PURPOSE

The purpose of Hydrogen Safety Task 31 is to develop and conduct effective risk management techniques, testing methodologies, test data, and targeted information products that will facilitate the accelerated adoption of hydrogen systems. The specific objectives of this task are:

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

STATUS OF THE TECHNOLOGY

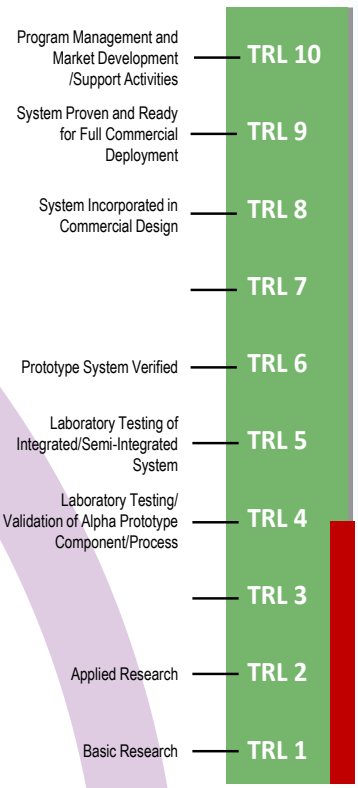
The lack of operating experience with hydrogen energy systems in consumer environments continues to be a significant barrier to the widespread adoption of these systems and the development of the required infrastructure. During recent years, a significant international effort has been initiated for the development of necessary codes and standards required for the introduction of these new systems. However, 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, which impacts other areas such as insurance and public acceptance.

TECHNOLOGY READINESS LEVELS

Physical phenomena and modeling –This task is at technology readiness level 4.

Hydrogen Storage Systems and Materials - Laboratory Testing/Validation of Alpha Prototype Component/Process. Design, development, and lab testing of technological components have beem performed. Results have provided evidence that applicable component/process performance targets may be attainable based on projected or modeled systems.

Early Markets: Risk Identification and Hazards - Laboratory Testing of Integrated/Semi-Integrated System. Component and/or process validation in relevant environment (Beta prototype component level).



FRAMEWORK SUMMARY

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

TASK 31

HYDROGEN SAFETY

William Hoagland

Element One, Inc.

7253 Siena Way, Boulder, Colorado 80301, USA
whoagland@elem1.com

+1 303 530-1140

Operating Agent for Canada and the United States

VITAL STATISTICS

Term

Phase 1: 2010-2013

Members

Canada (Through 3-31-2013)
France
Germany
Greece
Italy
Japan
Norway
Switzerland
The Netherlands
United Kingdom
United States

2012 Expert Participants

2011 Expert Participants (31)

Canada
- Andrei V. Tchouvelev
- Aaron Hoskin
- Pierre Bénard

EC
- Daniele Baraldi

France
- Gilles Bernard-Michel
- Sidonie Ruban

Germany
- Thomas Jordan

Greece
- Alexandros Venetsanos

Italy
- Alessia Marangon
- Marco Carcassi

Japan
- Kenji SATO
- Sam Miyashita

Norway
- Dag Bjerketvedt
- Olav Roald Hansen
- Prankul Middha

The Netherlands
- J.M. (Koos) Ham
- Nico Versloot

UK
- Deborah Willoughby
- Philip Hooker
- Stuart Hawksworth
- Vladimir Molkov

USA
- Bill Pitts
- William Buttner
- Chad Blake
- Daniel Dedrick
- Jiann Yang
- Jay Keller
- John Khalil
- Jeffrey Lynn Lachance
- Carl Rivkin
- Steven C. Weiner

increasingly relying on Quantitative Risk Assessment (QRA) to achieve 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. This task is a follow-on task to Task 19 (2004-2010) and was approved in 2010 for a period of three years. It is being accomplished within four subtasks:

SUBTASK A - PHYSICAL EFFECTS KNOWLEDGE GAPS

This subtask will address knowledge gaps on the physical and chemical properties of hydrogen as a gas or a liquid in support of the work performed in the other subtasks and to increase the knowledge base on hydrogen properties relevant to safety issues. The task will tackle issues pertaining to sources, release phenomena, dispersion processes, ignition, and combustion modes. Experimental, theoretical, and numerical analyses are covered by this task.

