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Risk Analysis of Natural Gas Pipeline: Case Study of a Generic Pipeline

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1. Introduction

Today the natural gas covers 20% of energy consumption in Europe (ENEA). The use of gas as a fuel has many advantages which justify its use.
These features put the gas in a favor position both to generate electricity as domestic fuel. This involved the installation and maintenance of complex piping systems for the transportation and distribution of gas, located in highly populated areas. Due of this situation, accidents caused by gas leaks cause substantial economic loss and a high number of victims among the population.
So it is important to study the origin and the main characteristics and consequences associated with such accidents to improve safety measures and reduce the risks associated with the use of gas.
To do this first analysis, the most common approach is the historical analysis, namely the collection and processing of information relating to incidents in gas transport and distribution systems.
The historical analysis conducted by Montiel and Halen. (Montiel, Vilchez, Arnaldos, & Casal, 1996) uses the database MHIDAS, which collects incidents from 95 countries, and ESTRALL database, which contains 140 accidents occurred mainly in Spain, through the integrated database MHARS with the incidents until today. These incidents were divided according to their origin and shown in the following figure.

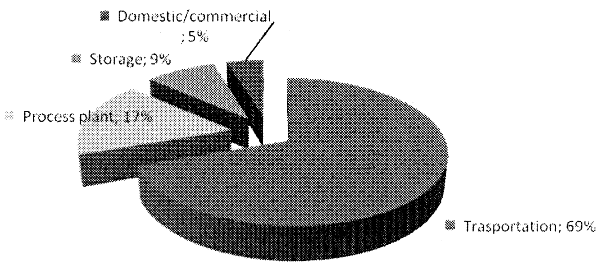

Figure 1.1 Historical analysis of accidents of natural gas

As you can see, the major contribution is given by transport, for this reason the study focuses on risk associated with pipelines.

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In following section introduce concepts of risk analysis and report a study carried out in generic section of pipeline that transports natural gas. In particular, we calculated the reconstruction of local risk.
Before proceeding with the calculation of the risk area was necessary to make preliminary studies: the breaking point of a line segment, influence of weather conditions.

2. Risk Analysis

The methodology for risk assessment consists of a series of analysis and calculations used to determine the root causes of broken pipes and their consequences, taking into account the individual and social risk. Such analysis can be summarized by the following points:

- Product type and substance transport
- Identification of risk sources
- Analysis of the level of protection
- Frequency of occurrence of rupture or failure
- Analysis of consequences

The procedure that was followed for the risk analysis is proposed Dziubinski (Dziubinski, Fratczak, & Markowski, 2006).
The simulated effects are shown in the table with their reference values which identify areas of damage.

Table 2.1 Reference value for indentify areas of damage

Psychic Phenomena	Area of strong impact High lethality (zone A)	Area of irreversible damage (zone B)	Area of reversible damage (zone C)
Explosion	0.3 bar	0.07 bar	0.03 bar
Fire	12.5 kW/ m^2	5 kW/ m^2	3 kW/ m^2
Flash Fire	LFL	½ LFL	------

3. Preliminary Test for Calculus of Consequence

The following sections show the preliminary simulations performed for selecting the break point of the section of pipe examined and check the effects of weather conditions. These considerations are necessary to define a methodology that will be applied to simulate the effects of the gas network.

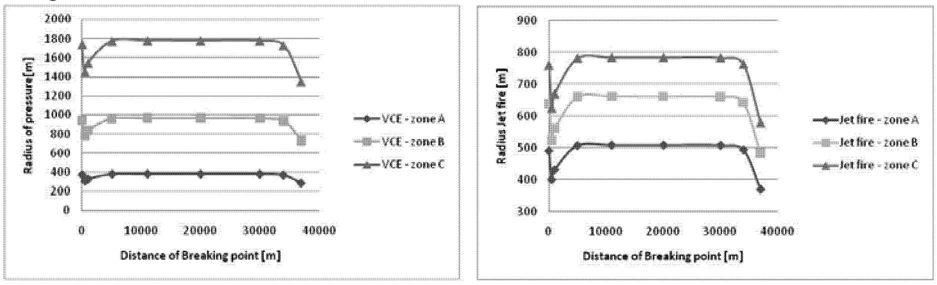
3.1 Distance of breaking point

Changing the break point of the section of the pipe appears to be the release of different intensities and therefore different consequences. For this reason it was decided to perform simulations by varying the distance from the origin of breaking a stretch of pipeline.
To make this simulation we considered the following section. The section is characterized by the following data:

