BS60080:2020 Guidance on the placement of permanently installed detection devices using software tools and other techniques: What is the scope and intention of the new standard?

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The paper presents the recently developed BSI standard, 'BS60080:2020 Explosive and Toxic Atmospheres: Hazard Detection Mapping - Guidance on the placement of permanently installed detection devices using software tools and other techniques'. The paper focuses on the gap in guidance on Fire and Gas (F&G) Mapping, and how the standard is of benefit to the safety community and facility operators.

The standard is intended to be applied to applications where:

a) optical flame detection is used as a means of detecting flaming fires in internal and external environments;

b) a gas detection system is used as a method of explosion protection;

c) the hazard arises from the release or accumulation of explosive gases and vapours; or

d) the hazard arises from the release or accumulation of toxic gases

The paper discusses one of the most challenging activities faced by a design engineer: determining the quantity and location of flame and gas detectors in the hazardous industries. To ease this challenging activity the standard provides guidance on the most commonly used methods of mapping and/or modelling; prescriptive, volumetric and scenario based, and attempts to clarify much of the misinformation within the industry on how best to effectively design a F&G System.

The paper provides an overview of the flow of the standard. Starting from guidance on the determination of which method to apply based on the application, and the performance-based risk analysis which determines the performance targets of the system - and the subsequent impact each of these crucial factors can have on the design.

The paper then discusses the progression of the standard to provide an overview of detection technologies, with the primary guidance then provided in a section on flame and gas mapping techniques. Interpretation of what 'adequate detection coverage' practically means is also a pivotal part of the standard which will be elaborated in this paper. Guidance is also presented on the life cycle of the system and various project phases, such as detailed engineering, and the subsequent level of effort which would be applied to the F&G placement study, addressing scheduling constraints, management of change and human factors etc.

Installation, commissioning, system validation, operations and maintenance, and finally competence shall also be addressed in the paper, with an overview of how these are implemented in the standard.

In addressing such factors, the paper presents the tools necessary to determine how many detectors a facility requires, and where to position them to achieve consistent and verifiably effective coverage.

Keywords: Flame Detection, Gas Detection, F&G Mapping, Hazard Detection, BSI Standards

Introduction to the standard

Gap in the market

Historically, one of the most challenging issues in Fire and Gas (F&G) detection is: 'How many detectors do I need, and where do I put them?' A fair question in the context of a facility processing hazardous material where traditional detection codes are simply not applicable. Placing heat detectors on a grid is intuitively not adequate for external processing facilities exposed to the harsh external environments like the North Sea, or a hazardous material storage facility. How, therefore, can we adequately position flame and flammable gas detectors, such that target fire sizes and gas clouds of concern can reliably, and verifiably, be detected?

As a result of this challenge, the Oil and Gas Industry led the way with what is widely referred today as 'F&G Mapping'. Just after the turn of the century, companies including Shell and BP formalised their practices into their own internal guidance documents, detailing methodologies against which F&G Detection systems should be designed where national/ international codes are not applicable. In 2005, Micropack (Engineering) Ltd. introduced the concept of F&G Mapping to the ISA84 committee, which later rolled out 'ISA TR84.00.07 Guidance on the Effectiveness of Fire and Gas Detection' [ISA, 2018], however widespread application of the standard has not occurred, anecdotally as a result of confusion on how to apply it and the resultant inconsistency of design.

This has led to the desire for a British Standard on hazard detection mapping to provide clear guidance on mapping, as well as assisting in bringing hazardous industries to a comparable level of detection analysis as that applied in the Oil and Gas Industry. It is important to note this does not mean the implementation of similar detection layouts as those applied in Oil and Gas (if the risk is lower, fewer detectors are generally applied). The desired outcome is that the same level of *consideration* of the placement of F&G detection devices is applied, even if this means very few devices are actually installed as a result of the risk assessment.

Inconsistency in design

A major driver in the development of the standard, as discussed, was the inconsistency in designs of F&G Detection devices in applications where detection standards such as BS5839 [BSI, 2019] are not applicable. In hazardous facilities such as these, the application of performance-based design is required. Where no guidance is available, placement of devices is left to the discretion of the designer. This is not necessarily solved by the application of guidance however, which is pivotal in the appreciation of the new standard.

In 2010, the ISA guidance provided a platform for the technique of F&G Mapping to be discussed within a wider audience, many of whom unfamiliar with F&G detection technology and design methods. The result has often been further confusion and inconsistency in fire and gas detection design, with strands of interpretation causing fractures across facility types, global regions, and even within companies as to how to address the fire and gas detection problem.

While the BSI standard attempts to tighten this guidance, the potential for inconsistency still exists, as with any performance-based approach. The standard does, however, provide guidance on how and where to apply the various methods, and places emphasis on competence when applying such an analysis. The dangers of applying an inappropriate methodology to a certain facility (i.e. applying scenario based modelling to a standard offshore oil and gas facility) can result in either an over engineered detection system, or even worse, an unsafe design [Sizeland, 2019].

