WHITE PAPER

Sensor Selection - Getting It Right For Flammable Gases

In gas detection terms, pellistors have been the primary technology for detecting hydrocarbons since the 1960s. This is because they are, in some circumstances, the most reliable and cost-effective means of monitoring flammable levels of combustible gases. This white paper will explore the circumstances in which the traditional usage of pellistors should not be relied upon, and instead the situations where infrared (IR) technology should be considered, particularly across the oil and gas industry.

Exploring the pros and cons of both technologies and the conditions under which IR sensors should be seriously considered as an alternative to pellistors will provide a useful resource for those in the sector to use to their advantage within their own environment.

CROWCON

Detecting Gas Saving Lives

Infrared sensors' weakness is that they are susceptible to severe mechanical and thermal shock. They are also strongly affected by gross pressure changes.

Which Gases Pose the Risk?

With a very real risk of explosion or fire in many industrial environments because of the presence of flammable gases or vapours, it is important to protect workers from the dangers prevalent in all given situations.

The gases that pose these risks are frequently hydrocarbons, and are composed of carbon and hydrogen atoms. A hydrocarbon references any of a class of organic chemicals made up of only the elements carbon (C) and hydrogen (H). Within these gases, carbon atoms join together to create the framework of the compound, and the hydrogen atoms attach to them in many different configurations.

The different hydrocarbon molecules vary in size, with the smaller hydrocarbon gases being highly flammable. As the molecular size increases, flammability decreases and the compound properties go from volatile liquids to fuel oils, lubricating oils and then to tars and waxes.

For those working in environments where flammable gases are a threat, be they hydrocarbons, or other flammable gas, such as hydrogen or ammonia, gas detection is crucial to alert the user to a hazard. Using the most appropriate sensor technology is an essential part of ensuring safety.

Although this paper primarily explores portable gas detectors and monitors, it is important to mention that similar analogues apply for fixed point detection.

So let's delve a little deeper into pellistor and IR technology, to provide further information on how to determine the right technology for the hazards in different environments.

As part of a site-specific risk assessment, all parameters should be considered to fully understand which the best technology of choice should be.

Detection Technology Available

Pellistor sensors use the combustion of a gas to detect it, and so they provide a direct measure of flammability. A pellistor is based on a Wheatstone bridge circuit (as shown in the diagram below/Fig 1), and includes two "beads", both of which encase platinum coils. One of the beads (the active bead) is treated with a catalyst, which lowers the temperature at which the gas ignites around it.

This bead then becomes hot from the combustion, resulting in a temperature difference between the active and other "reference" beads. This causes a difference in resistance, which can then be measured. As the amount of gas present is directly proportional to it, it allows for the gas concentration to be determined. It is necessary to note here, however, that an accurate measure of the gases present may not be achieved in this instance as it depends on calibration and the gas hazard mixture present. In high gas concentrations, the combustion process can be incomplete, resulting in a layer of soot on the active bead.

While the use of combustion to detect flammable gases may sound unwise, the design of pellistor sensors ensures the safety of the method. The hot bead and electrical circuitry are securely contained within a flameproof sensor housing (as shown in Figure 2), behind the sintered metal flame arrestor (or sinter) through which the gas passes. Due to being confined within the sensor housing, an internal temperature of 500°C is maintained allowing for the occurrence of controlled combustion. Safely isolated from the outside environment by the sinter, the pellister provides peace of mind for operators due to its inbuilt safeguards.

Infrared technology sensors use the absorption of IR by hydrocarbon gas molecules in order to detect the presence of the gas. Infrared is part of the electro-magnetic spectrum that sits between visible light and microwaves, and encompasses frequencies that range from 0.003x1014 to 4x1014 cycles/sec (or 1000 to 0.75µm). This technology can be employed in different ways to detect flammable gases. Here, we will explore NDIR technology, which is commonly used in personal gas detection.

NDIR is a term commonly used in the gas detection sector to refer to NonDispersing Infrared, and tends to be the most common type of sensor used to measure carbon dioxide, or CO2. The sensor utilises an infrared (IR) lamp and directs waves of light through a tube filled with a sample of air. This air then travels toward an optical filter in front of an IR light detector.

