Statistics, lessons learnt and recommendations from the analysis of HIAD 2.0 database

Jennifer Wen, Marta Marono, Pietro Moretto, Ernst-Arndt Reinecke, Pratap Sathiah, Etienne Studer, Elena Vyazmina, Daniele Melideo

Presented by Trygve Skjold

European Hydrogen Safety Panel (EHSP)

24 May 2022
Background

The Hydrogen Incidents and Accidents Database (HIAD) was firstly developed within the HySAFE Network of Excellence by the Joint Research Centre of the European Commission (JRC).

Updated by JRC as HIAD 2.0 in 2016.

Since its launch in 2017, the EHSP has been working closely with JRC to enlarge and improve HIAD 2.0.

Sources of HIAD 2.0:
- Public, from scientific literatures, news.
- Other public not hydrogen-specific databases such as French ARIA, European (SEVESO) eMARS, US CSB, NTSB, OHSA national nuclear authorities, etc.
HIAD 2.0 Database structure

H₂ supply chain
- Production
- Transport & distribution
- Refuelling

H₂ applications
- Road vehicles
- Non-road vehicles
- Stationary fuel cells
- Laboratory/R&D
- (Petro)chemical industry
- Other

Unignited releases
- No loss of confinement
- Jet fire, deflagration, pool fires, etc.

Causes
Consequences
Corrective measures
Lesson learned

Lesson learned
How to access HIAD

While HIAD 2.0 database is offline due to maintenance, those who need to access the information should contact pietro.moretto@ec.europa.eu

Since 2021 not accessible online, but via an Excel file.
Overview of the data collection and assessment process

- Data collection
- Data processing
- Events validation and publishing
  - EHSP and JRC
  - JRC
  - EHSP
  - Clean Hydrogen Partnership

- Statistical analysis
- Lessons learnt
- Recommendations

- Reporting

- Publishing and dissemination
The methodology

- Quantities of hydrogen involved (Seveso threshold or the amount of hydrogen involved)
- Human consequences (fatalities, injured with hospitalisation, slightly injured)
- Economic consequences (property damage or economic cost)

**Nature** of event (explosion, fire, unignited release, near miss)

**Cause** (system design error, material/manufacturing error, installation error, job factors, Individual/human factors, organization and management factors)

Results from the statistics analysis (1)

The analysis reported here is based on the 706 incidents, which were in the database as of May 2021. A total of 576 of these events were considered to be statistically relevant and formed the basis for the statistical analysis to inform lessons learned and recommendations.
Results from the statistics analysis (2)

- **Hydrogen system initiated events** (75%)
  - Explosion: 35%
  - Fire: 24%
  - Leak no ignition: 13%
  - Near miss: 13%

- **Non-hydrogen system initiated events** (25%)
  - Explosion: 7%
  - Fire: 2%
  - Leak no ignition: 3%
  - Near miss: 3%

*Clean Hydrogen Partnership*
Results from the statistics analysis (3)

Operational mode

- Normal operation: 66%
- Outside normal operation: 33%
- Unknown: 1%

Causes (multiple entries per incident possible)

- Material/manufacturing error: 35%
- Installation error: 11%
- Individual/human factors: 29%
- Job factors: 14%
- System design error: 27%
- Safety management system factors: 49%
Lessons learnt

The lessons learned are grouped into the following four main categories:

- System design
- System manufacturing, installation, and modification
- Human factors
- Emergency response
Lessons learnt in relation to cascading effects


Cascading effects of minor events could result in extremely serious consequences

Example (Event ID477) of cascading effects: Gangeung Hydrogen Tank Explosion Accident, May 2019, South Korea
Example (Event ID477) of cascading effects

Prosecutor’s report on Gangeung Hydrogen Tank Explosion Accident, May 2019, South Korea

The following text is adapted from the English translation by INERIS about the contributing factors:

- Oxygen removing component omitted in the system …
- Buffer tank static spark remover was omitted during construction…
- Operator made fault by running water electrolysis system lower than operation power level, which induced increase of O₂ concentration…
- The O₂ concentration was detected as > 3%, which required O₂ detector and remover. However, the operator ignored this issue and continued operation to reach 1000 hours of required experiment validation time.
- Safety management team did not follow safety regulation to daily test hydrogen quality.
Lessons learnt related to human factor

