The Role of Engineering Judgement in Fire and Gas (F&G) Mapping

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What is F&G Mapping?

It is the age-old question in F&G detection design: How much coverage is enough? An interesting topic, and one which does not have a straight forward answer.

While many of the guidance documents (although these are few and far between) will put forward a target coverage, some interpret this literally and it becomes an unquestionable requirement, like a PFDavg on a Safety Instrumented Function (SIF) in a Safety Integrity Level (SIL) calculation. In truth, this is an impractical philosophy to incorporate in F&G detection design, and the application of such arbitrary figures has led to some wildly over engineered systems, in addition to some dangerous shortcomings in others.

Of course, these target percentages will vary dependent upon the philosophy being applied. An example of this is the difference between the target gas cloud volumetric approach and the spacing requirement of gas detection methodologies. When reviewing the requirement for detection of a target gas cloud, the user will assess the percentage coverage of each volume, and determine if the coverage is adequate. This philosophy allows the stipulation of a target percentage of, for example, 80% coverage. If we apply spacing, however (as in BP GP30-85 [Ref 1]), we inherently must hit 100% coverage. Although this is not explicitly referenced in documents prescribing spacing, if the requirement is to have a device every 5m, for example, and we achieve less that 100% coverage from the layout, we have fundamentally not achieved compliance with that philosophy.

How do we calculate coverage and what are the assumptions? Is a target percentage coverage an appropriate litmus test of effectiveness?

To determine how much emphasis should be placed on the percentage coverage achieved, we must initially accept the limitations and assumptions in the calculation process itself. Taking flame detection as an example, a performance target must be set. This is typically a target fire size, expressed in Radiant Heat Output (RHO), or a multiple thereof [Ref 2&3]. A common misconception of this is that we are specifying that this target fire size is a credible fire in that area. This is historically not true; however, some designs can apply such a technique. Instead what this value is showing is the RHO of a fire at a given distance from a piece of process equipment where a fire could begin the process of escalating to an uncontrollable condition.

The multiples of RHO commonly seen (10kW, 50kW, 100kW etc.) are generally taken from a certified detection capability to the 1 ft squared n-Heptane pan fire (approx. 40kW RHO) [Ref 4]. This detection distance can then be extrapolated to larger or smaller fires using the inverse square law. It can be claimed that an n-Heptane fire is not credible in a specific area therefore the target fire should be changed. If this approach is to be applied, designers must be aware of the intention of the target fire size methodology.

We also must be careful in changing these targets too far from what the flame detectors are certified against. Flame detectors are rarely (if ever) formally certified to detect 8m gas jet fires, for example. Mapping based on these fires therefore includes many, potentially flawed, assumptions on how the flame detector will respond to the fire. Furthermore, using algorithms which claim to calculate the RHO which travels beyond small bore pipework and blockages to show sufficient coverage of areas with no direct line of sight to a flame detector could be misleading. Care should be taken to ensure this analysis is validated against formal testing of the actual device it claims to map. In practice, this appears not to be undertaken.

Looking at these design strategies and assumptions we can see that the percentage coverage which we end up with must be evaluated in far greater detail than a simple pass/ fail criterion [Ref 5]. This is even before the designer accounts for many of the practical issues affecting flame detectors. These factors include environmental conditions, differing day to day flame buoyancy and burning characteristics, and differing environmental conditions which desensitise flame detectors resulting in a different detection capability each day, to name a few [Ref 6].

3D F&G Mapping Outputs and how these can be Interpreted

The following case study has been generated to show the difference in detection layouts, and demonstrate the difficulty in determining adequacy of coverage [Ref 7]. This study shows the dangers in determining detection adequacy based on percentage coverage alone, using little engineering judgement, or worse yet using software alone to create the detection layout with the sole purpose of hitting the target percentage in question.

The first assessment shows a detection layout with generic flame detectors (with 25m detection distance to the 1ft² pan fire), with a generic risk volume grade requiring detection of a 50kW fire. The detector locations are representative of a layout based on practical mounting locations. The simplistic assessment criteria are akin to those which can be applied within many auto optimisation assessments.

Figure 1: Preliminary Assessment 1 Grademap (Blue area showing a slice through the generic risk volume of 50kW RHO Fire Target)

