Gas & Flame Detection:

Hydrogen Fuelling Stations

MSA
The Safety Company

Pollution and emissions caused by the use of fossil fuel is arguably one for the most important issues facing the planet today. Decarbonization targets, with net zero emissions by 2050, set in various parts of the world drive the efforts in finding alternative, green energy sources.

Whilst over the last two decades there has been very significant investments in renewables such as wind turbines and solar arrays that have resulted in the reduction of Hydrocarbons used, challenges remain. Unlike traditional Hydrocarbons which may be stored and consumed when energy is required, storage of electricity will require mass battery capacity, bringing with it equally compelling challenges such as abstraction of rare elements, transportation of raw materials, pollution during the manufacturing process and recycling costs.

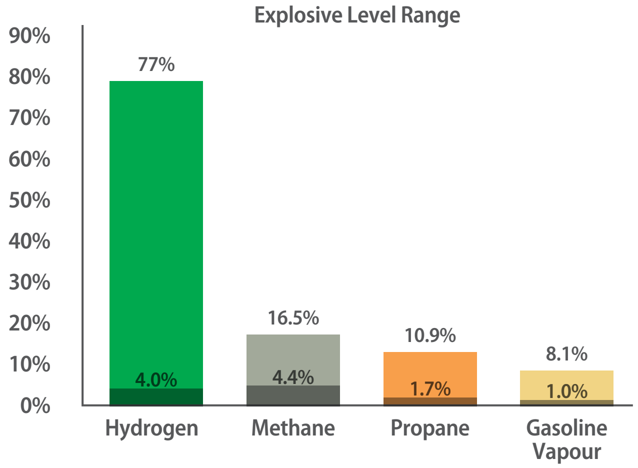
Decarbonizing transport will require a balance of EPVs and alternative fuels to power vehicles. Hydrogen is considered to be one of a number of alternative fuel sources to achieve this aim.

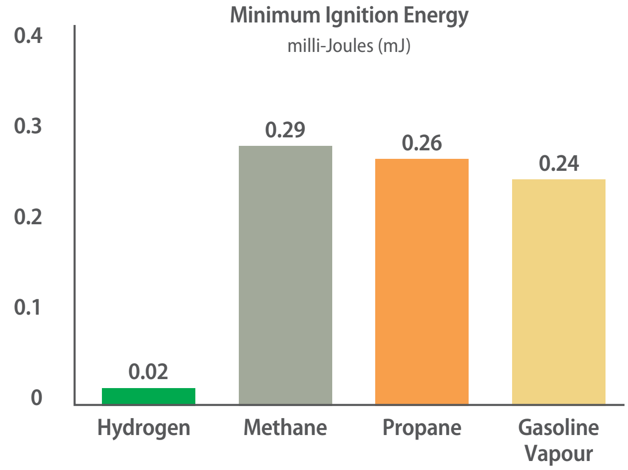
WE KNOW WHAT'S AT STAKE.

Application

Hydrogen is a flammable elemental gas with a wide flammability range. As hydrogen's minimum ignition energy in air at atmospheric pressure is approximately 0.02 mJ, it may be easily ignited. To provide some context, this is approximately ten times less than for the other typical gases or fuels, such as methane, propane or gasoline. Whilst Hydrogen is a safe and effective fuel source, it does require a change in thinking, processes and procedures, we also need to consider the human fuel intersect e.g. electrostatic discharge resulted from insulating, non-conductive materials or even clothes is able to ignite hydrogen as reported in UK's HSE-RR715 Report (p. 2.3.3.2)[1].

Hydrogen comparison to common fuels





Hydrogen's chemical properties pose unique challenges because it is colourless, odourless and undetectable by human senses. It is lighter than air and hence difficult to detect where accumulations cannot occur. When ignited, the flame of burning hydrogen is also nearly colourless and invisible with low radiant heat, compared to other combustible gases and may not be visible unless it is within a very close distance.

