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Hydrogen Leak Detection: Monitoring and Control Methodologies

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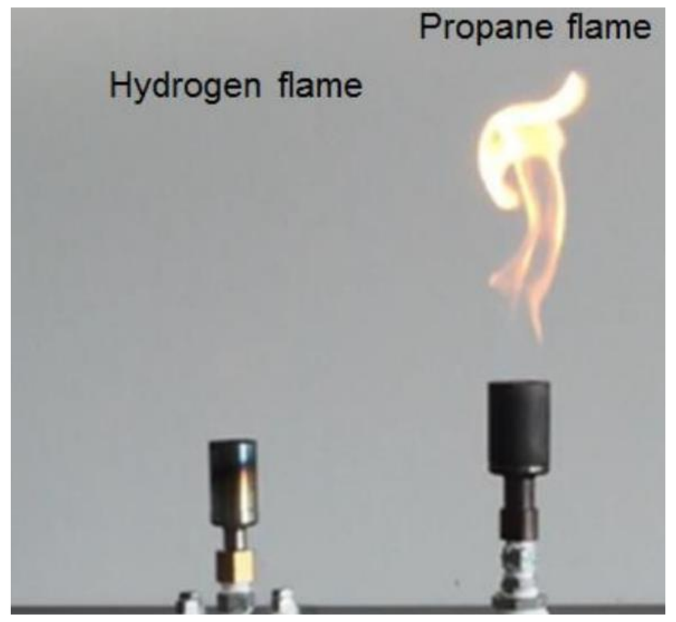
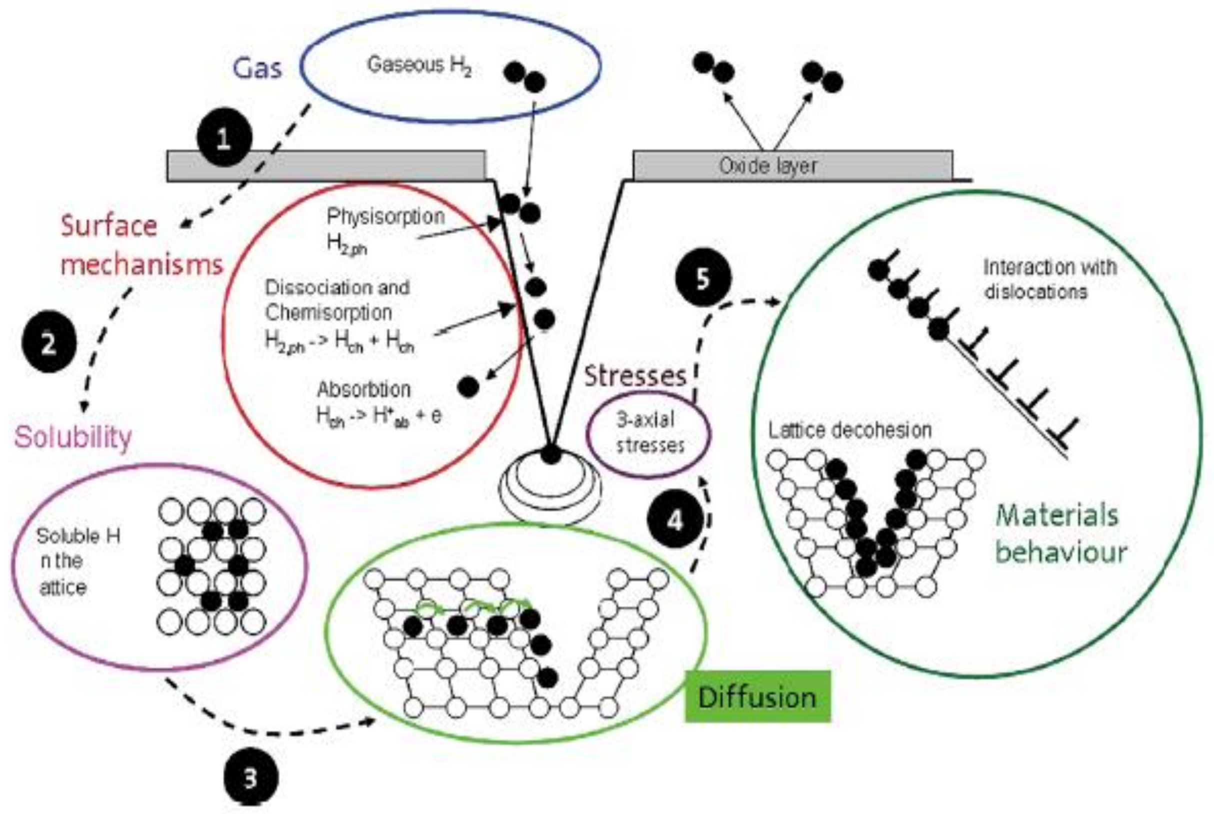
A **promising gas** for reducing environmental pollution and the use of fossil fuels is **hydrogen**. Hydrogen has a low density, a wide flammability range and a low minimum ignition energy.

If a leak occurs, there is a potential risk of hydrogen forming flammable mixtures with air, leading to the possibility of jet fires. It's important to note that hydrogen flames are invisible in daylight.



Because hydrogen molecules are exceptionally small, they can infiltrate materials, undermining both their microscopic and macroscopic tensile strength, fatigue strength, and fracture toughness. This phenomenon is known as hydrogen embrittlement (HE).



Several research studies have delved into the analysis of hydrogen losses to construct a comprehensive model for the distribution of concentrations over time and space. This model plays a crucial role in calculating a **safety distance**, a paramount parameter in ensuring safety in the proximity of hydrogen infrastructure.

