

## VI.7 Hydrogen Safety

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### *Subcontractors:*

*MRS Enterprises, Bethesda, Maryland*

*GTI, Des Plaines, Illinois*

*International Code Council, Country Club Hills, Illinois*

*Energetics, Inc., Columbia, Maryland*

### **Objectives**

- Draft a comprehensive safety plan to be completed in collaboration with industry. The plan will initiate the research necessary to fill safety information gaps and enable the formation of a Safety Review Panel, by 2004.
- Integrate safety procedures into all DOE project funding procurements. This will ensure that all projects that involve the production, handling, storage, and use of hydrogen incorporate project safety requirements by 2005.
- Publish a handbook of Best Management Practices for Safety. The Handbook will be a “living” document that will provide guidance for ensuring safety in future hydrogen endeavors by 2010.
- Build consumer confidence that hydrogen can be as safe as the fuels in widespread use today.

### **Technical Barriers**

This project addresses the following technical barriers from the Safety section of the Hydrogen, Fuel Cells and Infrastructure Technologies (HFCIT) Program Multi-Year Research, Development and Demonstration Plan:

- B. Access to Industry Proprietary Data
- E. Obtaining Industry Input and Consensus
- G. Lack of Understanding among Procurement Officials
- H. General Counsel Acceptance of Procurement Requirements
- I. Variation in Standard Practice of Safety Assessments for Components and Energy Systems
- K. Existing Data are Proprietary or Not Easily Accessible
- L. Expense of Data Collection and Maintenance
- M. Quality of Data

### **Approach**

- Assemble a review panel of hydrogen safety experts.
- Design and implement safety guidelines for all DOE hydrogen procurements.
- Review safety plans and procedures of all DOE hydrogen projects through site visits and other mechanisms.

- Facilitate and participate in industry efforts to develop safety codes and standards for hydrogen and fuel cell technologies.
- Support the compilation of critical data needed to ensure safety is maintained in all aspects of the future hydrogen economy.
- Support widespread information sharing/education/training on all the above.

### **Accomplishments**

- Officially formed the DOE Hydrogen Safety Review Panel (11 members plus two direct support staff), held two panel meetings, and provided a draft charter to DOE for review and adoption.
- Revised and updated Guidance for Safety Aspects of Proposed Hydrogen Projects, a resource and set of guidelines for DOE procurements and safety plan deliverables.
- Completed the first four DOE project safety review site visits to date (6/30/04) with three more scheduled in FY 2004; submitted first site visit evaluation to DOE.
- Incorporated a safety template for presentation and a one-page summary for panel review into the 2004 program review meeting.
- Designed and initiated hydrogen emergency response training program at the Hazardous Materials Management and Emergency Response (HAMMER) training facility.
- Conducted successful Hydrogen and Fuel Cells Summit VIII in Miami, Florida, focused on the sharing of safety, codes and standards information between government, industry and standards development organizations.
- Continued quarterly publication of the Summit newsletter, circulation of more than 1,000
- Published two modules of the “Regulators' Guide to Permitting Hydrogen Technologies” – one for fuel cell technologies and one for hydrogen vehicle refueling stations.

### **Future Directions**

- Conduct three more DOE project safety review site visits in FY 2004; anticipate conducting a total of 20-30 project reviews in FY 2005, including safety plan reviews for new project starts.
- Initiate development of a risk-based protocol for evaluating project safety on a consistent basis.
- Finalize design of training “burn props” at the HAMMER site and initiate construction; conduct at least two classes for audiences not requiring hands-on props for training, for example fire marshals; finalize HAMMER collaboration with external organizations, for example the Department of Transportation, National Association of State Fire Marshals, California Fuel Cell Partnership, State of Florida.
- Continue widespread sharing of data and information related to hydrogen safety through participation in industry meetings, publications, and compilation/documentation of safety best practices identified by the Hydrogen Safety Review Panel.

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### **Introduction**

Safe practices in the production, storage, distribution, and use of hydrogen are essential components of a hydrogen economy. A catastrophic failure in any hydrogen project could irreparably damage the entire transition strategy. The goal of this activity is to develop and implement the practices and procedures that will ensure safety in the

operation, handling, and use of hydrogen and hydrogen systems for all DOE-funded projects, and then to widely communicate these practices and procedures to the external communities that will play critical roles in the development of the future hydrogen infrastructure. Ultimately, our goal is to build public confidence that hydrogen can be as safe as the fuels in widespread use today. Without such confidence, the hydrogen economy cannot succeed.

## **Approach**

The safety program involves a large degree of external stakeholder input. Expertise is gathered from hydrogen manufacturers, the energy industry, the insurance industry, fire protection, academia, aerospace, and others to provide the widest range of perspectives on safety possible. Input is obtained through involvement in a variety of activities, as detailed under the Results section.

