Rupture of a liquid fuel pipeline
July 28, 1989
Rosteig - [Bas-Rhin]
France

Explosion
Fire
UVCE
Piping / pipeline
Naphtha
Building works (subcontracting)
Victims

THE FACILITIES INVOLVED

The structure involved in this accident was built in 1969 and had been run by a company specialised in pipeline operations on behalf of the chemical industry or the oil and gas industry. It was responsible for transporting some 4,000 tonnes of naphtha[1] a day into the Carling chemical plant. The diameter of this pipeline measured approx. 400 mm.

Inside the zone where the accident occurred, piping was configured like a siphon with a 120-m elevation difference on one side and 100 m on the other. Three pipelines crossed this particular zone:

- the pipeline involved in the accident, also called the Sarre crude oil pipeline (A);
- a disused pipeline filled with water from the former Lorraine Refinery (B);
- a gas pipeline (DN 450).

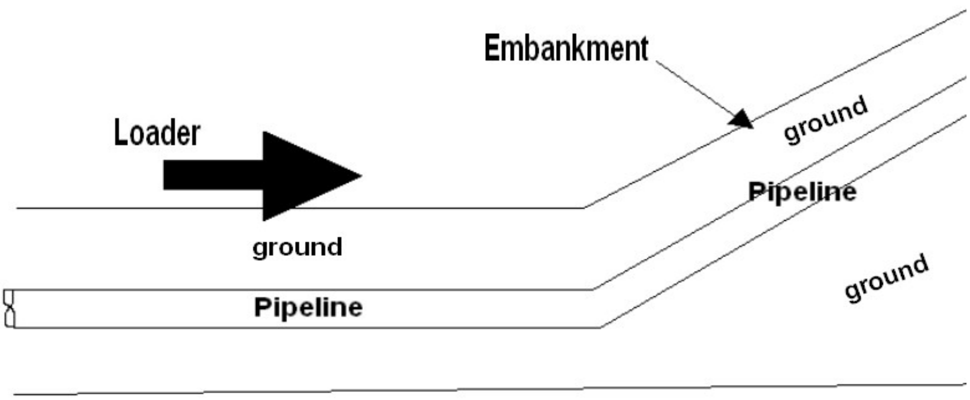
Pipeline A was positioned a distance of 19 m from the gas pipeline, with the disused line B lying in between, 13 m from line A. At the specific location of perforation, the pipe was buried roughly 1.20 m belowground.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

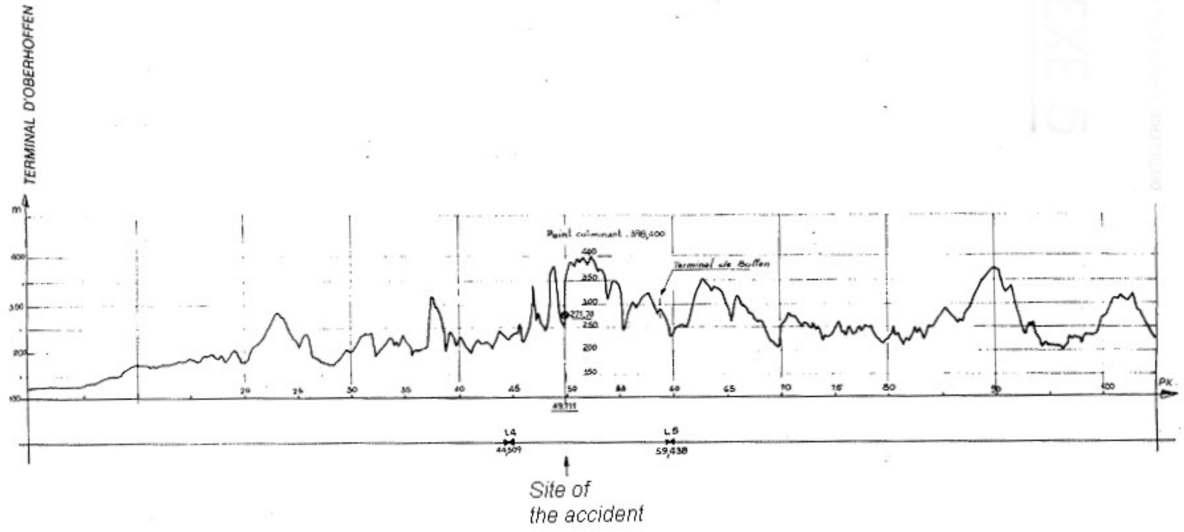
At 9:55 am, within the municipality of Rosteig, the bucket on a loader struck and punctured the Sarre oil pipeline while performing earthworks for a horizontal platform on an adjoining privately-owned parcel.

