SAFETY IN EUROPEAN GAS TRANSMISSION PIPELINES
8th Report of the European Gas Pipeline Incident Data Group

Comprising:

Bord Gais (Ireland)
DGC (Denmark)
ENAGAS, S.A. (Spain)
Fluxys (Belgium)
Gasum (Finland)
GRT Gaz (France)
National Grid (UK)
N.V. Nederlandse Gasunie (The Netherlands)
NET4GAS (Czech Republic)
OMV Gas GmbH (Austria)
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Ren Gasodutos S.A. (Portugal)
Snam Rete Gas (Italy)
Swedegas A.B. (Sweden)
SWISSGAS (Switzerland)

N.V. Nederlandse Gasunie
mr. D. van den Brand
Project Manager EGIG
P.O. Box 19
NL - 9700 MA GRONINGEN

N.V. Nederlandse Gasunie
mr. R. Kenter
Secretariat EGIG
P.O. Box 19
NL - 9700 MA GRONINGEN

Website: **http://www.EGIG.eu**

The EGIG encourages the reader, who would like specific information not available in the report, to make direct contact with the companies involved. Company addresses are available on the EGIG website.

SUMMARY

In 1982 six European gas transmission system operators took the initiative to gather data on the unintentional releases of gas in their transmission pipeline systems. This cooperation was formalised by the setting up of EGIG (**E**uropean **G**as pipeline **I**ncident data **G**roup). Nowadays, EGIG is a cooperation of fifteen major gas transmission system operators in Europe and it is the owner of an extensive database of pipeline incident data collected since 1970.

Uniform definitions have been used consistently over the entire period. Consequently, on condition that the data is correctly used and interpreted, the EGIG database gives useful information about trends which have developed over the years. Indeed, the EGIG report demonstrates the safety performances of the existing transmission pipeline system in a main part of Europe and also provides a broad basis for statistical use.

This paper introduces the EGIG database and presents the most important data analyses and their results. The results of the analyses are commented on and give the most interesting information that can be extracted from the database. Linking of results of different analyses takes place when possible.

Conclusions and facts from the 8th EGIG report

- EGIG has maintained and expanded the European Gas pipeline incident database. Transmission companies of fifteen European countries now collect incident data on more than 135,000 km of pipelines every year. The total exposure, which expresses the length of a pipeline and its period of operation, is 3.55 million km·yr.
- The statistics of incidents collected in the database give reliable failure frequencies. The overall incident frequency is equal to 0.35 incidents per year per 1,000 km over the period 1970 to 2010.
- The 5 year moving average failure frequency in 2010, which represents the average incident frequency over the past 5 years, equals 0.16 per year per 1,000 km.
- The five year moving average and overall failure frequency has reduced consistently over the years, although it has tended to stabilise.
- The high contribution of external inference emphasises its importance to pipeline operators and authorities.
- External interference incidents are characterised by potentially severe consequences.
- External interference incidents have reduced over the years so that they are now of a similar order to that of corrosion and construction/material defects.

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SUMMARY

1 Introduction

The use of pipelines for the transport of large quantities of natural gas to industry and to commercial and domestic consumers represents a reliable mode of transport of energy.

In 1982 six European gas transmission system operators took the initiative to gather data on the unintentional releases of gas in their transmission pipeline systems. This cooperation was formalised by the setting up of EGIG (European Gas pipeline Incident data Group). The objective of this initiative was to provide a broad basis for the calculation of safety performance of pipeline systems in Europe, thus providing a reliable picture of the frequencies and probabilities of incidents. Nowadays, EGIG is a cooperation of fifteen major gas transmission system operators in Europe and it is the owner of an extensive database of pipeline incident data collected since 1970. The participating companies are now:

Bord Gais (Ireland)
DGC (Denmark)
ENAGAS, S.A. (Spain)
Fluxys (Belgium)
Gasum (Finland)
GRT Gaz (France)
National Grid (UK)[1]
NET4GAS (Czech Republic)
N.V. Nederlandse Gasunie (The Netherlands)
OMV Gas GmbH (Austria)
Open Grid Europe (Germany)
Ren Gasodutos S.A. (Portugal)
Snam Rete Gas (Italy)
Swedegas A.B. (Sweden)
SWISSGAS (Switzerland)

Considering the number of participants, the extent of the pipeline systems and the exposure period involved (from 1970 onwards for most of the companies), the EGIG database is a valuable and reliable source of information. The regional differences such as population density, geological conditions are not taken into account. The EGIG report is annually updated and is available on the following internet site: www.EGIG.eu .

[1] Representing National Grid, Scotia Gas Networks, Wales and the West Utilities and Northern Gas Networks.

International developments for pipeline databases

The International Gas Union (IGU) performed an investigation in which world wide databases were compared. Most of the existing databases world wide give a collection of incidents but no system information like the total length of the pipeline grid or a subdivision of this are compared with the number of incidents.

In order to develop a world wide database from the individual databases a lot of work has to be done in collecting and maintain updates of the system information. For the EGIG only the changes from year to year have to be undertaken.

2 EGIG DATABASE

The EGIG database is a database of pipeline and incident data. The start of collected pipeline data and incident data of natural gas transmission pipelines was 1970.

System information
General information about the pipeline system is given per year on pipeline length categorised according to:

- Diameter
- Pressure
- Year of construction
- Type of coating
- Cover
- Grade of material
- Wall thickness

Incident information
The required criteria for an incident to be recorded in the EGIG database are the following:

- The incident must lead to an unintentional gas release,
- The pipeline must fulfil the following conditions:
    - To be made of steel
    - To be onshore
    - To have a Maximum Operating Pressure higher than 15 bar
    - To be located outside the fences of the gas installations
    - Incidents on production lines or involving equipment or components (e.g. valve, compressor) are not recorded in the EGIG database.

Specific information about incidents comprises:

- The characteristics of the pipeline on which the incident happened,
- The leak size:
    - Pinhole/crack: the diameter of the hole is smaller than or equal to 2 cm
    - Hole: the diameter of the hole is larger than 2 cm and smaller than or equal to the diameter of the pipe
    - Rupture: the diameter of the hole is larger than the pipeline diameter.
- The initial cause of the incident
    - External interference
    - Corrosion
    - Construction defect/material failure
    - Hot tap made by error

        - Ground movement
        - Other and unknown
- The occurrence (or non-occurrence) of ignition
- The consequences
- Information on the way the incident has been detected (e.g. contractor, landowner, patrol)
- A free text for extra information

Additional information is also given for the individual cause:

- External interference:
    - The activity having caused the incident (e.g. digging, piling, ground works)
    - The equipment involved in the incident (e.g. anchor, bulldozer, excavator, plough)
    - The installed protective measures (e.g. casing, sleeves)
- Corrosion:
    - The location (external, internal or unknown)
    - The corrosion type (galvanic, pitting, stress corrosion cracking “SCC” or unknown)
    - Whether or not a pipeline was in line inspected
- Construction defect/material failure:
    - The type of defect (construction or material)
    - The defect details (hard spot, lamination, material, field weld or unknown)
    - The pipeline component type (straight, field bend, factory bend)
- Ground movement:
    - The type of ground movement (dike break, erosion, flood, landslide, mining, river or unknown).
- Other and unknown:
    - The sub-causes out of category such as design error, lightning, maintenance.

3 Analyses and results

3.1 Introduction

The statistical analyses are based on the calculation of indicators such as failure frequency and ignition probability.

The failure frequency is calculated by dividing the number of incidents by the exposure. The EGIG report presents two kinds of failure frequencies, the primary and the secondary. They refer to the notions of total and partial exposure respectively. These notions are defined below.

- Exposure is the length of a pipeline multiplied by its exposed duration and is expressed in kilometres-years [km·yr]. Example: company A has a constant length of transmission pipelines over 5 years of 1,000 km. Its exposure is then 5 times 1,000 km, so 5,000 km·yr.
- The total system exposure is the exposure as defined above, calculated for the complete system.
- The partial system exposures are the exposures calculated per design parameter, e.g. per diameter class or per depth of cover class.

In order to illustrate recent trends a 5-year moving average has been introduced. The 5-year moving average means that the calculations have been performed over the 5 previous years in question.

3.2 Trends of the European gas transmission system

This paragraph gives information on the trends of the European gas transmission system. It not only shows the evolution of the exposure but also which design parameters tend to be more or less used in today's construction. This paragraph gives a picture of the European gas transmission system from 1970 up to the present. Figure 1 to Figure 4 are examples of the pipeline data which is collected by the pipeline operators.

