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Vol. 17, No. 1

contents

The new logo you see for the Atom this month was created by Kathi Geoffrion Parker, a designer in the Public Information Office. She has been at LASL four years and in her present position for two; you have seen other examples of her work here and in other publications. Cover photo: Bill Jack Rodgers.

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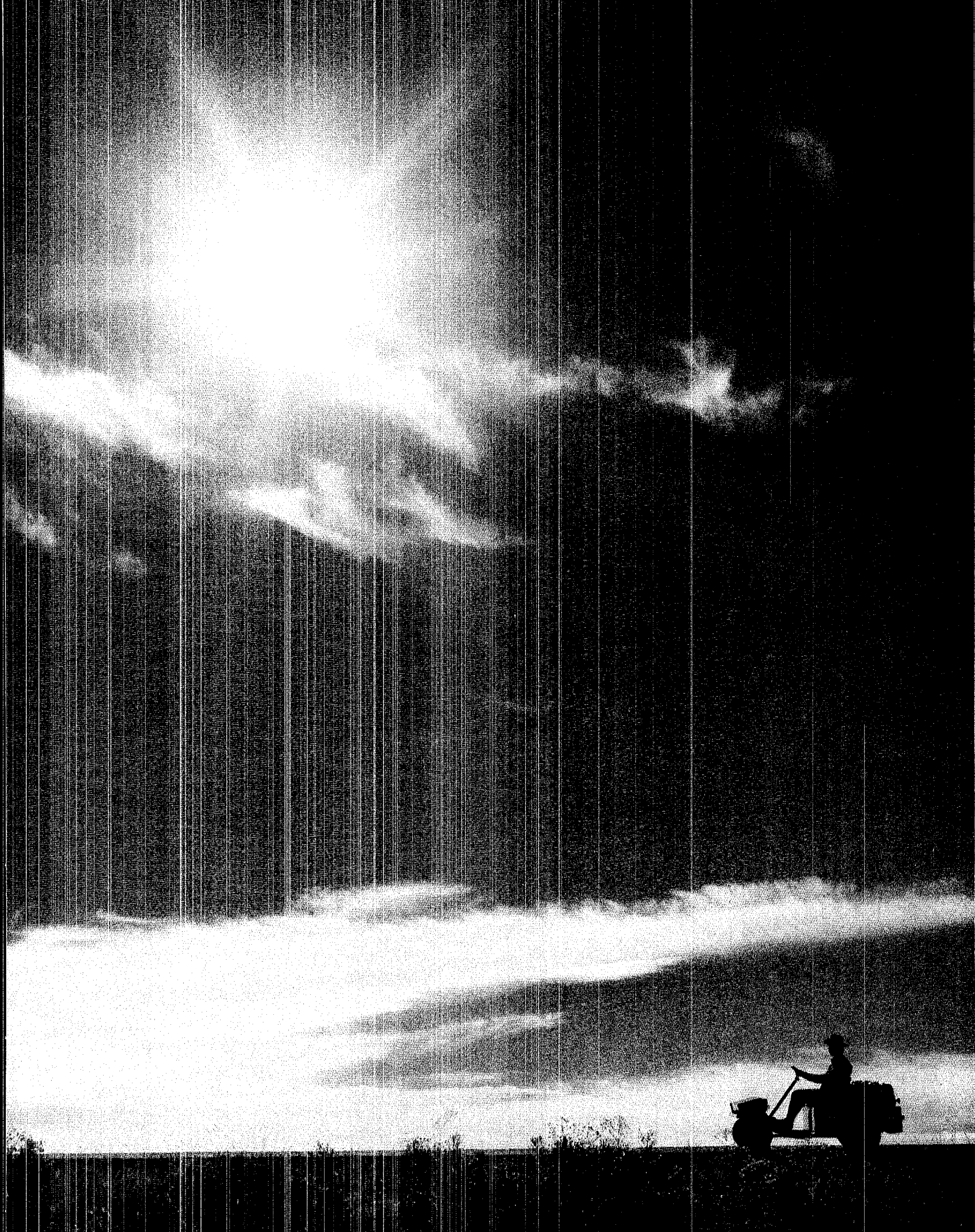


The fuel cell is not limited in use to the space capsule. At LASL, it has been used to power an electric golf cart—promising little pollution, no noise, and high efficiency.

"fill it up with methyl"

By JEFF PEDERSON

If you have ever visited Johnson Space Center near Houston, you may have seen a fuel cell. This ingenious item delivered power to space capsules for America's space missions, by converting chemical fuel directly into electricity. As a byproduct, it also supplied the astronauts with their drinking water.

The fuel cell, however, has neither been relegated to the Houston display nor limited to the space capsule. At LASL, it has been used to power an electric golf cart—a possible precursor of automotive transportation. As America looks for non-oil energy supplies, the fuel cell is garnering its share of technological attention.

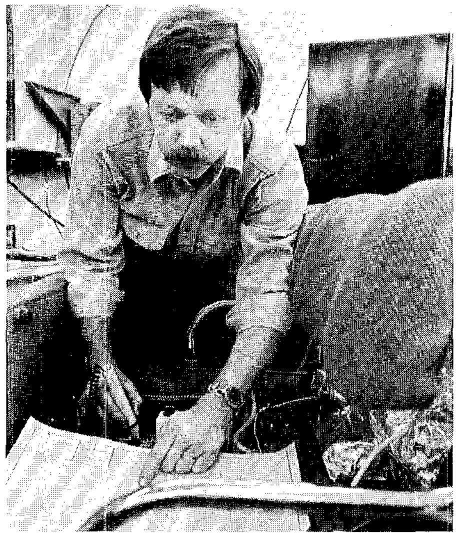
Fuel cells on the highways appear to promise little or no pollution emissions, virtually no noise, quick refueling, and an efficiency twice that of the gasoline engine. The golf cart prototype at LASL's Engineering Development Group (E-4) is the first use of a phosphoric acid fuel cell to provide transportation power on Earth. It is designed to run on methyl alcohol and air, although right now its fuel cell is powered by hydrogen and air. That in turn powers a conventional electric motor, which moves the wheels.

Efficient Source

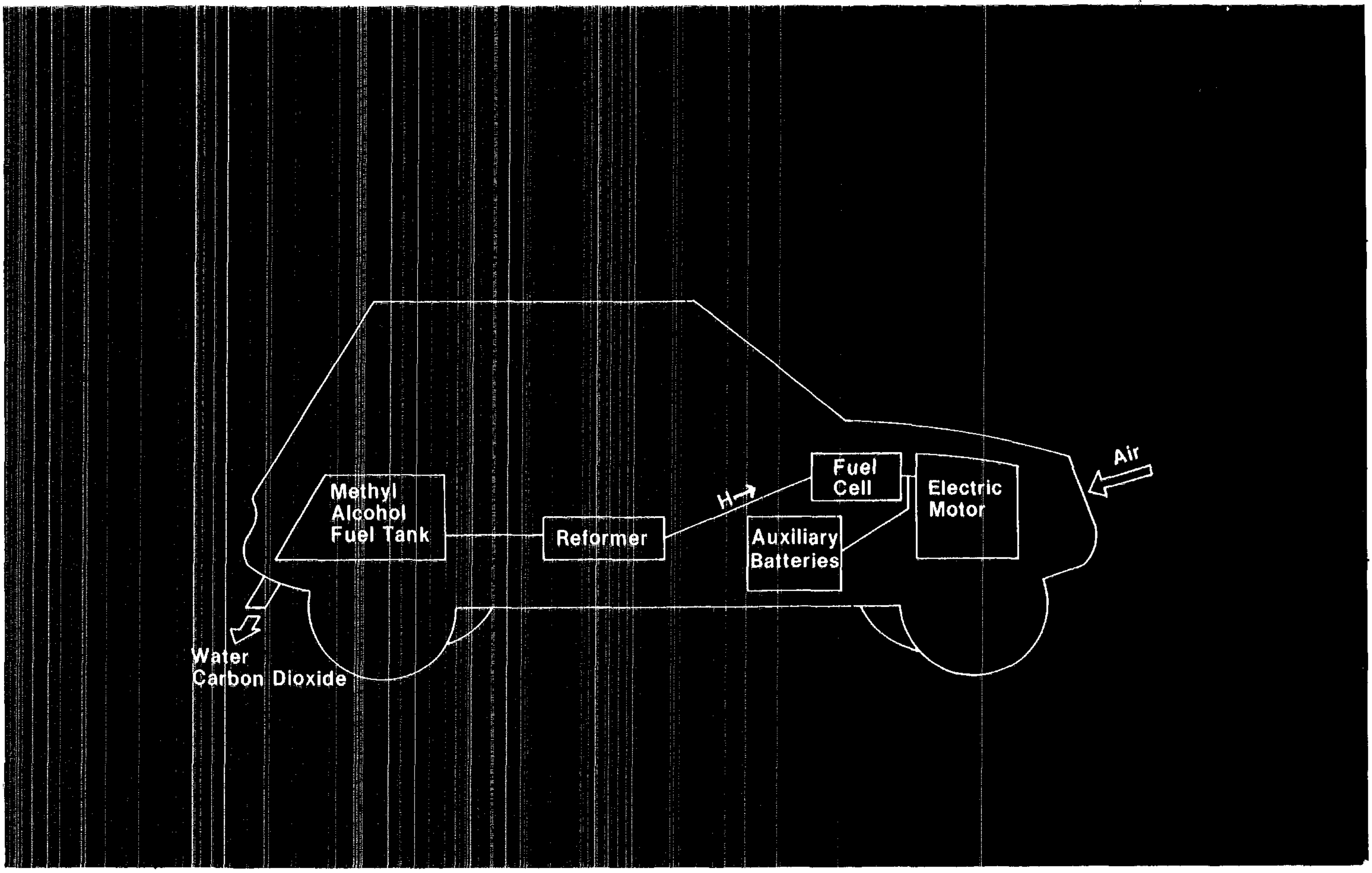
"Basically, we have a very efficient source of energy conversion," said J. Byron McCormick, a member of the golf cart team at E-4. A fuel cell vehicle would operate, he noted, with about double the efficiency of an internal combustion engine car, considering how much fuel is converted to transportation energy in each case (roughly 40 per cent versus 18 per cent, depending on conditions).

In addition, fuel cells offer benefits that other alternative systems, like batteries alone, cannot. The range of a fuel cell car, for instance, is more than 400 miles, compared with 50-100 miles for battery cars. Methyl alcohol fuel would yield the gasoline equivalent of about 70 miles per gallon at steady driving speeds of 55 mph over level roads. Fuel tanks could be filled readily, compared with an overnight recharging period for batteries. And fuel cells, used in parallel with batteries, would provide a power range comparable to that of today's gasoline automobiles.

LASL began considering the fuel cell's applications in 1976, and hosted a workshop on the topic here in 1977, along with Brookhaven National Laboratory. To the participants, the idea made technological sense, said McCormick, but many also realized the fuel cell would have to compete with the gasoline engine and its industry spinoffs, which together account for one of every six jobs in the country. The present auto also claims 75 years of design and evolution, and the consumer is not likely



Ron Bobbett provided much of the vehicle's design. Here, he checks out part of the circuitry with a digital volt meter.
Photo by John Flower



If methyl alcohol is the fuel, the byproducts are water and carbon dioxide. If hydrogen is the fuel, water is the only byproduct.

to switch brands unless the newcomer proves to be a comparable product.

The Department of Energy then provided funds for an "applications scenario" to determine possible prices of vehicles and fuels, measurements of weights and volumes, and applications for the passenger car, the bus, and the delivery vehicle. Preliminary results have attracted attention in scientific circles, as well as on national television and on newsprint.

A different "battery"

Behind the interest lies a relatively simple concept, roughly analogous to the operation of the batteries in a home flashlight.

In a dry cell battery, packaged chemicals react to produce an electrical current. Once one of the key chemicals is depleted, the battery is "dead."

