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# Hazard Mapping Case Study on a Compressor House

William Pittman*, PhD
*Fire and Gas Detection Consultant*
*Micropack Detection (Americas)*
Chris Heaney
*Fire and Gas Detection Consultant*
*Micropack (Engineering) Ltd.*
Jim Scoggins
*Regional Consultant*
*Micropack Detection (Americas)*
*Presenter E-mail: williampittman@micropackamericas.com

**Abstract**

Compressors and pumps are amongst the most common sources of leaks in hydrocarbon processing facilities. Preventing leaks is the task of maintenance and inspection programs. Ignition sources are difficult to eliminate given the low ignition energy for most gases. So, when leaks occur, explosions and fires often follow. It is then the task of flame detection systems to sound the alarm quickly and possibly activate automated response systems.

The design of these detection systems is of critical importance. Owners and operators need to have confidence in the system and its ability to quickly identify fires in the area of interest. This requires conducting a geographic coverage assessment, preferably aided by well-designed software tools, to calculate coverage levels and identify any concerning gaps in coverage.
The authors present a case study where-in the detector layout of a proposed compressor house is assessed and optimized using 3D modeling. The assessment process and results are reviewed to highlight important aspects of the process and key outcomes.

**Keywords:** Case Study, Compressor, Fire, Normally Unoccupied Facility, Fire detection, Flame detection, Loss prevention

## Introduction

Leaks from high pressure gas compressors are a common and potentially devastating occurrence. Compressor houses are typically sources of heightened concern for operators because they combine key risk factors. Hydrocarbon vapors are present at very high pressures with multiple potential leak locations packed into a relatively small geographic space. The typically high level of congestion around the compressors further increases the risks associated with high pressure jet fires and vapor cloud explosions by making fire propagation and flame acceleration more likely. Even the best and most proactive preventative maintenance and monitoring programs at occupied facilities will not always succeed in keeping high pressure flammable gases and hydrocarbon liquids contained within the process equipment. When leaks occur, it is generally safe to assume that the resulting fuel-air mixture will eventually find an energy source sufficient for ignition. This can occur near the point of release, but this is often not the case and the consequences are generally far more severe when it is not. Where there are leaks fires and explosions will occur. It is the task of fire and gas detection systems to sound the alarm as quickly as possible and initiate mitigation systems, minimizing the resulting damage.

Fires and explosions tend to wake the neighbors, if there are any, and get the attention of local and sometimes national media - sometimes the attention of the US Congress as well. The rapid and effective operation of shutdown and blow down systems in compressor houses has the potential to not only limit losses and minimize downtime for repairs, but also make the operator look a lot better when the story hits the papers. Such was the case with a 2013 compressor station fire at a Williams facility in Pennsylvania. The role that automated safety systems played in mitigating the release and explosion received significant attention in an otherwise brief article that appeared in the local paper.[5]

Williams' track record since 2010 gives an unfortunate testimonial as to how often such incidents can occur and the losses they can inflict. A March 2012 explosion in Springville Township, Michigan blew a hole in the roof of a Williams facility. Just two weeks after the previously referenced incident in Pennsylvania - in the same calendar month - an explosion at another Williams compressor station in New Jersey injured two construction workers sufficiently to require hospitalization and lead to minor injuries for 13 others.[7,8] Yet another incident at an LNG facility in Washington less than two years later, in 2014, injured five workers and caused $69 million dollars in damage. Williams was less fortunate in that case as the fire and gas detectors at that facility had been disabled, unbeknownst to some of the personnel there, causing a delay in the activation of emergency shutdown systems.[9] Williams also lost three workers in an explosion at a Gibson, Louisiana gas facility in October 2015 though that incident was not attributed to the compressor house.[10]

Micropack was approached to assess the fire and gas detection requirements of a new compressor station a client was preparing to build. The client has had issues in the past with compressor fires at similar facilities including fires that went undetected for unacceptably long periods. The client therefore wanted to use a more rigorous design approach to verify the effectiveness of the design. This paper reviews the case study to provide an overview of the hazard mapping process, the results obtained and the benefits of such studies.

Optical flame detection evolved out of the need to provide faster and more accurate fire detection and to better protect equipment and personnel than what was previously possible with traditional smoke and heat detection technologies. The technology has now advanced to the point that 1 $ft^2$ n-heptane test fires can be detected at distances of 200 ft or more in 10 seconds or less.[2,3,6] However, for detection to occur the fire must be within range and within the effective field of view of the detector, established through standardized testing methods. This therefore makes the design of detector layouts a critical and sometimes difficult process given the number of large and small obstructions in process areas that can prevent timely detection.

In the absence of assessment tools, fire detection layouts using optical-based detectors have traditionally been based on expert judgement - “eye-balling” it. This can be problematic if the designer is unaware or misinformed as to the field of view or effective range of the detector being used as these vary widely in the industry. It can be very difficult to determine which of two (or more) possible layouts provides the best coverage, or if any of the proposed systems actually provide a level of coverage that the system owner would consider acceptable. Documenting and auditing the design, and identifying discrepancies between the system as designed vs as installed could also be difficult. Geographic coverage assessments (GCA), or Hazard mapping, evolved from the need to address these issues. Early assessment methods used 2D drawings, pencils and paper. More recently computers and 3D models have begun to be used to improve the accuracy of the studies. GCAs are now used with increasing frequency in the oil and gas industry and beyond to ensure system performance meets expectations and to demonstrate compliance with performance-based regulations.