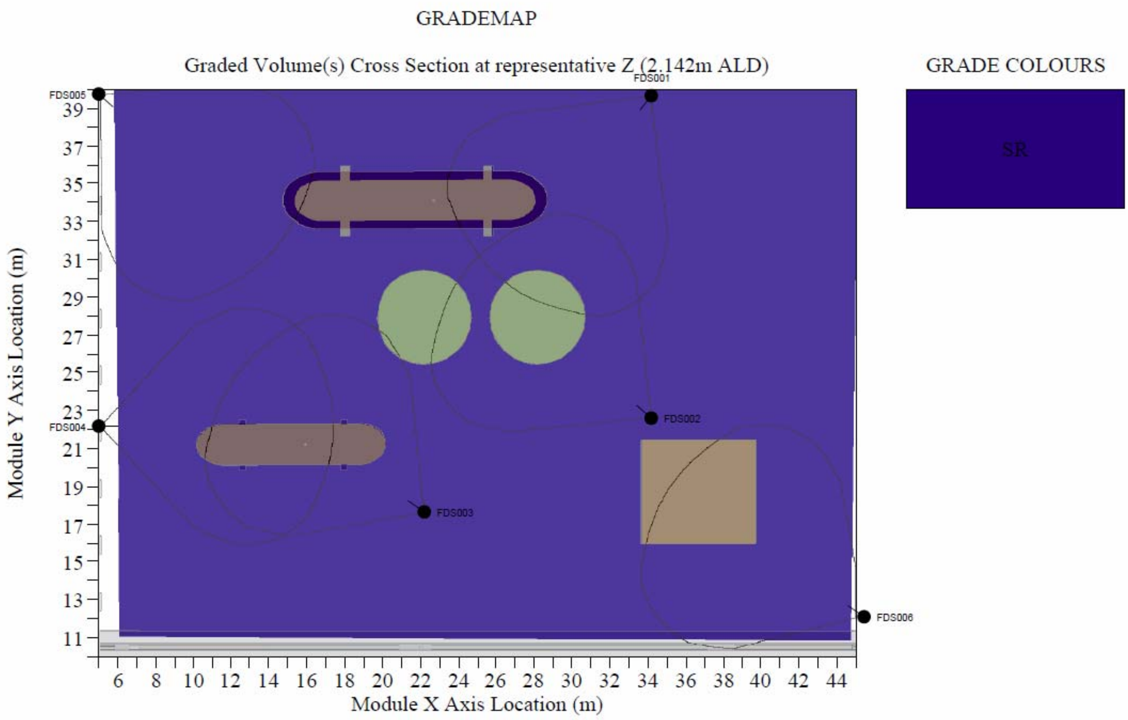


Figure 2: Preliminary Assessment 1 Assessment Volume (1 of 2)

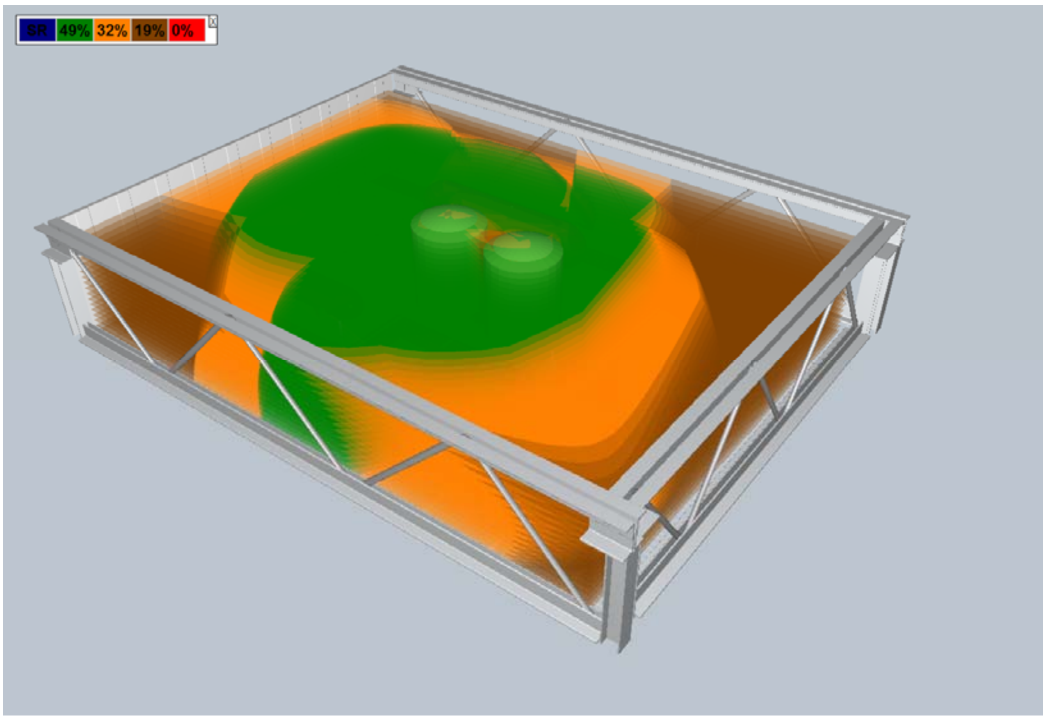


Figure 3: Preliminary Assessment 1 Assessment Volume (2 of 2)

