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Investigating the Application and Role of H_2S Gas Detectors in the Safety of Mines and Oil, Gas and Petrochemical Industries

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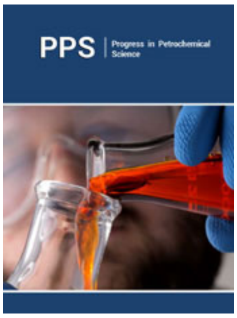

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Abstract

Hydrogen sulfide gas is a deadly and very dangerous gas that is formed as a result of the decomposition of sulfur-containing organic materials. There are natural gas, crude oil, mines and wells. The release of this gas in mining and oil reservoirs minimizes the safety of personnel. H_2S gas can cause severe pollution in the environment and cause many human and financial losses. To overcome this problem, it is necessary to use gas detectors. For this reason, the use of H_2S gas detectors in mineral and hydrocarbon extractions helps us find the percentage of H_2S gas emissions in different parts of a mine and oil reservoir on a ppm scale and take timely measures to deal with it. Let's apply it by emitting gas into the environment. This device produces signals and transmits them to the controller room so that the central computer can generate the necessary warnings. It is very important to address the issue of raising the safety level in the work environment and reducing the possible damages caused by the release of H_2S gas into the environment. The H2S gas detector is a type of detector with electrochemical cells, designed and produced by domestic experts in a knowledge-based company. In this study, an H_2S gas detector is introduced and its design and application stages in mines, oil, gas and petrochemical industries are reviewed.

Keywords: Gas detector; H_2S gas; Petrochemical industries; Safety

Introduction

H_2S gas is a toxic and hazardous byproduct of the oil and gas industries [1]. Like Nitric Oxide (NO) and Carbon Monoxide (CO), Hydrogen Sulfide (H_2S) is considered a gas transmitter due to its participation in significant physiological and pathological processes [2]. With rising global oil prices, oil companies have begun to compete closely for petroleum exploration, drilling and production [3]. In all stages of oil production from an oil reservoir, time is one of the basic parameters in the drilling, production and operation of the reservoir [4]. The main goal of all operating companies is to maximize the production of the reservoir and the optimal operation of the drilled well [5]. While drilling exploratory, developmental, descriptive, repair and other operations wells, several mechanisms can be identified and analyzed and interpreted to help diagnose and assess the extent of the damage. This research has tried to study the main mechanisms related to increase the safety in the oil, gas and petrochemical industrials. One of the risks that can exist in the mentioned high-risk industries is the release of hydrogen sulfide gas, which highlights its study and investigation [6]. Hydrogen sulfide gas is one of the most dangerous toxic gases in mining operations and hydrocarbon reservoirs and its level should be measured and controlled regularly in order to raise the safety level [7]. This gas may appear in different stages of drilling operations [8]. Hydrogen sulfide, or sour gas, whose chemical name is hydrogen sulfide, belongs to the family of mineral gases. It is a colorless and highly toxic gas that dissolves easily in water and is flammable and explosive. Hydrogen sulfide is a dangerous and deadly gas that smells like rotten eggs in low concentrations and is sweet in high concentrations. This gas is explosive and if it is exposed to an open flame or a source of spark in concentrations between 4% and 44% in the air, it will cause fire and explosion [9]. Its flame is blue in color, and with increasing temperature and heat, the intensity of its ignition increases. When it leaks, because it is heavier than air, it spreads for a long distance without moving upwards and if it ignites, it causes a lot of human and financial losses. This gas can quickly destroy the sense of smell. Therefore, it should be noted that the reason for the disappearance of the smell is not due to the decrease in gas but rather to its increase.

