Rupture of a heated fuel tank

25 December 1988

Berre l'Etang (Bouches-du-Rhône) France

Structural rupture
Refinery
Fixed storage
Hydrocarbons
Pressure surge
Building works / modifications
Fatigue
Corrosion
Property damage

THE FACILITIES INVOLVED

Close-up on the unit:

The T837 tank involved in the accident was located in the storage zone of a refinery. Equipped with a capacity of 15,000 m^3, this tank contained heavy hydrocarbon compounds, with high sulphur concentrations, held at a temperature of 127°C ("straight-run" residue stemming from an atmo spheric distillation column). This facility was a fixed-roof tank 30 m in diameter and 22 m high, featuring 10 ferrules, a stirrer and oil heating coils fastened along the tank bottom. In order to avoid air / water intake that might cause an explosion or pressure surge due to mixing with hydrocarbon contents, the tank was rendered inert by means of injecting overheated water vapour into the roof and exhaust through one of the flues. Operational as of 1971, this T837 structure was initially installed along with 3 identical tanks in a single retention basin, bordered by a passage of pipes containing vapour and both liquid and liquefied hydrocarbons.

The tank had already been repaired twice subsequent to roof deterioration. Due to leaks in the inerting pipe system, water had entered the vapour cloud, leading on two occasions to an internal pressure surge that caused the rim angle / roof welds to break. During the second repair job in June 1981, the roof and one of the ferrules were replaced and explosion hatches installed. To satisfy the needs of work crews, an opening was introduced into the shell and then covered by a 2.05 x 1.60-m fillet welded plate on both inside and outside. Following these repairs, the tank was tested and the vapour heating coil then replaced by the oil coil, which was also successfully tested.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

On December 25, 1988, the tank was undergoing filling: the allowable flow rate was set at between 80 and 160 m^3/hr, i.e. for a level rising rate of 0.12-0.25 m/hr. By 3 am, the level had reached 20.4 m (13,500 m^3) at 1.1 m below the high-level alarm and 1.5 m from the roof. Measurements were collected using a radar level gauge accurate to within 2 mm. The highest filling level recorded until that time had been 19.6 m. The other tanks contained respectively 1.14 m of low-sulphur residue (tank T836), 10.55 m and 0.94 m of distillate (T826 and T827).

At 3 am, the shell of tank T837 suddenly ripped open. According to the metallurgical expert evaluation conducted on April 28, 1989, the tear was initiated along an internal vertical weld of the plate obstructing the opening placed in 1981 to accommodate the repair works. This evaluation also indicated that a 1.05-m long crack, with maximum depth of 2.5 mm, had been present in this specific zone, as observed over a 0.70 m segment.

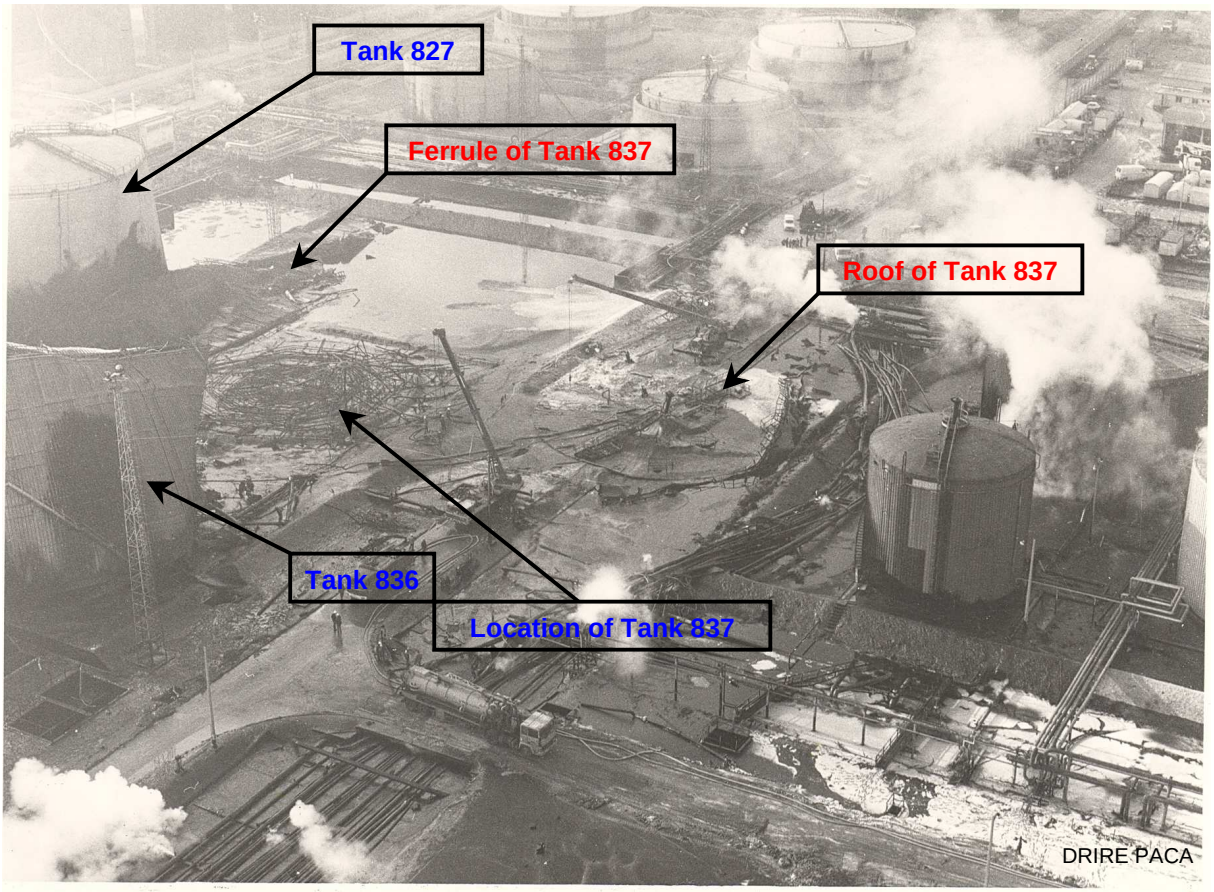
Moving to the lower part of the tank, the tear continued until reaching the shell/bottom seal, at which point it extended by shear force on both sides of the circular shell/bottom weld over the entire tank circumference. Towards the top of the tank, the split spread vertically through six of the ferrules, to a point 8 m below the roof where it intersected the shell/internal reinforcement angle seal. Once again, like on the bottom, the break continued to extend by means of shear force simultaneously on both sides of the seal over 3/4 of the circumference, before branching to the roof.