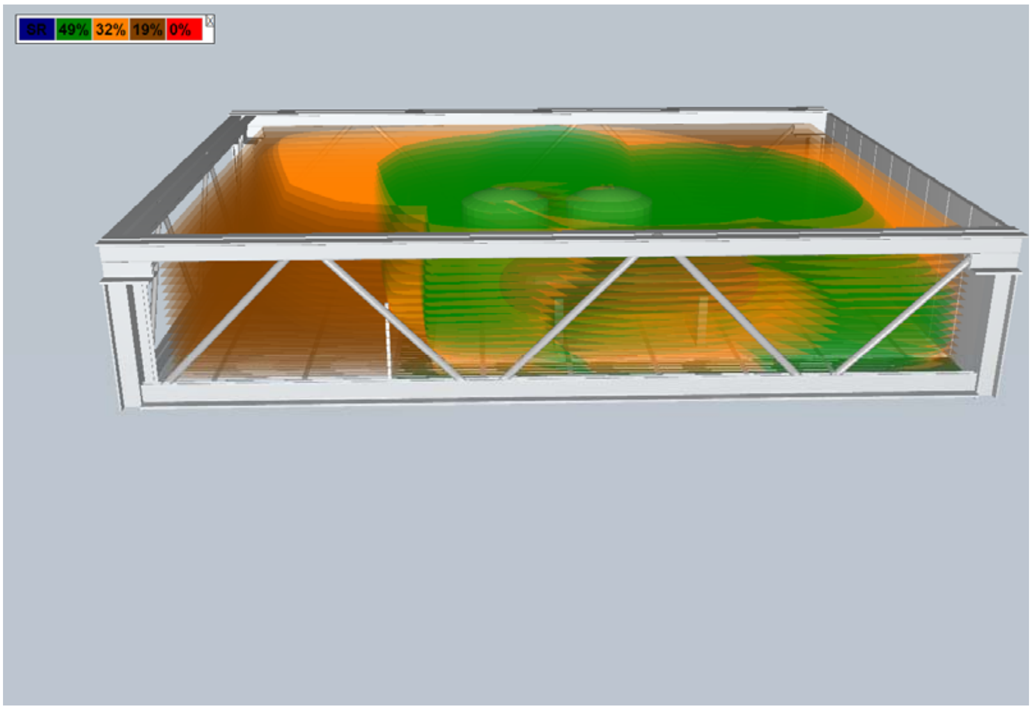
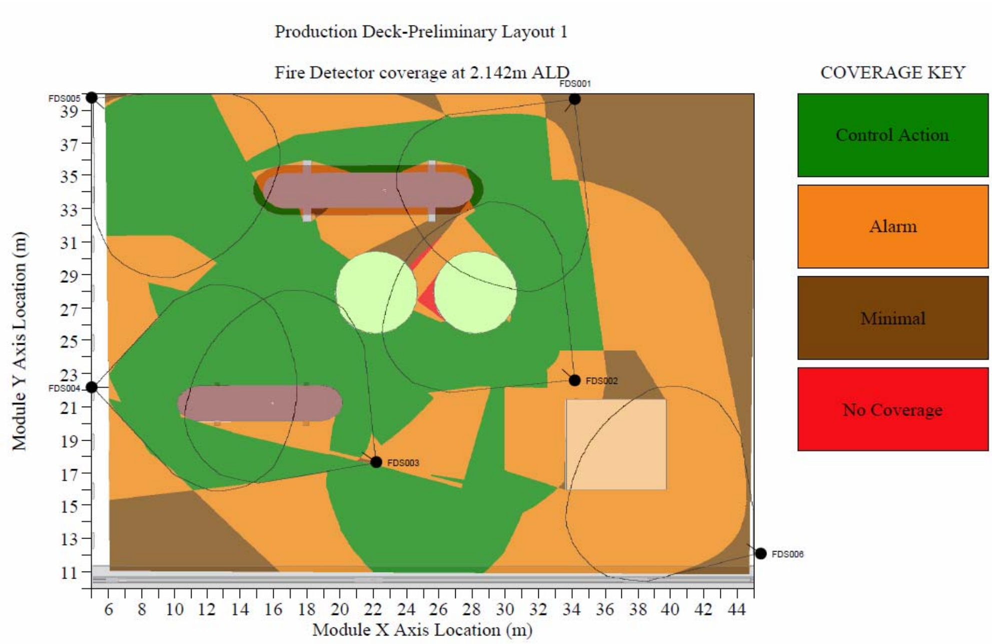


Figure 4: Preliminary Assessment 1 Assessment (Horizontal Slice)



When reviewing the coverage achieved above, it is obvious that if an auto optimisation analysis is carried out for this layout and generic risk grade, we would require additional detectors to hit a target percentage coverage of 80%, for example. When we apply an adequate risk based approach, however, we can begin to see that the layout may not be so bad as shown above.

The next assessment introduces the application of specific flame detectors on the market with varying detection distances (a mixture of the Dräger Flame5000 with detection distance of 44m detection distance to the 1ft² pan fire and the Detronics X3301 with 30.5m detection distance to the 1ft² pan fire). This assessment also introduces risk based grading with target fire sizes varying in the assessment from 10kW to 250kW based on a risk based approach to fully optimise the system.

Figure 5: Preliminary Assessment 2 Grademap (Red showing high risk volume, orange showing medium risk volume, green showing low risk volume)

