SIXTH FRAMEWORK PROGRAMME
Sustainable Energy Systems

NETWORK OF EXCELLENCE

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Safety of Hydrogen as an Energy Carrier

HIAD Specification and definition of its contents, operation and structure

Deliverable No 22

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Summary

This report describes the specification of the Hydrogen Incident & Accident Database (HIAD) to be developed under HYSAFE. It gives the background motivation for developing HIAD, its database structure, data collection and quality assurance, operational and data confidentiality aspects as well as the development process to be performed under the next 18 months period.

It shall be noted that HIAD will not become a standard industrial accident database, but a collaborative and communicative process in the form of a web-based Information System to promote safety actions taken by industrial and other partners as a consequence of hydrogen related incidents and accidents.

Keywords: Hydrogen events, HIAD, database development, safety, risk deliverable 22

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1 INTRODUCTION

1.1 Background

Under the EU's 6th framework programme, a Network of Excellence project named *HySafe – Safety of Hydrogen as an Energy Carrier* has been established.. The formal kick-off meeting was held 31/03-01/04/2004 and organised by the project co-ordinator Forschungszentrum Karlsruhe GmbH.

As stated in Annex I – Description of Work (DoW) dated 12/12/2003:

The HySafe network will focus on safety issues relevant to improve and co-ordinate the knowledge and understanding of hydrogen safety and support the safe and efficient introduction and commercialisation of hydrogen as an energy carrier of the future, including the related hydrogen applications. The overall goal of HySafe is to contribute to the safe transition to a more sustainable development in Europe by facilitating the safe introduction of hydrogen technologies and applications.

A number of work packages (WPs) was defined, 17 in total, for the first 18 months of the project, with the participation of 25 partners.

One specific WP was devoted to database development, namely the **WP5 – Hydrogen Incident and Accident Database (HIAD)** which will be described in more detail in the sections below.

HIAD is defined in the DoW to be one of the Integrating Activities and thereby having a central position in the project. Hence, it will be important to communicate and acquire input from other WPs. Initially the most relevant ones are 1, 4, 7, 9-13, and 17. In this phase the work being done in these WPs is particularly important in defining the needs and requirements for HIAD which have to be accounted for in the development of the database. Input from WP12 is considered most important at this stage.

HIAD will be one of the tools for communication of risks associated with hydrogen to all partners and beyond, which is one of many intentions that the HYSAFE project has. For all persons involved in risk management, it is realised that learning from past accidents and incidents helps you to prevent them in the future. Hence, this shows the importance of having access to databases holding accident and incident information.

The use of incident databases as a management tool provides an opportunity for organisations to check its performance, learn from its mistakes, and improve its management systems and risk control. Knowledge of events having the potential for inducing hazardous situations will also contribute to the corporate learning and memory.

1.2 WP5-HIAD organisation and budget

The WP5 work has been lead jointly by DNV and JRC. In addition, WP5 involves 6 companies and institutions who will serve as important discussion partners. This co-operation is vital since it will enable sharing of experience with databases and hydrogen, clearly define what is needed and required from HIAD and its practical use, and to verify and help DNV/JRC such that the development stays on the right track. In addition, these partners will serve as an important resource for where to find relevant data, to identify existing reporting regimes and to share their own experience with accident/incident recording. The table below shows all the participants and the estimated contribution (man-months) from each.

Table 1: WP5-HIAD organisation and budget

	Company	*No. of person-months*	*Company representative name*	*Company representative details*
Lead	Det Norske Veritas AS (DNV)	5	Espen Funnemark	E-mail: espen.funnemark@dnv.com Tel: +47 67 57 74 94 Fax: +47 67 57 99 11 Address: Veritasveien 1, N-1322 Høvik, Norway
	European Commission - Directorate-General Joint Research Centre (DG JRC) - Institute for Energy (JRC-IE)	4	Christian Kirchsteiger	E-mail: christian.kirchsteiger@jrc.nl Tel: +31 224 56 5118 Fax: +31 224 56 5641 Address: Westerduinweg 3 - 1755 LE Petten, Holland
Partners	Institut National de l'Environnement industriel et des RISques (INERIS)	0.5	Nicolas Dechy	E-mail: nicolas.dechy@ineris.fr Tel: +33 3 4455 6506 Fax: +33 3 4455 6200 Address: Parc Alata, B.P. n°2 60 550 Verneuil en Halatte, France
	VOLVO Technology Corporation	0.5	Paul Adams	E-mail: paul.adams@volvo.com Tel: +46 31 772 4680 Fax: +46 31 772 4070 Address: Dept 6120 CTP, SE-412 88 Göteborg, Sweden
	TNO Prins Maurits Laboratory Division Munition Technology and Explosions Safety - Research Group Explosion Prevention and Protection	0.5	Nico Versloot	E-mail: versloot@pml.tno.nl Tel: +31 15 284 34 65 Fax: +31 15 284 39 54 Address: Lange Kleiweg 137, 2280 AA Rijswijk, The Netherlands
	Norsk Hydro ASA	0.5	Ms. Sandra Nilsen	E-mail: sandra.nilsen@hydro.com Tel: +47 35 92 39 66 Fax: +47 35 92 32 63 Address: P.O. Box 2560, N-3908 Porsgrunn, Norway
	L'Air Liquide	1	Mr. Jean-Yves Faudou	E-mail: jean-yves.faudou@airliquide.com Tel: +33 1 406 25 678 Fax: +33 1 406 25 011 Address: 75, quai d'Orsay, F-75321 Paris Cedex 07, France
	The Health and Safety Executive	0.5	Mr. Gordon Newsholme	E-mail: gordon.newsholme@hse.gsi.gov.uk Tel: +44 151 951 4761 Fax: +44 151 951 3602 Address: Room 342, Magdalen House, Stanley Precinct, Bootle, Merseyside L20 3QZ, United Kingdom
	Total no. of man-months:	12.5		

1.3 WP5-HIAD objectives and purposes

As outlined in the DoW the overall objective of HIAD in this first phase of the HYSAFE project (months 1-18) is to reach an agreed specification and definition of the database content and structure. It is important to note that developing the actual database/software application and populating the database with past event information is not part of the scope of work for this first phase.

More specifically, HIAD will:

- Contribute to the integration and harmonization of fragmented experience and knowledge on hydrogen safety in Europe across professions and countries.
- Contribute to the progress in common understanding of hydrogen safety and risk; which are the hazards, causes and consequences of accidents/incidents associated with hydrogen.
- Be a harmonised tool for safety and risk assessment providing input to risk management, CFD studies, safety assessment, and risk analysis. E.g. for Quantitative Risk Analyses (QRA) this involves input to the hazard identification, release frequency and ignition probability estimations, cause and consequence evaluation, etc. HIAD should also enable generation of common generic accident and incident statistics.
- Be a common basis for hydrogen risk management and studies to quantify the risks associated with hydrogen applications.
- Keep the industry updated with recent accidents/incidents involving the use of hydrogen, along with trend analyses; should aim to be the source for hydrogen accident/incident information.
- Serve as a common methodology and format for hydrogen accident/incident data collection and storage.
- Be a source for understanding hydrogen accident phenomena and scenarios and hazard potential; what are the hazards; what can go wrong, how and why do accidents/incidents develop, etc.
- Encourage and facilitate industry partners to share experience. One single partner may experience only a few (or no) own accidents. But by having access to a pool of events experienced by others (HIAD) will give him a better and wider basis for decisions related to risk mitigation measures, emergency preparedness, etc.

