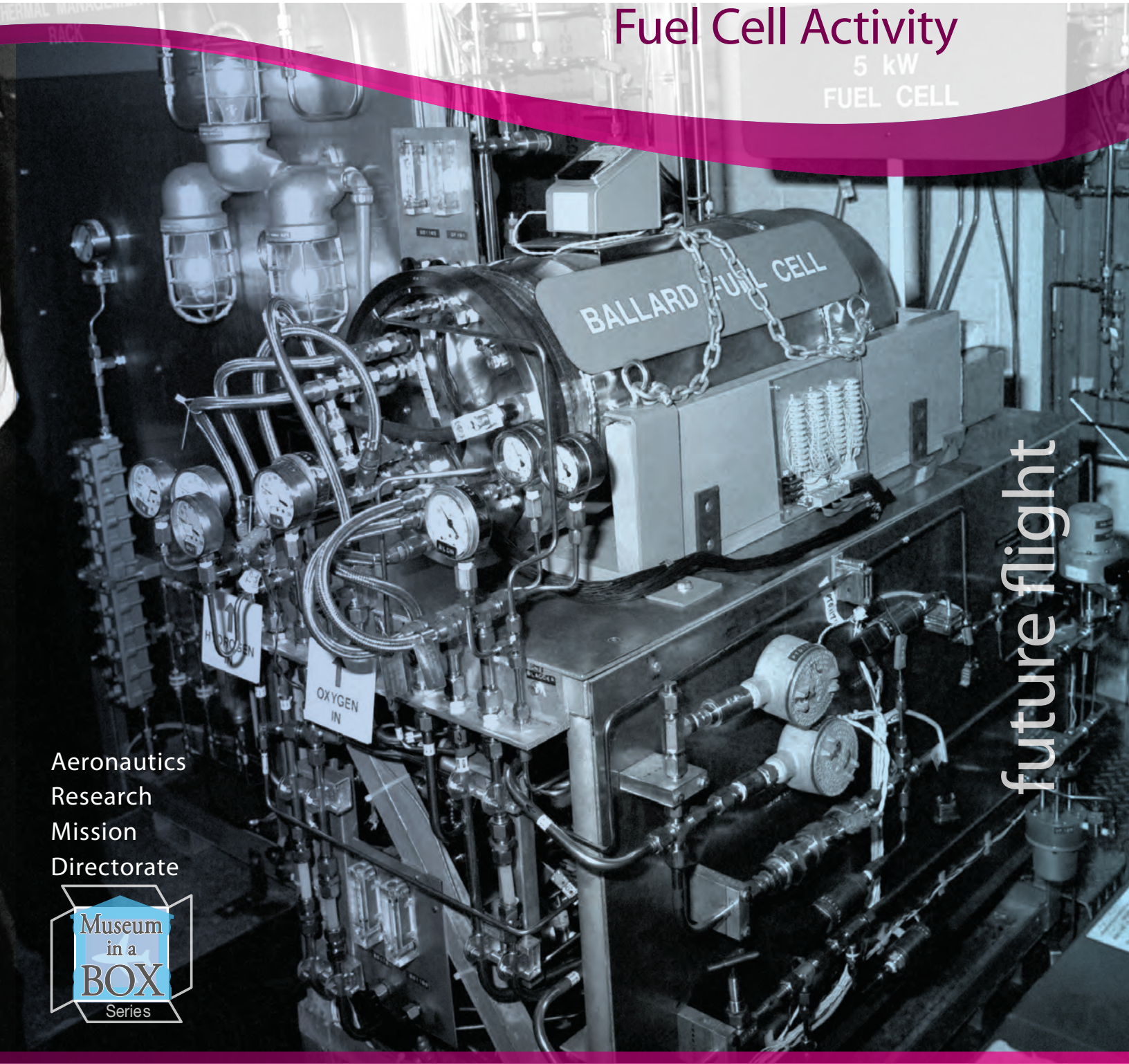
National Aeronautics and Space Administration

