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Analysis of hydrogen incidents to support risk assessment

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ABSTRACT

Hydrogen is an emerging alternative fuel, yet its properties like wide flammability range, extremely fast burning rate (order of magnitude larger compared to natural gas) and the considerably high amount of energy released when it burns or explodes render it as dangerous, if not handled with care. Hydrogen Incident Reporting Database (HIRD) is one of the various databases which have been generated to collect incident information in hydrogen industry. In this study, 32 chosen (from HIRD) hydrogen processing incidents have been analyzed to learn about their root causes. As a result of the study, statistical values about the effects, causes and consequences as well as a check-list for avoiding these incidents, have been developed. The support to risk assessment is mainly directed to the analysis of weak points and system optimization. For support of various aspects of risk analysis an extension of incident analysis and its documentation is recommended.

1. Introduction

A superior fuel must be a convenient transportation fuel, it should be versatile (easily convertible to other forms of energy), it must have high utilization efficiency, must be environment friendly, cheap and safe [1]. Keeping these factors in mind, hydrogen outshines all of its present competitor fuels and comes out to be the most suitable for present and future use [1,2]. Hydrogen's high energy content, low ignition energy, fast burning speed, extensive flammability and detonability ranges make it a highly unsafe fuel, if not handled with care [3]. A pre-requisite for commercial application of hydrogen is that the safety of the required infrastructure is investigated and that its design is made such that the associated risk is at least not significantly higher than that of existing fuel supplies [3].

Knowledge gained from incident analysis and investigations help industries to form a better safety management system which ensures a safer and healthier working environment in their facilities [4]. Recently, due to lack of a comprehensive hydrogen incident database, techniques like Bayesian approach have been used to fit hydrocarbon failure frequency data to hydrogen for its risk and safety distances calculations [5–7]. But the Bayesian approach is still in the developing phase [5]. The data on hydrogen incidents is not so scarce, but it is scattered (as shown in Table 4). In the past, researchers [8,9] have tried to combine the original hydrogen incident data and have performed conventional statistical analysis to extract useful information on hydrogen safety. The approach is still useful and provides information on which direction to exert the future research efforts. Such information from the analysis of incidents can also support some steps in the risk assessment shown in Table 1.

In risk assessment possible incident scenarios have to be defined (steps 3, 6). Potential system and external effects have to be evaluated (steps 3, 6–8). The risk analysis can be improved if the scenarios included are not only based on hypothetical weak point analysis, but also on real incidents. Comparing the consequences/effects of real incidents with

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Table 1 – Risk assessment steps.

Step #	Description	Step #	Description
1	Task description	7	Weak point analysis/ Risk analysis part 2
2	General data	8	Risk evaluation
3	Risk potential study	9	Optimization I
4	Working concept	10	Multi-objective optimization (Optimization II)
5	Specific data	11	Minimization of residual risk
6	Weak point analysis/ Risk analysis part 1		

the results of the consequence calculation, it is possible to validate the used models. Furthermore, the incident analysis gives information about frequency of the initiating event (leakage, pipe rupture …), and probabilities (ignition/ explosion).

The present study investigates 32 selected hydrogen incidents, which have taken place in the hydrogen processing industry. Potential causes of the incidents have been analyzed and based upon these causes, general recommendations (lessons learned) have been made to avoid them in future. Table 3 represents the terms used in the analysis of these 32 H_2-based incidents.

2. Data collection

Learning from previous incidents is an old and effective technique in the process industry. For this reason, various databases were generated which started acting as platforms for the collection of incidents related to hydrogen (see Table 4). These databases pose extensive information on H_2-incidents. Out of

Table 2 – Incident information to support risk assessment steps, examples.

Risk analysis/weak point analysis (support of weak point analysis step 6)
• Initiating event (external fire, explosion, valve opening, power failure, freezing of valves/safety valves, human errors at maintenance, control, material, management, operation
• Safe guards (common cause failure)
• System consequence (damage of internals)
• Incident scenarios (domino effects)
Consequence calculation (validation of consequence calculation steps 3, 7)
• Release (leak size, one or two phase flow)
• Dispersion (heavy/neutrally buoyant gas)
• Consequence/effect (flammability distance, heat radiation, deflagration or detonation)
Frequency and probability calculation (Risk assessment steps 3, 6, 7)
• Frequency of initiating events
• Failure probability of safeguards
• Ignition probability
Recommended improvements (Risk assessment steps 6, 9, 10, 11)

Table 3 – Terms used in the study of H_2-incidents.

Term	Definition
Incident	The loss of containment of material or energy.
Near miss	An event, which under slightly different conditions might have become an incident.
Analyzed causes	Possible root causes leading to undesired event (incident or near miss). They have been characterized as Primary and Secondary Causes. Primary causes are the event-initiating happenings while the Secondary are those which followed the Primary causes.
Consequence	A measure of expected effects of the results of an incident (in terms of effect to personnel and plant damage).

these databases, Hydrogen Incident Reporting Database (HIRD) [10] was selected for incident analysis due to a number of reasons.

- HIRD is based purely upon hydrogen based incidents.
- Technical information regarding incidents is posted well in detail on the server which gives a better understanding of incidents to the readers.
- Probable causes are reported along with the scenario descriptions.
- Consequences are stated as 'property damage' and 'deaths/ injuries'.
- Suggestions regarding 'lessons learned' are made.
- HIRD categorizes incidents into various sections like valves, pipes, storage vessels etc. This not only makes navigation into various kinds of incidents easier but it also helps in estimating the most vulnerable portions of the process plant.
- Dates of the incidents are mentioned which makes easier to predict the incident frequency in various time intervals.
- Database is regularly and frequently updated.

HIRD currently poses a total of 194 incidents (last updated: 16/05/2011) and is maintained by the Pacific Northwest National Laboratory (PNNL), USA. The main criteria for consideration of any safety event record in HIRD are availability of sufficient information to establish "lessons learned" of relevance to hydrogen production, storage, transmission and use [4]. These "lessons learned" are part of the database software used to collect the incident information. To secure the privacy of the industries, all the names of the data providing entities are omitted carefully, and rest of the data, along with all the technical details provided, is updated on the server.

The 32 incidents collected from HIRD for analysis are most relevant to hydrogen processing industry. These don't include any domestic, refueling station, NASA or transportation incidents. These include incidents related to valves, piping, flanges, storage vessels, process vessels etc. While selecting, it was kept in mind that necessary information about the incident is available, based upon which it was possible to prepare the check-list.