The fuel cell also produces an electrical current from chemicals. But it receives its "juice" potential from the outside in a continuous flow, unlike the self-contained dry cell. One one side of the fuel cell, at the negative electrode, hydrogen enters. On the other side, the positive electrode, air or oxygen enters. (If methyl alcohol is used as fuel, a reformer first breaks it down to provide hydrogen, one of its components.)

A porous carbon membrane in the fuel cell induces the hydrogen and oxygen to combine. This membrane contains a trace amount of platinum as a catalyst. Electrons are stripped from the hydrogen and made to flow in an electrical circuit externally. Ions (nuclei minus electrons) flow through the membrane, which is impregnated with a phosphoric acid electrolyte.

"Tailpipe" products

The byproducts from this reaction don't resemble the pollutants from your car's exhaust at all. If methyl alcohol is the fuel and is run through a reformer to provide hydorgen, the byproducts are water and carbon dioxide. If hydrogen alone is the fuel, the only byproduct is water. Either way, about the only sound from the experimental golf cart at E-4 is the hum from the blower motor, which is used to keep components cool.

Fuel, of course, must be produced for this kind of vehicle. You can't pull up to the neighborhood filling station today and top off your tank with methyl alcohol. Group E-4 feels that methyl alcohol—commonly known as wood alcohol—is a promising fuel candidate, however. Another alternative fuel, hydrogen, is more flammable and must be kept at present under pressure in

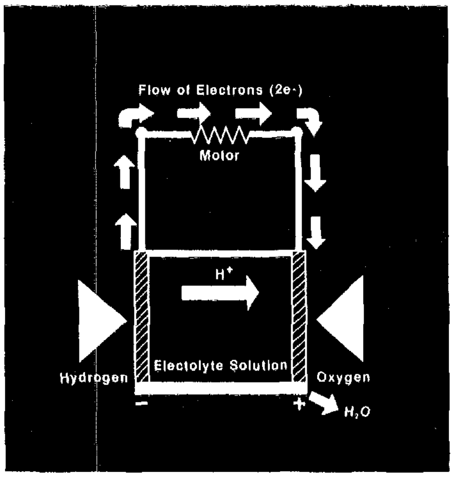
Hydrogen enters the fuel cell at the cathode, oxygen at the anode. A membrane induces them to combine; electrons are made to flow.

metal cylinders. (Other Laboratory programs actively investigate different storage techniques, including liquid, and may ultimately resolve current hydrogen storage limitations.)

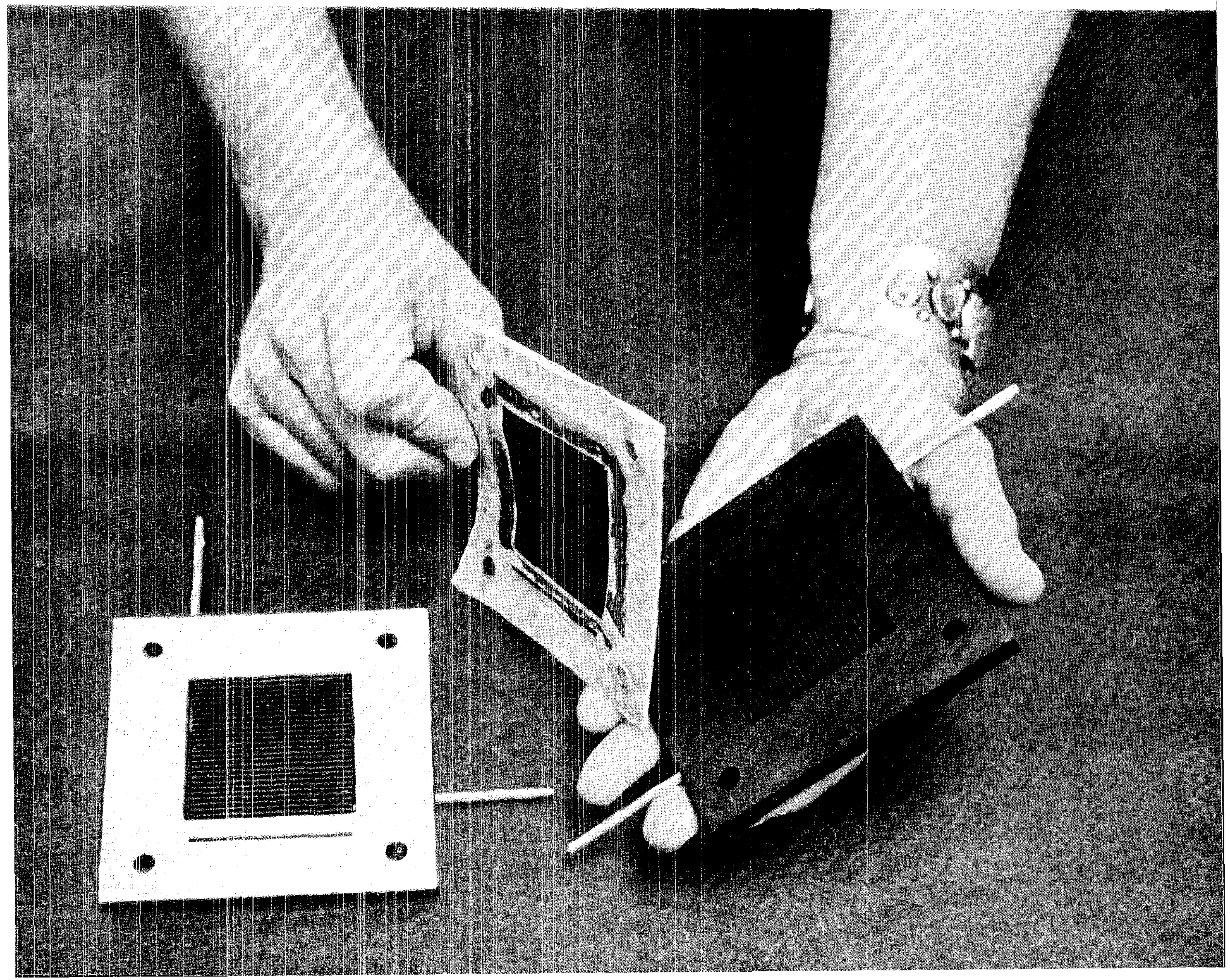
Methyl alcohol can be made from coal or wood, and its production is not dependent on imports. Additionally, if coal is used, impurities can be separated so they aren't released into the atmosphere, as happens to some extent in a coal-fired electrical plant. Oil companies that own coal mines have indicated their support for using methyl alcohol as a future fuel. Today, most methyl alcohol is made from natural gas.

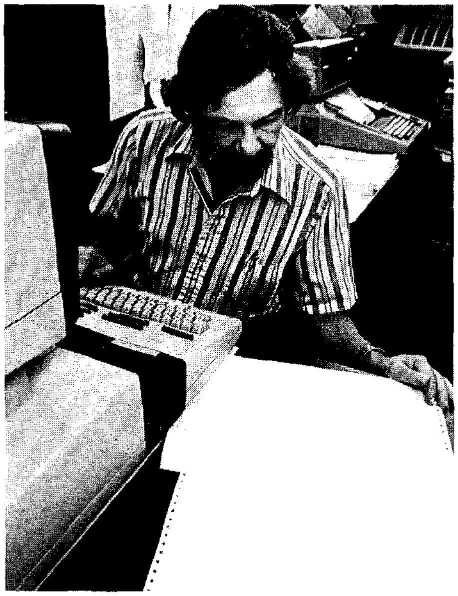
Methyl alcohol, familiar to many as the fuel in Sterno cans, burns with a blue flame and has a very good energy density per volume. Before the modern petroleum era, methyl alcohol and sister fuels were used for lighting (as of 1830) and for heating and cooking (particularly in Paris).

In fact, during the world wars in this century, all kinds of vehicles in Germany and France used wood burners mounted behind the driver or on trailers. Chips were distilled to make alcohol vapors which were barely able to drive the vehicles. Around 1920, the U.S. began to produce methyl alcohol for use as a solvent, in plastic manufacture, and for fuel injection in piston aircraft engines.



A small 0.6-volt fuel cell, taken apart to show graphite squares on each side where oxygen and hydrogen enter, and the carbon paper membrane which contains a catalyst. Somewhat like cells in a car battery, fuel cells are stacked up for voltage. Current is a function of the ribbed area that is exposed to the catalyst.
Photo by John Flower





Dave Lynn, working with computer simulations of vehicle performance. Basic data from the golf cart go into a model to see if simulations can be verified. So far, the correlation is high with the cart and with the Electra Van, a battery-powered vehicle also used to verify computer models.
Photo by John Flower

The valuation projected a sticker price for a fuel cell Volkswagen Rabbit of about $7,300. Buses and delivery vans were also studied.

Evaluations

The golf cart team at E-4 is comprised of many persons. Aside from McCormick, there is Ron Bobbett, who provided much of the vehicle's design; Dave Lynn, who worked with computer simulations; Bill Kerwin, here on a sabbatical from the University of Arizona; and Chuck Derouin and Paul Salazar, both of whom worked on mechanical design.

Part of the team's work dealt with evaluating fuel cells in four prospective vehicles. First, the city bus has attractive features for conversion, including present pollution and high operating costs. The city bus market represents a potential 5,000 vehicles yearly that could use fuel cells.

The highway bus, the study continued, could use fuel cells economically and technically around 1990. Along with city buses, highway buses account for some 22 per cent of the transportation energy consumed in the U.S. each year.

Looking at consumer vehicles, the evaluation projected a sticker price for a Volkswagen Rabbit, powered by fuel cells, of about $7,300. A fuel cell automobile might be accepted by consumers, the study said, because such a car has low noise, low pollution, and high reliability. Fuel cells would have a lifetime of about 6,000 hours, and the price per unit is expected to drop dramatically if demand stimulates mass production.

Delivery vans, the fourth type of vehicle to come under preliminary study, showed most promise using a small fuel cell with substantial onboard battery storage. The fuel cell then recharges the batteries during stops in the delivery route. Fuel cells, however, promise lower maintenance costs. Battery-powered vans have already been shown to require 30-40 per cent less maintenance than conventional vehicles, as demonstrated by the Bell System and by the United Parcel Service.

