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TABLE OF CONTENTS

AD INDEX


3
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XCell®
SENSORS

Forestall Fire and Explosion Hazards from Liquids

Understand the factors that lead to risk and the available mitigation options

By Vahid Ebadat, Stonehouse Process Safety

Many process plants handle flammable liquids. Sometimes, the vapor of such a liquid forms a flammable concentration inside process equipment and, sometimes, even outside that equipment. This can pose risk of fire, flash fire or, if the vapor resides within a vessel or a building, explosion. All cases in which flammable vapors occur demand special study and precautions to control this risk to ensure the safety of people, plant, community and your business.

In this article, we'll look at how the properties of volatile liquids influence fire and explosion risk, and how developing a "basis of safety" can mitigate this risk. We'll specifically consider the techniques available for risk reduction through vapor control, use of inert gas, ignition source control, and explosion protection — and the importance of effective implementation and upkeep of safety measures.

ASSESSING THE RISK

A fire or, indeed, a flash fire will occur when a fuel (a flammable liquid vapor), an oxidant (usually the oxygen in air), and an ignition source concurrently exist in one location. These three elements are commonly visualized as the "sides" of a fire triangle. If these three elements are concurrently present within a confined space, an explosion will result.

To begin the assessment of the risk of fire or explosion at a facility and to determine the necessary measures for ensuring safety, you must gather certain information on the flammability characteristics of the liquids (and their vapors) on site. This information relates to conditions for forming a flammable vapor atmosphere, the vapor's ease of ignition, oxygen levels to prevent explosion and the pressure of explosion.

You must assess several safety-critical flammability properties:

- Conditions for combustion — flash point per ASTM D93, and lower and upper flammability limits (LFL and UFL) per ASTM D681;
- Ease of ignition — minimum ignition energy (ASTM E582), and auto-ignition temperature (ASTM E659);
- Controlling oxidant — limiting oxygen for combustion (ASTM E2079); and
- Explosion effects — maximum explosion pressure (EN 13673-1), and maximum rate of pressure rise (EN 13673-2).

Note that processing conditions such as temperature, pressure and presence of second phases/mixtures influence the flammability characteristics of liquids. Unfortunately, very limited data are available on the flammability properties of liquids or liquid mixtures at low and elevated temperature and pressure conditions. Therefore, if you are handling/processing flammable liquids at conditions other than ambient temperature and atmospheric pressure, you must experimentally determine their flammability properties at representative process conditions.

MANAGING THE HAZARDS

Properly dealing with fire and explosion hazards requires control of three key elements — vapor concentration, oxidant concentration and ignition sources — as well as effective explosion protection.

Control of vapor concentration. Methods of controlling the vapor concentration at a safe level include maintaining the liquid below its flash point temperature or providing adequate ventilation to keep the concentration of vapor under its LFL.

Flash point is defined as the lowest temperature, corrected to the standard atmospheric pressure of 14.692 psi (760 mm Hg), at which enough vapor exists above a liquid surface to form an ignitable/flammable mixture with an oxidant (usually the oxygen in air). Therefore — if possible — maintaining the liquid temperature below its flash point will ensure an insufficient concentration of vapor exists above the liquid surface to form a flammable mixture.

You can measure flash point via either closed-cup or open-cup methods. The closed-cup method prevents the escape/dilution of vapor to the surroundings and therefore results in a lower flash point value. Results from the closed-cup method usually are used to assess flammability conditions within closed process and storage vessels for liquids.

Incorrectly specified electrical equipment can generate arcs and sparks.

For processes where the order of adding various liquids to a vessel isn't critical, it's best to first add the liquid(s) with higher flash point as doing so might reduce the likelihood of the formation of a flammable atmosphere in the vessel.

Providing adequate ventilation would maintain the concentration of vapor in the work area and perhaps within the process equipment under the LFL (preferably below 25% of the LFL).

The supply (and) exhaust of air in a building generally is referred to as dilution ventilation and is intended to dilute the contaminated air with uncontaminated air for controlling potential airborne health hazards, fire and explosion conditions, odors, and nuisance-type contaminants. According to NFPA 30, "Flammable and Combustible Liquids Code", a ventilation rate of not less than 1 $ft^3/min/ft^2$ (0.3 $m^3/min/m^2$) of solid floor area should suffice to maintain the concentration of vapors within the area at or below 25% of the LFL.

Ventilation should include all floor areas and pits where flammable vapors can collect.

Note that dilution ventilation isn't as effective as local exhaust ventilation (LEV) for capturing vapors at the sources of release, for example during liquid dispensing or at the openings of vessels and equipment that contain flammable liquids. LEV is an engineered system that — if correctly designed, installed, utilized and maintained — will capture the vapor at its source and transport it to a safe exhaust point, scrubber, thermal oxidizer or filter.

Control of oxidant concentration. Limiting oxidant concentration (LOC) is the minimum quantity of an oxidant that's required for flame propagation through a homogenous gas/vapor mixture. Replacing oxidant with an inert gas (typically, nitrogen, carbon dioxide or argon) — commonly referred to as inert gas purging/blanketing or simply inerting — can keep oxidant under the LOC. Inerting doesn't replace the flammable vapors but instead reduces the concentration of oxygen to a level insufficient to support combustion. Note that LOC depends on the nature of the fuel as well as the type of inert gas employed.

You can use a number of inerting methods, including vacuum purging, pressure purging, combined pressure/vacuum purging, sweep-through purging and siphon purging, to reduce the oxidant concentration to a pre-determined safe level (Table 1).

Method	Description
Vacuum Purging	A vacuum is drawn on a vacuum-rated vessel until a desired pressure is reached; then the inert gas is introduced up to atmospheric pressure. More than one purge cycle may be necessary to reach the desired oxidant level.
Pressure Purging	An inert gas pressurizes a pressure-rated vessel up to a safe pressure; the inert gas is allowed to diffuse and then the inert gas mixture is vented to atmospheric pressure. More than one purge cycle may be needed to achieve the desired oxidant level.
Combined Vacuum/Pressure Purging	Uses both vacuum and pressure alternately to purge the vessel. The vessel must be pressure/vacuum-rated.
Sweep-Through Purging	Inert gas is added into the vessel through an opening, and the mixed gas is exhausted from the vessel through another opening, usually on the opposite side of the vessel.
Siphon Purging	Vessel first is filled with a liquid such as water or any other compatible liquid. The inert gas is added to fill the space as the liquid is drained out of the vessel.

INERTING METHODS
Table 1. These are common options for inerting.

Safety Margin			
Oxygen concentration is continuously monitored and controlled with safety interlocks		Oxygen concentration is not continuously monitored and controlled with safety interlocks	
LOC ≥ 5%	LOC < 5%	LOC ≥ 7.5%	LOC < 7.5%
Operate at least 2% below worst credible case LOC	Operate at no more than 60% LOC	Operate 4.5% below the worst credible case LOC	Operate at no more than 40% of the LOC

REQUIRED SAFETY MARGINS
Table 2. NFPA 69,"Standard on Explosion Prevention Systems," mandates these margins.

Table 2 summarizes the safety margins required by NFPA 69, "Standard on Explosion Prevention Systems," based on the LOC value and whether the oxidant concentration is continuously monitored.

Generally, control of vapor concentration, if viable, is a better option than inerting, which poses an inherent asphyxiation hazard if containment of the inert gas is lost.

Control of ignition sources. This involves identifying and eliminating all credible ignition sources that would have sufficient energy to ignite the flammable atmosphere under both normal and foreseeable abnormal operations. Typical ignition sources include heat sources, friction/impact sparks, electrical arcs and sparks, and electrostatic discharges.

In processes where heat is applied (e.g., drying of solvent wet materials), you must maintain the temperature below the auto-ignition temperature. Additionally, you should insulate/shield hot surfaces.

Measures to avoid friction/impact sparks in locations where flammable atmospheres may exist include:

- Regular inspection and maintenance of mechanical equipment to prevent overheating and sparking due to their failure;
- Conducting hot work operations under a "hot work permit" system in accordance with NFPA 51B, "Standard for Fire Prevention During Welding, Cutting and Other Hot Work."

Incorrectly specified electrical equipment can generate arcs and sparks. Therefore, you must ensure that the electrical equipment suit their operating environments. Article 500 of the National Electrical Code/NFPA 70 contains guidelines that specify hazardous area classifications and determine the type and design of equipment and wiring methods permitted in classified areas. The intent of Article 500 is to prevent electrical equipment from providing a means of ignition for an ignitable atmosphere. NFPA 497, "Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas," provides guidance on classification of locations for vapor/air atmospheres.

General precautions for controlling electrostatic ignition sources include:

- Preventing accumulation of static charges on conductive (metal) items with effective bonding and grounding so the items remain at zero electrical potential (voltage). A resistance to ground less than 106 ohms generally suffices for this purpose. Effective bonding and grounding requires identifying and grounding conductive equipment and objects within a process that could become electrostatically charged, as well as periodic inspection and testing of the bonding and grounding systems.
- Ensuring people are properly grounded. The human body is a conductor and, if left electrically insulated from ground during normal activity, the voltage (potential) on the body typically can reach 10–15 kV. This translates into a spark energy in the range of 10–30 mJ. Operators can become electrostatically charged by actions such as walking on an insulating surface, manually pouring liquids and powders from one container to another, or brushing against surfaces.

