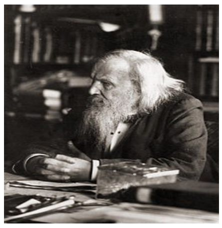
FACT SHEET

Pipelines



D.I. Mendeleïev
Use of tubes in transporting hydrocarbons

An older technology, the first pipelines to carry hazardous materials or pollutants were introduced in the United States during the 1860's. The inventor of the periodic table of the elements (D.I. Mendeleïev)[1] was in fact an active participant in their development by improving the concept favoured in ancient Rome of conveying water by means of gravity (aqueducts).
Today, millions of tonnes of oil and chemical products, along with billions of m³ of natural gas, are routed every year through the French pipeline transport network, whose characteristics will be recalled below.
As a highly means of transport with a lower risk of accidents than the alternatives (road, rail, waterway), pipeline use still entails a number of risks, notably in the case of a leak or burst along the line. The loss of fluid being channelled can lead to hazardous phenomena of the type: fire or explosion with thermal and pressure surge effects in the presence of flammable gases or liquids; and pollution of the soil, subsoil, water table and watercourses.

Primary indicators

The French network

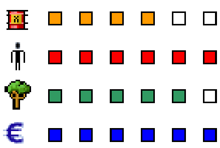
Total length of the French network of pipelines for transporting hazardous products equals 50,000 km, with an average age of 40 years and a breakdown as follows:

- 73 % — Natural gas (36 500 Km)
- 19 % — Hydrocarbons (9 500 Km)
- 8 % — Chemical products (4 000 Km) ethylene, oxygen, hydrogen, brine, etc.

These pipeline segments mostly run underground, except for the instruments necessary for their operations (stations dedicated to pumping, compression, expansion, isolation, interconnection). 25% of the routes of such facilities cross a designated nature reserve or an ecologically sensitive zone.

1. Accident study

The ARIA database catalogues 309 events recorded on French pipelines between 1 January 2006 and 31 December 2013. The primary accident occurrence indicators (breakdown of accidents on the basis of products transported, causes and consequences are presented in a summary table on page 2. These events involve steel pipe sections (along the transport lines) as well as their ancillary installations (pumping stations, compression stations, scraper stations, etc.). Another 70 foreign events were also catalogued over this same period for the important lessons they provide. Such is the case for the Marshall accident, considered one of America's most noteworthy events (ARIA 44816), or Germany's Wesseling accident (ARIA 43139).



ARIA 44816 - 25 July 2010 - MICHIGAN - United States
A pipeline transporting crude oil extracted from the Alberta (Canada) tar sands and heading into the U.S. burst over **a 2 m length**. This rupture occurred during a planned facility shutdown operation.
Over nearly 17 hours, **3,800 m³ of crude oil spilled into the ground before polluting the KALAMAZOO River via the TALMADGE stream**. A corrosion problem caused this accident.

[1] "The essence of materials for engineers", Robert W. Messler - page 499.

Analysis of 309 French accidents between 1 January 2006 and 31 December 2013	*Nb accidents*	*%*
Products transported		
Natural gas	*190*	*62*
Including ancillary installations	*112*	*36*
Liquid hydrocarbons	*37*	*12*
Including ancillary installations	*12*	*4*
Chemical products (ethylene, hydrogen, oxygen, etc.)	*82*	*26*
including brine ducts	*58*	*19*
Consequences (not mutually exclusive)		
Fatal accidents	*2*	*>1 %*
Accidents with injuries	*8*	*3*
Pollution incidents	*41*	*13*
Causes (not mutually exclusive)		
Corrosion	*59*	*19*
including brine ducts	*33*	*11*
Works adjacent to pipeline facilities	*52*	*17*
Physical malfunction : weld, tube shape defects, etc.	*15*	*5*
Natural causes : lightning, frost, etc.	*20*	*6*

Works in the vicinity of pipelines constitute the major cause of accidents recorded, when focusing on leaks in the lines and when excluding ancillary installations and cases of brine duct corrosion. The same scenario tends to be repeated: during construction taking place independent of the pipeline, earthworks equipment damages or punctures the facility. Organisational deficiencies often lie at the source: no preliminary regulatory filing (works programme declaration and/or declaration prior to commencing works), lack of familiarity with the rights-of-way inherent in running a pipeline, and difficulties in communication among the various actors.

Equipment malfunctions mainly pertain to defective welds. A series of accidents has also exposed problems with ancillary components like: flange joints, isolation devices, valves, pump seals, and check valves.

Moreover, corrosion is the source of many cases of pipeline leaks or longitudinal breaks. The events catalogued principally involve the following:

- external attack on pipe segments or their supporting elements as a result of environmental characteristics;
- defects in the facility's cathodic protection or protective lining;
- internal attack on tube walls due to the physicochemical characteristics of the fluid being transported (frequently encountered for brine).