HIAD will, when fully operative, be a central European hydrogen accident and incident database and a reporting regime/platform which will fulfil the objectives set out for HIAD and for HYSAFE in general. But the first step on the way to achieve this is to defining how HIAD should be developed and operated, which is the main work in WP5.

1.4 WP5-HIAD scope of work and deliverables

In the DoW the WP5 work is divided into the following two subtasks 5.1 and 5.2.

<u>Subtask 5.1.</u>

Develop a common methodology and format for data collection (i.e. database structure). Discuss and obtain consensus on data confidentiality aspects, i.e. decide on the extent of anonymisation of information in the database. Define the structure of the database. Define inclusion criteria, i.e. what type of events should be recorded in the database.

<u>Subtask 5.2</u>.

Obtain background information by performing screening of relevant existing databases (of the partners or databases accessible by partners) and reporting regimes. Clarify whether the database should include population/exposure data. Decide on database operation, maintenance and availability.

The work to be undertaken in these two tasks may be broken down and detailed as shown below.

- Develop a common methodology and format for data collection. Harmonise/standardise the way of recording, what should be recorded and how it should be stored. A kind of "best practice" or "standard".
- Discuss and obtain consensus on data confidentiality aspects. HIAD is intended to hold information from various data providers. It is therefore of utmost importance that there is common understanding in what way and on which level the data records should be anonymised in order not to reveal the source.
- Define inclusion criteria, i.e. what type of events should be recorded in the database; accidents, hazardous situations/incidents (potential for developing into accidents), near-misses and occupational accidents. The decision should be weighted against the current and past degree/level of recording of hydrogen events and the potential use of this information in the future.
- Identify user needs and requirements. Input from WP5 partners and other WPs.
- Perform screening of relevant existing databases. Mapping activity – "state-of-the-art". WP5 partners play an important role here. Serve as basis for HIAD specification.
- Clarify how to deal with equipment/system exposure data. This type of data is needed in order to calculate accident/incident frequencies and probabilities. The decision whether such data should be part of HIAD (or as a supplementary/separate dataset) has to account for the main use of HIAD in the future. Nevertheless, such data collection work is extremely difficult and time consuming. <u>Found not feasible at this stage.</u>
- Define a reporting regime. Based on the screening activities and the established needs and requirements it will be defined how hydrogen accident/incident data should be submitted to HIAD.
- Define the structure of the database. Based on the screening activities and the established needs and requirements it will be defined how hydrogen accident/incident data information should be represented in HIAD.
- Define how the database should be operated and maintained and kept up-to-date. This task will deal with how HIAD should be operated and by whom and how the operation should be financed. The operation of HIAD will comprise systemisation, error checking and verification of received data, support data providers, provide HYSAFE with statistics and case descriptions, do marketing, etc.
- Define database availability/accessibility and IT solution. This concerns the database application and selection of IT platform. The chosen solution has to bear in mind the

HYSAFE's goal of HIAD being a ***fast, reliable and easily accessible source of hydrogen accident/incident information***. It is important to plan for a tool with a high level of user-friendliness through an excellent user interface. This task should also identify possible software developers of HIAD with a corresponding budget.

This report, which is the main deliverable from WP5 to the HYSAFE project in this phase, is also intended to serve as an important basis for the actual IT development which is planned for in the next phase of HYSAFE (months 18->).

2 SURVEY OF RELEVANT DATABASES

2.1 Purpose

During the work of defining the HIAD database structure, a number of well known and relevant accident databases covering a wide range of industries were identified and investigated in order to create ideas and take advantage of already existing and well proven solutions and data formats. It should be noted that these databases hold information about hydrogen accidents, but none of them with the only scope of storing events related to hydrogen.

In addition, the purpose of conducting this survey was also to identify potential sources of hydrogen accidents and incidents which could be utilised in the future work of populating HIAD with relevant historical hydrogen events. The various database operators have to be contacted in order to clarify whether their data could be shared and in what way.

2.2 Results and implications

The databases being survey were the following (in alphabetical order):

- Air Liquide's internal database
- ARIA – Analyse, Recherche et Information sur les Accidents (Barpi)
- PSID – Process Safety Incident Database (CCPS)
- EIGA (European Industrial Gas Association)
- FACTS – Database for accidents with hazardous materials (TNO)
- HCLIP – HydroCarbon Leak and Ignition Project database (DNV)
- IChemE database (Institute of Chemical Engineers (IChemE))
- MARS - Major accident Reporting System (JRC Ispra – MAHB)
- WOAD – Worldwide Offshore Accident Databank (DNV)

The survey clearly shows that none of the consulted databases are sufficiently detailed and specified for hydrogen applications and complying with the aims and objectives of HIAD. Creating a database not only to be used for storage and retrieval of information would require another level of detail and specifications. Hence, it was found necessary to develop the HIAD database structure in such a way that sufficient details about e.g. causes, releases, fires, explosions and consequences are assured. In addition, in order to avoid that HIAD only focuses on the negative effects of an accident, it was decided that it also should contain information about post-event actions when and if performed, would increase safety in the future.

3 PURPOSE AND USE

The overall purpose of HIAD is to assist all stakeholders (industry, authorities, general public) in better understanding the relevance of hydrogen-related incidents and accidents as well as the safety actions taken and to provide a methodology to contribute towards improving hydrogen-related risk assessment and management.

It is of utmost importance to highlight **that HIAD is not a standard industrial accident database tool but a collaborative and communicative process in the form of a web-based Information System to promote safety actions taken by industrial and other partners as a consequence of hydrogen related incidents and accidents** (See also Section 5).

The reason for this conceptually new and innovative approach is the unfeasibility of the "classical" alternatives:

- There is currently no European or other international legislation which would make it mandatory to report hydrogen related incidents and accidents to a closed, partly open or open user group; therefore, a classical database reporting scheme with a group of data providers and a set of obligations put together in Terms of Reference (ToR) does not work for HIAD. JRC made this exercise with HYSAFE during the first 18 months period and the feedback on the proposed ToR was almost entirely negative.
- Further, as we are dealing here with a still largely new and rapidly developing technology, there is currently not sufficient trust among industrial partners to share knowledge among a closed user group consisting of other industrial partners; therefore, again, a classical "lessons learnt from accidents" type of database does not work for the case of HIAD.