Many studies have been done on the origin of hydrogen sulfide in reservoirs and mines. The results show that Ge and Cl doping has no benefit for H_2S detection [10]. It will be possible to determine these sensors' limitations in the future and to identify the most promising ways to make these technologies usable in practical settings [11]. By increasing oxygen vacancies and playing a catalytic role in the oxidation of H_2S, the samples' improved sensing ability is validated. DFT calculations and in situ studies also disclosed the sensing mechanism of the samples [12]. According to Yang et al. the luminescence responses for H_2S detection are caused by the interactions of H_2S with the CDs and the anchoring ligands as well as the energy transfer between the ligands and the CDs [13]. In hydrocarbon mines and reservoirs, one or more mechanisms can cause hydrogen sulfide to form in them [14]. According to these studies, the main sources of hydrogen sulfide production in reservoirs and mines are activity of sulfate-reducing bacteria, thermochemical reduction of sulfate, thermal breakdown of sulfur-containing organic compounds, hydrolysis of metal sulfides and migration from other areas [15]. The ability to predict the presence of hydrogen sulfide in extraction from mines and oil fields will be a very good idea for reducing the risk of exploration and production in mines and oil reservoirs [16]. In all cases, increasing the safety of the personnel's working environment is of particular importance and a priority in all work fields. Serious and timely warnings from gas detectors are one of the most reliable ways to prevent personal injuries. Also, an important point that should be remembered in the discussion of financial damages is that this gas causes serious damage to the metals of equipment and facilities used in drilling and the exploitation of reservoirs and mines, as well as sealing parts used in maintaining fluids and system pressures. As a result, the preventive maintenance program should be in a way that protects the equipment as much as possible in the environment containing H_2S and minimizes their damage by giving a timely warning by the gas sensor.

Hydrogen Sulfide (H_2S) is an undesirable compound in mines and oil and gas reservoirs, which not only reduces the economic contribution of valuable hydrocarbons in reservoirs but also has toxic effects and causes corrosion of reservoir and mine exploitation equipment. In this research, the origin and dangers of hydrogen sulfide in reservoirs and mines have been identified. Its detection and measurement methods have been reviewed, and one of the sure ways to deal with it, which is the use of a gas sensor (H_2S), has been suggested. The use of hydrogen sulfide gas detectors in reservoirs and mines will play an effective role in reducing problems and increasing their extraction efficiency.

Materials and Methods

Characteristics of hydrogen sulfide gas (H_2S)

Hydrogen Sulfide (H_2S) is a colorless, deadly, highly toxic and flammable gas that is released from the decomposition of sulfur-containing organic materials. Because it is heavier than air (with a density of 1.189), it tends to accumulate in the lower levels and at the bottom of mines. It burns with a blue flame and produces Sulfur Dioxide (SO_2). In high concentrations, this gas reduces the sense of smell and causes death. This gas is explosive, and if it is exposed to flame or spark, it causes fire and explosion in concentrations of 4% to 44%. This gas is soluble in water and oil and easily reacts with metals, such as calcium and magnesium in concrete. Since H_2S toxic vapors are heavier than air, they may spread without moving upwards, and if ignited at a point far from the source of the flame, they may move towards the source. However, it mixes well with air and spreads in the atmosphere. The detector devices measure its emission on a concentration scale in terms of parts per million ppm.

The origin of hydrogen sulfide gas production (H_2S)

In fact, the process that causes the production of oil sometimes causes the creation of H_2S simultaneously and unintentionally. H_2S gas, which is formed from the decomposition of organic materials, is not only a problem in the mining, oil, and gas industries, where there are fatal contacts with this gas in several industries. This gas can appear as a byproduct in the sewage, rubber, artificial silk, paint and tanning industries. Several industries use hydrogen sulfide as an industrial chemical, such as pulp and paper mills and heavy water. Of course, hydrogen sulfide is often produced as a by-product and waste during other processes. Among the most important sources of H_2S gas emissions, the following can be mentioned:

A. Changes in organic matter by bacteria in septic tanks (sewage) and water channels.

B. The process of drilling operations, tunnel construction, coal mines and marshes.

C. Drilling operations in different layers of the earth to discover oil and gas.

D. As a by-product of some industrial activities.

E. Along with the gases of volcanic activity.

Dangers of releasing hydrogen sulfide gas (H_2S) in the environment

Effects of contact with gas (H_2S) on human health

Clinical evidence has shown that H_2S gas may cause syncope in one or more workers due to its immediate asphyxiating effects. In recent years, there have been many cases of fatal poisoning of sewage workers, oil refineries, lead and zinc sulfide mines and coal mines. The degree of danger of hydrogen sulfide depends on the concentration of this gas, and it can have various contacts with a person, including:

a) Acute contact: In acute poisoning, the amount of chemical substance entered into the body is high and the symptoms develop within a few minutes to four hours. If treatment is not given, it will lead to death within a few hours to a few days. When a person inhales hydrogen sulfide gas in low concentrations, this gas enters his bloodstream through the lungs. For protection, the body's defense mechanism starts to break down and oxidize the hydrogen sulfide gas and turn it into a harmless compound. Acute poisoning with hydrogen sulfide gas may occur without any warning because the sense of smell is quickly disabled by this gas and causes death within seconds. Although in more acute poisoning, the death rate is higher, if the rescue operation is done in time and quickly, there is a possibility of survival.

b) Chronic contact: In acute poisoning, the amount of chemical substance entered into the body is high and the symptoms develop within a few minutes to four hours. If treatment is not given, it will lead to death within a few hours to a few days. When a person inhales hydrogen sulfide gas in low concentrations, this gas enters his bloodstream through the lungs. For protection, the body's defense mechanism starts to break down and oxidize the hydrogen sulfide gas and turn it into a harmless compound. Acute poisoning with hydrogen sulfide gas may occur without any warning because the sense of smell is quickly disabled by this gas and causes death within seconds. Although in more acute poisoning, the death rate is higher, if the rescue operation is done in time and quickly, there is a possibility of survival.

The following numbers and figures are for information about the effect of different concentrations of this gas in the air on people and the resulting risks. The permissible contact limit is 6ppm. Concentration in Parts Per Million (ppm): 50-100ppm (at this concentration, the eyes and respiratory system will itch after one hour of contact). 200-300 ppm (in this concentration, after one hour, the eyes get bruised and the respiratory system gets itchy). 500-700ppm (at this concentration, confusion, headache, and nausea within 15 minutes and after 30-60 minutes, anesthesia and possible death). 700-900ppm (in this concentration, it quickly causes anesthesia and after a few minutes, it causes death). More than 1000ppm (in this concentration, it causes death in an instant).

Effects of exposure to H_2S gas on equipment

This gas reacts with metals, plastics, rubber, tissues and nerves. The reaction of H_2S with some materials leads to a phenomenon known as the embrittlement of materials by hydrogen sulfide. H2S is soluble in water and liquid hydrocarbons; it dissolves and forms a weak acid that can create holes in metals such as steel and cause them to corrode in the presence of oxygen or carbon dioxide. It produces Iron Sulfide (FeS) in the walls of the tanks, which is highly flammable and during the repair of the refinery, it should be done in accordance with the safety instructions. For this reason, where the presence of H_2S gas is expected, more care and precision are considered in the design and construction of tanks, drilling pipes, equipment, and their raw materials. By using this strategy, it is possible to increase the working efficiency of the equipment and reduce the costs associated with it.

Identification, measurement and evaluation of hydrogen sulfide gas

Fixed gas detection equipment

A. This equipment includes controllers, display screens, sensors or sensors of communication cables and is installed in places where there is a possibility of hydrogen sulfide gas. If the amount of H_2S gas reaches the dangerous limit, an alarm or warning sign is used.

B. Mobile equipment (portable): This equipment has a hydrogen gas pump and sensor that is attached to the worker's waist and shows the amount of this gas as soon as it enters the area containing hydrogen sulfide gas.

C. Laboratory equipment: in order to identify the worker's exposure to H_2S gas, they measure the amount of hydrogen sulfide in the breathing air. This is done with special laboratory equipment. Samples should be taken to the laboratory within 2 hours of contact.

Individual methods

a) Sense of smell: hydrogen sulfide gas in low concentrations smells like rotten eggs. As the gas increases, its smell changes and gives off a sweet smell. When the concentration increases, H_2S gas paralyzes the respiratory system, and the person loses their sense of smell. Therefore, this method is not reliable for gas detection and should be avoided.

b) Irritation of respiratory tracts: among all irritating and toxic gases, hydrogen sulfide gas is the only gas that strongly irritates and inflames the respiratory tracts, so by inhaling this gas, a person can quickly realize the presence of gas in the environment. This method should not be used as the main method for gas detection due to injuries to the respiratory system.