The carbon and hydrogen atoms that make up a hydrocarbon molecule are held together by covalent bonds (as shown in Figure. 3). These bonds have a natural frequency at which they vibrate. When exposed to infrared, the covalent bonds in hydrocarbon molecules absorb the IR of the same cycles/sec that are the natural frequency of the bonds. The amount of IR absorbed can be used to measure the concentration of gas present.

In practice, two IR emitters within the sensor each generate a beam of IR light (illustrated in Figure 4). Each beam is of equal intensity and is deflected by a mirror within the sensor onto a photo-receiver, which measures the level of IR received. The "measuring" beam, with a frequency of around 3.3µm, is then absorbed by the gas if it is present.This reduces the beam's intensity when it reaches the photo-receiver. The "reference" beam (around 3.0µm) cannot be absorbed by hydrocarbon gas molecules, and so arrives at the receiver undiminished. The %LEL of gas is ascertained by the difference in intensity between the beams measured by the photo-receiver.

Fig 1 Wheatstone bridge circuit diagram

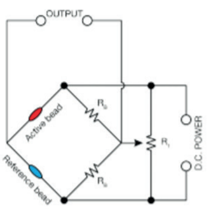


Fig 2 Pelsistor sesor construction

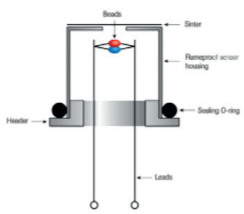


Fig 3 Methane; one carbon and four hydrogen atoms linked by covalent bonds

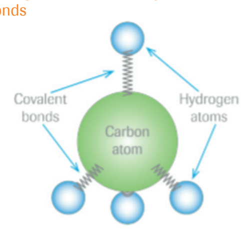
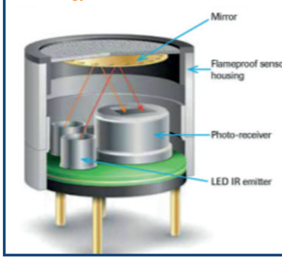


Fig 4 Operation of NDIR technology sensor



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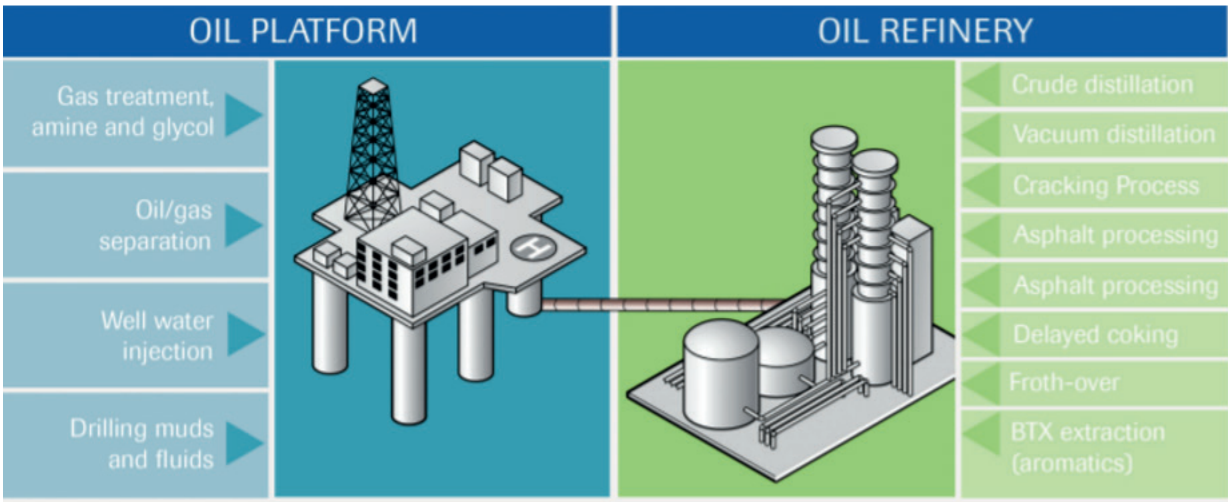
Drawbacks with Pellistors

Now that we have fully explored the way in which the available technology works, it is necessary to look at the drawbacks of said technology to ascertain which is the best choice for usage in the detection of flammable gases.

