DEVELOPMENT OF TOOLS FOR RISK ASSESSMENT AND RISK COMMUNICATION FOR HYDROGEN APPLICATIONS

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ABSTRACT

For decades risk assessment has been an important tool in risk management of activities in several industries world wide. It provides among others, authorities and stakeholders with a sound basis for creating awareness about existing and potential hazards and risks and making decisions related to how they can prioritise and plan expenditures on risk reduction. The overall goal of the ongoing HySafe project is to contribute to the safe transition to a more sustainable development in Europe by facilitating the safe introduction of hydrogen technologies and applications. An essential element in this is the demonstration of safety: that all safety aspects related to production, transportation and public use are controlled to avoid that introducing hydrogen as energy carrier should pose unacceptable risk to the society.

History has proven that introducing risk analysis to new industries is beneficial, e.g. in transportation and power production and distribution. However, this will require existing methods and standards to be adapted to the specific applications. Furthermore, when trying to quantify risk, it is of utmost importance to have access to relevant accident and incident information. Such data may in many cases not be readily available, and the utilisation of them will then require specific and long lasting data collection initiatives.

In this paper we will present the work that has been undertaken in the HySafe project in developing methodologies and collecting data for risk management of hydrogen infrastructure. Focus is laid on the development of risk acceptance criteria and on the demonstration of safety and benefits to the public. A trustworthy demonstration of safety will have to be based on facts, especially on facts widely known, and emphasis will thus be put on the efforts taken to establish and operate a database containing hydrogen accident and incident information, which can be utilised in risk assessment of hydrogen applications. A demonstration of safety will also have to include a demonstration of risk control measures, and the paper will also present work carried out on safety distances and ignition source control.

NOMENCLATURE

The nomenclature in this paper is based on [1] and [9].

Acceptable risk, Tolerable risk	Risk which is accepted in a given context based on the current values of society
Blast wave	Intense pressure wave set in motion by the shock waves and hot product gases of a deflagration or detonation that impinges on the surroundings, typically air
BLEVE	Boiling Liquid Expanding Vapour Explosion
Confinement	Physical restriction, sufficient to influence the combustion process
Deflagration	Flame or chemical reaction moving through a flammable mixture at a rate less than the speed of sound in the unburned mixture
Detonation	Exothermic chemical reaction coupled to a shock wave that propagates through a detonable mixture or medium
Explosion	Rapid equilibrium of pressure between the region of energy release (system) and its surroundings
Flammability	Concentration of a fuel in an oxidizer below which a burning reaction cannot be sustained
Flammability limits	Lower (LFL) and upper (UFL) vapour concentration of fuel in a flammable mixture that will ignite and propagate a flame
Harm	Physical injury or damage to the health of people, or damage to property or the environment
Hazard	Potential source of harm
Ignite	Cause to burn or to catch fire
Ignition energy	Energy required to initiate flame propagation through a flammable mixture
Protective measure	Means used to reduce risk
Risk	Combination of the probability of occurrence of harm and the severity of that harm
Risk analysis	Systematic use of available information to identify hazards and to estimate the risk
Risk evaluation	Procedure based on the risk analysis to determine whether the tolerable risk has been achieved
Safety	Freedom from unacceptable risk
Shock wave	Large-amplitude compression wave in which there is a rapid and great change in density, pressure and particle velocity.
Stoichiometric mixture	Mixture of reactants in a chemical reaction that optimises production of the reaction products
Systematic risk management	An iterative process of risk assessment and risk reduction
Vapour cloud explosion	Gas explosion, flame moving through a flammable mixture of a fuel and an oxidizer

INTRODUCTION

Hydrogen has been introduced as the perfect energy carrier: Hydrogen is cleaner than traditional motor fuels – the exhaust is almost pure water, hydrogen can be produced using almost any other energy source and hydrogen is more flexible than electricity / batteries in terms of energy storage and use capabilities.

A major challenge introducing hydrogen as an energy carrier is safety. Any energy carrier will have the potential for an unintended violent release of energy, causing harm to property and to people. For the oldest energy carriers such as wood, coal and town gas, protective measures were developed through trial and error. When nuclear power production was introduced, its potential for disaster had already been demonstrated and systematic risk management methodology, including quantitative risk analysis, was developed. Systematic risk management has demonstrated its effectiveness and is today a part of the overall management for most sectors of energy production.