It is for this reason that JRC and DNV chose a conceptually different approach for developing and operating HIAD:

The **HIAD philosophy** must be expressed in two phases: a **Trust-building Phase** and a **Trust-acquired Phase**. The former is dedicated to building trust amongst all stakeholders vis a vis hydrogen-related incidents/accidents. This will probably last the duration of the HYSAFE project (3 years). The latter phase would realistically start once a cross-sectoral and multi-disciplinary hydrogen risk culture across the various interest groups has been established. However, once a User Working Group (UWG) is established that fully interacts with the HIAD Process, then it would be possible to consider that the Trust-acquired Phase has started.

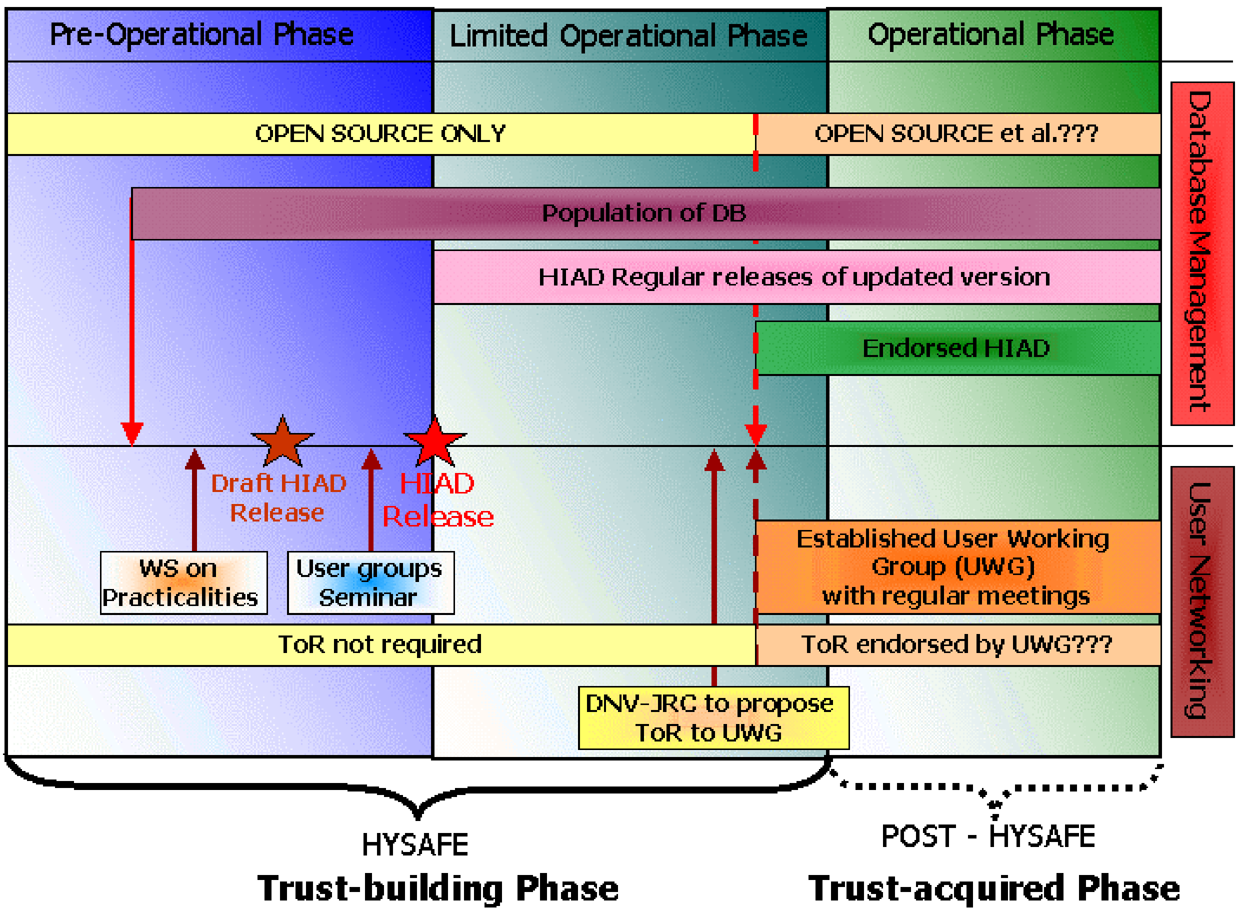
The **HIAD Process** is subdivided into 3 phases*: pre-operation* (before the HIAD release), *limited operational* (regular updates of HIAD to HYSAFE-selected users) and *operational* (regular updates of HIAD to unlimited users). Figure 1 portrays this subdivision.

HIAD aims to:

- ***Collect information on hydrogen-related events***. A flexible web-based architecture, with a user-friendly interface will be created to collect information on hydrogen-related events. Initially, this information will come from publicly available open sources (Trust-building Phase). In the long-term (after HYSAFE period), a common user-driven methodology of data collection is envisaged, supported by endorsement from a User Working Group (Trust-acquired Phase).

- ***Provide stakeholders with unbiased information hydrogen-related events***. During the Trust-building Phase, information on events from open source will be collected and put together. Industrial and other partners within HYSAFE are encouraged to report their own versions of the same events in order to highlight (their) safety actions taken and illustrate differences in risk perception from different sources. Thus, "unbiased" information will be made available to stakeholders as an outcome of a communicative process. During this phase, the stakeholders will be limited to those identified by the HYSAFE Consortium. However, it is envisaged that during the Trust-acquired Phase, HIAD will be made available to a wider range of interest groups (operators, authorities, general public, etc.).
- ***Communicate information on hydrogen-related events***. Lessons learned, good practice, etc. are valuable information that could be derived from HIAD. Thus, during the Trust-building Phase, information from open source will be analysed anonymously and communicated to all interested users, including the HYSAFE Consortium. During the Trust-acquired Phase, HIAD will provide a more targeted service that spans various interest groups (operators, authorities, general public, etc.).

Figure 1: HIAD Timeline Overview

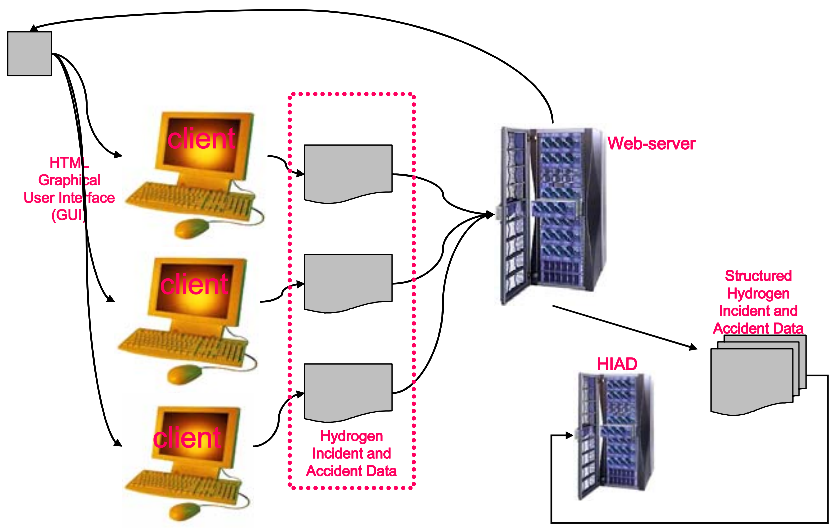


4 HIAD DATABASE STRUCTURE

The main challenge when specifying HIAD was to develop a tool that should serve various purposes such as being a data source for risk assessments, experience transfer and risk communication. In addition it should be easy to use, the user friendliness encompassing the tasks of recording and extraction of information/data by having a professional and modern user interface, was given high priority. As mentioned earlier, the threshold for including an event in HIAD should only be that the event has any relation with hydrogen.