GRADES 5-12

Fuel Cell Activity



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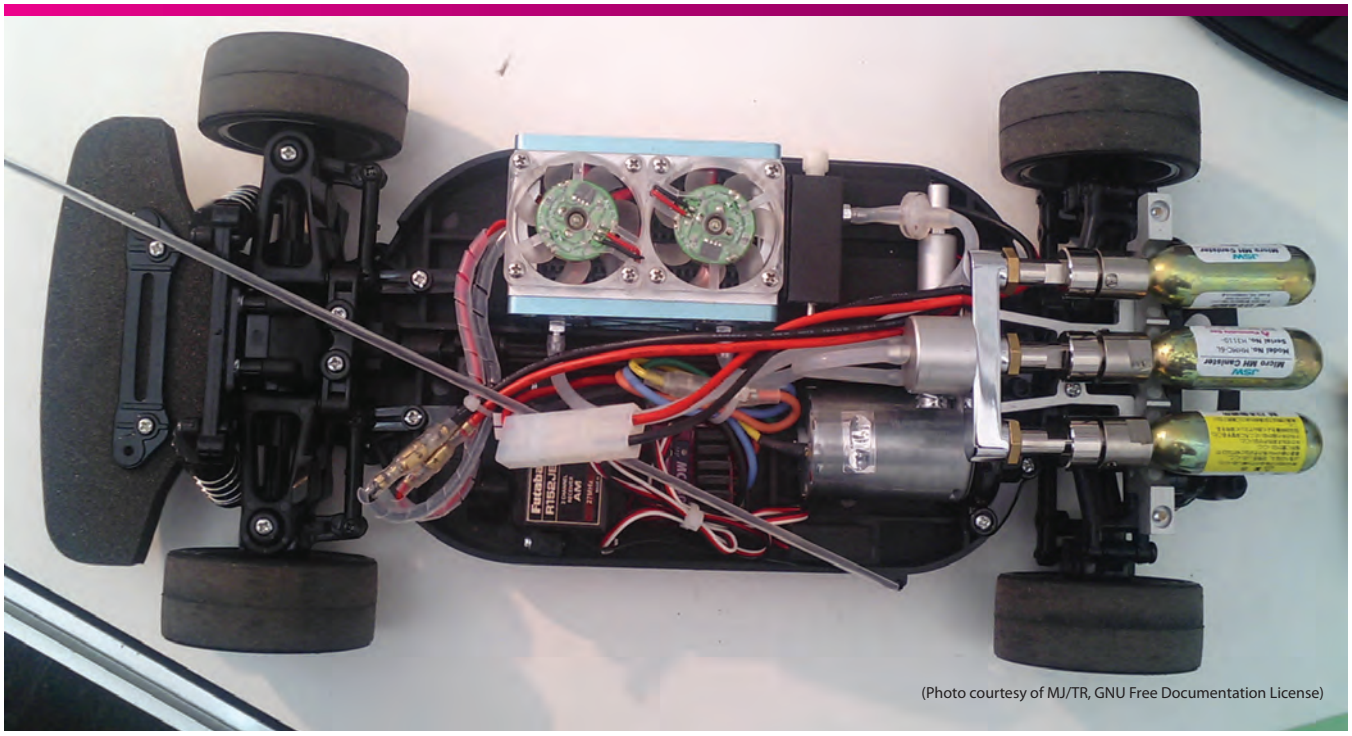
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Fuel Cell Activity

Lesson Overview

By observing this demonstration, students will learn about properties and changes in matter as water is converted into its elemental components using solar electricity and a fuel cell. They will also learn how the same fuel cell creates electricity by converting hydrogen and oxygen into water.

Objectives

Students will:

1. Discover how a hydrogen fuel cell can power a small car.

Materials:

In the Box

Thames & Kosmos™ Fuel Cell Car & Experiment Kit

Safety goggles (1 pair)

Philips head screwdriver

Small knife or scissors

Metric ruler

Provided by User

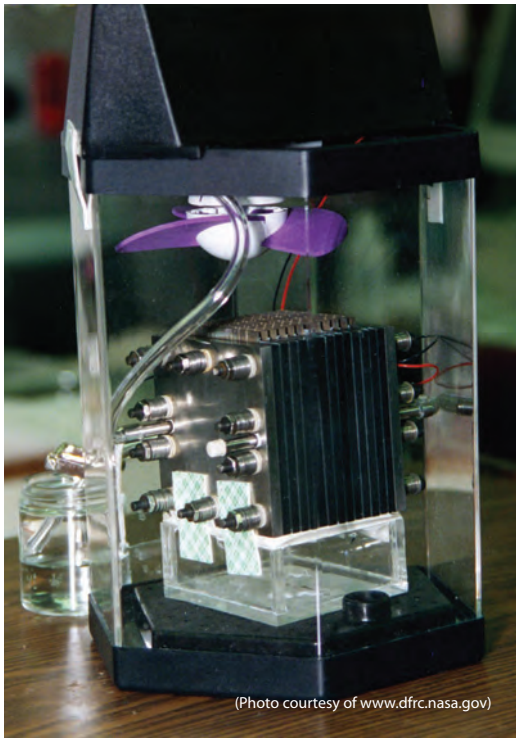
Sunlight / lamp

Distilled water

GRADES **5-12** **Time Requirements:** 1 hour

An Introduction to the Fuel Cell

The ability to produce power without damaging the environment is a continuing challenge. Fossil fuels like gasoline, natural gas and coal all come from non-renewable sources and when burned, they increase the levels of air pollution and may harm the environment. Batteries, such as those found in flashlights and MP3 players, have limited lifetimes and often end up being disposed of in landfills which over time leach hazardous chemicals into the earth. There are many environmentally friendly alternatives available today, such as solar, wind, geothermal and hydroelectric power. These power sources often depend on a power grid for the distribution of electricity. Fuel cells however are different. They have near-zero emissions, are quiet and efficient, can work in almost any environment and do not need a grid for distribution. It can also operate in a temperature that is lower than the cell's normal operating temperature.



(Photo courtesy of www.dfrc.nasa.gov)

A fuel cell combines a fuel, such as hydrogen, with an oxidizer (oxygen) to produce electrical power. It works in a similar way to a battery but it never runs down or needs to be recharged. Like a battery which has a positive and negative end, a fuel cell has two electrodes: the positive (cathode) and the negative (anode), both of which are separated by an electrolyte, similar to the gel in a standard battery. With the battery however, one of the electrodes is slowly eroded as electricity is produced whereas in a fuel cell, the electrode is not. This means the cell can produce electricity for as long as fuel and oxidizer are available.

NASA's Glenn Research Center in Cleveland, Ohio has been at the center of NASA's fuel cell research and development since 1963. It helped to develop the fuel cells that were the primary source of power on the Space Shuttle fleet as well as develop fuel cells for electric vehicles and energy-storage systems.

Fuel cells may soon be seen in many areas of our lives. For example, they may replace the auxiliary power unit (APU) on commercial aircraft, which provides electricity when the engines are not operating. They could also be used in cars or personal electronics. They are even being considered for use on future missions to Mars and beyond.

