RISK ASSESSMENT FOR HYDROGEN CODES AND STANDARDS

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ABSTRACT

The development and promulgation of codes and standards are essential to establish a market-receptive environment for commercial, hydrogen-based products and systems. The focus of the U.S. Department of Energy (DOE) is to conduct the research and development (R&D) needed to strengthen the scientific basis for technical requirements incorporated in national and international standards, codes and regulations. In the U.S., the DOE and its industry partners have formed a Codes and Standards Tech Team (CSTT) to help guide the R&D. The CSTT has adopted an R&D Roadmap to achieve a substantial and verified database of the properties and behavior of hydrogen and the performance characteristics of emerging hydrogen technology applications sufficient to enable the development of effective codes and standards for these applications. However, to develop a more structured approach to the R&D described above, the CSTT conducted a workshop on Risk Assessment for Hydrogen Codes and Standards in March 2005. The purpose of the workshop was to attain a consensus among invited experts on the protocols and data needed to address the development of risk-informed standards, codes, and regulations for hydrogen used as an energy carrier by consumers. Participants at the workshop identified and assessed requirements, methodologies, and applicability of risk assessment (RA) tools to develop a framework to conduct RA activities to address, for example, hydrogen fuel distribution, delivery, on-site storage, and dispensing, and hydrogen vehicle servicing and parking. The CSTT was particularly interested in obtaining the advice of RA experts and representatives of standards and model code developing organizations and industry on how data generated by R&D can be turned into information that is suitable for hydrogen codes and standards development. The paper reports on the results of the workshop and the RA activities that the DOE's program on hydrogen safety, codes and standards will undertake. These RA activities will help structure a comprehensive R&D effort that the DOE and its industry partners are undertaking to obtain the data and conduct the analysis and testing needed to establish a scientific and technical basis for hydrogen standards, codes, and regulations.

1.0 INTRODUCTION

Hydrogen has an established history of industrial use as a chemical feedstock, but its use as an energy carrier on a large-scale commercial basis remains largely untested and undeveloped. The development and promulgation of codes and standards are essential to establish a market-receptive environment for commercial, hydrogen-based products and systems. The focus of the U.S. Department of Energy (DOE) is to conduct the research and development (R&D) needed to strengthen the scientific basis for technical requirements incorporated in national and international standards, codes and regulations.

In the U.S., the DOE and its industry partners have formed a Codes and Standards Tech Team (CSTT) to help guide the R&D. The CSTT has adopted an R&D Roadmap to achieve a substantial and verified database of the properties and behavior of hydrogen and the performance characteristics of emerging hydrogen technology applications sufficient to enable the development of effective codes and standards for these applications. Information from this database will be made available to appropriate standards and model code development organizations (SDOs), local authorities, and industry to enable the development of safe, performance-based technical codes and standards that will accommodate eventual changes in technology, thus minimizing the need to develop new codes and standards as technology evolves.

Along with comprehensive data on hydrogen behavior at the anticipated smaller scale of retail and consumer applications, additional R&D to quantify the hazard relative to this scale is necessary. Approaches to this R&D might include scenario analyses, risk assessments as well as experimentally generated data from production mock-ups to identify and analyze the potential hazards of these facilities. Instead of having to extrapolate hazard information and existing code requirements developed from or for larger industrial and commercial facilities, SDOs will be able to use data directly to write requirements suitable for smaller-scale applications.

The DOE has sponsored R&D on hydrogen behavior in response to needs expressed by key SDOs. However, to develop a more structured approach to the R&D described above, the CSTT conducted a workshop on Risk Assessment for Hydrogen Codes and Standards on March 10, 2005. The purpose of the workshop was to attain a consensus of invited experts[1] on the protocols and data needed to address the development of risk-informed standards, codes, and regulations for hydrogen used as an energy carrier by consumers. Participants at the workshop identified and assessed requirements, methodologies, and applicability of risk assessment (RA) tools to develop a framework to conduct RA activities to address, for example, hydrogen fuel distribution, delivery, on-site storage, and dispensing, and hydrogen vehicle servicing and parking. The CSTT was particularly interested in obtaining the advice of RA experts and representatives of SDOs and industry on how data generated by R&D can be turned into information that is suitable for hydrogen codes and standards development.

