HYDROGEN FLUORIDE (HF) PERIMETER MONITORING

Comparison between Laser Based – Open Path Gas Detection and Traditional – Fixed Point Gas Detectors.

HIGH HAZARD RANK APPLICATION
APPLICATION OVERVIEW

HF ALKYLATION UNIT
The Refinery is required to follow the American Petroleum Institute (API) Recommended Practice 751 for the ‘Safe Operation of Hydrofluoric Acid Alkylation Units’ – for more information click here.

The End-User had been using Traditional – Fixed Point Gas Detectors that have been a continual maintenance burden and operations had lost faith in the detectors due to reliability issues.

The End-User has been looking for an alternative for their Hydrogen Fluoride (HF) Electro-Chemical Sensors as a Quantitative Risk Assessment (QRA) determined that additional detection was required to suitability Mitigate Risk.

It was determined that Laser Based – Open Path Gas Detection was to be used at the perimeter boundary of the Hydrogen Fluoride Alkylation Unit.

Boreal Laser’s Open Path Gas Detectors protect over 80% of the world’s Hydrogen Fluoride (HF) Alkylation Units.

HIGH HAZARD RANK APPLICATION
According to the Semi-Quantitative Hazard Assessment of ISA TR84.00.07-2018, this is considered a ‘Grade A’ High Hazard Rank Application primarily due to:

1) High mechanical probability of failure of the equipment within the process area.

2) High pressures and concentrations of the gas.

3) High confinement and congestion within the process area.

This ‘Grade A’ Hazard Rank means that a “life-threatening toxic hazard could occur from a relatively small gas release at a distance well outside the localized area of release”.

THREAT OF A RELEASE
To demonstrate that a “life-threatening toxic hazard could occur from a relatively small gas release”, we used the USEPA’s Aloha within Figure 1.

The USEPA has developed a modeling software called ALOHA (Areal Location of Hazardous Atmospheres) which is used widely to plan for and respond to chemical emergencies.

ALOHA allows you to enter details about a real or potential chemical release, and then it will generate threat zone estimates for various types of hazards.
OPEN PATH GAS DETECTION

PATH PLACEMENT & AREA COVERAGE

Four (4) Laser Based – Open Path Gas Detectors were installed on the perimeter boundary of the process unit. These are as shown below in Figure 2.

FIGURE 2 – AREA OF INFLUENCE

The shaded ovals represent the 5m (15ft) radius of the Geographic Area Coverage of each Laser Based – Open Path Gas Detector.

DETECTION PLACEMENT:

For Open Path Gas Detection, it is typical to mount the paths at a height between 2m (7ft) to 4m (13ft) above grade.

This helps to minimize beam block but will still be mounted low enough to detect the plume of gas.

The Geographic Area of Influence also has a radius of 5m (15ft), which will extend down to grade (shown in Figure 3).
FIGURE 3 – MOUNTING HEIGHT

Laser Based – Open Path Gas Detection is typically mounted at a height between 2m (7ft) - 4m (13ft).

FIGURE 4 – TIME LAPSE WITH LASER BASED – OPEN PATH GAS DETECTION:

EXPLANATION OF NOISE
Zero Gas Noise can be generated from spectroscopic, mechanical, or atmospheric sources. Zero Gas Noise can produce gas concentrations up to two (2) times our published Minimal Detectable Limit (2x MDL) – this is defined as our Lowest Actionable Concentration (LAC).

Boreal Laser’s published Lowest Actionable Concentration (LAC) for Lo-Range Hydrogen Fluoride (HF) it is 0.8 ppm-m.

The Logfiles from the GasFinder were pulled to review the collected data. The concentrations of Hydrogen Fluoride (HF) detected ranged from 20-160 ppm-m which is well beyond the Lowest Actionable Concentration (LAC) – these ‘alarms’ were real.

AFTER COMMISSIONING
SPURIOUS ‘FALSE ALARMS’
One (1) month after the Laser Based – Open Path Gas Detectors had been commissioned, the End-User called saying that they’re experiencing ‘instrument noise’ and that operations is losing confidence in the system due to the ‘false alarms’ as shown in Figure 4.

Operations was adamant that there were no leaks during this time and there was no correlation or response from the Electro-Chemical Sensors to prove otherwise.

Maintenance sent over a screenshot of their Human Machine Interface (HMI) that showed the ‘false alarms’ that occurred over a one (1) month period.
OPEN PATH - ALARM THRESHOLDS
Setting Alarm Thresholds for Open Path Toxic Gas Detectors is easy and straightforward.