The methodology and target fire sizes used by Micropack and presented in this paper are consistent with the requirements for geographic coverage assessments in ISA TR 84.00.07.[1] As part of this process, Micropack reviews site plot plans, area classification drawings, P&IDs, PFDs, and H&MBs.

**Model Sectioning, Conditioning and Review**

Geographic coverage assessments (GCA) can be carried out using 3D models or 2D plot plans. Assessments conducted using 3D models of the actual facility are, of course, considerably more detailed and accurate and, therefore, greatly preferred. However, detailed 3D computer models are a relatively recent addition to the engineering and design process and as such are often not available for older facilities. Since the project discussed here involved a GCA on a newly planned and designed compressor station a 3D model had been made and it was provided by the client for the assessment. A screenshot of the client provided 3D model, viewed in Navisworks Freedom, is shown in Figure 1. The client-provided model also includes the surrounding topography of the site.

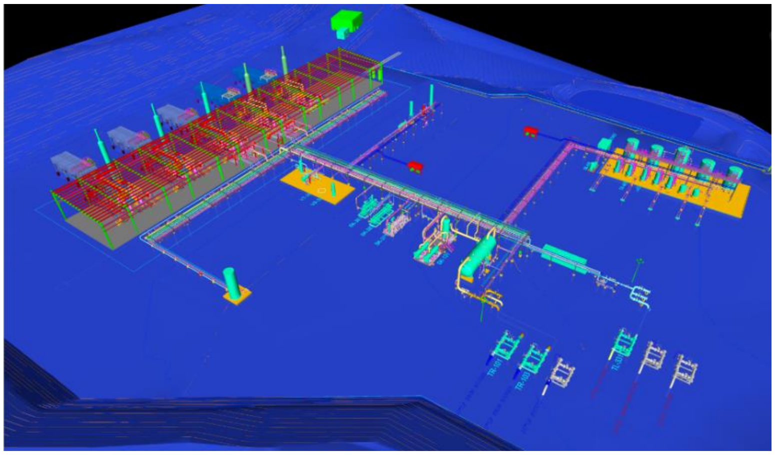

**Figure 1:** Complete 3D model of the onshore pumping station

3D models are often quite large with entire, multi-deck offshore platforms in one 3D file. While this is good from a visual and design perspective, these large models - often made of tens if not hundreds of millions of polygons - can be extremely difficult to work with without very expensive, high-end computers, and may be impractical to work with even then. It is therefore usually necessary to section the model, making separate 3D files for each fire area, allowing each area to be assessed individually.

For this project, the provided 3D model covered the entire pumping station. However, the scope of the assessment only covered the compressor house and a bunded area with several large storage tanks. The model was therefore sectioned to create separate model files for the compressor house and the bunded tank area with the out-of-scope areas removed. The sectioned models may require additional conditioning. This may include model simplification to reduce the number of polygons involved to make the software run faster and more smoothly. The model may also need to be converted into one of the file types supported by HazMap3D, the software used to conduct the GCA. These simplifications and conversions sometimes result in aberrations in the model and it is therefore necessary to review the final model, compare it to the original and confirm that the final model is acceptably accurate.

The model for the compressor house required some additional modification. The compressor house is designed to contain 6 compressors, but one of the compressors will be added in the future. The pumping station will only have five compressors when it comes online and the provided 3D model only includes five compressors with an empty bay for a 6th, shown in Figure 2.

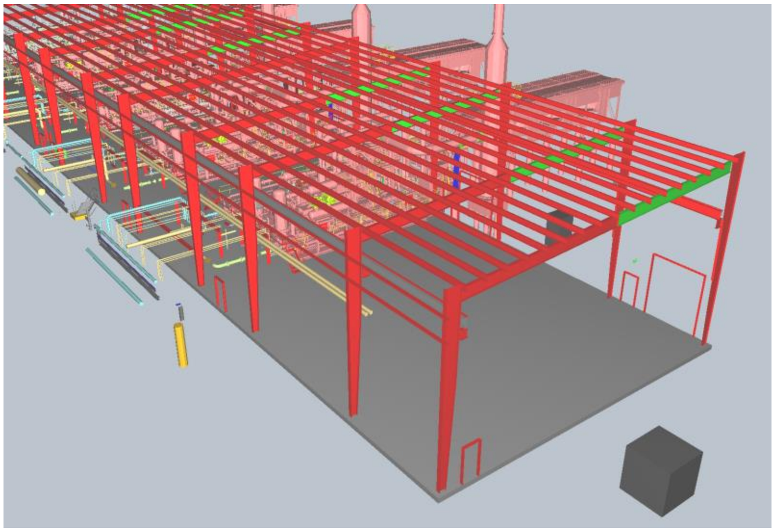

**Figure 2:** Vacant Bay in provided compressor house model

The client wanted the fire and gas detection system to account for the 6th compressor so that a reassessment is not required when it is added. The 6th compressor was therefore added to the model. An image of the final model, as it appears in HazMap3D, is shown in Figure 3.
Because the assessment model is created from the client-supplied model the coordinate system from the client model is preserved and used in the assessment model, even though large pieces of the original model have been removed. Figure 4 provides a look at a single compressor in the

model, showing the level of detail that can be achieved in the 3D model, which allows for a more accurate assessment of coverage volumes.

