Waterstofaggregaat - Hydrogen Power Module

WP5 Veiligheidsaspecten en Risico's – HAZID-studies

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NLHydrogen

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Introduction

The objective of WVIP work package 5 “Hazard Identification Studies” is to assess potential safety risks by executing so called Hazard Identification studies (HAZID) for a number of concrete applications of hydrogen in the public domain. In particular:

1. To identify typical safety hazards and to assess safety risks of a number of concrete cases associated with the production, storage, transport and use of hydrogen.
2. To identify and assess potential risk mitigating measures in order to control safety risks of hydrogen in the public domain.

The deliverables of this work package are intended for all parties involved in the production, storage, transport, distribution and end use of hydrogen in the public domain.

The HAZID cases are selected by the TEC of WVIP and involve:

- Case 1 Hydrogen refuelling station
- Case 2 Hydrogen transport by road (tubetrailer)
- Case 3 Local hydrogen production
- Case 4 Hydrogen Power Modules
- Case 5 Service & maintenance
- Case 6 (mobile) Bunkering of hydrogen

This report covers case 4: ‘Hydrogen Power Modules’ and provides insights in typical safety risks and recommendations for risk mitigation and control.

Summary

This report covers case 4: ‘Hydrogen Power Modules’. It provides insights in typical safety risks and recommendations for risk mitigation and control. This report includes an introduction to the Hazard identification methodology (HAZID) and a narrative for production of electricity by a hydrogen powered generator set. This type of sets is used to provide power in places where no (public) power connection is available, such as construction sites and temporary outdoor (public) event locations.

The HAZID study is executed under the umbrella of the Dutch Hydrogen Safety Programme (Dutch acronym: WVIP). Uptake of the findings and recommendations of this HAZID case takes place within WVIP.

1. Introduction

The HAZID is organised in the context of the WVIP (Dutch acronym of Waterstof Veiligheid Innovatie Programma (WVIP, Dutch for Hydrogen Safety and Innovation Program). In working group 5 safety risks are assessed for typical use cases with methods and tools that are based on (inter) national standards and/or guidelines.[1] Further information can be found on the website of the WVIP, which also describes the complete WVIP scope. This scope includes:

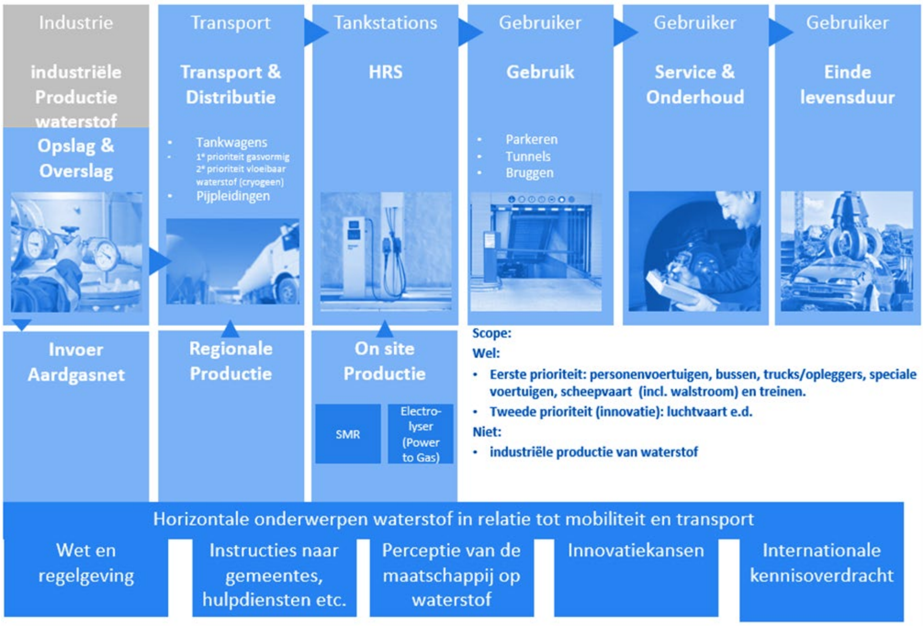

Figure 1: Scope WVIP This report contains the results and recommendations of the HAZID regarding the production of hydrogen, next to a hydrogen fuelling station