Responsible engineer

In order to apply the standard, a relevant degree of competence is required. In a niche area such as F&G Mapping, competence in a relevant field can be challenging to find. In order to assist with this, the standard provides some guidance on what 'relevant competence' may entail.

As a minimum, pertinent to the roles and responsibilities of individuals, the following factors are provided as a starting point in reviewing competence:

- Knowledge and education with respect to the appropriate local, national and international standards applicable to flame and gas detection systems, including those standards as specified in the Bibliography.
- Appropriate knowledge of the legal and safety regulatory requirements pertinent to flame and gas detection.
- Engineering knowledge, education and relevant experience appropriate to specific hazards and required risk analysis.
- Engineering knowledge, education and relevant experience appropriate to the detection technologies of flame and gas detectors.
- Engineering knowledge, education and relevant experience appropriate to the complexity and novelty of a flame and gas detection system design.
- Engineering knowledge, education and relevant experience appropriate to the application or use of flame and gas detection system.
- Understanding of the potential consequences of an event should a gas leak or open flame not be detected.
- Previous experience and its relevance to the specific duties performed to support and complete a flame and gas detection mapping study.

Philosophy behind the standard

How many detectors do we need and where do we put them?

To simplify the intention and content of the standard, BS 60080 [BSI, 2020] aims to answer the following questions:

1) How many detectors do I need?
2) Where do I place them to maximise effectiveness?

Throughout the development process these two questions were at the forefront of the group decision making. These questions helped to decide what content was required, and the subsequent sections which would be included. If additional content was proposed at any point, it would be included only if it helped to answer one or both of those pivotal questions.

Such factors which would clearly be connected to these questions include the detection design methodology selection, hazard analysis, detection technology selection, management of change for the facility, practical considerations including installation and maintenance requirements, how to determine the adequacy of the detection coverage etc. The potential of spurious trips also informs technology selection and requires consideration in the positioning of detectors.

The standard also provides overall guidance on the full life cycle of a flame and gas detection system as it is important to emphasise that mapping and/or modelling is an ongoing activity and not simply a starting position for a new facility. Routine surveillance of detector coverage during the full life cycle of a facility ensures that facility modification, change in hazards, etc. are all considered, and the management of change highlights any deficiencies.

Scope of the standard

The standard provides guidance on the placement of permanently installed F&G detectors (including ultraviolet, infrared and visual flame detectors, flammable gas/vapour detection and toxic gas detection), along with the setting of performance standards for coverage, placement of devices and technology selection.

The standard is based on existing and established sensing and detector technologies and configurations. It does not exclude emerging technologies or innovative ideas, however it is advised that unless there is reasonable and practical evidence that these technologies offer equal benefits, caution is advised.

The standard is relevant to applications where:

- optical flame detection is used as a means of detecting flaming fires in internal and external environments;
- a gas detection system is used as a method of explosion protection;
- the hazard arises from the release or accumulation of explosive gases and vapours; and
- the hazard arises from the release or accumulation of toxic gases.

The standard also provides guidance on operations, maintenance and the availability/reliability of the system to complement relevant standards.

The following are excluded from the standard:

- hazards that are a product of vehicle exhaust fumes;
- applications in the domestic and general public environment;
- applications in mining and tunnelling, heating ventilation and air conditioning, medical applications or environments; or
- toxic gas detection with regard to business continuity, e.g. food tainting.

Mitigation effectiveness is also an important aspect of F&G detection design but is out of scope of the standard.

The standard refers to flame and gas coverage factors but does not specify target coverage factors for different applications. Coverage factors are only broad targets and are easily manipulated by changing device sensitivities, alarm trip levels, voting configurations, target gas concentrations, target flame size and other factors.

Flow of the Standard

In order to provide a clear guide on how to answer the two pivotal questions, the standard follows the following flow:

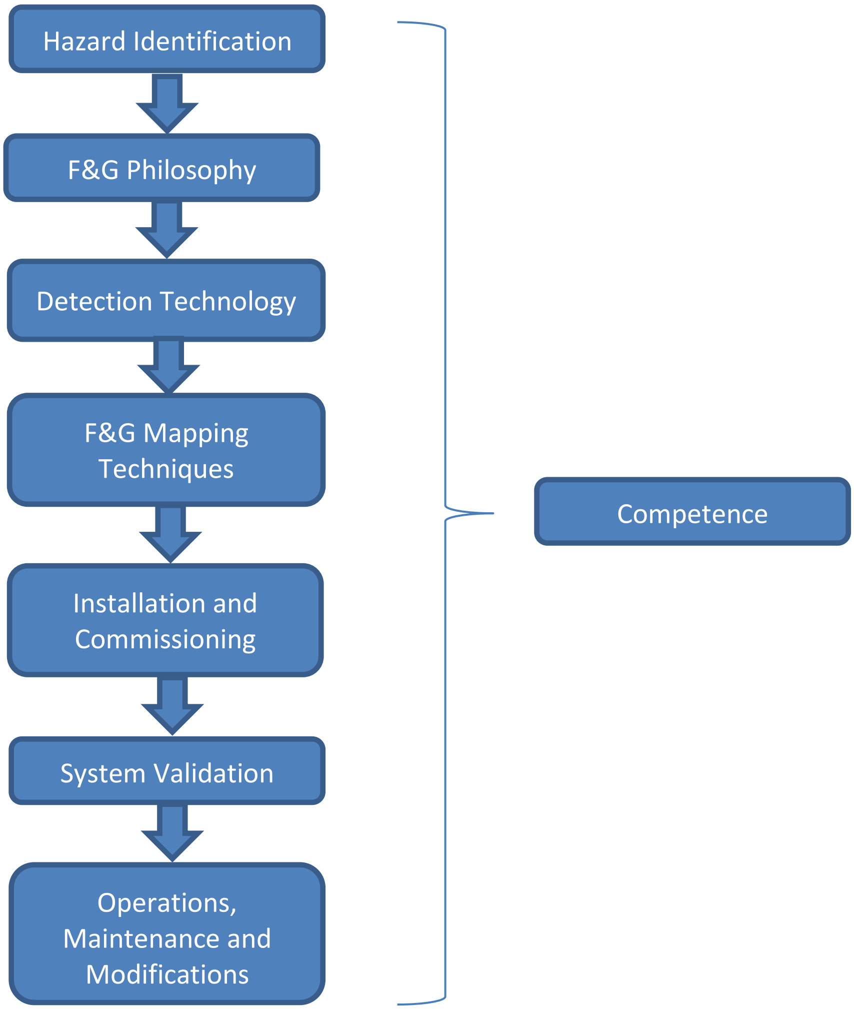

Figure 1: Flow of BS 60080

Within each of those sections identified above, factors impacting how many detectors are required and where to place them are addressed for each facet of F&G Detection design. The clause on F&G Mapping Techniques is the most detailed section covering a wide range of factors as discussed in the following section.

F&G Mapping Techniques

Flame Detection

In order to provide guidance on the specific techniques which can be applied to flame detection coverage mapping, the standard provides guidance on the considerations which should be made regarding the fire risk. These factors include the properties of the flame. Such properties which can impact the technique and analysis process include consideration of whether the hazard is a pool fire, or a pressure induced momentum driven/ jet fire. Connected to this is the consideration of the spectral characteristic of the anticipated flame. This will influence the detection technology which can be applied and the positioning of devices to optimise detection capability to the specific portion of the flame that the devices will be most sensitive to. This may also include liaising with the device manufacturer as this detail is not published and should not be part of an automated detection 'likelihood' calculation through software black boxes. The environment will also play a pivotal role in the assessment of adequacy, along with the source of fuel/ escalation within the area.

Within the standard, guidance is also provided relating to the grades and performance requirements of the flame detection system. This includes information on voting of devices to reduce false executive action activation and provision of system redundancy, along with guidance on the notion of target fire size in assessing coverage. As flame detectors operate on the inverse square law, the typical practice of assessing risk grades based on the allowable maximum target fire is expanded in the standard. Factors including point source modelling of flame detection coverage and the consideration of flame detector sensitivity is also included. This aims to ensure an appropriate sensitivity of devices is applied based on the environment to reduce false alarms, but also to ensure this is accurately accounted for within the design. This should ensure the assumptions in detection coverage are accurately reflected in the as built design.

Change management is also an important area in which guidance is provided. This primarily focuses on the requirement to monitor changes to the area through either process or hazard alterations which may impact the assumptions of the mapping study, or to verify proposed changes to the detection layout to ensure such an alteration will maintain adequate coverage. Such changes may be a result of new structure which blocks the original field of view of a device, or due to a technology or sensitivity change as a result of regular false alarms. The resultant coverage alteration from the change would need to be verified and accepted.

Each of these factors included in the standard are present with the aim to ensure that adequate coverage is maintained. Which introduces the complex issue of what can be deemed as 'adequate' coverage. Guidance is presented on this process of analysis and promotes the application of risk assessment of the escalation potential, to assign a performance target for the system, and to subsequently map the area to verify if the coverage meets this target. This can be through the application of a target percentage coverage, however this can be a problematic form of adequacy analysis as the following figure shows.