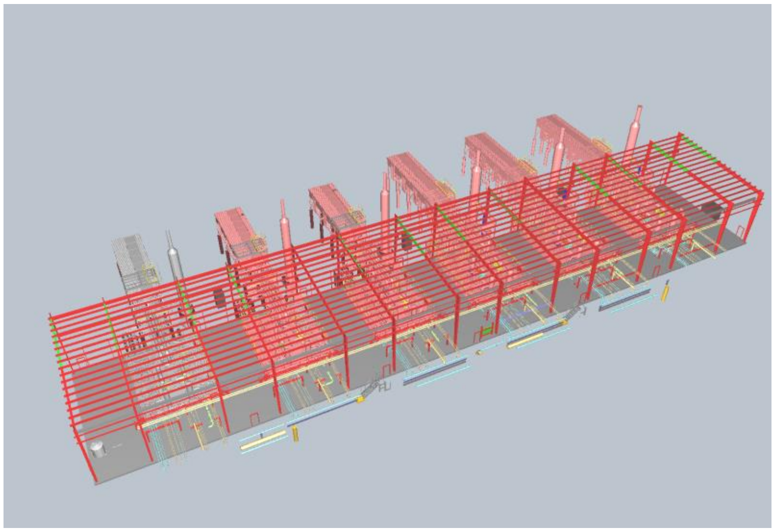

**Figure 3:** Bird's eye view of the Final 3D compressor house assessment model, as shown in HazMap3D, viewed from the East.

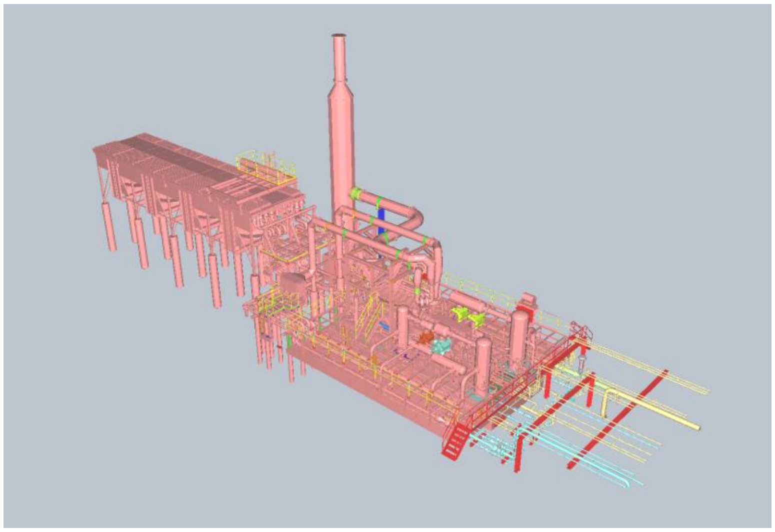

**Figure 4:** View of a single compressor, without the rest of the model, viewed in HazMap3D.

Part of the model verification process touched on previously should include a confirmation that the model dimensions have been properly specified during import into HazMap3D and the facility is modeled as being the correct size. The compressor house for the pumping station is relatively large, measuring approximately 100 m by 21 m with a ceiling over 10 m high. Using the wrong units during model import could result in a model that's only 8.5 m wide and 44 m long, if, for example, centimeters were used in place of inches during model import.

Risk Ranking and Grading

Pieces of equipment or process areas are typically assigned a risk ranking or grade as part of the geographic coverage assessment. The grade is assigned based on a combination of factors including the materials, temperatures and pressures involved, the value of the equipment and surrounding equipment and the likelihood that the fire will spread and damage surrounding equipment. Risk rankings typically include low risk (LR), medium risk (MR), and/or high risk (HR) grades. Special Risk (SR) categories may be created to address unusual hazards that require additional attention and scrutiny.

Grades can be assigned by those conducting the GCA or specified by the client. In this case, the client assigned the risk grades based on their own in-house risk ranking and acceptance criteria. In cases where grades are assigned by the client Micropack still reviews relevant process information to ensure that no important fire hazards have been missed and will propose changes to the client grading where it is thought to be necessary or appropriate.

For this compressor house the key components of the compressors were designated as MR with no LR or HR graded equipment in the compressor house. Figure 5 shows the graded volumes for the entire compressor house. Figure 6 shows the graded volumes on a single compressor for clarity. The MR grade has been applied to the compressor engine as well as the scrubber, suction and discharge bottle for all three stages of each compressor. This effectively assigns a MR grade to the entire volume around and between the major components to each compressor. The internal volume of the engines and each of the small vessels in the compressors were excluded from the flame assessment to prevent an underestimation of the coverage level provided.

