Companion Guide to

HYDROGEN:
The Matter of Safety

A Twenty-minute Video

A Cognizant Media Production
presented by
Hydrogen 2000, Inc.

Acknowledgements

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International Association for Hydrogen Energy
Praxair, Inc.

Acknowledgement of additional support from script reviewers, participants in the video, and organizations providing additional video materials appear on the inside back cover.

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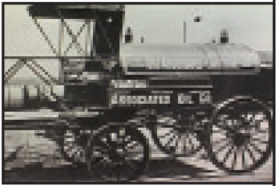
What's Gasoline?



The summary of the Report of the Congressional Horseless Carriage Committee. (1875)

"A new source of power, which comes from a distillate of kerosene called gasoline, has been produced by a Boston engineer. Instead of burning the fuel under a boiler, it is exploded inside the cylinder of the engine. This so-called internal combustion engine may be used under certain conditions to supplement steam engines. Experiments are underway to use an engine to propel a vehicle.

This discovery begins a new era in the history of civilization. It may someday prove to be more revolutionary in the development of human society than the invention of the wheel, the use of metals, or the steam engine. Never in history has society been confronted with power so full of potential danger and at the same time so full of promise for the future of man and for the peace of the world.

The dangers are obvious. Stores of gasoline in the hands of the people interested primarily in profit, would constitute a fire and explosive hazard of the first rank. Horseless carriages propelled by gasoline engines might attain speeds of 14 or even 20 miles per hour. The menace to our people of vehicles of this type hurtling through our streets and along our roads and poisoning our atmosphere would call for prompt legislative action even if the military and economic implications were not so overwhelming. The Secretary of War has testified before us and has pointed out the destructive effects of the use of such vehicles in battle. A few of them with a small cannon mounted behind a steel shield could decimate infantry, break up a cavalry charge, and even seriously threaten the efficacy of field artillery by lightning-like flank attacks. Furthermore, our supplies of petroleum, from which gasoline is extracted only in limited quantities, make it imperative that the defense forces should have first call on the limited supply. Furthermore, the cost of producing it is beyond the financial capacity of private industry, yet the safety of the nation demands that an adequate supply should

Hydrogen:
The Matter of Safety

New energy technologies and supporting infrastructures that meet environmental and economic objectives are entering the marketplace. Among the most promising of these clean, renewable technologies are hydrogen-powered fuel cells for transportation and electricity generation. This brochure and video will provide you an overview and background of safety issues.

All fuels burn and pose fire and explosion risks if their combustion is not controlled, so safety is always an issue with fuels. Most people are familiar with hydrocarbon fuels such as gasoline, propane, and natural gas. Tens of millions of people pump gasoline into their cars every day. It is commonplace for natural gas or propane to be piped into homes for use in appliances such as water heaters, stoves, and furnaces. The risks associated with the use of these fuels is accepted because systems that use them achieve sufficient levels of safety.

Hydrogen as a fuel is a new idea to most people. It

be produced. In addition, the development of this new power may displace the use of horses, which would wreck our agriculture. We therefore earnestly recommend that Congress set up a Horseless Carriage Commission which will have complete control over all sources of gasoline and similar explosive elements and all activities connected with their development and use in the United States.

These measures may seem drastic and far-reaching, but the discovery with which we are dealing involves forces of nature too dangerous to fit into our usual concepts.

For the immediate protection of the public, we further recommend the enactment of legislation along the lines of the British Red Flag Act."

is not uncommon for the layperson to think of hydrogen as dangerous because of erroneous connotations with the hydrogen bomb or as the cause of the Hindenburg airship incident. Only a hundred years ago gasoline was also viewed as dangerous. An 1875 report by the U.S. Congress' Horseless Carriage Committee warned that the "stores of gasoline... would constitute a fire and explosive hazard of the first rank." Those with concerns were soon won over as equipment and procedures were developed, allowing gasoline to be used safely.

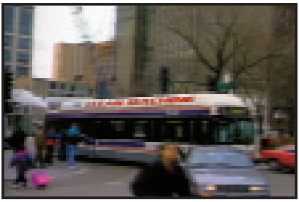
Likewise, hydrogen systems can be designed that are safe. The transition to hydrogen should be easier than the transition from horse and buggy to gasoline powered automobiles because industry and NASA already have decades of experience safely handling hydrogen.