The **vigilance and monitoring of hydrogen leaks** involve the continuous observation and assessment of potential hydrogen gas emissions within a given environment. This proactive approach is crucial for ensuring safety in various industries, especially in scenarios where hydrogen is used or stored. The monitoring process typically employs sensors, detectors, or other analytical methods to detect and quantify the presence of hydrogen in the air.

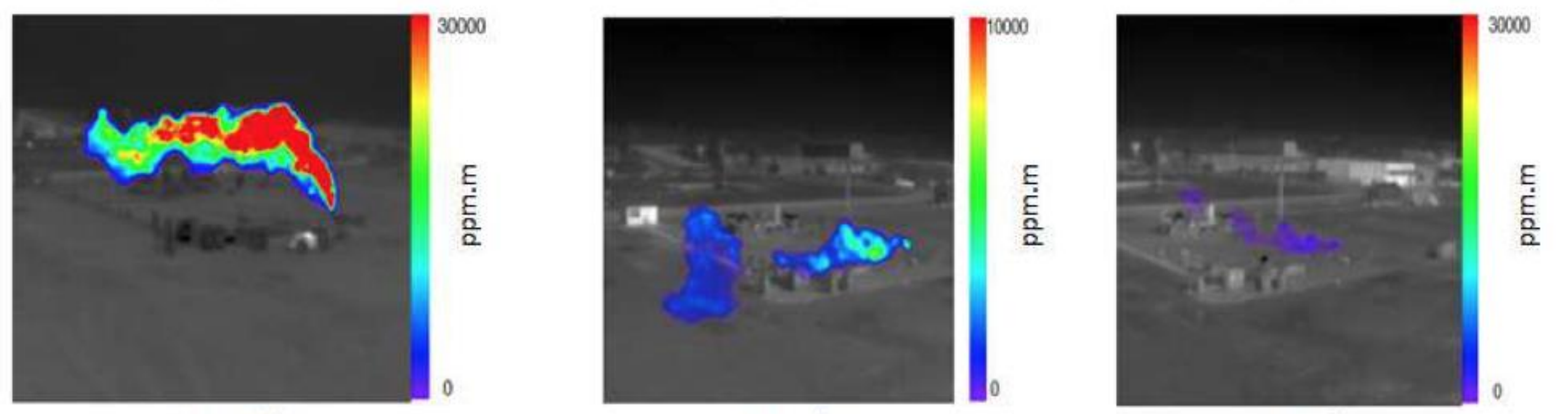
This emphasis on monitoring is particularly vital in the context of aging infrastructure, where ageing over time may increase the likelihood of leaks. Additionally, external factors such as natural disasters can further contribute to the need for vigilant monitoring, as they may elevate the risk of hydrogen-related incidents. By actively tracking and addressing hydrogen leaks, industries can mitigate potential hazards and enhance overall safety measures in their operations.

Monitoring hydrogen leaks can be effectively conducted utilizing **platforms** equipped to acquire data, including photographs and/or videos, from diverse altitudes. This approach offers a diversified spatio-temporal resolution, allowing for a comprehensive understanding of the dynamics surrounding potential hydrogen emissions. By employing platforms such as aerial drones, satellites, or other remote sensing technologies, data can be gathered from different perspectives and elevations. This approach enhances the ability to detect and assess hydrogen leaks across varying spatial scales and over different time intervals.

Drones, or unmanned aerial vehicles (UAVs), stand out as highly versatile and flexible platforms controlled by a ground operator. Operators can pre-set flight plans or make real-time adjustments to direction, altitude, and speed during flight. Drones are particularly effective for covering smaller areas, providing data with greater precision and resolution.

The use of drones for monitoring purposes requires the integration of specialized devices, commonly known as sensors. These sensors are designed to detect released gases or small fires that might be challenging to identify through conventional means. The designated tools enable the capture of **photos and/or videos** from safe distances. This methodology proves especially advantageous in environments where the presence of flammable or corrosive substances poses a risk of compromising or causing malfunctions in the monitoring equipment. Using drones with these sensors enhances safety measures and allows for effective surveillance in potentially hazardous or challenging conditions.

Several research studies have employed a drone-mounted infrared camera to identify and detect different materials leaks from a storage tank. By utilizing infrared imaging, the drone can capture temperature variations of the gas, providing a valuable tool for monitoring and addressing leaks in a timely manner. In a study by Druart et al. (2021), a drone-mounted infrared camera was employed to identify methane leaks. The experiment involved three distinct flight heights: 80 meters, 40 meters, and 20 meters, each simulating gas losses at rates of 200 g/s, 10 g/s, and 1 g/s, respectively. The findings demonstrated that, notably, even at an altitude of 80 meters, the smallest methane leak could be accurately and clearly detected using this technology.



200g/s 10g/s 1g/s

Two methods are proposed to address the issue of detecting hydrogen leaks:

1.Schlieren Method for Gas Detection: The Schlieren method is an optical technique that leverages density variations in a transparent medium, providing a means to visualize and record gas flows. This approach utilizes the bending of light rays caused by density variations within the gas, resulting in patterns known as Schlieren lines or density shadows. By employing a sensing system, such as a high-sensitivity camera mounted on a drone, changes in light intensity within these density shadows can be captured. The resulting images effectively highlight variations in gas density, enabling the real-time monitoring and visualization of leaks or flows (Hargather and Settles, 2012).

2.Thermal Camera for Hydrogen Leak Detection: Hydrogen, due to its low minimum ignition energy and high heat of combustion, has the potential to generate jet fires upon release, producing significant heat. This can be readily detected using a thermal camera installed on a drone. The thermal imaging capability allows for the real-time monitoring of hydrogen leaks by capturing variations in heat patterns. This method provides an efficient means of identifying and addressing potential safety concerns associated with hydrogen leaks.

Reference

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