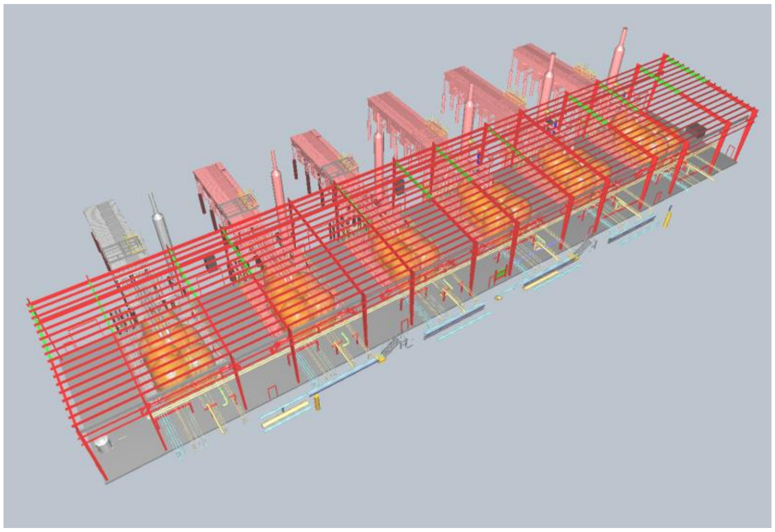

**Figure 5:** Graded volumes in the compressor house shown in HazMap3D

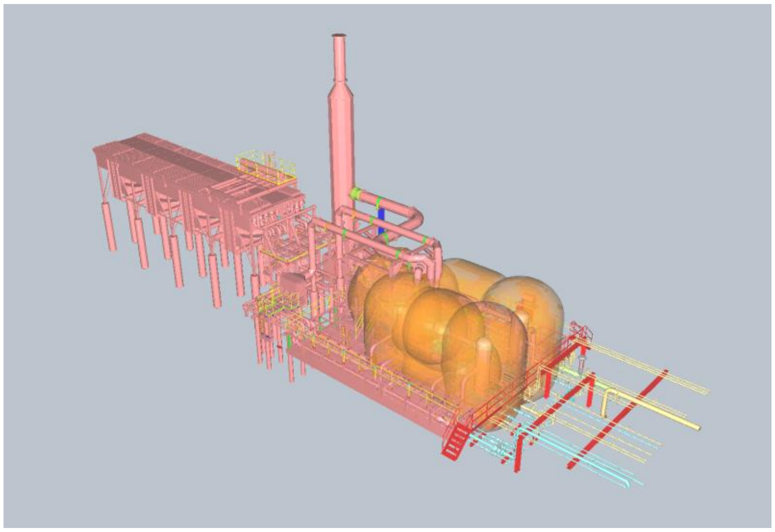

**Figure 6:** Graded volumes for a single compressor, viewed without the rest of the model in HazMap3D.

Once assigned, the grade of a piece of equipment or area can determine or affect, the size of the target fire the system should be able to detect, the size of the graded volume or area, and the level of coverage that is desired. For example, a LR piece of equipment may require that a 250 kW RHO fire trigger an alarm whereas an alarm is expected in response to a 50 kW RHO fire for MR equipment and 10 kW RHO for HR. Ninety percent coverage is usually desired with HR equipment where 60% or 70% is often considered acceptable for LR equipment. For this project, 80% coverage with the ability to detect and alarm in response to a 100 kW RHO fire was expected for MR graded equipment. These are desired levels of coverage that are used as a target to shoot for or as a rule of thumb, not a rigid target that must always be met.
The client specified fire and gas protection philosophy called for control action to occur with 1ooN voting and for stepped-up control action to occur in response to a fire confirmed with 2ooN voting.

**Detector Selection and Placement**

In some cases, 3D models of existing facilities will have flame and gas detectors incorporated into the 3D model. As the fire and gas detection system for this facility had not yet undergone formal design, no detectors have been installed and the detectors are not present in the model. Within the assessment software the flame detectors are represented by semi-transparent volumes that indicate the expected field of view of the detector. The size of this volume depends on the horizontal and vertical field of view and range of the specific detector being viewed as well as any desensitization factor that has been applied.

The hazard mapping software used in this study includes a database of FM Global certified flame detectors commonly used in the industry and it can therefore accurately model a wide range of detectors that a client might have installed at a facility or which they may have selected for installation. If a client is using a detector that is not currently included in the software’s database this can usually be addressed through a minor software update. Where the type of detector is not known or where a detector model has not yet been selected, the software can model flame detectors as a generic single-frequency IR detector with a typical, conservative field of view and an effective range or 10 or 25 m.

The client had elected to use the Drager Flame 3000 and Flame 5000 visual flame detectors in the compressor house. The decision was made to model all the detectors as Flame 5000 during the assessment. The Flame 5000 has a shorter detection range (44 m vs 60 m) as well as narrower horizontal and vertical fields of view as compared to the Flame 3000, but offers the possibility of supplying live video feeds to the control room and video recording of alarm events, which the Flame 3000 does not.[2,3] Therefore, modeling all the detectors as a Flame 5000 provides the maximum number of possible video feeds to the control center while also providing a conservative assessment of the provided coverage. Should the client decide to install Flame 3000s instead, higher coverage levels would be expected.

