A COORDINATED STRATEGY

Joshua Hernandez and Helena Hjortsberg, Emerson, outline how the right instruments and system components combined with an effective strategy can help protect industrial plants and facilities.

To anyone responsible for safety at a hydrocarbon storage and transfer facility, the names Buncefield and Caribbean Petroleum Bayamón will likely conjure up thoughts of catastrophic explosions and fires resulting from overfilling incidents. Analysis of these and similar disasters suggest such incidents are the result of failures, or the absence, of four systems:

- The plant's basic process control system (BPCS), leaving operators with a false indication of the fullness of a given tank.
- Overfill protection mechanisms, which should automatically shut down a transfer when nearing capacity, but instead allow liquid fuels to escape.
- Gas detectors, which should call attention to flammable vapour clouds forming from a spill in progress.
- Fire detectors, which should trigger suppression systems and alert operators when a fire breaks out.

These systems represent sequential layers of protection for the facility, moving from prevention to mitigation (Figure 1), each offering an ability to stem an incident before it moves to the next level of damage.

This article will take a brief look at all four of these systems individually in the context of fixed and floating roof tanks to understand how they can be improved and optimised to deliver their protective function.

Understanding overfill prevention

The most effective way to avoid an incident is to keep flammable liquids inside the tanks. The most common source of releases, outside of a pipe or valve failure, is overfilling, as was the case in the incidents previously mentioned. Such incidents happen when operators do not have an accurate indication of a tank's contents and end up forcing in more liquid than it can hold. This stems from ineffective level instrumentation, resulting in poor situational awareness for the operators: the tank they are trying to fill is already fuller than they realise. This should be stopped by an automatic safety system that is able to shut down a liquid transfer, or at least trigger an alarm to warn operators of the developing situation.

An effective overfill prevention system provides a combination of instrumentation to implement a data management and safety strategy. In most situations, as the level nears capacity, the system will indicate a high-level alarm and warn operators so they can stop the transfer. If they do not, at a high-high level point, the system will trigger a safety instrumented function (SIF) to activate an emergency shutdown (ESD) of the relevant pumps and valves, bringing the transfer to a halt. This is a disruptive act, so it is better for operators to handle the situation before the high-high level is reached.

This approach calls for at least two level instruments: one conventional to send data to the BPCS and operators, governed under API 2350, and the second instrument is certified to the required safety integrity level (SIL), compliant with IEC 61511, to provide the SIF. The two systems are typically referred to as automatic tank gauging (ATG) and automatic overfill prevention system (AOPS), respectively (Figure 2). These exist side-by-side, operating in parallel to provide two layers of protection.

This setup typically uses two level instruments with separate signal processing as required to provide the SIFs. The ATG side will usually include a multiple-point temperature probe to provide a more accurate picture of the tank's contents since temperature affects net volume. This volume is calculated in real-time by inventory management software, which includes alarm functions triggered by high- and high-high level measurements.

The AOPS side can be configured to reflect the SIL requirement for the facility. SIL 2 and 3 are both common and achievable by selecting an appropriate level device. This should involve application of a non-contact radar level gauge, optionally a vibrating fork level switch either with SIL 2 or SIL 3 certification under IEC 61508. Both of these are available with SIL 2 certification and some extend to SIL 3 under IEC 61508. The AOPS can send its data to the inventory management software without interfering with its ability to function independently.

The Rosemount 5900S Radar Level Gauge is available in a SIL 3 2-in-1 version with two independent units, requiring only a single tank penetration, so it can be used for both level and independent overfill prevention measurements.

An effective AOPS following this approach can provide a 99% coverage factor, but this does not eliminate the need for additional layers of protection. The shutdown mechanisms to turn off pumps and close valves must also perform flawlessly but are outside the immediate control of the AOPS. Additionally, there are other potential causes for leaks and spills, such as operator error.