Step #1 - You will start by using the same Part Per Million (ppm) Alarm Thresholds you would for Fixed Point Gas Detectors:
- **Hi-Alarm**: 3 ppm
- **HiHi-Alarm**: 9 ppm

Step #2 - For Open Path Toxic Gas Detection, we’ll need to use the industry based assumptions for plume sizes based upon the confinement of the area:

- Within *Enclosed or Congested Areas*, it is assumed that the plume could be between 5-10 m (15-30 ft) in diameter by the time it is passing through the Active Measurement Path.

- Within *Open Areas*, it is assumed that the plume could be between 10-20 m (30-60 ft) in diameter by the time it is passing through the Active Measurement Path.

Since this is a perimeter monitoring application and in an *Open Area*, we’ll use the more conservative *10 m assumed plume size*.

Step #3 – Multiply the Part Per Million (ppm) Alarm Threshold by the Assumed Plume Size:

**Open Path Hi-Alarm Threshold:**
3 ppm (Hi-Alarm) \( \times \) 10 m (Plume) = 30 ppm·m

**Open Path HiHi-Alarm Threshold:**
9 ppm (HiHi-Alarm) \( \times \) 10 m (Plume) = 90 ppm·m

For more information, visit our [website](#).
FIXED POINT GAS DETECTORS

DETECTOR PLACEMENT
Within the HF Alkylation Unit, there were several Electro-Chemical Sensors used to detect Hydrogen Fluoride (HF) as shown below in Figure 6.

FIGURE 6 – DETECTOR PLACEMENT:

GEOGRAPHIC AREA COVERAGE
FIGURE 7 – AREA OF INFLUENCE:

Geographic Area of Influence
5m (15ft) Radius
is based upon the
Smallest Gas Volume of Concern
5m (15ft) Diameter

If the Geographic Area of Influence covers the percent volume of the defined process area, then the Area Coverage requirements are met.

In High Hazard Rank Applications within Enclosed or Congested Areas, it is assumed that each of the Gas Detectors has a Geographic Area of Influence (i.e., a radius) of 5m (15ft).

While the physical contact area of the Electro-Chemical Sensors is only around 1 square inch, the Geographic Area of Influence comes from the smallest gas volume of concern, which is a plume diameter of 5m (15ft).

As shown in Figure 8, the Traditional – Fixed Point Gas Detectors look as if they should provide excellent Geographic Area Coverage.

The green circles around the Gas Detectors highlight the Geographic Area Coverage.

FIGURE 8 – GEOGRAPHIC AREA COVERAGE:

NO RESPONSE TO SAMPLING
At first, operations had lost faith in the Laser Based – Open Path Gas Detector as they were unaware of the sub-ppm detection thresholds and one (1) second speed of response. Operations worries quickly moved to the performance of their Electro-Chemical Sensors.

Not only had the operational activity of sampling produced concentrations that exceeded the Open Path HiHi-Alarm Threshold (i.e., 90 ppm-m) but there was no evidence of a response from the Electro-Chemical Sensors.

Operations wondered what else they may have been exposed too.
SPEED OF RESPONSE

The Center for Chemical Process Safety recommends that “the response time for toxic [gas detectors] should be within 30 seconds of initiation analysis” (i.e., T90 Response Time <30 Seconds) so the Final Control Elements can prevent a further Escalating Scenario.

One of the possible explanations is that Electro-Chemical Sensors used to detect Hydrogen Fluoride (HF) have T90 Response Times that are impermissible for use in Fire & Gas Safety (FGS) Systems due to their slow speeds of response.

See the table below in Figure 9 for the T90 Response Times published by the respective manufacturers.

T90 Response Times are defined as the amount of time the detector requires to register at least 90% of the exposed concentration.

**FIGURE 9 – T90 RESPONSE TIMES:**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Detectable Range</th>
<th>T90 Response Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensidyne (SensAir)</td>
<td>0-10 ppm</td>
<td>&lt;45 sec</td>
</tr>
<tr>
<td>Teledyne (Model 100)</td>
<td>0-100 ppm</td>
<td>≤90 sec</td>
</tr>
<tr>
<td>ATB Analytics (Sure-Shot)</td>
<td>&gt;1,000 ppm</td>
<td>30 sec [Catastrophic Releases Only]</td>
</tr>
<tr>
<td>Honeywell (Series 3000)</td>
<td>0-12 ppm</td>
<td>300 sec</td>
</tr>
</tbody>
</table>

Often Alarm Thresholds are set much lower than where the T90 tests occur but nevertheless, the speed of response from Electro-Chemical Sensors for Hydrogen Fluoride (HF) are too slow to be the primary sensing element to initiate executive action such as direct actions on process or evacuation.

