COLLABORATIVE ACTIVITIES ON HYDROGEN SAFETY UNDER THE INTERNATIONAL ENERGY AGENCY'S HYDROGEN IMPLEMENTING AGREEMENT

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Abstract

In October 2004, the International Energy Agency Hydrogen Implementing Agreement (www.ieahia.org) approved the initiation of a collaborative task on hydrogen safety. During the past twelve months a work plan has been established and several member countries have committed to participate. Because of the nature of the International Energy Agency, which is an international agreement between governments, it is hoped that such collaboration will complement other cooperative efforts to help build the technology base around which codes and standards can be developed. In this way the new task on hydrogen safety will further the IEA Hydrogen Agreement in fulfilling its mission to accelerate the commercial introduction of hydrogen energy. This paper describes the specific scope and work plan for the collaboration that has been developed to date.

1.0 Introduction

The lack of operating experience with hydrogen energy systems in consumer environments has been recognized as a significant barrier to the widespread adoption of these systems and the development of the required infrastructure. During recent years, a significant international effort has been initiated for the development of necessary codes and standards required for the introduction of these new systems. Such codes and standards are usually developed through operating experience in actual use that is accumulated over time. Without such long term experience, there is a natural tendency for such codes and standards to be unnecessarily restrictive to ensure that an acceptable level of safety is maintained. One possible effect is to hinder the introduction of hydrogen systems and thus the operating experience upon which future infrastructure is developed. Likewise, this lack of operating data impacts other areas such as insurance cost and availability and public acceptance.

The overall goal of the new IEA task on hydrogen safety is to develop data and other information that will facilitate the accelerated adoption of hydrogen systems. A well coordinated and executed task on hydrogen safety will directly support the accomplishment of the Hydrogen Implementing Agreement's stated mission:

> *"…to accelerate hydrogen implementation and widespread utilization."*

Hydrogen has been commonly used in a number of applications for the last one hundred years. Much experience has been gained for its production and use as an industrial chemical and in space programs, where it has become the fuel of choice because of its high energy-to-weight ratio. An understanding of hydrogen's physical properties is well established, and many experimental efforts have attempted to fully characterize the risks and hazards related to hydrogen. The actual risks and hazards can only be determined within the context of real systems and real operating experience. Previous experience with hydrogen has not been with systems that will interface with consumers, but in controlled environments with trained personnel.

Because there is neither a large amount of operating experience nor a well-developed infrastructure for hydrogen energy systems, many of the evolving codes, standards or local regulations have the potential to become unnecessarily restrictive or burdensome to the would-be early adopters of the these new technologies and systems. As more experience and familiarity is gained with these new systems, many of the early restrictions may be eased and others may be strengthened. Real operating experience must include experience with the actual risks and hazards of new equipment and systems. This means a more detailed understanding of what safety related events, or accidents, might occur, and what range of impacts are to be expected.

2.0 Description of the Collaborative Program

The specific objectives of the hydrogen safety task are to:

- develop testing methodologies around which collaborative testing programs can be conducted;
- collect information on the effects of component or system failures of hydrogen systems; and
- use the results obtained to develop targeted information packages for selected hydrogen energy stakeholder groups.

Three types of activities will be conducted under this subtask: 1)Risk Management, 2) Field Testing, and 3) Information Dissemination. They are described below.

2.1 Risk Management Activities

Acceptability of new systems is traditionally measured against regulations, industry and company practices and the judgment of design and maintenance engineers. However, contemporary practice also incorporates systematic methods to balance risk measurement and risk criteria with costs. Management decisions are increasingly relying on Quantitative Risk Assessment (QRA) for managing the attainment of acceptable levels of safety, reliability and environmental protection in the most effective manner. QRA is being applied more frequently to individual projects and may be requested by regulators to assist in making acceptance and permitting decisions. It is a quantitative analysis methodology that can effectively fill in for the lack of operating experience for hydrogen systems in the pubic rather than industrial domain.

2.1.1 Survey existing QRA methodologies for relevant case studies

Participants will provide information on the methodologies for quantitative risk assessment of relevant case studies conducted in their countries. This information will be analyzed from the methodology point of view and tabulated to present the full variety of existing methodologies in relation to risk assessment of both complete systems and major components. This task will provide a thorough understanding of the composite scope of interest and capability of the participating international community in risk assessment and permit the individual participants to assess respective approaches. It will also serve as a reference in the event international projects require QRA.