Use of static dissipative footwear combined with conductive or static dissipative flooring provides a practical means to ensure grounding of people working in locations where flammable atmospheres might exist. Static dissipative footwear must have a resistance-to-earth between 106 ohms and 108 ohms. Alternatively, personnel can use grounding wrist straps but these may not be practical where people must move around.

An explosion can propagate through ducts, pipes, chutes, conveyors, etc.

- Considering use of conductive or static dissipative items such as containers, hoses, liners and coatings with a surface resistivity <1011 ohm/square instead of non-conductive (insulating) items that could accumulate electrostatic charges and readily ignite flammable vapor atmospheres.

Explosion protection. If you can't prevent formation of a flammable atmosphere and can't reliably identify and eliminate all sources of ignition, then the possibility of a fire, flash fire or explosion exists. Under such conditions, you should implement explosion protection measures to safeguard people and minimize damage to facilities. Of course, you still should take all reasonable steps to reduce the possibility of formation/spread of flammable atmospheres and to exclude potential ignition sources. Explosion protection measures include:

- Explosion containment — This involves constructing the equipment to withstand the maximum explosion pressure resulting from the deflagration of the fuel/air mixture within the equipment.
- Explosion suppression — Early detection of an explosion and rapid injection of a suitable flame suppressant can prevent the explosion pressure from reaching a level that could damage the equipment. After activation, the system will attain a "safe" reduced pressure well below the unsuppressed explosion and prevent enclosure rupture and damage.
- Explosion relief vending — The underlying principle here is that an explosion in a vessel causes relief vent(s) of sufficient area to open rapidly and relieve hot gases and (burning) materials to a safe location and prevent over-pressurization of the protected enclosure. Relief venting is relatively inexpensive compared to containment and suppression methods and is simple to install and maintain in many cases. Venting of explosion products (flame, heat and materials) to the inside of a building usually isn't acceptable unless you can install a vent duct to direct the products of combustion, from the vent to a safe location outside the building or consider a flameless vent.
- Isolation — An explosion can propagate through ducts, pipes, chutes, conveyors, etc. Therefore, regardless of the type of explosion protection method under consideration, you also must consider "explosion isolation" measures to prevent the explosion from propagating from where it originates to other locations in the facility. The first step in isolating an explosion is to avoid unnecessary connections. If this isn't possible, consider mechanical or chemical isolation systems.

PROPERLY TACKLE RISKS

To effectively evaluate and manage flash fire and explosion hazards, you must:

- Assess the explosibility characteristics of all potentially flammable liquids at your plant;
- Understand your processes and operations well;
- Perform flash fire and explosion hazard analyses to identify locations where flammable atmospheres are, or could be, present under both normal and abnormal conditions; potential ignition sources, again under normal and foreseeable abnormal conditions; and the effectiveness of existing safety measures;
- Establish a "basis of safety" — practical measures for prevention, protection and isolation to ensure safety;
- Ensure in-house process safety competency;
- Implement written safety management programs; and
- Conduct regular inspection and maintenance of equipment and the facility. ●

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Take a Layered Approach to Safety

Combine sensor technologies to mitigate gas and flame risk

By David Opheim, MSA Safety

One of the most important jobs in the hydrocarbon refining, petrochemical and pipeline industries is fire safety, followed closely by dangerous gas and vapor leak detection, repair and mitigation. With many facilities now running 24/7 365 days per year, the need for well-maintained, safe and secure complex plant processes and equipment is higher than ever.

In addition, many facilities include unmanned hazardous processes such as high operating process pressures, temperatures and large volumes of product throughput required for efficiency and to meet customer demand.

In these types of facilities, the risk of combustible or toxic gas release and open-area fire ignition is an especially significant hazard. Many sites also include the potential for serious propagation of fire or explosion when flammable liquid or gas storage tank farms, pipeline compressors or fuel transfer loading terminals are located nearby. The impact of such events unfortunately is well-known, including loss of life, injury, damage to equipment and operations and adverse effects on surrounding communities and the environment.

The good news is new flame and gas detection system technologies now are available offering enhanced detection and diagnostic capabilities. These capabilities optimize detector availability, accuracy and sensor health to help provide optimal onsite protection.

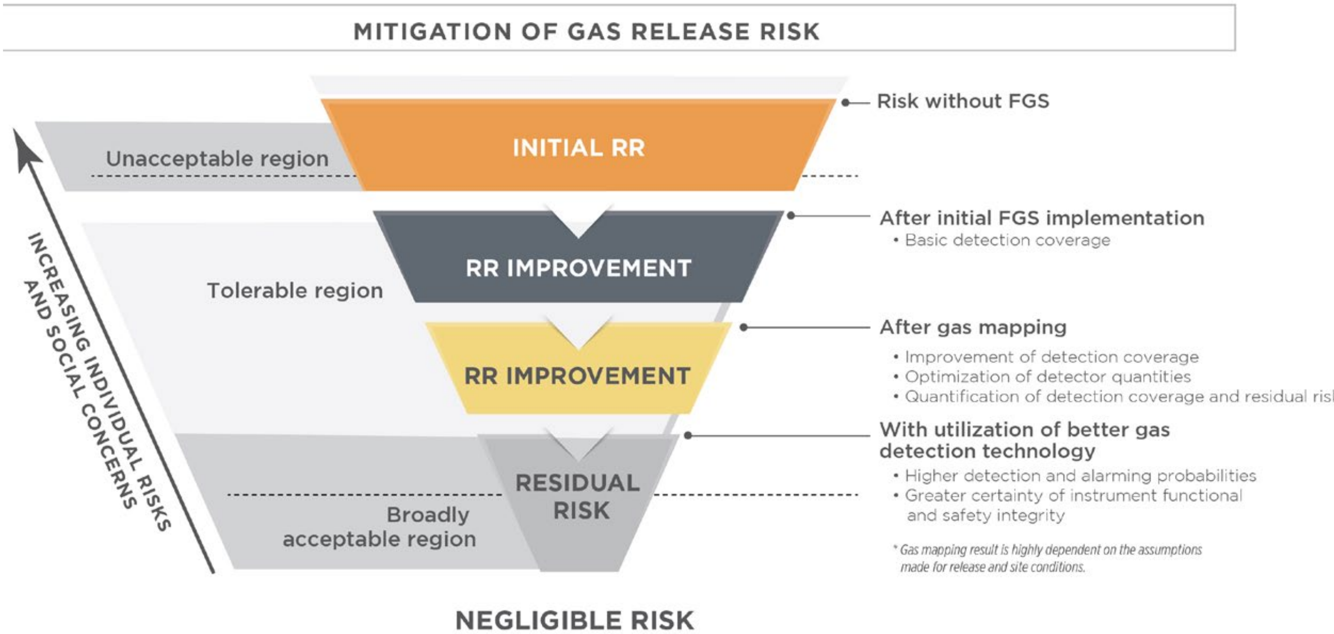

Figure 1. This chart shows the relationship between levels of risk and in-place fire and gas safety systems.

These next-generation detectors also deliver robust, intelligent sensing technologies that combine advanced signal processing algorithms, health diagnostics and digital communication capabilities to detect fire and gas hazards quickly, communicate these events to people and systems that need to know and energize mitigation processes and systems automatically (Figure 1).

These capabilities generally enhance the level of protection attained from the installation of a fixed flame and gas system and can improve overall availability while reducing testing, calibration and maintenance costs. These benefits are achieved by leveraging new sensor supervision and self-calibration capabilities along with updating legacy work practices based on previous generation instruments (Figure 2).

Furthermore, 3-D hazard analysis modeling and mapping software tools are available that enable assessment of fire and gas system effectiveness based on proposed detector location coverage, availability and mitigation effectiveness.