Types of gas measurement systems

A. Fixed gas measurement system: In this system, detectors are installed at the required operational level and connected to a central panel and if there is gas in the environment, the result is announced as the percentage of gas present, an alarm or both, by sending a signal. Of course, it may activate automatic prevention systems.

B. Portable gas measuring system includes gas measuring tubes and gas measuring devices with sensors.

Types of gas measuring sensors (based on performance)

a) Proximity sensor (catalytic)

b) Electrochemical sensor

c) Infrared sensor

Introducing the H_2S detector

This sensor is used to measure the amount of hydrogen sulfide gas in the air. Wherever there is a possibility of H_2S gas spreading, the sensor based on an electrochemical converter converts the presence of H_2S gas into a 20-4mA signal and transmits it to the data analysis set (Figure 1). The practical principles of this device are such that the presence of gas in the vicinity of the sensor appears as a voltage at the output of the converter. The voltage is proportional to the amount of gas at that point and after being amplified and converted into a current, it is transferred to the data analysis set. This detection device is placed in places where the possibility of H_2S gas release is greater, so that the presence of the gas in the environment is known as soon as possible and the necessary measures can be taken to deal with it (Figure 2 & 3).

Size	160 mm × 140 mm × 100 mm
Weight	2.2kg
Power	4.5 – 36 VDC 4-20mA loop-powered
Operating temperatures	-40 to +85 °C
Display	3.5 Digit LCD Gas Concentration, Calibration mode and sensor fault status
Calibration method	Via 2 Reed switches
Electrical output	2 wire 4-20mA
Terminals	Screw Plug
Sensor type	Electrochemical
Measurement Range	0-50 ppm, 0-200 ppm
Sensor Range	0-2000 ppm
Repeatability	1% of signal
Zero Drift	<2% Signal loss/month
Response Time	≤30 Seconds

Figure 1: Technical specifications of the H_2S detector.

Figure 2: The left side of the sensor assembly and the right side of the H_2S gas warning signs.

Figure 3: The image of the H_2S gas sensor set model GDS Corp.

Results and Discussion

The sensor itself is safe and explosion-proof. A correct and accurate prediction of the sensor installation location is extremely important. Because if it gets damaged and is far from the source of H_2S gas emissions, it cannot have the necessary efficiency for us. When working in the mining environment, in long mining tunnels, or on oil drilling platforms, we must be careful of other risks such as moving machines, cranes and others. All safety precautions must be followed during storage. Be careful when inspecting external connections that are exposed to chemicals. We should always be ready to listen to the warnings in order to prevent damages with appropriate measures. Care must be taken to predict a safe place to install the detector. In drilling rigs, four sensors are usually installed in the standard mode: one in the mud tank 11 exiting the well, one in the mud tank 12 entering the well, on the drilling platform 13 and the fourth sensor is installed under the structure of the drilling rig 14 near the well opening. All these installation locations are the first places where H_2S gas can be emitted. Before installing the sensor, the mechanic and head of the drilling rig should be consulted for the best installation location. As mentioned earlier, this sensor is directly related to the drilling mud circulation system and should be installed in a place that is far from the mixer, inlet and outlet. When the amount of gas in the air reaches 5ppm, the gas detector sets an alarm automatically. Of course, this sensor can sense from 1ppm to 500ppm and operate at a temperature of -40 to +65 degrees Celsius.

Conditions for connecting the sensor to electrical equipment and communications

In Figure 4, the general diagram of the electrical connections of the H_2S gas detector is shown. The wiring of the connections must be in a state where the power supply is disconnected and the polarity is correct. The connection cable is a two-wire type. The red color is for nutrition, and the black color is for nutrition. Care should be taken not to have a reverse connection. In the figure below, this method of connection and communication of the device is well displayed and the data analysis circuit can be seen in the general order from the sensor to the unit. The whole circuit is isolated from the data analysis set by safety protection (Figure 5). The connection method is that the output wires from the sensor go to the distribution box and from there they are connected to the distribution box inside the cabin by a pair of wires (preferably with a shield). Warnings are activated when the gas near the sensor exceeds the set limit. Warnings include the following: If the gas is more than 10 Parts Per Million (ppm), an audible warning and a yellow light Audible warning and red flashing light if gas exceeds 20 Parts Per Million (ppm) (Figure 6).

