Rupture of a crude oil pipeline

26 May 2014

St-Vigor-d'Ymonville (Seine-Maritime) France

Release
Pipeline
Hydrocarbons
Works
Corrosion
Site clean-up
Protected natural zone

THE FACILITIES INVOLVED

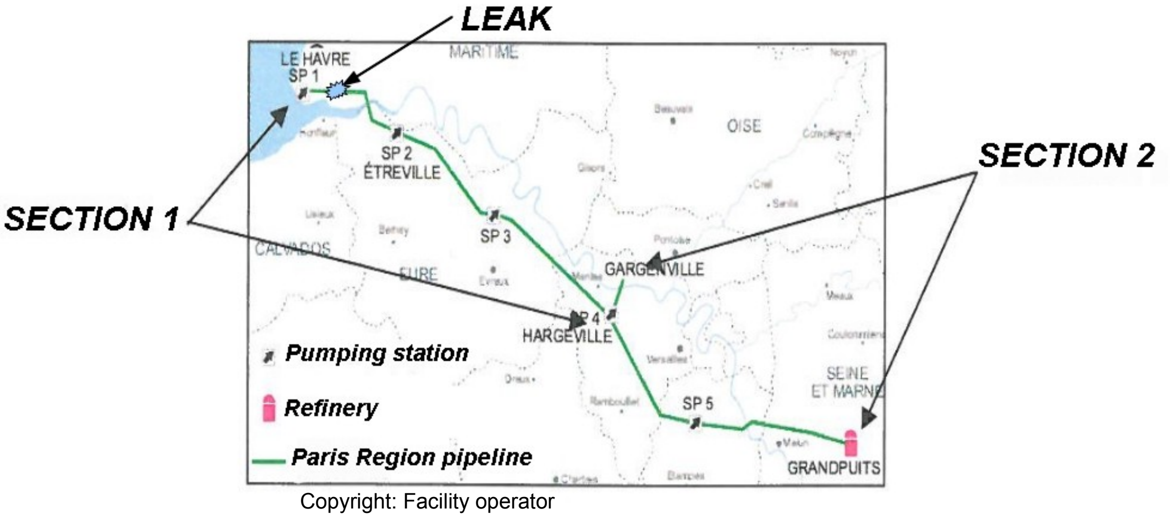
The facility involved in this accident was a pipeline called "PLIF" (acronym for Paris Region Pipeline) operated by an oil company located in Gargenville (Department 78).

The line's primary characteristics were as follows:

- nominal diameter (ND): 20 inches (508 mm);
- service pressure: 69 bar;
- year placed into service: 1965;
- buried depth: approx. 1 m in a clayey soil;
- length: 260 km;
- maximum flow rate: 1800 m^3/h;
- capacity to transport roughly 6.5 million tonnes of product annually;
- number of pumping stations: 5.

The pipeline was transporting crude oil from the Le Havre Port (76) to the Grandpuits Refinery (77) in the Paris Region. This line was also transporting finished products from the refinery to the Gargenville storage.

The leak occurred at the level of a trench running through the Hode marshland, part of which had been classified within the SEINE Estuary national nature reserve. It was actually identified 1.5 km beyond the boundary of this reserve, in the part located between pumping stations PS1 and PS2.



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THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

Accident chronology

6:00 am: Automatic shutdown of one pumping station (PS2) owing to low pressure readings. Shutdown of the other pumping station (PS1) by the crew foreman, followed by complete closure of the pipeline.

6:05 am: Call received from a lorry driver after seeing a geyser erupt on a field.

6:11 am: Isolation of the pipeline (closing of block valves at the Le Havre Port and around the line's SEINE crossing in Tancarville).

7:30 am: Oil company personnel arrive at the scene.

8:00 am: Activation of the External Emergency Plan, followed by mobilisation of crisis units.

9:00 am: French military police "Gendarmerie", fire department, city hall, Environment Agency representatives all on-site, installations secured.