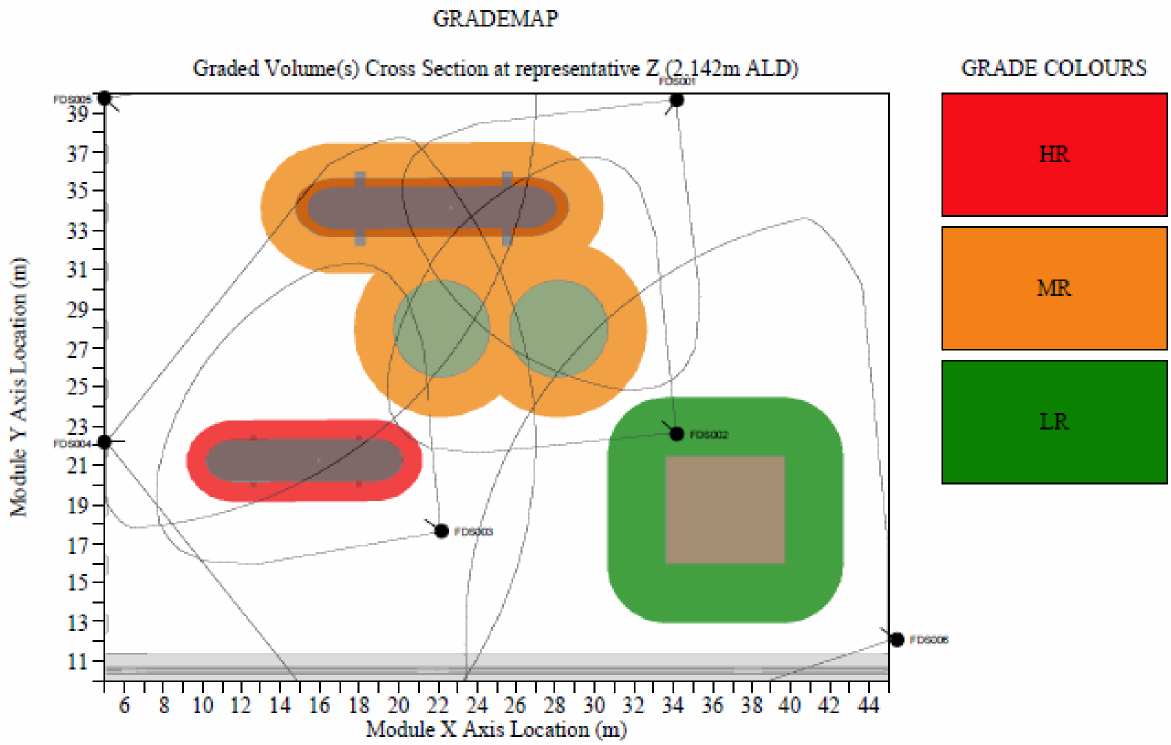


Figure 6: Preliminary Assessment 2 Assessment Volume (1 of 2)

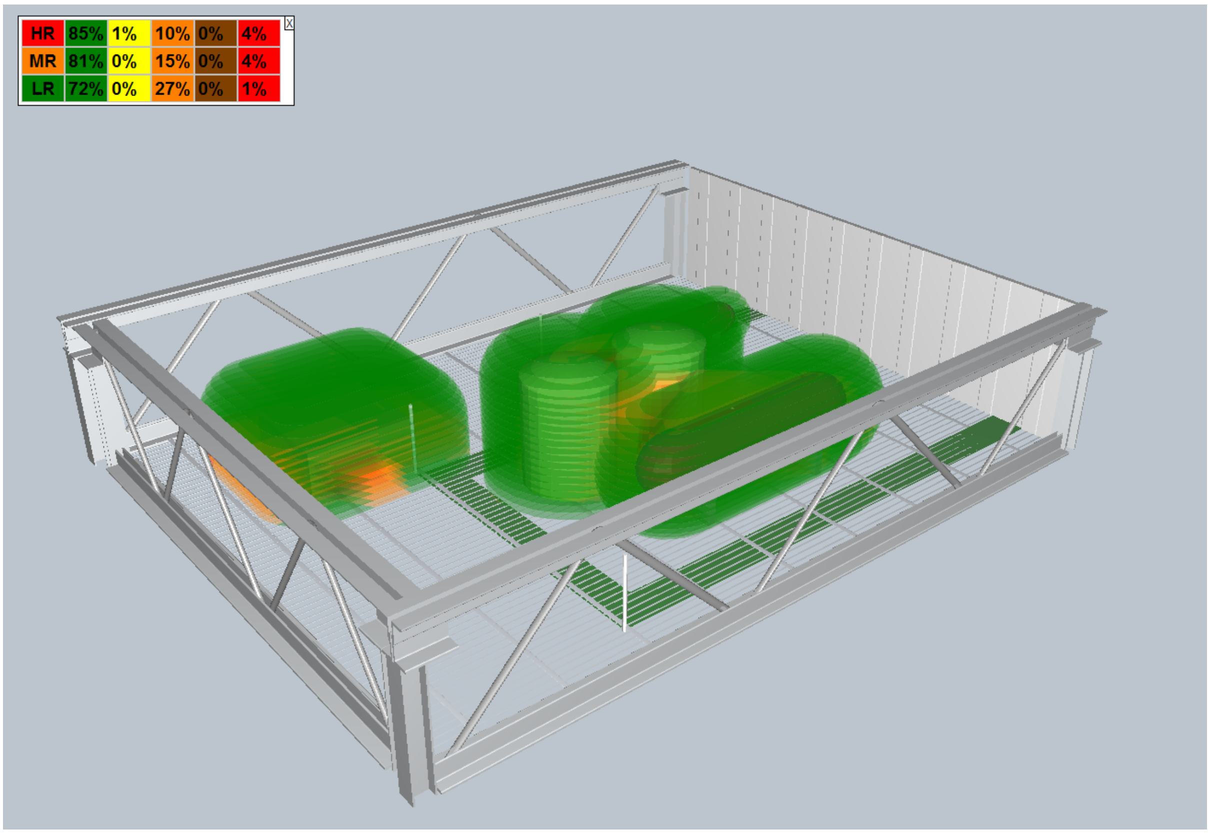


Figure 7: Preliminary Assessment 2 Assessment Volume (2 of 2)

