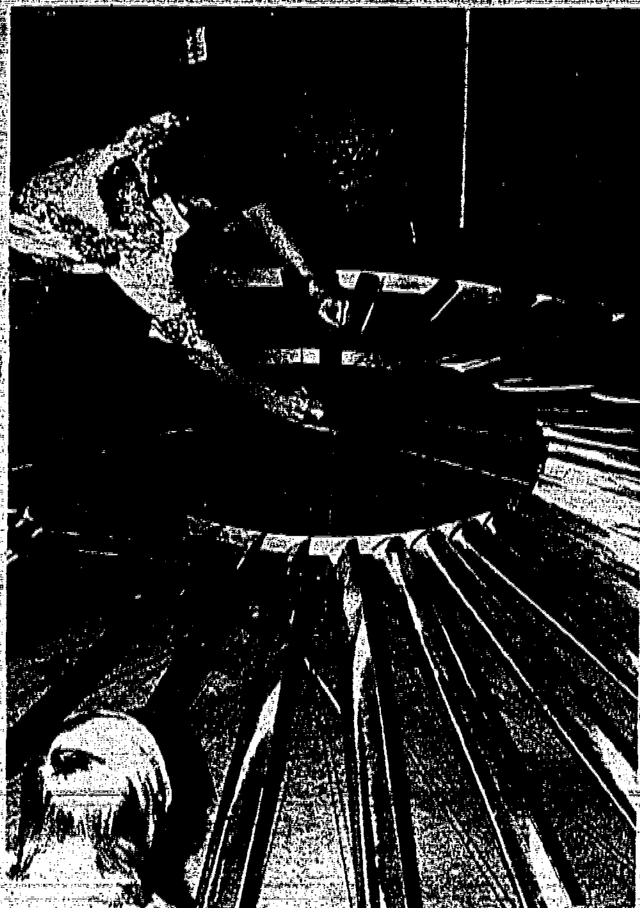
The procedures to achieve this success are introduced in this article, but space will not permit reports on how to construct, on a low budget, specific projects such as small engine dynamometers, human horsepower dynamometers, flame propagation demonstrators, atmospheric engines, concentrating solar collectors and electric generating wind turbines.

Few teachers are lucky enough to have bond issue or capital outlay monies to finance the necessary equipment for the energy laboratory. The majority must operate in existing facilities which are designed for other subjects (auto mechanics, small engine repair) and on yearly departmental budgets, which are ridiculously low.

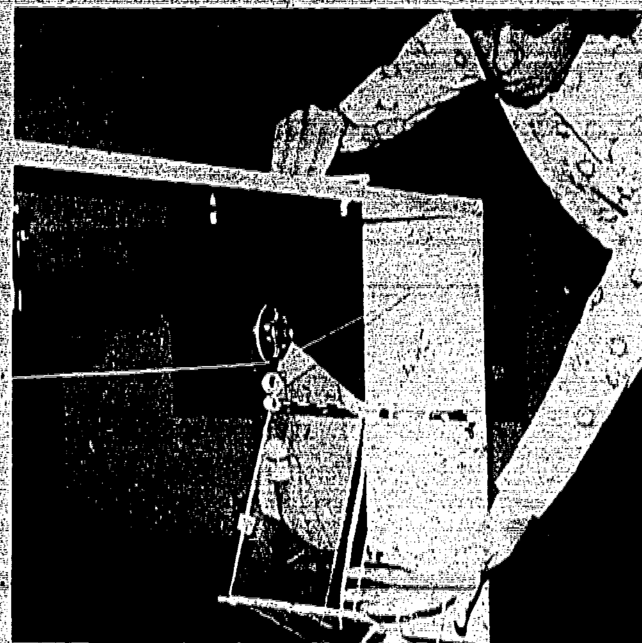


1975 American Society of Mechanical Engineers (A.S.M.E.) winning "efficiency vehicle". Builder: student Vince Kuntz.

The secret is to identify the field of energy conversion technology and formulate your philosophy, based upon the rationale of Industrial Arts education. Industrial Arts, in its broadest concept, is really general education, and belongs in the academic high school, for all students. Such a rationale of Industrial Arts applied to energy education is a good case for convincing your department chairman, the school administrators and the Board of Education of the value of a technological study of energy and power. Traditional auto mechanics courses may not meet the needs of the students for entry into the new and emerging energy/power occupations. Just such a presentation to the Board of Education in 1968, explaining why an energy program was needed over that of the existing auto mechanics course, gave initial support to the West Seneca East High School program.



The W.A.S.P. team's 12' diameter electric generating wind turbine, under construction.



Western New York engineering competition winner James Capece begins an official run with his materials handling entry.

The key word in any presentation is preparation. Be certain that you know the philosophy of Industrial Arts. Be sure you have the self conviction and rationale for an energy program logically derived. List the course goals and objectives. Organize a topical outline which describes the major areas to be taught. Show the length of the program: 18 weeks, 36 weeks, etc. Include an explanation describing how the course is going to be conducted. Later, based upon administrative approval of your proposal, this same description can be used by the guidance department to tell prospective students about the new energy technology program.

A comprehensive energy program should be based upon the concepts and principles approach, through testing and experimentation. Such a program has little time to concern students with maintenance and repair of laboratory energy systems or engines. Mechanics training can be obtained at the local vocational center, which specifically deals with these matters. Yet, in reality an energy technology course, at the high school, articulates well with the vocational center. Having future vocational students receive the advanced conceptual education and basic skills greatly enhances their manipulative competencies if they select further study in mechanics training. This program also provides excellent preparation for entry into post-secondary technical and higher education studies.

With surprisingly little difficulty, the Board of Education enthusiastically approved our curriculum request. In addition, the Board sent a directive to our other high school advising similar curriculum change action. This same program was cited as being the number one automotive course in New York state several years prior.

National materials handling entrants with their egg carrying machines. Left to right: Mark Taylor, Russ Fuller and James Capece.

The curriculum change to add energy concepts progressed slowly. However, change is continually taking place. The lack of funding forced the development of instructional apparatus and equipment as part of the lab program. At first, small engines (model airplane engines and lawn mower types) were used to obtain necessary activities. These were supplemented by experiments with expansion (heated pistons), the utilization of measuring instruments, calibration of flowmeters (for measuring energy input flow rates), displacement, compression ratio, valve timing of a four-stroke cycle engine, and model vehicles. The application of energy systems to models closely depicts full scale concepts and principles. The testing of these model vehicles (model rockets, airplanes, land vehicles and hydro machines) provides students with a *feel* for performance.

Each semester one new piece of equipment or a new activity is added to the program. Practicing teachers know that without adequate activities, the best theoretical programs will die.

Inter-class competition helps with the all important motivational problem. Some of these include:

1. paper airplane design contest for performance
   a. duration of flight
   b. longest (distance) flight

2. coil spring powered land vehicle
   a. for obtaining the greatest lineal distance from a standard energy source (mouse trap spring)
3. materials handling contest
   a. delivering a marble along a horizontal string and depositing it in a container in the shortest period of time.
4. materials handling contest
   a. delivering a raw egg in a machine of student design which is powered by standard rubber bands to a solid wall (25 feet away from start) in the shortest period of time *without breaking.*
5. solid propellant rocket car contest
   a. with limited materials designing a model land car powered by a rocket engine (Estes Co.) which can travel a prescribed straight line course on a guide wire (200' or more) in the shortest period of time.

The obvious question relates to where many of the materials and supplies can be obtained if there are no monies. Here are some examples:

1. When building an Automated Savery Atmospheric engine, there was a need for a natural gas flow meter of considerable accuracy. A telephone call to National Fuel Gas resulted in their donation of a $600.00 laboratory instrument to our program.

Energy Technology students pose with their winning science and engineering projects. Teacher Gierke shares in their triumph.

2. When looking for a method to incorporate wind energy in our course, the Federal government helped with its income tax write-off for donations made to educational institutions policy. This opportunity was presented to a local farmer who gladly took advantage of this by donating a 46 year old water pumping mill which the students restored and is currently standing on its 30' tower for experimentation purposes.

3. Our 8' diameter, concentrating solar collector required many materials. A call to the local division of Hooker Chemical resulted in the donation of 20 gallons of polyester resin. A local plastics fabricating company donated tools, materials and expert supervision to the project.

4. Help was needed during the design phase of the Flame Propagation demonstrator project. A call to our local electric utility company resulted in the engineering and materials needed.

5. Many of the machines and experiments which populate our lab are constructed as an indirect result of the teacher's imaginative nature for trying not to throw out anything which might be used later. Salvaged items from surplus include rocket components to junked computers.

6. The greatest accomplishment of the program occurred this school year. With the help of our library, our energy technology laboratory has raised just over $5,000 in cash, equipment, materials and services for our students' entry in the national alternate energy competition.

By contacting local industries and service organizations (Lions and Kiwanis Clubs) the names and addresses were obtained for potential donors to whom a project prospectus could be sent. Over 60 of these descriptive bulletins were sent out with the request that the student representatives and teacher be allowed to give a slide presentation and talk to their membership.

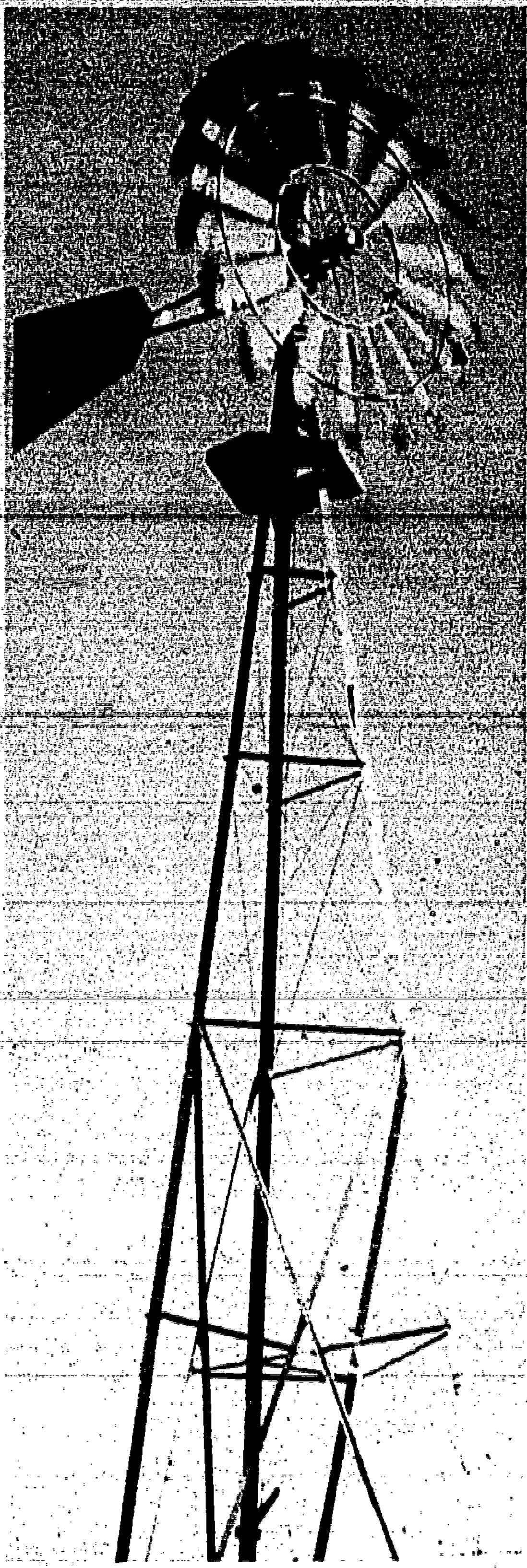
After two weeks, follow-up phone calls were made to the recipients of our bulletins to see if they had received the material. As mentioned earlier, the response was most gratifying. One-third of those contacted donated something to our energy cause. The local West Seneca Kiwanis Club and National Fuel Gas each donated $500.00 and represent our largest contributors. Each contributor was sent a thank you letter which contained the signatures of all Wind and Solar Power (W.A.S.P.) members. They will also receive regular student edited progress reports showing how their donations are being utilized.

Many of the program accomplishments described above relate directly to public relations. When a program and students do something worth mentioning, write a short article, include a photograph, and submit this to the local newspaper. If your school system has a newsletter which goes out to the taxpaying public, include your noteworthy energy article.

When the community sees that the schools are *teaching for the future* with applications to real world problems by motivated, enthusiastic students, many problems which seemed insurmountable will begin to fade.

Keep in touch with your district administrator in charge of curriculum, for any state or Federal grants which may become available. In a dynamic and current area such as energy, attention is demanded for any well thought-out and carefully written proposals.

The energy teacher must keep current of the leatest publications, as something new happens almost every day. Some excellent sources include:



Completely reconditioned 8' diameter water pumping windmill. Students spent their summer in the Energy Technology Lab to complete the work.

Free Publications: (ask to be added to their mailing list)

Resources
Resources for the Future
1755 Massachusetts Avenue N.W.
Washington, D.C. 20036

Petroleum Today
Circulation Department
P. O. Box 441
Detroit, Michigan 48231

PPG Products
Public Relations
One Gateway Circle
Pittsburgh, PA 15222

Insulation Reporter
National Mineral Wool Insulation Assn.
382 Springfield Ave.
Summit, N.J. 07901

E.A.R.S. Catalogue
Environmental Action Reprint Service
2239 East Colfax Avenue
Denver, Colorado 80206

Energy Reporter: Federal Energy Administration Citizen Newsletter
Federal Energy Administration
Washington, D.C. 20461

The Texaco Star
135 East 41st Street
New York, N.Y. 10017

Power From Oil
Metropolitan Petroleum Co.
380 Madison Avenue
New York, N.Y. 10017

Aerospace
Aerospace Industries Assn.
1725 DeSales St. N.W.
Washington, D.C. 20036

Chemecology
Manufacturing Chemists Assn.
1825 Connecticut Ave., N.W.
Washington, D.C. 20009

Sources of vertical file information: (free pamphlets, posters, etc.)

Tips on Saving Energy
Council of Better Business Bureaus, Inc.
1150 17th St., N.W.
Washington, D.C. 20036

Marilyn Edwards
Public Information – NASA Windmill Project
NASA - Lewis
Cleveland, Ohio 44135

Energy Activity Guide
Anne Bull
Park Project on Energy Interpretation
National Recreation and Park Assn.
1601 North Kent St.
Arlington, VA 22209

Information on windpower
Los Alamos Scientific Laboratory
Attn: J. D. Balcomb
Los Alamos, New Mexico 87544

Solar Energy, Geothermal Energy, How to Conduct an Energy Audit, Solar Collector Manufacturing Bulletin, Careers in Energy Industries

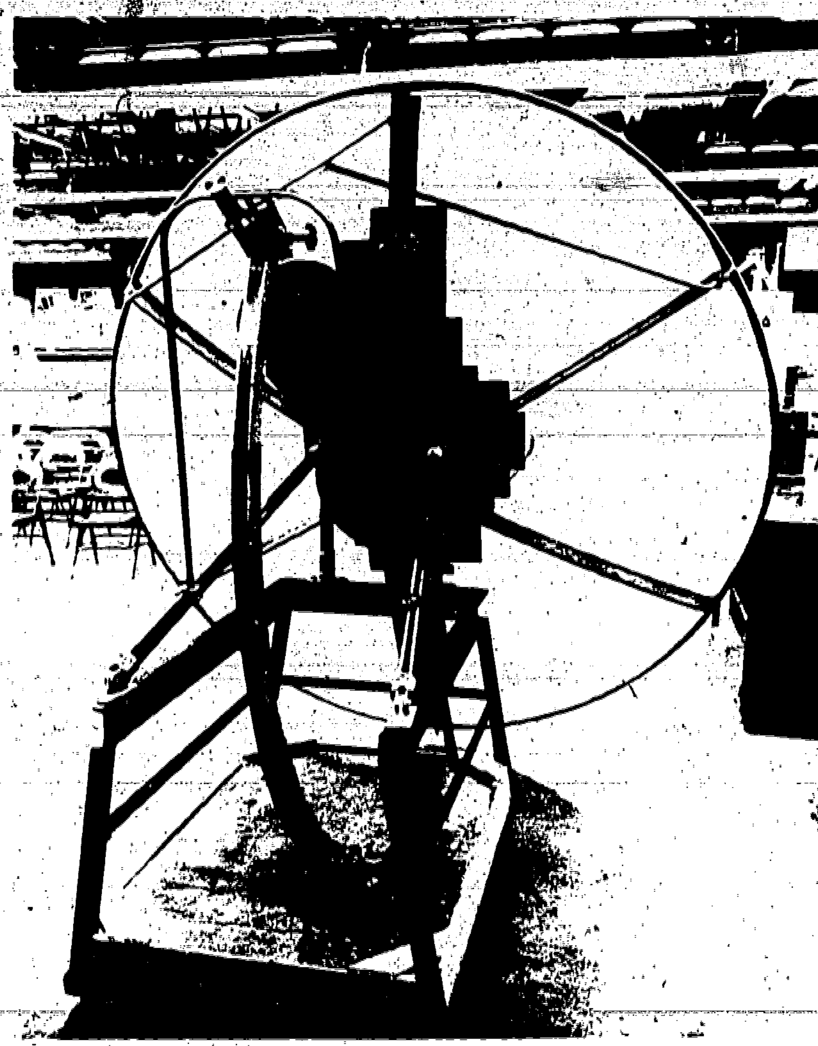
Information Dissemination Branch
ERDA Headquarters
Attn: R. Turnipseed
20 Massachusetts Ave., N.W.
Washington, D.C. 20545

Information on windpower
American Wind Energy Assn.
21243 Grand River
Detroit, Michigan 48219

Information on energy and power
Environmental Action
1346 Connecticut Ave., N.W.
Washington, D.C. 20036

School Energy Contests
Region Two
26 Federal Plaza
New York, N.Y. 10007

Information on solar energy
Sandia Laboratories
Public Information Division
Albuquerque, New Mexico 87115



The W.A.S.P. team's 8' diameter solar collector which is designed to produce electricity. Collector and wind turbine are part of this year's national inter-collegiate energy competition SCORE TRAIL.

Magazines which regularly feature articles on energy:

Alternative Sources of Energy
Route 2, Box 90A
Milaca, Minn. 56353
(Cost $5.00 for a one year subscription - 4 issues)

Mechanix Illustrated
Popular Mechanics
Popular Science
Science
Science News
Scientific American

Wind Power Digest
54468 CR 31
Bristol, Indiana 46507

(Cost $6.00 for a one year subscription - 4 issues)

Books for a basic energy collection in a school library:

Daniels, Farrington, *Direct Use of the Sun's Energy* New York
Ballantine, 1964. ($1.95)

Although written thirteen years ago, this book is still generally acclaimed as the best in the field, from a layman's point of view. Semi-technical in nature and loaded with practical, home-build projects, *Direct Use of the Sun's Energy* is a must for the alternate energies library.

U.S. Department of Energy

A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future, 1976. Volume I:
The Plan. Washington: U.S. Government Printing Office, 1976.
($2.00)

This publication outlines the official position of the government on energy-related matters. An enlightening section concerns itself with the roles of the private and public sectors, the Federal agencies and of E.R.D.A. with the national energy problem and the nature of its solution.

Chapters include: 1) The Plan, 2) Budget, 3) Implementing the Plan, 4) Developing the Plan. Special note should be made that there is an executive summary included, which precisely describes the key points of the book. A must for serious investigation.

Friend, Gil and David Morris. **Kilowatt Counter**: Milaca, Minn.:
Alternative Sources of Energy Magazine, 1975. ($2.00)

As stated on the cover ot this publication, the included material (34 pages) is, *A consumers' guide to energy concepts, quantities, and uses.* It is written in non-technical terms, aimed at the layman who is interested in learning more about energy and power, as it is related to his everyday life. There is an interesting quiz at the end of this booklet, entitled, *Testing your energy awareness.*

Healy, Timothy J. Energy, Electric Power and Man. San Francisco: Boyd and Fraser, 1974. ($9.95)

The best reference found to date on electric energy and the business of its generation. The text thoroughly covers the technology (in relatively simple terms), economics and environmental considerations involved. An excellent section deals with our country's future energy requirements and the demands which will be placed on the power system.

National Science Teachers Assn. **Energy - Environment Materials Guide.** Washington: NSTA, 1975. ($2.00)

This excellent resource lists the following:

1. Readings for teachers
2. Readings for students (K-6, 5-9, 8-12)
3. Guide to films and audio/visual materials
4. Guide to energy-environment curriculum materials
5. Sources of information and materials
6. Guide to government documents
7. Keeping current: Bibliographic and subject terms

This valuabe guide contains literally hundereds of sources of free materials. A must for the professional section.

National Science Teachers Assn. **Energy - Environment Source Book.** Washington: NSTA, 1975. ($4.00)

This source is loaded with well organized, up to date materials including many tables and graphs assembled from the nation's leading authorities on energy and the environment.

A companion to the **Material Guide**, especially outstanding chapters include: **Evidence of a Crisis, Energy Production and the Environment, Energy: What it is, What it Does, and The Exponential Century.**

Reynolds, William C. **Energy: From Nature to Man.** New York: McGraw-Hill, 1974. ($10.00)

An excellent source (on the teacher's level) which was developed for use in a course about energy and energy technology, aimed primarily towards non-engineering students. High school science and mathematics seems adequate preparation for comprehension.

Especially good chapters include: **The Big Picture - an Overflow, Mechanics - it all Starts Here, Heat and Other Things, Flow System Energetics.**

Probably the best dissertation ever read on the Second Law of Thermodynamics and entropy is given in the chapter on heat. Highly recommended.

Scientific American. **Energy and Power**. San Francisco: W. H. Freeman and Co., 1971. ($3.95)

Besides having the most concise statement concerning the energy-power predicament in its Forword, **Energy and Power** contains eleven original works by prominent authors in the field, such as M. King Hubbert and Earl Cook, who have been widely quoted for the past several years.

The chapters in this book were first published in the September 1971 issue of **Scientific American**, which was the twenty-second in the series of single-topic issues published annually by the magazine.

State of Florida Department of Administration. A Floridian's **Guide to Solar Energy**. Cape Canaveral, Fla.: Florida Solar Energy Center, 1975. (Approx. cost: $2.00)

According to Florida's Governor, Reubin Askew, "... the information gap [illegible] scientist knows and what the public knows about solar energy has been increasing. This report was written to reduce this information gap."

This book contains excellent information on the [illegible] solar energy, applications of solar energy (especially solar water heating and space heating), and a section concerning the factors which affect the efficiency of solar systems.

The bulk of the [illegible] expert, Dr. Erich Farber of the University of Florida at Gainesville [illegible] book.

ENERGY CONSERVATION

"IS SOLAR POWER A PRACTICAL SOLUTION?

DR. CHARLES ALEXANDER:

'By 1985, more than half of all new homes will be heated and cooled by the sun.'

The energy crisis of the last two years has generated a complexity of problems, the most pressing of which center around the search for an alternative to fossil fuels. Many diverse solutions have been proposed, at this time, the most practical appears to be the utilization of the power of the sun.

Solar energy is a free, unlimited and non-polluting source of [illegible] its potential [illegible] supplement to and eventual replacement for fossil fuels has met with general public apathy, probably because we have not yet been acutely enough affected by the shortage of conventional fuels. Lack of public interest also stems from the fact that solar energy space heating systems are unfamiliar to most people and require a relatively high initial capital investment.

[illegible] solar energy [illegible] developed by many small companies differ greatly; many are of questionable [illegible]. There is, however, a handful of firms conducting valuable research and developing viable solar energy systems. Will these systems have general application [illegible]? Will they become increasingly available in the near future and if so, what will they cost? Are they really an economical alternative?

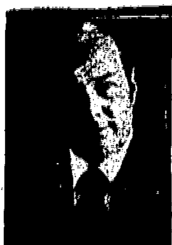
[illegible]

for using solar energy is quite simple. Most significant problems are in the area of refinements in mass production and in construction techniques. However, we expect these problems to be solved shortly.

Partial results of three major studies funded by the National Science Foundation show that about two-thirds of all new buildings are potential solar candidates. This amounts to approximately 40 million buildings by the year 2000.

Our own independent study agrees with these projections. We expect that by 1985, more than half of the new homes being built will be heated and cooled by the rays of the sun. Obviously, then, solar energy is a useful energy source, and we no longer need to ask when we will move toward the utilization of solar energy, for we have already entered the Solar Age.

Dr. Charles Alexander is an associate professor in the Department of Electrical Engineering at Youngstown State University, Youngstown, Ohio, and the director of the university's solar energy task group.



TERRENCE R. CASTER.

"Using solar power, a homeowner can become, in effect, his own utility for as long as he owns the house."

Until recently, most solar heated h[illegible] much to test the merits of the heating [illegible] as we move from the experimental stage [illegible]

[illegible] Building Manual, Spring Summer 1975 [illegible] are about to install our first air conditioning unit. Our subdivision [illegible] has [illegible] priced from $125,000 [illegible] acceptability [illegible] range.

[illegible]

his home by factory-trained dealers. He can become, in effect, his own utility for as long as he owns the house. Sun power is a fuel that belongs to all of us, and one that no country can embargo.

