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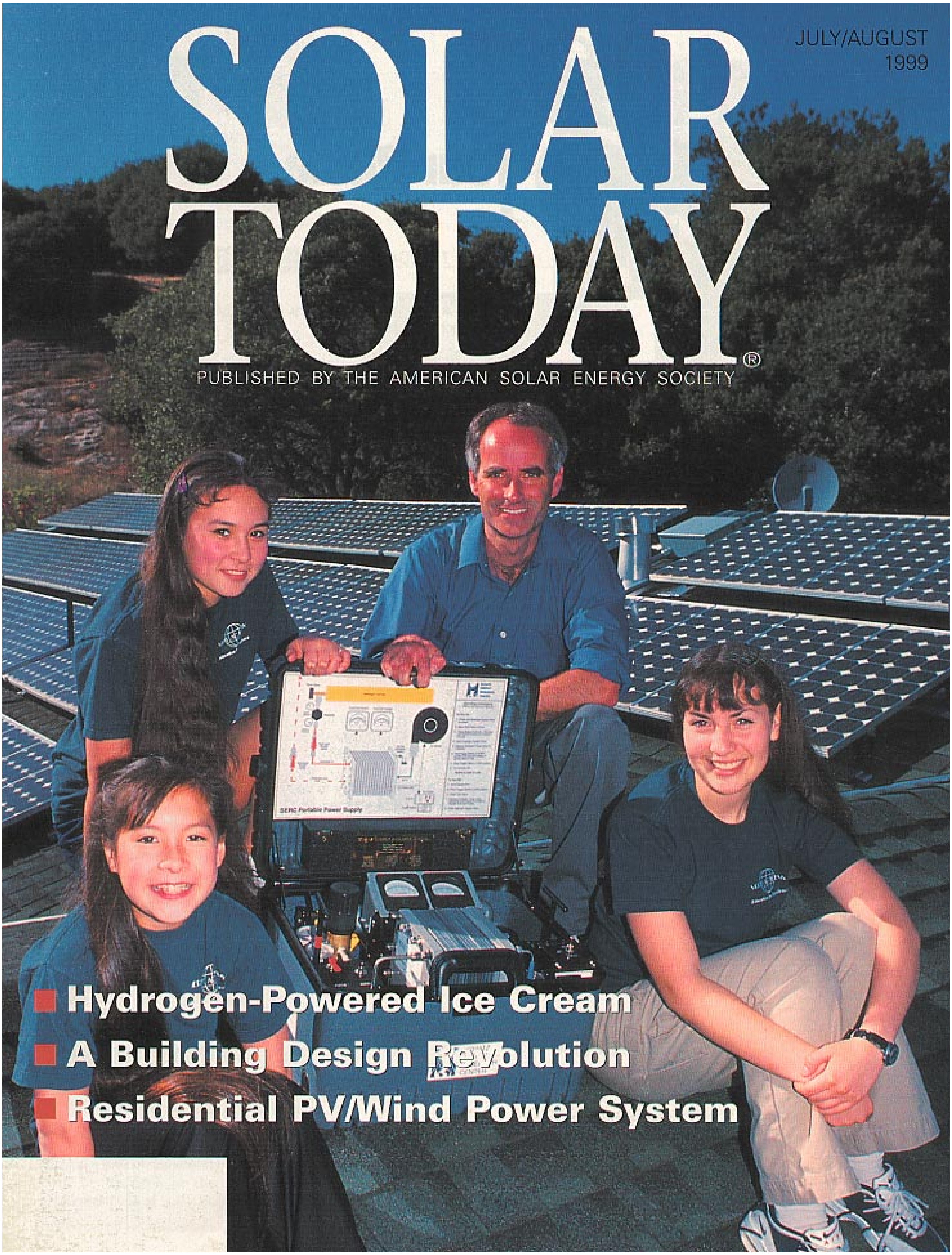



- Hydrogen-Powered Ice Cream
- A Building Design Revolution
- Residential PV/Wind Power System

