Benefits of Gas Detection Mapping in Complex Process Facilities

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Flammable and toxic gas releases have long been identified as causes of major accident events in upstream oil and gas facilities. These accident scenarios pose risk to personnel and asset, and lessons learnt from near misses and accidents have well been studied. Data from the UK Health and Safety Executive (HSE, 2008) suggest as much as 40% of major releases are not detected by fixed gas detection equipment, and even higher for significant releases.

Equipment suppliers have developed an array of different detectors that act as the first step in mitigation of gas release events, however locating them appropriately is fundamental to the overall system performance. There are several approaches for gas detector placement used today; these vary in both complexity and effectiveness.

This paper will discuss the benefits of using quantitative Computational Fluid Dynamics (CFD) dispersion analysis and computer based optimisation to determine the best possible gas detector coverage and placement. This approach is considered amongst process safety experts to be most accurate as well as most difficult to execute.

The authors will discuss the gas detector placement approach and associated challenges in designing and executing one of the world’s largest onshore oil and gas projects, equivalent in terms of tonnage to approximately 30 offshore platforms.

Keywords: Major Hazards, Fire & Gas Mapping, Fire & Gas Detection Systems, Loss Prevention, Quantitative Risk Assessments, Risk Based, CFD, Gas Dispersion Modelling

Introduction

Tengizchevroil (TCO) is the operator of the Tengiz and Korolev reservoir oil fields in western Kazakhstan, which contain more than 25 billion barrels of original oil in place. The current stabilized crude production is more than 600,000 barrels of oil per day. Chevron holds a 50% interest in TCO, which operates the two oil fields.

The Future Growth Project & Wellhead Pressure Management Project (referred to as FGP) is planned as the next major expansion of TCO’s oil production capacity. The expansion includes three new facilities: Pressure Boost Facility; 3GP Process Plant; 3GI Sour Gas Injection Plant. The project also includes major upgrades to the existing field gathering system and new field facilities including multi-well pads, meter stations and pipeline networks. FGP is a Major Capital Project (MCP) for TCO, currently in execution phase. Once operational, FGP will consist of high pressure, sour gas operations, within large modularised processing units.

For complex process facilities handling flammable and toxic hazards like Tengiz, the fire and gas (F&G) detection system becomes an essential safety design mitigation. In the event of a potential release, gas detector placement becomes critical for early alarm to alert/evacuate personnel and enable timely control (isolation/emergency shutdown, initiate fire protection systems, depressurisation) to minimise escalation. Figure 1 shows how the F&G detectors act as a barrier to safeguard against major hazard escalation.

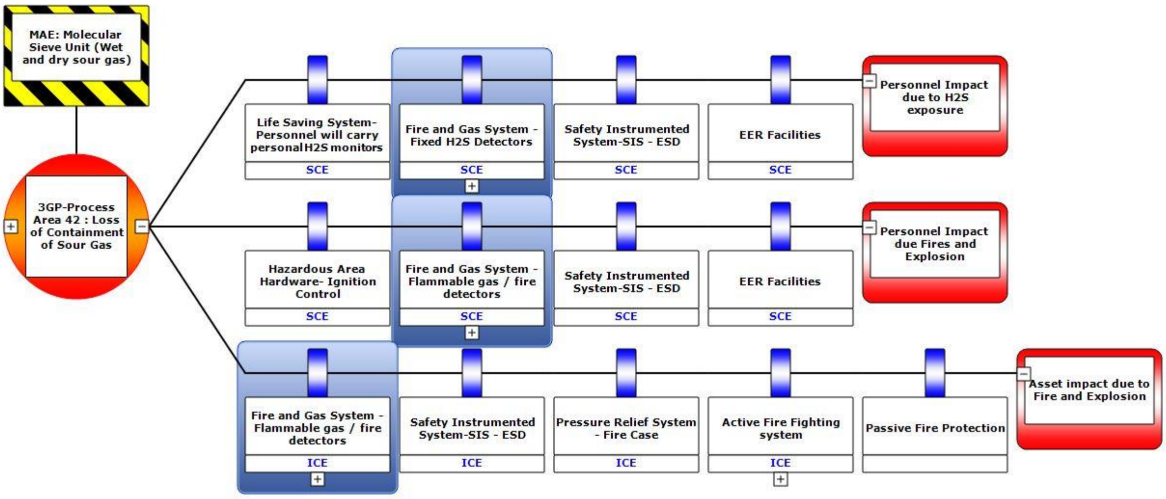


Figure 1 – Bowtie diagram: layers of protection following the initial release

Due to the scale of FGP, approximately 3,500 flammable and toxic gas detectors were located within the processing plant areas alone, after the completion of Front-End Engineering Design (FEED). This was based on company standards and expert judgement in applying a 'prescriptive' based approach. Whilst the reliability of gas detectors from vendor data is reportedly high, the location and coverage is fundamental to the overall performance of the gas detection system. Past assessment has shown using prescriptive, non-optimised detector layouts can lead to some areas of the plant design having detectors adding little to no value. With risk assessment techniques becoming increasingly used for designing engineering safeguards, TCO considered using the gas mapping 'performance' based techniques to optimise the position and improve the degree of coverage for the large quantity of detectors identified from FEED.

