Mitigating Risks with Fire and Gas Detection (Article)

Extracted from: https://www.abs-group.com/Knowledge-Center/Insights/How-to-Mitigate-Risk-with-Fire-and-Gas-Detection-Mapping/

EXTREME LOADS AND STRUCTURAL RISK

Fire and Gas Detection Systems (FGS) are critical components for the overall safety and operation of any facility and its personnel. Using dedicated field devices, FGS detection continuously monitors heat, smoke, temperature and toxic or combustible gas levels. Furthermore, it is included under the Occupational Safety and Health Administration (OSHA) provisions with the intent to minimize the catastrophic consequences of toxic, reactive or explosive chemicals. Discover more about the application of FGS detection and mitigation systems, including how they can mitigate your risks.

Mitigating Fire and Explosion Risk

FGS detection and mitigation is a safeguard against unacceptable fire and explosion risk. FGS actively identifies the release of flammable materials and mitigates the consequences by various means, including:

- Active Alarms
- Water Spray Fire
- Explosion Deluge
- Emergency Shutdown System (ESD)
- Ignition Source Isolation

An FGS that has been properly designed will not prevent a hazardous consequence from occurring; however, it can reduce the likelihood of a small leak escalating into a much larger consequence that could damage equipment or fatally injure personnel.

Three (3) Ways to Determine FGS Effectiveness

There are three factors that determine the overall performance of an FGS, as measured by the risk reduction it provides.

1- **The Detection Rate**: A poor detection rate can limit a system’s overall effectiveness. A study by the Health and Safety Executive (HSE) looked at eight years of hydrocarbon release data and found that the effective detection rate was only 60%. In addition, the detection of many releases was delayed, which allowed flammable clouds to grow larger and the consequence to increase. This illustrates that despite reliable mitigation systems, sufficient risk reduction will not occur unless the detector coverage is also high. For FGS functions, detector coverage should be analyzed with the same (if not more) quantitative rigor as the verification of the average probability of failure on demand for the hardware design.

2- **Availability of the Mitigation System**: This is the probability that the system will perform as designed. The International Society of Automation (ISA) framework (ANSI/ISA-61511-1-2018 / IEC 61511-1:2016) gives requirements for the specification, design, installation, operation and maintenance of a Safety Instrumented System (SIS) and calls for the allocation of safety functions to determine the Safety Integrity Level (SIL). For an FGS, an SIS is used to implement one or more safety functions, composed of any combination of gas and fire sensors, logic solvers and final elements such as isolation valves, water spray, etc. Layer of Protection Analysis (LOPA) is one method that can be used for selecting the appropriate SIL of your SIS.

3- **Effectiveness of the Mitigation System**: This can generally be determined via some level of analysis, using software such as FLACS Computational Fluid Dynamics (CFD) package. The water spray systems must be adequately engineered in order to effectively reduce the consequences of a fire or explosion incident. Likewise, evacuation alarms must be audible to personnel in occupied buildings.

The combination of FGS detector coverage, availability and mitigation effectiveness can be seen below in the example event tree.

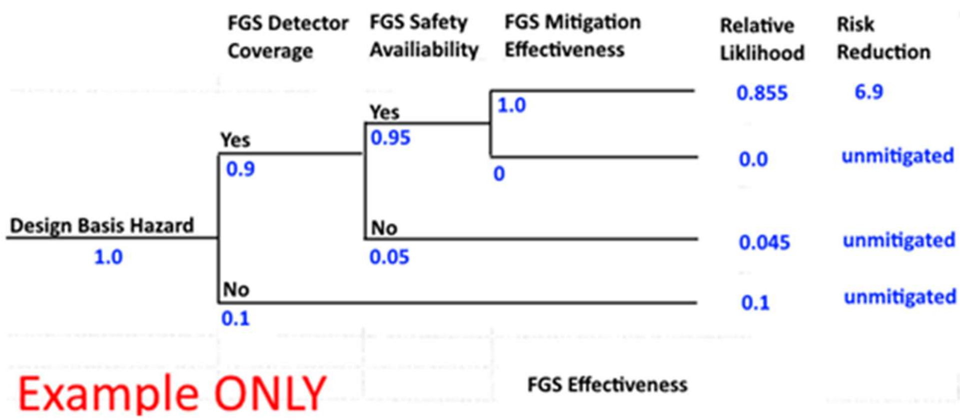

Figure 1: FGS System Mitigation Overall Risk Reduction

The Benefits of Performance-Based Approach

Several FGS designs are based on prescriptive methods, experience or rules of thumb. These approaches are less than ideal since they fail to quantify the true risk reduction of FGS designs. A better design method is a performance-based approach, as described in the comprehensive framework ISA TR 84.00.07-2018. This approach is "intended for use in evaluating the effectiveness of fire and gas systems in process industry applications. It addresses the implementation of FGSs to reduce the risk of hazardous releases involving safety impact."

FGS Risk Analysis: Semi-Qualitative vs. Fully Qualitative

FGS functions can be designed to provide an order of magnitude (10) risk reduction for the most critical systems; however, not all systems will require this level of performance. Determining the target performance of an FGS function should be accomplished using hazard and risk analysis employing either a semi-quantitative or fully quantitative method. A semi-quantitative method uses process characteristics like pressure, ignition probability and equipment congestion to determine a hazard score for the area, which can then be used to target a detector coverage percentage. A fully quantitative approach would model discrete leak scenarios and their consequences, along with leak frequencies. This risk can then be compared to company criteria to determine the necessary level of risk reduction.