2. Narrative

A hydrogen genset or power module is a device designed to generate power in places where no power connection is available, such as construction sites. A hydrogen genset typically consists of a fuel cell and battery system interconnected by an DC/DC inverter, and a DC/AC inverter to provide the desired AC output. The specific system under consideration is a 30 kW unit with a fuel cell system built around 3 low temperature PEM fuel cell stacks. The genset is combined with an external hydrogen storage which consists of standard hydrogen cylinder bundles at 200 bar.The module consists of a system of 3 batteries and 3 PEMFC fuel stacks, a DC/DC and a DC/AC inverter. The hydrogen storage is external and consists of standard H2 bundle packs at 300 bar. The environment considered in the HAZID is the public domain and specifically the scenario of a (music) festival.

The Hydrogen Power Module includes:

- 3 PEMFC fuel cell stacks
- Cooling circuit (Demin water) for fuel cell stacks
- DC/AC inverter, 230/400 V, 30 kW discharge power
- DC/DC inverter, 300 V
- Hydrogen cylinder pack (50), 300 bar, 1.06 kg hydrogen per cylinder, total 16.96 kg

[1] (Inter) National standards and guidelines include Publicatiereeks Gevaarlijke Stoffen (PGS) Handreiking Generieke Risicobenadering, ISO 31010 (Risk management - Risk assessment techniques) and NEN-EN ISO 17776 (Petroleum and natural gas industries - Offshore production installations - Major Accident hazard management during the design of new installations)

3. Methodology, activities and meetings

3.1. HAZID team

The HAZID team consisted of the following persons, with their respective roles:

- Project leader HAZID TNO
- Expert TNO
- HAZID Chair TNO
- Scribe NEN, co-PM WP 5
- HAZID/ Design expert TNO
- Safety Advisor Veiligheidsregio
- Safety Advisor Veiligheidsregio
- Expert Linde Gas
- Expert Hydrogen Power Module – HPM Manufacturer
- Expert Hydrogen Power Module – HPM Manufacturer
- Expert Hydrogen Power Module – HPM Manufacturer
- Expert hydrogen stack – Hydrogen stack manufacturer

3.2. Meeting dates

The HAZID was conducted in 1 session (live) on 2 December 2022 in TNO, location The Hague.

3.3. HAZID methodology

This HAZID is executed according the Terms of Reference (ToR) for this project, which includes a description of the HAZID methodology as based on (inter) national standards and guidelines, such as Publicatiereeks Gevaarlijke Stoffen (PGS) "*Handreiking Generieke Risicobenadering*" and NEN-EN-ISO 17776.

The main objectives of the HAZID study is to identify and assess potential hazards and safety risks for a typical hydrogen genset in terms of probability of occurrence and potential effect, including identification and assessment of risk mitigating measures.

Several categories are used in order to identify hazards and assess risks, including:

- Hazards related to external and environmental conditions.
- Hazards related to specific (design) aspects of the installation.
- Hazards of the activity in relation to health of workers and people in the vicinity.
- Project implementation issues; i.e. hazards or points of attention in relation to regulations, norms and standards for the activity.

The risk assessment includes four 4 sequential steps

1. Identify typical scenarios by team brainstorming and use of guidewords. Typical scenarios are derived in each hazard category, including descriptions of typical initiating (top) events.
2. Assessment of potential causes and consequences of the scenario.
3. Assessment of potential barriers.
4. Risk assessment of each scenario in terms of probability (scale A-E) and consequences for both people and the environment (scale 1-6). By use of a risk assessment matrix a relative risk level is determined (see figure 2).