The planned user/system interface is shown graphically in Figure 2.

Figure 2: HIAD user/system interface



The six building blocks of HIAD are illustrated in Figure 3.

Figure 3: HIAD building blocks

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

The HIAD database structure should be such that the information held by HIAD should be relevant for risk assessment exercises and related modelling development work. In addition, the information recorded for each event should be such that it serves the objective of corporate learning about risks and safety related to hydrogen applications.

Details about each field being defined to be included in each of the 6 blocks are outlined in full in Appendix A. In addition, suggested and non-exhaustive option lists are given in Appendix A for some of the fields/entries in the database.

However, some examples of fields and required information for each block are given in the following Table 4.1.

Table 4.1: Examples of fields in the HIAD database

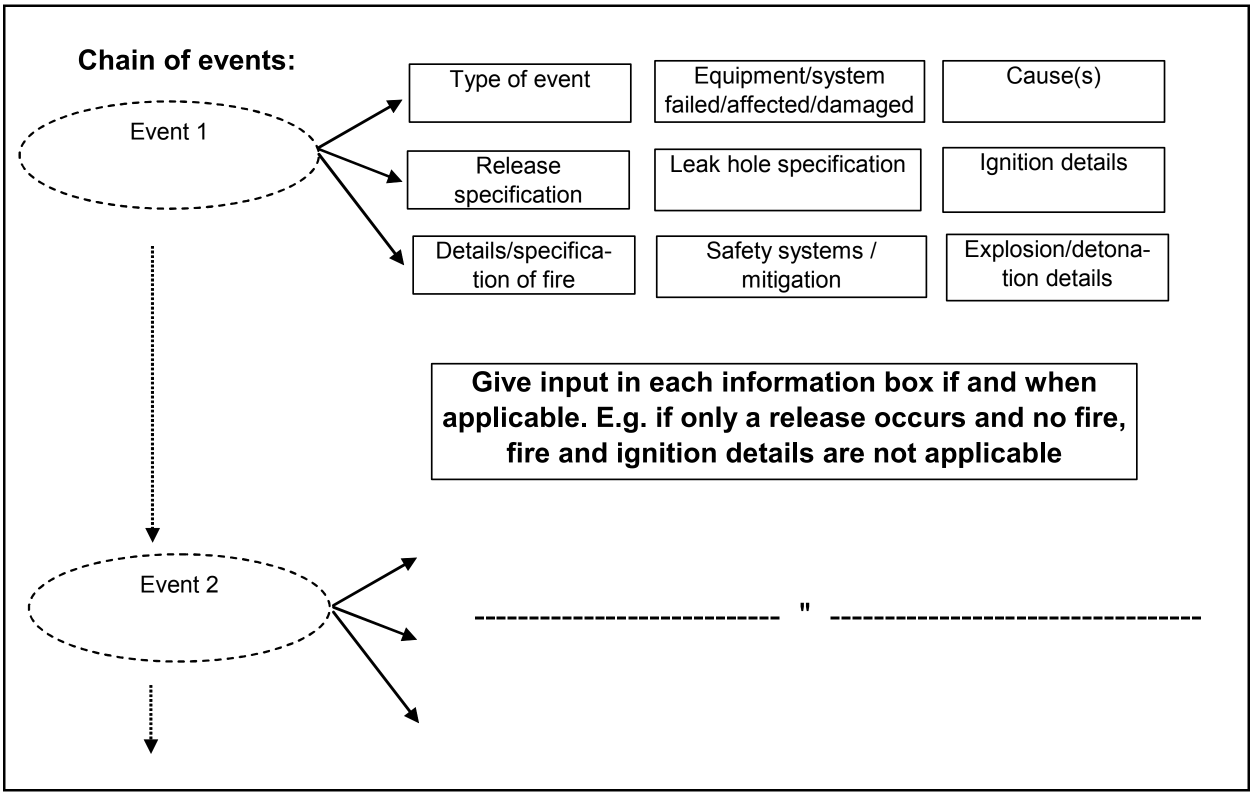
1. HIAD Administration	• Index • Information sources • Dates of entry and last revision • HIAD operator and data provider details
2. Pre-event conditions	• Date and time of event • Weather conditions • Geographical location • Type of H2 application • Operation phase or mode
3. Nature of event	• Systems and components affected or involved • Chain of events • Causal relations • Relevant safety systems and emergency response • Releases, fire and explosion specifications/details
4. Consequences of event	• Fatalities and injuries • Property, environment and economical loss and damage; description and costs involved
5. Post-event actions	• Clean-up and restoration • Legal/legislation initiatives • Lessons learned • Investments made
6. References	• Hyperlinks/references to files and documents, web-sites, etc. • Specification of attachments, e.g. maps, drawings, photos, etc

Recording of information in the various fields in the database will be through a combination of pre-defined option lists (drop-down or tick-box types) and free text. It should be noted that the status of the suggested option lists (as shown in Appendix A) shows that refinements and detailing is required. This work is planned as part of the specification for actual software development.

Regarding input in the numerical fields it will be clearly indicated what unit should be used. The SI system will be used for that purpose to the extent possible. Furthermore, a free text possibility should be available for every field/entry to specify further or explain in detail the selected option/code.

Regarding HIAD information block 3 – Nature of event, it is proposed that relevant details should be given for each event in the defined chain of events, which constitutes the full accident scenario. The required input is depending on type of event. This is illustrated in the following Figure 4.

