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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000604
Building Research Note, 1975-10

BUILDING RESEARCH NOTE

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Ottawa, October 1975

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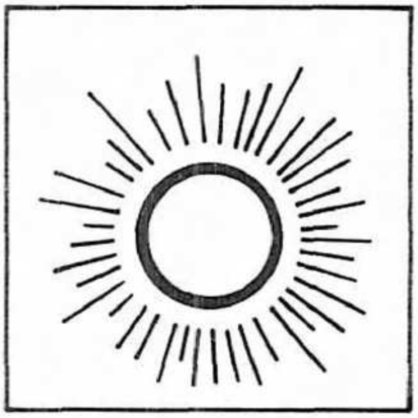
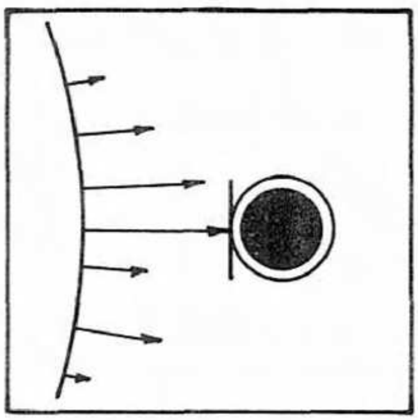
THE SUN

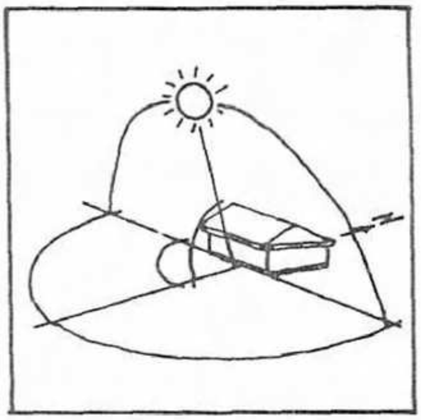


It has been calculated that the sun shines with a constant power of 380 million billion billion watts per second. Through two fusion reactions, the sun transforms an inconceivable 657 million tons of solar hydrogen into 652.5 million tons of helium ash every second. The remaining 4 1/2 million tons of mass is converted to solar radiant energy. It is this process that obeys Einstein's law $E = mc^2$. The sun's energy, for all practical purposes, represents an unlimited supply of radiant energy.

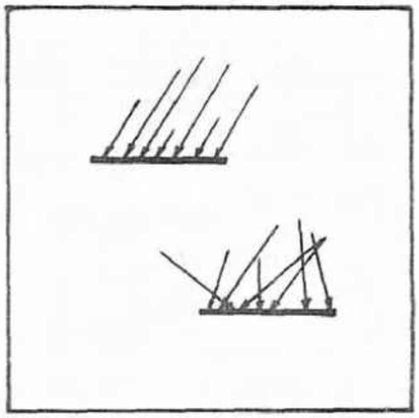


The sun's energy is received at the earth's surface in a form of electromagnetic radiation extending from x-rays of 0.1 micron in wavelength to radio waves 100 metres long. It has been established that 99% of the sun's electromagnetic radiation is contained within the wavelengths of 0.28 and 4.96 microns. At the earth's surface, just beyond the atmosphere, available solar power has been defined as the solar constant. Through measurement and extrapolation, the value of the solar constant was found to be 429.2 Btu per hour per square foot. This is the universally accepted measure for the solar constant.

French version of this paper was presented at the meeting of The French Canadian Association for the Advancement of Science (ACFAS), in Moncton, N.B., 7-9 May 1975.

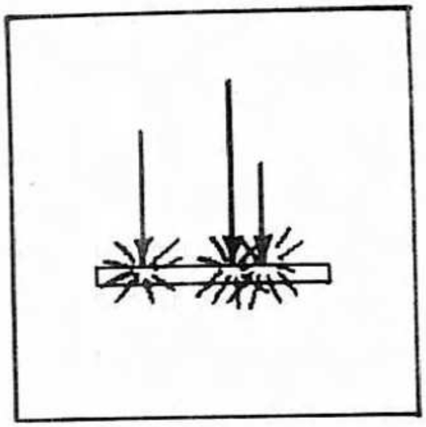


If we station ourselves at a fixed point on this rotating sphere, two important phenomena must be appreciated. The first is the apparent path of travel of the sun in relation to this location on the earth's surface. The second relates to the sky condition, whether it is clear or overcast. A third point which deserves mention is the quality of the atmosphere directly surrounding the location in question. This atmosphere may be clear or may be partly contaminated due to man-made pollution or some natural phenomena causing high levels of particulate matter to be present.

