HYSAFE: The European Network of Excellence on Hydrogen Safety

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1. Introduction

Introduction and commercialisation of hydrogen as an energy carrier of the future make great demands on all aspects of safety. Safety is a critical issue for innovations as it influences the economic attractiveness and public acceptance of any new idea or product.

However, research and safety expertise related to hydrogen is quite fragmented in Europe. The vision of a significant increased use of hydrogen as an energy carrier in Europe could not go ahead without strengthening and merging this expertise.

This was the reason for the European Commission to support the launch on the first of March 2004 of a so-called Network of Excellence (NoE) on hydrogen safety: HySafe [9].

With its 6th Framework Programme the European Commission has introduced these NoE's as a new tool to facilitate collaboration within organisations with expertise in a given topic (hydrogen safety for instance). Ultimately, this collaboration should turn into integration of research programs and eventually integration of resources. Technical excellence and optimised research are tangible outputs of this integration.

Besides the development of an integrated, competitive scientific and industrial community in Europe on hydrogen safety, HySafe intends to be capable of jointly addressing the challenges presented by the safe transition from current fuels to a regular use of hydrogen in daily life. Technical expertise and activity encompass hydrogen release, ignition, fires, explosions, risk assessment and mitigation techniques.

2. Consortium and network structure

Twenty five partners decided to set up a consortium to embark on this journey towards a strengthened hydrogen safety expertise in Europe. This consortium gathers partners from 12 European countries and one partner from Canada. There are 12 partners from public research institutions, 7 industrial partners and 6 universities.

Name of Institution	*Country*
Forschungszentrum Karlsruhe GmbH	DE
L'Air Liquide	FR
Federal Institute for Materials Research and Testing	DE
BMW Forschung und Technik GmbH	DE
Building Research Establishment Ltd	UK
Commissariat à l'Energie Atomique	FR
Det Norske Veritas AS	NO
Fraunhofer-Gesellschaft ICT	DE
Forschungszentrum Jülich GmbH	DE
GexCon AS	NO
The United Kingdom's Health and Safety Laboratory	UK
Foundation INASMET	ES
Inst. Nat. de l'Environnement industriel et des RISques	FR
Instituto Superior Technico	PT
European Commission – JRC - Institute for Energy	NL
National Center for Scientific Research Demokritos	EL
Norsk Hydro ASA	NO
Risø National Laboratory	DK
TNO	NL
University of Calgary	CA
University of Pisa	IT
Universidad Politécnica de Madrid	ES
University of Ulster	UK
VOLVO Technology Corporation	SE
Warsaw University of Technology	PL

Table 1: HySafe consortium members with their national origin

The basic organisational structure of the network consists of the Coordination Committee (CC), the Network Governing Board (NGB), the Advisory Council (AC) and the Project Management Office (PMO).
The NGB is the decision making assembly consisting of one representative per consortium partner. It usually meets once a year.
The CC is composed of the workpackage leaders, the coordinator, and representatives of other relevant hydrogen related projects in the 6th Framework Programme, namely StorHy for H_2 vehicle storage, HYWAYS for hydrogen development road mapping and NATURALHY for the use of existing pipeline structures. The CC meets four times a year to report on progress and to develop recommendations for the NGB.

The coordinator, Forschungszentrum Karlsruhe, is the single interface of the network with the European Commission. Supported by the PMO he provides the daily management of the network.

The Advisory Council is an elected set of 12 experts which advises the NGB in all technical / scientific affairs. Worldwide representatives sit in this advisory council.