THE CHALLENGES

Fire and gas system management teams generally express three concerns about their fixed gas and flame detection systems:

- Adequate sensor placement and coverage
- Proper installation, operation and maintenance requirements
- Cost of ownership and obsolescence challenges

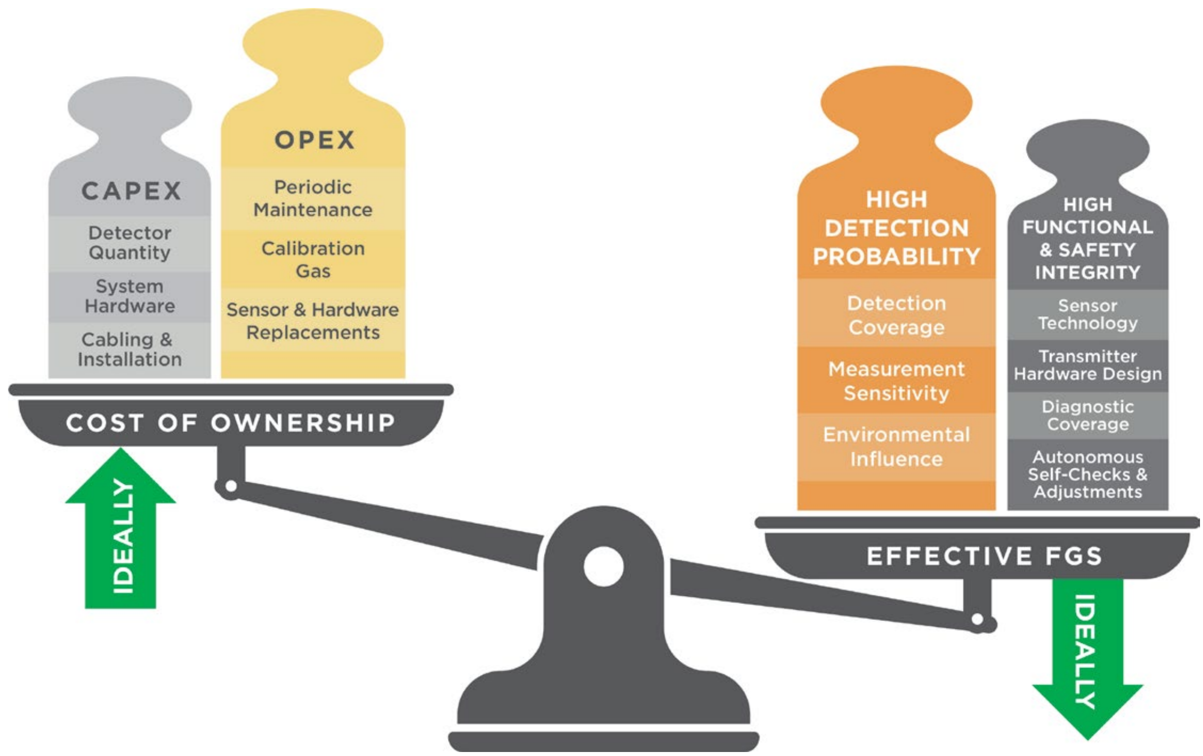

Figure 2. Effective fire and gas detection systems help improve cost of ownership.

Many industrial facilities, including chemical plants, refineries and gas processing plants, are large and complex with areas that house tightly placed equipment, piping and tanks. Many areas are partially or fully exposed to the outdoors, subjecting instruments to seasonal temperature extremes as well as high winds, rain, snow, fog and condensing humidity.

For these reasons, no single gas or flame sensing technology is appropriate for all applications or locations. Depending on the individual site, the surrounding environment and the nature of the leak source, a specific gas or flame sensing technology that is appropriate in one place may not be appropriate in another.

The differing composition of dangerous gas species can complicate optimal gas sensing and detection methods further. For example, gas and vapor density or buoyancy can impact the specific area where a gas could accumulate within a building or enclosed space, or how a dangerous gas cloud will behave and disperse in an operating gas process train.

When optical flame detectors are being considered, the potential impact of hot compressors, engines, reactors or flare stacks located in or near the high-priority fire zone must be considered when evaluating potential detector installation points, elevations and alignment angles. These are just a few examples of important considerations related to

Typical system detection devices include flame and gas detectors as well as smoke, heat and other initiating device signals.

the successful design, installation and operation of fixed flame and gas systems.

FLAME AND GAS DETECTION SYSTEMS

Let's start by reviewing the overall mission of a fire and gas detection system. The system is intended to monitor and protect people and assets continuously against fire and life-safety hazards such dangerous gases and other abnormal situations. Fire hazards can include both flash fires and potentially combustible or explosive gas leaks, as well as toxic or poisonous gas or vapor clouds, leaks or releases.

These systems also can monitor important manually initiated fire alarms and emergency shutdown signaling devices as well as facility-related information such as specific work areas in bypass mode where people are performing maintenance overhaul work in a hot zone, and wind direction and velocity for outdoor areas with other process trains located nearby and possibly upwind.

Typical system detection devices include flame and gas detectors as well as smoke, heat and other initiating device signals. System alarm and hazard mitigation devices include alarm horns and strobes, emergency shutdown signals and suppression release solenoid valves. The system logic solver monitors the status of the critical fire and gas signal inputs and energizes required output signals when the detectors have identified pre-alarm or alarm conditions.

The logic solver's functional operating logic usually is defined within a cause and effect matrix. When a validated alarm condition has been identified, the system logic solver will initiate all required alarm signaling devices to let people know what action to take and also energize hazard mitigation equipment including fire suppression discharge if required onsite.

Many sensing technology choices are available when it comes to flame and gas detection instruments. All have strengths and weaknesses depending on the project or jobsite's specific requirements. It is not uncommon for the optimal solution to consist of a combination of different sensing technologies, i.e., a layered approach to onsite fire and gas hazard detection.

FIXED GAS DETECTORS

When choosing gas sensing and measurement technologies, evaluate their appropriateness for your needs. For example, point detectors monitor a specific area, and perimeter monitors sense gas clouds along a fixed line of sight or path (Figure 3). Catalytic bead, point infrared (IR) and electrochemical sensors are all designed for point monitoring while ultrasonic acoustic gas detectors provide area and zone monitoring. Open-path IR or laser-based open-path systems are used in perimeter gas monitoring applications.

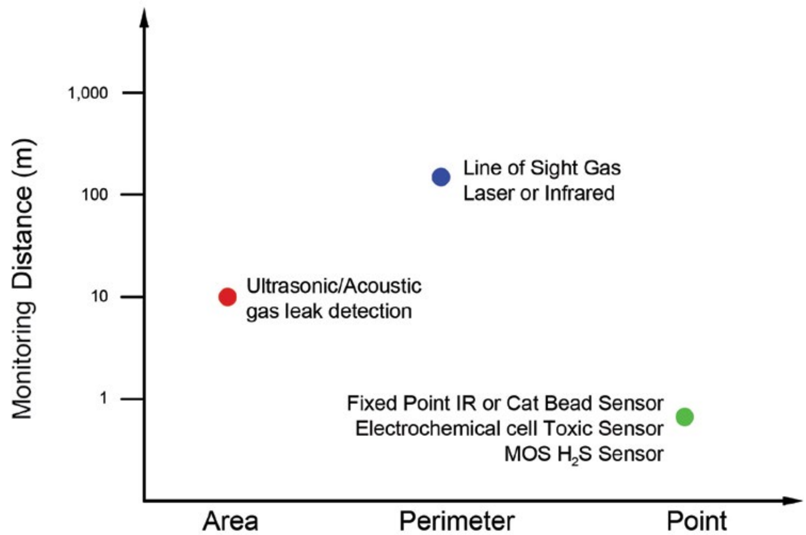

Figure 3. Each gas sensing technology provides a different coverage area.

Catalytic bead (CB). Catalytic bead combustible gas detectors measure flammable gases in concentrations below the lower explosive limit (LEL). They use an actively heated, coated wire coil (bead) to catalyze ambient combustible gases that impinge upon the CB measurement chamber.

As the active bead temperature increases from the catalytic reaction, the sensor's Wheatstone bridge signal output changes proportionally to represent the concentration of the combustible gas present within the measurement chamber. Catalytic bead gas sensors are suitable for detection of both hydrocarbon and hydrogen gases and offer a wide operating temperature range.

Electrochemical (EC). Electrochemical gas sensors function in a manner similar to micro-chemical fuel cells or batteries. They use polarized electrodes within a measurement cavity filled with electrolyte. When molecules of the target gas permeate a membrane and enter the electrolytic cavity, a reaction occurs, generating an electrical current that is proportional to the concentration of the analyte.

Different cell types have been developed for detection of specific toxic gases, such as carbon monoxide, hydrogen sulfide and oxygen enrichment or deficiency. They are best suited for detecting toxic gas in the parts-per-million (ppm) range or for oxygen enrichment or deficiency in confined spaces.

Point infrared (PIR). Infrared gas detectors use two wavelengths — one at the gas absorbing "active" wavelength and the other at a "reference" wavelength not absorbed by the gas. In point IR detectors, hydrocarbon gas concentration is measured via the infrared absorption of an optical beam known as the active beam.

A second optical beam, known as the reference, follows the same optical path as the active but contains radiation at a wavelength not absorbed by the gas. They are best suited for detecting hydrocarbon gas, especially in low-oxygen environments such as ducts or inaccessible areas such as ceilings. They require minimal maintenance.

Laser-based open-path gas detection. The enhanced laser diode spectroscopy (ELDS) gas detector is an open-path noncontact method of detecting specific toxic or flammable gases. When a gas cloud of interest intersects the ELDS transmitter's laser beam, the ELDS receiver module measures the wavelengths of light absorbed and then performs a Fourier-transform spectroscopic analysis to identify concentration of the target gas. These instruments are best suited for toxic gas monitoring along a property fence line; boundary; or linear rows of equipment such as pumps, valves or storage tanks.

Ultrasonic gas leak detection (UGLD). These detectors respond to the ultrasonic acoustic signature a pressurized gas leak creates. This signature is unique to the specific pressure behind the gas leak, and the instrument can generate a leak alarm when it detects the signature.

A key strength is the gas of interest need not impinge upon a measurement chamber as with other gas sensing technologies. In this case, a microphone is used to listen for the acoustic signature of a gas leak. These instruments are best suited for use in windy outdoor installations and high ventilation indoor spaces where the gases to be detected are under pressure.