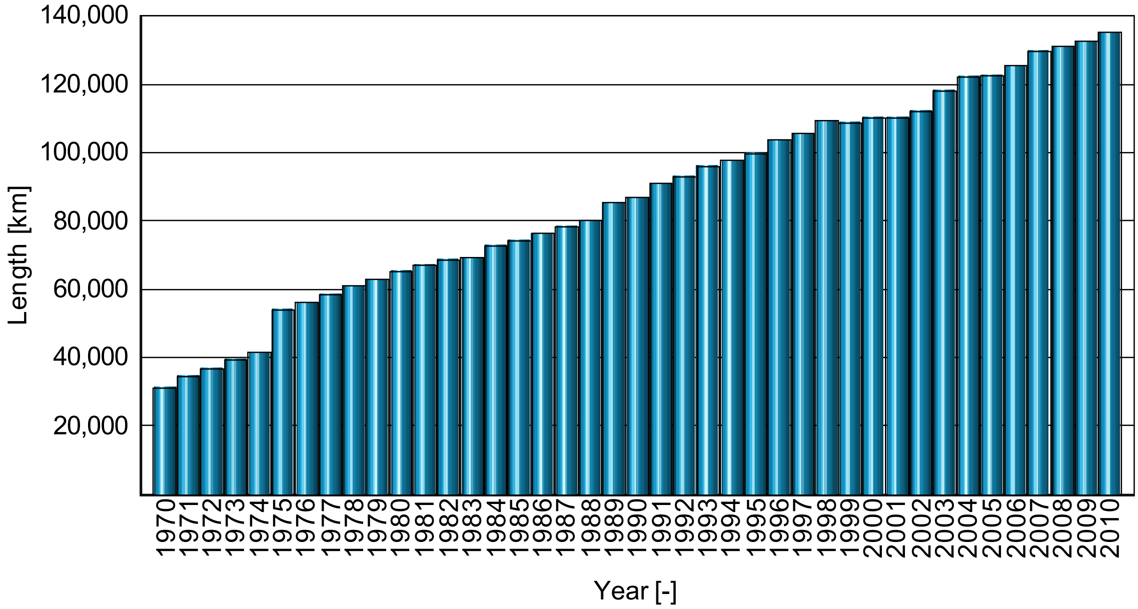

Figure 1: Total length of the European gas transmission system in EGIG

Figure 1 shows a linear increase in the length of the European gas transmission system in EGIG, which has significant step changes in the years 1975, 1991, 1998, 2003 and 2007. These changes correspond to new members joining EGIG. In fact EGIG is now covering about 50% of all gas pipelines in Europe.

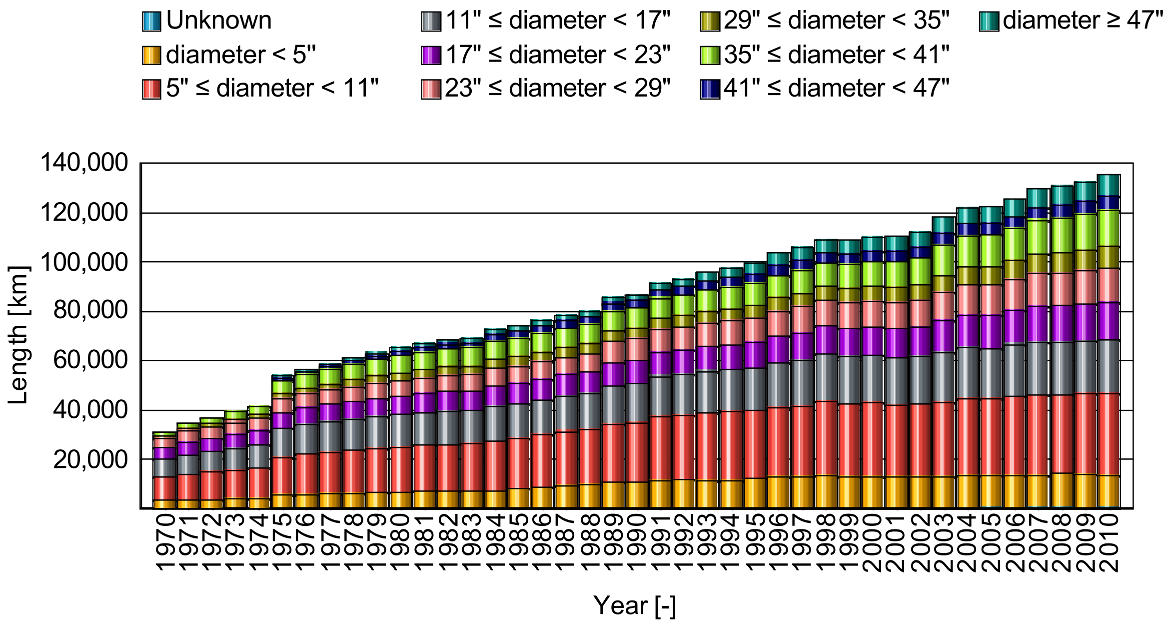

Figure 2: Total length per diameter (d) class

Figure 2 demonstrates that the 5'' ≤ d < 11'' and the 11'' ≤ d < 17'' classes are still the most commonly used. Figure 2 to figure 4 are examples of the pipeline data which is collected by the pipeline operators.

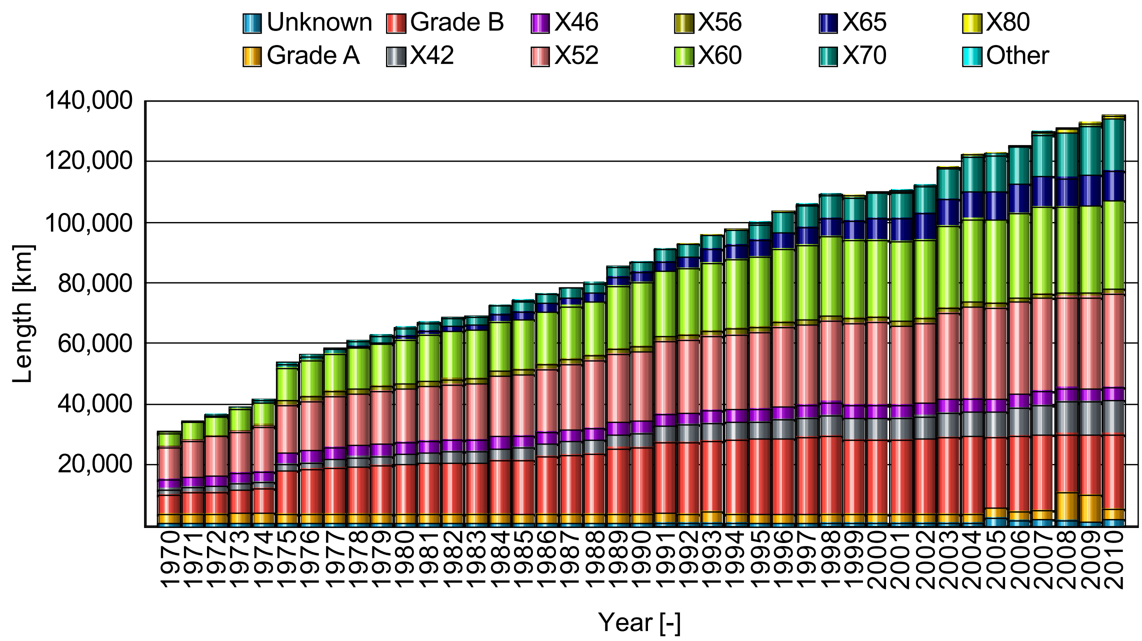

Figure 3: Total length per grade of material

Figure 3 demonstrates that three grades of material are predominant, namely: Grade B, X52 and X60. Together they represent approximately 62% of the total.