At the point of impact (elevation: 271.7 m), the loader was extracting ground materials from an embankment with a 15% slope, in which the punctured pipeline had been buried at an average depth of 1.2 m.



1 Lightweight cut (distillate) of petroleum within the gasoline family (C_5-C_{11}), often used as a base product within the petrochemical industry (especially as a unit of steam cracking).

Once perforated, the Sarre pipeline was no longer operational, yet still contained naphtha under a hydrostatic pressure of close to 10 bar (16.6 bar at the Oberhoffen pumping station, elevation: 127.7 m). Since the pipeline was shut down, pressure at the leak point was determined by the liquid column height (approx. 120 m).



Lengthwise profile of the pipeline

According to several witness accounts, including that of the loader driver, naphtha was spewing 5 to 10 m high at the point of impact. A thick yellowish fog formed and filled the valley below the site. In just a few minutes, a very foul-smelling layer spread over a several-hectare land area and headed towards the village of Rosteig. Nearby residents were evacuated in the direction of the village as well.

At 10:05 am, the local gendarmerie station was alerted by phone and dispatched a patrol unit to the scene. As the unit's vehicle got to within approx. 300 m of the pipeline perforation, the engine suddenly accelerated and then apparently stalled.

Around 10:15 am, a gas cloud ignited and exploded: the sound of the explosion could be heard as far away as 20 km.

Emergency crews quickly arrived on the scene and a safety perimeter was set up.

At 10:20, the site operator initiated decompression of the pipeline by means of draining the remaining product towards the line's low point located in Oberhoffen (106 m^3 of product were recovered); then, beginning at 10:50 am, all valves both upstream of the accident site (over a distance of 5 km) and downstream (10 km) were closed.

The decision was made to let the naphtha escaping through the break in the pipe continue to burn under close supervision: this combustion generated a flame some 2 m high that gradually diminished as line pressure decreased.

Taking advantage of the effects of a night-time drop in temperature on flame intensity, a wooden cone was forced as a plug into the pipe opening on July 30 around 6:15 am, followed at the end of the morning by installing a mechanical sleeve once the line had been partially cleared.

At this point, the evacuated residents were allowed to return home.


Repair work (temporary installation of a cone) and extinction (Source: DRIRE Alsace)

Consequences of this accident:

This accident gave rise to an array of consequences:

Human consequences:

A gendarme, who sustained very serious burns, died in the hours following the explosion. The other gendarme, as well as a civilian on the scene before the cloud ignited, succumbed to their burns a few days later.

Property damage:

The explosion and fire caused considerable destruction: tens of residences were heavily damaged by the blast of the explosion (broken window panes, roofs blown off, etc.) and entire buildings were levelled.

Several hectares of woodland were consumed by flames over a 3-day period.

Dangerous materials released:

The quantity of naphtha released could be estimated on the basis of topography of the pipeline alignment, characteristics of the pipe break and its naphtha contents, and the steps and timeline of the operator's intervention.

The operator evaluated the total quantity of naphtha released at approx. 220 m^3 (or 150 tonnes), with the majority of contents escaping during the first hour after the break, at an initial leak flow rate estimated to be 100 l/sec.

Economic consequences:

The supply of naphtha via the pipeline to the chemical plant, whose daily needs were in the neighbourhood of 1,400 tonnes, was interrupted for more than 3 weeks.

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:

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

The "Hazardous materials released" index was rated at "2" as a result of the 150 tonnes of naphtha released (*SEVESO* upper tier: 25,000 tonnes - parameter 'Q1').

The "Human and social consequences" index was assigned a score of 4 given that the accident caused 3 deaths (2 gendarmes and a civilian) (parameter 'H3').

Both the "Economic consequences" and "Environmental consequences" indices could not be rated due to missing data on these indicators.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The accident was caused by earthworks conducted at the site by a small public works contractor on behalf of the owner of a privately-held parcel through which the pipeline passed.

The geological context of the accident area was probably also a factor. The presence of a hard rock like pink sandstone likely exerted an influence on the sequencing of earthworks operations as well as on vehicle driver manoeuvres in performing the assigned task. Prior to the leak becoming apparent, the loader driver had not suspected any impact with a pipeline whose presence underground, according to driver testimony, was not known ahead of time. Given the absence of any warning mesh (not mandatory), no device alerted the driver of a pipeline running underground.