FIRE DETECTORS

Numerous fire detector technologies are available, including point/spot, area/zone optical detectors and perimeter/linear fire detection technologies (Figure 4). Most optical flame

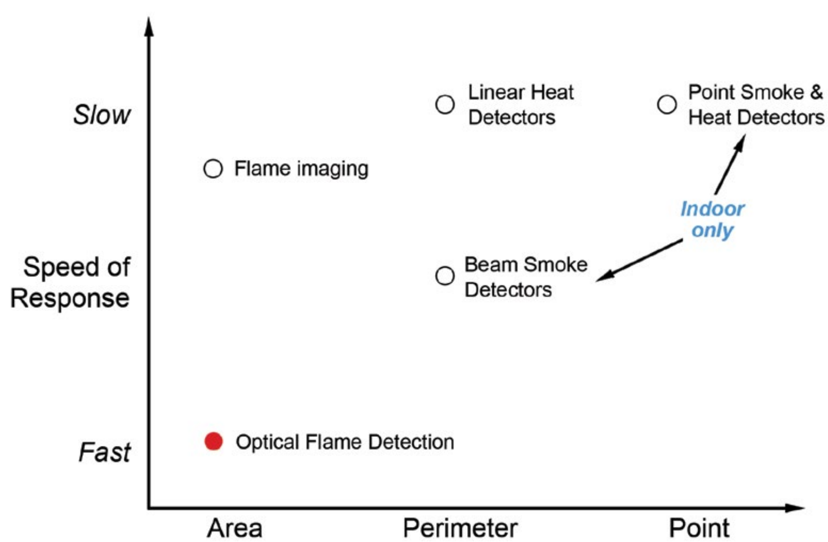

Figure 4. Available technologies offer a range of response times and coverage areas.

detectors are designed for open-area monitoring because of their relatively large and adjustable field of view (Figure 5). Point and beam smoke detectors are designed primarily for indoor installations, while heat detection technologies also are optimal for indoor or semi-enclosed spaces.

Optical flame detectors. The most common optical flame detectors are combination ultraviolet and infrared (UV/IR) and multi-spectrum infrared (MSIR) types. These detectors measure radiant energy in multiple spectral energy wavelengths and use sophisticated signal processing algorithms to analyze radiant energy levels, ratio-metric relationships of the signal levels and modulation or flicker rate of the IR energy. The algorithms are designed to enable fast and reliable flame detection while rejecting nonfire energy sources (false fire alarms) at the same time.

All optical flame detectors have a limited field of view as a function of fire size or radiant heat output and rely on a line-of-sight transmission of radiant energy from the source to the detector. It is important to always select the proper detector to match the radiant emissions expected from the flames to be detected. Because flammable fuels often emit unique spectral signatures, not all detectors can detect all fuels.

FIRE AND GAS SYSTEM CONTROLLERS

Many industrial applications require the use of a fire and gas system controller to monitor installed flame and gas detection instrument status and to energize alarm notification devices or hazard mitigation equipment to control and suppress any potential propagation of the detected gas hazard or fire (Figure 6).

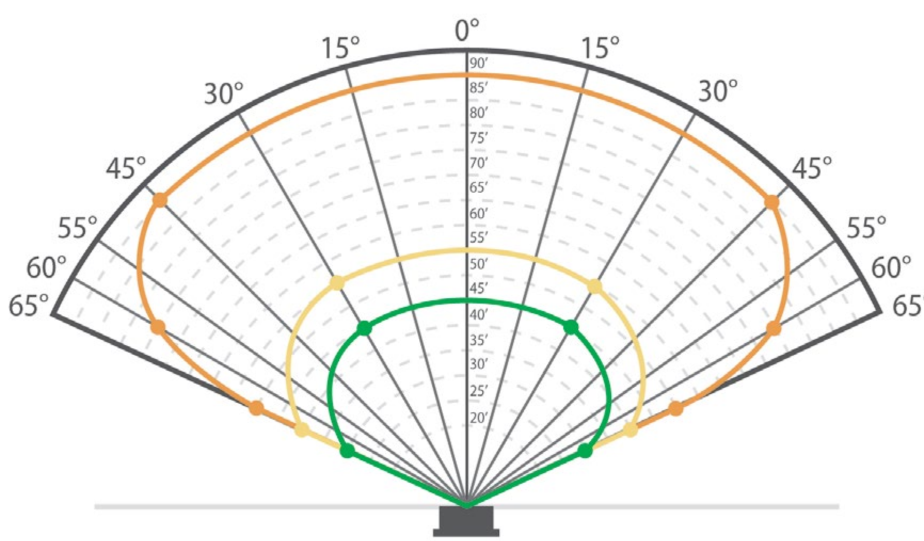

Figure 5. Optical flame detectors have a large and adjustable fields of view.

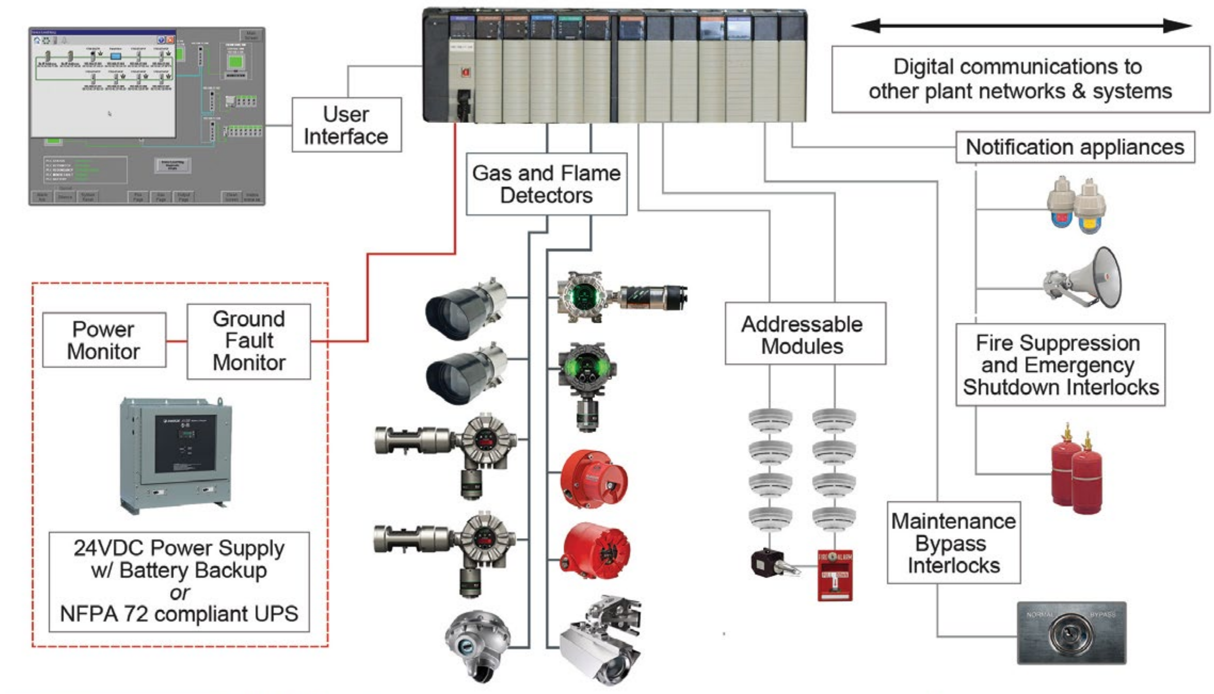

Figure 6. This diagram portrays a typical fire and gas system design.

The principal components of a fire and gas system include the controller, sometimes referred to as a logic solver; HMI panel with touchscreen to enable easy interaction with system diagnostics and historian; system power supply; and battery backup.

Many controllers now support digital communications to other plant networks using Modbus or EtherNet/IP protocols. Another useful digital protocol supported by some instruments and systems is HART communications. HART enables users to gain access to a number of useful instrument diagnostic parameters and is used primarily for device configuration, calibration, diagnostics information and documentation.

LAYERS OF PROTECTION ANALYSIS

Designing an effective gas and flame monitoring system is best accomplished through a layers of protection analysis (LOPA). The LOPA process begins with a five-step accident scenario process to:

1. Identify possible accident scenarios.
2. Select a "most likely" accident scenario.
3. Identify the initiating events and frequencies.
4. Determine the independent protection layers (IPL) required and estimate the probability of failure on demand.
5. Estimate the total risk with frequency and consequence of each event using baseline IPLs.

By comparing the most-likely accident scenarios against the facility's tolerable risk threshold, safety engineers can determine the optimal fire and gas detection technologies and system equipment needed to mitigate and reduce risk down to an acceptable level (Figure 7).

