

Application of Portable Gas Detectors in the Petrochemical Industry

1. Introduction

For more than 20 years CoGDDEM members have been at the forefront in the development of the worldwide gas detector industry and this article examines in some detail just 2 applications where portable gas detectors are used widely in the development of safe working practices in the petrochemical industry. This article studies the application of portable detectors used for:

- Hot work gas testing prior to the issue of a Hot work Permit and
- Purge gas testing, following either direct or indirect purging operations

The petrochemical industry for the purpose of this article also includes both onshore and offshore oil and gas plant.

2. The Portable Gas Detector, used for Hot Work Gas Testing

Without a doubt, the most frequently undertaken type of gas testing within these industries is Hot-work Gas Testing, namely, making sure that there are no flammable gas leaks or accumulated vapour clouds in the immediate vicinity of a hot worksite prior to the issue of a Hot-work Permit and then making certain no flammable gas or vapour cloud arrives on the worksite whilst the Permit is in force. For many industries this must represent 90% or more of all gas testing undertaken. Hot work in the context of this article refers to any work having the slightest spark potential, not just naked flame work involving cutting and welding but such actions as a needle gunning and other duties having a lesser spark potential. Many companies subdivide their Hot work Permits into naked flame and lower spark potential sub-categories.

Detectors suitable for this application need to be able to measure flammable gas in air at levels well below the Lower Explosive/Flammable Limit (LEL or LFL) of the materials that could form a flammable hazard at the worksite. By default, many portable gas detectors are calibrated for methane gas but it should be appreciated that if the flammable hazard at the worksite is perhaps a solvent, motor spirit, or one of the heavier hydrocarbon gases, for example, pentane, then the gas detector should be re-calibrated for that material which could represent a fire or explosion hazard at the worksite and which gives the lowest response on the gas detector. The main principle used in Hot-work gas detectors is 'catalytic combustion', using either a platinum hot wire or other catalytic bead sensor, colloquially known as 'pellistors', where the flammable gas in the sample of air being tested is burnt on the sensor and the heat generated by the combustion is measured to produce the indication on the detector. It should be appreciated that a methane calibrated detector needs to have its sensitivity increased by approximately twice to be correctly calibrated for the pentane class hydrocarbons. Modern gas detectors of this type usually have a meter or digital display and are scaled 0 - 100% LEL, with audible and visible alarms, which are usually adjusted to activate at 20% LEL

An equally important facility required within the specification of a Hot-work portable gas detector is the ability to aspirate a sample of the atmosphere being tested into the detector. Your Author frequently expresses concern at the lack of aspirators on-site and the appreciation of their importance in gas testing a hot-work site. There seems to be reluctance in using aspirators, perhaps because it is perceived as being a slower method of gas testing. I answer this reluctance by posing the following questions:

- How would you test for leakage from a flange on a windy day?
- How would you test for the containment of flammable gases within the lagging of the clad pipeline?
- How would you test a drain for the presence of heavy flammable gas vapours?

Whilst you, as the gas tester, may not find a gas leak or accumulation in the above examples, with a non-aspirated, diffusion detector, you can be fairly certain that any spark from the hot work would do the job for you!

2.1 Mechanisms of Gas Leakage

To make the most enlightened use of a portable gas detector, when Hot work gas testing, the Authorised Gas Tester- (AGT) needs to appreciate the mechanisms by which a flammable gas cloud or vapour accumulation is generated on-site. In essence there are 2 principal mechanisms whereby a loss of containment gas hazard is generated, these are:

1. A medium/high pressure uncontained gas leak which usually generates a neutrally buoyant cloud of gas, heavily diluted with the surrounding air by a process of turbulent diffusion, and which moves once away from the pressure jet effects as a neutral cloud mixed in with the prevailing air stream. As mentioned in the last paragraph however, this simple extreme scenario can become more complicated when the leak occurs with containment, within a building or where the pipe-work is clad.
2. A vapour cloud generated when a volatile flammable liquid evaporates, or a liquefied gas 'boils off'. These vapour clouds are always heavier-than-air, sinking to low lying voids, spaces and drains and for this application an aspirating gas detector is essential. It should be noted that vapour clouds travel considerable distances in drains and display many movement and containment properties of a liquid

2.2 The Procedure of Hot-work Gas Testing

With an appreciation of how the gas hazard is generated, the process of Hot-work gas testing at the worksite is therefore fairly logical and a variant of the following sequence is usually adopted:

1. Using a correctly calibrated and functional gas detector, equipped with an aspirated sampling system, the Authorised Gas Tester- AGT - checks for leakage from plant components, valves, flanges, pumps seals, compression fittings etc. in the immediate vicinity of the proposed hot work site, extending to a radius of approximately twice the spark potential of the work. If a hot-work habitat is being used, detailed testing takes place within the habitat
2. The AGT then assesses the direction of the air stream/wind approaching the hot worksite and tests the atmosphere up-wind of worksite to confirm that no gas or vapour hazard is being blown on to the work-site from another area of the plant
3. The AGT then walks around the worksite at a sensible distance, relevant to the work being planned, where he tests for gas hazards in any other streams of the air approaching the worksite, or vapour clouds in any low-lying voids, spaces or drains, any hazards that need to be removed from site or an assessment of any other work taking place - after all, one job can influence another, and finally
4. The site worker then positions a flammable gas detector as a site monitor, to monitor for the approach of gases or vapours on to the hot-work site whilst the work is in progress. This detector obviously will be in its atmosphere diffusion-sampling mode and ideally should have loud audible and bright visible alarms. A common sense approach needs to be adopted in positioning the site monitor in a place where it is most likely to detect an approaching hazard but factors such as:
 - Wind direction,
 - Proximity to high pressure plant generating neutrally buoyant gas clouds,
 - Close proximity of plant containing volatile hydrocarbons or condensate liquids which could give rise to heavy vapour clouds moving at low level, particularly in a banded area
 - Proximity of site boundary fences

3. The Portable Gas Detector, used for Purging Operations

Purging in its entirety is a complex subject that can be subdivided into two main categories:

- **Direct purging**, namely purging directly from air to gas or from gas to air. The gas supply companies when purging pipelines undertake this type of purging widely and successfully. Direct purging is quite acceptable as pipelines are linear structures and providing the velocity of the gases involved are kept within acceptable limits, the quantity of mixed gas and air, perhaps representing a flammable hazard, is kept to a minimum and direct purging becomes a well accepted safe working practice for pipeline companies
- **Indirect Purging** is the displacement of one gas, for example natural gas, by an inert gas, frequently nitrogen, followed by displacement by air or vice versa. In other words, an inert gas is sandwiched between the natural gas and the air thereby preventing them mixing and the formation of a flammable gas mixture. Without a doubt, the most misunderstood type of gas testing is that involving nitrogen purging

For the purposes of this article, as purging is a complex subject when all its ramifications are considered, with few exceptions I am going to limit this article to consider the indirect purging of natural gas filled vessels.

3.1 The main categories of indirect purging are as follows:

A. Displacement Purging

The displacement method involves purging the vessel or pipeline with nitrogen to a specified End Point. With pipelines, minimal mixing of incoming and outgoing gases occurs and whilst the procedure is similar to direct purging, the difference of course is that nitrogen separates air from the natural gas and therefore prevents the formation of a flammable-gas-in-air mixture. For the displacement purging of vessels the converse requirement is that a low purge velocity is required to maximise stratification and therefore reduce mixing using the difference in relative densities of the two gases to assist in the efficiency of the purging operation. This type of purging can be undertaken very successfully and very efficiently when there is a wide difference in the density of the two gases involved and a good example is the power station application, whereby generators running in pure hydrogen are purged with carbon dioxide.

B. Slug Purging

Slug purging of linear or nearly linear structures usually uses less purge gas; a slug of inert gas is inserted as a barrier between the flammable gas and air, the purge should be continuous and the purge velocity should remain high to prevent stratification

C. Pressure Purging

This involves successive pressurisation and de-pressurisation of a vessel until an acceptable End Point is reached. For successful pressure purging thorough mixing of the gases in the vessel is necessary and so for complex or long vessels, innovative techniques need to be applied, which combine pressure and displacement purging. Although the mathematics for calculating how many pressure purges are necessary to reach a defined end point is not complicated, the practice rarely seems to follow the theory and additional pressurisation / depressurisation cycles are necessary; this is usually because the mathematics pre-supposes perfect mixing of the purge gas within the vessel – which rarely happens. In general, more purge cycles at lower pressures and a bit of time to allow better mixing will use less purge gas to reach a defined end point

D. Dilution Purging

Where generous volumes of purge gas are available, this technique provides for rapid purging. Here large volumes of purge gas at high velocities deliberately create turbulence. This technique can be used on plant having complex geometries that cannot be adequately pressurised

3.2 Purge Gas Velocity and Density

The higher the velocity at which the purge gas enters the vessel, the greater is the scope for mixing and this is clearly desirable in some circumstances, as it helps to prevent stratification

The relative densities of the purge gas and the gas being purged can also have an influence on the purging operation and to prevent stratification as a general rule, where nitrogen is being used to purge Natural gas, a minimum velocity of 0.6 metres/second is sought in straight linear structures

3.3 Purge End Points

Triangularity graphs are used in determining purge end points. These are in the form of an equilateral triangle upon which can be plotted any mixture of flammable gas, inert gas and air, these graphs also display the zone within which a gas mixture is flammable or explosive will be obtained if the purge is incorrectly undertaken.