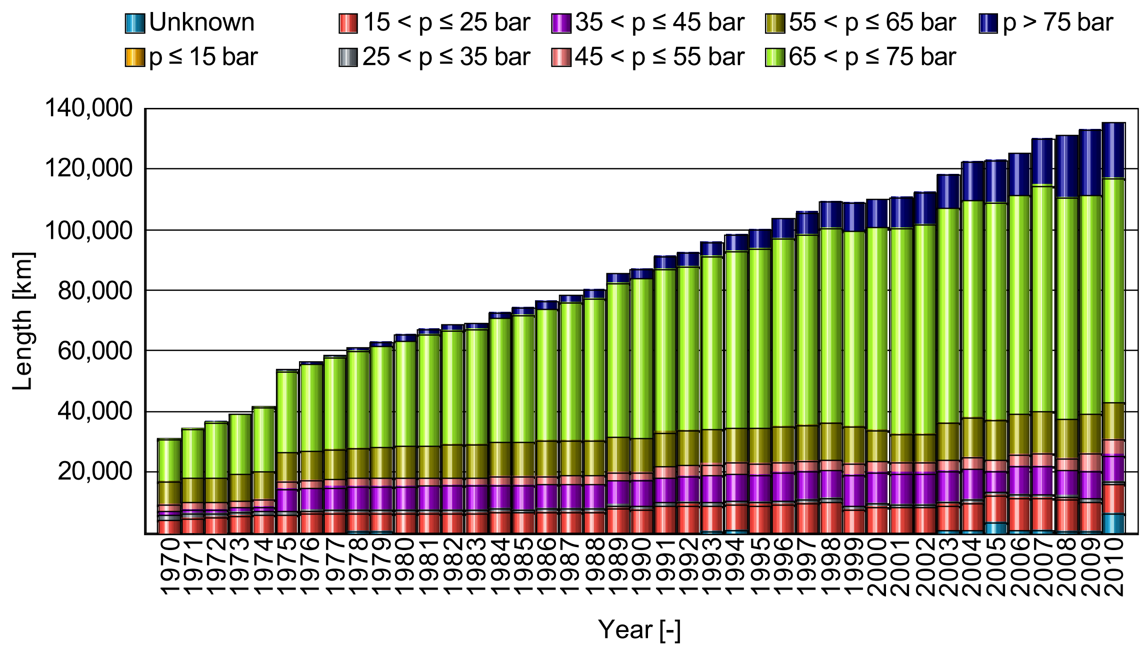

Figure 4: Total length per Maximum Operating Pressure (p) class

Figure 4 shows a predominance of the high Maximum Operating Pressure pipelines. The trend is clearly to operate the pipelines at 65 bar and above.

Exposure

Figure 5 shows the increase of the exposure over the years. The exposure is the length of a pipeline multiplied by its exposed duration and is expressed in kilometres-years [km·yr]. For the period 1970-2010, the total system exposure was equal to 3.55 million km·yr.

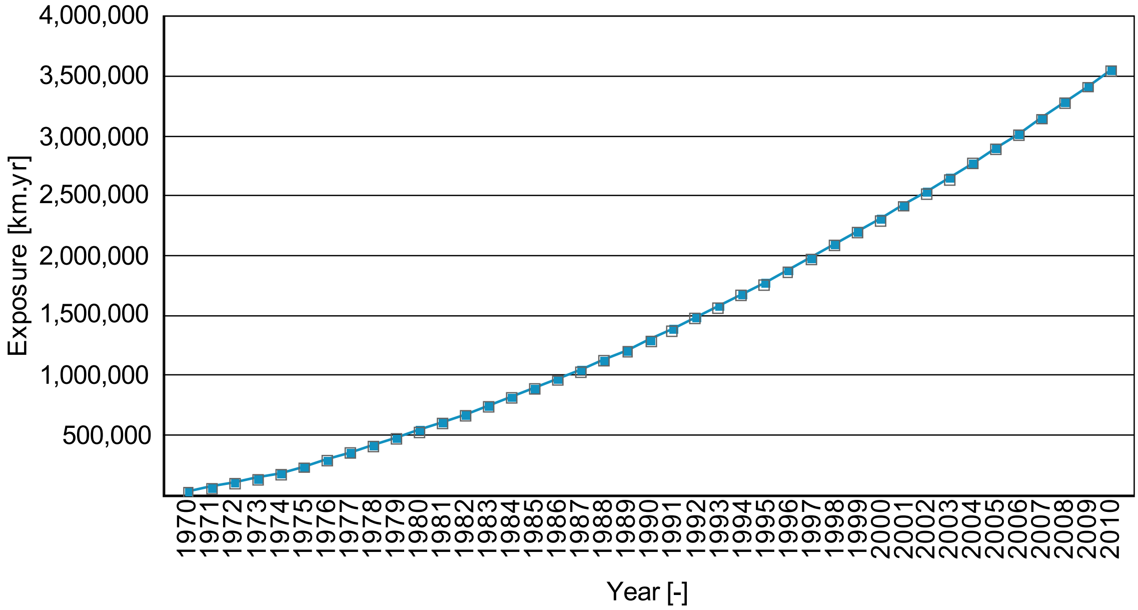

Figure 5: Evolution of the exposure

3.3 Failure frequencies analyses

This paragraph deals with the calculation of safety indicators, namely the primary and secondary failure frequencies. These calculations refer to three notions: the total system exposure, the partial system exposure and the number of incidents.

3.3.1 Number of incidents

In the seventh EGIG report, which covers the period 1970-2007, a total of 1,173 incidents were recorded.

In the last three years 76 incidents were reported by the EGIG members, which bring the total number of incidents to 1,249 for the period 1970-2010.

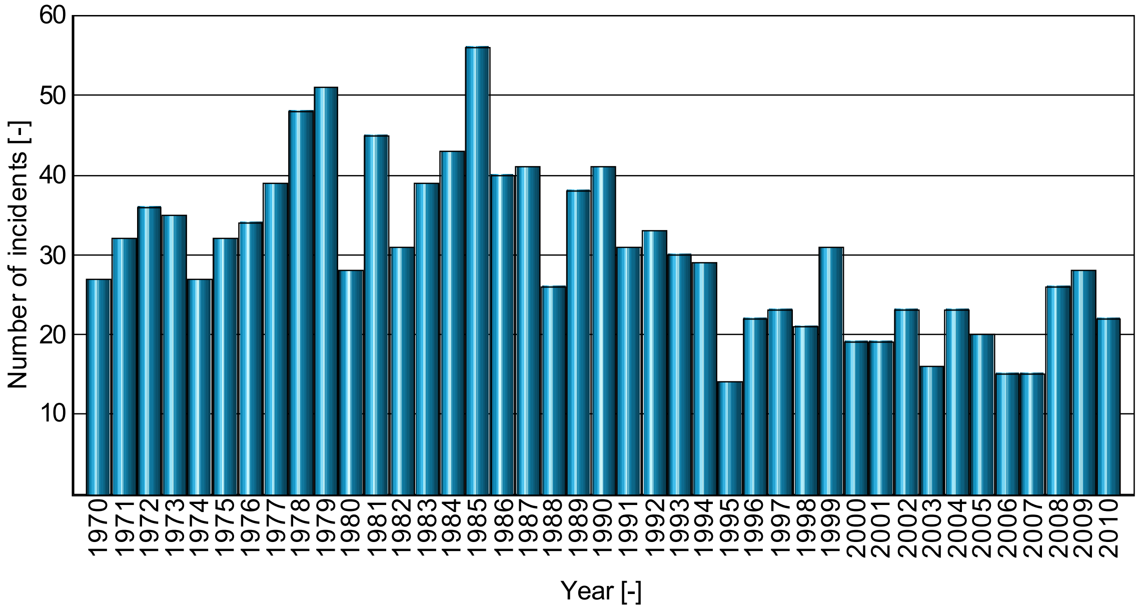

Figure 6: Annual number of incidents

3.3.2 Primary failure frequencies

The primary failure frequency is the result of the number of incidents within a period divided by the corresponding system exposure (Figure 5). Depending on the period studied, the number of incidents varies and so does the system exposure.

The EGIG has compared the primary failure frequencies of different periods, namely the total period (1970-2010), the period corresponding to the seventh EGIG report (1970-2007), a period of 40 years, 30 years, 20 years, 10 years and the period of the last 5 years (2006-2010).

The primary failure frequencies of these periods are given in Table 1.

Period	Interval	Number of incidents [-]	Total system exposure [km·yr]	Primary failure frequency per 1000 km·yr
1970 - 2007	7th report 38 years	1173	$3.15.10^6$	0.372
1970 - 2010	8th report 41 years	1249	$3.55.10^6$	0.351
1971 - 2010	40 years	1222	$3.52.10^6$	0.347
1981 - 2010	30 years	860	$3.01.10^6$	0.286
1991 - 2010	20 years	460	$2.25.10^6$	0.204
2001 - 2010	10 years	207	$1.24.10^6$	0.167
2006 - 2010	5 years	106	$0.654.10^6$	0.162

Table 1: Primary failure frequencies

The primary failure frequency over the last five years was, in 2010, equal to 0.16 per 1,000 km·yr .