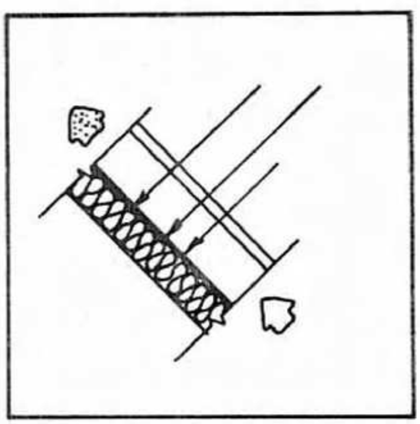


Insolation received on a horizontal surface is usually a conbination of direct and diffuse radiation: if it is received from the sun on a clear day, it is termed direct radiation; if it is received from an overcast sky, it is termed diffuse radiation. The Atmospheric Environment Services of Environment Canada publishes extensive records of radiation in a publication called Monthly Radiation Summary. These summaries provide detailed records of direct and diffuse radiation received at many meteorological stations throughout Canada. It is expected that data from many more Canadian cities will be included to meet the increasing demand for information relevant to the use of solar energy. Eventually these data will undoubtedly be used to produce solar maps which will indicate the amount and quality of solar energy available throughout Canada as well as the expected cloud coverage for various periods in the year.

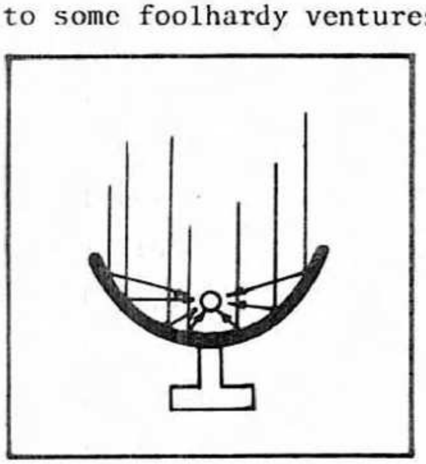
SOLAR ENERGY CONVERSION



The conversion of radiant energy to heat energy is accomplished through a device commonly called a solar collector. A solar collector is either one of two types: a flat plate (or low temperature) collector, or a focusing (or high temperature) collector. Both type of collectors convert radiant energy, in most cases, to sensible heat. This sensible heat is characterized by a change in temperature of the transport medium. The most common flat plate collectors use either air or water as heat transport media. Studies and research work indicate that flat plate collectors can exhibit an efficiency of conversion in excess of 50%.[1]



The focusing or high temperature collector concentrates radiation from a large collector area and beams it to a small target zone. This has the effect of producing very high temperatures in a specific area. This type of collector, though not as popular as the flat plate collector, holds promise of satisfying certain types of needs, ranging from domestic cooking to high temperature requirements of industry. The focusing or high temperature collector has, at present, one major drawback -- it can only use direct radiant energy because it cannot focus diffuse radiation. Eagerness to capitalize on the free fuel of solar energy using concentrating or focusing collectors has led to some foolhardy ventures.



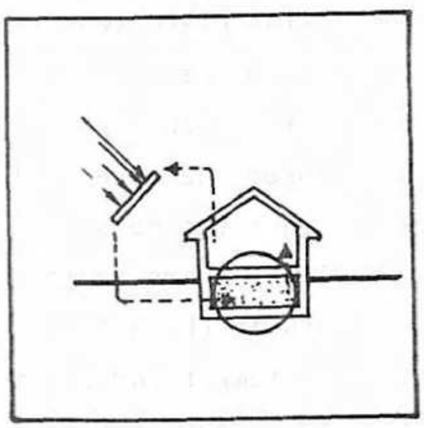
In 1946, the Indian Government franchised two factories to make a solar cooker for use by India's 300 million peasant farmers. After about one year of production, only 50 solar cookers had been sold. Apparently no one had realized that the peasant farmer eats his meal after daylight hours and that the women were reluctant to stand in the hot sun to produce a meal where ambient air temperatures sometimes reached as high as 100°F.[2]

coupled with a storage device which will supply energy on demand rather than only when it is available, they can provide an attractive method of obtaining high temperatures. Many different types of focusing collectors have been invented.