TCO conducted a pilot flammable and toxic gas detector mapping study in early Detailed Engineering Design to quantify the additional coverage using the mapping approach over conventional based techniques. The pilot study used a systematic method for assessing FGP process plant flammable and toxic gas hazards under specific releases scenarios, wind conditions and equipment obstructions. The pilot study was performed first to demonstrate the potential benefits to optimise the detector layout before committing to multiple CFD mapping studies using sophisticated modelling techniques. Furthermore, the results would need to be implemented back into design and execution, which comes with other technical challenges following FEED.

Project Pilot Study

Background

It is recognised there are limited regulatory and industry standards available on how to conduct gas detector mapping studies. Techniques for identifying coverage targets, plant areas for mapping, and the mapping approach (geographic versus scenario based) is largely left to internal company guidelines and/or safety consultancies to help develop.

TCO contracted DNV GL consultants to conduct the FGP pilot study after demonstrating the benefits of past offshore mapping results using QRA (Quantitative Risk Assessment) and computer based techniques. Similar studies could be used to meet FGP's aim to optimise the number of detectors, location and type (open path and/or point detectors) as identified in FEED, to achieve the best possible coverage.

DNV GL were also contracted at the time to provide QRA support to FGP which allowed easy access to risk input data required for the gas dispersion modelling, leak frequency assessment and subsequent mapping. FGP safety engineering teams worked with the consultants to align on the methodology to use for the pilot study. The gas dehydration module located within the 3GP oil and gas processing area was selected as the pilot case.

Methodology

The FGP gas mapping study applied a 'volumetric' 'scenario based' approach. The 'volumetric' approach has become standard application in oil & gas facilities offshore, and equally applies to onshore modules in highly congested and confined areas that can lead to a Vapour Cloud Explosion (VCE). The benefits of the 'scenario based' versus 'geographic' approach is well documented (DNV GL, 2016). The 'scenario based' approach predicts the behaviour of the potential leak scenarios though CFD modelling, and takes account of the physical effects (geometry, ventilation, weather conditions, release composition).

The methodology applied to the FGP pilot study involved performing many CFD simulations and using the results in an automatic gas detector location algorithm. The following key steps were involved in the gas mapping analysis:

- *Geometry:* the 3-dimentional (3D) model was recreated in the CFD software, which involved verification against the FGP SmartPlant model to ensure the pilot module was representative of the equipment/structural obstructions.
- *Definition of leak rate:* CFD explosion simulations were carried out to establish the flammable cloud size that when ignited can lead to an overpressure resulting in a damage threshold criteria. The design release rate was also established through dispersion scenario modelling that can produce such a damage threshold.
- *Scenario identification:* the heat and mass balance for the respective module was used to determine the composition and conditions for the releases.
- *Selection of wind conditions:* wind conditions (wind speed and wind direction) effect the ventilation flow patterns in the process areas and the effectiveness of the position of gas detectors. The FGP site location wind rose data was assessed to determine the site-specific wind speeds and directions.
- *Selection of leak location*: using the layout/process engineering drawings and 3D model, dispersion scenarios were modelled where leaks were most likely to occur (flanges, valves), considering various leak directions.
- *3D CFD simulations*: several CFD dispersion simulations for the selected leak points were performed, varying the wind conditions and leak direction and applying the design release rate.
- *Probabilistic simulations:* to determine the probability of detecting leaks in the process module, a program was used to develop a 3D map of the occurrence of gas leaks.
- *Detector allocation*: to determine the probability of detection given the occurrence of gas leaks in the unit, a program was used to determine the position of the gas detectors. This involves using an algorithm to allow allocation of detectors where there is higher probability of occurrence of gas clouds.

Results

By combining the CFD dispersion simulations carried out for all leaks it was possible to develop a potential frequency distribution map of the flammable and toxic gas for the pilot study module. Figure 2 shows the probability of gas presence at several vertical cuts of the pilot module to display where the probability of gas presence is higher. The map conveys realistic and specific module information to determine the probability of gas presence following an accidental release. This includes:

- Physics of dispersion (geometry, ventilation and nature of the gas).
- Realistic points of release (regions with higher number of potential leak sources).
- Potential release frequency (valves, flanges, process equipment).

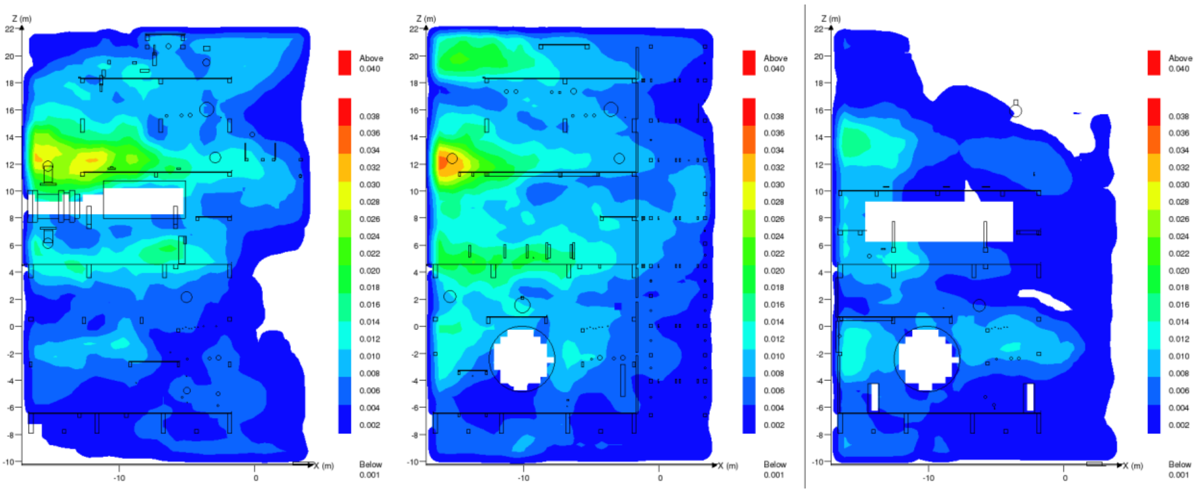


Figure 2 – Example map of flammable gas frequency plots at various elevation views

