Rupture and ignition of a gas pipeline
30 July 2004
Ghislenghien
Belgium

Explosion
Fire
Transport of hazardous materials
Natural gas
Public works
Pipe / gas pipeline
Victims
Safety perimeter

THE FACILITIES INVOLVED

The structure involved in this accident is an underground gas pipeline buried 1.10 m below the ground surface; it connects the port city of Zeebrugge (North Sea) with France. At the accident site, 2 gas pipes were operating at a distance of 7 m apart. One had a diameter of 90 cm and was built in 1982, while the other (which broke and ignited) was 1 m in diameter and installed in 1991. Natural gas flowed at a pressure of 80 bar, for a flow rate of 1.6 million m³/hr. The steel tubes were 13 mm thick.

At the exact spot of the gas leak, between markers U35 and U36, the pipe segment could be isolated between two remote-controlled sectional valves. A telemetry cable ran along the pipe so that in the event of rupture, the transport company's monitoring centre could be duly informed.

A GAS EXPLOSION IN BELGIUM

Piped natural gas has no smell, yet contains a distinct odour

Natural gas transported in distribution pipes to supply households is odorised in pressure reduction stations using a special product. This "odorising" ingredient makes it possible to detect, even in infinitesimal quantities, the presence of natural gas, which is critical to operating low-pressure distribution networks with complete safety. In most other European countries, the transport of natural gas at high pressure is not odorised either, for the following reasons:

- for industrial customers connected to the transport network, additional odorisation might be the source of natural gas consumption problems;
- different odorising practices among the interconnected European gas transport networks could cause safety problems during the international transport of gas;
- due to its composition and the presence of impurities, natural gas already has an odour. During a leak on the transport network, this odour is indeed perceptible.

Press release issued by the transport company, July 31, 2004

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

Around 8:15 am, fire-fighters were notified about a "gas leak" in a zone of the Belgian city of Ghislenghien, approximately 50 km from Brussels. This leak on the 100-cm diameter gas pipeline (DN 1000) was evidenced by a loud hissing, a tremor and the sudden creation of a cavity in the ground.

At 8:30 am, fire-fighters requested the assistance of the gas utility crew and set up a safety perimeter. Several tens of workers were present on a plant construction site and in a number of neighbouring companies. The leak increased in intensity, forming a whitish spray shooting some fifteen metres high.

At about 9:00 am, an explosion occurred; two minutes later, technicians were able to isolate the pipe segment between the two sectional valves. The gas cloud ignited, producing a "fireball" that subsequently transformed into a long flare whose height was estimated at 150-200 m. Depending on the estimation source, a temperature of around 3,000℃ was reached in the middle of the fireball.

A number of individuals, including fire-fighters and police officers, were thrown tens of metres. Showers of debris fell onto the roofs of businesses in the industrial park. Within a radius of 150 to 200 m, tens of vehicles caught fire and the roof coverings of nearby commercial property actually liquefied. A packaging company occupying 3,000 m² of space and located roughly 60 metres away also caught on fire.

An 11-m pipeline section weighing more than a tonne was projected a distance of 150 m against the enclosure of an industrial pastry shop, whose facade blistered. Rescue teams stayed close to their vehicles some 150 m from the scene while sprinkling their polyester cistern, which had become warped due to the thermal radiation.

The long flare kept burning for about 20 minutes. The flame subsided and then gradually extinguished once the gas supply had been shut off, exposing a dreary scene composed of a distressed population and scarred landscapes. The injured were transported to regional hospitals and France's national emergency response crews were dispatched to the site to assist Belgian health and safety authorities.

A ground vibration lasting more than 10 minutes was recorded and then propagated downstream of the pipe until a distance of 10 kilometres from ground zero. A witness living 3 km from the scene of the accident declared to have heard a sound similar to that of thunder around 9:00 am. This vibratory phenomenon propagated into the pipeline, causing flanges to loosen along with secondary leaks, some of which actually ignited. The step of closing pipe valves was further complicated by these vibrations.

The explosion created a crater 10 m in diameter and 4 m deep.

Consequences of the accident:

The consequences of this accident were multi-fold:

Human consequences:

With a human toll of 24 dead, including 5 fire-fighters, 1 police officer and 5 employees killed on the spot, plus 132 injured, this accident was qualified as Belgium's most serious industrial disaster in half a century.

Property damage:

An industrial zone sustained total devastation over a 200-m radius. A 4,000-m² cardboard mill, along with a filling station, a large number of roofs and cars were all destroyed. A portion of a construction site was also damaged and many agricultural fields burned.