Much work must still be done before fuel cells can be used in long range spacecraft, primarily because of the need to operate in extreme low pressure environments and low temperatures for extended durations. When perfected though, the technology will enable new space exploration as well as provide fuel savings, quieter operation and reduced environmental emissions.

For further information on the design, physics and operation of the hydrogen fuel cell, please refer to page 78 in the Thames & Kosmos® Fuel Cell Lab Manual included in the Museum in a Box.

Activity 1 Fuel Cell Car Demonstration

GRADES 5-12

Time Requirements: 1 hour

Materials:

In the Box

Thames & Kosmos™ Fuel Cell Car & Experiment Kit

Safety goggles (1 pair)

Philips head screwdriver

Small knife or scissors

Metric ruler

Provided by User

Sunlight / lamp

Distilled water

Worksheets

None

Reference Materials

None

Key Terms:

H_2O

Electrolysis

Fuel cell

Objective:

Students will discover how a hydrogen fuel cell can power a small car.

Activity Overview:

By observing this demonstration, students will learn how water is converted into its elemental components using solar electricity and a fuel cell. They will also learn how the same fuel cell creates electricity by converting hydrogen and oxygen into water.

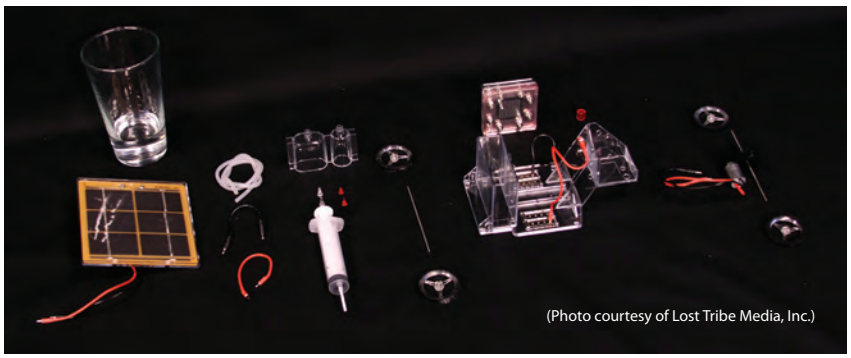
Activity:

Caution: The fuel cell kit contains many small, easily breakable parts. It is important to exercise caution during both the setup and the demonstration.

Caution: At no time should the fuel cell be disassembled. It contains a very delicate Nafion foil plate which WILL be destroyed unless opened in laboratory conditions.

WARNING: The fuel cell used in this kit creates hydrogen, a highly explosive gas. While the kit cannot produce enough gas to create a large explosion, care must be taken to avoid working near heat sources or open flames. Before starting this demonstration, read ALL of the safety information contained on pages 3 and 41 of the Thames & Kosmos® Fuel Cell Lab Manual included in the Museum in a Box.

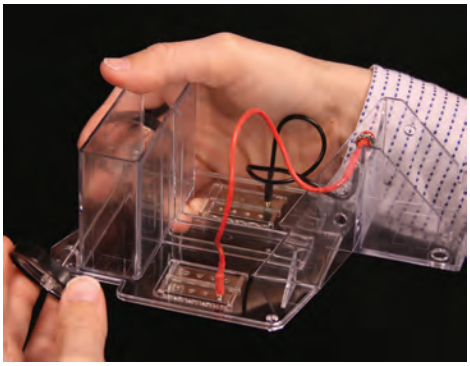
The kit will require time to build and charge prior to the demonstration. It takes approximately 30 minutes to assemble the vehicle itself, with an additional 30 minutes required to charge the gas tanks and demonstrate the vehicle moving.



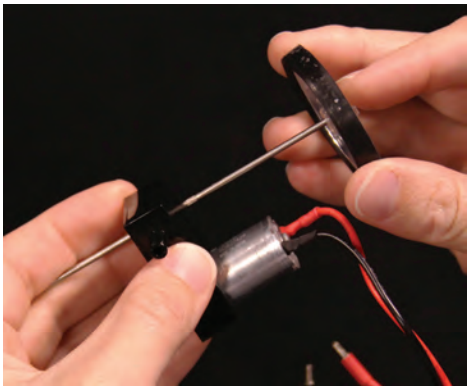
Img. 1 Exploded view of Fuel Cell Car Kit

Assemble the car as follows:

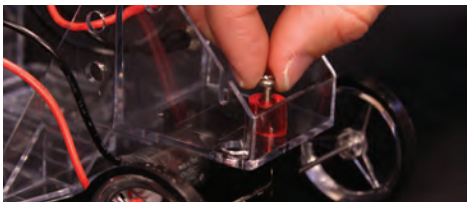
a. Pass a metal axle through the holes in the rear of the body and attach a wheel to each end.



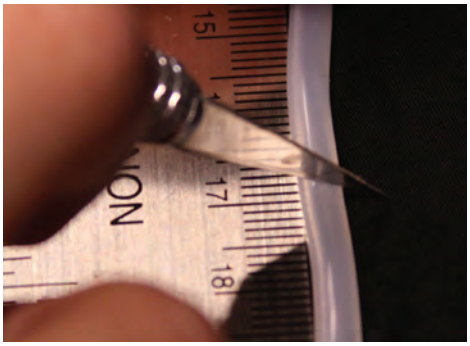
b. Attach a wheel to each end of the axle on the motor assembly.



c. Attach the motor assembly to the body of the car using the Phillips screw and spacer.