For the ‘scenario based’ approach, the coverage provided by the gas detection network is simply defined as the fraction of detected leaks. Figure 3 shows the coverage for the pilot study module as a function of the number of detectors. The curves are provided for the flammable gas detector network and are described below:

- *Baseline detector network:* existing gas detector network using conventional approach and 2D layout drawings.
- *Optimised detector network 1:* optimised gas detector network where detectors are positioned where the probability of presence of gas is highest, using both point gas detectors and line of sight gas detectors.
- *Optimised detector network 2:* optimised gas detector network, using point gas detectors only.

F&G systems use voting of multiple detectors (e.g. 2ooN) to perform executive actions such as emergency shutdown. The voting logic provides robustness and reliability against spurious trips. The F&G system also performs activation of alarms and local F&G beacons on single detector voting (e.g. 1ooN). Therefore, both voting logics are used when assessing results in the mapping study.

The dashed lines represent the coverage for the *baseline detector network*. The *baseline detector network* provides a maximum coverage of approximately 12% for 1ooN and of 6% for 2ooN. The solid lines represent the coverage of the detector layout obtained from the optimization exercise for both point and line of sight detectors.

The *optimised detector network 1* shows coverage in the range 70-80% (respectively for 2ooN and 1ooN) with approximately 50 detectors (including both point and line of sight detectors).

The dash-dot represent the optimized detector layout based on point detectors. The *optimised detector network 2* shows coverage of 50-80% (respectively for 2ooN and 1ooN) with the deployment of approximately 80 point detectors.

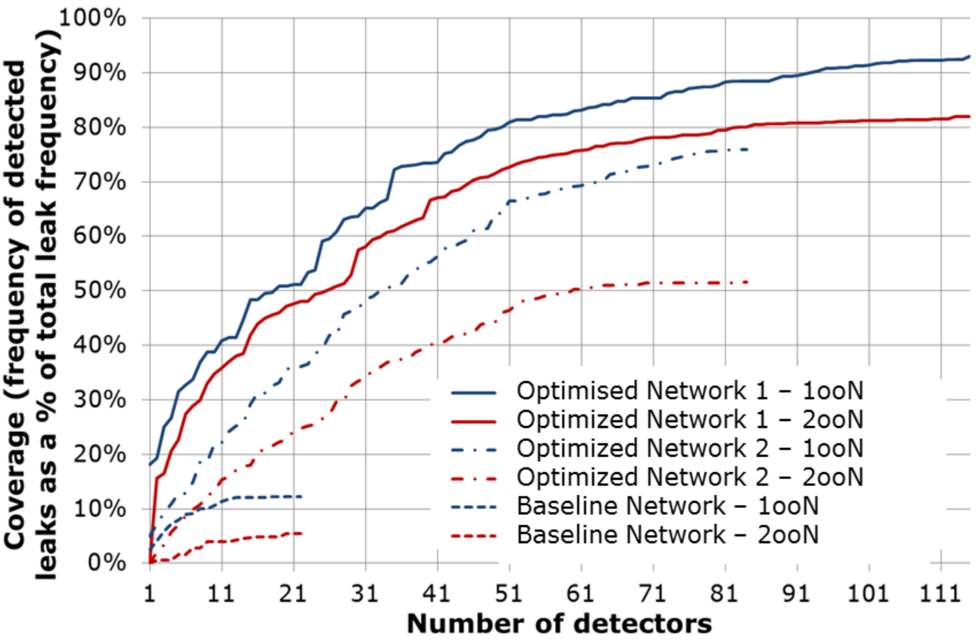


Figure 3 – Flammable gas detector network: coverage versus number of detectors for pilot module

Similarly, the results are presented in Figure 5 for the toxic gas detector network for point detectors only. The dashed lines represent the coverage for the *baseline detector network* with a maximum coverage of approximately 25% for 1ooN. The solid line represents the *optimized detector network* which shows a coverage of 80% for 1ooN with approximately 25 detectors.