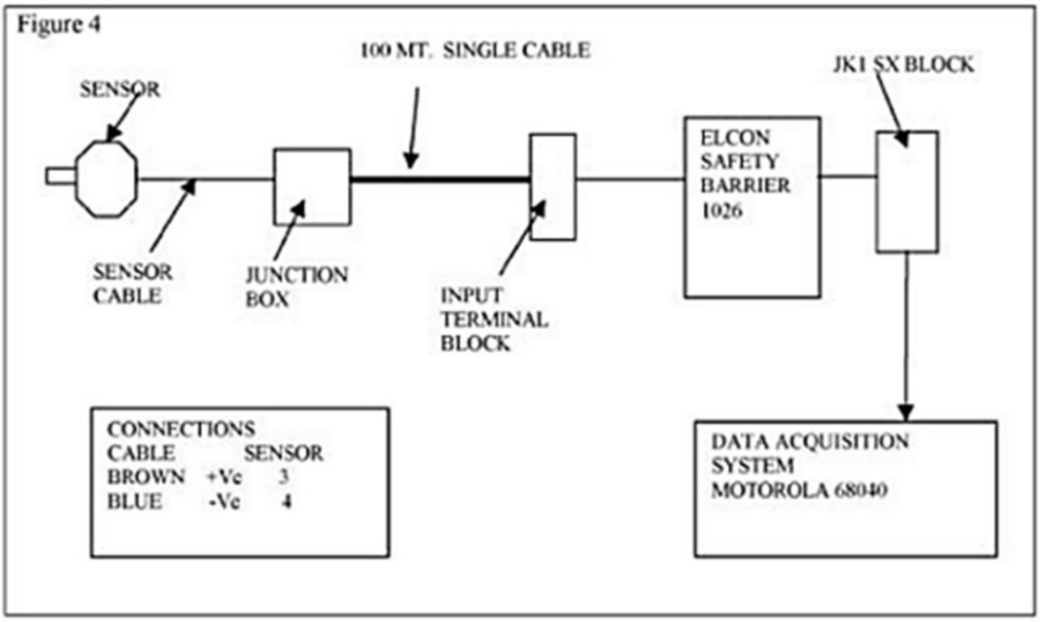

Figure 4: Data analysis circuit set from the H_2S gas sensor to the surface graphing unit.

