TANKS & TERMINALS

A SUPPLEMENT TO HYDROCARBON ENGINEERING

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CONTENTS

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ON THE FRONT COVER

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PROBE AND PREVENT

Raul Risi, TTK, France, outlines how early detection of storage tank leaks can be achieved through sense cable and probe technology.

The petroleum and petrochemical industries experience accidents on a regular basis due to loss of containment, resulting in detrimental health, environmental and economic consequences.

In a study published in 2013 by the Joint Research Centre (JRC) of the European Commission, 62 of the 99 cases of failure assessed were reported to have originated from leaks.[1]

Storage tanks have generally been involved in some of the most severe accidents in EU and Organisation for Economic Co-operation and Development (OECD) member countries, most often because they have led to sizeable fires, some of which have required a number of days to extinguish. The majority of storage tank accidents considered in the study were predominantly caused by environmental impacts, due to leaks or ruptures at the base of the tank.

Another study assessed 435 fire and explosion accidents at a number of oil depots in China, which also caused significant casualties, besides environmental pollution and large economic losses.[2] According to the study, approximately 24% of the reported accidents occurred in the oil storage area, and approximately 51% in the loading and unloading operation area.

This article discusses to what extent early leak detection can constitute an effective means of preventing accidents in storage tank terminals – two case studies are presented to this end.

Case study: Belgium

On 25 October 2005, an accident occured at an oil storage terminal in Kallo, Belgium. The terminal contained seven storage tanks, in a large bund made with earth dykes (image A, Figure 1). The accident was presented in a technical report in France's Analysis, Research and Information on Accidents (ARIA) database.[3]

The accident

At around 18:15 pm, a major leak at a 40 000 m^3 storage tank, D2, was detected. The operators in the control room of the refinery were alerted by a low level alarm from D2. The tank contained almost 37 000 m^3 of crude oil before the release. The level history in the control system indicates that,

Figure 1. Rupture of crude oil storage tank in Kallo (a) and in Ambès (b).

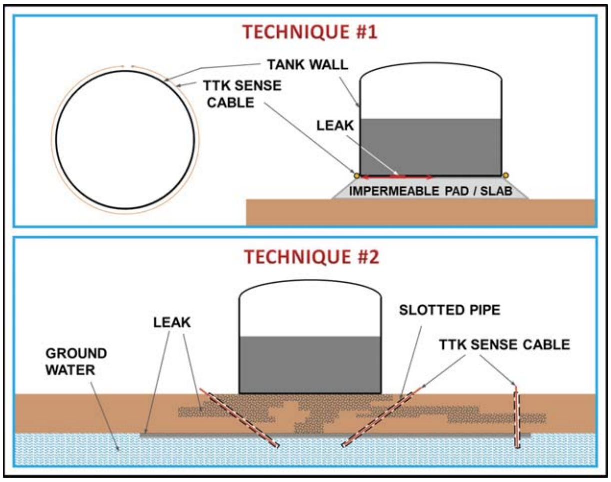

Figure 2. Recommended techniques for storage tank retrofitting.

after a short period of leakage, almost the entire inventory of D2 was released within 15 minutes.

The incident has been classified as a 'major accident', according to the criteria set in Annex VI of the Seveso II Directive.

D2 was an atmospheric storage tank with an external floating roof and a cone-up bottom. The storage tank had a diameter of 54.5 m and a height of 17 m. It was built in 1971 in line with the specific construction standards of API 650.

D2 was fully inspected in 1990 and was put into service in 1991. From 1994, external inspections were performed every three years. The reports of these inspections contained almost no remarks. A full inspection of D2 was scheduled for 2006.

Primary causes

During the operational life of D2 a gutter was formed in the bottom of the tank. This gutter is situated at a distance of 1.5 m from the tank shell. Due to the formation of the gutter, water could no longer flow into the drain water system to be removed. The accumulation of stagnant water in the gutter caused strong corrosion, which significantly reduced the thickness of the bottom plates in that area.

The release initially started with a small leak, which was not visually detected. In the second phase of the accident the resistance of the foundation under the tank was greatly reduced locally (as a result of the fluidisation of the sand bed) and, due to the hydrostatic pressure of the crude oil on the tank bottom, the bottom ruptured over the length of the gutter. The force of the discharged crude oil was sufficient to destroy a part of the tank foundation and sweep away a part of the underground.

