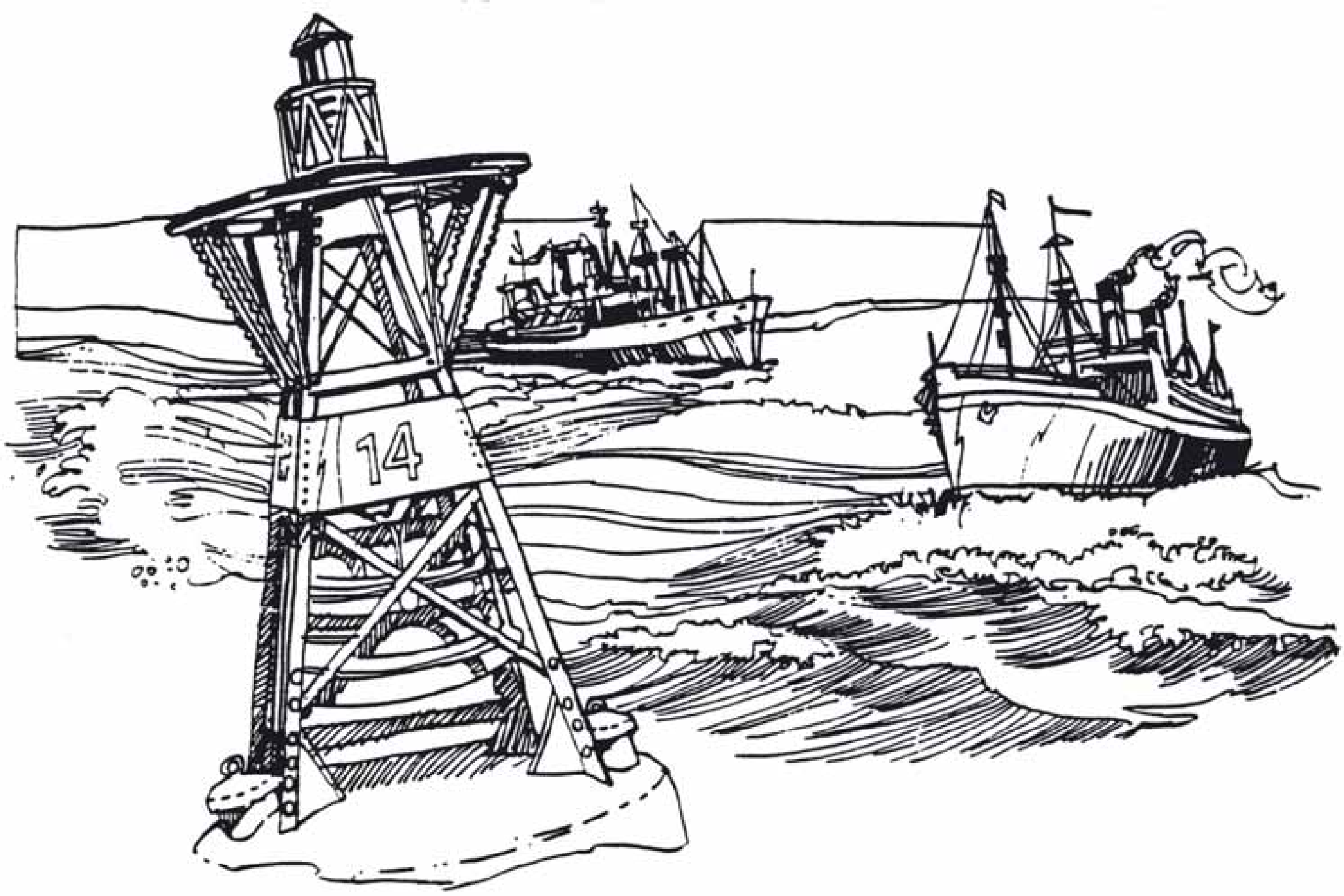
Exploration -Power from Ocean Waves

Waves and Whistles



Fossil fuels such as coal and oil are not renewable over the span of human generations, and their use may be increasingly limited by environmental concerns over global warming and acid rain. To meet the energy needs of a growing world population, engineers in coming decades will be challenged to economically generate power from solar energy sources.