Hydrogen Main Properties

Identification

Chemical Name	Hydrogen
CAS Number	1333-74-0
EINECS	215-605-7
UN Number	1079
Chemical Formula	H_2
Synonyms	PROTIUM

Chemical & Physical Properties

Boiling Point	-252.77 °C
Melting Point	-259.14 °C
Molecular Weight	2 g/mol
Flashpoint	-240 °C
Ignition Temperature	560 °C
Ignition Energy	0.02 mJ
Density (Specific Gravity)	0.08989 g/l
Relative Gas Density	0.07 g/l
LEL: Lower Explosivity Level	4 VOL-%
UEL: Upper Explosivity Level	77 VOL-%

Not unsurprisingly, the legislative norms created for the safe use of Hydrocarbon fuels may not be appropriate for Hydrogen and consequently new norms have been introduced.

[1]HSE - RR715 Research Report: Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version

General guidelines according to ISO 19880-1

The selection of applicable technology for hydrogen fuelling stations is guided by requirements defined in ISO19880:2020. This is a complete set of standards covering all equipment and operations of refuelling stations dispensing gaseous hydrogen, defining also requirements for leak detection systems as one of the required mitigative methods within the protective layer.

Contained within the ISO 19880-1:2020[2] standards are specific requirements to provide for mitigation procedures that reduce the potential for formation of a flammable mixture (see p. 5.3.2) and that a release of flammable gas, must be detected.

Following are some specifics regarding fixed flame and gas detection system allowing for such mitigation and personnel protection:

- Fire detection systems – based upon a risk assessment (unique to each fuelling station), hydrogen fire detectors should be provided, securing the area from further flame escalation (see p. 5.3.6)
- Asphyxiation hazard prevention with monitoring oxygen deficiency – fixed gas detector should trigger visual and sound alarms at the entry and in confined spaces area with reduced oxygen levels (see p. 5.5.2).
- Leakage hazards in enclosures and buildings containing hydrogen equipment – based on measured hydrogen levels by flammable gas detection system, higher ventilation rate is initiated (see p. 7.11.3).

Alarms and safety actions

Hydrogen detection systems initiate the activation of safety systems at maximum hydrogen concentrations as stated below (see p. 11.2.3):

- LOW ALARM for triggering safety actions and personnel alert, max. 25 % LEL,
- HIGH ALARM for emergency shutdown and personnel alert, max. 50 % of LEL.

Note: Both set points can be lowered depending on the station risk assessment, for example, for enclosed areas with a high level of congestion.

Upon reaching a stage 1 alarm level, possible mitigation measures are not limited to, however may include:

- Closing hydrogen delivery and depressurisation of equipment,
- Electrical equipment de-energization, if not designed for use combustible areas,
- Increased ventilation rate.

Additionally, and as contained within ISO 19880-1:2020, reference is made to alternative and complimentary technologies such as ultrasonic gas detectors (see guidance B.4.3).

Additional gas detection considerations

Maintenance operations that may generate an ignition source within the restriction distances should be authorised and are, wherever possible to be avoided whilst the installation is in operation. Where maintenance has to be performed, e.g. in case of service necessity the atmosphere must be continuously monitored using portable, transportable or, if applicable, fixed hydrogen detection equipment.

[2] 19880-1:2020 Gaseous hydrogen — Fueling stations — Part 1: General requirements

Fixed Gas & Flame Detection Technologies for Hydrogen Fuelling Applications

Hydrogen's primary hazard is production of a flammable mixture that can lead to fire or explosion. Considering the very low ignition energy required to precipitate an incident a layered fire and gas detection system should be considered. (Figure 1)

In the event of a loss of containment, differing technologies all play their part in a detection leading to a shutdown. Therefore a system may not only consist of gas detectors but should also include ultrasonic gas leak monitors and flame detection.

Ultrasonic gas leak detectors can rapidly respond to high pressure releases of hydrogen at levels as low as 3g/s to provide the earliest notification of an incident having occurred.