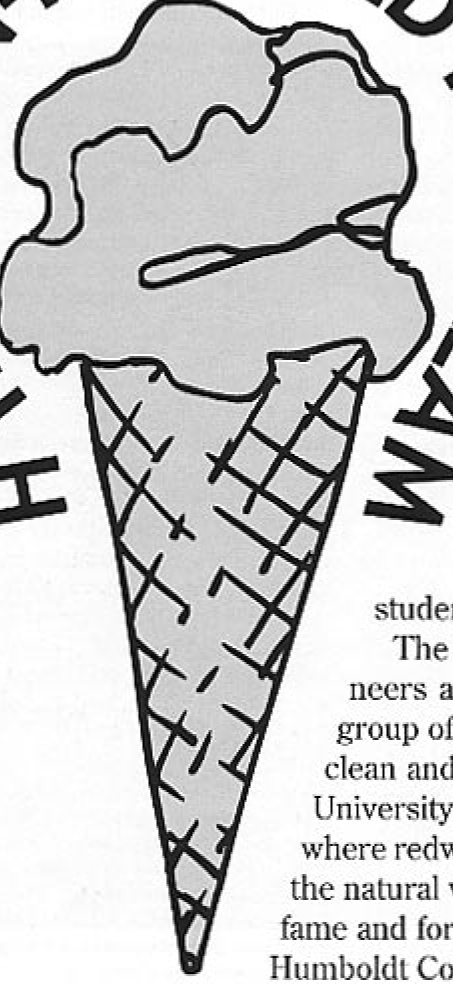
Eighth-graders use a hydrogen fuel cell to make ice cream and educate the public about clean hydrogen energy.

**by Christine Parra, Susan Ornelas and Jim Zoellick**

Susan Tatsui-D'Arcy

*Nicole D'Arcy, project director, serves up ice cream made with the hydrogen fuel cell to students (from right to left) Cody Young, Brian Hostetter, Maro Van Valer-Campbell, Joanne Arguello and Jaclyn D'Arcy.*

# HYDROGEN-POWERED ICE CREAM



"Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has."

When Margaret Mead wrote those words, she may not have realized that the most effective, "thoughtful, committed citizens" could be children—students ranging in age from ten to thirteen. They're the students of the Merit Academy, a small, private educational institution located in Santa Cruz, California. And they believe they have the power to change the world. The students are initiating change by making ice cream using an ordinary electric ice cream maker powered by a fuel cell system. Two Merit Academy students tell their story on page 31.

The system was custom designed and manufactured by the engineers at the Schatz Energy Research Center. At Schatz, we are a group of engineers and scientists committed to promoting the use of clean and renewable energy. Our center is located at Humboldt State University in Arcata, California—the pristine and remote North Coast where redwoods meet the ocean. Independent thinking and protection of the natural world are important to us. Many of us have foregone greater fame and fortune in favor of the peace and quality of life that we enjoy in Humboldt County.

Our biggest projects include building a solar hydrogen/fuel cell system for our local marine laboratory; designing, fabricating and installing fuel cell power systems for a fleet of vehicles in the City of Palm Desert; and creating portable fuel cell systems for remote power. Within a few weeks, we will begin construction of the largest solar hydrogen generation and dispensing station in the country to refuel the fuel cell fleet in Palm Desert.

### The Hydrogen/Ice Cream Connection

We are the engineers behind the design and fabrication of the fuel cell power system for the ice cream maker, which we call the Stack-in-a-Box™. In this system, hydrogen stored in a standard lecture bottle is fed to a proton exchange membrane (PEM) fuel cell to produce DC electricity (see "Stack-in-a-Box," page 32). Our recently patented low air pressure design ensures a high fuel cell system efficiency. A small inverter converts the fuel cell's 12 VDC electricity to 110 VAC electricity for the ice cream maker. The ice cream cylinder bowl (the variety containing a refrigerant within its walls) is pre-frozen, and each batch of ice cream is made in about 25 minutes. One lecture bottle of hydrogen (56 standard liters [0.5 liter compressed]) lasts about 1-1/2 hours, or long enough to make three batches of ice cream. We have made the Stack-in-a-Box™ easy to use and the students have used it over and over again with a perfect safety and operating record.