When introducing hydrogen as a major energy carrier for public use, learning from the past is an obvious preference. Learning from the past will implicate both utilising the systematic risk management methodology and continuously utilising the experience available from past and present hydrogen applications.

1.0 CHALLENGES INVOLVED WITH THE INTRODUCTION OF HYDROGEN AS AN ENERGY CARRIER

1.1 Hydrogen Properties

Hydrogen is the lightest of all elements and is at normal pressure and temperature an odourless, colourless gas. Hydrogen is lighter than air, highly diffusive and has low viscosity (leaks easily). The small hydrogen molecules will diffuse through almost any material, as well as fittings and seals, especially if stored at high pressure, [1].

Hydrogen mixed with air is flammable over a wide range (4 % to 75 % by volume) and will burn with a flame not visible in daylight [1]. Hydrogen can deflagrate but can also detonate. At concentrations close to stoichiometric mixture the minimum ignition energy is as low as 0.017 mJ [1], but at lower concentrations it will be higher; minimum ignition energy of 10 mJ for 4 % hydrogen in air was reported by Swain [8]. The auto ignition temperature is 585 ^{o}C [1].

A long term effect on vessels containing hydrogen is degrading of the mechanical properties of the vessel material. This effect has been shown both on metallic and non-metallic materials; the phenomenon is called hydrogen embrittlement [2].

Hydrogen may cause asphyxiation by means of displacement of air, but has otherwise no harmful effect on humans [1].

1.2 Public Perception of Hydrogen Safety

When discussing hydrogen and safety with non hydrogen experts, the word “Hindenburg” is almost certain to be mentioned. (Try a Google search with Hydrogen and Disaster.) The Hindenburg airship accident in May 1937 was not thoroughly investigated at the time, but the general opinion was soon formed: The disaster was caused by a hydrogen fire. Later investigations has pointed out that the pictures of the burning airship are not consistent with a hydrogen fuelled fire – and that the flammable coating of the airship may be a more likely source of fuel. The spectacular pictures of the burning airship are however part of the public image of hydrogen and risk.

Another spectacular accident associated with hydrogen is the Challenger space shuttle explosion in 1986. The immediate cause was found to be an O-ring failure [3], and cold weather (below design specifications) a contributing cause.

Real hydrogen accidents reported are generally less disastrous. Ignition of oxy-hydrogen gas resulting in an audible blast wave is however an experiment most of us have seen or even tried at school. Such a “hands on” experience will enhance the impression of any hydrogen blast incident reported by media.

1.3 Risk Control and Public Perception of Safety

The public perception of risk related to hydrogen may be an obstacle to the introduction of hydrogen as an energy carrier. But it will also heighten the general alertness and contribute to the acceptance of protective measures enforced. Selecting the appropriate protective measures and convincingly demonstrating their effectiveness for risk control are the recommendable means for public acceptance of hydrogen as an energy carrier.

Implementation of new safety regulation and enforcement of protective measures are often the result of catastrophic accidents.

The European directive on the control of major-accident hazards involving dangerous substances [4] is in everyday language named after the Seveso accident in 1976, but has also incorporated lessons learned from the Bhopal toxic gas accident and the Mexico City BLEVE. This legislation has enforced the requirement of risk assessment and demonstration of emergency preparedness as well as reporting of major accidents in the Major Accident Reporting System.

The UK Offshore Installations (Safety Case) Regulations from 1992 were initiated by Lord Cullen's investigation report [5] on the Piper Alpha explosion, where 167 people lost their lives. This legislation has also influenced the offshore installation legislation for other sectors of the North Sea. Risk assessment and demonstration of safety is today a requirement for offshore installation in the Norwegian and Danish sector of the North Sea, as well as the British.

Investigation of an accident and implementation of safety measures is a way of preventing a similar accident from happening again. It is also an action taken for dealing with the anxiety the accident created and a way of honouring the victims of the accident. Learning from accidents should also involve utilising the investigation conclusions for identifying not so similar potential accidents and implementing measures to prevent them. Systematic risk management will also require learning from the accidents that did not happen, so-called “near-misses”.