Figure 4: Illustration of input requirements for chain of events



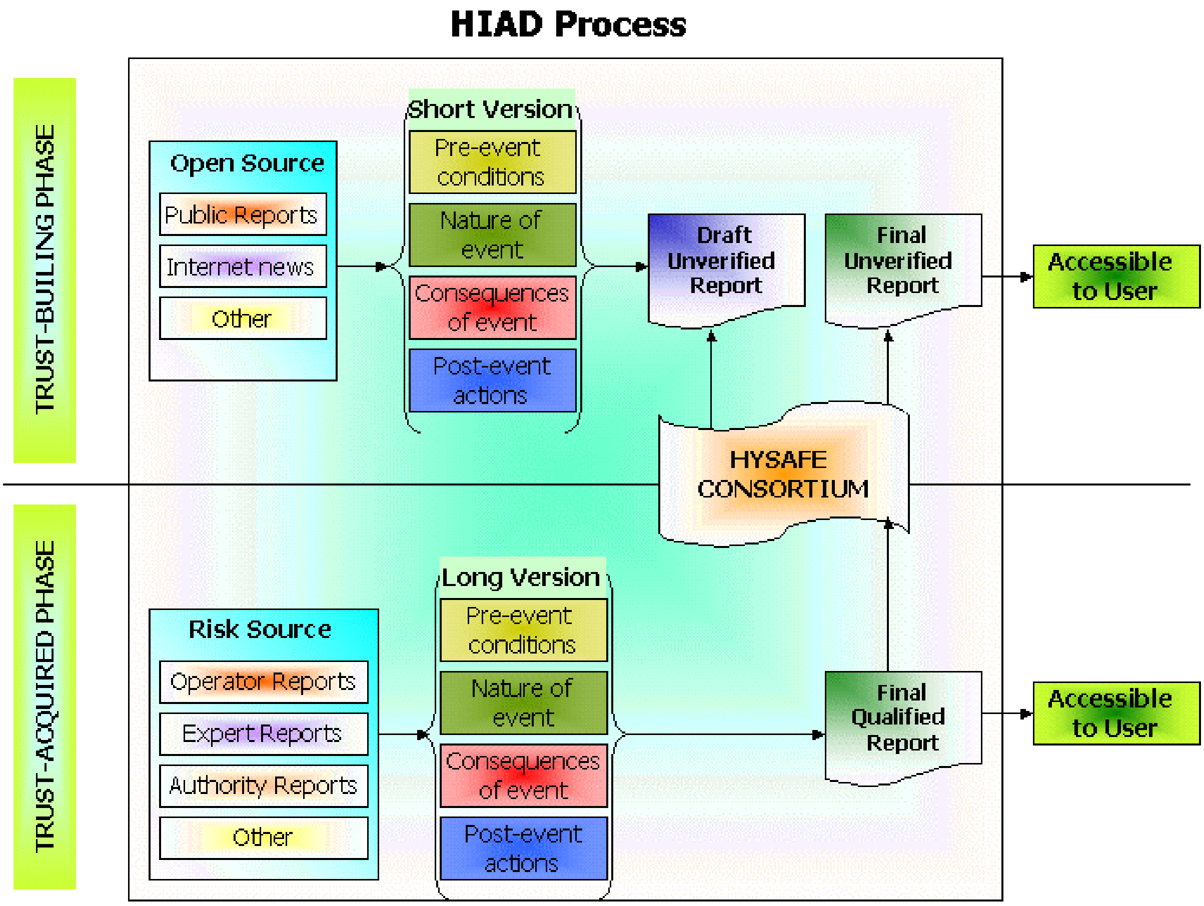
5 DATA COLLECTION AND QUALITY ASSURANCE

As described above, in the initial *Trust-Building Phase*, data are collected from JRC, DNV and other HYSAFE partners from public reports, Internet news and other sources (e.g. provided by industrial partners within HYSAFE). This information is then transformed by DNV and JRC into "short versions" of HIAD event reports, the *draft unverified report* can be commented by the HYSAFE Consortium (ideally the risk source owner, i.e. mostly industry) before it is becoming a *final unverified report* stored in HIAD and accessible to all HIAD users.

In the ensuing *Trust-Acquired Phase*, risk source owners themselves insert the necessary information, such as operator reports, expert reports, authority reports, directly in the web-based HIAD application. This is done in the format of a "long version" of a HIAD report. Next, the report is checked for Quality Assurance by DNV and JRC, and a *final qualified report* is then accessible to all HIAD users via the web-based application.

In other words, information on hydrogen incidents and accidents becomes qualified as soon as it is compiled by the risk source owners themselves.

Figure 5: HIAD Process



6 OPERATION OF HIAD

From the above Figures 1 and 5 the operational process of HIAD is already defined. As mentioned, the HIAD Process is divided into three phases:

- *Pre-operation*.
- *Limited operational*.
- *Operational*.

7 DATA CONFIDENTIALITY ASPECTS

As already mentioned above, from the very start of the HYSAFE project, JRC and DNV found it important to prepare a document for each of the HYSAFE Consortium partners to sign in order to assure that hydrogen (related) accident and incident data was shared among the partners through the HIAD. A "Terms of Reference" (ToR) / "Memorandum of Understanding" (MoU) was prepared and circulated to the WP5 partners. Comments were received and in conclusion the document was found too formal and signing such an agreement was not possible without a legal (company internal) review upfront. The reasons, essentially related to lack of trust among partners regarding data confidentiality, have already been described in Section 3.

Hence, in conclusion it was decided to leave the formal concept of a ToR/MoU and try to deal with the problem through alternative means which have been outlined in Sections 3, 5 and 6 of this report. The selected solution is intended to assure that all HYSAFE partners will contribute to the work with populating HIAD and thereby overcoming the issue of confidentiality.

8 ACHIEVEMENTS

The achievements being obtained during the first 14 months of the work with WP5 and the HIAD database are complying with the objectives set out in the DoW. More specifically:

- A common methodology and procedure for data collection is developed.
- Inclusion criteria, i.e. what type of events should be recorded in the database, are defined
- Ways of handling the issue of data confidentiality are defined.
- Screening of relevant existing databases and reporting regimes is performed in order to create ideas and take advantage of already existing and well proven solutions and data formats.
- The structure of the database is defined; i.e. an agreed format of how hydrogen related events' data information should be represented in HIAD.
- Operation and maintenance of HIAD is defined. This includes e.g. systemisation, error checking and verification of received data, support data providers, etc.
- HIAD availability/accessibility and IT solutions is proposed.
- Basis for the actual development of HIAD is prepared and is documented in this report

The WP5 work has also contributed to the important task of *Integration* through:

- All HYSAFE partners was invited to comment on HIAD proposal
- Consensus among the partners of WP5 on the database structure

- Utilising skills and experience across professions within the group and beyond
- The HYSAFE partners are planned to take an active part in the work for populating the database with past and future events
- Producing a tool to be shared and used by the partners in the Consortium

9 NEXT STEPS

The further work with HIAD is outlined in the WP5 JPA for the months 13-30. This encompasses the development of the HIAD software application and the work with populating HIAD with relevant historical hydrogen events. Both these tasks are discussed in more detail in the two sub-Sections below.

9.1 Future development of the software application

The objective of this task is to develop a fully operable web-based HIAD database application based on the basic specifications outlined in this report, see Section 4 and Appendix A. The application should enable recording, storage, retrieval and analysis of hydrogen event data. It is proposed that HIAD should be located on the JRC server with a direct link to the general HYSAFE website. According to the proposed time schedule, the application should be available by month 26, i.e. 1 May 2006.

Due to its experience with development and operation of similar types of EU level event databases in the past, it has been agreed that JRC-IE, Petten, will perform the software development.