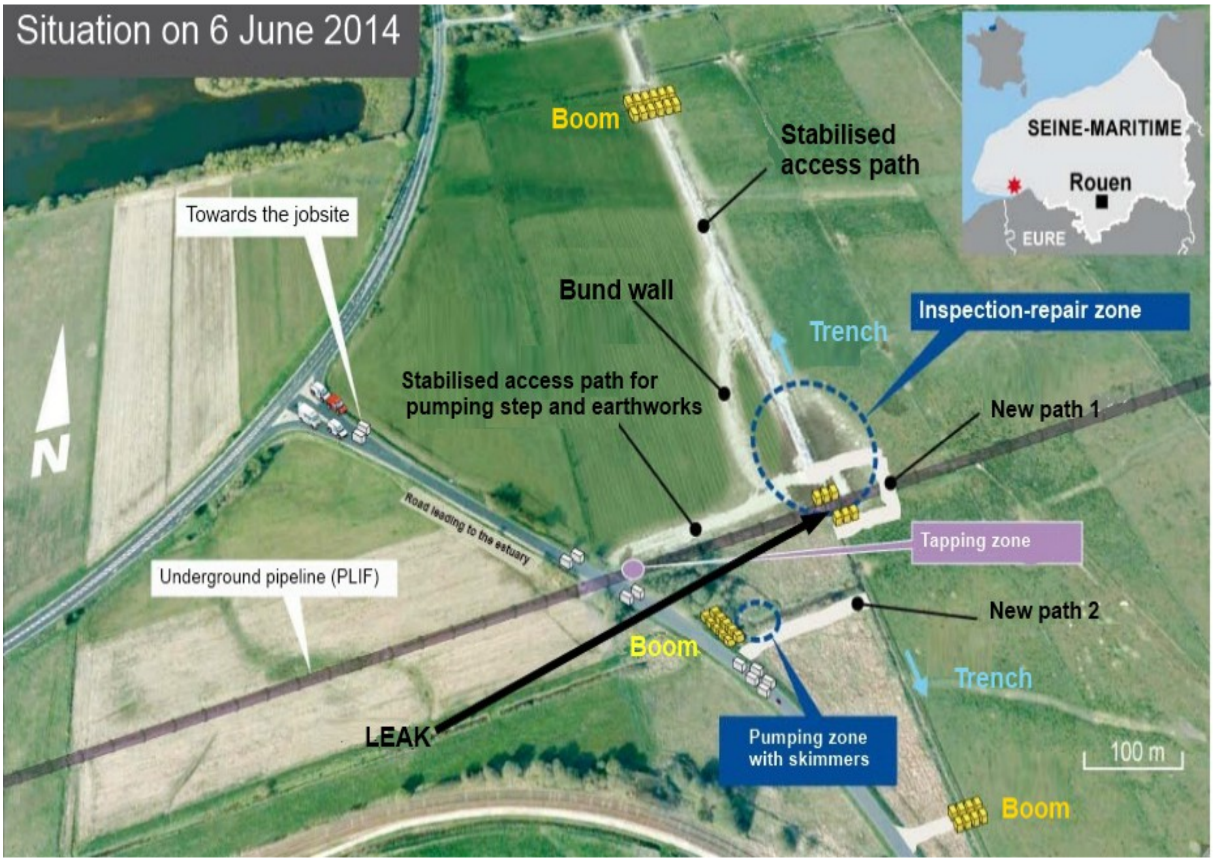
9:45 am: On-site deployment of the initial pump vehicles.

9:50 am: Issuance of the first press release by the pipeline operator.

11:20 am: Immediate protection measure adopted - deployment of oil containment booms in the trenches.

3:00 pm: Beginning of pumping operations at the most easily accessible point.

3:30 pm: Preparation of access routes leading to the northern, southern and western pumping zones, and initiation of pumping operations.



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The consequences

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Environmental impacts

The pipeline operator estimated the quantity of oil dispersed into the environment during the leak at roughly 500 m^3.

The oil spread and fouled 820 meters of trenches (submerged at the time), with the oil pooling at the bottom over 650 meters of this length. Both flora and fauna were immediately affected by oil at the surface.

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The oil geyser resulted in a falling oil spray that stuck very tightly to parts of plants above ground.
14,000 m² of meadow, used mainly for the production of animal feed and beef cattle grazing, were adversely affected by the oil spill. Some 48,000 m² of surface were sprayed by oil (micro-droplets on the above-ground parts of plant life).

Via a trench, the oil also spilled into a willow plantation.

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The presence of crude oil was not detected in the groundwater.

Aquatic fauna

About fifteen dead pike, eel and crayfish were recorded.
Many dead aquatic beetles, Planorbis snails (flat rolled shells), Limnea (spiral shells), Sphaeriidae (bivalve molluscs), Odonata larvae (dragonflies and damselflies) and an adult damselfly were also identified in the trenches.
Jumping frogs could be observed on several occasions in the polluted zones.

