Overflow of a gasoline tank inside a refinery

22 October 2011

Reichstett (Bas-Rhin)

France

Oil depot
Hydrocarbons
Automatism
Sensor
Test periodicity
Material failure

THE FACILITIES INVOLVED

The site:

The refinery is located north of Strasbourg on a site covering more than 160 hectares. Refining activities started up in 1963 and until 2011 effectively supplied fuels throughout eastern France, along with liquefied petroleum gas to a filling centre set up in the vicinity (see Fig. 1).

The refinery contained a number of classified facilities subject to administrative authorisation with easements. The site was in fact classified "upper-tier" Seveso due to the quantities of flammable and/or toxic substances being manufactured and handled. Since 2011, the refinery part of the site has been idle. All sensitive facilities were gradually placed in safe operating mode according to a predetermined schedule. The refining units were taken offline. The shift crew consisted of 6 staff members: 1 control operator acting remotely (working from console displays) and 5 fire-fighters, including one safety team leader.

The site's oil depot however continued to operate, albeit at a reduced level of activity.

Figure 1: Aerial view of the refinery
(source: P. BANTZHAFF)

The specific unit involved in this accident:

Figure 2: View of the storage tanks
(source: DREAL Environmental Agency, Alsace)

Tank T 495 - 17 m in diameter and 18 m high - had been fitted with a floating roof, a radar-based operating level measurement installed in a vertical shaft, and a safety high-level measurement system (independent of the operating level and also performed in a vertical shaft, Fig. 2).

The radar-based level measurement system was equipped with three alarm levels: operating level, high level, and high-high level.

The high-high level safety measurement relied upon a system called MIP (for Marine Instrument Petroleum) that operates according to a different principle than the radar-based level measurement (Fig. 3). This system comprised a plunger hooked up to a hose connector and a spring, plus a vertical shaft connected to both the spring and a mercury bulb switch. With this set-up, the switch activation triggered a high-high level signal visible in the control room, thus initiating immediate shutdown of the transfer operation.

The tank was configured as a retention basin; it featured an outer ring to collect stormwater, including water stemming from the floating roof via a drain. The water accumulating in the tank was then recovered by a collector pipe running along the outer ring.

Hydrocarbon detectors, coupled with the site alarm, were installed on the collector pipe for water recovered by the outer ring as well as on the collector pipe for water recovered around the pumping station used to transfer hydrocarbons from one tank to another.

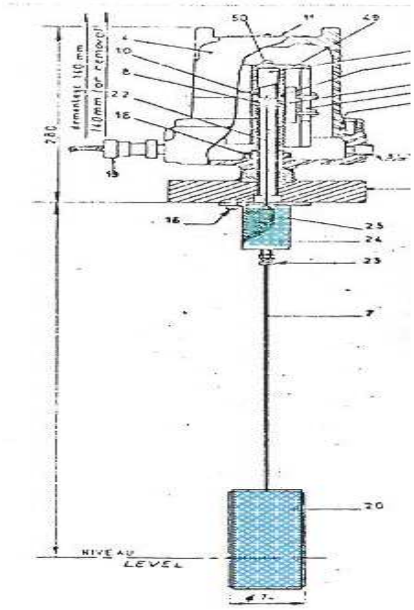

Figure 3: MIP operating diagram (source: Site operator)

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

Hydrocarbon fuel was being transferred in the refinery's depot in compliance with operating instructions. Tank-to-tank transfer of gasoline is a standard procedure that involves incorporating into an automated system (i.e. a calculator) the operating height of the recipient tank upon completion of the transfer step.

A 3,750-m^3 transfer of 95-octane rated gasoline from tank T 488 to tank T 495 was undertaken at the end of the afternoon. At 8:01 pm, the "hydrocarbon vapour" detection was triggered in the analyser room at the pumping station. A technician entered the room and smelled the gasoline. With his radio, he informed the control operator, who deduced that this detection was most likely related to the only ongoing transfer, i.e. between tanks T488 and T495. This transfer was immediately halted; the control operator then initiated the programmed alert procedure.

