A risk-based approach to identifying the location of fire and gas detectors for an onshore process plant

Stuart Buchanan, KG Technical Manager, Ineos Manufacturing, Grangemouth

Mike McKay, Senior Safety Consultant, ABB Consulting, Warrington

Operators of high hazard process plants have a requirement to identify potential process safety hazards and to implement and maintain suitable prevention and mitigation controls. When handling flammable and/or toxic substances the mitigation risk control measures often include fire and gas detection systems.

Whilst published guidance is available for locating fire and gas detectors on offshore Oil and Gas facilities there is no equivalent guidance for onshore plants. Ineos, in acquiring the Grangemouth site, inherited a fire and gas detection standard that was based around offshore guidance and wished to create a new standard using a risk-based approach.

This paper describes the risk-based approach developed by Ineos Grangemouth for identifying the location of fire and gas detectors for existing assets. It also describes the steps taken by Ineos Grangemouth in implementing the recommendations for applying the new standard.

Keywords: Fire and Gas Detection Systems, Mitigation Safeguards,

Background

When Ineos acquired the Grangemouth site from BP, they also inherited the design standards to which the plant had been built. The fire and gas detection standard used on the Grangemouth site was based upon a standard developed from offshore operations. As such it was judged not suitable to the nature and escalation potential of the hazards on the Grangemouth site. Moreover it generated onerous requirements that were not tailored to the fire or gas (flammable and toxic) hazards associated with the operations on the Grangemouth site.

Ineos Grangemouth wished to develop a new standard that was more attuned to the fire and gas hazards on the Grangemouth site. The new standard aimed to ensure compliance with legal and insurance requirements, but also to provide a more workable fire and gas detection provision based upon an understanding of fire and explosion development and the role that fire and gas detection plays in controlling the escalation of hazardous events.

Moreover Ineos Grangemouth wanted the new standard to provide a set of rules that clearly describe the requirements for fire and gas detectors and the subsequent positioning of these detectors, rather than being reliant on complicated computational fluid dynamics (CFD) modelling.

Why Fire and Gas Detection?

Fire and gas detection systems are recognised as an important safety critical element in process plants. The purpose of fire and gas detection systems is to detect the hazardous event as early as practical, with minimum nuisance alarms and total installation / maintenance costs. Timely detection of fire or gas releases may prevent major fire and explosion hazards or gas releases which have the potential to result in high consequence hazardous events, such as explosions leading to personnel fatalities or significant asset damage.

The performance of a fire and gas detection system is largely dependent on the coverage offered by the detection system. This in turn is a function of the number of detectors used and their layout. However little guidance is available as to where to locate fire and gas detectors to obtain a reasonable balance between coverage and costs.

Hazard Identification and System Safeguards

In the words of Trevor Kletz: "*What you don't have, can't leak*" and therefore if an inherently safe approach is taken there is no need to consider the consequences of a loss of containment.

However where plants and processes handle flammable or toxic materials, then a loss of containment can result in potentially harmful consequences. These consequences are typically identified through risk assessment using techniques such as Hazard Identification (HAZID) or Process Hazards Review (PHR).

The purpose of these reviews is to identify the potential for hazardous events, generally associated with the loss of containment of hazardous substances or the release of stored energy, with consequences such as fires, explosions, toxic gas releases or environmental impact. The risk associated with the hazardous event is determined from the hazardous event severity along with the likelihood of the event occurring. The hazardous event severity is based on the ultimate consequence of a loss of containment of a hazardous substance. The likelihood is based on the estimated frequency of the initiating event, taking into account the system safeguards and the probability that these safeguards fail to operate, and the probability that these events escalate leading to harm such as an operator fatality.

Safeguards can be seen in terms of prevention or mitigation. Preventative safeguards take place after an initiating event has occurred and prevent the loss of containment from occurring. Mitigation safeguards take place after the loss of containment has occurred and prevent the ultimate consequence from being realised. Mitigation safeguards, can be further divided into detection safeguards and correction safeguards.