The design of solar heat collectors involves research and development in many different areas. A technology is emerging which is interested in the performance of glasses, plastics, metals and insulation, particularly for their ability to absorb radiant energy, exhibit low emissivity and performance with respect to convective losses.[3] In Australia and the U.S., certain research and development departments have been involved in the study of selective surfaces and antiradiant structures for solar collector design. Many studies have been carried out on glasses and plastics to increase the efficiency of radiation transfer to collecting surfaces.

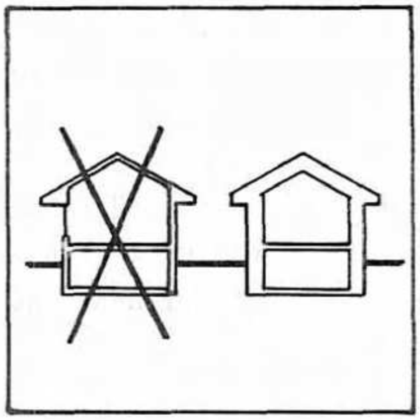
SOLAR ENERGY STORAGE

Owing to the sporadic nature of solar radiation, a solar collector by itself does not constitute a dependable source of heat energy. Thus it is necessary to complement a solar collector with a device called a heat storage unit which will hold surplus heat energy to be supplied on demand. The storage of heat energy can be accomplished in two ways. The first method is termed the storage of sensible heat. Usually sensible heat storage involves materials that will exhibit a rise in temperature as the heat energy is accumulated within the storage unit. Some of the more common materials used for this purpose are rock or stone, and water. The second method of heat storage is accomplished through the use of heat of fusion of certain materials that accumulate heat energy in a change of state. The materials most commonly used for this purpose are usually waxes or salt hydrates, both of which are still relatively inexpensive.



To illustrate the heat storage capacity of these two types of storage devices, consider first the sensible heat approach. If we had a well-insulated storage container and wanted to store 2 million Btu's of heat energy using rock or stone, 1000 cubic feet of aggregate raised to 100°F above ambient temperature would be required. This heat energy represents about 4 to 5 days of heating for a typical single-family dwelling. Similarly, if we were to use heat of fusion material as a storage device, and if we used a material called sodium sulphate decahydrate (commonly known as Glauber salt), a similar heat storage capacity could be obtained with about 210 cu ft of Glauber salt. This volume represents approximately 10 tons of heat of fusion material. Dr. Maria Telkes of the University of Delaware has conducted extensive studies into heat of fusion of different storage materials.[4] Dr. Telkes points out that there are many engineering problems that must be overcome in the use of heat of fusion materials; among these are the corrosive effects of the materials on the container as well as their stratification and heat transfer characteristics.

OTHER CONSIDERATIONS



In addition to the provision of heat energy through this new source, it is important to note that improvement in the quality of design and construction of buildings would considerably increase the efficiency of heat energy utilization. This means that increased insulation, reduced window area, controlled air leakage, and careful construction detailing should be exercised in future designs, particularly if the effort could reduce the needed area of solar collector and volume of the storage unit.

SOLAR HEATING APPLICATIONS

Many applications of solar heating are under way. The Intertechnology Corporation planned and designed a solar heating system for the Fauquier High School in Warrenton, Virginia. Five classrooms totalling 4,100 sq ft were allocated for this demonstration project. The system was declared operational on 19 March 1974, and it has been claimed that since that date all of the heating requirements of the classrooms have been met with solar energy except for brief periods during which the system was shut down for alterations. The system consists of a 2,540 sq ft of collector surface and two 5,500 gallon, concrete storage tanks for water. The storage was designed to meet the heating loads of the classrooms for a minimum of five days. The cost to the school for heating these classrooms is approximately 25 cents per day; this includes the cost of the electrical energy required to operate the pumps and controls.[1]