This paper reports on the results of the workshop and the RA activities that the DOE's program on hydrogen safety, codes and standards will undertake. These RA activities will help structure a comprehensive R&D effort that the DOE and its industry partners are undertaking to obtain the data and conduct the analysis and testing needed to establish a scientific and technical basis for hydrogen standards, codes, and regulations.

1.1 Purpose and Objectives

The purpose of the workshop was to help define whether and how risk assessment (RA) activities should be conducted to inform hydrogen codes and standards development. The objectives were to:

1. engage stakeholders to explore RA tools and discuss viability of RA work for hydrogen codes and standards,
2. obtain input from stakeholders on key RA activities that the DOE should undertake,
3. develop consensus on protocols and data needed to develop risk-informed standards, codes, and regulations,
4. define performance requirements that RA should meet to support the decision-making process, and
5. identify next steps and action items.

2.0 RISK AND RISK ASSESSMENT

2.1 Types of Risk Assessment

Risk is defined by the events that could occur, the resulting consequences, and the associated probabilities. As such, risk is a determined by the specific system configuration, operation, and environment. The level of effectiveness of mitigation measures also affects risk. Since all such variables

[1] Participants are listed in Appendix A

cannot be fully identified and neither their consequences nor probabilities of occurrence can be precisely quantified, only estimates of risk can be derived for a particular system.

Risk assessment links risk accounting and decision-making. Risk accounting spans a spectrum of techniques from qualitative, subjective expert panels to quantitative, probabilistic risk assessments (PRA), with requirements for data, analysis, time, and budget increasing from the former to the latter. That said, resource investments in PRA also return more quantitative and more objective results. Techniques such as Failure Mode Effects Analysis (FMEA) lie in between the two ends of the spectrum. Such techniques, up to and including PRA, can be classified generally as quantitative risk assessment (QRA). To the degree that parameters that drive risk analyses are assigned meaningful numbers and numerical estimates of risk are produced, such techniques fall under the category of Quantitative Risk Assessment (QRA). Depending on the nature of the decision that needs to be supported, this is either a necessary requirement or merely a nice formality. If a choice is being made between two options for which risk is the determining factor and one option is *prima facie* much more risky than the other, then a quantitative assessment is unnecessary. If the decision is inherently a quantitative one (e.g., setback distances for fuel storage) and relative risk assessment is not obvious, then a quantitative assessment may be necessary.

The "gold standard" for risk accounting is PRA and is typically applied in cases where decision-makers implement a quantitative risk-based performance standard. A PRA relies more on data and models than expert opinion and consists of three main elements: initiating events, accident progression, and consequence analysis. PRA is more commonly found in RA for specific designs and engineered systems than in codes and standards development. Without explicit regulatory drivers, the additional cost and time investment in PRA is typically justified by either (1) the magnitude of the potential consequence in terms of lost lives or dollars, or (2) the avoidance of features or designs that can be shown to provide little expected risk reduction for the associated expense of production or deployment. Any justification for PRA in codes and standards development would be made based upon a combination of these two factors.

On the other end of the risk accounting spectrum, expert panels can provide relatively fast, inexpensive, and holistic estimates of risk for a wide variety of decision-making processes. A key output of expert panels is a consensus among experts to support a particular estimate of risk as part of a decision-making process and the availability of such experts to support their assertions in public hearings or formal testimony.

Since the ultimate results of a successful code or standard are improved decisions by designers or regulators, a key consideration in selecting a risk accounting technique is confirming that the output of the risk accounting actually translates into better decisions. If QRA does not lead to better decision-making, it should not be done; i.e., first do no harm. As a first step, one should decide formally how the outputs of a QRA will be translated into the actual code or standard in question. This translation could be as specific and direct as a quantitative risk performance standard (e.g., fewer than N fatalities/year attributable to fueling incidents), or as broad as a demonstrable equivalence between the expected risks from hydrogen fueling and the present risks posed by gasoline or compressed natural gas fueling.

2.2 Risk Assessment and Decision-Making

The choice of a risk accounting technique must be driven by the requirements of the decision-making process that RA is intended to inform. These requirements, perhaps in order of relevance to the codes and standards decision-making process, include whether the decision concerns a particular component or system design, whether a quantitative estimate of risk that explicitly incorporates uncertainty in that estimate is needed, the degree to which the decision must be transparent and auditable, and the cost and time constraints of the decision-making process.