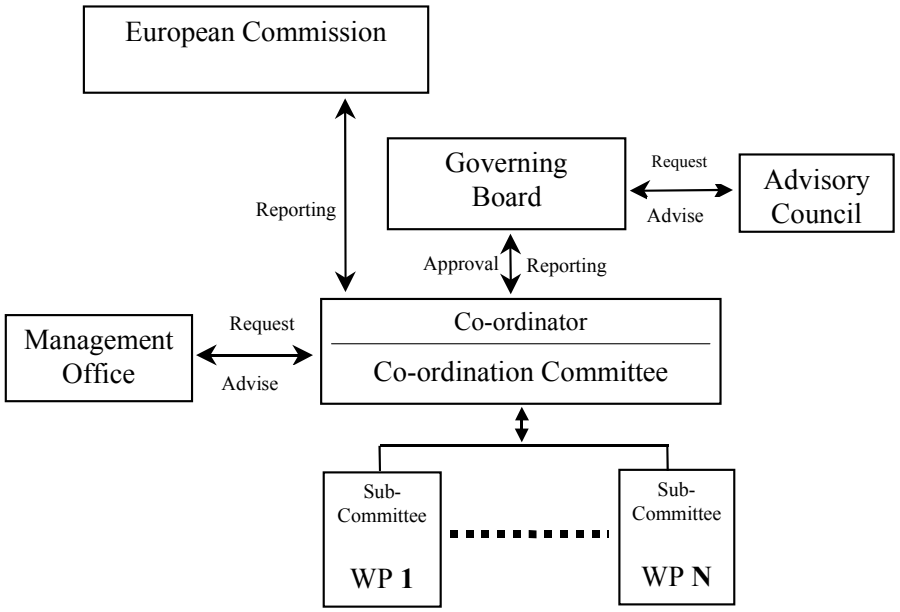

Figure 1: Schematic diagram of the management structure

3. First year achievements

During the first year, a certain number of tasks were performed jointly by the partners in so-called "integrating activities". We will report here on few of those tasks, which illustrate the wide and complementary range of competencies and expertise that the network enjoys:

- A methodology was applied to identify and rank safety issues and phenomena, relying on expert judgement by members of the consortium, spanning industry, safety and regulatory bodies, research organisations and universities. Input from the Advisory council was also sought. Over 160 accidental events were identified. The next step was to rank them according to their relevance to safety. This lead to a first ranking of events with a group of issues consisting of 55 events which were judged of high importance, and 18 events for which a strong disagreement between experts was found – therefore necessitating further discussions. The last on-going step is to rank the physical phenomena in terms of level of available knowledge. Crossing events which rank high in terms of safety, and underlying phenomena for which knowledge, or modelling, or experimental data, is deemed insufficient, will allow the network to identify areas for which R&D work is necessary to close safety issues. For example one such area is related to the use of hydrogen in confined or partially-confined spaces. The InsHyde project, presented below, aims at precisely performing experiments and modelling work to better assess safety issues related to these applications.

- In parallel to the above activity, a questionnaire was established and answered by the HySafe members in order to map the present status of projects dealing with hydrogen and hydrogen safety. A description of 69 projects was received. Overall, it seems that very little work is being performed to produce standards for the safe handling of hydrogen. An additional inquiry was also submitted to the expert community in order to identify short, medium and long term research priorities. It showed a high interest in hydrogen-fuelled vehicles and pointed to the lack of standards and regulations concerning use of such vehicles in tunnels and car parks – in general confined spaces [1].

- Experimental facilities are necessary tools for developing and validating hydrogen safety strategies. One of the first tasks performed by the network was therefore to compile a list of the different facilities operated by the partners [8]. The ultimate goal of this activity is the buildup of a set of complementary specialised research facilities in order to enable the network to jointly perform experimental work. It therefore contributes directly to the integration process. The list of facilities can be consulted on the HySafe website [9]. It contains the description of nearly 80 facilities for testing of leaks, dispersion, and

combustion as well as equipment performance. Beyond the facilities themselves, work is on-going to survey experimental techniques and to elaborate common quality standards in terms of experimental practice. This is organised in partially public workshops. Aside from reviewing experimental capabilities, past experimental data on hydrogen release, ignition and explosion were also gathered.