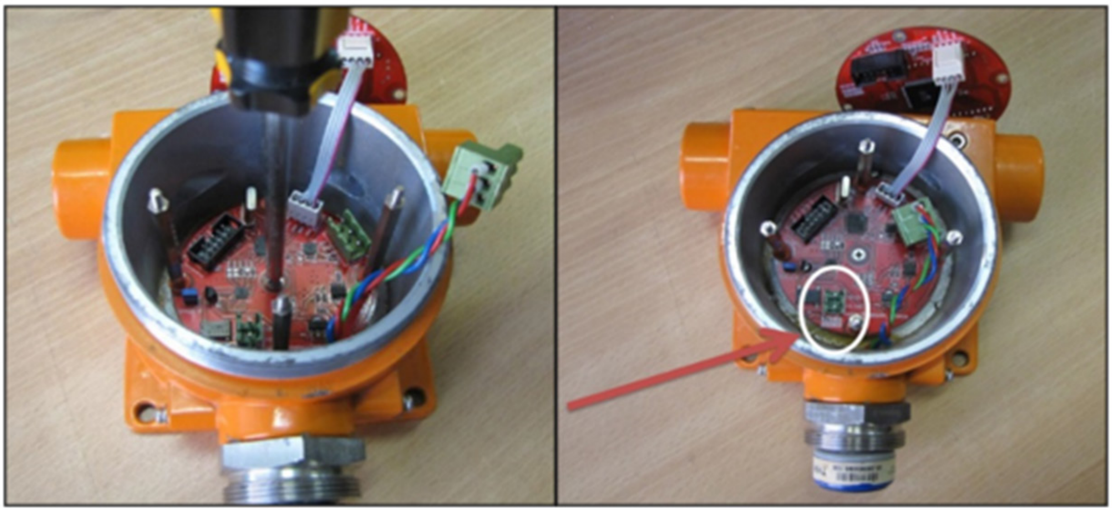

Figure 5: Board and internal components of the H_2S detector.

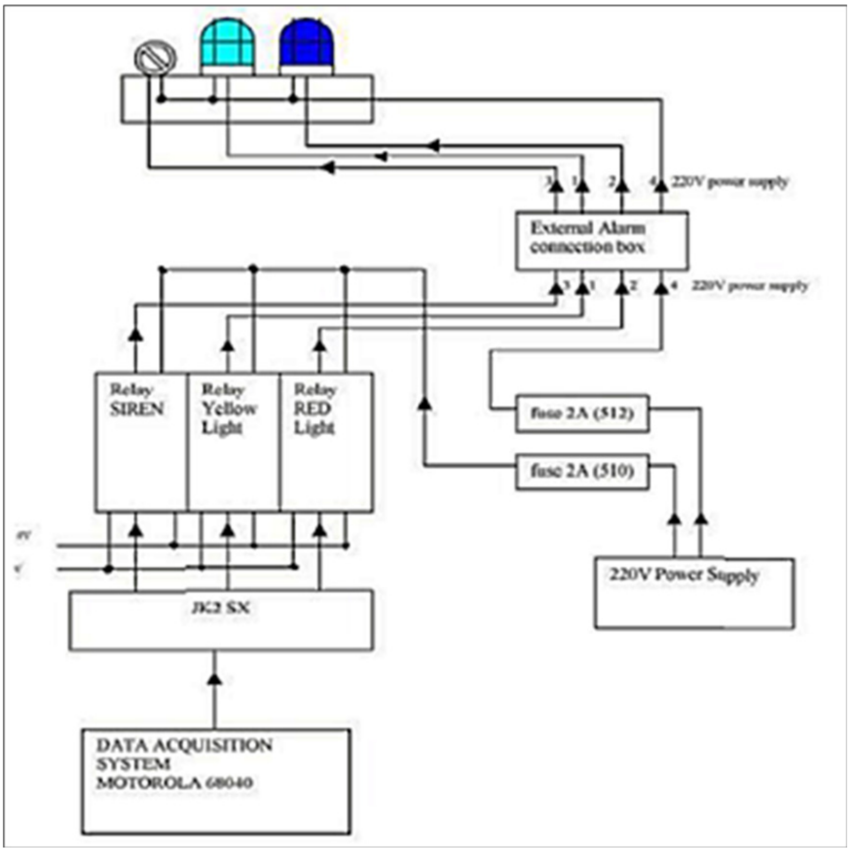

Figure 6: Data analysis circuit set from the processor unit to the warning set.

Calibration of H_2S gas sensors

Gas sensors must be adjusted and checked regularly to ensure the accuracy of the sensor and its reading system. For regular testing of gas sensors, it is better to install them in a place where they are easily accessible. Usually, the time to visit and calibrate the sensors is provided by the sensor manufacturer in its catalog. However, experience shows that in the period of 30 days after installing the sensor, it is better to monitor and check the sensor regularly because the degree of compatibility of the sensor with the environment in which it is installed will be determined within the same period of 30 days. became. Issues and problems such as the effect of direct heat, the level of humidity, and the vibration of the installation place will show their effect easily during these thirty days. If you intend to test the gas sensor after installation, the best test schedule is four days between the sensors in the first thirty days. Adjusting the gas sensors on site is much easier than the laboratory calibration method, and it generally includes two steps: first, the zero is adjusted and then the reading range or measurement of a certain range is adjusted.