Whilst hydrogen monitors such as catalytic or electrochemical cell type sensors will provide notification of a gas release, in all cases the gas must be at the point of detection in order for the detector to respond.

To further protect a plant against fires, hydrogen-specific flame detectors can supervise the process and adjacent areas.

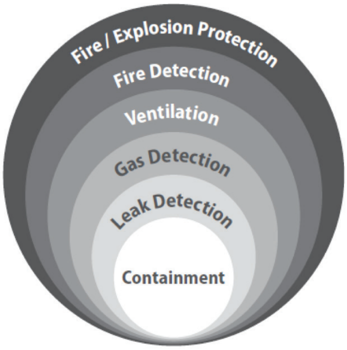


Figure 1. *Schematic of protective barriers for a hydrogen accident sequence.*

The mitigative layers – technology overview

Ultrasonic leak detection

When a containment system fails, hydrogen gas escapes at a rate that is proportional to orifice size and internal system pressure. Such leaks can be detected using ultrasonic monitors that detect airborne ultrasound produced by turbulent flow above a predefined sound pressure level. Using ultrasound as a proxy for gas concentration is a major advantage of this technique, as ultrasonic gas leak detectors do not require transport of gas to the sensor element to detect gas, and are unaffected by leak orientation, gas plume concentration gradient and wind direction. Such features enable ultrasonic gas leak detectors to be an ideal choice for supervision of pressurized pipes and vessels in open, well ventilated areas of fuelling station.

Depending upon the level of background ultrasound, for example, a single detector can respond to a small hydrogen leak at approximately 8 m from the source. As illustrated in Figure 2, even small leaks can generate sufficient ultrasonic noise to afford detection within most industrial environments. While audible acoustic noise typically ranges between 60 and 110 dB in industrial sites, ultrasonic noise levels (frequency range of 25-100 kHz) span from 68 to 78 dB in high noise areas where rotating machinery such as compressors and turbines are installed, and rarely exceed 60 dB within low noise areas.

Consequently, ultrasonic gas leak detectors can detect hydrogen leaks without being affected by back-ground noise. And as instruments respond to the gas release rather than the gas itself, instruments can alarm rapidly, often within milliseconds.

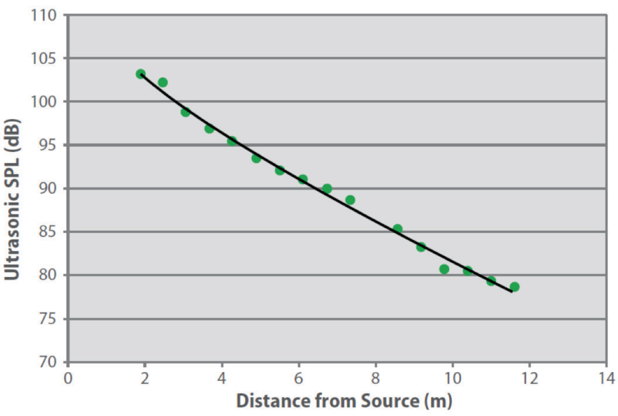
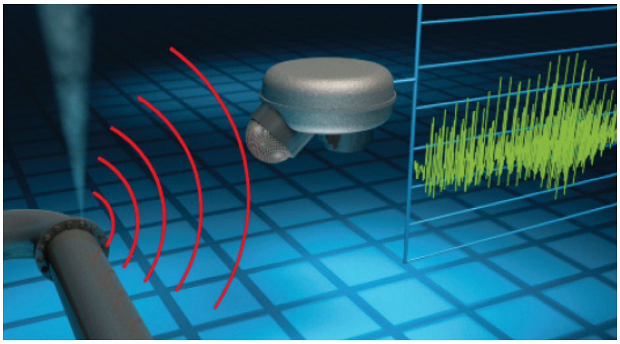