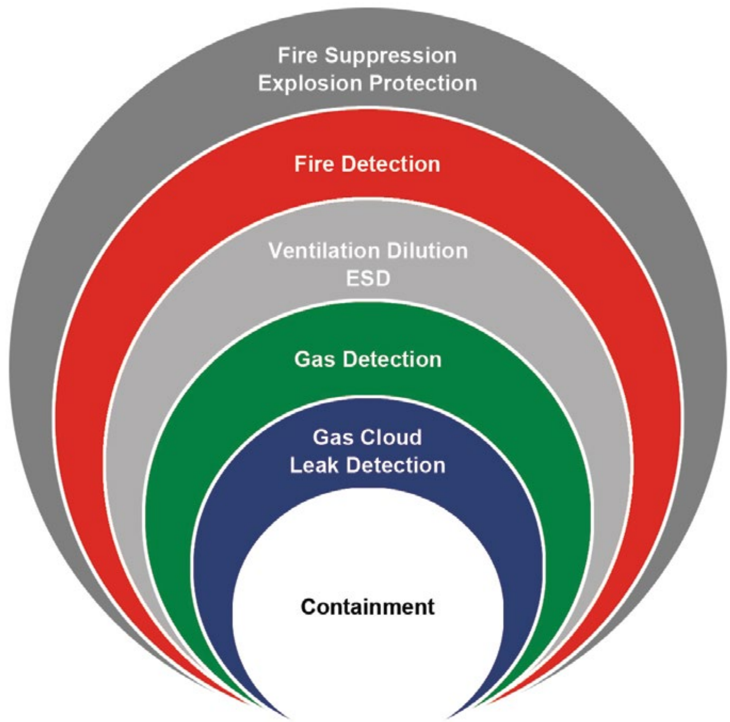

Figure 7. Layers of protection analysis is used in risk assessment.

Let's look at a hypothetical flame coverage mapping example at a chemical plant (Figure 8). Site personnel identified that liquid transfer pumps had leaked in the past, and unfortunately one of these leaks resulted in a small fire. Because no flame detection was installed, the fire wasn't extinguished until an employee had noticed the flames. The user was very concerned about potential fire propagation due to the proximity of fuel storage tanks to these pump skids.

The three panels shown in Figure 8 indicate the level of optical flame detection coverage attained. The left hand panel shows the highest risk potential ignition points

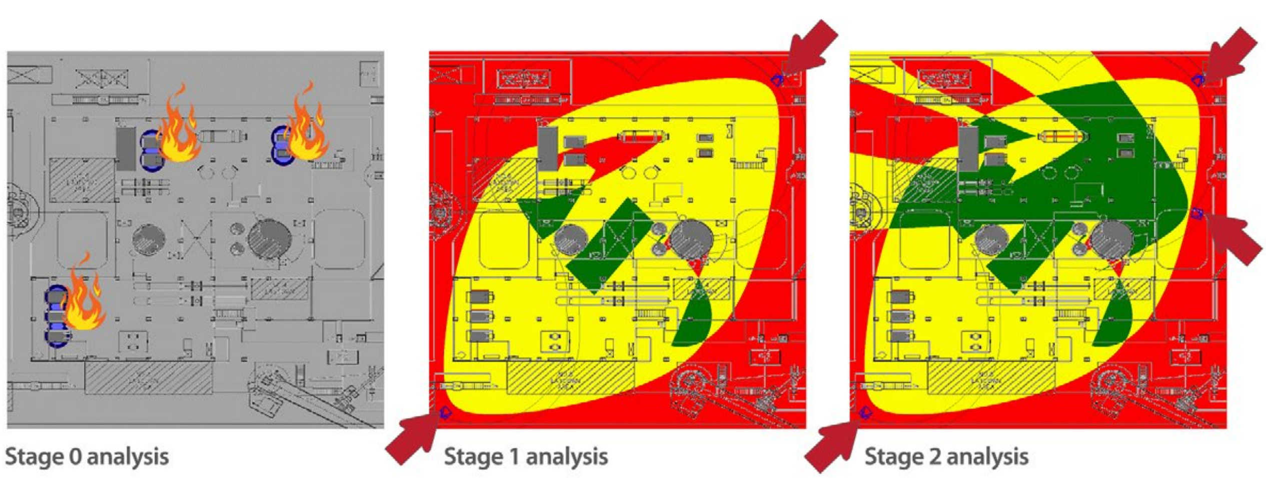

Fig 8. Detector mapping helps to visualize coverage scenarios.

If technicians cannot access a detector easily, it most likely will not be maintained regularly.

without detection. The next panel shows coverage with two flame detectors installed at the red arrow locations. Note that the green zones indicate double coverage, yellow zones indicate single coverage, and red zones indicate no flame detector coverage. The third panel indicates the coverage attained by adding a third flame detector.

Whenever detector installation locations are being considered, the owner or designated installer should audit the flame detection coverage map against the reality of the jobsite whenever possible. This task generally requires a site walk-down with coverage map in hand and a laser-aiming accessory to validate field-of-view coverage the proposed install locations would provide.

Issues commonly encountered during location validation include undocumented obstruction or blockage; inadequate mounting structure or accessibility; high structural vibration levels; high heat levels; or interposing clouds of process smoke, steam or other problematic environmental conditions. Proposed locations also should be selected with consideration given to a means of physical access for optics cleaning, maintenance, testing and routine inspection. If technicians cannot access a detector easily, it most likely will not be maintained regularly.

CONCLUSIONS

Fire and gas hazards exist at many industrial jobsites. Thankfully most end users recognize the presence of these hazards and execute due diligence in analyzing their hazardous operations and defining effective and sensible layers of fire and gas detection, notification and mitigation as required to ensure they are providing a 24/7 safe working environment.

The combination of next-generation point, zone and perimeter hazard sensing technologies combined with proper notification, control, mitigation and communications systems provides plant managers with layers of sophisticated and effective protection that can significantly reduce an accidental gas leak and fire ignition event's detrimental effects. ●

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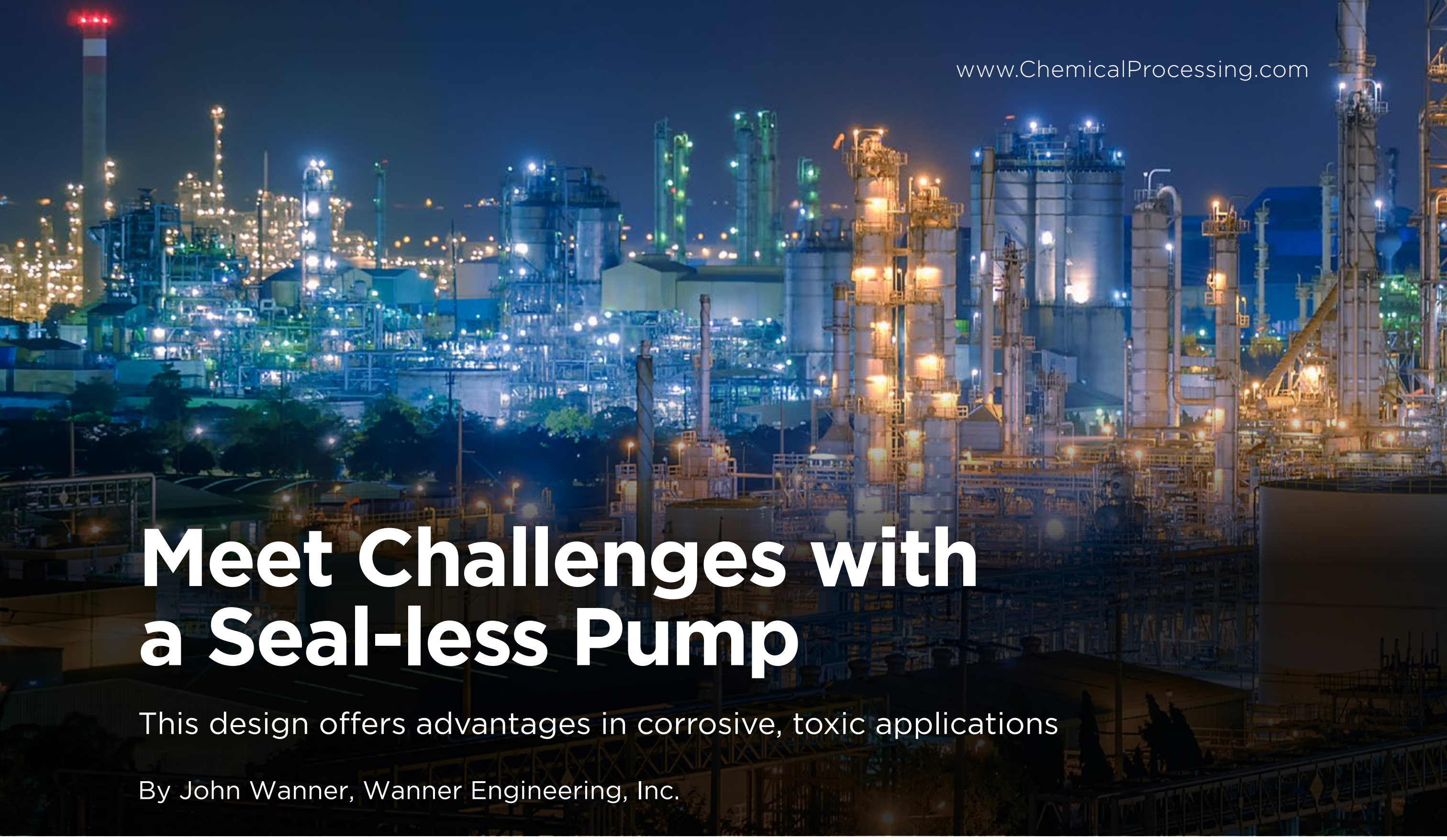

Meet Challenges with a Seal-less Pump

This design offers advantages in corrosive, toxic applications

By John Wanner, Wanner Engineering, Inc.