A. Zero adjustment: Many believe that the best way to zero a gas sensor is to apply nitrogen or a mixture of clean air with a certain humidity to the sensor and then measure the sensor's output signal. Of course, this method may be used for environments such as food laboratories, hospitals, etc., but in industrial environments, this method is not an interesting one because the normal environment in such places has minimal gases that can be used as zero indicators. You should also consider the normal humidity level of the environment. In this case, the zero setting of the sensor is very realistic.

B. Setting the specific range: Setting the range of the gas sensor can be both very simple and very complex. In the case that the gas sensor is used to monitor safe and normal gases, setting the sensor's performance range by creating and applying a field of a combination of target gases to a certain extent can lead to determining the sensor's performance range. On the other hand, if the gas sensor is H_2S, then the risk of calibrating the sensor is very high. Some engineers recommend that in these cases the sensor should be transferred to the laboratory for calibration and then tested in a safe environment. Of course, this method is very accurate and with very low risk, but it is costly and time consuming. In this case, the use of plastic bags 25 containing a very small amount of the target gas or the use of calibration containers 26 are suitable alternatives to calibrate the sensor on site.

Maintenance and repair of the H_2S gas detector

In the maintenance and monthly control of the device, the utmost care must be taken. In addition to the weekly and monthly tests of the device during the period of use, after each project, its service and maintenance should be done so that, in addition to increasing the life of the sensor, its accuracy can be maintained in the next projects and it can perform the best and the least. have failures during the operation. Connections and distribution boxes should be regularly checked for oxidation and good sealing to be explosion-proof. If necessary, seal with appropriate materials, such as grease. If we don't have a signal sign, all the connections should be checked from the sensor part. If all the connections were correct and there was no signal sign, then change the sensor and check the signal sign.

Operational application of H_2S gas detector in oil, gas and mining industries

Use in drilling devices for exploratory, development and descriptive oil and gas wells: due to the presence of H_2S gas in hydrocarbon reservoirs, there is a possibility of hydrocarbon eruption and H_2S gas rising at any moment and this sensor is used in various parts of drilling devices, including vibrating screens in the well opening, the surface of the drilling platform and the return mud tanks and the entrance to the well. Use in oil exploitation and refinery units: because this gas is soluble in water and liquid hydrocarbons, the extracted crude oil carries a lot of gas and H_2S gas is released when the crude oil comes into contact with the open air. be made, the release of this gas may happen in all stages of crude oil refining and it becomes more intense with increasing temperature. For this reason, the use of this sensor is emphasized in all stages of crude oil refining, especially in places where the possibility of H_2S gas emissions is high. Use in gas refineries: due to the presence of H_2S gas in natural gas extracted from gas reservoirs, it is recommended to use this detector in all stages of separation and refining. As of now, due to the significant amount of hydrogen sulfide gas (more than 5000ppm) in the South Pars gas fields, a lot of sensors have been used. Therefore, the safety instructions related to drilling, offshore exploitation services and gas transfer to the offshore refinery are mandatory.

In addition to the oil and gas industries, H_2S gas is also emitted in other environments, such as mines. That the possible risks caused by its release in the environment are not only less than those in the oil and gas industries, but sometimes even more due to the conditions in mines and digging long tunnels for extraction. The mines in which this sensor can be used are as follows: Use in sulphide mines, especially lead and zinc mines. Among the mines in which H_2S gas emissions are higher, we can mention sulphide mines, especially lead and zinc mines. Use in coal mines: The release of this gas in coal mines has also been reported. In some mines, such as Parodeh Tabas coal mine, the changes in Methane (CH_4) and Hydrogen Sulfide (H_2S) gas levels at different times of tunneling and coal mining have been investigated. These changes indicate the presence of a low percentage of hydrogen sulfide gas in such mines. As it was stated, the release of H_2S gas, even at very low levels, can cause irreparable damage to personnel (Figure 7).