Throughout all development phases follow-up, software testing, and trials and quality assurance will be performed. More specifically, the following work tasks are identified:

- Introduce and present the HIAD concept to the developer
- Evaluate developer's proposal for work
- Refine and complete the HIAD specifications given in this report to comply with developer's requirements
- Follow up developer's work through close co-operation
- Test functionality, user interface, layout, etc, and define needs for updates
- Prepare and agree a maintenance plan with developer
- Prepare necessary documentation to assure proper operation and use and consistency in the data
- Facilitate installation and access of application
- Prepare for continuous and future recording

9.2 Populating HIAD

As soon as the HIAD software is ready for use, the work with populating the database with past events should start along with quality assurance activities of input. However, identifying potential data sources and preliminary data collection is foreseen to start much earlier and could be performed in parallel with the software development. Please refer to Section 5 for details. According to the proposed time schedule, the data collection and recording in the database should be completed by month 30, i.e. September 1 2006. From this point in time and on, provisions should be made such that HIAD is populated with new hydrogen events on a continuous basis.

10 REFERENCES

APPENDIX A
HIAD DATABASE STRUCTURE- DETAILS

In this Appendix all details related to the proposed HIAD database structure is outlined together with a brief explanation of the various fields/parameters and the proposed units/formats and options/codes to be used. Furthermore, some fields are identified as requiring an explicit "option list" and hence such lists are attached. Please note that these lists are non-exhaustive and preliminary at this stage and hence, they are to be completed as part of the actual software development work. It is foreseen that the user accesses the option lists and make a selection either via tick-boxes or drop-down lists. Details about all aspects related to the user interface will be worked out during the early phases of the database application development.

A.1. HIAD database structure

FIELD/ DESCRIPTOR number	FIELD/DESCRIPTOR	COMMENTS/SPECS
1 - ADMINISTRATION		
1-1	Event code/index	Unique event number (index) for identification and reference. In order to accommodate for the possibility of having more records on the same event, the format is suggested being as follows. However, only one qualified record per event will be allowed. Records with *unverified* information: U<3-digit number unique for the event><3-digit number for multiple entries of the same event><year of event, 4 digits> Records with *qualified* information: Q<3-digit number unique for the event><year of event, 4 digits>
1-2	Data provider	E.g. name of person and affiliation and/or company. Free text
1-3	Date of entry	Format: DD/MM/YYYY. A "calendar picker" will be used to ease input
1-4	Type of information source(s) and specification	E.g. company internal reports and documents, public domain information, research reports, other databases, etc. Specify in more detail in free text
1-5	Date of last revision	Format: DD/MM/YYYY. A "calendar picker" will be used to ease input
1-6	Revised by	HIAD Operator id/signature/name
2 - PRE-EVENT CONDITIONS		
2-1	Date of accident	Format: DD/MM/YYYY. A "calendar picker" will be used to ease input
2-2	Part of day	Morning, noon/lunchtime, afternoon, evening, night
2-3	Time of day of accident (initial/start)	Hour of day, 00-23 hrs
2-4	Weekday	Monday - Sunday
2-5	Season	Winter, spring, summer, autumn
2-6	Weather conditions - Visibility	m
2-7	Weather conditions - Type of weather	Rain, snow, fog, thunder, etc
2-8	Weather conditions - Temperature on location	ºC
2-9	Weather conditions - Wind speed	m/s
2-10	Weather conditions - Wind direction	N, NE, E, etc
2-11	Weather conditions - Humidity	%

FIELD/ DESCRIPTOR number	FIELD/DESCRIPTOR	COMMENTS/SPECS
2-12	Accident scenario (comprising the whole chain of events) identified in a kind of risk assessment?	Yes/no. If yes, specify: * Risk assessment known to the risk source owner before the event? * Who did the risk assessment * When was the risk assessment done (date) * Type of analysis technique applied * Estimated frequency * Reference
2-13	Geographical location	Country, state/county, place, road number, address,… (standardised format). Introduce option list on 'country' to ease input. Location co-ordinates (standard format)
2-14	Application	Production plant, Transport and distribution, Refuelling stations (Including production at refuelling station) and stationary applications, Road vehicles (lorries, commercial/private cars,….), Other propulsion systems/vehicles (off-road vehicles, trams, ships, aerospace….), Portable applications, Other applications. *Ref option list* ***Application***
2-15	Storage/medium	Gaseous, Liquid, Other
2-16	Storage quantity	m3
2-17	Actual pressure	bara/barg/psi
2-18	Design pressure	bara/barg/psi
2-19	Location description (on-site/local, where accident takes place)	Industrial plant, Open/suburban, Urban (street canyon); vehicles, Enclosure (private/public/maintenance garage,..), Tunnels/overbridges, Buildings, etc., Refuelling stations (vehicles), Covered bus stations, loading bays (vehicles), Other
2-20	Potential ignition sources	Identification of potential ignition sources, i.e. the ones which were present at the time of accident
2-21	Surroundings description (off-site next to or in the vicinity of where accident takes place)	If applicable. Other road, populated area, buildings/houses, park, other industry, etc
2-22	Stage of application	Laboratory (experiments), Field testing (demo applications, full scale demos, etc), Commercial use
2-23	Phase of operation mode or activity shortly prior to or during accident	Examples: Production - maintenance/shut down, public use - vehicle driving, etc.
2-24	Potential consequences	Free text. Evaluate/discuss maximum potential loss in case of e.g. failure of safety systems (causing escalation), less efficient emergency actions, unfavourable weather conditions, more traffic and parked cars, etc.
2-25	Description/summary of pre-event conditions	Free text. To be used for both "unverified" and "qualified" information records
3 - NATURE OF EVENT		
3-1	Describe/list of systems and equipment involved/failed/affected/damaged in the event	Free text, supported by a scanned drawing if found necessary
3-2	Event causing the most damage	H2 release, H2 fire, H2 explosion, H2 not involved ("external event", but affecting/ damaging/ threatening

