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Student Construction of a Working Solar Collector

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STUDENT CONSTRUCTION OF A WORKING SOLAR COLLECTOR

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Introduction

Student constructed projects may serve as the basis for studies of the advantages and limitations of solar energy. An eighth grade science class at Miami University's McGuffey Laboratory School completed a study of solar energy with the construction of a window unit solar collector. The collector was installed in a south window of the science room in time for use and testing during the winter of 1980. The class activity developed after numerous individual projects allowed students to test variables that would be important in the design, construction and use of such a unit. Students performed a variety of individual investigations to test construction materials, methods of insulation, heat storage, angle of collecting surface, and heat absorption and transmission of different materials. The results of individual investigations were important considerations as the project was being planned. One student then built a small scale model as a science fair project. Tests with the model were positive enough to encourage other students to cooperate in the construction of a full-scale working unit.

The class project was a double chambered unit, 8 feet long by 3 feet wide (see figures 1 & 3). The lower (cold) chamber was insulated with 1-inch thick Styrofoam insulation sheets. The upper (hot) chamber was insulated, lined with sheet aluminum, adorned with 20 staggered rows of nine aluminum beverage cans, painted black and covered with quarter-inch plate glass. On a cold clear day the sun's rays warm the blackened surfaces. As the temperature of those surfaces increases, air in the upper chamber, warmed by contact with the heated metal, rises and follows the upward path of the chamber which empties into the room (figure 1). This decreases the internal air pressure and forces colder air from the room into the lower chamber of the collector. The cold lower chamber air then flows into the upper chamber of the unit where it is warmed and returned to the room.

Design

Specific features of the collector were determined by compromising characteristics suggested by student experiments with practical considerations. The second story window at McGuffey School allowed the unit to be longer than if it were placed in a first floor window. The 38-inch window width limited the width of the collector. The dimensions

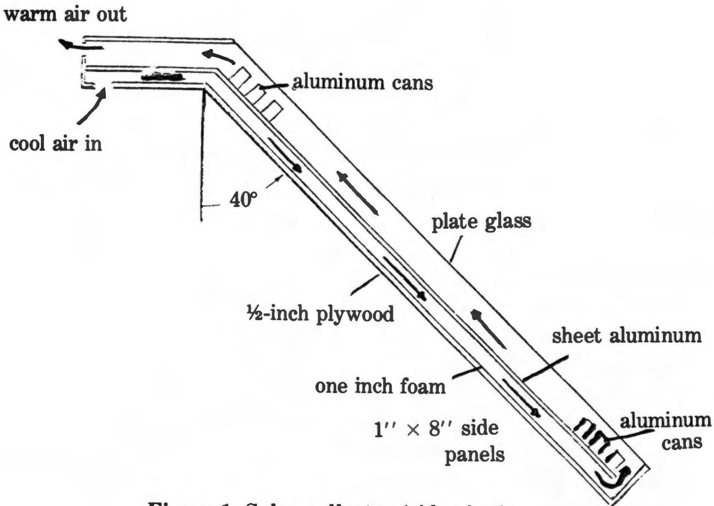

Figure 1. Solar collector (side view).

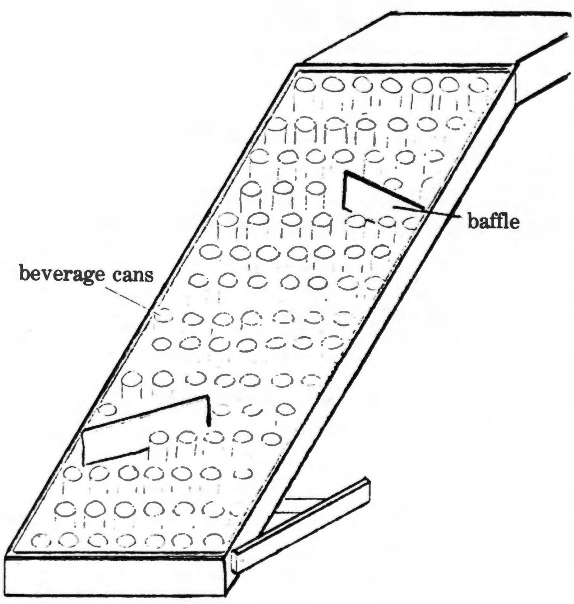

Fig. 3 Solar collector (oblique view).