Fire and Gas Detection System as a Mitigation Safeguard

Without suggesting that the fire and gas detection system is an independent layer of protection (IPL), as understood in the context of functional safety, the definition of an IPL may help in understanding the function of the fire and gas detection system.

CCPS provides the following definition of a safeguard: "*Any device, system, or action that either interrupts the chain of events following an initiating event or that mitigates the consequences. A safeguard can be an engineered system or an administrative control. Not all safeguards meet the requirements of an IPL.*"

Therefore to be effective, the fire and gas detection system must be capable of detecting fire or gas releases promptly so as to prevent the potential escalation of the loss of containment to a major fire or explosion or toxic gas release. The challenge is to identify the locations where the risk from a loss of containment can be effectively identified and mitigated by fire and gas detectors.

To be an effective protective function, the response to a fire or gas release needs to be considered. This should also take account of the consequences of the releases and may be based around operator investigation and intervention or executive action or a combination. For example audible and visual alarms, automated water deluge or fire suppressant initiation, HVAC or process isolation.

Equally the level at which detection occurs should be set so as to enable genuine losses of containment to be identified promptly whilst, as far as practical, avoiding spurious detection. Where the response involves operator action, then the level at which detection occurs should allow sufficient time for an effective response.

Approach to Fire and Gas Detector Locations

The performance of a fire and gas detection system is largely dependent on the coverage offered by the detection system. This in turn is a function of the number of detectors used and their layout.

One of the difficulties is identifying where to locate gas detectors systems. Too often a literature search will end with the phrase "there are no specific standards governing gas detector location". This is untrue. Paragraphs 8.3 and 8.4 of BS EN 60079-29-2:2015 [1] provide some considerations for where detectors should be located. Additionally, when considering the release of hydrocarbons, the Energy Institute's model code of safe practice part 19 [9] provides some supplementary advice.

The starting point in locating gas detectors is to identify where gas accumulation can occur which can create a significant hazard. Standard ISA-TR84.00.07-2010 [10] identifies two basic approaches to assessing the required coverage for a fire and gas detection system. These are geographic or scenario approaches.

The geographic approach establishes the potential size of gas clouds from a release. It then undertakes a geometric review to determine a regular array of detectors, arranged spatially, to achieve the required coverage performance. The scenario approach undertakes an assessment of the potential release scenarios, in terms of frequency and dispersion modelling of the release to achieve the required coverage.

The Energy Institute's model code of safe practice part 19 notes that gas detection "should be provided where scenario-based analysis has identified potential gas releases in installations and the need for early detection of accidental loss of containment." The Energy Institute's model code of safe practice part 19 also notes that plants may contain toxic substances and that detection strategies should take into account potential release scenarios and their consequences.

Detailed guidance on locating fire detection systems is provided through standards such as EN 54 [4], BS 5839 [3], NFPA 72 [5] or equivalent national standards. However, for production areas, the fire detectors should be located based on potential fire scenarios and their consequences.

Development of the (New) Ineos Grangemouth Fire and Gas Detection Standard

The function of Fire and Gas detection is never to prevent a loss of primary containment, but to control the possible escalation. The primary function for the Grangemouth site is to focus on personnel safety. This is the need to warn personnel of gas and fire hazards enabling evacuation of areas. The response to Fire and Gas detection should also be determined so that it does not result in personnel being placed at an increased risk due to subsequent exposure to toxic or flammable vapour hazards.

The potential for Fire and Gas systems to limit escalation with commercial impact, or as part of fire and explosion control and mitigation, is a secondary concern.

In developing the new standard for fire and gas detection systems, there are a number of aspects identified within both BS EN 60079-29-2:2015 [1] and the Energy Institute's Model Code of Safe Practice part 19 [9] that should be covered. The new standard therefore included sections on:

- Definition of the required competencies for those involved in specifying and maintaining the fire and gas detection systems.
- Requirement for Fire and Gas Detection. For Ineos Grangemouth it was noted that it should cover "toxic" gas release as well as flammable releases and fire scenarios. It also emphasised that "toxic" also included oxygen deficient and oxygen enriched atmospheres.

