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IoT-BASED BIOGAS LEAKAGE-DETECTING DEVICE

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Abstract: A biogas leakage detection service needs to be included in the continuous maintenance routine of every competent plant operator. In addition, biogas includes hydrogen sulphide (H2S), a hazardous gas that has been responsible for several fatalities in the agricultural sector of the United Kingdom; these deaths have been attributed to the management of slurry tanks. Because hydrogen sulphide is heavier than air, it will accumulate on the ground. It has the potential to build up in tight places that have inadequate ventilation, and it may go undiscovered until someone enters the space, which may have potentially catastrophic consequences. To detect gas leakage, an Internet of Things (IoT) enabled gas leakage detection system is an intelligent method. Leakage of gas is a significant safety hazard in a variety of settings, including households, industries, and piped gas distribution networks. The most significant businesses that are susceptible to fire hazards include refineries, oil and gas industries, and supply-chain companies that deal with flammable gases and liquids.

Keywords: IoT, Biogas, Sensors, Gas Sensor, Leakage Detecting Device

I. INTRODUCTION

In modern times, sensors have become an integral component of every embedded system module. A sensor is a device that can detect and report any changes in its surroundings at the location where it is placed. The fundamental distinction between a sensor and an actuator is in their input-output relationship. A sensor converts a physical quantity input into an electrical quantity output, whereas an actuator converts an electrical quantity input into a physical quantity output. There is a wide range of sensors easily accessible for diverse uses. Among them are a temperature sensor, flow sensors, pressure sensors, proximity sensors, radio sensors, optical sensors, gas sensors, position sensors, and several more [1]. This research aims to examine the functioning, various kinds, measurement methodologies, and applications of gas sensors.

A gas sensor, also known as a gas detector, is a device with the ability to detect the presence of gas in its surrounding area. This gas sensor can detect hazardous gases, combustible gases, and flammable gases, as well as measure their concentration. It may be used for the goal of raising alarms and constructing safety systems [2]. Gas sensors are utilised in various applications, including detecting gas leaks in residential and industrial settings, identifying hazardous gases in coal mines, monitoring oxygen levels in sewage treatment plants, detecting toxic gases in the environment to prevent human casualties, analysing alcohol breath, medical applications such as electronic noses, assessing air quality in underground tunnels for maintenance or upgrades, and more.

II. GAS SENSING TECHNOLOGIES

Various sensing methods may be used to study a gas sensor that detects both the presence and concentration of gas. Not all gas sensors operate using the same approach. The implementation of the sensor's properties might vary depending on the operation [3].

METAL OXIDE-BASED GAS SENSOR

A metal oxide gas sensor is essentially a kind of chemo resistor. These devices are mostly used to detect certain gases. The oxide layer reacts with the molecules of the target gases, resulting in a modification of the sensor's resistance [4]. Metal oxides, such as tin dioxide, copper oxide, and vanadium pen oxide, are often used in the oxide layer to induce a modification in resistance when they react with certain gases. The metal oxide gas sensor is the ideal choice for both industrial applications and civil usage [5]. In the metal oxide gas sensor, it is necessary to warm the sensitive layer in order to enhance the adsorption on the surface of the layer. In addition to sensitivity, there is another characteristic known as selectivity that may be enhanced by doping or increasing the size of the sensor array. The curve is defined by many criteria including sensitivity, selectivity, stability, reaction time, and recovery time.

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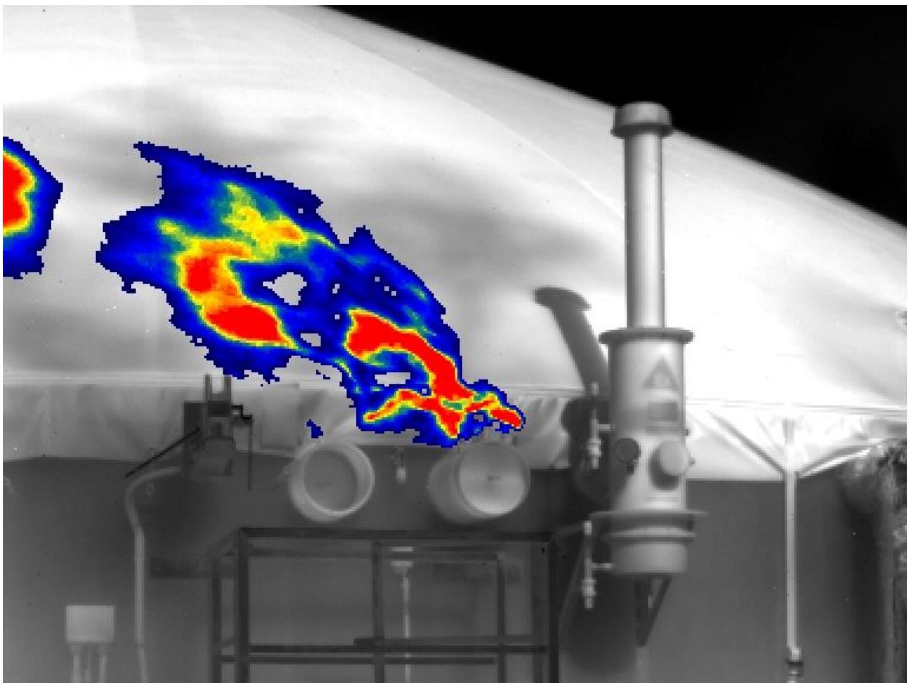