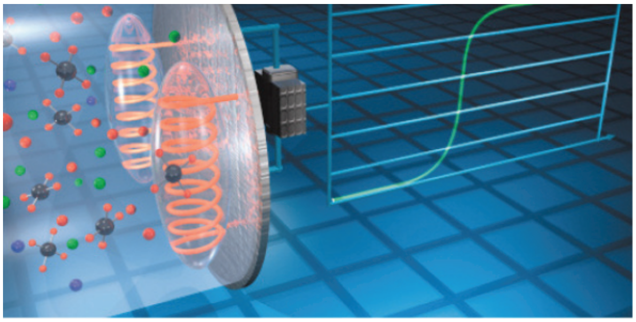
Figure 2. *Sound pressure level as a function of distance for hydrogen leaks. Leak size = 1mm-diameter orifice, differential pressure = 5,515 kPa (800 psi), leak rate = 0.003 kg/s. The curve is to guide the eye.*



Point gas detection

As previously indicated, there are two types of point gas detectors commonly used for the detection of Hydrogen, these can be either based on catalytic or electrochemical sensors.

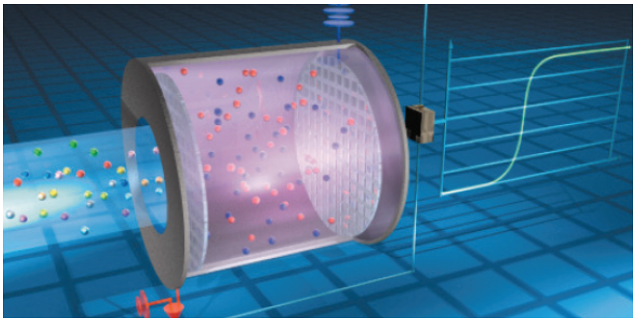
Catalytic gas detection works on the Wheatstone bridge principle, where the target gas enters the sensor through a sintered disc (sometimes referred to as a flash-back arrestor) comes into contact with the pellistors (or beads as they are commonly known) and is then oxidized. The amount of gas measured is directly proportional to the amount of gas present and results are read either locally via display on the device or remotely at a control unit located in a safe area. The operational range of these sensors is in the range of 0-100% LEL.



Catalytic sensor

Electrochemical sensors use an electrochemical reaction to generate a current proportional to the gas concentration. The sensor is a chamber containing a gel or electrolyte and electrodes. The gas sample enters the casing through a membrane; oxidation occurs at the working electrode and reduction takes place at the counter electrode, resulting in ions flow which creates a current. Measurement of this current is converted into a displayed gas reading.

The operational range of electrochemical cells for the detection of hydrogen is typically 0-1000ppm making this type of technology very much more sensitive than that of a catalytic sensor. However it should be noted that the response time of electrochemical cells are often higher than that of catalytic type sensors and therefore may be better suited for applications where Hydrogen gas would be contained within an enclosure e.g. within a fuel cell / compressor housing where the very earliest detection of a release with small gas concentrations is required.

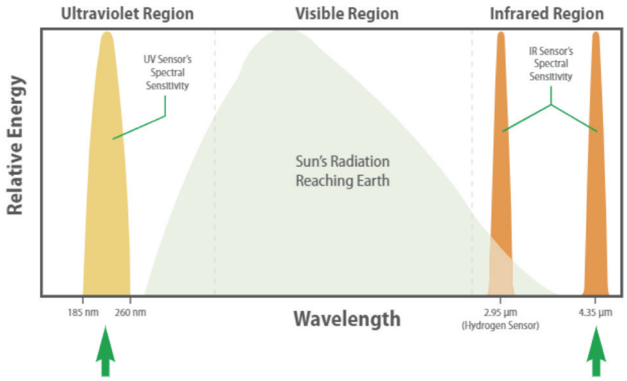


Electrochemical sensor

Hydrogen flame detection

In the event that the mitigative layers of protection have been defeated and fire event has occurred, hydrogen-specific flame detectors provide a warning that additional propagation methods must be deployed.