Several decision-making processes were identified and need to be kept distinct. Large companies employ Quantitative Risk Assessment (QRA) techniques as part of product design and engineering to help ensure a certain level of product reliability and safety. National policy decisions, for example, on investment priorities to improve homeland security, involve applications of RA techniques with broader perspectives and needs. Other decision-making processes in which RA techniques can be applied include regulatory processes, such as in the siting of nuclear reactors or in establishing requirements for self-certification of vehicle safety. Clearly, such applications of RA techniques are different in varying degrees in terms of purpose and scope from what might be expected for hydrogen codes and standards development.

The decision-making process of interest is the development and adoption of hydrogen standards and codes, especially the technical requirements incorporated in them to ensure a minimum level of safety. Code development organizations have traditionally relied on expert panels, who, in turn, often rely on historical assumptions and practices to set requirements. These organizations, however, are moving toward a more quantitative, data-driven process, such as FMEA, to set requirements appropriate to an acceptable level of risk and will consider the best data and analysis available at the time of the code development and revision process. To improve its code development work, the National Fire Protection Association (NFPA), represented by Carl Rivkin, Senior Chemical Engineer, identified as key research needs better data and understanding about:

- system risks, including long-term risks;
- weak points in systems and optimizing risk mitigation;
- long-term component failure;
- loss history of hydrogen or comparable systems;
- human error factor in accidents, especially in public interaction with hydrogen.

If possible, the NFPA would like to be able to identify the 10% of activities that create 90% of the risk and focus code development efforts these key accident initiating events.

The International Code Council (ICC), represented by Darren Myers, Manager of Contracts and Consulting, placed highest value on succinct statements concerning requirements, especially those that are vetted by a national consensus process, to inform its code development process. There is a "hierarchy of safety" envisioned by the ICC to protect:

- people
- the public
- property

In setting requirements for separation distances for on-site hydrogen storage, the ICC envisions risk in the following order or hierarchy:

- pressure relief device (PRD) failure
- localized failures (valves, o-rings, couplings, nozzles) and equipment (compressors, vaporizers)
- high-pressure releases
- fire, earthquake, flood

At the recent public hearing for the 2006 code cycle, the ICC adopted barrier wall requirements in the International Fire Code because they were unable to reconcile the available hydrogen behavior data with separation distances between bulk hydrogen storage containers and other uses.

2.3 Risk Assessment Requirements--Data

Both risk assessment and decision-making require data, especially if more quantitative risk accounting techniques are used to inform a decision-making process. The property loss insurance industry, represented by William Doerr, Research Director, Risk and Reliability, for FM Global, provided one example of the data requirements for risk informed decision-making, particularly in the case of land transportation losses due to fire and explosion. Historical property loss data are extensive but also limited in that these data are compiled mainly from large companies and many losses are unreported. Data are compiled for both causes and contributing factors, but the largest data category for both causes and contributing factors is "unknown." Other categories for causes of land transportation losses include electric and wiring failures, accidents during loading and unloading, and fires due to sparks and exposed flames. For contributing factors, other categories for losses include unsafe operation, flammable materials and electrical equipment, and arson and vandalism.

In considering RA for hydrogen codes and standards from the perspective of the property loss insurance industry, it is important to address the entire life cycle from manufacturing (production) to recycling of hydrogen-fueled products. Factors that address the adequacy of current practices to protect the existing petroleum or natural gas fuel infrastructure for land vehicles provide a baseline for data requirements to estimate risk associated with a new fuel infrastructure. Such data should address the adequacy of site location and design as well as equipment integrity and personnel training to deal with prevention, control, and early detection of fuel releases; prevention, control, and mitigation of ignitions; and protection, control, and mitigation of property losses.

In general, data requirements for RA include experimental data, such as hydrogen behavior under certain release conditions and materials compatibility to hydrogen exposure under defined conditions; historical data on accidents; and industry data on comparable systems and associated risks. Better experimental data are being obtained as laboratory and field experiments proceed in industry, universities, and national laboratories. Access to such data, particularly those compiled by industry, will require better collaboration among researchers and agreements to protect business-sensitive data. Comprehensive and sustained international collaboration is also needed to obtain the data most effectively and in time to better inform RA and the codes and standards decision-making process. Collaborative R&D and sharing data will help establish a foundation for harmonized technical requirements in international standards and global regulations. Hydrogen behavior data are needed to address all three components of a typical PRA: initiating events, accident progression, and consequence analysis.

