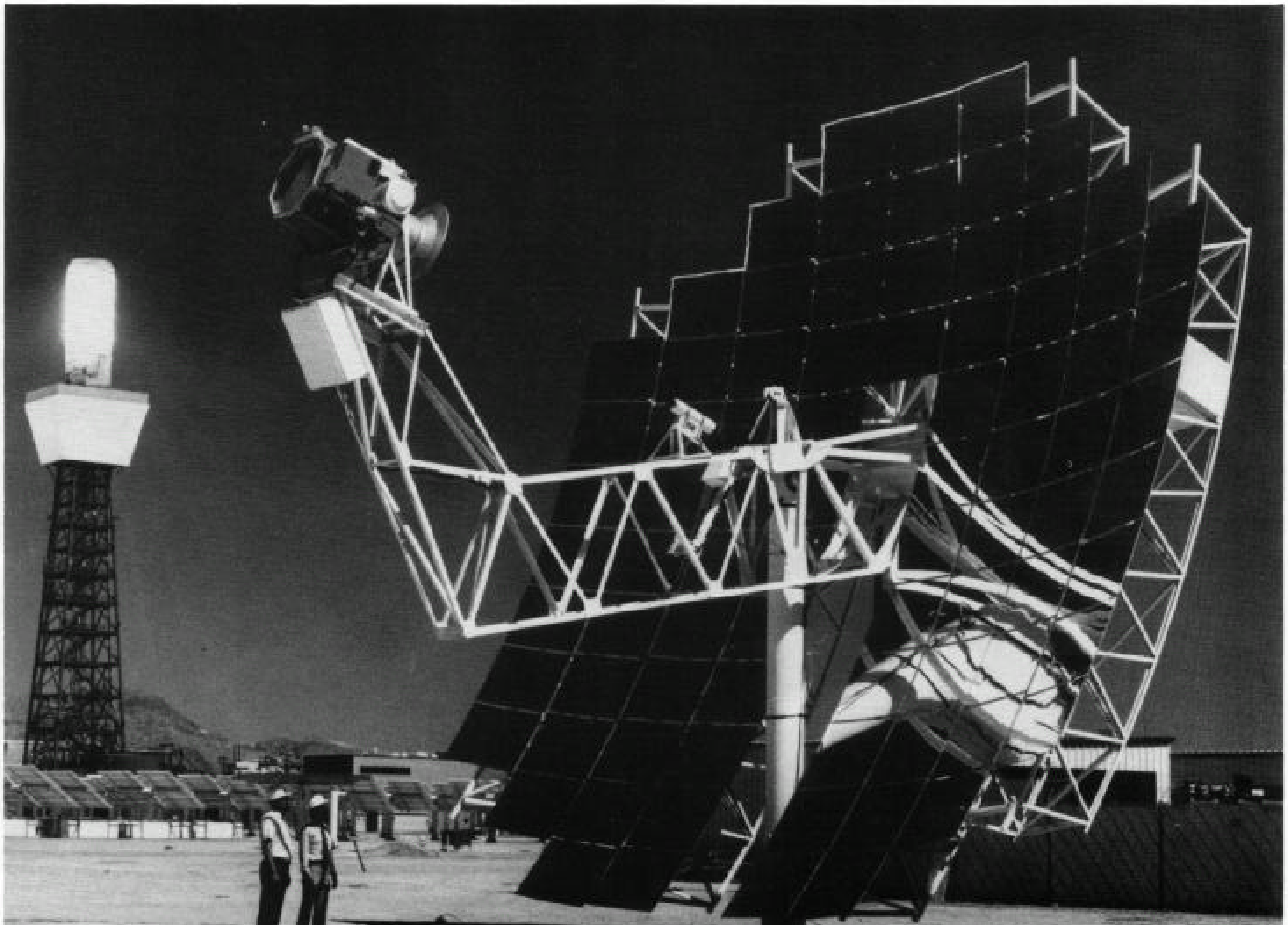
Hydrogen

Journal of The American Hydrogen Association®



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With Liquid Hydrogen Tankers, There will Be No More Oil Spills...

A Hydrogen Tanker.
With liquid hydrogen transport ships, oil spills from accidents and regular tanker operations will no longer pose environmental problems.
(Courtesy of General Dynamics, Inc.)

As the industrialized countries make a transition to a hydrogen energy system, oil tankers will evolve into cryogenic liquid hydrogen transport ships that will not pollute the oceans during their regular operations. It is not commonly known that most of the oil that is released into the oceans is not due to accidents but from normal operations where sea water is routinely used to clean excess oil from the tankers. This will not be necessary with liquid hydrogen transport ships. Although the fuel might be lost in the event of an accident, the liquid hydrogen is non-toxic and would rapidly vaporize and dissipate harmlessly into the atmosphere. This means that the extensive ecological damage that has been caused by tanker accidents and routine operations would finally be stopped.

Table of Contents

HYDROGEN

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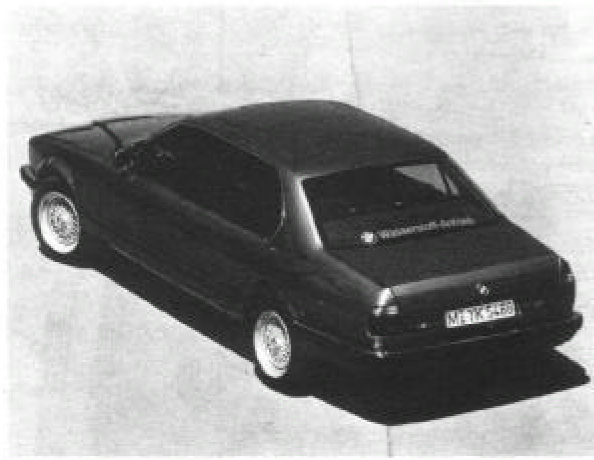
About The Cover

A SOLAR POINT-FOCUS "DISH" CONCENTRATOR "ON SUN," (Dagget, CA) - Manufactured by McDonnell Douglas Corporation (Huntington Beach, CA), this high-temperature solar concentrator has been integrated with a 25-kilowatt Stirling engine electrical generator set (Genset). This system has been field tested by Southern California Edison Company in cooperation with the Electric Power Research Institute (EPRI). Test data have shown conversion efficiencies of 28 percent compared to photovoltaic cells which are typically about 12 percent efficient.

Eight of these concentrators were initially built. From a manufacturing standpoint, the Stirling dish genset is like an automobile, which means it can be mass-produced for large-scale hydrogen production. Stirling dish systems were initially developed in the U.S. by John Ericsson right after the civil war in the 1880s. Called "Sun Motors," thousands of the units were sold as water pumping systems until they were eventually displaced by electric motors and utility grid systems. Mass producing Stirling gensets on a scale sufficient to displace fossil fuel and nuclear systems would facilitate an unprecedented economic boom for American industry. Photo courtesy of H. Braun, *The Phoenix Project*, Copyright © 1990.

A Liquid Hydrogen-Fueled BMW

BMW is the first major automobile manufacturer to modify a vehicle to operate on liquid hydrogen fuel. Hydrogen can be manufactured from water, and when it is burned in an engine, the water is returned as the primary exhaust by-product. This means that hydrogen is non-toxic, clean burning, and completely renewable. Moreover, with hydrogen fuel on board a vehicle, it would then be possible to have a small and highly efficient fuel cell Stirling engine cryocooler system that could provide air conditioning without the use of ozone-destroying chlorofluorocarbon (CFC) Freon gases.



Photos courtesy of BMW of North America.

A liquid hydrogen vacuum-jacketed storage tank (referred to as a dewar) in a well-insulated trunk. The liquid hydrogen dewar consists of an aluminum tank that is within an outer steel tank. A well-insulated vacuum is maintained between the two tanks. Extensive field experience by NASA has shown that liquid hydrogen is considerably safer than gasoline in the event of an accident. Because hydrogen is the lightest of all the elements in the universe, it will rapidly dissipate away from passengers in the event of a mishap. This is in contrast to gasoline and other hydrocarbon fuels that are relatively heavy and therefore tend to stick to passengers, causing more serious injury.

Hydrogen Fleet Demonstration Project

A Consortium of Arizona Cities is planning to implement the largest fleet of hydrogen-fueled vehicles in the world

by John Posner

PHOENIX, ARIZONA - Senator John McCain (R) Arizona, met recently with AHA president Roy McAlister and Vice President of Research, Harry Braun. The meeting was arranged by Mr. Darrel Baxter, who is the manager of fleet vehicles for the City of Tempe (Arizona), as well as the chairman of the Rocky Mountain Fleet Managers Association.

Baxter, who also attended the meeting with Senator McCain, has been instrumental in launching a fleet vehicle hydrogen demonstration project in cooperation with his counterparts in the Arizona cities of Phoenix, Scottsdale, Mesa and Glendale.

