© Shutterstock.com

Preparing hydrogen for safe public applications

By Stephen B. Harrison on Nov 04, 2025

As hydrogen's use expands beyond its traditional chemical and industrial applications, safety procedures must adapt to accommodate users without specialist expertise.

The molecule has long been central to various processes and industries and will remain so. The need to mitigate climate change is making hydrogen relevant for domestic, commercial, and consumer applications where it has not been used before.

Safety is of paramount importance in all hydrogen applications. Nobody should get hurt, and assets must be protected through the energy transition. Safety equipment, procedures and smart controls already exist. When these are properly applied by people with appropriate training, each economically viable hydrogen application can be implemented without concern.

Hydrogen in our cars and homes

Roadside refuelling stations for gasoline and CNG are common. Electric charging points are also becoming prevalent. Alongside these, hydrogen refuelling stations for heavy trucks and passenger cars are being implemented.

These are not staffed with technical experts who have had years of safety training, and they are used by professional haulage drivers and members of the public. Safety must be designed into these facilities without relying on the hydrogen safety expertise of the user.

The concept of blending hydrogen into natural gas distribution pipelines is being explored. This hydrogen-methane mixture might be used in homes for heating or cooking on a stove. There are precedents for using flammable gases such as natural gas, town gas and bottled LPG in domestic and commercial buildings. Despite this, the introduction of hydrogen represents a change, and smart control systems are required to ensure public safety.

Mitigating the two main hazards

The two key hazards associated with hydrogen gas are pressure and flammability.

Over-pressure in equipment can lead to catastrophic failure and a massive release of hydrogen. Powerful explosions and intense fires can be the result. Over-pressure is prevented by using mechanical relief valves, which vent hydrogen to prevent mechanical damage. In the vent header, hydrogen must not mix with air or other oxidant gases before release into the atmosphere, either directly, through a flare or a gas scrubber.