On the scene, the local monitoring team reported:

- the presence of gasoline in the outer ring of tank T495;
- a gasoline flow in the oily water sewer system via the drain line, which had remained open;
- the absence of gasoline in the retention basin due to the fact that the oily water purge valve had been left open;
- the floating roof, thrust by the gasoline, had bumped the upper edge of the tank structure.

From indications displayed on the monitoring screen, the control room operator determined that this tank overflow had caused the loss of 200 m^3 of gasoline. This initial estimate was subsequently revised downward upon learning the findings of investigations conducted by both the depot operator and fire-fighters.

The internal emergency plan was activated around 8:15 pm. In recognition of the inherent explosion and fire risks, the operator notified the fire department. The local authority (Prefecture) was also informed of the incident.

Fire-fighters arrived onsite near 9 pm, followed by police forces and a local authority representative. The Classified Facilities Inspectorate, alerted around 9:20 that evening, reached the scene at about 10:30 pm.

Consequences:

No victims were reported from this accident. Property damage was limited to the floating roof, which remained stuck to the upper edge of the tank shell. After several hours of investigation, the gasoline loss could be evaluated at approx. 20 m³. The gasoline was eventually recovered and routed to a slop tank (i.e. containing liquid residue) for treatment.

This event generated no impact outside of the site boundary; none of the areas of interest cited in Article L. 511-1 of the French Environmental regulation had been adversely affected.

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in Ferbruary 1994 by the Member States' Competent Authority Committee for implementing the 'Seveso' directive on handling hazardous substances, and in light of information available, this accident can be characterised by the four following indices :

Dangerous materials released	■	□	□	□	□	□
Human and social consequences	□	□	□	□	□	□
Environmental consequences	□	□	□	□	□	□
Economic consequences	□	□	□	□	□	□

The parameters composing these indices and their corresponding rating protocol are available at the following Website: http://www.aria.developpement-durable.gouv.fr.

The "hazardous substances released" index received a "1" rating due to the spill of gasoline in a quantity between 22 m³ and 30 m³, amounting to some 20 tonnes.

The "human and social consequences" index was not scored given the absence of victims.

The "environmental consequences" index was also unrated as no environmental impacts could be observed.

Moreover, the "economic consequences" index was not scored since the amount of property damage on the tank roof, when added to the loss caused by immobilisation of both the damaged tank and other tanks during the investigation, product losses and the cost of treating recovered product, were less than €100,000.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THIS ACCIDENT

The suspected faulty operation was intended to prepare a product for shipment to the Strasbourg oil port prior to loading onto a barge. The instruction submitted by the unit manager to the control operator sought to ensure that the gasoline transfer from tank T 488 to tank T 495 reached a point of filling to the "high operating height" level, so as to avoid tripping the alarm during gasoline transfer. This product movement was entered into a calculator in the control room, with automatic shutoff programmed by the system at the height recorded upon completion of the high operations phase.

The ullage of tank T 495 (i.e. gasoline height in the tank) was relayed to the control room console by a radar-type, high-level sensor indicating gasoline height in the vertical shaft (see Fig. 5).

The control operator, stationed in the control room, could visualise on a screen the gasoline level inside the tank. Relayed by radar, the reading displayed on his screen provided a measured gasoline level in the vertical shaft but not the actual gasoline level inside the tank. Water present at the bottom of the tank could rise into the vertical shaft as a result of the thrust generated by gasoline movement in the tank during this transfer process. Therefore, a height difference could occur between the gasoline level in the tank and its corresponding level in the vertical shaft.

The radar-based control system appeared to be operating normally with no preliminary indication observable by the control operator that the height being read by the radar was lower than the actual gasoline level in the tank (Fig. 6). During tank overflow, the height difference between the radar reading and the actual gasoline level in the tank was 3.3 m: the level reached inside the vertical shaft from the radar reading, as displayed on the control room screen, was just below the operating height whereas the actual liquid level had reached tank height.