Developing Hydrogen and Fuel Cell Systems

Hydrogen energy systems are developing rapidly (see pages 26-30). In major cities around the world, there

The most recent research on the Hindenburg incident provides strong evidence that rules out hydrogen as causing or contributing to the accident. The more likely scenario: A large concentration of static electricity built up on the airship and discharged across the outer covering shortly after the inner metal frame was grounded. The covering fabric was made of a cotton substrate and doped with chemical compounds. The primary dopant was cellulose butyrate acetate combined with iron oxide and powdered aluminum, a composition not unlike that used in solid rocket propellants. The static discharge triggered a reaction of the highly volatile chemical combination.

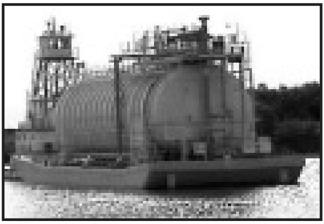
are demonstrations of fuel cell electric buses fueled with hydrogen. Auto industry giants in the U.S., Germany, and Japan have invested hundreds of millions of dollars to develop efficient, non-polluting fuel cell cars. The "Big Three" auto makers plan on having fuel cell cars available to consumers as early as 2004. Major oil companies, including Royal Dutch/Shell group, Texaco, Atlantic Richfield, and BP/Amoco are positioning themselves to supply hydrogen as a transportation fuel. Supporting infrastructure to manufacture, transport, store, and dispense hydrogen is being demonstrated, and required standards are being developed to guide the safe design of these systems.



It's not just the transportation sector. In the near term, we may see an even greater impact on stationary applications. Fuel cell power plant field tests are being conducted or planned for 2000 and 2001 by companies such as Ballard Power Systems, Plug Power, GE Fuel Cell Systems, International Fuel Cells, Inc./ONSI Corp., NiSource, and others. These demonstrations will be in homes, schools, office buildings, hotels; any place needing power generation. International Fuel Cells already has power plant systems operating in 84 U.S. cities and in 11 other countries in Europe and Asia.

Production and Use of Hydrogen

Hydrogen was first recognized as a distinct element in 1766 by the English chemist, Henry Cavendish, who called it inflammable air. His new discovery was found to form water on combustion with air, which led to it being named hydrogen, which means 'water former.' Hydrogen was little used until early in the nineteenth century when 'town gas,' a mixture of hydrogen, methane, carbon dioxide, and carbon monoxide made from coal was used for cooking and lighting.



Today, hydrogen is an important chemical commodity. In the U.S. alone, more than eight million tons are produced annually, mostly by steam reforming natural gas. Hydrogen has been transported safely both as a cryogenic liquid and as a compressed gas by rail, barge, truck, and pipeline for decades for use in the aerospace, food, petrochemical, and semiconductor industries. Industry has an excellent safety record with hydrogen because it understands the risk and how to manage it.

The space program also has a long history with hydrogen. NASA uses about nine thousand tons annually, mostly as a fuel in manned and unmanned booster rockets. NASA was also the first to use fuel cells powered by hydrogen as a dependable source of electric power and water on manned missions.

Hydrogen is most commonly used as a gas, and is generally piped directly from production to consumption. When hydrogen is stored, it is stored in either a compressed state under high pressure (for example, it is typically stored at 2,400 pounds per square inch in tube trailers) or as a cryogenic liquid at below minus 253 degrees Celsius (20 degrees above absolute zero). When volume is a consideration, hydrogen may be stored as a liquid. One and a half million cubic feet of hydrogen as a liquid can be stored in the same space it takes to store 100,000 cubic feet of hydrogen as a gas. Electronics plants, NASA, and food processors typically store hydrogen as a liquid.

Safety-Related Characteristics of Fuels

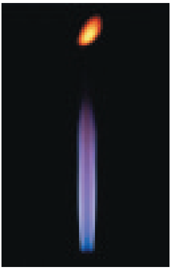
Hydrogen was shown to be as safe as or safer than conventional fuels in several comparative safety analyses, shaped by three factors:

1. Flammability Limits, the range of composition over which fuel/air mixtures will burn.

2. Fuel Burn Rate, or how fast a flame front moves through a mixture of fuel in air.

3. Health and environmental hazards from toxicity of fuels and their combustion products.

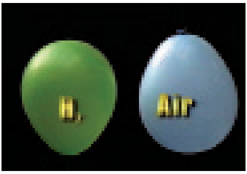
Hydrogen Properties and Characteristics



• Hydrogen is colorless, odorless, and has no taste.

• Hydrogen burns with a pale blue flame that is virtually invisible in daylight. (See cover, “broom test” photo).

• Hydrogen is the lightest of all elements. With a specific gravity of 0.0696, or about 1/16th that of air, it has a very high diffusion rate. This causes it to be buoyant and to rapidly disperse when released in air, two great safety assets in open environments, because a leak or release is quickly diluted and rendered harmless. Hydrogen diffuses four times faster than methane, and ten times faster than gasoline vapors.