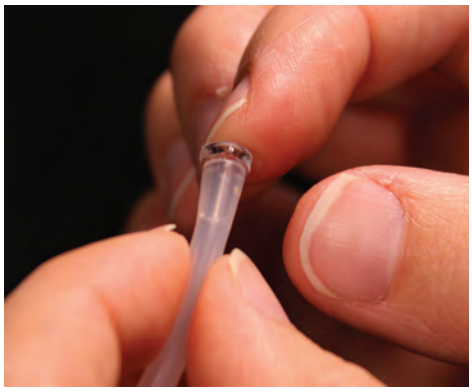


d. If necessary, cut the rubber hose into the following lengths: 1 of 6cm, 2 of 5cm, 2 of 17cm. It is important to be accurate when cutting the hose.

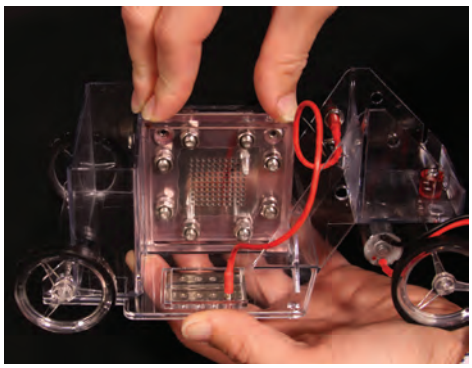


e. Plug one end of each of the 5cm hoses using the red plugs provided.

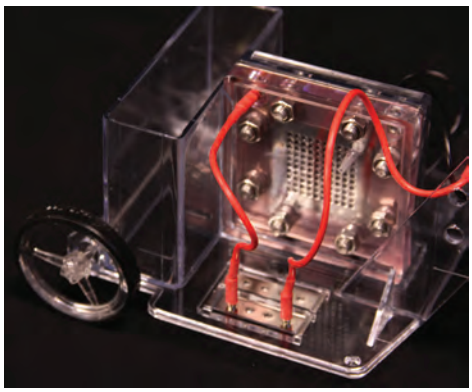
f. Plug one end of each of the 17cm hoses using the transparent plugs provided.



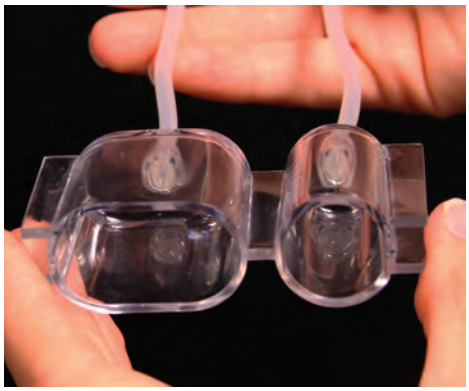
g. Insert the fuel cell into the slot provided in the car, ensuring that the red side is facing the right side of the car.



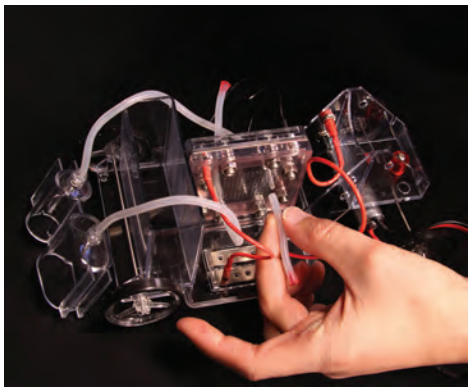
h. Place one end of the red wire into the hole in the red side of the fuel cell; insert the other end of the wire into the hole next to it on the body of the car. Do the same with the black wire on the opposite side.



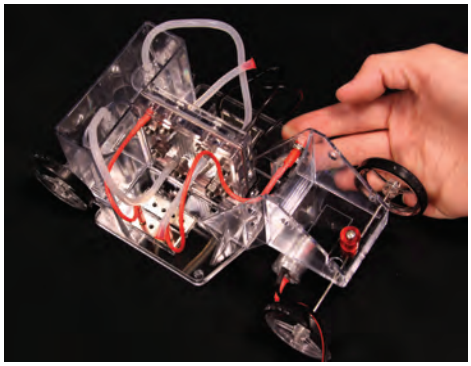
i. Pass the 17cm hoses (with transparent plugs) through the bottom of the gas tanks and pull until each transparent plug is firmly secured in the hole at the top of the tank.



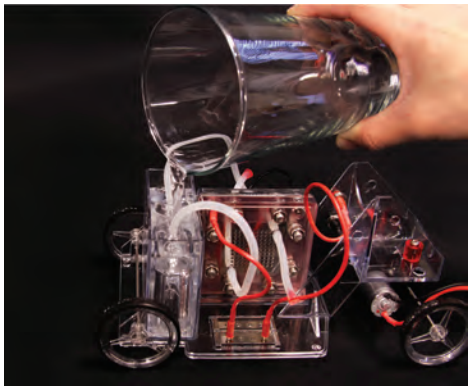
j. Attach the hose from the larger tank to the port on the bottom of the red side of the fuel cell, while the hose from the smaller tank connects on the opposite side. Attach the 5cm hoses to the top ports.
You will notice that the fuel cell has a red and a blue side. The red side is referred to in the Thames & Kosmos® Fuel Cell Lab Manual as the "Hydrogen" side, while the blue side is the "Oxygen" side.