**EFFECTIVE DETECTION RATE**

**FIGURE 10 – DETECTION NOT GUARANTEED:**

It is difficult if not impossible to predict exactly where a plume of gas will travel. While buoyancy of the gas needs to be considered, the wind/air currents can heavily influence the trajectory of the plume. Especially for Traditional – Fixed Point Gas Detectors, it is highly probable that it can be mounted within a ‘measurement dead zone’ where the plume of gas physically cannot travel too.

The Center of Chemical Process Safety states that it is seldom appropriate to mount Gas Detectors close to the source of release. This is especially true when the process contains elevated pressures because the initial momentum jet can push beyond the Gas Detector. It is ideal to mount the Gas Detectors far enough back that the momentum jet has
had a chance to decelerate, and the plume has had a chance to form.

**FIGURE 11 – LEARNED BODIES**

“A “credible” release may not necessarily be detectable with any degree of certainty.” – Center of Chemical Process Safety

“Release data showed that the effective detection rate was at best 60%.” - ISA-TR84.00.07-2018

“Approximately 36% of major gas releases and 69% of significant gas releases were undetected by gas detectors.” – UKs HSE RR1123

There are three (3) Learned Bodies that have published independent studies that have shown that Traditional – Fixed Point Gas Detectors (i.e., Electro-Chemical and Catalytic Bead Sensors) may not be as effective as hoped:

1) “A “credible” release may not necessarily be detectable with any degree of certainty.” – Center of Chemical Process Safety.

2) “Release data showed that the effective detection rate was at best 60%.” – ISA-TR84.00.07-2018.

3) “Approximately 36% of major gas releases and 69% of significant gas releases were undetected by gas detectors.” – UKs HSE RR1123.

**FIGURE 12 – SIMPLE PATH PLACEMENT:**

Due to the large area coverage, fail-safe capabilities, and fast speed of response, this greatly simplifies placement of the Laser Based – Open Path Gas Detector.

Increasing the Geographic Area Coverage has the single greatest effect on improving the overall Risk Mitigation Capabilities of the Fire & Gas Safety (FGS) System.
GET YOUR DESIGN RIGHT

STARTS WITH THE SENSING ELEMENT

In High Hazard Rank Applications, Laser Based – Open Path Gas Detection has the following advantages over Traditional – Fixed Point Gas Detection that enables you to make the SAFe Decision (i.e., Suitable, Acceptable, and Feasible):

1) **Suitability:** Laser Based – Open Path Gas Detectors thrive where Traditional – Fixed Point Gas Detectors do not survive (i.e., Frequent/Continuous exposure to Gas and High/Low Temperatures & Humidity), along with not requiring routine calibrations/intervention and not having any consumable parts.

2) **Acceptability:** While Laser Based – Open Path Gas Detection compared to Traditional - Fixed Point Gas Detection will provide the Fire & Gas Safety (FGS) System with greater Risk Reduction Factors (RRF) due to its Larger Area Coverage, Faster Speed of Response, and Fail-Safe/Diagnostic Capabilities.

3) **Feasibility:** Due to the High Hazard Rank, the application will require High Detector Area Coverage and Laser Based – Open Path Gas Detection will be the more economical solution, especially if replacing >4-5 Traditional – Fixed Point Gas Detectors.

In High Hazard Rank Applications, Laser Based – Open Path Gas Detection can help protect the reputation of the engineers designing the Fire & Gas Safety (FGS) System, reduce the liability to their organization, and protect personnel in the field by focusing on the three (3) items below:

1) **Your application may be more Hazardous than originally thought** because modelling shows that Life Threatening Concentrations may extend further and faster than anticipated.

2) **Your application may need more Gas Detectors than what was originally designed** because the Recognized and Generally Accepted Good Engineering Practices (RAGAGEP) for High Hazard Rank Applications are now requiring greater Geographic Detector Area Coverage than before.

3) **Look at Vendor Supplied Data and assess in your application if Traditional – Fixed Point Gas Detectors provide you with the Speed of Response required** for your Fire & Gas Safety (FGS) System to provide the Recovery Actions required to adequately Mitigate the Risk (e.g., Evacuate, Shelter-in-Place, or making Direct Actions to Process like De-Energize, Isolate, De-Pressurize, etc.).
How to Mitigate Risk

Risk Reduction Factors (RRF’s)

Figure 15 – Specifics to Mitigating Risk:

Detect the Hazard

Confirm Release

Recovery Actions

The Center for Chemical Process Safety recommends that “the response time for toxic [gas detectors] should be within 30 seconds of initiation analysis” (i.e., T90 Response Time <30 Seconds) so the Final Control Elements can prevent a further Escalating Scenario.