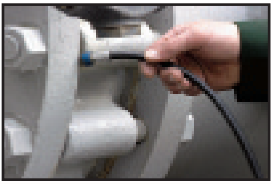


• Hydrogen contains the highest energy per unit weight of any fuel. One pound of hydrogen has three times the energy content of one pound of gasoline, making it the fuel of choice for the space program where weight is crucial.

• Hydrogen has a wide flammability range; 4% to 75% by volume with air (gasoline 1.4% to 7.4% by volume in air). Actual limits vary with pressure, temperature, and water vapor content.

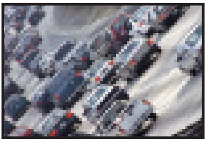
• Hydrogen has a low ignition energy—as little as 0.017 millijoules in contrast to 0.25 millijoules for other hydrocarbon fuels.

• Hydrogen has a small molecular size, allowing it to leak more easily through porous materials, cracks, or bad joints than other common gases at equivalent pressures.



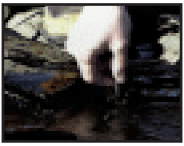
• Hydrogen is generally non-corrosive and non-reactive with typical container materials. At certain temperature and pressure conditions, it can diffuse into steel and some other metals, causing a phenomenon known as 'hydrogen embrittlement.' Because of this, hydrogen handling equipment must be designed and maintained to high safety standards to ensure integrity.

• Hydrogen is non-toxic and nonpoisonous. In contrast, the combustion products of diesel and other conventional fuels, along with methanol, are toxic from an inhalation standpoint.



• As with any gas, asphyxiation is possible if hydrogen displaces oxygen.

• There are few significant environmental hazards associated with the accidental discharge of hydrogen. In contrast, spills of gasoline or diesel that can enter a waterway, drainage system, or sewer system pose a serous risk of fire or explosion, especially in a waterway with an unvented covered section where vapors can accumulate.



• Storage of liquid hydrogen poses a frostbite hazard if skin comes in contact with the super-cooled pipes, tanks, valves, or other components.

General Safety Considerations

The primary hazard associated with all fuels, including hydrogen, is fire. A potentially flammable mixture is formed whenever hydrogen is exposed to air in a closed environment. The ignition energy required to start a hydrogen fire is low. Even small amounts of static electricity can create enough of a spark to set things off, so precaution must be taken to prevent static discharge during dispensing and other processes. As with other gaseous fuels, if burning hydrogen gas is confined the resulting pressure and temperature rise can trigger an explosion.

When storing and dispensing fuels, there's an increased chance of a leak resulting from a structural failure to a tank or connector. Systems storing gaseous hydrogen at high pressure and liquid hydrogen, which is maintained at very low temperatures, are robustly designed to handle the pressure and temperature extremes without leaking.

Because hydrogen is colorless and odorless, it is more difficult to detect than other fuels. NASA and industry employ sensors to detect leakage in hydrogen containment systems, and both have excellent safety records.

Well-engineered hydrogen powered vehicles and associated hydrogen dispensing systems can be expected to be at least as safe as gasoline, natural gas, and propane vehicle systems. In some cases, such as a collision in an open space, a hydrogen powered vehicle poses less of a hazard than a traditional gasoline-powered vehicle because of the reduced risk of a flammable fuel leak.

Comparative Safety of Hydrogen and Other Fuels

Dr. Michael Swain, a researcher from the University of Miami, has been studying the comparative safety of hydrogen and other fuels for more than a decade.

Tank Leak Test

Dr. Swain found that one characteristic of burning hydrogen that gives it a safety advantage over hydrocarbon fuels is its relatively low heat radiation. When hydrocarbon fuels such as gasoline and diesel burn in air, they produce high temperature carbon soot that radiates heat. Because hydrogen produces virtually no soot during combustion, this greatly reduces the radiant energy from a hydrogen flame.

In the tank leak test, a hydrogen leak equal to three thousand cubic feet per minute was vented from a tank mounted in the trunk of a parked automobile and ignited, resulting in a 30 foot high flame. Temperature sensors placed inside the car and around the outside barely registered above normal even when the high pressure flame was no more than a foot away. The same experiment conducted with gasoline or other hydrocarbon fuels under most conditions would have heated the inside of the car and shattered the rear window causing a flash fire.