Figure 1. Gas Cam

ELECTROCHEMICAL GAS SENSORS

Electrochemical gas sensors operate by allowing the gas to permeate through a porous membrane and reach an electrode. At the electrode, the gas undergoes oxidation, resulting in the generation of an electrical signal. This electrical signal is directly proportional to the gas concentration. The system is composed of two terminals, namely the anode and cathode.

The anode facilitates the process of oxidation, whereas the cathode facilitates the process of reduction. The gas is transported to the electrode surface via the capillary opening and then permeates through the hydrophobic barrier via diffusion. The membrane serves to prevent the leakage of liquid electrolytes and provide a sufficient electrical signal at the detecting electrode. A reference electrode is used to maintain a constant voltage at the sensor electrode. The flow of current between the sensing and counter electrodes is created as a result of the ongoing electrochemical reactions taking place on the electrode surface, specifically owing to the electrochemical interaction with the target gas [6].

CAPACITANCE-BASED GAS SENSOR

As a method for detecting the concentration of the gas, the capacitance-based gas sensor detects the difference in the dielectric constant that exists between the electrodes. When compared to the permittivity of space, the dielectric constant is defined as the ratio of the permittivity of a substance to that of space. Permittivity, sometimes referred to as electric permittivity, is a basic constant that establishes a relationship between the intensity of an electric field and the amount of electric displacement [7].

Alterations in the dielectric coefficient of the film may be detected by the capacitive sensor by the use of inter-digitized electrode structures, which are analogous to the plates that are found in a normal capacitor. According to the basic principle, the capacitance will increase when the dielectric constant of the film is lower than that of the analyse, and conversely, the capacitance will drop when the dielectric constant of the film is larger than that of the analyse.

OPTIC METHOD GAS SENSOR

Gas detection with optical techniques [8] often relies on ellipsometry, spectroscopy, and interferometry. There are only a limited number of gas sensors used in commercial applications that rely on optical methods. The spectroscopic analysis encompasses two distinct techniques: absorption and emission.

The absorption approach relies on the specific wavelength of the gas to determine the concentration, since the degree of absorption changes accordingly. Optical technologies provide several benefits compared to nonoptical approaches. An infrared source is used as the optical source in absorption spectroscopy.

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ACOUSTIC WAVE GAS SENSOR

Chemical sensors have inherent limitations, notably the challenge of mitigating secondary contamination. Ultrasonic technologies provide improved means of addressing these limitations.

GAS CHROMATOGRAPHY

Gas chromatography (GC) operates based on the idea of Partition Chromatography [8]. It is a chemical analysis tool that is used to separate the various compounds present in a sample. The process consists of two distinct phases: a mobile phase and a stationary phase. The mobile phase is comprised of the carrier gas, while the stationary phase consists of the packed column. This is a laboratory analytical method. The Gas Chromatograph (GC) has many essential components, including the carrier gas, flow regulator, thermo stated oven (consisting of the injector, column and detector), integrator, and display system.

At first, the sample solution is introduced into the instrument, where it is carried by a gas stream via a separate tube called the sample column. The carrier gas most often used is either helium or nitrogen. The different constituents are segregated inside the column, and the detector quantifies the amount of constituents that exit the column [10].

The equipment is injected with a reference sample of known concentration to measure a sample of unknown concentration. The concentration is determined by comparing the retention duration and area of the standard sample peak to that of the test sample.

III. APPLICATIONS OF GAS SENSOR

The Gas sensor has several uses across different disciplines, some of which include:

- Home safety and Industry safety
- Detection of harmful gases in mines
- Environmental monitoring
- Fire detection
- Alcohol breath tests
- Boiler control
- STP
- E-Nose (Grading of agro-products like coffee and spices)

HOME SAFETY AND INDUSTRY SAFETY:

Gas sensors are crucial in domestic settings as they aid in the identification of dangerous gases. Due to the distinct features of many gases, certain dangerous gases might go unnoticed, potentially leading to catastrophic consequences [11]. Gas sensors are crucial for detecting and alerting the presence of such gases. Gas sensor applications such as carbon monoxide detectors, LPG leak detection and alarm systems are now routinely found in many households to avert human casualties. Industries manage many types of hazardous gases that might be combustible, poisonous, or flammable. Industries use gas leak detection systems to ensure the safety of workers in such conditions. These systems are capable of detecting gas leaks that occur in pipes and alerting the workers.

