STEAM TURBINE

OBJECTIVE:

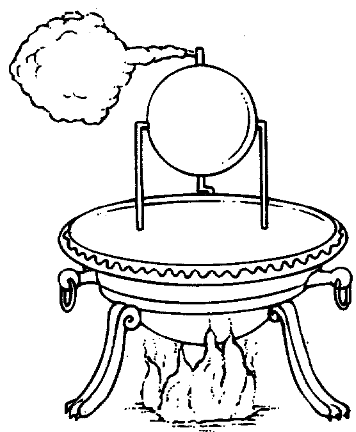
You will understand how a steam turbine generates power and will demonstrate this with a model steam turbine.

INTRODUCTION:

A steam turbine is a machine that generates power using the pressure from escaping steam. Probably the first to demonstrate this use of steam was the Greek scientist Hero in the first century AD. His aeolipile (see figure 1) works on a principle devised by Isaac Newton (1642–1727) that "each action has an equal and opposite reaction." The steam escaping in opposite directions from two exhaust tubes causes the metal sphere to rotate. Although the device demonstrated the potential of steam, it was not used for any practical purpose.

The steam engines developed in the early eighteenth century to drive machinery worked on the same principle, using the expansion of steam within cylinders to drive a piston. In 1884 British engineer Charles Parsons (1854–1931) devised the first commercial steam turbine, in which jets of steam pushed against blades to turn a rotor. His design was a response to demands from the electricity industry for generators that could run at very high speeds. Parsons' steam turbine was used to power ships, revolutionizing sea travel—both passenger and military—by allowing for higher speeds.

Figure 1



Today, most electricity is generated by power stations using steam turbines. The steam is produced by burning fossil fuels such as coal or gas, or using nuclear power. In this investigation you will show how jets of steam can be harnessed as a source of power.

TIME NEEDED:

1 hour

MATERIALS:

- empty can, about 6 in. high, with press-on metal lid (e.g., 1-quart paint can)
- metal file
- straight-sided cork
- ruler
- pen
- 8 1 in. x 1/2 in. strong plastic strips (e.g., cut from a plastic ice cream container)
- 6-in. and 14-in. lengths of 1mm-diameter copper wire
- heat- and water-resistant glue
- X-acto® knife
- cutting board
- pliers
- bunsen burner
- tripod
- metal gauze
- 12-in. length of thread
- paper clip
- awl about 1/4 in. in diameter
- transparent tape

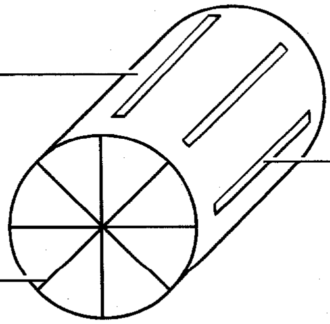
Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Be careful when using the knife. Do not overheat the metal can, and keep well back from the apparatus when the turbine is in operation.

PROCEDURE:

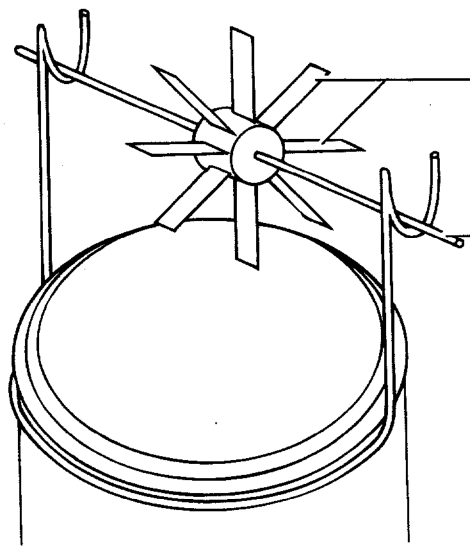
1. Using the X-acto® knife and working on a cutting board, carefully cut off one end of the cork so that it is 3/4 in. long. Use a ruler and pen to mark out eight equal sections on one end of the cork. Use these marks as guides for you to cut eight 1/2-in.-long and 1/8-in.-deep slots at equal intervals around the cork (see figure 2). It is important to do this as accurately as you can so that the turbine will be well balanced.

Figure 2



2. Using a metal file, sharpen one end of the shorter length of copper wire into a point, and slowly and carefully push the wire through the exact center of the cork. Position the cork halfway along the wire. The wire is the turbine spindle.
3. Carefully insert the plastic strips into the slots in the cork, gluing the strips in place if necessary, so that the strips each project about 7/8 in. from the cork. The strips form the blades of the turbine.
4. Use pliers to bend the longer length of copper wire into a semicircle to fit around the can with two u-shaped supports, about 2 in. long, projecting vertically on either end for the turbine spindle. The two supports must be arranged so that the spindle, when resting on the supports, is horizontal and its blades are about 1/2 in. from the top of the can (see figure 3).