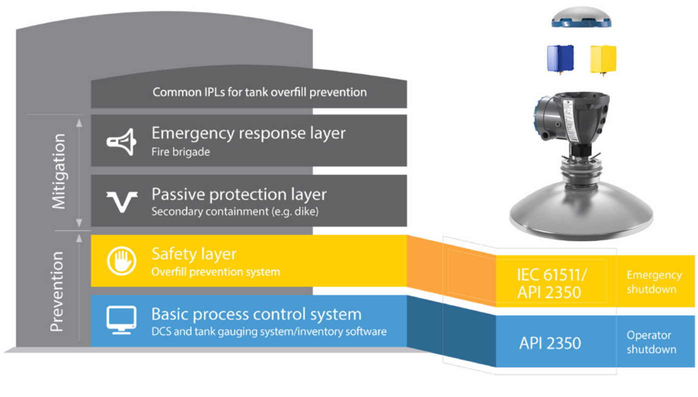

Figure 1. The first line of defence against overfills is an effective basic process control system.

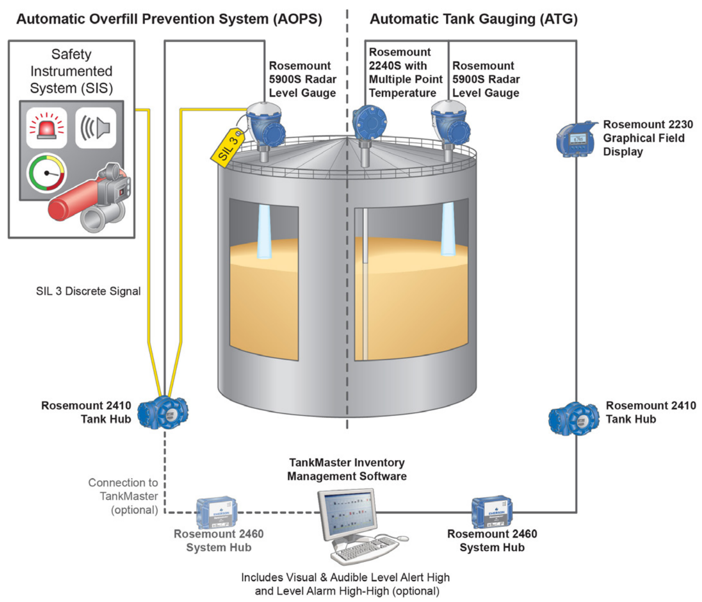

Figure 2. The ATG and AOPS exist side-by-side, but separately, so they can function independently. Emerson's Rosemount^{TM} 5900S Radar Level Gauge is available in conventional and SIL-rated versions.

Flammable and toxic gas detection

Flammable gases such as vapour clouds can be formed from liquid fuel spills, but the same concerns apply to escaping propane and methane from pressurised tanks. In some situations where sour products are handled, hydrogen sulfide (H_2S) accumulating in tanks may also be a factor causing potential toxic exposure for workers, in addition to fire hazards.

There are several technologies able to detect flammable and toxic gases, each with its own capabilities and designed to perform a specific type of

Figure 3. An open path combustible gas detector, such as Emerson's Rosemount 935, can detect a cloud of gas moving through its line-of-sight from the transmitter to the receiver even if it has diffused to a relatively low concentration.

Figure 4. An ultrasonic gas leak detector, such as Emerson's Incus Ultrasonic Gas Leak Detector, can capture the sound of a compressed gas leak.

Figure 5. Flame detectors, such as Emerson's Rosemount 975 family, look for radiation in specific wavelengths emitted by hydrocarbon or hydrogen-based combustion.

task. When used in combination, they complement each other to provide thorough, overlapping detection coverage.

Fixed point flammable gas detectors

Fixed point flammable gas detectors are the most common and use one of two sensor technologies. Infrared sensors respond to the specific light wavelengths absorbed by the vapour or gas. Catalytic bead sensors facilitate an internal chemical reaction in the presence of a variety of gases and vapours, both hydrocarbon and non-hydrocarbon-based. Both technologies depend on a cloud drifting to the individual sensor with sufficient concentration to be detected.