- Simulation tools such as Computational Fluid Dynamics Codes (CFD) are increasingly being considered for safety assessment demonstrations in many industrial fields as tools to model accidental phenomena and to design mitigation (risk reducing) systems. Thus, they naturally complement experimental programmes which may be expensive to run or difficult to set up. However, to trust numerical simulations, the validity of the codes must be firmly established, and a certain number of error sources (user effect, modelling errors, discretisation errors, etc) reduced to the minimum. Code validation and establishment of "best practice guidelines" in the application of simulation tools to hydrogen safety assessment are some of the objectives pursued by the HySafe network. As an example of this validation effort, benchmark exercises were conducted during the first year of the project, in the area of hydrogen dispersion and hydrogen explosion [6] & [7]. These exercises will continue over the next periods.

- A database of accidents and incidents involving hydrogen was initiated [5]. It will compile in a unique tool a documented list of past experience. Besides spreading knowledge about accident causes and progression, the database will also be helpful to define mitigation measures and emergency procedures.

- A survey of methods for zone classification and determination of safety distances has also been undertaken. This survey output consists of a list of good practice document currently used for zoning. It also covers the methodology followed by some of the partners to define safety distances around hazardous installations [4].

4. Future priorities and associated projects

Working together on common projects is the essential means to better know each others' capabilities and eventually to reach integration. For the new yearly planning of 2005/2006 two internal projects have been decided which account for HySafe current work priorities on "(Partially) confined releases" and "Mitigation techniques".

- **InsHyde**

In a medium term, one could expect an increasing number of hydrogen systems to be used (co-generation processes) or stored (mobile applications) inside buildings (dwellings, garages,…). Whereas outside location would be favourable in most cases to prevent leaking hydrogen from accumulating, indoor location will remain in many cases a necessity in many cases.

However, it seems that no clear recommendation exists today to provide advice on the safe use of hydrogen systems in confined spaces. Many questions remain unanswered and especially those related to hydrogen dispersion behaviour depending on the leaking regime. Effect of safety measures such as ventilation is also insufficiently understood although it is a fundamental and widely used hazard control technique.
This project intends to investigate realistic indoor leaks and ultimately to provide recommendations for the safe use / storage of indoor hydrogen systems.

The specific objectives may be summarised as to:

- provide information on main hazards when using hydrogen in confined spaces (hydrogen dispersion behaviour, fire and explosion potentials, ignition),
- provide information on the regulatory and standards framework for the use of hydrogen systems inside buildings,
- help end-users and designers to assess potential leaking rates (risk assessment) and regimes of planned and existing indoor hydrogen systems,
- give advice on ventilation performance (reliability, flow, layout,…) to ensure that leaking incidents do not allow hydrogen to accumulate,
- and finally give advice on sensors positioning and performances based on expected releases and buildings layout.

Results from this project and related recommendations shall be published in an open document.

- **HyTunnel**

Hydrogen powered vehicles and fuel-supply trucks in the confined space of a tunnel could pose a serious hazard of fire and explosion to the tunnel and its users. A number of critical scenarios in tunnels have been identified. The distribution and mixing characteristics of hydrogen and any potential development of fire and

explosion under normal and emergency mode of operation of the tunnel ventilation need to be understood. The appropriate safety concepts of existing tunnels might have to be revised. For future constructions, design characteristics need to be determined, aiming at a synchronous advance of vehicle and infrastructure technology.

This CFD-simulation based study is intended, where possible, to address various mitigating design measures, hydrogen flow rates, combustion speeds, pressure loads, and ignition times and locations.

In summary, the technical objectives are to:

- review current regulations and standards on fire and explosion mitigation techniques in tunnels,
- review scenarios of hydrogen-powered vehicle or fuel supply truck accidents,
- understand distribution and mixing characteristics of hydrogen, and any potential development of fire and explosion under normal and emergency mode of operation of the tunnel ventilation system, with and without existing or future mitigation measures,
- undertake CFD simulations & in a second phase verification experiments,
- develop guidelines for tunnel and vehicle safety systems countering hazards associated with the release of hydrogen in a tunnel,
- propose a road map for the introduction of the guidelines to the appropriate forums for introduction to appropriate legal requirements, etc.