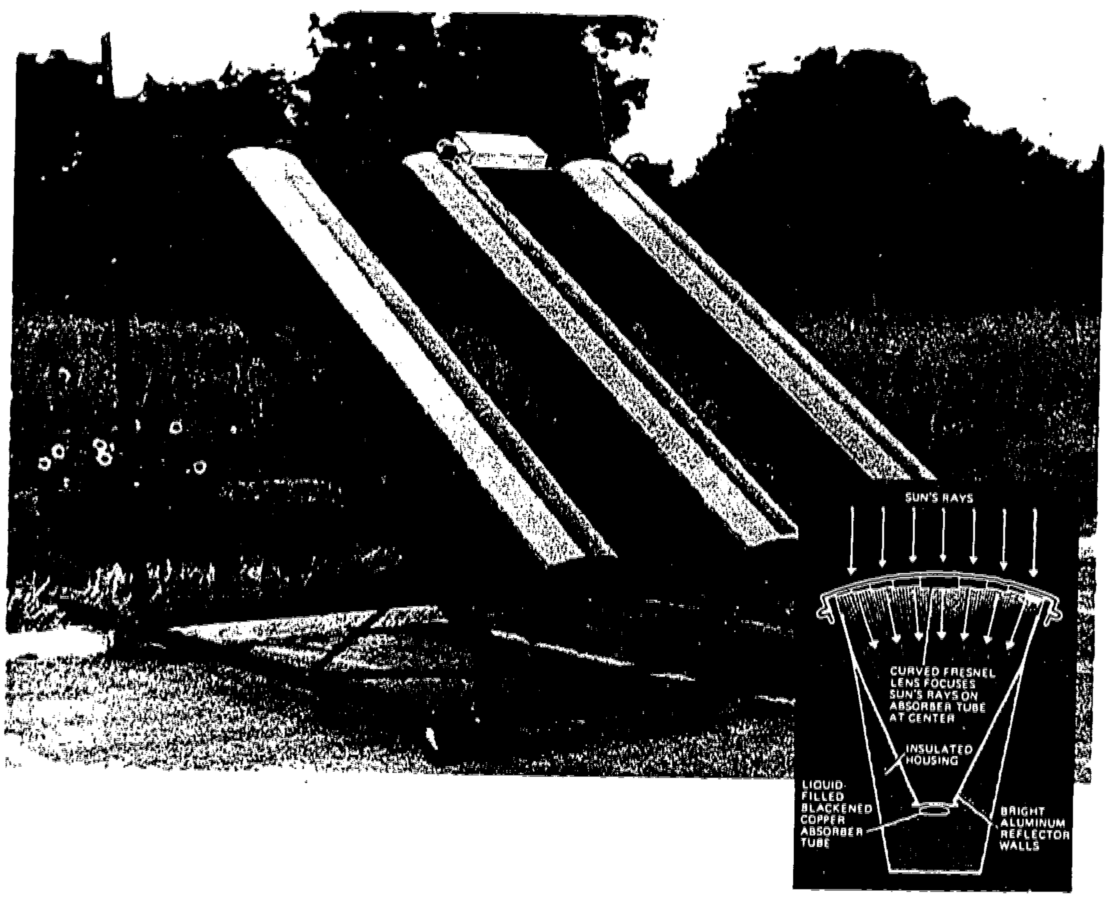
My company, Energy Systems Inc., started a research program over a year ago that has resulted in the solar collector panel we are now producing. Out collector has an eight-pass aluminum fin absorber with copper tubing to pipe the heated water to the storage tank. The collector is enclosed in an aluminum frame and covered with two layers of tempered glass. We have broken ground on a manufacuting plant in San Diego that will be able to turn out up to 1,000 collector panels every eight-hour shift. One day's production could furnish the energy needed to supply 250 families with up to 90 percent of their hot-water needs for years to come. In other words, each day's output will produce enough aluminum solar panels to save the United States from 15 to 18 million Btu's of energy each day which would otherwise have to come form conventional fuels

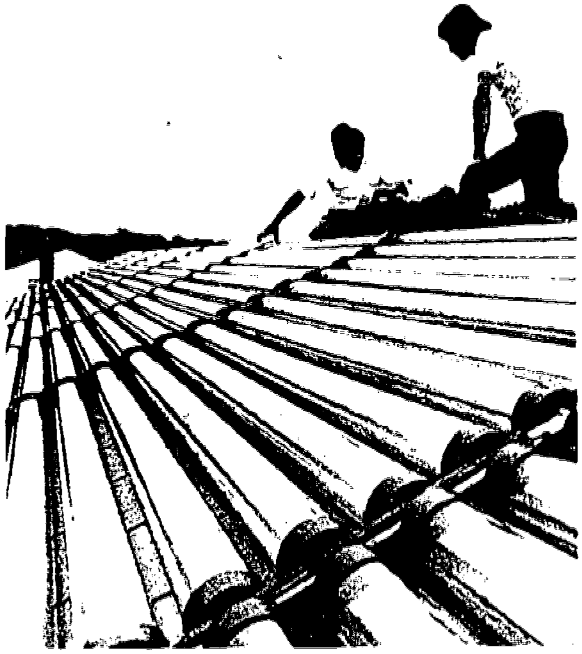
Until recently the federal and state governments have been slow in responding to solar energy applications. All the consumer needs is encouragement in the form of tax incentives and low-interest loans. The Energy Conservation and Conversion Act of 1975 is a step in the right direction. A few states, most notably Florida, have made great strides in supporting solar energy, but support from the federal government is nowhere near the help needed. One thing we must do is encourage more active government support on all levels.

[illegible]
believes *[illegible]*
next *[illegible]*

PRODUCTS THAT HARNESS THE SUN

Typical solar systems circulate water or some other medium through collectors, usually placed on a roof. Sunlight striking the collectors heats the water to 100-200 degrees. Pipes conduct the water to a storage tank, where heat is extracted from the water to supply part of the energy required by domestic heating and cooling equipment. (Because it cannot store enough energy during prolonged sunless periods, a solar system will not fully satisfy a building's heating and cooling needs.) Many of the principles involved in harnessing the sun are neither new nor highly technical. But until the oil crisis, the public was apathetic about solar research. But few major manufacturers are producing residential solar equipment at this time. For the most part, they are leaving the field to local firms. On these pages we show a selection of pioneering solar products. Be aware that the solar industry today compares with the auto industry early in this century, when small machine shops built and sold experimental cars for which there were inconclusive performance data. Recognizing this, the Federal Department of Consumer Affairs warns prospective purchasers of solar equipment to be wary of exaggerated performance claims.

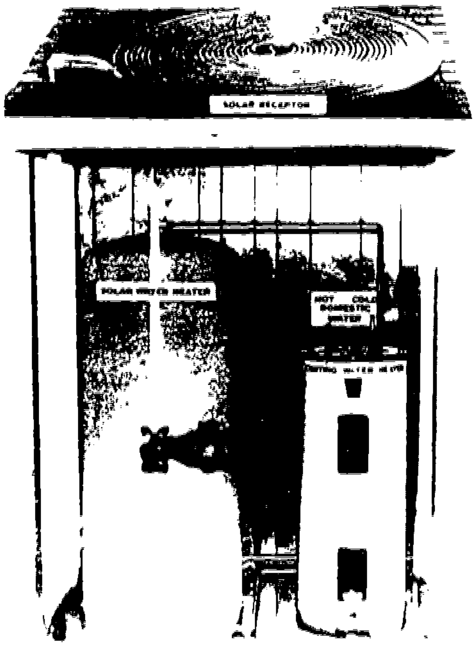


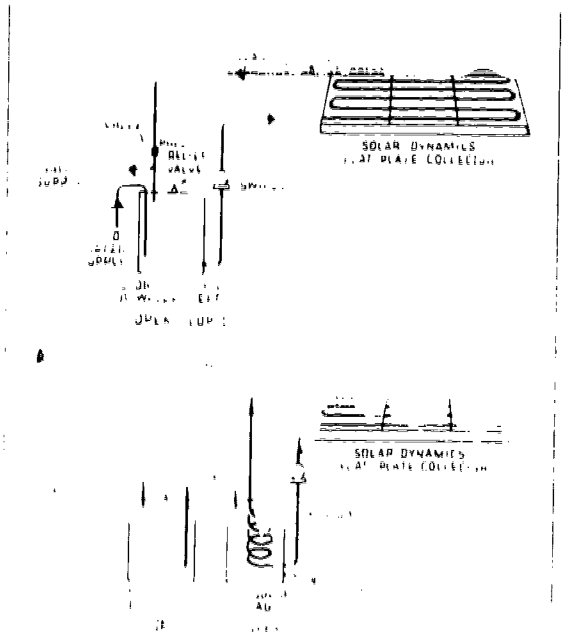


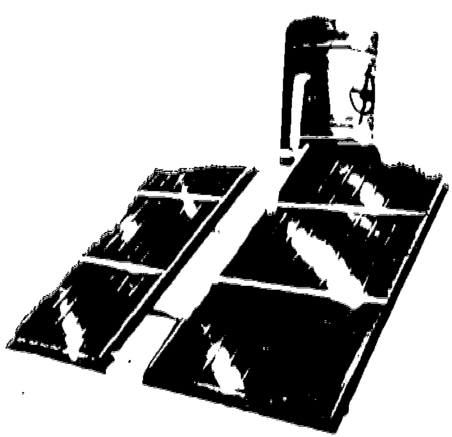
integrated systems. The assembly of a patchwork system can pose problems [illegible] contractor may not be qualified to solve. So when you shop for solar heating, shop for an integrated system engineered by specialists. A small but growing number of manufacturers and design groups is now packaging systems to help consumers avoid the perils of assembling components. Among these firms, in addition to others listed on following pages, are Energy Systems, San Diego, Calif.; PPG Industries, Pittsburgh, Pa.; Sunwork, Guilford, Conn.; and the foremost of the solar pioneers, Edmund Scientific, Barrington, N.J. Most solar systems use flat plate collectors like those in the drawing above. Northrup Inc., Hutchins, Tex., has developed a new type of collector that is compatible with the firm's heating and cooling products. The collector, which swivels to track the sun, has a Fresnel lens that concentrates the sun's rays on a pipe filled with heat transfer fluid. It reportedly delivers almost twice as much energy per square foot as a conventional flat plate collector. Three of the new collectors are shown [illegible] above left. The inset details how they work. [illegible] Warren, N.J., has introduced a complete system for space and domestic water heating that sells for about $4,500. The system uses still another approach to solar collection: acrylic *Solar Tubes* below. They are said to be cheaper, easier to install and 50 percent more efficient than flat plate units.

[illegible]

solar-heated water circulates in a closed loop, it can be treated with corrosion inhibitors and with antifreeze to permit the collector to function in winter. Solar Research, Granada Hills, Calif., packages a system like this, which includes two PPG collectors, 52-gal. tank, heat exchanger, pump, and electric controls. Universal Solar Systems, Ocala, Fla., markets a similar assembly. Seen in a display model, it uses five solar receptors (collectors) made of flat vinyl coils, through which heat-transfer fluid circulates. It costs about $1,300. Sol-Therm, New York, N.Y., offers an open-loop system that has no moving parts. Sunlight heats water in the collectors, reducing its density and making it rise into the tank, where it can be drawn off. Incoming cold water sinks to the bottom of the tank and into the collectors to finish the cycle. The system must be drained in freezing weather. Sav Heater, is another open-loop system From Fred Rice, Van Nuys, Calif., it employs cylindrical modules that serve as both collectors and storage vessels Each module holds 12 gal of water The system's curved surface affords maximum exposure to the sun's changing angles

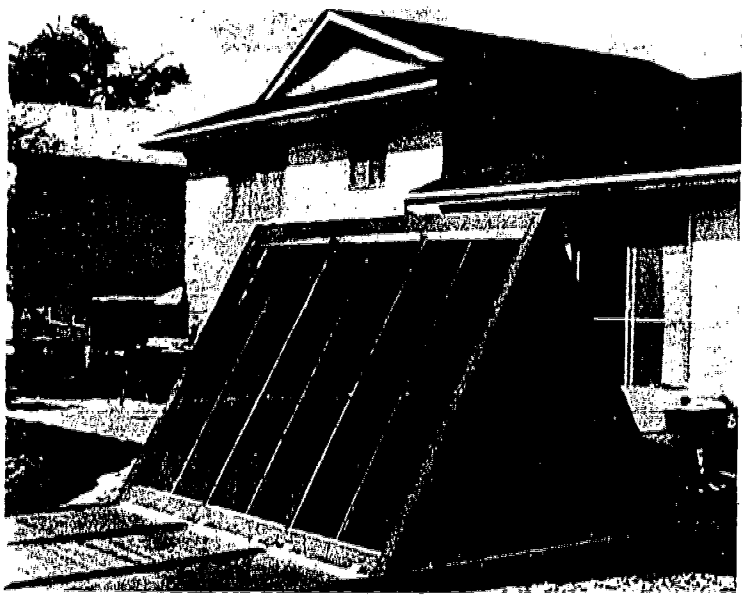


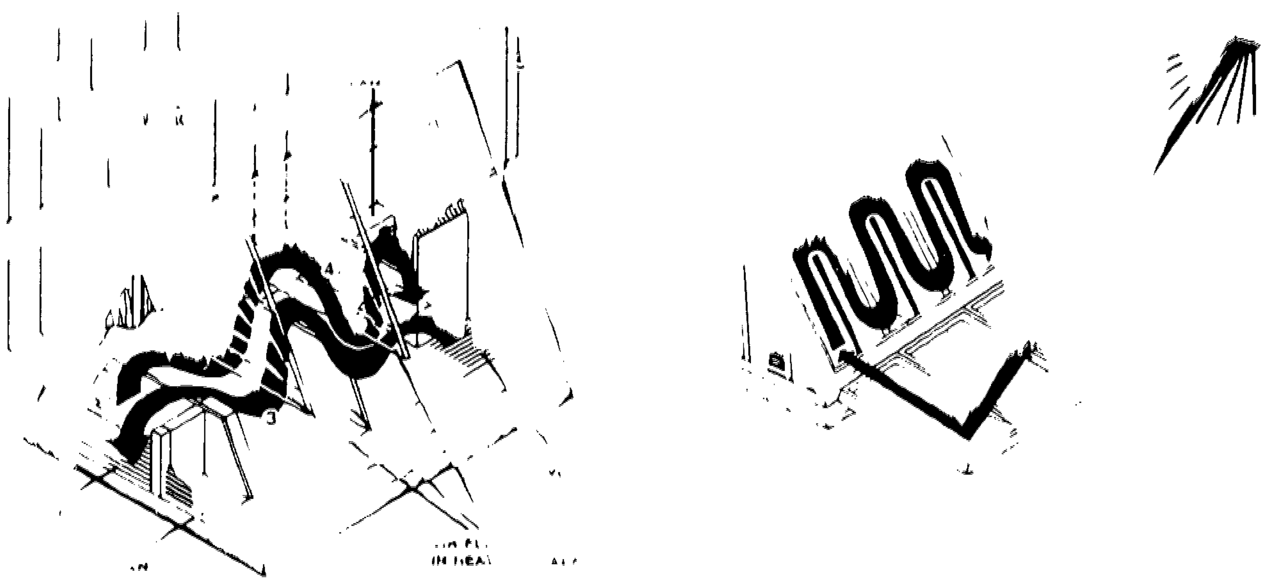




SOLAR FURNACE

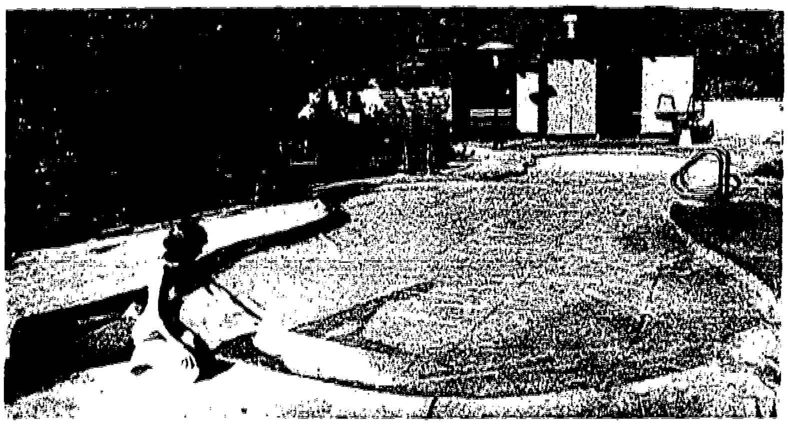
Most solar systems use water as a heat-transfer medium. A solar furnace, as its name implies, uses air. The furnace seen here was developed by International Solarthermics Corp., Nederland, Colo., and is being made by several manufacturers, including Solar-Aire, White Bear Lake, Minn., and Solar Power, Glenside, Pa. It is freestanding and totally compatible with existing forced warm-air heating systems. So it adapts to heating remodeling as easily as to new construction. Like other solar space heaters, it is an euxiliary system, designed to supply most of a home's heating needs but not all. Study the drawings: Aluminum collectors on the side of the A-frame structure, absorb solar energy, which is intensified by a horizontal reflector on the ground. Air warmed by the collectors transfers its heat to a storage battery composed of stones Air forced through the stones by a blower becomes hot and enters conventional ductwork to heat rooms. The stone storage battery can retain enough heat to warm the average house sufficiently for three to five sunless days

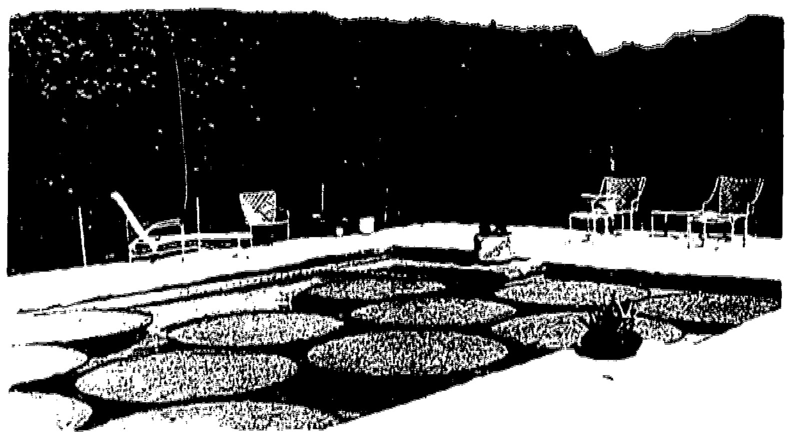




POOL HEATING

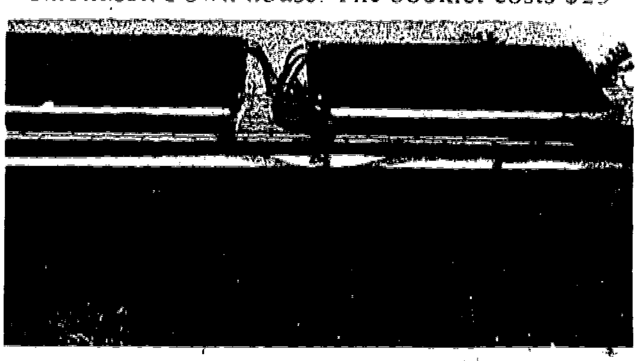
Several companies offer pool-heating systems that in operation resemble the domestic hot-water systems described on the preceding page. These companies include Burke Rubber, San Jose, Calif., and Fafco, Redwood City, Calif., reported on in previous issues. Here we show tow other approaches to pool heating. L. M. Dearing Associates, Studio City, Calif., developed the *Solar Pool Blanket*. Transparent and only 3/16' thick, the blanket contains thousands of encapsulated air cells between two flexible plastic sheets. It traps about two-thirds of the solar energy that strikes it. Overa a period of several sunny days it can raise and maintain pool-water temperatures 10 to 15 degrees without pumping or auxiliary heating. It also conserves water and chemicals and minimizes heat loss. One person can fold or roll it up. Catel Mfg. Co., Monrovia, Calif., makes the *Solar Circles*. Like the blanket, they transfer solar energy to a pool and reduce the loss of heat, chemicals, and water through evaporation. They have 5' diameters, are made of plastic, and store easily, but can also be left in the water while the pool is in use. For best results they should cover approximately two thirds of the pool's surface. The circles can raise water temperatures as much as 15 degrees.

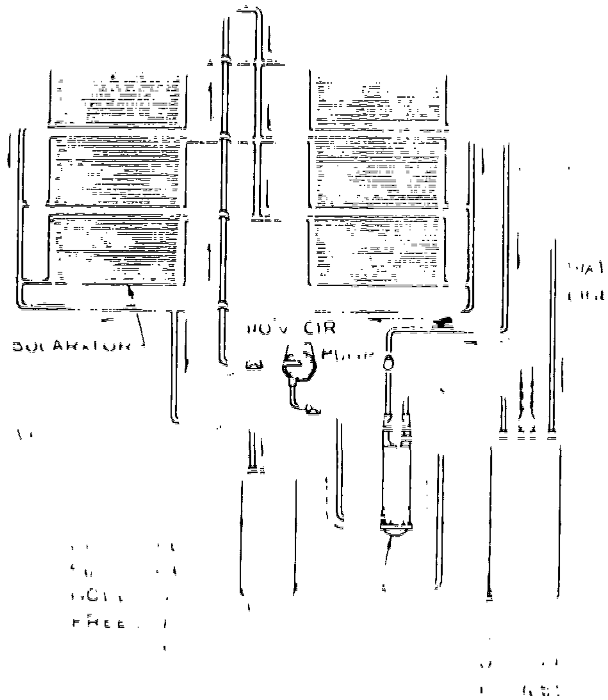


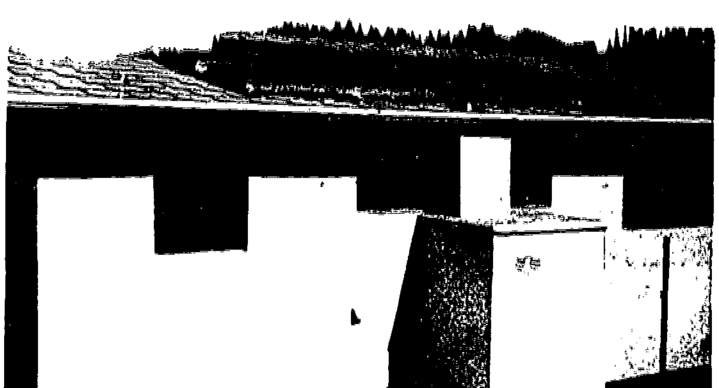


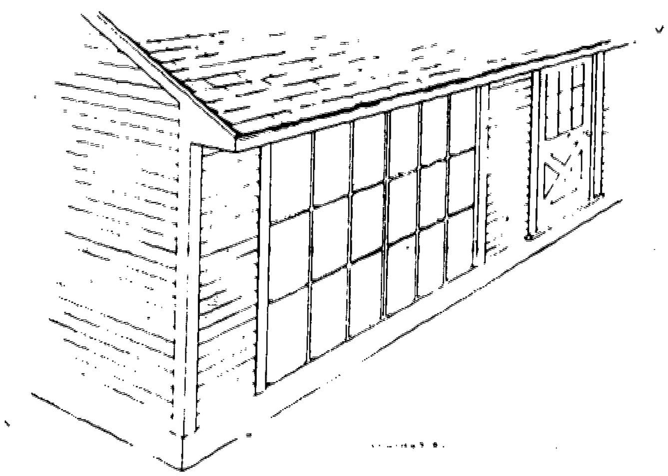
DO-IT-YOURSELF SYSTEMS

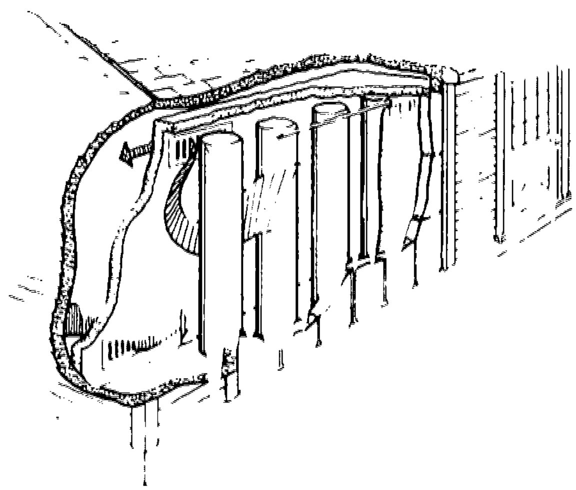
The installation of a simple solar-heating system is primarily a plumbing project—one that a handy homeowner can do himself. The domestic water-heating systems described on a preceding page, for instance, do not require great skill to assemble. Seen here are systems specifically geared to the do-it-yourself market. The *Solarator* collectors are the heart of a system available from Fun & Frolic, Madison Heights, Mich. They were developed by Professors Conan E. Fisher and Edward J. Konopka, sell for about $40 each, and reportedly have been used in more than 15,000 installations. Instructions available from the company tell how to use the collectors in various applications, from pool heating to space heating. The drawing shows how to tie them into a domestic hot-water system. Gardenway Laboratories, Charlotte, Vt., is marketing a compact system for people who want to test the potential of solar energy without making a major investment in it. Called *Solar Pioneer Model 22* the system costs about $250. It consists of a 3'x8' Sol R Tech collector, AC electric pump, 20' of nylon tubing and connectors. You can use it to heat domestic water or connect it to a fan coil unit to heat small rooms, greenhouses or sheds. William B. Edmonson, editor and publisher of Solar Energy Digest, San Diego, Calif., is offering a 56 page booklet that contains plans and specifications for building his *Solarsan* system which can heat or cool buildings and heat domestic water and swimming pools. Photo shows *Solarsan* system installed in Edmondson's own house. The booklet costs $25.



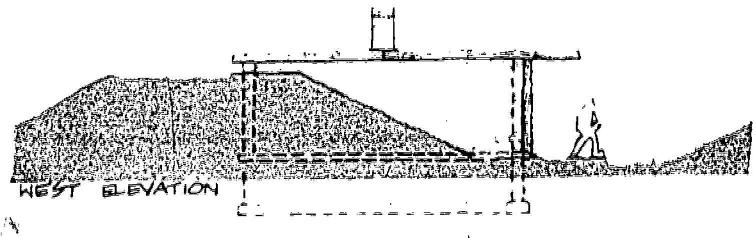


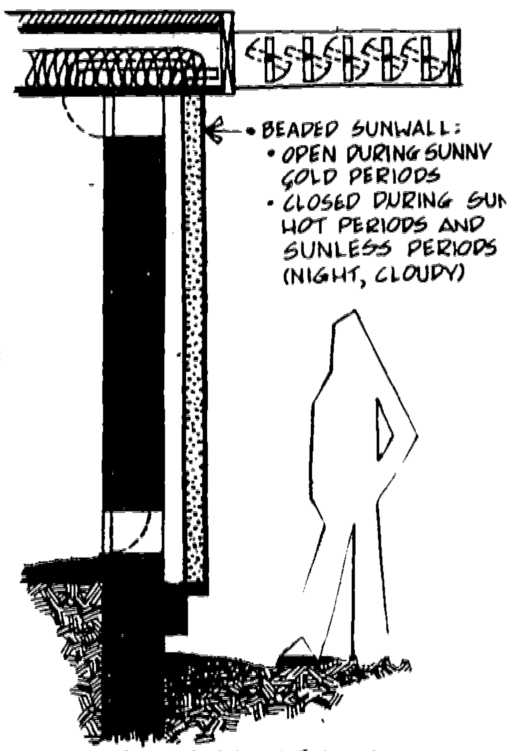


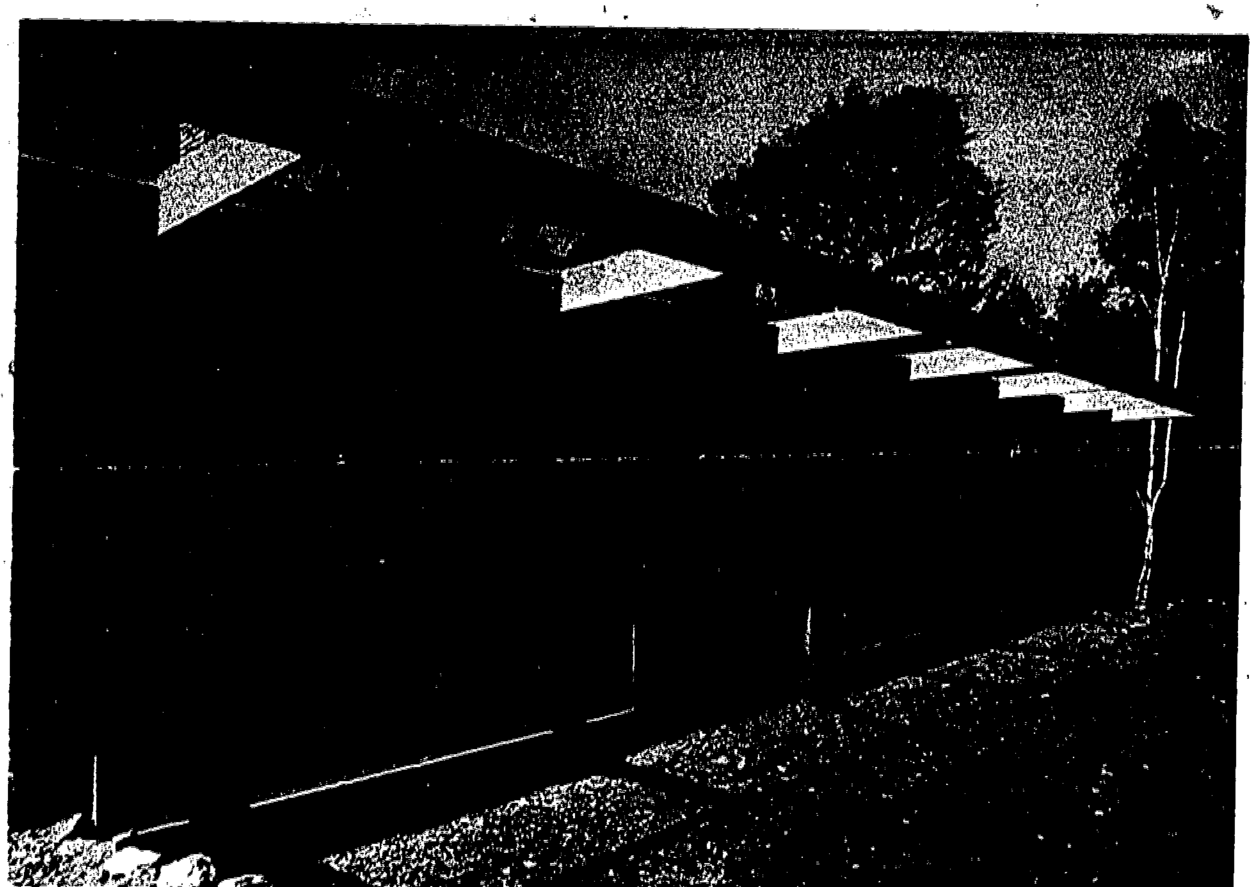




TWO IN ONE: A HOME AND A SOLAR COLLECTOR







PHOTOGRAPH ABOVE BY NEW HAMPSHIRE TIMES; DRAWINGS, WILLIAM J. WARD, JR.