The main consequences were:

- The released crude oil filled the whole bund (40 000 m^2 large) up to a height of 1 m.
- After the release, the storage tank was leaning forwards and a part of the storage tank's foundations had disappeared.
- The part above the bund clay-layer was polluted over the whole area of the bund; the depth of this pollution varied from 10 cm up to 1 m.
- The significant amount of crude oil that was captured in the bund caused strong odour pollution in the wide surroundings of the depot.
- A small amount of crude oil (approximately 3 m^3) was ejected out of the bund.

Case study: France

This accident, also presented in a technical report by ARIA, occurred on 12 January 2007 at a depot for oil and petroleum products comprising 28 tanks.[4] The depot is located along the banks of the Garonne River, in an area in Ambès containing 'jalles', or pits and swampy channels (image B, Figure 1).

The accident occurred on tank no. 1602, built in 1958 and containing a floating roof. On the day of the accident, the facility was storing approximately 12 000 m^3 of light crude oil.

The accident

During the afternoon of 11 January 2007, a small leak was observed in the retention chamber of tank no. 1602. A tank draining operation was planned for the next day for safety reasons. In the interim, water was poured into the bottom of the tank via the bleed valve in order to limit the amount of oil leaking.

On 12 January 2007, at 8:00 am, a portion of the tank bottom broke and the full crude oil inventory spilled in a matter of a few seconds.

The earthen dykes were able to mechanically withstand the wave effect. However, 2000 m^3 of crude oil overflowed and spread on the ground and roads, both in the immediate area around the depot and outside the site.

Primary causes

A number of critical questions were raised over both the effect of corrosion and the influence of the tank's unconsolidated bed on the overflow.

The storage tank bottom had last been inspected on 3 April 2006; the inspection method applied was a complete scan of the bottom according to the magnetic flux loss protocol. The accident report indicated thickness losses of between 20% and 50% over the central part; losses of 20 – 80% on the periphery; and a likely 2-year life span for the tank bottom. As a consequence, repair work had been performed and then verified.

The main consequences of the accident were:

- Most of the 2000 m^3 of oil that spilled outside the basins was confined within site boundaries, although 100 m^3 was released, polluting the Garonne River as well as 2 km of ditches and infiltrating deep enough to reach the water table.
- The day after the accident, traces of the spill were observed more than 20 km downstream of the depot, as well as on the Dordogne River. The succession of tidal movements exacerbated the level of pollution along some 40 km of riverbanks on the Garonne, Dordogne and Gironde rivers. The most heavily fouled 10 km stretch was found on the right banks of the Garonne and Gironde.
- A hydrogen sulfide (H_2S) odour could easily be detected up to several kilometres downwind from the site, necessitating the wearing of masks at the depot.
- Economic losses were estimated at over €50 million, including operating losses.

Preventing adverse effects of time on industrial facilities

Whether the focus lies on tanks, pipes or other equipment, and regardless of their level of utilisation, it is likely that all facilities will lose some of their initial reliability in terms of operations and safety over the course of time. The sizeable loss of confinement at Kallo and Ambès are just two recent examples from a long list of incidents. It is significant that in both cases a small leak was reported before catastrophic failure.

A presentation made in October 2015 at an OECD Special Session on the ageing of hazardous installations shared this analysis:

- Corrosion is the first cause of underlying accidents involving ageing of installations; fatigue is another recurrent cause.
- Prevention should be placed into a comprehensive management approach including incorporation of early [leak] detection.[5]

Another study that lists early leak detection as one of the different recommended measures is a technical report by ARIA, which states that several techniques can be applied to detect a leak in the bottom of a storage tank while the storage tank is in duty. A possible leak detection technique consists of sensing cables placed underground at fixed distances.[4]

As part of the available toolkit of preventive measures that allow early leak detection – particularly of leaks caused by corrosion – monitoring cables based on the absorption of hydrocarbons and petrochemical products represent an effective solution.

Figure 3. An example of an installation with monitoring wells, able to cope with pre-existing soil pollution.

Figure 4. Examples of sense cable installation for aboveground pipes and transfer lines.

Addressable sensing cable technology

TTK has developed a patented addressable system based on direct sensing cables and probes, allowing early, accurate and reliable leak detection.[6,7]

The functioning principles of the sensing cable are:

- A sensor element composed of coextruded, conductive silicone that absorbs hydrocarbon liquids or their vapours in case of physical contact with them.
- Increasing electrical resistance as a consequence of the induced swelling.
- A sensing circuit composed of multiple cables (or 'sections') of nominal length.
- Each section is provided with an embedded microprocessor-based electronic module, housed in a liquid-proof shell (IP68 rated), so that each section becomes autonomous from the rest of the string.
- Electronic modules communicating with a remote alarm panel through a low-power digital communication bus fit for hazardous areas (Ex zone 0).