The failure frequency over the past five years is less than half the primary failure frequency over the entire period showing the improved performance over recent years.
Figure 7 shows the evolution of the primary failure frequencies over the entire period and the last five years.

Figure 7 illustrates the steady drop of the primary failure frequencies and the failure frequencies of the 5 years moving average. The primary failure frequency over the entire period declined from 0.87 per 1,000 km·yr in 1970 to 0.35 per 1,000 km·yr in 2010. The moving average primary failure frequency over five years decreased by a factor 5 (0.86 to 0.16 per 1,000 km·yr).

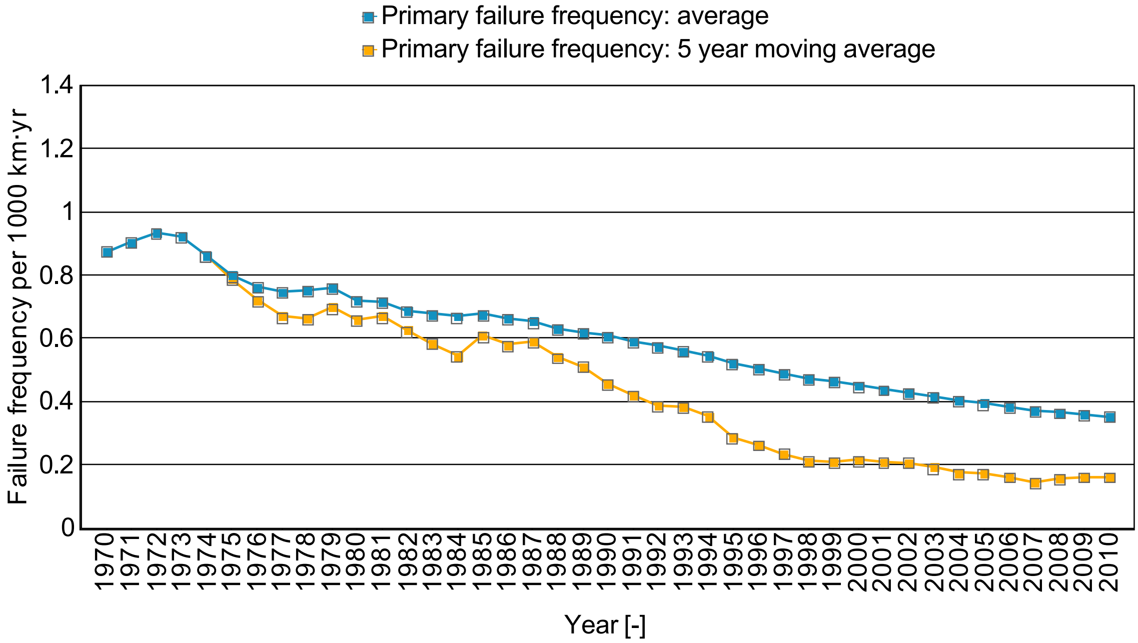

Figure 7: Primary failure frequencies

Analysis of incident causes gives an insight to which causes effort should be focused.
Six different causes have been identified and are given in Figure 8 in association with the percentage of incidents they represent.

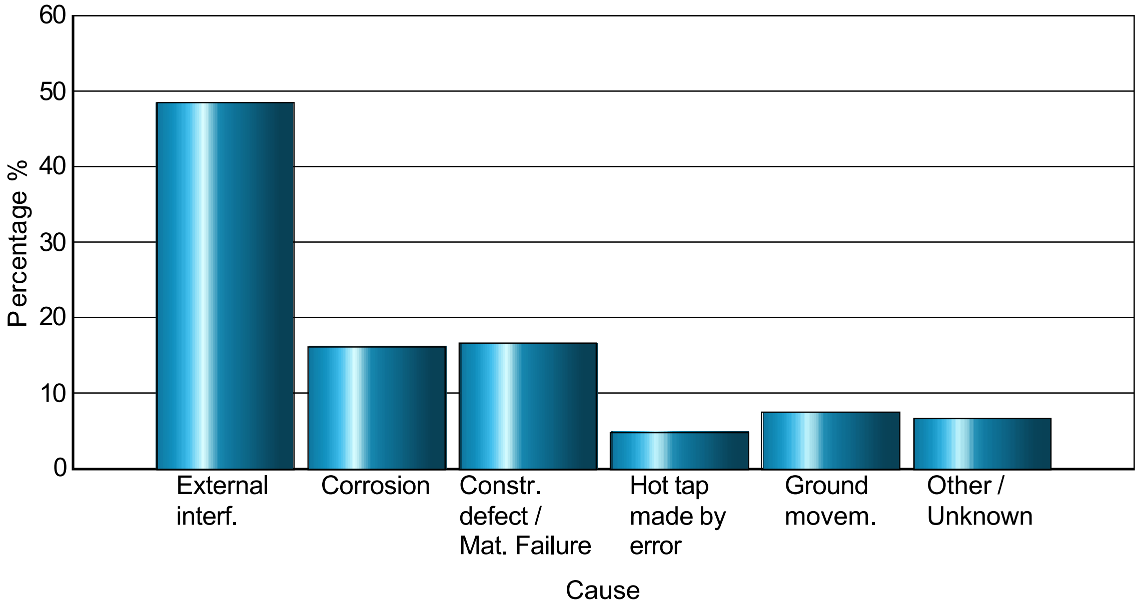

Figure 8: Distribution of incidents per cause

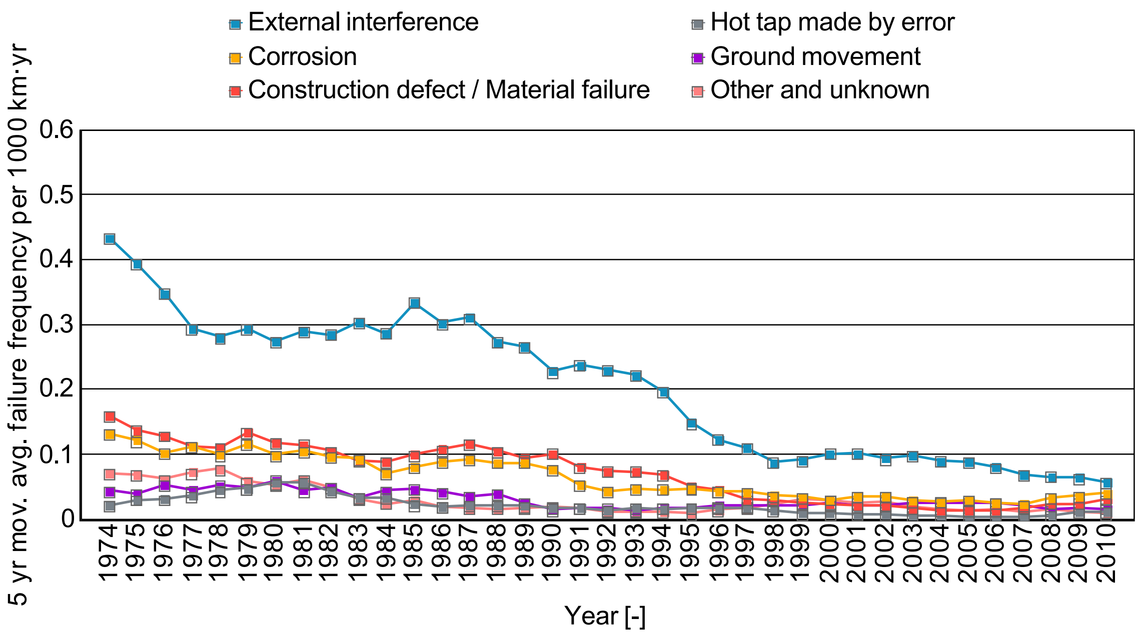

Figure 9: Primary failure frequencies per cause (5-years moving average)

Figure 9 illustrates the reducing failure frequency over the years. This has been due to technological developments, such as: welding, inspection, condition monitoring using in-line inspection and improved procedures for damage prevention and detection.

