Fire and Gas Detection System Philosophy

1 Purpose

This document provides background information on different Fire and Gas Detection System technologies and key concepts to keep in mind when selecting and designing them.

2 Scope

This document can be referenced for any fire and gas detection system project or fire and gas mapping study.

3 Definitions

Fire Detection System: A fire detection system is an alarm system that identifies fires in a specific area by measuring the heat, smoke or flame they generate.

Gas Detection Systems: A fire gas detection system is an alarm system that identifies gases or vapors not normally expected to be present or, at higher concentrations, in a specific area or volume.

RAGAGEP: An acronym for Recognized and Generally Accepted Good Engineering Practice.

Quantitative Risk Assessment (QRA): A QRA is a structured process used to identify, analyze, and quantify risks of a hazardous event using probability and consequence information.

Flame Mapping: Flame Mapping is the use of 2D or 3D mapping software to determine the required number, and optimal location of, flame detectors in order to achieve a reliable view of a fire (as assumed or calculated).

Gas Mapping: Gas Mapping is the use of 2D or 3D mapping software to determine the required number, and optimal location of, gas detectors in order to achieve a reliable view of an assumed or calculated cloud size.

4 Principles of Operation / Purpose

Fire and Gas Detection Systems (FGDS) are used to identify fires and the loss of containment of materials (initiating events) that will generate hazardous gases or vapors. A FGDS will provide continuous and automatic monitoring of areas, buildings or specific equipment and should communicate with the facility Emergency Communication System (ECS) if an initiating event is identified.

When ***combined with*** timely employee actions and/or interlocked with other equipment, an FGDS can limit the escalation of consequences that can occur over time during a fire or hazardous material release.

Typical Methanol Plant Fire Protection Philosophy,

A) operator detection of an initiating event could take up to 10 minutes in a process area and up to 20 minutes in a non-process area.
B) response by mobile fire protection equipment and structural firefighting could take another 10 minutes.
C) the goal of fire protection systems is to prevent the fire from resulting in a combined loss of $50 million USD, escalating to additional units or fire zones, and to minimize the visibility of a fire to the surrounding community

It can be assumed, then, that emergency response efforts may not begin for 20 to 30 minutes after the initiating event commences.

The consequences from fires and leaks in petrochemical units and tank farms can escalate rapidly.

The purpose of the FGDS is to reduce the time lag between when the initiating event commences and when the consequence mitigation efforts start, such that goals stated in part C) become achievable.

If reducing the “time lag” alone is not sufficient to reduce the consequences of a hazardous initiating event to the levels stated in part C), interlocking the FGDS with a fixed fire protection system or emergency shutdown system should be considered. For example:

- Fixed fire protection systems, like automatic deluge water spray systems, can dilute methanol leaks and/or slow the rate of the fire growth and provide the Emergency Responders with a less intense, slower moving fire to contend with.
- Emergency Shutoff Valves, installed on pipelines and upstream of process pumps, can be used to isolate the leak immediately upon detection.

5 Design Basis

FGDS follows a basic process control system in form and function: sensors are connected to a processor that issues an output signal to a field device. And just like a process control system, the FGSD processor can utilize a logic solver and sensor voting systems to reduce spurious alarms.

The design of an FGDS starts with an understanding of the physics of the initiating event(s) coupled with well-defined consequence mitigation objectives. This information will determine the sensitivity and reliability needs of the FGDS, which in turn will drive technology selection. The assumptions and values used in these first steps should be clearly stated in all documentation and understood by all parties.

An FGDS can have a *Performance* based design or a *Prescriptive* based design.

A Prescriptive based design explicitly relies upon subject matter expertise coupled with one or more prescriptive RAGAGEPs (such as fire codes). The premise of this approach being that an FGDS designed and installed per proven standards and practices by competent personnel should be highly effective and reliable.

A Performance based design relies upon subject matter expertise and computer modeling programs to better understand the nature of initiating event(s) and design the FGDS to meet a performance target. Often, these targets consist of "quantifiable risk reduction" goals.

The ability of a particular FGDS design to meet quantifiable risk reduction objectives, assuming multiple different initiating event scenarios, is known as "Effectiveness".

Flame and Gas Mapping studies are tools used within a Performance based FGDS design.

Flame and Gas Mapping Effectiveness is a function of its

- Ability to identify the initiating event (fire or gas release) in a monitored area (also known as Coverage)
- Degree of reliability (also known as Probability of Failure Upon Demand - PFD)

Regulatory officials and insurance companies may require a prescriptive approach with adherence to a specific RAGAGEP rather than a Performance based approach. Either approach will affect the FGDS design and should be confirmed as early in the project as possible.

Prescriptive RAGAGEPs for FGDS design include, amongst many others, NFPA 72, National Fire Alarm and Signaling Code, Factory Mutual Data Sheet 5-48, Automatic Fire Detection and ANSI/FM 121303-2025 Guide for Use of Detectors for Flammable Gases.

The primary RAGAGEP for performance based design of FGDS is ISA-TR84.00.07 – 2018, Guidance on the Evaluation of Fire Combustible Gas and Toxic Gas Effectiveness. The foreword of this document states that:

• General fire and gas system safeguards with no specific risk reduction claimed should be implemented per application-specific standards from local jurisdiction having authority.

• • FGS functions with claimed FGS risk reduction factor (RRF) less than or equal to 10 should be implemented per applicable requirements of ANSI/ISA-84.91.01-2012, *Safety Controls, Alarms and Interlocks in the Process Industries.*

• • FGS function with claimed FGS risk reduction factor (RRF) in excess of 10 should be implemented per the applicable requirements of ANSI/ISA-84.91.01-2012 and ANSI/ISA- SA-TR84.00.07-2018

Regardless of the approach used, engineering judgement and process expertise should be utilized for FGDS projects before any complicated "computer modeling" is done.