Historical data on operations risk address the frequency of accidents and component failures at hydrogen fuel production, storage, distribution, and dispensing facilities. Such data are often proprietary and not readily available. The DOE, perhaps, could broker sharing of such data by creating a data collection format and protocol that would protect access to and confidentiality of such data. The DOE has served such a role in developing a national Alternative Fuels Data Center (http://www.eere.energy.gov/afdc) and is continuing this role as part of the Controlled Fleet and Infrastructure Learning Demonstration in which industry teams are installing and operating hydrogen fueling stations. For more information, on the demo, go to http://www.eere.energy.gov/hydrogenandfuelcells/tech_validation/fleet_demonstration.html.

Other data sources include the U.S. Fire Administration, National Fire Incident Reporting System (NFIRS) (http://www.nfirs.fema.gov) and NFPA, Fire Incident Data Organization (http://www.nfpa.org). The National Aerospace and Aeronautics Administration (NASA) would also have extensive data on hydrogen incidents, but the relevance of that data to commercial hydrogen facilities may be limited.

2.4 Risk Assessment Requirements—Risk Criteria

In addition to data, the other key requirement for RA are risk criteria, or "terms of reference," by which the significance of risk is assessed. In other words, risk criteria define and set the maximum tolerable level of risk that those involved in the decision-making process are willing to accept. This level of acceptance may be, for the most part, explicit in the case of product design and engineering, or implicit in the case of societal behavior. For hydrogen codes and standards, the decision-making process involves both but must ultimately be based on what level of risk is considered to be appropriate so that the requirements in the codes and standards reduce risk to such a level. Requirements should not be written to accommodate either a higher level of risk that stakeholders will not tolerate or be based on worst-case accident scenarios that will lead to unreasonably higher costs.

There are several ways to set the terms of reference. Many countries recognize a need to establish a risk standard. Andrei Tchouvelev, representing the Canadian Transportation Fuel Cell Alliance (CTFCA), described the terms suggested by a Canadian standard, CAN/CSA-IEC 300-3-9-97,which is based on an international standard, IEC 300-3-9-95:

- predicted frequency of mortality or morbidity to an individual (individual risk);
- frequency versus consequence plots (known as F-N curves where F stands for frequency and N the cumulative number of people suffering a specified level of harm or the cumulative cost of damage) for societal risk;
- statistically expected loss rate in terms of casualties, economic cost or environmental damage;
- distribution of the risk of a specified damage level, presented as a contour plot, displaying levels of equal damage.

For the codes and standards decision-making process, it will be difficult to achieve a consensus to set explicit terms of reference, such as those shown above, as there is no formal risk standard policy in the U.S. A good approach may be to set relative terms, such as the maximum level of risk that consumers implicitly accept today with the existing gasoline and compressed natural gas fueling infrastructure. The terms of reference could be an equivalent level of risk with that of the gasoline fuel infrastructure. As hydrogen fuel is a new technology, the terms of reference may have to be stricter (lower risk) than the existing fuel infrastructure because of public perceptions and attitudes toward new technologies in general and toward hydrogen in particular. A key activity for the DOE will be to work with stakeholders to obtain the data and conduct the analysis to make more explicit the maximum level of risk consumers are willing to tolerate with the existing fueling infrastructure.

2.5 Risk Assessment Requirements—Key Stakeholders

A major objective of the workshop was to obtain “buy-in” from key stakeholders on what level of QRA would best inform the hydrogen codes and standards development and guidance on what QRA activities would add the most value. Model code development organizations, represented by the ICC and NFPA, endorsed the value of QRA data in their decision-making processes. Both emphasized, however, that their processes would proceed according to schedules set by their code development cycles with or without such data. The QRA activities supported by DOE should address the information and data priorities identified by the ICC and NFPA described above. Such information and data need to be presented in a form in which their relevance to code requirements can be understood and appreciated by people who have the authority and responsibility to adopt and enforce these requirements. As hydrogen technologies mature, the need to conduct hazard analyses and QRAs should diminish as risk-informed requirements are incorporated into model codes.