Finally guidelines for vehicle and tunnel safety systems shall be developed countering hazards associated with the release of hydrogen in a tunnel, which will be forwarded for consideration by bodies such as UNECE WP29 for vehicles.

5. Dissemination of expertise

- **E.Academy of Hydrogen Safety**

Educational and training programmes on hydrogen safety matters are considered to be of vital importance to the emerging hydrogen economy. A lack of professionals with expert knowledge in hydrogen safety and related key areas will not only impose a serious setback on innovative developments in the hydrogen economy, but also thwart ongoing efforts to achieve public acceptance of the new technology [2,3]. Therefore, the network embarked on the establishment of an e-Academy on Hydrogen Safety. An International Curriculum on Hydrogen Safety Engineering is being developed to form the backbone of the e-Academy of Hydrogen Safety [2,3]. Moreover, the curriculum helps to identify and demarcate the knowledge framework of the subject matter, and its relationship to other branches of engineering. This, to avoid duplication of educational efforts, but also to achieve cross-fertilisation with existing engineering programmes by the introduction of topics with an emphasis on hydrogen safety.

- **International conference on hydrogen safety**

The present conference has been organised by the HySafe consortium. It is seen as a key place to exchange worldwide information on hydrogen safety. It is the first Conference solely dedicated to the hydrogen safety topic. The conference is organised in cooperation with the Japanese Project ArdentHy, the EC projects StorHy, NATURALHY and CUTE, the International Association for Hydrogen Energy and the Italian National Firecorps. The sessions will be co-chaired by industry and research specialists. Future editions of this conference will be organised on a biennial basis.

- **Regulations and Standards**

Development of hydrogen safety related legal requirements, standards and codes of practice should provide a good basis for the implementation of safe and homogeneous technical solutions for different hydrogen applications. In practice a working group has been set up within the network which aims at:

  - following standardisation (mainly ISO TC 197 and IEC TC 105) and regulation (mainly UN GRPE WP29) development,
  - reporting on these developments inside the consortium,
  - discussing these development and contributing to them with the help of outputs from HySafe work.

Besides, one should note that a strong emphasis is put in HySafe activities on practical results and recommendations / good practices documents that can be of a direct use by the industry, standardisation groups and policy makers.

- **Report on hydrogen safety**

The report on hydrogen safety is intended to deliver biennially information on existing knowledge, gaps and progress on hydrogen safety issues ranging from basic physical and chemical knowledge (dispersion, combustion) up to practical information related for instance to state of the art risk control measures or emergency response plan. It will pull together existing scientific and technical information shared between members of the consortium. Every partner is contributing to this document. It is a living document that aims to provide technical support to people in their everyday safety work. The first edition of the report is expected for the first semester of 2006.

6. HySafe Relationships and conclusion

Most of HySafe partners are also involved in on-going European projects related to the development of hydrogen as an energy carrier. It therefore provides good relationships between this network and the hydrogen community. Besides, HySafe is providing inputs to the European Hydrogen and Fuel Cell Technology Platform and aims, in this group, at playing a central role in the mapping of research priorities on hydrogen safety in Europe [11]. Moreover, HySafe is seeking to contribute to the safety assessment of hydrogen related European Community funded projects.

HySafe is looking for an official recognition from the International Partnership for the Hydrogen Economy. This should contribute to organise and to address hydrogen safety issues on a worldwide basis. In addition, nearly half of the participants to the IEA task 19 [10] on hydrogen safety are members of HySafe. This task aims at promoting exchange of safety data and methodologies among members of the IEA hydrogen implementation agreement.

HySafe is also open to external supporters who can contribute to its technical work. In return, supporters benefit from first hand information. A supporter can be any organisation working in the fields related to hydrogen safety including research, equipment, product development, safety assessments, education, regulations, codes and standards. To become a HySafe supporter, application can be downloaded from the HySafe website [9].

In the long term, HySafe envisages through a long lasting self-sustaining structure to continuously provide technical support on hydrogen safety and to organise European research in this field.

Acknowledgement

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