Communication is also a principal emphasis for maximizing impact of safety program activities. All of the data and information obtained (of a non-confidential nature), and recommendations developed through activities of the Hydrogen Safety Review Panel, for example, are to be made widely available through public presentations and an eventual release of a best practices database. Training, testing and verification activities to be undertaken at the HAMMER site will be documented and made available through various media to the greatest number of recipients possible, including those that cannot travel to the HAMMER site. Open sharing of information is the primary purpose of the annual Hydrogen and Fuel Cells Summit meeting and the quarterly summit newsletter. Achieving the stated objectives requires a high degree of communication in all safety program activities.

## **Results**

The safety program was able to achieve a number of accomplishments in different areas despite the funding limitations introduced by FY 2004 budget earmarks. A few planned activities were postponed until FY 2005 while others were reduced in scope, but the program has still yielded significant progress towards achieving its objectives. Results are reported by task area below.

### ***Hydrogen Safety Review Panel***

Establishment of a safety panel (Table 1) was called for in the HFCIT Multi-Year Program Plan (June 2003). The panel was officially formed at the start of FY 2004 with the following members/affiliations:

In addition, the safety panel is supported by Pacific Northwest National Laboratory and

**Table 1.** Hydrogen Safety Review Panel

Addison Bain, Chair	NASA (ret.)
Carol Bailey	Sentech
Harold Beeson	NASA White Sands
Bill Doerr	FM Global Research
Don Frikken	Becht Engineering
Jim Hansel	Air Products and Chemicals
Richard Kallman	City of Santa Fe Springs, CA
Harold Phillippi	ExxonMobil Research and Engineering
Jesse Schneider	DaimlerChrysler
Rody Stephenson	Jet Propulsion Laboratory (ret.)
Bob Zalosh	Worcester Polytechnic Institute

Energetics, Inc. The first two official meetings of the panel were held December 11-12, 2003, in Washington, DC; and June 17, 2004, in Miami, Florida in conjunction with Hydrogen and Fuel Cells Summit VIII. Since its formation the Panel has participated in several activities.

The expertise of the panel is to be first used for reviewing DOE-funded projects (Table 2) and safety plans utilizing a panel-developed protocol and providing DOE with recommendations for safety improvements. The panel, its services, and work products are assets to funded project teams who perform their own risk assessment and mitigation and are responsible for their own safe operating practices. In this manner, the panel helps bring safety best practices to bear on the hydrogen program as a whole. In FY 2004, the panel initiated the seven project safety review site visits detailed in the table below.

Four site visits have been completed. Only the one report from the first site visit to the Las Vegas Hydrogen Energy Station has been completed. The remaining three reports from site visits completed to date are still under preparation. The Las Vegas review did not identify any serious safety issues of immediate concern, but some discussion items related to dispenser hardware, fill-rates, and procedures, hydrogen piping, and storage tank

inspection plans were deemed worthy of additional consideration. The review was also particularly helpful in obtaining input from the project team on protocols for future site visits. A presentation on the four site visits to date was given at the Hydrogen and Fuel Cells Summit VIII, Miami, Florida, June 17, 2004 and can be accessed at [http://www.pnl.gov/fuelcells/docs/summits/summit8/summit8\\_agenda.pdf](http://www.pnl.gov/fuelcells/docs/summits/summit8/summit8_agenda.pdf).

**Table 2.** Hydrogen Project Safety Review Site Visits in FY 2004

Program Area	Project Title	Contractor
Technology Validation	*Las Vegas Hydrogen Energy Station	Air Products Las Vegas, NV
Production	*Algal Systems for Hydrogen Photoproduction	NREL Golden, CO
Production	*Renewable Electrolysis Integrated Systems Development and Testing	NREL Golden, CO
Fuel Cells	Innovative Low Cost/ High Efficiency Hybrid PEM Fuel Cell Power System	Nuvera Fuel Cells Cambridge, MA
Fuel Cells	Advanced MEAs for Enhanced Operating Conditions	3M St. Paul, MN
Storage	Hydride Development for Hydrogen Storage	Sandia National Laboratories Livermore, CA
Storage	*High Density Hydrogen Storage System Demonstration Using NaAlH <sub>4</sub> Based Complex Compound Hydrides	United Technologies Research Center E. Hartford, CT
* Project review site visits completed as of June 30, 2004		

The panel also undertook a review of *Guidance for Safety Aspects of Proposed Hydrogen Projects, July 2003 Revision 1*. This document, currently available on the DOE-HFCIT website, is used by DOE as a guideline for proposal and project teams to develop safety plans to meet solicitation and/or project deliverable requirements and is referenced in all hydrogen procurements. The revised draft,

submitted to DOE for review, provides a more comprehensive number of techniques that could be selected for identifying safety vulnerabilities, descriptive text, and relevant examples.