Ocean waves are a tertiary form of solar energy, in that unequal heating of the Earth's surface generates wind, and wind blowing over water generates waves. Despite the fact that nearly 75% of the Earth's surface is covered with water, waves are a largely unexplored source of energy compared with the progress that has been made in harnessing the sun and wind.

Commercial use of wave power is now limited to small systems of tens to hundreds of watts aboard navigation buoys. As the buoy heaves up and down in waves, the oscillating water column (OWC) in the center pipe of the buoy's hull acts like a piston, pushing air out the top of the pipe and drawing it in. This pneumatic power can be converted directly to sound through a foghorn, or indirectly to light by spinning a turbine-generator, which charges an electrical storage battery (figure 1) Ocean wave energy conversion for utility-scale power generation is not yet a commercial technology, but shore-based demonstration plants using the OWC process described above have operated in Japan, Norway, and the United Kingdom (Figure 2). The output of these plants is much larger, however, ranging from tens to hundreds of kilowatts.

Objectives

In addition to illustrating a potential energy source that the students may not have thought about, this activity, is intended

(1) To demonstrate the energy transformations that take place in converting wave motion and force into useful work (Figure 3).

(2) To have high school students develop a solution for obtaining one-way rotation of a pneumatic turbine in a reversing airflow.

(3) To suggest extended activities that the students can pursue on their own.

Materials

The following materials are needed:

(1) A five-gallon bucket (or sink that can be filled to a depth of at least 8 inches)

(2) A source of water near the demonstration site

(3) A plastic water bottle with screw cap and large drinking straw (Figure 4). These are about the size and shape of a tennis ball can, and are frequently seen in the hands of car drivers, joggers, and kids on skateboards. They can be bought at drugstores or supermarkets and are often handed out as promotional items-you may already have one lying around the house.

(4) A turbine wheel whistle of the type that might be used by a bad stand-up comedian or handed out as party favors (Figure 5). They can be bought at novelty stores or party supply shops.

(5) A small, sharp-bladed utility knife.

Figure 1

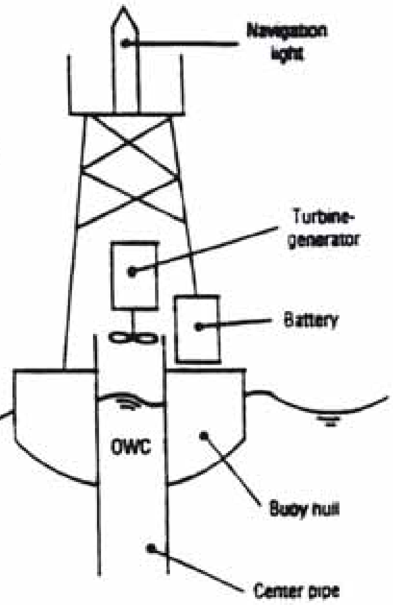


Figure 2

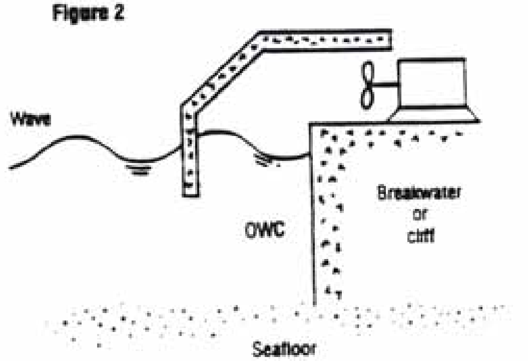
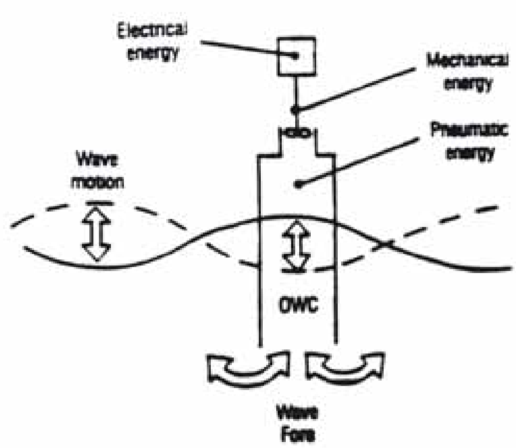


Figure 3



(6) Six strips of opaque adhesive tape (plastic, electrical, or duct tape all work), 1.5 inches long by 3/4-inch wide.