Merchant gas companies, represented by Air Product and Chemicals and BOC Gases, endorsed the value of QRA activities. They remind us that hydrogen has been produced, distributed, and used in large quantities in the industrial sector for over a half-century. They stressed the need to focus any QRA efforts on “step-out” activities—those commercial and consumer-scale activities for which there is little or no industrial experience—such as dispensing nozzle and hose failures, nozzle misconnections, leaks from and failures of mechanical joints in dispensing systems, pressure relief device failures on on-board storage containers, vehicle collisions and vehicle fires at fueling stations, and accidents transporting and delivering hydrogen as the frequency and number of locations of delivery increase. On-site production of hydrogen, distributed generation combined with fueling (aka power parks), and home fueling should be included as step-out activities. For many of these step-out activities, information from existing petroleum and natural gas fueling operations may provide a baseline from which to assess hazards and risks of hydrogen fueling.

Energy companies, represented by BP, ChevronTexaco, ExxonMobil, and Shell, conduct PRA as part of corporate business and product engineering and design activities to help manage financial risk exposure. They endorsed QRA efforts for codes and standards development, but remind us of the significant differences in scope, purpose, and design between such efforts and those practiced by industry. That said, the first step would be to define the system(s) for which QRA is to be conducted for codes and standards purposes. Subsequent steps include identifying the spectrum of events to be assessed within the system(s) and assessing the hazards associated with these events. Data from existing and planned hydrogen vehicle and fueling demonstrations should be acquired in formats appropriate for the type of QRA activities to be supported.

Other industries, represented by the American Petroleum Institute, CTFCA, GE Global Research, the National Hydrogen Association, and the US Fuel Cell Council, in general endorsed the value of conducting QRA activities to inform the hydrogen codes and standards process. It was suggested, however, that a cost/benefit analysis be conducted to assess the value-added of a risk-informed codes and standards process compared to "business-as-usual" (BAU) where the judgment of expert panels and the use of data as and where available are the norms of practice. Requirements incorporated in codes and standards provide a minimum "safety template" that can be enforced through various processes by jurisdictions having authority, but what is gained by conducting QRA activities in conjunction with the codes and standards process? Would individuals or society as whole be safer and would hydrogen technologies gain wider commercial use in less time? Should security against terrorism be considered as part of RA activities and should environmental enhancement be included in balancing individual risk against societal values?

If the answer is "yes" to the last two questions above, the challenge is that any risk assessment effort will use resources that could also be spent in many other ways to also improve safety for individuals and society and enable hydrogen technologies to gain wider commercial use in less time. We must be able to assess quantified benefits compared to the cost of delivering those benefits. In other words, there are opportunity costs of spending resources, for example, on "high quality" data collection and analysis. Furthermore, if we are to obtain benefits from accepting such costs, we must also have a method to determine the relevance and appropriateness of the data and analysis for decision making relative to the specific risk being evaluated. Also, if these data have been collected by multiple organizations under varying conditions, we must document the conditions and take into account the effects of such variations on the risk assessment.

3.0 CONCLUSIONS

All stakeholders represented at the workshop endorsed the value of QRA activities to inform the hydrogen codes and standards development process, although conducting a benefit/cost analysis to get a better understanding of the value-added of such activities over a BAU scenario was recommended. Both qualitative and quantitative RA activities were deemed useful, but within the spectrum of RA accounting techniques described during the workshop, the gold standard, probabilistic risk assessment (PRA), was considered more appropriate for risk accounting as conducted by industry for product design and engineering than for code development organizations dealing with requirements for safe commercial-scale use of hydrogen. A code development and enforcement official representing the Kern County (CA) Fire Department stated that the level of detail typical of a FMEA would be appropriate for the codes and standards development process. Follow-up discussions and smaller meetings with specific stakeholders to better define their QRA needs and requirements were recommended.

The workshop identified a need for two types of QRA efforts: one at a high, or societal, level and one that addresses specific "step-out" activities in the commercial sector with which there is little or no experience in the industrial sector. Data and analysis needs and requirements must also be addressed for both types of QRA efforts. A high-level QRA should focus on defining the maximum tolerable risk that society has implicitly accepted with the gasoline fuel infrastructure. More explicit terms of reference, such as those based on individual risk of fatality or injury, F-N curves for societal risk, or likelihood of property damage may be useful for the private sector when assessing risk, but are not appropriate for the codes and standards development process.