**The students have used the Stack-in-a-Box™ over and over again with a perfect safety and operating record.**

The PEM fuel cell power system that we delivered to the Merit students has a peak power of 250 W, which means that it can run a variety of electrical/electronic appliances. We tested the system by using it to make smoothies in a blender, watch videos on TV and run a computer. The system is portable and independent. You don't have to be in a lab to use it. It can provide

## Making a Difference—One Cone at a Time

by Nicole D'Arcy

Here at Merit Academy, we (the students) make ice cream using a hydrogen fuel cell-powered ice cream maker. We are concerned about the future and are learning about the hydrogen economy.

During a class debate in January 1998, we considered the issue of whether military force should be used against Saddam Hussein in Iraq. Recognizing not only that Iraq and the Persian Gulf have some of the world's major fossil fuel reserves, but also that the region has been politically unstable, we discussed the need to look for alternative fuels.

We concluded that by replacing fossil fuels as the nation's primary energy source with something clean, renewable and domestically produced, U.S. dependency on Persian Gulf oil could be eliminated. In addition, there would be environmental benefits from not using fossil fuels. Air, water and soil pollution, acid rain and the greenhouse effect are problems that can be reduced or eliminated with the substitution of clean energy sources. With this in mind, we discussed energy sources including solar, wind and hydropower, with hydrogen as a storage medium.

Susan Tatsui-D'Arcy

*Nicole D'Arcy tightens the bolts on the fuel cell stack.*

Our school administrator, Susan Tatsui-D'Arcy, began researching makers of hydrogen fuel cells. After talking to people at several organizations, she was directed to Dr. Peter Lehman of the Schatz Energy Research Center. He agreed to work with us.

The first task the Schatz engineers gave us was to "determine the load." What would we use the fuel cell power system to run? An electric toothbrush? (No fun.) A hairdryer? (An energy hog.) Finally, we settled on an ice cream maker. Everybody likes ice cream!

We met the Schatz team at Humboldt State University in November of 1998 to learn about the solar hydrogen cycle and how fuel cells work, as well as to build a foundation for our work together. Merit Academy received a $30,000 grant from the U.S. Department of Energy (DOE) to build the hydrogen fuel cell. We subcontracted Schatz to design the fuel cell stack and integrate it into a power system. Once the fuel cell stack parts were fabricated, two of us traveled to Schatz in January 1999 to assist in assembling the stack. A month later, Schatz staff delivered the fuel cell power system to us in Santa Cruz.

We have been taking the hydrogen-powered ice cream maker on the road to different high schools and elementary schools, public and private, to show other young people how hydrogen works as an alternative energy storage medium. In addition, we were invited and funded by DOE to exhibit in Washington, D.C., at the National Hydrogen Association's Annual Conference in April 1999.

DOE also brought us back to Washington, D.C., two weeks later to the Renewable Energy Caucus. We met people from all areas of the renewable energy infrastructure. Describing how our fuel cell works and discussing the hydrogen economy with members of Congress and attendees was exciting.

Entering the building with our hydrogen lecture bottles was an event in itself. Even though DOE financed our trip so we could present the fuel cell, the U.S. Capitol Police wouldn't let us in the building with hydrogen gas—it was against regulations. We had to call in the bomb squad and the police to check out the half-liter canister of hydrogen. And airline security guards think that our fuel cell is a bomb, so when we ship the fuel cell, we expect delays and extensive questioning.

While in Washington, D.C., a South Coast Air Quality Management District (SCAQMD) manager from California offered to finance our trip to exhibit the fuel cell at the National Marketplace for the Environment in Anaheim, California, and the Environment Youth Summit in Diamond Bar, California. We have even received invitations to exhibit our fuel cell in China and Japan. Serving ice cream at student conferences always makes our exhibit very popular!

At the same time, we have been taking a university-level chemistry class, and have completed our research reports about various aspects of hydrogen. These reports are available to the public by calling us at Merit Academy or visiting our web site.

We believe we have the enthusiasm and potential to educate the public about renewable energy. Through our efforts in the media (television news, radio talk shows, TV documentaries and newspapers), as well as at conferences and schools, we hope to bring attention to hydrogen as a viable and clean carrier of renewable energy. Our goal is to demonstrate the hydrogen fuel cell in third-world countries to encourage the youth to develop renewable clean energy.