Our product is an Enhanced Sensing Element called Laser Based – Open Path Gas Detection that provides the easiest and most cost-effective way to significantly improve the Risk Mitigation capabilities of their Fire & Gas Safety (FGS) System (i.e., increasing Risk Reduction Factors (RRFs)) by specifically focusing on strengthening these three (3) critical areas:

1) Geographic Area Coverage: Increasing the Probability of Detection offers the greatest Risk Reduction Factor (RRF) return.

2) Safety Availability: Use a SIL2 Suitable and Fail-Safe Device that survives leaks and releases of gas.

3) Mitigation Action Effectiveness: Prioritize being able to Alarm Faster and at Lower Concentrations.

#1 - Geographic Area Coverage:

Figure 16 – Probability of Detection:

Traditional - Fixed Point Gas Detectors vs. Lased Based – Open Path Gas Detectors

Laser Based – Open Path Gas Detection is the most economically viable option to minimize both the Total Install Cost + Total Operational Cost (TIC-TOC) in High Hazard Rank Applications.

According to ISA TR84, for a ‘Grade A’ High Hazard Rank Application, to sufficiently protect your reputation, limit your own personal liability, and protect your colleagues - your design will require greater than 90% Geographic Area Coverage.

For ‘Grade A’ Hazard Rank Applications (HHRA) that require ≥90% Geographic Area Coverage, Laser Based – Open Path Gas Detectors (LB-OPGD) provides a solution that significantly increases the Probability of Detection, greatly simplifies Detector Placement, and is often the more Economically Feasible option to enable you to reduce your risk and stay under your projects budget.
#2 - SAFETY AVAILABILITY

FIGURE 17 – FAIL-SAFE SENSING ELEMENTS:

Gone are the days of living under the illusion of protection with Traditional – Fixed Point Gas Detectors. The Fail-Safe Operation and Smart Diagnostics of Laser Based – Open Path Gas Detectors (LB-OPGD) will raise a specific status inhibition or fault conditions the moment the detector is no longer protecting your colleagues and yourself.

FIGURE 18 – NO CALIBRATION

With Laser Based – Open Path Gas Detection, there is no longer a requirement for routine calibration or calibration gases. With the Internal Reference Cell, all the adjustments to eliminate measurement drift are done autonomously and automatically.

The Function Test is easy to perform, simply hold the response cell within the Laser Beam to ‘Bump’, ‘Challenge’, or ‘Verify’ a response to actual target gas.

#3 – EFFECTIVE MITIGATION ACTION

FIGURE 19 – TIMELINESS OF ALARMS:

As per ISA TR84, “Fixed Detectors are the primary means of safety to alert personnel who either are not in the area at the time or are within the area but not immediately exposed to a hazardous release. The goal is to either prevent personnel from entering the area or evacuating personnel from the area, depending on their initial location”.

Laser Based – Open Path Gas Detection can enhance your Mitigation Action Effectiveness by:

1) Quickly and confidently alarm at incipient levels that are As Low As Reasonably Practical (ALARP).
2) Rapid recovery actions prevent a further escalating event (i.e., prevents a bad scenario from getting any worse).
FINAL THOUGHT EXCERCISE

WHAT IF ONLY ONE THING CHANGED?
Suppose that operational or maintenance personnel was in an adjacent process unit that was downwind at the time of the sample procedure taking place – remember they do not don the same PPE.

In this instance, Electro-Chemical Sensors were proven to not illicit a response to concentrations that exceeded the HiHi-Alarm Threshold. The fortunate point in this instance is that the release was intermittent.

However, how confident are you that the Electro-Chemical Sensors can detect small incipient leaks from the packing of a valve or the seal of a pump?

These releases are continuous and have the potential to accumulate – the Center of Chemical Process Safety states that plume can easily travel >30m (>100 ft) in 15-30 seconds.

If you cannot find and fix the small leaks, then you're much more likely to create an escalating scenario to where you can no longer adequately mitigate the risk.

MITIGATION OF ENOUGH RISK

For Grade ‘A’ High Hazard Rank Applications, the requirement is for the design of you Fire & Gas Safety (FGS) System is improve the Risk Reduction Factors by a factor of 10.

The purpose of the Risk Reduction Factors (RRFs) is to reduce the frequency of occurrence and the severity of harm. When grading the effectiveness of your Fire & Gas Safety (FGS) System, it is on its ability to detect and mitigate the design based hazard.

In the event of an incident in your facility, are you confident that you’ve mitigated enough risk?

Knowing now what we do, as a Technician, Engineer, or Manager – are you 100% confident about using Traditional – Fixed Point Gas Detection for your next High Hazard Rank Application?