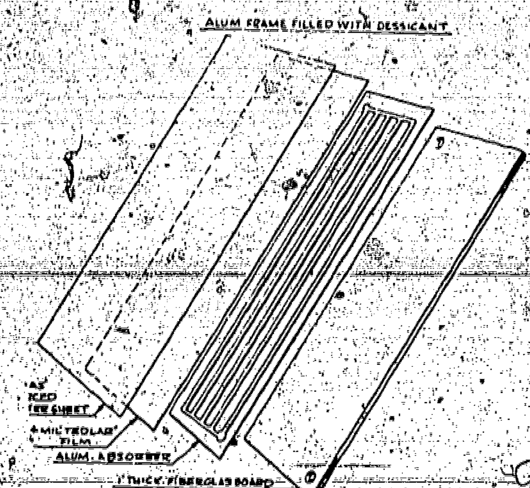
[illegible] facing [illegible] two transl[illegible] collect[illegible] [illegible] the structural wall of house, in contrast to most coll[illegible] that are set at an angl[illegible] the [illegible] projection above panels can be fitted with louvers or removable panels. [illegible] are moved to a closed position on summer days to block sunlight from hitting collector panels and windows and subsequently heating interior. Su[illegible]wall is filled [illegible] pellets to provide additional insulation to keep house cool in summer. Dampered vents at top and bottom of concrete wall control air circulation.

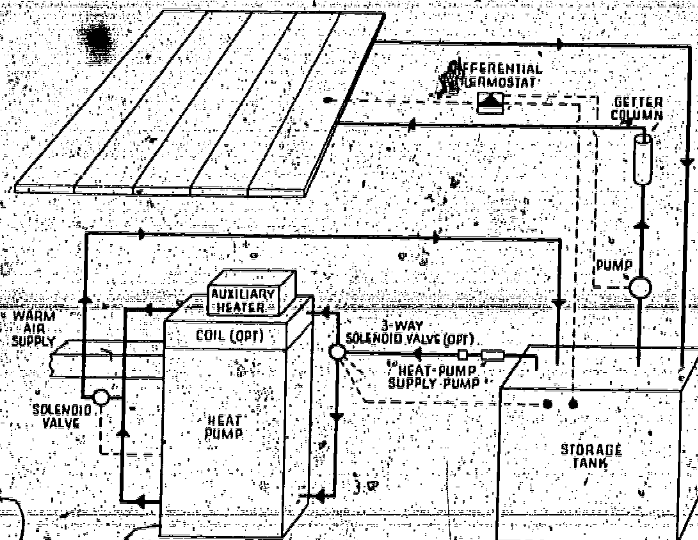
South-facing facade, reveals the successful joining of a traditional Cape Cod exterior with an array of solar collector panels mounted on the roof. Clapboards sheathe the structure. Side deck provides outdoor living space. Contemporary light-filled living room, opposite, is two stories high with a glazed gable end and a game loft. Decorator was interiors by Priscilla of Hartford.

[illegible] efficiently, most solar systems must heat water to at least 100 [illegible] uses a York heat pump that can extract heat from water that [illegible] the system's collector to function even when sunlight [illegible] components are linked [illegible] pump turns off and direct [illegible] is above 100 degrees.

TRADITION ADAPTED TO NEW TECHNOLOGY

Combining traditional styling with space-age technology, this Cape Cod owned by Mr. and Mrs. William P. Ward of Quechee Lakes, Vt., has a solar heating system teamed with a heat pump. Flat plate collectors on the south roof trap solar energy to heat the water in the closed circuit system. The warm water returns to a 2,000 gal. storage tank below the first floor. Hot water from the tank flows to the heat pump. The heat pump works like an air conditioner. Here, instead of extracting heat from indoor air and releasing it outdoors, it extracts heat from the tank of water and distributes it through forced-air ducts. In summer, the heat pump's refrigerant loop can be reversed to supply central air conditioning. The system was designed by Sol-R-Tech of Hartford, Vt., which designs and markets completely integrated solar heating systems.





ADVENTURES IN ALTERNATE ENERGY

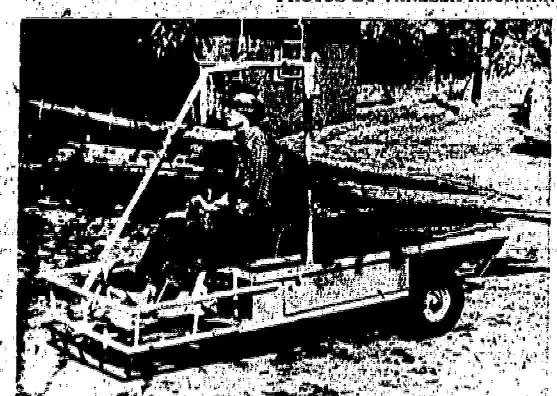
Michael Hackleman: Electric Truck is Wind-powered, too

By Edward Morgan

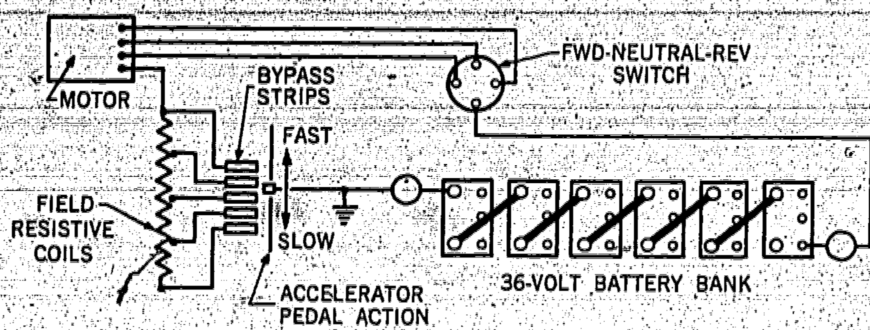
One day last fall, Michael Hackleman and a couple of his co-workers at a California cooperative called Earthmind hefted a 400-pound wind turbine onto the back of Ox, their home-built electric truck. Michael flipped a switch, and Ox trundled off silently to a remote site, where a 47-foot-tall octahedron tower stood waiting to be topped off. They unloaded the turbine, plugged their 32-volt tools into a socket on the front of the truck, and soon had the windmill mounted and churning out power. Power that would later be fed *back* to Ox in a happy energy symbiosis.

Earthmind is one of many self-sufficient energy-research groups that are beginning to dot America's landscape in this fuel-short era. Such communities share a common faith with DIY'ers—in low-technology, ruggedly individualistic solutions to the energy crisis.

PHOTOS BY VANESSA NAUMANN



Earthmind's electric truck (left) is handy hauler for farms, lots, or remote work sites. Check local laws to see whether such a vehicle would be street-legal. It's versatile, drawing current from windmill, in background of photo above, as well as from standard battery charger. Upper left Michael Hackleman runs his 32-volt drill directly off the truck, using it as a remote "generator." (Don't run conventional AC tools or appliances without an inverter, however.) In wiring diagram below, batteries are wired in series. Earthmind is contemplating adding more batteries to the truck, wired in parallel, to increase capacity.



PS has featured electric cars in this series before #Feb. '76; Apr. '76'; like those two, the Earthmind truck has a limited range and speed due to the realities of battery storage. But that shouldn't be much of a problem for a *workhorse* application on a farm or remote site.

'Ox was originally an industrial truck, rescued from the rust heap in a Goodwill yard in California's affluent Orange County. The original price was $200, but, relates Hackleman, *we noted the fact that the batteries were very evidently dead, so we talked them down to $95.*

The truck's motor had a series field rated at 24 volts, 41 amps, and 1.5 hp at 1700 rpm. This provided a lot of torque, but didn't permit the luxury of regenerative braking, which would put energy back into the batteries. The oil-bath gearbox and gear ratio limited the vehicle to a top speed of about 10 mph. This fact, plus the ample truck bed, prompted Earthmind to adapt it for use as a utility vehicle instead of trying to turn it into a passenger car.

Adapting the vehicle

Hackleman torched off the cumbersome, top-heavy front cab and replaced it with a frame assembly welded together of thin-wall electric conduit bolted to the front end. This frame was designed to protect driver and passengers as well as the control linkages (accelerator, brake, and steering). Later, a roof, siding, and windshield will be added to this support, which becomes *something to hang onto in rough terrain.*

A bank of used, six-volt, 180-amp-hour truck batteries now serves as the power-storage medium. Standard golf-cart batteries will be installed at replacement time, however. As an added innovation, Earthmind is contemplating adding two more six-volt batteries to the bank to create two sets of 24 volts in parallel. In this manner, says Hackleman, we double our capacity, or, in other words, cut the rate of discharge of any one battery in half. Therefore, the extra weight (about six percent more) is justified by the overall increase in efficiency of power transfer, by the increased life of batteries, and a lower voltage at the motor.

Acceleration is simple and straightforward, using a pedal-type switch. The farther the pedal is depressed, the fewer the number of resistance coils that are in series with the motor and therefore the greater the speed of the motor.

Hackleman admits that this type of control has drawbacks: At low speeds, it wastes power by dissipating heat, and it develops very little torque. As a solution, he suggests solenoid-switching controls, which would take power from taps, thereby varying the number of batteries hooked in series to the motor. But another problem arises: charging batteries that have been unequally discharged.

An electronic chopper control is the only real answer to efficient electric-vehicle circuits, Hackleman concludes, but the expense is prohibitive for the average person.

Yoking up tools

Tools, lights, and appliances can be yoked onto Ox via a household wall receptacle that Hackleman mounted on the front of the vehicle. Earthmind's tools, of course, can work directly from the 30-40 VDC drawn from the windmill, or from current stored in Ox's batteris. We simply drive to wherever we need power and plug our 32-volt saw or drill directly into the outlet, says Hackleman. (To operate conventional tools, they use an inverter rated at 110 VAC.) And it's just as easy to hook up electrodes across the battery for arc-welding.

Into the future

We've come to think of Ox as being a process, not a product, says Hackleman. Future plans include a monitor panel to display voltage and current, and switches for horn and lights.

Hackleman, who is research director at Earthmind, has written Electric Vehicles: Design and Build Your Own, which should be on sale this month. (Two of his earlier publications include *Wind and Windspinners* and *The Homebuilt, Wind-Generated Electricity Handbook*) The electric-vehicle book (160pp.) is $6.50, check payable to Earthmind, address below.

To inquire about these books, or to ask a specific question about the Ox electric truck, send a stamped, self-addressed envelope to Michael Hackleman, c/o Earthmind, 5246 Boyer Rd., Mariposa, Calif. 95338.

TURN YOUR FIREPLACE INTO A FURNACE

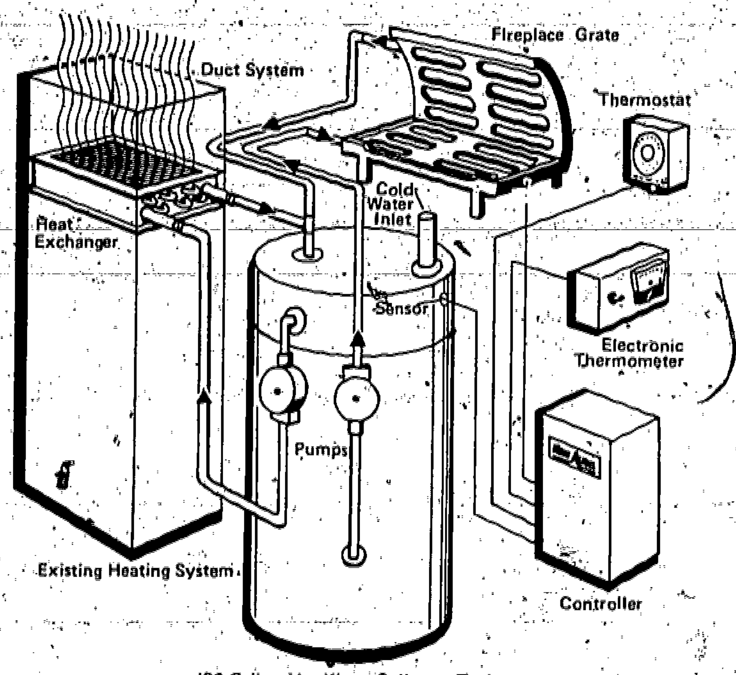
Your fireplace wastes about 80 percent of the heat it produces. It's pulled up the chimney and replaced by cold air suctioned in from the outside.

Southeastern Solar Systems, Inc. (4705-J Bakers Ferry Rd., Atlanta, Ga. 30336) says you can increase efficiency with its new fireplace heat-extraction system–so you use 50 percent of the heat your fireplace produces. The system has a box-channel steel grate that draws heat from the fire. Water pumped through the grate transfers the heat to your existing forced-air or hot-water system. Heat distribution to any or all rooms is controlled by thermostate or blower. Because all of the system's piping is stainless steel or copper, it can also be converted to heat potable water in your home.

Operation of the fireplace system is completely automatic. A sensor detects the fire when it's lit and actuates the circulating pump. When the fire dies down and ther's no longer any usable heat, the pump shuts itself off.

Originally designed as a backup for solar-heated homes, the heat extractor is now being offered as a primary heating system. If you're willing to chop a sizable store of firwood, you could save up to 98 percent of your fuel bills, the manufacturer claims. The system collects enough heat in four hours to heat the average home for an entire day.

Total cost of the system is $699, plus installation. Extra piping and labor generally run about $300, but instructions are included for installing the system yourself. It's guaranteed for five years–Southeastern says it should last 20.–Nancy Smith



120 Gallon Hot-Water Collector Tank

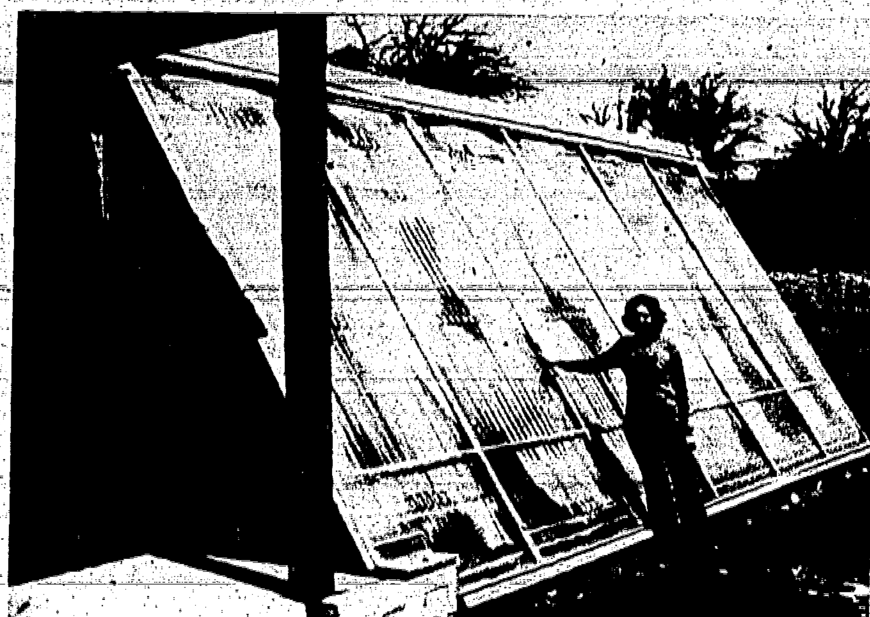
87

David and Cynthia Edney
SOLAR-ASSISTED HEAT PUMP

By Edward Moran

Belfast, where this hous is located, is on northwestern New York's *cold shoulder*–that 7,00-degree-day blizzardy tract abutting Lakes Erie and Ontario. Last winter, the Edneys spent an average of 85 cents a day to stay warm in the 1128-sq.-ft. house they built themselves with selected professional help.

The *house*, complete with $7200 worth of solar and wood-heat equipment, cost Dave and Cynthia Edney about $25 a square foot. That's the going rate for a lot of solar *collectors* these days, like the ones in the *world's most advanced solar home*. Dave, a mechanical engineer, and Cynthia, a chemist, are convinced that a well-designed energy-efficient house is not an impossible dream for young couples (he's 30, she's 28).



So how did the Enneys end up heating their home for $26 in January of That Winter of '77? By a judicious mix of domestic technologies, both in overall disign and in the heating system itself. The house is a single-floor ranch style with two bedrooms and a family room. It's slab-on-grade, except for an excavated 12-by-12-ft. basement; a 24-by-30-ft. garage/shop is attached.

The walls of the house (post-and-beam construction, with no interior load-bearing walls) are six inches thick. The roof, nearly flat to maintain an insulating snow load in winter, has aluminum sheeting to reflect heat in summer. And it's got six inches of insulation. Grape vines plated around the west-facing porch (great-grandma knew how to keep her cool) reduce heat gain on summer afternoons. The garage and shop are on the north side to shield the living area from harsh winds. A *closed-door policy*, an old but oft-forgotten trick, zones heat into living areas in winter. The family room, for example, is self-contained, with wood stove and spring water for use under extreme comditions.

There are three major components to the Edneys' heating system: a York solar-assisted heat

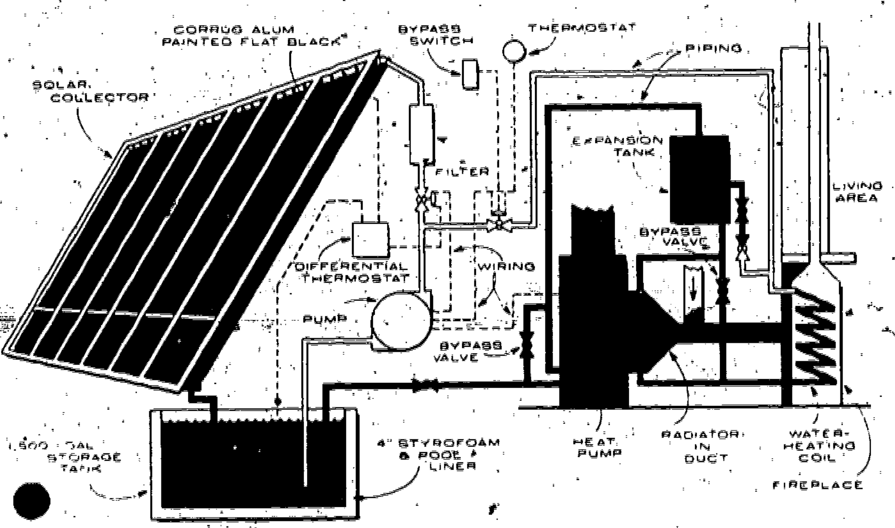
Dave Edney monitors all gauges and meters twice a day, for continuous-performance data. Edney reports solar-collector efficiency averages 60 percent.

The 280-sq.-ft. aluminum trickle collector dwarfs Cynthia Edney. Heat pump (above) is capped with insulated duct. Piping at rear brings water to and from water-heating coil in fireplace.

pump; the flat-plate trickle collector that supplies the pump; and a backup fireplace, complete with outside venting and water-heating coil.

The heat pump extracts heat from the solar-heated water and supplies that heat to the forced-air sustem using a refrigeration cycle. The process is reversible to provide cooling in summer. When water temperatures are between 45 degrees and 85 degrees, the heat pump comes on line. Above 85 degrees, the house is heated directly by water through a radiator in the forced-air duct (see diagram); below 45 degrees, the fireplace supplies auxiliary heat.

The fireplace is equipped with heavy metal doors that can be closed for good draft control. Air preheated around the firebox supplements the heat pump, and water from the coil is pumped to the solar storage tank to replenish the supply, or can be used for domestic hot water. The fireplace supplied about 16 percent of the total heat requirements last winter. Its combustion air is supplied from the outside, a sensible setup: Why waste indoor air you've paid to heat when the fire could do just as well with colder air?



The drain-down collector on the south wall is corrugated aluminum sheet painted flat black and double-glazed with acrylic, with four inches of Styrofoam insulation behind. Water trickles over the 280-sq.-ft. collector at a rate of 25 gpm and flows into a below-ground 1500-gal. concrete tank that provides about two days' storage.

The Edneys estimate that it would have cost $284 to heat their house with an electrical-resistance system last winter. *This gives us a system C.O.P. (coefficient of performance) of approximately 2.33,* they say.

The table below indicates performance data for the last heating season. To ask a specific question, send a stamped return envelope to the Edneys, c/o Belfast Specialties Co., P.O. Box 501, Belfast, N.Y. 14711.

Performance data 1976-1977

Month	Collector run. time (hr.)	Monthly heat requirement (Btu)[1]	Degree days in month	% heat supplied by solar[2]	Operating cost of system[3]
Dec.	87.5	6,799,360	1328	84	$26.79
Jan.	128.5	7,823,360	1528	80	28.96
Feb.	141.1	5,002,240	977	96	28.50
Mar.	145.3	3,527,680	689	100	21.05
Apr.	72.4[4]	2,370,560	463	100	16.72

[1] House heat loss at − 10° ≈ 5120 Btu/degree day

[2] Total hours of auxiliary heat required, divided by hours in month

[3] Figured from electric meters on heat pump and water pump, and from hour meters, based on electric rate per kilowatt hour

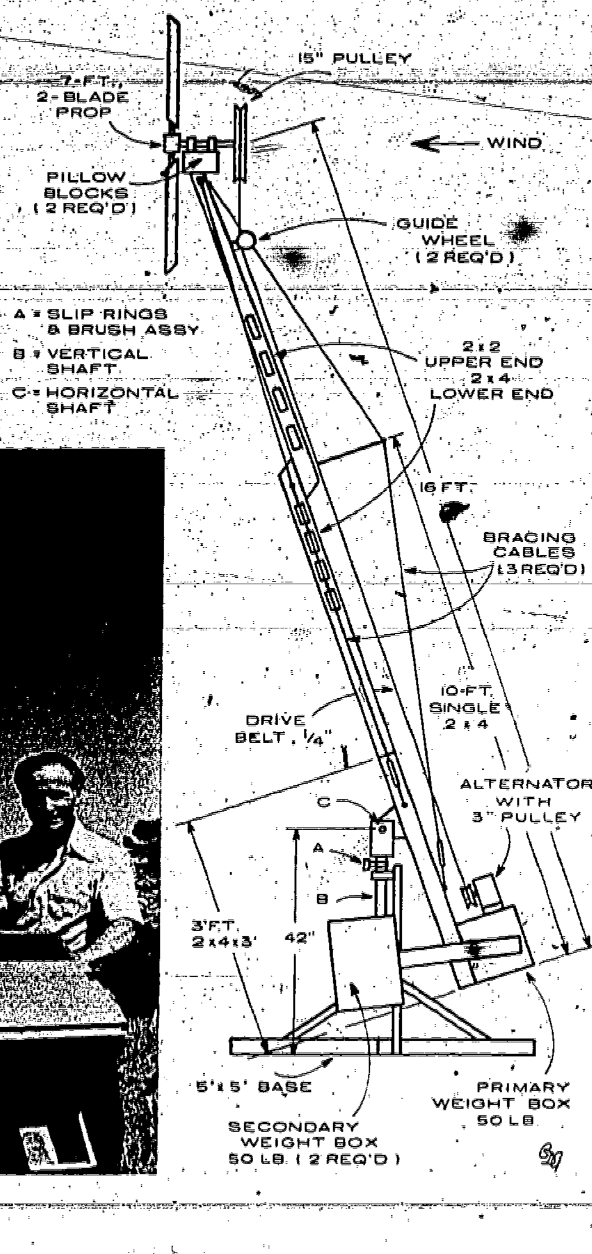
[4] Reflective aluminum covers were installed on April 13, when storage temperature reached 145°. System was shut down from this point, except for the heat pump. Covers will be in place until early October; heat will be provided from storage or from the fireplace until then.

Stephan Sieradzki: WINDMILL ON A BOOM

By Edward Moran

Someday in the not-distant future, Steve Sieradzki hopes to take his windmill along on a fishing trip. A flexible tower similar to the one pictured here will be mounted on the roof of his van. When he arrives at his favorite fishing spot, he'll raise the 10-foot prop skyward and fill ballast tanks with water to stabilize it. The power generated–400 watts in a 15-mph wind–will be used to cool the beer and cook the fish, he says–quite an energy-saving angle.

Although Sieradzki hasn't yet built this mobile unit, he has created a novel DIY windmill at his Fairdealing, Mo., home. Unlike most rigs, it's not mounted on a fixed tower, but on a flexible boom that rises and falls with the wind–for safety, efficiency, and ease of maintenance.



Flexible-boom windmill is designed to "lean" in high winds, preventing dangerous overspinning. The propeller assembly can also be brought down to the ground for easier maintenance. Unit disassembles easily for storage and moving. Inventor Sieradzki plans to mount smaller mobile unit atop his van.

Anyone who's ever handled a spinning windmill, from the tiny water-pumpers on the plains to the gaint NASA/ERDA job at Sandusky, knows the importance of speed control: A rig can rip itself to pieces if the blades overspin in a strong wind. And faster doesn't always mean better when it comes to generating power. Further, mounting the propeller atop a 20- to 60-foot mast means the milltender has to shinny up to dizzying heights every time anything needs attention.

Why not bring the prop down to the ground, and solve both problems? Sieradzki reasoned. So he designed a windmill on a boom like that of a hoisting crane and balanced it by counterweights (here, rocks in wooden boxes), so that the prop is lifted to its maximum height and automatically adjusts to face the wind.

"I use very light construction braced by steel cables and mounted on a base similar in operation to an antiaircraft gun mount," he says. "In fact, a German 88mm mount would make an excellent base for a 50-foot boom."

When the Wind Blows ...