5.1 Fire Detection Systems

Fire detection systems work by identifying the Heat, the Smoke or the Flame generated by a fire. Therefore, the selection process for fire detection technology should be driven by the anticipated *fire type and size AND the expected/desired response to a fire.*

The fire alarm control panel (FACP) powers and supervises the fire detection devices in the field, performs the logic functions, and powers the output functions, such as alarms and interlocks with separate hardware systems. Fire detection system design and components are highly regulated in most areas of the world. As such, the FACP is normally required to be certified for fire protection service and to be serviced by certified technicians.

The FACP should be connected to the Facility Emergency Communication System. It can communicate directly with the Basic Process Control System, but should be independent of it.

Multiple FACPs are needed if there are multiple fire detection zones / multiple buildings. The Main FACP should talk to the other FACPs and be installed in a continuously staffed area such as the Security Building or a Control Room.

Wireless technology is available for some fire detection system technologies. This option can dramatically reduce installation costs, as the installation of wiring to connect detectors and multiple FACPs is typically the most expensive component of a new system.

Prior to selecting and installing fire detectors, a Fire Hazard Identification study should be completed to identify and sort fire risks by fuel type, location and desired response time.

There are three categories of fire detectors

- Heat (Thermal) Detectors
- Smoke Detectors
- Flame Detectors

Heat (Thermal) detection technology is usually employed for identifying large or long burning fires that generate large amounts of heat. As a rule, these detectors are slower to identify incipient stage or smoldering fires than Smoke or Flame detectors.

Thermal detectors are designed to activate when a certain ambient fixed temperature is reached or when the ambient temperature rises at a high rate. Some devices can do both functions.

The second variable for heat detectors is their Response Time Index (RTI). The RTI is a measure of the thermal sensitivity of the device. The lower the RTI Value, the quicker the device will react, AND potentially the fewer detectors that are needed to monitor a given area.

<u>Fixed temperature</u> detectors generally have the simplest Heat Detection technology and require less calibration and maintenance than smoke or flame detectors. These devices are heated up by direct radiant energy and ambient air temperatures.

Standard fixed-temperature fire detection devices for the petrochemical industry include:

- Automatic Sprinkler Heads
- Fusible Links
- Linear Heat Detectors

Automatic sprinkler heads are the most common fixed-temperature detectors. They are used in fire sprinkler systems as both a detection and a water application device.

Sprinkler heads can also be used as a detection and release system for separate fire protection systems, such as deluge water spray systems and foam systems. When used in this application, they are called “Pilot Heads”.

Automatic sprinkler heads have fusible links or quartzoid bulbs that fail when exposed to temperatures more than ambient for a few minutes. Typical temperature ratings for sprinkler heads range from 165°F (office area) and 286°F (flammable liquid processing areas) to +600°F (industrial oven or incinerator that creates high ambient temperatures).

Sprinkler heads can be obtained with different RTI measurements in addition to different temperature ratings. RTI is normally a metric measurement. There are Fast Response Heads (RTI of 50 meters-second$^{1/2}$ or less) and Standard Response Heads (RTI of 80 meters-second$^{1/2}$ or more).

Sprinkler heads used with automatic sprinkler systems are usually located under a ceiling or some other flat surface that will act as a heat collector. They are normally installed on a gridded pattern (80 to 140 sq.ft./head). All sprinkler heads, even Fast Response Heads, must be heated up over some period (roughly 30+ seconds). Ceiling levels higher than 30 ft. will require a review by a fire protection SME to determine sprinkler head selection.

When used as part of a Pilot Head based Fire Detection System, sprinkler heads are arranged in a gridded pattern over the entire hazardous area (such as a methanol pump alley) or are placed as close as practical (3 to 9 ft. / 1 to 3 m) to the fire hazard (such as directly over a methanol pump). Pilot head systems are often installed outdoors as part of automatic deluge water spray systems and may not have a flat overhead surface to collect the heat. Pilot head fire detection response is predicated upon the presence of intense fires such as those fed by large flammable liquid releases.

There are prescriptive RAGAGEPs (such as NFPA 13 and 15) covering sprinkler head placement and layout when they are used in either application, as well as their inspection, testing, and maintenance needs. A sprinkler head is expected to have a useful life of 25+ years in most applications.

Alternate technology fixed temperature fire detection devices are available for areas where sprinkler systems are not practical.

Fusible Links are small bi-metallic objects that fail when exposed to a sustained thermal load. The failure of a fusible link (or fusible plug) can be used to release a pressurized fluid or a mechanical device such as a spring or weight drop-based actuation system.

As such, in addition to their use in sprinkler heads, fusible links can also be used to initiate the closure of “Fire Doors” and “Emergency Block Valves” in a fire. These devices will activate if their fusible links fail for any reason; that is one of the features that makes them “fire safe.”

Fusible links have temperature ratings ranging from 165°F to +500°F. They work quickly when there is direct flame impingement. The long term exposure to a moderate heat source, such as a nearby area heater, can induce a spurious failure mode known as “cold flow”. Therefore, a fusible link should have a temperature rating of at least 50°F more than its ambient temperature.

There are a few RAGAGEPs that directly cover fusible links as standalone devices. It is standard industry practice to replace them annually, as they are low-cost items.

“Fail Close” pneumatic actuation systems are often used with Emergency Block Valves. Exposed plastic pneumatic tubing is often used in lieu of a fusible link as a fire detection sensor. The downside of this approach is that the use of plastic tubing will increase the risk of spurious failure, as plastic is not as robust as a fusible link or has a well-defined melting point.

Linear Heat Detection Systems (LHDS) use long, light weight sensor cabling for thermal detection that connect to a Zone Monitor Unit that communicates with remote Fire Alarm Control Panel.