The client fire and gas protection philosophy calls for two detectors to be installed for each compressor, and would therefore call for twelve detectors to be used to monitor this compressor house. However, the layout of the compressors appeared to offer the potential for a smaller number of detectors to be used while still obtaining acceptable coverage. The assessment process allows for these options to be explored and for the coverage provided by competing layouts to be compared objectively. This is done by first modeling the existing or currently proposed detector layout, typically referred to as the baseline design. The software provides detailed information of the level of coverage, where gaps in coverage exist, and how much each detector contributes to the overall level of coverage. This information can then be used to modify or fine-tune the layout to address any unacceptable gaps in coverage or eliminate excessive redundancy.

**Baseline Assessment Results**

As the compressor station has not yet been built, there was no detailed information on the location and orientation of each detector in the client-proposed baseline layout. Because of this, the detectors were placed by Micropack based on information provided by the client in the project kick-off meeting. Twelve Drager Flame 5000 detectors were modeled in the compressor house as being mounted 8 m above the local deck (ALD) with a 10° downward tilt relative to the horizontal. Normal practice calls for the detectors to be positioned approximately 3 to 4 m ALD to allow for them to be installed and replaced using portable ladders. However, the detectors have been placed higher in this case because the compressors are also elevated. At an elevation of 8 m ALD the detectors can still be easily field tested from the ground using portable LED test lights. The detectors were situated so that they would be mounted to steel structural supports along the Eastern wall of the compressor house. These were thought to be the best available mounting points to avoid issues with excessive vibration.

The detectors were specified to face at a 45° angle relative to the eastern wall with six oriented towards the Northwest and six oriented towards the Southwest. Figure 7 shows the overlapping field of views for the detectors in the compressor house. The detectors are modeled with an effective viewing distance of 27.8 m (63% of the maximum) to account for desensitization. This desensitization factor was determined using a method widely used in the industry.[4]

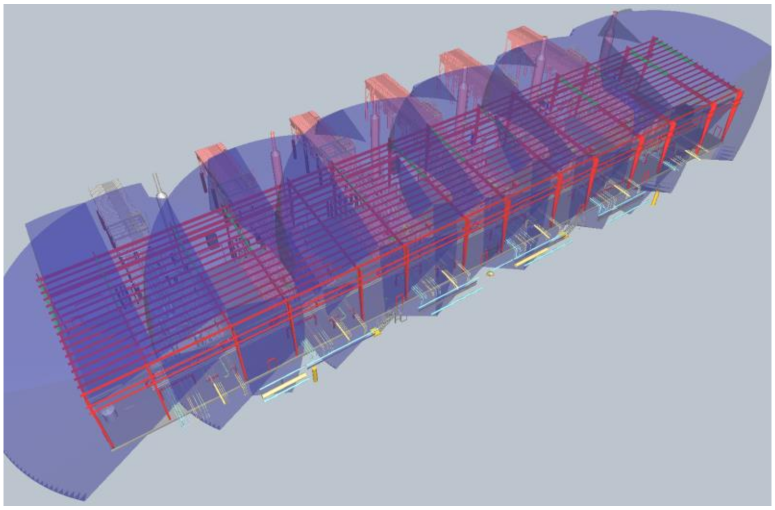

**Figure 7:** Detector Field of view for baseline detector arrangement.

This twelve-detector arrangement yielded a 2ooN coverage of almost 78% with 1ooN coverage for an additional 11% of the graded volume. The remaining eleven percent of the graded volume, mostly along the back and underside of the compressors had no coverage. Much of this area is difficult to obtain a clear line-of-sight to these areas because of obstruction from piping and equipment and the placement of additional detectors provide minimal improvements to coverage. For context, a 24-detector layout - using 12 additional detectors along the Western wall of the compressor house at 5 m ALD - only achieves 1ooN coverage for 92.8% of the graded volume and leaves 7.2% uncovered. It is hard to imagine many would argue a 5% improvement to 1ooN coverage is worth the addition of 1 or 2 detectors, much less 12, when the system already meets specified performance targets.

Figure 8 shows a graphical depiction of the detector coverage for the baseline layout overlaid onto the 3D model for one of the compressors. The baseline configuration can be seen to provide very good coverage of the upper and eastern facing sides of the compressor with coverage levels dropping towards the rear and underside of the compressor.