These instruments simultaneously monitor infrared and ultraviolet radiation at different wavelengths. Radiation is emitted in the infrared by water molecules created by hydrogen combustion; emission from such heated water or steam is monitored in the wavelength span from 2.7 to 3.2 µm. An algorithm that processes IR radiation modulation allows these detectors to avoid false signals caused by hot objects and solar reflection. The UV detector is typically a photo discharge tube that detects deep UV radiation in the 185 to 260 nm wavelength range.



Due to absorption by the atmosphere, solar radiation at these wavelengths does not reach the earth's surface; thus the UV detector is essentially immune to solar radiation. This combination of IR and UV detection improves false alarm immunity, while producing detectors that can detect even small hydrogen fires at a range of 5 m.

Figure 3 shows the detection range of a hydrogen-specific flame detector for a plume 15 – 20 cm (6 – 8 inches) high and 15 cm (6 inches) in diameter. As observed in this case, the flame detector can detect the on-axis range of 18 m (60 ft) up to ± 65°, providing broad angular coverage.

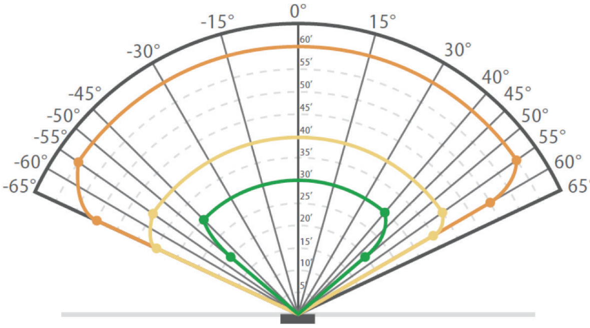


Figure 3. *Detection range of a FL500 UV/IR - H_2 Detector. Size of hydrogen fire: 15 cm (6in) diameter and 15 - 20 cm (6 - 8 in) high.*

Conclusions

Ultrasonic gas leak detection, electrochemical or catalytic bead gas detection and hydrogen flame detection have different strengths and vulnerabilities, and respond to differing hazard manifestations e.g. the detection of a release by sound, the detection of gas within the atmosphere or the presence of fire.

Further, each technology operates in a different area, for example catalytic detectors as point instruments and ultrasonic leak detectors and hydrogen flame detectors as area monitors. As for their unique properties, the combination of detectors increases the odds that hydrogen gas dispersal or fire is identified early on, either prior or post ignition. For effective system response to a gas leak, it is also important to take into account the correct positioning of gas detectors. Consideration should be given to relative density of hydrogen which is 0.07g/l, making it very much lighter than air.

Therefore, point detectors using catalytic and electrochemical sensors should be mounted above possible leak sources. Suggested locations include (HSE-RR715 Report, p. 9):

- areas where leaks are possible and gas can accumulate,
- connections that are frequently separated (i.e. hydrogen refuelling connections),
- in building air intake and exhaust ducts drawing possible leaks into or outside the building.

Since ultrasonic detectors use ultrasound as a proxy for gas concentration, it is a major advantage of this technique in that they do not require the gas to be at the sensor in order to detect a gas release. When choosing installation location mainly background noise and big structures that could attenuate or block the ultrasound before reaching the detector should be considered.