Aggressions from natural sources have involved lightning strikes, landslides and structural excavation work subsequent to flooding. Intense cold waves are also correlated with the occurrence of accidents as they adversely affect the operations of check valves installed at expansion stations on gas pipelines; moreover, cold fronts initiate freezing/thawing phases in the products being transported, which in turn induce mechanical stresses capable of causing the line to burst.

2. Characteristics of pipeline leaks and ruptures

The ARIA database contains 157 cases of line leaks or breaks (with the length of the opening exceeding the pipe diameter) occurring over the linear section of facilities between 1 January 2006 and 31 December 2013 (excluding ancillary installations). This figure represents an average of 20 leaks per year, which corresponds to averages derived from the other professional databases, whose range varies from 20 to 25 leaks a year. France is positioned around the European average, as indicated by the following data:

Comparison among databases

Primary indicators

ARIA 2006-2013, gas (excluding ancillary installations / French line length): 2,2.10-4 /km.year
ARIA 2006-2013, gas (including ancillary installations / French line length): 5,9.10-4 /km.year
EGIG 2006-2010, gas (excluding ancillary installations / European line length): 1,6 . 10-4 / km.year
EGIG 2006-2010, gas (including ancillary installations / European line length): 2,8 . 10-4 / km.year

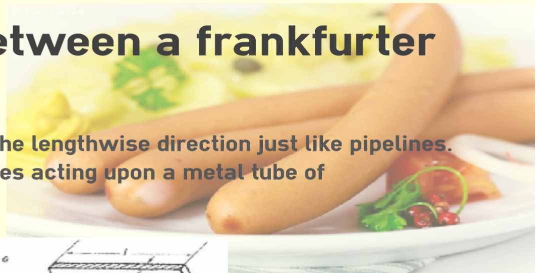
ARIA 2006-2013, hydrocarbons (excluding ancillary installations / French line length): 2,4.10-4 /km.year
ARIA 2006-2013, including ancillary installations / French line length: 3,7.10-4 /km.year
CONCAWE 2007 - 2011, excluding ancillary installations / European line length: 2,4 . 10-4 / km.year
CONCAWE 2007 - 2011, including ancillary installations / European line length: 3,3 . 10-4 / km.year

ARIA 2006-2013, brine ducts (French line length): 17,5.10-4 /km.year
ARIA 2006-2013, chemical products (French line length, excluding brine): 6,2.10-4 /km.year

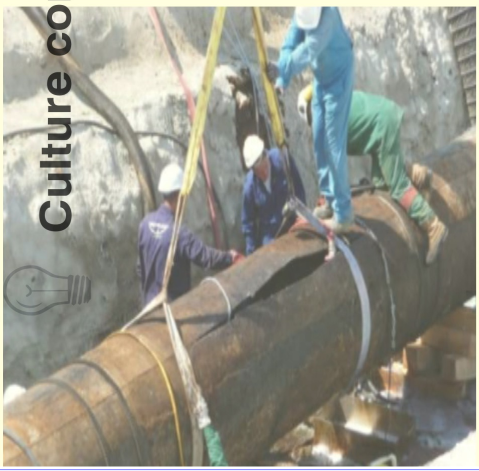
The trend in leak causes over the past 5 years seems to be moving towards a higher proportion of accidents tied to installation ageing (corrosion, defective welds, fatigue, etc.) and less damage due to neighbouring utility works. Over the past 5-year period, 8 cases of pipeline rupture have been recorded.

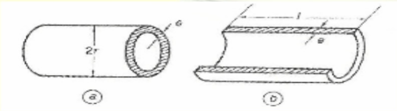
Culture corner

What's the difference between a frankfurter and a pipeline?



When cooking frankfurter, they always break in the lengthwise direction just like pipelines. This phenomenon may be explained by the stresses acting upon a metal tube of thickness e subjected to pressure P :





Transverse rupture (a) and longitudinal rupture (b) of a pipe subjected to internal pressure.

We consider that the pipe is closed at both ends. Up until the breaking point, the stress forces are in equilibrium with forces being exerted by the pressure. The axial force due to pressure equals $pr^2\pi$, and the stress σ_{ax} acting upon the annular surface $2r\pi e$ ensures the equilibrium: $pr^2\pi=2r\pi e\sigma_{ax}$, which in turn yields: $\sigma_{ax}=(pr)/2e$. For a longitudinal rupture, pressure p acts upon the cross-section $2rl$ giving rise to the stress σ_{az} on cross-section $2el$, hence: $p2rl=\sigma_{az}2el$, which leads to: $\sigma_{az}=(pr)/e=2\sigma_{ax}$. This expression, referred to as the "boiler formula", indicates that the azimuthal stress is two times greater than the axial stress, thus drawing the conclusion that rupture always occurs in the longitudinal direction.