As far as the cause of external interference is concerned, the 5-years moving average has levelled off at around 0.1 per 1,000 km·yr since 1997. From 2003 the 5-years moving average of the external interference is gradually decreasing from 0.10 to 0.06. However external interference remains the main cause of incidents, but the differences with incidents of other causes, especially corrosion and construction defects/ material failures are small.

Improvements in the prevention of external interference incidents are obtained through a more stringent enforcement of land use planning, the application of one-call systems for the digging activities of external parties (in several counties there is now a legal requirement to report digging activities) with the adoption of appropriate actions by the gas companies like supervision or marking of the pipeline in the direct neighbourhood of the digging activities.

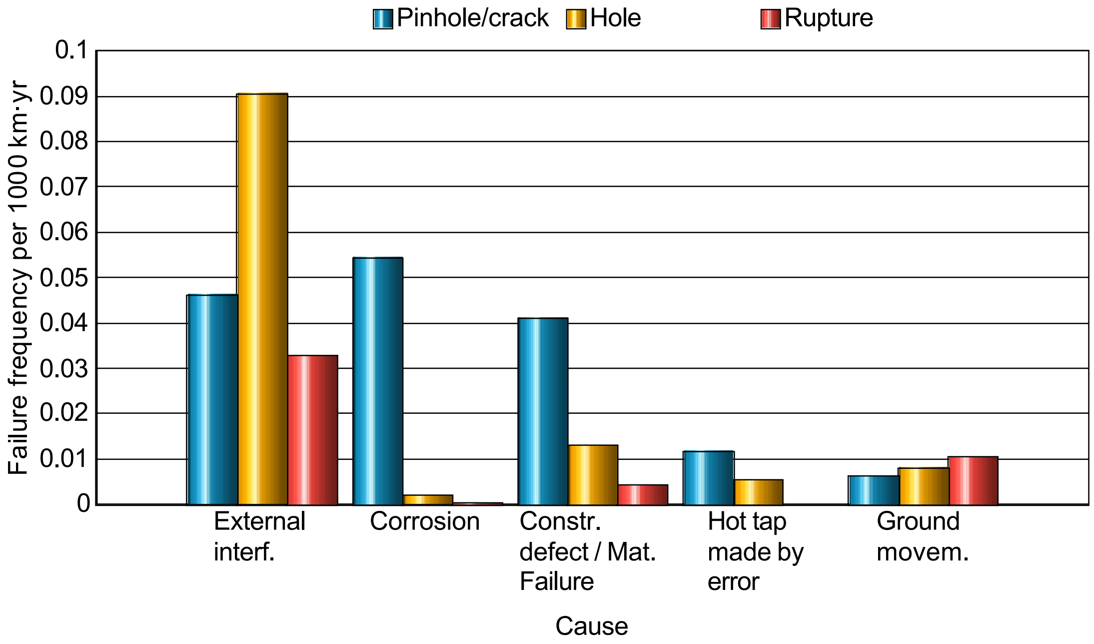

Figure 10: Relation primary failure frequency, cause and size of leak (period 1970 - 2010)

Figure 10 shows that over the whole period the bigger leak sizes (holes and ruptures) are especially caused by external interference, which is also the most common cause (approximately 50% of the incidents), followed by ground movement.

3.3.3 Secondary failure frequencies

Secondary failure frequencies are calculated by dividing the number of incidents by a partial system exposure. Partial system exposure means, for example, the exposure related to one diameter class or one year of construction.

The calculation of secondary failure frequencies is done to consider the influence of 'design parameters' (pressure, diameter, depth of cover, etc.) on the causes and consequences of the incidents.

For six damage causes relevant for the EGIG database the most appropriate secondary failure frequencies have been calculated according to the following design parameters:

- External interference: the diameter of the pipeline, the depth of cover and the wall thickness.
- Corrosion: the year of construction, the type of coating and the wall thickness.
- Construction defect/material failure: the year of construction.
- Hot tap made by error: the diameter of the pipeline.
- Ground movement: the diameter of the pipeline.
- Other and unknown: main causes.

For Ground movement and other or unknown causes also other more relevant considerations are reported.

In the next figures some examples of the secondary failure frequencies are given.
We invite you to download the full report (www.egig.eu) to study all analysis of secondary failure frequencies.

3.3.3.1 Relation between external interference, size of leak and design parameter

Figure 11 to Figure 14 show the relation between the consequences of the incidents caused by external interferences and the diameter of the pipeline, the depth of cover and the wall thickness. In Figure 12 also a further breakdown of the diameter classes as a function of the leak size is depicted.
Although the graphs are presented separately it must be noticed that design parameters are in a way correlated. No quantitative correlations between parameters have been studied in the EGIG report.