When the electrical resistance reaches a factory pre-set value, the alarm panel receives a leak alarm from the electronic module, with the localisation of the leak on the affected cable highlighted by a unique address.

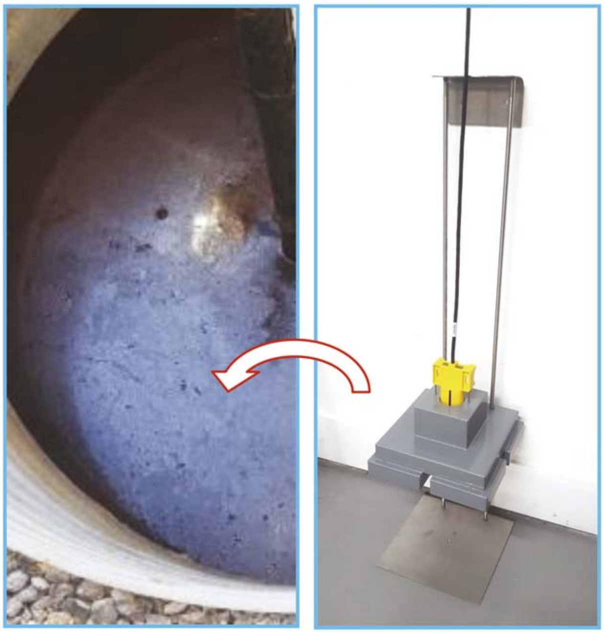

Figure 5. TTK floating sensing system designed to cope with pollution present in water.

Since the hydrocarbon absorption process is reversible, the sense cable can be reused. This allows easy site leak testing after installation, under real conditions.

The outer surface of the sensor element is electrically insulated and hydrophobic, and is not affected by environmental conditions such as water, dust/dirt, etc.

The sensing cables are available in standard lengths (3 m, 7 m, 12 m and 20 m), which can be interconnected to form a continuous sensing circuit up to 800 m long.

Three references by TTK are available, with different sensitivity:

- FG-OD: standard response.
- FG-ODR: less sensitive, where hydrocarbons can be present in normal operation.
- FG-ODC: enhanced sensitivity (for heavy crude oil, HFO, vapours, etc.) – about three times faster than FG-OD.

In particular, FG-ODR cable is designed to focus on sensing fresh leaks rather than vapours and some contaminants.

The addressable sensing cables are maintenance-free:

- No calibration is required, and regular circuit spot tests can be performed.
- Cable cleaning is required only in the event of contact with heavy contaminants.
- A 10-year supplier warranty is provided.
- They are capable of providing reliable leak detection on storage tank terminals.

For storage tank retrofitting, either of the following two techniques based on sense cables have been recommended/implemented:

- Aboveground installation, storage tank built on an elevated impermeable pad or slab: sense cable placed at the foot of the tank wall, thus avoiding contamination from pre-existing soil pollution, as shown in Figure 2. This arrangement allows the sensing of leaks both from the bottom plate and tank wall.
- Underground installation, soil and groundwater quality monitoring: sense cable placed inside a slotted pipe within a small diameter, low-depth well, as shown in Figures 2 and 3. Low-cost, widely available microdrilling tools are employed to drill the bores. False alarms, due to pre-existing contaminants, are avoided by using low sensitivity sense cable and/or hydrocarbon-absorbing mesh placed around the sense cable.

On new builds, it is recommended to install the sense cables underneath the bottom plate, inside slotted pipes provided with a filtering sleeve. The sense cables, which can be deployed with different patterns (straight rows or circular strings), are accessible via external pits.

Similarly, monitoring of underground lines is also performed using sense cables placed inside slotted pipes.

On aboveground lines, it is recommended to strap the sense cable at the bottom of the pipe after placing it inside a wrap-around braid for UV-protection, as shown in Figure 4.

TTK has also developed a punctual sensor (probe) and a floater specially designed to avoid false alarms caused by small quantities of contaminants. This system is typically installed at tank bund low points/sump pits. A guiding system for the floater, with adjustable height, is also available (Figure 5).

Conclusion

The oil and petrochemical industries have experienced numerous losses of containments, some of them with severe consequences for human health, the environment, and companies' finances.

Implementation of early leak detection constitutes an effective means of accident prevention.

The arrangements described in this artice, based on reusable, addressable sense cables and probes, constitute a new approach to achieving accurate and reliable early leak monitoring of storage tanks. T&T

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