There are a couple of factors, particularly in oil and gas applications, where pellistors should not automatically be assumed to be the right choice. Perhaps the most serious drawback of pellistors is their susceptibility to poisoning (or irreversible loss of sensitivity) or inhibition (also known as reversible loss of sensitivity) by many chemicals found in the industry.

Compounds containing silicon, lead, sulphur and phosphates at just a few parts per million (ppm) can have a serious impact on the functionality of pellistor performance.

Silicon-based compounds, such as silicones, silanes and siloxanes, (henceforth referred to as “silicons” in this article for consistency) are widely used as defoamers and anti foamers, and are known to significantly increase efficiencies in many production processes. Please refer to Figure 5. Silicons are used to reduce waste, maintenance costs and processing time. Problems reduced through the use of silicons include cavitation in pumps to excessive process fouling.



Silicons - Potent Pellistor Poisoners

Even at very low levels, silicons can act as a poison to pellistor-based sensors. They do this by coating the catalytic surface, and preventing the catalysis of the reaction which is the basis of pellistor sensitivity. A case study that illustrates this point is that of a company who replaced a window pane of the room where they stored gas detection equipment. Silicon-based sealant of a standard type was used in the process, and as result, all their pellistor sensors failed their subsequent testing. Fortunately this company routinely tested all its sensors. Without regular checks this incident could have led to serious ramifications. As it was, the problem was picked up, and no one came to any harm.

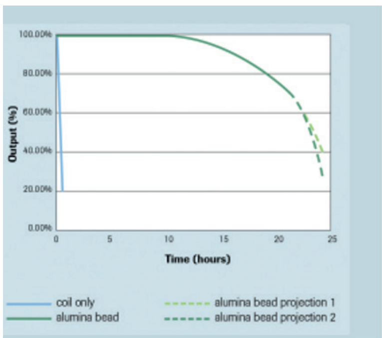
To understand more fully the issues of pellistor poisoning, let's delve further into the science of the process.

Different chemicals degrade pellistor performance at different rates. The alumina bead structure used in pellistors is intended to increase resistance. Hexamethyldisiloxane (HMDS) is a volatile organosilicon compound used as a solvent, and as a reagent in organic synthesis, used to investigate effectiveness.

In Chart 1 (shown below), the alumina bead significantly improves performance over the platinum coil on its own. Nevertheless, even at levels as low as 10 parts per million (ppm) HMDS, the output of the pellistor with beads is significantly impaired after just 20 hours of exposure. As time progresses, the level of output degradation accelerates.

It seems reasonable to project that after 24 hours (just 3 8-hour shifts), sensor output could easily be at 40% of what it should be, or worse. This demonstrates why regular testing is required, and why portable monitors used for personal safety and for proving the area environment must be tested prior to use to avoid serious harm.

Chart 1 Affects of 10ppm HMDS on sesor output



Foam has a significant impact on capacity and efficiency of the oil production and refining processes, from the wellhead, through refining and even during shipment of the finished product. Increased waste, maintenance costs and processing time are caused by process problems, ranging from cavitation in pumps to excessive process fouling.

Silicons are widely used as an antifoaming agent to eliminate foaming and increase productivity, and so reduce production costs and save money. This extensive use of silicons needs to be taken into account when assessing the gas detection requirements at different points along the production, refining and transportation process.

Pellistors Lack of Suitability

Pellistor-based sensors are also unsuitable for functions such as the filling or purging of tanks with either flammable or inert gases, where either low oxygen or high levels of flammable gases may cause them to fail. Pellistors burn gases to detect them, but without oxygen, the gas doesn't burn and so completely undermines the pellistor mode of detection.

Exposure to low levels of the target gas (such as 50% LEL or below) can actually assist in maintaining the cleanliness of the beads, as it effectively 'burns off' soot. However this also throws up issues, as the sooting caused by even a brief exposure to higher gas levels can cause the zero to drift, affecting pellistor performance, or even cracking the bead in some cases.

Exposure to concentrations in the high percent of LEL of flammable gas will soot up the pellistor completely and irretrievably. The LEL refers to the lower explosive limit , which is the minimum concentration in air at which a gas is flammable.