At a distance of 200 m, the medium gas pressure reducing station (located on the cardboard mill parking lot) was so hot that its plastic recording box melted, causing a leak that ignited and set 6 vehicles ablaze.

The heat from the blast was felt nearly two kilometres from the scene of the accident.

View overlooking the industrial zone

The accident occurred in the vicinity of Belgium's A8 motorway linking Brussels and Tournai; the road had to be closed to traffic in both directions.

View from the motorway

Economic consequences:

In October 2004, an estimation of the damages caused by the accident indicated an amount of 100 million euros.

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*' directive on handling hazardous substances, and in light of 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 Materials Released" index received a "5" rating due to the significant quantities of natural gas discharged (parameter "Q1"). A calculation based on the volume of gas contained in a damaged pipe section 15 km long allowed estimating this quantity to be at least equal to 700 tonnes (i.e. a volume of approx. 1 million m³ of natural gas).

The "Human and social consequences" index was set equal to 5 as well, since 24 people, both employees and rescue workers, lost their lives as a result of the accident (parameter "H5").

The "Economic consequences" index recorded a "6" rating, on the basis of the October 2004 estimation of 100 million euros in losses sustained (parameter "€17").

No data was reported regarding consequences identified on animal or plant species or on water and soil resources: the "Environmental consequences" index therefore was left blank.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

An expert appraisal conducted on the pipe section ejected 150 m from the blast revealed scratch marks. This observation led investigators to focus on a potential mechanical aggression that would have weakened the pipe wall; 3 to 4 mm of material remained at the level of the scratch, thereby creating a zone of lower pressure resistance.

Based on an expert's investigation report, the Tournai Prosecutor's Office confirmed in July 2006 the hypothesis of "an external aggression" acting on the gas pipeline during previous earthworks held at the site.

ACTIONS TAKEN

Following the incident, an emergency number was set up to inform families and close friends/relations of the disaster. Official statements of solidarity and testimonials were issued throughout the day of the accident.

Moreover, the Ghislenghien catastrophe caused a major stir in the fire-fighting community, among both staff fire-fighters and volunteers. During the national funeral ceremony, over 3,000 members of this community were in attendance to pay their respects to their fallen colleagues. Questions were raised over the prudence of installing such a major gas pipeline adjacent to industrial facilities.

Once the repair work had been completed, the line was placed back into service on September 8 at a reduced pressure level. The pressure was gradually raised so that by September 10, a service pressure of 70 bar had been restored. Several tests were performed and proved to be conclusive.

The decision to resume gas pipeline operations was submitted to review and consultation by local authorities, neighbouring residents, businesses and occupants of the industrial zone, as well as the Belgian Ministry of Ecology.

The other gas pipeline, which was only slightly damaged during the accident, was placed back into service on August 9.

Within the scope of the criminal investigation into the disaster, 8 individuals and 6 corporate entities were indicted on counts of involuntary manslaughter, including the operator of the high-pressure gas distribution network.

LESSONS LEARNT

This accident has confirmed the need, when conducting facility safety studies, to apply an approach that integrates:

- Possible accident scenarios, given the structural and operating characteristics of the target facilities (nominal diameter or dimension, maximum service pressure, tube thickness, altimetry, volume between sectional valves, etc.);
- Prevention measures;
- Measures adopted to limit personal effects and exposure;
- Measures adopted to mitigate other consequences;
- The range of intervention techniques available.

A separate phase of allowing operations to return to normal was deemed potentially necessary, depending on the specific consequences.

Possible accident scenarios:

While **road works near transport pipe networks** are the cause of accidents, incidents arise under **other circumstances** as well. Leaks occurring on equipment or on insulating fittings have also been observed.
An analysis of the various possible scenarios for the rupture or perforation of a pipeline section over several sensitive zones (adjacent to one end of the section or in the middle) warrants a very detailed examination to accurately determine the types of difficulties capable of arising. These findings in turn enable implementing an effective strategy for handling pipeline valves at the time of an accident, so as to limit the discharge of hazardous materials and their potential consequences.

The shape and direction of the spray (i.e. either vertical or horizontal), its abrupt drop to atmospheric pressure and external diffusion, in addition to the explosive zones subsequent to a defect on the infrastructure, serve to justify conducting risk analyses for each scenario along with the introduction of appropriate limitation measures. The same applies to the internal effects of pressure reduction, which is capable of propagating vibrations along the pipeline and exposing pipeline components (flanges, valves, etc.) to fatigue damage.