The first phase of the project involves converting 25 fleet vehicles to operate on hydrogen fuel with state-of-the-art and advanced fuel storage and injection technology. Phase 1 has a time-line of 24 months and a tentative budget of about $3 million. McCain indicated that the timing was right for such a proposal; and he offered to arrange the necessary meetings with key representatives in Washington, D.C., from the EPA and Departments of Energy and Transportation.

When completed, this will be the largest hydrogen-fueled fleet of vehicles in the world. The project will include an advanced carbon storage technology (refer to Hydrogen Storage Systems article on page 10 of this issue) as well as research by investigators at several universities including Arizona State University to help determine the most cost-effective methods of extracting hydrogen from biomass resources such as sewage sludge, paper, and other garbage.

Hydrogen for the fleet vehicles will initially be generated from water with an electrolyzer. In the daytime, the electricity will be generated with a solar point-focus concentrator Stirling engine electrical generator set (i.e., dish genset). Suitable solar concentrators have been developed by McDonnell Douglas, and the 25 kilowatt (kW) output Stirling engine power conversion unit is being developed by Cummins, the largest diesel engine manufacturer in the world.

During the night time and on weekends, off-peak electricity will be provided to the electrolyzers by the local utility companies, who are always seeking ways to balance their electrical loads. Assuming off-peak electricity can be provided at about $0.03 to $0.04 per kilowatt hour (kWh), the cost of the resulting hydrogen will be expected to be comparable to gasoline costing in the range of $1.00 to $1.40 per gallon.

Senator John McCain, (R) AZ

According to Braun, "those are very competitive numbers, particularly given the fact that when you purchase gasoline at the pump for roughly the same price, you are not paying for the cost of environmental damage, health and economic effects that result from production, refining, transporting, storing, and burning the gasoline."

According to Herb Hayden, one of the Hydrogen Fleet Project Engineers, "An operating fleet of hydrogen vehicles will enable us to demonstrate the practical value of hydrogen as an extremely clean, renewable fuel."

"We will apply readily available technology to convert existing cars and trucks to run on hydrogen, and make fuel on-site using the domestic energy systems already in place."

"The fleet will also help demonstrate the value of the fuel-cell electric vehicles being developed and new renewable energy resources such as solar electricity and fuel from waste." Δ

Cheaper Solar Power Fuels Hydrogen Hope

Hydrogen, an environmental dream come true, soon could become an inexhaustible and pollution-free energy source

by Victor Dricks
THE PHOENIX GAZETTE: Sept. 3, 1990

Long regarded as tantalizingly beyond reach, the dream of using hydrogen gas as an inexhaustible and pollution-free energy source soon may become feasible.

For decades, scientists have dreamed of using hydrogen as a substitute for oil and other fossil fuels, which have been linked to global greenhouse warming, acid rain, urban air pollution and ozone depletion.

The simplest of all chemical elements, hydrogen is an environmentalist's dream come true: It is an exceptionally clean-burning fuel, producing water vapor and trace amounts of nitrogen oxides, but no carbon monoxide, carbon dioxide, sulfur dioxide or soot - the principal constituents of air pollution.

Hydrogen can be obtained by using electricity to break up water molecules through electrolysis, a process familiar to every high school chemistry student. Two electrodes - one positive and the other negative - are placed in a solution of water that has been made conductive by the addition of an electrolyte, such as sulfuric acid or potassium hydroxide. When current is applied, the water molecules separate, liberating hydrogen and oxygen gas.

Hydrogen can be used to store energy and can be moved through natural gas pipelines for use in automobiles, aircraft and industry. Since it can be converted into electricity through the use of fuel cells, hydrogen often is viewed as an ideal "energy currency."

Traditionally, it has been too costly to use electricity to split water molecules to obtain hydrogen.

But recent advances in the efficiency of photovoltaic cells - like those used in pocket calculators to directly convert sunlight into electricity - and breakthroughs in solar thermal technology have sharply reduced the cost of solar power and soon may make it possible to produce hydrogen economically.

"Arizona can become a Saudi Arabia-class energy exporter," said Harry Braun, author of "The Phoenix Project," a book recently published by Research Analysts of Phoenix.

The book describes the economic and environmental advantages of converting from an oil-based to a hydrogen-based economy.

"We can make Arizona incredibly rich as a state by exploiting the potential of this new technology, Braun said.

"Widespread use of hydrogen, rather than fossil fuels, could also solve all of our major environmental problems. We would have a pollution-free city even with 10 times the number of cars we now have on the road."

"The hydrogen solution has been overlooked by a lack of public awareness, dismissed as a technology that is 20 years in the future, or discounted as uneconomical," said Herb Hayden, a communications and electrical engineer with Arizona Public Service Co. and a member of the American Hydrogen Association, a 200-member organization.

"The truth is, ongoing research and development since the energy crisis of the 1970s, though slowed during the past decade, has produced breakthroughs in solar energy conversion," he said.

Luz International Ltd. of Los Angeles is producing electricity from sunlight at a cost now comparable to oil, gas, coal or nuclear energy. Moreover, Luz officials expect the cost of their solar power to drop by 25 percent over the next five years, making sunlight the cheapest form of energy available throughout the Southwest.

Other Savings

The cost of electricity from silicon photovoltaic cells also is plummeting. In the early 1970s, a cell capable of generating 1 watt of power cost more than $100.

Improved manufacturing dropped the cost to $20 a decade ago and to about $4 today. Last spring, Solarex, the largest U.S. owned manufacturer of solar cells, began producing foot-square modules capable of producing power for only $1 per watt, and by the end of the decade, Solarex expects to be able to cut that cost in half.

> **"Arizona can become a Saudi Arabia-class energy exporter."**
> **Harry Braun**
> **Author of "The Phoenix Project"**

This would make it possible to produce hydrogen at a cost of about $2 per equivalent gallon, higher than gasoline or oil, but without their environmental drawbacks, according to a Princeton University study.

To cut the cost of producing hydrogen even further, Braun and other proponents envision use of solar dish "Gen Sets." These devices, which could be placed in large field arrays throughout the Arizona desert, have a large parabolic reflecting dish that focuses the sun's rays, creating a fireball about 1,500 degrees Fahrenheit. This heat then could be used to drive a free-piston Stirling engine to produce electricity that can be used for making hydrogen elsewhere on-site.

These engines do not have a crankshaft, valves or any physically connected moving parts prone to wear and tear. The primary components consist of a power piston supported by hydrostatic gas bearings. When heat is applied to the engine, a column of gas expands, driving the piston back and forth.

Smog Reduction

Converting even a small percentage of the cars on the road to hydrogen-burners could reduce smog substantially in polluted urban areas, according to Roy McAlister, president of Trans Energy Corp., a Tempe consulting firm.

According to McAlister, waste heat from standard automobile engines could be used to convert a portion of gasoline directly into hydrogen, which then could be burned as fuel. This increases fuel efficiency and range dramatically, and removes heat and carbon dioxide from exhaust produced by a running engine.

Mercedes-Benz and BMW have invested millions of dollars in studying how hydrogen could be used directly as an automobile fuel, either in liquefied, super-cooled form stored in vacuum tanks or as a gas, stored in superactivated carbon particles.

See Solar: Continued on page 16

World Survival Foundation Donates Car For Hydrogen Conversion

The World Survival Foundation has donated the use of a new 1991 Oldsmobile Cutlass Calais to the American Hydrogen Association (AHA) for conversion to hydrogen fuel. The car will be modified by AHA engineers in the AHA laboratory and test facility in Tempe, AZ and prepared for showroom stock racing. This will allow the vehicle to enter competitive racing events while still being street-driveable for demonstration purposes.

The Cutlass is equipped with a 180-HP, High-Output Quad Four engine, four-wheel disk brakes, all-wheel independent suspension, and a roomy trunk for one or two compressed gas hydrogen fuel tanks.

These features, incorporated into a stylish vehicle that is a symbol of U.S. automotive technology, make the Cutlass an ideal, and highly-competitive hydrogen conversion car.

Much of the fossil fuel technology in today's automobiles was developed, tested, and proven at the world-famous "brick yard" of the Indianapolis 500 or at other race tracks around the world. Over 50 million people annually watch some kind of motor racing event that showcases personal achievement and mechanical perfection.

It seems appropriate, therefore, for AHA to pursue a program of hydrogen racing development to promote the virtues of solar-produced hydrogen as a clean fuel. It is a win-win situation for everyone.

Hydrogen is essentially a ZERO emissions fuel, producing no hydrocarbons, carbon monoxide, particulates, or carbon dioxide when burned. It also has the highest power by weight of any fuel. It can improve engine efficiency and is safer to use than conventional fossil fuels. The technology, however, needs to be made more cost-effective, and on-board vehicle storage systems need to be improved.

Roy McAlister, President of AHA, accepts keys of Cutlass Calais from Demetri Wagner, Director of World Survival Foundation

The competitive proving grounds of racing sport are the ideal laboratories. Hydrogen can turn performance-hungry competitive motor racing into a "green" sport.