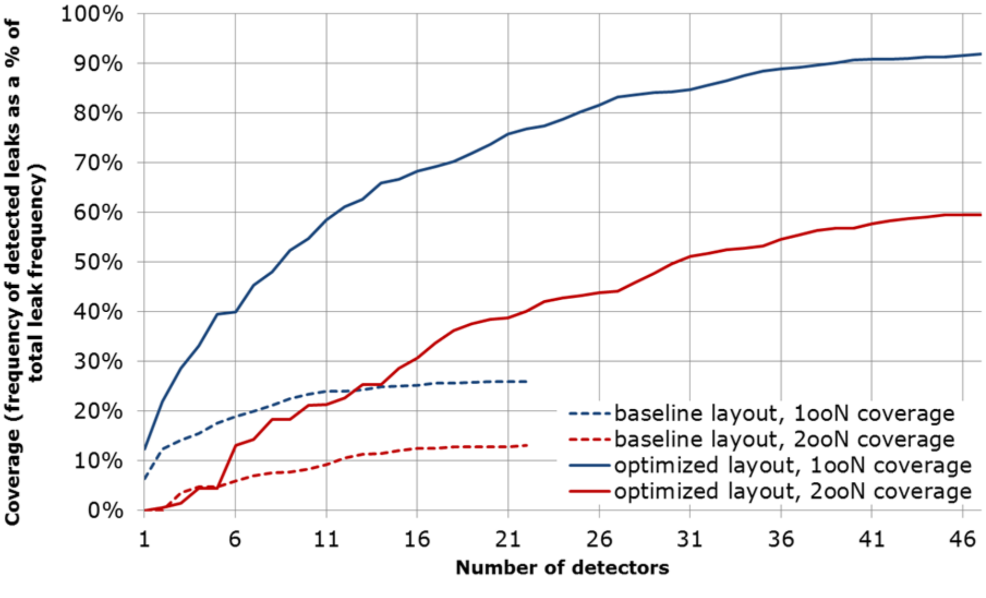


Figure 4 – Toxic gas detector network: coverage versus number of detectors for pilot module

The mapping study output provided a visualisation of the location of detectors for the required coverage (1ooN, 2ooN) with a list of spatial coordinates for the optimized detector location. An example of the isometric view of the pilot module with flammable gas detectors is shown in Figure 5.

The project engineering team also needed to consider human factor constraints related to placing detectors onto the SmartPlant 3D model. Sophisticated algorithms cannot always locate detectors in suitable locations, and manual effort was required to utilize the results from the gas mapping exercise and convert to an acceptable design. This is discussed further in the Execution Strategy section.

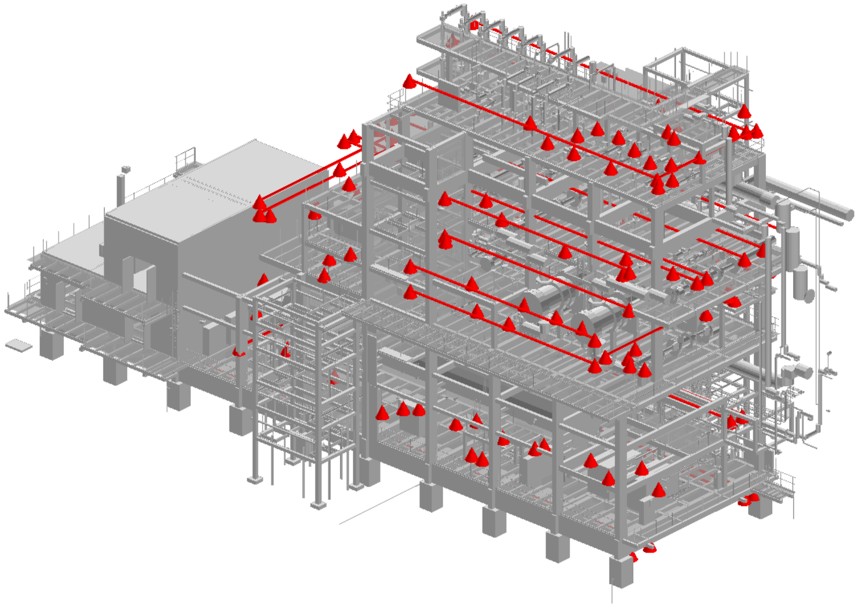


Figure 5 – Isometric view of module with flammable gas detectors optimised with point detectors (cones) and line of sight (red line)

The pilot study demonstrated the project could obtain a significant improvement in detector coverage using the optimised detector network (gas mapping) versus the baseline network (conventional approach). With repositioning gas detectors within the FGP modules, better detection coverage could be achieved for the same number of detectors.

The results also showed the benefit of increasing detector numbers within the process module. Industry provides limited guidelines on what an acceptable target risk reduction is for onshore facilities. The project found achieving a desired coverage (e.g. 90% 1oo1) was not always useful and feasible, and an alternative metric for detector coverage was to consider the additional risk reduction benefit offered from additional detectors. For example, there were occasions where relatively safe modules had more detectors than hazardous modules, and increasing coverage did not offer much benefit.

Being overly conservative with detector numbers can lead to large and expensive instrumentation infrastructure resulting in a significant maintenance burden in future operations. Therefore, the right balance is required for gas detectors, especially when designing for large onshore process facilities.

Further Studies

Following the pilot study, TCO executed a total of eleven mapping studies which showed similar coverage benefits. The mapping analysis for each module were prioritised with the fabrication sealift window to ensure the results could be implemented into the design without impacting the project schedule. Other TCO challenges and considerations with executing the gas mapping results back into the project F&G layout design are further discussed below.

Execution Strategy – Challenges and Solutions

Determination of Modules to Map

Using sophisticated modelling for large complex process facilities can be both an expensive and time-consuming task. For a project the size of FGP, with over 250,000 tonnes of steel structure, it was impractical to map all process areas when considering cost and schedule constraints. Furthermore, some process areas were of lower risk and conducting mapping for only a small number of detectors would not be cost beneficial.

Early in detailed design, a review was undertaken to determine the most appropriate facilities to map for the F&G detector placement. This was done using the following screening criteria:

- Geometric complexity: facilities identified with good ventilation, leak sources uniformly spread out, and minimal congestion and confinement, were not mapped.
- Module selection: utility modules and other modules with limited hydrocarbon inventory were not mapped.
- Module similarity: modules that closely resemble other modules, e.g. the train 1, 1st stage compressor versus train 2, 1st or 2nd stage compressor, were mapped once and the main principles for detector placement were then applied to all other resembling modules.