FIELD/ DESCRIPTOR number	FIELD/DESCRIPTOR	COMMENTS/SPECS
		H2 application/equipment)
The following information shall be recorded for each event in a chain of events which constitute the undesired outcome:		
3-3	Type of event in the chain of events	*Ref option list* ***Event***
3-4	Cause(s)	Categories: Equipment, human, environment/external, "other" Specification: *Ref option list* ***Cause*** Identify whether direct or indirect cause No fixed no. of entries ->user defined
	Safety system(s):	I.e. engineering as well as organisational measures
3-5	Safety system(s) installed for mitigating/controlling/preventing this event (in the chain) to occur	Manual or automatic. Specification; technical description, function, etc. Specify each one separately if several. : *Ref option list* ***Safety system***
3-6	Safety system(s) worked OK (preventing further escalation/development)	Specify. Ref. list in field above.
3-7	Safety system(s) failed/impaired	Specify. Ref. list in field above
3-8	Emergency action(s) taken	Specify action related to evacuation/rescue, consequence mitigation (procedures, people involved, etc),
3-9	Evaluation of emergency action(s) taken	Specify what was OK, and what did not work according to procedures or intention
H2 Release: Numbers recorded may either be exact and measured values or estimated values		
3-10	Release type	Liquid or gas, compressed, mixtures
3-11	Release concentration	H2 % in carrying or surrounding medium
3-12	Release duration	Time period from start of unwanted release to its containment. To be given in seconds
3-13	Initial release rate	m3/s
3-14	Pressure of release source	bara/barg/psi
3-15	Release amount/volume, total	m3
Release of other agent(s):		
3-16	Type	Liquid or gas
3-17	Name	Name of substance
3-18	Concentration	% in carrying or surrounding medium
3-19	Duration	Time period from start of unwanted release to its containment. To be given in seconds
3-20	Initial release rate	m3/s
3-21	Released amount/volume, total	m3
Leak hole specification:		
3-22	Hole shape	Crack, gap, rectangular, circular/near circular, other shape
3-23	Hole dimension, length	mm
3-24	Hole dimension, width	mm
3-25	Hole dimension, diameter	mm
3-26	Hole dimension, "other"	Describe
3-27	Hole area	E.g. in sq mm (calculated, estimated)

FIELD/ DESCRIPTOR number	FIELD/DESCRIPTOR	COMMENTS/SPECS
Ignition details:		
3-28	Ignition occurred	Yes/no
3-29	Ignition delay time	0 for Immediate, when delayed give the time in e.g. seconds
3-30	Ignition source(s)	Specify the ignition source(s) causing the fire
Details/specification of fire:		
3-31	Cloud size	Area (m2) and volume (m3)
3-32	Flame size	Area (m2) and volume (m3)
3-33	Flame type	Jet, flash,…. Include lengths (m)
3-34	Heat radiation	MW/m2
Explosion/detonation details:		
3-35	Detonation/deflagration	Yes/No. If yes, describe extent of damage caused by the detonation/deflagration in free text
3-36	High pressure storage explosion	Yes/No. If yes, describe extent of damage caused by high pressure in free text
3-37	Electric: High voltage exposure	Yes/No. If yes, describe extent of damage caused by the high voltage exposure in free text
3-38	Description/summary of nature of event	Free text. To be used for both "unverified" and "qualified" information records
4 - CONSEQUENCES OF EVENT		
4-1	Number of persons affected	On-site, Emergency/rescue personnel, off-site
4-2	Number of persons at risk	On-site, Emergency/rescue personnel, off-site
	Victims:	
4-3	Fatalities	Distribute no of fatalities, part of body affected, etc as per "type of person" (position/function….). **See section A3 for further details**
4-4	Injuries	Distribute no of injuries, part of body injured/affected, type of/severity of injury, etc as per "type of person" (position/function….). **See section A4 for further details**
4-5	Environmental/ecological damage	Describe in free text long term and short term consequences including the extent/time of delay
4-6	Property loss (type) - Establishment/ plant	Specify in detail as much as possible in free text
4-7	Property loss (type) - off-site property	Specify in detail as much as possible in free text
4-8	Economical loss (monetary) - Establishment/ plant	Specify in detail the breakdown of cost of damaged property, loss of production, reputation, trust, etc. in free text
4-9	Economical loss (monetary) - off-site property/3rd party	Specify in detail the breakdown of cost of damaged property, loss of production, reputation, trust, etc. in free text
4-10	Cost of emergency response actions	Specify in detail the breakdown of cost in free text
4-11	Cost of clean-up and restoration	Specify in detail the breakdown of cost in free text
4-12	Description/summary of consequences	Free text. To be used for both "unverified" and "qualified" information records

FIELD/ DESCRIPTOR number	FIELD/DESCRIPTOR	COMMENTS/SPECS
5 - POST-EVENT ACTIONS		
5-1	Clean-up and restoration actions	Describe in free text which/any actions that have been undertaken in the work for normalisation/reconstruction
5-2	Event investigation undertaken	Yes/no. If yes, specify undertaken by whom in free text
5-3	Research investments based on results of the event investigation	Yes/no. If yes, specify in free text (not mandatory)
5-3	Official/authority actions taken - Legal/legislation changes	Yes/No. If yes, describe in free text
5-4	Official/authority actions taken - Other measures/actions	Yes/No. If yes, describe in free text
5-5	Lessons learned - Measures/remedial actions taken to prevent recurrence e.g. technical, organisational	Describe in free text
5-6	Lessons learned - Measures taken to improve/upgrade emergency response plans and equipment	Describe in free text
5-7	Investment in risk-awareness raising and communication initiatives	Yes/No. If yes, describe in free text
5-8	Description/summary of consequences	Free text. To be used for both "unverified" and "qualified" information records
6 - REFERENCES		
6-1	Links	Files, web-sites, publications, etc
6-2	Attachments (if available and not compromising confidentiality/anonymity)	Maps, photos, etc

A.2. Option lists

In general, if none of the available options is applicable, use option "Other" and specify/explain in free text. As stated before, these lists are preliminary and will be detailed, adjusted and completed in the next phase of WP5.

(i) Applications

1. Production	2. Transport and distribution	3. Refuelling stations and stationary applications
1.1 thermo-chemical	2.1 pipeline GH2	3.1 Hybride beds
1.2 electrolysis (small scale at refilling station)	2.2 pipeline LH2	3.2 LH2 tanks
1.3 Biological (photosynthesis in cyanobacteria and algae)	2.3 pipeline mixture NG/H2 (NATURALHY)	3.3 GH2 tanks
1.4 Biomass fermentation	2.4 truck transport of compressed GH2	3.4 Refuelling station cryogenic H2
1.5 Biomass pyrolysis / gasification	2.5 truck transport of LH2	3.5 Refuelling station GH2
1.6 steam/methane reforming	2.6 sea transport of compressed GH2	3.6 Refuelling station blend CNG/GH2
1.7 Partial oxydation of hydrocarbons	2.7 sea transport of LH2	3.7 Stationary application
1.8 Thermo-chemical	2.8 Refuelling station cryogenic H2	
1.9 Coal gasification	2.9 Refuelling station GH2	
1.10 Photochemical processes		
1.11 Nuclear	2.10 Refuelling station blend CNG/GH2	
	2.11 rail transport of compressed GH2	
	2.12 rail transport of LH2	

4. Road vehicles (lorries, commercial/private cars,….)	5. Other propulsion systems/vehicles (off-road vehicles, trams, ships, aerospace….)	6. Portable applications
4.1 commercial vehicle	5.1 ships	
4.2 passenger car	5.2 aircraft	
	5.3 aerospace/rocket	
	5.4 motorcycles	
	5.5 trams	
	5.6 trains	
	5.7 wheelchairs	

