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THE PLANNING OF AN INDUSTRIAL GAS DETECTION SYSTEM FOR LARGE PETRO-CHEMICAL COMPLEXES

1 The Use of Gas Detection as part of an overall Safety System – The 'Ground Rules'

There is a popular belief that when you install a gas detection system you make the installation safe. This incorrect and dangerous statement cannot be further from the truth. An installation cannot be made safe by such a simple action; the safety of any installation begins at the design stage - good engineering and materials, and follows through construction to the development of safe operating practices undertaken by trained and competent personnel. After the correct engineering and development of safe operating practices only then can gas detection accept a role to assist and improve the overall safety of the installation.

A fixed gas detection system has one prime role, that of a safety device. In the normal operation of a process the gas detection system should never be activated, its initial task is that of a 24 hour 'sentinel', monitoring chosen atmospheres looking for the occurrence of an abnormal event which could indicate the failure of a plant item or an incorrect and potentially hazardous operating practice.

Under such circumstances the second task is for the gas detection system to provide a rapid response to the abnormal event, such that remedial action can be taken before the developing gas or vapour cloud can become of a size such that catastrophe becomes a possible result.
A gas detection system of the type envisaged for an installation should never be used to monitor the operation of a process or procedure, which is the role of a process analyser. In the event of a gas detector being used to monitor a process, there is a very real risk that operating personnel will grow accustomed to a regular activation of gas detection system due to 'normal' operations.
Under such circumstances there is a very real danger that the occurrence of an abnormal and hazardous event will pass unnoticed and not differentiated from a 'normal' operation.

2 How do you decide the Size of the Gas Detection System?

There is no 'correct' size for a gas detection system. It is clear that the larger the system becomes for a fixed site volume, the greater is the probability of detecting a small toxic or flammable gas cloud and that the time taken to detect will similarly reduce as the system size increases. This logic however excludes both the capital cost of such a system and its ongoing cost of ownership.
A compromise therefore becomes necessary between the benefit of a system and its cost.
This compromise is by definition subjective; it can be based on many factors, for example:-

(a) a sum of money within a budget

(b) a philosophy, such as perimeter monitoring at, say, 20 metre intervals

(c) mathematical predictive modelling to assess the time to respond to known events and providing a gas detection system to be faster in response than the required time to respond

(d) personal opinions of experienced plant personnel

(e) the analysis of the perceived hazard on an area by area basis

In reality, the final decision as to system size is usually a combination of these factors and such is the case your Author presents here, with major contributors to the proposal, both from operational and safety personnel regarding the relative hazard interpreted to a more absolute view by specialist experts.

3 Assessing the Site - the Experience of Local Area Experts
Each large petro-chemical or oil/gas complex is unique and whilst common factors can be found in similar processes, the design engineering, components and working practices of each site is so markedly different that it is necessary, or at the least most desirable, to use the knowledge and experience of site personnel as an input to the decision making process of system size and location, particularly if that decision making process is to be based on any observed quantity other than a matrix perimeter or volume distribution. In general, this Consultancy advocates obtaining detailed and knowledgeable advice from two sources:-

(a) The **Safety Department** of the company

(b) Each **Operational Department** within the company.

From the **Safety Department** comes information regarding:-

(a) Incidents that have occurred at the plant together with cause and effect.

(b) Processes that are problematic and common to several areas of the plant.

(c) Areas that are seen as being 'sensitive' from a public awareness viewpoint,

(d) New processes planned for existing areas where the nature of a hazard may change or increase.

From each **Operational Department** comes:-

(a) The consolidation of many years experience in the day-by-day running of their area in the refinery.

(b) Those areas and processes that are seen as being more problematic or hazardous.

(c) Those areas where incidents have occurred.

This Consultancy considers the input from these local area experts to be most valuable in the assessment of the **relative** hazard, the assessment of the **absolute** value of a given hazard is provided directly by specialist experts.