Preparing the model

(Figure 6):

(1) Cut the bottom off the water bottle.

(2) Remove the straw and cut a hole, approximately 1/2-inch square, next to the edge of the cap

(3) Use four strips of tape to mount the whistle over the drinking straw hole.

(4) Make a one-way "flap valve" by folding a strip of tape back on itself such that only 1/4 to 3/8-inch of adhesive surface is exposed, and tape this adhesive surface to the underside of the bottle cap, right next to the edge of the cap.

(5) If possible, test the model in a sink or bucket of water at home, to make sure that there isn't excessive "blow-by" around the edges of the flap valve or base of the whistle.

(6) Once satisfied that the flap valve is working properly, stick the last strip, of tape to the top of the cap, over the flap valve window. This will conceal it from the students and prevent the flap valve from functioning during the first part of the demonstration.

(7) Be sure to let the teacher know that You'll want to work with team of 4-5 students at a time (small enough to gather around the bucket or sink and still see what's going on). Also verify that a water supply will be handy- you may have to fill the bucket ahead of time.

Prior to attending the demonstration the engineer should make the following preparations

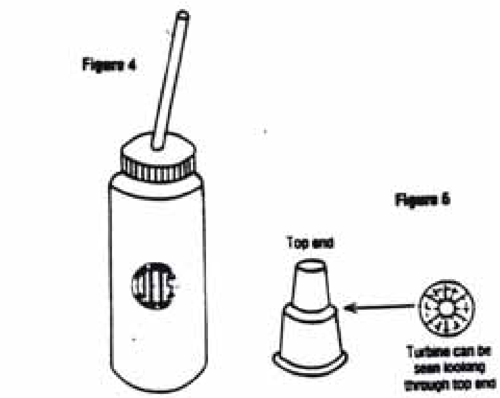
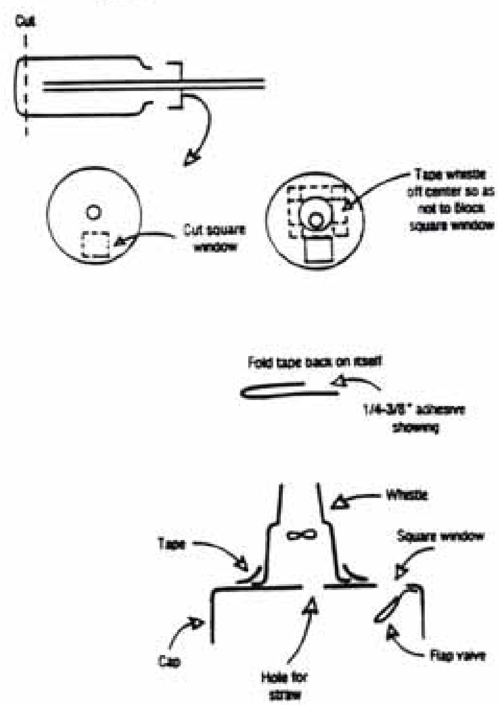


Figure 6



At the Demonstration

(1) Give a brief (3-minute) overview of the need to develop renewable energy sources and the potential of ocean waves. A chalkboard sketch of Figure 3 of this guide might help the students better understand the oscillating water column process. Also pose: the following problem to the students: "How can the resulting air flow of the oscillating water column be converted to one-way rotation of a generator shaft"- Each team should come up with its best solution while: waiting for (and after) its turn to watch the demonstration.

(2) Fill the bucker or sink to within 2-3 inches of the top, if this hasn't already been done.

(3) Demonstrate to each team that as the bottomless bottle is moved up and down, the turbine "whistles." The students should be given a chance to look down into the whistle to see the turbine blades reversing direction at the top and bottom of each stroke (Figure 7). Ask them to speculate on the negative consequences of this direction reversal ("interrupted or uneven flow of power, " '"high stress on the turbine blade or shaft," and "loss of efficiency because: the turbine has flywheel inertia and can't reverse direction instantly" would be correct answers).