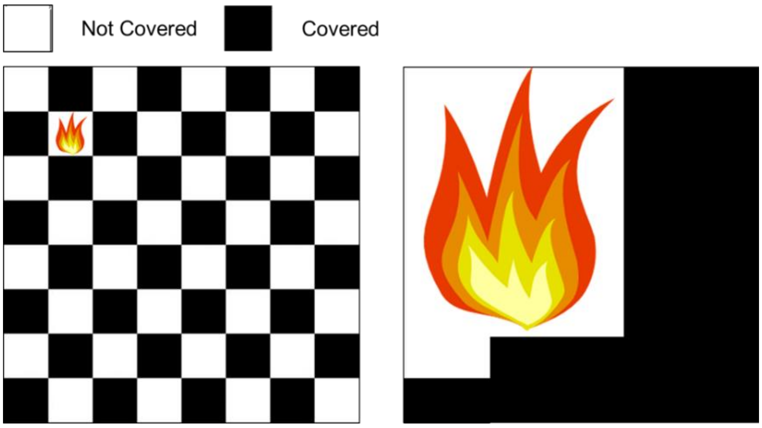

Figure 2: Percentage coverage chess board analogy

Figure 2, as presented in the standard, shows that 50% coverage for example can result in drastically different configurations. The example on the right could not be classed as acceptable as such a large fire could exist undetected and cause a significant escalation event. The left hand side chess board type coverage, however, could be classed as acceptable dependent upon various factors including but not limited to: the specific fire which can be present; the specific detector which is applied; the specific portion of the flame exposed to the device; the elevation in which the small blockages occur in relation to where the flame can exist; the location where the blind spots are located etc. Such information then allows the designer to make an informed decision regarding whether the design is adequate or not. This helps to demonstrate that a target % coverage is rarely an adequate form of design strategy and that each individual area should be analysed within its own merit by a competent designer who understands the environment, detection and risk in place. It also aids to show why automated coverage tools which make sweeping assumptions on detection capability may be dangerous.

Flammable Gas Detection

With respect to flammable gas detection mapping, guidance begins with the overview of considerations to be made prior to the mapping process, covering factors like fluid states and dispersion characteristics. Similar to reviewing the flame properties in flame detection, the guidance discusses the impact of whether the risk involves a gaseous release, gases liquified by the application of pressure, gases liquified by refrigeration, liquid releases with gas accumulation potential etc.

Unlike flame detection, gas detection set points require consideration, along with voting. The set points of flammable gas detectors can impact the resulting design and placement of the device as this has an impact on the sensitivity of the device (similar in a way to the sensitivity setting of a flame detector – the higher the sensitivity i.e. the lower the set point, while being more prone to false alarm).

Flammable gas detection also differs to flame detection in the sense that the devices are passive, requiring gas to come into direct contact with the device. The guidance therefore focuses on the target accumulations or releases which would aim to be detected. As it is virtually impossible to detect all gas leaks [Hilditch, 2019], the risk assessment focuses on the type of accumulations and releases which could develop to an explosion hazard, for example an accumulation of flammable gas within a heavily congested and confined processing area of an offshore facility.

Despite this fundamental difference in assessment, the guidance within the standard follows a similar route in providing guidance on change management, such as the consideration that applying a dispersion based scenario gas mapping design may cause significant problems when changes are implemented during the life of the site. This guidance could therefore mitigate a potentially expensive and time-consuming process of re-design and detection layout alteration when even the most basic of changes are implemented in the process area.

As with flame detection, guidance is also provided regarding assessing the adequacy of the layout. While the considerations differ between flame and flammable gas detection, the standard follows a similar structure to ensure the correct considerations are applied dependent upon the application and what type of system is being designed.

Toxic Gas Detection

Different again is the guidance relating to how to map a toxic gas detection system. Toxic gas detection design presents a significant challenge as there is limited design guidance, literature and empirical data which can be used as a basis against which to design the placement and quantity of fixed toxic gas detection devices in a hazardous area. While guidance and data exists which refers to the design of devices themselves and performance requirements of such devices, these do not answer the fundamental questions posed by BS60080 – how many do we need and where do we place them?

In light of this, the group focused on the philosophy behind why a site would require fixed toxic gas detection devices, and what the founding principles should be with respect to where to locate them. From this mindset, the guidance for toxic gas detection differs slightly from flame and flammable gas detection. Much of the guidance takes the form of considerations which should as a minimum be taken into account to ensure personnel protection. As the toxic problem can take a vast number of forms, it is even more important that facilities review the risks independently and ensure that their fixed toxic gas detection meets the requirement of a mitigating factor for their specific toxic hazard.

This guidance includes considerations ranging from the standard considerations of set points and voting, but focuses more on the relationship between response of the system, and action which can be implemented (whether this is process isolation, evacuation, stay in place etc.), as demonstrated in the following Figure.