Demonstration of safety is an essential element in the safe introduction of hydrogen as an energy carrier. Systematic registration and investigation of hydrogen incidents and utilisation of the conclusions for analysis of risk and implementation of risk control measures should aid the public trust in these measures’ ability to control risk. When it can be demonstrated that hydrogen as an energy carrier is no more dangerous than other common energy carriers, the risk will be perceived as acceptable among the public, and maintaining the public alertness will be the major challenge. Again, registration and investigation of incidents and publication of the conclusions will be an essential part of risk management.

2.0 RISK ASSESSMENT IN OFFSHORE PETROLEUM EXPLOITATION - COLLECTION AND UTILISATION OF DATA

Offshore rig owners and platform operators are and have always been in constant need to effectively control risks and prevent harm to the workers on board their installations and to the environment. This means that they need to focus on Safety, Health and Environment (SHE) issues to same extent and according to the same standards as for maintaining their oil and gas production rates and volumes, control financial losses, and further to keep good progress in exploration and development of new and unexploited reserves.

For nearly 6 decades man has explored, developed and utilised the huge offshore oil and gas reserves throughout the world. Naturally, this industry has faced a large number of accidents and incidents causing injuries, fatalities and damage. It is obvious that working in harsh environments poses a number of challenges and hazards which have to be dealt with in order to operate in a safe manner and avoid losses.

Hence, the industry was obliged to work out strict operational and safety regulations and make sure that the actors involved give priority to the work of controlling risk, i.e. by effective prevention and loss control through well established safety regimes and cultures.

The offshore industry realised very early that collecting and systemising accident information should be included as a central part of their safety management tasks. Consequently, a number of initiatives were taken to create systems for data collection and recording purposes, first as huge paper archives, and then on electronic formats as the IT development enabled the users to easily retrieve, share and store accident data. This took place both on national and company levels. Hence, databases holding offshore accident information, hydrocarbon release data and Reliability, Availability and Maintainability (RAM) data are numerous and several data collection regimes exist either as part of national databases covering a number of industries or tailor-made systems for offshore data. Severe accidents in the offshore industry world wide claiming many lives and causing large environmental damages have throughout the years forced national authorities and regulators to sharpen the requirements towards operators and rig owners regarding their systems for accident recording and to actively make use of the information therein in order to improve safety.

Quantitative Risk Analysis (QRA) have been undertaken for the industry for many years to give the rig owners and platform operators a decision tool for risk management and for documenting compliance according current national and international standards, rules and regulations, e.g. the Safety Case regime in the UK. When doing a QRA the analyst needs data, models and statistics for risk calculations. Since, as said above, the offshore industry has been focusing on data collection for a long time and thereby the data material is extensive, lots of efforts have been invested in many countries (especially in Norway and UK) to produce relevant data models and accident and incident statistics for almost all types of hazards relevant for offshore operations, and on such a form that it is almost readily available for an analysis of an offshore installation or project. In addition efforts have been allocated to collect and process *population data* such as number of platform/rig/well-years, number of wells drilled, number of lifts/hoists, etc. This data is required in order to calculate frequencies and probabilities. Examples of important input to a QRA may be: ignition probability models, failure and repair rates for offshore process equipment and systems, frequencies and models for hydrocarbon releases, blowouts, platform/ship collisions, falling objects, structural collapses, capsizes, groundings, etc. Often this kind of data is obtained from a huge data material and hence is considered representing a high degree of reliability.

3.0 WHY DO WE NEED ACCIDENT DATA

3.1 General

If industries, organisations and companies are to effectively control risks and prevent harm to people or the environment, they need to manage Safety, Health and Environment (SHE) issues with the same degree of expertise and to the same standards as their other core business activities.

Any industry, organisation or company should aim for improving its performance and allocate the necessary resources so that accidents, incidents and hazardous situations are reduced or eliminated.

It is acknowledged in most industries that it is of utmost importance to learn from accidents and incidents of the past to prevent them to happen in the future and to mitigate their consequences. I.e. an important part of the work towards achieving effective risk control one should learn from events, failures and errors committed in the past, and not only within their own industry or company, but also look beyond and draw lessons from elsewhere.