2.1.2 Comparative quantitative risk assessment of hydrogen energy stations for transportation and power applications with existing systems using conventional fuels

It is appropriate that the reference for new hydrogen systems, like refueling stations or back-up power systems, be similar to facilities for related fuels like natural gas that have an established safety record. This is a familiar reference point for the public, regulators and insurers who have a vested interest in safety. Acceptance of hydrogen systems will be more likely if the safety of hydrogen installations can be compared favorably or at par with an already familiar fuel technology. The participants will also pool data on such information as failure rates and other QRA input data will help generate a database for international reference. The participants will provide detailed technical information on their findings from comparative risk assessments of relevant case studies.

2.1.3 Probabilistic risk and consequence analysis enhancement

Risk associated with unwanted hazardous events is a combination of two factors: the likelihood of the event and the seriousness of the event. There is a large accumulated body of knowledge on both the likelihood and severity of unwanted (accidental) events in conventional fuels such as gasoline, propane and natural gas (methane). The corresponding analyses for hydrogen have been highly dependent on the information and procedures for the latter conventional fuels. However, it is becoming increasingly apparent that dependency on data and models and modeling techniques derived from the conventional fuels can generate highly divergent evaluations of the behavior of hydrogen upon release and the consequences.

This effort will be closely related to a testing program aimed at providing data on component and system failure rates. A lack of experience with hydrogen systems in consumer environments creates a corresponding lack of credible failure rate data for quantitative risk assessment. Both probability and consequence analyses as well as failure rate data for these systems use approaches that often lead to very conservative risk estimates. However, they also show a strong sensitivity to those modeling parameters and boundary conditions used when based on well-established conventional approaches. This emphasizes the need to base quantitative risk analyses for standardized hydrogen systems and consumer retail facilities on hydrogen-specific data and modeling techniques. This includes the real failure rate of key components installed in such systems with respect to their size and operating conditions as well as on scientifically and experimentally based data and methodologies for predicting consequences of failures of key components.

Participants in this activity will identify specific interests and concerns of hydrogen industries in their countries as they relate to the testing conducted under the testing program. Based on these interests and concerns, we will conduct two parallel sub-activities:

2.1.3.1 Hazard identification and analysis and accident progress analysis

Hazard identification and analyses will be carried out using such tools as Hazard and Operability Studies, Failure Modes and Effects Analysis or other hazard identification tools as appropriate to the application. A composite failure mode compilation will also be prepared to assist in gathering failure rate data for hydrogen applications from this program from the literature and from the IEA Annex program. It is expected that this effort will also provide direction for the experimental program by identifying the nature of the hazards that require testing to generate data for quantitative assessment.

Accident progression analysis will serve as the operational framework for testing programs as well as for numerical modeling activities. It integrates the hazard analysis and builds the subsequent accident progression scenarios into fault and event trees. Data requirements to quantify these fault and event trees will guide the experimental programs. These risk analysis structures serve as the vehicle to accept the results of analyses and experimental modeling and relate them to the end-user requirements. This sub-activity will begin by using industry standard failure rates and progressively introduce hydrogen-specific project data as they become available to further refine the risk assessments.

2.1.3.2 Modeling component failures

Advanced modeling tools such as Computational Fluid Dynamics (CFD) will be used to:

- better understand the properties of hydrogen gas, in particular its dispersion and deflagration-to-detonation transition during various types of intended and unintended releases in enclosed, semi-enclosed and open air environments;

- assist ongoing codes and standards development efforts for hydrogen systems including establishment of ventilation requirements, clearance distances and hazardous locations; and

- improve consequence analyses of identified failure scenarios of hydrogen components to be used for quantitative risk assessment.

1.2 Testing program to evaluate the effects of equipment or system failures under a range of real life scenarios, environments and mitigation measures

For almost all risk analysis methodologies reference data is used for validating modeling and calculations of risk probabilities and/or consequences. With hydrogen being relatively new in large-scale use the question remains whether there exists sufficient validation data worldwide to perform calculations with the methodologies highlighted in risk management activities. These methodologies could point out the lack of data on hydrogen safety issues which makes it difficult to draw conclusions related to regulations (e.g. considering safety distances). Besides that, new applications and equipment have been suggested for hydrogen operating under more extreme conditions than applications and equipment used for conventional fuels. The safety features for these new applications and equipment should be tested and analyzed. This will also lead to the identification of new accident scenarios addressed under the risk management effort.