Terrestrial fauna

Mammals, macro-invertebrates (flying insects, land-borne insects, molluscs, shellfish, beetles, spiders, worms, wood louses, grasshoppers, etc.), birds (homing pigeons) were all fouled.
Smaller traces of fouled mammals (coypus, muskrats, wild boar, roe deer) were also logged, thus indicating an attempt to flee the polluted zone. Muskrats and coypus are dependent on aquatic environments; they proceeded to dig galleries into the banks of the trenches. These galleries were totally inundated by the oil. A dead muskrat in one of the trenches and a survivor bogged down in a stretch of meadow were discovered.
A fouled pigeon was found dead; 2 others were transported for rescue to the CHENE Association in Allouville-Bellefosse (76). The owners were notified via Internet by means of the numbers on the birds' bands.
Two moorhens and a mallard were found dead, unable to free themselves from the oil.
The vast majority of fauna present at the site were in the midst of their breeding period, which encompasses spring and/or summer; this pollution outbreak caused a sizeable and direct loss of the season's reproduction by depleting the species of individuals, juveniles and embryos. Afterwards, the pollution clean-up effort represented a constant nuisance, lasting several months through the end of the reproductive period. The species experiencing the greatest impact were most likely bats and small mammals, whose habitat adjoined the affected zone.
Beef cattle potentially grazing in the vicinity were kept away from the pollution source.

Economic impact

Throughout this pollution incident (spanning clean-up, repairs, rehabilitation and monitoring), the pipeline operator enlisted assistance from:

- 60 subcontracted firms and partners with a stake in the effort;
- 100 individuals;
- 20,000 hours worked over a 5-month period.

The total cost of this incident was on the order of €8.5 million, including direct and indirect expenses.

European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in Ferbruary 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 "Environmental consequences" index was rated "3" since a 6.4-ha ground area had been polluted "parameter Env13".

The "Economic consequences" index reached a "4" due to the cost of environmental clean-up, decontamination and rehabilitation, which were valued at over €1 million "parameter €18".

The "Hazardous substances released" index was not scored since crude oil is not among the products listed in Appendix 1 of the Seveso 2 Directive in effect at the time of the accident. Moreover, no human or social consequences were reported.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The oil leak occurred subsequent to the widening of an 87 cm long opening positioned along the upper generatrix of the pipeline on both sides of a circular coupling weld between two rolled-welded tubes. The longitudinal welds on this pair of tubes were located away from the rupture zone. An approx. 4 meter length of pipeline was removed and appraised by an expert. The section of burst pipeline displayed along its upper generatrix many signs of shock, dents and scratches as well as macroscopic deformation in the form of flattening and ripples. The outer surface of the circular coupling weld was also damaged, thus indicating that the damage occurred after installing and welding the tubes.

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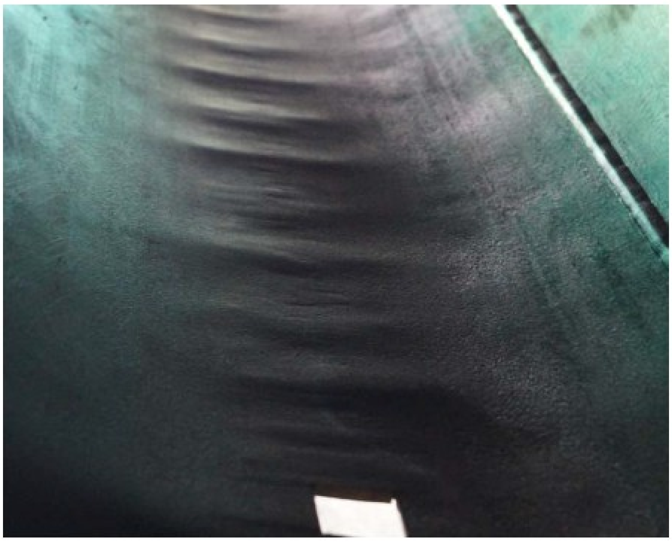
The morphology and location of this external damage reveal that it was probably caused by heavy equipment, subjected to a scraping effect from a power shovel and/or a track roller crossing over the ground.