A Spirit Of Competition

Demetri Wagner, AHA's manager of racing development, observes, "There is something about the challenge of competition that catches the American spirit like nothing else can. Make a declaration that you are the best at anything and there will be ten others to challenge you to prove it in fair competition. That spirit, for better or worse, has sparked many great accomplishments."

"The American Hydrogen Association has a strong desire to bring the promise of hydrogen to the level of everyday Americans. So why not enter the 'race to save the planet' and add a little serious competition," Wagner continued.

An AHA hydrogen Racing Team is now forming around the Cutlass conversion project. Can this car be made into a competitive racing vehicle powered by hydrogen? "Absolutely," says Wagner. "We already have some trade secrets that will make this car a serious competitor for gasoline-powered cars. Our first possible competitive event could be a try at the hydrogen fuel land speed record at the Bonneville Salt Flats in August." Interested persons who would like to support the team are encouraged to participate.

Major sponsorship is being sought to further AHA racing development, and additional funds are needed now to fund the hardware conversion of the Cutlass and a national promotional campaign for the converted vehicle. Δ

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Hydrogen Storage Systems

Storing hydrogen on board vehicles is a critical aspect of utilizing hydrogen fuel

by Harry Braun

TEMPE, ARIZONA -- As most readers of this journal are aware, once hydrogen has been produced, it must then be stored as either a compressed gas, a cryogenic liquid, or in a solid hydride material.

With respect to automotive applications, it is possible to store hydrogen as a high pressure (3,000 psi) gas, although the storage tanks (dewars) are so bulky that the range of the vehicle is typically limited to about 60 to 80 miles.

Liquid hydrogen is similar to gasoline in terms of space and weight, but it is more difficult to handle and store in comparison with conventional hydrocarbon fuels like gasoline. In addition, a liquid hydrogen storage dewar will have to be roughly twice as heavy and four times as large as a gasoline tank for an average automobile.

Hydride storage systems (which absorb hydrogen like a sponge, and then release it when heat is applied) have been successfully demonstrated for years by U.S. Investigators at Brookhaven National Laboratory and tested by major auto manufacturers like Daimler Benz in Germany, but the iron-titanium hydride systems being used are about 18 times heavier than the liquid hydrogen storage systems being tested by the engineers at BMW.

For example, if a range of 500 kilometers (310 miles) is to be provided, the iron-titanium hydride storage system would weigh about 2,600 kilograms (5,700 pounds). In contrast, a liquid hydrogen dewar providing a similar range would weigh about 136 kilograms (300 pounds). A comparable tank of gasoline would weigh about 63 kilograms (138 pounds).

Carbon Composite Storage Systems

A more promising technology is being developed by investigators at Syracuse University in New York, which involves the use of very lightweight, high surface area carbon composites that have the ability of storing chilled gaseous hydrogen (which is cooled to about 150 degrees Kelvin at about 1,500 psi) with weight and volume characteristics that are comparable to gasoline tank systems.

These carbon composites, which resemble "Kitty Litter" pellets, take advantage of the porous structure of activated carbon to provide an incredible 2000 square meters of potential hydrogen storage area per gram of material. As with hydrides, charging and discharging the carbon composite tank is a matter of changing temperatures and pressures. When the hydrogen pressure is increased and its temperature lowered, the gas is absorbed onto the carbon. When the temperatures are increased and pressure is relieved, the hydrogen is then released.

Recall that gasoline is made up of both hydrogen and carbon (C_8H_{18}). A favorable aspect of carbon is that it is able to compact hydrogen atoms closer together to the extent that a hydrogen tank is about 3.5 times larger by volume for the same energy content. When the carbon goes into the engine to be burned, however, it produces carbon monoxide, carbon dioxide, and unburned hydrocarbons that result in the formation of photochemical smog. Carbon platelets also get deposited on the engine surfaces and contaminate the engine oil, causing the bearing surfaces to wear.

The carbon composite storage system is able to take advantage of the favorable qualities of carbon with respect to storing energy in a small area without having all of the disadvantages that are associated with allowing the carbon to be burned in the engine.

Although the carbon composite hydrogen storage system has been under development for more than a decade, it has yet to be field-tested in an automotive vehicle. (Roughly $500,000 is required to complete the necessary development work.)

Fleet Demonstration Project

AHA engineers are working in cooperation with numerous state and federal agencies to modify twenty-five vehicles to use hydrogen fuel. If the project continues on schedule, several of the vehicles will incorporate the advanced carbon composite storage systems.

When completed, this will be the largest hydrogen-fueled fleet of vehicles operating in the world.

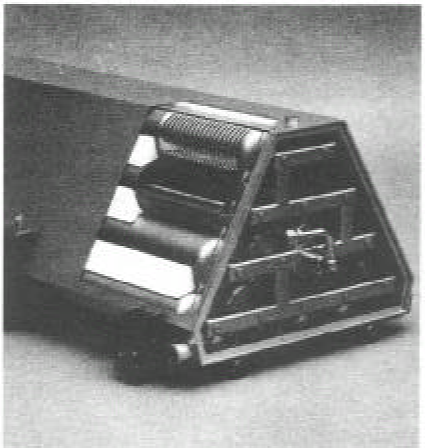
Electric Vehicle Considerations

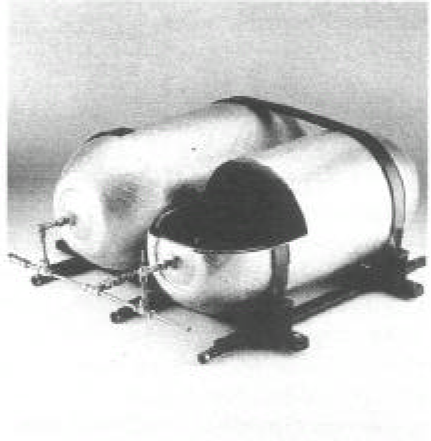
With existing lead-acid batteries it is worth noting that if an electric vehicle were to have a 500 kilometer (310 mile) range, the weight of the batteries would be around 3,000 kilograms (6,600 pounds).

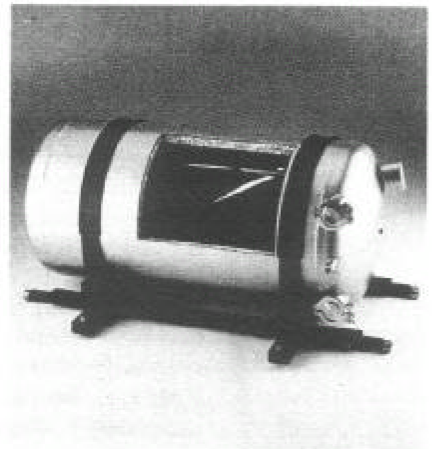
Advanced lead-acid batteries used in a General Motors prototype vehicle (named the Impact) would reduce the weight to about 2,400 pounds. More efficient zinc-air battery systems have the potential of reducing the weight to about 1,000 pounds. The most efficient electric vehicles in the future, however may not be energized by batteries at all. Instead, they will use "fuel cell" systems that electrochemically convert hydrogen and oxygen directly into electricity, with pure water as a by-product.

Fuel cells were initially developed in England in the year 1839 by Sir William Grove, but they were not utilized for practical applications until the 1960s when NASA used them in the Gemini and Apollo manned spacecraft to provide electricity as well as drinking water for the astronauts. When hydrogen fuel becomes readily available, fuel cells (which are 2 to 3 times more efficient than conventional gasoline-fueled spark-ignition engines) will be mass-produced for automotive applications, thereby making electric vehicles truly practical by eliminating the heavy battery storage systems that are presently required.

One thing is clear: it is now possible to manufacture emission-free vehicles. Whether emission-free vehicles in the future will be storing their energy in lightweight batteries or in lightweight hydrogen storage systems is not important. As long as the emission-free objectives are achieved, may the best engineering team win. Δ







Metal hydride hydrogen storage units

Gaseous hydrogen is absorbed by metal powder in tubes, forming so-called hydrides. In this process, i.e. during refuelling, heat is released. The hydrogen storage unit is therefore designed as a shell-and-tube exchanger. The tubes containing the hydrogen bonded to the metal are surrounded by water; this water takes care of the heat transfer which takes place when hydrogen is added or removed.