A refinery without a working pump is either a refinery abandoned or under construction. Pumps serve many critical and diverse applications at oil and gas refineries, and several different types of pumps perform these functions ably. The choice of which pump to use for a specific process rests on how a particular pumping technology can meet the challenges of the liquid being pumped.

Compared to plunger pumps with packing and other types of pumps with dynamic or mechanical seals, a positive displacement diaphragm pump that is “seal-less” can offer several performance advantages. This article presents the technology of a seal-less pump and explains how the seal-less design meets several pumping challenges in a range of refinery and petrochemical applications.

PLUNGER VS. SEAL-LESS TECHNOLOGY

The packing in a plunger pump must leak to provide lubrication. An external lubrication system can be used, but this requires an extra cost for equipment and introduces another component that requires maintenance.

Instead of external lubrication, the process fluid often is used to leak through the packing — both the plunger and packing must be compatible with the product being pumped — but this causes plunger wear and creates issues for maintenance, emissions containment and cleanup and disposal costs. Packing also requires frequent, time-consuming adjustment and then replacement as it wears.

A seal-less pump isolates the power (hydraulic) end from the liquid (process fluid) end (Figure 1). It has no packing or dynamic or mechanical seals that leak, wear or need adjustment or replacement. Furthermore, the seal-less design has no leak path, so VOC emissions are contained, and the need for external lubrication equipment, as well as plunger wear problems, are nonexistent.

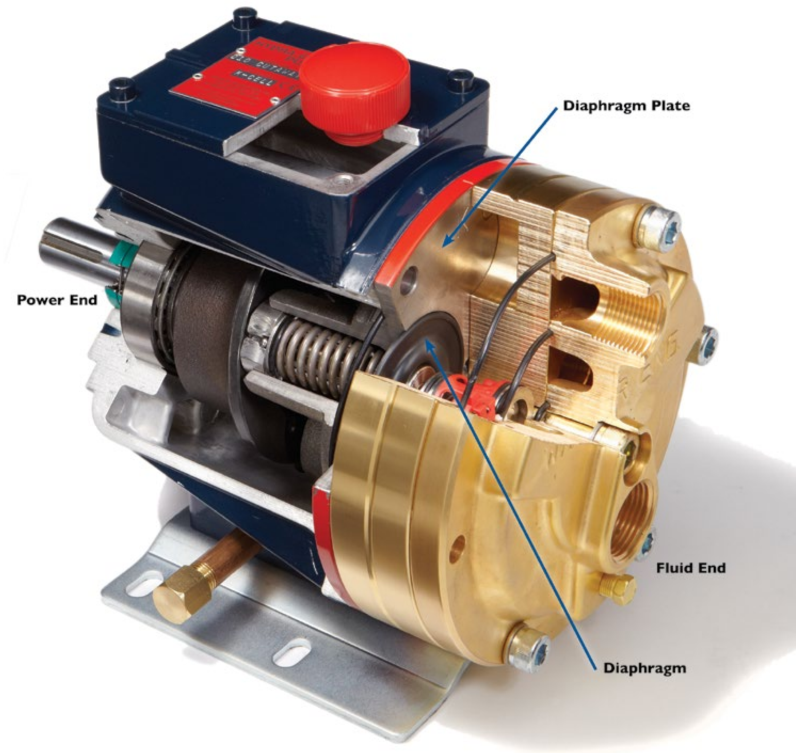

Figure 1 . The fluid is processed strictly within the pump head, separated from the power end by a diaphragm plate and the diaphragms.

SEAL-LESS PUMP TECHNOLOGY ABSTRACT

Figure 2 shows the parts of a seal-less pump's power (or hydraulic) end and fluid end.

The power end parts include:

1. Drive shaft
2. Tapered roller bearings
3. Fixed-angle cam
4. Hydraulic cells

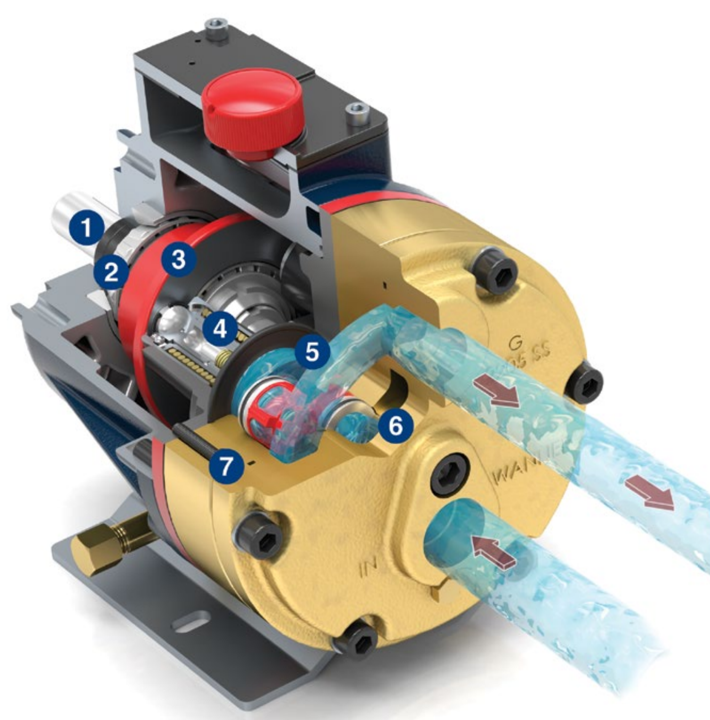

Figure 2. Unlike pump technologies that use packing or seals, the hydraulics of a seal-less pump do not come into contact with the fluid being processed.

As the drive shaft turns (rigidly held in the pump housing by roller bearings), the fixed-angel cam (a "wobble plate") nutates,

Seal-less pumps can be found serving many upstream, midstream and downstream purposes.

oscillating forward and backward, converting axial motion into linear motion.

The hydraulic cells move sequentially and replenish themselves with lubricating oil on the rearward strokes so that the cells remain filled with oil on the forward strokes.

The fluid (or liquid) end parts include:

5. Hydraulically balanced diaphragms
6. Horizontal disk check valve assembly
7. Discharge valve assembly

The oil held at the back side of the diaphragms causes the diaphragms to flex forward and backward when the wobble plate moves. This provides the pumping action.

Fluid enters the pump head (manifold) on the backward stroke and flows though the horizontal disk check valve assembly.

The fluid is then forced back out of the pump by the forward stroke through the discharge valve assembly.

OTHER PERFORMANCE BENEFITS OF THE SEAL-LESS DESIGN

As stated, seal-less pumps do not have the maintenance, downtime or containment issues associated with pumps that have seals or packing. The seal-less design technology also provides other performance benefits:

- *Run-dry capability.* Running dry can cause catastrophic failure in pumps with mechanical seals. A seal-less pump will operate indefinitely without damage if the suction line becomes blocked or is closed. A seal-less pump also will run without damage if other conditions prevail, such as insufficient liquid supply, excessive vacuum at the inlet of the pump or inadequate discharge pressure.
- *Abrasives and particulates handling.* Integrated within the seal-less design, spring-loaded, horizontal disk check valves can process abrasive, undissolved particles (up to 800 microns in size, depending on the pump model) that would damage or destroy other types of pumps. This design and construction also eliminate the need for fine filtration in many applications.
- *Pumping of low- to high-viscosity fluids.* The seal-less design and availability of a range of metallic and nonmetallic materials of construction enable thin and nonlubricating liquids as well as highly viscous fluids to be pumped reliably.
- *Low stress, low pulse.* The hydraulically balanced diaphragms can handle high

Flow (ft3/hr)	Pressure (psi)	Energy Used (kW) Centrifugal	Seal-less	Energy Saving	Potential Annual Savings*
21	290	1.54	0.50	67%	$250
53	290	2.00	1.44	28%	$134
148	580	9.34	6.10	35%	$778
268	580	15.4	11.00	28%	$1,056

* *Based on pumps running 2,000 hr/yr @ 12 cents/kwh.*

Table 1. Using lower horsepower motors to meet the same flow and pressure requirements, a seal-less pump can offer significant energy savings.

pressures with little stress. This multiple-diaphragm design also provides linear, low-pulse flow. The use of expensive pulsation dampeners may not be necessary.

- *Reduced energy costs.* Compared to technologies such as screw pumps and multi-stage centrifugal pumps, seal-less pumps require lower horsepower/kilowatt motors to achieve the same performance. This efficiency can provide a significant reduction in the cost of electricity to operate the pump (Table 1).