The largest solar heated building planned anywhere is a 278,000 sq ft project for Denver Community College, Westminster, Colorado. This building will be designed to have 50,000 sq ft of solar collector with a heat storage reservoir of 400,000 gallons of water. This project is due to be completed in the fall of 1976.[3]

Le Centre national de la Recherche scientifique (C.N.R.S.) in Odeillo, France, has built three solar heated houses. Two of these were single-family dwelling units; the third was a three-unit building. One of the single-family dwelling units built in 1967 uses 860 sq ft of collector area for a house volume of approximately 10,000 cu ft. During the past eight years, it has been established that two thirds of the heat used by these houses was provided by solar energy.[3]

The Thomason Solaris System has been built into several houses in the Washington, D.C., area. The first system installed has a record of 14 years of continuous operation with the sun supplying the major portion of heat energy required during the heating season. One of the Thomason projects employs a solar collector covering the entire south facade which is approximately 15 x 60 feet. The storage unit consists of 1,600 gallons of water surrounded by 50 tons of low-cost, fist-size stones. Heat from the water bin passes to the stone storage which is then drawn out by air circulated over the stone storage. This system provides a supply of heat for about five moderately cold days and is claimed to provide between 65 and 75% of the year-round heating requirement, including domestic hot water supply.

In Canada, there are a number of projects at various stages of development which are of interest. The first is the Gananoque House at Larry's Landing, R.R. #3, Gananoque, Ontario. This house, owned by Larry South, was designed by Greg Allen and built in 1974. It is a four-bedroom, two-storey house with a total usable floor area of 2,200 sq ft excluding the garage. The system consists of 230 sq ft of collector surface mounted on the south side of the roof. The system uses water as a heat transport medium and 4,000 lb of paraffin wax as a heat of fusion storage unit. Auxiliary heat requirement is provided by a large stone fireplace which has water circulating in the stainless steel clad tubing that surrounds the flue. This hot water is directed to the heat of fusion storage where it will be used again for space heating. It is estimated that this solar heating system will provide about half the heat requirements of this particular house.

Lorriman, Ferguson and Lee are planning a two-storey, solar heated house of about 1600 sq ft to be situated in the Toronto area. The solar heating system will consist of 800 sq ft of collector surface coupled with two water storage tanks each with a 2500-gallon capacity. The system will also use a heat pump to raise the temperature of one storage container by taking it from the other. It is expected that this approach will raise the efficiency of heat transfer within the system.

The Hoffman House, another solar heated building, was built in 1968 by Eric W. Hoffman in Surrey, British Columbia. A solar heating system was designed and retrofitted to this building in 1971. In addition to the house heating, a swimming pool solar heater was added to this unit in 1974. The house is located at the 49th degree north latitude. The total floor area of the house including the basement is 2,700 sq. ft. It uses a flat plate type solar collector 460 sq. ft. in area. It has two vertical cylindrical uninsulated water tanks totalling 800 gallons which are held within an insulated basement room. The house is heated by air that has circulated by gravity convection through the tank room. The system is claimed to provide 50 per cent of the space heating and domestic hot water requirements. Auxiliary heaters are electric baseboard units.

John Hix, Architect, and Frank Hooper, Engineer, University of Toronto, are currently designing a solar heated house to be built in Mississauga, Ontario. It is a two-storey, single-family residence of 2,400 square feet, resembling a modified "A" frame building. It will exhibit more than 800 square feet of collector surface and host a 70,000 gallon water storage unit.

In addition to a variety of demonstration projects, there are approximately 50 manufacturers throughout the United State and Canada, who are marketing solar collectors and other related hardware. The items manufactured include: solar collector panels, photovoltaic solar cell systems and arrays, concentrating collectors, solar water heaters, low-cost cooking units, and complete retrofitting solar heating systems.

SOLAR ENERGY RESEARCH

The two most active countries in solar energy research today are the United States and Japan. ERDA (Energy Research and Development Administration), one of the United States federal funding agencies, was recently granted 57 million dollars to subsidize research and development expenditures for solar heating experiments. The United States has at present before its Congress forty bills dealing with various phases of solar and wind energy utilization whose objects are to meet its future energy requirements by the exploration of alternative sources of energy.