The size of the line opening measured about 40 cm^2, corresponding to the size of a tooth on the loader bucket.

The head of the contracting company, who was aware of this pipeline's existence, had not informed the pipeline operator of his intention to perform works adjacent to the pipe's alignment, even though the prior dissemination of such information had been clearly set forth in a provision of the January 22, 1975 Prefectural order.

The naphtha contained in the pipeline flowed out through the opening at an initial rate estimated at 100 l/sec. The characteristics of both the product and weather conditions (slight wind, high outdoor temperature) favoured the formation of a flammable gas cloud. At the time of ignition due to an unidentifiable source (i.e. an Unconfined Vapour Cloud Explosion, or UVCE) some 20 min after perforation by the loader, the volume of ignited gas was evaluated at 10,000 m^3, generating a shockwave responsible for the damage to homes located up to 400 m from the leak.

The thermal effects proved fatal for the two gendarme officers inside their vehicle, which had come to within 250 m of the leak before stalling, and for the civilian taking photographs roughly 150 m from the same spot.

ACTIONS TAKEN

Preservation of the safety perimeter was closely monitored by the local gendarmerie, fire-fighters and employees of the pipeline operations company for the two days before undertaking works to plug the pipe leak.

The administrative staff responsible for overseeing pipelines held several meetings involving, among others, the Carling chemical plant operator, the Sarre oil pipeline operator and a company specialised in inspecting welds on pressurised facilities. The purpose of these sessions was to analyse the consequences of this accident and then establish a procedure for conducting pipeline repairs.

Repair work took place August 14 through 19, 1989 and entailed the following major steps (see diagram below):

- welding of a 4-inch tap and perforation at the lowest point on the siphon;
- drainage of the naphtha contained inside the siphon;
- filling of the pipe with water;
- welding of two 2-inch taps on both sides of an installed tube (12 m) to inert the pipe section;
- on-load tap drilling;
- production of two cryogenic plugs to frame the tube;
- drainage of water between the two plugs;
- cut-out and installation of the tube using a nitrogen sweep;
- presentation, squeezing of the replacement tube, and electric arc welding performed on each side of the tube placement, with nitrogen sweep;
- radiographs taken of connection points, and verification of all welds by a specialised inspection authority;
- recovery of water contained in the pipe.

Subsequent to the satisfactory radiographic inspection of welds, repairs on the pipe lining were completed on August 18th and 19th.

Moreover, a meeting was held on August 13 at the Rosteig Town Hall in order to officially inform the press and village residents, as well as to lay out safety measures to be implemented at the site.

On August 20, tests were carried out on the broken pipe section at 110% of maximum service pressure in the presence of representatives from the operations monitoring unit (pressure at the point of the accident: 72 bar - pressure at the low point of the pipe section: 76 bar).