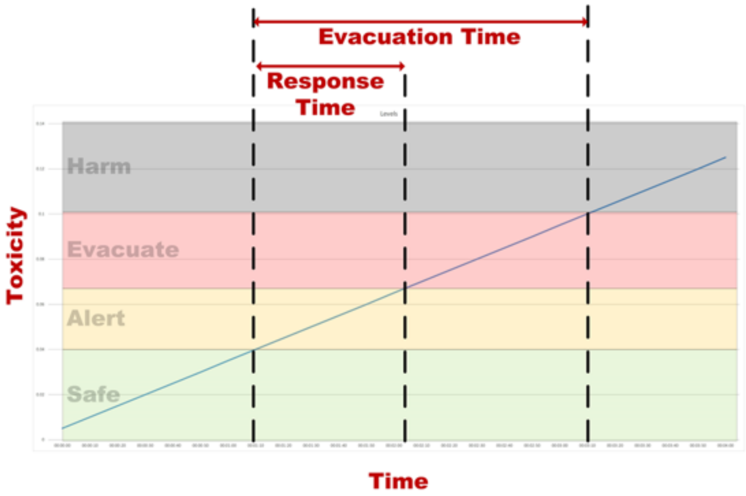

Figure 3: Response time from a toxic gas release

As part of this analysis the designer should consider the occupancy, means of escape, purpose of the area, nature of the gas (i.e. toxic concentration), inventory size, facility geometry, mitigation factors etc. Adequacy can then be analysed based upon the consideration of the specifics and the risk grades and performance targets which are set to meet the facility requirements after the risk assessment.

Prescriptive, Volumetric or Scenario based design

In practice there are typically three approaches applied. These three different mapping methods are discussed within the standard, with guidance on the strengths and limitations of each:

- prescriptive;
- volumetric; and
- scenario-based.

Typically, prescriptive methods are the most simplistic with the level of complexity and effort increasing progressively towards the employment of scenario-based methods, however the results of the analysis do not necessarily improve as the method becomes more complex. The most important emphasis as prescribed in the standard is the application of the best method based on the nature of the facility, the risks present, and the corporate philosophy regarding risk and detection mapping (if applicable).

The mapping methods can be considered analogous to qualitative (prescriptive), semi-quantitative (volumetric) and fully-quantitative (scenario-based) applied to risk assessment. The concept of proportionality is generally recommended in the standard, with the selected methodology chosen based on the level of risk. Detail on these approaches is provided in each section addressing flame and flammable/ toxic gas detection to allow the best method to be applied specifically to the detection requirements.

Application Examples

Flame Mapping

The following is a worked example showing one possible representation of flame detection mapping as prescribed in BS60080.

The example assumes the area has been processed through a risk assessment as discussed in the standard. Vessels V-001 and V-002 present a medium risk to the area (containing pressurized flammable liquid). Vessel V-003 presents a low risk as it is a storage vessel for flammable liquid at atmospheric pressure. Table 1 shows the performance target fire sizes (in Radiant Heat Output [RHO]) applied to the area.

Table 1: List of risk grades

Equipment tag	Grade	Grade volume extension from equipment	Fire size (RHO) alarm (1ooN)	Fire size (RHO) control action (2ooN)
V-001	Medium risk (MR)	2 m	50 kW	100 kW
V-002	Medium risk (MR)	2 m	50 kW	100 kW
V-003	Low risk (LR)	2 m	250 kW	500 kW

Figure 4 represents the volume in digital form, where performance targets have been added.

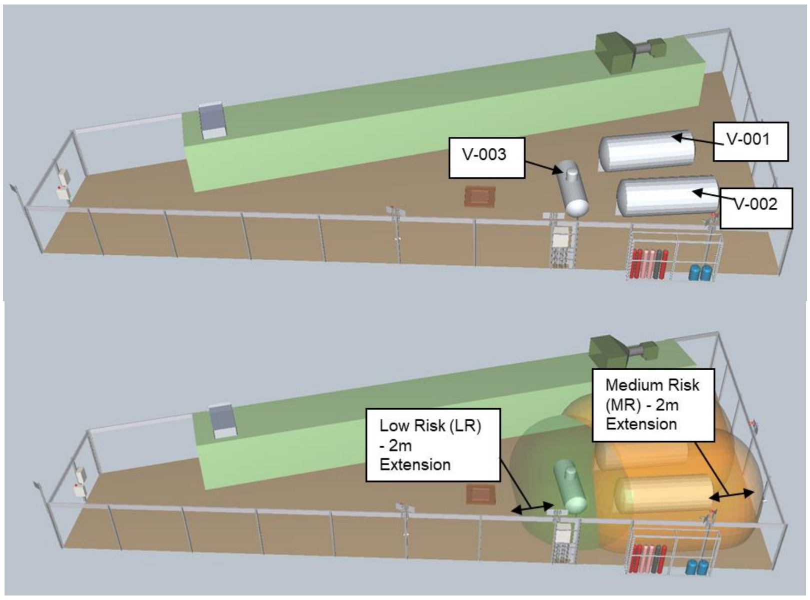

Figure 4: Grademap volume

Figure 5 shows the location of two flame detectors which have been placed in the model. A generic flame detector cone has been applied in the example. In reality, the specific flame detector being installed should be modelled.

