Hydrocarbon spill during a transfer operation

17 July 2010

Speyer

Allemagne

Refinery
Hydrocarbons
Unloading
Pipe
Leak
Site clean-up
Procedures

THE FACILITIES INVOLVED

The site:

The refinery is located along with other firms in the city's industrial park adjacent to the banks of the Rhine River. This site was producing hydrocarbon-based compounds with high added value along with solvents for use in many sectors, including the automobile industry, pharmaceuticals, phytosanitary products, cosmetics, and as inputs in fine chemicals, the electronics sector and plastics transformation.

The site's installations consisted of a distillation unit, several tank farms and a transfer facility comprising filling stations for road and rail tankers, as well as a system for loading and unloading boats (i.e. a floating wharf) set up in a dock also used by the park's other tenants.

Aerial view of the site

The involved unit:

A rack of pipes connected the port to various storage facilities and was required to cover distances ranging between 300 and 500 m. The aboveground pipes were positioned from 30 to 50 m from the floor, which had only been sealed in spots; the pipe layout ran below (underground) the municipal street system and above roads within the plant boundary.

Wharf in the industial dock

Production facilities and pipes rack

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The accident occurred during transfer of a hydrocarbon mix from the river barge to the plant's on-site tank farm.

In preparation for a transfer of n-alkanes C5-C6 from a 500-tonne barge (containing approx. 750 m³) on 17 July 2010, measures were carried out the previous day (16 July) until 3:45 pm to prepare the filling of a 1 000 m³ fixed roof tank. For the tank hook-up, it was also necessary to install a hose (nominal diameter: 80) on a pipe rack connection (nominal diameter: 150).

These works were performed by means of checklists describing each manual step of the task. Once all required actions had been completed, the operations manager inspected again all connections and pipes.

Another pipe inspection was conducted on the 17th at midnight by an operative on the night shift.

Chronology of events:

12:30 am: The barge moored at the wharf. A routine briefing was then held between the boat's crew and site staff.

12:45 am: A sample was taken for laboratory analysis. The product received was mainly hazardous due to its characteristic of being an very flammable liquid highly toxic for aquatic organisms. Under the Dangerous Substances Classification and Labeling Directive, this product was classified as corresponding to the following risk labels: R 11, R 38, R 48/20, R 50/53, R 62, R 65 and R 67.

1:30 am: After acknowledging laboratory results in the control room, the crew received authorisation to start the boat's pump at an initial service pressure of 50 m³/h. An operative witnessed flow inside the tank (thanks to acoustic verification, flow noises).

1:45 -2 am: The pump malfunctioned twice, for undetermined reasons. Installations (i.e. pipes, valves, and measurement, control and regulation devices) were all checked, and no defect was observed.

2:30 am: An operative surveyed the pipes between the tank and the port, without detecting any leak.

2:45-3 am: The boat's pump was restarted, this time under high pressure (100 m³/h).

3:10 am: In the control room, an operative noticed differences between the pump's operating mode and the tank's filling status.

3:12 am: The pipes were surveyed again; this effort led to identifying a puddle of hydrocarbon fuel.

Transfer operations were immediately halted; fire-fighters from both the site and municipal department were called to the scene. The spill was covered with foam. Gas measurements were undertaken outside the site boundary.

The puddle was subsequently pumped by a specialised subcontractor.

The consequences of the accident:

Restarting the boat's pump at high pressure (100 m³/h instead of 50 m³/h) had caused an expansion compensator installed on the pipe to burst. The leak released 120 m³ (i.e. approx. 80 tonnes) of hydrocarbons, which in turn penetrated into the unsealed ground.

Dislodged pipe bracket

Damaged expansion compensator

The European scale of industrial accidents:

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

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

The "hazardous substances released" index was rated a "4" due to the discharge of 80 tonnes of n-alkanes C5-C6.

No human or social consequences could be identified; the corresponding index was therefore not scored.

Some land area and groundwater were polluted by hydrocarbons. The "environmental consequences" index was thus estimated at "1".

The decontamination of polluted soils cost €480,000, yielding an "economic consequences" index value of 3.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The pipe's expansion compensator burst due to the pump's repeated malfunctions and restarting under high pressure. Post-accident investigations revealed that a water hammer phenomenon occurred and was then accentuated by the following technical aspects:

- The 450 m long pipe could not be positioned along a constant incline due to both geographic constraints and the site layout.
- Repeated pump malfunctions led to its cavitation, triggering the formation of cavitation bubbles.
- Pump start-up under more strenuous operating conditions led to a pressure surge that exceeded the pipe design pressure (16 bar).
- The narrowing cross-section (a nominal diameter drop of 150 to 80), combined with improperly placed support systems and the expansion compensator design, was responsible for leading to the breaking point.

Flexible hose for tank connection

Pipes rack

Expansion compensator before the accident

Expansion compensator taken apart after the accident

General purpose information on the water hammer phenomenon:

- Definition: Peak pressure reached following a very abrupt velocity change
- Circumstances: Inside a pipe during pump malfunctions / restarts* and valve closures
- Cause: Fluid inertia / difference in fluid compressibility
- Consequences: Destruction of pipes, compensators, supports, foundations and ancillary facilities
- Preventive measures: Special start-up procedures subsequent to pump malfunctions; predefined valve closing times; use of vacuum release devices.