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electricity anywhere and anytime—on the beach, in the mountains and at a picnic, day or night.

Because of their extensive nationwide demonstration schedule, the students now know a great deal about the everyday operation of our Stack-in-a-Box™. With their natural ability to connect with people, they are effective at communicating technical information without getting bogged down in lengthy explanations, as adults might. They are adept at starting up the system and at exchanging empty cylinders for full ones. Even more important, they are good at thinking through what's going on as they perform certain operations, and they have even done their own troubleshooting and experimentation. In other words, the fuel cell system provided more than an opportunity for demonstration and rote learning—it was an invitation into the world of science, which the students accepted with enthusiasm.

### Why Fuel Cells?

Since the beginning of the Industrial Revolution, heat engines have generated electricity and produced mechanical power. Heat engines produce electricity in multiple steps. First, a fuel is burned to generate heat. This heat is then used to produce steam or other hot gases that are allowed to expand and produce mechanical power. The mechanical power is used to turn a generator and produce electricity. But with each of the steps described above there are inherent inefficiencies. In addition, the extraction, refining and combustion of fossil fuels produce harmful emissions as well as political problems.

In contrast, fuel cells extract the chemical energy of hydrogen one molecule at a time rather than burning it in bulk (see "How does a Fuel Cell Work?," page 33). Inside each cell of a fuel cell stack, hydrogen and oxygen combine to form water. For each hydrogen molecule that is oxidized, two electrons are pushed through an external circuit to power an electrical load. The only byproducts are water and heat. There are no harmful emissions. Fuel cells generate electricity efficiently, cleanly and quietly.

The hydrogen that fuels a fuel cell system can be derived from water using electricity from the sun or wind. In this process of electrolysis, passing electricity through water causes it to split into its components, hydrogen and oxygen. The hydrogen is captured for use in a fuel cell. In this way, hydrogen can store solar, wind and other forms of renewable energy.

We can transport hydrogen from areas of the country or world that are rich in renewable energy resources (such as deserts) to cities, where the energy demand far outstrips the renewable energy supply. In addition, hydrogen allows us to concentrate solar or wind energy for applications that require large amounts of power, such as vehicles. In short, using hydrogen makes it possible to store, transport and concentrate renewable energy, which is available only at certain times, in certain places and in diffuse amounts. Hydrogen makes a sustainable energy economy possible anywhere, anytime and for any application.

### What's Next?

Although the science behind fuel cell operation is not new (the first concept cell appeared in 1839, developed by Welsh scientist William Grove), the technology is still in its infancy. The first fuel cell stacks were installed by Allis Chalmers in tractors in 1959. Then they were used in aerospace in the 1963 Gemini space missions and the 1968 Apollo moon missions. Today, fuel cells are used on the space shuttle and companies are developing fuel cell systems that will eventually provide power to cars and buses as well as homes.

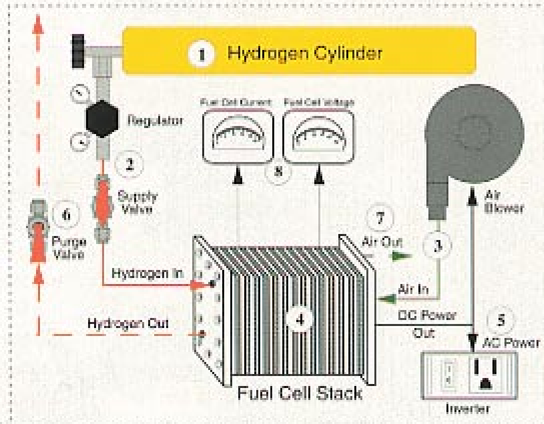
Fuel cells work. The biggest remaining challenge is cost. The materials cost for the Stack-in-a-Box™ was $10,000. But then all prototypes made in laboratories are expensive. Not long ago, you could spend as much

### Fuel Cell System Specifications

| | |
|---|---|
| Fuel Cell Type | PEM |
| Number of Cells | 15 |
| Fuel Cell Rated Power | 150 W |
| Fuel Cell Maximum Power | 250 W |
| Fuel Cell Maximum Operating Temperature | 45 °C |
| System Voltage | 12V |
| System Weight | 30 lbs. |
| Fuel Cell Stack Efficiency | 59% (LHV) |