- Internal diameter = 1200 mm
- Length section = 37 km

- Pressure = 70 bar
- Pumped flow = 140.4 kg/s

The type of fracture is catastrophic as the diameter of the pipe.
The variation in the distance breaking tract has reproduced the following results, shown in figure 3.1.

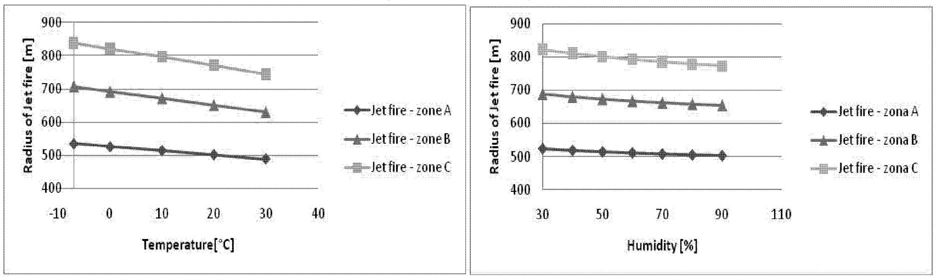


(a) (b)

Figure 3.1 Calculation of consequences in function on the distance of the pipeline: (a) Vapor Cloud Explosion;(b) Jet Fire

3.2 Influence of weather conditions

Weather conditions greatly influence the calculation of the jet fire. As can be seen from the figure increasing temperature decreases the radius of the jet fire, infact the flame temperature and the combustion is influenced by weather conditions. The same influence can be seen with the change of humidity.



(a) (b)

Figure 3.2 Calculation of consequences of jet fire in function of: (a)Temperature;(b) Humidity

For the analysis of the risk of the national network have taken the seasonal average weather conditions of each region. The data were found in the report prepared by ISPRA "The indicators of climate in Italy in 2008”. For this section the weather condition are: temperature of 15°C and humidity of 70%.

4. Local Risk

The local risk is expressed by the frequency value (year) which, at some point in a geographical area, you may experience the loss of reference, namely the death of an individual.

The methodology of calculation this parameter is describe in Purple Book of TNO (TNO, 1999) and consists of three steps: calculation of consequences, calculation of frequencies and finally the re-composition of the risk.

4.1 Calculation of consequences

The line taken into consideration is the same as the preliminary study that was described above. For the calculation of the consequences was the code used for calculating PHAST(DNV software).

The consequence are derived from event tree (Mathurkar H.N., Gupta A.).

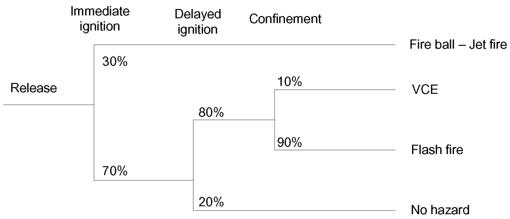


Figure 4.1 Event tree for Hazardous incident for natural gas pipeline

The following table shows the results obtained from a release of natural gas. The data were reported through the use of ArcView in a georeferenced map, in figure 4.2.

Table 4.1 Consequence

	VCE [m]	Jet fire [m]	Flash Fire [m]
Area of strong impact - High lethality	813	511	1060
Area of irreversible damage	2074	666	2034
Area of reversible damage	3821	790	