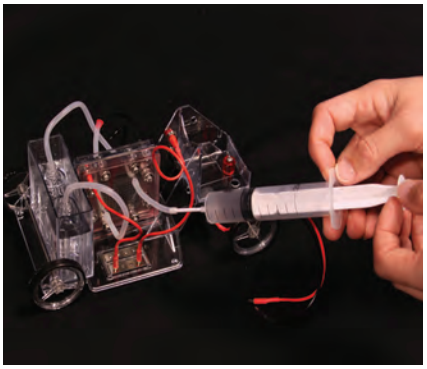
k. Place the gas tank assembly into the carrier on the back of the car, ensuring that the hydrogen tank (the larger tank) is on the right side of the vehicle.



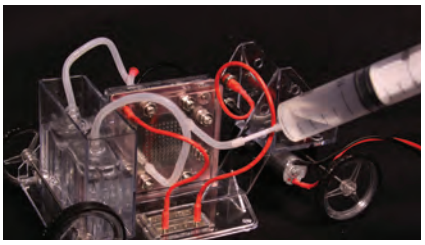
l. Carefully pour distilled water into the water tank on the back of the vehicle, filling it full. It is important to ONLY use distilled water. Regular tap water contains minerals which will damage the fuel cell.



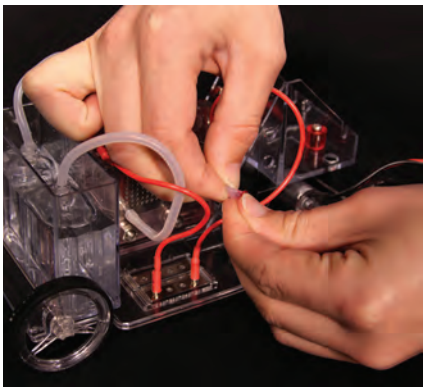
m. Remove the red plug from the end of one of the short 5cm hoses and then carefully insert the tip of the syringe into the end of the hose. This will be a snug fit. Next, slowly draw backwards on the plunger to pull water from the tank into the fuel cell.



Caution: Do not let the tank fully empty. The purpose of this step is to remove all air from the system! It may be necessary to disconnect the syringe, push forwards on the plunger to empty it and then reconnect more than once to fully draw all the air out of the fuel cell.



n. Once the syringe has filled with water, disconnect and immediately reconnect the red plug. It may help to pinch the tube to prevent air from re-entering the system.

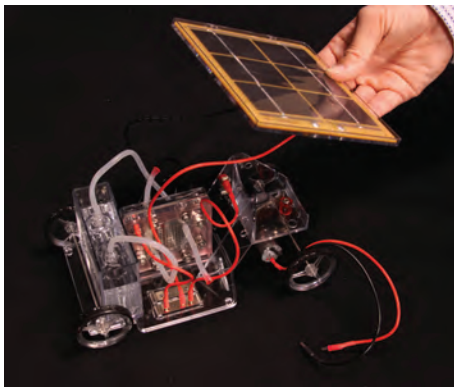


o. Repeat the process on the other side of the fuel cell.

By this stage, you have a completely assembled car that is ready to use. The remaining steps will convert the water into its individual components of hydrogen and oxygen, then convert them back into water, generating electricity in the process. It may be beneficial for the students to start the demonstration at this point, which will take an additional 30 minutes to complete. As you complete each step, explain what is happening to the students.

1. **Use the assembled fuel cell car as follows to demonstrate to the students how the fuel cell generates electricity:**

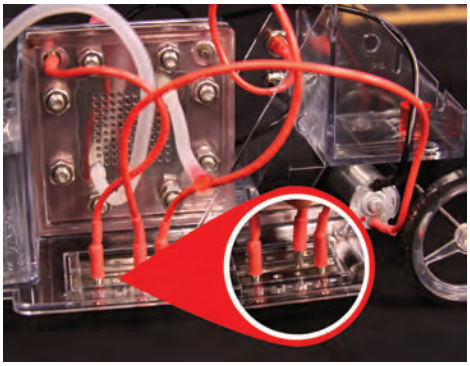
   a. Connect the wires of the solar panel to the car, ensuring that the red wire connects to the red side, the black wire to the black side. Place the assembly under a lamp, or near a sunny window. There is no need to mount the solar panel to the car.

   Once the wires to the solar panel are connected, electricity is powering the fuel cell, converting the water into its base elements, hydrogen and oxygen. This separation of hydrogen and oxygen is called electrolysis. It takes approximately 15 minutes for the fuel cell to fill the gas tanks completely, at which time you can move on to the next step.

   b. Disconnect the solar panel and set it to one side.
   It is likely that your students are already familiar with solar power. Therefore it is important to demonstrate that it is completely detached and no longer producing electricity.

   c. Attach the wires from the motor to the plug holes in the body. Connect the red wire to the right side of the car, the black wire to the left.

   At this point the fuel cell begins to work in the opposite direction, taking the hydrogen and oxygen gases and converting them back into water. As this happens, electricity is produced which powers the motor.

   d. Place the car on the ground and let it go!

Discussion Points:

1. **What just happened?**
   The fuel cell is a two-way device; it can either produce gas from water, or water from gas. In step (2a), we used the fuel cell to convert water, or H_2O, into its base elements, hydrogen and oxygen, which were stored in the tanks on the back of the car. After disconnecting the solar panel, which provided the source of electricity needed to power the conversion, the production of gas stopped and the fuel cell started to consume gas instead. As the cell converted the gases back into H_2O, it also produced electricity, which then powered the motor in the car.

2. **What does H_2O mean?**
   H_2O is the chemical formula for the compound we commonly call water. In the case of distilled water, each molecule contains 2 hydrogen atoms and 1 oxygen atom. Every substance can be described this way. For example, table salt is NaCl, or one part Sodium (Na) to one part Chlorine (Cl).