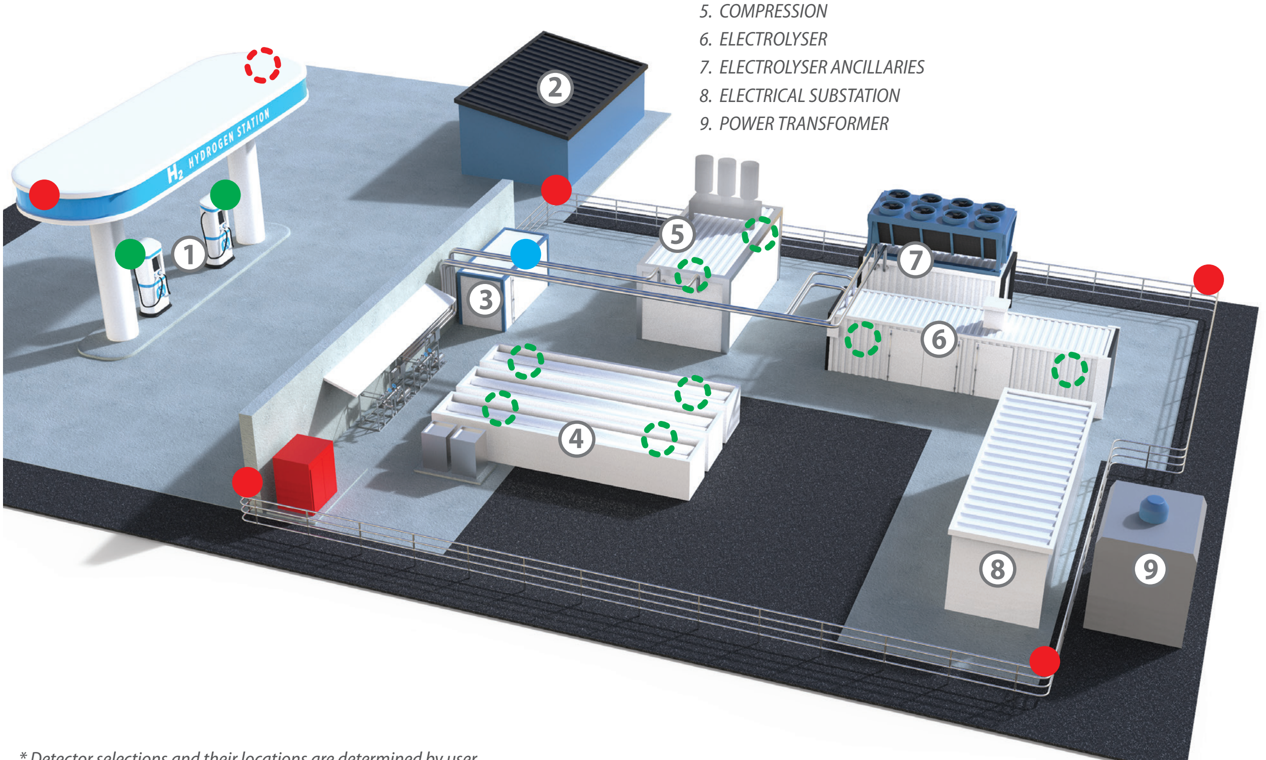
Below is an illustration of how these technologies are used in a hydrogen fuelling station with on-site hydrogen production.

Note: Determining optimal quantity and location of a fire and gas detectors is critical to ensure the detection system's effectiveness. Fire and gas mapping is one of the solutions that assists in the evaluation of fire and gas risks within a facility and help in reduction of undetected leak risks towards an acceptable risk profile. Fire and gas mapping includes placing of detectors in appropriate locations to achieve best possible detection coverage.

Typical Hydrogen (H_2) Fuelling Station Layout*

1. DISPENSERS
2. CONTROL ROOM
3. INSTRUMENT & ANALYSIS ROOM
4. STORAGE
5. COMPRESSION
6. ELECTROLYSER
7. ELECTROLYSER ANCILLARIES
8. ELECTRICAL SUBSTATION
9. POWER TRANSFORMER

Combustible Gas Detector
Ultrasonic Gas Leak Detector
Hydrogen Flame Detector



** Detector selections and their locations are determined by user.*
MSA offers a fire and gas mapping service to assist with detector placement.