- Specifying the detectors so that they are suitable for the hazard being detected, the area in which they will be installed and how they will interface with the plant and operations personnel.
- Maintenance and re-calibration of the detectors.
- Auditing of the fire and gas detection system.

This paper does not cover the required competencies for those involved in fire and gas detection systems. Nor does it cover the auditing of these systems.

To support the new standard for fire and gas detection systems, a guidance note was developed to provide a structure in determining where fire and gas detection should be provided, as well as general information on detector types suitable for the hazards expected.

What Hazards should Fire and Gas Detectors Address?

The selection and specification of Fire and Gas detectors should be based upon the potential for initial event escalation along with the risk (severity and likelihood) of the ultimate hazardous event. The requirement for Fire and Gas detection should be defined on the basis of the following types of basic hazard:

- Toxic gas;
- Flammable gas;
- Fire.

BS EN 60079-29-2:2015 [1] provides additional factors to consider when determining the location of gas detectors. These include:

a. The combination of sources of release with propagation effects;

b. Whether the sources of release can be inside or outside confining structures, buildings etc.;

c. What can happen at access points such as doorways, windows, tunnels, trenches etc.;

d. Local environmental conditions;

The new standard and the supporting guidance note therefore recognised that detectors may be required, depending on the hazards present, in enclosed areas whether occupied or not as well as open areas, whether congested or not.

Identifying Which Hazardous Events should be Protected

One of the challenges in developing a new standard for Ineos Grangemouth was how to identify potential release scenarios and their consequences whilst making use, as far as possible, of existing safety studies and engineering documentation.

Larger losses of containment are more typically associated with major process upsets such as overpressure or overfill. These hazardous events can be identified through hazard studies, which will also define protective safeguards to reduce the likelihood of a loss of containment from occurring. However smaller losses of containment tend to be more difficult to provide engineered safeguards for or there is limited cost benefit in their provision. In those instances, where the loss of containment may be due to a defect in the equipment, or failure of small bore attachments (instrumentation, nozzles etc.) or from a flange leak or corroded pipe, then fire and gas detection may be a more reliable safeguard.

However this is not always the case, and specific hazardous events may arise with the potential to lead to larger losses of containment where fire and gas detection is identified as a mitigation safeguard. For instance: a loss of quench water to a reformer outlet may result in component failure and the release of a large flammable gas cloud. In this instance gas detection may provide a mitigation barrier against a loss of quench water to supplement the preventative safeguards such as trips and alarms.

Fire and Gas Detectors for Enclosed Areas

Enclosed areas are taken to be buildings (permanent and mobile) throughout the plant such as control rooms, sub-stations, instrument marshalling rooms, storage sheds, production buildings etc. The main hazards associated with enclosed areas were deemed to be:

- Gas ingress into an enclosed area (through the air intake into the area);
- Gas release within an enclosed area;
- Fire within an enclosed in an area.

Ineos Grangemouth has a separate standard covering analyser houses, including fire and gas detection so these were excluded from the new Fire and Gas detection standard.

Two generic hazardous events were identified, where gas ingress into an enclosed area through the air intake into the area could lead to a hazard, where gas detection is recommended. These are:

- The enclosed area is located in an ATEX area and where the enclosed area contains sources of ignition (e.g. occupied buildings or electrical equipment rooms).
- The enclosed area is adjacent to plant areas that have significant inventories and which could generate a toxic gas cloud with the potential to drift downwind.

If detection is required to prevent gas ingress to an enclosed area, then this should be located on the air inlet to the enclosed area. For offshore installations, the HSE provide advice on gas ingress through HVAC duct inlets [7, 8].

The response to the presence of gas should be determined. For instance a fast-response may be appropriate to ensure that gas is prevented from entering the enclosed area. Also determine whether the air intake needs to be physically isolated and does this need to be SIL-rated.

