

CATEGORY

Hydrogen safety

Hydrogen handling and key process safety steps



Hydrogen use is expected to grow enormously in the coming years, both for storing and transporting energy and as a carbon-free fuel. To do this safely, a few crucial points are important to consider and act upon.

Introduction

Safe operations – regarding workers, plant & equipment, communities and the environment – should be the foundation of any industrial or commercial process. With hydrogen gaining widespread attention as an energy carrier for a growing range of applications in both industry and transportation, it is vital that any company working with hydrogen, or planning to work with it, is well aware of the safety hazards involved.

This ABB mini-brief is intended to provide a basic outline of key safety points to be considered when expanding the use and application of hydrogen. Of course different companies and plants will be at different stages on their hydrogen journey, with some just getting started while others have been using hydrogen safely for many decades.

“Risk” is normally defined as the combination of “likelihood” and “consequences or hazards” of an event occurring, and the improper handling or processing of hydrogen can lead to serious negative outcomes. If a company doesn’t understand the consequences of an hydrogen release, and the likelihood of it being released, then **handling hydrogen could become a very high risk activity.**

In this area ABB is well equipped to help because, based on our long hydrogen processing experience, we understand how to control these risks. Thus with hydrogen applications expected to grow exponentially in the near future – both at mature operating companies as well as at newcomers entering the hydrogen sector – we feel these safety points are worth communicating.

We believe this overview will provide both a good starting point as well as a timely refresher for interested readers such as:

- safety managers
- designers
- process engineers at energy and chemical companies
- EPC firms and electrolysis technology companies
- analysts and policy-makers

What is hydrogen?

Hydrogen is the most abundant element in our entire universe. On the Earth, however, it exists only in compound form, combined with other elements. The most familiar examples are hydrogen combined with oxygen to form water (H₂O) and hydrogen combined with carbon - meaning hydrocarbons (C_xH_y) - found in natural gas and petroleum.

Thus elemental hydrogen is not a naturally occurring compound, and therefore not available directly as an energy source on Earth. But it can be used as an energy “vector” or carrier and this is currently attracting enormous attention for applications ranging from small scale off-grid power supply to large scale industrial processes. This energy storage potential can be used in a wide variety of energy applications, including decarbonization of transport and industry as well as contributing to electrical grid network flexibility.

Indeed, the use of hydrogen as a low cost energy vector is gaining ground due to better renewables economics and access. This, combined with the drive to reduce carbon dioxide emissions and increasing carbon taxes, have made it very attractive.



Hydrogen thus brings with it much-needed flexibility in the Energy Transition. One key advantage of hydrogen is its high energy density, which is approximately three times higher than gasoline or diesel fuel on a mass basis. Another benefit is that it is environmentally benign, because when it is combusted carefully it generates only water vapor as emissions.

The key safety concerns

Storage and handling of hydrogen involves safety issues that must be understood and mitigated to ensure secure operations. The key safety characteristics of hydrogen that make it potentially hazardous are a result of the fact that:



It has a **low ignition energy**, and leaks from piping flanges, for example, are particularly hazardous because the simple friction induced by the leak itself can be a source of ignition.



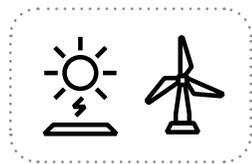
If it were to leak and ignite, it can under certain circumstances **burn with an invisible flame** and the radiated heat from a hydrogen flame is much lower than typical hydrocarbon flames, making it dangerous to personnel since the flame may not be detected.



It is **highly flammable over a very wide concentration range** and can even detonate given the correct conditions. So it presents a very significant explosion hazard.