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The tube appraisal conducted by an inspection body established that the sudden pipeline break, followed by gradual development of multiple longitudinal corrosion cracks due to stress, was initiated from the outer skin of the pipeline, in the strain-hardened zone with mechanical deformation.

<u>Inside the rupture zone</u>, six lunula corresponding to pre-existing longitudinal cracks representing some 35% to 50% of the wall thickness could be identified. These lunula were characterised by an advanced state of oxidation, or even corrosion, that did not match the ultimate rupture zones and moreover proved that they predated the actual rupture. The presence of radiating bands from the external surface suggested crack onset from this surface. The remainder of the pipeline surface offered a clean appearance without any loss of thickness due to corrosion. Furthermore, no corrosion on the tube's internal surface could be detected.

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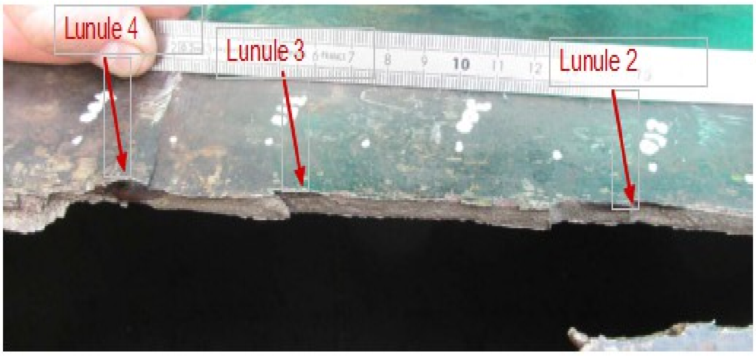
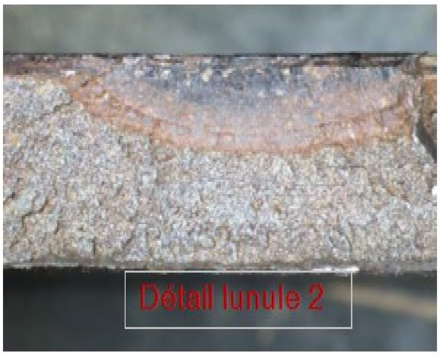
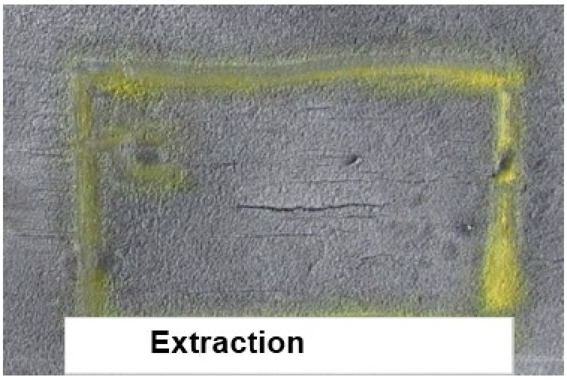




Outside the rupture zone, on the outer surface of the liner and along the upper generatrix, the magnetic particle inspection evaluation revealed the presence of crack-type anomalies associated with the identified mechanical damage that had strain-hardened the metal and caused the tube to flatten over its upper generatrix. Mechanical stresses at the level of the connection with the non-flattened zone had thus formed.


Extraction


After cleaning
the magnafluxing products


Cracking face after opening


Close-up of the lunula

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Inspections conducted on the pipeline prior to the accident

Since the pipeline was over 30 years old (50 years since its inauguration), the mandatory comprehensive assessment within a period of less than 6 years had been respected. The inspections performed on the pipeline had been as follows:

2013: Running scrapers - geometric and thickness measurements + crack detection. The definitive reports had been transmitted to the oil transport company by the commissioned inspector just before the accident;

2009: Inspection conducted by the tube lining contractor by means of measuring the electric potential gradient (known as the Direct Current Voltage Gradient, or DCVG, method);

2008: Running scrapers - geometric and thickness measurements (by the assigned inspector).

These inspections and, more specifically, the reports submitted to the transporter never mentioned unacceptable tube degradation at the level of the rupture. The measurements recorded in 2008 and 2013 by scrapers however revealed both the existence of tube deformation far below the acceptance criteria (1.2% of the ND, for a tolerance set at 6%) and a collection of defects that were identified as a field of inclusions (metal impurities, typically without any consequences).