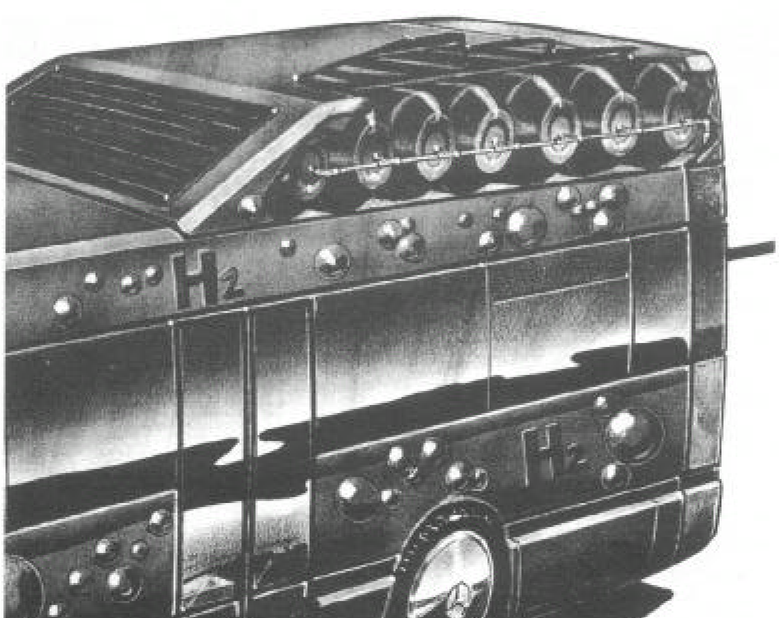
High-pressure hydrogen storage units

Gaseous hydrogen is stored under high pressure in containers made from composite materials for reasons of weight savings. High-strength fibres (e.g. aramide, glass or carbon) are wound around a gas-impermeable inner metal container to give it the required strength. This is a simple method of supplying the engine with hydrogen under high pressure (internal mixture formation).

Liquid hydrogen storage units

At standard pressure, liquid hydrogen has a boiling point of −253 °C and must therefore be stored in containers with highly effective insulation. Double-walled tanks with vacuum superinsulation are ideal for this purpose. However, vaporisation losses still amount to about 1 to 2% per day. For supplying the engine with hydrogen, especially under high pressure, a cryogenic pump is also required.

Courtesy of Daimler-Benz AG, Stuttgart, Germany



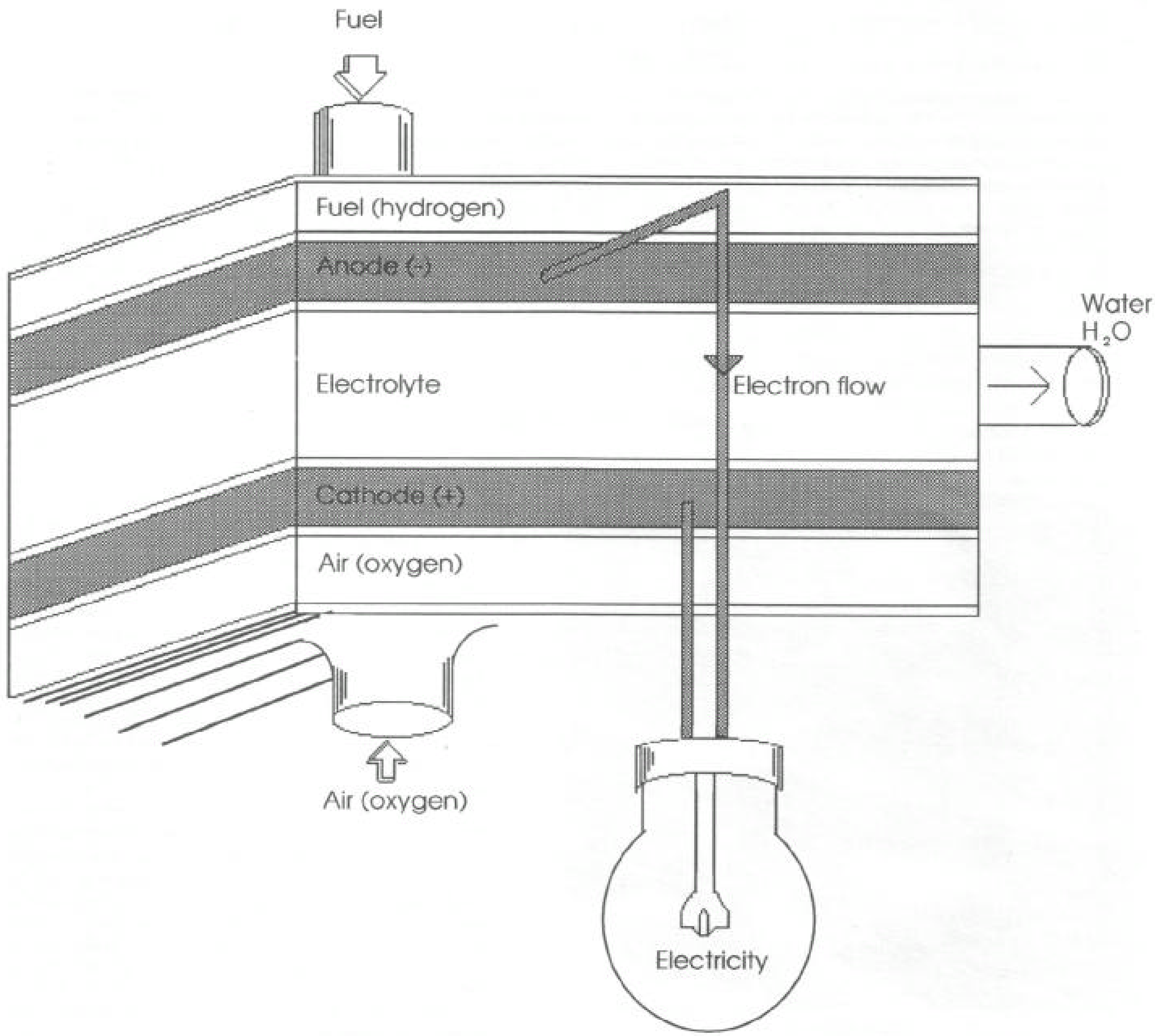
Hydrogen-Fueled Engines:

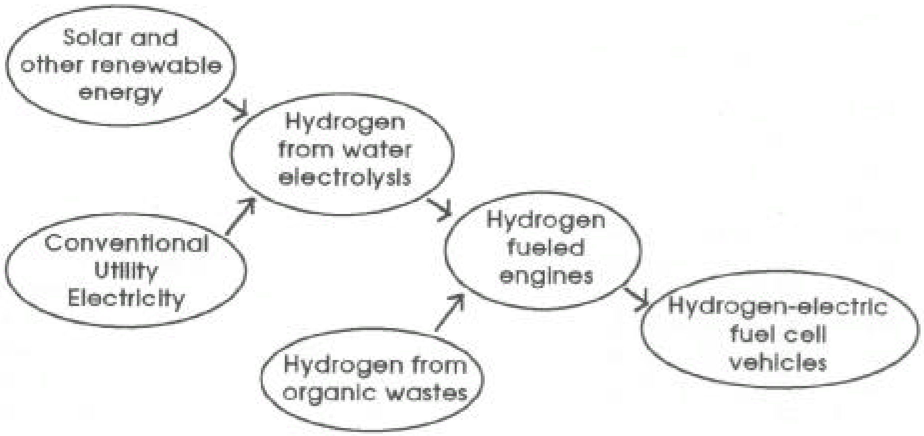
Various automotive research engineers in the Netherlands, Brazil and the Soviet Union are involved in hydrogen research and development. Hydrogen-fueled engines have been shown to be more energy efficient because of their complete combustion. Moreover, gasoline and diesel-fueled engines form carbon deposits and acids that erode the interior surfaces of the engine and contaminate the engine oil. This, in turn, increases wear and corrosion of the bearing surfaces. Since hydrogen-fueled engines produce no carbon deposits or acids, it is anticipated they will require considerably less maintenance. In addition, hydrogen fuel can also be utilized with more efficient Stirling cycle engines or fuel cells that could allow electric vehicles to be truly practical.

Automotive engineers have been aware of hydrogen's favorable combustion characteristics since the early 1900s. A German engineer, Rudolf A. Erren, began optimizing internal combustion engines to use hydrogen in the 1920s, and he is generally recognized by the hydrogen technical community as the father of the hydrogen-fueled engine. Erren modified many trucks and buses, and Allied forces even captured a German submarine in World War II that had not only a hydrogen-fueled engine, but hydrogen-powered torpedoes as well that were initially designed and patented by Erren and his associates. Δ

A Fuel Cell

Whereas an electrolyzer is a device that utilizes electricity to separate water into hydrogen and oxygen, a fuel cell reverses the operation; taking hydrogen and oxygen and combining it electrochemically, providing electricity and pure water as a by-product. The basic fuel cell has no moving parts, is highly efficient, and its only emission is water. A fuel cell is 2 to 3 times more efficient than an internal combustion engine. Many of the hydrogen fuel cell technologies are available today, but they are utilizing "reformer" systems which convert fossil fuels, such as natural gas and methanol, into hydrogen for the fuel cell. When these fossil fuels are used to produce the necessary hydrogen, carbon dioxide is produced as a waste by-product.