The use of incident databases as a management tool has shown that it provides an opportunity for an organisation or company to check its performance, learn from its mistakes, and improve its management systems and risk control. Comprehensive knowledge of events having the potential for inducing hazardous situations, will also contribute to the corporate learning and memory. On company or plant level, the lessons to be learned from consulting accident databases are both qualitative as well as quantitative. They can range from the identification of accident scenarios or initiating events not being predicted in advance to quantitative statistical calculations and estimations to be used in risk or safety analyses. They also increase the safety culture of personnel working in risky technology industries by making them aware of the factors (technical, organisational, human, etc.) and the dynamics that led to an accident. On a national or international level, Safety Authorities are utilising accident databases as an operative and a management tool in several ways, such as following up of the overall safety level within the area of the authority's interest, resource allocation concentrated and prioritised on the most accident-prone areas and in accident prevention. Accident information taken from a database may also support surveillance visits, in conducting accident investigations and in the work of developing of rules and regulations.

3.2 Risk assessments and accident data

For decades risk assessments and analyses have been an important tool in risk management and control of activities in several industries world wide. It provides among others, authorities and stakeholders with a sound basis for creating awareness about existing and potential hazards and risks and making decisions related to how they can prioritise and plan expenditures on risk reduction.

In a Quantitative Risk Analysis (QRA) the main objective is to quantify risk and in order to be able to do this properly and producing credible and reliable results it is of great importance to have access to relevant accident and incident information and data. Such data may in many cases not be readily available, and the utilisation of them will then require specific and long lasting data collection initiatives.

If a database is to be utilised for risk management clear aims and objectives for the database need to be developed at a very preliminary stage. It will have to be 'fit for purpose' and should reflect the business needs. An organisation needs to know why it needs a database, what information it is to hold, and how to use or analyse the information therein.

A trustworthy demonstration of safety of future hydrogen applications and use will have to be based on history and facts as mentioned above. Thus, an important contribution to this work is to allocate efforts and resources to establish, operate and maintain a central database containing hydrogen accident and incident information, which can be utilised in future risk assessments of hydrogen applications.

Under the EU's 6th framework programme, a Network of Excellence project "*HySafe – Safety of Hydrogen as an Energy Carrier*" was established and defined. In this project, a specific Work Package (WP) was devoted to database development, namely the **WP5 – Hydrogen Incident and Accident Database (HIAD)**.

HIAD is planned to be one of the tools for communication of risks associated with hydrogen to all partners in the HySafe Consortium and probably beyond at a later stage. In addition, HIAD will serve as a common methodology and format for data collection and storage. HIAD is aiming to hold high quality information of historical accidents and incidents related to hydrogen production, transport (road/rail/pipeline), supply and commercial use. The database will be maintained such that it is updated with the latest information concerning each event for example in order to take advantage of results from accident investigations. Hence, HIAD will, when fully operable be an important source for most tasks constituting a risk analysis process, such as hazard identification, estimation of probabilities and consequences and to propose risk reduction measures. During the preparatory work of developing HIAD, it was acknowledged that there are a number of larger databases throughout Europe which hold information about hydrogen accidents, but none of them with the only scope of storing events related to hydrogen.

3.3 The HIAD database

During the work with developing HIAD, the challenge was to develop a tool that should serve various purposes such as being a data source for doing risk assessments and reveal trends and being a source for experience transfer and risk communication. In addition it should be easy to use, so the user friendliness encompassing the tasks of recording and extraction of information/data by having a professional and modern user interface, was hence given high priority.

It has been decided that HIAD should not be limited to real accidents and incidents, but should also include hazardous situations and near-misses. An example of this is that HIAD should contain all hydrogen releases irrespective of size/volume and not only those that ignited. One benefit of this is enabling the estimation of ignition probabilities from the HIAD data.

The planned user/system interface is shown graphically in Figure 1.

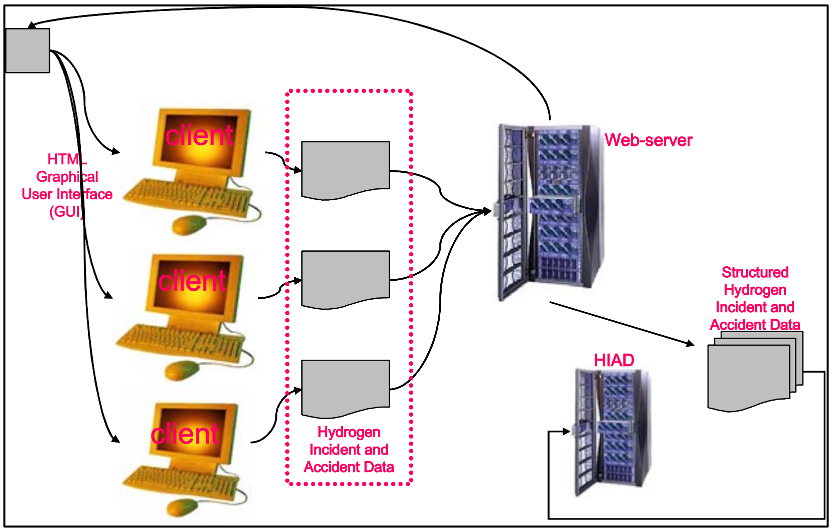


Figure 1. HIAD user/system interface

The building blocks of HIAD are illustrated in the figure below.