Due to its malfunction, the second "MIP" system failed to sound the high-high level alarm. The tank overflowed and gasoline spread towards the tank's outer ring, eventually reaching the oily water network, since the purge valve had remained open. This open valve position was a measure practiced during periods of heavy rainfall in order to avoid clogging the outer ring and to ensure good working order of the drain on tanks fitted with a floating roof.

The personnel on duty responded quickly after detecting hydrocarbons around the oily water network pumping station, located over 300 m from the tank. Using explosimeters, depot personnel recorded the presence of hydrocarbon vapours: at the pumping station, in the gutter running around the periphery of tank T 495, and leading to the underground oily water network. Concentrations measured at these points remained below the lower flammability limit (LFL).

Figure 4: View of the tank's floating roof after the overflow (source: Site operator)

Depot employees, assisted by fire-fighters, proceeded by covering all gasoline vapour emission sources (top of the tank, the tank's outer ring and around the pumping station zone) with foam. A safety perimeter was set up and moved as the situation evolved for responders; this perimeter was gradually reduced as individual areas were verified one by one to be free of gasoline vapours at the oily water network.

From drawings furnished by the operator, fire-fighters were able to identify gasoline at retention basin manholes. It was then attempted, though unsuccessfully, to recover the gasoline with a tanker truck whose cistern had been depressurised. Around 2 am, the operator placed a call to a specialised subcontractor equipped with an "ATEX" lorry for explosive atmospheres, but the company's certified personnel could not be reached.

Given the unfavourable weather conditions, responders' fatigue and the overall absence of adequate resources, the crisis response unit decided to postpone gasoline recovery until the next day. An onsite monitoring strategy was implemented; all sensitive zones were covered with foam and controlled with an explosimeter.

According to operator investigations, this overflow was caused by the two following conditions:

- The vertical shaft on the radar-based system for verifying operating levels (Fig. 6) was not equipped over its height with orifices to allow for unrestricted flow of gasoline into the tube. This shortcoming led to a false reading of gasoline level in the tank due to the presence of heavier water; the level read by the control operator in the control room was therefore actually lower;

- The high-high level barrier (MIP system) was inoperable despite recent verification. The vertical measurement shaft on this sensor contained orifices over the longitudinal generatrix, allowing gasoline to pass and thereby eliminating any risk of false reading due to the presence of water heavier than the product.

Figure 5: View of the radar device on tank T 495 (source: DREAL-ALSACE)

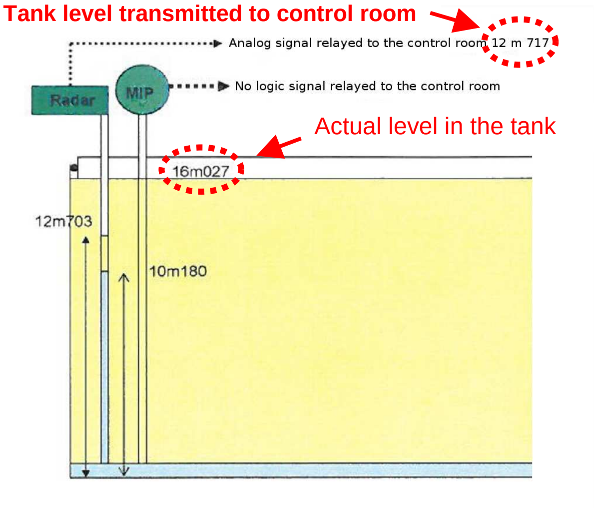

Figure 6: Presence of water in the control shaft of tank T495, observed after lowering the floating roof to 16 m during accident investigations (source: Site operator)

ACTIONS TAKEN

The Classified Facilities Inspectorate visited the site around 10:30 pm. The situation had not yet been brought under control. The actual quantity of gasoline spilled from the tank was disputed. Investigations undertaken by fire-fighters on the one hand and an analysis of information output by the computerised monitoring of transfers on the other yielded a range of 22 to 30 m^3. This quantity interval was explained and justified by the operator in the accident report submitted.