were finally determined when two 3-feet by 4-feet sheets of quarter-inch thick tempered plate glass were obtained free of charge. The glass came from doors that had been damaged during shipment. Most other materials were donated by parents. Standard dimension lumber was used so that construction could be accomplished by students using hand tools. Most of the lumber had served some previous use, and students felt positive about recycling old materials. The materials list was as follows:

—two 3′ × 4′ × ¼′′ glass panels
—two 4′ × 8′ × ½′′ exterior plywood sheets
—twenty-five feet of 1′′ × 8′′ pine stock
—twenty-two feet of window moulding
—three sheets of 3′ × 10′ × 1′′ styrofoam insulation
—thirty-six square feet of sheet aluminum
—two hundred 12 oz. aluminum bererage cans with convex bottoms
—assorted nails, wood screws, and sheet metal screws
—three tubes of latex caulking compound
—one-half gallon flat black exterior latex paint
—five 12 oz. spray cans of high temperature flat black enamel paint

Used sheet aluminum was obtained free of charge from a newspaper which used the material as offset printing plates. The only materials bought by the school were screws, caulking compound, insulation and paint.

Construction

The project became a joint science/woodworking project. Both teachers provided direction and class time. The required tools were as follows:

—table saw with fine toothed blade
—claw hammers
—screwdrivers
—drill motor and an assortment of bits
—medium and fine sandpaper
—caulk applicator
—safety goggles
—ear protection
—leather work gloves
—exacto knives
—carpenter's square

The construction was divided into seven separate job assignments. Students signed up for one or more assignments, depending on their interest, skills and available time.

1. **Frame assembly.** The side panels, end panels, collector bottom and chamber dividers were all cut and assembled. Whenever possible, standard size lumber was used so that it was necessary to cut for length only. Most of the cutting could then be done by students using a hand saw. The most difficult parts of the assembly were fitting the chamber dividers to the side panels and joining the top and bottom side panels where they meet at a 130° angle.

2. **Insulation.** After the frame was cut and before the frame was completely assembled, students cut and installed Styrofoam insulation. The bottom, the sides and the lower end panel each received a 1-inch layer of Styrofoam insulation. The lower side of the chamber divider was similarly insulated.

3. **Can Cutting.** Aluminum beverage cans were used to collect and disperse heat. Aluminum has a high specific heat and the cans were readily available. Students saved cans at home or participated in collecting parties through thier neighborhoods after school. The bottom half of each can was used and the top half returned to a recycling station. Only cans with convex bottoms were used, because convex bottoms deflect more light to the sides of the cans allowing more heat to be absorbed.

Getting 200 cans cut in half was the most difficult problem encountered during the project. The thin metal bent out of shape when a hacksaw was used. Metal shears worked but the job became tedious and "boring." An attempt was made to use a table saw, but even the finest toothed blade mutilated cans before they could be cut. The technique that eventually worked was to use a table saw with the blade on backwards. The teeth of the rotating blade hit the cans at a more favorable angle, severing the metal without bending the cans. A wooden jig was constructed to hold the cans during the cutting process (see figure 2). The jig was clamped on the saw table with the blade protruding through the jig at the desired cutting location. The blade functioned best when allowed to protrude no more than 5 or 6 millimeters. Cans were lowered into the jig with the blade revolving. When the can met the blade, the can was carefully rotated until completely severed. Two hundred cans were thus prepared with relative ease.

Necessary safety precautions were taken. Students wore safety goggles to avoid injury from possible stray aluminum particles. Heavy leather gloves were worn to avoid cuts from sharp jagged edges. Ear protection was worn because of the loud noise of the can cutting.

4. **Sheet aluminum installation.** All exposed exterior surfaces were covered with sheet aluminum. This included the top side of the chamber divider where cans would be attached and all side and end panels in the upper chamber. The aluminum was cut by scoring with an X-acto® knife kept on line with a steel straight-edge.