SUBTASK B – HYDROGEN STORAGE SYSTEMS AND MATERIALS

During the period of November 2010 through October 2013, Subtask B plans to focus on the following technical areas:

- Safety, reactivity, and risk mitigation of hydrogen storage in different forms
- Safety and risk mitigation measures of hydrogen storage systems and system interfaces for mobile and stationary applications
- On-board vehicular storage systems materials compatibility issues
- Enabling technologies for fire suppression systems and fire suppression agents compatible with hydride storage material
- Safety categorization framework for hydrogen storage materials and associated life cycle impact assessment (LCIA)

SUBTASK C - EARLY MARKETS: RISK IDENTIFICATION AND HAZARD ANALYSIS

Commercialization of new hydrogen technologies for mobility, stationary, and materials handling applications will result in potential significant involvement of consumers. This dictates to adjust traditional approaches to risk characterization and hazard analysis of industrial hydrogen focused mostly on operator / worker safety in a new reality – widely exposed members of the public. Safety assessment methods, data, and use of prevention and mitigation features need to be tailored to address specifics of early markets which include lack of data and understanding of specific phenomena. Improvement in the data, models, and risk assessment methods are needed in order to generate defensible RCS requirements. This new reality underlines the need to establish systematic data collection from new hydrogen-based operating facilities (i.e. hydrogen forklift materials handling facilities, car and bus fleets, stationary power units, etc.), specifically failure / leak frequency data. Since new technologies are penetrating densely populated urban environment, special attention should be paid to risk mitigation technologies and methods such as sensors, barriers / walls and safety distances. These findings and methods are being analyzed and communicated to relevant stakeholders within international codes & standards development activities to ensure those requirements are risk-informed and evidence-based.

SUBTASK D - KNOWLEDGE ANALYSIS, DISSEMINATION AND USE

2011 Meetings:
April 16-18, 2012, Paris, France

October 4-5 2012,
Bethesda, Maryland, USA

Safety knowledge tools can take many forms and serve to help disseminate the wealth of information that already exists on the safe use and handling of hydrogen and to remove barriers to the successful commercialization of hydrogen and fuel cell technologies. This subtask will enhance databases and websites that have been integral work products and accomplishments of Task 19. New tools and collaborations will be developed to serve worldwide interest in expanded applications of hydrogen and hydrogen systems. Subtask D supports the work product development in the other subtasks to ensure that knowledge dissemination for broad use becomes an integral goal of Task 31 as a whole. Subtask D work scope includes the following collaborations:

D.1 Hydrogen incident reporting, analysis and lessons learned

D.2 Hydrogen Safety Best Practices

D.3 Hydrogen Safety Bibliographic Database

D.4 HyTEX Database

D.5 Training materials for regulators and public safety officials

D.6 Risk Communications

ACTIVITIES AND RESULTS IN 2012

PROGRESS AND ACCOMPLISHMENTS

The key accomplishment of the hydrogen safety task is in the value of sharing research results and the insights gained insights during the technical experts meetings. This collaborative activity is a great aid to harmonising research results and to identify gaps in the current R&D programs. This provides for a unifying voice to provide consistent, technically based input to the development of risk-informed regulations, codes and standard development.

Task Experts Meetings – To facilitate technical information exchange, two experts meetings were conducted during 2012. This first meeting was conducted at the offices of Air Liquide in Paris, France, April 16-18, and the second was conducted in Bethesda, Maryland, October 4-5.

End of Task Stakeholder Workshops – During the consideration of the most effective manner of dissemination the results of Task 19, Hydrogen Safety, the conduct of workshops or seminars was proposed to convey the results of the task and to begin a dialogue with stakeholders concerning the issues of safety while there are not sufficient regulations, codes, and standards to guide the design and approval of such systems. The conduct of HIA workshops was first considered after the IEA HIA became a co-organizer of the Third International Conference on Hydrogen Safety in September 2008.

Two workshops, one in Europe and one in North America, were planned. Although the workshops were originally planned to be held in 2011, they were delayed pending sufficient sponsorship. The North American Workshop was successfully conducted in October 2012 in Bethesda, Maryland, USA. The second workshop, to be held in Europe, has been delayed until 2014. The planned size of the workshops is 50-75 persons, and the invitation list for these workshops is intended to ensure that the workshops have the right

mix of stakeholders from among permitting authorities, codes and standards developers, early adopters, etc.

White Papers – The hydrogen safety collaboration intends to develop a series of white papers regarding subjects where the collaboration has resulted in a consensus on a particularly technical or outreach topic. During 2012, Task members, led by Dr. Steven Weiner of PNNL (USA) developed a white paper entitled, "Advancing the Hydrogen Safety Knowledge Base. This white paper is also the subject of a paper presented at the Fifth International Conference on Hydrogen Safety to be held in Brussels in September 2013.

MILESTONES AND STATUS

- Spring 2012 Task 31 Experts Meeting – Complete
- Fall 2012 Task 31 Experts Meeting – Complete
- Fall 2012 North American End of Task Workshop – Complete
- Spring 2011 European End of Task Workshops – Delayed to 2014

OUTREACH AND COMMUNICATION

Strategy and Activities

Most of the world's experts on hydrogen safety are participating in this task, and they are active in the International Conference on Hydrogen Safety which is held every two years. The last meeting was held in San Francisco, California, USA in September 2011 where Task 31 experts were authors of 33 presented papers and posters.