Risk matrix								
				Probablity (Frequency of occurence)				
Consequence (Effect class)				**Scarcely**	**Seldom / rarely**	**Now and than**	**Regular**	**Often**
	People	**Environment**		Never heard of in industry	Has occurred in this type of industry/sector	Has occurred in similar type of company	Has occurred several times in similar type of company	Has occurred several times in a year on one location
				A	**B**	**C**	**D**	**E**
Zero	No injury Medical treatment (First Aid)	No / limited effect (pinhole leaks)	**1**	1,5	2,0	2,5	3,5	4,5
Minor	Medical Treatment case, substited work Slight health damage, no irreverse effects	Minor effect (small leak)	**2**	1,9	2,5	3,1	4,4	5,6
Major	Major injury, Lost Time injury Irreverse health seffects	Local effect (major leak)	**3**	3,8	5,0	6,3	8,8	11,3
Severe	Disability One fatality	Severe / regional effect (small equipment rupture, large leak)	**4**	5,6	7,5	9,4	13,1	16,9
Very severe	More than one fatality (<50)	Very severe / national effect (large equipment rupture, very large leak)	**5**	7,5	10,0	12,5	17,5	22,5
Catastropic	Many fatalities (>50)	Massive / international effect (loss of containment complete asset)	**6**	11,3	15,0	18,8	26,3	33,8
				(green)	1 t/m 4	Low risk level		
				(yellow)	4,1 t/m 10	Medium risk level		
				(orange)	10,1 t/m 15	High risk level		
				(red)	15,1 t/m 34	Very high risk level		

Figure 2: Risk matrix used during HAZID.

4. Conclusions and recommendations

4.1. Findings

The findings in this section include a summary of very high (red), high (orange) and medium (yellow) risks. The details of all risks and recommendations are minuted in the HAZID (Excel) worksheet.[2]

Very high risks (red):
- No very high risks

High risks (orange):
- 1.2.5: Proximity to transport corridors lead to accident (collision) of car/truck and aggregate/hydrogen package. Probability of accumulation of hydrogen in an enclosed space, and potential explosion hazards.

Medium risks (yellow):
- 1.1.1: Extreme weather conditions, freezing and shrinking in piping/couplings/equipment leading to external leaks on gas from high pressure hydrogen tanks. Potential consequences are, leakage, frosting and fire.
- 1.1.1: Extreme weather conditions and freezing of soil lead to slippery roads, accidents, and collision of vehicle with stationary aggregate on a construction site potentially resulting in leaks and fire.
- 1.2.1: Accident of the Hydropower unit with a trailer along / through densely a populated area (e.g. festival). Potential consequences include thermal runaway.
- 1.2.4: Risk related to use of nearby land. Nearby heat or ignition sources or falling objects.
- 2.2.5: Third party intrusion / vandalism can lead to many possible scenarios.
- 2.2.10: Failure of fittings lead to leaks, e.g. from flanges, connections.
- 2.2.14: Heat radiation due to external fire leading to various consequences and risks for people.
- 2.5.1: Fire in aggregate/hydrogen package and unavailability of a fire water system.
- 3.1.2: Large hydrogen leak leads to lack of air, suffocation, explosion/fire risk.
- 4.1.1: User company selection constraints, lack of stability and contractual conditions lead to unqualified personnel.
- 4.1.2: Legislation, governmental contracting requirements and permit requirements can be challenging to interpret and apply, especially for new players.
- 4.1.3: Additional engineering/company guidelines & standards lead to external standards which are insufficiently disseminated (to all market parties) and implemented.
- 4.2.1: Hazard studies have not been executed correctly.
- 4.2.2: Absence of Hazards and Effects Register
- 4.2.3: Absence of Q&A measures
- 4.3.2: Absence of medical support service, firefighting support, evacuation
- 4.3.3: controlled burn out of fire by firefighters lead to total loss.