From the screening review, eleven modules or process areas were selected to perform the detailed gas mapping analysis; this equated to around 10% of the project scope.

Schedule Constraints

With all MCPs, meeting schedule becomes paramount to successful execution in order meet production profile demands when the facility becomes operational. To support early fabrication in parallel to completing Detailed Design Engineering, the design team needed to determine how many detectors were required before the module 3D model reviews were 60% complete, and before the optimised mapping analysis was conducted. This was done using TCO’s standard prescriptive approach in FEED, a method that is based around both the location and type of leak source. Given the likely differing outcome between the prescriptive and mapping approaches, and further model development changes, the team added extra detectors to the total count. Even though change is never desirable for an MCP, deletions proved to be easier mechanism to manage over additional detectors.

The schedule pressure also required the design teams to reduce the duration of the mapping exercise. With the modules being designed in a staggered approach, teams could apply lessons learned from the first mapping studies to later modules in the sequence. This reduced the mapping exercise from the initial 3 months per process module, to around 6 weeks. Examples of the lessons learnt and optimisation measures employed were as follows:

- Preparing a bespoke 3D model file with all the hydrocarbon inventories highlighted and virtual volumes deleted;
- Reducing geometry reviews by using of slides in presentation format and amendments conducted over email/phone;
- Reducing the amount of CFD modelling to determine the hazardous gas cloud size by applying learnings from other mapping exercises; and
- Developing a standard report format, list of common assumptions and actions register.

Working Alongside Contractors and Consultants Effectively

A significant amount of preparatory work was required to conduct the gas mapping studies. Most of the resourcing for this effort was provided by the EPCM (Engineering, Procurement and Construction Management) contractor. Furthermore, given that the contractor prepared the final set of detector location drawings, it proved advantageous to involve the EPCM F&G engineers in the entire mapping process. This allowed the EPCM engineers to understand the behaviour of the potential gas cloud and effect of geometry in influencing the design changes to the detector layout rework.

The project also realised time savings by using the same consultancy to complete both the QRA and gas mapping work. Much of the leak frequency and stream data was already available following completion of the QRA. This reduced the requirement to transfer information to other 3rd party consultancies.

Having the EPCM contractors involved in the whole process also had an unintended benefit. The engineers quickly learnt from the gas mapping exercises what the successful coverage strategies were. This led to improvements in coverage on the initial F&G layouts using the prescriptive based approach to match outcomes closer to the mapping results. This led to detector layouts requiring less change post mapping and less work for the Main Automation Contractor when designing the F&G system cabinets. Examples of the principles utilised were:

- How gas accumulates on stair cases, and other solid or semi-solid obstructions;
- Coverage of leaks on well ventilated PSV (Pressure Safety Valve) platforms;
- Coverage around air cooler tube bundles;
- HVAC (Heating Ventilation Air Conditioning) air flow within enclosures and the effects of intakes and exhausts on gas accumulation; and
- The size and shape of a typical explosive plume (example plume shown in Figure 6).

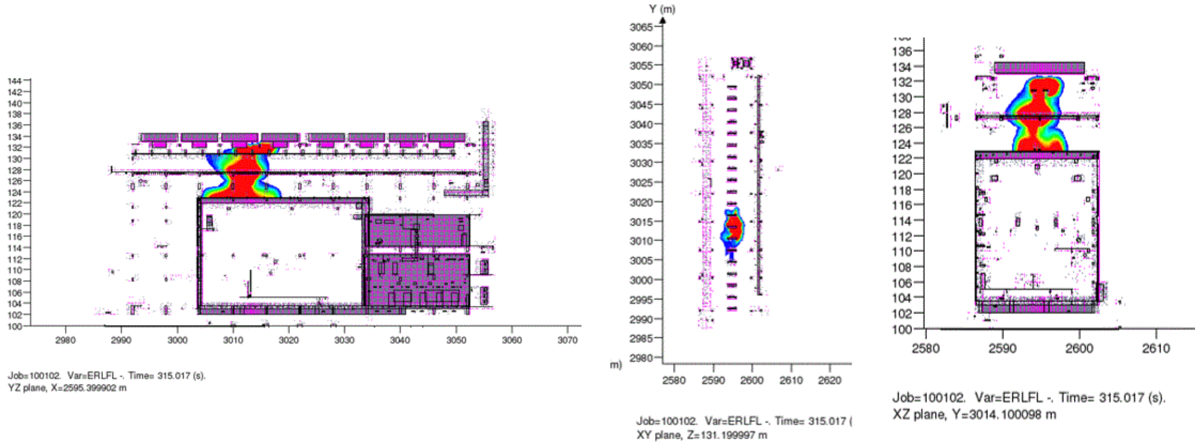


Figure 6 – Flammable gas concentration heat maps for a release from a fin-fan cooler (shown in different planes)

Handling the Graphics

The SmartPlant 3D software package is not only a graphics package, but also a database that contains information on each structure or piece of equipment. For example, project deliverables such as piping isometrics can be directly produced from the 3D software package. A disadvantage of this is that the size of data files is very large and not simple to handle. Furthermore, the consultant had not purchased the full software package to allow review of the FGP geometry and the information contained within the data files. This required the design teams to engage with the project information management specialists to output files into more generic file types that could be used by the consultant. Overall this proved to be a very time-consuming process. A potential lesson learnt for future projects is to evaluate the benefit of the consultant obtaining a short-term licence for the 3D software package. Although the software is expensive, this can save a significant amount of time if mapping involves several different modules or process areas.