1. HIAD Administration			
2. Pre-event conditions	3. Nature of event	4. Consequences of event	5. Post-event actions
6. References			

Figure 2. HIAD building blocks

Information held by HIAD and being relevant for risk assessment exercises and related modelling development work could be such as environment/location and application, release size and volume, ignition sources and ignition time (‘ignition modelling’), fire characteristics, description of consequences (input to work with safety distances), damage cost, and causal relations (input to fault tree construction). All information recorded for each event will in general be important for the corporate learning about risks related to hydrogen applications and serve as ballast for the risk analysts in their hazard identification phase of any risk analysis. This work is by experience considered as the most crucial one in the sense that hazards and risk elements not captured here will not be included in the further risk assessment process.

In the section of HIAD named ***Accident specification*** it is required that the whole “chain of events” is given and that each event is recorded separately with relevant details. Examples of parameters are given below.

- Type of event (release, fire, explosion, collision, collapse, etc)
- Causal relations (primary, secondary; human, technical and external)
- Relevant safety/mitigation systems installed; which ones functioned OK and not
- Emergency actions
- Release specifications (type, size/volume, rate, etc)
- Ignition, fire and explosion/detonation specifications

For the ***Consequences*** part, damages to persons, assets, environment and economy should be recorded. This information could be such as number of fatalities and injuries, degree of injury and extent and cost of property damage and ecological impact. Impact on the society and infrastructure should also be recorded if relevant and information is available.

In the first version of HIAD, *population data* will not be included as an integrated part of the database. Such data is needed in order to calculate frequencies and probabilities and comprising data such as number of plant and refuelling station years, kilometres driven by tankers transporting hydrogen and private cars using hydrogen, pipeline kilometre-years, etc. Hence, the risk analysts themselves need to do some work on this kind of data during their analysis process and combine this data with the information captured from HIAD.

4.0 UTILISATION OF DATA FROM HIAD FOR DEMONSTRATION OF SAFETY

4.1 Cost Effective Safety

A general perception of hydrogen as easily ignitable and that ignition is almost certain to result in an explosion, may lead to several safety measures implemented to prevent formation of an ignitable hydrogen gas cloud, e.g. very high ventilation rates required for buildings. This in turn could imply that garages will have to be rebuilt or forced ventilation systems installed. In some areas this will in turn require heating of garages. Before such investments are decided, one should make systematic investigation to ensure these measures are the most cost effective and necessary.

4.2 Methodology for determination of safety factors – and how to utilise data today and in the future – using ventilation requirements for garages as an example

Safe introduction of hydrogen as an energy carrier, especially as a vehicle fuel, will lead to development of several safety requirements to be set, e.g. ventilation requirements for buildings where hydrogen vehicles are allowed to park.

Such requirements are in force today for garages for conventional ICE or gasoline vehicles, e.g. in Norway. The National Office of Building Technology and Administration in Norway has published guidelines for calculation of required ventilation rates for private garages [8] (unofficial translation): “Garages must be ventilated such that the level of gasoline vapour and exhaust may not reach a harmful level. There should be vents both at floor level and at ceiling level. (…) Garages shall, independent of smoke ventilation, have separate ventilation for removal of exhaust gases. (…) For garages with a floor space up to 50 m^2 with natural ventilation, the air inlet vent openings should be at least 0.2 % of the floor space, as should the air outlet vent openings.”

The ventilation requirements are set based on assessed normal occurrence of gasoline vapour and exhaust from a car, as well as considerations on what levels of gasoline vapour and exhaust may be harmful to humans. Similar considerations will have to be done for hydrogen, but as the ignitable level here may be lower than the level harmful to humans, ventilation requirements should be determined by the low flammability limit (LFL). But bearing in mind that unignited hydrogen (as opposed to gasoline) is harmful to humans only in concentrations where displacement of air causes a decrease in concentration of oxygen, the probability of ignition should also be accounted for as well as ability of flame propagation in lean hydrogen-air mixtures containing up to 10% hydrogen concentration by volume.