At 3:20 am, the refinery's internal response team was notified; at 3:40 the facility-wide alarm was sounded and a crisis unit could be assembled by around 4 am.

Outside the refinery, local gendarme officers completed their rounds and fire-fighters from the town of Berre were placed on alert yet not immediately deployed to the scene.

The wave of hydrocarbon product from the tank heated at 127°C (density: 0.95) rolled well past the con fines of the retention basin, extending some 8 ha inside the plant and covering many of the installation's internal roads. Damage was caused to one of the adjacent tanks (T836), with low-sulphur residue, completely deforming it and lifting it onto its base.

The shell fitted to the T837 tank fell onto the adjacent T827 tank, which was storing high-sulphur distillate, in turn deforming several ferrules and partially stripping the roof. Afterwards, the tank located diagonally opposite (T826), in the same common basin with a straight-run low-sulphur residue, was displaced. Carried by the power of this hydrocarbon wave, the roof of tank T837 along with 4 pieces of ferrule that had remain attached drifted 45 m from their original location.



The visbreaker was shut down, and all other refinery unit activities were scaled back; the pressure of the flare system was reduced in order to prevent cinders from igniting the slick. Clogged by residue, the freshwater supply channel for processing systems was isolated to keep the quantity of fouled water to a minimum.

Damaged by the wave, the petroleum transport lines running in trenches were also leaking product, adding to the size of the fuel spills. Until 8:30 am, fuel oil kept flowing out of a pipe via a flange, whose threaded rods had been twisted by the tension created when the hydrocarbon wave passed over.

Consequences of the accident:

A fire-fighter had to be transported to the infirmary for minor injuries sustained when a truck overturned, and a technician was slightly hurt while manipulating a shutoff valve on the fire-fighting water supply system.

The resulting wave, containing 13,500 m³ of fuel residue from tank T837 along with product stored in adjacent tanks, either destroyed or displaced a wide array of equipment, including:

- two 15,000-m³ capacity tanks (i.e. T827, with 630 m³ of high-sulphur distillate, had its ferrules smashed by the ferrule on tank T837 and its roof damaged; and T836, with 770 m³ of low-sulphur residue) were completely destroyed. The 15,000-m³ capacity tank T826, with 7,090 m³ of high-sulphur distillate, was not ripped open despite being displaced by the wave;
- pipes of heavy fuel and fuel oil residue running 50 m from the destroyed tank were twisted, ripped apart or blasted against the bund walls of neighbouring basins (leaks without subsequent fire outbreak);
- pipelines carrying vinyl chloride and ethylene were displaced yet did not leak;
- butane and propane pipes under construction were twisted and shifted;
- an electrical transmission tower fell;
- the stirrer junction boxes and motors inside the bund wall were damaged;
- masonry debris was found more than 100 m from its original location.

Pollution was prevented from entering the nearby *Berre Pond* by means of installing a floating dam to help channel residual water containing hydrocarbons to a 20,000-m^3 stormwater basin. Moreover, this product congealed very quickly inside the refinery and retention basin, making it much easier to confine.