The sensor cable is made of two intertwined rigid metallic conductors, covered by a heat-sensitive material with a protective outer jacket sleeve.

The sensor cabling can be installed on top of critical electrical and instrumentation cable trays, on floating roof and fixed roof storage tanks, directly under the ceiling of highly congested areas or other spaces not suitable for spot type fire detector technology.

LHDS are relatively simple to install using clips and other small hangers. They are also weather resistant and have inherently safe options, from an electrical classification standpoint.

The cabling can be obtained for different desired temperature alarm points and different ambient temperatures. Most vendors offer an alarm range of 45°C to 185°C. The cabling is color coded per their temperature alarm set points.

The latest version of LHDS technology is “Digital”. Digital systems are capable of detecting heat anywhere along its sensor length and providing that information to the control panel.

The downside of LHDS are (a) the sensitivity of the sensor cabling to mechanical damage and (b) the dependence upon the product vendor to do the design work and put together a reliable sensor layout that also meets RAGAGEP requirements.

Many vendors have offices globally and are listed for fire protection service by both UL and the FM Approval Agency and several other certification authorities.

Inspection, Testing and Maintenance requirements are mostly driven by the Vendor recommendations. If mechanical damage is avoided, these systems should have a useful life of 10+ years.

Rate of Rise Heat Detectors measure the rate at which the air temperature changes during a fire event using mechanical or electronic systems. Measuring the change in temperature can provide a faster alarm response than measuring for a fixed temperature in a space.

Typically, these devices can be equipped with a fixed temperature feature as well.

These devices are less affected by dusty conditions, are more reliable, less expensive and have fewer maintenance requirements than smoke detectors.

The downside to these detectors is that they are more complicated than most fixed temperature fire detectors, do not detect smoldering, slow growth fires and can be affected by rapid swings in ambient temperatures unrelated to a fire. They are no longer widely used, but are a good option when fixed temperature fire detectors are not expected to respond quickly enough or advanced technology (expensive) fire detection devices such as Flame Detectors are not desired.

Device spacing requirements vary with the vendor and the features of the area being protected.

Inspection, Testing and Maintenance requirements are found in several RAGAGEPs and by the Vendor. The detectors should have a useful life of 10+ years.

Smoke Detectors identify fires through the products of their combustion. They are very good at identifying fires that do not generate a visible flame or large amounts of heat in their incipient stage.

Smoke detectors are routinely used for life safety reasons in occupied buildings, in sensitive, high value areas such as electrical and computer rooms and utility rooms with electrical gear and motors.

Smoke detectors are more susceptible to spurious activation than Thermal detectors. Therefore, their FACP are often programed such that multiple detectors must activate before initiating an alarm or activating an interlocked extinguishing system.

Unlike smoke detectors used in the home, commercial grade smoke detectors are required to have hard-wired power sources.

Smoke detection systems are inspected / tested semi-annually in most jurisdictions. Individual detectors are usually replaced every 10 years. Smoke detection systems have an expected life span of 20 years.

There are three basic categories of smoke detectors. The categories are based upon the type of smoke they detect and their sensitivity (ability to detect very small amounts of smoke). They are:

- Ionization
- Photoelectric
- Air Aspirating

<u>Ionization Smoke Detectors</u> contain a small radioactive source, which is used to ionize the air. Smoke particles do not ionize well and reduce the ion flow to a charged plate. This technology is good at detecting smoke that has a very low visibility.

These detectors are often combined with photoelectric smoke detectors in a single fire detection system to provide a broader range of detection capability. This combined approach is commonplace when a smoke detection system is used to activate a gaseous extinguishing system in a computer room.

<u>Photoelectric Smoke Detectors</u> use a small internal light beam to detect smoke particles.

“Spot / Point” photoelectric smoke detectors are the most common detectors used. They are found in many office buildings and homes. They are good at detecting slow moving, and smoky fires.

They are typically laid out in a gridded pattern (~200 to 500 sq.ft./head). Spacing between detectors is determined by the height of the ceiling, air flow in the building and the nature of the expected fire. Tall structures, in particular, offer challenges to their use.

<u>Beam Smoke Detectors</u> are a type of photoelectric smoke detector that project a light beam across the supervised area into a photoelectric cell. Unlike spot detectors, these detectors work well in tall open buildings such as 18+ ft. high electrical rooms or warehouses.

The Light Beam projector can be spaced 330 ft. (100 meters) from the photoelectric receptor. The beams can be spaced up to 60 ft. (18 meters) apart. They should be elevated 1.5 ft. (0.5 m) above the normal level of traffic and obstructions within the building.

False alarms due to temporary obstructions can be off-set by microwave motion detectors and other technology.

The units have windows that need to be kept clean and must be kept carefully aligned. They can be functionally tested with smoke or aerosols.

Laser Smoke Detectors are a type of light-scattering spot type photoelectric smoke detector. They are roughly 100 times more sensitive than a conventional photoelectric detector. They are "intelligent" and can be used in more sophisticated (addressable) fire alarm systems. In areas where high air flow can impede normal detection, grouped laser detectors can use algorithms to compensate for ambient conditions.

Laser type smoke detectors are a more reliable, if slightly less sensitive option, to Air Aspirating Smoke Detectors.

Air Aspirating Smoke Detectors, also known as High Sensitivity Detectors, are the most sensitive smoke detection technology. These systems utilize a multi-point sampling system and an on-line analyzer to monitor the air for smoke in high criticality rooms or equipment. Their ability to detect smoke (known as sensitivity) is highly adjustable and can be three plus orders of magnitude greater than a normal photoelectric smoke detector.