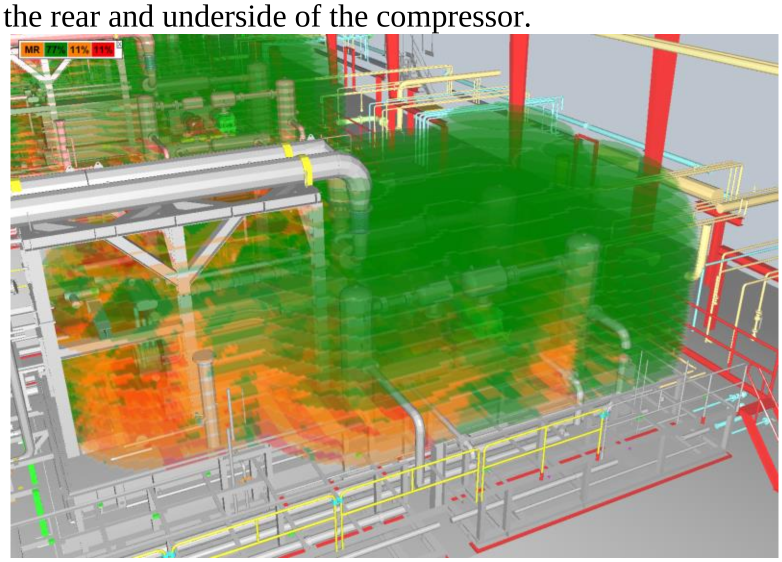


**Figure 8:** Visual depiction of geographic assessment result for the Southernmost compressor shown in HazMap3D.

Table 1 provides a numerical breakdown of the overall coverage and the contribution of each detector to the overall system. Pan and Tilt indicate the orientation of the detector. Pan ranges from 0 to 360 degrees with 0 degrees corresponding to an Eastern orientation. The tilt indicates the angle relative to the horizontal with a downward tilt being considered positive - flame detectors normally have a downward tilt of between 10 and 40 degrees. Because the assessment model is generated from the client-supplied model, the coordinates of the detector are defined and given using the same coordinates used in the client-model with the elevation defined relative to the local deck.

**Table 1:** Detector contributions to system coverage for the baseline layout

| | **Pan (°)** | **Tilt (°)** | **Individual** | **1ooN** | **2ooN** | **>2ooN** |
|---|---|---|---|---|---|---|
| **All Detectors** | | | | 88.8 | 77.8 | 62.0 |
| **Det01** | 135 | 10 | 21.5 | 86.7 | 74.6 | 57.4 |
| **Det02** | 225 | 10 | 10.4 | 88.4 | 76.1 | 58.3 |
| **Det03** | 135 | 10 | 27.8 | 88.0 | 74.7 | 57.6 |
| **Det04** | 225 | 10 | 20.7 | 88.3 | 75.9 | 55.7 |
| **Det05** | 135 | 10 | 28.9 | 88.1 | 75.3 | 57.0 |
| **Det06** | 225 | 10 | 27.8 | 88.3 | 75.6 | 56.6 |
| **Det07** | 135 | 10 | 30.2 | 88.1 | 75.4 | 55.8 |
| **Det08** | 225 | 10 | 29.3 | 88.1 | 74.8 | 57.7 |
| **Det09** | 135 | 10 | 23.7 | 88.0 | 75.2 | 54.3 |
| **Det10** | 225 | 10 | 30.3 | 87.8 | 73.9 | 57.7 |
| **Det11** | 135 | 10 | 12.0 | 88.2 | 75.8 | 57.1 |
| **Det12** | 225 | 10 | 23.3 | 86.1 | 74.6 | 56.5 |

The 1ooN and 2ooN coverage columns in Table 1 give the percentage of the graded area that achieves that level of coverage if that detector is removed from the system. For example, if Det01 is eliminated, 2ooN coverage drops from 77.8% to 74.6%.

Based on Table 1, the baseline layout generated based on client practices detailed in their fire and gas protection philosophy and the project kick-off meeting is a good one. It meets and exceeds the 80% coverage level expected for MR areas with 1ooN coverage and nearly meets it with 2ooN coverage. The numerical breakdown in Table 1 also shows that the system has a sufficient level of redundancy that the failure or loss of any one detector does not significantly reduce overall coverage and does not cause the system to drop below the 80% coverage expected of it.

That 1ooN coverage for the targeted fire size is not achieved for 11% of the graded volume is not as concerning as it may at first appear given the size and location of the gaps, and the types of fires expected. The compressors handle high pressure gas. Jet fires are the most likely fire for the system to detect. Pool fires will not occur and fires on the underside of the compressor - where the largest gaps in coverage occur - are relatively unlikely. The remaining coverage gaps are relatively small and a high-pressure jet fire is unlikely to be able to "hide" within those small volumes.

Based on this, the baseline layout is a well-designed system. However, it may not represent an optimal layout. Table 1 suggests that it may be possible to eliminate several detectors with minimal loss of system performance. This can be inferred from that fact that Table 1 shows

3ooN coverage is achieved for 62% of the graded volume and the 3ooN coverage remains over 50% even with the loss of any single detector.

Detector Layout Optimization

Based on Table 1, Det02, Det04, Det06, and Det11 contribute relatively little to the overall system coverage and can likely be eliminated. Det05, Det07 and Det08 can also be seen to contribute only marginally to the overall coverage. Based on this, detectors Det02, Det04, Det08, and Det11 were removed and a new assessment was run. Table 2 shows the overall coverage levels and individual contributions of each detector for the reduced 8 detector layout.

