HYDROGEN SAFETY IN OIL REFINERIES AND BEYOND

The adoption of hydrogen (H_2) as a zero-carbon renewable energy source promises a global revolution. The safety of H_2 gas, due to its highly combustible, flammable and asphyxiate nature, however, poses a safety challenge in terms of production and distribution. Hydrogen, however, has been used safely for decades in oil/gas refineries in critical process applications where its hazards are well known, it is safely monitored, and there are lessons to be learned.

Hydrogen Gas Characteristics

Fire, explosion, and asphyxiation are the primary safety considerations associated with handling hydrogen gas, especially considering its wide flammability range of 4 to 77 percent of volume in air. The main areas of risk can be categorized as shown in Figure 1. In oil/gas refineries, with their complex mazes of tanks, pumps, and piping, H_2 gas leaks are a serious hazard across the facility.

Figure 1: Hydrogen Accident Risk Factors

Hydrogen gas is invisible to the eye and has no odor, making it undetectable by human senses. H_2 is lighter than air and can drift outside. It is commonly understood that in confined inside areas it will rise upwards to ceiling level displacing oxygen. However, pressurized outdoor hydrogen gas leaks can be hard to detect as the gas jet direction can be unpredictable, making it difficult to detect in refinery spaces where accumulations cannot occur.

Typical Refinery Applications

Oil refineries are large producers and consumers of H_2 gas. Hydrogen plays a pivotal role in many refining operations, from hydrocracking—reduction of heavy gas and gas oils to lower molecular weight components—to treatment of gas streams, and catalytic reforming.

In catalytic reforming processes, H_2 is also used to prevent carbon from reacting with the catalyst to maintain production of lighter hydrocarbons and to extend catalyst life. Not surprisingly, refineries use large volumes of H_2 that are sometimes produced on site or purchased from H_2 production facilities.

In oil/gas refineries, the primary hazards associated with H_2 gas include respiratory ailments (oxygen deficiency), component failure, ignition, and burning. Although a combination of hazards occurs in most leak incidents, hydrogen's primary hazard is production of a flammable mixture that can lead to fire or explosion. As hydrogen's minimum ignition energy in air at atmospheric pressure is approximately 0.02 mJ, hydrogen is easily ignited.

Layered Gas and Flame Safety

In order to address hazards posed by H_2, fire and gas detection system manufacturers work within the construct of layers of protection to reduce hazard propagation. Using such a model, each layer acts as a safeguard, preventing the hazard from becoming more severe. Figure 2 illustrates an H_2 gas leak hazard propagation sequence.

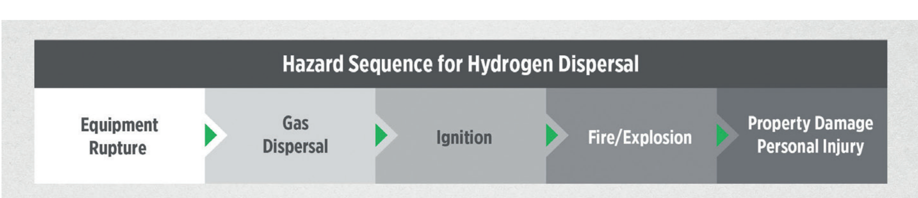

Figure 2: Hydrogen Gas Leak Dispersal Sequence

Key challenges for oil/gas refineries handling or storing hydrogen, with supporting hydrogen production plants, include detecting leaks outside, where the gas can't accumulate, and installing detectors appropriately within different risk zones. A robust and layered strategy for fire and gas detection is needed (Figure. 3).

To detect H_2 leaks requires several distinct, yet complementary sensing technologies that provide layers of protection in oil/gas refineries (Figure 4). Such technologies include ultrasonic leak detection, conventional catalytic bead gas detection, electrochemical cells and UV/IR flame detection, supported by plume modelling and gas mapping to demonstrate system effectiveness.

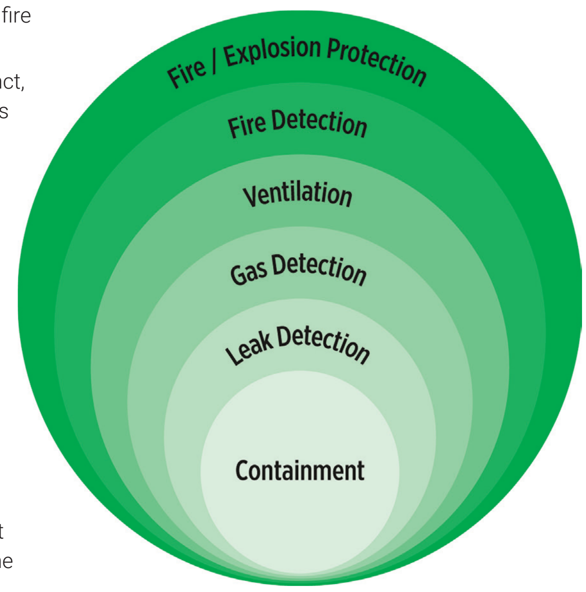

Figure 3: Hydrogen Hazards Layers of Detection

Ultrasonic Detection of H_2 Leaks

When pressurized hydrogen gas leaks, it generates an ultrasonic sound at the exit point. Ultrasonic monitors detect airborne ultrasound produced by turbulent flow above a predefined sound pressure level. Depending upon the level of background ultrasound, a single detector can respond to even a small hydrogen leak some distance from the source.