Dealing with Change through the Design Process

As discussed previously, completing mapping at the 60% model stage often meant the design required changes following completion of the F&G detector layout drawings. For example, vendor data was often missing and the consultants needed to estimate the geometry of the vendor equipment. Most of the time the changes were not significant to detector layouts, but this was not always the case. This presented two challenges, the first was to discover all the omissions and keep track of the changes throughout the design development process, and secondly, determine if the changes were significant enough to have an impact on detector design. If a change was required, the project used concentration heat maps produced from the mapping studies as an approximate assessment, to make detector adjustments.

Not only were the process safety engineering teams reacting to design development changes, but there were also occasions when changes to the module design were required due to the mapping work. This also needed to be carefully managed. An example can be taken from the 3GI sour gas compressor enclosures that were mapped. During the initial mapping work, detailed ventilation maps were created which showed how fast air moves in all parts of the enclosure. These maps show ‘dead spots’, defined as air moving at less than 0.1m/s. Dead spots are particularly hazardous for personnel since hazardous gas can accumulate for even small-scale releases. On more than one occasion, the CFD ventilation maps required further adjustment of HVAC inlets and outlet positions to remove any dead spots within modules. These were significant changes which needed to be implemented before the mapping studies could progress, and on some occasions necessitated restarting the mapping exercise again. Figure 8 below shows an example of the level of ventilation within a specific example module. The warmer colours show high air velocities and the colder colours show low air velocity.

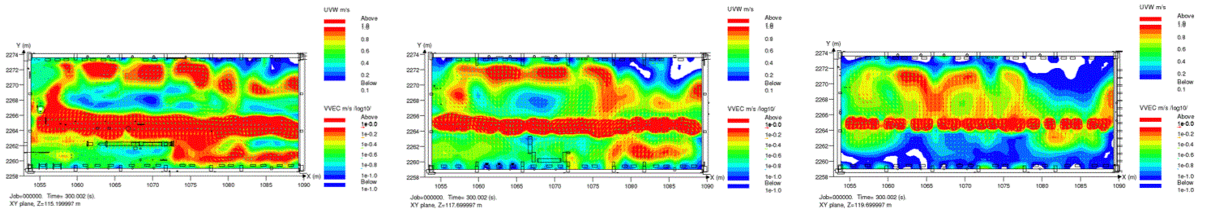


Figure 7 – Air velocity maps (plan views at differing module elevations)

Determination of Appropriate Coverage

Determining when the design had adequate detectors and hence coverage was one of the most challenging parts of the mapping exercise since little direct guidance exists in the industry and within company specifications. Most industry discussion around this topic suggests the preferred method is by using the level of coverage achieved (either geometric or frequency based). The project initially used a frequency based coverage method; locating detectors according to where gas is calculated to be most frequently present. However, it soon became apparent that this yielded unexpected outcomes where some low risk modules would have as many detectors as higher risk ones. In other cases, a very large number of detectors would be required to obtain a reasonable coverage (around 80%) particularly when leak sources were so well spaced and there were not too many areas where hazardous gas clouds could congregate.

Continuing with this methodology would have not been an effective use of project capital. To resolve these issues the project team conducted a coarse risk assessment and determined when adding additional detectors would no longer be of significant risk benefit. This was tied back to the mapping work by the consultant producing an output which showed the potential frequency of gas being detected by each detector, and optimizing detector placement based on risk from the mapping results. The project found that this resulted in a more balanced approached where higher levels of coverage were placed around higher risk areas. An example of an output produced from this exercise is shown in Table 1.

Voting logic and redundancy is also another factor that needs to be considered alongside this assessment. Some detectors were shown to have a large coverage requirement, and if the detector resulted in fault during normal operations, a significant coverage could be lost in the area. The project found adding another detector nearby helped to alleviate this issue. This was only applicable where detector faults do not vote as is the design case for FGP. For other process facilities where a fault is a vote to trip, this factor is not relevant when considering the need for additional detectors.

Overall, optimization of the F&G detectors between FEED and Detailed Engineering Design allowed for a reduction of around 20% in the total number of devices, based on enhanced performance in the following areas: 1) boundary detection around module fire zones were removed given the improved coverage demonstrated larger leaks were would not be missed 2) increased use of line of sight and acoustic detection 3) use of mapping studies to focus detection on more hazardous areas rather than applying ‘blanket wide’ coverage.

Tag in model	n	type	x(m)	y(m)	z(m)	1ooN Coverage	2ooN Coverage	Frequency detected 1ooN	Delta	Frequency detected 2ooN
M014-FZ001-NGC02	2	open path	3342	2686	105.6	16.07%	1.87%	7.14E-03	2.84E-03	8.30E-04
M015-FZ001-NGC07	7	open path	3271	2687	105.6	27.81%	12.51%	1.24E-02	1.50E-03	5.56E-03
M015-FZ001-NGC08	8	open path	3271	2700	105.6	30.51%	12.95%	1.36E-02	1.20E-03	5.76E-03
M014-FZ003-NGC10	10	open path	3338	2700	118.8	36.35%	13.09%	1.62E-02	1.30E-03	5.82E-03
K001-FZ011-NGC15	15	open path	3284	2739	104.2	44.05%	17.52%	1.96E-02	1.00E-03	7.79E-03
K002-FZ011-NGC20	20	open path	3321	2739	104.2	49.13%	22.33%	2.18E-02	7.00E-04	9.93E-03
M014-FZ003-NGC22	22	open path	3317	2686	123.4	51.59%	23.43%	2.29E-02	6.00E-04	1.04E-02
Pump-FZ011-NGC27	27	open path	3277	2737	102.4	55.06%	28.20%	2.45E-02	5.00E-04	1.25E-02
SC-FZ011-NGC65	65	point	3359	2715	104.2	65.42%	46.37%	2.91E-02	2.00E-04	2.06E-02