The full detail of using triangularity graphs goes beyond the scope of this article but as an example, your Author when undertaking a nitrogen purge of a high methane content natural gas filled vessel established the 2 purge End Points as follows:

- When De-commissioning the vessel from Natural gas to nitrogen: 7.5% Natural gas in nitrogen and
- When re-commissioning the vessel from air to nitrogen: 7.7% oxygen in nitrogen

3.4 Monitoring Purge End Points using Gas Detectors

The specification for portable gas detectors employed in purging operations is fairly demanding and depending upon the type of purging being undertaken and where you are in the purging sequence, so varies the range and type of detector required. For maximum flexibility the detector, which shall be BASEEFA certified or equivalent to an appropriate standard, will be capable of measuring at each of the following 3 scenarios:

- For measuring small quantities of natural gas in air, for example during the de-commissioning of a pipeline by direct purging, you need a detector capable of measuring flammable gases in air at sub-LEL concentrations. For this application, just the same as for Hot-work gas testing, a catalytic combustion gas detector is most frequently used, although infrared-based detectors are becoming available.
- When measuring volumes of natural gas in nitrogen you CANNOT USE a catalytic gas detector, as these detectors WILL NOT INDICATE CORRECTLY and under many circumstances WILL NOT INDICATE at all! You must use a detector capable of measuring the percentage natural gas by volume in the absence of oxygen. For this application you require a detector incorporating a thermal conductivity gas sensor or the more recently developed infrared absorption based instruments. Thermal conductivity based instruments measure the heat conducting properties of the gas mixture but this inferential technique will only provide accurate results if the detector is zeroed and calibrated with a correct gas mixture
- When either direct or indirect purging operations are being undertaken there is a requirement to measure the percentage oxygen in natural gas or nitrogen respectively. The preferred technique with most portable gas detectors employs an electrochemical cell, although some instruments are available incorporating a paramagnetic oxygen sensor

3.5 Calibration of Portable Gas Detectors used for Purging Operations

If a portable gas detector is to be used for purging then it must be calibrated correctly:

For the measurement of flammable gases in air during direct purging operations, portable catalytic flammable gas detectors are normally used, scaled 0 - 100% LEL where, for Natural gas operations, 100% LEL represents 5% methane-in-air (the minimum quantity of methane in a methane-air mixture that will just ignite to produce a self-propagating flame); these detectors are normally calibrated with 2.5% methane-in-air and are adjusted to read 50% LEL on their indicators

Portable thermal conductivity based detectors are normally scaled 0 - 100% GAS and are usually zeroed in air and calibrated using appropriate methane-in-nitrogen gas mixtures. With such a wide dynamic range, ideally test gas mixtures should be obtained to confirm adequate precision at either end of the scale, for example 10% methane-in-nitrogen and 90% methane-in-nitrogen. It is perhaps a 'fine point of tuning' to mention that when measuring natural gas-in-nitrogen, for example, during the de-commissioning of a Natural gas filled vessel, thermal conductivity detectors should ideally be zeroed in nitrogen rather than air; zeroing in air will introduce an under-read of the Natural gas figure of about 1.6% vol. and this figure needs to be incorporated in setting the de-commissioning purge End Point – see 3.3

Portable oxygen detectors invariably use atmospheric air at 21% oxygen as the calibrating gas

John Sonley, an Associate Member of CoGDEM, wrote this article. He is a Partner in JMS Consultants who provide Offshore Petroleum Industry Training Organisation (OPITO) Approved Authorised Gas Tester Assessed Competence Training Courses (Unit AGT1) and fixed installation engineering services

Unit AGT1 training courses provide the underpinning knowledge and competence assessment for Authorised Gas Testers involved in the following scenarios:

- (a) Gas Hazards and Hot Work Gas Testing
- (b) Gas Hazards and Confined Spaces/Vessel Entry Gas Testing
- (c) Inerting and Nitrogen Purging Operations
- (d) Sour Gas (Hydrogen Sulphide) Operations

In addition, the Consultancy provides an on-site survey, design, audit and training service to the oil, gas, petrochemical, power and shipping industries worldwide in the correct choice, application, use and maintenance of both portable and fixed gas detection systems.