Following expert appraisal of the pipeline liner by a specialised organisation and a repeat analysis of scraper data (an in-depth assessment of results), it was revealed that the visible ripples on the tube's upper generatrix most likely caused a rebound or too steep of an incline for the ultrasound sensors on the crack detection scraper, thus leading to a discontinuous reading of the crack responsible for initiating rupture. This situation yielded a poor interpretation of results, as the analyst had drawn the conclusion of a field of inclusions instead of a crack.

Subsequent to the DCVG measurement campaign conducted in 2009, no loss of tube liner had been reported around the defect. Nonetheless, the damaged section displayed considerable pieces of the original (pitch) liner missing, which was a requisite condition for the appearance of corrosion zones, as the expert had noted. This point remained unexplained.

ACTIONS TAKEN

Following the accident, the main concerns focused on containing the pollution and undertaking clean-up works as a means of reducing impacts on the natural environment. Moreover, the resumption of facility operations with sufficient guarantees relative to the line's structural integrity, to avoid having to shut down the Grandpuits refinery, was another concern.

For this purpose, on 27 May, the Seine-Maritime Department Prefect signed an emergency executive order:
- requesting the pipeline operator to adopt measures limiting the spread of pollution;
- supervising the resumption of pipeline service (subject to: completion of a report on the accident causes, release of the most recent pipeline inspection reports, statement of anticipated repairs, proposed restart conditions, etc.) and submitting the resumption plan to the proper oversight authorities for approval.

Measures adopted to eliminate the pollution threat

As of the morning of 26 May, the pipeline operator installed containment booms in the trenches and initiated pumping at the points easiest to reach.

During the afternoon of the same day, the oil company began preparing access routes (through a marshy zone) to clear the way for heavy machinery and pursue pumping operations.

The pollution was completely confined using earthen dams reinforced by an impermeable membrane. Fences and anti-amphibian screens were installed to prevent local fauna from entering the polluted zone.

The 4500 m^3 of crude oil, water and sediments pumped from the zone were discharged at the Normandy Refinery site (located a few kilometres away), where a settlement protocol had been implemented specifically to manage this accident. These 4500 m^3 included the 2100 m^3 of crude oil resulting from the pipeline drainage step prior to its repair.



Surface water monitoring was introduced outside the confined zone, while groundwater verifications relied on the deployment of 4 piezometers.

To clean the willow plantation, the FOST (Fast Oil Spill Team) unit was contacted for assistance. This unit is a Marseille based skills centre affiliated with the oil company; it offers trained response teams along with a ready supply of equipment for eliminating hydrocarbon pollution.

A remediation plan was drawn up under the aegis of representing CEDRE (Centre for Documentation, Research and Experimentation on accidental water pollution, created in 1979 subsequent to the Amoco Cadiz shipwreck) and in collaboration with competent authorities; its contents were based on the following principles:

- mowing and clearing of zones affected by sprayed crude oil;
- production of a topographic map of trench bottoms and meadows, yielding the profile to follow during rehabilitation work;
- rehabilitation of the designated drainage trenches;
- stripping of topsoil and potentially deeper in order to limit the contributions of non-native soils as much as possible;
- filling of excavated zones in conforming to the initial topography, with earth imported from a neighbouring zone (avoiding the hauling of non-native soils);
- acceptance of all works performed with CEDRE and in the presence of recognised competent authorities.

This remediation plan was associated with an established monitoring programme dedicated to local groundwater, flora and fauna.

Pipeline repairs

Repairs to the pipeline involved cutting out the liner, including the opened length, and replacing the missing section by new tubes. Prior to performing this operation, it was necessary to place a tap on the pipeline around 100 m from the leak to allow proceeding with the drainage step (2100 m^3 of crude recovered). Special precautions (explosion meter measurements, sprinkling, and presence of a response team) were required to prevent risks during the cut-out works. Pumping down the water table lasted throughout the duration of this programme in order to maintain access to the zone.

A steel duct was installed at the site of the trench crossing, thus providing mechanical protection for the pipeline, while avoiding any repeated damage to the facility (during completion of the pollution removal mission, trench cleaning, etc.).