Eight panel members also served on review teams at the Annual Program Review in Philadelphia, Pennsylvania, May 24-27, 2004. A safety template was developed for principal investigators to use in their presentations. Project teams prepared one-page summaries to help the panel assess specific safety aspects/issues related to each project. It is anticipated that the summaries will assist the entire panel in planning FY 2005 activities, safety reviews, and site visits.

### ***Hydrogen Education/Training***

The Safety Program achieved a number of successful education and training milestones during the course of FY 2004.

#### *Hazardous Materials Management and Emergency Response (HAMMER) Training Center*

The HAMMER site is an existing DOE facility originally developed for training emergency responders on hazardous materials management, fire and spill safety, search and rescue, and other areas. A hydrogen training capability is being added to HAMMER, and a number of planning meetings involving DOE, HAMMER, various national laboratories, and others took place in FY 2004 in anticipation of project startup in FY 2005. Training to be offered will include not only various testing and verification activities but also a number of “props” that offer hands-on experience for audiences such as emergency responders or permitting officials who will be asked to approve future installations of these technologies. HAMMER will facilitate the integration of Federal players, primarily the U.S. Departments of Energy and Transportation, with numerous public and private sector organizations that have expressed interest. To date such organizations include the National Association of State Fire Marshals, the California Fuel Cell Partnership, and the State of Florida, along with various manufacturers of hydrogen equipment.

Training activities will focus on protecting the health and safety of workers, the public, and the

environment by reducing risks, preventing accidents, and ensuring effective emergency response to potential accidents. HAMMER helps to fill a critical need for the successful transition to the hydrogen economy by reassuring stakeholders (and the public) that the hydrogen economy of the future will be just as safe as the fossil fuel economy of today. Hydrogen safety training at HAMMER will begin in FY 2005.

Feedback on the planned props is being obtained from a broad array of industry personnel, including the safety panel, fire marshals, professional trainers, and others with relevant experience to ensure the props will optimally provide the kinds of training needed.

#### *Fuel Cell Summit Newsletter*

The quarterly Fuel Cell Summit newsletter reaches more than 1,000 readers in the building codes community, manufacturers, standards development organizations, and others interested in keeping abreast of safety, codes and standards development in the hydrogen and fuel cells arena. For many readers, the newsletter is the only source of information they receive on hydrogen and fuel cell technologies. Issues from FY 2004, as well as earlier years are accessible from the program website at <http://www.pnl.gov/fuelcells/newsletter/>.

#### *Hydrogen and Fuel Cells Summit VIII*

The annual Hydrogen and Fuel Cells Summit meeting on June 15-17, 2004, was regarded a great success based on the survey forms received following the event. This annual meeting typically brings together about 100 personnel involved in furthering codes and standards related to hydrogen and fuel cells, and focuses on mutual sharing of information and experiences. The open communication even among competing interests in the industry is unprecedented in many attendees' experiences. One aspect always noted by attendees is the unexpected participation of personnel from diverse backgrounds in focusing on the common goal of hydrogen and fuel cells implementation. Participation in the summit led the State of Florida to request a tour and involvement in the planned HAMMER training activities. Presentations, results and attendee lists from this and previous summit

meetings are available from the program website at [http://www.pnl.gov/fuelcells/summits/current\\_summit.stm](http://www.pnl.gov/fuelcells/summits/current_summit.stm).

#### *Regulators' Guide to Permitting Hydrogen Technologies*

In support of the hydrogen program codes and standards objectives, the "Regulators' Guide to Permitting Hydrogen Technologies" was developed through a collaborative effort involving the National Fire Protection Association, the International Code Council, Pacific Northwest National Laboratory, and the National Renewable Energy Laboratory. The guide is intended to provide an introduction to and relevant background on the subject technologies, to identify applicable codes and standards for permitting their installation, and to provide useful case study information. The guide is intended for use by permitting officials, manufacturers, and installers interested in pursuing implementation of related technologies. Module 1 of the Regulators' Guide is entitled Permitting Stationary Fuel Cell Installations and Module 2 is Permitting Hydrogen Motor Fuel Dispensing Facilities. All three of the Guide components can be downloaded from [http://www.pnl.gov/fuelcells/permit\\_guide.stm](http://www.pnl.gov/fuelcells/permit_guide.stm).

#### *Fire Safety Training Recommendations*

In support of the development of fire safety training materials for first responders and code safety enforcement personnel, a series of in-depth interviews with members of that community has resulted in a substantial number of recommendations regarding content, format, and distribution of these materials. MRS Enterprises, Inc., under subcontract to Pacific Northwest National Laboratory, has provided a summary of these recommendations. The current plan is to incorporate the eventual development of these materials into the comprehensive training and education activities scheduled for the HAMMER site.