DETECTION OF HARMFUL GASES IN MINES:

Mines are locations where many accidents might result in catastrophic events. Coal mine workers are exposed to a range of dangerous gases. Several operational safety and working environment regulations are established to enhance the well-being of workers in such settings. Despite the implementation of many preventative measures, the levels of dangerous gases in such environments might fluctuate [12].

Additionally, some gases possess the characteristics of being colourless, odourless, and tasteless, making them imperceptible to workers. To address such problems, these gas sensors, in conjunction with electronics, may function as an alert system.

ENVIRONMENTAL MONITORING:

Currently, the ecosystem is undergoing significant transformations as a result of pollutants, mostly emitted by cars. With the growing number of automobiles, there is a corresponding rise in pollution. These contaminants pose a significant risk to human health, leading to a range of respiratory ailments. Gas sensors are used to construct an air quality monitoring system that has previously been deployed in several cities for environmental research purposes.

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FIRE DETECTION:
A gas sensor may be used for the detection of fire or smoke. This sensor may be used to construct an alarm system that, upon detecting fire or smoke, can initiate the activation of sprinklers or exhaust gas, so mitigating the severity of the incident. This technology is versatile and may be used in many settings such as homes, schools, hospitals, and enterprises.

ALCOHOL BREATH TEST:
An example of a gas sensor application is the Alcohol Breath test analyser. This is the predominant technology used by law enforcement to detect individuals who engage in the act of operating a motor vehicle while under the influence of alcohol. This gadget can ascertain the content of alcohol.

BOILER CONTROL:
Additionally, this is used in other industries, particularly chemical facilities. The chemical plants have sizable boilers where chemicals undergo reactions to generate a blend of gases. It is necessary to maintain constant surveillance of these boilers to detect any leaks or irregularities. The gas sensors, together with supplementary sensors and electronics, are deployed in the surroundings to detect any potential leakage. The Bhopal gas catastrophe, considered one of the most significant disasters in the world, occurred as a result of the explosion of the boiler tank [13].

SEWAGE TREATMENT PLANTS:
There has been an increase in the occurrence of fatalities among humans in sewage treatment facilities in recent years. The Sewage emits a range of hazardous gases with an unexpected concentration that may be fatal. The workers perilously undertake the task of removing obstructions in the sewage tunnels and chambers, unaware of the potentially lethal nature of the poisonous gas, which may sometimes result in fatality. Gas sensors may function as warning devices that detect the levels of harmful gas concentration.

E-NOSE:
The construction of an E-Nose, which may be used in many applications, has been facilitated by recent advancements. An electronic nose is a collection of gas sensors used to measure the concentration of different gases. Within the food business, this gas sensor may be used to assess the quality of food by analysing its odour. It ensures uniformity in manufacturing batches and aids in the identification of contamination. The E-Nose is also used in the medical industry for analysing pathogenic microorganisms, forecasting lung cancer, and identifying viral and bacterial infections, among other applications.

IV. MONITORING SYSTEM FOR GAS LEAKAGE DETECTION

Sensor Nodes: IoT systems include clusters of sensors distributed across susceptible or monitored regions. These sections, located inside the plant, are enclosed spaces where potentially dangerous chemical reactions occur. Gas filling or bottling stations are facilities designed for the storage and transportation of gases.

Low Power Communication Protocol: IoT protocols include a range of low-powered RF-wide area networking technologies. LoRa is the protocol that is most often used. The sensor nodes constitute a wireless sensor network. The Lora protocol facilitates the transmission of data from sensors to the Internet Gateway. The Internet Gateway then transmits the data to the Cloud Platform.

Cloud Platform: The system saves data based on predetermined criteria and utilises machine learning algorithms to do data analytics, transforming the data into valuable insights. Furthermore, this data is sent to the user interface via the Internet gateway. The whole procedure is fully secure and provides expedited data processing.

User Interface: It might be either a specialised application or a centralised command and control centre. Using this interface, an unlimited number of people may access real-time information. Actuator nodes will initiate controlling activities such as deactivating valves and notifying relevant parties. All of these functions are executed remotely [14].

Leakage hotspots
Despite the confidence of an AD operator in the performance of their plant, all anaerobic digesters include intrinsic vulnerabilities that render them prone to methane leakage.

