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The IEA Hydrogen Implementing Agreement's Collaboration on Hydrogen Safety

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1 Introduction

In October 2004, the International Energy Agency Hydrogen Implementing Agreement (www.ieahia.org) initiated a task to collaborate on hydrogen safety. This Task 19 on hydrogen safety will be completed in October 2010, and a new proposed three-year task is under development. This task was intended to 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 goal of the IEA Hydrogen Implementing Agreement to accelerate the commercial introduction of hydrogen energy. This paper describes the task's specific scope and work plan, its results to date, and what future work is anticipated.

Hydrogen has been commonly used in a number of applications for the last one hundred years, and much experience has been gained from 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, but actual risks and hazards can only be determined within the context of real systems and operating experience. The existing lack of operating experience with hydrogen energy systems has been recognized as a significant barrier to their widespread adoption, and in recent years, several international efforts have been initiated to develop codes and standards to facilitate their introduction. Such codes and standards are usually developed through operating experience accumulated over time, but without long term experience, there is a natural tendency for such codes and standards to be unnecessarily restrictive.

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 task on hydrogen safety directly supports the accomplishment of the Hydrogen Implementing Agreement's stated mission:

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

2 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.

During the first three years, the collaboration completed several products:

2.1 Risk Assessment Methodologies Survey

The Risk Assessment Methodologies Survey has been completed during the first three years of collaboration and is being updated to include additional information on:

1. Ignition probabilities;
2. Risk criteria; and
3. Consequence tools

2.2 Review and Analysis of Risk Assessment Studies

This report has been completed and has been posted on the Task 19 web site.

- **Knowledge Gaps White Paper**

  This report identified gaps in knowledge that added uncertainty to the risk analysis methodologies. This document has been posted on the Task 19 web site.

3 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.

4 Survey Existing QRA Methodologies for Relevant Case Studies

Participants provided information on the methodologies for quantitative risk assessment of relevant case studies conducted in their countries. This information was analyzed to present the full variety of existing methodologies in relation to risk assessment of both complete systems and major components. The goal of this activity is to provide a thorough understanding of the composite scope of interest and capability of the international community in risk assessment and permit the individual participants to assess respective approaches. It also serves as a reference for international projects that require QRA.

5 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 also pooled data on such information as failure rates and other QRA input data will help generate a database for international reference.

6 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 is 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.

Based on these interests and concerns, we conduct two parallel sub-activities:

- Hazard identification and analysis and accident progress analysis
- Modeling of component failures

7 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.

The main effort under the testing task was to create a Hydrogen Testing and Experimental Database (HyTEX) and populate it with all available data. This database will include other existing databases either by linking or direct inclusion. This database has been launched and is currently undergoing beta testing. As such it is only available to participants of Task 19.

Another activity of the Experimental and Testing subtask is that 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.

8 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.

9 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