Hydrogen: We Should Start Now

by Herb Hayden, P.E.

Energy conservation and efficiency improvements can be highly productive and cost-effective ways of partially solving our energy and pollution problems. It is estimated that we can double fuel economy with available technology. Importantly, improved efficiency helps make renewable energy alternatives more cost-effective.

Unfortunately, though, conservation and efficiency improvements are not sufficient. The earth is finite-sized with limits to its resources. Furthermore, we — the earth's people — get to pay the bills for accidents, cleanups, and global energy conflicts, no matter who is to blame. So it remains necessary to adopt new energy sources that are safe, clean, and don't run out.

Hydrogen fuel from solar energy certainly qualifies in these departments. But to allow a real-world marketplace introduction, economically and without major governmental sponsorship, it is the versatility of hydrogen fuel that we must exploit. Here's how.

First, note the common complaints: "We'd have to build a whole new infrastructure and it would cost too much," or "the public is just not ready for hydrogen." These are concerns to note, but they may not be so difficult to overcome. With modest development, we could put any number of vehicles on the road, fueled with hydrogen made at home using electric utility power. These would be conventional piston-engine cars using direct injection for superior fuel efficiency and performance with hydrogen.

By negotiating a deal with the local power companies for the best off-peak rate, we could get hydrogen fuel costs per mile comparable to gasoline. Later, adapting electric vehicles powered by hydrogen fuel cells instead of batteries could achieve nearly double the fuel economy and have more power and range than the battery electric vehicles.

The growing fleet of natural gas vehicles provides another immediate application for hydrogen fuel. Though natural gas is not a true long-range energy solution, it is an immediate step in the right direction. Adding about five percent hydrogen to the methane fuel for these vehicles can reduce their emissions dramatically while improving their thermal efficiency.

The trick is to make the right hydrogen products. We need not start with major-project price tags. We need conversion products consumers, like you and me, can afford. A good, reliable and economical working-man's electrolyzer, for example. Add some good affordable storage tanks and engine conversion systems, and off we go.

Though the majority of the public is not ready to become hydrogen pioneers, there certainly are enough fleet owners and individuals interested in fostering the development of new, cleaner-burning renewable fuels to support initial production quantities of these hydrogen products.

Of course, most electric power is still fossil or nuclear-based, so we wouldn't be done yet. But look what we will have done: instead of using gasoline, which is largely derived from imported oil, we'd now be using electric power, which is, for the most part, based on domestic fuels and is widely available. We create a new demand for clean domestic power, we displace imported oil, and we achieve much-improved vehicular efficiency and zero vehicular emissions.

Clean, renewable energy supplies include all of the existing hydropower and wind generation sources. Additional hydropower is generally not available, but much more wind energy could be added in certain areas of the country. Solar energy is almost universally available to pick up the balance. Here in the Southwest, where there is no shortage of sunlight, solar generation could replace all of our fossil energy consumption using no more land area than is now devoted to coal power.

Photovoltaic systems are cost-effective for remote power applications, and line-focus solar thermal systems are considered to have become cost-effective since their introduction in Southern California.

But of all the solar power generating technologies, it is estimated that solar dish-Stirling engine systems, though not as mature as the line-focus systems or as well-known as photovoltaics, have been demonstrated to have the highest efficiency and the lowest potential cost. The dish-Stirling industry has not been adequately funded, nor is it currently targeted for commercialization, but new public demand for clean renewable energy could stimulate an opportunity for mass production.

The key point is that the right hydrogen conversion products would pay their own way in today's market using utility-generated electricity; and they would prompt the growth of solar generation systems. The result would be a highly effective marketplace conversion. Every hydrogen-related system that relieves our dependence on oil is an advancement in renewable energy technology. The potential market is so large that every major energy and manufacturing company in the country has a tremendous opportunity to participate.

Recent acts here in Arizona have set the stage for just such activity. The Arizona Corporation Commission (the public utility regulatory agency) has taken the position that new peak-power generation should preferentially be so-

See Now: Continued on page 16

One Man's Trash...

by Sara Tennant

A reasonable solution to our energy and waste disposal problems can be achieved by using biomass wastes as an energy source

Introduction

Treatment and disposal of waste products, the need for fuels, and the damage to the environment caused by the burning of fossil fuels are serious problems which the world must manage. The proper use of waste as fuel or for producing energy could help alleviate these problems. Obviously, waste needs to be disposed of, and it is worth exploiting for energy purposes.

Discussion

By far, the most widely used method of obtaining energy from waste products is by burning. In India, cattle dung is burned because there is a scarcity of wood. Unfortunately, this practice releases the carbon content as carbon dioxide and keeps the nutrients in the excrement from entering the soil. Burning doesn't only occur in underdeveloped countries, though. We have many trash-incineration-for-energy operations here in the United States. Combustion can reduce garbage 90% by volume and 75% by weight. Emissions, while still present, are much cleaner in the newer facilities, as compared to those built in the 1970s and earlier. The Semass Waste-to-Energy Facility in Rochester, Massachusetts, shreds and burns trash from 32 communities, generating more than 50 megawatts. Part of that electricity is used to run the plant, and the rest is sold to a local utility.

But even with the decreased emissions, critics of incineration contend that it still pollutes the air, hinders recycling, and produces ash that contains high concentrations of heavy metals like lead and mercury. Richard Denison, a scientist with the Environmental Defense Fund, says, "Incinerators do not dispose of waste. They are waste processors that create wastes that must themselves be managed." The ash from the plants is placed in monofills, which are sanitary landfills for one kind of waste, or mixed with household waste in an ordinary landfill.

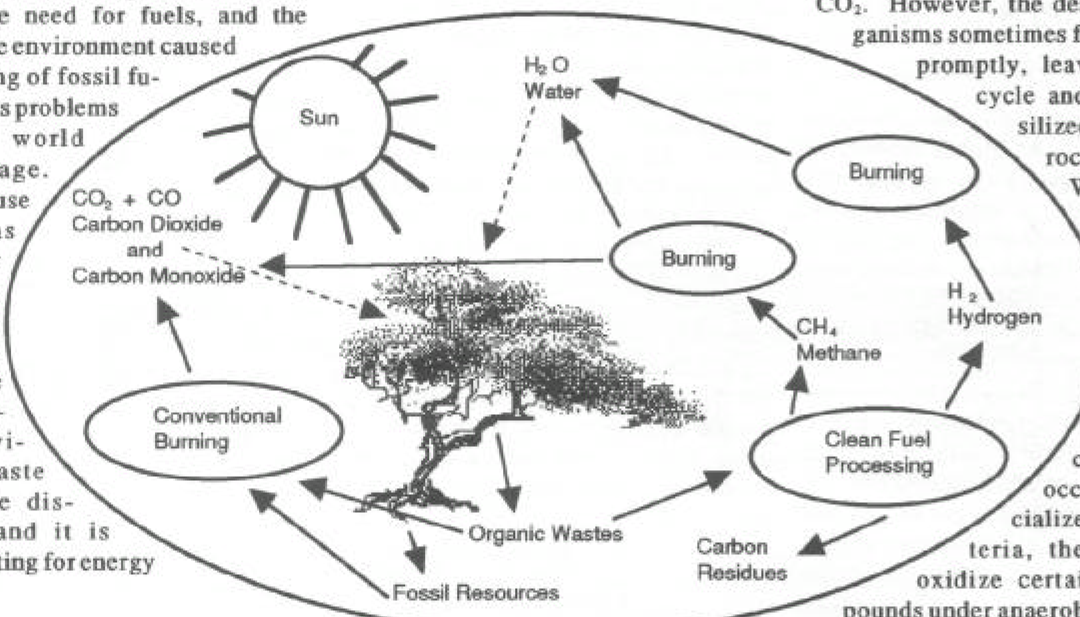


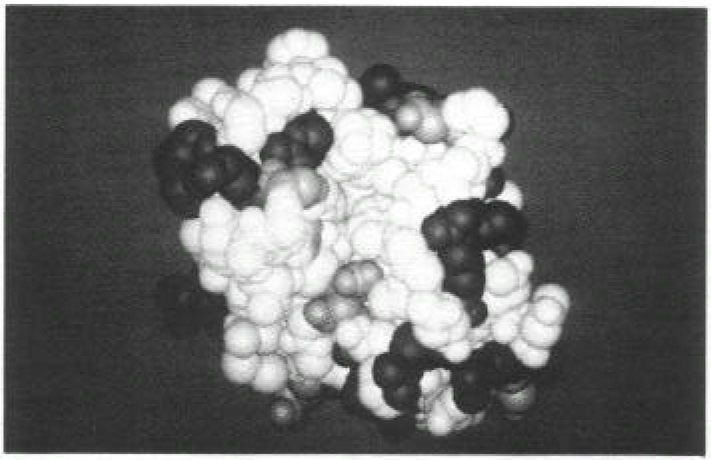
Illustration of the carbon and water energy cycles. The source of the cycle energy is the sun. Note that the only part of the cycle which can be free of carbon wastes to the atmosphere is the production and use of hydrogen.