Table 1 – Example output from mapping exercise showing coverage obtained by each detector

Operations Perspective

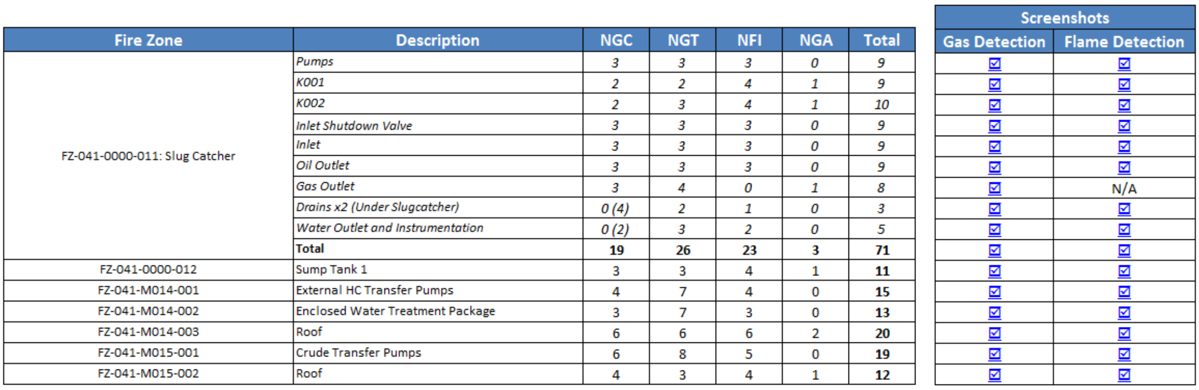
Human Factors & Ergonomics

When F&G detectors are placed in their final positions they must not clash with any escape routes, maintenance volumes and walkways. They must also be located where they can be accessed conveniently for inspection, testing and maintenance. With a confined and congested design due to modularisation, working within these constraints was onerous. The optimisation algorithm to locate detectors in the most optimal position could not account for human factors engineering. This required human judgement to appropriately locate final detector positions. There were two possible approaches to conduct this. The first approach (which the project initially adopted) was to take the optimised detector layout and move each detector to where they could be accessed. However, this sometimes resulted in significant changes to the F&G detector layout where the level of coverage was adversely affected. The second approach (which the project adapted to) was for the consultants to manually locate ‘dummy’ detectors in all the possible accessible locations in the module and then allow the optimisation algorithm to only choose the best detectors from this reduced selection. This required more upfront work, but resulted in a final design with less changes and one where the coverage calculated was very close to the actual coverage achieved. The project issued detailed guidelines on the human factor requirements for F&G detectors, so that the consultants could understand how to fill the module with the ‘dummy’ detectors correctly.

Effective Handover of Work for Operations Phase

It was recognised that transferring significant body of mapping reports and analysis to the operations team in a meaningful and useful way could be challenging. The operations team require information to help them determine if detectors were faulty, what potential impact this could have on the coverage. In addition, operations would need to know the impact from brownfield changes, and how the F&G devices need to be modified and/or added. This meant much of the design documentation produced in mapping report studies may not be useful for those aims.

The project undertook an activity to produce a mapping handover report. An example the front sheet and information provided in shown in Figure 8. This electronic document listed all the detectors in an area, the type of detector (toxic, acoustic, flammable etc) with a link to where the detector is located, along with the coverage each detector it is expected to achieve. An example of the visual representation of coverage is shown in Figure 9.



Fire Zone	Description	NGC	NGT	NFI	NGA	Total	Screenshots	
							Gas Detection	Flame Detection
FZ-041-0000-011: Slug Catcher	*Pumps*	*3*	*3*	*3*	*0*	*9*	☑	☑
	K001	*2*	*2*	*4*	*1*	*9*	☑	☑
	K002	*2*	*3*	*4*	*1*	*10*	☑	☑
	Inlet Shutdown Valve	*3*	*3*	*3*	*0*	*9*	☑	☑
	Inlet	*3*	*3*	*3*	*0*	*9*	☑	☑
	Oil Outlet	*3*	*3*	*3*	*0*	*9*	☑	☑
	Gas Outlet	*3*	*4*	*0*	*1*	*8*	☑	N/A
	Drains x2 (Under Slugcatcher)	*0 (4)*	*2*	*1*	*0*	*3*	☑	☑
	Water Outlet and Instrumentation	*0 (2)*	*3*	*2*	*0*	*5*	☑	☑
	Total	**19**	**26**	**23**	**3**	**71**	☑	☑
FZ-041-0000-012	Sump Tank 1	3	3	4	1	**11**	☑	☑
FZ-041-M014-001	External HC Transfer Pumps	4	7	4	0	**15**	☑	☑
FZ-041-M014-002	Enclosed Water Treatment Package	3	7	3	0	**13**	☑	☑
FZ-041-M014-003	Roof	6	6	6	2	**20**	☑	☑
FZ-041-M015-001	Crude Transfer Pumps	6	8	5	0	**19**	☑	☑
FZ-041-M015-002	Roof	4	3	4	1	**12**	☑	☑