These systems have the sensitivity to detect overheated electrical components in metal cabinets prior to actual ignition. Assuming a well-trained technician can respond in less than 10 minutes, this can be a very valuable consequence mitigation strategy. These systems can also be interlocked with a gaseous extinguishing system to protect very sensitive and valuable rooms.

Air Aspirating Smoke Detection Systems require the air they sample to be very clean under normal operating conditions. Air filtration systems, routine recalibrations and system sensitivity adjustments downward may be required if there are ambient levels of dust. As such, they should be installed with a great deal of care.

Flame Detectors use (individually or combined) infrared (IR), ultraviolet (UV) and Camera based technology to optically detect a fire. Flame detectors are very good with fires that rapidly produce flames and are generally the most sensitive of all fire detectors. They are often interlocked with emergency shutdown systems or fire suppression systems.

The fire's fuel source is the most important variable is selecting a flame detection system. The invisible flames associated with Hydrogen are notoriously difficult to identify with hardware or the naked eye. The blue flames generated by Methanol and Ethanol fires can also be challenging to many fire detectors.

Flame detectors work on a line of sight basis. They have a field of view, known as their "Cone of Vision" or "Field of View" of 30 to 60 degrees off of center in all four directions and a distance range up to 65+ meters / 225+ ft.

There are no detailed prescriptive industrial guidelines specifically addressing the selection and placement of flame detectors. Vendor literature will provide specific performance data of each detection device depending upon the fire fuel size and type.

Methanol fires are very different from the flame detectors industry standard, Heptane fire, and will generate different detection device performance data.

Once the flame detector models are chosen for the fire risks identified, detector placement and orientation can be determined using equipment specifications, area drawing reviews and field tours.

As a supplement to the above "professional judgement" driven design process, many Flame Detection vendors and 3rd party service organizations offer Flame Mapping studies to assist in the placement of flame detectors in the field. ***Mapping Studies are required if the flame detection system is being used to determine a quantitative risk reduction value for the FGDS.*** They are also a good practice if the area in question is highly congested or a redundant level (N+1) flame detection is desired.

Annex A and B of ISA-TR84-00.07-2018, Guidance on the Evaluation of Fire, Combustible Gas and Toxic Gas System Effectiveness, are the most common tools used to conduct Mapping Studies. More information on the Mapping Studies are included later in this section of this document.

IR detection is the common approach to optical flame detection. A standard IR detector will detect flames in two different bands within the IR spectrum to minimize false alarms from welding or sunlight reflection. They are often used in smaller spaces such as paint booths.

A triple IR, also known as a Multi-Spectrum IR, detector is the standard flame detection device used in petrochemical facilities. These detectors have multiple internal sensors and a microprocessor to sort through the signal noise to achieve a long flame detection range in a highly reliable manner. Some models can detect flames from fuels such as Methanol, Methane, Syngas and Hydrogen, while other models work best on heavier fuels such Heptane and Diesel.

UV detectors are often used to detect fires that do not emit on the IR spectrum, such as Metal, Sulphur or Hydrogen. They are highly sensitive devices, and have a reputation for being set off by flashing lights and sunlight reflection. Therefore, they are typically used within enclosed rooms where detection speed is critical.

Detectors utilizing only UV technology can be made more reliable through programming and using them in a cross-zone such that two detectors must identify a flame before they alarm. UV detectors have a reliable range of distances of 10 to 30 meters.

Combined UV / IR detection in a single device can be used to reduce spurious activation issues and to improve sensitivity to unusual fires such as those involving aerosol filling operations or hard to detect flames (such as hydrogen or methanol).

Cameras

Optical fire detection with cameras is a rapidly evolving area of fire detection with multiple vendors operating around the world. The information below should not be considered all inclusive. New detection systems are being developed continuously.

Cameras can be added as accessories to many IR based flame detectors to help operators understand the scope of the incident, or they can be used as the fire detection devices themselves.

CCTV cameras with “visual flame” technology are able to process live video images and detect the characteristic properties of flames visually with flame detection algorithms and on-board digital signal processing. They can then transmit or record these video images to a remote screen for viewing.

In many cases, the sensitivity of the camera is pre-set by the vendor to a specific flame type and size. The camera’s cone of vision is similar to a multi-spectrum IR detector; however, these cameras typically have a shorter range of visual distance (~ 10 meters). The detection systems are reportedly very resistant to common false alarms from flares and hot work.

The process for determining the placement of these detectors mirrors that of IR based flame detection devices. Flame Mapping is common. SIL rated hardware is available if desired.

This technology works especially well for operations that have minimal outside support and rely upon Control Room operators to trouble shoot alarms and activate emergency shutdown systems.

High sensitivity IR cameras can be programmed to look for thermal anomalies over very large areas, such as warehouses and notify operations / security of potential fires.

This type of detection technology is used as a supplement to traditional fire detection systems in North America. In China, IR camera technology has been coupled with very small, and adjustable fire monitors to provide water based firefighting in buildings with roofs more than 14 meters high; as an alternative to automatic sprinkler protection. Adaption of this technology to outdoor process unit fire protection needs is expected to occur at some point in the near future.

<u>Oil & Mist Detectors</u> are installed in small engine and turbine rooms as well as hot oil pump rooms. These detectors are designed to look for obscuration from an oil mist release rather than a specific type of smoke, but can do both, even if not certified as a fire detection system. Photo-electric smoke detectors can also be pressed into this service or used to supplement the area protection.

5.1.1 Flame Mapping

A Flame Mapping study can help a FGDS designer optimize the layout of IR type fire detectors and/or confirm if redundant detector coverage (if desired) has been obtained. This study is a requirement if the FGDS is part of a QRA.

All flame detectors have a set field of vision. Their ability to detect a fire is limited by

- their distance from the fire,
- the nature (size, intensity and fuel) of the fire and
- their unobstructed view of the fire.