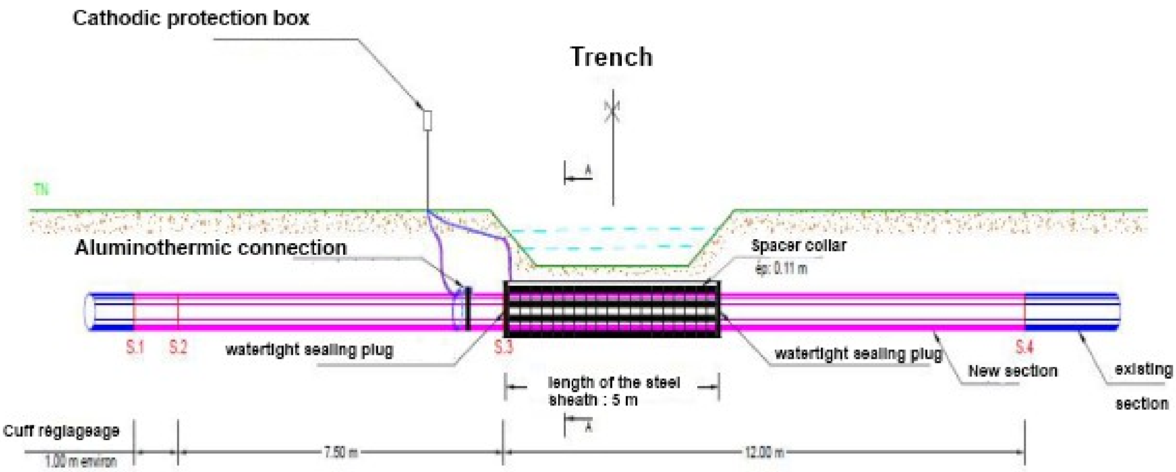

Diagram Pipeline operator

Resumption of pipeline service

In exchange for issuing their approval to resume pipeline service, the DREAL Environment Agency requested that the operator submit proof that:

- no defect similar to the one that caused the rupture was present at any spot along the entire pipeline. As such, the full set of scraper data was reanalysed by the subcontractor responsible for performing the scraping in 2006 and 2013. No signal comparable to that recorded around the leak could be identified along the remaining pipeline;
- the series of degradations recorded during scraper inspections carried out at the end of 2013 (denting, loss of thickness, cracking) was acceptable given the level of pipeline pressure and applicable regulatory criteria.

To satisfy this requirement, the oil transporter, assisted by a new service provider, prioritised all defects recorded over the entire pipeline, after conducting a new more detailed analysis of the raw scraper data for some of these defects. Based on this prioritisation step, the pipeline operator devised a digging program split into several phases, beginning with the most serious defects. This strategy enabled restoring pipeline service gradually (with pressure being incrementally increased in the line as the inspection campaign and necessary remedial works were completed).

In light of the items mentioned above (i.e. slight deformation in pipeline roundness leading to the appearance of cracks and potentially a leak), the operator ultimately decided to investigate by uncovering any dent exceeding 2% of the nominal diameter (even though the regulatory tolerance stood at 6%).

LESSONS LEARNT

The search for cracks by scraper is a technique rarely practiced by pipeline operators. This type of control is expensive (reaching several hundred thousand euros); moreover, the technology is still nascent and undergoing constant evolution. Also, interpreting the results requires a special skill set.

In looking for cracks over the entire pipeline length in addition to running the other types of scrapers and conducting a DCVG control, the transporter had made use of the most efficient state-of-the-art techniques in performing the inspection campaign.

Upon examination of just the crack detection scraper data, it was very difficult to suspect the existence of cracks at the level of this rupture. However, cross-referencing these scraper data with readings from scrapers used to record geometric measurements and thickness (presence of dents and ripples on the upper generatrix) would have perhaps alerted the analyst to the potential existence of a critical defect. It thus seems important for the interpretation of data stemming from an inspection to be cross-correlated with available data derived from other controls. An adapted methodology needs to be developed for this specific purpose.

It also seems relevant to revise or complement the acceptance criteria established in the GESIP guide dedicated to dents (<6% of the tube's nominal diameter, 2% around the welds), in particular whenever deformations lie in the upper part of the pipeline. In the present case, the deformation only amounted to 1.2% of the nominal diameter, yet this was sufficient to trigger the appearance of multiple cracks that ultimately caused the leak. In the context of a combined defect, GESIP guide criteria were no longer applicable. Once a dent is detected, given its position and size, an appropriate response would apparently be to dig a trench for carrying out more extensive inspections from outside the pipeline so as to verify the absence of cracks, especially on older pipelines.

Lastly, this accident should lead transporters and/or service providers to recalibrate the models they use to process and interpret data.