Fuel cell future

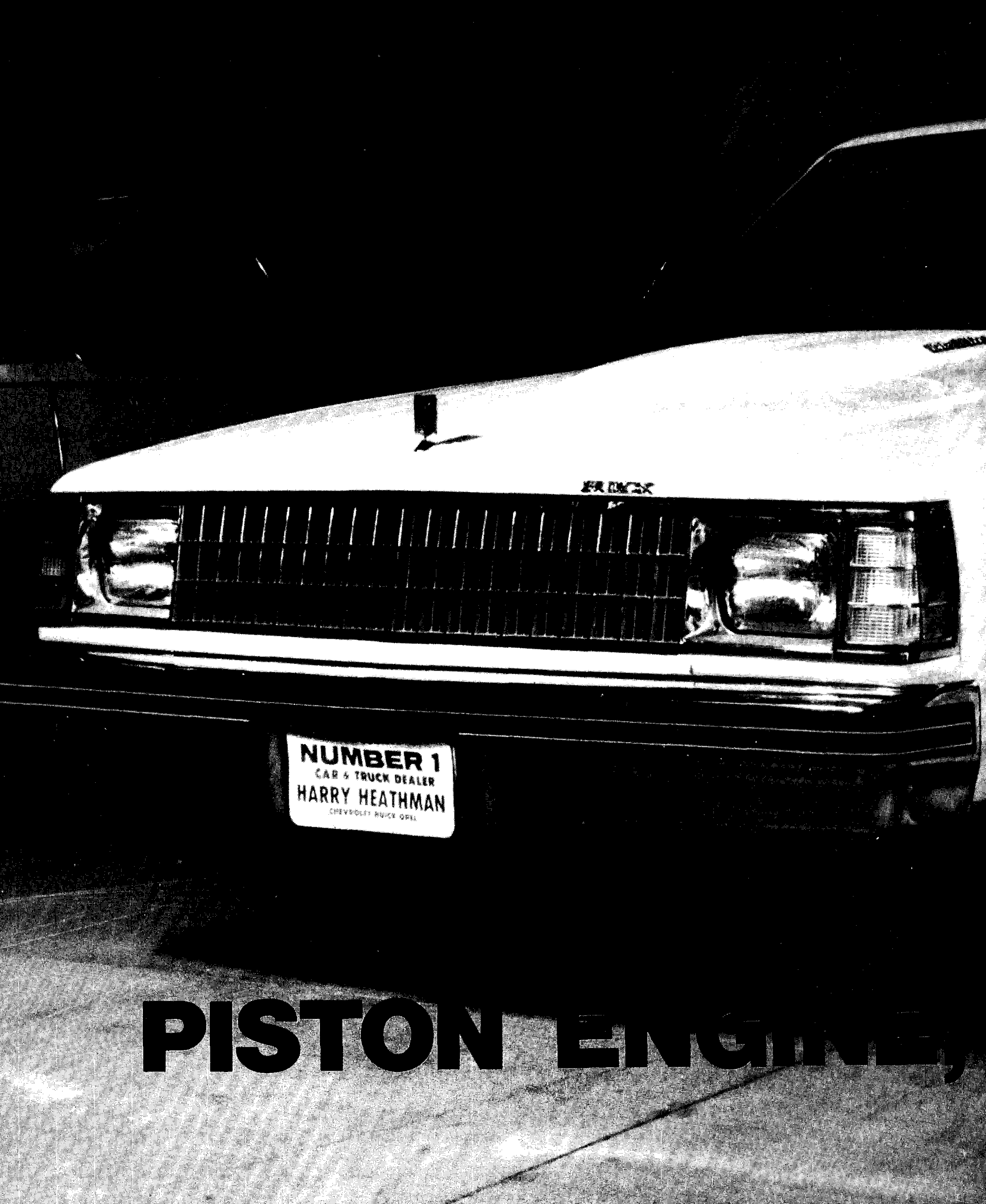
At E-4, researchers have been running the fuel cell golf cart successfully, and in the process have been verifying computer codes on performance. The cart has a four-horsepower motor, rather than the standard two-horsepower motor used on golf course carts. The cart contains a full-size controller, similar to what a passenger car would use. It has enough power to drive, say, a Volkswagen Rabbit at moderate speeds.

Even if fuel cell cars (which the golf cart team would ultimately like to see built) are not an overnight sensation, they still could impact our present gasoline use. A slight change in petroleum use of the 100 million vehicles now on American roads, for instance, would mean a substantial savings annually. Fuel cell-powered fork lift trucks, used in confined warehouse spaces, would be less polluting than a gasoline vehicle, and longer running than one which uses batteries.

People at E-4 are optimistic for the potential of fuel cell vehicles. Results from the economic and system analyses, and actual performance of the golf cart, show tradeoffs must be carefully performed if the fuel cell vehicle is to ever compete with the difficult standards set by the internal combustion car.

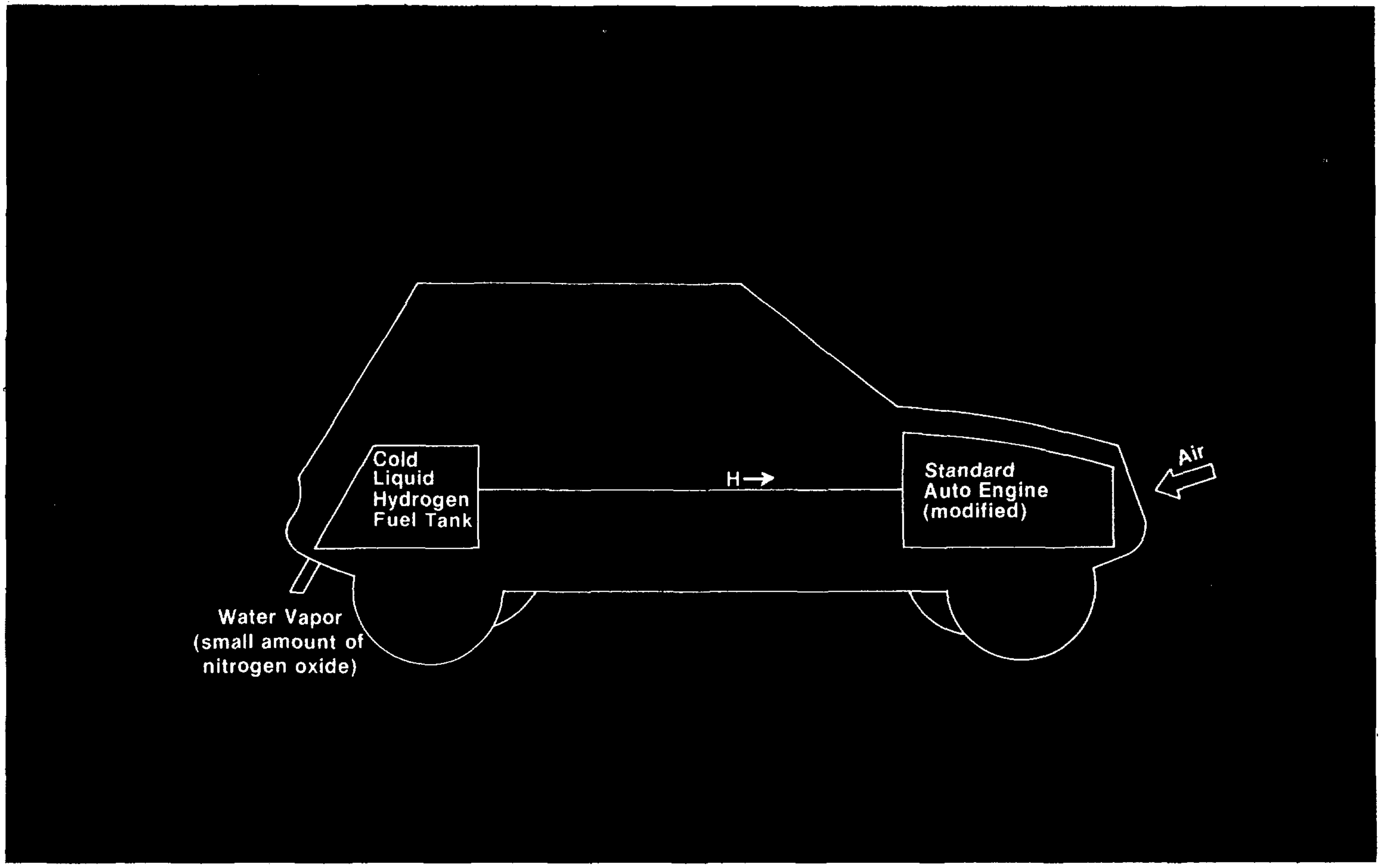
"We are aiming at evolution, not revolution," said McCormick.

Tanks of hydrogen and oxygen currently feed the fuel cell in the LASL golf cart, although the research team feels that methyl alcohol would be a better storage source of hydrogen in the years to come.
Photo by Bill Jack Rodgers



PISTON ENGINE,

Photo by Billings Energy Corporation



The owners of a 1979 Buick Century sedan drive their turbocharged V-6 vehicle into a refueling station. The attendant quickly mates two fittings and one electrical connection. A semi-automated sequence then checks the refueling system for leaks, removes air from the lines, and fills the car tank from the storage tank at the station. The lines are then purged and disconnected. The owners drive away.

This scenario sounds standard, but the fuel involved is liquid hydrogen. The place is Los Alamos, and the time is between the present and October 1981. Walt Stewart of Group P-10 received the Buick Century from the New Mexico Energy Institute early this year.

"We are using a standard car engine for this project," said Stewart. "We may in the future make modifications, but we will work with a minimum of modifications initially."

The 40-gallon liquid hydrogen tank in the Buick comes from the DFVLR, a government agency of Western Germany (Deutsche Forschungs-und Versuchsanstalt fur Luft-und Raumfahrt). The tank has been tested for cool down, heat leak, and refueling times. The DFVLR is also providing the refueling station, which will be connected to the liquid hydrogen storage tank already at the Laboratory.

Within the next two years, LASL plans to demonstrate the hydrogen car and its refueling station, while researchers attempt to assess the use of hydrogen as a fuel and its operating costs. Hydrogen probably will not be used as a gasoline substitute for some years, but that prospect could change if it can be produced more cheaply, if petroleum imports are drastically cut, or if pollution from cars is to be significantly reduced.

The future fuel?

Running a prototype hydrogen car is not as simple, of course, as the scenario reads at the beginning of this story. But the advantages of hydrogen over other fuels in the list of alternatives are thought-provoking.

Hydrogen can be separated from the oxygen in water, one of the world's most abundant compounds. Hydrogen offers high efficiency as a fuel. And hydrogen is compatible with present uses, such as the internal combustion engine, and with primary energy sources, from nuclear to coal to solar.

When burned with air, hydrogen produces some nitrogen oxide but no carbon monoxide, carbon dioxide, or unburned hydrocarbons—all of which come from gasoline or synthetic fuels. Although hydrogen can be produced

Liquid hydrogen at present can compete with gasoline for weight and cruising range, but it requires a larger fuel tank because it provides only 25 per cent of gasoline's energy by volume.

from America's vast coal reserves, the best long term option is to separate it from water by electrolysis or thermochemical dissociation, according to scientists at LASL.

The economic hitch, however, is that at present LASL buys bulk liquid hydrogen at a price equivalent to $3.66 per gallon of gasoline. As with any synthetic fuel, it requires more energy to produce hydrogen than is available from it when it is used.

Safety is an important concern raised with the use of hydrogen. It has a low ignition energy and gives almost instant combustion in an engine, but these properties also make pre-ignition and flashback more likely than with gasoline. If liquid hydrogen is used, as at LASL, a large, well-insulated metal container is required because the fuel must be kept at a low temperature (−423 degrees F). Consumers of the future will want assurances that liquid hydrogen won't present any increased hazards during refueling or in a collision, and won't be lost when stored for several days, as a heat leak causes the liquid to change to a gas that is automatically vented for safety.

The prototype car

Back in 1973, LASL experimented with a Dodge pickup truck that was retrofitted for a hydrogen fuel system. Now, a larger scale test with the Buick is beginning.

The car has been running on hydrogen in shakedown experiments and will soon be fitted with a liquid hydrogen tank at LASL. Modifications to the engine involve replacing the gasoline carburetor with one that will mix a gaseous fuel with air, and adding a water injection system to eliminate flashback.