At least for the initial QRA efforts, the consensus of the workshop was that the terms of reference should be based on parity or equivalence with the existing petroleum or compressed natural gas fuel infrastructure. Such parity, once established, will provide a baseline from which to assess whether requirements incorporated in hydrogen codes and standards provide a level of safety consistent with the terms of reference. Data on initiating events, accident progression, and consequences of failures for the gasoline fuel infrastructure must be obtained and analyzed. The life-cycle hazards of hydrogen fuel need to be compared against those for gasoline and compressed natural gas. For example, the hazards and risks of on-site, bulk storage of hydrogen need to be compared to those for gasoline and compressed natural gas.

It was emphasized during the workshop that a QRA is only as good as the data and analytical techniques upon which is it based. A dedicated and sustained effort to access the needed data will be required. The NFPA recently established setback distances for hydrogen storage based on expert judgment that hydrogen is no more hazardous than compressed natural gas. A similar judgment of equivalence was made for liquid hydrogen and liquid natural gas, although in this case hydrogen may be unfairly disadvantaged by this determination. The technical and scientific bases for these determinations need to be better established by both experimentation and analysis.

The participants created three working groups to conduct the immediate next steps needed to further progress made during the workshop. Working Group 1 will address issues raised during the workshop concerning QRA at a high, or societal, level that also apply to RA in general. These issues include the terms of reference, or maximum tolerable level of risk based on parity or better with the existing gasoline fuel infrastructure; definition of the system(s) and identification of the "step-out" activities for which QRA is to be conducted; and a benefit/cost analysis of the development of risk-informed hydrogen codes and standards versus a business as usual baseline. The initial members of WG1 are GE Global Research, CTFCA, National Renewable Energy Laboratory, and Sandia National Laboratories.

Working group 2 will take the next steps on data issues by preparing a roadmap for data requirements and access. The roadmap will identify the data needed, where such data may be available and how that data may be accessed, and the R&D required to obtain data that are unavailable. The initial members of WG2 are Acutech, Air Products and Chemicals, BP, and Shell Global Solutions.

Working Group 3 will work with model code and standards development organizations to facilitate the use of QRA data and analysis in the decision-making processes of these organizations. The Working Group will also refine QRA requirements so that the level of detail and format of QRA data and analysis are most relevant and effective in their decision-making processes. The initial members of WG3 are Air Products and Chemicals, ICC, NFPA, and the US Fuel Cell Council.

Although the workshop included representatives of industry in the United Kingdom and Canada, the perspective of discussion was primarily that of the United States. Risk assessment for hydrogen codes and standards also requires an international perspective, and the activities described above under each Working Group would benefit greatly if expert from countries other than those represented at the workshop could be included. At the International Conference for Hydrogen Safety, the author and co-authors will seek experts from other countries who might be interested in collaborating with any of the Working Groups in particular or on risk assessment in general.

4.0 ACKNOWLEDGEMENTS

The DOE, on behalf of the CSTT, and the authors of this paper acknowledge the contributions of all of the participants for the success of the workshop. The willingness of the presenters and participants to share knowledge and discuss issues provided much insight on the activities that the DOE should consider supporting to facilitate the development of risk-informed hydrogen codes and standards. The presentations discussed in the paper are available at www.eere.energy.gov/hydrogenandfuelcells.

5.0 APPENDICES

5.1 List of Participants

Organization	Representative
Acutech	David Moore
Air Products and Chemicals	Tom Joseph
American Petroleum Institute	Bill Erny
BP	Steve Hall
BOC Gases	Bob Boyd
Canadian Transportation Fuel Cell Alliance	Andrei Tchouvelev
ChevronTexaco	Wilbert Lee
Daimler-Chrysler	Jesse Schneider
U.S. Department of Energy	Pat Davis
U.S. Department of Transportation/NHTSA	Larry Blincoe
U.S. Department of Transportation/Volpe	Neil Meltzer
ExxonMobil	Dave Owen
GE Global Research/NHA	Susan Townsend
International Code Council	Darren Myers
Kern County Fire Department	Kevin Scott
National Fire Protection Association	Carl Rivkin
National Renewable Energy Laboratory	Jim Ohi
Sandia National Laboratories-CA	Jay Keller, Chris Moen
Sandia National Laboratories-NM	Roger Cox
Shell Global Solutions	Les Shirvill
US Fuel Cell Council	Robert Wichert
Washington Safety Management Solutions	Mukesh Gupta