It is a very small molecule, and because it dissociates into hydrogen ions at elevated temperatures it **can diffuse or be absorbed into metals**, leading to hydrogen embrittlement of equipment and pipework.



intermittent energy sources

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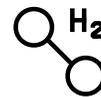
reduced cost of PV and wind turbine generation

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urgent need to decarbonize

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increase in hydrogen projects

The current market situation

The potential that hydrogen offers to act as a flexible energy vector, particularly for renewable but intermittent energy sources like solar and wind power, has created huge amounts of interest as the cost of installing photovoltaic (PV) and wind turbine generation has decreased. Therefore worldwide there is an increasing number of projects to generate, store, transport and use hydrogen – fueled further by the urgent need to decarbonize.

Many green hydrogen projects are being undertaken both by numerous newcomers with no prior safety experience of handling hydrogen, as well as by existing companies moving from grey to ultimately green hydrogen. The existing companies already handle hydrogen and are mature in their Process Safety Management (PSM) journey but are needing and requesting specific hydrogen safety knowledge for their expansions. **This widespread scaling-up of industrial production volumes for hydrogen, as well as rapid growth of smaller off-grid operations, all involve safety risks that must be addressed.**

For either category - newcomer or mature - any serious safety incident could have catastrophic consequences for the employees, local communities, the environment and the company's reputation and potentially its future. If an incident were to be serious enough, it could also damage the public perception of the entire and promising hydrogen sector for a long time into the future. An example of this is the explosion at the Uno-X hydrogen refueling station at Kjørbo near Oslo, Norway in June 2019 which had a severe impact on the fuel cell vehicle sector, since drivers could not refuel their vehicles.

Of course, many industries and companies have very safe and successful experience of using and generating hydrogen over many decades, such as chemical plants using reforming for hydrogen production or cracking furnaces generating ethylene and propylene with hydrogenation reactors. But as the pace of growth increases, safety must not be overlooked.

3 Key Steps for Safe Handling of Hydrogen

To make sure that hydrogen is safely handled, systematic Process Safety Management procedures must be understood and practiced from day one. Years and decades of experience here at ABB have shown us that there are three crucial steps that need to be prioritized to help ensure hydrogen safety.

Key steps for Process Safety Management



1 **First of all, build on the right foundations and ingrain safety culture by starting at the top. There is no alternative:** The leadership team must be totally committed to the highest level of process safety management regarding hydrogen adoption or expansions. If you lead from the top – with some individual on the company board responsible for PSM – that helps drive the process safety culture and sets you up for success. Many of the most successful players already working with hydrogen, and who are good at managing their process safety, have a company director responsible for PSM.

New entrants into the promising hydrogen market must recognize that it is extremely important to have this 'top led safety culture'. Safety underpins sustainability and is the foundation of any good operating company. Keeping people safe and alive is certainly the most basic first step in any sustainability program. Also, safe operations usually reinforce efficient operations, and that means reduced emissions, another key sustainability factor.

2 **The second key step is: Identify all credible hazards in the early stages of the design process, even at the concept stage.** If you can spot hazards early and design them out or mitigate them, it costs a lot less to alleviate them at that stage of the design process rather than later on. Even simple things, like minimizing the number of flanges in the design or the installation of hydrogen flange guards where flanges are unavoidable, are important to do early on.

To help accomplish this, there is a hazard study suitable for every project stage. HAZOP (hazard and operability study), one of the most common techniques, involves a structured, team-based assessment of a firm's design to ensure that the consequences of design deviations are fully understood. This study also determines if suitable and sufficient protective measures have been incorporated into the design.

However there is more than just Hazard Study 3, with the techniques going from Hazard Study Zero all the way through to 7. Zero is the interesting one because it covers inherent safety, so it asks you crucial questions very early in the concept stage, potentially helping to design out hazards from the start of a project. Then these studies and solutions roll on to support further layers of safety pillars, as you pass through the design process into the next stages.

3 A third more specific step is to make sure any hydrogen hazards that are identified are fully controlled. One of the main reasons hazardous area classification and controls are important is hydrogen's low ignition energy, as mentioned in Section B above. As hydrogen use expands – particularly green hydrogen from electrolysis of water using renewable energy – electrolyzers will become more commonplace. Electrolyzers involve very high electrical demands, which is another potential ignition source, in close proximity to potential leaks.