When considering the need for detection of a gas release - or a fire - in an enclosed area, especially production buildings, then the consequence should be identified. In particular, are personnel likely to be in the vicinity in normal operation, or is the area a walkway or designated building entrance or emergency exit. Also the consequence should be considered in terms of the plant items present - do they present a high hazard (e.g. turbines) or high business value (e.g. electrical equipment.) Fire and gas detectors therefore provide an early warning of an event that could lead to a more significant event if left unchecked.

Hazardous events in an enclosed area which may require fire or gas detection include:

- Where the enclosed area has its own specific internal gas release hazard, for example flammable stores and toxic handling.
- Where machinery is present that can release fumes into the enclosed area (e.g. diesel motors) in normal operation. This may include carbon monoxide and carbon dioxide or depletion of the oxygen atmosphere.
- High hazard equipment (e.g. turbines, compressors etc.) handling flammable materials.
- Naturally ventilated areas with plant containing flammable gas inventories with a zone 1 leak source within the enclosed area.
- Oxygen detection should be considered where the oxygen concentration may be diluted, e.g. due to nitrogen leaks, or enriched, e.g. due to releases of pure oxygen.
- Equipment in the enclosed area is easily damaged and is critical (e.g. fire pumps)
- Any fire would be difficult or dangerous to control

The response to the presence of gas or fire, and where alarms annunciate, should be determined. For instance it may be necessary to repeat an alarm in the vicinity of an enclosed area to ensure that personnel do not enter. Consideration should be made as to whether an automated response is required (e.g. to shutdown plant or to initiate a sprinkler system).

Gas Detection for Flammable Gas Release

As is noted previously in this paper, the major hazard associated with a release of flammable material is that of a fire or an explosion. This has the potential to cause significant safety, environmental and business impact.

The severity of the hazardous event is a combination of the size and nature of the loss of containment of flammable material coupled with the degree of confinement (congestion) of the area into which the release could occur. Flammable gas detection should be considered for all areas where ignited gas clouds could cause damage from explosion overpressure.

In determining potential sources of leaks, reference should be made to the plant hazardous area classification, with the zone being an indication of the likelihood - as well as the size - of the release. In general flammable gas detectors should be considered for areas with a single large zone 1 release or multiple smaller zone 1 releases, with the size of release requiring a detector being a function of the degree of congestion around the source of release.

Where the hazardous area is attributable solely to periodic manual operations (e.g. sampling, drum filling) then flammable gas detectors would probably only detect gas releases associated with the manual operation. In this instance flammable gas detectors would not be required.

The guidance note also recognised that the following situations should be considered for releases, in addition to those associated with zone 1 areas:

- Areas where significant volumes of flammable gas could be released which may migrate (either on-site or off-site) to areas with potential sources of ignition.
- Bunded and kerbed areas that will retain and collect inventories of combustible / flammable process liquids, which would remain in liquid state for a significant period.

Gas Detection for Toxic Gas Releases

The major hazard associated with a release of toxic material is that of a significant safety impact through exposure to toxic vapours and potential fatality or major injury. Due to the materials handled and the mitigation barriers to prevent a major accident to the environment (MATTE), the environmental impact from a release was excluded.

In considering what constitutes a toxic release, the toxic exposure limits should be specified in terms of concentration and response time. Typically the list of toxic substances is derived from a COMAH safety report, in particular all substances handled on the plant that are referenced in Schedule 1 Part 2, or Schedule 1 Part 3 (as Category 1 or Category 2 fluids). Toxic materials also include oxygen-depleted and oxygen-enriched atmospheres. The leak points for toxic materials will be those that have high leak potential, e.g. pump seal, instrument manifolds, i.e. similar to those for flammable materials.

However whilst toxic gas detectors provide mitigation, they should not be relied on by personnel for overall safety, nor should they distract from the need for formal working practices to protect personnel from the toxic gas hazard. This is because some toxic gas detection devices are suitable for detecting leaks in lethal service chemicals, but are not sensitive enough to detect the lower exposure limit concentrations for personnel protection.