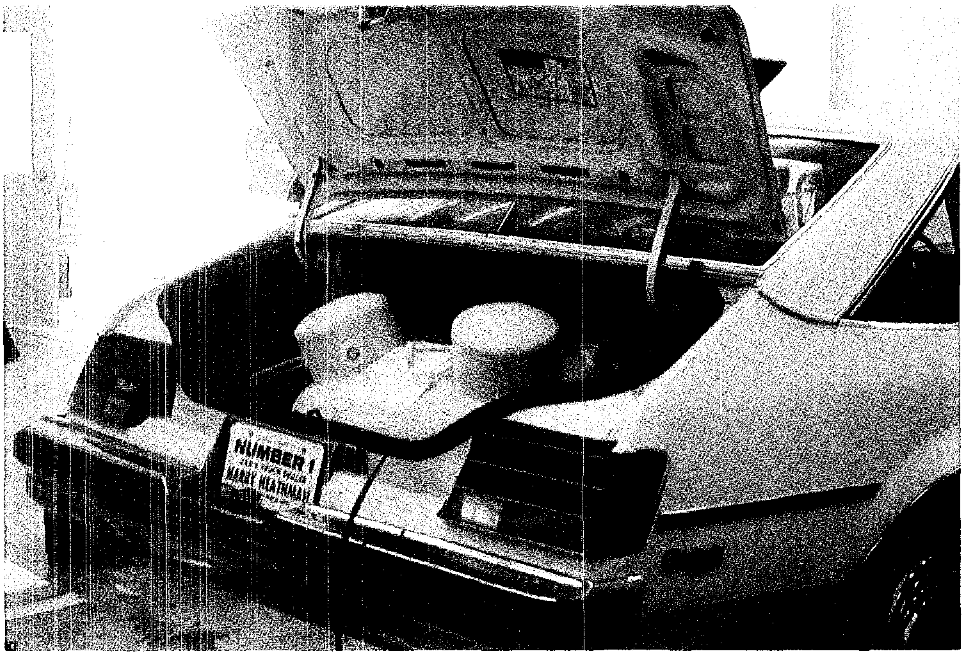


Photo by Walt Stewart

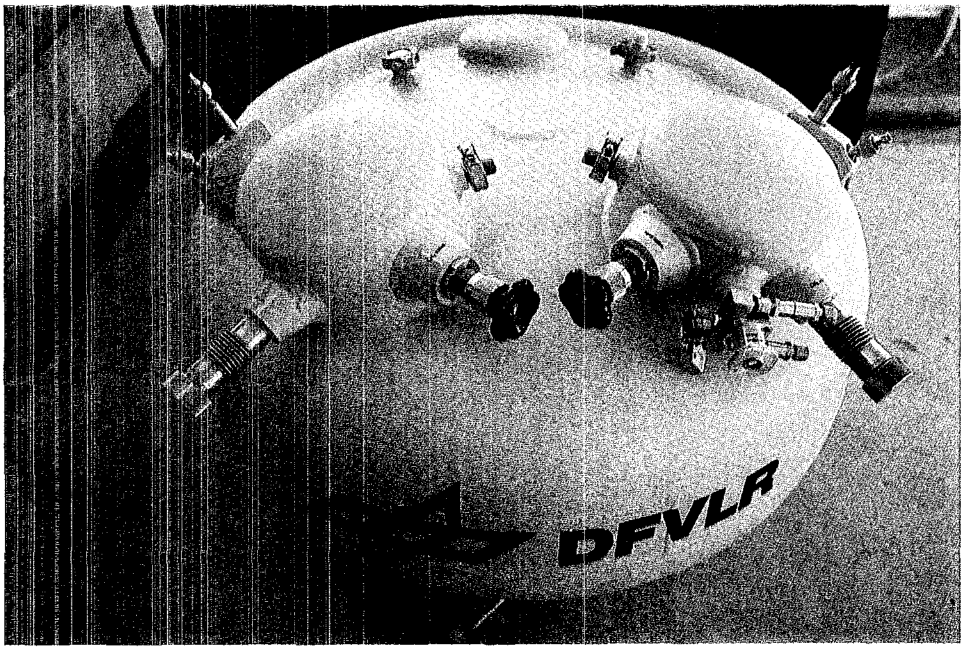
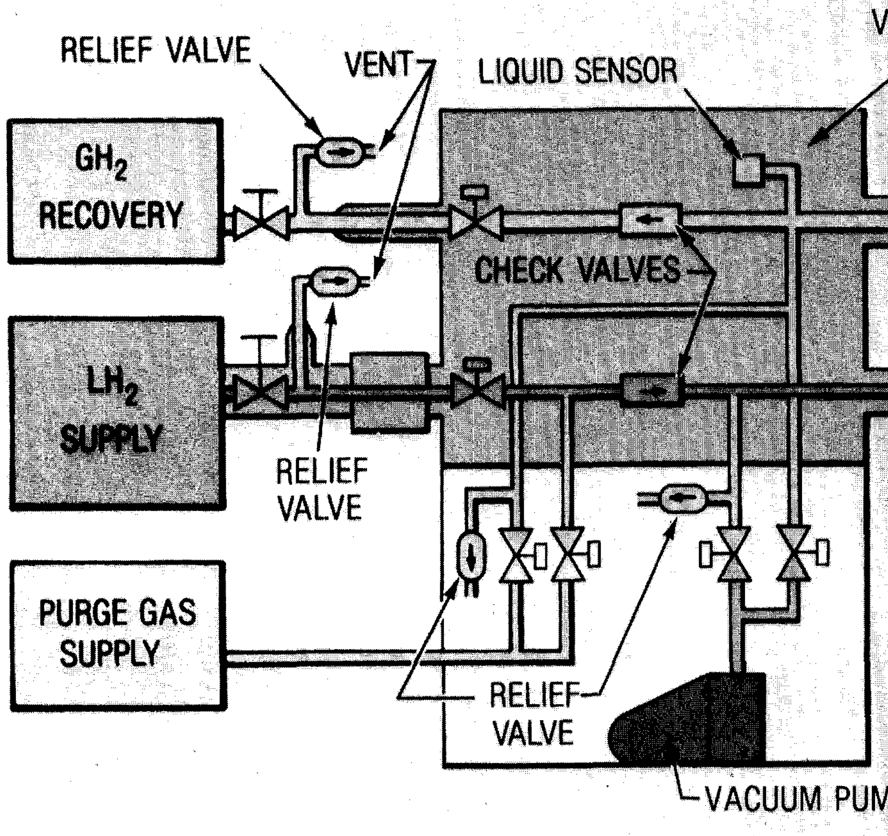


Photo by Bob Pena



The refueling station will deliver hydrogen to the car semi-automatically. Safety is an important concern raised; a mobile system will permit public demonstrations.

The gasoline tank will be removed and the insulated hydrogen tank will be installed in the trunk. The trunk will be vented and isolated from the passenger compartment. Emission controls will be removed. The spark plugs will be changed and the ignition timing will be altered.

The refueling station provided by DFVLR will be connected to a 14,000-gallon liquid hydrogen tank here and the lines, pumps, connections, and sensing units will be carefully checked.

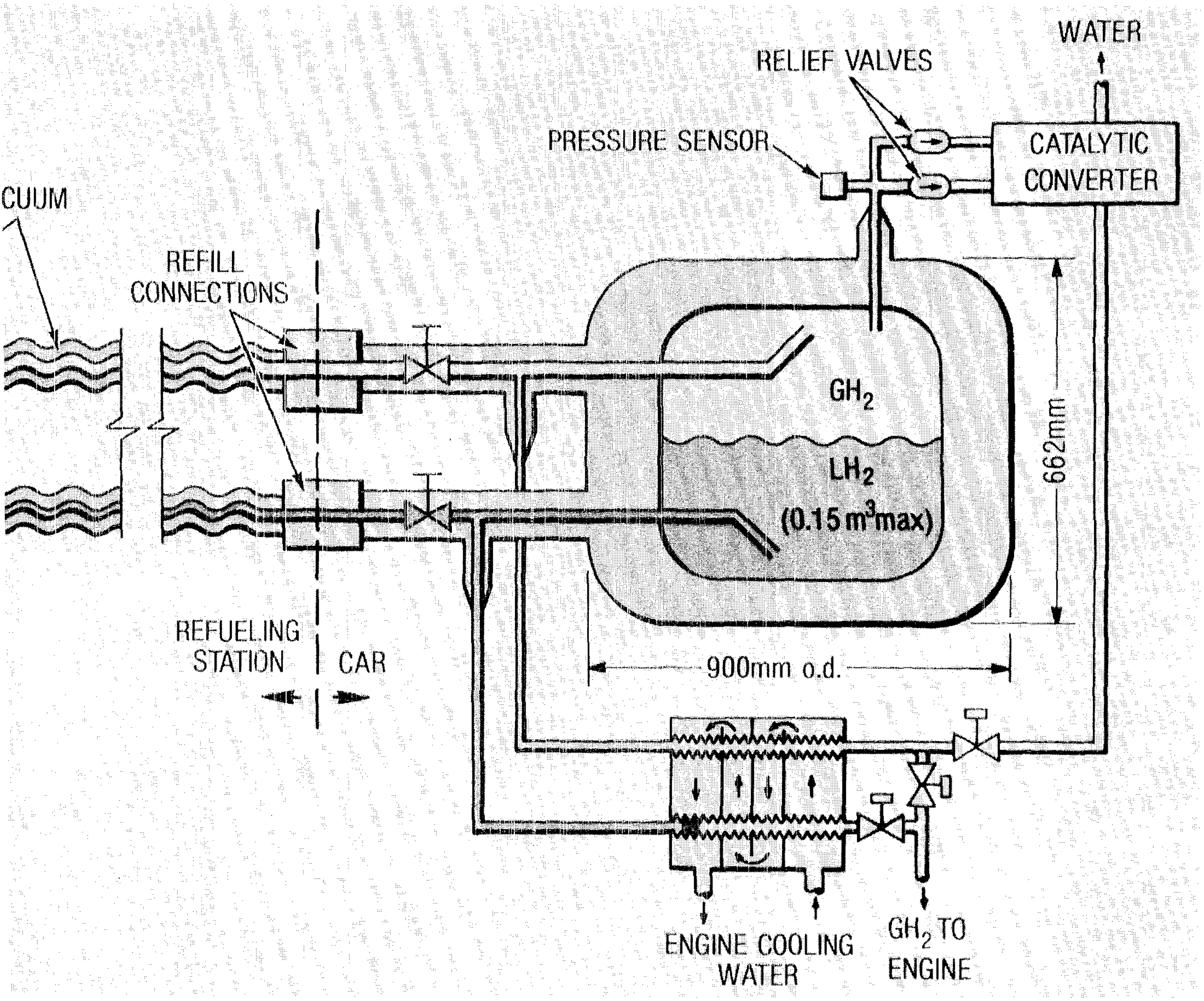
Much concern centers around the fuel tank carried in a hydrogen car. The Buick's tank will be about 26 inches high and 34 inches in diameter. Depending on the number produced, such a tank would cost from $900 to $2,200. Its inner and outer shells are made by welding together commercially available pieces. The space between is filled with insulation and is evacuated. The inner shell has three connecting tubes: one to fill or withdraw the liquid hydrogen; one to withdraw gaseous hydrogen; and one to attach safety relief valves. Inner plates prevent layer stratification and sloshing.

If the tank is closed, the pressure gradually increases as heat leaking in causes some of the liquid hydrogen to evaporate. The relief valve will open after about 48 hours, and hydrogen will be vented. One safe way to handle this hydrogen is to combine it with oxygen in the air in a catalytic converter to form harmless water. Hydrogen could then be lost at a rate such that a full tank of liquid hydrogen would evaporate in about 16 days. "Sniffers" around the project and in the car will determine if hydrogen is being released.

A liquid hydrogen tank available here could be equipped to provide a mobile refueling station that would permit the Buick to be demonstrated at public events away from the Laboratory.

Within two years

Within two years, the hydrogen car team will address many questions. They



also expect to meet several goals.

The vehicle, for instance, is to provide a minimum fuel economy of 5.6 mpg of liquid hydrogen. It is to accelerate from 0 to 50 mph in 13 seconds. It is to produce less than one gram per mile of nitrogen oxide to begin with, and ultimately less than 0.4 gram per mile—the present goal of gasoline engines.

If Group P-10 achieves the goal of 5.6 mpg for hydrogen, this would translate into 5,425 BTU per mile—less energy than the EPA estimated gasoline mileage of 17 mpg or 6,765 BTU per mile. The vehicle's range would then be 220 miles on the 40-gallon tank of liquid hydrogen.

Early hydrogen cost estimates indicated it would be 50 per cent more expensive than gasoline. The total costs, however, remain unknown. The project aims at developing better cost forecasts and safety checklists for hydrogen vehicles. This perhaps could lead to a larger demonstration with a fleet, possibly at LASL or possibly to be used as shuttles between Los Alamos, Santa Fe, and Albuquerque.

Other hydrogen options

Liquid hydrogen is one of several forms the stored fuel can take. It can be carried as a compressed gas, considered impractical because the *container weight is 100 times the fuel* weight, and because there are additional safety problems. Metal hydrides—solids that absorb hydrogen somewhat as a sponge absorbs water—can be heated to release the fuel, preferably by using engine waste heat. There are several programs to develop hydride automobiles, but so far the vehicle ranges are low and refueling times are long. One firm, for instance, will sell you a converted Chrysler Corp. Omni and an electrolyzer to free hydrogen from water, but it is a heavy vehicle because of the hydride it carries and is limited to less than a 100-mile range on hydrogen.