Fixed point detectors are usually deployed where there is a concentration of equipment and therefore multiple potential release points. Since ambient air movement affects where a cloud might drift, several units are typically distributed around target areas.

It is common practice to separate the instrument's sensor from its transmitter so the sensor can be placed in the best position to capture a gas cloud, while the transmitter can be mounted where it is easier to reach for configuration and service. This minimises the need for technicians to enter potentially dangerous locations. Distances up to 1500 ft (450 m) between sensor and transmitter can be spanned, allowing transmitters to be installed in centralised clusters, while the sensors are mounted in suitable locations.

Open path combustible gas detectors

Open path combustible gas detectors send a focused source of infrared light from a transmitter to a receiver (Figure 3) to detect combustible gases moving through the line-of-sight path from the transmitter to the receiver. These cover a wider area, at least in one direction, than a fixed-point detector, and are therefore deployed like a fence around the perimeter of equipment and tank clusters. Detection is subject to ambient air movement, so most facilities deploy multiple units.

Ultrasonic gas leak detectors

Ultrasonic gas leak detectors should be deployed only where there are pressurised storage tanks. These listen for the characteristic sounds made by pressurised gas leaks in frequencies above audible range (Figure 4). Using multiple piezoelectric sensors, these instruments can respond to these specific sounds very quickly. Response can be immediate as there is no need to wait until enough gas has escaped to reach a threshold concentration. Their limitation is that they respond to any escaping pressurised gas, so they cannot differentiate between escaping propane and a compressed air leak.

Toxic gas detectors

Toxic gas detectors are different in that they perform a monitoring function and are not used with conventional safety instrumented systems (SISs). There is usually no ESD connected to a release of H_2S. A sensor typically activates a local alarm and sends a warning to the control room to alert operators and other personnel in the plant.

This flexibility provides an opportunity to use WirelessHART®-enabled instruments to send data to the larger monitoring host system, rather than the costlier wired connections required by SIFs. Consequently, wireless toxic gas monitors are the least expensive to deploy. Placement of toxic gas detectors concentrates around those tanks where sour products tend to be stored, and around supporting equipment since the corrosive nature of H_2S can frequently create leaks.

Flame detectors, the last automated protection layer

In the event of a leak, whatever the cause and whether or not gas detectors have identified that a flammable cloud exists, it is paramount that flame detectors determine if a fire has broken out as quickly as possible. This is the last layer of automated protection. Beyond this, the facility depends on physical barriers and first responders. Flame detectors trigger multiple safety functions, including sounding alarms, initiating fire suppression systems, and activating ESD functions to isolate tanks.

Detection technologies have come a long way. Old-fashioned heat detectors delivered a slow response, having to wait until temperatures increased sufficiently and reached the sensor. Early ultra-violet (UV) radiation-based sensors were often de-tuned to avoid false alarms and rendered ineffective due to smoke absorbing UV, effectively blocking the sensor's ability to see the fire.

Fortunately, flame detectors available today can respond very quickly to a fire, even in the presence of heavy smoke. They detect multiple specific wavelengths in UV and IR bands generated by hydrocarbon or hydrogen-based fuel combustion. The ability to pinpoint these wavelengths allows an operator to specify sensors optimised for the products handled at the facility, which improves sensitivity while minimising the potential for false alarms.

Flame detectors are directional, and therefore deployed like surveillance cameras, often positioned above critical equipment looking down (Figure 5) to get a minimally obstructed view at a specific area of coverage.

Since they cannot see around tanks, multiple units need to be installed. In congested areas where equipment such as valve clusters are mounted at ground level between tanks, additional flame detectors can be mounted lower to fill in areas which cannot be seen from higher positions.

Elements of a larger strategy

All the individual topics discussed so far must come together to create a coordinated strategy to link all the protective layers. The selection of various protective devices and how they are integrated with an overfill protection system and larger safety systems must be analysed and planned carefully by experts. Preserving a facility's ability to operate while avoiding safety and environmental incidents calls for the right strategy, equipment, proof-testing, and personnel training. T&T