Boilover of a crude oil tank

30 August 1983

Milford Haven [Wales]
United Kingdom

Explosion / Boilover
Fire
Refinery
Fixed Storage
Floating roof
Flare
Hydrocarbons (crude oil)
Difficulties of response
Fatigue / Cracks

THE INSTALLATIONS IN QUESTION

Site:

The site involved is a tank farm of one of the three refineries close to the harbour area of Milford Haven. The refinery was set up in 1973 and has increased its annual production capacity to 5 million tonnes with 67 storage tanks by 1983.

The storage tank in question TO11 had a floating roof installed and was the biggest tank of the site with a 94,110m^3 capacity. The tank was 78m in diameter and stood 20m high. It was set up in a 16,222m² containment dike by itself. The floating roof is a single deck[1] annular pontoon type roof with 24 radial pontoons. Two fixed roof storage tanks with an individual capacity of 13,000 m^3 containing distillate are implanted in a containment area next to that of the tank TO11. An 83 m flare is located at 99 m of the bund wall closest to the tank TO11's containment dike.

Circumstances:

The violent winds blowing in this coastal area of Wales caused cracks to form on the surface of the floating roof. These cracks were regularly repaired. During a roof inspection carried out few days before the accident, cracks as long as 28 cm, and seepage of crude oil were observed on the surface of the pontoon's membrane.

On the day of the accident, the storage tank was half full and contained 47,000 tonnes of light crude oil (flash point of 38℃ (311 K)) from the North Sea. No transfer of cr ude oil was carried out during the last 24 hours.

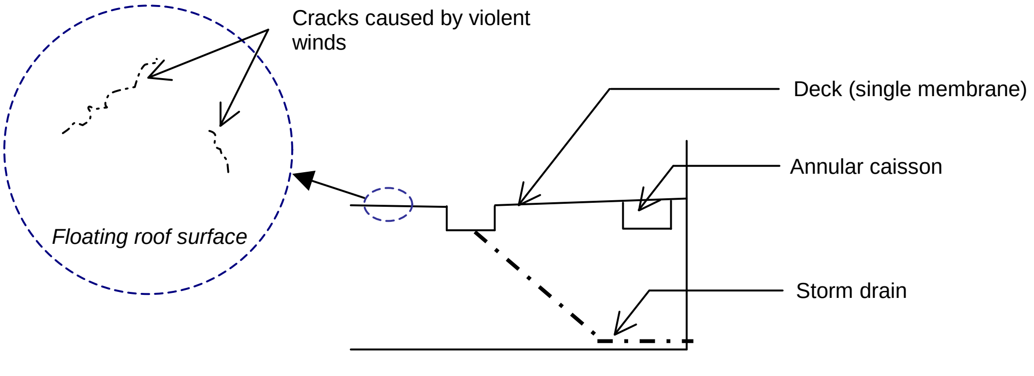

Diagram of a single deck annular pontoon storage tank

[1] The single deck floating roof comprises a central circular membrane called deck that directly sits on the stored liquid and is bordered by an annular caisson divided into compartments impermeable to the liquid. These compartments ensure the floatability of the structure under normal operating conditions, in the event of accumulation of rainwater on the deck or when the deck collapses.

THE ACCIDENT, ITS BEHAVIOUR, ITS EFFECTS AND CONSEQUENCES

Accident:

On 30 August 1983, at 10.45 am, a compressor of the catalytic cracker broke down. At 10.50 am, flames were seen on the roof of the tank TO11. At 10.55, due to the lack of fixed fire protection device, the fire department of the refinery sprayed the tank roof with foam liquid using a canon fixed onto an aerial platform. The firemen required up to 26 water canons to cool down the tank shell and protect the two adjacent distillate tanks with a water curtain. However at 11.05 am, the cracks on the floating roof opened and the accident worsened: flames as high as 12m covered half of the surface of the tank and by noon spread to the entire surface. The access ladder to the roof was exposed to the radiation from the furnace and could thus not be used for rescue purposes, preventing the firemen from pulling fire hoses till the roof. By virtue of a mutual assistance agreement signed between refineries, the foam compound stock is stored in Haven and could be dispatched wherever needed.

At noon, the tank TO11 started to empty at a rate of 1,700 tonnes per hour while the crude oil burnt at 300 tonnes/hour. Draining the tank completely while its shell was swelling then seemed unpractical. It was easier to empty the two adjacent tanks. The water accumulated on the roof of the tank TO11 from the fire fighting operation, rain and crude oil weighed about 700 tonnes. The roof sank a bit further down providing an increased supply of hydrocarbons to the surface. Since the refinery had only 63 m³ of foam compound, the internal rescue team was no longer in a position to control the fire. The municipal fire-fighters took on the management of the operations.