With this in mind, pellistor sensors are not suited to detection at %vol levels. In all these instances, the failed pellistor would produce no output when exposed to gas, giving the dangerous false impression of a safe environment. If relying on pellistor detectors in environments where poisons, inhibitors or high gas levels may be encountered, regular and frequent testing prior to use is the only way to ensure that performance is not being degraded.

Pellistor technology is considerably less expensive than IR technology, which is a good indicator of the comparative simplicity of the detection technology.

Imperfect Infrared

Infrared technology is superior to pellistors in all of the circumstances highlighted so far. This is because the mode of operation means that IR technology is not susceptible to poisoning or inhibition.

Therefore in environments where silicons, lead, sulphur or phosphate-based compounds may be encountered, IR sensors are the sensor of choice, and can be used with confidence, when pellistors' performance could not provide the same peace of mind.

As mentioned, the sooting of pellistors which is caused by exposure to high levels of flammable gas, can partially or completely impair its effectiveness. IR sensors do not suffer the same fate and so are not affected under these conditions. This feature, combined with their effectiveness in low/no O2 environments, makes IR sensors ideal for tank filling and purging applications where flammable or inert gases may be in the high percent volume levels and O2 levels are low.

IR technology provides fail-safe detection. In normal operation, IR is emitted and received. If either beam fails, the system will register a sensor failure. In normal pellistor operation, conversely, a lack of output is ordinarily an indication that there is no gas present, but this could also be the result of a fault. Again, the importance of testing is raised again here, with this being the only way in this instance to confirm whether a pellistor is functioning as it should be.

Although IR has enhanced functionality compared to the pellister in the circumstances we have explored thus far, it is important to note that IR technology is not always the best choice in every situation.

For example, if absorption by hydrogen molecules is at the wrong frequency, IR sensors will not detect the gas. Hydrogen is highly flammable, and either a pellistor or an electrochemical H2 sensor is required if it is a possible hazard. Infrared sensors' weakness is that they are susceptible to severe mechanical and thermal shock. They are also strongly affected by gross pressure changes. In circumstances where the mirror can become heavily affected by condensation, the IR beam can deflect away from the photo-receiver.

Some fixed systems employ heaters to overcome this last problem, but this option tends to be too power-hungry for routine use on portable units. However, the choice of sensor should not default to a pellistor under these circumstances as there could still be poisons or other factors that would severely impact pellistors. As part of a site-specific risk assessment, all parameters should be considered to fully understand which the best technology of choice should be.

Pellistor technology is considerably less expensive than IR technology, which is a good indicator of the comparative simplicity of the detection technology. IR sensors require the use of digital techniques, such as complex signal processing and thermal compensation, in order to obtain the gas reading. This adds to the production cost further.

In working environments where either technology would be suitable, the issue of cost will be an important selection criterion. While IR technology is more costly to purchase, pellistor maintenance costs are liable to be greater, because the sensors tend to require more frequent replacement. The total cost, including the on-going testing and maintenance, should be considered on a site-specific basis to determine the most cost-effective option, coupled with the fail-safe benefits.

Across any site there may be an array of diverse environments in which the utilisation of different sensors is advisable. There is also scope within different areas that will see a combination of risks that require both a pellistor and IR sensor in one device.

Making the Right Choice

When assessing the best sensor technology to use in your personal gas monitors, there are many factors to consider. Risks to assess, as explored in this paper, include poisoning, inhibition or sooting, the exposure to high flammable gas levels, low oxygen environments and the need to detect hydrogen. Lifetime ownership costs is also a factor that should be considered in line with an organisation's budgeting.

Across any site there may be an array of diverse environments in which the utilisation of different sensors is advisable. There is also scope within different areas that will see a combination of risks that require both a pellistor and IR sensor in one device.

Ultimately, the prime objective for safety is to select the best detection technology for the hazard and the operating environment. This paper provides guidance on the performance of both pellistor and IR sensors that should enable the users of gas detectors to assess the best technology for their hazards and operating environment.

The final decision comes down to the line managers and teams working within the environment on a day to day basis. However, for those keen to seek a second opinion and to assess the best sensors which can ensure the safety of their environment and workforce, please reach out to a member of Crowcon's team to find out more.