Figure 3

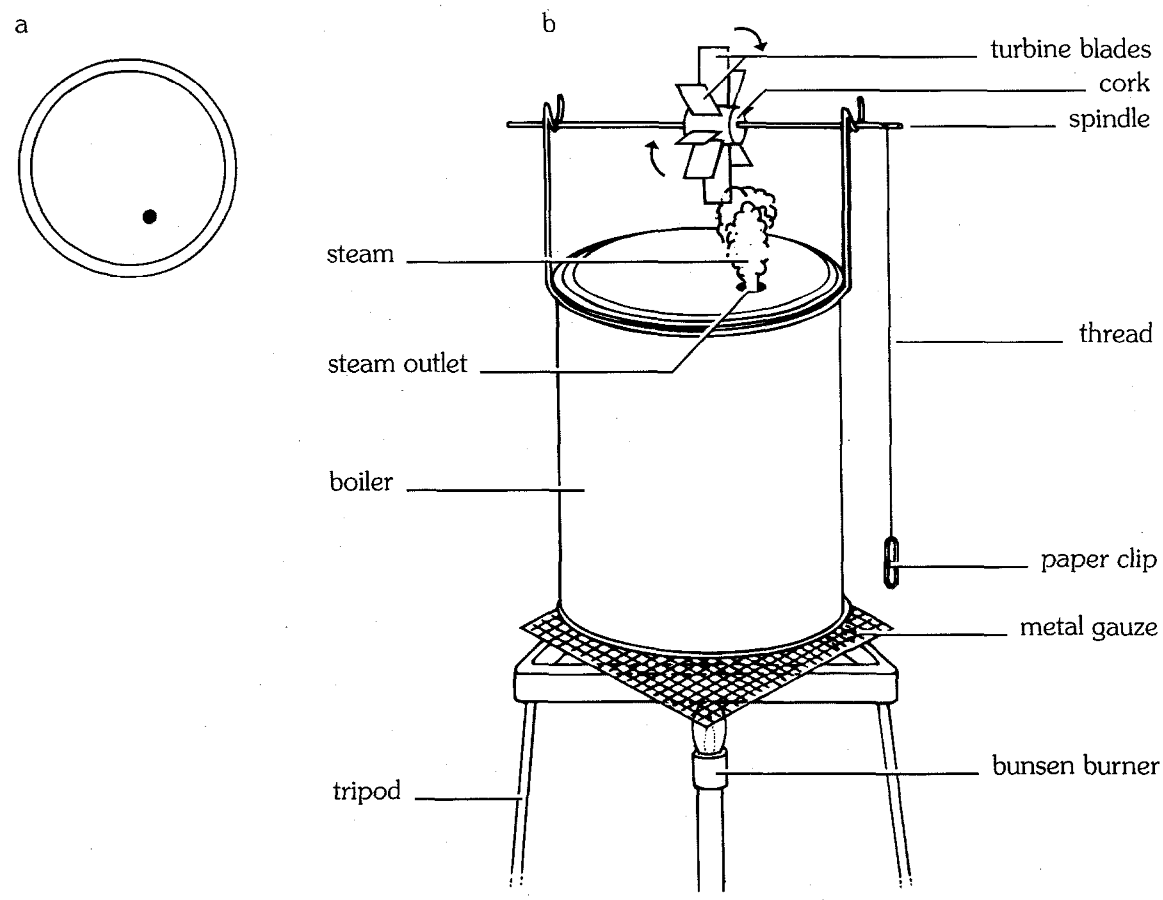


5. Remove the turbine spindle from its supports. Tie one end of the thread to one end of the turbine spindle, and tie the other end of the thread to a paper clip.
6. To complete the steam turbine, make the can into a boiler. To do this, use the awl to make a hole in the lid. The hole needs to be off-center, directly underneath the turbine blades and toward their outer edge (see figure 4a).

7. Put about 1 in. of water in the can, replace the lid tightly, and place the apparatus on a tripod and metal gauze above a bunsen burner. Make sure the apparatus is stable.

8. Replace the turbine spindle in its supports. Heat the can, and watch what happens when the water begins to boil (see figure 4b). Reduce the heat when the turbine is spinning fast. The lid is a safety valve, so keep well away from the apparatus when the turbine is in operation.

Figure 4



9. Do not let the water boil dry. Switch off the bunsen burner and allow the can to cool before touching it.

ANALYSIS:

1. What happened in step 8 when the water began to boil?
2. Suggest two ways in which you could alter the design or operation of your steam turbine to produce more power.
3. In the steam turbine you have constructed, the spindle provides rotational power to lift objects and, on a larger scale, drive machinery. Most steam engines of the eighteenth and nineteenth centuries, on the other hand, used pistons within cylinders to harness steam power. Do some research. How did these engines convert the back-and-forth movement of a piston to a rotational movement for driving machines?
4. What are the advantages of steam turbines over piston-driven steam engines? Why are piston-driven steam engines no longer in common use?
5. Internal combustion engines (gas- and diesel-powered engines that burn these fuels in a chamber within the engine) have superseded steam engines in many applications, such as in small vehicles. Do some research to find out why this is.

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES

Our Findings

VII. POWER

7.14 Steam turbine

1. When the water begins to boil, a jet of steam escapes from the hole in the can, strikes the blade of the turbine, and causes the turbine to turn on its spindle, so generating the power necessary to raise the paper clip.
2. Without changing the design you could operate the turbine at a higher temperature, which would generate more pressure, making the steam escape at a higher speed and so turning the turbine blades more quickly. This would be dangerous, however. Alternatively, you could make a boiler from thicker metal, use more water, and operate the turbine at higher temperatures and pressures. You could also explore making the hole bigger through which the steam escapes. There is likely to be an optimum size for the steam outlet which would turn the turbine blades with greatest efficiency.
3. "Sun and planet" gears on a flywheel—designed by Scottish inventor James Watt (1736–1819)—were used to convert a back-and-forth movement of a piston to a rotational movement. A belt on the flywheel transferred power from the flywheel to the factory machines.
4. Steam turbines provide rotational power directly, whereas piston-driven steam engines need to have a system of mechanical linkages to convert output into rotational power. Steam engines are large, heavy, not very efficient, and have relatively low speed output. Steam turbines, on the other hand, use steam more efficiently and at higher output speeds. As a result, piston-driven steam engines have been superseded by steam turbines.
5. Compared to steam engines, internal combustion engines are much lighter, more adaptable and efficient, and they have higher output speeds. Nowadays, they are the first choice for powering transport devices on land, sea, or air.