* Following pump malfunction, the system restart process becomes a critical step. Cavitation bubbles suddenly burst in the event of a pressure increase, and the existing velocity differences generate peak pressures capable of reaching 2 or 3 times the values output by Joukowsky's formula[1].

ACTIONS TAKEN

The hydrocarbon spill was immediately covered with a foam blanket. This task was further complicated by the difficulty of sorting spilled hydrocarbons from extinction water that remained after a fire drill held shortly before that time by local fire-fighters. The gas measurements recorded outside the site boundary indicated that the lower flammability limit had not been exceeded. The next morning, a specialised subcontractor proceeded to pumping of the foam blanket and hydrocarbon puddle. The bulk of the product (some 100 m³) however had penetrated into the unsealed ground (sandy soil). A long-term procedure, approved by the appropriate authorities, was launched: soil decontamination, well drilling and pumping out hydrocarbons (insoluble in water) from groundwater aquifers. This process is still currently underway.

[1] Joukowsky's formula: dp = rho x a x dv
dp = pressure variation
rho = density
a = wave propagation velocity
dv = velocity variation

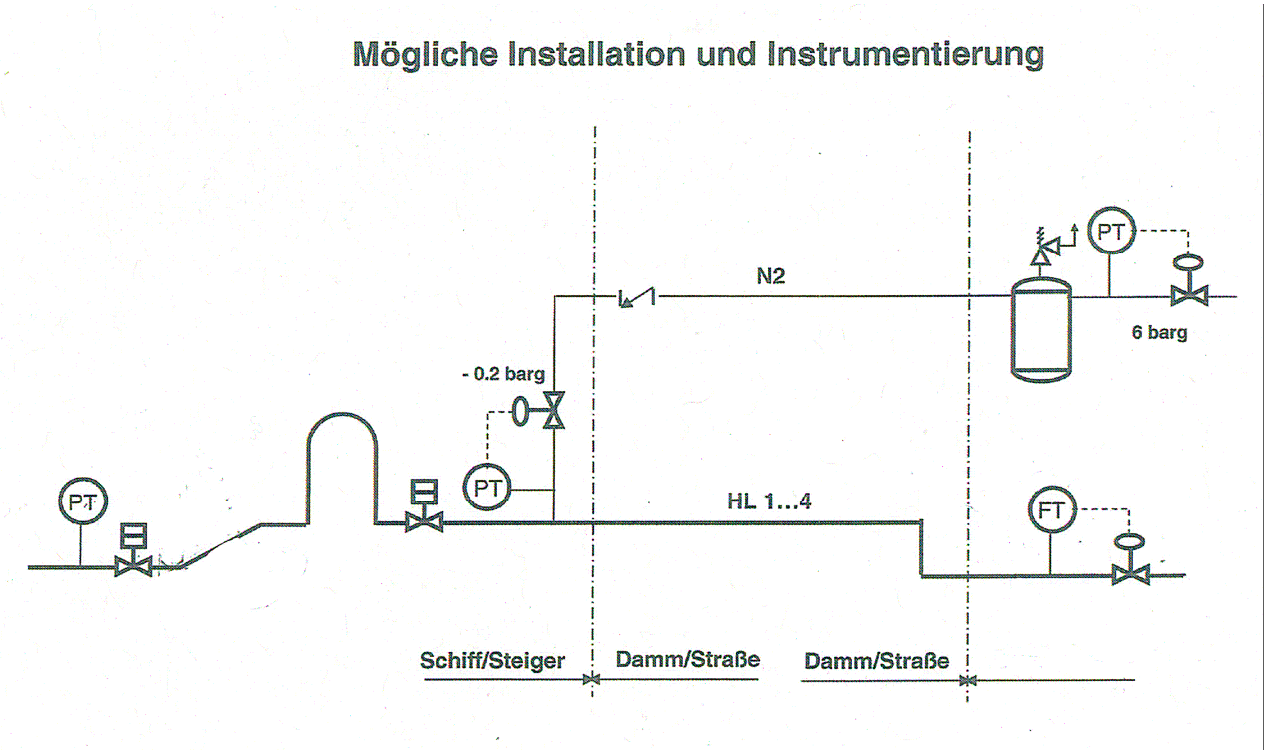
Place of the accident the day after

Hydrocarbons pumping

LESSONS LEARNT

Given the infeasibility of exercising direct authority over a boat's crew or controlling all technical characteristics of their installations, other pump malfunctions are capable of occurring in the future. A system equipped with a vacuum release function was therefore installed to mitigate the ensuing water hammer risks: flow rate measurement equipment around the wharf detected flow rate drops at the outlet and activated a compressible gas (nitrogen) injection, so as to ensure that moving fluid masses would not collide with the static fluid masses in causing peak pressures beyond the pipe's designed strength. Moreover, the number of narrowing cross-sections and expansion compensators was reduced to the bare minimum required. Once the installation had been renovated, just a single pipe was responsible for conveying product between the port and on-site tanks.

In addition, the loading/unloading instructions provided to site personnel and vessel crews were verified and updated.



Planned installation and instrumentation layout