As noted earlier, ISA-TR84.00.07-2018 offers Performance Guidance on Fire and Gas Detection System Design.

- Annex A provides a *sample technique* for selecting and risk ranking targets (equipment that is expected to generate a fire).

- Annex B provides two *examples of procedures* for evaluating fire detection coverage:
    - Geographically based - OR
    - Scenario based

The ISA document offers multiple disclaimers stating these are examples of potential procedures. The reality is that most Flame Mapping Studies published by IR Detector Vendors or other 3rd party experts diligently follow these procedures. As such, it is critical that site personnel understand how these procedures work and what options the owner/users have in calibrating the procedures to meet their needs.

The procedures outlined in both Annexes are complicated semi-quantitative exercises, and as stated in their introduction, are not expected to achieve a risk reduction factor greater than 10.

The Hazard Ranking Procedure within Annex A can be applied to major pieces of equipment or an area. It can be used for both Fire and Gas Detection systems. It has a strong Life Safety bias and is a generic risk ranking tool that does not specifically evaluate fire hazards.

The Risk Ranking example in Annex A of the ISA-TR document is NOT mandatory. Alternate risk ranking tools can be used.

The end result of the process, is that the process equipment/area is risk ranked as

- High,
- Medium,
- Low or
- No Risk.

Anything above No Risk. Is a "Target"

The Risk Ranking of a Target determines the fire or gas detection performance goals for that Target.

The Risk Ranking results should be validated by site personnel (or completed by Site personnel) prior to advancing to the Flame Mapping Step.

Water and steam type equipment and utilities in general should be excluded from this study as flame detectors will not do a good job at identifying fires originating from these Targets.

Once the Risk Ranking and performance goals are set, a Coverage Assessment is done. There are two types of Coverage Assessments: Geographic and Scenario based.

The Geographic Coverage Assessment is the most common choice in the process as it is simpler than the Scenario Coverage Assessment to do. It will be discussed first.

The Geographic Coverage Assessment system measures the ability of a fire detection system to

- monitor a specific volume (cube shaped) in space in and around a Target,
- with one or two (N+1) detectors.

This assessment measures the obstructions to the field of view of the detector(s) as a fraction of the Coverage Area Cube.

<u>DETAILS w/reminders</u>

A) Select the threshold fire magnitude/intensity that requires detection. The standard value is a 1 ft. by 1 ft. pan of heptane.
   - *This can be adjusted per local conditions and fuels. Verify the modeling company understands site fire hazards.*

B) A three dimensional box (cube) is drawn around all, or part of, the Targets using detailed drawings of the area. This box is the "Coverage Area" in Flame Mapping.
   - *Coverage Area size and location should correspond to the actual fire risks posed by the targets.*

- *Process vessels will usually require more than one detector if their Coverage Area is not specific to flanged connections, sample points and other leak points. associated with this equipment.*
- *A sanity check on the Coverage Areas should be done prior to the mapping.*

C) The ability of one and two flame detectors to see the entire Coverage Area is measured by the Mapping Software as a **%** value. Higher is better for this value.
   - The % value requirement is set by the Risk Ranking of the Target. (H=90%, M=80% or L=60%). *These are arbitrary numbers. Site input is needed.*
   - Partial obstructions such as discharge piping can lead to very low values for pump coverage*. Detector location may makes a big difference in coverage.*

D) N+1 detector coverage will increase the reliability of the detection system.
   - *Verify which Targets need N+1 coverage prior to starting the mapping study.*

A Scenario Coverage Assessment approach assigns a fire scenario to a Target (such as pump seal fire) and then models the size, shape and orientation of the flames potentially generated by the scenario.

For outdoor equipment, the flames from a fire are usually modeled to on a 360 degree basis assuming variable wind direction.

The Scenario Coverage Assessment system measures the ability of a fire detection system to

- Detect the flames generated by the scenario.
- with one or two (N+1) detectors.

Detecting the expected flames from a Target fire is usually easier than monitoring 100% of a Coverage Area. The Performance expectations for a Scenario assessment are therefore, usually in the 90% to 100% range.

This approach is far more detailed than the Geographic Coverage Assessment and thus lends itself to a higher degree of quantitative analysis.

<u>DETAILS w/reminders</u>

A) Select the threshold fire magnitude/intensity that requires detection. The standard value is a 1 ft. by 1 ft. pan of heptane.
   - *This can be adjusted per local conditions and fuels. Verify that the modeling company understands site fire hazards.*

B) N+1 detector coverage will increase the reliability and cost of the detection system.
   - *Verify which Targets need N+1 coverage prior to starting the mapping study.*

C) The consequence (flame) modeling process can be time intensive.
   - *A standard list of assumptions can be used to streamline the process.*

5.1.3. Fire Detection System Installation Reminders

For projects involving an existing process unit, a tour of the area with the detector vendor and a marked up drawing showing detector locations is recommended.

- Look for obstructions, steam traps and dripping water near the point of detector installation before the design is finalized.
- IR detectors need to be aimed slightly downward (water runoff) be accessible for cleaning, be out of the way of routine equipment maintenance and never be a personnel safety (head knocker or tripping) hazard.

5.2 Gas Detection Systems

Gas detection systems identify hazardous vapors and gases generated by the loss of primary containment (LOPC) events. The materials of interest can be combustible and/or toxic.

Gas detection systems consist of detection devices and a controller. The detection device or the controller can be integrated into a Basic Process Control System, a Safety Instrumented System or a fire alarm control panel. Confer gas detection supervisory requirements with the technology vendor. Wireless technology options is rapidly growing for many systems.

Gas detection technology selection and design basis is driven by a) the size and nature of the anticipated LOPC event, b) the local conditions and c) the expected / desired response to the LOPC event.