Garage Leak Simulation

In this simulation, hydrogen was compared to equivalent amounts of gasoline, LPG (liquid petroleum gas - of which propane is the main constituent), and natural gas leaked in a ventilated garage-sized enclosed space to observe the manner in which vapors would accumulate and determine the potential for the formation of flammable concentrations.

With gasoline, a constant leak from an equivalent puncture of a fuel line onto the garage floor quickly resulted in a highly volatile vapor cloud that would fill the entire lower portion of the space. The LPG leak produced similar results. Both situations would be highly explosive in the presence of an ignition source. When hydrogen was leaked at the rate at which it would leak from a similar puncture, it's lighter-than-air weight caused it to dilute, rise, and dissipate rapidly. For the hydrogen to catch fire, the ignition source had to be placed within a foot or two of the leak.

While every situation is different, these experiments suggest that when used in properly designed systems, hydrogen is not more dangerous than fuels like gasoline, LPG, and natural gas, and in some ways, hydrogen may be safer than the hydrocarbon fuels used for nearly a century.

How to Manage a Hydrogen Fire

The protocols for fighting a hydrogen fire are similar to the basic rules for fighting any fire fueled by a gas. The first thing to do is to eliminate the fuel source. If this is not an option, the fuel source is generally allowed to burn itself out under controlled conditions to minimize the risks of injury and danger to the surrounding area.

Safe Design, Operating Practices, & Safety Systems

The risk involved in working with hydrogen can be minimized by following standard design parameters for current equipment and procedures. Fire marshals and other authorities concerned with safety can refer to several sources for guidance on properly designed hydrogen systems. A number of organizations and agencies are now cooperating in the development of standards that will allow for the expanded range of applications for hydrogen (see page 17).

The primary issue in building safe hydrogen systems is to minimize the risk from leaks and sources of ignition. The design of safe systems and procedures for managing hydrogen compares with the standards in use for other flammable gases. A key consideration in all hydrogen systems is adequate ventilation. Warning systems such as hydrogen gas sensors and flame detection devices should be in place. There are several effective sensor options available:

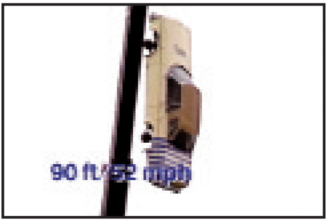
- Flammable gas detector - chemical reaction to detect hydrogen
- Infrared detector - detects heat
- Flame detector - detects heat and focuses on a specific wave length put out by hydrogen flames

Warning systems should have visible and audible signals, and should be sufficiently redundant to prevent any single-point failures from disabling the system.

Systems are typically designed to include tripping automatic pressure relief valves and other devices to minimize the hazard. Good training and a well designed set of procedures that emphasize safe operation is critical.

Hydrogen Tank Drop Test

Tanks are designed so that the chance of rapid release is very small, even in a severe accident. To reduce or eliminate the chance of failure, pressurized vessels used in hydrogen systems are designed to meet rigorous DOT and ANSI/AGA NGV2 cylinder certification standards. Tanks are designed to withstand more than twice their operating pressure and are tested at one and a half times their rated pressure. Samples randomly selected from production lines from each tank design must withstand pressures of 2.25 to 3.5 times operating pressure without bursting. NGV2 certification standards require that the cylinders be subjected to pressure cycling, flaw tolerance, gunfire, and bonfire tets at service pressures. These tests are then followed by burst tests.



To illustrate that gaseous hydrogen can be stored safely on vehicles, one tank manufacturer performed a series of vehicle drop tests to simulate rear end collisions. Pressurized tanks were installed in vehicles and dropped from heights ranging from 30 up to 90 feet, simulating a rear-end collision of up to 52 miles per hour. These tanks did not lose pressure, and exceeded the NGV2 requirement for new tanks in subsequent burst tests.

Conclusion

In the coming decades, hydrogen and fuel cells will assume a greater role in meeting the world's energy needs. Hydrogen, like electricity, is a clean energy carrier. When derived from renewable energy sources, hydrogen has the potential of providing an inexhaustible supply of energy to fuel our cars, homes and industry without generating pollution or greenhouse gases of any kind. It can also be economical and have a relatively high margin of safety when produced, stored, and dispensed properly.

Codes, Standards, and Guidelines

The current codes, standards, and guidelines that are specifically for hydrogen were developed for industrial applications. Organizations such as the International Standards Organization Technical Committee 197 (ISO/TC 197), the National Hydrogen Association, and the Canadian Hydrogen Association are working on developing codes, standards, and guidelines for the design and operation of nonindustrial hydrogen and fuel cell systems including automobiles and refueling stations. These organizations have drawn on the Natural Gas Vehicle Coalition codes development as a model. The first listing that follows includes key hydrogen-specific and related codes and standards that have been used for years by industry. The second list contains key standards and guidelines that are under development. This list is not intended to be comprehensive, but to illustrate the wide body of experience available in handling hydrogen systems.