REFINERY APPLICATIONS

Seal-less pumps can be found serving many upstream, midstream and downstream purposes. Typical refinery applications include catalytic injection, crude oil sampling, high-pressure water, caustic soda wash-down, sour gas injection, emission control and pumping slurry for sulfur dioxide removal or acidic neutralization. Figure 3 shows a seal-less

Figure 3. This seal-less pump used for chemical injection at an oil refinery replaced a pump with seals to reduce maintenance and downtime associated with seal adjustment and replacement.

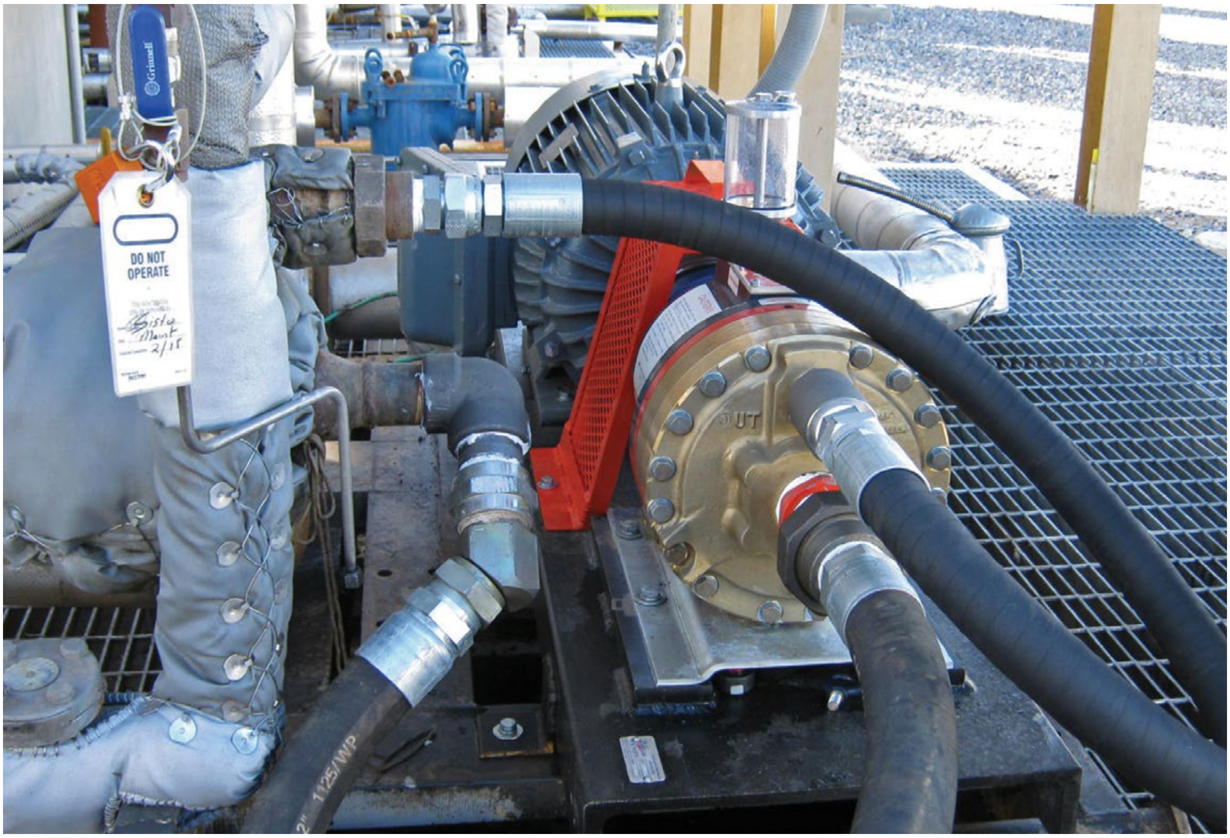

Figure 4. A seal-less pump is used for natural gas drying. The seal-less pumping chamber has no leak path, so potential emissions such as carbon dioxide are contained.

pump used for chemical injection. A seal-less pump is used for natural gas drying in Figure 4.

Specific types of fluids pose many pumping challenges to service these and other applications:

- *Crystallization and other abrasive particulates.* Crystallization can occur in acids and caustics if exposed to air. Crystals and other abrasive particulates, such as nonsoluble particles found in slurries, can damage seals and other pump components that require a lubricating film. A seal-less pumping chamber with tight tolerances has no leak path for air to enter and react with the process fluid. Equipped with spring-loaded, horizontal disk check valves, a seal-less pump can also handle solids, often up to 800 microns in size.
- *Nonlubricating process fluids.* Solvents, de-ionized water, hydrocarbons and waste chemical streams are nonlubricating fluids used in chemical processing. Packed pumps need to leak the process fluid through the packing to lubricate the pump, and the same is the case for many pumps with dynamic seals. That causes packing and seals to wear, which results

in downtime to replace these components. If the process fluid that needs to leak through seals or packing is harmful, associated cleanup costs are incurred. The actuating oil in a seal-less pump lubricates the power components in the hydraulic end, which is isolated from the liquid end. There are no packing or seals that leak and need to be replaced. Overall, this reduces downtime, lowers maintenance costs and almost eliminates environmental cleanup costs.

- *Viscous liquids.* Crude oil sampling in refineries requires a pump that can handle low- to high-viscosity liquids. A seal-less pump with low-shear pumping action can process liquids containing a range of viscosities from 0.01 to 5,000 cPs.
- *Containment.* Hydrogen sulfide has the odor of rotten eggs and is poisonous, corrosive and flammable. It is difficult to contain hydrogen sulfide saturated in am amine or brackish water. A seal-less pump chamber provides 100% containment of hydrogen sulfide and other harmful process fluids, including acids and condensates.
- *Corrosive chemicals.* Produced water transfer and disposal, as well as sour water injection, can have hydrogen sulfide, carbon dioxide, sodium chloride or other impurities that form acidic solutions. They can damage a pump with packing or seals. A seal-less pump with no leak path and corrosion-resistant liquid end materials protects both the process and the pump.

TOUGH APPLICATIONS CALL FOR A SEAL-LESS DESIGN

Although pumps with packing and mechanical or dynamic seals have proven themselves in many service applications, at times they are at a disadvantage compared to seal-less pumps. With no seals or packing to leak, adjust or wear and with no leak path, there is less downtime, lower environmental costs and lower annual maintenance cost.

In addition, a seal-less pump can process the full spectrum of low- to high-viscosity fluids, handle abrasive particulates that would affect other types of pumps adversely and run dry without damage to the pump.

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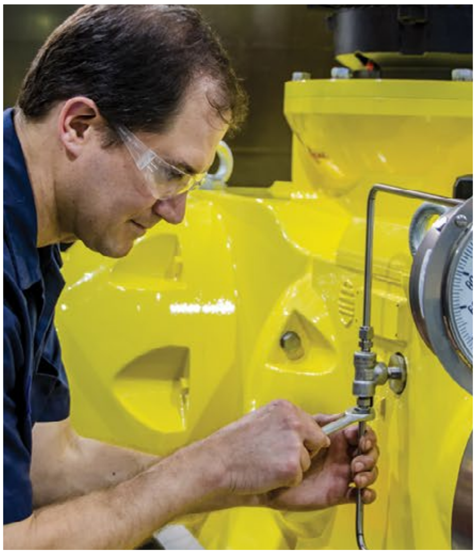

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Successfully Sample Sticky Hydrocarbons

Proper technology and design techniques ensure safe, reliable sampling of viscous and hot process streams

By Seth Martin, Tech-SORce and Billy Terry, SOR Controls Group

In the refining and petrochemicals industries, the term "heavy products" is used when describing streams such as heavy gas oils, tars, resins, asphalts or bitumen. Collecting samples of such media presents a unique set of challenges for petroleum processing facilities; often the materials sampled are hot, viscous and even corrosive, making them particularly hazardous for operators to collect and transport for analysis. Using a dedicated system to collect samples of heavy products is further complicated by the media's sticky consistency and tendency to solidify and clog up the system's piping.

SAMPLING STATION
Figure 1. Sampling heavy gas oils, tar, resins, asphalts or bitumen is accomplished with a well-designed heavy product sampling station.

Designing a heavy products sample station (Figure 1) that can resist plugging while still maintaining personnel safety is an important part of establishing the system as an effective engineering control. In practice, it is more difficult than it seems on the surface. For anyone who has been tasked with designing and installing a sample system for residuum in a refinery or surfactants or resins in a chemical processing facility, the experience undoubtedly was similar. While every sampling application has its own set of challenges, some specific design techniques can be used to mitigate long-term issues associated with closed-loop grab sampling stations used for heavy products.

THE FAST LOOP IS FUNDAMENTAL

Regardless of the process media, one of the most commonly used and important features of liquid grab sampling is the incorporation of a fast loop in the design. Simply put, the fast loop is an interconnected section of piping where liquid travels from the process line to the sample station for collection and back to the process line. The fast loop's purpose is to deliver the process stream directly to the sample station so that the collection obtained is representative of the process at the exact time the grab sampling occurred.

The fast loop is a far better method for obtaining representative samples when compared with other techniques, such as running the process media to a drain or sewer to eliminate dead volume before a sample has been gathered. Fast-loop or speed-loop designs also are used when designing online analyzer applications for the chemical and petrochemical industry. Figures 2a and b show two common methods for incorporating a fast loop into an engineered sample point.