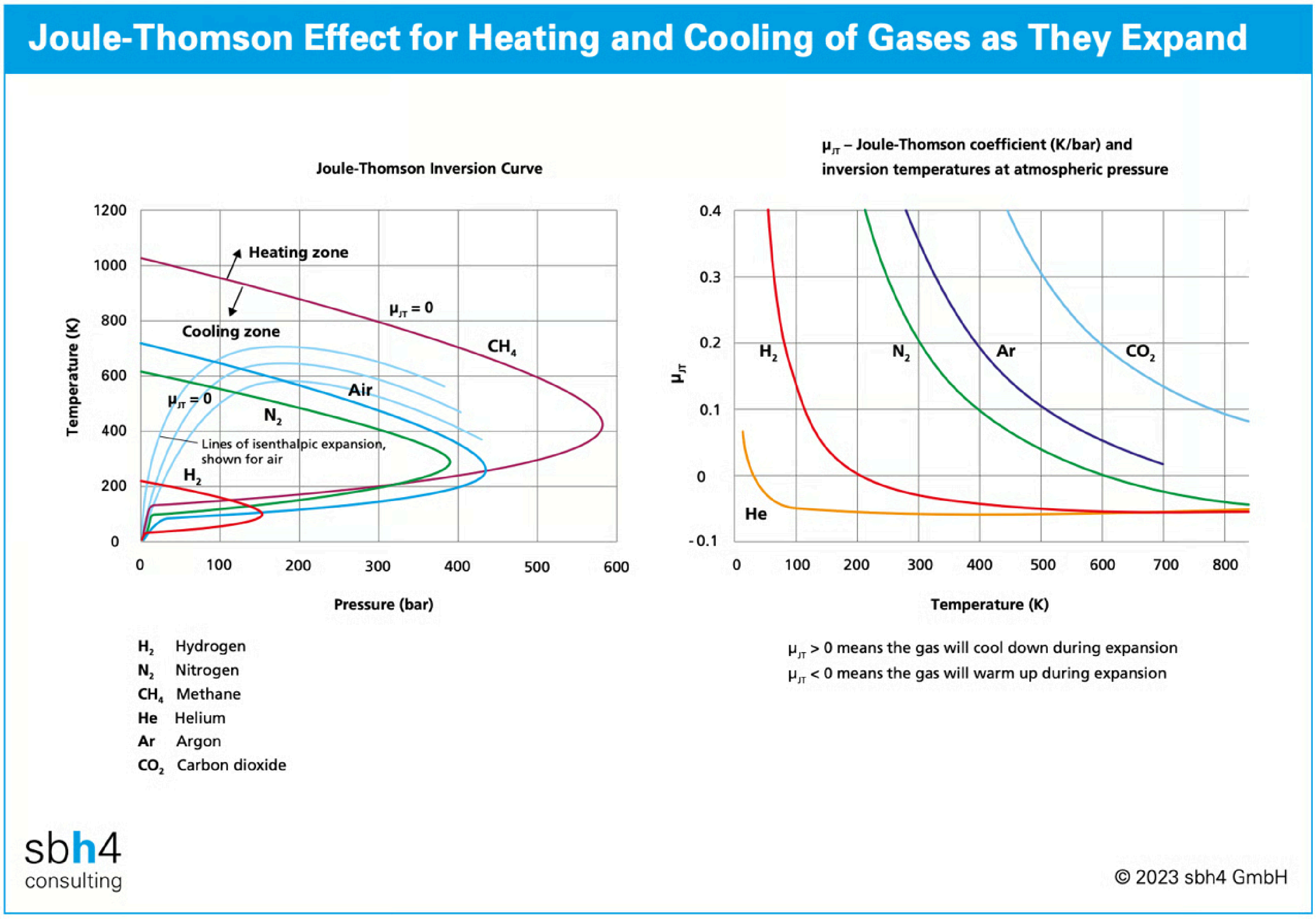
If hydrogen does leak from a high-pressure source, it can be detected rapidly using various techniques. Fixed gas detectors use sensors to identify the presence of a flammable gas and are located close to likely leak points such as valves and pipe flanges. However, the gas detector relies on the leaked hydrogen passing over the sensor. Wind direction changes can suppress the signal, meaning potentially explosive hydrogen leaks go undetected.

To support gas detection, flame detectors can be installed. They are immune to wind direction changes, but are only activated after a leak has been ignited. Hydrogen burns without producing CO2. Furthermore, the unburned hydrogen is also an inorganic molecule. This means that conventional flame detectors, which rely on the Infra-Red (IR) signatures of methane and CO2 molecules, are not suitable for hydrogen. Specialised flame detectors operating in alternative IR and ultraviolet (UV) wavelengths are required for hydrogen flames.

Hydrogen mobility

To ensure there is sufficient fuel storage capacity on a hydrogen-fuelled vehicle, compressed hydrogen gas is stored at 700 bar in carbon-fibre composite tanks.

In the event of a fire in the vehicle, the pressure in the storage tank will increase as it heats up. If it explodes due to overpressure, it will seriously injure or kill[1] the occupants of the car or the haulage vehicle cab. To prevent this, the hydrogen storage tanks are fitted with a thermal pressure relief device (TPRD), which vents hydrogen in a safe direction away from the vehicle occupants in the event of a fire near the fuel tank. The TPRD operates in a similar way to water sprinklers in a hotel or commercial building.



© sbh4 consulting

To fill an FCEV's tank, hydrogen is stored at the refuelling station (HRS) at up to 1,000 bar. A release of hydrogen from this pressure will heat the gas instantaneously to above its auto-ignition temperature due to the Joule-Thomson effect. This heating will result in a flame or explosion. Joule-Thomson expansion of natural gas and air are used to liquefy these gases. On the other hand, when hydrogen is released from a very high pressure to the atmosphere, it heats up rather than cooling down.