The leaning tower is almost vertical in winds up to a preset limit (say 25 mph), and the prop faces squarely into the wind. Above this limit, however, the wind overcomes the counterweights and pushes the boom over, downwind and closer to the ground. This tilting of the shaft reduces the area of the spinning propeller that faces the wind, thereby preventing rpm from exceeding dangerous limits. Pressure on the structure is also reduced, permitting lighter construction.

Present rigid towers, the inventor points out, must be designed to take the highest wind force for their area—a force that occurs rarely or never. When such a blast does come, Sieradzki's prop will be lowered to within 10 feet of the ground, where it will stay until reset at its operating height after the storm—a further protection to the equipment.

Built principally of recycled materials, the windmill-on-a-boom cost Sieradzki about $75. He obtained the alternator from a junked car, and used shock absorbers from an old truck to cushion the boom and prevent it from slamming into the swing-limiting stops. For the drive belt, he recommends using round polyurethane belting because it's extremely tough, yet elastic enough to keep the belt under proper tension.

A store-bought propeller can be costly; Sieradzki made his of 0.032' fiberglass sheet. It weighs but 3 1/2 lb., a boon because it keeps the rig from becoming top-heavy and makes the prop more responsive to changes in wind conditions. One warning if you decide to build a windmill of this type: A prop spinning at 300 rpm is a lethal weapon; you won't want it to come down closer than 10 feet to the ground, hence the swing-limiting stops mentioned earlier.

Generating Electricity

Sieradzki's primary goal was to test a novel design, and he admits that the power output of the device could stand improvement. By using a 5:1 stepup belt drive, he obtains 200 watts at 12 volts in a 15-mph wind.

The generator is located near the lower end of the boom; power is transmitted from the prop and removed via slip rings at the base.

Steve Sieradzki plans to make further refinements of his concept (when he's not working on a solar-powered engine that also occupies much of his time). He thinks his idea can be adapted to large-scale applications, such as in populated areas where there might be aesthetic objections to rigid towers; he envisions an array of *invisible* windmills that could be deployed automatically at night or during high winds.

To ask a specific question, send a stamped return envelope to Stephan Sieradzki, P. O. Box 81, Fairdealing, Mo. 63939.

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INTRODUCTION

Central Dauphin School District initiated a new program in their Industrial Arts Department in September, 1975.

Under the direction of Mr. Lou Reda, Industrial Arts Department Head, Mr. Wm. Morris, Supervisor of Secondary Education, Dr. John Hine, Curriculum Development, Mr. W. H. Bittle, Principal of C.D. East Jr. High School and Mr. Mike Filepas, Industrial Arts Instructor at East Jr. High, the pilot program was started.

The students designed, built and installed a solar heating unit at East Jr. High.

Filepas, a graduate student at Penn State University, is doing his masters thesis on *The Design and Construction of a Solar Heating Unit for 40 degree Latitude*. After two years of research, a low cost solar unit was designed and built. The students at East Jr. High and two students from the Dauphin County Vo-Tech School (former students of Mr. Filepases) worked on the unit.

With the help of Mr. Ed Hine, Electricity and Drafting Instructor at East Jr. and Mr. John Chlebowski, Metals Instructor, Filepas wrote and set up a test program at their school. The program went very well and in three months the unit was completed and installed in Filepas's home.

Mr. Paul Wighaman and two members of the Governor's Energy Council made a visit to East Jr. High and met with Mr. Bittle and Mr. Filepas to see the solar unit and its workings. To their knowledge, this was the first school district in Pennsylvania to actually build and install a solar unit.

The students were very excited about the whole project and incorporated what they learned in geography, earth science and industrial arts to build the unit.

Once installed, the unit was monitored 18 hrs. a day, seven days a week for one year by JoAnn Filepas (wife of Mike) and his family.

Materials were cheap and industry was more than willing to help. Pittsburgh Plate Glass donated the glass and was very helpful by sending tehcnical information to the school.

The Central Dauphin Administration gave their support and Mr. Wm. Morris and Dr. John Hines supported the program all the way. Without the support of the principal, Mr. W. H. Bittle, working with his industrial arts department, the project wouldn't have been completed.

The second year of the program is now into full swing. This year other possible designs are being considered by the students and Ed Hine and his electricity students are working on a new electrical system.

Lou Reda, Department Head, and Dr. Hines are in the process of looking into state or federal funds.

John Chlebowski has students welding and fabricating sheet metal in his metals area and is writing a new curriculum for the solar application of metals.

Any interested persons may write to Dr. John Hines, Curriculum Development, or Mr. Lou Reda, Industrial Arts Department Head, Central Dauphin School District, 600 Rutherford Road, Harrisburg, PA 17109 for any information you may need pertaining to *Solar Heating for Industrial Arts*.

Mike Filepass

SOLAR HEATER SUPPLIES

3	Cans of P.P.G. Quick Dry Zinc Chromate Primer; 1 Quart of Wrought Iron Black
7	2x8x8's
4	4x8x1 Styrofoam
4	Sheets 20 Guage Al. 2'x6' @ 9.89 each
	Insulation (3 1/2' Corning Fiberglass Angle Mild Steel 1/8x1x1 @ .26 - 28' Glass 1/2"x6'x4' @ .25 sq. ft, (2 sheets)
2	Quarts Alkyd Epoxy Enamel
5	Rolls of 6x15 insulation
3	3/4 Plywood Sheets (T&G)
2	Tubes Vinyl Caulking
2	4" to 3" Reducers (1.09 each)
1	9.95 Fasco Mdl. 648S Fan
1	21.99 Fasco Mdl. 663 Fan
1	Roll of 50' Venting Hose (4" Dia.)
1	Box 10"x20" Air Filters
1	Extension pipe; 1 Reducer 4"-3"; 2 Plastic 4"-T
6	Ton 4A Stone (Limestone)
1	Mdl. 648S Fasco Fan

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FILEPAS SOLAR COLLECTOR DATA

DATE	TIME	AMB. TEMP.	COLL. TEMP.	AIR into HOUSE	WEATHER
2-20-76	11:30 A.M.	40°	156°	85°	Sunny
	1:00 P.M.	40°	120°	92°	"
	12:00 Midnight	29°	52°	70°	Night
2-23-76	12:30 P.M.	28°	140°	72°	Cloudy
2-25-76	1:00 P.M.	64°	190°	90°	Sunny
2-26-76	12:30 P.M.	64°	209°	86°	Sunny
2-27-76	7:20 A.M.	49°	X	72°	
2-28-76	1:00 P.M.	60°	164°	122°	Sunny
	6:00 P.M.	58°	74°	88°	"
	12:10 A.M.	41°	X	80°	Night
	11:00 P.M.	36°	X	86°	Night
2-29-76	9:30 A.M.	39°	X	80°	Cloudy
	11:30 A.M.	46°	170°	122°	Sunny
	10:30 P.M.	44°	X	88°	Night
	1:00 A.M.	39°	X	83°	Night
3-1-76	7:00 P.M.	49°	X	86°	Night
3-2-76	3:30 P.M.	38°	X	72°	Rain
3-3-76	8:45 A.M.	39°	X	60°	Rain
	2:40 P.M.	38°	X	62°	Rain
3-5-76	6:10 P.M.	56°	X	70°	Rain
3-6-76	10:00 A.M.	38°	100°	80°	Sunny
	11:30 A.M.	42°	X	96°	Sunny
	11:45 A.M.	42°	X	102°	Sunny
	2:00 P.M.	42°	X	108°	Sunny
	5:00 P.M.	42°	96°	84°	Sunny
3-7-76	11:00 A.M.	40°	140°	110°	Sunny
	11:00 P.M.	40°	X	70°	Dark
3-8-76	5:00 P.M.	40°	X	80°	Dark
3-10-76	5:00 P.M.	38°	X	94°	Dark
3-11-76	1:00 P.M.	42°	170°	120°	Sunny
	3:00 P.M.	40°	90°	90°	Sunny
3-13-76	12:30 P.M.	50°	X	100°	Sunny
3-22-76	1:00 P.M.	40°	X	110°	Sunny
3-23-76	1:00 P.M.	50°	X	100°	Sunny

COLLECTOR TEMP. for AUGUST/SEPT./OCT.

8-11-76	2:00 P.M.	80°	180°	Sunny
8-12-76	3:00 P.M.	86°	182°	Sunny
8-13-76	12:00 MN.	86°	186°	Sunny
9-21-76	12:00 Noon	68°	178°	Sunny
9-22-76	12:00 Noon	60°	170°	Sunny
10-18-76	12:00 Noon	41°	200°	Sunny
10-19-76	12:00 Noon	47°	200°	Sunny
10-28-76	12:00 Noon	38°	200°	Sunny
10-29-76	12:00 Noon	50°	225°	Sunny

NOTE: On Jan. 2, 1976, the temperature in the collectors was the same as in October and higher than in August.

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SUPPORT FRAME, BAFFLE and DUCT WORK CONSTRUCTION

Metals Area

FRAME CONSTRUCTION

MATERIAL:

1/8"x1"x1" Angle Iron

The following outline includes:

Procedures and equipment needed

Mini demonstrations that are conducted at each step as construction progresses

I Measurement and layout of all necessary lengths

a. Proper use of ruler, try square, layout dye and scriber

II Cutting stock

a. Power hacksaw demonstration

III Deburring

a. Proper use of file and file card

IV Layout of all necessary drilled holes

a. Same tools as in # I - plus center punch

V Drilling of all necessary holes

a. Drill press and electric hand drill demonstration

VI Layout of all weld lap joints

a. Same as in # I

VII Assembly of frame

a. Major demonstration incorporating welding, riveting, and clamping

VIII Apply finish

a. Spray and brush painting demonstration

DUCT WORK and BAFFLE CONSTRUCTION

MATERIAL:

20 Guage Half-Hard Aluminum Sheet

The following outline includes:

Procedure and equipment needed

Mini demonstrations that are conducted at each step as construction progresses

I Cutting sheet stock to required sizes

a. Squaring shear demonstration

II Deburring

a. Proper use of file, file card and emery cloth

III Layout of all necessary drilled holes on both duct work and baffles

a. Demonstrate layout tools

IV Drilling

a. Demonstrate drill press and electric hand drill

V Layout of all necessary folds, bends and cuts on duct work and baffles

VI Develop and assemble all duct work

a. Demonstrate sheet metal bender–pop riveting

VII Develop baffles – Assemble to reflector face

VIII Prepaint all metal surfaces before final assembly

a. Zinc chromate

IX Fasten duct work into reflector frame

SOLAR HEATING COLLECTOR

CONSTRUCTION and FABRICATION

(Hot Air System)

1. Construct collector frame

   a. measure and cut framing material to length two 2x8x8's and two 2x8x4's

   b. fasten collector frame with glue and 16d nails (Weldwood Plastic Resin Glue)

   c, glue and fasten 1/4"x4'x8' plywood to the collector frame

2. Cut stringers for collector glass – two 3/4"x1"x4' and
   two 3/4"x1"x8'

3. Construct solar unit base using 2"x10"x10's with 2x10 joists 16" o.c.

   a. fill the collector base with 2 inches of polystyrene insulation and 6 1/2" of fiberglass insulation. The floor of the base is 3/4" tongue and groove plywood subflooring.

4. Place the collector on the base and fasten the collector to the 55 degree collector frame.

5. Using heavy duty aluminum foil, cover the inside of the collector and the back of the collector unit.

6. Place 4" of polystyrene insulation inside the collector box and cover the insulation with 20 gauge aluminum, primed with one coat of zinc chromate and two coats of flat back epoxy paint. CAUTION: The AL^2 collector base should be made from two pieces of AL^2 overlapped to allow for contraction and expansion.

7. The stringer should now be placed over the aluminum holding the AL^2 in place.

8. Cut holes in the AL^2 and collector back to allow hot air to circulate from the collector to the storage area. Duct work is now put in position.

9. Place one layer of 1/4' glass on the stringer and caulk.

10. The second stringer is now placed in position and the second layer of glass is placed on this stringer.

11. The back and ends of the storage unit are made from 2"x4"x8' frames and 1/4" exterior fir plywood.

12. Insulate the back and ends with 3 1/2" fiberglass insulation and cover with 1/4" plywood.

13. Cover the interior of the storage unit with heavy duty AL^2 foil to stop ultraviolet radiation and reflect heat back to the stones.

14. Mount all electric motors and complete all wiring.

15. Fill the collector storage area with Pennsylvania 4A limestone to within 24" to the top of the storage area.

16. Cut a 4" dia. hole near the top of the storage unit.

17. 4" plastic pipe runs from the solar unit into the house.

This pipe may be above ground insulated with fiberglass insulation and plastic, or can be installed under the ground below the frost line.

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THEORY OF OPERATION

The solar heater control consists of five main parts. They are the power supply, the switching circuits, the control circuits, the temperature sensors and the blowers.

The power supply is a triple unit providing -5 volts at 100 MA, +7 volts at 2A and +9 volts at 1A. All three supplies are electronically regulated and have a common ground. the -5 volts is used for the negative supply of the IC's. The +7 volts is used for the positive supply of the IC's and the relay circuits. The +9 volt supply feeds the bridge circuits and also supplies the timer.

The bridge circuits consist of the five (calibrate controls, the five thermistors and two on-board resistors. Bridge circuits were chosen because of their high sensitivity. The bridge circuits feed three IC comparaters on the control board. The three comparators control the relay switches and a special timer. The timer is activated when the solar collectors are much warmer than the heat storage areas. This causes the blowers to oscillate on-and-off about once very five seconds. This prevents the extreme heat difference from cracking the collector's glass.

The switching circuits are simply an interface between the low power thermisters and integrated circuits, and the high power blowers. They include three power relays, three relay drivers and associated circuitry and the manual power controls and indicators on the front panel. Triacs could have been used in place of relays, but relays were chosen for the sake of simplicity.

The blowers are all of the squirrel cage type and all but one are mounted inside the collector. The one that is not mounted inside the collector is mounted inside the house where it can pull the heat from the collector to inside the building. There is also an auxiliary blower which can only be turned on manually. This blower is used when the operator wishes a faster air circulation inside the collector.

This unit plugs directly into a standard 110-120 volt A.C. outlet and draws less than 1000 watts with all blowers running.

ELECTRICAL PARTS LIST

Part Number	Part
C101, 103, 105	2000mf 25v Electrolytic capacitor
C102, 104	100mf 25v Electrolytic capacitor
C106	200mf 15v Electrolytic capacitor
C201, 202, 205, 206	1000mf 15v Electrolytic capacitor
C203	5mf 15v Electrolytic capacitor
C204	.01mf 1kv disc capacitor
D10	50 PIV 2A Silicon Rectifier
D102-106	50 PIV 1A Silicon Rectifier
D107	5.6V 1/2W Zener Diode
D108	11.5V 1/2W Zener Diode
D109	9.1V 1/2W Zener Diode
F301	Fuse 10A Slow-Blow
F302	Fuse 1A
1301, 302	S.C. Min. Bay. Inc. Pilot Lamp (120 MB)
1303-305	S.C. Min. Bay. Neon Pilot Lamp (NE-51)
K201	Relay 6V coil SPST 1A contacts
K301-303	" " " " 25A "
Q101	ECG 129 Transitor
Q102, 103	2N3055 "
Q201	ECG 123 "
Q301-303	ZN3055 "

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Part Number	Part
IC201, 202, 204	Integrated circuit ECG 910, LM710
IC202	" " NE-555V
R101	330r 1/2W 10% Resistor
R102	270R 1/2W 10% "
R103	680r 1/2W 10% "
R104	1200r 1/2W 10% "
R105, 106	1000r 1/2W 10% "
R201,202, 205, 208	1000r 1/2W 10% "
R203	180Kr 1/2W 10% "
R204	100Kr 1/2W 10% "
R206, 207	3000r 1/2W 5% "
R301-303	47Kr 1/2W 10% "
R304	1Meg-potentiometer 2W linear taper
R305-309	3500r potentiometer 2W linear taper
R301, 303, 304	Toggle Switch SPST 15A contacts
S302	Toggle Switch SPST 3A contacts
S305	Toggle Switch DPST 15A contacts
T301	Transformer 12.GV C.T. 2A
T302	" 12.6V 1A
Th301-305	Thermistor 3000r cold

Miscellaneous Items:

QUANTITY	
2	Fuse Holder 3AG Panel Mount
5	Single Con. Min. Bay. Panel Mount Lampholder
2	Green lens
2	Amber lens
1	Red lens
1	1 lug terminal strip
5	2 lug terminal strip
1	4 lug terminal strip
3	6 lug terminal strip
30 ft.	6 cond. 20 guage cable
50 ft.	4 cond. 14 guage cable
50 ft.	Single cond. 14 guage hook-up wire
50 ft.	Single cond. 20 guage hook-up wire
1	Power Supply Circuit Board
1	Computor Circuit Board
1 pkg.	Hardware, assorted
3	Heatsink drilled for one TO-3
1	Heatsink drilled for two TO-3
1	Thermostat

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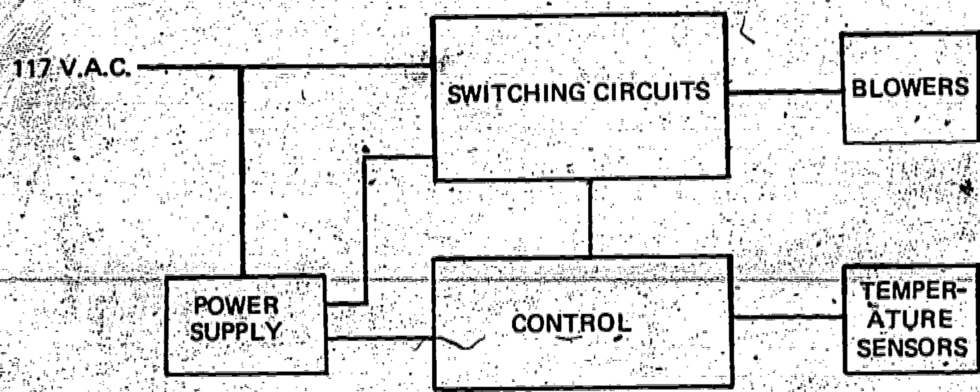
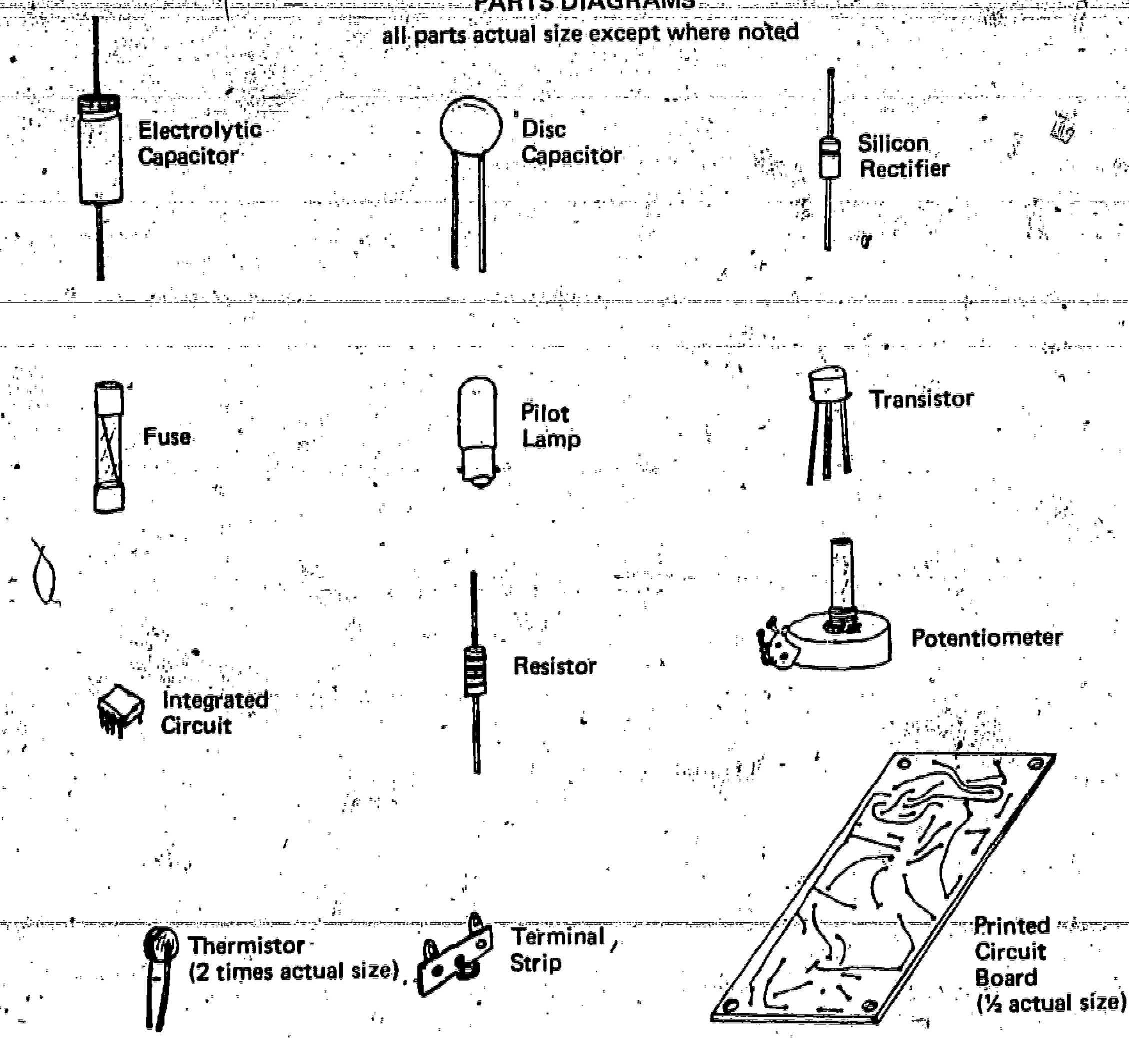
BLOCK DIAGRAM



PARTS DIAGRAMS

all parts actual size except where noted



FIVE SOLAR WATER HEATERS YOU CAN BUILD

By Edward Moran

Ken Herrington, the evolution of a system

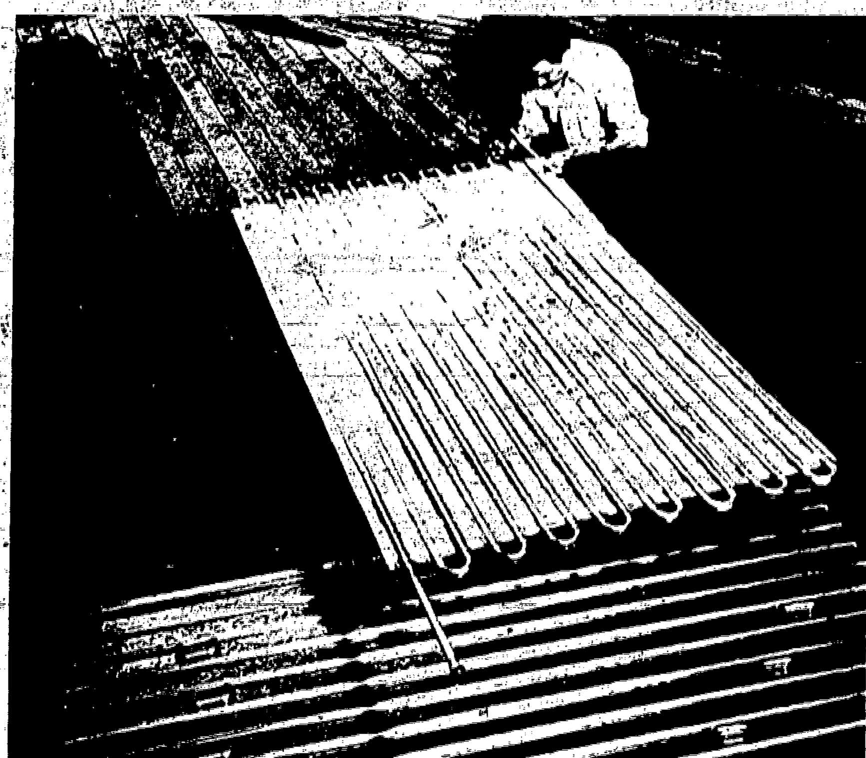
Ken Herrington just can't say no when it comes to homegrown energy. When we featured his fireplace heater in this series we werent aware that we'd met up with an avid craftsman who is turning his ranch on a northern California hilltop into a veritable alternate-energy lab.

Over the months, we've been fed dozens of photos (Herrington is a topnotch industrial photographer) of solar pool heaters, solar greenhouses, solar water heaters, storage tanks, piping, heat exchangers–each device carefully built and tested by this do-it-yourselfer.

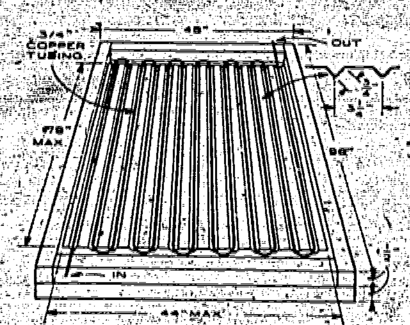
We asked Herrington to show us plans for an inexpensive, easy-to-build collector that a typical homeowner could put together with a few tools and a little spare time. Materials for the collector shown in photo 1, cost exactly $160.73, wholesale; assembly takes a few hours.

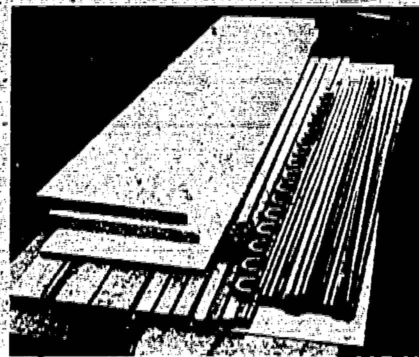
This model is by no means Herrington's first version; and we're sure it won't be his last; he sees solar research as an evolving process, and is always making innovations. His first 4-by-8 collector, built last year, was little more than a plywood box with a flat metal plate to which copper tubing had been soldered. Later, he added fillets of heat-transfer cement to improve performance. Then he came up with the idea that's the basis for the collector described here: Instead of merely soldering pipes to a flat plate, he reasoned, why not first nestle them in V-shaped groves?

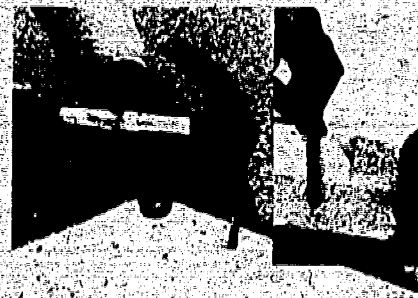
At first, he used individual strips of metal, crimped V's down the center, then screwed them together (phosos 5 and 6). A much simpler method is shown in photo 4: You can ask a sheet-metal shop to punch out a 24-guage sheet to the specs given in our drawing.



Here's a dimensioned drawing



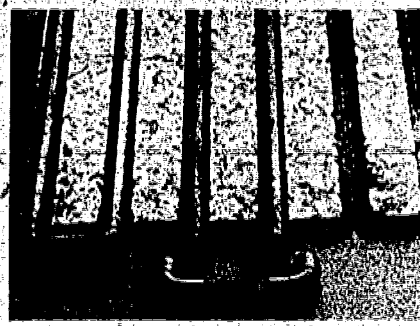




1 **Number and spacing** of V grooves can be varied (compare drawing and photo). Shown: 4-by-8-by-1½" bead-board panels, 17 tubes of 80-by-¾" copper; 16 sets of copper return bends and couplings, and plywood (optional). Also needed: a 78-by-43-in. sheet of 24-gauge galvanized metal, and fiberglass.