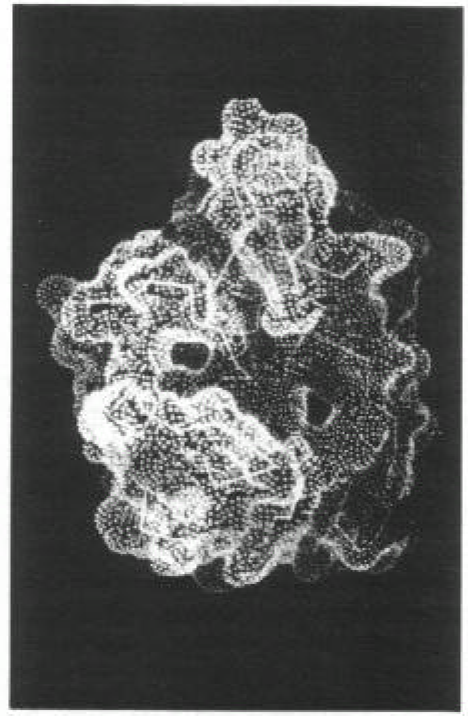
A more refined way energy is obtained from waste is through bioprocessing to produce cleaner fuels. Bioprocessing encompasses a number of natural cycles, primarily the carbon cycle. In the carbon cycle, through photosynthesis, CO_2 is extracted from the atmosphere and carbon is incorporated into the organic molecules which make up living substances. Some CO_2 is given off through plant respiration, but some remains in the plant bodies until they die or are eaten by animals. This CO_2 can either be given off by animal respiration, eliminated in body wastes or remain in their bodies until the animals die. The wastes from animals and dead bodies of plants and animals are usually broken down by decomposers, and the carbon is returned to the atmosphere as CO_2. However, the dead bodies of organisms sometimes fail to decompose promptly, leaving the carbon cycle and becoming fossilized as coal, gas, oil, rock, or diamonds. When we burn fossil fuels, then, that "trapped" CO_2 returns to the cycle.

The methane cycle is a branch of the carbon cycle that occurs when a specialized group of bacteria, the methanogens, oxidize certain carbon compounds under anaerobic (oxygen-free) conditions, ultimately producing methane. One natural habitat for these bacteria is the prestomach of a ruminant animal, such as the cow. *It is estimated that bovine flatulence adds 85 million tons of methane to the atmosphere annually*! It is probably safe to assume that the methane coming directly from cows won't be utilized, however, because it is easier to obtain the gas resulting from the decomposition of organic matter such as raw sewage or agricultural wastes. Another common habitat for methanogenic bacteria is in the bottom of stagnant ponds - hence - the name "marsh gas."

The anaerobic environments are improved upon by experimenting with different factors such as moisture and temperature in the controlled situations used in industry. The waste materials are usually placed in concrete tanks or vats

See Trash: Continued next page





Enzymes

Research has shown that the least expensive method of extracting hydrogen will come from biomass resources such as sewage sludge, paper and other garbage. The hydrogen can be extracted from biomass with naturally occurring enzymes that have been performing in this way since life began on the primordial Earth nearly four billion years ago. Enzymes and other proteins are at the heart of metabolism. The two images are of the enzyme subtilisin. The top image is of the molecular structure of atoms (excluding hydrogen), whereas the image to the right is a dot pattern of the enzyme's surface that was generated by a Cray supercomputer. Other enzymes have a completely different structure and appearance. Computer graphics modeling and photography by Arthur J. Olson, Ph.D., Research Institute of Scripps Clinic, Copyright © 1985.

Trash: Continued from previous page

where conditions can be controlled; the microorganisms are added and allowed to act upon the waste to produce the methane. The setup is similar to that used to produce fermented products like beer and sauerkraut. An attractive feature of this technology is that hugh operations are not necessary.

In China, thousands of family-sized and community-sized units have been constructed, using cattle dung for the most part, although experimentation with agricultural wastes such as rice straw is now being done. The organic wastes are then converted to methane, leaving a solid residue that can be used as a medium-grade ammonia-containing fertilizer.

Methane's value as a fuel can partially be measured by its "heat of combustion," which simply is the number of kilocalories liberated per kilogram of the substance burned. Methane's heat of combustion is 13,200 kilocalories per kilogram, as compared to gasoline's, which stands at 10,500 kilocalories per kilogram. This means that more energy can be obtained from methane than from an equal weight of gasoline.

Methane burns much more cleanly than gasoline, and contributes less CO_2 to the atmosphere when it is burned. Unfortunately, the leakage that would inevitably occur were methane adopted widely as an automotive fuel would have a proportionately greater effect on global warming than CO_2 because methane has a greater heat-trapping ability.

Hydrogen is another fuel which can be produced through biological processes similar to those which yield methane. This is done by choosing microorganisms that produce hydrogen instead of methane or carbon dioxide, and adjusting the conditions in their environment so as to help them thrive against competing microorganisms. Hydrogen posesses all of methane's positive attributes as a "clean fuel." In addition, hydrogen's heat of combustion is a whopping 34,200 kilocalories per kilogram, and it contributes nothing at all to the Greenhouse Effect. In fact, hydrogen actually helps decrease the amount of excess CO_2 in the atmosphere when it is obtained through bioprocessing where the carbon from the waste material is captured in a process similar to fossilization. This carbon residue is an important building material and is quite useful in manufacturing. The primary emission from hydrogen combustion is steam which, best of all, later returns to the environment as pure water.

Conclusion

Our waste management and fuel shortage problems are not going to go away by themselves. We need to help them along, because it is evident from past experience that "progress" will not cease, that there will only be more garbage and less fossil fuel in the future. Bioprocessing wastes for fuel could well be a great part of the clean energy solution. Global warming could be slowed, resources could be saved, waste could be taken care of and put to good use, landfill space could be saved for better purposes, and natural fertilizer could be created for areas that need it most. Δ

Solar: continued from page 6

According to Braun, conventional automobiles could be converted to burn liquid or gaseous hydrogen at a cost of about $1,000 per vehicle.

While solar energy long has been regarded as a source of "peaking power" for periods of high energy demand in the daytime, the electricity produced by solar plants could be used to make hydrogen during the daytime for use around the clock.

Energy Oasis

According to a 1989 study by John Ogden and Robert Williams of Princeton University's Center for Energy and Environmental Studies, electricity from a 24,000 square-mile array of photovoltaic cells could be used to produce enough hydrogen gas to transform the sun-drenched deserts of the Southwest into an energy oasis to satisfy the energy needs of the entire country.

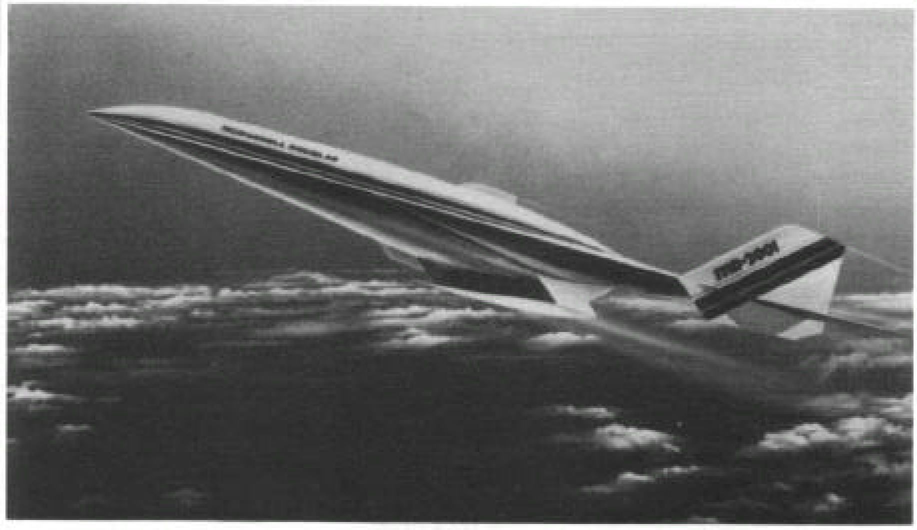
The availability of inexpensive land in the Yuma area and water from the Central Arizona Project gives sunny Arizona the key ingredients necessary to become a major producer of solar electricity and hydrogen, which can be transported via pipeline at a fraction of the cost of transmitting electricity long distance by wire. Δ

Now: Continued from page 13

lar-supplied. The Commission will attempt to weigh total costs, including environmental factors, in regulating new power generation. The Arizona State Advisory Committee on Energy Policy and Planning states that governmental fleets should lead the way with conversions to non-polluting renewable fuels, and optimum use should be made of existing energy transmission systems. The Committee suggests that the State and its energy providers assist in transitions to renewable energy uses and to low-emission vehicles.