Onsite power

Fuel cells are commonly used in Japan and South Korea to convert natural gas to heat and power. They are typically used in blocks of residential flats, hotels, and offices. In the future, the same concept can be used with hydrogen as the fuel to replace natural gas and de-fossilise this energy system.

Data-centres which enable the internet, cloud computing and AI are also keen to decarbonise their operational footprint. Some are looking to use large hydrogen-fed fuel cells for this purpose.

Hydrogen can be delivered to data centres by trucks which store up to 1 tonne of high-pressure hydrogen. It is common for the hydrogen trailer to be decoupled from the tractor unit and connected to the end user site by a high-pressure hose. When the trailer is empty, a full trailer of hydrogen is delivered, and the truck tows away the empty one for refilling.

The consequences of towing a hydrogen trailer away while it is still connected to the data centre would be catastrophic. To mitigate this, an electronic breakaway cable is attached to the gas hose. If the trailer is erroneously towed away whilst it is still connected to the data centre, the electrical cable is broken. The loss of this electrical connection drives smart control systems to close valves on the truck and the end-user site to minimise the amount of flammable hydrogen that can leak.

Expert training

Training is essential for those involved in designing hydrogen systems. They must understand the unique properties of hydrogen, like its very high flame speed, low ignition energy, and low density, to design appropriate installations and equipment.

Multiple standards exist in this area, such as the ISO 22734-1:2025[2], which covers "Hydrogen generators using water electrolysis". This standard makes recommendations about parameters to measure and the corresponding smart controls and safety measures that can be invoked.

By focusing on training for the experts who design hydrogen systems and smart controls around them, it will be possible to build emerging hydrogen infrastructure and end-user equipment in a robust way. This will eliminate the need for complex training for end users, who will often be members of the public without any knowledge of the hazards associated with hydrogen.

Cost-effective technologies

Domestic systems and cars must work at the intersection of safety and affordability. Mass production of sensors and other safety system components used in high-volume production of cars and heating boilers will enable this. But the transition of hydrogen from the chemical industry to applications where the general public is involved requires a shift in the technologies used and the mindset of the teams designing these safety systems.

Early hydrogen leak detection on board the buses, trucks, trains and cars will mitigate the hazard of using hydrogen as a fuel. To achieve this, a specification for an on-board hydrogen sensor has been proposed, which specifies that the sensor reacts to the leak within seconds[3]. Sensors capable of achieving this ultra-fast response are under development[4]. A smart control system incorporating such a device can respond to a leak and automatically close valves on the hydrogen storage tanks to minimise the amount of gas that has leaked.

Many leak detection systems rely on chemical reactions in sensors to identify a leak. However, many different gases can trigger a response. For example, a catalytic bead sensor will detect many flammable gases, including methane, carbon monoxide and hydrogen. In some use cases, such as an industrial steam methane reformer or a domestic boiler running on a blend of natural gas and hydrogen, these three gases can be present at the same location.

A limitation of the commonly used, cost-effective catalytic bead sensor is that it requires a reaction between the fuel gas (hydrogen) and oxygen (from air). To detect a hydrogen leak in an inert background gas such as nitrogen, sonic leak detection or a different type of sensor technology must be used.

Sonic hydrogen leak detectors[5] listen for the characteristic signature of a gas as it rapidly flows from high to low pressure. These devices are increasingly being integrated into smart control systems alongside chemical gas detectors and flame detectors.

Speciation of the hydrogen leak, separate from the other flammable gases, is complex. A new generation of MEMS-based sensors[6] is being developed precisely for this purpose to enable a higher degree of granularity in smart control systems.

References

[1] https://www.mdpi.com/1996-1073/16/1/241/pdf?version=1672041001

[2] https://www.iso.org/standard/82766.html

[3] https://www.sciencedirect.com/science/article/abs/pii/S0360319909016620

[4] https://www.nature.com/articles/s41467-021-22697-w

[5] https://hysafe.info/uploads/papers/2021/194.pdf

[6] https://www.sciencedirect.com/science/article/abs/pii/S0925838822037896