The slight breeze prevented the accident from spreading and the cloud of smoke rose vertically outside the area of action of the rescue team. In addition, the security guards limited the number of rescue workers in the high risk zone to a strict minimum.

Despite additional resources from the Haven public fire protection department and other industrial sites as part of the mutual assistance agreement, the shortage of foam compound remained the major problem. According to estimates, the fire fighters were short of 40m³ of foam compound to the 160 m³ collected.

At 11.30 pm, a limited foam application split the flames into two causing a slop-over[2].

At midnight, the tank overflowed causing the first “classical boilover”[3] that resulted in a fireball with a radius of 90m and a flame attaining 150m in height. A large quantity of fiery crude oil was ejected spreading the fire to the containment dike, destroying most of the fire fighting equipment and forcing the rescue team to stop operations. Six fire-fighters sustained mild injuries during their retreat.

On 31 August at 2.10 am, a less intense second boilover occurred and the connection between the shell and the tank bottom gave in at four points releasing fiery crude oil into the dike. The bund wall over 5m high could however retain all the matter released. The thermal insulating material of the distillate tanks in the adjacent containment dikes caught fire and one of the tanks gave in, spreading the fire to the second containment dike. This fire was brought under control by the rescue team in 30 minutes.

During the night, additional fire fighting equipment and 305 m³ of foam compound were sent to the refinery from all over Great Britain. At dawn, the rescue team found out that the fiery crude oil had spread over the bund wall. At 8.00 am, the equipment required was available and the foam compound stock replenished. The rescue team then sprayed the foam compound to cool down the adjacent tanks to prevent the fire from spreading any further. At 9.15 am, the fire in the containment dike was brought under control and finally put out at 2.00 pm with the foam compound. A foam canon was used to reduce the intensity of the fire and help the rescue team get closer. At 2.30 pm, the tank fire was targeted that included three fire pockets behind the twisted shell of the tank.

On 1 September at 2.00 am, the foam compound stock was exhausted and the winds started to blow: the fire caught on to the entire surface of the tank. It was only at 8.00 am, when the foam stock was replenished that the foam attack started with three foam canons. The fire was brought under control at 10.00 am and declared extinguished at around 3.00 pm.

The operation called for 150 firemen, 50 fire engines, 44 fire-fighting pumps, 6 aerial platforms and 70 foam tanker trucks. More than two days and 765 m³ of foam compound diluted at 3% and 6% were required to extinguish the fire. A backup of firemen from the neighbouring counties helped relay the teams exhausted due to the heat and length of the operation.

[2] When water or foam is projected onto a fiery heavy hydrocarbon pool, an emulsion along with production of vapours causing an overflow without violent projection may be observed in the upper surface of the burning liquid.

[3] During a “classical boilover”, the tank fire causes the formation of a hot zone that travels faster than the flame front. Moreover, when the hot zone comes in contact with the water bottom, the product is projected resulting in foaming (the tank overflows) and a fire ball. In the event of “thin layer boilover” the product is consumed and a homogeneous composition is maintained without any hot zone being formed. It is the flame front that evaporates the water bottom when it comes in its immediate vicinity.

Consequences:

Six firemen sustained mild injuries during the first boilover. One of them was hospitalised.

The tank TO11 was destroyed, the adjacent tanks were seriously damaged and 17,800 tonnes of crude oil were consumed. The cost of this accident was assessed at about 10 M £ (value in 1983, i.e. about 26 M € in 2007). There were no production losses.

An evacuation plan was organised but not implemented since very few residents lived in the vicinity or were exposed.

The thick column of black smoke that rose several hundred metres above the refinery resulted in “soot rains” in the villages and the surroundings.

It must be noted that the rules in vigour allow three tanks identical to the TO11 to be implanted in the same containment dike. This option was not exercised in the depot.

European scale of industrial accidents:

By applying the rating rules of the 18 parameters of the scale made official in February 1994 by the Committee of Competent Authorities of the Member States which oversees the application of the ‘SEVESO’ directive, the accident can be characterised by the following 4 indices, based on the information available:

The parameters that comprise these indices and the corresponding rating method are available at the following address: http://www.aria.developpement-durable.gouv.fr.

Level 4 is attributed to the “Dangerous materials released” index since 17,800 tonnes of light crude oil from the North Sea (classified as flammable by the Seveso directive, flash point 38 ℃) was released.

Level 2 attributed to the social and human consequences corresponds to the six firemen who sustained mild injuries during the first boilover (H5 parameter).

The economic index is rated at 4 on account of costs relating to internal material damage that amount to 26 M€ (€15 parameter).