American Petroleum Institute, (USA)
API 941, Steels for H2 Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants

American Society for Mechanical Engineers, (USA)
ASME, Boiler and Pressure Vessel Code

ANSI/ASME B31.3, American National Standard Code for Chemical Plant and Petroleum Refinery Piping

Canadian Standards Association, (Canada)
CSA B51, Code for Boilers, Pressure Vessels and Pressure Piping Code Containing Hydrogen

CSA B51-M, Construction and Inspection of Boilers and Pressure Vessels

Compressed Gas Association, (USA)
CGA G 5.4, Standard for Hydrogen Piping Systems at Consumer Locations

CGA S 1.2, Pressure Relief Device Standards, Part 2 - Cargo and Portable Tanks for Compressed Gases

CGA P-6, Standard Density Data, Atmospheric Gasses & Hydrogen, Third Edition

CGA S 1.3, Pressure Relief Device Standards, Part 3 - Compressed Gas Storage Containers

CGA G-5.3-90, Commodity Specification for Hydrogen, Fourth Edition

CGA G-5-1991, Hydrogen

CGA S 1.1, Pressure Relief Device Standards, Part 1 - Cylinders for Compressed Gases

Dept. of Transportation - NHTSA, (USA)
FMVSS No. 301, Fuel System Integrity

FMVSS No. 303, Fuel System Integrity of CNGVs

FMVSS No. 304, CNG Fuel Containers

Federal Specification, (USA)
BB-H-866, Gaseous Hydrogen Grades for Cutting and Welding and as a Lifting Medium for Balloons

ZZ-H-461D, Hose and Hose Assembly, Rubber, Gas (Acetylene-Hydrogen, Air and Oxygen)

Hydrogen Industry Council, (Japan)
Hydrogen Gas Consumption Standards

National Fire Protection Association, (USA)
NFPA 30A, Automotive & Marine Service Station Code

NFPA 50A, Standard for Gaseous Hydrogen Systems at Consumer Sites

NFPA 50B, Standard for Liquefied Hydrogen Systems at Consumer Sites

NFPA 52, CNG Vehicular Fuel Systems

NFPA 55, Compressed & Liquefied Gases in Portable Cylinders

NFPA 58, Storage & Handling of Liquefied Petroleum Gases

NFPA 70, National Electrical Code

NFPA 88A, Standard for Parking Structures

NFPA 88B, Standard for Repair Garages

NFPA 496, Purged & Pressurized Enclosures for Electrical Equipment

NFPA 497A, Classification of Class I Hazardous Locations

NFPA 497M, Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous Locations

NFPA 513, Standard for Motor Freight Terminals

NFPA MY-HLH-88, Electrical Installations in Hazardous Locations

NFPA 853, Installation of Stationary Fuel Cell Power Plants

Natural Gas Vehicle Coalition, (USA)
NGV2, Basic Requirements for CNGV Fuel Containers
NGV1, CNGV Fueling Connection Devices

The High Pressure Gas Safety Institute of Japan, (Japan)
The High Pressure Gas Safety Law

Under Development
The ISO/TC 197 was established in 1990, and has nine work items underway. The National Hydrogen Association began working on hydrogen standards development in 1995, and currently has seven work groups. The NHA works closely with the ISO/TC 197, and, once a particular work item is sufficiently developed, it is passed on to the ISO/TC 197 for further development.

International Standards Organization
ISO/WD 15594, Airport hydrogen fuelling facility

ISO 13984, Liquid Hydrogen - Land vehicle fuelling system interface

ISO 14687, Hydrogen Fuel - Product specification

ISO/CD 13985, Liquid hydrogen - Land vehicle fuel tanks

ISO/WD 13986, Tank containers for multimodal transportation of liquid hydrogen

ISO/AWI 17268, Gaseous hydrogen - Land vehicle fuelling connectors

ISO/WD 15866, Gaseous hydrogen blends and hydrogen fuel - Service stations

ISO/WD 15869, Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks

ISO/WD 15916, Basic requirements for the safety of hydrogen systems

National Hydrogen Association, (USA)
WG1, Connectors

WG2, Tanks and Containers

WG3, Refueling Stations

WG4, Codes and standards for the use of electrolysers and fuel cells at customer sites

WG5, Self-service refueling

WG6, SAE Coordination

WG7, Codes and standards for maritime unique applications of hydrogen

Resources

The following listings of publications and organizations represents key resources, each containing a wealth of further information, including additional references and more extensive bibliographies, depending on your requirements. Information on ordering relevant documents published by the listed organizations is available on most of the cited web sites.