Prevention measures:

At the Ghislenghien site, the gas leak lasted more than 45 minutes before igniting and, in so doing, created a pressure surge. This time lapse raised a number of questions. Experts found that gas had already started leaking from the pipeline, yet no automated shutoff mechanism had been triggered and no technician had been dispatched to the scene.

In some cases, structures are fitted with a system that automatically closes valves in the event of a pressure drop, thereby limiting the quantities of gas discharged and mitigating the pressure effects should an explosion occur.

It is also critical to control valve operations, especially during periodic inspections, in addition to regularly testing the positive safety systems (while keeping in mind that such systems must be easily manipulated by a technician in the event of an extreme emergency or failure of automated controls). Safety and rescue drills also assist in identifying potential organisational difficulties and implementing necessary corrective actions.

Cathodic protection systems, the state of linings and the regular application of an instrumented scraper to detect zones of insufficient thickness constitute other technical components vital to structural safety.

Over the past few years, considerable progress has been achieved in the design, construction and monitoring of pipelines.

In France, a system has been introduced to notify of the intent to begin construction work (the "DICT" protocol) adjacent to gas transport or distribution pipelines. Moreover, the company with plans to undertake construction work is required to obtain information from the local city hall on the location of existing pipes within municipal territory and, if applicable, to request details from each pipeline operator.

The specification of compensatory measures within an urbanised or industrial zone might be a necessary course of action. Improvements, such as a revamped marking system or the use of concrete slabs, installation or construction methods (additional steel thickness, creation of an embankment, etc.), operations and information measures (e.g. enhanced monitoring, decrease in maximum service pressure, information dissemination to neighbouring residents and companies capable of undertaking works near the pipelines) are types of measures that strengthen the safety of facilities responsible for transporting combustible gases, liquid or liquefied hydrocarbons, and chemical products.

Measures adopted to limit personal effects and exposure:

Controlling urbanisation patterns plays a predominant role in limiting the effects of a potential accident capable of exposing third parties to strong thermal fluxes and excess pressure waves.

The route of facilities conveying hazardous substances within an urban or industrialised zone, along with the layout of cut-off and control devices, would need to be studied in great detail.

Measures adopted to mitigate consequences:

The presence of a flare extending over 100 m high subjected nearby installations to major thermal impacts and caused many fires around the periphery of the accident zone. The pipe shutdown step was complicated due to the onset of powerful vibrations propagating along the pipeline trajectory.

Beyond the actual physical damage, psychological consequences may prove dramatic and require professional accompaniment by a counselling office and extended psychological monitoring of the exposed individuals.

The range of intervention techniques available:

Working to repair a gas leak is always a dangerous operation. A wide safety perimeter must be set up **quickly** around the leak zone. In the event of a massive leak, absorption efforts must not lead to sending repair crews as close as possible to the leak, but instead favour operating cut-off and control devices located upstream and downstream of the zone. When intervention necessitates assigning personnel to seal an area with a minor leak, such a strategy must only expose the minimum number of emergency crew members, all of whom possess appropriate training and equipment.

Furthermore, both the explosibility measurements and hot spot prevention steps need to be conducted with considerable attention to detail and precautions, given that a simple cell phone can trigger combustion.

Gas pockets are capable of migrating into confined spaces, hence the explosibility measurements must be conducted without underestimating the risk of explosion and collapse to the target structures.

During the appearance of a substantial leak, it is prudent to very quickly cut off gas supply in the damaged section. Intervention procedures, designed to supplement gas utility services and fire-fighting and police practices, make it possible to clearly define the roles of each actor: valve shutoff, establishment of safety perimeter, assistance provided to the population, etc.

Accident records inventoried of other cases of gas transport pipeline ruptures:

ARIA 14768 - Grenoble accident, January 18, 1984

ARIA 22787 - Perry accident (United States), February 12, 2002 (*)

ARIA 18513 - Carlsbad accident (United States), August 19, 2000 (*)

ARIA 35176 - Appomattox accident in Virginia (United States), September 14, 2008 (*)

(*) It should be pointed out that the type of gas transported in the United States does not necessarily comply with the physicochemical characteristics imposed in Europe.

For information purposes, the length of the gas transport network is 130,000 km in Western Europe, according to the European Gas Pipeline Incident Data Group (Website: http://www.egig.nl*), and 300,000 km in the United States.*