Figure 8 – Example front sheet of mapping handover report

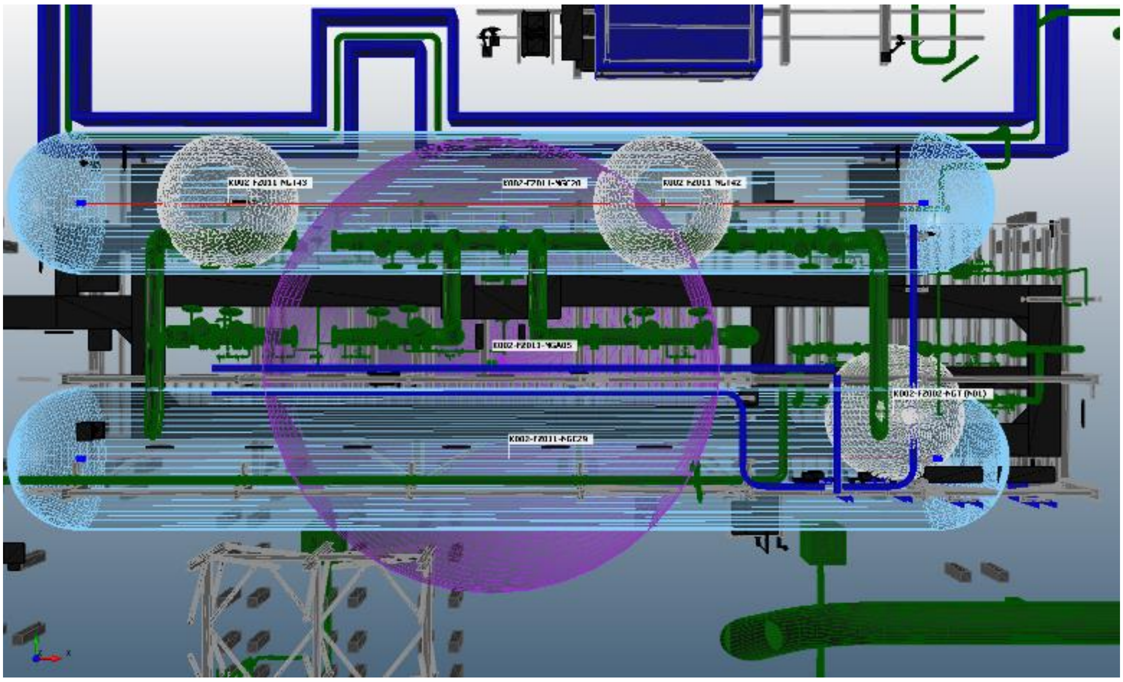


Figure 9 – Example screenshot showing coverage envelopes for line of sight detectors (light blue), acoustic (purple) and point detectors (white)

Effective Use of Different Detection Technologies

As well as the use of the standard point gas detectors, the project also used acoustic and line of sight detectors in areas where they were considered more effective. Acoustic detectors are particularly useful (as are toxic gas detectors for inventories that contain toxic gas) at detecting small leaks that could lead to further escalation and/or safety and asset integrity issues. Acoustic detectors can cover a large 3D area and are particularly useful around high-pressure gas inventories. The consultants developed an algorithm during the mapping exercises to optimally locate acoustic detectors.

Line of sight detectors, although more expensive than point detectors, were used where they could replace at least three flammable point detectors. During completion of the mapping exercise, the consultant adapted the optimisation algorithm to select the most appropriate detector (between point and line of sight detection). The output in Figure 3 shows the differences between the ‘optimised layout 1’ (point and line of sight detection) versus ‘optimised layout 2’ (point detectors being only).

Conclusions

Determining the optimal quantity and location of detectors is critical for detector systems to effectively protect people, property and the environment. Gas mapping was performed using ‘risk based’ techniques to help quantify the release frequency of FGP process plant modules. Taking account of the facility geometry and other specific parameters, CFD analysis was used to calculate both the hazardous gas cloud and determine where hazardous gas concentrations where most likely to occur. An algorithm was applied to place detectors in favourable locations to improve overall detector coverage and performance. By moving the same number of detectors to where the probability of gas presence is highest, the project could obtain a much higher coverage. It was found that the main benefit from the application of this gas detection mapping approach was that key parameters such as coverage, plant availability, cost and schedule could be closely managed and optimised.

From an operations perspective, the most challenging aspect was to ensure the completion of the gas detection mapping activity fit seamlessly into the execution of a modern large-scale onshore project. Today’s MCPs are staggered in approach whereby often the design is still ongoing yet construction activities have commenced. This means the transmission of design information between users and stakeholders has limited room for error or delay. Gas detector placement needs to occur with the required information and modifications at the various stages of the detector design process.

From this unique experience, many design and execution lessons were learnt. For example, when to commence the gas placement process, providing stakeholders with the information they need before the process is fully complete, implementing human factor requirements into the mapping phase, determining the correct coverage, using gas detector technologies effectively, and ensuring the design integrity is maintained throughout fabrication, construction and commissioning phases.

It is believed the approach applied by the project has improved risk reduction, by designing a more effective F&G system, and allowed for better management of the F&G design during project execution. In addition, the Material Take-Off documents showed that gas detector numbers in the processing areas reduced from 3,500 in FEED to 2,750 in Detailed Engineering Design by focusing efforts on risk reduction and device optimisation.

References

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