Publications

The Sourcebook for Hydrogen Applications, Canadian Hydrogen Association (CHA) and the National Hydrogen Association (NHA), for Natural Resources Canada and the U.S. Department of Energy. Published by TISEC Inc., Montreal, Quebec, 1998.

This is a single-volume reference tool of prevailing practices, applicable codes, standards, guidelines and regulations for the safe use of hydrogen. It provides an outline of key safety considerations for non-industrial applications. A content outline can be seen on the NHA web site, www.hydrogenus.com/nha/sourcebk.htm. The Sourcebook package includes a paper and electronic version on CD-ROM. It is available from both the NHA and the CHA (contact information beginning on page 23), or directly from the publisher:

TISEC Inc.
2113A St. Regis Boulevard
Dollard, Montreal, Quebec H9B 2M9 Canada
800-531-2863

Safety Standards for Hydrogen and Hydrogen Systems, National Aeronautics and Space Administration, Office of Mission Assurance, NSS 1740.16, Washington, DC, February 1997

This document establishes a "uniform Agency process for hydrogen system design, materials selection, operation, storage, and transportation." It includes the minimum guidelines for NASA. To obtain the document, contact:

NASA Headquarters
Director, Safety and Risk Management Division
Office of the Associate for Safety and Mission
Assurance, Washington, DC 20546
202-358-2406

Direct-Hydrogen-Fueled Proton-Exchange-Membrane Fuel Cell System for Transportation Applications, Hydrogen Safety Report, Directed Technologies, Inc. for the Ford Motor Company and the U.S. Department of Energy, DOE/CE/50389-502, May 1997

This safety analysis presents the results of a detailed review of the safety characteristics of a hydrogen-fueled fuel cell-powered vehicle. Emphasis is given to high pressure gaseous hydrogen onboard storage. In the analysis, the normal operation of a vehicle was considered. The analysis also studied refueling, storing the vehicle in a garage, collisions and operation in a tunnel. Risks and failure modes that have the potential to lead to hazardous conditions are identified, and potential countermeasures to prevent or reduce the results of a failure are presented. The risks of a hydrogen-fueled vehicle are compared with gasoline, propane, and natural gas.

Available to DOE contractors from:

Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
423-576-8401

Available to the public from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Organizations

American National Standards Institute
11 W. 42nd St., 13th Floor
New York, NY 10036 USA
212-642-4900
Web Site: www.ansi.org

American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990 USA
800-THE-ASME
Web Site: www.asmeny.org

Canadian Hydrogen Association
5 King's College Road
Toronto, Ontario M5S 3G8 CANADA
416-978-2551
Web Site: www.h2.ca

Canadian Gas Association
20 Eglinton Avenue West
Suite 1305, P.O. Box 2017
Toronto, Ontario M4R 1K8 CANADA
416-481-1828
Web Site: www.cga.ca

Canadian General Standards Board
Ottawa K1A 1G6 CANADA
819-956-0894
Web Site: w3.pwgsc.gc.ca/cgsb/

Canadian Standards Organization
178 Rexdale Blvd.
Etobicoke, Ontario M9W 1R3 CANADA
416-747-4000
Web Site: www.csa.ca

Compressed Gas Association
1725 Jefferson David Hwy., Suite 1004
Arlington, VA 22202-4102 USA
703-412-0900

International Code Council, Inc.
5203 Leesburg Pike, Suite 708
Falls Church, VA 22041
703-931-4533
Web Site: www.intlcode.org

International Standards Organization
The secretariat of ISO/TC 197 is held by the Bureau de normalization du Quebec on behalf of the Standards Council of Canada.