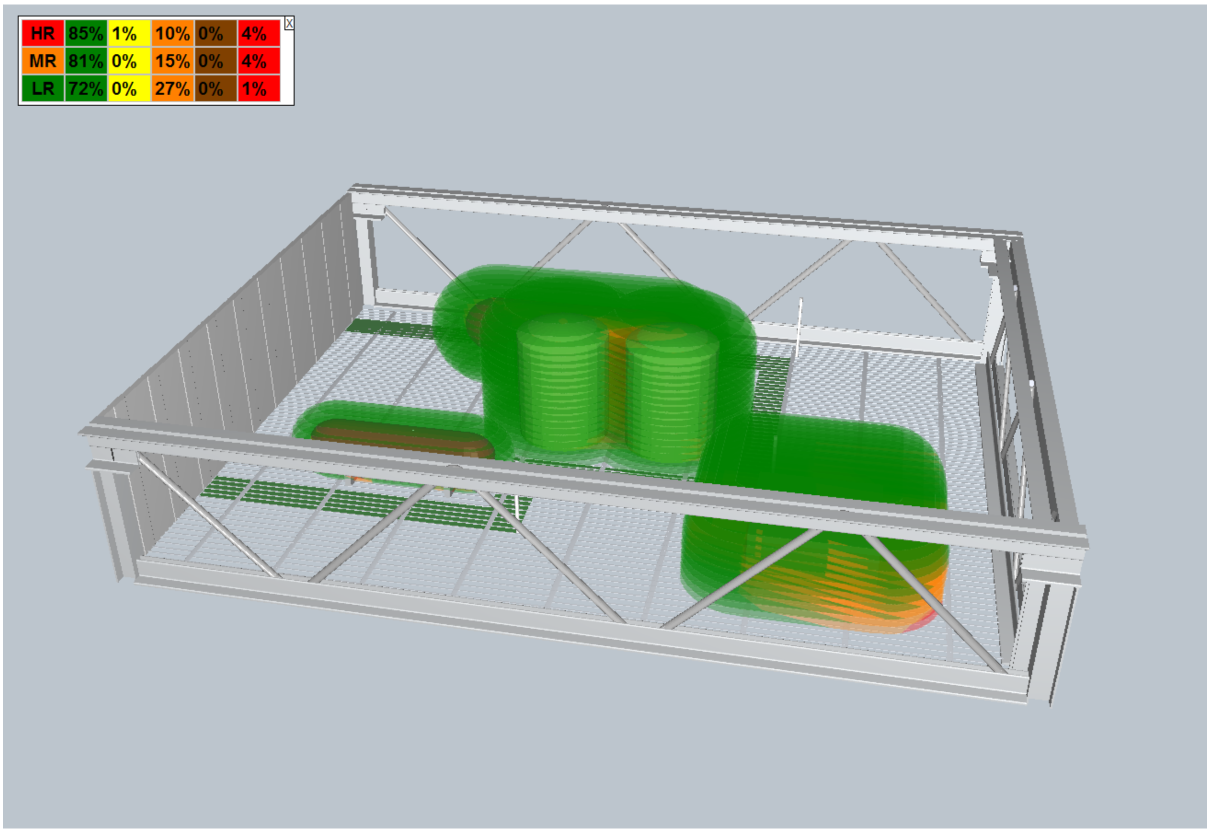
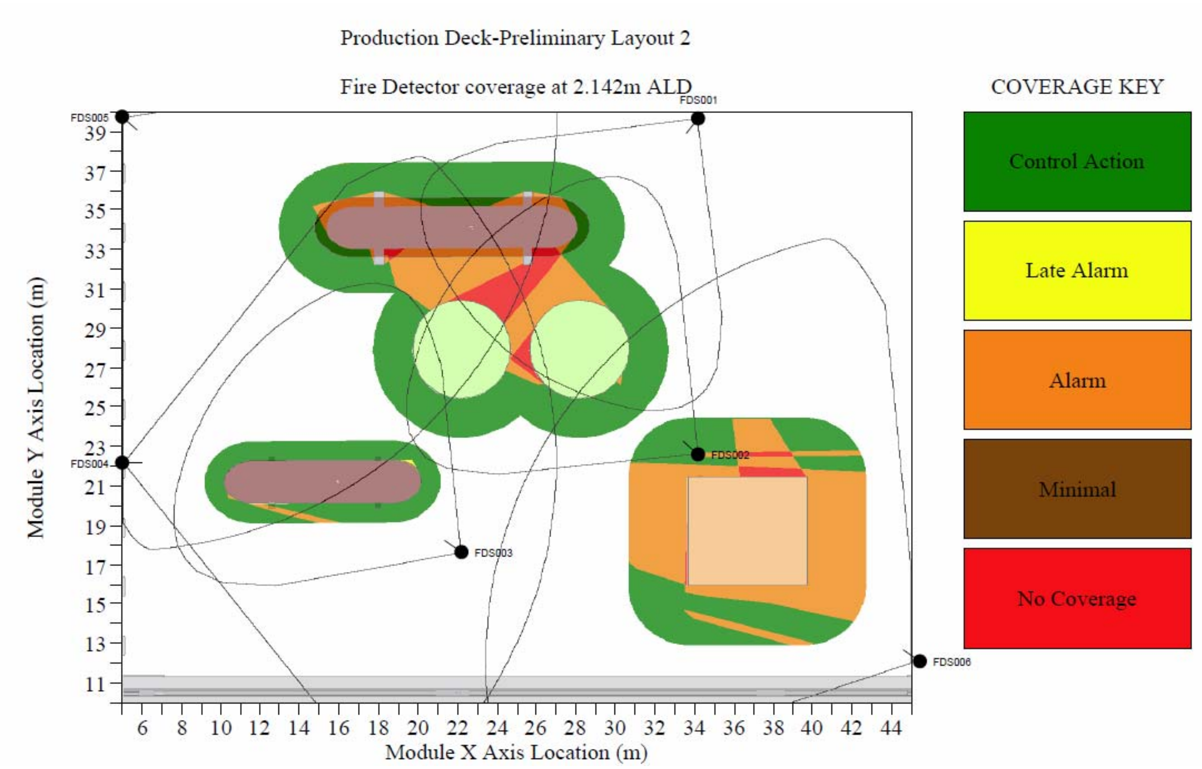


Figure 8: Preliminary Assessment 2 Assessment (Horizontal Slice)



We can see this assessment achieves at least 80% coverage of the graded area for high and medium risk areas, and over 70% coverage for low risk areas. If we are designing the system just to hit this target, we have done our job. On closer inspection, however, we can see significant areas of blockage which cannot be regarded as suitably covered (figure 8). If we were we to have a fire within this area, the escalation potential could be significant. For this example, some relocation is required to make the coverage adequate, despite hitting 80% coverage.