Electrolyzers are typically located inside buildings. This means that if there are hydrogen releases from the process the concentration can rise rapidly and very easily enter the flammable region, if there isn't adequate ventilation. This occurrence, combined with the potential ignition sources, presents a very significant explosion hazard. These factors need to be considered in the early specification and location of electrical equipment.

As hydrogen fuel cells are increasingly applied to transport, hydrogen refueling points for ships, buses, trains, HGV-trucks and even automobiles are becoming more widespread, bringing people into closer contact with hydrogen. The unique properties of hydrogen and this increasing proximity to people needs to be considered in the design phase of a project, as well as in the operations – when humans can do unpredictable things.

Many countries are exploring the addition of hydrogen to their natural gas networks, and industrial sites are also considering the implications of the use of pure hydrogen. Generally the natural gas networks do not operate at elevated temperatures and therefore the hazard of hydrogen embrittlement would not be an issue for reuse of equipment. However where repurposing of equipment in the presence of hydrogen at elevated temperatures occurs, the impact on materials of construction needs to be fully considered.



Major UK petrochemicals plant works closely with ABB to ensure process safety

For more than 20 years ABB has cooperated closely with a large UK petrochemicals plant to ensure process safety. In recent years the plant has made major changes by progressively moving from a naphtha-based feedstock to ethane and is now transitioning fully to use 100% ethane feedstock. This shift to lighter feedstocks has changed the process hydrogen balance and hydrogenation reactions, so it now requires the use of pure hydrogen, sometimes at high pressure.

Aside from the process technology implications associated with hydrogen, a key process safety issue concerns the potential for hydrogen to ignite upon release. This is where ABB's process safety expertise in handling hydrogen is extremely helpful.

Using a systematic, staged approach

The process changes have been implemented following a formal staged approach to Hazard studies. ABB has provided specifically-accredited Hazard Study and SIL leaders covering Hazard Study stages 1, 2(HAZID) and 3(HAZOP). SIL determination has involved the updating of existing HAZANs and LOPAs and the creation of new LOPAs. (HAZAN = Hazard Analysis; LOPA = Layers of Protection Analysis; SIL = Safety Integrity Level study).

Cooperation has grown deeper over time

Since 2000 the plant management has engaged ABB to lead their Process Hazard Review (PHR) studies, proactively learning from internal and external incidents, checking that previous PHR actions have been fully implemented, and also reviewing all plant and organizational changes. ABB conducts five yearly rounds of PHR/SIL/LOPA studies which help reduce the risk of incidents and demonstrate risks are ALARP (As Low as Reasonably Practicable), which is a key requirement under the COMAH (Control of Major Accident Hazards) regulations. Over the years, the teamwork has grown deeper in terms of process safety, and now covers all aspects of risk assessment, COMAH, human factors, and SIL assessment.



We can support your Process Safety Management

Although there are more aspects to making hydrogen generation, handling, storage and use as safe as possible, by following these key steps you will be well on the road to hydrogen process safety:



1) Building a committed, top-leadership-driven corporate process safety culture



2) Making sure hazards are identified at the earliest stages in design and mitigated cost effectively



3) Thoroughly controlling any operational hydrogen hazards that are identified, you will be well on the road to hydrogen process safety

With this as a foundation, you'll be well placed to implement hydrogen safety in the most effective manner and avoid the worry and sleepless nights that can occur when handling hydrogen.

If and when needed, our capable ABB Process Safety Team, which has both broad and deep experience in hydrogen, would be happy to guide and support you in these areas.

To learn more about ABB's hydrogen offering and ways we can work with you on your hydrogen journey, get in touch with us at these links:

- **ABB hydrogen site**

<https://new.abb.com/process-automation/energy-industries/hydrogen>

- **Consulting services web pages**

<https://new.abb.com/process-automation/process-automation-service/engineering-and-consulting>