(4) Once all teams have seen the first part of the demonstration, each one should describe its best solution to the direction reversal problem. Ask the teacher to list these on the board. Some teams may suggest complex gear mechanisms or hinged turbine blades. Others may say it can't be solved. Any team suggesting a one-way valve will be rewarded with the satisfaction of seeing their idea work in actual practice!

(5) While going over the list of solutions on the board, emphasize that engineers are creative problem solvers, and that part of the engineering process is to find solutions that are "elegant but simple." A gear mechanism for the oscillating water column may be elegant, but is more complex than other solutions involving many moving parts requiring lubrication and eventual replacement when they wear out. Hinged turbine blades are subject to high stress as they flip at the end of each stroke- the failure of a single blade may force disassembly of the entire turbine to replace the failed blade. In addition to being functional a well-engineered design should also be reliable (long-term durability), economical (both to build and maintain) and practical (ease of repair or replacement).

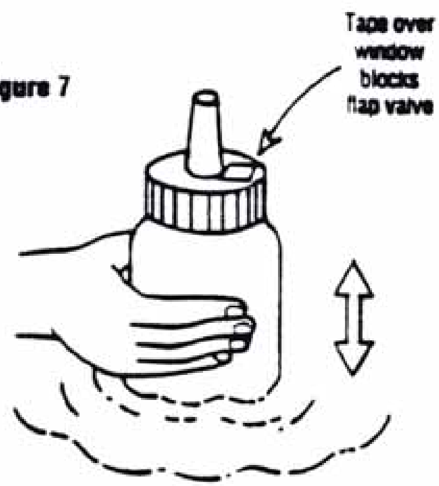


Figure 7

(6) A one-way flap valve is a better solution because it has fewer moving parts (only the flap valve hinge, as opposed to multiple gears or turbine blade hinges), can use the standard turbine design without requiring new manufacturing equipment ($$$!), and is totally removed from the power train for case of repair or replacement.

(7) Remove the strip of tape that was covering the flap valve window, and repeat the demonstration of Step (3), so that each team of students can verify that indeed, the turbine blades spin in one direction regardless of whether the bottomless bottle is moving up or down (Figure 8).

(8) If time permits, you can explain that it is the flywheel inertia of the turbine that keeps it spinning while air is being drawn in through the flap valve. Can the students think of a valve system that would direct air through the turbine on both strokes? One possible solution is shown in Figure 9.

Extended Activities

Before leaving the classroom you can suggest ways the students might experiment on their own. Several bottles could be manifolded together, plumbing the air flow into a single turbine. If two such bottles were placed at either end of a pitching raft (say, tied to a piece of wood), the air flow through the turbine might be steadier. Encourage them to test different shapes and sizes of floating platforms in a swimming pool (where their friends will have to make the waves), or at the shores of a lake or river, where the waves are of the same small scale as their models.

This activity was proposed by George Hagerman of SEASUN Power Systems in Alexandria, Virginia. Mr. Hagerman has conducted wave energy resource and technology assessments for private utilities and state governments in California, Hawaii, North Carolina, and Virginia, and is chairman of the American Society of Civil Engineers Ocean Energy Committee.

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Figure 8

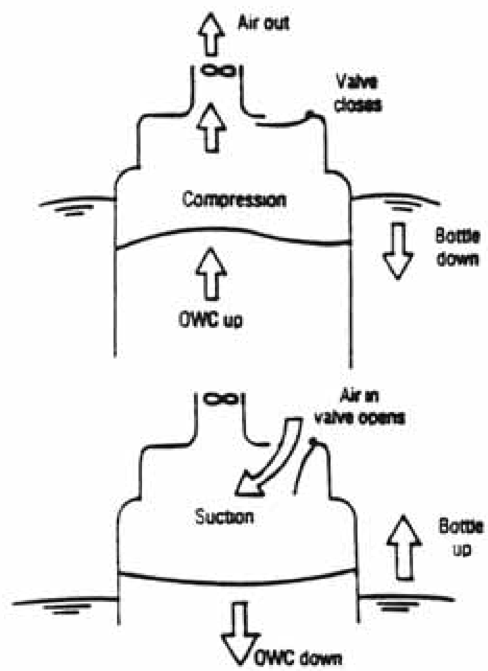

Figure 9