Liquid hydrogen at present is the only form of hydrogen than can compete with gasoline for weight and vehicle range; but it will require a larger fuel tank than gasoline, because it provides only 25 percent of the energy of gasoline by volume. Hydrogen provides, however, nearly three times the chemical energy of gasoline by weight.

The 1973 LASL pickup truck project showed a 58 per cent increased efficiency over the normal truck operation of 13 mpg of gasoline, and the vehicle had a range of more than 250 miles. It also had, however, only about 70 per cent of the power that it had when running on gasoline.

With the Buick project, Group P-10 hopes to pave the way for future use of hydrogen vehicles, even though hydrogen may not be economically competitive for a generation.

In the meantime, the U.S. is still *importing half of its oil—at a cost of* some $8 million each hour.

—JLP

Hydrogen may be used to power vehicles, gasify coal, or generate electricity. We may need 10 to 20 times as much hydrogen in the year 2000 as we do today.

making hydrogen

Photos by LeRoy N. Sanchez

The Arab oil embargo of 1973 prompted politicians, lay persons, and scientists alike to rethink America's petroleum imports situation and to look for energy substitutes. In our automobile society, a great deal of thought has gone toward transportation alternatives, two of which are the subjects of preceding articles in this Atom issue.

Both the fuel cell vehicle and the hydrogen car use hydrogen as the base fuel. In one case, hydrogen would be obtained by methyl alcohol stored on board and used to run an electric motor. In the other case, liquid hydrogen would be stored in a metal container and used to power a conventional engine.

Aside from these, many new uses of hydrogen may be expected. Hydrogen may be used to gasify or liquefy coal, or to refine oil shale, or be blended with natural gas or synthetic gas, or be used directly to heat buildings or generate electricity. We may need 10 to 20 times as much hydrogen in the year 2000 as we do today.

Problem of economy

One problem of hydrogen, however, is not how well it works or the low amount of pollutants it produces. It is one of economics and storage, a problem of not yet having the "hydrogen economy" that some futurists point to.

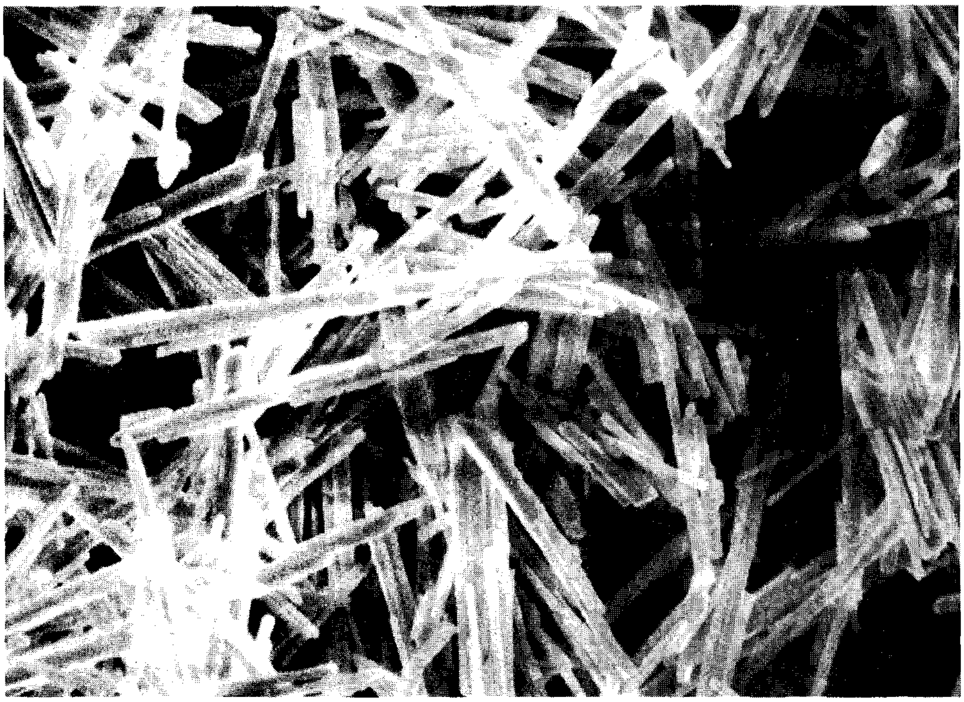
"The $64 question is that you can't use hydrogen if you can't produce it," said Ken Cox of Group CMB-3, who is involved in studies of hydrogen production.

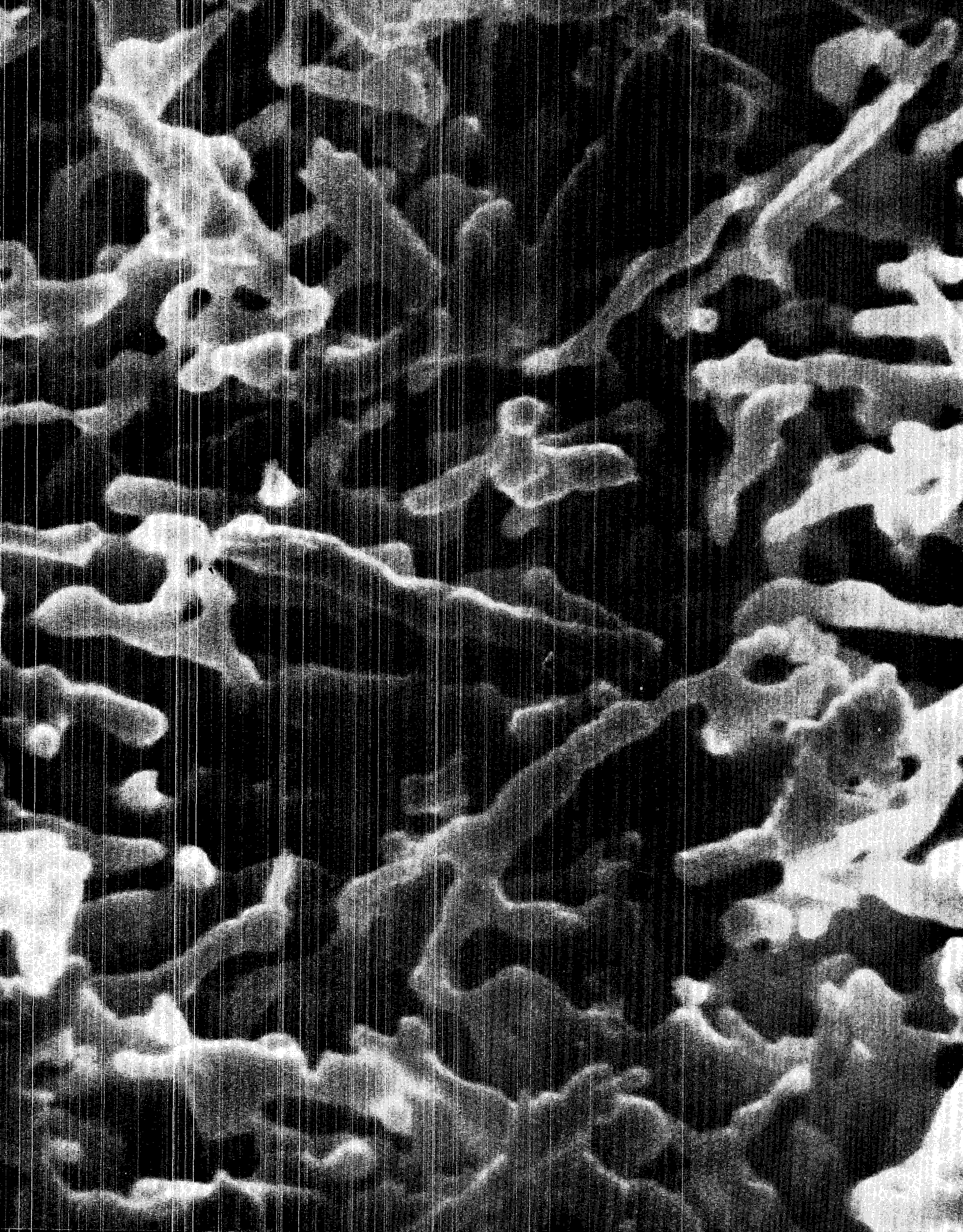
His succinct tautology says plenty. Water is one of the "ashes of the universe," a combustion product. Energy is released in the formation of water, which is an inexhaustible supply of hydrogen. To dissociate water and produce hydrogen and oxygen from it requires a net input of energy.

The traditional method of extracting hydrogen from water is by electrolysis, a common high school demonstration experiment. This is still one alternative, but because there are inherent inefficiences in electrical power generation, the overall efficiency of electrolytic hydrogen production can never be more than about 40 per cent. At present, it is limited to about 30 per cent.

Enough electricity would be needed, in fact, that hydrogen production on a large scale would require a plant powered by coal, fission, solar, fusion or other energies. Such a plant would work, but there are potentially more efficient approaches, using these same energy sources.

Scanning electron micrographs show the appearance of bismuth oxysulfate crystals before and after they have passed through the rotary kiln at Group CMB-3. The "matchstick" photo is at 1,200 magnification and the "sponge" image is at six thousand magnification.





Many approaches

The "direct" approach, for instance, would involve the heating of water until it dissociated at 3,000 to 4,000 degrees K. That's not feasible, because technology can't sustain temperatures in that range in a commercial process—construction materials won't hold up.

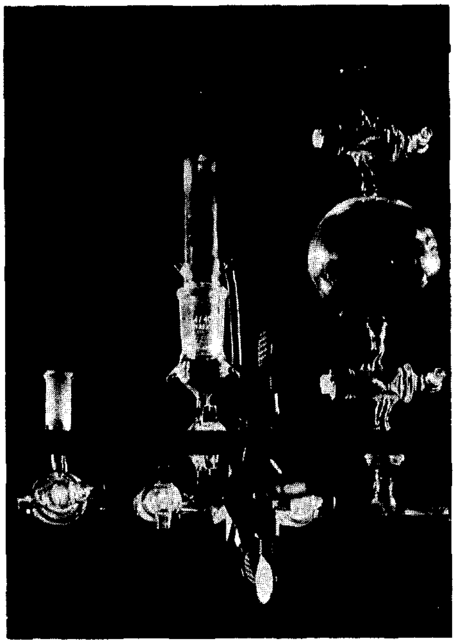
A "step-wise" approach, with permutations, involves the use of water and heat at lower temperatures in a thermochemical cycle (1,200 degress K). Such a cycle converts water to hydrogen and oxygen, as with electrolysis, but each cycle is a closed loop and uses intermediate chemicals that are regenerated over and over again as they pass through the process.

Out of many hydrogen thermochemical cycles invented on paper, only a few have been shown to work in the laboratory. These include the sulfur-iodine cycle, the hybrid sulfur cycle, the cadmium cycle, and the bismuth sulfate cycle, among others.