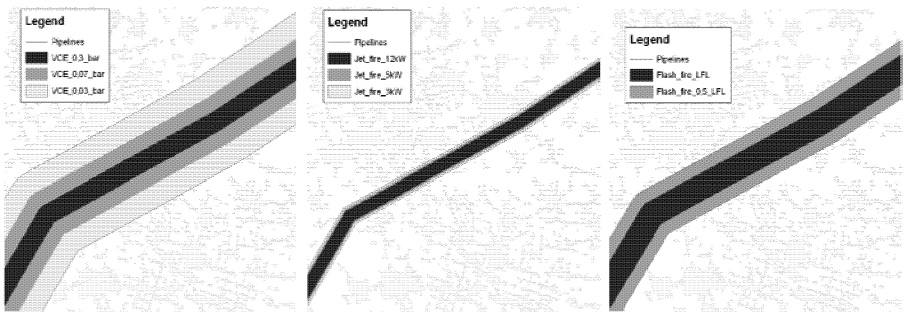


Figure 4.2 Consequence in georeferenced map

4.2 Failure frequency

An important date for risk assessment, in particular to calculate the local risk, is the failure frequency of the equipment. In this case the data were derived from 7th EGIG reports (EGIG, 2008), that contains information on pipelines and incidents.

In the table 4.2, shows the primary failure frequency of different period: total period (1970 – 2007), the period corresponding to the 6th EGIG report (1970 – 2004), the period of the last 5 years (2003 – 2007) and the final year.

As proposed by Mathurkar (Mathurkar HN, Gupta A.) the catastrophic rupture accounts for 13% of cases and the remaining 87% of the issue through a crack or hole. So taking into account the frequency of breakage of the period 1970 - 2007, the type of release is characterized by the frequency of occurrence:

- catastrophic rupture = 4,84E-05 event/km*years
- release by crack or hole = 3,24E-04 event/km*years

Table 4.2 Primary failure frequency of different period

Period	Number of incident	Total system exposure [km*years]	Failure frequency [1000 km*years]
1970 – 2007	1172	3.15 10^6	0.37
1970 – 2004	1123	2.77 10^6	0.40
2003 – 2007	88	0.62 10^6	0.14
2007	14	0.13 10^6	0.11

Also we must also consider the probability of ignition is 33% of issue.
Thanks to the technique of the tree of events, figure 4.1, is possible to calculate the frequency of occurrence for each result generated by the release of natural gas, starting from the probability that this consequences occurs.
So whereas a catastrophic failure frequency of occurrence for the consequences of a release of gas are summarized in table 4.3.

Table 4.3 Frequency of event for consequences of catastrophic release

Consequence	Probability	Frequency of event [event/km*years]
Fireball - Jet fire	30,00%	4,79E-06
VCE	5,60%	8,94E-07
Flash Fire	50,40%	8,04E-06
No hazard	14,00%	2,23E-06

The analysis of incident causes on pipelines has shown that external interference make the greatest contributions, nearly 50%. The external interference may be the wrong use of excavating machines.

4.3 Calculus of local risk

Following the methodology proposed by the purple book the TNO and Young-Do Jo (Young-Do Jo, Jong Bum Ahn, 2003) is possible to calculate the local risk. The areas identified are a function of distance from the release point.
In figure 4.3 and table 4.4 shows the results of the reconstruction of the risk considering how often "normalized", by not taking into account the length of line, it is expressed in events / km * year.

Table 4.4 Local risk

	Distance	Frequency [event/km * years]
zone 1	376	1,37E-05
zone 2	452	1,13E-05
zone 3	511	9,25E-06
zone 4	547	8,99E-06
zone 5	813	8,94E-06
zone 6	1060	8,04E-06
zone 7	2034	0,00E+00

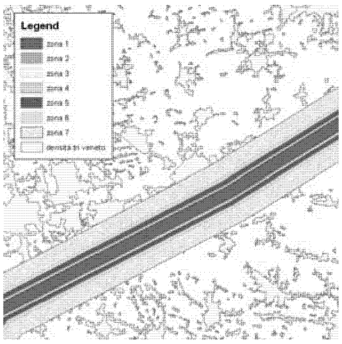


Figure 4.3 Local risk

5. Conclusion

This analysis of a generic section highlights that the risk associated with pipelines is not negligible as it is believed that an event is acceptable when the frequency of occurrence is less than 10^{-6} event/km*years. If you consider that the most frequent incidental cause is due of external interference, such as the wrong use of excavating machines, the risk can be reduced of the 50%. Then applying a careful policy of job control and greater information between the agencies and industries involved, the local risk can be strongly contained.

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