There is no indication available for any possible environmental consequences.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Origin of the accident:

Two factors jointly contributed to this accident:

- ✓ The presence of **flammable vapours** on the surface of the floating roof formed by the small quantities of crude oil that trickled through the fatigue cracks caused by violent winds.
- ✓ The projection of a **cinder** from the 83m high flare onto the roof of the tank TO11. Following the break down of a compressor of the catalytic cracker, significant quantities of gas were diverted from the flare network and burnt. This was inconsistently used to incinerate several products leading to carbon deposits.

Problems in rescue operations:

The problems encountered during the rescue operations were due to several reasons:

- ✓ Absence of a fixed fire protection system on the tank (fixed water spray systems, foam box, etc.) that let the fire spread.
- ✓ Foam compound supplies were planned to fight only the floating roof joint fire, which was the main accident scenario retained for such tanks at that time making the fire fighting operation less efficient during the 12 hours preceding the first boilover.
- ✓ Huge size of the tank TO11: 4,778 m² of surface area, 20m high difficult to access using foam nozzles.
- ✓ Intense heat responsible for:
  - o Destroying the fire fighting equipment on several occasions
  - o Disintegration of the foam in the tank TO11 during the attack on the second night
  - o Difficult conditions of operation for firemen who could only maintain the front line for a few minutes.

- ✓ Presence of fire pockets hard to access behind the metal folds of the tank forcing the firemen to mount a wagon pipe and a foam canon on a refinery crane to spray foam.
- ✓ Connection problems between the fire-fighting pumps and the foam tanker trucks sent on site forcing the firemen to design a new joint on site.

These obstacles encountered during the rescue operations delayed attack on the tank fire resulting in the formation of a hot zone in the tank that distilled the crude oil to reach the decanted water layer at the bottom of the tank causing the boilover.

It must also be noted that draining the tanks at the beginning of the accident would have been risky as small quantities tend to heat up sooner and are likely to cause an explosion due to overpressure in the fixed roof distillate tanks (see Edouard Herriot Port accident in Lyon - ARIA 4998) and hasten the boilover of the tank O11.

ACTION TAKEN

Further to this accident, the operator equipped the tanks with fixed fire extinguishing devices (foam boxes, fixed water spray systems, etc.).

LESSONS LEARNT

The colossal fire that resulted from the recurring problems of degradation of the permeability of the floating roof and break down of the compressor in the refinery section of the site has underlined several organisational and technical issues :

- ✓ On the site design:
    - o Presence of fixed fire protection devices on the tanks to facilitate rescue operations. A foam box would have probably put out the joint fire and the fixed water spray system would have prevented the empty portion of the tank from deformation and folding. The fixed and mobile fire protection devices must be adapted to the site's configuration.
    - o Presence of sufficient foam compound stocks for major accidents and appropriate fire extinguishing devices suited to the surface area and the quantities of product likely to catch fire.
    - o Exhaustive risk analysis by taking the cascade effects into account and not ruling out certain phenomena such as floating roof tank on fire.
    - o Studying the advantages and shortcomings inherent to large capacity storage sites and to surface areas of the corresponding containment dikes.
    - o Adapt the distance between the flare and other facilities especially according to weather conditions.

- ✓ On the site management:
    - o When a malfunctioning is known or detected, take into account the risk associated with any degradation of the situation and plan out measures to face or overcome the crisis while giving priority to repair operations rather than waiting for scheduled maintenance operations.
    - o Adapt the flare clean up frequency to its use to avoid incandescent particles from being projected onto the other facilities of the refinery.
    - o Share feedback: positive and negative aspects, problems in rescue operations, etc.

- ✓ On rescue operations:
    - o Perform fire drills for such extreme scenarios and clearly define the responsibilities of the operator and the public authorities during rescue operations.
    - o Weigh the advantages and shortcomings of quick rescue operations with limited resources against waiting for additional resources to launch a massive attack.

Accident feedback generally show that hydrocarbon fires involving large surface areas and a product volume of several thousand meter cubes are specially hard to control and require significant extinguishing and cooling resources. Failing which, these fires can last for long durations and spread to adjacent facilities (ARIA 2914, 3610, 4998, 6052, 6076, 31312, etc.).

Other accidents presenting phenomena such as "boilovers" and listed in the ARIA database include:

- ✓ *ARIA 6051, Japan, Yokkaichi, 1955, the explosion of a 8,000 m³ tank that was 90% full with FO resulted in several victims including firemen*
- ✓ *ARIA 6052, Venezuela, Tacoa, 1982, the explosion of a 40,000 m³ tank that was 40% full with heavy fuel oil claimed 160 lives and resulted in 500 injured persons*
- ✓ *ARIA 6076, Greece, Thessalonica, 1986, eight firemen sustained injuries*

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