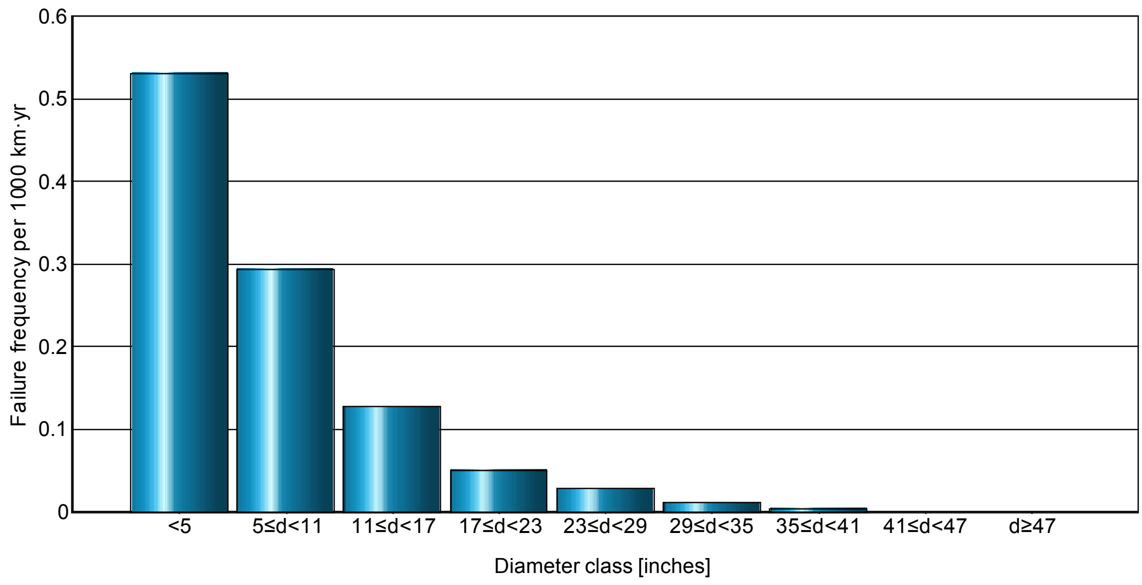

Figure 11: Relation external interference and diameter (d) class

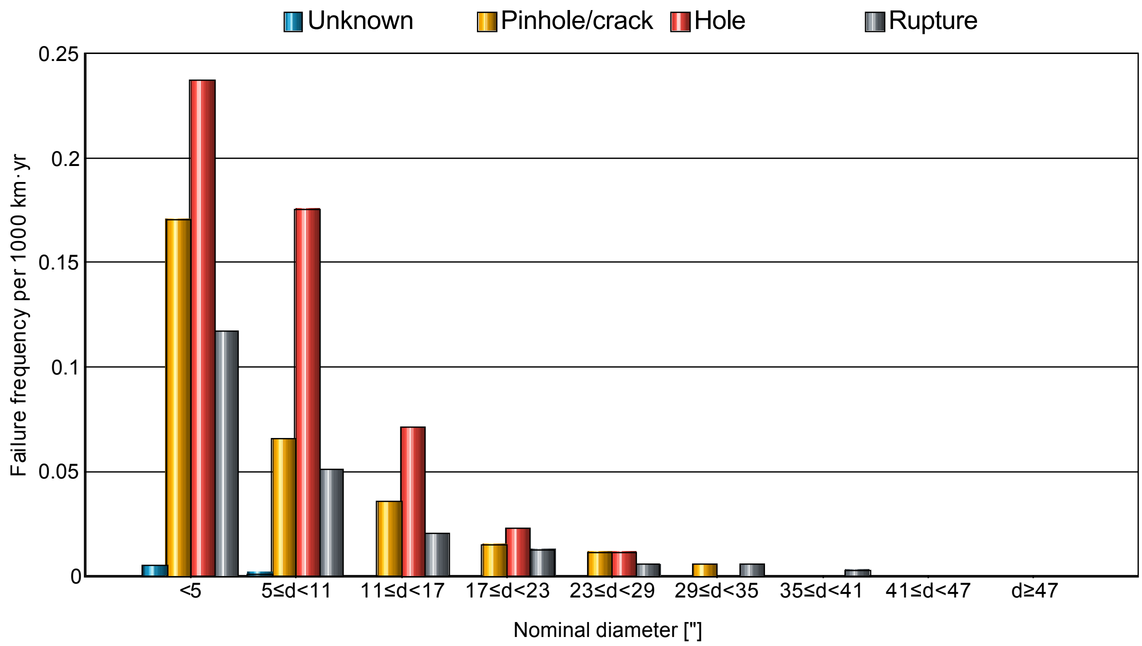

Figure 12: Relation external interference, size of leak and diameter (d) class

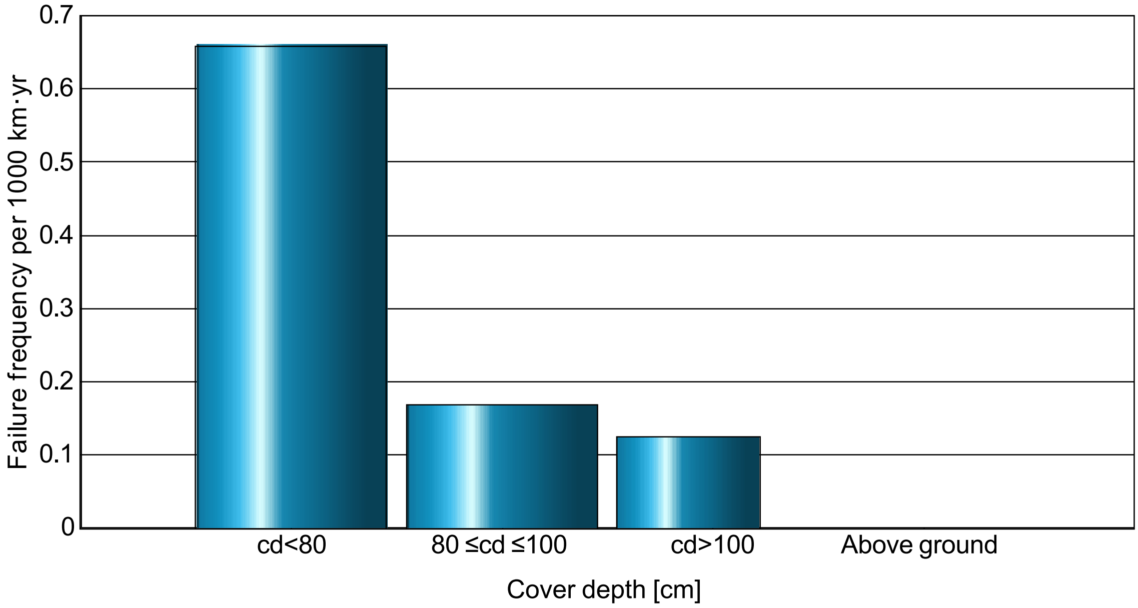

Figure 13: Relation external interference and depth of cover (cd) class

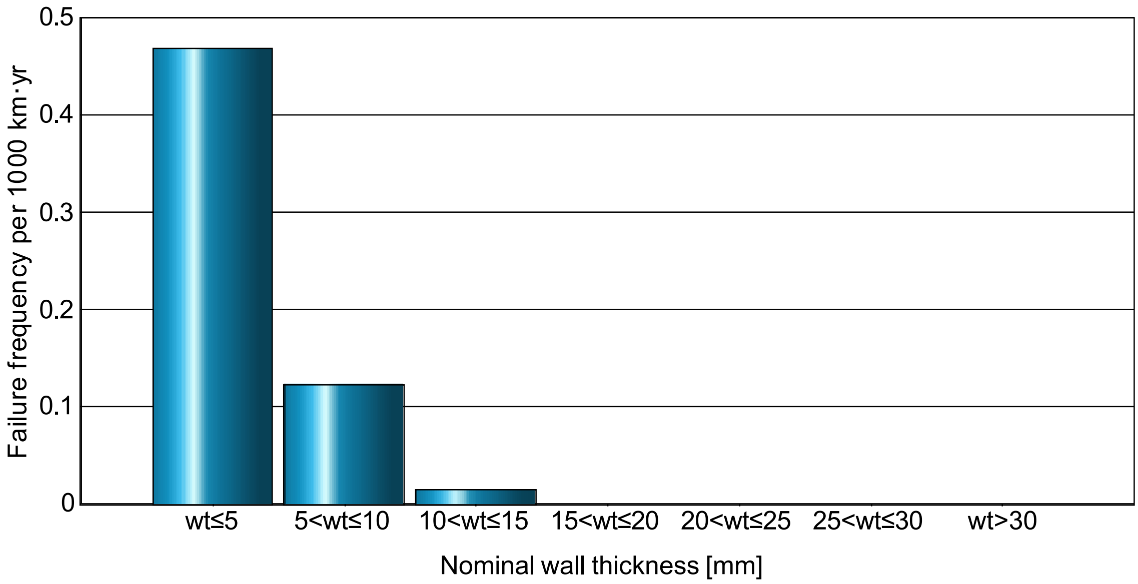

Figure 14: Relation external interference and wall thickness (wt) class

From these figures some general conclusions can be drawn:

- The first conclusion (Figure 11) is that small diameter pipelines are more vulnerable to external interference than bigger diameter pipelines. This can be explained by the fact that small diameter pipelines can be more easily hooked up during ground works than bigger pipelines, the second reason is that their resistance is often lower due to thinner wall thickness.

- The second conclusion is that the depth of cover is one of the leading indicators for the failure frequencies of pipelines. Pipelines with a larger depth cover will have a lower primary failure frequency (Figure 13).
- It seems that wall thickness is an effective protective measure against the impact of external interferences
- The more severe incidents like ruptures and holes occurs mainly at pipelines with smaller diameters (Figure 12).

3.3.3.2 Relation between corrosion, size of leak and design parameter

Figure 15 to Figure 18 show the relation between the failure frequencies of incidents caused by corrosion and the year of construction of the pipeline, the type of coating and the wall thickness.