The probability of ignition of a gas cloud will be dependent on the probability of a (sufficiently strong) ignition source being present (Q) and the probability that this ignition source (while present) is exposed to a gas concentration within the flammable area, Pv. The overall ignition probability, P_I, can be expressed as:

$$P_I = 1 - \prod_{i=1}^{n} (1 - P_{vi} \cdot Q_i) \qquad (1)$$

The Pv –factor will depend on the release rate, the velocity of the released gas and of the dispersion conditions in the surrounding area, e.g. air exchange rate and relative density. The release rate and the velocity of the released gas will normally decay with time while the air exchange rate will normally be stable – or increased on demand as a protective measure. If the air exchange rate is sufficiently high compared to the release rate, an ignitable gas cloud will not be formed. Concentration profiles may be modelled rather accurately for confined spaces and with acceptable accuracy for open areas. Modelling of concentration profiles for semi-confined spaces will require more complex modelling, e g CFD.

The flammable concentration of hydrogen may however vary depending on the present conditions. The lower flammability limit of hydrogen in air is 4 %, but it has been demonstrated by Swain [8] that hydrogen air plumes are not ignitable at locations where 4.0% hydrogen exists, horizontally away from the leak. For a hydrogen leak at Mach 0.10 the distance from the leak to the ignition site must be at or below 75% of the maximum distance to 4%. For Mach 0.20 the value is 57%. This will certainly complicate ignition modelling based on experimental data only.

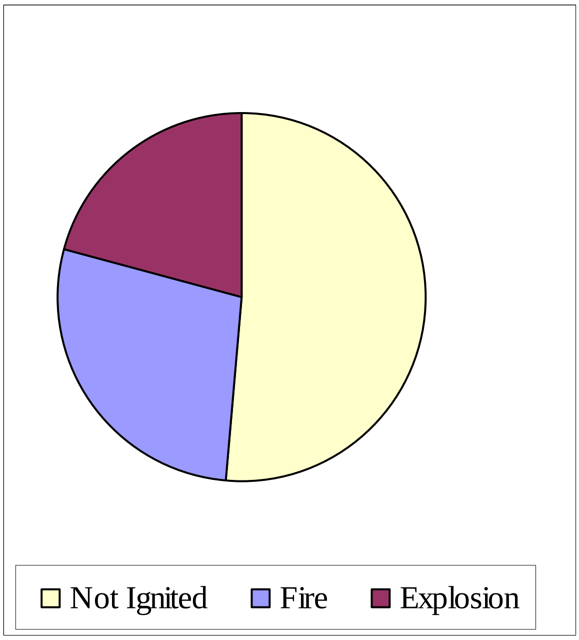
Swain also reports that the minimum ignition energy was found to be relatively high (compared to gasoline) for low concentrations of hydrogen, decreasing with higher concentrations. This parameter may be attributed to the probability of a sufficiently strong ignition source being present.

Analysing incident reporting data has shown that a considerable portion of reported hydrogen leakages are never ignited, though evaluated as sufficiently large to form an flammable gas cloud.

An analysis of 72 hydrogen leaks reported in the EIGA database [6] gave the following output, also presented in Figure 3 and Figure 4.

49 % of the reported hydrogen leaks were ignited (see Figure 3) and 43 % of the ignited leaks (21 % of total) resulted in an explosion in form of a blast wave. For ignited leaks in confined spaces, 75 % resulted in an explosion (see Figure 4), and the half of those 75 % were ignited either in an electrical cabinet or by hot work. Unfortunately, the descriptions of the extent of damage from the explosions are not sufficient for evaluation of what the blast wave overpressure may have been.

This rough screening of data indicates that hydrogen leaks may not be very easy to ignite. The overall fraction of leaks ignited is certainly high, but when looking into the ignited leaks, a large portion of them were exposed to a rather strong ignition source. Moreover, one can expect that while most of the ignited leaks are reported, a prominent part of the unignited leaks are not.