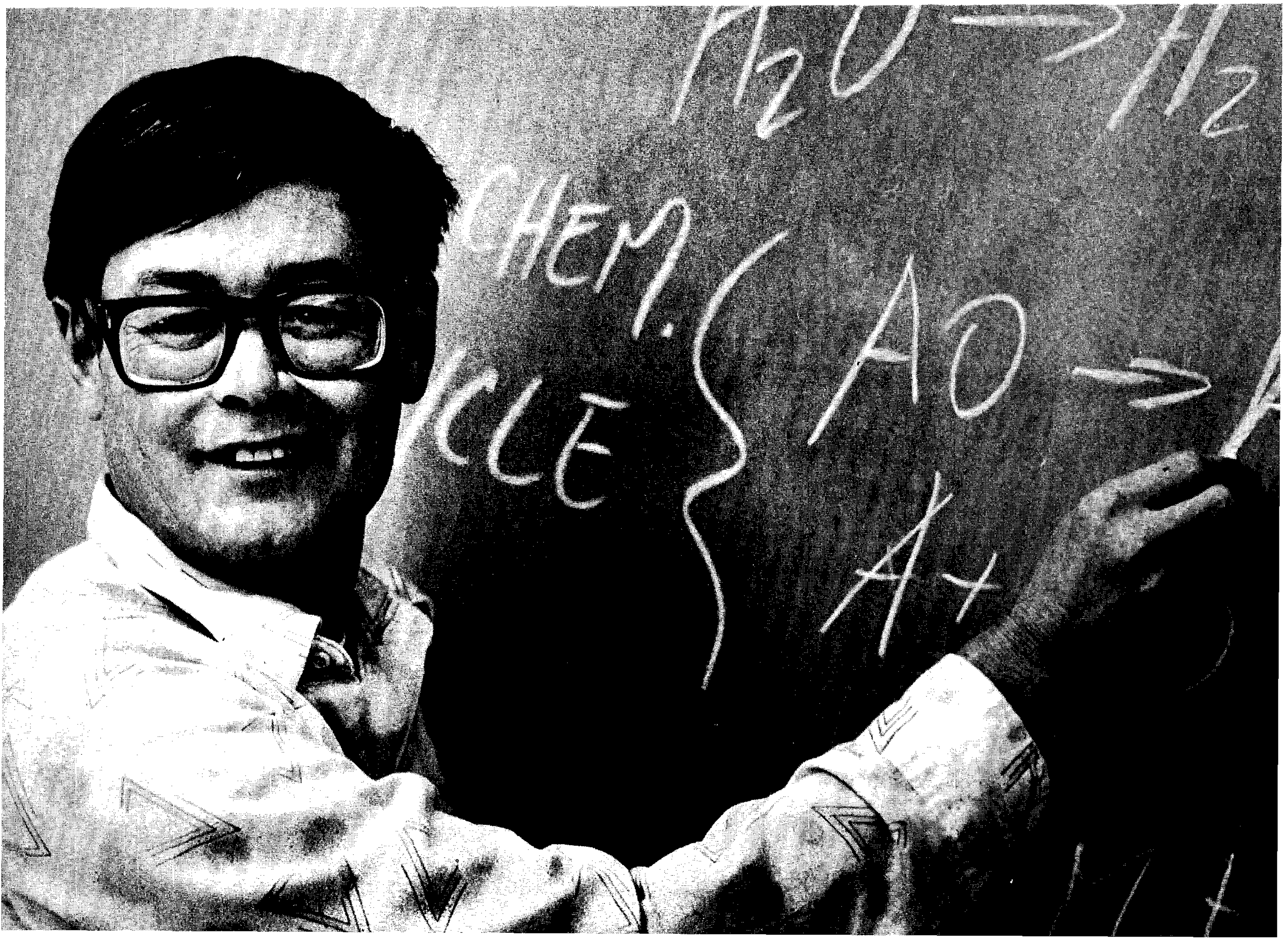
Work at LASL

Thermochemical cycles, or the "step-wise" approach, have been investigated at LASL since the early 1970s. Presently, such work here is funded from the Department of Energy's Basic Energy Sciences Office and the DOE's Division of Energy Storage Systems (STOR). Money for this other-than-oil-fuel research is also spent at other U.S. locations and in Europe and Japan.

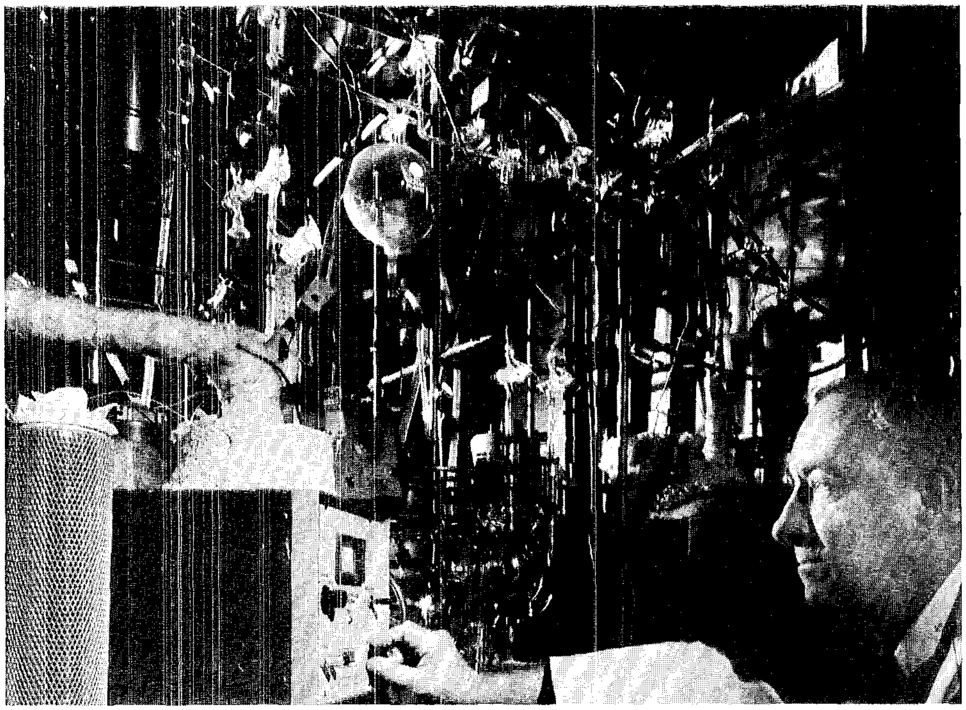
The LASL bismuth sulfate cycle, a four-step thermochemical process outlined in a separate box with this story, may have advantages over others, such as the hybrid sulfur cycle, because it does not use sulfuric acid at high temperatures or high concentrations. The temperatures required for



Ken Cox: "The $64 question is that you can't use hydrogen if you can't produce it."



Hydrogen still costs two to three times the price of natural gas and will require vast amounts of energy to produce. But the raw materials are abundant and the promise of clean energy is great enough to spur research.



Wes Jones measures pressures of sulfur dioxide, sulfur trioxide, and oxygen in equilibrium with bismuth compounds. Data will help predict the efficiencies of the bismuth sulfate production cycle for hydrogen.

decomposing solids, in addition, can be lower than in other similar cycles.

A design for this cycle was developed, based on a fusion reactor of the future. Thermal energy, transferred from the lithium blanket around a fusion chamber, goes into two heat streams for the high temperature and the partial electrolysis requirements of the cycle, respectively.

The LASL bismuth sulfate cycle is a promising approach to hydrogen production, Cox concluded in a recent report to a DOE review meeting. But it requires a heat source, such as a fusion or solar reactor, to provide temperatures of about 1,500 degrees K. This cycle bypasses the need to evaporate sulfuric acid, and has an estimated efficiency of 50 percent.

There are, however, crucial issues to be resolved—including low voltage electrolysis, the recovery of heat in the process, and the handling of copious amounts of solids in a high-temperature vessel.

Other assistance

In LASL's more basic research program, cycles that promise higher efficiencies are being studied for use with a higher temperature energy source than may be obtained from solar energy. The cadmium carbonate cycle is one example, and is illustrated in a separate box with this story. Other cycles being investigated here have involved lanthanum, cerium, molybdenum, and a variety of chemical compounds.

LASL acts as an evaluator for the DOE when it needs outside judgments on other proposals. LASL also performs systems studies to see how thermochemical hydrogen cycles can be linked to alternate energy sources.

Mel Bowman of the Chemistry-Materials Science (CMB) Division is the project's principal investigator as well as the U.S. technical contact for thermochemical hydrogen research under the International Energy Agency (IEA). A meeting in fall 1979 of the IEA Thermochemical Hydrogen Annex was hosted by LASL and attracted more than 60 delegates, including participants from many foreign countries (Italy, West Germany, Japan). The next IEA meeting will be held in Tokyo, following the third World Hydrogen Energy Conference this June. LASL persons will participate in both events and will present papers on their research.

Other persons involved in the program are Terry Wallace, CMB-3 group leader; Ed Onstott from CMB-8; and Caroline Mason, Wes Jones, Charles Hollabaugh, and Charles Peterson, all of CMB-3.

Hydrogen as a fuel does not quite make sense in today's economy. It still costs two to three times what natural gas does, for production and space heat uses. Hydrogen will require vast amounts of energy to produce, whether the process be electrolysis or thermochemical cycles. But the raw materials are perhaps the most abundant on this planet, and the promise of clean, alternative hydrogen energy is great enough to spur domestic and international research in this field.—**JLP**

1. The LASL bismuth sulfate cycle, a four-step thermochemical process:
   (1) $2\,H_2O + SO_2 \quad H_2SO_4 + H_2$ (by aqueous electrolysis)
   (2) $H_2SO_4 + 1/3\,Bi_2O_3 \quad 1/3\,Bi_2O_3.3SO_3 + H_2O$ (at low temperature)
   (3) $1/3\,Bi_2O_3.3SO_3 \quad 1/3\,Bi_2O_3 + SO_3$ (at 1,000 degrees K)
   (4) $SO_3 \quad SO_2 + 1/2\,O_2$ (at 1,200 to 1,500 degrees K)

2. The cadmium carbonate cycle:
   (1) $Cd + CO_2 + H_2O \quad CdCO_3 + H_2$ (at low temperature)
   (2) $CdCO_3 \quad CdO + CO_2$ (at medium temperature)
   (3) $CdO \quad Cd + 1/2\,O_2$ (at 1,800 to 2,000 degrees K)

IDEAS TO THE PUBLIC

Technology Transfer:

Although we're concerned with basic investigations, our work invariably creates spinoff ideas that aid the taxpayer in one form or another.

By JOHN AHEARNE

Photos by LeRoy N. Sanchez

Although LASL is billed as a nuclear research facility primarily concerned with basic scientific investigation, the work inevitably generates spinoff ideas that the scientists, technicians, or administrators turn into quick returns for the public that foots the bill for our endeavors.

Further, the recent emphasis on industrial cooperation and technology transfer has accelerated the process of developing the laboratory idea into practical uses. For example, under LASL's industrial staff member program, companies may send a member of its staff, at company expense, to work in a LASL program for typically one to two years. Both LASL and the involved companies say the exchange of information and the perspectives on both technical and nontechnical issues (economics, institutional barriers to commercialization) are very valuable.

The following are brief examples of LASL industrial cooperation and technology transfer divided into the categories of transfer and commercialization, spinoffs, and techical cooperation and assistance. These examples were compiled with the help of Gene Stark of LASL's Technology Liaison Office. They don't represent all such efforts (some of which were discussed in a Nov.-Dec. 1975 Atom story) but help to show the many areas of LASL involvement.

Cell sorting

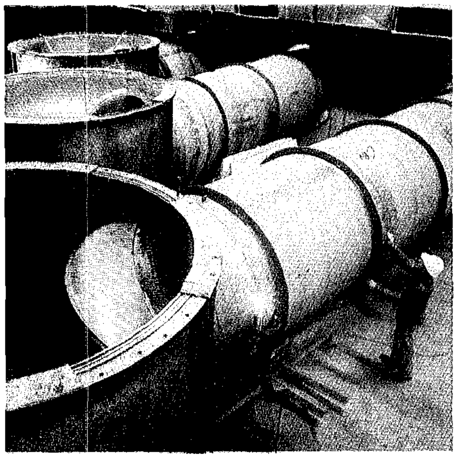
—Flow cytometry and cell sorting technology, the equipment and some of the techniques for which were developed at LASL, has been adapted for commercial use by four companies. The technology allows biomedical researchers to select and sort specific cells quickly and in great quantities.

With flow cytometry, in Group LS-2, the cells are made to flow rapidly through a chamber where thousands of cells are measured each second. Focused laser light illuminates individual cells, and optical measurements of cell size, structure, and chemical composition can be made. Flow cytometry is useful not only in basic research, but is now being applied to disease diagnosis, genetic disease identification, tumor cell identification, studies of the effects of radiation therapy on cells, studies of the effects of drugs and toxic agents on cells, and development of chemotherapeutic cancer treatment schedules.