5. **Can installation.** The aluminum cans (top half removed) were nailed into the floor of the upper chamber using a metal punch that had the tip broken off and filed flat. The nails were started with a tap from a hammer, but were secured by holding the punch over each nail and

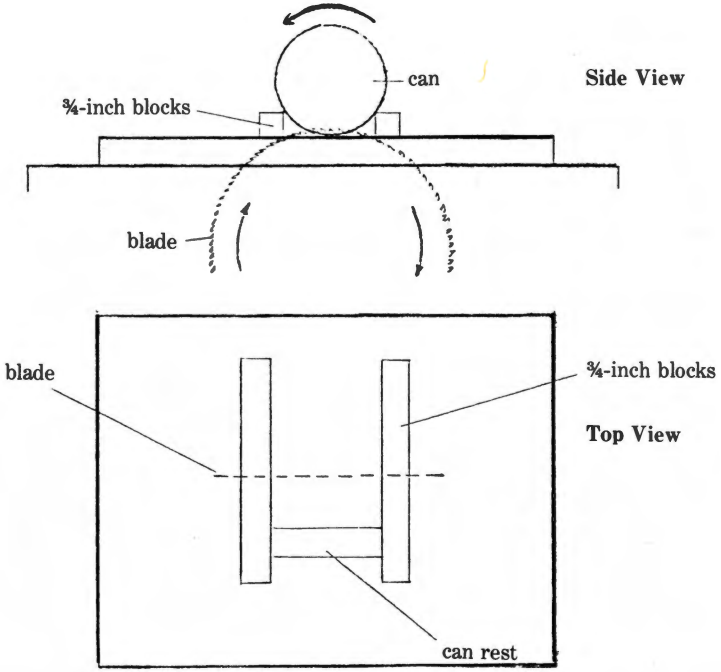

Figure 2. Can cutting jig.

striking the punch with a hammer. Carpet tacks were used at first but did not prove satisfactory. The tapered shanks loosened from vibrations caused by the installation of additional cans. Best results were obtained using one-inch lath nails; any narrow shanked nail with a relatively large head should be satisfactory. The rows of cans were staggered so that air moving through the hot chamber would come into contact with as many heated cans as possible before returning to the room. Gloves were worn during this operation because of the sharp edges of the cut aluminum cans.

6. **Caulking and painting.** Joints and cracks were filled with latex caulk. The cans and aluminum sheeting were painted with high temperature flat black spray enamel. High temperature paint was necessary because use of regular paint would cause an annoying burned paint odor. Spray paint was used because of the difficulty of painting all surfaces of each can with a brush. The rest of the box was brush-painted with flat black enamel.

7. **Final assembly and installation.** The plate glass was installed and secured with window moulding. Installation in a first story window would have been simply a matter of providing the unit support on the ground. Installation in a second story window required a supporting framework constructed from two-by-fours. The frame was attached near the bottom of the side panels and butted against the building for support (see figure 3). Getting the solar collector from ground level into the second story window required the use of a fork lift to lift the unit up and into the window.

Classroom Use

There are many different investigations requiring different levels of interest and understanding that students may perform with a functioning solar collector. Students may collect data reflecting outside weather conditions and their effect on the output temperature of the solar collector. Graphing, interpreting and communication skills may be sharpened by the display of the data. Records of the number of use (sunny) days during the late fall, winter and early spring as a check on the frequency of use could be prepared. On weekends, when building heat is off, comparisons could be made of room temperature in the solar heated room and in similar unheated rooms. In rooms with thermostatically controlled heating, fuel savings may be indicated by comparing the amount of time the heating system in the solar heated room operates with the amount of time identical systems operate in similar rooms without a solar collector. Other students may want to work on ways of improving the design. Determining conditions of optimum heat flow would be an example. By controlling the rate of intake of room air into the cold chamber, and by monitoring the resultant exhaust temperatures and air flow rates, optimum heat transfer conditions could be determined.

The construction and subsequent use and testing of a classroom solar collector has had many benefits. Participating student have seen their efforts result in the positive use of recycled materials. They have also learned that they are capable of employing simple construction techniques to provide a useful way of coping with energy concerns. The unit has provided a working model of some principles of thermodynamics, and has provided the basis for numerous experimental projects.

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Is Science Atheistic?

". . . research performed in a truly scientific manner can never be in contrast with faith because both profane and religious realities have their origin in the same God."

Pope John Paul II
Vatican II Ecumenical Council

Teachers Institute

The second annual Institute for Teachers of Talented High School Students will be held June 21-26. For further information contact Robert E. Bonner, Director of Summer Programs, Carleton College, Northfield Minnesota 55057.