3. **Why does the water have to be distilled? What does that mean?**
   Think of a typical bottle of spring water. It says right on the label that it contains "minerals which are important to health," which is true. Unfortunately, what is good for humans and animals isn't good for fuel cells. Minerals, which are very small crystals found in drinking water, clog the fuel cell and prevent it from working.

   Distilling is a process where a liquid, water in our case, is heated to the point of evaporation (steam). That steam is collected on a cooled surface where it condenses again back into liquid water. This is the distilled water that can be used by the fuel cell. As the mineral crystals could not be carried in the steam, the distilled water is 100% pure H_2O, with no additional minerals.

This demonstration is just one of many experiments that can be performed using this kit. The other activities available with the Fuel Cell kit are listed below. Detailed instructions can be found in the Thames & Kosmos® Fuel Cell Lab Manual.

1. **Page 50 / Experiment 9: Splitting of Water Through Electrolysis**
   In this experiment, students will make an electrode and apply a small electrical current to water in order to witness the separation of the oxygen and hydrogen molecules.

2. **Page 52 / Experiment 10: Test to Demonstrate Presence of Hydrogen**
   Continuing on from Experiment 9, students will collect the gas bubbles created and test to see if the gas reacts to an open flame.

3. **Page 54 / Experiment 11: Calibration of the Gas Tanks**
   Students will use a graduated syringe to calibrate the scale on the gas/water tanks.

4. **Page 57 / Experiment 12: Assembly and Filling of the Fuel Cell**
   Similar to the fuel cell activity just completed, in Experiment 12 students assemble a fuel cell and prepare it for use.

5. **Page 59 / Experiment 13: Splitting of Water in the Fuel Cell**
   Similar to the fuel cell activity just completed, in Experiment 13 students convert water into hydrogen and oxygen.

6. **Page 60 / Experiment 14: Qualitative Gas Analyses: Test to Demonstrate Presence of Hydrogen, Glow Test to Prove Presence of Oxygen**
   This experiment expands on the skills learned in Experiment 10, testing the different gasses produced by the fuel cell and determining their properties.

7. **Page 61 / Experiment 15: Quantitative Measurement of Gas Generation Rates**
   Having discovered that the fuel cell produces gas, students will now determine the rate at which gas is produced.

8. **Page 65 / Experiment 16: Electrical Measurement of the Electrolysis: Determination of Current and Voltage**
   In this experiment, students will measure the voltage and current output of the solar panel being used to perform the electrolysis.

9. **Page 66 / Experiment 17: Efficiency of Water Electrolysis**
   Students will use the numbers discovered in Experiment 16 to calculate the efficiency of solar electrolysis.

10. **Page 68 / Experiment 18: Influence of Light and Shade on the Splitting of Water**
    Students will adjust the amount of light hitting the solar panel and note the change in the rate of electrolysis.

11. **Page 70 / Experiment 19: A Game of Patience: Complete Splitting of all the Water in the Fuel Cell**
    Students will measure the amount of time it takes for electrolysis to generate 24ml of hydrogen gas.

12. **Page 71 / Experiment 20: Another Math Problem: How much Water was there in the Fuel Cell**
    Using math, students will determine how much water can be created with 24ml of hydrogen and 12ml of oxygen.

13. **Page 72 / Experiment 21: Solar Splitting of Water, is it better than with the Lamp?**
    Students will compare the difference in efficiency of a solar panel using either a lamp or the Sun.

14. **Page 72 / Experiment 22: How long does the Gas Remain in the Tank?**
    Students will discover the porous nature of plastics and discover that it is a poor choice for long term storage of gasses.

15. **Page 76 / Experiment 23: It moves!**
    Experiment 23 contains many of the steps just completed in this demonstration.

16. **Page 80 / Experiment 24: Starting the Motor**
    Students will discover how the electric motor used to power the car can also be used as a generator.

17. **Page 81 / Experiment 25: Another Way of Turning**
    Students will use the electricity produced by the electric motor to provide electricity to the electrolysis process.

18. **Page 82 / Experiment 26: Measurements on the Generator**
    In this experiment, students will continue to measure and analyze the output of the electric motor.

19. **Page 83 / Experiment 27: Range of the Car**
    By tethering the car to a post, students will measure the distance traveled on a single tank of fuel.

20. **Page 84 / Experiment 28: An Airy Matter**
    Students will discover how the efficiency of the fuel cell is affected by the use of regular air as opposed to the 100% oxygen supply.

21. **Page 85 / Experiment 29: A Crane with Hydrogen Drive**
    Students will build a crane powered by the fuel cell motor and measure the amount of weight it can lift.

22. **Page 86 / Experiment 30: What is the Power of the Crane?**
    Students will calculate the mathematical performance of the crane built in Experiment 29.

23. **Page 87 / Experiment 31: Energy Delivered by the Crane**
    Students will calculate the energy of the crane from Experiments 29 and 30 in Joules.

24. **Page 88 / Experiment 32: Measurement of No-load Voltage, Operating Voltage and Short Circuit Current of the Fuel Cell**
    In this experiment, students will measure the voltage output of the fuel cell in a variety of situations.

25. **Page 90 / Experiment 33: Efficiency of the Fuel Cell**
    Students will calculate the mathematical efficiency of the fuel cell.

26. **Page 93 / Experiment 34: Hybrid Solar Hydrogen Car**
    By combining the power of both the fuel cell and solar panel, students will explore how to extend the range of their vehicle.