Ms. Sylvie Gingras, secretary of ISO/TC 197
Bureau de normalisation du Quebec
333, rue Franquet
Sainte-Foy, Quebec G1P 4C7 CANADA
418-652-2238
e-mail: sgingras@criq.qc.ca
or

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P.O. Box 500
Trois-Rivieres, Quebec G9A 5H7 CANADA
819-376-5139
e-mail: Tapan_Bose@UQTR.UQuebec.ca

Japan Industrial Gases Association (JIGA)
3-2-6, Kasumigaseki
Tiyoda-ku
Tokyo, 100-0013 JAPAN
81-3-3580-0886
Web Site: www.jiga.gr.jp

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101 USA
617-770-3000
Web Site: www.nfpa.org

National Hydrogen Association
1800 M Street N.W., Suite 300
Washington, D.C. 20036-5802 USA
202-223-5547
Web Site: www.hydrogenus.com

Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15096-0001USA
724-776-3760
Web Site: www.sae.org

The High Pressure Gas Safety Institute of Japan
Sumitomo-shin-toranomon BLDG.
4-3-9, Toranomon, Minato-ku
Tokyo,   105-8447 JAPAN
81-3-3436-6103
Web Site: www.khk.or.jp

Selected Demonstrations and Prototypes

The following examples of hydrogen and fuel cell demonstrations and prototypes, all taken from press releases issued in a six month period from late 1999 to early 2000, illustrate how rapidly these technologies are developing and entering the market.

TRANSPORTATION

Toyota Chairman Hiroshi Okuda told reporters in Tokyo in July 1999 that his company will be the first to mass-produce a pollution-free fuel-cell electric car when it offers such a vehicle for the 2003 model year.

DaimlerChrysler will be the first auto maker to offer fuel cell vehicles for sale in Europe and abroad. 20 to 30 Citaro low-floor city buses will be available for sale to transit companies. Europe is the world's largest bus market, and manufactures more than 14,000 coaches and 10,000 city buses annually.

Ford Motor Company began operating North America's first gaseous and liquid hydrogen filling station at its research complex in Dearborn, Michigan in August 1999. Among the first to "fill up" at the $1.5 million facility will be the company's hydrogen fuel cell sedan, the P2000 HFC, as well as a hydrogen-fueled internal combustion engine vehicle based on the engine used in Ford's Contour, Mystique, and ZX models.

DaimlerChrysler and **Nippon Mitsubishi Oil Co.**, Japan's largest energy provider, entered into an agreement in October 1999 to jointly study fuel-cell powered vehicles and fuel infrastructure options for fuel cell vehicles. Japan has 29 public "Eco-Stations" that dispense natural gas, methanol and liquid petroleum gas as well as electricity to alternative fuel vehicles.

General Motors Corp. stopped production of the EV-1 and turned its attention to hybrid fuel-electric systems and fuel cells.

Munich Airport is the site of the world's first public liquid and gaseous hydrogen filling station. Since May 1999, CleanEnergy 7-series **BMW** shuttle vehicles have been refilling at the fueling robot, and have covered more than 10,000 kilometers. The NECAR 4, a zero-emission vehicle based on the **Mercedes** A-class electric cars, began shuttling flight crews, airport employees and other visitors for a three week trial beginning on January 31, 2000. The project is a joint venture involving 13 well-known firms including the BMW group, MAN AG, and FMG, as well as the Bavarian state government.

The California Fuel Cell Partnership was formed in April 1999 to push to commercialize fuel cell electric vehicles. Its members include auto manufacturers (**DaimlerChrysler, Ford, Honda, Volkswagen, and Nissan**); energy providers (**ARCO, Shell, and Texaco**); a fuel cell company (**Ballard Power Systems**); and the State of California (Air Resources Board and the California Energy Commission). DOE's office of Energy Efficiency and Renewable Energy is also involved in the Partnership, and works with state government partners to provide insight into identifying and resolving potential technical and infrastructure barriers for fuel cell-powered cars and buses, and to help secure needed resources. The Partnership has also added new associate partners who bring specific expertise to aid in fuel, vehicle, and bus demonstration activities. **Air Products and Chemicals, Inc.** of Allentown, Pennsylvania; **Linde AG**, headquartered in Germany; **Praxair** of Danbury, Connecticut, and Methanex, a methanol production and marketing firm. They will assist the energy partners with hydrogen fuel infrastructure needs, particularly at the Partnership's Sacramento-area facility. All are global industry leaders in the production, distribution and technology of industrial gases, and all have experience developing or providing hydrogen fuel delivery systems for vehicle manufacturers.

Additional associate partners include the Alameda-Contra Costa Transit District, which operates a fleet of 700 public transit buses in the San Francisco Bay Area, and SunLine Transit Agency, which operates a fleet of 50 alternative-fueled buses in the Palm Springs area of southern California. These transit agencies will serve as test sites for the first phase of the Partnership's bus demonstration program. As part of that effort, next year each agency will acquire two fuel cell-powered buses and include them in regular revenue service on scheduled routes throughout their service areas; up to twenty fuel cell-powered buses will be deployed by 2003.