The testing program will focus on both testing and experimental data, i.e., testing data as collected by checking the performance of applications and equipment and experimental data as collected by experiments with hydrogen release, ignition, fire, explosions and preventive and protective measures. In other words, testing data is more equipment specific, whereas experimental data is more hydrogen specific. Experimental data in particular will give new insight in controlling the size of hazardous areas. Reducing the size of the hazardous area will result in less stringent mitigating measures.

Therefore, the following approaches will be taken under this collaboration:

1.2.1 Survey on existing testing and experimental data

A survey will be carried out to collect testing and experimental data as much as possible. The data will be related to the specific application and/or equipment, use, testing conditions, testing methodologies, instrumentation, and so on.

1.2.2 Survey on ongoing or planned test projects

A survey will be carried out to give an overview of ongoing or planned testing and experimental programs and projects. This will also include an overview of testing laboratories and facilities existing worldwide.

1.2.3 Analyzing existing data in relation to risk management

In this activity the results of the risk management efforts will be linked to the testing program. Lack of data arising from analyzing methodologies in the risk management activity can be compared to the existing data. If data is not available this could give rise to new recommendations on testing and experimental programs, if yet not already covered by ongoing or planned testing projects.

Other activities may be undertaken based on the specific experience and interest of the Participants.

1.3 Development of Targeted Information Packages for Stakeholder Groups

The development of a homogenous worldwide infrastructure will be necessary before hydrogen energy can achieve widespread utilization and public acceptance. Safety concerns caused by the lack of real operating experience (and the cost of their mitigation) are major inhibitors to the accelerated development of such infrastructure. As information is collected during the testing program, a beneficial impact can only be achieved if it is conveyed to those stakeholders who will participate in the development of the new infrastructure.

The goal of the information dissemination activity will be to use the results obtained in the testing and evaluation program to develop targeted information packages for stakeholder groups (permitting officials, insurance providers, system developers, and early adopters of these new products and systems). This activity is more advanced in some countries compared to others that could benefit from the experiences gained in the infrastructure development process.

1.3.1 International requirements for siting hydrogen energy technologies

The U.S. recently published some permitting guides, and the U.S. and Canada have created a Hydrogen Sourcebook. PATH has extended their matrix to include the U.S., Canada and Japan. The UK is beginning to address hydrogen as well, trying to understand its properties and determine a process for permitting. Australia is also beginning to address the hydrogen question nationally. One sub-activity would be to compile the existing procedures and requirements for the IEA countries, identifying gaps (for example, if certain countries do not have a process for siting hydrogen energy systems). A second phase would then draw upon the available information to fill the gaps. The intent is not to harmonize such requirements, because regions throughout the world need to adopt the technical data into their own code (or regulatory) structure. The intent is to make information about what is being done successfully available to all IEA countries to accelerate the national adoption of codes and regulations.

1.3.2 Development of an Intelligent Virtual Hydrogen Fueling Station

In Canada, a joint Stuart Energy/Tisec collaboration has been initiated to establish a virtual hydrogen fueling station that would define setbacks for the components of a fueling station and other design constraints. This project is being accomplished in collaboration with the California Fuel Cell Partnership’s Codes & Standards Working Group to share information for a similar project in California.

1.3.3 Development of comprehensive information documents

One of the mandates of the Canadian Transportation and Fuel Cell Alliance is to ensure that there are no barriers in the areas of codes and standards and in training and certification of personnel to the development of demonstrations to accelerate the widespread use of hydrogen energy. In addition to their work to facilitate the adoption of reasonable codes and standards, the Alliance has a mandate to produce comprehensive materials documenting the work to develop codes and standards, reducing and organizing this information for distribution to the targeted stakeholder community including advisory bodies, regulatory officials, project developers and the general public. This work could easily be adapted for international collaboration and be the basis for a Canadian contribution to an IEA Hydrogen Safety Task.

More Information

More information about the IEA and this task may be found by contacting the operating agent, William Hoagland at william@hoagland.us , or from the following web sites:

www.iea.org

www.ieahia.org

www.ieah2safety.com

REFERENCES

All references may be obtained at www.ieah2safety.com.

1. Task 19, Hydrogen Safety – Work Plan, April 17, 2005.

2. Proceedings, Experts meeting, Paris, France, March 7-8, 2005

3. Task Annex, Hydrogen Safety, February 21, 2005.