High pressure, unconfined releases of lighter than air materials such as Syngas are very difficult LOPC events to identify. Heavier than air material releases and gases confined inside of buildings are far easier to identify.

Toxic gas detection generally requires a far higher level of detection sensitivity than does combustible gas detection sensitivity.

Unlike fire detection systems, prescriptive RAGAGEPs play a very small role in the gas detection system selection process.

Computer modeling of the LPOC event (gas mapping) can be very useful tool in determining detector placement. More information on this topic is found later in this document.

There are four categories of gas detectors.

- Point Detection
  - Catalyst Bead –
  - Infrared
  - Electrochemical
- Line of Sight (Open Path)
- Acoustic Leak Detection
- Gas Cloud Imaging Camera

Point Detection

Point detectors are the most common type of gas detectors in use. They require direct contact with the vapor/gas and provide a single point of information on the release. They provide information in the form of % of Lower Flammable Level (LFL) and Parts per Million (PPM) by volume. They work best in confined enclosures.

Catalyst Bead

Catalytic gas detectors are the most mature of all the gas detection technologies. A catalytic bead sensor detects any combustible gas that can be oxidized to produce heat. If the gas can burn in the air, this sensor will detect it.

Catalyst bead detectors can be used to detect most combustible gases including hydrogen at lower levels of LFL.

The detectors are relatively inexpensive to install. They require routine calibration and can be poisoned when exposed to very high concentrations of the measured gas. This exposure can result in full or partial loss detector sensitivity. They do not have self-diagnostic capabilities.

Infrared

Infrared gas detectors use an infrared light source to identify a high concentration of a molecule and provide a continuous readout of 0 to 100% of the LFL.

The detectors require very little routine maintenance and are not subject to poisoning by high levels of exposure. They can be used to detect most combustible gases, but not usually hydrogen.

This type of detection is often combined with Line of Sight type gas detectors when a very high level of coverage is desired.

Electrochemical

Electrochemical gas detectors measure the concentration of a gas in air by oxidizing or reducing the gas at an electrode and measuring the current.

These detectors are used for toxic and exotic gases such as hydrogen sulfide, sulfur dioxide, hydrogen, oxygen, carbon monoxide, chlorine, ammonia and nitrogen.

These detectors usually require routine calibration.

Line of Sight (Open Path)

Line of Sight, also known as Open Path gas detection is used to detect gas clouds passing over large areas. It consists of a transmitter and receiver placed in a direct unobstructed line across from each other. The transmitter emits a high-energy beam. The detector unit measures the emitted energy from the beam at specific spectral bands particular to a given gas.

As the transmitter and receiver can be set up to 200 meters apart, this technology is often used to detect releases of heavier than air materials, and other low traveling gas clouds crossing the perimeters of tank farms and process battery limits. These detectors do not provide LFL data or highly specific location information.

Historically, this technology was susceptible to spurious alarms from fog and steam. Its performance has improved over time. It is not suitable for hydrogen detection.

These detectors are robust and require little routine maintenance.

Acoustic Leak Detection

Ultrasonic gas leak detection uses acoustic sensors to identify fluctuations in noise. The acoustic sensors can detect a range of ultrasound frequencies (25KhHz+) while excluding audible frequencies (0 to 25KHz). This technology can identify pressurized gas leaks (such as hydrogen or syngas) without coming into direct contact with the gas regardless of wind direction.

Ultrasonic gas leak detection is restricted to high pressure leaks (> 10 bar/145 psi) that can produce acoustic emissions at levels substantially higher than background noise. They are often located in open outdoor process areas or around big equipment such as gas turbines.

They do not provide information on the leaks in % of LFL or PPM, instead they measured acoustic levels are converted into probable leakage rates.

Their installation requires an acoustic survey of the area be done first.

Gas Clouding Imaging Camera

Gas Cloud Imaging Cameras use hyperspectral imaging technology and machine learning analytics to identify leaks and measure the volume and concentration of the leaked gas.

The cameras are installed in strategic locations (usually at higher elevations) with an expanded range of view. The cameras can pan and zoom and will transmit images to remote monitoring locations. They can be programmed to different types of leaks.

Operators can manage the camera feeds and adjust camera movement as needed through their basic process controls system. Alert levels are built into the software such that the operators don't have to constantly monitor the cameras.

The cameras can detect most combustible and toxic gases. Hydrogen detection may be a problem and should be confirmed with the vendor.

This is very new technology. Long term reliability and performance data is not readily available.

5.2.1 Gas Mapping

Modeling potential combustible and toxic gas releases can be a useful step in the gas detection placement process, particularly in open unconfined areas, inside of enclosed areas with forced ventilation systems or when highly toxic materials are a concern.

Point and Line of Sight gas detectors can be used in combination to identify the leaks.

If a Risk Reduction Factor > 10 is desired for the FGDS, ISA-TRA84-00.007-2018 should be used as a guidance document. Please note that the Example Applications within this document are not mandatory, but just examples.

All Gas Detection Systems designs start with a Hazard Analysis of the area of interest done by knowledgeable persons. The analysis should include

* Materials processed
* Process pressure and temperature
* Potential sources of target gases
* Occupancy of the facility
* Degree of confinement and congestion in the process area

For Performance Based design, this step should be followed by *Identification of Areas of Concern* and *Development of Risk Scenarios.* This is followed by *Analysis of Consequences*. At this stage **gas mapping** can be done.

To do a semi-quantitative analysis, a *Hazard Frequency* for the scenarios will need to be estimated.

These steps are followed by several other risk evaluation steps as detailed in ISA-TRA84-00.007-2018.