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Properties and changes of properties in matter

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Structure and properties of matter
- Interactions of energy and matter

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

Reference Materials

Glossary

Electrolysis:
The process by which a direct electrical current (DC) is used to force a non-spontaneous chemical reaction

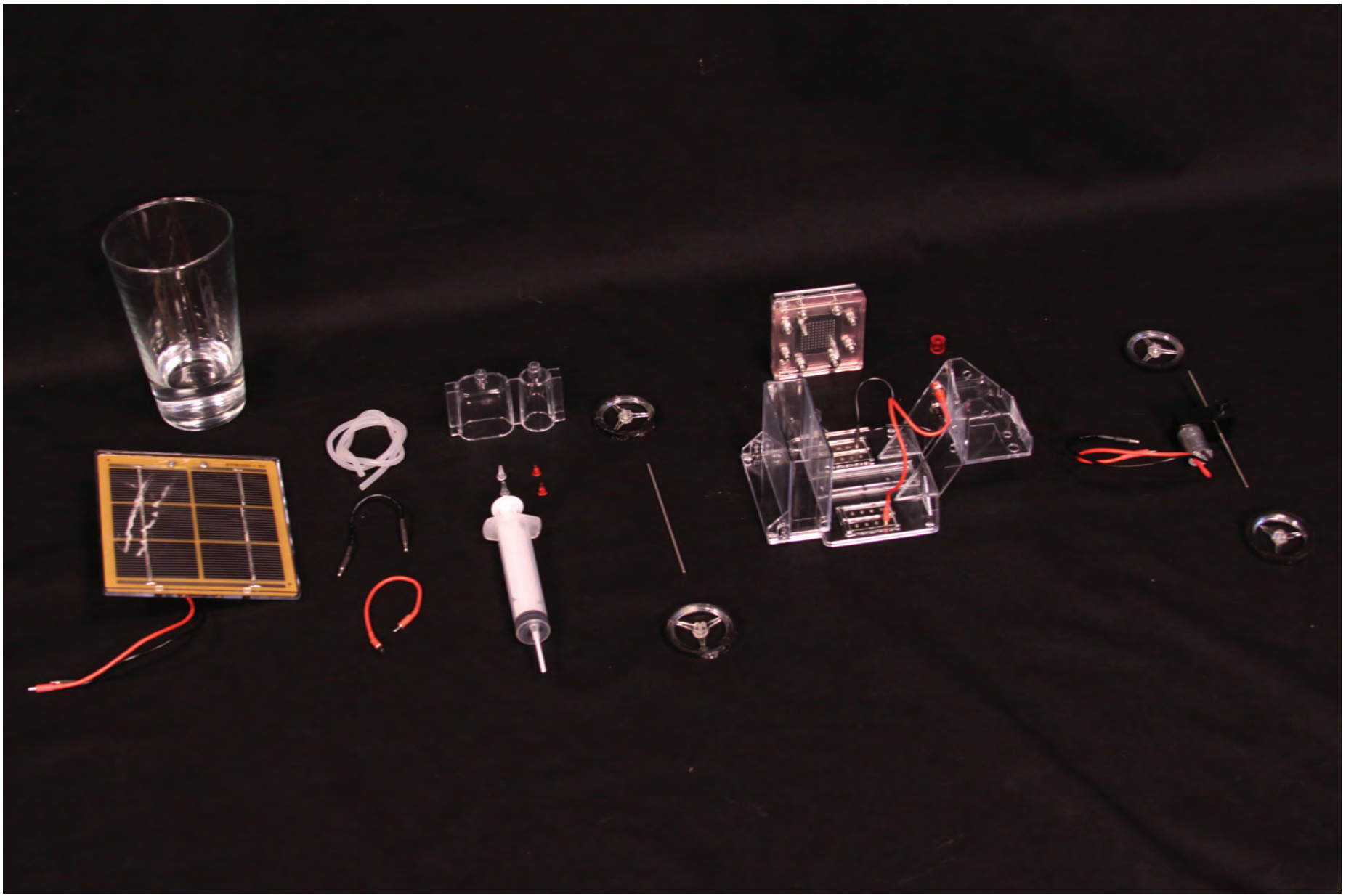
Fuel cell:
A device that converts chemical energy from a fuel into electricity through a chemical reaction with oxygen or oxidizing agent

H_2O:
The chemical name for pure water, which is comprised of two parts hydrogen to one part oxygen

Power Grid:
A system of power lines, transformers and other equipment that distributes electricity to a large area

Images

Img. 1 Exploded view of Fuel Cell Car Kit



(Photo courtesy of Lost Tribe Media, Inc.)