2 To form a tray for the piping, glue beadboard strips to flat beadboard panel, driving in ¼" wood dowel to hold surfaces together firmly.

3 **After edges are set,** glue an inch of fiberglass insulation into place with butyl-rubber cement from adhesive caulking tube. Pipe grid goes on top.



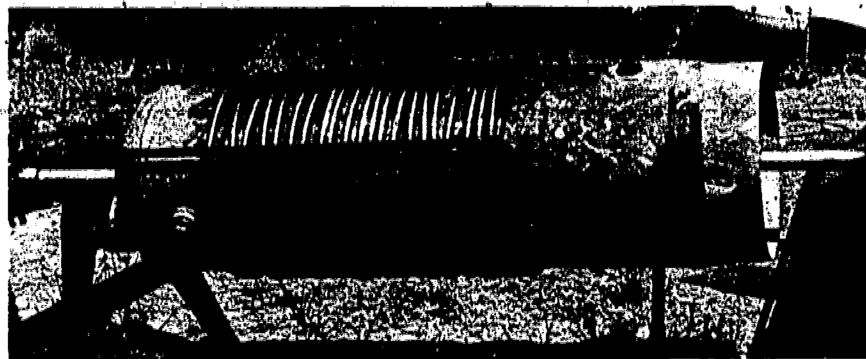
4 **Pipes are soldered** into V grooves in sheet-metal plate. If the copper return bends are unavailable, use street ells and couplings, as here.

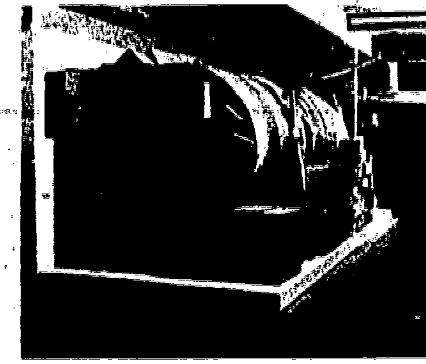
5 **Earlier version** used strips of V-grooved metal held together with sheet metal screws. You may find this easier to keep flat while soldering.

6 **Use a C clamp** to hold strips in place while screwing them together. Continuous beads of solder are run down both sides of each pipe.

7 **Seat the piping assembly** in the beadboard box. Paint flat black, then attach glazing in plywood frame; bolts along edges hold it together.

Condensation can fog single-glazed unit, reducing insolation. Herrington recommends spraying cover with moisture retardant, such as Sun Clear. In photos at right, paper mask shows effectiveness; treated area stays clear on dewy morning, next day. **Heat-exchanger tank** (bottom) holds 80 gallons. Copper tubing brings solar-heated water to heat tap water inside. Mallett-bend tubing around tank, cover with Thermon cement, foil, 4" foil-backed fiberglass, then brick up in basement (right) to retain heat. (Photo shows incomplete installation; bricks are later boxed in.)





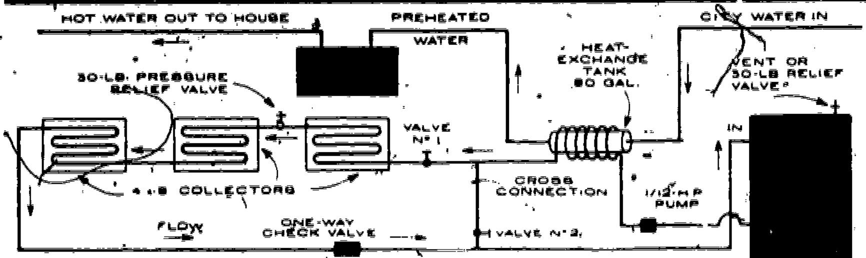


Diagram shows possible setup, linking three 4-by-8 solar panels into a conventional hot-water system for backup. Check valves permit solar collectors to be bypassed at night or on cloudy days, when you'd draw on stored water. Pressure-relief valve is necessary to prevent damage in case of steam buildup. For most American climates, heat-exchange system is recommended.

The original plywood box has given way to one made from steam-expanded polystyrene (beadboard), which costs about $10 for a 4-by-8-by-1 1/2" panel. (Herrington also recommends Celotex's Technifoam, slightly more expensive, but more durable.) Edging for the box is a 1 1/2"-wide strip (cut from another beadboard panel) glued around the perimeter (see photo 2). An inch of fiberglass insulation (photo 3), avoids any danger of the beadboard melting due to the heat of the pipes.

The 4-by-8 size was chosen to take advantage of standard materials sizes. Copper pipe comes in 20' lengths, which can easily be cut to three 80" lengths. With return bends or street ells added (photo 4 and 5), the piping assembly should just snug into the beadboard box (photo 7). Before inserting, though, clean all surfaces thoroughly with soap and water, then cover with a flat black paint.

Herrington doesn't think double glazing is necessary in his climate; it would prevent convective heat loss more effectively in colder areas. He single-glazes with Kalwall Sun-Lite premium fiberglass cover (.025" thick), bolting it in a frame of plywood strips and sealing it with butyl-rubber silicone.

From collector to system

The diagram is Herrington's [illegible] provide hot water for a typical household. [illegible] easily [illegible] placed on south-facing roof or, if you have the space—as Herrington does—mount them on the ground or on a fence.

Summer heating of hot water in my climate is simple," he tells us, "[illegible] sq. ft. [illegible] should supply all my needs. Winter is a different matter; I need at least 90 to 100 sq. ft. of collector.

Herrington uses the heat exchanger loop to insure a more constant supply of water on cloudy days and at night. Also, since he uses a water conditioner to prevent rust and foam (Rust Raider Heating System Conditioner), he must keep his tap water separate from the water that is pumped through the system.

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Performance

In winter, the preheated water may leave the heat exchanger at 95 degrees; on a sunny summer day, it might be as high as 130 degrees. Space doesn't permit us to detail all the careful monitoring Ken Herrington has made on his system. He would rather err on the side of caution, so intent is he on not making any unwarranted claims.

Some figures he sent us for the middle of February are instructive. During a week in which daytime temperatures ranged from 50 degrees to 91 degrees, he reports tank temperatures rose by 40 degrees to 50 degrees each day, when the solar system was working (from 80 degrees to 121 degrees the first day; from 100 degrees to 150 degrees the next). This works out to a mean of about 180 Btu per hour per square foot of collector.

Further performance data are included in a data packet Herrington is offering for those who want more information. Send $5 to Ken Herrington, 759 22nd St., Oakland, Calif. 94612. If you want to ask a specific question (free), include a stamped return envelope.

J. DON FIELD, ROOFTOOP "TRICKLE" COLLECTOR

Not to be outdone by Ken Herrington's elaborate system, a Roanoke, Va., experimenter, working independently from previous PS articles, has also been checking out solar water heating.

Photo and diagrams illustrate the 42-sq.-ft. aluminum collectors that Field installed on his due-south-facing roof more than a year ago. It's a trickle collector: Water flows directly over a corrugated-aluminum surface backed by a slab of insulation. (At press time, Field reports some success with a new copper-tube collector he built recently.)

Materials for the aluminum unit cost Field about $300. He reports average monthly savings of $7 (150 to 165 kw shaved off his power bills); so payback time is about four years.

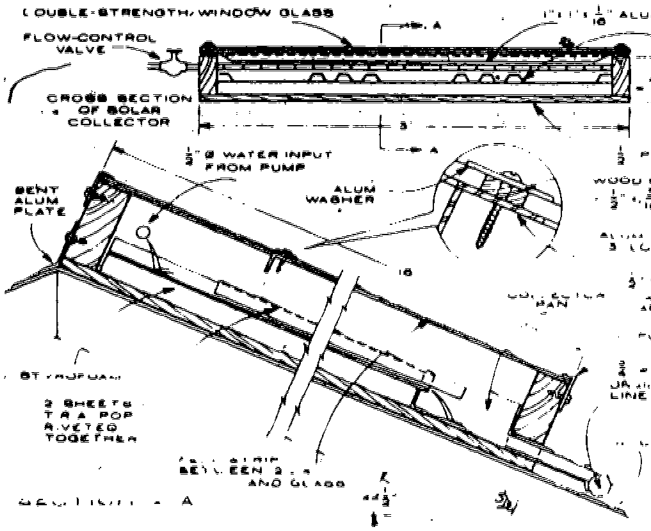
As with Herrington's system, this setup needs a heat exchanger. If an aluminum collector is used, it's a good idea to mix in water inhibitors to prevent corrosion. Field retains his electric water heater as a backup.

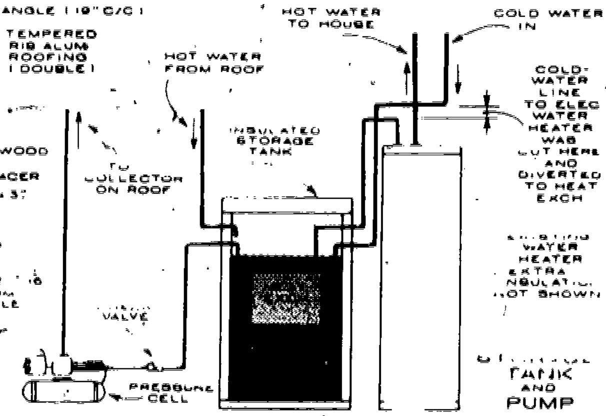
Collector assembly

Field chose aluminum over copper for its lower price and a [illegible] collector size for the convenience of using standard cut lumber. A basic box is first made by nailing 2-by-4's to a sheet of 4 by 8 by 1/2" plywood. Next, add a 1 1/2" thick layer of insulation. Initially, Field used Styrofoam, but now recommends using fiberglass.

Atop the insulation goes one sheet of temper-rib aluminum roofing painted flat black. A collector pan at the lower end leads to a 3/4" PVC drain line. The entire collector is covered with double strength window glass.

A year ago April, Field was ready to test the collector using a temporary [illegible]-gallon tank. On a day when ambient temperature was 42 degrees Fahrenheit, he was able to heat the five gallons from 55 degrees to 120 degrees in 90 minutes.





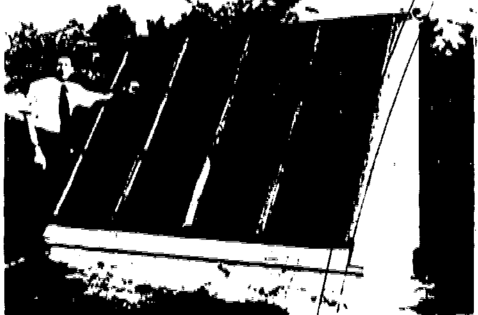
Water pumped up to rooftop collector (left) trickles down between two sheets of corrugated aluminum. Diagram above shows heat exchanger and tie in with backup heater

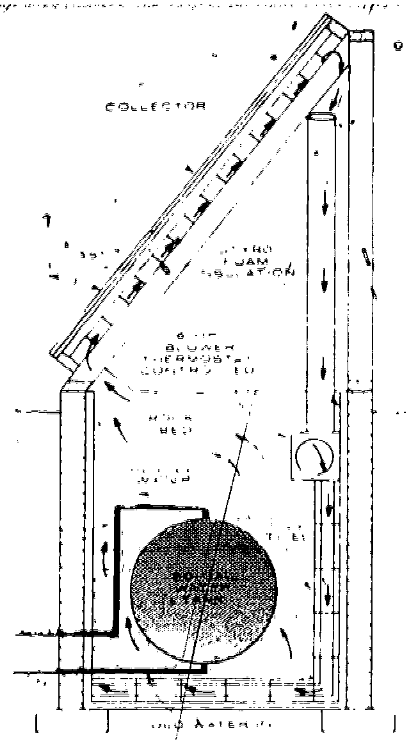
... became discolored by water passing over it. Field solved ... problem by riveting another sheet of black aluminum over the existing one and running water between them.

What ... insulated storage is the answer. Field made a 100-gallon tank from two sheets of 4 by 8 ... 1/2" plywood, coated the inside with fiberglass, then wrapped top, bottom, and four sides with two inches of Styrofoam. Later he decided to add ... mil polyethylene ... the water line inside to prevent leaks. For a heat exchanger, tap water is run through coils of 3/4 ... copper pipe submerged in the tank; this preheated water then enters the electric heater nearby.

Performance ... temperatures of 12... degrees on ... days and 115 degrees ... December, January and February. With the new copper collector added (which doubled the original size), late afternoon tank temperatures generally ranged from 90 degrees to 130 degrees, with a peak of 142 degrees on Feb. 27 (ambient temperature 70 degrees). Field's electric heater was not used at all from Feb. 10 2...

JOHN SNELL, CIRCULATING-AIR COLLECTOR





[illegible] built a freestanding unit in his backyard [illegible] underground piping

[illegible] collector surface is made of [illegible] A-frame structure beneath it a 180 cu ft underground storage pit acts as a heat trap for the heated water [illegible]

[illegible]

RON HANNIVIG: ROOFTOP

What started as a do-it-yourself project two years ago has since blossomed into a full-time solar distributorship for Ron Hannivig. The tank/collector module described here is the original homemade version that anybody can try.

Tank and collector are exposed on the roof, so it's a natch for Hannivig's Florida climate. (For colder locations, use the heat-exchanger systems, such as Herrington's or Field's.)

This system works on the thermosiphon principle, thus eliminating the need for a circulating pump. As water in the collector is heated, it expands, rises, and passed into the storage tank. Denser cold water then fills the collector, and the cycle continues as long as the sun keeps shining.

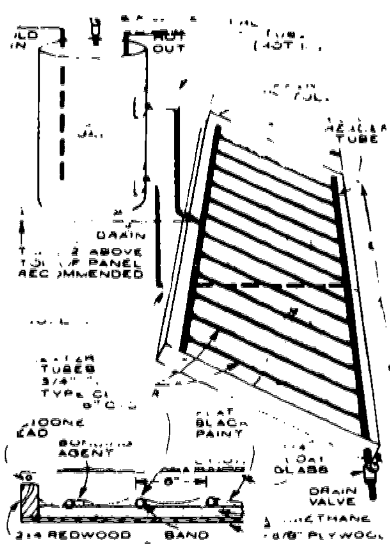
Note that the photo shows two 40-gallon tanks, one standing and one lying. Local building codes made this setup more practical, though the drawing shows a singe vertical tank, which can be a full 80 gallons, or as big as the system can handle.

Economics. Cost of materials for the collector [illegible] $250 and the tanks were purchased off-the-shelf for $150. Estimated pay-back time is about three years. Hannivig reports that during the balmy Florida summer, his system can provide up to 95 percent of his family's hot water requirements, in winter up to 65 percent.

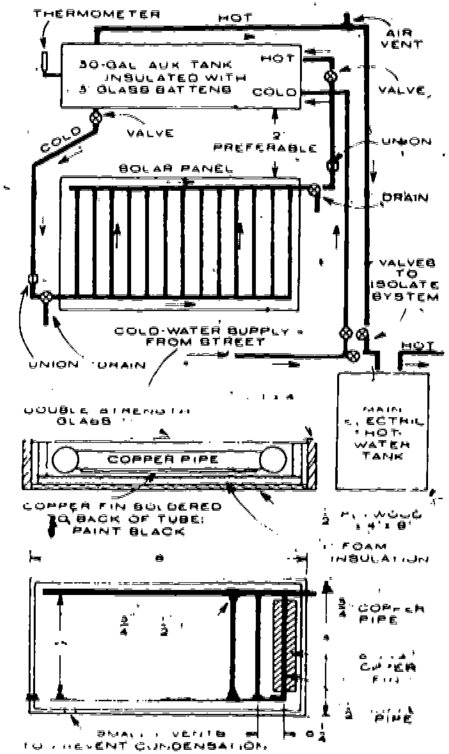
Construction. The wood frame collector covers [illegible] sq. ft. (two [illegible] panels) insulated with 1 1/2" of urethane. Three quarter inch copper tubing (see diagram) is connected and mounted on top of the urethane. In the device shown, sand was packed around the pipes for heat transfer (see detail) and sprayed with a stucco binding agent. Assembly was then painted flat black. Finally, 1/4" float glass was silicon bonded to the sides of the frame for an effective weather tight glazing. Pressure-relief valve is a must.

Performance. Hannivig [illegible] 130 degrees [illegible] solar-heated water generally available at 135 degrees - 140 degrees during the day.

[illegible] send a stamped return envelope to Ron Hannivig [illegible] Fort Lauderdale, Fla. 33312



PETER WEST, THROUGH-THE-WALL COLLECTOR



Why allow fuel bills to dampen your vacation? This summer heater is the least complicated of the five presented here. Specifically, it's designed to supplement an existing electric hot water system from March through November at a vacation home on the Delaware coastline, where the mean annual sunshine totals about 2600 hours. Copper was chosen to offset the effects of salt laden air. The system is not freeze proof, lacking a heat exchanger.

Once again the thermosiphon principle [illegible] hot panel preheats water that's siphoned to a 30-gallon storage tank sitting [illegible] several feet above the collector.

Economics. West invested [illegible] 16,000 to 18,000 Btu per day [illegible] for a total savings of $[illegible] from March through October [illegible] four to five years.

[illegible]

[illegible] with good [illegible] the [illegible] Cut the panel and paint it flat black [illegible] made of 3/4" exterior plywood to which [illegible] bottom and sides with [illegible] urethane foam insulation [illegible] 30-gallon [illegible] ceiling mounted, wrapped in four inches of fiberglass insulation and boxed with [illegible] plywood.

[illegible] that the system peaked at 115 degrees [illegible] was [illegible] degrees) and stayed at 95 degrees through [illegible] washing machine, dishwasher and showers.

For specific questions [illegible] Fairfax, Va. 22030

Solar Water Heating: tips for getting started

Even if you've read this month's cover story, and have been religiously following PS's heavy coverage of solar energy, you might still have some doubts you'd like resolved before you take the plunge. It's not surprising that many people are taking a wait-and-see attitude: The industry is new, claims and counterclaims are flying fast, and sometimes it's hard to separate the charlatan from the honest entrepreneur.

Consumer awareness is the key, whether you're building a system from scratch or buying components off the shelf. Check out some of the books and periodicals in my Alternate Energy Bookshelf (listing PS, Jan.) Learn what the solar research experts are saying, find out what kind of performance can reasonably be expected from a solar water heater--then you won't be bamboozled by a fast-talking salesman making outlandish claims.

Setting standards

Part of the problem is that not everyone [illegible] measuring performance. But this doesn't mean that we can't talk about performance in a meaningful way. The National Bureau of Standards is actively considering an interim standard which is now being circulated to researchers for comments. This report, *Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings*, is available for $1.90. The final standard is bound to resemble this interim report in many respects. You might also look at Development of Proposed Standards for Testing Solar Collectors and Thermal Storage Devices.

[illegible] figuring out instantaneous efficiency (briefly, the amount of solar radiation that is captured by a collector and absorbed by the transfer medium per collector area over a given amount of time.)

[illegible]

Copper, aluminum [illegible] choice will be determined by [illegible] water heating system. Copper is generally superior [illegible] transmission qualities and its resistance to environmental damage. Copper [illegible] can be smaller than aluminum ones and much smaller than plastic ones and still [illegible] the same [illegible] heat. But copper is costlier and could get even scarcer as time goes by. The main problem with aluminum is the danger of corrosion.

[illegible]

[illegible]

[illegible] a leeway of 20 degrees on either side of your latitude. Rate of water flow [illegible] a difference. Our five DIYers experimented with various flow rates but [illegible]

BILL RANKINS AND DAVID WILSON, SOLAR WINDOW

This month's energy project is a natural for the do-it-yourselfer who would prefer to experiment with a basic solar device before talking some of the complete systems featured here in previous months.

A solar window requires neither an ERDA contract nor a master plumber It is easily assembled on a Saturday afternoon, and is an ideal heating supplement for locations that don't permit a permanent array of rooftop collectors–apartment houses, for example.

There's no provision for heat storage, so the window is useful only as a daytime supplement, but outlet temperatures on sunny days average between 100 and 120 degrees, report Bill Rankins and David Wilson. Air is circulated through the unit by natural convection, although blower, thermostat, or automatic dampers could be added.

The air-flow diagram shows how cool air is heated in the insulated *tongue* of the collector then rises through the lip into the house The collector automatically pulls in colder air to replace it If you use a fan to force-feed the air through the collector, says Wilson, you will move a greater quantity of air, but will have a lower temperature provided by the heating process.

Site planning

As with any collector, the solar window must be oriented to take full advantage of the sun The window that receives the most sunshine most of the time is the obvious candidate, but because of the portability of the solar window, you could install several of them, to capture more sunlight Furthermore, by adjusting the base support, you could adapt the collector to seasonal angles of solar incidence without too much difficulty The unit can be anchored to the ground installed in a second-story window over a porch roof or attached to a shelf, as a window air conditioner would be.

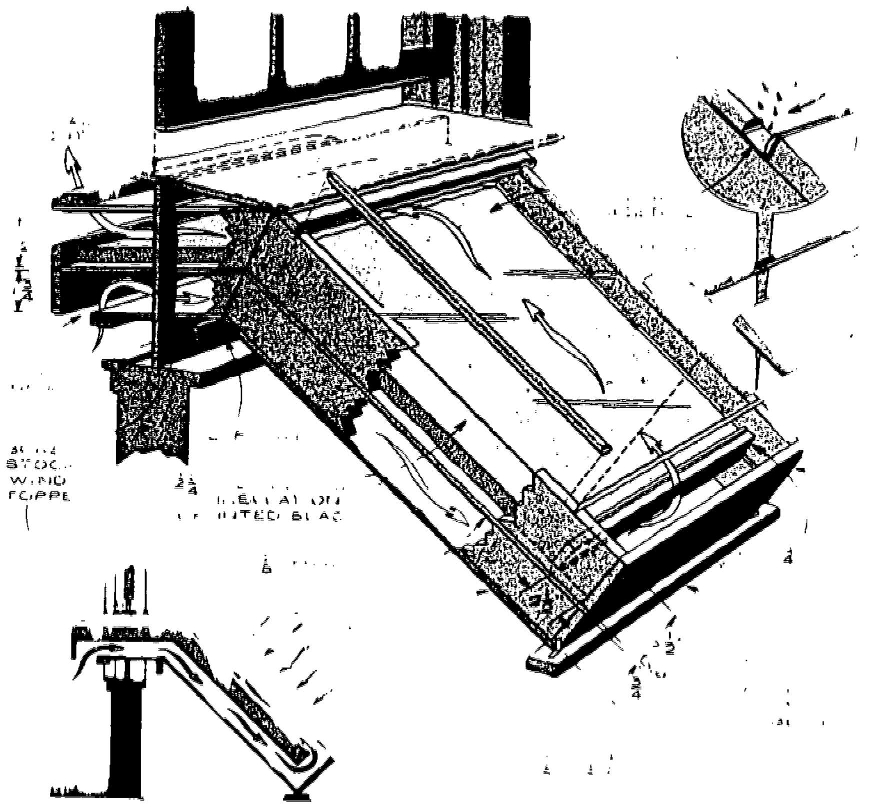
Collector attaches to existing sill; it's supported by specially built frame—or by roof below upstairs window. View from window (photo, upper right) is not appreciably impaired. You can even adapt the device for a storm window

Assembly details

Actual dimensions will vary, of course, depending on each window sash, but the thickness of the insulation and glazing given here has worked well for Rankins and Wilson. Before you start to assemble the collector, paint all wood parts (both sides) with two coats of out door paint or spar varnish. Make a box first, by cutting 1x4's at a 67 1/2 degree angle and making a hockey stick by attaching the two pieces with a sheet-metal strip. Add the top lip and nail on the bottom hardboard sheet, plus the end piece.

Make another assembly just like the first [illegible] together, the two air circulation channels will be created (see diagram). In effect this puts the heat-absorbing surface on a 1/8" hardboard sheet that is fixed 1 3/4" over the hardboard bottom (creating the lower cold air channel). Rankins and Wilson use a 23" wide section of 2 3/4" fiberglass insulation batt with its kraft paper backing painted black. They secured this batt at each end with screen mold and 3/4" nails. If you have an unfaced batt, you can cover the fiberglass with a thin sheet of metal and paint that black.

[illegible] and the [illegible] stock with duct tape on the outside. Glass could be used as a cover [illegible] Rankins and Wilson decided to use five- to 10-mil acetate sheet. It was less expensive and easier to work with. They pulled it tight and tacked it down under the screen mold with 3/4" nails, then trimmed off excess. For a tight rain seal they advise varnishing the wood before nailing and caulking afterwards. Moisture in the collector will be evaporated by the sun and will pass into your house as excess humidity.



An added bonus: When the wind blows, the plastic cover ripples slightly, creating a natural pump to move the air through the collector, says Wilson.

Installing the collector

When you install the collector in the window, the hot air outlet at the room must be either horizontal or pitched upwards for proper air flow. Add a rain cover, and seal any leaks between collector and frame with duct tape and insulation. To prevent reverse convection at night or on cloudy days, make two snug-fitting wood doors, to plug up the intake and outlet. If you are mounting the collector on a roof beneath a window, bolt it with angle braces; any hole can be quickly repatched with tar if the collector is moved elsewhere.

Variations are possible. For example, Wilson suggests using an elongated version of the collector to link a basement window with a ground floor window.

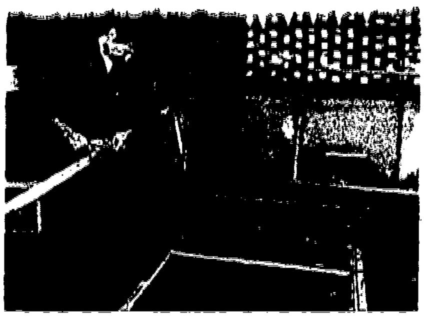
Rankins and Wilson have written and published two books [illegible] complete with many illustrations and dimensioned diagrams. For a price list or to ask specific questions about the solar window, send a stamped return envelope to them c/o [illegible] P.O. Box 111[illegible] Black Mountain, NC 28711.

E. PAUL MINK, SUN POWER FOR SPACE HEATING

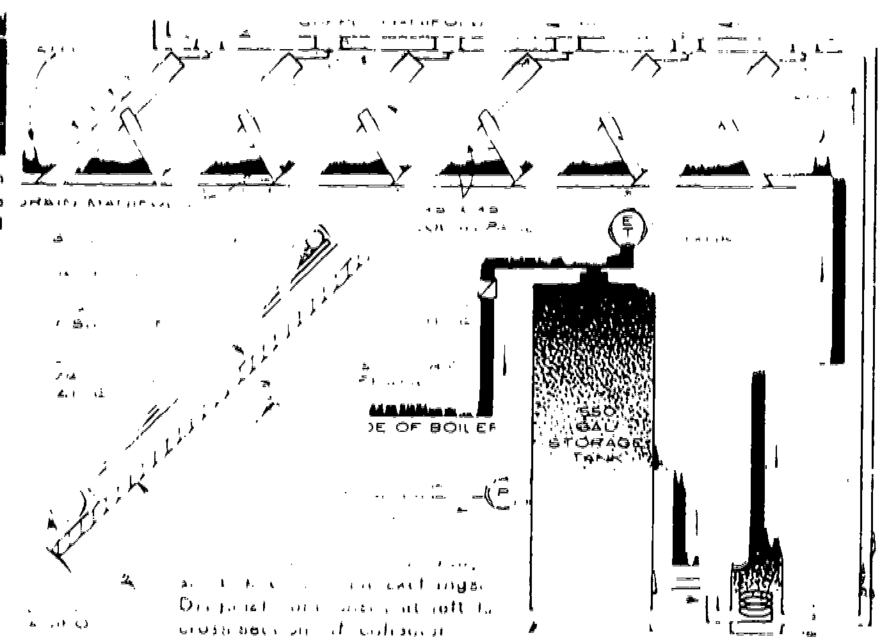
By Edward Moran

Paul Mink is every exception to the rule. Few homeowners who get into solar energy install a total space-heating system from the start. Many prefer to experiment with an elementary water heating system before tackling more complex projects.