(ii) Event

- Continuous H2 release in confined area
- Continuous H2 release in open atmosphere
- Continuous H2 release in partially confined atmosphere
- Detonation
- Explosion
- Fire/smoke
- Flow from safety valves/relief openings to unsafe location
- Flow inside tank
- Flow of hydrogen into container (confined area) from leak outside container
- Formation of explosive mixture inside application
- Formation of explosive mixture outside application
- Instantaneous H2 release in confined area
- Instantaneous H2 release in open atmosphere
- Instantaneous H2 release in partially confined atmosphere
- Mixing of oxygen/H2 inside process equipment
- Oxygen release inside container
- Reverse flow from downstream high pressure sections
- Other

(iii) Safety system

- Brake-away coupling
- Buried pipeline
- Continuous mechanical ventilation
- Cooling system
- Corrosion protection
- Design of building / tunnels to withstand hydrogen explosion
- Detector
- Early fire detection system
- Early leak detection system
- Emergency ventilation
- Explosion relief area/panel
- Fire extinguishing system
- Fixation/mooring/anchoring/fastening arrangement
- Flame arrestor walls
- Flame quenching system
- Flushing system
- Fragments' arrestor/protective walls
- Hazardous area classification
- Heat insulation
- Ignition probability reduction measure
- Inert atmosphere inside container
- Infrared thermic radiation scanning system
- Isolation system
- Layout/design of facility
- Mechanical reinforcement
- Odorization system installed
- Physical barrier to avoid external impact

- Physical isolation
- Physical protection to avoid external load
- Physical separation of potential leak sources
- Placement/location of critical equipment to avoid external impact
- Pressure monitoring system
- Pressure relief device
- Process operative arrangement
- Safe discharge of H2 release
- Safety distance
- Sensor
- Shutdown system
- UV thermic radiation scanning system
- Valve
- Ventilation, mechanical (specify number of air changes per time unit)
- Ventilation, natural (open space)
- Other

For each system identified, the recorder is asked to specify/describe the specific systems and if applicable, enter the number of systems or devices of the same type (e.g. 10 isolation valves, 6 flow meters, etc).

(iv) Cause

It is identified as necessary to work out categories for causal relations and factors depending on the actual hydrogen application and causal type, e.g. technical, environmental, human factor, etc. It is obvious that some causes may be general such that it is applicable for several applications. Hence, a matrix like the one shown below would be required. The matrix/table is not complete and is only included here for illustration purposes and just to give an indication of our intention and goal.

	APPLICATION				
CATEGORY/ GROUP	Production	Transport & distribution (rail, vehicle, pipeline)	Refuelling stations and stationary applications	Public use, cars, buses, etc.	Other propulsion systems/vehicles (off-road vehicles, trams, ships, aerospace….)
Technical/ mechanical	Component/ system failure or malfunction				
	Vessel/container failure				
	Instrument/control/ monitoring device failure				
	Corrosion/fatigue/material failure				
	Design failure/error				
	Chemical aggression (corrosion, incompatibility)				
	Thermal aggression (welding)				

	APPLICATION				
CATEGORY/ GROUP	Production	Transport & distribution (rail, vehicle, pipeline)	Refuelling stations and stationary applications	Public use, cars, buses, etc.	Other propulsion systems/vehicles (off-road vehicles, trams, ships, aerospace….)
Operation	Runaway reaction				
	Unexpected reaction/ phase-transition				
	Boil off and overpressure				
	Electrostatic accumulation				
	Excessive pressure build-up				
Human/ person	Operator error (e.g. wrong equipment/ tools used)		Driving off/backing while refuelling	Reckless driving	
	Operator health (includes ailments, intoxication, death, etc.)		Hose not properly connected	Road not properly maintained	
	Wilful disobedience / failure to carry out duties			Brakes not activated	
	Malicious intervention			Inappropriate use	
Organisation	Management organisation inadequate				
	Management attitude problem				
	Training/instruction: none, inadequate, inappropriate				
	Supervision: none, inadequate, inappropriate				
	Design of plant/equipment/system: inadequate, inappropriate				
	Isolation of equipment/system: none, inadequate, inappropriate				
	Maintenance/ repair: none, inadequate, inappropriate				

	APPLICATION				
CATEGORY/ GROUP	Production	Transport & distribution (rail, vehicle, pipeline)	Refuelling stations and stationary applications	Public use, cars, buses, etc.	Other propulsion systems/vehicles (off-road vehicles, trams, ships, aerospace….)
Environment	Extremely high temperature exposure (heat)			Difficult driving conditions	
	Extremely low temperature exposure (frost)			Natural event (lightning, earthquake, landslide,..)	
	Natural event (lightning, earthquake, landslide,..)				
3rd party	Sabotage	Sabotage		Reckless driving	
		"Human failures"			
Other external	Neighbouring/adjacent fire				
Other, general					
Unknown					

It is required that the recorder adds extra details and specifications for the option(s) being selected, e.g. option *Component/ system failure or malfunction* should be supported with text like *valve opened unintentionally*. Some other guidelines for recording:

- The user should try to identify the whole causal chain (direct/immediate->indirect/basic)
- Causes of ignition (ignition sources) treated separately
- Causes could be classified as events (domino) and hence not included here

A.3. Reporting of fatalities

When recording accidents causing fatalities it would be beneficial for analysis purposes to give as much details as possible about the number of fatalities grouped as per their occupation and function, the type/severity/size of fatal injury and part(s) of body affected. Related to the latter, it is proposed to use a kind of a graphical "injury/fatality pointer", e.g. the schematic picture of a human body on which the affected parts can be highlighted. As an example, the other type of information mentioned could be recorded as shown below. It should be noted that if several fatalities (>1) is recorded per occupation/function category and having different types of injuries, it would be necessary to add new lines to the table.

Occupation/type/function of casualties	Number of fatalities	Type of fatal injury	Comments/text
Persons with specific safety knowledge related to the hydrogen application (e.g. operators, technicians)			
Persons involved in the technical part of the application, but without specific safety skills (e.g. 3rd party maintenance workers)			
Persons using the application (e.g. vehicle drivers, fuel-station users etc.)			
Persons not directly involved (passing, close presence, "random", inhabitants…). Specify details in free text			
Total number of fatalities			

Regarding fatal accidents the recorder should try to indicate how many died momentarily and after some time caused by serious injury.

The various options for type of injury are shown in the following section.

A.4. Reporting of injuries

If an accident causes one or more injured persons, it is, as for fatal accidents, necessary to record appropriate details about the persons being injured, i.e. grouped as per their occupation and function, the type/severity/size of injury and part(s) of body affected. If applying a graphical visualisation of which part(s) of the body being affected as proposed, one could use different colours to indicate severity. It is proposed to use the same input form as for fatalities as shown in the previous section.

Type of injury (fatal or not) could be categorised according to a list as shown below. As for the other option lists outlined in this appendix, it is considered as preliminary and hence not complete.

- Burns
- Fracture
- Crush
- Bruise
- Shock
- Laceration
- Dislocation
- Cut
- Twisted
- Amputated
- Bleeding
- Hernia
- Asphyxiation
- Intoxication
- Internal lesion
- Anoxia
- Chemicals
- "Multiple"

Each selected option should be supported with details in free text, if found necessary.