- Lack of regular maintenance or inspection, special attention for safety devices during maintenance
- Reoperation after repair
- Individual/human factors, lack of clear instructions
- Reusing tanks or pipes previously containing flammable liquid or gas without thorough purging

Definition of Health and Safety Executive (HSE)

Example of recent incident -
Hydrogen fuelling station explodes in Norway


- The incident was attributed to an assembly error of a specific plug in a high-pressure hydrogen storage tank.
- It started with a hydrogen leak from a plug in one of the tanks in the high-pressure storage unit.
- This leak created a mixture of hydrogen and air that ignited and created a pressure wave.
- The specific source of ignition is yet to be identified.
- The low-pressure steel and composite storage units were neither the source of the leak, nor the ignition source, and no tanks ruptured in the incident.
Statistics related to EHSP identified safety principles (SP#)

0. Design and material compatibility with H₂ safety
1. Limit H₂ inventories, especially indoors
2. Limit formation of H₂ cloud, e.g. by ventilation
3. ATEX zoning analysis
4. Combined measure to detect and counter H₂ leak and fire
5. Avoid ignition sources using appropriate materials or installations in different ATEX zone, e.g. by removing electrical systems or provide electrical grounding
6. Avoid/reduce congestion in respective ATEX zones
7. Avoid confinement. Place storage in open or spaces with large openings.
8. Provide efficient passive barriers as second defence line
9. Train and educate staff in hydrogen safety
10. Report near misses, incidents and accidents to suitable databases and include lessons learned in your safety plan

Structure of recommendations at a glance

Table 3: Structure of the recommendations at a glance

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Operational mode</th>
<th>Hydrogen energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industrial sectors</td>
<td>H₂ transport and distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H₂ powered vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laboratory / R&amp;D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power generation</td>
</tr>
<tr>
<td></td>
<td>Other industrial sectors</td>
<td>Nuclear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aerospace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemical/petrochemical</td>
</tr>
<tr>
<td></td>
<td>Human factors</td>
<td></td>
</tr>
</tbody>
</table>
Recommendations for different operational modes

- Adequate training of personnel is key (SP9) - training of new personnel as well as periodic updated training of existing personnel.
- Both passive and active safety measures should be appropriately considered (SP7, SP8).
- Leak detection (SP4) and ATEX zoning (SP3, SP5) should be applied to improve safety.
- Regular inspection and maintenance.
- When operational/equipment changes are made, the maintenance/inspection procedures should also be updated accordingly.

https://eta-safety.lbl.gov/content/integrated-safety-management-ism
Recommendations for hydrogen energy applications – system design

- Perform Process Hazard Analysis for any new/updated installations (SP1-10);
- Use materials which are compatible with hydrogen services. In some incidents, such problem resulted in the need to change standards and codes for pressure vessels (SP0);
- Install adequate leak detection and mitigation barriers (SP4, SP8) for critical systems.

https://risk-engineering.org/safe-design/
THANK YOU!

The report from the analysis can be found at [https://www.fch.europa.eu/sites/default/files/documents/Lessons%20learnt%20from%20HIAD%202.0-Final.pdf](https://www.fch.europa.eu/sites/default/files/documents/Lessons%20learnt%20from%20HIAD%202.0-Final.pdf)

A paper based on the analysis was presented at the International Conference on Hydrogen Safety 2021 and awarded the best paper prize.

A modified version of the above paper has been published in the International Journal of Hydrogen Energy in Gold Open Access. It can be downloaded free at the following link:

[https://reader.elsevier.com/reader/sd/pii/S0360319922012976?token=B67B5AC502387E7B7CE7CC15DABAE2731A101F1BEF7D7A2DED8F4B0DE060A2CD430485A0C110D758A00ADE1D884AD5D&originRegion=eu-west-1&originCreation=20220414145607](https://reader.elsevier.com/reader/sd/pii/S0360319922012976?token=B67B5AC502387E7B7CE7CC15DABAE2731A101F1BEF7D7A2DED8F4B0DE060A2CD430485A0C110D758A00ADE1D884AD5D&originRegion=eu-west-1&originCreation=20220414145607)