Not so for this Maryland DIY'er. And no matter that his [illegible] oriented on a favorable east-west axis. Last winter Paul Mink assembled and installed a prominent array of 14 solar collectors across his suburban rooftop. Thirty gallons of a 50/50 water/antifreeze solution flow from the collectors to a heat exchanger in the basement, where water in an adjoining mammoth 550 gallon tank is heated for delivery to boiler and radiators. Mink projects that his system will cut his heating bills in half—maybe more—this winter.



Inventor Mink assembles collectors in his workshop (above). Below, because of incorrect pitch of roof, collectors had to be mounted in frames. All components are available off the shelf.



I haven't tapped my faucet water into the system yet, he told me, with a sigh. Haven't had the time. That project is planned for later this year, as is a plan to air-condition the Mink home with water from a deep well.

The solar project is really the most visible element of an all out energy conservation plan. Before he lifted a solar thumb, Mink reinforced attic insulation with Styrofoam; added storm doors and windows; outside-vented his furnace, even painted his white house a redwood hue for greater heat absorption. These preliminary steps cost him about $150. The solar project cost about $3000, but Mink figures a payback of seven years, based on a projected annual saving of $400 in fuel oil.

Making the collectors

Each collector is a box formed of [illegible] ply [illegible] and fitted with an absorber plate of [illegible] sheet aluminum. Mink piggybacked two 24" wide sheets and folded over their edges, which he sealed with silicon rubber. This created an envelope through which the fluid could drain and, of course, absorb heat. The metal absorber plate is anchored atop 3 1/2" of fiberglass insulation (see cross section diagram).

Fluid [illegible] silicon rubber. All pipes are P[illegible] (PVC) [illegible] feet of piping was exposed (that running between collectors and basement). Heat loss was significant so Mink insulated the supply manifold with polyurethane and built an insulated [illegible] around the drain manifold.

At present [illegible] Sun Lite [illegible] paneling [illegible] Kalwall [illegible] Mink has experimented with double glazing and with other plastic materials but is satisfied with the Sun Lite because of the relatively low temperatures involved and because he doesn't want to [illegible] this installation. The paneling is attached to the frame with a strip of L shaped aluminum and [illegible] metal screws to provide a good weathertight seal.

[illegible] inlet [illegible] Supply and [illegible] headers are vented to the air and the supply line has [illegible] to the drain [illegible] pressure buildup [illegible] everything drains down [illegible]

[illegible]

NORBERT KLEMP, SOLAR POOLHEATER ON A PEDESTAL

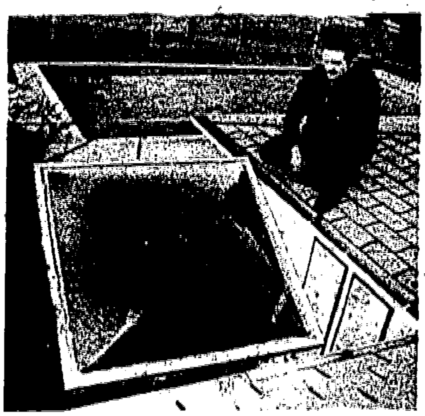
By E. F. Lindsley

For the past three seasons, Norbert Klemp has been heating his 18-by-36-foot swimming pool with an extremely rugged and compact home-built solar heater. Unusual? Not these days: Prompted in part by recent restrictions on gas and electric heaters in many localities, more and more pool owners are turning toward solar energy.

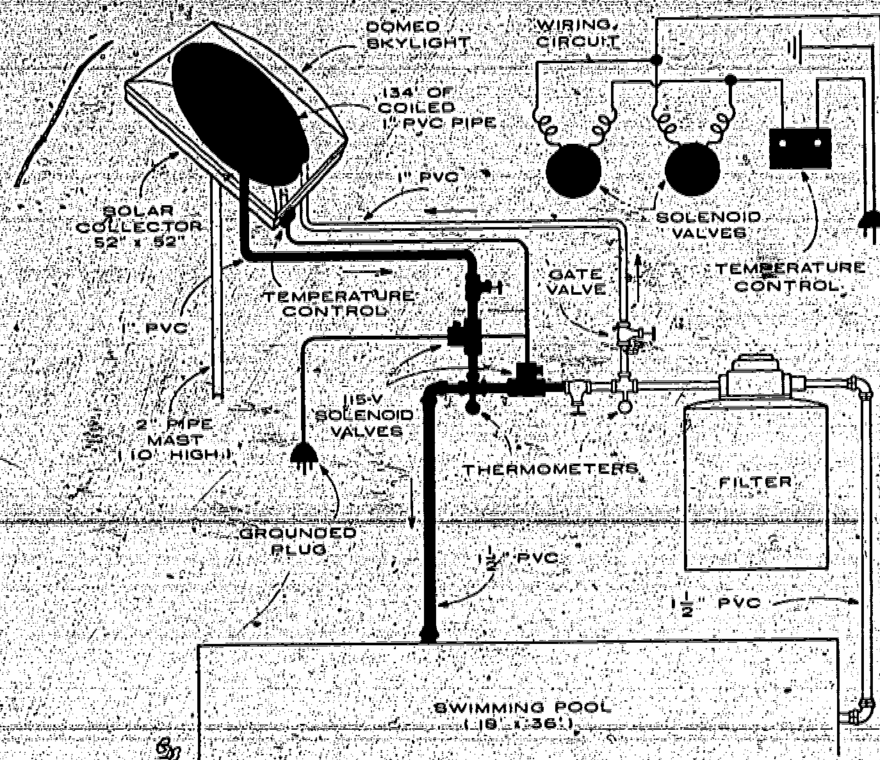
In this southern Wisconsin climate, where the swimming season extends from about Memorial Day through Labor Day, a solar heater can make evening swim parties an attractive option, and may even extend the swimming season.

Klemp's unit typifies what can be done at low cost and with very simple construction. Materials cost him about $100, half of that going for two 115-volt solenoid water valves and an automatic temperature-sensing device. These valves (see diagram) direct water flow either through the collector or around it, depending on the availability of solar heat. The valves are activated automatically, so there's no need to pay much attention to the system other than for normal maintenance.

Klemp's collector, at first glance, appears to be a black garden hose coiled inside a flat bubble and mounted atop a flagpole. The *bubble* is a plastic skylight dome and the hose is really one-inch polyvinylchloride piping 134 feet in length. Some experimenters prefer copper piping because of its superior heat-transfer capabilities and its resistance to environmental damage. Since Klemp chose plastic piping, he had to use more of it to compensate for its relatively poor thermal characteristics



[illegible] adjust angle of orientation [illegible] changes in sun's location. In [illegible] photo, inventor Klemp points to temperature sensor on plywood panel base. Filter and plumbing details are shown below. Two solenoid valves, one in heater return valve (above hand), the other as a bypass in filter output line (to right of hand), respond to sensor on panel.



Choice of materials is, however, less critical here than for a domestic hot-water or space-heating collector, because optimum pool temperatures (75 degrees to 80 degrees Fahrenheit) are much lower than for other applications. If you do use plastic, you've got to be extra careful about maintaining a constant water flow when using the solar mode. Stagnant water can freeze on a cold day or boil and rupture the pipes on an extremely hot day. You can avoid these problems by draining the collector when shutting down the solar mode–as at night or in winter. Klemp's system accomplishes this automatically, of course.

Follow the sun

The freestanding, mast-mounted collector makes it easier for a pool owner to take full advantage of the sun's rays, especially if he doesn't have a south-facing roof or patio cover. Since he uses his pool during the summer months, Klemp tilts his collector 30 degrees from horizontal. It is adjustable as the azimuth changes: It would be tilted more nearly vertical in winter.

As long as collector temperature remains below 100 degrees Fahrenheit, the filter pump works as normal, moving water through the solenoid-controlled bypass valve into the pool. But once the temperature sensors record 100 degrees, the bypass valve automatically closes and the return valve from the collector opens (see diagram). The solar mode is activated intermittently, depending on temperature.

It was still winter when I visited Klemp to take these photos, but he assures me his heater does a good job during the swim season–that his pool was consistently warmer than others in town, by at least 5 degrees.

To ask a specific question, send a stamped, return envelope to Norbert Klemp, 4806 W. Cedar Creek Rd., Grafton, Wis. 53024.

O. W. WOOD: SOLAR + WOODSTOVE HEATS HIS WATER

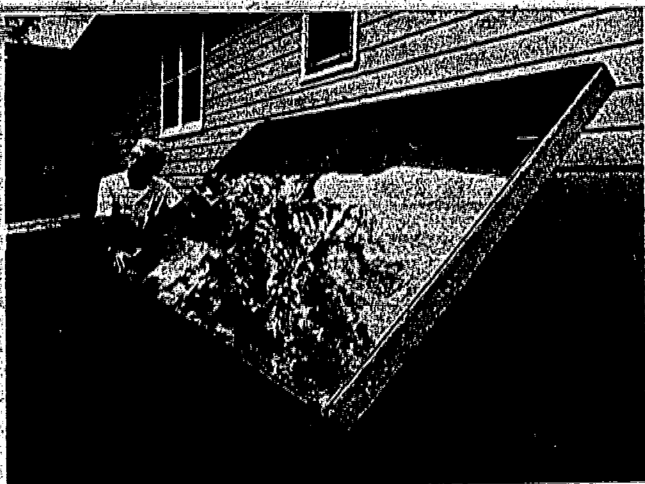
By Edward Moran

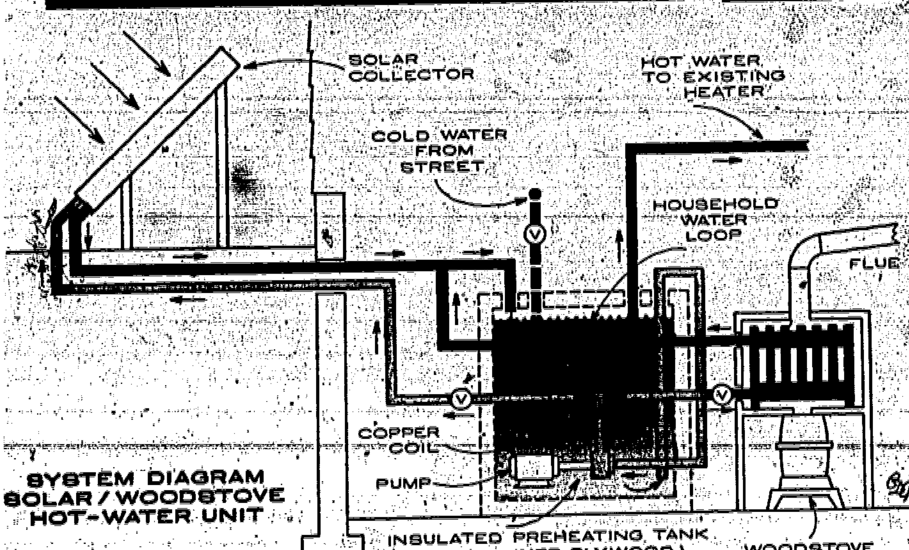
Last winter, as temperatures sank below zero in New Jersey, O. W. Wood sauntered down to his basement, calmly turned a valve, and threw some wood into a potbelly stove. Before long, hot water began flowing into his cubical storage tank–water that had been heated by both solar and wood.

Two years ago, Wood combined these two alternate sources of energy into a neat and compact package that has cut his family's oil consumption by nearly 30 percent. Blueprints and further data are available directly from the inventor (see address at end of this article).

System components

The Wood package consists of a ground-mounted solar collector and a stove and storage tank that take up only 30 square feet in the basement (see photos). All of the hot water required by three adults runs through the system, says Wood. On the average, the solar system heats 10,000 pounds (1200 gal.) of water each month–formerly heated by an oil-fired space-heating furnace.





Dual water-heating system combines solar collection with wood backup. In photo at left, vinyl-glazed collector is mounted at ground level to avoid problem of inappropriate roof pitch. Maintenance is simplified, too. In photo at right, inventor Wood checks storage tank; at his left is potbelly stove capped with radiator (enclosed in fiberglass-lined galvanized-iron box). Two-inch-thick Styrofoam insulation is pressed into place between all tank risers. Heated stove water and heated collector water merge outside tank and enter tank via pipe through lid. This permits air to enter collector and assist drain-down when required. Valves can be manually adjusted to shut off woodstove loop on warm, sunny days. Backup heater might still be required, depending on climate and demand for household water.

The wood booster is especially useful when the solar unit is unable to supply hot water on its own–on cloudy days or during the coldest season (November through February). In these months, Wood tells me, as little as 15 pounds of wood meets the needs of 2 1/2 days.

Low-budget collector

Wood says his 32-sq.-ft. collector gives him about 100 Btuh per square foot. Highly efficient manufactured collectors can do better, but not at $5 per square foor, which is how much Wood spent on materials. And the collector is mounted at ground level, which eliminates the need for costly–and heat-losing–piping runs.

The collector is designed to drain down when the sun isn't shining, but the system can be adapted to permit use of antifreeze solution. (Note the closed domestic-water loop in the diagram.)

The frame is of plywood, edged with pine, to which inch-thick Styrofoam has been spot-glued. Four 60-ft. coils of 3/8' o.d. copper tubing are required for the collector; they're installed at a slight pitch so water will drain down easily. The eight-foot run to the basement storage tank is 5/8' garden hose wrapped in fiberglass and vinyl.

Wood recommends assembling the collector with glue, C clamps, and screws instead of nails. To enhance heat absorption, he covered the entire surface with cement (two 80-lb. bags of Sakrete should do the job, he says), and painted it flat black.

Glass is excellent 'as a covering'. Wood believes, but expensive. Instead, he uses a sheet of clear vinyl five-mil thick. To prevent the cover from sagging in the sun, he glued some wood spacers to the cement surface.

Storage tank

Wood's vinyl-lined plywood tank holds 3000 pounds (about 350 gal.) of water when full. Heated water from solar collector and wood stove enters through the lid (see diagram). Heat is transferred to the domestic loop via a copper heat-exchange coil suspended in the tank. Because of the considerable water pressure on all sides, Wood recommends using plenty of wood screws in construction. And the vinyl inner lining must be completely waterproof. (A swimming-pool technician might be able to handle this part of the job.) Finally, a pump was installed to draw from the bottom (coldest) section of the tank. Total cost for tank construction was $312. Used copper piping would have reduced this expenditure, claims Wood.

Wood-burning booster

A potbelly stove with a cast-iron radiator mounted on top completes O. W. Wood's heating system. (A water-jacketed stove would work too, he claims.) For safety, Wood first pressure-tested the radiator, and installed 1/2' fiberglass insulation on the radiator enclosure.

To order plans, send $25 in check or money order to O. W. Wood, 82 Church St., Liberty Corner, NJ 07938. To ask a specific question (free), enclose a stamped, self-addressed envelope.

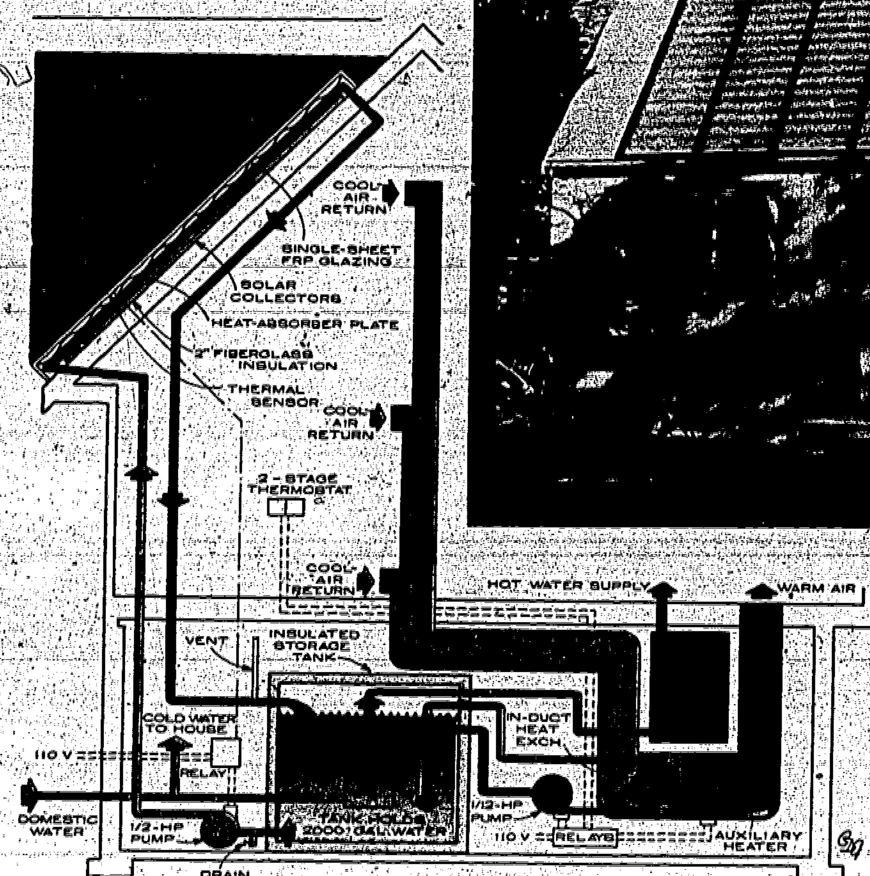
PS UPDATE, THE NEWEST SOLAR-HEATING EQUIPMENT

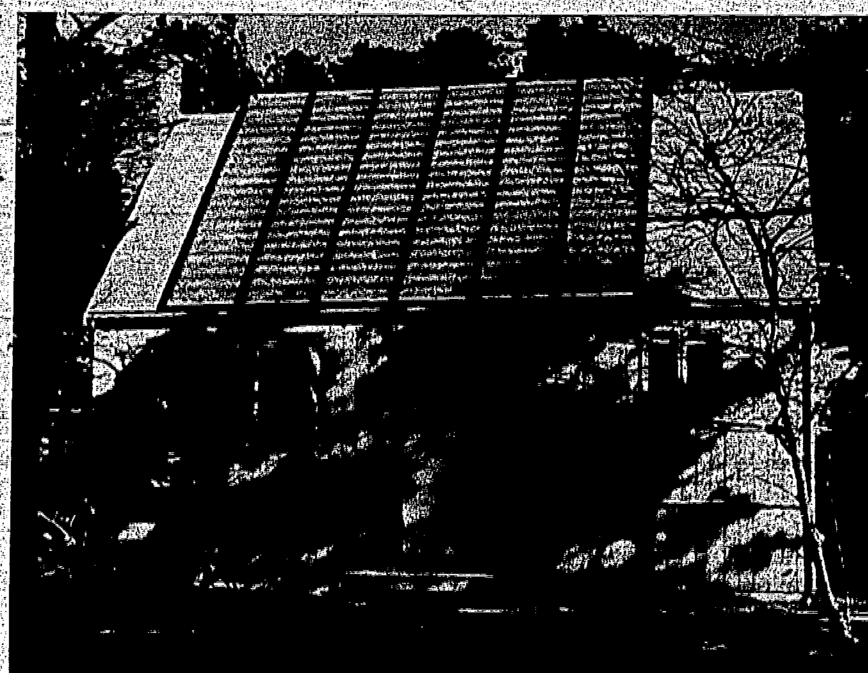
By Richard Stepler

Suddenly, it seems everyone's talking about sun power. It makes newspaper headlines and television specials. Even your next-door neighbor may be talking about putting solar collectors on his roof.

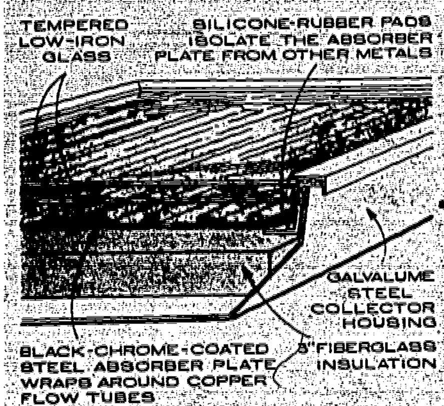
Why suddenly? Much of the interest was sparked by the brutal winter of 1976-77, which shocked many Americans with its record high heating bills. Perhaps the catalyst was provided by President Carter's proposal for solar tax credits, included in his energy message last April. In any case, the public's interest in solar energy is at an all-time high. And a record number of manufacturers are now able to provide the most reliable and economical solar-heating equipment ever.

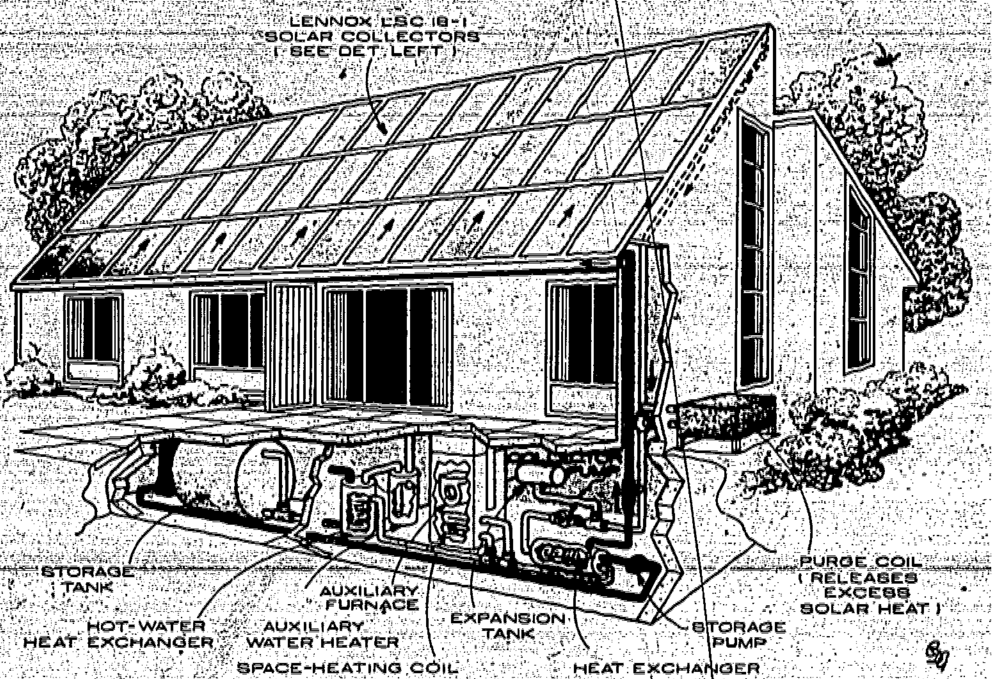
Bigger companies are now producing solar hardware. The names should be familiar:





Acorn Sunwave 420 Energy System is designed for company's factory-built homes, garages. Copper tubes are clamped to aluminum absorber plate in 4-by-20-ft. collectors; glazing is fiberglass-reinforced plastic. Untreated water is pumped through collectors to vinyl-lined plywood storage tank; collectors self-drain in subfreezing temperatures. Installed cost of complete six-panel (420-sq.-ft.) system: $7200.





Lennox Solarmate space- and water-heating system uses transfer fluid to carry heat from collectors to space-heating coil, storage tank, and water heater. Backup is oil- or gas-fired Lennox furnace or heat pump, plus water heater. Collector's steel absorber plate (detail, above) is formed around copper flow tubes and sealed with solder filler. Complete system will be offered later this year; hot-water system (available now) costs from $1200 to $3000, installed.

Iowa-based Lennox Industries, in cooperation with Honeywell, will market a complete solar-heating package (see drawing) through Lennox's 6000 dealers. Aldready available is a domestic hot-water system (average installed cost: $1500). A dealer-training program covering the design, installation, and servicing of solar-heating systems began this summer.

General Electric, which initially offered a flat-plate collector with its solar-assisted heat-pump system (see drawing), has now developed an advanced evacuated-tube collector. GE plans to have the units in production at its Valley Forge plant about the time you read this.

ITT's Fluid Handling Division offers pumps, heat exchangers, and valves for solar heating systems. The company also provides a design manual to help contractors and engineers plan solar projects.

Glass manufacturers–Owens-Illinois and Libbey-Ownes-Ford–are joining rival PPG in the solar fluid. O-I is putting its Sunpak evacuated-tube collector on the market this hear (see last month's cover story for a description of tow prototype systems). LOF has taken a more conventional approach with its Sun Panel–a double-glazed flat-plate collector.

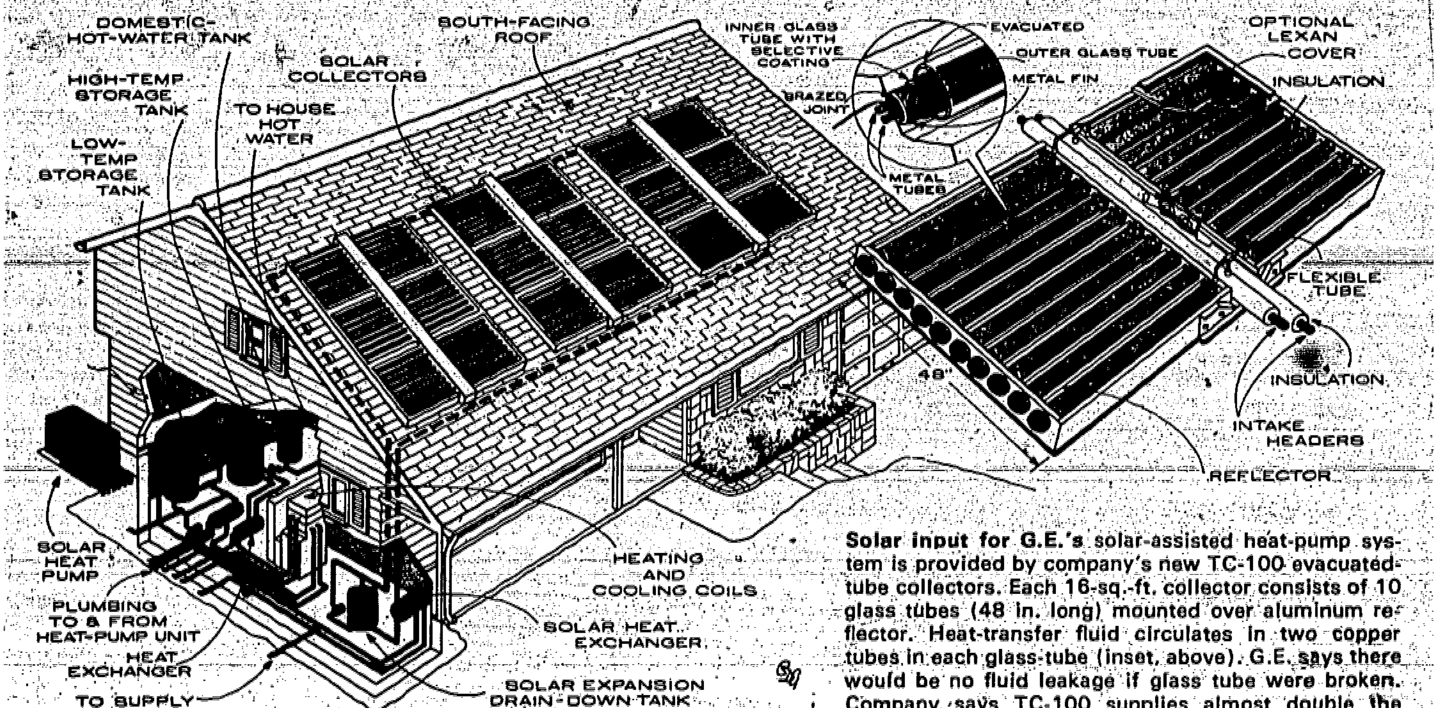
Westinghouse's new Solar Heating and Cooling Division offers a solar-assisted air-to-air heat pump, using air-type collectors made by Sunworks (see drawing). Al Weinstein, division manager, says a system costs about $10,000.