Industry moved quickly on commercialization because the techniques from the Life Sciences (LS) Division represent a quantum leap in cell study technology, and are potentially as important to biomedicine as the development of the electron microscope.

Energy storage

—Cryogenics experts are working with engineers of the Bonneville Power Administration, Portland, Oregon, to develop a superconducting magnetic energy storage system for stabilizing long alternating current lines. Such lines



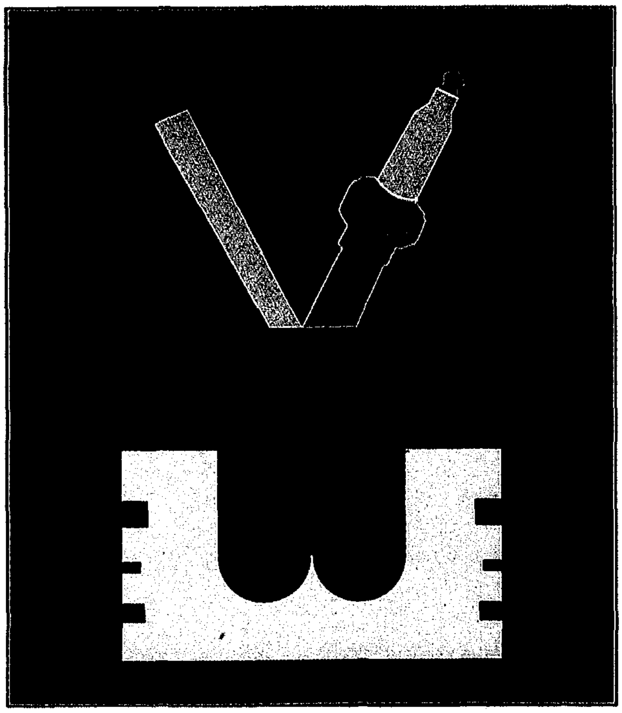
FACING PAGE: Welder Norlin G. Opp inside a beam transport tube at Antares, the laser complex scheduled for initial experiments in 1983. Antares is designed to test the efficiency of CO_2 lasers to drive fusion targets. ABOVE: Alan Olcott of L-Division near one of the tubes of the 72-beam facility. Another person on the project is Leo Dodd, industrial staff member from Eastman Kodak.

traditionally are prone to fluctuations of electrical current that can limit their capacities or cause system damage. The storage device, a magnet kept extremely cold with liquid helium, would store sufficient energy to feed current into the lines and absorb current from them to stabilize the flow.

As a result of LASL's basic research at Group P-10, a 30-megajoule system is being designed and fabricated by General Atomics Corporation for the Bonneville line from the Pacific Northwest to southern California.

Agriculture sciences

—Technology transfer in agricultural biosciences is being accomplished by



IDEAS TO THE PUBLIC

LASL is a world leader in computer graphics. This is a concept of a direct-injected, stratified charge automobile engine under study here, at GM, Princeton University, and Sandia-Livermore.

extensive publications in trade journals of the livestock industry and by wide distribution of Laboratory reports.

Electronic identification from the Electronics (E) Division and serological disease detection are two main areas of technology transfer being pursued. Electronic identification technology allows the agriculture industry to monitor and control livestock. A small electronic "tag" placed under the skin of the animals transmits identification and body temperature data to compact, remote receiving equipment. The system, which can be tied into a computer, can streamline feeding and disease detection. The system has also generated interest in other industrial areas, such as inventory control and transportation. One company was founded solely to pursue LASL technology in this field, while two others have indicated they will be producing equipment based on LASL designs.

A process known as enzyme immunoassay was developed at LASL for use in detecting a variety of diseases in animals as well as analyzing for environmental contaminants and residues. Laboratory scientists are working with a private firm to develop an automated processing system for the enzyme immunoassays, while another company recently sent five representatives to Los Alamos to investigate the possibilities of producing automated equipment for the serological blood tests.

A portable, hand-held electronic device for field treatment of commonly occurring cancer eye in cattle was developed at Group MP-3, and five manufacturers contacted in recent months reported more than 800 units had either been sold or were on backorder for a total retail sales figure in excess of $400,000.

Nuclear safeguards

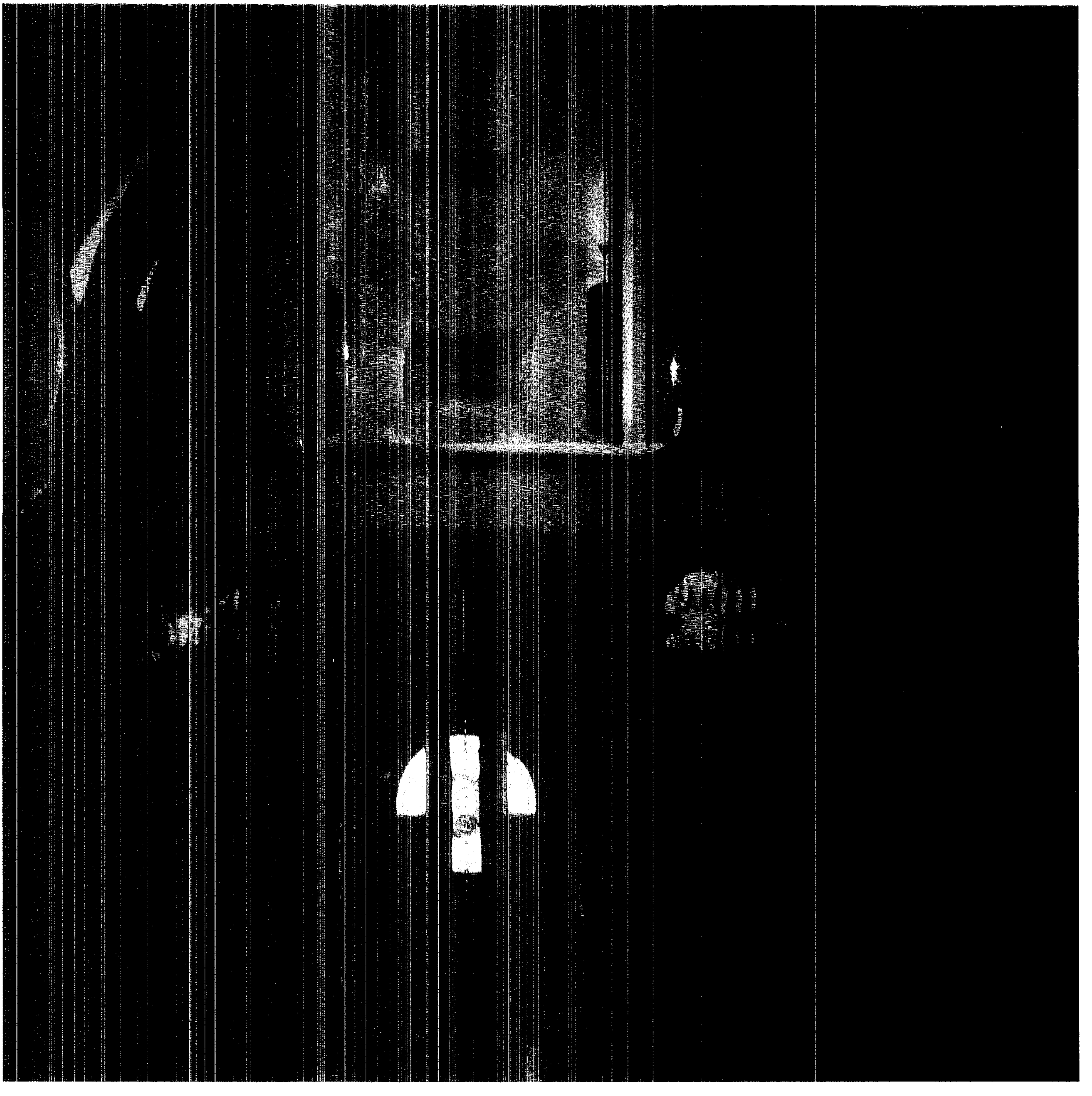
—LASL has long been a leader in nuclear safeguards—keeping track of radioactive materials—and has developed technology and equipment toward that end. Two devices for the dissolution and analysis of nuclear material are being manufactured by private firms using LASL designs. One company is manufacturing a Teflon lined metal container to LASL specifications that can withstand extreme temperatures and pressures. The container is used to process difficult-to-dissolve materials that have minute amounts of radioactive elements in them. The high temperatures and pressures are necessary to speed the otherwise slow dissolution process. Dissolving nuclear materials allows easier analysis with another LASL product called the automated spectrophotometer for analyzing nuclear fuels. LASL scientists are now reviewing proposed descriptive technical literature for an analyzer being manufactured by a Massachusetts company.

The Chemistry-Materials Science (CMB) Division also provides reference materials to government and industry for use in calibration and quality assurance of chemical analysis for radioactive materials.

—Several LASL-developed instruments for nuclear safeguards and nondestructive assay have been developed for commercial sale by about a dozen companies throughout the country. These devices result from work in

Groups Q-1, Q-2, Q-3, Q-4, and Q-5. They include the segmented gamma scanner, neutron coincidence counter, ^{252}Cf shuffler system, random driver, multi-energy gamma assay system, enrichment meter, enrichment monitor, fuel rod scanner, and nuclear materials detectors. The devices are all for detecting the presence of radioactive material and providing assay data. In addition, equipment like the fuel rod scanner can examine rods for reactors and measure the fissile content and pellet-to-pellet uniformity.

Flow cytometry and cell sorting techniques developed at LASL have been adapted by four companies. Specific cells, with the aid of a laser, are illuminated and measured at rates of thousands per second.



Electronic identification allows the livestock industry to monitor animals. Immunoassays were developed to detect diseases and analyze environmental contaminants.

Labeled isotopes

—The transfer or organic and biochemical synthesis technology from the LASL synthesis group (LS-5) to private industry has been one of the goals of the stable isotopes program since its beginning. The synthetic methods and procedures resulting from the LASL operation have been used by most companies marketing stable isotope labeled compounds. In addition, research institutions and companies manufacturing radioactive labeled compounds have also used methodology developed at LASL. Isotopes of certain elements are used in a variety of medical and agricultural applications.

Lasers

—Although the final goal of commercial laser fusion power is several decades away, the LASL program has a policy to involve industry early—especially in the development of advanced technology—so that industry will have a growing role in the program and be ready to assume the responsibility for ultimate commercialization.

Fluid analysis

—The numerical methodology for analyzing the dynamics of reactive fluids has been successfully transferred by Group T-3 to a major automotive company for its use in the analysis of combustion in internal combustion engines. The research capability of the automotive industry has thus been significantly upgraded. Several automotive manufacturers are either in the process of acquiring this technology or are making plans to do so. LASL work in the dynamics of spray droplets will also soon be available to the automotive industry for its studies on the use of fuel injection devices.

Glass sealing

—The need for an outside supplier to furnish high alumina segments joined with an inorganic material for LASL's controlled thermonuclear fusion effort resulted in the transfer of LASL glass sealing technology from CMB-Division to two private firms.

Computers

—LASL has become a world leader in the development of computer graphics, and documentation on the Laboratory's common graphics system and graphical analysis system has been provided to several organizations from Group C-6.

—A LASL computer program for predicting the flows and pressures in any facility's ventilation system subject to a tornado is being used by architects, engineers, and regulatory agencies. The application is for system designs and safety analysis. Group WX-8 recently held a workshop for industry and government representatives on the use of the program. LASL is also operating a test facility in which full-size capacity filters and other ventilation system components are tested. The data from these tests are being transmitted to industry with the objective of improving ventilation equipment designs.

Explosives

—In past years, LASL has provided the Army and Air Force with pressure vessels capable of containing explosive events. Recently, Groups M-2 and M-4 provided design information for a pressure vessel suitable for studying the destruction of chemical warfare weapons, without danger to operators. LASL was able to confirm to reactor laboratories that pressure vessels exist that would be suitable for studying the meltdown of a reactor fuel rod without the possibility of hazardous materials being dispersed. Such pressure vessels may be of great value to the reactor industry in designing safer machines.