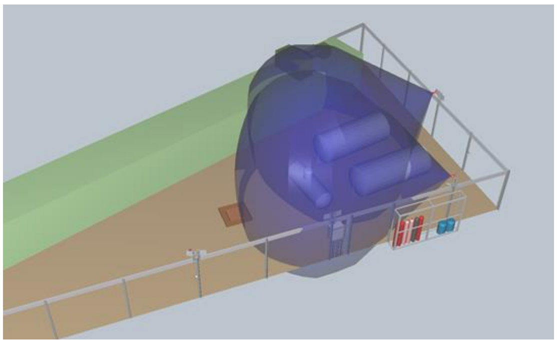

Figure 5: Existing flame devices

Figure 6 represents the assessment of coverage in both 3D and 2D forms.

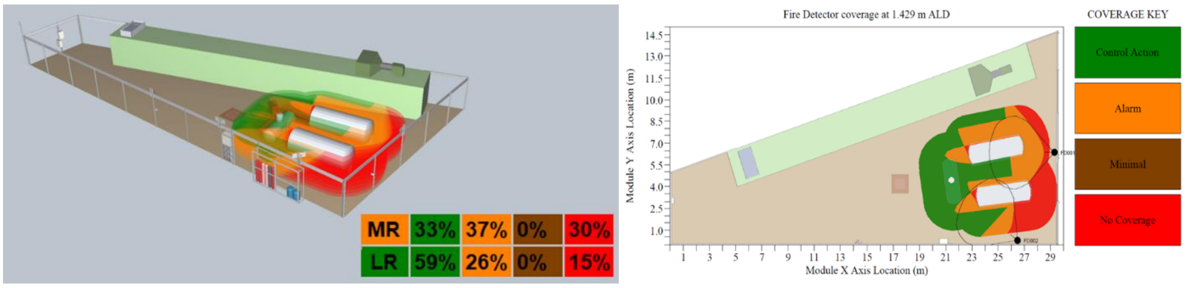

Figure 6: Existing coverage representation

From this point, the engineer applies judgement to determine coverage adequacy. If significant gaps exist where fires could burn undetected, or redundancy is required, additional detection can be considered. An additional detector is added for clarity in Figure 7.

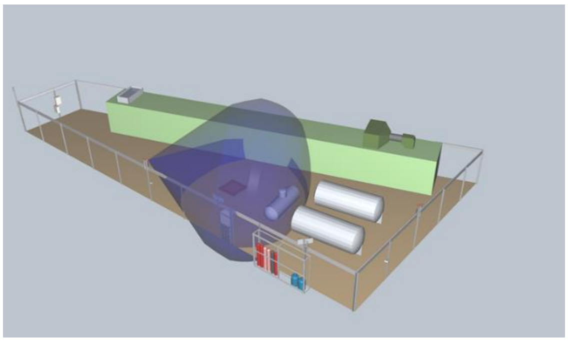

Figure 7: Additional detector location

Once the required alterations are made to the detection layout, the updated coverage is assessed to verify if an adequate design has been achieved. The following Figure 8 shows the updated assessment coverage for the engineer to evaluate.

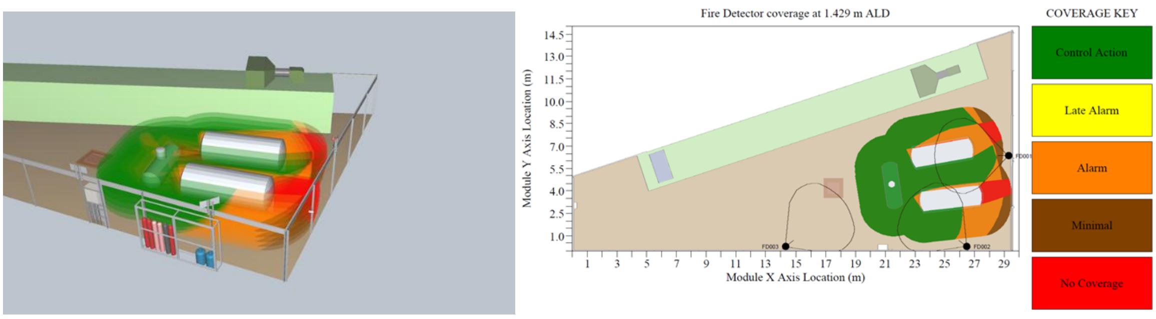

Figure 8: Updated coverage assessment

Note the flame detection footprint cone shown in the figures above is representative of the detection distance to a 10kW RHO flame. This is for illustrative purposes only and does not reflect the capability of the device. Flame detection capability is assessed as per the inverse square law as discussed in the standard. This allows the requirements in Table 1 to be fulfilled.