#### *International Activities*

The U.S. experience with hydrogen has led to interactions with other countries wishing to learn from the nation's experience. Recently, China has requested assistance from the U.S. in preparation for the 2008 Summer Olympics, where they intend to

build and employ a small scale hydrogen infrastructure. This ties to China's larger plans to eventually develop a hydrogen economy in their country. In May 2004, a U.S. delegation traveled to China to participate in a one-day "Vision" workshop intended to comprise the first step in development of a Hydrogen Roadmap for China, similar to the Hydrogen Roadmap developed for the U.S. Energetics, Inc., responsible for producing the U.S. Hydrogen Roadmap, is being supported by the Hydrogen Safety Program to likewise produce a China Hydrogen Roadmap. More than 50 scientists, government officials, and business leaders met at the May meeting to discuss the challenges and opportunities associated with hydrogen energy development in China. The major conclusions from the meeting were:

- China can be a major international player in hydrogen energy technologies, and perhaps the world leader among developing nations. Effective international collaborations (bi-lateral and multi-lateral) will be one of the keys to China's success.
- Favorable and consistent national energy and environmental policies are needed, especially in the early stages of research, development and demonstrations, for progress to be made toward the development of the hydrogen economy in China.
- The Beijing Olympic Games in 2008 is an important opportunity to showcase hydrogen technologies in China, expand public awareness, strengthen hydrogen-related businesses, and conduct tests to identify ways to improve the costs and performance of hydrogen technologies.

A workshop proceedings report will be available in August 2004. A follow-on hydrogen energy roadmap workshop is scheduled for October 2004.

#### *Codes and Standards Support*

Collaboration and participation of multiple parties is the key to the development of codes and standards that are helpful to the greatest number of technologies and organizations. The greater the number of organizations and individuals involved (within reason), the more comprehensive, equitable and effective codes and standards that will be

ultimately developed. DOE supports participation of numerous organizations and individuals in the codes and standards development process. GTI, Inc. is one organization whose participation in codes and standards activities is supported through the hydrogen safety program. GTI has been involved in gaseous fuel pipeline safety issues for decades, and their perspective is invaluable in the deliberations of various standards development organizations. In FY 2004, the safety program supported GTI's participation in various meetings of the American Society of Mechanical Engineers, the Society of Automotive Engineers, the International Codes Council, the Canadian Standards Association, and the International Electrochemical Commission Technical Committee 197 on Hydrogen. Trip reports from these various meetings are available upon request.

#### **Conclusions**

The hydrogen safety program is addressing several of the technical barriers outlined in the multi-year program plan. Many of these involve information or data issues: either the lack of it, unreliable quality or consistency, or difficulty in accessing. Together with the other national laboratories working on producing or verifying hydrogen data (i.e., Sandia National Laboratories and the National Renewable Energy Laboratory) the means for addressing these issues are underway. DOE's self-examination of safety practices and procedures in its own projects will be a critical contribution to the future availability of related information. The education and training activities to be undertaken will ensure that this information gets out into the public domain where it is needed. The continuance of all of these efforts is crucial.

However, further work is also needed. The widespread distribution and use of hydrogen as a commercial energy carrier is still a relatively new endeavor, and many necessary systems have not yet been developed. Safety must become an initial design criterion rather than an afterthought. For example, the need for leak detection sensors diminishes as system designs evolve to make leaks less likely, such as when a fitting is eliminated. The development of inherently safe system designs is a superior approach to less robust designs that must

employ ancillary sensors and leak mitigation equipment after the fact to make them safe. Holistic system design strategies that reduce or remove safety liabilities should be pursued. Investigation of both generic design principles and those specific to individual systems whose designs remain somewhat immature, such as underground bulk hydrogen storage, are needed.

Finally, just as important as ensuring safe practices and procedures in all research and demonstration activities is the assurance to the general public (which includes code officials, fire marshals, etc, who will make future go/no go decisions regarding installation of these technologies) that hydrogen is no less safe than other fuels accepted and used every day. Much information remains to be prepared before hydrogen and hydrogen technologies can achieve the status of being "safe" in the public eye, however, particularly in consideration of the kinds of real world conditions that all technologies face in the hands of the general public. Modern society is accustomed to performing (or at least the possibility of performing) its own system maintenance and modification on personally-owned property. Conversely, many systems in widespread use today (e.g., vehicles, residential air conditioning equipment, etc.) frequently receive little or none of the maintenance recommended by the original manufacturer. How will the integrity of systems built to exacting safety standards and tolerances be assured ten years hence, once they are beyond the careful attention and control of a highly trained development workforce? Principles, techniques and practices for ensuring safety in the real world must be investigated now, before these systems are released into the public domain.

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