—The weapons technology developed for explosive pipe closures in Group M-6 has often been presented to visitors as having potential as an oil or gas well blowout preventor, and recently several companies have followed up on the possibility.

Oil shale

—LASL has been interacting informally with a large corporation in an effort to develop a practical method to fracture and ignite oil shale underground, so that the hydrocarbons in shale can be brought to the surface and refined into oil, without having to mine ore to the surface. Group G-7 leads this effort.

Geosciences

—Industrial cooperation has been very important in the geosciences. Interactions include providing technical advice to industry, performing market surveys to induce industry to produce equipment required for our programs, and informing and involving industry in a general manner aimed at developing an industrial base of interest and expertise for ultimate commercialization. For example, as part of the geothermal hot dry rock program, LASL scientists have developed borehole fracture mapping concepts and tools with the creation of deep reservoirs for the ultimate removal of the heat in the rock. Several oil and gas companies have expressed interest in this technology.

—The seismic monitoring networks established around LASL's Fenton Hill geothermal hot dry rock experiment and in the Los Alamos region have been of interest to development firms that are considering such monitoring of their own geothermal fields.

—There has been a continuing wide interaction with the petroleum companies associated with the geothermal hot dry rock program— using deep, natural heat in the earth as an energy source. The interaction has varied from providing significant advice to LASL, to the Laboratory supplying data to tool companies. The cooperation has led to important advances in equipment and procedures, including core bits, a high-temperature turbodrill, shock absorbers, borehole survey, and directional steering instrumentation.

Tomography

—Tomography, a materials x-ray inspection process, is being used to detect stress fractures in certain reactor plumbing by one research facility, and a heavy equipment company has become interested in the process for inspection of ceramic turbine blades. Involved are groups M-1 and M-8.

These successful transfers are due both to the good, applicable ideas developed at our Laboratory and to the perseverance of many members of the technical staff and management in championing the ideas to the outside and working to overcome institutional barriers to the successful transfers.

LASL is one of nearly 200 laboratories from 11 agencies that belong to the Federal Laboratory Consortium for Technology Transfer. Members work together to promote both primary and secondary uses of technology. Through the Consortium, industry and government on the state and local levels seek existing federal expertise to adapt or commercialize.

As a Consortium member for more than five years, LASL has provided assistance directly to industry and to state and local governments. This has been done both with our in-house capabilities and by identifying sources of expert help from other quarters.

Gene Stark, LASL's representative to the Consortium, is coordinator for the mid-continent region of the U.S. and chairs its Energy Technology Group. This group, comprised of member Department of Energy laboratories, addresses cooperation between labs and industry, discusses methods of commercialization, and pursues initiatives with industry groups.

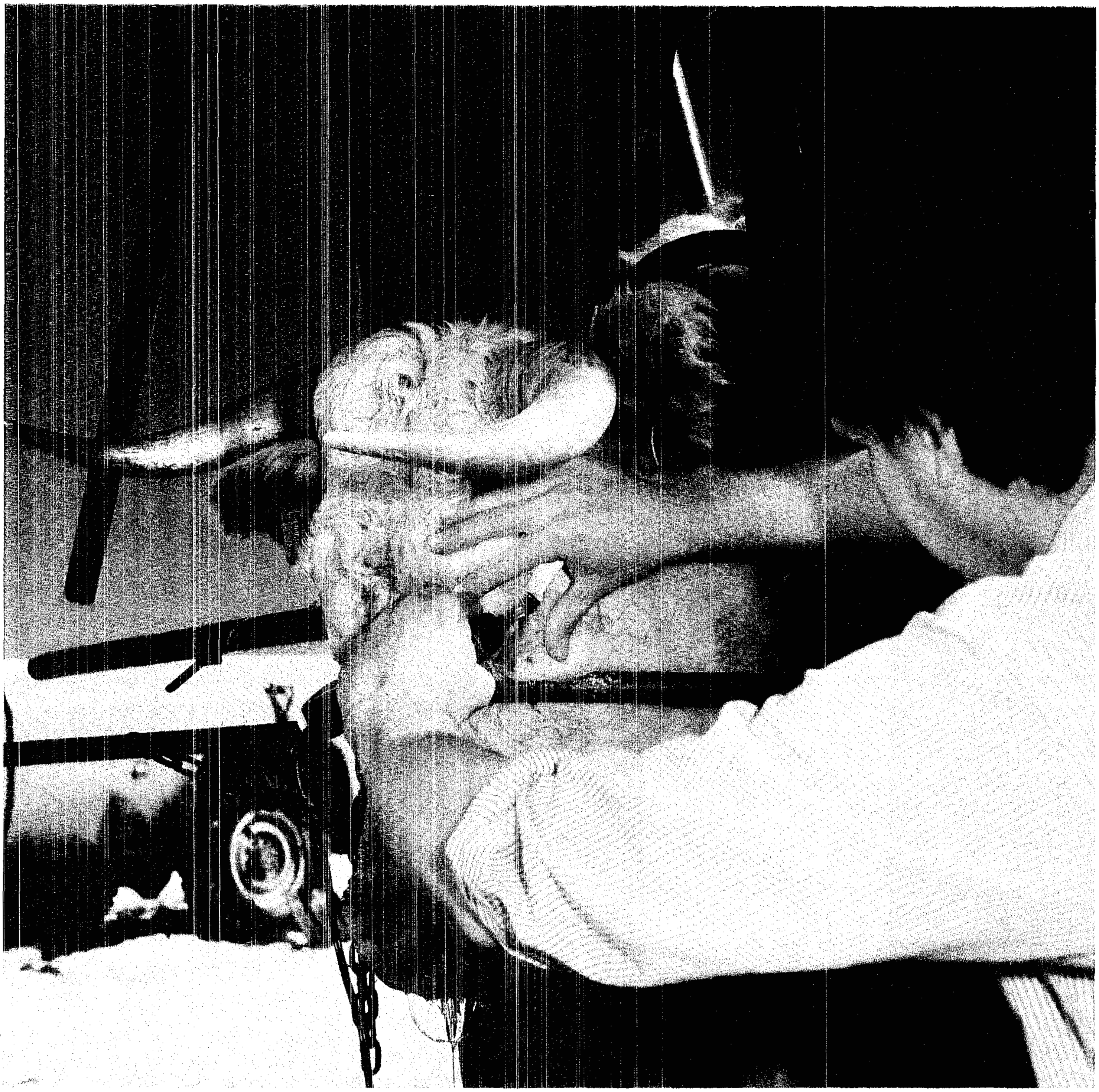


Photo by Fred Rick

short takes

Years Ago

30

H-bomb will proceed

President Harry S. Truman has announced the U.S. will proceed with plans to construct a hydrogen bomb. There is no comment from officials as to what that means locally, but Washington has said some of the research for the project will be conducted in Los Alamos. Some scientists have raised moral questions over the bomb, which reportedly could lay waste to 300 square miles, but physicist Arthur H. Compton said the work was realistic because Russia knows the secret of the atomic bomb, Britain is perfecting a weapon, and Canada and France have atomic reacting piles.

Fuchs trial under way

The trial of Klaus Fuchs, a German-born scientist, begins this week in London. Fuchs is accused by the British government of giving A-bomb and H-bomb secrets to the Russians in 1945 and 1947 while he was a British subject. The FBI announced it has worked with direct British contact in breaking the case. Fuchs, 38, worked in Los Alamos from late 1943 to June 1946, and had access to top secret weapons information.

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Housing requests swamp office

Since the announcement that a second $1 million would be spent for housing modifications, LASL's Community Relations Office has been a place of pandemonium. Bob Porton and John Stevenson last week sent out 500 applications to employees who sought a modification to their quarters. In addition, 100 telephone calls are being received daily. Under the point system, List A is for under-housed families, List B is for adequately housed families, and List C is for those who want miscellaneous additions to houses without regard to family size.

Unique reactor in offing

A unique reactor, involving unclad fuel elements and a revolving core, is expected to go to the construction phase this year. Called "Turret," the reactor will be operating in about two years. The experiment is designed to demonstrate that a temperature of 2,400 degrees F can be achieved, paving the way for eventual synthesis of gaseous and liquid hydrocarbons from coal. The project is carried on jointly by the AEC and the Bureau of Mines.

10

A few microseconds longer

An increase from 2.5 to 10 millionths of a second isn't much, but for Scylla IV-3 it represents a significant improvement in the constant evolution at Project Sherwood. There, reactions basically are initiated by compressing an ionized light-element gas such as deuterium in a very strong magnetic field. Scylla I produced the world's first scientifically proven controlled thermonuclear reaction in 1957 and the device is now at the Smithsonian Institution.

New on the mountain

The year's big drawing card on Pajarito Mountain is the ski area's first chair lift, which is expected to calm the anxieties of those who hate to wait in lines that carry 1,200 skiers per hour. The scenic ride up the mountain face just west of Los Alamos is 3,000 feet; the rise between upper and lower terminals is 900 feet. To accommodate the terminals and lift towers, the Lone Spruce run was extended by 1,500 feet and widened to 150 feet.

Taken from files of Los Alamos News, LASL Community News, and The Atom.

Among Our Guests

Walter Sullivan, science editor with the New York Times since 1966 and veteran of five Antarctic trips, spoke about condensed matter and black holes during a visit to Los Alamos. Sullivan is the 1978 winner of the National Science Foundation's Distinguished Public Service Award. Photo by Bill Jack Rodgers

The first U.S.-hosted meeting of the International Energy Agency's Man-Made Geothermal Energy Systems (MAGES) Executive Committee was held in January at LASL's study center. Some of the participants, who came from abroad and from the U.S., included (from left) Richard Neumann of the Federal Republic of Germany; Arthur Fehr and Ladislaus Rybach of Switzerland; Greg Nunz who manages the national hot dry rock program at LASL; and Porter Grace from the Department of Energy's Albuquerque office. Rybach is chairman of the committee.
Photo by Jeff Pederson

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etc...

Two persons have agreed to become LASL Fellows, during which time they may pursue research of their choice. Mark Kac, a professor at the Rockefeller University in New York, is an authority on probability theory and its relationship to mathematical analysis and physics. Robert H. Kupperman, mathematician, has been with the U.S. Arms Control and Disarmament Agency since 1973.

LASL has a new "People to People" program, instituted by the Public Affairs Department and scheduled monthly. The purpose is to give employees the chance to interact with top management. The first program during the noon hour featured Director Donald M. Kerr. Future topics will include organization, budgeting, policies, and programs.

A new Deputy Assistant Director for Institutional Relations has been named. She is Judith M. Liersch, who has joined the staff of Frank DiLuzio. The office provides a way for LASL, government, universities, and industry to interface. Liersch served two years in the DOE where she administered a 10-state energy conservation pilot program.

errata/addenda

The December 1979 story on geothermal surveys in New York state contained an omission. Correct is: The 3 New York areas have not been shown to contain developable levels of hydrothermal energy, such as hot water or steam, but they do have relatively high amounts of heat locked in impermeable rock.

Visitor Peter E. Glaser, seen in the November 1979 issue, emphasized solar energy conversion from space to electrical power on Earth. He is a vice president of Arthur D. Little, Inc.

patents

Patent 4,161,950 or "Electrosurgical Knife" was granted to James D. Ross, Robert E. Cowan, Robert H. Newell, and Charles W. McCabe of LASL. The abstract states that an electrosurgical knife blade of insulating material, having a pair of electrodes adapted to be connected to a radio frequency generator, cauterizes small blood vessels as the blade penetrates the tissue.

Patent 4,171,464 or "High Specific Heat Superconducting Composite" was granted to William A. Steyert, LASL. The invention pertains generally to cryogenics and to composite superconductors. The latter is formed from a high specified heat ceramic and a conventional metal conductor, which are insolubly mixed together.


LOS ALAMOS SCIENTIFIC LABORATORY