Extracted from the book by Istvan Berkes – Everyday physics

3. <u>Accidents prevention in France</u>

The set of catalogued events, including the most recent, underscore the importance of focusing more closely on controlling pipeline ageing and monitoring works taking place in the vicinity. For this reason, in 2010 the Ministry of Sustainable Development launched an obsolescence prevention plan, intended for industrial facilities and based on detailed facility assessments conducted by individual operators, in addition to overhauling the regulations applicable to jobsite safety adjacent to pipeline networks (involving a works declaration reform or damage prevention reform).

3.1 Operational monitoring

According to the Ministerial order issued on 5 March 2014, i.e. the so-called "multi-fluids order", pipeline operators are required to define **Monitoring and Maintenance Programmes (MMP)**. This obligation imposes that transporters adapt their risk control measures and reinforce actions to verify both the structural integrity and ultimate repair on networks' most vulnerable zones. The regional Directorate for the Environment and Development Agencies (DREAL) were assigned to examine the safety reports and MMP to ensure their completeness.

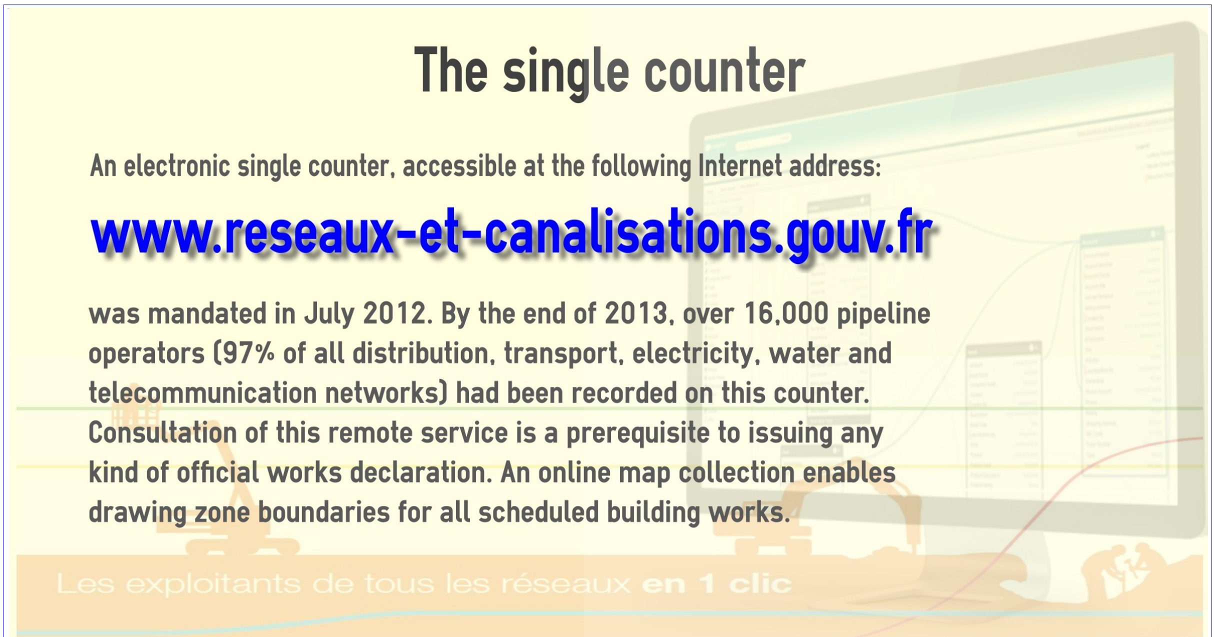
From a technical perspective, in order to avoid external corrosion of pipelines, steel tubes are lined with a waterproof protection (formerly pitch, nowadays polyethylene or polypropylene) and moreover protected by means of a cathodic system. Pipelines currently in service are monitored for the most part either by running an array of instrumented scrapers to detect various defect categories like deformation, loss of thickness, cracks (magnetic/ultrasound measurements) or shape flaws (roof effect of tubes, as evidenced during the Crau accident - ARIA 36654), or by taking electrical measurements on the surface to identify any lining defects. The relevant tubes can then be easily located, repaired, replaced, or targeted for closer supervision.

However, **the ageing of installations raises fears that the situation may become exacerbated if Monitoring and Maintenance Programmes have not been adapted to the vulnerabilities of the various pipe segments** according to the periodic evaluation of their structural integrity. Special attention also needs to be paid to those segments inaccessible to inspection: enclosed segments, presence of elbows preventing the use of scrapers or making the cathodic protection ineffective.

3.2 Damage protection reform and urban planning controls

As discussed above, works on adjacent streets and utility lines account for a major share of primary accident causes. For this reason, a single counter system has been created by the administration in order to streamline the declaration of such works and create a network among the various actors.

Other measures serve to effectively complement the urban planning control process as regards pipelines. Supervising the line's itinerary by foot reconnaissance and flyover are examples of techniques commonly employed by transporters.



Moreover, **public utility easements** specific to the set of hazards implied by existing pipelines will gradually be introduced between 2014 and 2018 so as to better control urban development projects in the vicinity of pipelines.