4. 'Firming-up' System Size
When either installing a gas detection system as new or improving an existing installation, financial constraints will probably make necessary the formulation of an 'Essential Detection' regime, that is, a gas detection system based initially and critically on 'Special Hazards', 'High Hazards' and 'Medium High Hazards'. To incorporate lesser hazard areas at this stage could be considered undesirable as it would dilute the emphasis towards the 'Special Hazards'. From financial constraints it is likely that the installation would be completed in a series of time separated tranches but certainly the first tranche would concentrate on this 'Essential Detection' regime

5. Deciding what's 'Essential'
Prioritising the various gases and vapour hazards at a complex is undertaken on an area by area basis in discussion with local experts. It is an analytical and detailed process which should not be hurried and whilst some general principles can be decided within an office, significant site survey studies are essential prior to locating sensors. The 'platform' from which the detailed design is developed pays particular attention to risk assessments from considering inventory, volatility, pressure, temperature, flammability and toxicity of the materials involved

Whilst in an ideal world we would aim to detect gas leaks, from financial and engineering constraints fixed sensors are usually placed so as to detect gas accumulations which could create a 'Significant Hazard'. At this stage therefore we need to define what is a 'Significant Hazard'? Whilst there will be many different views, one definition could be an event where people would get hurt and plant/buildings get damaged. Within the oil and gas industry there is some support for defining this as the energy released when a 5 metre diameter gas cloud containing a stoichiometric gas mixture ignites - approximately 10 % natural gas in air for a high methane based natural gas. Remember you only need an overpressure of approximately 150 millibars within a normal building to damage the structure
Following this regime one would be required to place a gas sensor in a horizontal 4 metre triangular matrix in 'Special Hazard' risk areas

In addition to the flammable hazard of the many different hydrocarbons processed within complex, there is also invariably the toxic hazard of hydrogen sulphide and in your Author's opinion when the volumetric concentration of hydrogen sulphide in a high pressure gas system is greater than 500ppm H_2S then the area becomes a hazard from a toxic gas viewpoint

6. Where do you Position the Gas Sensors?
Factors which should be taken into account in determining suitable locations of sensors are discussed as follows:

6.1. Are we are monitoring an indoor or outdoor site?
Indoor sites with mechanical ventilation enable objective and precise sensor location based on measured air movements through the building – use 'smoke-tubes' to monitor air movement. Outdoor monitoring is not so easy, where variations in wind direction and speed beneficially require the use of gas detectors based on modern optical technologies equipment

6.2. What are that potential sources of gas and vapour leaks?
At any location where there is a break in the pipe-work system there is potential for leakage and such components as valves, flanges, pumps seals, pressure regulators, sight glasses, compression fittings and plant subjected to a large temperature excursions and high levels of vibration are all vunerable to leakage. Clad pipework and components in many cases increases the perceived hazard, as the inventory of leakage products can be high relative to plant where containment is unlikely

6.3. What Hazard – High Pressure Gas Leaks or Vapour Clouds?
Gas leaks from valves and flanges where the pressure is greater than 2 - 3 bar tend to form diluted gas/air clouds through turbulent diffusion with the surrounding air and once away from pressure jet effects the gas cloud tends to be close to neutral density and moves under the action of prevailing air movement.
The very opposite of this scenario applies to vapours clouds formed from evaporating or boiling liquids, for example liquid propane and butane. These vapour clouds obey the laws of density and flow as heavy concentrated clouds, influenced by the topography of the site and local air movement. These very hazardous vapour clouds flow into voids, spaces and drains and in many circumstances represent a far more serious fire and explosion hazard than high-pressure gas leaks, which if uncontained and you're lucky, rapidly dilute themselves and dissipate in prevailing air movements.

As air movement and direction is important in both of these considerations, the assistance of the local meteorological station to obtain a 'Wind Rose' for the area, which defines a prevailing wind direction and strength over a defined period of time, is useful

7. Which Gas Sensor is best?

7.1. Catalytic Flammable Gas Detectors
For many decades the catalytic flammable gas detector or 'pellistor' as it is colloquially known, has been the workhorse for flammable gas detection on industrial plant.
It is also recognised there are many failure mechanisms for these sensors which are 'fail-to danger' in principle and many articles have been written over the decades describing 'poisons' likes silicone rubber sealant which permanently reduce their sensitivity. Whilst modern catalytic sensors show a far greater resistance to this effect it must still be perceived as a severe weakness which is ameliorated only by labour-intensive maintenance, notably by exposure of the sensors to standard test gas mixtures at very regular intervals and confirming correct functioning

7.2. Infra red Flammable Gas Detectors
As an alternative to the use of pellistor technology in the detection of flammable gases, sensors based on light beam absorption have been developed, offering the characteristics of a potentially long life, fast response time and fail to safety - or more correctly, fault indication.
Most hydrocarbons absorb infra-red radiation in the 2.3 or 3.3 micron range as this corresponds to a harmonic or fundamental frequency of vibration of the C - H bond in its stretch mode. The sensor measures the amount of radiation that is absorbed at these wavelengths by a volume of gas and this absorption gives a measure of the amount of hydrocarbon present. Normally a reference sensor is also employed operating at a nearby wavelength where absorption by the gas being detected does not occur.
From this technology, over the past 20 years both 'point' detectors and Open Path or Line of Sight (LOS) infra-red gas detectors has been developed, where a modulated infra red source and its detectors are separated by distances of up to 150 metres.