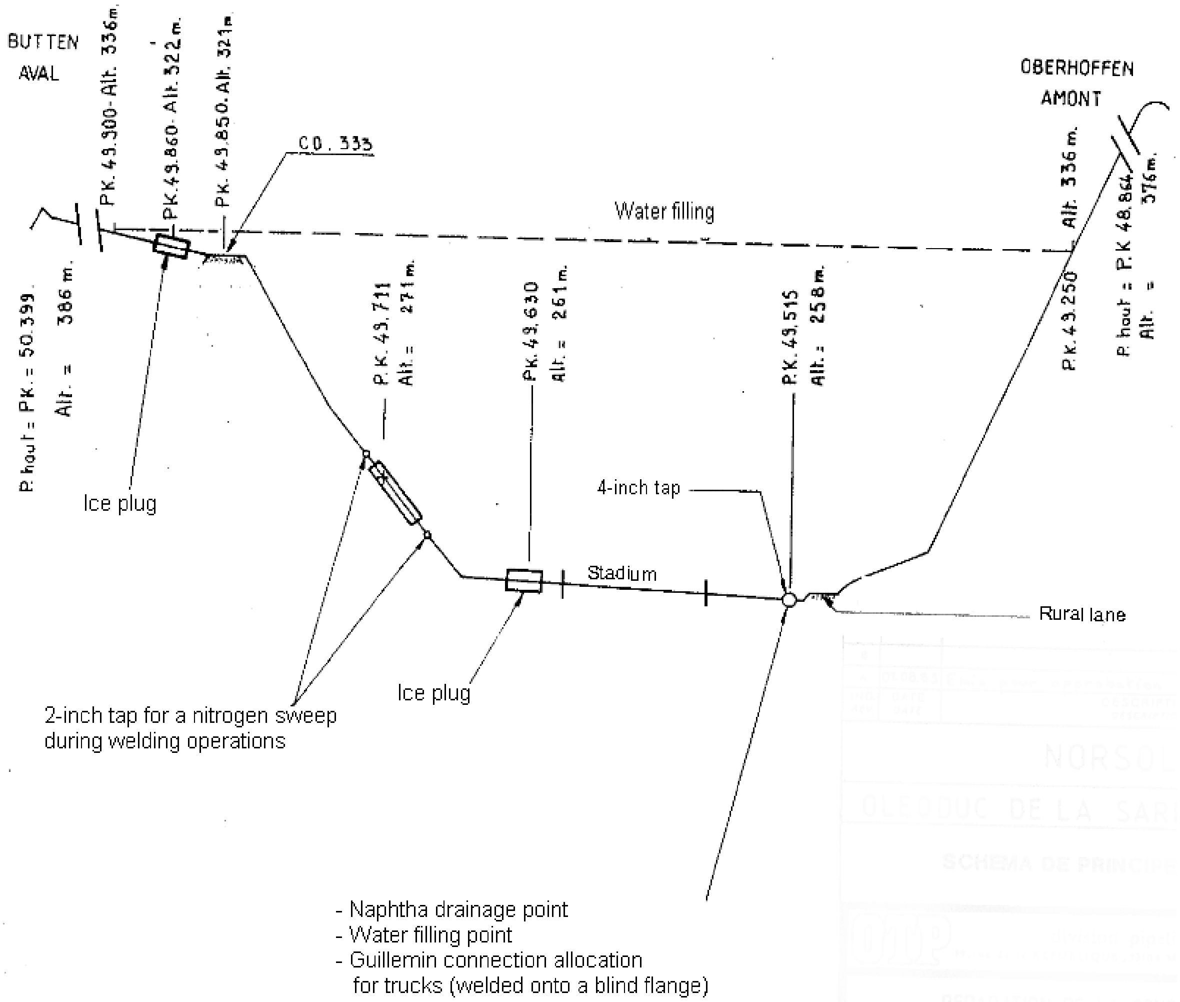


Diagram of repair work

Undergoing revision at the time of the accident, the pipeline's emergency response and monitoring plan had not anticipated the scenario of a massive leak of liquid product capable of constituting an explosive cloud, hence the lack of specific response procedures for this accident.

The pipeline inspection unit undertook, in collaboration with the materials transport company, drafting a new plan, as per prescriptions stipulated in the Ministerial decree dated April 21, 1989 establishing safety regulations for pipelines transporting liquid or liquefied hydrocarbons.

It was proposed that Prefectural offices transmit to all town halls in the Alsace Region's two departments a set of recommendations for enhancing safety in the vicinity of underground facilities (gas pipelines, electrical lines, fuel transport pipes).

A judicial investigation was commissioned. The parcel owner and head of the earthworks contracting company, both of whom were aware of the pipeline's existence, were charged with criminal counts as well as on civil grounds. The ruling issued by the Saverne Criminal Court was referred twice to lower Appellate jurisdictions and then, on two occasions, argued before the High Appeals Court. As of now, the case has still not been resolved.

LESSONS LEARNT

Following this accident, several measures were adopted at the national level to improve pipeline safety.

1 – Urban planning oversight

Based on the report issued by the pipeline inspection unit, regulations for such facilities were strengthened to ensure greater protection of personal safety, property and the environment through mandating a risk analysis study for the most potentially hazardous facilities.

Despite the implementation difficulties encountered, oversight of the land planning process beyond the 5-m easement width exerts tremendous influence on mitigating the impacts of accidents capable of exposing third parties to intense thermal fluxes and excess pressure waves. In the village of Rosteig, in addition to the 3 deaths caused under the conditions described above, the effects of heat and pressure surges were at the origin of considerable damage to homes several hundreds of metres from the pipeline.

The introduction of mitigation steps in residential or industrial zones may become necessary. Technical measures could serve to improve the safety of pipelines transporting liquid or liquefied hydrocarbons, chemical products and combustible gases; such features include:

- increase in the minimum underground depth for buried pipelines beyond the current regulatory specification;
- adoption of a margin of safety applicable to tube thickness;
- installation of a slab (made of concrete or polyethylene) above the pipeline;
- placement of concrete lateral abutments;
- introduction of protective sleeves for running pipes;
- installation of a warning mesh;
- addition of a sufficient number of cut-off devices.