Two (2) Ways Detector Coverage Can Be Quantified

There are two methods for determining detector coverage: Geographic and Scenario-based.

1- **Geographic Coverage** starts by locating a design bases' fire or gas cloud size in the area of concern and measuring what fraction of positions are detected by the current layout. This is the smallest allowable hazard that if detected results in the desired level of risk reduction. (For a flammable release, it may be the gas cloud size that can cause unacceptable occupied building damage.) It is important to note that while a smaller design basis hazard will have a higher risk reduction, it will also require more detectors to meet the necessary detection coverage rate.

In the example below, our experts utilized FACET3D software to randomly locate the design hazard throughout the area of concern using a Monte Carlo approach which can vary the cloud width/height while maintaining the design volume. The result is an overall detector coverage fraction and a heat map showing which areas have the highest rates of non-detection and are good candidates for additional detectors.

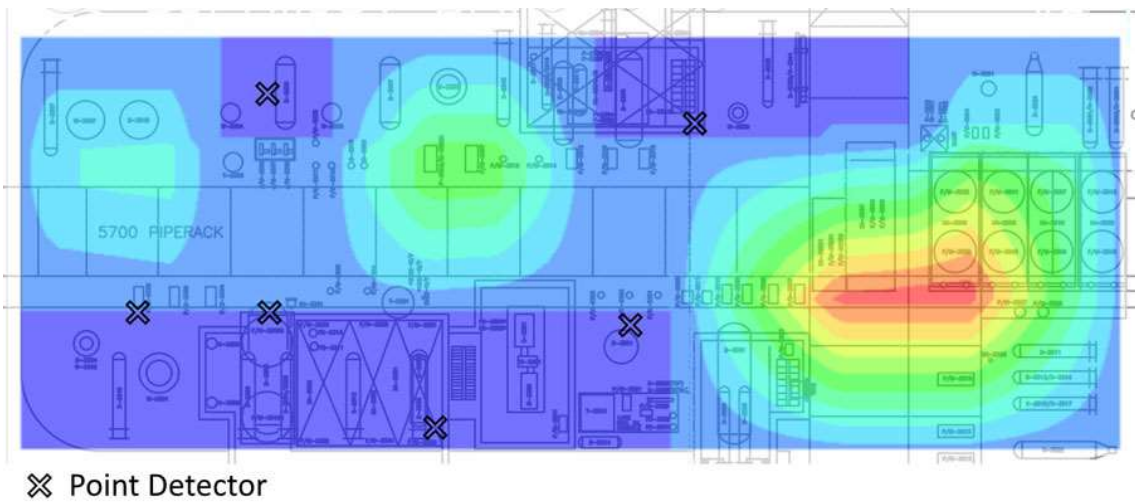

Figure 2: Detector Layout Heatmap using Geographic Method

2- **Scenario-based Coverage** rates a model's discrete leak scenarios at equipment locations using a leak size capable of producing a design basis consequence. Each scenario is released in multiple directions and a successful detection by the network is assessed. The final detection coverage rate is the ratio of detected leak scenario cases divided by the total leak scenario cases. Scenario-based coverage allows for more targeted detector placement near the hazard source and can include the influence of site-specific equipment and geometry on the dispersion or fire spread. However, a downside is that it requires more consequence modeling to ensure all leak sources are accounted for in an area.

Case Study: Optimizing Detector Placement

We performed an assessment of an indoor facility where detectors were already in place. The client wanted verification of the assumption in a recent Process Hazard Analysis (PHA) that the FGS would provide an order of magnitude risk reduction for explosion hazards that could impact the control room. We started by defining a design basis gas cloud that could impact the control room. This cloud size was different for the 1st and 2nd floors of the reactor building due to congestion levels. Next, we used the geographic method to assess the detector coverage for each floor and the building as a whole. The current layout detected 87% of the design basis cloud locations. The client had an internally developed FGS availability of 0.95 based on the system probability of failure on demand. We helped evaluate the water deluge suppression mitigation effectiveness using the FLACS CFD software and were able to show that the effectiveness was very high for explosion suppression (effectiveness = 1). Therefore, the overall risk reduction factor was 1/(1-(0.87*0.95*1.0))=5.8.

In order to increase the risk reduction, we recommended additional detector locations based on heat maps generated during the detector coverage analysis. Four additional detectors were recommended at specific locations which resulted in a detector coverage of 97%. The new risk reduction factor was 1/(1-(0.97*0.95*1.0))=12.7 which met the design goal of one order of magnitude.

How Can ABS Group's Approach to FGS Reduce Risk?

ABS Group is experienced in facility siting, consequence, frequency and risk modeling. Our FGS design services leverage this experience which allows us to map out your existing or proposed detector layout coverage factor. Our LOPA experts can then assess mitigation availability and effectiveness using our advanced modeling capabilities like CFD. We have the experience to apply ISA TR 84.00.07-2018 in full and evaluate your FGS function using a performance-based approach.