DaimlerChrysler Fuel Cell Subsidiary and **Shell** successfully developed and tested a multi-fuel processor technology to turn gasoline into hydrogen for powering environmentally friendly fuel cells in February 2000. During an 18 month research cooperation, the two companies developed and tested the compact 50 kilowatt multi-fuel system. It performed under stationary and dynamic operating test conditions at the Xcellsis laboratories in Nabern, Germany. With continued development, such systems could enable fuel cell vehicles to use gasoline.

Shell and **DaimlerChrysler** are participating in the "Iceland Project," a consortium of companies and the Iceland government working to convert Iceland from a fossil-fuel based infrastructure to hydrogen fuel.

General Motors introduced the Opel Zafira fuel cell vehicle at the annual Geneva Motor Show in February 2000. The Zafira is a demonstration fuel cell vehicle based on GM's popular European passenger van that GM will use to test global fuel cell technology on the road this year. The Zafira's fuel cell stack -- the significant element of the fuel cell system that replaces a vehicle's conventional engine -- achieves full power nearly 12 times faster in freezing conditions than the same design achieved recently. The Zafira will pace the marathon at the Summer Olympics in Sydney, Australia.

STATIONARY

Ballard Generation Systems shipped its second 250-kilowatt fuel cell power generator for field testing in a heating plant in Berlin, Germany in April 2000.

Dana Corp., Texaco, Southern Company, and Salt River Project teamed up in November 1999 to demonstrate and evaluate proton exchange membrane fuel cells for both small and large-scale applications at the Houston Advanced Research Center.

Plug Power demonstrates the first home fuel cell powered electricity generator system in Latham, NY in December 1999.

NiSource and the **Institute of Gas Technology** will demonstrate several field unit systems in the Chicago area in 2000 that will provide electricity for heating, air conditioning, and hot water in residential and small commercial markets. The systems combine a fuel-processor and fuel cell stack, and are about the size of a home furnace. The fuel processor changes a fuel such as natural gas or propane into hydrogen, the hydrogen is fed into the fuel cell, and electricity is produced. The systems should be available to consumers by the end of the year 2000.

New Jersey Resources Corp. and **GE Fuel Cell Systems** join together to distribute and install the GE fuel cell system in homes and businesses throughout New Jersey. Twenty residential test units will be in place in the summer of 2000, and will be available to consumers in 2001. Commercial units are expected to be in place in 2002.

Northwest Power Systems of Bend, Oregon, announced two pre-commercial fuel cell systems, rated one kilowatt and three kilowatts, for on-site electric power generation on December 1, 1999 in New Orleans. The devices integrate a **De Nora Fuel Cell** with Northwest Power's fuel processor. The one kilowatt system, suitable for portable applications, will be field tested in the second half of 2000. Commercial sales will begin in 2003.

International Fuel Cells, Inc. and **ONSI Corp.'s** fleet of 200 PC25™ commercial fuel cell power plant systems accumulated more than three million hours of in-service operation in October 1999, and produced more than 444,000 megawatt-hours of electricity and billions of BTU's of usable thermal energy. The power plant systems are operating in 84 U.S. cities and in 11 countries in Europe, Asia, and North America. They generate power for hospitals, hotels, schools, military installations, waste water treatment plants, manufacturing plants and municipal facilities. Examples of some of the sites: the Conde Nast Building at 4 Time Square in New York City, February 2000; the Onendaga-Cortland-Madison Board of Cooperative Educational Services (OCM BOCES) computer center in Syracuse, NY; and the Liverpool High School Liverpool, England in February 2000.

GPU Inc. and **Ballard Power Systems** formed BGS in December 1996 and have been working since then to develop and ultimately commercialize a range of products utilizing fuel cells for use in homes and businesses. These products, ranging from a 250 kilowatt unit for commercial buildings to a 1-10 kilowatt unit for homes, will be delivered and tested in field trial programs during the next few years. A 250 kilowatt BGS fuel cell power plant is now operating at the Crane Naval Air Station in Indiana and others will be installed soon in Europe and Japan. Other partners, Alstom SA of France and Ebara of Japan, will provide BGS with manufacturing capabilities and access to the European and Japanese markets. BGS, with two Japanese partners, Tokyo Gas and Ebara Corporation, will develop a prototype one-kilowatt fuel cell system that will provide electric power, heat and hot water for Japanese homes. In North America, a collaboration with Coleman Powermate, Inc., a subsidiary of Sunbeam Corporation, will develop power products using fuel cells for portable and standby uses, such as during severe weather disruptions. Fifty prototype units will be produced and tested. Coleman subsequently plans to market the products to North American consumers through its network of retailers and distributors.

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