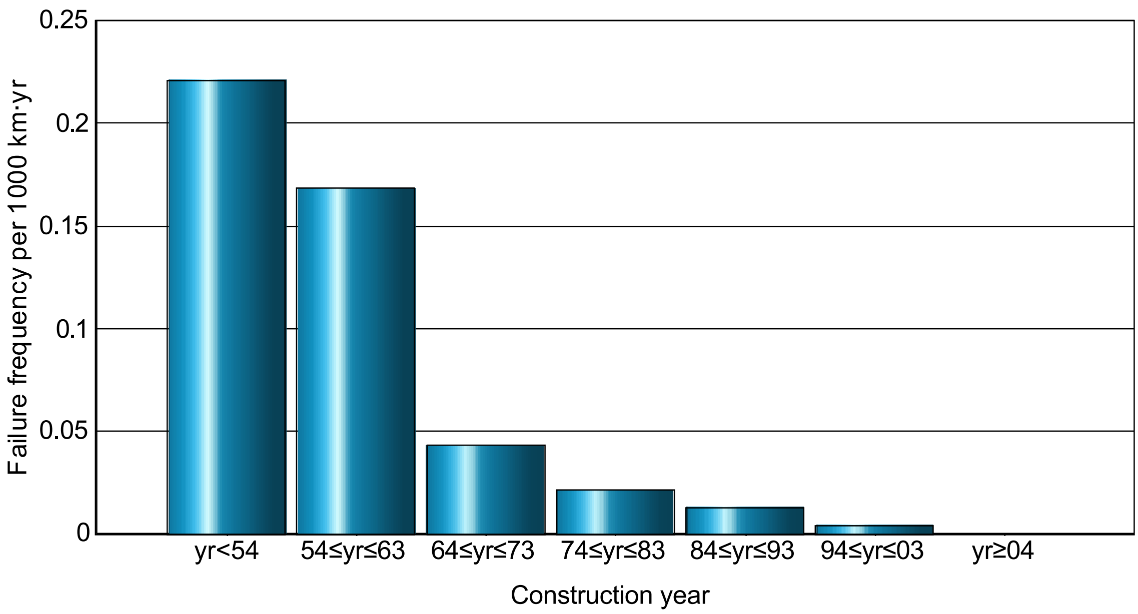

Figure 15: Relation corrosion and year of construction (yr) class

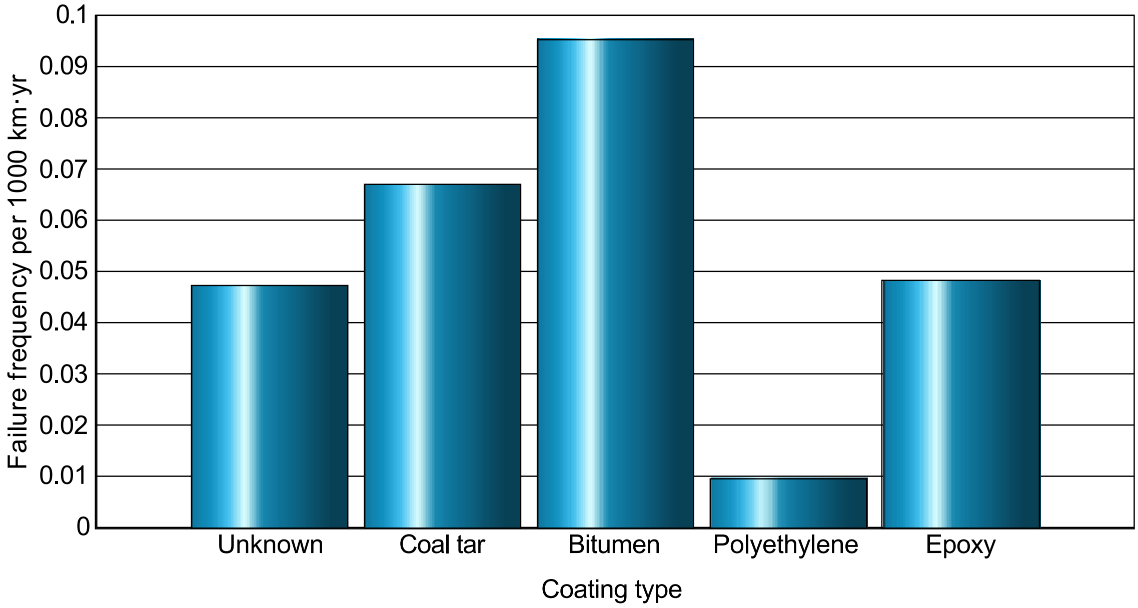

Figure 16: Relation corrosion and most common type of coating

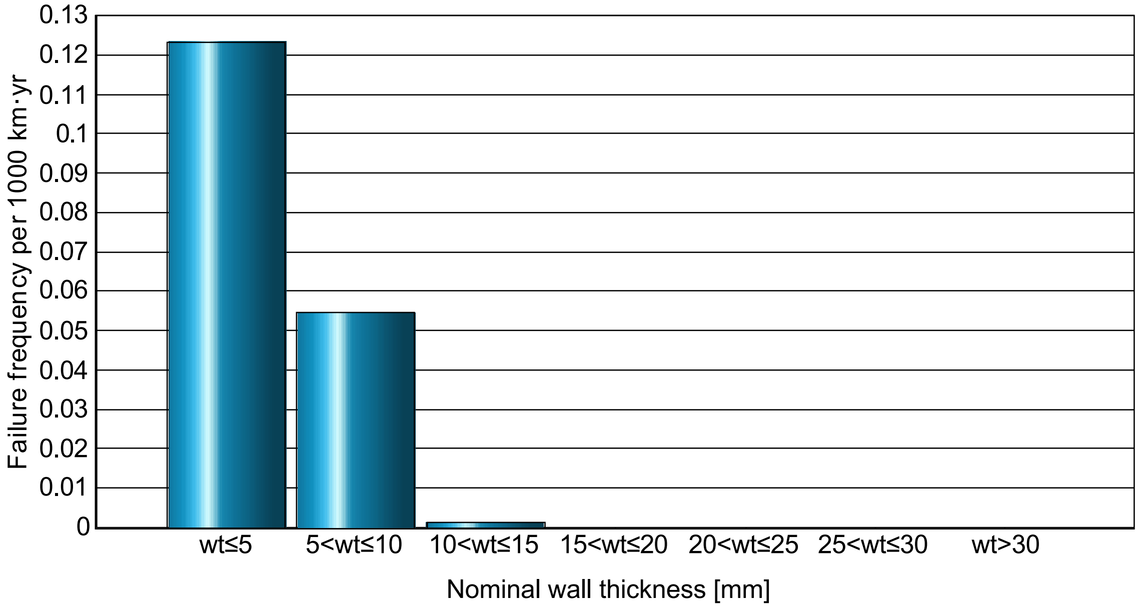

Figure 17: Relation corrosion and wall thickness (wt) class

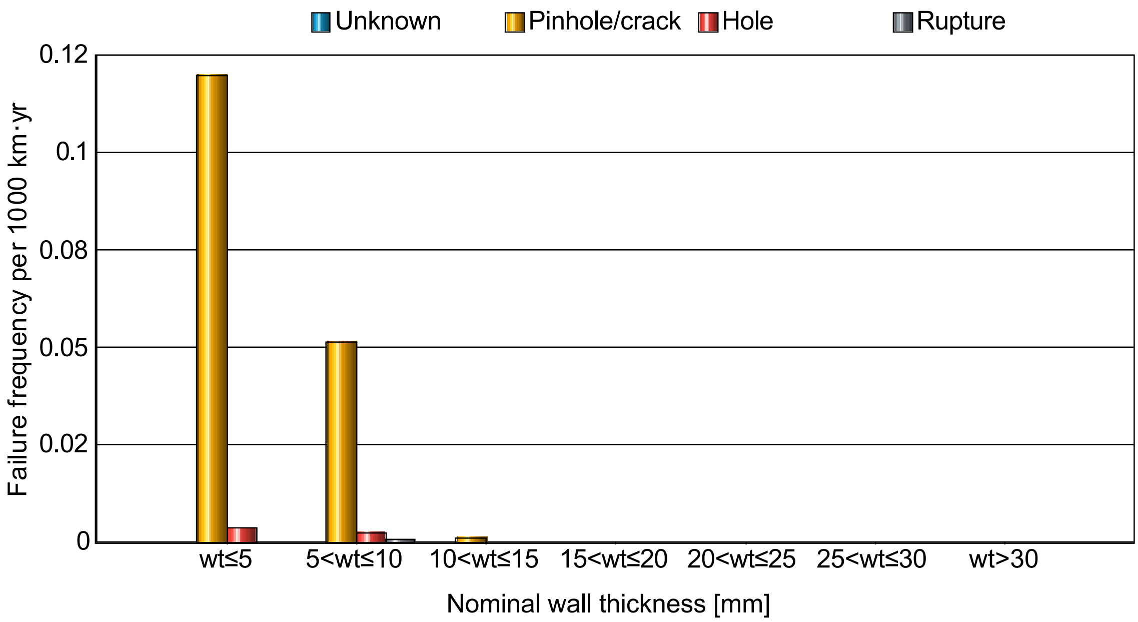

Figure 18: Relation corrosion, size of leak and wall thickness (wt) class

Corrosion has been identified as the third most common cause of incidents (16%). Figure 18 shows that corrosion often results in smaller leak sizes (pinholes and cracks), whereas very few holes were observed and only one rupture occurred on a pipeline, which was constructed before 1954. This rupture was caused by internal corrosion of a pipeline originally used for the transportation of coke oven gas.

Figure 15 illustrates the link between the year of construction of the pipelines and the failure frequencies whereas Figure 16 shows the relation between the most common type of coatings and the failure frequencies. From these figures it seems that older pipelines, with predominantly tar coatings, will have higher failure frequencies.

Corrosion is a phenomenon of deterioration of the pipelines. Corrosion takes place independently of the wall thickness, but the thinner the corroded pipeline wall, the sooner the pipeline fails, as Figure 17 illustrates. The failure point of a thinner pipeline is reached more quickly. Corrosion on thicker pipelines takes longer before causing an incident and therefore has more chance to be detected. Different protective measures are undertaken by pipeline owners to overcome the problem of corrosion. These measures are for example cathodic protection and pipeline coating. In line inspections and pipeline surveys also allow corrosion to be detected at an earlier stage.