**Table 2:** Detector contributions to system coverage for the 8-detector layout

| | **Pan (°)** | **Tilt (°)** | **Individual** | **1ooN** | **2ooN** | **>2ooN** |
|---|---|---|---|---|---|---|
| **All Detectors** | | 10 | | 86.3 | 65.2 | 41.6 |
| **Det01** | 135 | 10 | 21.5 | 79.9 | 57.1 | 34.6 |
| **Det03** | 135 | 10 | 27.8 | 85.1 | 59.7 | 28.9 |
| **Det05** | 135 | 10 | 28.9 | 85.5 | 61.4 | 30.6 |
| **Det06** | 225 | 10 | 27.8 | 82.6 | 56.8 | 30.5 |
| **Det07** | 135 | 10 | 30.2 | 85.2 | 60.7 | 29.2 |
| **Det09** | 135 | 10 | 23.7 | 84.8 | 58.4 | 34.3 |
| **Det10** | 225 | 10 | 30.3 | 83.9 | 60.9 | 34.6 |
| **Det12** | 225 | 10 | 23.3 | 82.5 | 59.3 | 35.4 |

The elimination of these four detectors resulted in an 8-detector layout with 2ooN coverage for 65% of the graded area and 1ooN coverage over an additional 21%, for a total 1ooN coverage of 86%. While the coverage provided is not as comprehensive as that provided by the baseline layout, the achieved coverage level still exceeds the desired coverage level of 80% specified by the client and does so with 33% fewer detectors. This 33% reduction in the number of detectors only reduces 1ooN coverage by 2% of the graded volume. Most of the loss of 2ooN coverage was seen on the outer sides of the Northernmost and Southernmost detectors. Figure 9 shows the coverage level on the southern side of the southernmost detector. While the level of redundant coverage in the system has been significantly reduced, Table 2 shows that the system can still tolerate the loss of any single detector while still maintaining 1ooN coverage at or above the 80% level desired by the client. The loss of Det01 has by far the most significant impact on system 1ooN coverage with the loss of Det06 causing the largest reduction in 2ooN coverage. The reduction in redundant coverage can be seen mostly clearly in Table 2 with the 20% reduction in 3ooN coverage as compared to the baseline layout.

Given that the detectors are designed to indicate a fault state and report a detected fault to the control room, and given the very high reliability of the detectors, it’s considered unlikely that two or more of the eight detectors will be in fault at the same time provided reasonable inspection and maintenance practices are adhered to.

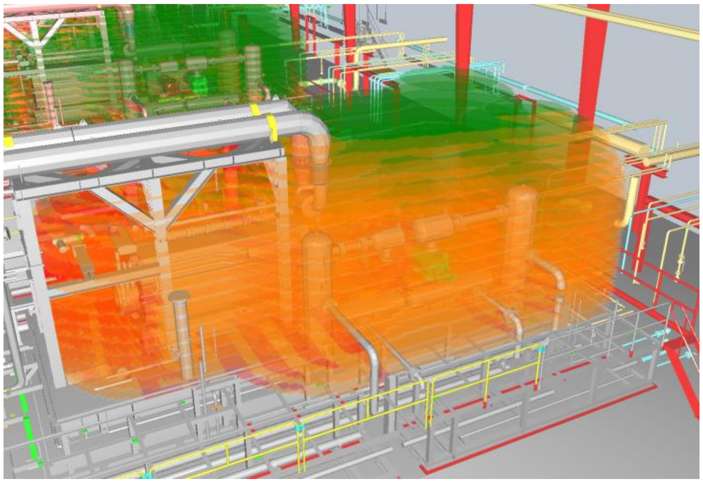

**Figure 9:** Coverage loss on the Southern side of the Southernmost detector shown in HazMap3D

**Revision Based on Client Feedback**

Soliciting client comments on and approval of the proposed changes is a vital part of any process that involves modifications to safety critical systems. Even if the system satisfies company specific or project specific performance goals, concerns may arise from the client, who may want to go beyond specified minimum coverage goals for any of a number of reasons.

While the 8-detector layout met the targeted performance level and the client was pleased by the prospect of reducing the detector count, the client was concerned about the gaps in 2ooN coverage at the far sides of the building and asked that two detectors be added to address the large gaps in 2ooN coverage on sides the Northernmost and Southernmost compressors.

Detectors were added to the Northwest and Southwest corners of the compressor house oriented towards these 2ooN coverage gaps, situated approximately 6 m ALD. The location and fields of view of these additional detectors is shown in Figure 10. This placement ideally situated these detectors to close the gaps in 2ooN detection on the sides of these compressors while also keeping them geographically separated from the detectors in the northeast and southeast corners of the compressor house.

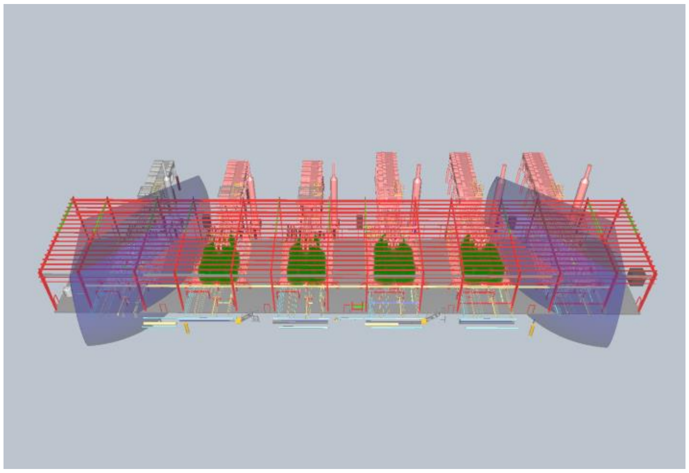

**Figure 10:** Field of view for detectors located in the Northwestern and Southwestern corners of the compressor house.

The additional detectors addressed the gaps in 2ooN coverage, resulting in a 10-detector layout that provided almost 74% 2ooN cover and over 88% 1ooN coverage, nearly matching the coverage levels achieved in the baseline layout - the two layouts are within 0.5% of each other for 1ooN coverage - while achieving a 16% reduction in detector count. Table 3 provides a breakdown of the layout and the coverages provided.