Figure 2. Biogas Leakage

Reducing the risk

The hazards associated with gas leakage are evidently substantial and often costly. Nevertheless, the procedure of detecting a leak is straightforward and cost-effective, so aiding in the prevention of a potentially catastrophic disaster. Therefore, any conscientious plant operator needs to include a gas leakage detection service as a crucial component of their continuous maintenance programme.

V. CONCLUSION

Regarding the topic of leak detection, this pertains to the identification and localization of leaks, particularly in the context of using a Gas Cam for remote detection. All crucial aspects related to gas measurement in biogas facilities have been addressed. In the second blog post, we focused on the examination of personal protection measures in biogas plants, namely the measurement of the individual gas concentrations in the raw biogas. The issues encountered in biogas plants were addressed in a solution-focused manner. Furthermore, the presentation included demonstrations of the potential applications of gas monitoring instruments.

REFERENCES

[1]. C. Sansone, S. Manfredi, E. Di Tucci, S. De Vito, G. Fattoruso, and F. Tortorella, "A novel approach for detecting alerts in urban pollution monitoring with low-cost sensors," in Measurements and Networking Proceedings (MN), 2022 IEEE International Workshop on, 2022, pp. 89-93.

[2]. Mahmudur Rahman Hera, Amatur Rahman, Afia Afrin, Md Yusuf Sarwar Uddin, and Nalini Venkatasubramanian. 2021 AQBox: An air quality measuring box from COTS gas sensors. In Networking, Systems and Security (NSysS), 2021 International Conference on. IEEE, Dhaka, Bangladesh, 191–194

[3]. Sadashiv Desai, Nitin & Alex, John Sahaya Rani. (2020). IoT-based air pollution monitoring and predictor system on Beagle bone black. 367-370.10.1109/ ICNETS 2.2020.8067962.

[4]. Ricciardella, Filiberto & Vollebregt, Sten & Polichetti, Tiziana & Alfano, Brigida & Massera, Ettore & Sarro, Lina. (2020). High-sensitive gas sensors realized by a transfer-free process of CVD graphene. 10.1109/ICSENS.2016.7808638.

[5]. Adefila, K.; Yan, Y.; Wang, T. Leakage detection of gaseous CO2 through thermal imaging. In Proceedings of the IEEE International Instrumentation and Measurement Technology Conference, Pisa, Italy, 2021; pp. 261–265

[6]. Liang Zhu, Bing Zou, He Zhang, Zhen Wang and MinJiang, "Design of Multi-sensor Wireless Monitoring System and its Application in Natural Gas Purification Plant", Published in Mechatronics and Automation (ICMA), 2022 IEEE International Conference on, Date of Conference 2022, DOI:10.1109/ICMA.2022.7237525.

[7]. P. C. Jain, R. Kushwaha, "Wireless Gas Sensor Network for Detection and Monitoring of Harmful Gases in Utility Areas and Industries", Sensing Technology (ICST), pp. 15-64, 2022.

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[8]. Prashant Shrivastava, Edwin Basil Mathew, Ayush Yadav, Parijat P. Bezbaruah, Malaya D. Borah,” Smoke Alarm-Analyser and Site Evacuation System (S.A.A.N.S.)”, 2021 Texas Instruments India Educators' Conference, Publication Year: 2021, Page(s):144 – 150
[9]. Januar Miraswan, Kanda & Ulfa Maulidevi, Nur. (2020). Particle swarm optimization and fuzzy logic control in gas leakage detector mobile robot. 150-155. 10.1109/ICACOMIT.2020.7440195.
[10]. Alphus D. Wilson and Manuela Baietto, Advances in Electronic-Nose Technologies Developed for Biomedical Applications, Sensors 2021, 11(1), 1105-1176; doi:10.3390/s110101105
[11]. Abdul Sayeed and Mohammed Suhail Shameem, Electronic Nose, Advances in Medical Informatics Volume 1, Issue 1, 2021, pp-06-09
[12]. Theofylaktos Pieri, Michalis P Michaelides, "Air pollution monitoring in Lemesos using a wireless sensor network", Electrotechnical Conference (MELECON) 2022 18th Mediterranean, pp. 1-6, 2022.
[13]. Chengxiang Wang, Longwei Yin, Luyuan Zhang, Dong Xiang and Rui Gao, Metal Oxide Gas Sensors: Sensitivity and Influencing Factors, Sensors 2020, 10(3), 2088-2106; doi:10.3390/s100302088
[14]. Electrochemical Sensors and Biosensors Danielle W. Kimmel, Gabriel LeBlanc, Mika E. Meschievitz, and David E. Cliffel Analytical Chemistry 2022 84 (2), 685-707 DOI: 10.1021/ac202878q