At this point, it is up to us, the business person and consumer, to get busy developing, marketing, and buying the right products. Right now these products do not, for the most part, exist in the marketplace, but they are viable. An environmentally-sound energy regime is primed for a major thrust into the markets of the 90s, and we should all work to be part of it.

The American Hydrogen Association is an educational and public awareness organization for individuals, businesses, and institutions with a common goal of prosperity without pollution. What can you or your company offer for clean, renewable energy? Get involved, and let us know about it. We'll help spread the good word. Δ



National Aero-Space Plane: The Hydrogen Flagship.
This aero-space plane will replace the current generation of space shuttle. With a cruising speed of 8,000 mph, the aero-space plane will be the most advanced hydrogen fueled vehicle yet developed.
Courtesy of McDonnell Douglas Corporation

Suggested Reading:

Some additional books and technical papers to read on energy systems that are available in most libraries.

Compiled by Irv Jorgenson

International Journal of Hydrogen Energy. The Official Journal of The International Association for Hydrogen Energy, PO Box 248266, Coral Gables, FL 33124, USA. The most complete and comprehensive source of hydrogen technical data available.

Principles and Applications of Stirling Engines, by Colin D. West. This book gives the history of the Stirling engine; the research and development done by various companies, as well as the economics of the systems, is very easy to read.

Energy Options - Real Economics And The Solar Hydrogen System, Technical Summary, by J. O'M. Bockris. Comprehensive overall view of problems facing the Solar Hydrogen System. A view of others now in use.

The Forever Fuel: The Story of Hydrogen, by Peter Hoffmann. One of the best books on hydrogen ever written. Comes highly recommended. Although out-of-print, this 1981 book is in most libraries. Δ

Notes On Oil, Gas Reserves & Uses

Research by Charles Terrey
Source of data: Energy Information Administration.

Almost 75% of the world's known oil reserves are in the Middle East. Over 80% of the of the reserves are controlled by OPEC. Only about 16% of the reserves are in the Western Hemisphere.

This does not mean that these percentages could not change. They, in fact, are changing. It turns out that the amount of proven reserves are increasing most rapidly in the Middle East.

The United States and Canada use almost twice as much oil per person as the European countries.

Almost two-thirds of our oil is used for transportation.

The Bush Administration's new energy policy wants to replace 25% of our oil consumption with natural gas in the next ten years.

We used an average of 56.8 trillion more cubic feet of natural gas in the period 1967-1989 than we added to our reserves.

The new energy policy calls for increasing the deficit on a limited commodity in which the reserves have decreased for the past 22 years. Calculations show that if we continue to find new natural gas at the same rate we have for the past 22 years, reserves of natural gas in the United States will be totally depleted in about 18 years if we follow the Administration's new energy policy.

If we continue to use oil at the present rate and do not find any new oil, the world will run out of oil in about 40 years. The rate of discovery of new oil is not great enough to increase the world's oil reserves. Increasing the standard of living for the people of the world will require additional energy supplies. The use of existing oil reserves for fuel will cause great damage to our environment.

Crude oil and natural gas reserves are used to make essential plastics, petrochemicals and medicines which are an essential part of our lifestyle, and it has been said that the use of oil and natural gas for fuel is like burning Rembrandt masterpieces in the fireplace so we can read a newspaper by the light. Δ

Letter From The Department Of Energy

Ed. Note: This letter was received by AHA member Charles Terrey in response to his January letter to D.O.E. (reprinted in the last issue of Hydrogen Today).

Dear Mr. Terrey:

Thank you for your letter of January 20, 1991, to Secretary Watkins supporting the use of hydrogen as an alternative transportation fuel and enclosing your comments on the Department of Energy's report, "Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector."

This report is part of an ongoing assessment examining how the U.S. transportation sector can make the transition away from complete dependence on petroleum products. We are studying the fuels that appear to be the most likely candidates for starting that transition.

Hydrogen has many positive attributes. However, the high cost of production and the difficulty of vehicle storage stand in the way of practical use in the near or mid-term. If these problems can be overcome, mainly through increased research and development that is also supported by the Department of Energy, hydrogen may provide an attractive long-term alternative.

The Department of Energy's efforts are aimed at estimating the costs and benefits of various ways to reduce the transportation sector's dependence on petroleum. With this information, the Administration, Congress, and the public can better understand the effects of various policy choices.

We are not aware of any analysis that supports your conclusion that a transition from petroleum to CNG, methanol, or electricity would be a "costly mistake" or an "environmental disaster." With regard to the long-term use of renewable fuels, we believe that increased use of CNG, methanol, or electricity will actually ease the eventual transition to biomass-produced alcohols or photovoltaic-based hydrogen.

Thank you for taking the time to give us your detailed thoughts on alternative fuels. We share many of your views and believe that, in the long term, a variety of alternative fuels will be necessary to meet the needs of the national transportation market.

Sincerely,

Linda G. Stuntz
Deputy Under Secretary
U.S. Department of Energy
Washington, DC 20585

The "high cost" of producing hydrogen can be easily resolved by mass producing solar-hydrogen production technologies, like the point-focus concentrator featured on the cover of this issue. Other proven solar technologies include biomass, ocean thermal and wind energy conversion systems. The issue of storing hydrogen on board vehicles has been addressed on page 10 of this issue. As long as these information gaps continue, hydrogen will continue to be thought of as a long-term rather than near-term solution. Ed. Δ

Key Points to Remember about the Solar-Hydrogen Energy System

by Harry Braun

1. Hydrogen is the only alternative fuel that is non-toxic, essentially pollution-free, and inexhaustible.

2. Hydrogen is the safest of all the other alternative combustion fuels. Because it is the lightest of all elements, hydrogen will dissipate up and away from an accident scene, whereas gasoline and other hydrocarbon fuels will stick to passengers like glue and burn them alive.

3. Hydrogen is the only energy option that can be integrated with virtually all other energy sources, such as electricity, natural gas, coal, nuclear or solar. Indeed, hydrogen is an ideal solar energy storage medium as well as a clean-burning fuel.

4. Hydrogen greatly facilitates recycling because it can also be economically manufactured from sewage, garbage, paper or agricultural wastes.

5. Hydrogen is the only energy option that could realistically allow the Southwestern United States to become an international energy exporter. Moreover, the large-scale development of solar hydrogen systems would create an unprecedented multi-billion dollar industry in states like Arizona and California, as well as countries like Mexico.

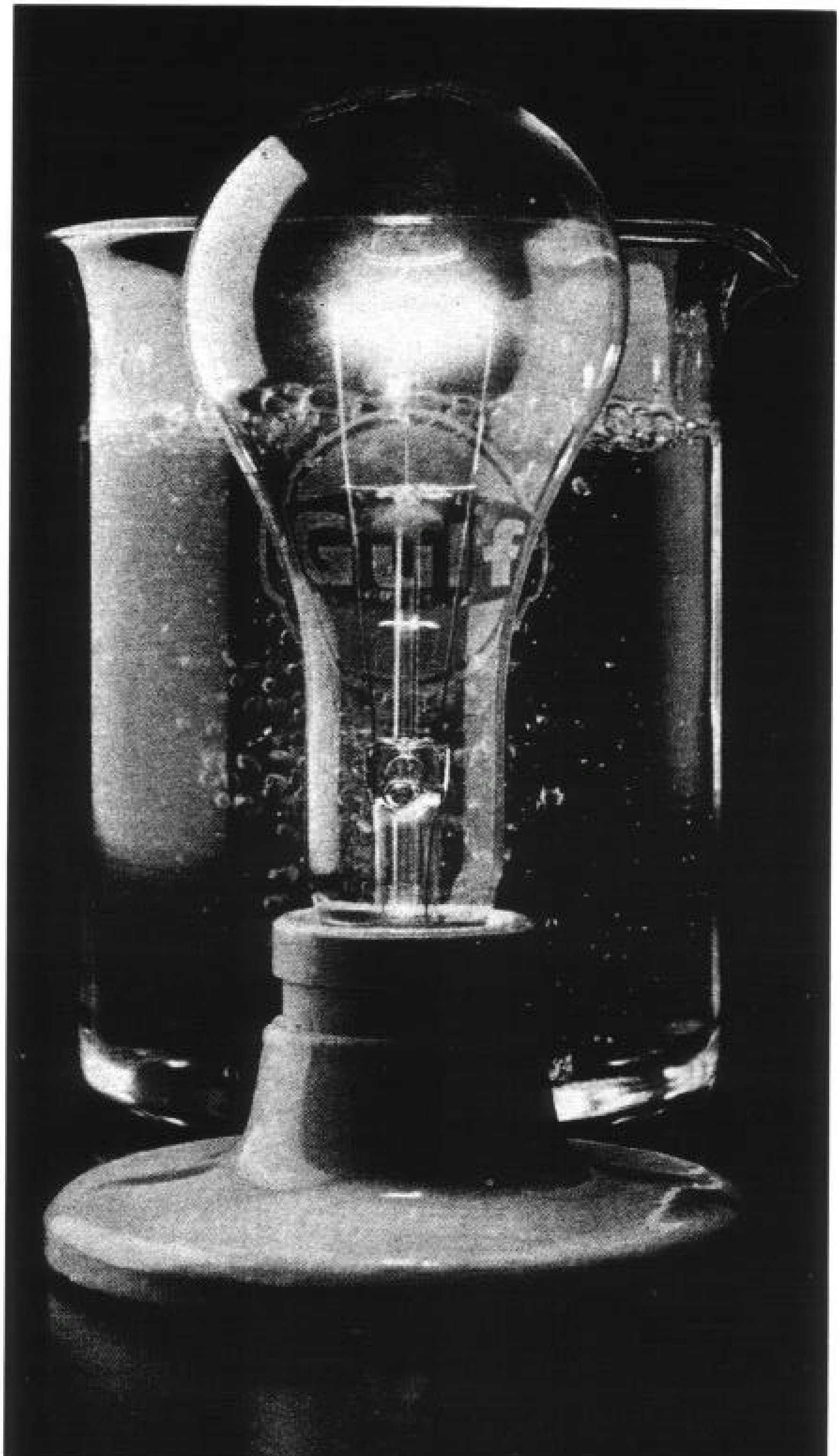
6. Virtually all biological organisms have been successfully using a hydrogen energy system on a global-scale for over 3.5 billion years.