MSA Gas & Flame Detection Solutions for Hydrogen Fuelling Applications

Low & Combustible Levels Detection

ULTIMA® X5000 Gas Monitor

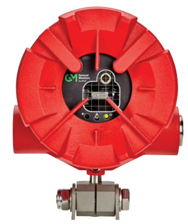
PrimaX® P Gas Transmitter

Series 47K Gas Sensors

Electrochemical and Catalytic combustion technology

Catalytic sensors offer simplicity, accuracy and relatively low unit cost in a single-point hydrogen detector. Catalytic sensors are suited for detection of combustible levels of hydrogen. Electrochemical sensing technology is used for very low parts per million concentrations allowing for early identification of a leak.

Flame Detection



FL500 UV/IR-H2 Flame Detector

UV/IR technology

UV/IR flame detectors are well suited for both indoor and outdoor use. The combined UV/IR flame detector offers increased immunity over either sensor type for detecting invisible hydrogen flames. They provide a fast response time and increased false alarm immunity against sources of radiation.

Compressed Hydrogen Leak Detection

Observer® i Ultrasonic Gas Leak Detector

Ultrasonic detection technology

Unlike conventional gas detectors that measure ppm or % LEL concentrations, ultrasonic gas leak detectors respond to the ultrasonic noise created by a pressurised hydrogen gas leak. This ultrasonic noise provides a measurement of the leak rate and establishes warning and alarm thresholds. It is ideally suited for compressor and storage tanks installations having pressure range of 350-700 bar, providing additional layer of instant hydrogen leak detection with response time of less than 1 second.

Controllers

SUPREMATouch Controller

9010/9020 SIL Controller

Fixed gas and flame detection controllers

MSA controllers provide flexibility, simple operation and reliability. The controller gathers signals from detectors that are connected to the controller and provides a local alarm to notify responsible personnel for the safety of hydrogen fuelling station, and required safety actions are triggered. In combination with MSA detectors it is the first choice for hydrogen leak and flame detection system application. MSA also offers controllers to help users meet SIL compliant design.

Controller solutions can be tailored for various sizes of facilities including system for fuelling stations.

MSA
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Portable Gas Detection

ALTAIR® io360
Area Monitor

ALTAIR® 4XR
Portable detector

ALTAIR® 5X
Portable detector with pump

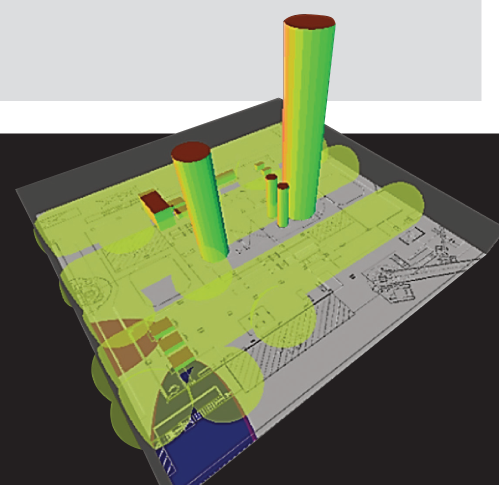
Area Monitors and Portable Gas Detectors

Hot work operations within hydrogen installation should be monitored continuously. Entries into the confined spaces are allowed only after conducting an atmosphere analysis, as well as continuously monitoring the inside atmosphere. Specially designed for sampling and monitoring, MSA offers a wide portfolio of rugged portable gas detectors, together with cloud-hosted Safety io Grid services.

Questions about sensor placement?

MSA's gas and flame mapping service combines 150 years of gas detection experience with 3D technology to help you maximize the effectiveness of every sensor.

Check out the link or scan for more information:
MSAsafety.com/gas-mapping



Note: This Bulletin contains only a general description of the products shown. While product uses and performance capabilities are generally described, the products shall not, under any circumstances, be used by untrained or unqualified individuals. The products shall not be used until the product instructions/user manual, which contains detailed information concerning the proper use and care of the products, including any warnings or cautions, have been thoroughly read and understood. Specifications are subject to change without prior notice.

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