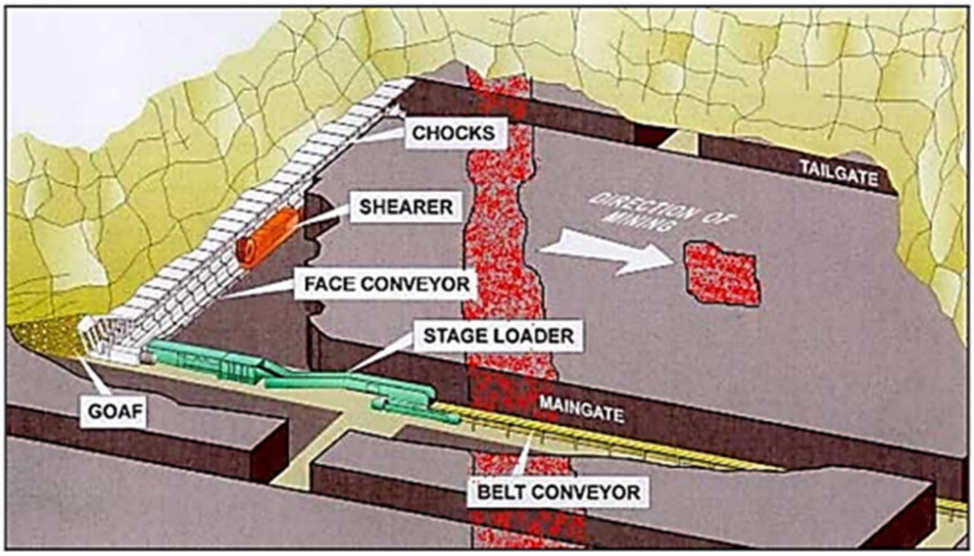

Figure 7: Sources of H_2S in high wall mines.

Practical control measures to deal with H_2S emissions in then mining and oil and gas industries

a) Use of sensors to detect and announce H_2S gas.

b) Measurement of the gas concentration in the working environment using lead acetate paper (CH3COOPb).

c) Fixed gas sensor systems (fixed monitors) and individual mobiles in dangerous areas for personnel.

d) Management controls: personnel training, shortening the work shift duration of persons exposed to hydrogen sulfide gas.

e) Engineering controls: using proper ventilation and reducing the number of pollutants; modifying the work process.

f) Use of personal protective equipment: In situations where technical engineering and management controls cannot reduce the level of contact with hydrogen sulfide enough, it is necessary to use personal protective equipment at the workplace.

The personal protective equipment required for hydrogen sulfide is:

A. Respiratory protection in the form of a full-face mask with a dedicated hydrogen sulfide absorption canister.

B. Eye and face protective devices in environments contaminated with hydrogen sulfide gas use safety goggles.

C. Skin protection equipment: rubber or neoprene gloves when exposed to gaseous or liquid hydrogen sulfide. Use of Self-Contained Breathing Apparatus (SCBA).

D. Combination of respirator and air supply system by air pipelines to work in enclosed spaces such as mine tunnels.

Summary and Conclusion

In this study, the importance of safety in the work environment has been shown well, so a lack of attention to this issue can lead to many life and financial losses. As discussed in this research, the release of H_2S gas in various environments, such as mines and oil and gas industries, and exposure to it can cause irreparable damage to personnel. In order to raise the safety level of the working environment from the very dangerous gas H_2S in industrial places, especially mines and oil industries, the use of a suitable and reliable solution is required. in such a way that this method has the least risk and loss of life and money. In any case, the time has come for all underground, open-pit mines and oil and gas industries to use control equipment, especially H_2S gas detectors and alarms. Therefore, according to the investigations carried out in this research and the introduction of the H_2S gas detector in terms of its capabilities and proper functions in timely dealing with H_2S gas, we come to the conclusion that the gas detection equipment, with its timely detection of many, prevents human and financial losses. Any kind of accident in the work environment causes loss of time, loss of life and loss of money. By preventing it, we can take steps toward the development of our business. The H_2S gas detector showed that it has a high accuracy of 1ppm and reacts with the release of H_2S gas at very low concentrations. This detection device, which is currently produced and manufactured by domestic experts, has no need to be imported anymore; it is better to be used in domestic companies and industrial organizations. In addition to supporting the domestic manufacturer, it is an effective step in reducing costs caused by accidents.

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