7. A transition from a "petroleum economy" to a "hydrogen economy" would fundamentally resolve many of the most serious environmental problems related to sewage disposal, global warming, acid rain, oil spills, and urban air pollution.

8. Although hydrogen-fueled engines have been developed since the 1930s, the widespread use of hydrogen as a fuel was impractical because of the difficulty of storing it on board the vehicle and the fact that it cost more to manufacture from coal or natural gas than it did to manufacture gasoline or diesel fuel from petroleum. The problem of hydrogen storage on board vehicles has essentially been resolved by the development of hydride and/or liquid hydrogen (LH_2) cryogenic storage tnaks. There are several solar technologies that have been developed, which could be mass-produced to generate hydrogen from the electrolysis of water at a price that is competitive with gasoline generated from petroleum. These include Stirling, point-focus concentrator "dish" Gensets and ocean thermal and offshore wind energy conversion systems. One of the least expensive methods of producing hydrogen may come from sewage treatment plants using bacterial microorganisms that have been optimized for that purpose.

9. A transition to renewable energy resources is not a technical problem - it is a political problem. In the same way that catalytic converters were to a large extent mandated by the actions of the California Legislature, state legislatures could - and should - mandate that after the year 2000, new automotive vehicles will no longer be able to be sold if they emit any toxic hydrocarbon or carbon dioxide emissions. The net result will be that hydrogen-fueled engines or electric fuel cells will result. Δ

"At Gulf, we're working on a way to light lights, cook meals, and heat houses with the energy stored in water."



"You probably remember from grade-school science that water is two parts hydrogen and one part oxygen," says Dr. John Norman.

"Here at General Atomic Company, a subsidiary 50% owned by Gulf Oil, a project is under way to extract hydrogen from water for use as a fuel: for heating, cooking, or anything that now uses petroluem or natural gas.

"There are 326 million cubic miles of water on earth, and hydrogen in every drop-a natural energy resource that won't run out."

"The extraction process is called thermo-chemical water-splitting. We know it works because we've done it. But it takes high temperatures - about 1600°F - so it's rather expensive.

"It may be the turn of the century before it becomes commercial. But it's an attractive idea. Hydrogen from a gallon of water has about half as much energy as there is in a gallon of gasoline.

"Hydrogen can be made into a liquid or gaseous fuel. It can be transmitted long distances more cheaply than electricity. And when hydrogen burns, it's converted back into water. Very tidy."

At Gulf, our first priority is to get all the oil and natural gas we can out of resources right here in America. But we're working on a lot of other ideas, too. Thermochemical water-splitting is one of them. We are also working on underground coal gasification, solar research, liquefied coal and other synthetic fuels, geothermal energy, and other alternative energy sources.

Basically the business we are in is energy for tomorrow.

Gulf

Gulf people: energy for tomorrow.

Gulf Oil Corporation

THE HYDROGEN ASSOCIATION
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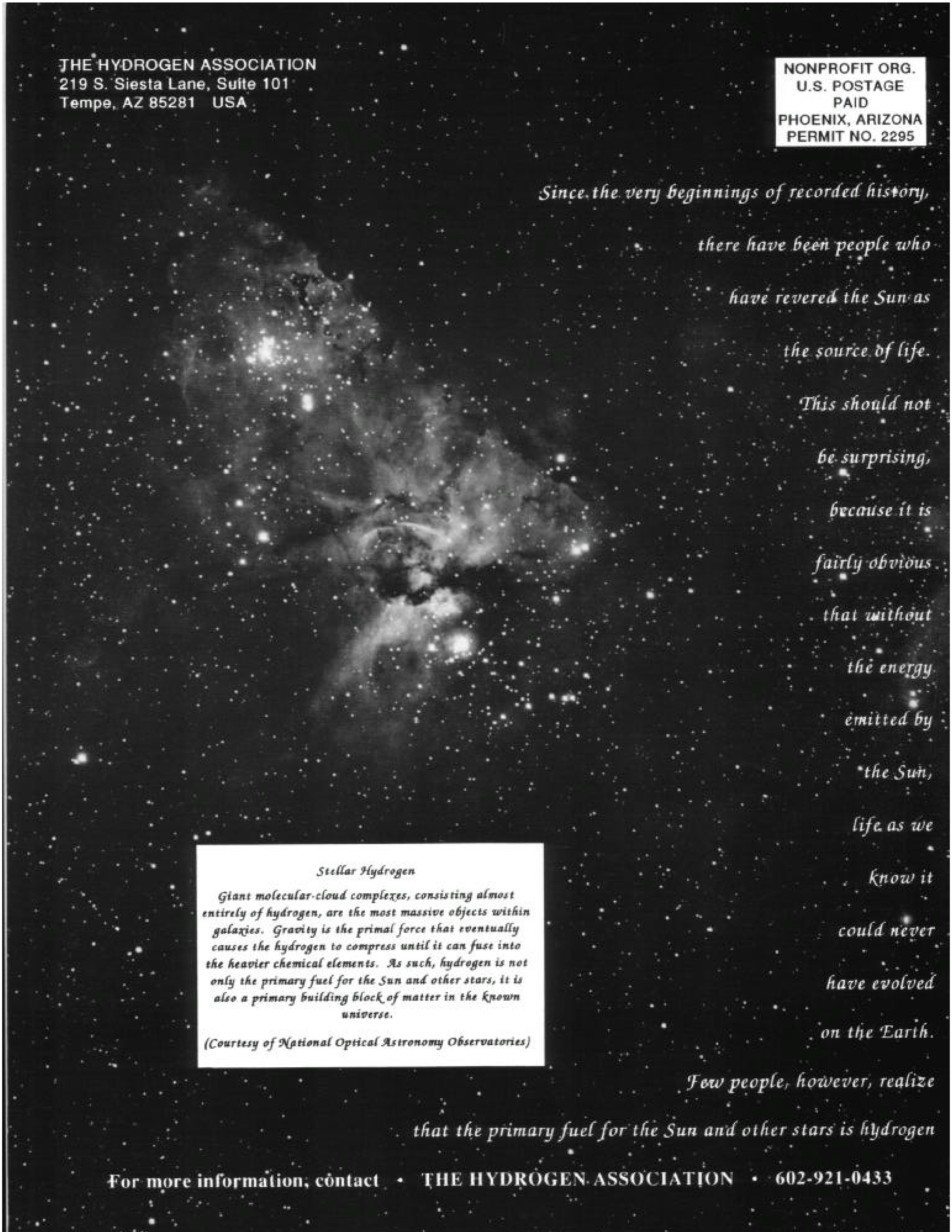
Tempe, AZ 85281 USA



Since the very beginnings of recorded history, there have been people who have revered the Sun as the source of life. This should not be surprising, because it is fairly obvious that without the energy emitted by the Sun, life as we know it could never have evolved on the Earth. Few people, however, realize that the primary fuel for the Sun and other stars is hydrogen

Stellar Hydrogen

Giant molecular-cloud complexes, consisting almost entirely of hydrogen, are the most massive objects within galaxies. Gravity is the primal force that eventually causes the hydrogen to compress until it can fuse into the heavier chemical elements. As such, hydrogen is not only the primary fuel for the Sun and other stars, it is also a primary building block of matter in the known universe.

(Courtesy of National Optical Astronomy Observatories)

For more information, contact • THE HYDROGEN ASSOCIATION • 602-921-0433