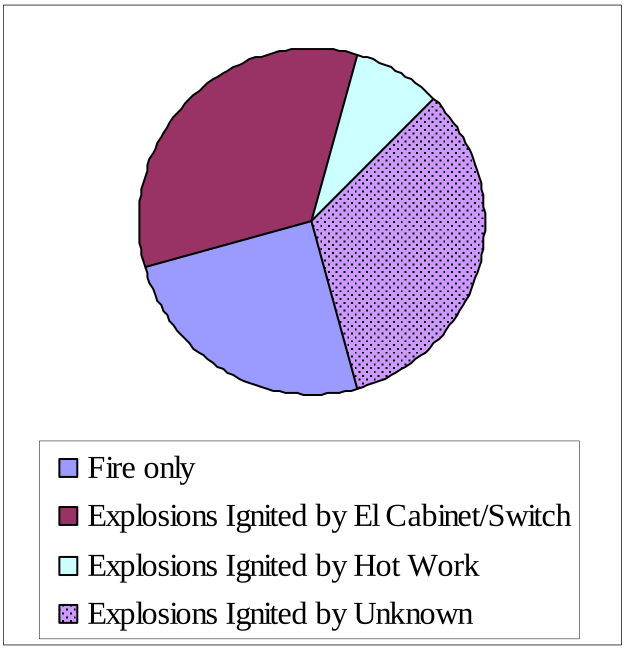


Figure 3. Hydrogen leak hazardous scenarios

Figure 4. Confined space ignited hydrogen leaks

When evaluating the probability of explosion if a hydrogen leak in a confined space is ignited, the main consideration will normally be if the leak is immediately ignited or not. Immediate ignition (ignition before a flammable gas cloud of significant volume is formed) will give a fire, while delayed ignition will give a vapour cloud explosion. The data analysed may be utilised for such an evaluation: A conservative evaluation would be that 75 % of the ignited leaks will give an explosion. A more detailed evaluation involving some considerations on type of ignition sources available, could be that if no electrical cabinets or switches are present and no hot work is to be performed in the building evaluated, the probability of delayed ignition can be reduced and that only 50 % of the ignited leaks will give an explosion.

With more complete reporting of unignited hydrogen leaks into the HIAD database, along with sufficiently detailed information, a more accurate modelling on hydrogen ignition probabilities for different environments will be feasible. One can then expect the estimated ignition probabilities to be reduced for most types of environment.

Incorporation of population data in the database will enable an evaluation of leakage size distribution and extent of gas clouds, which will further improve the ignition probability modelling.

These achievements should enable the evaluation of today’s ventilation requirements for garages, to determine whether they are sufficient for the introduction of hydrogen cars.

6.0 SUMMARY AND CONCLUSIONS

The overall goal of the ongoing HySafe project is to contribute to a more sustainable development in Europe by facilitating the safe introduction of hydrogen technologies and applications. In order to succeed in this work, a highly professional and reliable demonstration of safety is essential. This means that all safety aspects related to hydrogen production, transportation, distribution and public use are shown to be under control in order to avoid posing unacceptable risk to the society.

For many industries a QRA has for a long time been an important tool in risk management and control world wide. It provides among others, authorities and stakeholders with a sound basis for creating awareness about existing and potential hazards and risks and making decisions related to how they can prioritise and allocate resources on how to reduce or eliminate the probability of an accident and how to mitigate the consequences through proper preventive and emergency response measures.

A QRA's main objective is to quantify risk and in order to be able to do this properly and producing credible and reliable results it is of great importance to have access to relevant accident and incident information and corresponding population data. The initiative taken by the HySafe project to establish, operate and maintain a central database containing hydrogen accident and incident information, the *Hydrogen Incident and Accident Database (HIAD),* will assure that future QRAs of hydrogen applications are providing the industry, authorities and the public with traceable data for reliable and trustworthy risk assessment results. In the first version of HIAD, *population data* will not be included as an integrated part of the database and hence, relevant frequencies and probabilities can not be derived from HIAD directly. The ultimate future goal of HIAD, should be that the database is ***the*** source for most tasks constituting the risk analysis process, such as hazard identification and risk calculations and identifying effective risk reduction measures. Nevertheless, HIAD will serve as an important source for hazard identification and contribute to a common understanding of hydrogen risk elements. Furthermore it is realised that everybody involved in the development and expansion of hydrogen applications and use needs to learn from past hydrogen accidents and incidents in order to prevent them in the future.

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