*Schatz Energy Research Center*

## *Stack-in-a-Box™*



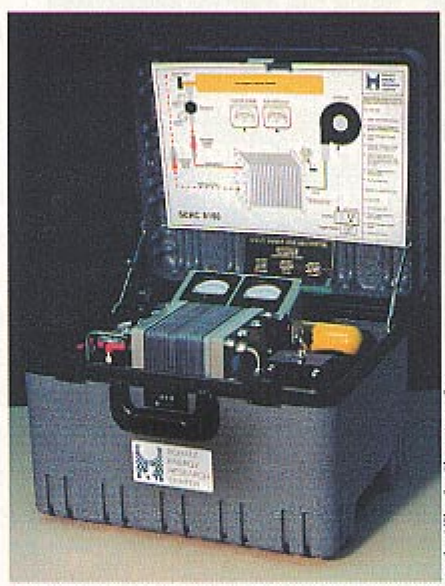

### *How Does it Work?*

The Schatz Stack-in-a-Box™ is a clean power generator that uses a fuel cell stack to generate electricity from hydrogen fuel. Hydrogen is supplied from a standard cylinder (1) through a pressure regulator and supply valve (2), to the fuel cell stack.

Oxygen is supplied by an air blower (3). DC electricity is generated in the fuel cell stack from the combination of hydrogen and oxygen (4). The 12 volt DC power from the stack is inverted to 120 volt AC power (5). The ice cream maker is plugged into the inverter.

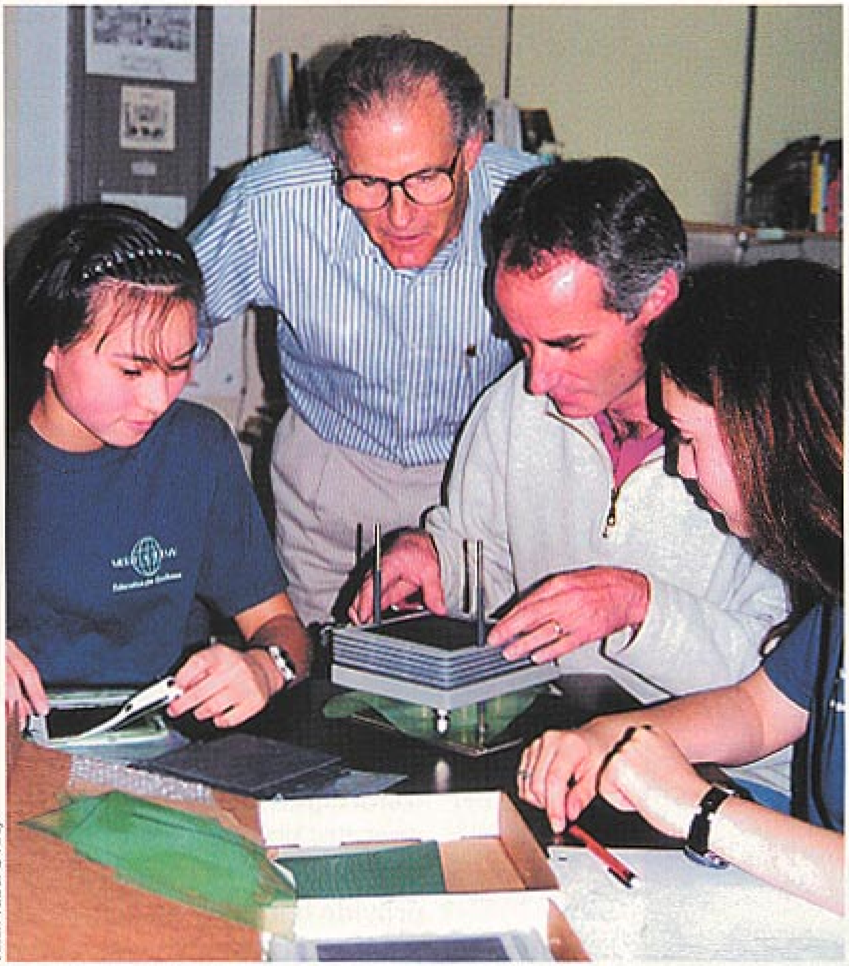
The hydrogen purge is used at start-up to flush the fuel cell stack (6). Since only the oxygen from the air is utilized in the stack, excess air flows through the stack to the air exhaust (7). Water that is generated in the stack is removed as a vapor in the air exhaust. The meters monitor the fuel cell current and voltage (8).