Fire Detection

In developing requirements for fire detection the risks associated with a fire should be considered. For onshore facilities, fire detection is recommended in areas where the potential hazard from a fire presents too high a risk to personnel, equipment, building or loss of production. However the provision of fire detection needs to be linked into the overall emergency response strategy. For instance small, prolonged fires have the potential for sudden thermally induced catastrophic failure of exposed equipment. In this instance fire detection can be used to limit the potential for sudden catastrophic failure - where there is time to take mitigating action before failure occurs. This is typical where primary containment is suddenly lost after a period of fire exposure.

Fire detection should also be considered where there is a steady rate of fire growth, but the rate is sufficiently slow to enable control and mitigating measures to be implemented before the fire becomes a major hazard. Equally, fire detection should be used to provide an audible alarm to any personnel present so that they are able to escape from a potentially hazardous situation.

Fire detection requirements for an area are determined by the risk in that area, and the fire detection system that provides the best escalation mitigation for that area. This should be supplemented by other safety studies, in particular fire risk assessments.

In determining potential sources of leaks that could lead to a release of flammable or combustible material, reference should again be made to the plant hazardous area classification. However this should be supplemented with local knowledge on the location of higher flash point materials (e.g. glycol), or combustible materials (e.g. synthetic heating fluids), or pyrophoric materials that are not captured within the hazardous area classification.

With an understanding of the potential fuel to feed a fire and leak sources, fire detectors should be considered for areas that:

- Do not have a permanent, manned presence (i.e. a fire has the ability to develop where nobody is aware).
- Where a fire could be in close proximity to susceptible machinery e.g. pumps, motors, cabling, etc. that could fail from flame impingement within a short exposure period, and which contains materials that have the potential to BLEVE or be above their auto-ignition temperature.
- Are poorly accessible for fire-fighting equipment.
- Are in close proximity to high value or high hazard equipment.

Specifying Fire and Gas Detector Systems

The new Fire and Gas detection standard identifies where the detectors should be located. However in order to be effective as a mitigation safeguard then the specification of the detector (including detection technology, placement and alarm levels) needs to ensure that Fire and Gas detectors:

- Are suitable for the hazard being detected;
- Are installed in areas that can detect the hazard;
- Interface with the plant and operations personnel without increasing the risk.

Guidance is widely available on the types of fire and gas detector, and which type of detector is appropriate for different hazardous events. In particular the HSE publication “The selection and use of flammable gas detectors” [6] and EI-19 [9] provide useful summary information.

Specification of Fire and Gas Detectors

Detectors should be specified to detect the flammable or toxic gas that gives rise to a hazardous event. If the requirement is for a dual purpose (e.g. flammable gas and toxic gas), then the type, and location, of detectors should be suitable for both requirements.

Detectors should also be capable of detecting hazards as they occur on the site, in particular considering onsite sources that will affect device detection performance. For instance detector performance can be adversely affected by common contaminants on a site, such as a hot or dusty process plant or by radiation sources.

For flammable gas releases:

- The correct choice of detector is most important if early detection is to be achieved;
- The detector should be correctly positioned, and properly mounted close to the likely release point (e.g. pump seal, valve packing etc.)

For toxic gas releases:

- Release of toxic gases, e.g., hydrogen sulphide, into the atmosphere will generally create a health hazard rather than an explosive hazard, although ultimately the latter situation may develop. In general the concentrations at which toxic gases need to be detected are far lower than for flammable gas detection. Flammable gas detectors should not be used for the detection of toxic gas, even if the latter coexists with a flammable gas of a different compound, e.g. H2S in conjunction with a hydrocarbon mixture, unless the toxicity level (STEL or SLOD) is similar to the flammable levels.
- When considering detectors for toxic gases, it should be noted that there are two major detection strategies, as follows:
    - Detectors for gases which create an immediate health hazard (danger to life), e.g. hydrogen sulphide, carbon monoxide, hydrogen fluoride, hydrogen chloride, chlorine gas. These gases usually have a STEL that is slightly higher than the TLV. In this instance detection shall be fast and reliable and preference shall be given to speed of response over precision;
    - Detectors for gases that create a health hazard on long-term exposure, e.g., carcinogenic gases such as vinyl chloride, benzene, toluene, etc. In this instance the detection shall be reliable and precise and should enable statistical analysis to determine long-term exposure data.