The FGDS Mitigation Effectiveness is a function of Detection Coverage (optimized using gas mapping), the FGDS Availability (hardware driven) and the “ability” of the Final Element to mitigate the consequences of the event.

And, while the hardware for many gas detection systems have SIL ratings of 1, 2 or even 3, it is quite difficult to obtain Detection Coverage and Final Element Ability of corresponding reliability.

5.2.2 Gas Detection System Installation Reminders

For projects involving an existing process unit or building, a tour of the area with the detector vendor and a marked up drawing showing detector locations is recommended.

Within enclosed areas identify potential areas of gas accumulation and the workings of the ventilation systems (mechanical and natural).

For outside areas identify prevailing winds and weather conditions that could impact detector performance.

Gas detectors should be accessible for calibration, and be out of the way of routine equipment maintenance and never be a personnel safety (head knocker or tripping) hazard.

Catalyst bead detectors can be poisoned if they are exposed to high concentrations of gases.

Toxic gas detection is different from combustible gas detection, especially from a sensitivity standpoint.

Line of Sight gas detection works best to identify large clouds or to monitor leak sources arranged in a straight line. Their field of vision cannot be obstructed.

APPENDIX A

FGDS Recommendations for Typical Methanol Plant Hazards

Compressors – handling flammable gases

Inside of buildings

Gas Detection

- Point type combustible gas detectors at points of vapor accumulation such as ceiling ridge lines or corners.
- Spot type toxic gas detectors at expected points of product release and along employee egress paths.
- Open path detectors can be installed where there are long open lines of sight.

Fire detection

- Automatic sprinkler or pilot head fire detection systems should be installed at roof level if the roof is less than 30 ft. / 9.5 m high. If the roof is very high, use flame detectors to cover the compressor case, and nearby flanges.
- Thermal detection or smoke detectors should be considered for lube oil systems.
- Flame Detectors or Cameras can be installed at higher elevations to take a panoramic view of the building and its contents.

A combination of Fire and Gas detection systems is common for these buildings.

Outside Equipment

Gas Detection

- Point type combustible gas detectors should be installed above or to the side of the compressor as close as practical to the machine.

Fire Detection

- Automatic deluge water spray systems activated by pilot head heat detection systems are a good fire detection option for compressors with big lube oil systems, such as machines with a steam turbine driver.
- Lube oil systems set underneath the compressor need to be monitored by a thermal detection system or a camera.
- Flame detectors can be used provided they have a good field of vision of the compressor case and associated piping.

Methanol Pumps

Methanol pump FGDS needs are largely driven by the type and size of the pump and its operating conditions.

Low Hazard methanol pumps (< 400 LPM) handling methanol at or near ambient temperatures (30°C)

Gas Detection

- Point type gas detectors installed near points of leak drainage or accumulation (sump) are common if extended duration leaks are a concern.

Fire Detection

- Flame detectors should be installed only if rapid fire escalation is a significant threat. They can be used to activate deluge water spray systems.

High Hazard methanol pumps (>400 LPM) or pumps handling methanol near its boiling point or operating above 10 barg can pose a significant fire and leakage risk.

Gas Detection

- Point type gas detectors installed within two meters of the pumps seal.

Fire Detection

- Pilot head fire detection systems are common if automatic deluge water spray systems are employed.
    - For outdoor processes the pilot heads and deluge water spray nozzles are typically set about 2 meters above the pumps
    - Indoor process units usually have these devices installed near the ceiling, but may drop down a pilot head over pumps in congested areas.
- Flame detection systems are a good option when a quick response is needed and/or no fixed fire protection systems are provided for the pumps or the area.
    - The flame detectors should have a clear and unobstructed view of the pumps and connecting piping and should be placed as to not interfere with routine maintenance.
    - One detector may be able to view more than one pump, however, in congested areas two detectors are usually used to supervise a pair of pumps.

NOTE: Supervised tandem seal pumps or “seal-less” technology pumps reduce, but do not completely eliminate, the leakage and fire risk. Depending upon the pump’s location and set up, these lower hazard technologies can be used as an alternative risk mitigation strategy.

Methanol Process Vessels

Process vessels containing significant amounts of methanol (such as > 2 m3) and operating above 5 barg can generate large leaks with or without a fire present. Temperature and the number of flanged connections increase the risk level as well. Accumulators, condensers, reboilers and filter vessels often meet this criteria.

Gas Detection

- Point type combustible gas detectors installed near drainage trenches or above areas of accumulation (sump) can identify leaks from multiple targets. IR based detectors are better here than catalyst bead detectors.

Fire Detection

- Pilot head heat detection systems set up in a gridded manner or on a vessel specific basis are often used in these areas to activate deluge water spray systems.
- Flame detection systems are a good option when a quick response is needed and/or no fixed fire protection systems are provided for the area or vessels.
    - Flame detectors are usually aimed at specific high risk areas on the vessels, although they can also be oriented to provide general area coverage.
    - Flame Mapping is an option; however, the fire hazard analysis and coverage determination assessments done at the front end of the mapping processes need the direct involvement of process personnel.

Methanol Storage Tanks

Storage tanks with fixed roof tanks or having internal floating roofs are generally not good candidates for FGDS installations unless there are extenuating circumstances such as:

There are multiple tanks and transfer pumps in a common diked area

The transfer pumps do not have readily accessible shut off valves or EIVs.

Gas Detection

- Point type gas detectors at sumps and within 2 meters of transfer pumps are the simplest way to achieve coverage.
- Line of Sight gas detection can be used to cover very large areas instead of multiple point type detectors.

Fire Detection

Fire detection for storage tanks is not recommended unless a local foam system or deluge water spray system needs activation or the tank farm is very large or effectively unattended AND there is no Gas Detection System in place.