This accident could have produced much more dire consequences had inflammable liquids been involved or had the wave broken some of the gas pipelines.

The European scale of industrial accidents:

By applying the rating rules of the 18 parameters on the scale officially adopted in February 1994 by the Member States' Competent Authority Committee, which oversees application of the "*SEVESO*" directive on handling hazardous substances and in light of available information, this accident can be characterised by the following 4 indices:

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

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

The "1" value ascribed to the "Human and social consequences" index reflects the slight injuries to both the fire-fighter and technician (parameter H5).

The "Hazardous materials released" index received no rating, since the (straight-run) distillate involved in the accident was not covered in Appendix I of the *Seveso II* Directive.

No indication was available regarding the economic impacts of this accident.

As a result of the measures adopted in response to these events, no environmental consequences could be identified.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The observations and simulations performed established that corrosion exposed to stress, in association with fatigue, was the likely cause of the initial crack. During the expert evaluation, a number of aggravating factors were also highlighted:

- notching effect, due to poor alignment of the plate with respect to shell curvature;
- fatigue, due in particular to cyclic service conditions and the wind effect;
- inappropriate mechanical characteristics of the metal used on the structure, as revealed by the high level of hardness under the welding seam;
- poor orientation of the sheet metal placed on the tank to obstruct the opening created in 1981, with respect to the lamination direction;
- high sulphur content in the products stored onsite, which is capable of inducing the phenomenon of corrosion by hydrogen.

Even though this crack undeniably led to vulnerability in the tank, it is still likely however that the crack itself did not directly cause the rupture. According to the enquiry commission (assigned to determine the specific causes and recommend interim measures to avoid repeating such an accident), water pockets at the bottom of the tank, stemming from inerting vapour condensation and trapped beneath the residue (density of stored product: 0.95), would have entered into contact with the heating coil or hotter residue zones and then vaporised. Based on the operations log, an abnormal rise in the vapour flow rate from 16 tonnes/hr on December 22 to 27 tonnes/hr prior to the accident was in fact recorded; moreover, out of the eight 0.8-m diameter explosion vents, several had been locked in an open position for several days: technicians no longer noticed vapour exhaust in the flue and three of the vents were found open following the sudden burst of the tank. This abrupt water vaporisation below the residue would have triggered a pressure surcharge in the tank and its subsequent rupture.

No procedural error by any unit or tank operational failure can be signalled.

This type of rupture had not been foreseen as a potential scenario for a major accident.

ACTIONS TAKEN

The first debris removal equipment was onsite and operational as of 7:20 am, and the scoured product was evacuated to a refinery zone set up within the former settling beds.

After the accident, the operator inspected the ethylene and VCM pipelines that had been moved and deformed by the hydrocarbon wave. While awaiting results of these verifications, the following safety measures were implemented:

- Reduction in the level of service pressure
- Pipeline inspection routine with selected gas intake, including a VCM intake
- Marking of the reserved zone and pipeline identification (e.g. an "in-service VCM" indication).

Repair works were undertaken following the accident for the purpose of reinstating the site for service in 1990.

Photographs taken on March 30, 1990 during site rehabilitation works

LESSONS LEARNT

Proceeding under the hypothesis of a sudden water vaporisation phenomenon at the bottom of the tank, caused by vapour condensation, the enquiry commission issued the following recommendations in June 1989:

- Elimination of explosion hatches, given that they are capable of doing more harm than good when left locked in an open position;
- Systematic verification of manhole closure, in addition to inspection of the flues designated for release of inerting vapours;
- Inspection and repairs, if necessary, of the work performed to ensure tank compliance: a metallurgical evaluation revealed that the tear had initiated along an internal vertical weld on the plate covering the opening introduced in 1981;
- Preservation of vapour inerting with just a single flue.

This accident also drew attention to:

- ✓ Tank modifications: choice of materials adapted to existing equipment (identical metallurgical composition), to stored or transported products (presence of sulphur, hydrogen, water, etc.), and to use conditions (heating, cycles, wind, etc.); and the appropriate configuration and positioning of all added parts;
- ✓ Inclusion of exceptional accidental phenomena, whose consequences however are potentially significant;
- ✓ Retention basin strength and layout: division into sub-basins could serve to confine the wave in a smaller space (by "breaking" wave speed through successive bund walls, smaller product volumes in the various compartments), in addition to reducing damage caused to adjacent facilities;
- ✓ Localization of pipe alignments, primarily pipes carrying combustible gas, so as to limit their vulnerability.

A fact sheet has been produced by the BARPI Office on the failure of large-capacity tanks, for the occasion of the 2007 IMPEL Seminar held in Paris on feedback from industrial accidents. This sheet can be downloaded from the Website www.aria.developpement-durable.gouv.fr under the heading: IMPEL Seminars / Paris (2007) / IMPEL 2007 - Accidents presented with analogies.

References:

- Accident file, Classified Facilities Inspection authorities for Environmental Protection.