by Susan Ornelas



Rudy Gillard - Chromogenics

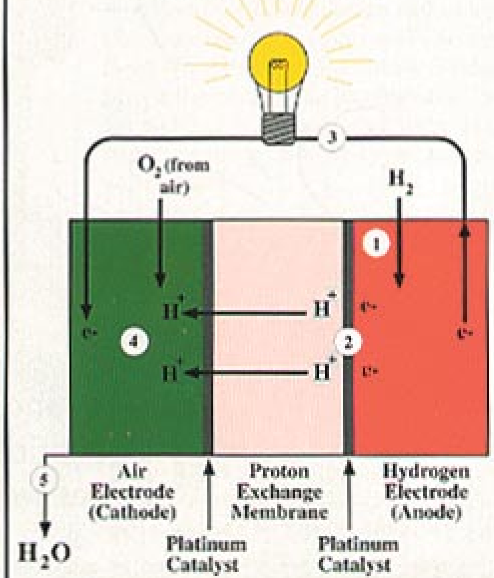
*The Stack-in-a-Box™ is easy to use and transport, making it an ideal educational tool.*



Susan Tabasi-D'Arcy

*Ron Reid, fuel cell specialist at Schatz Energy Research Center, assembles the fuel cell stack with Merit Academy students Nicole D'Arcy (left) and Joanne Arguello (right). Peter Lehman (director of the Center) looks on.*

## *How Does A Fuel Cell Work?*




A proton exchange membrane fuel cell consists of two electrodes sandwiched around an electrolyte, the proton exchange membrane. (1) Hydrogen fuel is fed into the anode where, (2) in the presence of platinum, the hydrogen molecules give up electrons and form protons ($H^+$).

The proton exchange membrane will allow only the proton to travel through the membrane. (3) The electrons travel in an external circuit to the cathode, creating electricity. (4) The protons flow through the membrane to the cathode, where they recombine with the free electrons and oxygen to form water. (5) The platinum catalyst assists in this reaction also.

The net result is that hydrogen's natural tendency to combine with oxygen and form water is utilized to produce electricity efficiently and cleanly.

A fuel cell stack is made up of a series of these individual cells. The surface area of the cell determines the current of the stack, and the number of cells in the stack determines the voltage.

by Susan Ornelas

as $400 on a new calculator (and this wasn't even the prototype), while today you spend $20. Better manufacturing techniques, automation, design improvements, volume component purchasing and mass production all will work together to reduce the price of fuel cell systems. The introduction of these systems in niche markets that can support high prices in exchange for quiet, clean, reliable, remote, power is crucial. Such an introduction will allow fuel cells to start their march down the learning curve and become affordable in more and more applications.

**Hydrogen makes a sustainable energy economy possible anywhere, anytime and for any application.**

The experience of the Schatz Center and the Merit Academy demonstrates that fuel cell power systems work reliably and can be operated safely. These systems are ready now to work in conjunction with renewable energy systems. Our society is on a path of reexamination—of rethinking how we spend our nation's financial and natural resources; of valuing clean air, water and soil; of opting for simplicity of lifestyle; and of understanding the difference between true needs and manufactured desires. One day, voluntarily or not, we will replace our fossil fuel economy with a conservation-based renewable energy/hydrogen economy. In the meantime, small groups of us continue to work to overcome the hurdles of cost and public acceptance, and to improve the technologies that will make a renewable energy economy possible.

This project represents one step in our efforts. Working with students from the Merit Academy reminded us to hang on to our convictions and to have fun as we do our research. We were heartened by their indefatigable eagerness to learn, their boldness and their effectiveness as renewable energy advocates. Students and engineers make a powerful team, one that combines strong science with the magic of young dreams—dreams that have the power to change the world. ○

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