In the following assessment, we see a detection layout where the coverage for the medium/ high risk areas does not achieve the target 80%. On closer inspection, however, we can see much of the areas of no coverage are small, insignificant volumes. This would mean addition of detection devices simply to cover these areas and increase the percentage would be excessive. In fact, the only area to hit the target percentage is the low risk area which achieves 73% coverage (tank graded green on the grademap). On inspection of the coverage of this piece of equipment, however, we can see that the coverage may need to be optimised further, despite hitting the target percentage.

Figure 9: Preliminary Assessment 3 Grademap (Red showing high risk volume, orange showing medium risk volume, green showing low risk volume)

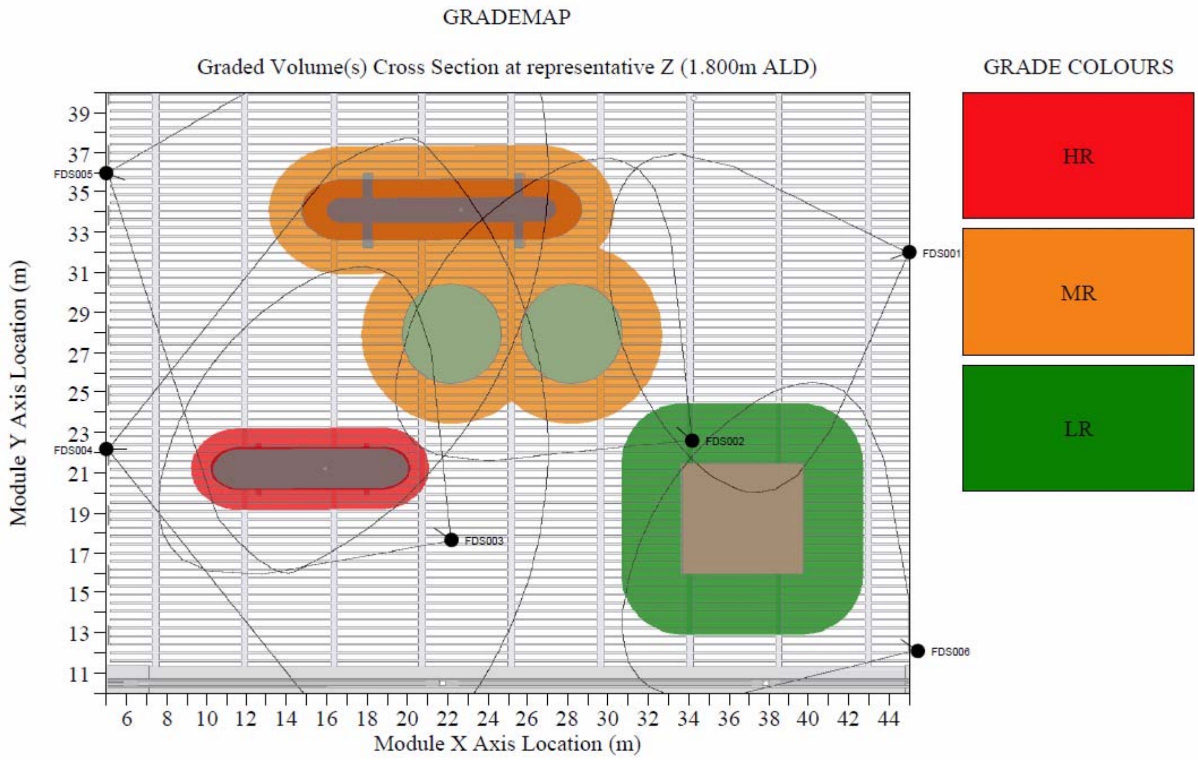


Figure 10: Preliminary Assessment 3 Assessment Volume (1 of 2)