An accident report explaining the causes of this overflow and proposing remedial measures was requested from the site operator. Regarding specific elements identified to be defective, the operator proceeded by:

- looking for similar configurations elsewhere on the site. 34 tanks were verified (with both floating and stationary roofs). These investigations also revealed the existence of 3 different MIP technologies installed on the tanks: use of a plunger for 7 tanks (including the T 495), a floater fitted on 14 tanks, and a mechanical scale on another 13 tanks;
- assessing the causes of malfunction experienced with the mechanical device for the high-high level (MIP) control. The site's MIP systems were tested: all activated normally, except for one installed on a crude tank, as the plunger system was unable to return to the rest position on its own and needed to be pulled down mechanically. Some slight seizing could be observed;
- ensuring that the protocol of relying on a subcontractor to resolve accidental situations was effectively in place under all circumstances, in terms of both human and technical resources.

LESSONS LEARNT

This accident prompted the depot operator to:

- improve the quality of information available on the control operator's console, including a more refined representation of ongoing transfer processes capable of alerting the technician of a deteriorating situation. Given the change in tank use patterns, operating conditions needed to be modified: no more tank-to-tank pouring and regularly scheduled purges due to the use of vapour (as was the case when the depot had been jointly run within the refinery complex);
- replace the 7 distinct MIP mechanical systems using a plunger to control operating levels by MIP systems based on a floater or mechanical scale device, deemed more reliable and easier to test. Moreover, the plunger

model was no longer being manufactured and its replacement had already been planned prior to closure of the refinery installations;

- revise MIP test conditions to include floater or scale type mechanical systems in order to ensure no defects under actual operating conditions. More specifically, testing of the floater-based MIP entails disassembly and an external test protocol. The device spring, subject to wear, is a known weakness of this level measurement technology;

- change the control device test periodicity within the operating range by using an environment more representative of actual conditions: *in situ* testing of the MIP in a liquid medium (gasoline or crude);

- consolidate the instructions related to the handling of purges and purge valves placed along the tanks' outer rings. While such handling techniques during periods of heavy rainfall count among the best practices adopted by the profession, these steps had not been strictly enforced;

- review the assistance contract signed with subcontractors so as to ensure the availability of ATEX-rated equipment (appropriate lorries and accessories) and personnel certified to use such equipment in high-risk zones, when faced with emergency situations and under all circumstances.

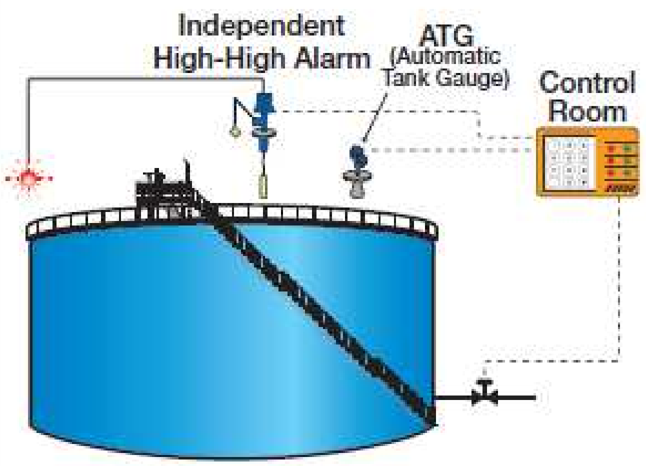

Figure 7: The American API 2350 Standard classes as Category III any storage tanks managed remotely; moreover, it recommends use of a high-high level safety sensor that is independent of the operating level (ATG) sensor and, preferably, offers self-diagnostic capacities relative to its malfunctions and defects.