For fire detection:

- Plant personnel are acknowledged as good detectors of incidents and their contribution should not be overlooked. In this instance manual call points, of the break-glass type, should be considered.
- CCTV technology and suitable software can deliver robust fire detection for a wide range of combustion products. CCTV technology has the potential to differentiate friendly fires (e.g. flares, fired heaters) from those of interest, and in principle is solar blind. CCTV technology also enables the detector's field-of-view to be matched to the application, and the technology has the potential to issue a warning when this is changed. Where linked to the control system, CCTV systems can also provide visual confirmation of an event. This removes the need for plant personnel to enter a potentially hazardous situation to investigate an alarm (e.g. a fire) as well as reducing the time required to initiate appropriate safety measures.

Location of Fire and Gas Detectors

Detector placement is addressed in a number of standards. In particular NFPA 72 [5] and BS 5839 [3] should be referred to in relation to specific detection technologies (e.g. oil mist, heat, smoke detectors).

One well recognised method for determining the location of fire or gas detectors is through CFD. This can identify the optimum location for detection. However, as noted previously the new standard was to provide a set of rules that describe the requirements for the positioning of fire and gas detectors rather than being reliant on CFD modelling.

The placement of gas detectors shall be based on their intended role and the nature of gases in the intended installation. They should also be close to the likely source of the loss of containment of process fluids.

Open path gas detectors should be installed in locations where their paths will not be interrupted by routine operations. These interruptions cause unnecessary nuisance fault indications at the control point.

Low-level gas detectors aimed at detecting dense gas hazards should be located no higher than 300 mm (1 ft) above local deck or grade. For liquids the detectors shall be installed at collection sumps or pits or at low points were collection could occur.

Drawings should be used that show the intended coverage of each detector, including overlapping voting coverage

Alarm Levels for Gas Detectors

Part of the specification of each detector should be to define the alarm level(s) for each detector and the response - operator or automated - to an alarm.

When a specified gas concentration or set point is exceeded, then the detector system should trigger an alarm. The alarm should not stop or reset unless deliberate action is taken. The alarm should be audible or visible or preferably both. The requirements for alarms are specified in performance standards such as BS EN 60079-29-2 [1]. Alarm prioritisation should also be undertaken using standards such as EEMUA 191 [11].

Gas detectors should be provided with two alarm levels so that the lower level, preliminary alarm, may be used to announce the onset of detector failure as well as providing a pre-alarm for actual releases.

However for open path gas detectors, little benefit is gained in having two levels of alarm, because their range is usually limited to a small band of 0 LEL metres to 5 LEL metres, and gas can be present up to 100% by volume. The difference between 20% and 60% of scale is roughly the difference of 2% by volume for the gases commonly encountered at Ineos Grangemouth.

Alarm Response to Fire or Gas Detection

As with all alarms, there should be a written clear alarm response plan. This plan should detail the differences in response to high, and high high, level and multiple alarms.

For an alarm warning that a fire or gas has been detected, the outline operator response is:

- Identify the specific fire or gas detector which is raising the alarm.
- Send a technician, equipped with appropriate PPE as required from COSHH assessments, and portable gas detection to the plant to interpret the alarm.
- The technician approaches the field location up-wind with portable gas detection to identify if the alarm is valid or not.
- If a leak is confirmed then contact the control room to inform them immediately so that appropriate action can be taken. As a minimum, the site alarm should be sounded and the process area(s) evacuated.
- If no leak is identified, then report as such and raise a maintenance request, at the highest priority response, to fix the faulty alarm.