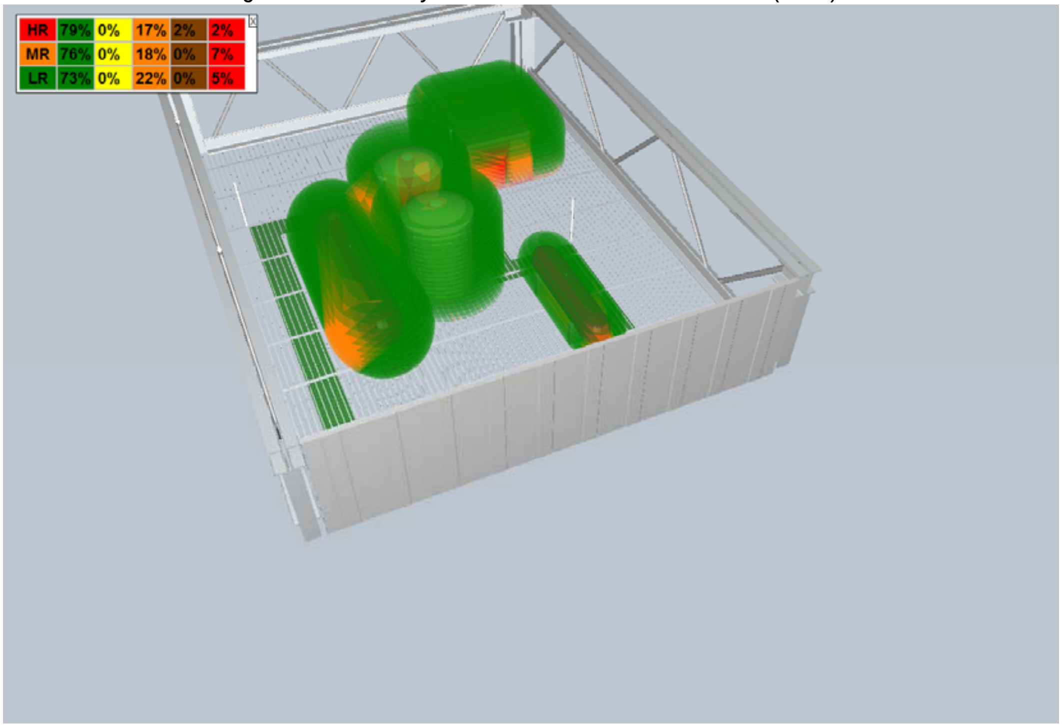


Figure 11: Preliminary Assessment 3 Assessment Volume (2 of 2)

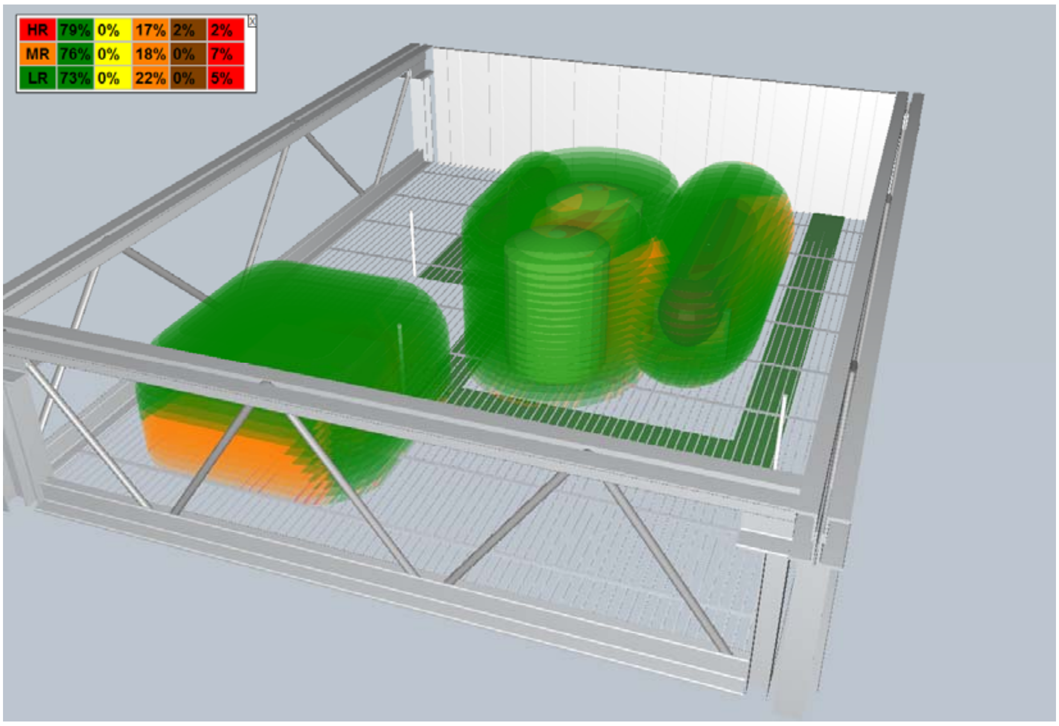
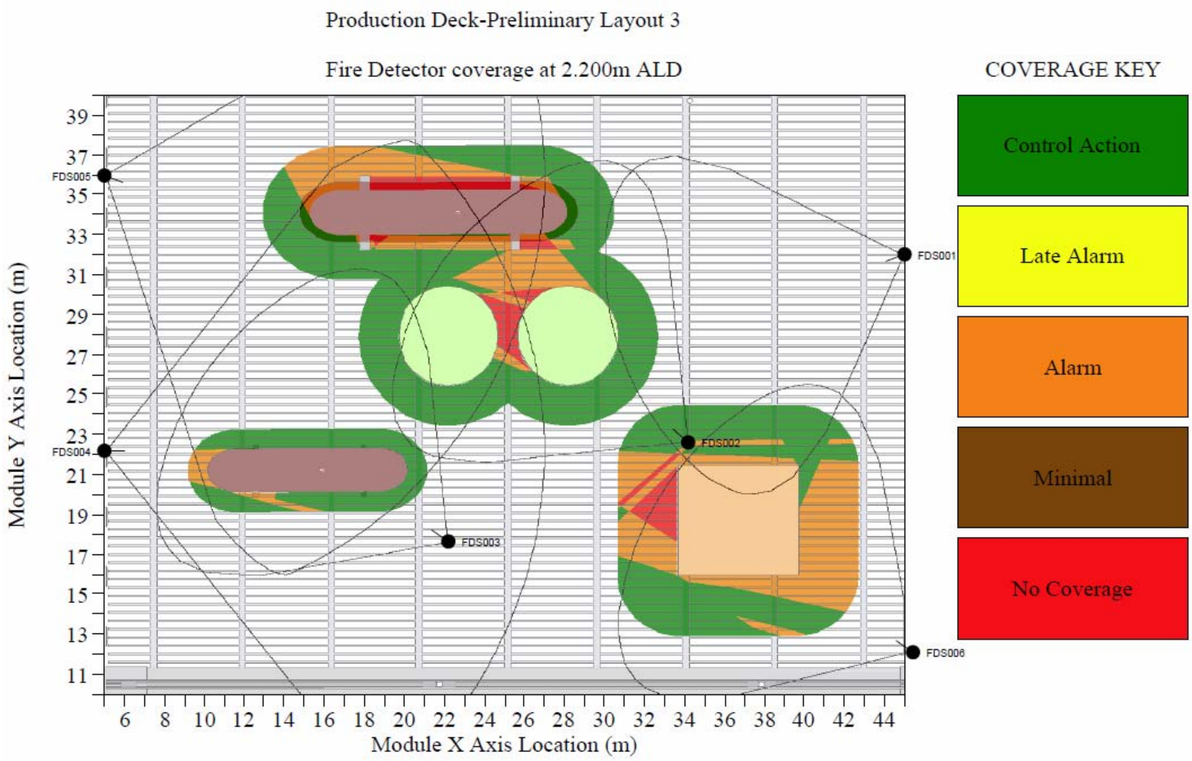