Task Communication and Outreach Table

PUBLICATION / PRESENTATION NAME	PUBS	PRES
International Collaboration on Hydrogen Safety	1	1
CFD Analysis	1	1
Introduction to Hydrogen Safety Engineering	1	1
Lessens Learned Fron Safety Events	1	1
HIAD Hydrogen Accident and Incident Database	1	1
A Homogeneous Non-equilibrium Two-Phase Critical Flow Model	1	1
Simulation of High Pressure Liquid Hydrogen Releases	1	1
Experimental Releases of Liquid Hydrogen	1	1
CFD Computations of Liquid Hydrogen Releases	1	1
CFD Modeling of LH2 DispersionUsing the Adrea-HF Code	1	1
Numerical Investigation of a Verticaql Surface on the Flammable Extent of Hydrogen and Mtthane Vertical Jets	1	1
Numerical Investigation of Subsonic Hydrogen Jet Relaease	1	1
Natural and Forced Ventilation of Buoyant Gas Released in a Full-Scale Garage	1	1
Duispersion and Burning Behavior of Hydrogen Released in Aa Full-scale Residental Garage in the Presence and Absence of Conventional Automobiles	1	1
Hydrogen Fuel Cell Forklift Releases in Enclosed Spaces	1	1
Validation Testing in Support of Hydrogen Codes and Standards Development	1	1
Development of an Italian Fire Prevention Technical Rule for Hydrogen Pipelines	1	1
Safety Assessment of Unignited Hydrogen Discharge From Onboard Storage in Garages with Low Levels of Natural Ventilation	1	1
Heliumk Release in a Closed Enclosure: Comparisons Between Simple Models, CFD Calculations and Experimental Results	1	1
IAHySafe Standard Benchmark Exercise SBEPv21: Huydrogen Release and Accumulation withing NON-VENTILATED Garage	1	1
Les Modelling Of Hydrogen Release And Accumulation Within A Non-Ventilatied Ambient Pressure Garage Using The Aderea-Hf Cfd Code	1	1
Measurements Of Effective Diffusion Coefficient Of Heloum And Hydrogen Through Gypsum	1	1
The Correlation Method To Analyze The Gas Mixing Process On The Basis Of Bos Method	1	1
Experimential Study Of Hydrogen Releases In The Passenger Compartment Of A Piaggio Porter	1	1
Hydrogen Methan Mixtures: Dispersion And Stratification Studies	1	1
Stydy Of Potential Lealage On Several Stressed Fittings For Pressures Up To 700 Bar	1	1
Use Of Hydrogen Safety Sensors Under Anaerobic Conditions - Impact Of Oxygen Content On Sensor Perforance	1	1
Self Ingition Of Hydrogen Jet Fires By Electrostatic Discharge Induced By Entrainded Particulates	1	1
Simulation Of Ddt In Hydrogen-Air Behind A Single Obstacle	1	1
Modeling Of The Flame Acceleration In Flat Layer For Hydrogen-Air Mixtures	1	1
Modeling Of Hydrogen Jet Fires Using Cfd	1	1
Determiantion Of Characteristic Parameters For The Thermal Decomposition Of Epoxy Resin/Carbon Fiber Composites In Cone Calorimeter	1	1
Fire Risk On High Pressure Full Composite Cylinders For Automotive Appliiations	1	1
TOTAL	**33**	**33**

Task Web Sites

Task 31 and its predecessor task have maintained three web based sites for the sharing of information. The first site created was www.ieah2safety.com which was used for all public reports generated under Task 19. That site also had a password-protected, members-only section to house non-public documents and presentations for the 10 experts meeting held since 2004. In 2011, a SharePoint site was established with the assistance of Sandia National Laboratories. It is only available to approved users, who are primarily the task experts from participating countries. Before a document is made public, it must undergo a strict vetting procedure to ensure that no publicly-sensitive information is released without participants' agreement. The third web site is the HyTEX database hosted by the University of Quebec, Trois Riviere. This web site is still being populated and is not yet public.

FUTURE WORK

ACTIVITIES/TARGETS FOR 2013

The task will conduct two experts meeting in 2013. The first meeting will be held in Buxton, UK at the Health and Safety Laboratory, and the second is tentatively planned to be conducted in Brussels, Belgium in conjunction with the Fifth International Conference on Hydrogen Safety.

The final task report for the period 2010-2013 will be submitted and presented at the Hydrogen Implementing Agreement Executive Committee meeting in December 2013.

A preliminary recommendation to continue the task for an additional three years is expected to be submitted in the Fall 2013. If approved, the task will begin project definition activities.

ACTIVITIES/TARGETS BEYOND 2013

The task ends in October 2013. No follow-on task has as yet been proposed, however, a recommendation will be forthcoming in Fall 2013.

R&D CHALLENGES

The main R&D challenges to accomplishing the Task goals is identifying and filling in knowledge gaps needed to develop a risk informed methodology for assessing risk before there is sufficient operating experience. This collaborative effort makes efficient use of resources by sharing results and coordinating input to national programs and international codes and standard development.