And giant automaker GM, through its Harrison Radiator Division, plans to develop and market solar hot-water system in 1978.

New, small companies are introducing some of the most exciting innovations, however:

Daystar Corp., founded only two years ago, has developed a flat-plate collector that features an ultrathin polymer structure between the cover glass and absorber plate. It both enhances solar transmission, says Daystar, and reduces heat loss due to radiation and convection. At least one independent engineering firm rates Daystar's collector above all others tested.

A new idea in control systems is complete prepackaging. Ecosol Ltd. offers an energy-recovery system that includes pumps, valves, electronic controls, an air handler, and a backup heat pump in a unit that very much resembles a conventional oil-or gas-fired furnace. That's no accident. *New trades are not going to be installing solar heating systems*, says Ecosol vice-president Bruce Rodin. We wanted a unit that would be familiar to electricians, plumbers, and heating contractors. Price of Ecosol's model 101 system: $3900 to $4200.



Solar input for G.E.'s solar-assisted heat-pump system is provided by company's new TC-100 evacuated-tube collectors. Each 16-sq.-ft. collector consists of 10 glass tubes (48 in. long) mounted over aluminum reflector. Heat-transfer fluid circulates in two copper tubes in each glass-tube (inset, above). G.E. says there would be no fluid leakage if glass tube were broken. Company says TC-100 supplies almost double the energy of a flat-plate collector. Price: about $20/sq. ft.

And Minnesota-based Sun-source Systems Corp. has developed a *black-liquid system*—the collector structure itself is transparent extruded plastic with a reflective backing; a blackened heat-transfer fluid is the absorber.

Meanwhile, some companies are expanding their lines of solar systems and components:

. PPG, which offered a *Baseline* solar collector with an aluminum absorber plate two years ago, now offers three different models: *standard* collectors with copper or aluminum absorber plates; a *Poll Plus* collector for swimming-pool or domestic-water heating; and a box-type collector for higher-temperature space-heating purposes.

. Grumman, the aerospace company, has been marketing solar space-and water-heating systems since late 1975 'see **Solar Water Heaters You Can Buy Now**, May '76'. The company's Sunstream collectors were originally all-aluminum; now there's a version with copper tubing (see drawing).

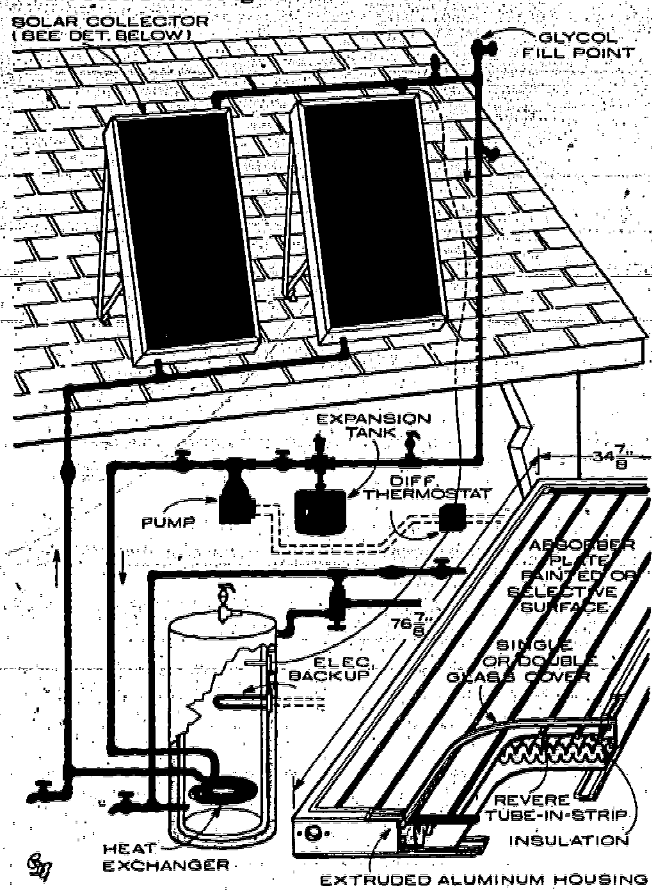
. Solaron, maker of the air-type space-heating system first reported in our March '75 cover story, now offers a domestic hot-water system, also with air as the heat-transfer medium (see drawing). Solaron reports that it now has distributors in 42 states.

Sunworks, a small independent company two years ago, has since been purchased by Enthone division of Asarco. In addition to its all-copper liquid-type Solector collector, the company now has an air version.

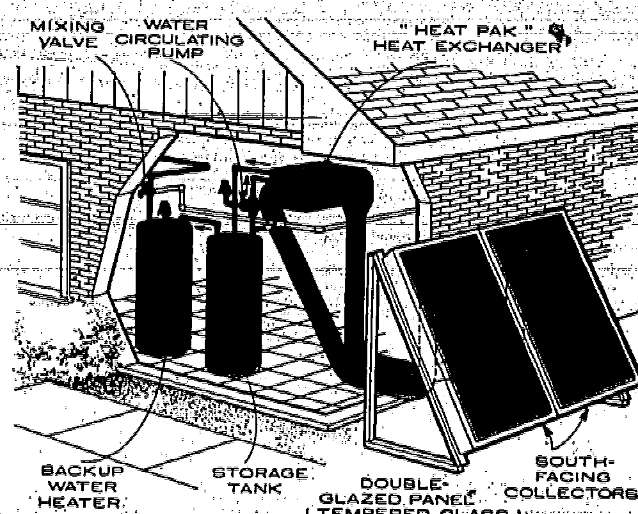
Revere, another company covered in our March '75 issue, has introduced its Sun Pride water-heating system, as well as a new *Tube-in-Strip* collector absorber plate (see drawings). Revere offers collectors for both new construction and retrofitting, plus a special collector for swimming-pool heating.

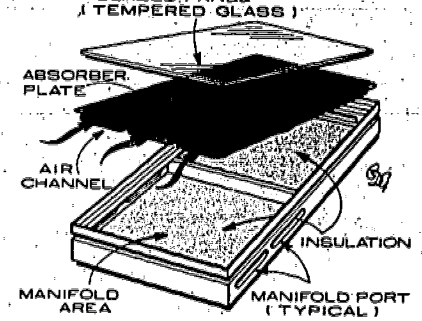
About a year ago, State Industries, the water-heater manufacturer, introduced a solar water-heating system that featured two aluminum collectors, Dow Corning's silicon heat-transfer fluid, an 82-gallon storage tank with backup electric element, plus controls. Price: $1895. A second-generation model recently unveiled uses a porcelain- and enamel-finished steel absorber plate with distilled water as the heat-transfer fluid. If temperatures drop below freezing, and air pump forces the water out of the collector. Price of the new system, which carries a 10-year warranty: $895.

Rho Sigma, a company that specializes in solar controls, has introduced a proportional control, which, instead of merely providing all-on or all-off control of solar collection, turns the heat-transfer fluid on and off gradually, according to the temperature differential between collectors and storage. This has advantages on days of low insolation, claims Rho Sigma's president Robert Schlesinger.



Revere now offers Sun Pride, a complete water-heating system with a glycol/water heat-transfer fluid. Price of components, including two collectors and a storage tank is $950. The company estimates installed price of $1500.





Solaron has added an air-type hot-water system to its line of solar products. There are no freeze-up or corrosion problems with this type of system, which uses water pump, blower, air-to-water heat exchanger. Price, about $1100.

Solar builders

The housing industry is hardly taking second place in all this activity:

. Acorn Structures, the precut-home company, manufactures a complete solar space- and water-heating system designed to fit its line of contemporary homes (see drawing).

. American Timber Homes has commissioned Donald Watson (architect for our March '75 cover home) to design two solar-house packages. The Solartran homes use Sunworks collectors for space and water heating, plus a greenhouse for passive solar heating.

. Stanmar, another maker of precut houses, says it will custom-design solar homes for its clients, using off-the-shelf hardware.

. A California builder, Blue Skies Radiant Homes, recently sold out its first solar subdivision. Price range of the homes: $37,900 to $46,400.

All this activity adds up to some impressive statistics:

In the March '75 issue, PS listed 33 manufacturers of solar equipment; a recent survey by PS staffers revealed nearly 200 companies–too many, in fact, for a complete listing in this issue. (To get your copy of the PS Solar Manufacturers' Index, see the last paragraph of this article.)

Solar-collector production, which totaled 136,000 square feet in 1974, reached nearly two million square feet in 1976, Richard Stoll, with the Federal Energy Administration's Task Force for Solar Commercialization, estimates that more than four million square feet will roll off the assembly lines in 1977. Those figures do not include low-temperature (under 100 degrees Fahrenheit) collectors for swimming-pool heating. According to Stoll, 3.875 million square feet of this type of collector alone were manufactured in 1976.

And earlier this year, Harvard's William A. Shurcliff issued the 13th and *final* edition of his **Solar Heated Buildings: A Brief Survey.** Shurcliff says he's quitting now *because the number of solar-heated buildings is increasing so fast, and duplicate designs are becoming increasingly common.* Shurcliff's survey shows that by the end of 1970, there were 24 such structures in the U.S. By the end of 1976, the number had climbed to 286. "The number of solar-heated buildings completed in the U.S. in 1976–namely 146–exceeds the total number completed in all preceding years–namely 140," he adds.

Federal, state, and local action

Government participation and encouragement is proceeding apace, though not with the vigor some solar advocates would like to see.

While no legislation to benefit solar installations has been enacted at the federal level yet, at least 35 states have already passed or are considering solar-related laws. These range from property-and sales-tax exclusions to so-called sun-rights laws. The latter would prevent your neighbor from planting a tree or building a fence or other structure that would shade a solar collector already installed on your property. (The city of Los Alamos, NM, has the first such ordinance, which prohibits casting a shadow on a solar collector between 9 a.m. and 4 p.m.)

Federal agencies are stepping up their solar-promotion programs. ERDA recently added 80 projects to 32 already selected in a five-year solar-demonstration program for nonresidential buildings. HUD has just announced grants in its third-cycle residential demonstration program. Grants in cycles one and two went to projects involving more than 1500 housing units.

How's business?

In a word: booming. Grumman's Joe Dawson described it recently as *unreal–one of our dealers in upstate New York just sold solar systems for three homes, a library, and a medical building in one week.* At last count Grumman had more than 70 dealers in 24 states and Canada.

G.E. says it has already sold out its production of evacuated-tube collectors through the end of this year. And that was before the company had even begun making them.

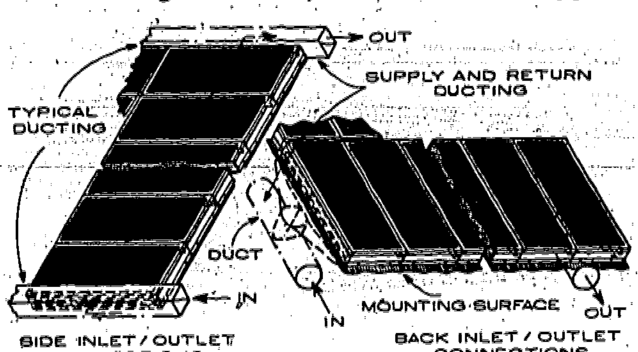
Bill Heidrich of Revere says that in the first quarter of 1977 business doubled over the same period in 1976. Heidrich sees a growing number of commerical and industrial installations. "Initially, all our systems went into residential construction; now we're installing the equipment in schools and hospitals," he says.

Ray Williamson, Solaron's marketing administrator, says that the company sold more solar gear in the second quarter of this year than it did in all of 1976. "If we didn't have access to extra manufacturing capability," says Williamson, "we couldn't keep up with demand."

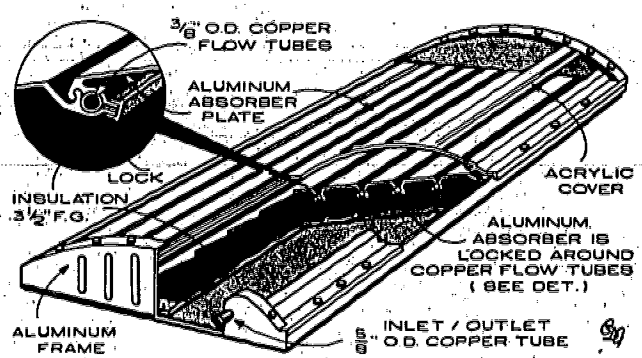
And the price?

The initial investment in solar hardware is substantially higher than that for conventional space- and water-heating equipment. A typical solar water-heating system–with two or three collectors, storage tank, and controlls–will run from $1000 to a little over $20000, installed. Add space heating, with more collectors and larger storage, and you're in the $500 to $10,000-plus bracket.

Charles Pesko, Daystar's marketing manager, says that a present fuel prices Daystar's solar equipment has a payback period of eight to 10 years. (That's the time it takes fuel savings to cover the cost of the solar hardware.) Daystar's prices: $2000 for a water-heating system; $8000 for a space- and water-heating system with 210 sq. ft. of solar collectors. "We really need to get the payback period down to under five years to get into the mass market," says Pesko. "Now–honestly –we're selling to an elite, first-on-the-block type of market."



Grumman's Sunstream division offers Finplank, a collector with copper flow tubes locked into aluminum absorber plate (inset). Price of 27-sq.-ft. model 60F collector: $300. Original model 60A, with aluminum absorber: $275.



Sunworks, maker of all-copper liquid-type collector, also offers an air-type model, which the company recommends for space heating. Absorber is selectively coated copper sheet. Collector (3 by 7 ft.) costs $12-14 a square foot.

John Dixon, of Dixon Energy Systems, a New England-based solar manufacturer, puts it this way: "Certainly, solar space heating in northern climates is not yet cost-effective. Solar water heating, however, is much better, and we think that payback periods of the order of 10 years are reasonable. Claims of much shorter payback periods, we think, are simply wishful thinking and will not be realized until oil and electricity prices have increased considerably. This, of course, is very likely to happen over the next decade or so, and then solar energy will be very cost-effective."

Dixon feels that solar equipment isn't going to come down in price, however: "The manufacturer of collectors is largely a matter of cost of materials, not labor. The installation, of course, is labor-intensive. But we don't expect that the materials used in solar collectors are going to get less expensive. Nor do we expect the cost of installation to decrease. Rather, all these costs are likely to increase along with noraml inflation."

Two recent government-sponsored reports reflect the consensus on the present state of solar economics:

- In a study prepared for ERDA, THE Mitre Corp. indicated that solar could already compete with electric heating in New York and in 12 other cities–including Atlanta, Los Angeles, and Seattle. But Mitre concluded that solar would be competitive with oil and gas only if the cost of installing the solar equipment was reduced 50 percent, or if these conventional fuels rise in price.

A computer team from the University of New Mexico predicts that solar will be cheaper than oil or gas in 26 states by 1985. In a study prepared for Congress' Joint Economic Committee, the team also concluded that solar is already cheaper than electric heat for new homes in 30 states.

Should you go solar?

Some factors to consider before you opt for solar: your space-and water-heating requirements; climatic zone; availability of sunshine; present fuel costs and what they're likely to be in 10 years–if that fuel is still available; means of financing the solar equipment (a high-interest loan could cut deeply into any projectes savings); and whether there's a suitable location for solar collectors and other equipment on your home or property. Armed with these facts (the sources listed at the end of this article will help you determine them), you're ready to talk to dealers and get quotes on systems.

To get your copy of the PS Solar Manufacturers' Index, send a stamped, self-addressed envelope to: Solar Index, Popular Science, 380 Madison Ave., New York, NY 10017.

For Further Information

Have a question on solar heating you want answered fast? You can dial the National Solar Heating and Cooling Center toll-free: (800) 523-2929; in Pennsylvania, call (800) 462-2983.

Buying Solar, a booklet put out by the FEA, will help you decide if solar will work for you. It's $1.85 from the Superintendent of Documents, U.S. Govt. Printing Office, Washington, DC 20402. (stock no. 041-018-00120-4).

Energy: The Solar Prospect, by Denis Hayes, ought to fire up even the solar pessimist. The booklet is $2 from the Worldwatch Inst., 1776 Massachusetts Ave., NW, Washington, DC 20036 (Worldwatch Paper 11).

Designing and Building a Solar House, by Donald Watson. This well-illustrated book is $8.95 (paper), $12.95 (hard cover) from Garden Way Publishing, Charlotte, Vt. 05445.

The Solar Home Book by Bruce Anderson (see review in **Shop Talk**, Jan. '77). $7.50 from Cheshire Books, Church Hill, Harrisville, NH 03450.

Solar Heated Buildings: A Brief Survey, 13th ed., by William A. Shurcliff. Capsule descriptions of the solar heating systems in 319 buildings in the US and abroad. $12 from Wm. Shurcliff, 19 Appleton St., Cambridge, Mass. 02138.

Economic Analysis of Solar Water and Space Heating. Div. of Solar Energy, ERDA, $1.85 from Superintendent of Documents, US Govt. Printing Office, Washington, DC 20402 (no. 060-000-00038-7).

The 1977 SUN Catalog, a 126-page catalog of solar components from various manufacturers. $2 from Solar Usage Now, Box 306, Bascom, Ohio 44809.

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Solar basics

A solar heating system consists of collectors, storage (water tank or rock pile), interconnecting pipes and/or ductwork, pumps and/or blowers, controls (differential thermostats, sensors), plus auxiliary heat source(s)—oil, gas, or electric furnace or heat pump. The latter are needed because no solar heating system can supply 100 percent of your needs and be economically competitive with conventional sources. Most systems aim for 50 to 75 percent of total heating requirements. (If a solar heating system were designed to supply *all* your heating requirements in the coldest months, it would be oversized for the balance of the heating season.)

The heart of any solar heating system is the collector; most often, these are flat-plate collectors—glass- or plastic-covered boxes that contain a metal absorber plate—usually copper, aluminum, or steel, or a combination of these metals. Other types of solar collectors include evacuated-tube collectors.

The sun's rays heat up the collector's absorber plate, and a heat-transfer medium—a liquid or air—carries off this heat for heating either space or water directly, or to storage for later use—at night or during cloudy weather.

An insulated pile of rocks is the storage medium in air-type systems; a water tank stores heat in liquid systems. A variation is the system developed by Dr. Harry E. Thomason, which uses a combination rock bed and water tank #PS, Mar. '74'. The systems are usually capable of storing enough heat to carry a house through three to five days of cloudy weather before the auxiliary heating system comes on.

How much collector you'll need depends on how much space (or water) you plan to heat. Rules of thumb: Collector area should equal one-third to one-half the square footage of the space to be heated; or one square foot of collector for every gallon of water to be heated daily.

Air systems, while not subject ot the leaking, freezing, and corrosion problems of the liquid systems, do require bulkier storage (rocks require up to twice the volume to hold the same amount of heat as water); also, ductwork takes up much more space than piping. These may be primary considerations in refrofit installations. And air systems are not as well suited as liquid systems for heating domestic water. (Solaron, however, claims to have overcome this disadvantage with its domestic system.)

Liquid systems deal with freeze-up problems in one of two ways:

• The collectors and all exposed pipes automatically drain when the temperature drops to freezing.

• The heat-transfer fluid contains an antifreeze or is a special liquid with a low freezing point. Dow Corning, for example, claims that its silicon-based fluid prevents freezing, boiling, and corrosion problems. It can operate, says Dow, from -50 degrees Fahrenheit to +600 degrees Fahrenheit.

A differential thermostat keeps a solar system working—collecting heat when the sun's shining, and storing it when it's not. This device turns on a pump or blower when a sensor mounted at the collectors indicates that the collectors are hotter than storage. When the collectors are *cooler* than storage, the differential thermostate stops the circulation until the next sunny day.

DAVE KRUSCHKE, SOLAR HOMESTEADING IN A BIOSPHERE

By E. F. Lindsley

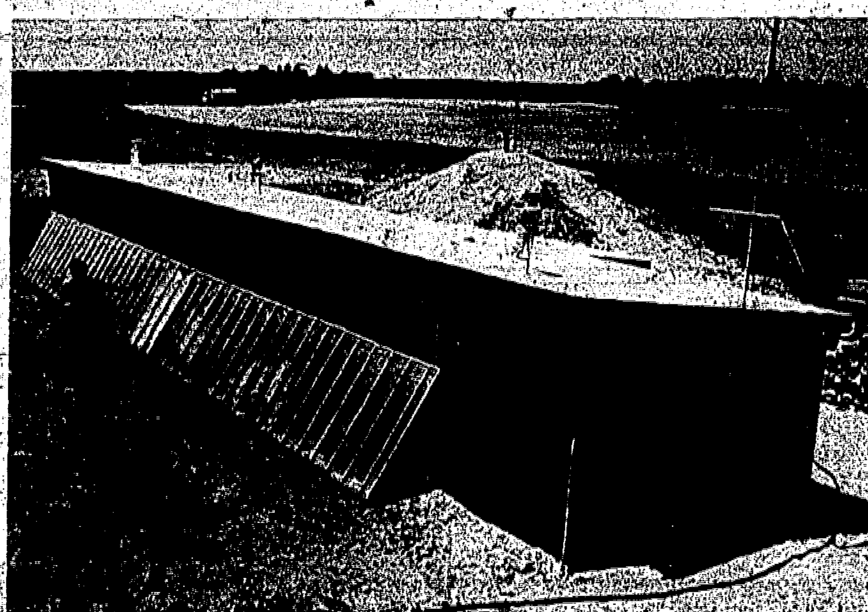
The house is not handsome, but Dave Kruschke didn't try to make it so. Situated here in the sand country of north-central Wisconsin, it is a successful and interesting experiment in *energy homsteading*—an indoor enviroment that features solar heating and indoor vegetable gardineing, even in wintertime.

The day I walked into the long, narrow building (64 by nine feet) was a typical spring day for this area—not cold, but not pleasantly warm either. When I went through the heat-trap entrance, I immediately felt a snug warmth and caught the lush aroma of growing things. I saw 21 55-gallon metal drums, filled with five tons of water, side by side near the *garden plot*. Dave Kruschke calls the setup his *biosphere*.

Kruschke made the house as simple and as rugged as he could It's of pole construction (6x6 timbers) with plenty of insulation: six inches in the roof, plus four inches of foam in the exterior plywood walls. The house rests on a 3 1/2-inch concrete slab with two inches of foam insulation underneath. Along the south edge of the slab runs the 4 1/2-foot-wide gardening trench, foam insulated on bottom and sides, and filled with earth.

The sun supplies half

Sunlight for growing and heating streams through the lower 5 1/2-foot section of the south wall, which is made of a double layer of four-mil polyethylene sheeting over 42 2x2 struts. A good deal of solar enegineering went into Kruschke's design. He estimates that this 308 square feet of south-wall collector provides his home with some 25-million Btu annually. After calculating heat losses, he determined that the only supplemental heat he'd need could be provided by a wood stove.



Exterior view shows the sloping, plastic-covered stretch of south wall that serves as a solar collector for both heating and growing food.

Dave Kruschke waters vegetables in indoor trough beside polyethylene south wall. Water-filled metal drums store heat.

The stove's output is calculated at 24 million Btu per year; at 45 percent efficiency, Kruschke needs about 54-million Btu of wood fuel. The sun, therefore, provides about half his total heating needs.

As the sun set, I watched the technique Kruschke devised to prevent the day's heat from escaping back to the outside. He snaps two-inch-thick foam panels into place against the sloping inner face of the wall. A short wooden arm, sprung by a screen-door hinge, kicks up against the top of each panel to secure it for the night. Not perfectly airtight, but fairly snug and effective, says Dave.

Storing the heat

At first, Kruschke had no means of storing heat, and the house tended to overheat during the day and cool off rapidly at night. As a solution, he installed those 21 water-filled drums, which absorb some of the daytime heat and release it more slowly at night (Even so, the house must still be ventilated during the day.) The drums can store about 100,000 Btu, but Kruschke admits their inefficiency: They are not interconnected, and the water in them doesn't circulate.

Kruschke puts it this way: On a day with good sunshine, the water in the barrels would, by evening, be about 65 degrees at the bottom, 75 degrees in the middle, and a little over 85 degrees at the top. In January, this is not enough to get you through the night, but if the fire goes out, we don't wake up freezing. It's also nice in the springtime, he adds, when the water temperature falls extremely slowly below 70 degrees.

Dollars-and-cents savings

Translating all this into energy savings is not as simple as Dave makes it sound. He says: We burn a little wood in October, a little in November, quite a lot in the next three months, a little in Markch, and almost none in April. He estimates that he's saved $101 in fuel oil over last year–equivalent, he says, to $56 in natural gas and $249 in electricity. This suggests to me that his insulation must be very effective. Even without the 25-million-Btu solar assist, his heating bill would have been very small. Kruschke hasn't, by the way, placed a value on the vegetables he grew and consumed.

Some after thoughts

I have conflicting feelings about the project. True, the house was inexpensive to heat and inexpensive to build (the overall $13/sq. ft. costs includes 5 1/2 acres, well, septic tank, and plumbing). Still, I was oppressed by the lack of window space, the single entrance door, the absence of a garage and shop space. I am especially dubious about a heating system that doesn't tend itself. Of course, even the pioneers knew that windows waste heat, that doors cause drafts.

Nicely drawn plans for this biosphere are being offered for $3.95; order them directly from Dave Kruschke at Route 2, Box 34A, Wild Rose, Wis. 54984.

Also, a frined of Kruschke, formerly with the nearby Windworks alternate-energy research group, wants to hear from other homesteaders who are working along similar lines. Send information to Steve Hartschel, Box 85, Route 4, Waupaca, Wis. 54981.

K. D. TENTARELLI: FOCUSING COLLECTORS HEAT A NORTHERN HOME

By Edward Moran

Even during frigid New Hampshire winters, the sun can be commandeered into providing into providing low-cost heat and hot water. So says Ken Tentarelli, this month's self-taught solar do-it-yourselfer. He devised a setup that includes motor-driven focusing collectors, thermostatic controls, and three-tank water storage. The system provides hot water for domestic and swimming-pool use, as well as space heating for a basement family room.