Figure 12: Preliminary Assessment 3 Assessment (Horizontal Slice)



Emphasis on Target Percentage:

As discussed, many of the standard guidance documents specify a target percentage of coverage for flame and gas detection systems. Values of 80% control action coverage or 95% 1ooN coverage and 90% 2ooN coverage are often referenced without a great deal of consideration of whether a percentage coverage tells the whole story. This leads us to one of the emerging industry debates – whether auto optimisation is currently a credible design strategy.

There are many critical factors to be considered before deciding if automating the detection layout is a suitable method. If an auto optimisation algorithm is basing the detection layout solely on meeting a target percentage, then there is no way of verifying if the coverage is 1) suitable, and 2) actually optimised. This is evident in the assessments above, and can be further exacerbated when considering different target fire sizes in the same assessment, something which is fundamental in a risk based mapping exercise.

Consider a scenario where we auto optimise a layout of detectors using a 30m detection distance and the target is 80% coverage for the volume. Algorithms are available which would certainly auto optimise the layout to this requirement. The designer must, however, determine if this is a suitable approach to apply. There may be areas in this volume where the detection distance can be expanded to 60m (for example allowing the fire to be larger before an alarm is required). There may also be areas where the detectors must be closer to the fire and the suitable detection distance is only 15m. These varying factors should be assessed in a single analysis is a suitably performed risk based mapping exercise.

Auto optimisation based on single fire size and generic risk grading, targeting a generic percentage coverage will ultimately provide too little coverage in areas of high risk, and too conservative a coverage in areas of low risk. This is the primary reason any *risk based* auto optimised layout requires further consideration than basic generic optimisation based on potentially flawed inputs. Therefore, in a risk based design, auto optimisation may be a suitable starting point, but the detection layout should be fully verified in a software which analyses multiple target fire sizes in the same volume if the design is to be stamped as adequately optimised.

A basic rule of thumb which can be applied is: If the coverage does not hit 80% don't worry – check the coverage as it may still be adequate. If the coverage is over 80% don't assume you are fine – check the coverage as it may still be inadequate.

Solutions:

Where a risk based approach is taken, it is important that each area assessed for F&G detection adequacy be analysed both in isolation, and in the greater context of the facility to determine if the coverage appears adequate. This process should not be carried out by a single engineer with a piece of software, but involve representation from the project team, having input from all relevant disciplines. This is due to adequacy not be determinable by hitting a basic target percent which can be automatically generated in a tool. Analysis of adequacy requires a significant amount of risk based analysis and input from multiple parties.

Having a target percentage recommended as a baseline is useful, but it is just as important not to let that dictate the resulting F&G design. One suitable approach would be to assign the risk grades based on the risk assessment and place devices in practical locations where these can be mounted while being as free from interference as possible. An assessment can then be carried out to confirm the adequacy of such a layout against different target fire sizes/ risk volumes to gain a full understanding of what the coverage will look like. Reviewing this coverage can then be carried out in a workshop environment with multiple disciplines commenting on issues from detector location adequacy against suitable risk targets, to suitable instrumentation for the area.

Reviewing the percentage coverage here is also critical to decide whether alterations should be carried out or not. This approach removes any uncertainty around the adequacy of a simplified auto optimisation, and also ensures that the project team are fully aware of any potential gaps in coverage, or areas where the system may be over engineered. This approach ensures the resultant design will be suitably optimised, but also in compliance with any relevant guidance.

References:

1. BP GP30-85, Group Practice on Fire and Gas Detection, Dec 2009
2. Shell DEP32.30.20.11-Gen, Feb 2014, Design and Engineering Practice for Fire, Gas and Smoke Detection Systems
3. ISA TR84.00.07 Guidance on the Evaluation of Fire and Gas System Effectiveness
4. Approval Standard ANSI/FM 3260, Radiant Energy Sensing Fire Detectors for Automatic Fire Alarm Signalling
5. Fire and Gas (F&G) Design for the Process Industry; Are there Real Dangers behind the Smoke and Mirrors of F&G Detection Mapping? J McNay, ISA Process Safety Symposium Nov 2015
6. Desensitisation of Optical Flame Detection in Harsh Offshore/ Onshore Environments, J McNay, Texas A&M Instrumentation Symposium, Jan 2015
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