**Table 3:** Detector contributions to system coverage for the 10-detector layout

| | Pan (°) | Tilt (°) | Individual | 1ooN | 2ooN | >2ooN |
|---|---|---|---|---|---|---|
| **All Detectors** | | | | 88.5 | 74.2 | 50.5 |
| **Det01** | 135 | 10 | 21.5 | 87.3 | 65.6 | 40.0 |
| **Det03** | 135 | 10 | 27.8 | 87.3 | 69.6 | 37.9 |
| **Det05** | 135 | 10 | 28.9 | 87.7 | 70.4 | 39.5 |
| **Det06** | 225 | 10 | 27.8 | 85.4 | 68.9 | 36.7 |
| **Det07** | 135 | 10 | 30.2 | 87.4 | 70.0 | 40.7 |
| **Det09** | 135 | 10 | 23.7 | 87.3 | 70.9 | 42.5 |
| **Det10** | 225 | 10 | 30.3 | 86.0 | 70.2 | 43.5 |
| **Det12** | 225 | 10 | 23.3 | 87.3 | 69.6 | 43.4 |
| **Det13** | 300 | 10 | 12.2 | 87.5 | 71.1 | 46.4 |
| **Det14** | 60 | 10 | 13.0 | 87.4 | 68.2 | 45.8 |

The hazard mapping software makes assessments like this possible by allowing an objective assessment of coverage levels provided for target fires of specified sizes. It allows practitioners to easily see where coverage gaps exist and then adjust detector locations or type or add additional detectors to address gaps. By providing information on the contribution each detector makes to the overall system performance, the software also makes it significantly easier to identify unnecessary detectors, detectors that are vital to overall system performance, and where more or less redundancy may be needed.

One of the chief hurdles that any engineering study or project has to overcome before being approved is justifying the expenditure of funds and resources. Each Drager Flame 5000 costs approximately $3,000. The installed cost of each detector can exceed $10,000 and each detector then incurs additional expense over it’s lifetime for testing and maintenance, albeit a relatively small amount given the ease of testing and the high reliability of the device. Because of this, it can be relatively easy for a hazard mapping study to pay for itself in the form of reduced detector counts and costs. The cost of the system and the assessment both pale, however, in comparison to the risk of a fire going undetected and being allowed to propagate by a poorly designed detection system. With valuable equipment on the line, it pays to have a well-designed system based on an assessment by qualified engineers.

The effect of detector FOV on system coverage

The ability of the software to use the real, verified by test data, field of view and effective range of the detectors in conducting the assessment is critical to the quality of the assessment. The impact that detector field of view and range has on the effectiveness of the overall system and the number of detectors required to achieve adequate coverage deserves special emphasis. To demonstrate this point, Table 4 lists the coverage levels achieved by the 10-detector system using the Flame 5000, and Flame 3000.

**Table 4:** Coverage levels obtained using different detectors with the proposed 10-detector layout.

| Detector Type | 1ooN | 2ooN | >2ooN |
|---|---|---|---|
| Draeger Flame 3000 | 89.9 | 79.5 | 60.4 |
| Draeger Flame 5000 | 88.5 | 74.2 | 50.5 |

Table 4 shows that the same layout - with no change in the number of detectors or the position of any detector - can provide significantly different coverage levels when different detector models are used, highlighting the importance of accurately accounting for field of view and range. Operators should be aware of this during the initial design and assessment of the system as well as during any MOC involving the replacement of a detector. The wider field of view and longer range of the Flame 3000 allows it to provide 2ooN coverage to an additional 5% of the graded volume when compared to the coverage provided by the Flame 5000. This is largely the result of the Flame 3000 having a wider horizontal field of view - 120° versus 90° for the Flame 5000.

## Conclusion

The authors have provided a flame detection assessment case study for the purposes of detailing the hazard mapping process, also called a geographic coverage assessment, conducted in a manner consistent with the guidance provided in ISA TR 84.00.07. A client provided 3D model was modified as necessary for the assessment process and imported into the assessment software. Grades were assigned to hazardous equipment containing flammable hydrocarbons and a baseline detector layout was generated based on the client's fire and gas protection philosophy and discussion with the client. The baseline layout was then assessed, and modifications were proposed to reduce excessive redundancies in the system and thereby reduce the installation, operating and maintenance costs associated with the system. This case study demonstrates the ability of hazard mapping, assisted with software designed for such studies, allow for the rapid and efficient design and assessment of flame detection systems using good engineering judgement.

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