If a fire detection system is desired, avoid detection systems with sensitive electronic parts. Instead consider installing:

- Linear thermal fire detection systems can be wrapped around the roof and over transfer pumps.

For tank farms with 20+ tanks, or large (50+ meter ID) open floating roof tanks.

- flame detectors and IR cameras can be used to monitor multiple tanks at once.

Process Gas Release

Syngas, methanol vapors, carbon monoxide, hydrogen, carbon dioxide and methane are usually handled at elevated temperatures and pressures in Methanol Plants.

When these gases leak from a flange located outdoors, they are extremely hard to identify as they disperse rapidly.

IR Flame and/or IR Camera type Gas Detectors can be installed to provide coverage over large open areas or expected emergency egress routes and personnel meeting / assembly areas.

Acoustic Gas detectors can be located in remote production areas where high pressure flange leaks have been identified as a potential problem.

Overhead Fin Fan Units

Overhead (air cooled) fin fan type heat exchangers are used to cool syngas or condense methanol vapors. Given the high air flow rates inherent to their operation and their typical high elevation, detecting gas leaks from a process tube or flange is extremely difficult. IR Camera type Gas Detectors are the only detection option that might work consistently.

The primary fire hazards to Fin Fan Units are generated at grade level. The heat generated by pool fires or process equipment fires located underneath them can be pulled into the Fin Fan Units resulting in unit failure and even collapse onto equipment below. Deluge water spray systems activated by pilot head fire detection systems can be installed underneath the Fin Fan Unit banks to protect them from external fire hazards.

Computer Rooms (Servers and I&O Rooms)

Smoke detection systems are usually installed in these rooms, even if they are protected by an automatic sprinkler system.

Typically, the more important the room and its contents are, the more sensitive the smoke detection system needs regardless of the Emergency Response Strategy.

Air Aspirating and Laser Smoke detection technology should be used for very sensitive and clean occupancies with an Emergency Response Strategy time requirement of less than 10 minutes. Typically, this means an automatic fire suppression system or on-site technicians.

Point type gas detectors can be installed in the inlet air supplies to this room for personnel protection or for electrical classification purposes.

Electrical Buildings (Motor Control Centers and Substations)

Conventional photoelectric and ionization smoke detectors are usually installed in these areas even if they are connected to a Clean Agent Fire Suppression System.

Point type gas detectors can be installed in the inlet air supplies to this room for personnel protection or for electrical classification purposes.

Other Equipment

Equipment handling **water**, **nitrogen, steam** or **compressed air are not good candidates for fire or gas detection systems** regardless of how critical they may be to production. If this equipment is placed inside a wooden structure, fire detection should be considered.

Gas fired equipment located indoors pose a building exposure hazard, which a methane detector might be able to reduce.

Ammonia refrigeration and scrubbing systems pose a toxic gas and fire/explosion hazard. There are specific industry guidelines for ammonia handling and storage. They will be different from those for making, handling and storing methanol.

Summary

Step 1 is Identifying and understanding the specific fire or gas releases scenario(s) of interest.

Step 2 is determining what actions need to be taken once the FGDS identifies a scenario to reduce the consequences to an acceptable level.

Step 3 is determining how sensitive and reliable the FGDS needs to be.

After these steps are completed, the FGDS technology can be chosen and implemented in the field per local conditions.

APPENDIX B

FGDS Activation Options

OPTION 1

The FGDS is set up as an alarm only. No process or fire protection equipment is interlocked. The FGDS Alarm goes to the Control Room and/or the Fire Department. Site Actions should generally follow the below sequence.

- Initiation of Evacuation procedures.
- Alert the Emergency Response Team
- Outside Operators investigate the issue with caution and,
    - conduct area mitigation measures such as
        - Close accessible process valves to minimize fuel release
        - Activate fire protection systems
    - Provide Control Room with additional information
- Board Operators initiate trouble shooting
    - Isolate leak source if possible with remote operated valves.
    - Initiate emergency shut down procedures
- Emergency Response Team Responds
    - Verifies personnel safety
    - Closed critical valves that are accessible
    - Initiate firefighting actions and
        - Extinguishes fire by…
            - Manually blocking in leak, or
            - Controls the fire spread until the fuel supply is exhausted

OPTION 2

The FGDS is interlocked with process, utility or fixed fire protection systems.

The goal being to reduce the fire risk by: a) bringing the operation down in a safe manner, b) isolating the leak and/or c) activating fixed fire protection systems.

FGDS based interlocks work in the same manner as process control system based interlocks. Device voting systems and multiple high level alarm points are used to reduce spurious trips.

Interlock Options (common to rare in descending order)

- Activate Deluge Water Spray Systems
    - Typically done with fire detection systems unless vapor suppression is desired.
    - Single device actuation is typical.
- Activate Foam Systems – Deluge or Sprinkler type
    - Typically done with fire detection systems unless vapor suppression is desired.
    - Single device actuation requirement is typical.

- Activate Foam Systems – Foam Chambers on storage tanks or diked areas.
    - Typically done with fire detection systems
    - Dual device actuation requirement is typical.
- Activate Clean Agent Extinguishing Systems
    - Typically done with fire detection systems
    - Dual device actuation requirement is typical. (smoke detectors)
- Activate Inerting or Ventilation System
    - Typically done with gas detection systems
    - Dual device actuation or high high alarm level requirement is standard
- Shut down Emergency Isolation Valves
    - Can be done with any type of FGDS
    - Thermal Detection such as Fusible Links are the most typical initiating device for this service.
- Shut down specific Process Equipment
    - Very rarely done. If done, usually tied to activation of multiple FGDS detectors.
- Initiate Process wide Emergency Shutdown System
    - Very, very rarely done unless there is a very large personnel safety issue involved.
    - Shutting down a specific piece of equipment or even a single valve may trigger a process wide shut down.