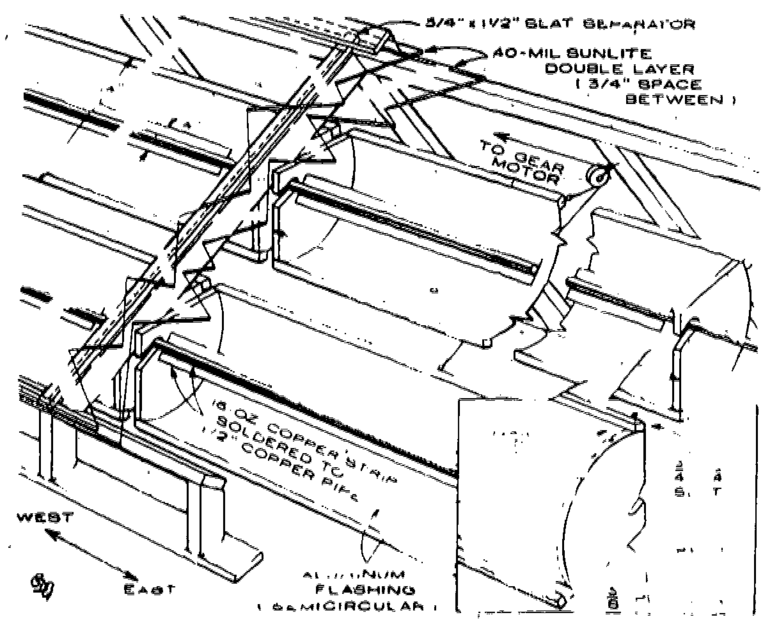
Motor-driven collectors

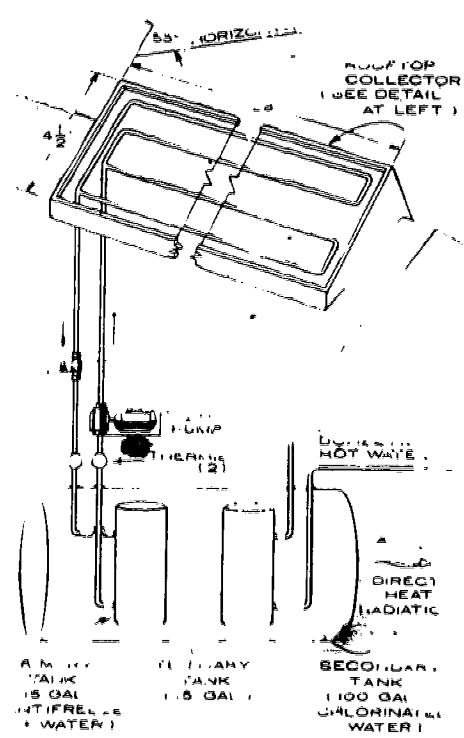
Most rooftop collectors in use nowadays are of the flat plate variety efficient and easy for a DIY'er to assemble in his garage workshop.

But Tentarelli advanced another step or two. He felt he needed a greater concentration of sunlight in his northern climate (latitude 48 degrees), so he built and installed an array of semicircular reflectors that aim sunlight even more directly on the water-bearing copper piping. These reflectors can be pivoted by a small motor to change their angle seasonally according to the sun's azimuth. Total expenditures for the collector: only $3 per square foot. [Our October cover story details some of the principles Tentarelli used in his collector design.]

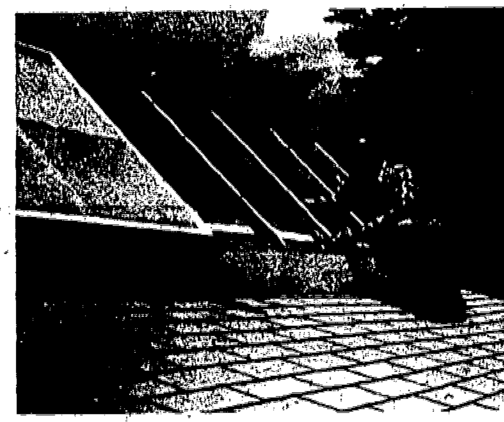
This is a closed loop system: A 50/50 water/antifreeze solution circulates through the collectors and transfers heat to the potable water loop in the triple storage tank (see diagram).

Tentarelli used 1/2" copper tubing in the collectors, for added thermal efficiency, he soldered





Focusing collectors employ semicircular reflectors made of flashing to aim sunlight onto copper piping (above). Gear motor (not shown) pivots reflectors to adjust to sun's azimuth. Heat radiating from insulated tank (right) warms basement room.



16-oz. copper strips around the pipes, then sprayed all surfaces with High-temperature flat black paint--the variety that's used for barbecues.

To make the reflectors, he bent aluminum flashing into a semicircular shape, and made a *trough* by gluing and nailing wooden strips along its length. He glued and screwed plywood braces to the ends, and *hung* the reflectors on the pipes (see diagram) so they can be rotated as needed. Lengths of twine serve as drive cables to the Airborne Sales motor.

Tests show collector temperatures jumped by 25 degrees when the reflectors were added. I was worried about oxidation of the flashing, Tentarelli told me, so I experimented with test strips, too: chrome-plated aluminum, metallized Mylar, even kitchen aluminum foil. When I opened up the collectors months later, I found none of them had deteriorated.

The collectors are double-glazed. Two sheets of Kalwall's 40 mil Sunlite translucent paneling were nailed to the plywood framework that houses the plumbing (see photo). Before nailing the sheets down, Tentarelli spread beads of silicon rubber between sheet and frame to achieve a watertight seal. The glazing doesn't sag even under an ice and snow load, he reports.

Basement storage tanks

Down below, water is stored in three tanks designed for heat exchange [illegible] closed 15-gallon tanks are submerged in a [illegible] 100 gallon galvanized steel tank that is itself enclosed in a urethane-insulated chamber. The primary tank contains the antifreeze/water fluid that circulates in the collector loop at a rate of four gallons per minute. The secondary tank contains chlorinated water: It stores heat and passes it to the tertiary tank that can be connected manually as either a domestic water preheater or a swimming pool heater. Tentarelli used the multitank approach as a failsafe mechanism. If either the primary or tertiary tank springs a leak, it will overflow into the secondary tank and not contaminate domestic water. Heat transfer in the secondary tank is by natural convection. "Under dynamic conditions," he says, "I have measured temperature differences as great as 18 degrees between primary and secondary fluids."

Controls

Two thermi[illegible] outlet; the pump is started at differential of 15 degrees and is stopped at a differential of 3 degrees. The zone valve is extremely important. It prevents circulation in the primary loop when the pump is off. Without this valve, water could thermosiphon back up to the collectors at night, and gained heat would be lost.

Savings

Tentarelli estimates his system has saved him an average of 200 kwh per month over the past year. At 5¢ per kwh, that adds up to about $120. He's been able to save an additional $80 in propane for his above-ground swimming pool; last June, the family enjoyed frolicking in 82 degree solar-heated water.

To ask a specific question, send a stamped, self-addressed envelope to K. D. Tentarelli, Woodside Dr., Atkinson, NH 03811

DINH KHANH: SOLAR BUBBLE KEEPS HIS WATER WARM

By Edward Moran

Dinh Khanh is no novice when it comes to energy conservation. In his native Vietnam, he helped edit a UN publication (called, coincidentially, Popular Science) that promoted energy alternatives for that oil-short nation. After moving to Florida two years ago, he translated a long-standing interest in thermodynamics into a workable and attractive solar water heater for his home. And he's working on an innovative alternative-vehicle project that we hope to tell you about in an upcoming issue.

Khanh's heater is different from the rooftop-mounted flat-plate panel that's currently the most common type of solar collector [see Five solar water heaters you can build, PS, May']. Instead of pumping his water through yards of convoluted piping, Khanh does what comes logically in his mild climate: He butts a 66-gallon water tank against the south wall of his home (see photo and drawing), encloses it within an insulated *bubble*, and achieves water temperatures that are nothing to shiver at.

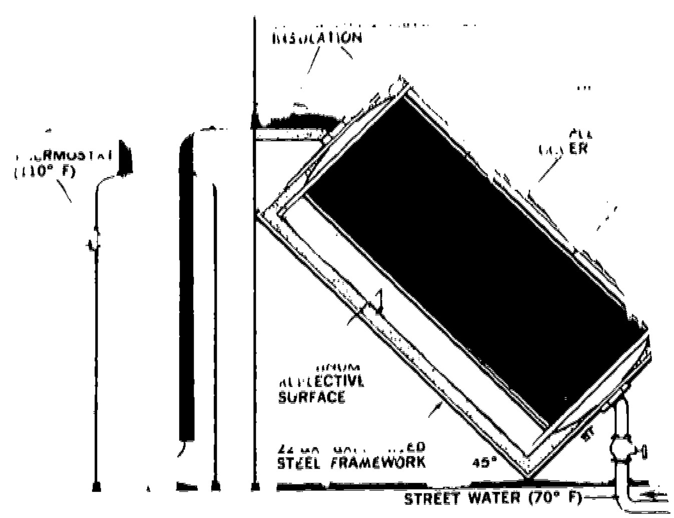
Materials cost about $180, and after a year's operation, the heater has saved the Khanhs more than half of their water-heating bills. This summer, says Khanh, I foresee an 85% saving

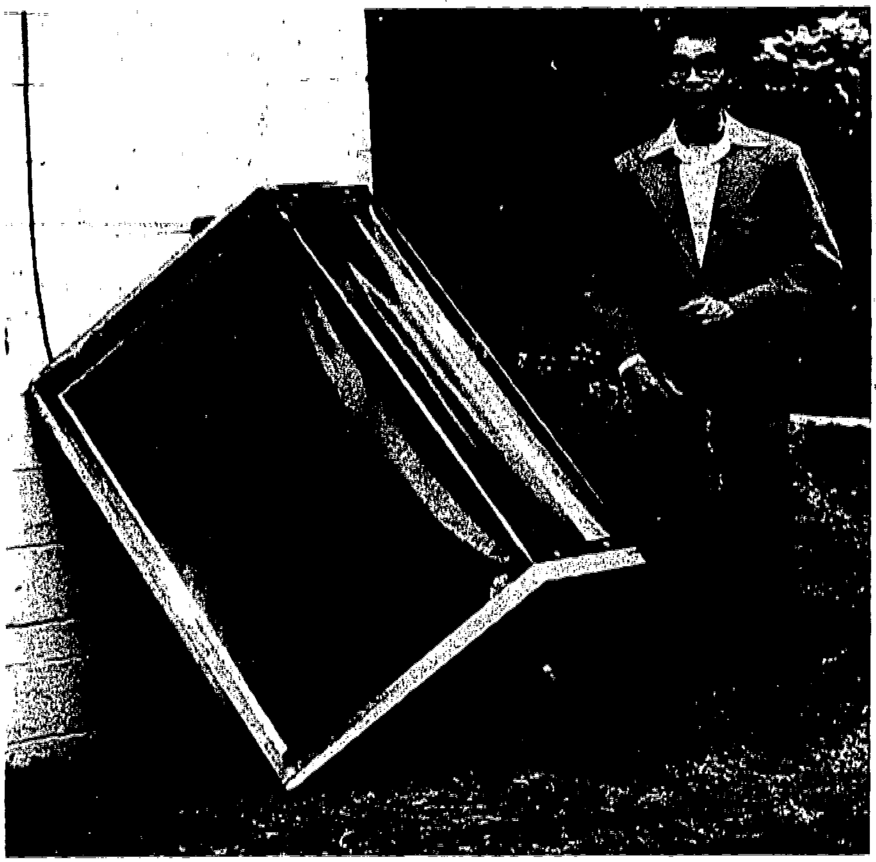
Inside the bubble

Khanh designed his heater using the principle that a [illegible] cylindrical tank would [illegible] sun's rays from sunrise to sunset (on half of its area, of course) when placed on a north-south axis tilted according to latitude. Calculating tilt angle is simple, merely add 10 degrees or so to your latitude (The drawing shows a 45 degree angle of inclination, which is about 15 degrees more than the latitude of Gainesville, Fla)

The tank is enclosed [illegible] transparent materials: Tedlar inside to trap infrared radiation and Plexiglas outside to retard heat loss

The main thing to [illegible] ratio between your tank's capacity and circumference that gives the best balance between a





Insulated, enclosed 66-gallon tank is butted against the south wall of house.

reasonable temperature rise and heat retention through the night. I recommend using 66-gallon or 42-gallon tanks that have diameters between 16 and 20 inches."

The bubble's framework is a sandwich, with aluminum on top (for reflection) 22 ga galvanized steel on the bottom, and fiberglass in between. The aluminum, placed four inches below the tank, is polished, and gives a concentrating ratio of about 1.5. The box's ends are formed with two 2x4 strips of pine. Insulation for the tank's end caps is provided by two inches of fiberglass and one inch of Styrofoam cut to shape and glued with a rubber adhesive.

Construction tips

It takes a little practice to bend the Plexiglas properly says Khanh, suggesting [illegible] with a strip heater provided by plastics manufacturers. When screwing the Plexiglas in place use large washers with rubber cushions, and drill oversized holes in order to prevent cracking.

This heating unit is designed for a relatively mild southern climate so [illegible] can be used directly, without a heat exchanger. Khanh feels that its usefulness could be extended to colder areas if another layer of Plexiglas were added. (He hasn't tried this, however; perhaps a more northerly experimenter might test this out and share his or her findings in a future article.)

Freezing, then, poses no problem, Khanh tells us that it would take really bad weather to freeze 65 gallons of water—about five days with no sun at all and an ambient temperature of 0 degrees Fahrenheit. Even if this happened, the ice would have room to expand because at the top of the tank, an air bubble is left above the outlet orifice, which is located at the center of the tank and not the highest spot (see drawing'.)

Performance data

Proof that the Khanh heater can be a workable unit for millions of households is suggested by the following data. Even on a *bad* day last winter, when outside-air temperatures ranged from 25 degrees-65 degrees, the solar tank supplied 90 degree water to the series-connected electric water heater, which raised it to a preset 110 degree level. Even after a night of subfreezing temperatures, the water in the tank remained at a comfortable 80 degrees overnight. And there have been days when the water temperatures reached 110 degrees in midafternoon, rendering the conventional heater superfluous.

Things get even better in warmer weather. This spring, Khanh's heater was tested at Santa Fe Community College in Gainesville. Over a two-week period in April, daytime water temperatures averaged between 135 degrees and 140 degrees, and nighttime readings slipped below 105 degrees only once--to register 98 degrees.

To take full advantage of the solar heated water supply, the four members of the Khanh family bathe in the evening, when temperatures are highest. And, as a further step toward conservation of resources, they have limited their daily consumption of hot water to the 60 gallons provided by the tank--about one-third less than that used by the typical American family.

To ask a specific question, send a stamped, self-addressed envelope to Dinh Khanh, [illegible] 12th Terrace, Gainesville, Fla. 32601

'S' ROTOR DEMONSTRATES WIND POWER

By Martin Greenwald

Wind energy will play a significant role in future power generating schemes. The number of colleges and universities offering courses in wind energy machine construction, repair, and insulation continues to increase as people become more aware of the possibilities of on-site wind generators.

We have developed prototype wind generators for inclusion in an alternate energy devices curriculum within the secondary school industrial arts laboratory. The design, construction, and evaluation of such devices provides students with various learning opportunities, including individual or group working conditions. Problem solving situations are encounged with each design undertaken. Materials for this type of project are readily available, often at either minimal or no cost.

Designs. Most wind energy devices are either horixontal or vertical axis machines, depending on the axis of rotation of the blades, or rotor assembly. Vertical axis devices are generally less complicated to fabricate than horizontal axis models. Of various vertical axis designs, the Savonius, or S rotor, configuration is simple, yet efficient, for extracting useable quantities of power from the wind. Depending on its size and complexity, the machine can either perform work, as in pumping water, or generate electricity.

The Savonius design was developed in the early 1920s by S J Savonius a Finnish sea commander. He discovered that if two half-cylinders facing in opposite directions were mounted on a vertical spindle, the airflow through one would spill into the other, making the rotor assembly spin rapidly. The shape of the resulting airfoil and airflow path resembled the letter S, hence the short form of the name.

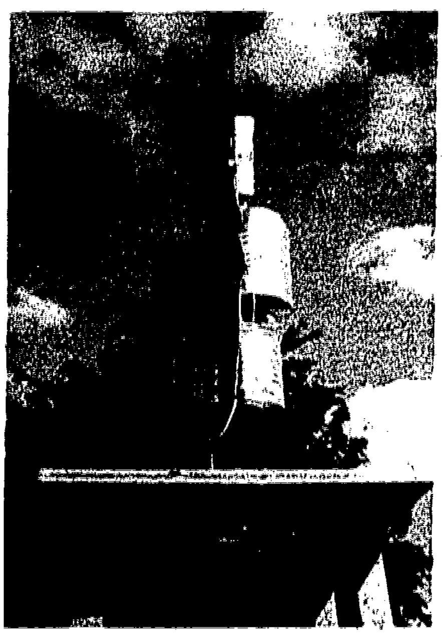


Fig. 1—This small three-stack rotor configuration drives a small dc generator.

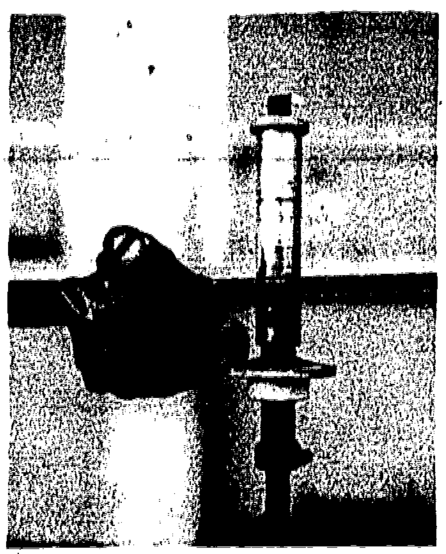


Fig. 2—The top bearing and generator drive mechanism for a small Savonius rotor.

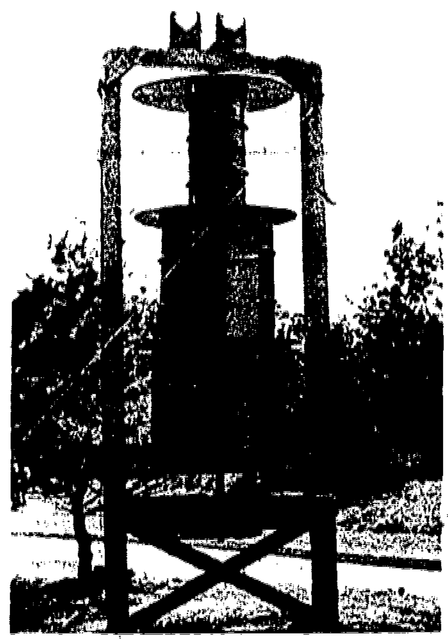


Fig. 3—A full-size generator; the unit drives an automobile alternator to charge a small bank of storage batteries.

Fig. 1 shows a three-stack S rotor configuration. The rotors, constructed of two No. 10 cans, are placed one on the other. The cans have been split in half, with the two halves offset approximately one-third their diameter to establish the airflow pattern necessary for rotation. Each stack is offset 120 degrees from the central axis of the machine to provide the proper air catching surface as the windmill rotates.

The center spindle is of 5/16" brass, silver soldered to each of the rotors. The top and bottom bearnings (in this case autoclave roller bearings) are welded into the top and bottom angle iron frames. A Slot-car (Fig. 2) is attached to the top frame and is driven by the rotation of the rotor

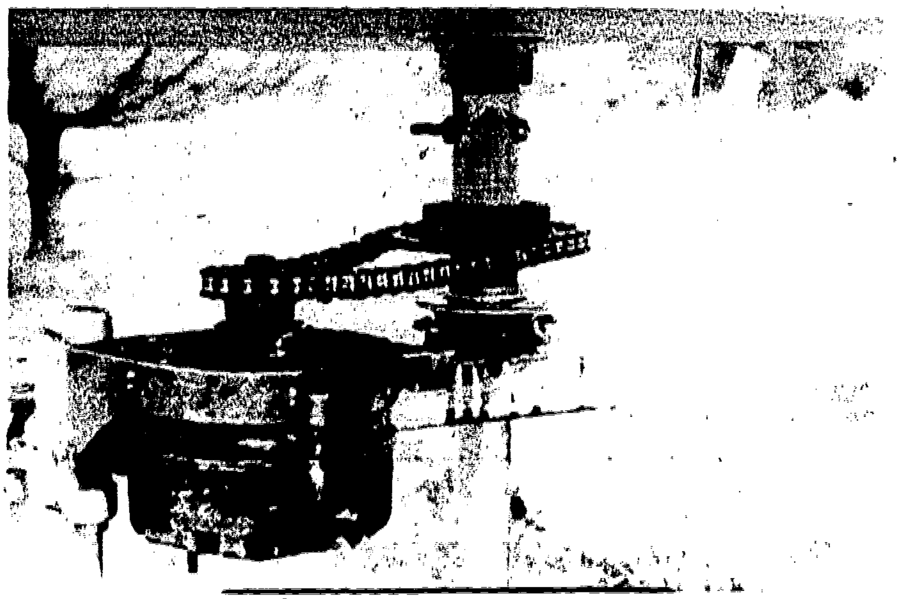


Fig. 4—Discarded throw-out bearings and a motorcycle chain drive provide a 1:10 power ratio.

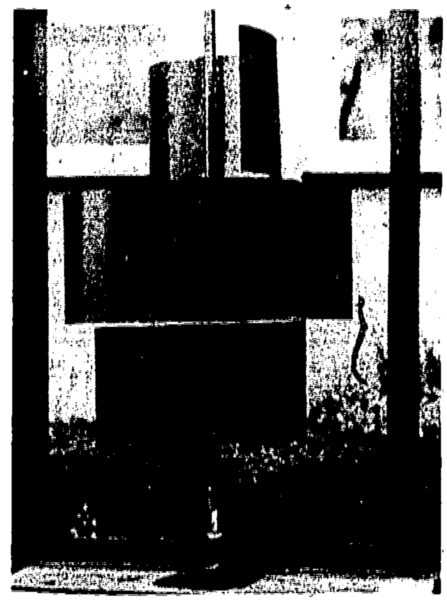


Fig. 5—This small rotor uses shaped aluminum sheet vanes.

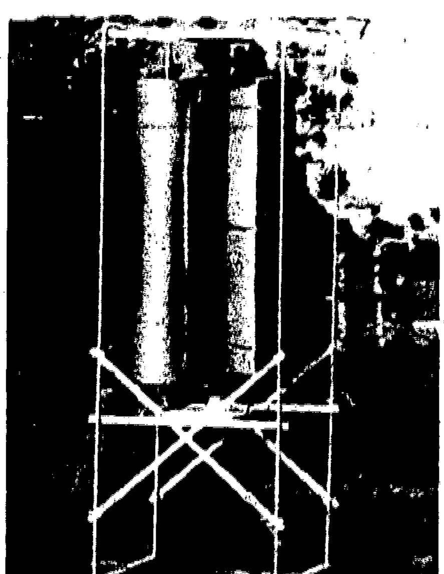


Fig. 6—Galvanized sheet steel rotor; steel drill rods radiating from the axis maintain shape.

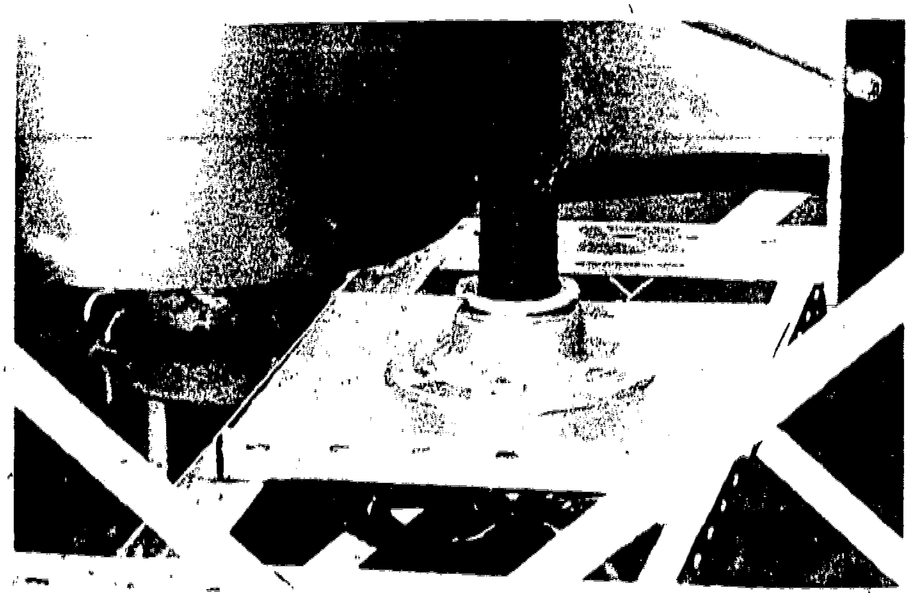


Fig. 7—Close-up of top side of drive shaft shows mounting detail of bearing assembly made from cast-off automobile axle hubs.

assembly. The motor is a permanent magnet dc generator, and when connected to a milliammeter will register current output in direct relationship to either an increase or decrease in wind velocity. The combination of lightweight and efficient bearing surfaces enables the machine to respond to subtle changes in wind velocity, thus demonstrating the S rotor principle while functioning as an efficient electric anemometer.

On a larger scale. The full-size electrical generating S rotor (Fig. 3) is designed to withstand significant amounts of centrifugal force built up by the rotor in high winds. The unit framework is constructed from 6" x 6" oak, fastened with hand-cut dado joints drawn together with 10" lag bolts. Resorcinal adhesive increases the strength of all jointed structural members.

The rotors are three 30 gal oil drums sawn in half on the portable circular saw. Rotor offset is similar to Fig. 1. Platforms, constructed from 3/4" CD exterior plywood and sealed with epoxy resin and two coats of oil base exterior enamel, are placed between each stack of rotors. Each drum is fastened to the platforms with 6" L brackets and 5/16" automotive grade machine bolts.

The center spindle is 1 1/2" iron pipe. Top and bottom bearings are Volkswagen thrust-out bearings, reamed to accept the pipe. The rotor drives a 55 A 14 V automotive alternator using a motorcycle chain drive mechanism with a ratio of 1:10 rotor to alternator speed (Fig. 4). Standard automotive ignition and charging circuitry is used for the battery charging circuit. The completed unit is anchored 24" in the ground and guyed at four points with 5/16" galvanized steel aircraft cable. Operating in prevailing winds of 12-15 mph, this unit will produce adequate current to charge a small bank of automobile storage batteries and deliver sufficient power to operate small power tools and lights.

Figs. 5 and 6 [illegible] vanes welded to the top and bottom plates [illegible] rotor [illegible]. The framework, generator and bearing assembly are similar to Fig. 1.

An elongated S [illegible] design [illegible] vanes are held in shape by a [illegible] the center spindle [illegible] the entire structure is framed in 1 1/2" slotted steel angle iron. The bearing assembly is made from discarded automotive axle hubs (Fig. 7). A chain drive mechanism similar to the unit in Fig. 3 is used to run the alternator driven battery charging circuit.