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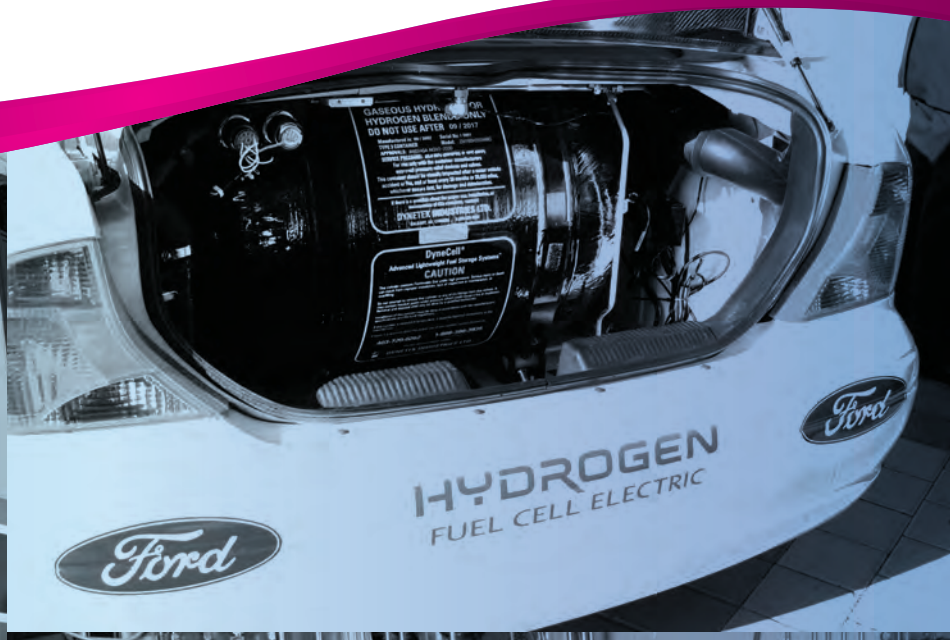
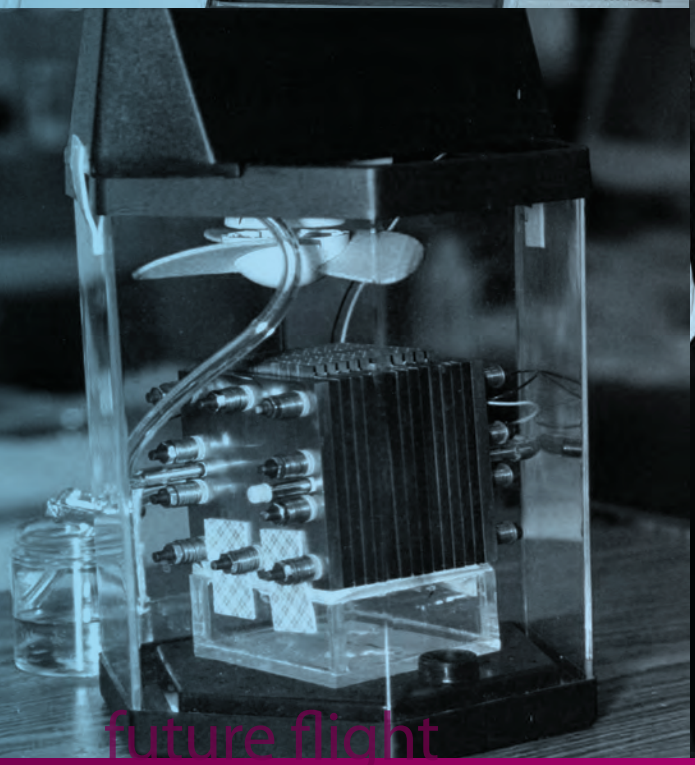
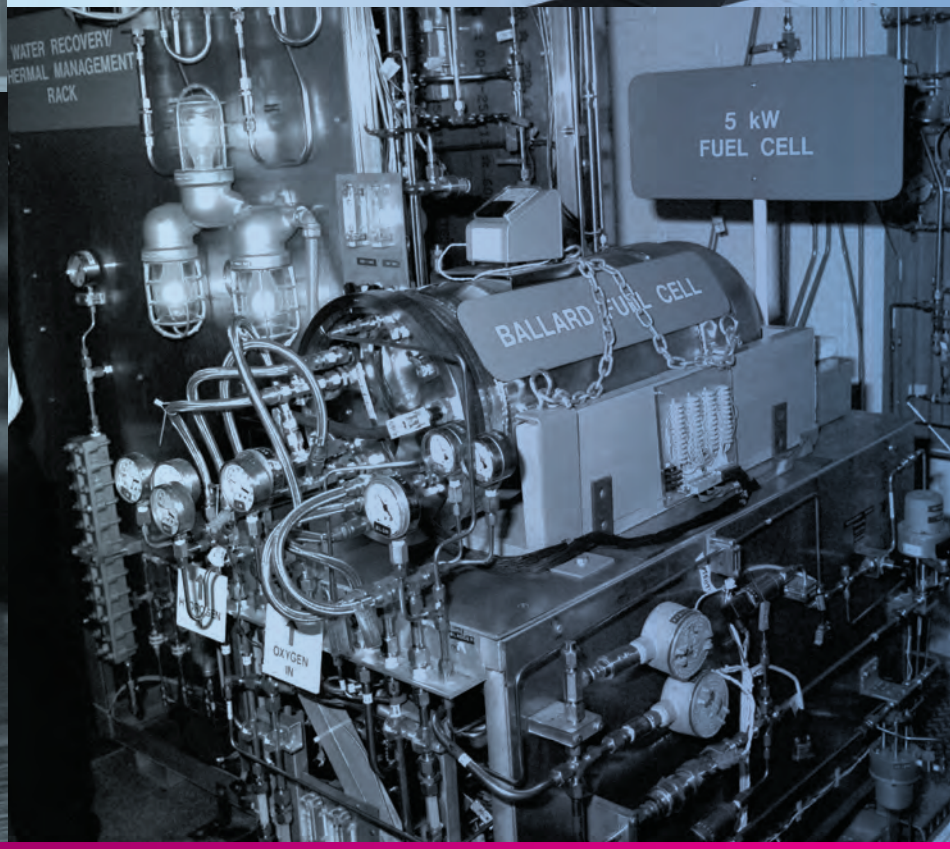
Museum in a BOX Series







future flight

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