[2] The minutes of the HAZID are reported in an Excel format, as demonstrated in Annex 1 of this report. The complete HAZID worksheet is available on request.

4.2. Conclusions

With the proper safety barriers implemented, limited risks are expected in the use of a hydrogen power module in the public domain. Risks for which additional measures should be implemented have been identified (see 4.1).

4.3. Recommendations

The main recommendations of the HAZID analysis are:

- Strive for uniform engineering standards and instructions.
- Standard training program for hydrogen handling. Also (contractually) safeguarded when working with external parties or customers, e.g. related to connecting bundles.
- Check on engineering standards for extreme (NL applicable) weather conditions (freezing), including a check on intrusion of water and freezing.
- A general point of attention is awareness and knowledge about safety aspects and risks about hydrogen. This applies to the entire public in general and to first responders an operators in particular.
- When placing the power module, collision prevention with vehicles should be managed, and mitigating measures such as collision impact safety measures should be implemented.
- Implement safety distances / working space for incident responders and operators of at least 3 meter around the installation possibly fenced off, only accessible by authorized and trained personnel. Safety distances may change depending on the capacity of the aggregate.
- Verify how earthing of bundles is covered in praxis and regulations.
- Verify procedures and criteria for connecting and disconnecting hydrogen packages during lightning and bad weather conditions.
- Hoses:
    - Consider fit for purpose, strength and type of hose and to keep the hoses as short as practicable for risk and safety.
    - Minimize the use of flexible hoses and couplings as much as practicable with respect to safety.
    - In case of a non-mobile stationary aggregate consider using pipelines instead of hoses.
- Check if flood risk is addressed in permitting procedures, e.g. flood plains low lying areas.
- Reconsider design criteria with respect to high temperature of bundles and increasing pressure (climate change, e.g. solar radiation).
- Review recommendations of the Kjørbo incident.
- Consider (coarse) QRA.
- Evacuation plan of the (construction) site during battery thermal runaways.
- Inform the environment of the (construction) site about smoke and/or other hazards, depending on the location (e.g. city / centre, event, along the highway).
- In the HAZOP / design of the hydrogen system / bundle, attention should be paid to the connection and the deflating of the bundle and the aggregate in shut down or emergency situations. Failure of the connections can also be covered in HAZOP / design.
- To further investigate ignition probabilities, scenario's, probabilities etc. See also knowledge gaps) WVIP WP 4. Incl. benchmark study on other gas transport scenarios.
- Probability of accumulation of h2 in an enclosed space, potential explosion hazards.
- Verify that the hydrogen aspect is sufficiently taken into account in existing risk analysis (and in extension regulation) of (conventional) modes of transport such as shipping, aviation,

drones related to 1) overflying and passing by hydrogen sites or 2) overflying or passing by by vessels / aircraft with hydrogen as fuel or cargo.
- Special attention to first responders and operators. Need for guidelines, instruction, training, and an inventory of knowledge gaps.
- Recommended to limit usage of power modules to outside usage and venting at a minimum of 3m height.
- Create an emergency plan per location. Not only emergency instructions on the emergency column also in the mind of the parties involved.
- Ensure accessibility, reserve a location for emergency services (fire brigade vehicles) near the hydrogen power module.
- Investigate if the hydrogen supply is automatically stopped in case of hose rupture.
- Recommended safety distance of at least 3m around bundles and the hydrogen power module.
- training of maintenance personnel
- Prepare maintenance philosophy (permit to work, work plans, agreements about switching of etc.)
- Explore necessity of assessment and training for key positions / mental pressure resilience of personnel.
- Organizations prepare for after care of fires exceeding 2 hrs.

Annex 1: HAZID worksheet

The HAZID worksheet is a separate Excel file with all notes and conclusions. For more information about this worksheet, please contact: electro.energy@nen.nl