Gas Mapping

The following is a worked example showing one possible representation of gas detection mapping as prescribed in BS60080.

As with the flame detection example, it is assumed that a risk assessment has been conducted and the requirement for gas detectors has been identified as per the guidance within the standard. The example shows plant which is located outside and has low congestion. There is a concern that an accumulation of flammable gas could ignite, causing explosion overpressures above 150 mbarg leading to personnel fatalities and damage to the facility.

Table 2 shows the estimated blockage ratio within the area.

Table 2: List of risk grades

<table>
<tr><th>Orientation</th><th>Blockage factors</th><th>Blockage ratio</th><th>Combined blockage ratio</th><th>Flammable gas detection performance target</th></tr>
<tr><td>North</td><td>Container</td><td>0.07</td><td rowspan="6">0.27</td><td rowspan="6">Open</td></tr>
<tr><td>South</td><td>Open</td><td>0.00</td></tr>
<tr><td>East</td><td>Vessels</td><td>0.03</td></tr>
<tr><td>West</td><td>Open</td><td>0.00</td></tr>
<tr><td>Grade</td><td>Solid Ground</td><td>0.17</td></tr>
<tr><td>Ceiling/ Roof</td><td>Open</td><td>0.00</td></tr>
</table>

With the volume being relatively open with little congestion and confinement, the volume is classed as open. With the concern being the ignition of a volume of gas causing an explosion, judgement has been used to set the target gas cloud size as 10m in diameter (twice the 5 m cloud size historically used based on the performance-based analysis).

The facility has a 2ooN voting configuration for both low and high level alarms. A dilution factor of three is applied to account for the difference in cloud size between low and high level alarms. The high alarm target gas cloud size is 10m and the low alarm target cloud size is 30m.

The target gas clouds sizes, detection technology and set points are summarised in Table 3.

Table 3: Flammable gas detection targets

<table>
<tr><th>Detection grade</th><th>Target gas cloud of concern</th><th>High alarm set point</th><th>High alarm target cloud</th><th>Low alarm set point</th><th>Low alarm target cloud</th></tr>
<tr><td rowspan="2">Open</td><td rowspan="2">10 m diameter between 100% LEL and 100% UEL</td><td>Point GD - 20%LEL</td><td>10 m</td><td>Point GD - 10%LEL</td><td>30 m</td></tr>
<tr><td>OPGD – 1.0LELm</td><td>10 m</td><td>OPGD – 0.5LELm</td><td>30 m</td></tr>
</table>

Figure 9 shows the 3D representation of the plant showing the volume where the mapping is performed.

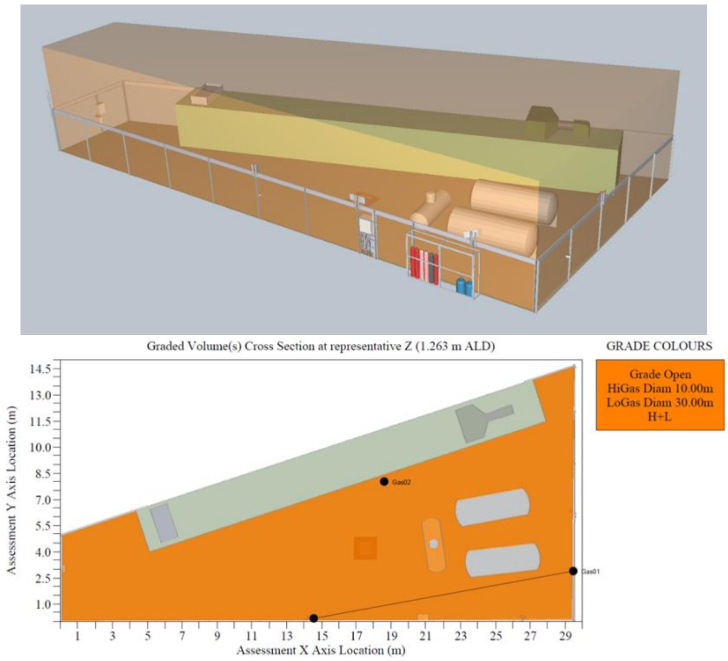

Figure 9: Volume to be mapped

Gas detectors have been placed in the 3D volume as shown on Figure 10. One Infrared Point Gas Detector (IRPGD) and one Open Path Gas Detector (OPGD) have been added to the area.

