INVESTIGATION

26

Solar Absorption

Lab

PURPOSE

- Design an experiment to calculate and compare the heat-absorbing capacities of various fluids under solar radiation
- Determine efficient applications and models for fluid solar-energy collectors, based on experimental results
- Compute heat absorption rates for passive solar materials

INTRODUCTION

As our supplies of fossil fuels become more difficult to find and extract, alternate sources of energy need to be exploited. It would be best if these sources were renewable and nonpolluting. One constant source of direct energy is the Sun. There are a few ways that solar energy can be utilized. One method, called **passive solar**, is to allow sunlight to be absorbed directly by a material such as stone, brick, or concrete on exposed interior walls, heating buildings without the need for pumps or other machinery. Another method is to let a liquid, such as water, absorb the solar energy and then circulate the heated water through a conventional hot water heating system. A completely different approach to solar energy converts the rays of the sun directly into electricity with the use of **photovoltaic cells**. All these methods use sunlight and convert it into useful energy for us to exploit. Heating solids and liquids to warm buildings is clean and competitive with conventional heating methods. Photovoltaic cells are also becoming competitive in certain applications.

Fig. 26-1

One-Thousand-Year-Old Passive Solar-Heated Homes in Mesa Verde, Colorado

Directly or indirectly, almost all our energy sources are a form of solar energy. Even though the sun is about 93 million miles away, the amount of solar radiation reaching Earth's surface in a few weeks is equal to the energy in the world's reserves of fossil fuels. On average, the upper atmosphere receives 1.37 kWh of energy per square meter each second. This is equivalent to almost 5 million joules/m²/s, or 2 cal/cm²/min.

The effect of this energy on a given surface area of Earth is dependent on many factors, such as actual distance from the sun, the latitude, and the local weather. Certainly not all this solar energy arrives at Earth's surface. Some of it is reflected directly back into space, and some is absorbed by dust, water vapor, and ozone in the upper atmosphere. About 47% of the energy is available at the surface for us to utilize. It has been estimated that if the solar energy hitting the land area of New Jersey, the fourth smallest state, were converted at 20% efficiency, it would meet all our energy needs at present day use rates.

The development of efficient absorbing materials is vital to developing economical solar energy. All materials have an ability to absorb heat. This heat can be quantified as the **specific heat**, which is the amount of heat, in calories or joules, needed to raise the temperature of one gram of material 1 degree C. In this investigation you will design an experiment to explore the ability of various liquids and solutions to collect solar energy.

Materials

- 150 mL beakers
- heat lamp
- pure water
- vegetable oil
- ethanol
- ethylene glycol (automotive antifreeze)

Procedure Suggestions

Step 1 Design an experiment to test at least five different liquids and/or solutions for their heat-holding capacity. Include the four substances listed above. Since darker substances are usually better at absorbing heat, you may want to mix different food coloring agents into some liquids. (Controls of uncolored substances will be necessary if you decide to test for coloring agents.) You can also test varying concentrations of salt solutions.

Step 2 Write out a concise set of directions that can be used if someone else wanted to repeat your experiment.

Step 3 Set up a table of data to record your measurements. You will report the initial and final temperatures along with the temperature change for each liquid. You will also need the time, in hours, that the fluids were exposed to the light source.

Step 4 Use 100 mL of each liquid or solution in a 150-mL beaker. Measure the mass of each liquid by weighing the beaker empty and then again after adding the liquid and subtracting the two values.

Step 5 Ideally, place your beakers in direct sunlight. If this is not possible, then use a heat lamp or other lamp placed about 1 ft above the beakers. Leave the beakers in the light for at least one class period. Convert this time to hours for the data table.

Show all work with proper units.

1. Assume all the energy the fluids absorbed was from the top surface. Calculate the surface area of each beaker. (You will have to do this only once if the beakers are of the same size.)

2. Calculate the heat absorbed by each fluid, including any control. The formula is:

$$q = mc\Delta t$$

where q is the heat in joules, m is the mass of the liquid or solution, c is the specific heat of the liquid, and Δt is the temperature change.

The specific heat is a measured constant for each substance. For this experiment, assume that all the water solutions have the same value as pure water.

Substance	Specific Heat
Pure Water	4.18 J/g/C
Vegetable Oil	2.0 J/g/C
Ethanol	2.46 J/g/C
Ethylene Glycol	2.2 J/g/C

3. Compute the number of joules absorbed by each fluid per hour.

4. Using the values calculated in the preceding computations, determine the number of joules per square meter per second ($J/m^2/s$) absorbed on the surface of your fluids.

Problems

5. From your data and calculations, which fluid was the best absorber, and which one was the least effective? What is the percent difference between the two?

6. Suppose you were designing a solar collector to be 50 m^2 (about one-half the surface of an average roof), facing south, and filled with your best absorber fluid. Based on your calculations, determine the following:

   a. How much heat would the collector absorb in one hour?

   b. How much heat would it collect on an ideal sunny day? (Assume that in much of the United States the Sun shines for about 8 hours in winter.)

   c. In a typical house using 80 kilojoules per hour, what percent of the heat needs would the collector produce?

7. Passive solar heating usually utilizes walls of concrete, brick, or stone to absorb the rays of the Sun during the day and then to re-radiate that heat back into the room during the time the Sun does not shine. Concrete can absorb 0.88 megajoules per square meter per degree change in Celsius temperature.

   How much heat could a concrete wall that is 3 meters high and 8 meters long absorb if its temperature changed 8°C?

8. Some hydrated salts, such as sodium sulfate decahydrate ($NaSO_4 \cdot 10H_2O$), are used as a method for storing the energy for periods of extended sunless days. Describe one method of utilizing this technique.