2 – Prevention against external aggressive agents

In addition to these technical measures, a strict monitoring programme was designed to better coordinate a policy of prevention against external aggressive agents responsible for casualties from accidents involving the pipeline transport of hazardous substances.

A pipeline monitoring system could be implemented by the site operator during works performed by third parties, in order to reduce the risk of external aggression in the vicinity of pipelines. In the village of Rosteig, the pipeline operating company had been subcontracting, even prior to the accident, a specialised firm to fly over the line at low altitude twice a month. The ground monitoring campaign was also repeated every other week. Each inspector was responsible for walking a distance covering roughly 20 km of pipeline section.

The inspection report issued subsequent to the accident suggested the potential of providing prescriptions in writing relative to works undertaken adjacent to the pipeline, given that the primary incidents or accidents on underground infrastructure stem specifically from external aggressions.

Since application of the October 14, 1991 decree and its implementation regulation voted on November 16, 1994, a daily computerised processing step has been introduced using receipts, correspondence and drawings regarding all contractor projects located within the easements imposed on the various facilities.

While tangible progress has been made over the past several years in the areas of pipeline design, construction and monitoring, accidents are still being recorded as a result of building works carried out in the vicinity of material transport lines.

France's Ministry of Sustainable Development has initiated, in conjunction with other concerned Ministries (mainly Industry and Labour), a major reform of Decree No. 91-1147 enacted on October 14, 1991 relative to the safety of building works conducted near utility networks, with special emphasis on gas distribution and the transport of hazardous substances. The key features of this reform include: setting up a single administrative entity, creating an expanded monitoring office, and improving training available to the various actors involved.

3 – Building awareness among the various actors

The lack of vigilance on the part of public works vehicle drivers, considered a leading external aggression on utility lines, would suggest upgrading the level of driver training from both a practical standpoint (e.g. choice of boring or earthworks techniques) and a theoretical one (interpretation of project drawings, knowledge of warning devices).

This problem of inadequate driver training has been exacerbated by the availability for individuals to rent heavy construction equipment, allowing them to proceed with building works unknowledgeable of the regulatory guidelines or basic safety rules to apply.

In addition to improved signalling (e.g. via terminals), the organisational measures typically introduced rely upon informing both the general public and the public works sector.

Higher-quality information coupled with greater awareness among local actors (elected officials, operators, emergency services, police, gendarmerie, residents, municipal planning staff) as part of the knowledge dissemination stage of a project offers a means for reducing accident occurrence rates, particularly in the case of external aggressions, while enhancing planning controls around infrastructure lines.

4 – Emergency response and the emergency plan

The response to a leak fed by a flammable liquid can become a dangerous predicament. A sufficient safety perimeter must be quickly set up around the leak zone.

In the event of a massive leak like the one experienced in Rosteig, the absorption step must avoid having responders perform tasks close to the leak zone, but instead activate cut-off devices upstream and downstream of the leak. When manpower is required to plug a smaller-scale leak, such interventions can only involve a minimum number of suitably-trained staff with appropriate equipment and protection.

Moreover, explosibility measurements and hotspot prevention need to be handled with great attention and precaution, as the simple presence of a cell phone or camera could trigger combustion. Pockets of flammable gas are capable of forming within confined spaces; all explosibility measurements must therefore be recorded without underestimating the relevant risks of explosion and structural collapse.

The emergency plan serves as a benchmark upon which the various actors can rely during an emergency situation. This plan contains an intervention protocol, established beforehand between the operator, fire-fighters and gendarmerie or police, with the aim of clearly defining the roles and conditions of each actor's function, whether it be shutting off valves, setting up a safety perimeter or assisting the local population.

Beyond keeping an emergency plan current with regular testing and adaptation to the types of fluids conveyed via the pipeline, the management of backup resources requires effective coordination between all field units involved (police, gendarmerie, fire-fighters, etc.) and site operators, while focusing on: relief for victims, installation of a joint control station covering all services, rectification of the safety perimeter, and communications oversight.

Accident records indicate many cases of ruptured pipelines carrying hazardous substances; these include:

ARIA 14768 - Accident in Grenoble (France), January 18, 1984

ARIA 22787 - Accident in Perry (U.S.), February 12, 2002

ARIA 35176 - Accident in Appomattox, Virginia (U.S.), September 14, 2008

ARIA 36654 - Accident on the Crau Plain (France), August 18, 2009.