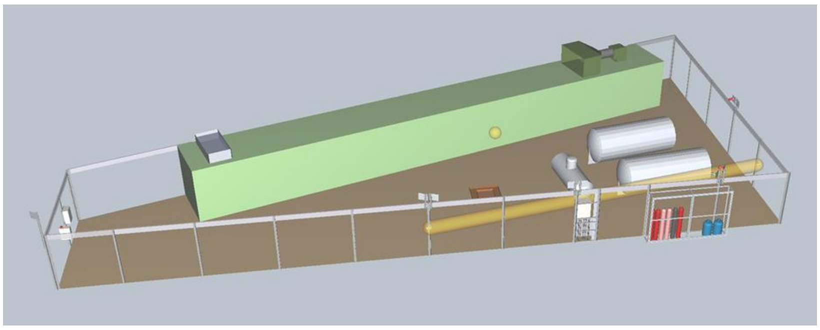

Figure 10: Existing gas detectors

Figure 11 represents the assessment of coverage. As combination of infrared open path and infrared point gas detection technology is applied to the area, the beam path absorption function and dense/ dilute clouds have been mapped in the area as defined in Table 3 and as discussed in the standard.

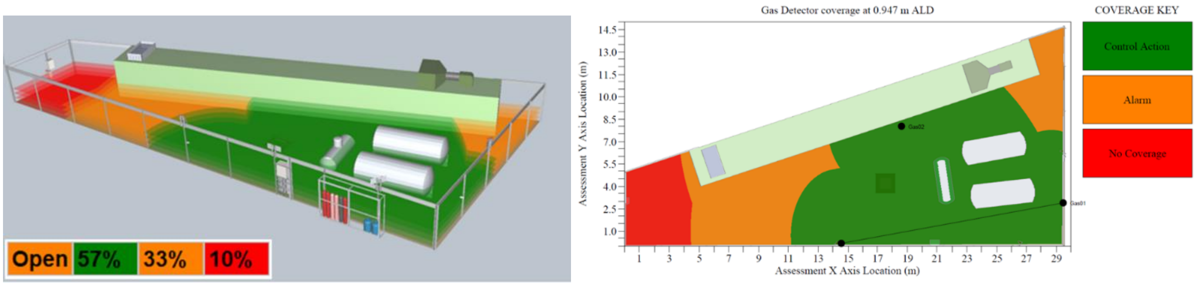

Figure 11: Existing assessment coverage

As previously discussed, and as described in the standard, percentage coverage in isolation is not a useful metric of coverage adequacy. If significant gaps exist where the cloud volume of concern remains undetected, or redundancy is required, additional detection should be determined. An additional detector is added for clarity in Figure 12 below, along with the updated coverage values.

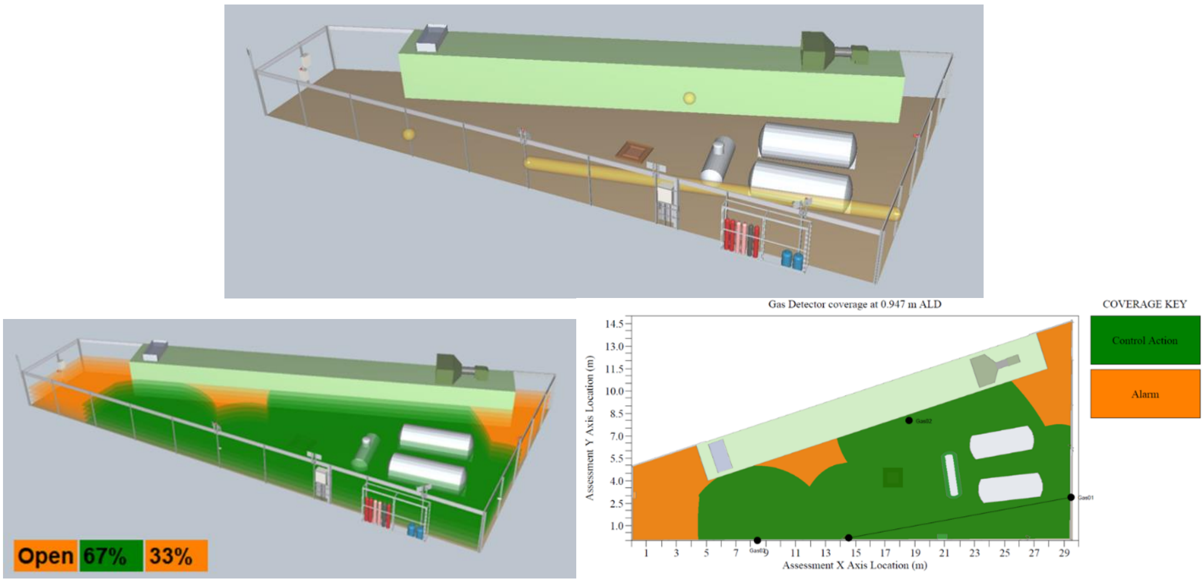

Figure 12: Additional IRPGD and coverage assessment

Conclusion

To conclude, the new standard, BS60080, is intended to provide guidance on the design of fixed F&G detection devices. This aims to bring the hazardous industries in alignment with respect to flame, flammable and toxic gas detection systems when considering how many devices are required and where they should be located. The standard will be available through the British Standards Institution (BSI Group).

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