PULLING THE PLUG

Another benefit of the fast-loop design is the elimination of dead volume in the system's piping. Dead volume refers to the sections of piping or tubing that connect the process with the sample station, or within the sample station itself, where media can become trapped and unable to move with the flowing sample stream (Figure 3). For heavy products, which tend to resist flow, dead volume in a sample station leads directly to plugging. Plugging the fast loop or the sample station will require

SAMPLE POINT FAST LOOPS
Figure 2a and 2b. Two common methods exist for incorporating a fast loop into an engineered sample point.

taking the unit out of service until it can be repaired.

Rather than incorporating a fast loop, some designs may forego the extra piping in favor of installing a ram/piston-style sample valve directly into a process line as an alternative means of reducing dead volume. All valves include some type of stem packing that has a finite lifespan and eventually will leak. If the production operation is continuous and you select a ram/piston type of valve without a fast loop, you could be forced to shut down the entire process line to repair the valve if it begins to leak.

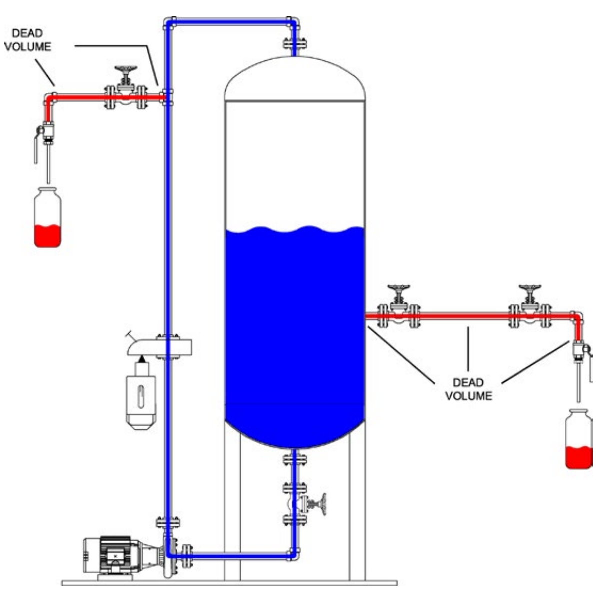
TOO HOT TO HANDLE

One of the primary obstacles associated with sampling heavy products is overcoming the temperature dependence of liquid viscosity. The chemical reactions and physical processes associated with heavy products often involve extremely high temperatures, so there may be a desire to cool the process stream before it reaches the sampling station. However, cooling a resin or a residuum low enough to retrieve the sample container by hand will cause the product's viscosity to increase, sometimes even solidifying, which could lead to the unintended consequence of plugging the entire grab sample station, rendering it unusable.

Instead of attempting to reduce the sample's temperature to a touchable level, consider a design that allows the sample valve to be operated from outside an enclosure, preventing operator exposure to splash or burn hazards. Rather than cooling the process before collection, allow the sample to cool inside the station's enclosure before retrieval and transportation to the lab. Letting the sample cool will require laboratory technicians to reheat the sample

A CLEAR TIP

Clearing the sample path after use can eliminate sample contamination and risk of plugging, but don't use a slop container. To clear the sample path with STEAM, use an adapter and hose assembly to direct the residual sample to a drain located in the bottom of the enclosure to keep the sample station clean and operational.



DEAD VOLUME
Figure 3. Dead volume in a sample station can lead to plugging.

SAMPLE PATH FLUSH CONFIGURATION
Figure 4. Use a twist lock flush adapter to direct steam and waste media in the sample pathway to the enclosure drain.

before analysis, but, in most cases, this does not present a problem and already is in practice.

ISOLATING THE STEAM PURGE AND SAMPLE LINE

Another important design often incorporated into heavy product sampling stations is the combination of steam heating and purging utilities used in conjunction with a flow-through style sample valve (Figure 4). Steam heating is an effective method for reducing the likelihood of plugging by imparting heat to the process stream, elevating it to temperatures that ensure the media will not be resistant to flow. Likewise, steam purging is used to clear the sample path of trapped process media when resolving plugging issues and potential sample contamination.

In addition, the flow-through style of sample valve gives the added benefit of isolating the sample path from the sample flow line, making it possible to purge the sample path independent of the process flow while the sample valve is in the closed position. Designs that block or partially block the process flow path to steam-purge the sample valve often will exacerbate plugging issues, requiring the sample station's complete removal to clear the line.

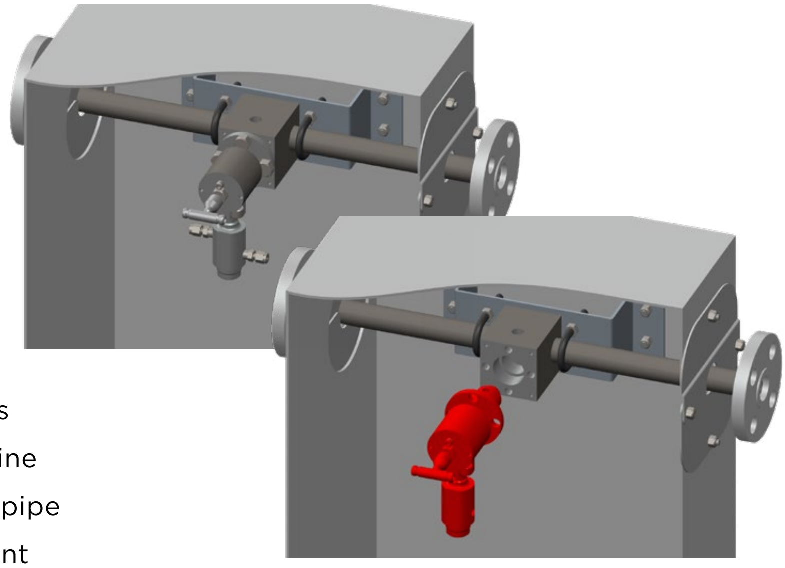
It is easy to understand why separating the sample path through the valve from the process sample line is advantageous in heavy product applications. When localized plugging occurs, the steam purge clears the blockage from the sample path without disrupting the process flowing in the sample line, clearing trapped material and eliminating the potential for sample contamination.

A REPLACEABLE CARTRIDGE FOR REDUCING REPAIR TIME

One final design feature often integrated with heavy product sampling systems is a sample valve with a removable and replaceable cartridge system that includes the sample valve's seat and ball/stem assembly. Many of the sampling stations installed in heavy product applications are mounted into piping systems, with a traditional process valve and welded or flanged connections. Performing maintenance requires removing the entire welded pipe spool from the process line, thus lengthening the overall time and effort needed to complete the repair.

Conversely, a sample valve with a removable/replaceable cartridge allows for separating the valve's critical components from the sample line without removing the valve body and pipe spool from the process line. In the event the sample valve encounters a plugging issue, the plugged cartridge can simply be removed from the sample valve body and replaced with a new one, whereas servicing a sample station mounted into a piping system involves multiple maintenance disciplines.

As shown in Figure 5, when it comes to the task of collecting heavy product samples or designing a system to do so, you must be prepared to consider and confront some unique challenges. However, with careful planning and a well-thought out sampling system design, incorporating some or all of these techniques, a sample of even the heaviest of products can be collected in a safe, reliable manner that is representative of your process. Although the risk of plugging always is present in these applications, you can increase the availability and reliability of this type of engineering control without increasing risk to operations while also reducing downtime when upsets occur.



REMOVABLE CARTRIDGE SYSTEM
Figure 5. This removable cartridge system includes the sample valve's seat and ball/stem assembly.

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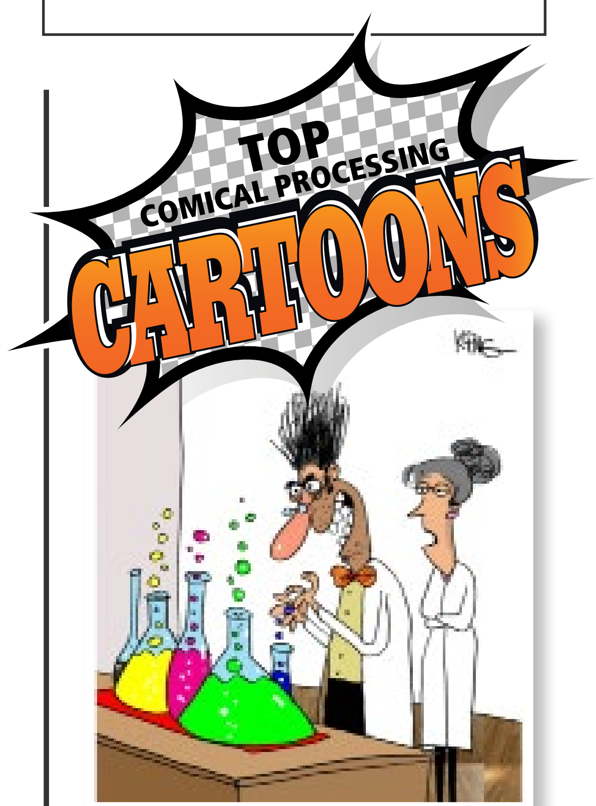

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