Early developments in this field were most unsatisfactory displaying instability, false alarming and fault indications from such simple things as sunlight reflecting from surfaces. In recent years, the quality and performance of these detectors has improved enormously with far higher levels of intelligence incorporated within their design. In recent years your Author has used one model with a multiple flash-tube light source which appears to be totally sun blind, incorporating intelligent feedback whereby if the received signal becomes attenuated by rain or fog, an instruction is sent to the transmitter to increase both the pulse repetition frequency and output power to compensate the shortfall. Reliable LOS detectors are now available which maximise coverage for outdoor site monitoring with a minimum of equipment and whilst the cost of LOS detectors is still fairly high, your Author is very confident that natural market forces will reduce prices as the number of reliable LOS products increase.; with this reduction in price, the days of the catalytic sensor for high-end market places will be limited.
As with all gas sensors however, there are important 'Golden Rules' that must be obeyed in their use – e-mail the Author for a copy!

7.3. Acoustic gas detectors

A recent development in the armoury of gas detectors is the ultrasonic gas detector whereby the sound at a ultrasonic frequencies from a pressure gas leak is detected by a sensitive microphone, the signal from which is then analysed by intelligent electronics. Your Author has had recent and most successful experiences of this principle with a Danish developed detector , where sensitivity and selectivity is achieved by setting the alarm level just higher than the ambient background level of ultra-sonic noise, correlating the most appropriate frequency band and the duration of the leak signal prior to activating an alarm

7.4 Electro-chemical cells for Hydrogen Sulphide

An electrochemical cell is a type of gas-battery developed from fuel cell research. These devices which are self powered micro fuel cells use a diffusion barrier to limit the amount hydrogen sulphide reaching a special permeable gas sensitive electrode surrounded by an acid electrolyte. A typical electro-chemical cell for ppm concentrations of hydrogen sulphide produces a very small signal that can be amplified and processed to produce an alarm signal. Since the fuel-cell is continuously operating it has, like a battery, a fixed lifetime related to the total exposure to gas, the temperature of storage and usage and to a lesser degree the humidity of the air in which it is used. Typically the lifetime of cells is between 1 and 2 years and replacement is then necessary. These sensors are your Author's preferred sensor for H_2S in temperate climates <u>but</u> their main weakness is their failure at high temperature and with an upper temperature limit of circa 40 °C; this prevents their use in hot climates where frequently sour gas is in abundance

7.5 Semiconductor gas sensors

One of the few options for hot climates, where electrochemical cells are in appropriate, is the semiconductor gas sensor; these detectors are hot running devices and so are undamaged by high operating temperatures
The solid state H_2S Sensor is a semi-conductor that changes in resistance when contacted by hydrogen sulphide. It consists of a substrate with a heating element and semi-conductor material deposited on its surface. As hydrogen sulphide is absorbed into the heated semi-conductor material there is a decrease in resistance in proportion to the amount of H_2S present. This change in resistance is then conditioned through a series of linearising and electronic amplifiers to provide an output signal. The main weaknesses these devices are twofold:

(a) A memory effect where the sensor tends to ‘go-to-sleep’ or displays a very slow response time to low concentrations of hydrogen sulphide unless it is regularly subjected to concentrations of the gas

(b) Their susceptibility to water which ruins the sensor! It is essential to keep the sensors stored in bone-dry conditions when deactivated and cold and most models are supplied with tight sealing sensor caps and silica gel capsules to maintain a bone-dry atmosphere within the sensor if ever they are de-energised.

In Conclusion …

A short article such as this cannot possibly present anything more than an ‘Introduction’ to the detailed thinking processes that are involved in the design of a large fixed gas detection system. From this introduction could be developed entire chapters considering the instrumentation alarm logic, ‘voting and zoning’, ‘availability’ and ‘redundancy’, transmission systems, ‘Ex’ zoning of the various areas according to the hazard …. and so the story continues