For a high high alarm it is also appropriate to identify any personnel in the area and whether they need to be evacuated or not.

For gas detectors on the air inlet to enclosed spaces, the response should be automatic and targeted at the hazard they are protecting against. Manual response can be considered if it can be demonstrated that it is sufficiently effective. The total response time of detectors, control systems, and dampers should be less than the time needed for gas to reach the area boundary after passing the gas detector.

It may be necessary, depending on the hazardous event, for the automated response to be subject to an appropriate SIL determination review to establish the required integrity of the system.

Maintenance and Re-calibration of Detectors

Fire and gas detectors should be included in the plant maintenance plans. Therefore, the location of detectors should consider how they will be accessed for maintenance.

The performance and accuracy of most detectors deteriorates with time. The rate of deterioration depends on the type of sensor and the operating conditions, for example a dusty, corrosive or damp environment. These factors will affect the frequency of inspection, maintenance and calibration.

The detector supplier will provide advice on the frequency of function checks on the detector. The detector supplier will also advise on whether the detector should be removed to a safe place outside the area being protected, such as a workshop for function checks. In this instance a replacement detector may be needed to monitor the area - unless the hazard has been removed, for example by shutting down the process or plant.

Roll-Out of New Standard

One of the key tasks in developing the new Fire and Gas standard was, after generating a draft of the new standard, to trial it on the Olefins plant at Grangemouth. The intent of this was two-fold:

- To demonstrate that the standard was fit for purpose, and to make improvements where necessary.
- To enable a gap review to be undertaken between current systems, in place, and those required by the revised standard.

It was during the review of the standard that the decision was taken to extract sections from the draft standard into a guidance note, thereby making the standard a more concise document. These revised documents were then trialled on the Ethanol plants at Grangemouth to demonstrate they were fit for purpose, as well as identifying the gaps between current systems and those required by the standard.

On completion of this review the standard and guidance note were released for implementation.

Conclusions

This paper discusses the development and roll out of a new standard, and associated guidance note, for fire and gas detection at the Ineos Grangemouth site. This standard has now been released and implemented throughout the Ineos P&O organisation at Grangemouth.

As the standard has been applied across different production units on the site, this has helped to identify:

- Where existing Fire and Gas detectors are provided, that can meet the requirements identified, without alteration;
- Where additional Fire and Gas detectors are required in order to meet the hazardous events identified by the review;

- Any existing detectors which require to be modified (e.g. type or location of detector, response to a detector alarm, maintenance / calibration frequency etc.) in order to meet the requirements of the hazardous event;
- Where Fire and Gas detectors are currently installed but are not required for compliance with the standard.

References

1. BS EN 60079-29-2:2015: Explosive atmospheres. Part 29-2: Gas detectors — Selection, installation, use and maintenance of detectors for flammable gases and oxygen.
2. BS EN 50073:1999 [withdrawn in 2007]: Guide for selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen.
3. BS 5839-1:2017: Fire detection and fire alarm systems for buildings. Code of practice for design, installation, commissioning and maintenance of systems in non-domestic premises.
4. EN 54-2 (2006): Fire Detection and Fire Alarm Systems Part 2: Control and Indicating Equipment.
5. NFPA 72 (2016), National Fire Alarm Code, National Fire Protection Association.
6. HSE publication: The selection and use of flammable gas detectors
7. HSE Research Report RR602: Assessment of gas detection strategies for offshore HVAC ducts based on CFD modelling.
8. Offshore Information Sheet No. 5/2008: Advice on gas detection strategies for HVAC duct inlets.
9. Energy Institute: Model code of safe practice part 19. Fire precautions at petroleum refineries and bulk storage installations. 3rd edition. 2012.
10. ISA-TR84.00.07-2010: Technical Report - Guidance on the Evaluation of Fire, Combustible Gas and Toxic Gas System Effectiveness.
11. EEMUA 191: Alarm Systems - A Guide to Design, Management and Procurement. 2013.