In Japan, a new initiative by the authorities has resulted in the formation of Project Sunshine. Its objective is to explore the use of solar energy, coal gasification and geothermal energy and the utilization of as many indigenous resources as possible to strengthen the autonomy of the Japanese energy supply. In 1974, Project Sunshine was allocated 2.4 billion yen, or 7.5 million dollars. It is estimated that this Project will continue for at least 20 to 30 years, and that by the year 2000 total expenditures will have exceeded 78 billion dollars. One aspect of Project Sunshine is a subproject entitled Solar House Heating and Cooling. This project is divided into four areas: residential solar-powered houses for the year 2000; retrofitting existing houses; apartment buildings; and schools, and business and commercial buildings.

This project has been given a very high national priority. Japanese authorities are encouraging research institutes and commercial establishments to forge ahead quickly in the development and application of technology to the use of alternative sources of energy. The Japanese are very much in favour of international cooperation in this field, particularly in the development of standards for equipment, the development of simulation models, and the adoption of uniform gauging standards for the efficiency of equipment.[(3)]

In Canada, a number of institutes and universities are actively conducting research in the field of solar energy utilization. The Brace Institute has been investigating methods for the utilization of solar and wind energy since 1959. More recently it has diverted its attention to the application of these energies in meeting Canadian requirements. In Ontario, Waterloo University is embarking on a number of projects related to solar and wind energy application. The University of Western Ontario is conducting research in solar refrigeration and heating and photosynthesis. A number of Federal Government Departments and associated agencies are investigating the potential of solar energy. These include the Department of Energy, Mines and Resources, the Ministry of State for Urban Affairs, and the National Research Council of Canada. The Division of Building Research, National Research Council of Canada, has been conducting extensive research on the transmission of solar radiation through glass, the development of techniques for modelling the transient thermal behavior of buildings, that is heat storage potential and internal loads, as well as the determination of solar energy availability through prepared design methods using the meteorological data compiled by the Department of Transport of Canada.[5,6] The University of British Columbia is conducting research on solar energy and heat transfer.

SOLAR ENERGY FUTURE

It has become quite clear that alternative sources will be required to meet our future energy requirements. Solar energy, though not a renewable resource, can be said for all practical purposes to be unlimited. There is no other source of such vast potential.

It should also be clear that at this stage of our developing technology old solutions do not necessarily apply to new problems. It is important, if effective new solutions are to emerge, that imaginative thinking and creative development be sponsored and encouraged. At this stage it is important that demonstrations projects be encouraged. Care must be exercised, however, to ensure that information obtained is sufficiently detailed and projects adequately documented to permit useful application of knowledge gained. It would be advantageous to coordinate as many of these projects as possible in an effort to limit duplication and to broaden the scope of experience. In time these projects will yield a sound and fundamental basis for the design of solar heating systems.

If future developments take place as anticipated, the scenario might be as follows. In the next few years, numerous demonstration projects will be sponsored and subsidized by a variety of private agencies as well as by governments. These projects will, it is hoped, yield sound design guidelines for a new technology. It should be realized that, although some of these projects will probably not succeed in attaining their stated objectives, they will nevertheless provide much useful information if they are carefully documented and all details made known to others interested. It is expected that within this same period a small proportion of residential buildings will already be using retrofitted solar heating systems made available through a commercial enterprise to supply a portion of the annual heating requirement. Following this initial exploratory period, many new buildings will have incorporated in their enclosure design partial systems for solar heating space, and possibly domestic hot water heating. At this time, it is thought that the most economical applications will be directed to multiple dwelling units, single-family dwellings, schools and some commercial occupancies which are low rise and have low occupant to floor area ratios.

Solar heating has not had extensive use primarily because of the initial high capital cost requirement and the low cost of fuels. With the fuel cost situation changed, this alternative has attracted renewed interest but it will be some time before a sound design methodology is established that will guide us to the systems most suitable for use in our climate. It is not expected that solar energy will replace all present forms of energy but its availability and unlimited quantity are certain to make it the most important source of the future.

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