Ultrasonic detection is ideal for monitoring pressurized pipes and vessels (e.g. open well-ventilated areas of storage facilities ranging from large production sites to smaller distribution hubs). These detectors are highly responsive, alarming rapidly in the time it takes for ultrasonic noise to travel from the leak source to the detector at the speed of sound.

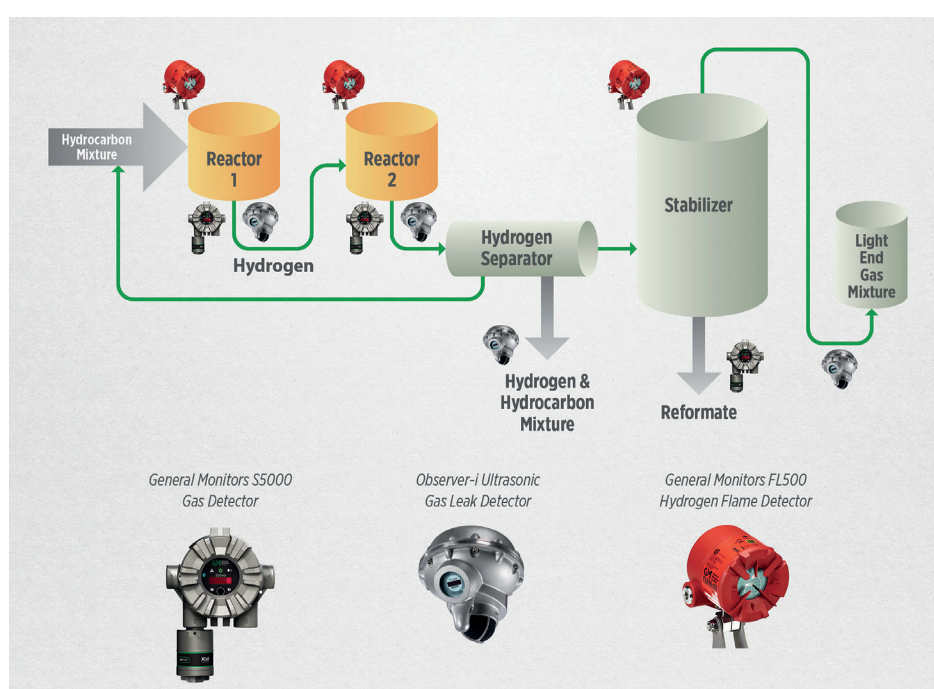

Figure 4: Oil Refinery With MSA Fixed Gas & Flame Detectors

Point Gas Detection of H_2 Leaks

In catalytic point gas detection, gas enters the sensor through a sintered disc (flash-back arrestor) and contacts pellistors (beads) and is oxidized. A Wheatstone bridge converts the change in resistance into a sensor signal proportional to the gas level present. Results are read either locally via the detector's display or remotely. Their operational range is 0-100% LEL.

Alternatively electrochemical sensors are used where electrochemical reaction generates a current proportional to the gas concentration. The sensor contains a gel or electrolyte and electrodes. Gas enters through a membrane; oxidation occurs at the working electrode and reduction takes place at the counter electrode, creating an ion flow generating a current, which is converted and displayed as the gas reading.

The operational range of H_2 electrochemical cells is typically 0-1000 ppm. Their ability for detecting these ppm levels of low gas concentrations makes them well-suited to areas where H_2 gas would be contained within an enclosure, such as a compressor housing where the earliest detection of a small gas release is typically required.

Hydrogen Flame Detection

In the event of flames or a fire resulting from an undetected gas leak, H_2 flame detectors provide a warning to deploy fire suppression and other safety actions. These detectors simultaneously monitor infrared (IR) and ultraviolet (UV) radiation at different wavelengths.

When hydrogen burns, radiation is emitted in the infrared spectrum by hot water molecules or steam created by combustion. An algorithm that processes IR radiation modulation reduces false signals caused by hot objects and sunlight reflection. The UV detector is typically a photo discharge tube that detects deep UV radiation.

The key benefit of using UV and IR sensors within a single instrument is the only alarm source shared between the two sensing technologies is a real fire. Due to absorption by the atmosphere, solar radiation at certain wavelengths does not reach the earth's surface, eliminating false alarms from solar radiation when appropriate range is monitored.

Conclusions

MSA Safety continuously examines gas and flame workplace safety risks and challenges posed when producing, handling, transporting, storing, and using H_2 and other gases alongside suggested industry best practices, safety measures, and sensor detection technologies. We never stop when it comes to developing the gas and flame detection technologies and safety solutions that prevent accidents with potential catastrophic consequences.

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