Three types of corrosion have been addressed by the EGIG: external corrosion, internal corrosion and corrosion with an unknown cause. External corrosion is located at the external surface of the pipe while internal corrosion is located at the internal surface of the pipe. Up to 2010 they represent:

Corrosion type	Distribution of corrosion incidents [%]
External	83
Internal	13
Unknown	4

Table 2: Distribution corrosion incidents.

3.3.3.3 Relation between construction defect, size of leak and design parameter

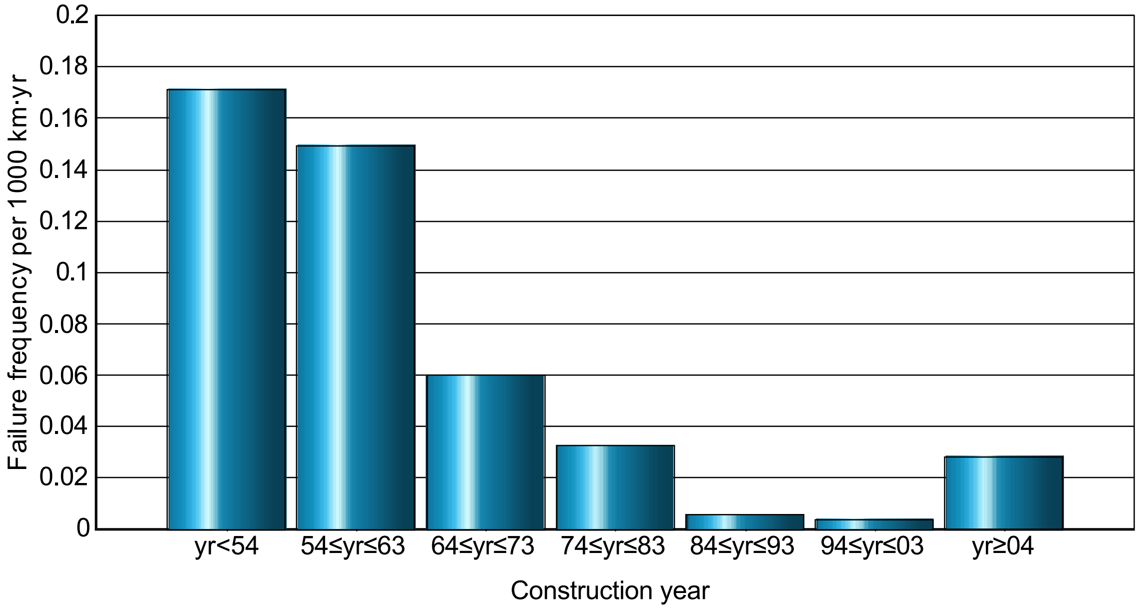

Figure 19: Relation construction defect/material and year of construction (yr) class

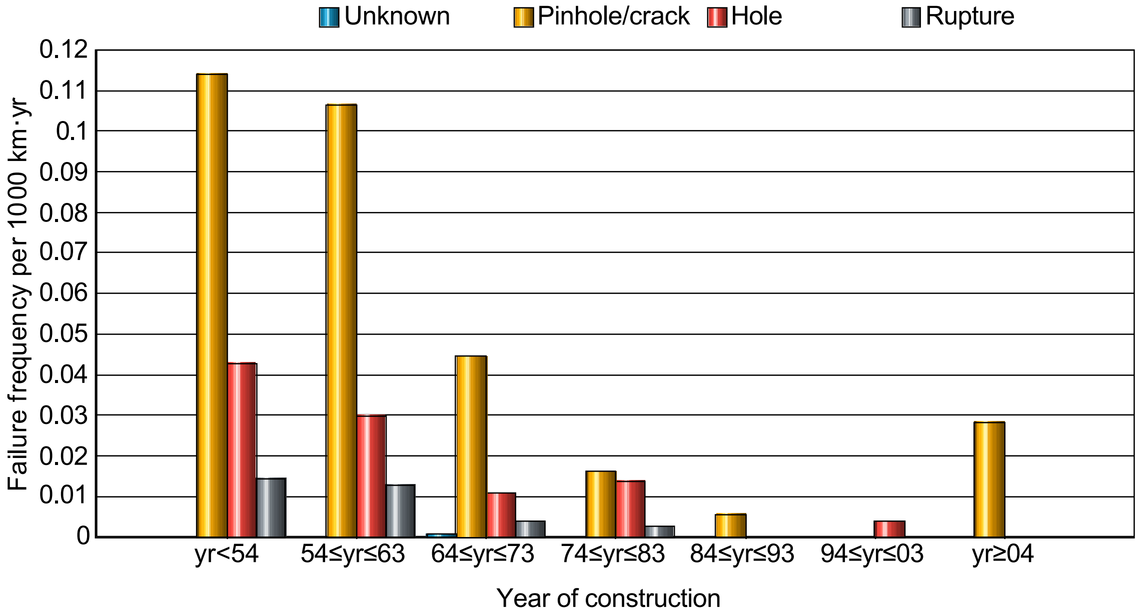

Figure 20: Relation construction defect/material, size of leak and year of construction (yr) class

Figure 19 shows that the older the pipelines, the higher the failure frequencies (due to construction defect/material). It seems that the new pipelines are less vulnerable to construction defect/material, which is synonymous to technical improvements. This phenomenon has also been observed in the ageing analysis (see paragraph 3.4.1)
Figure 19 and Figure 20 shows that the failure frequency of the class ‘ ≥ 2004 ’ seems relatively high. However this failure frequency is caused by 1 incident within a small amount of pipeline exposure (all pipelines constructed after 2003 in the database) giving a high unreliability.

3.3.3.4 Relation between hot tap made by error, size of leak and design parameter

The term "hot tap made by error" means that a connection has been made by error to a gas transmission pipeline.

Figure 21 illustrates that larger diameter pipelines are less vulnerable to hot tap in error. Figure 22 shows that this kind of error can lead not only to small size of leak (pinholes), but also to large size of leak (holes), especially with very small diameter pipelines.

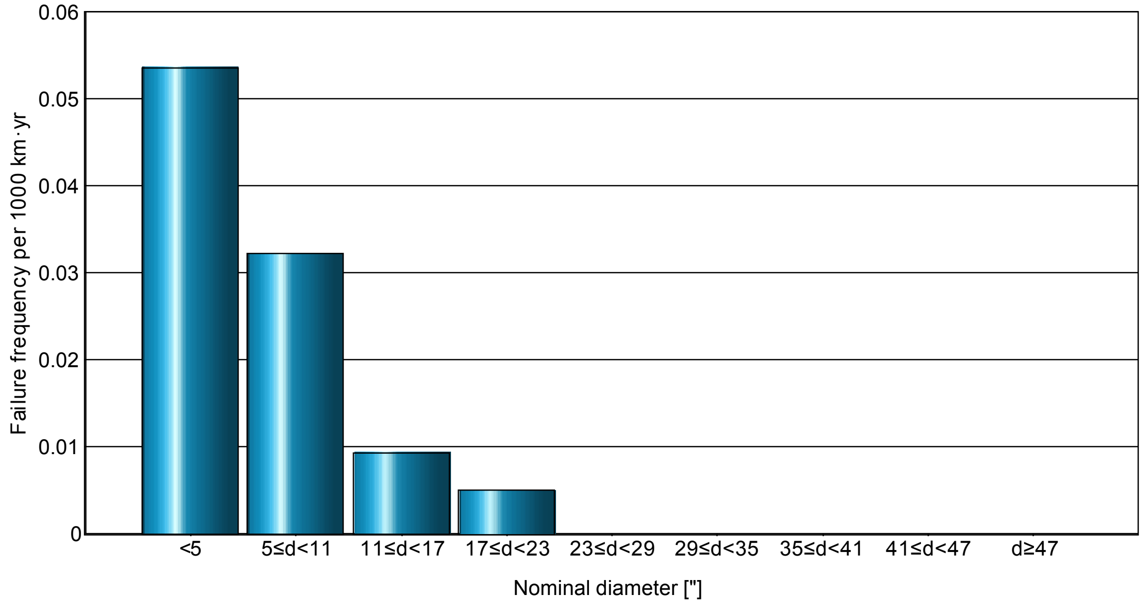

Figure 21: Relation hot tap made by error and diameter class

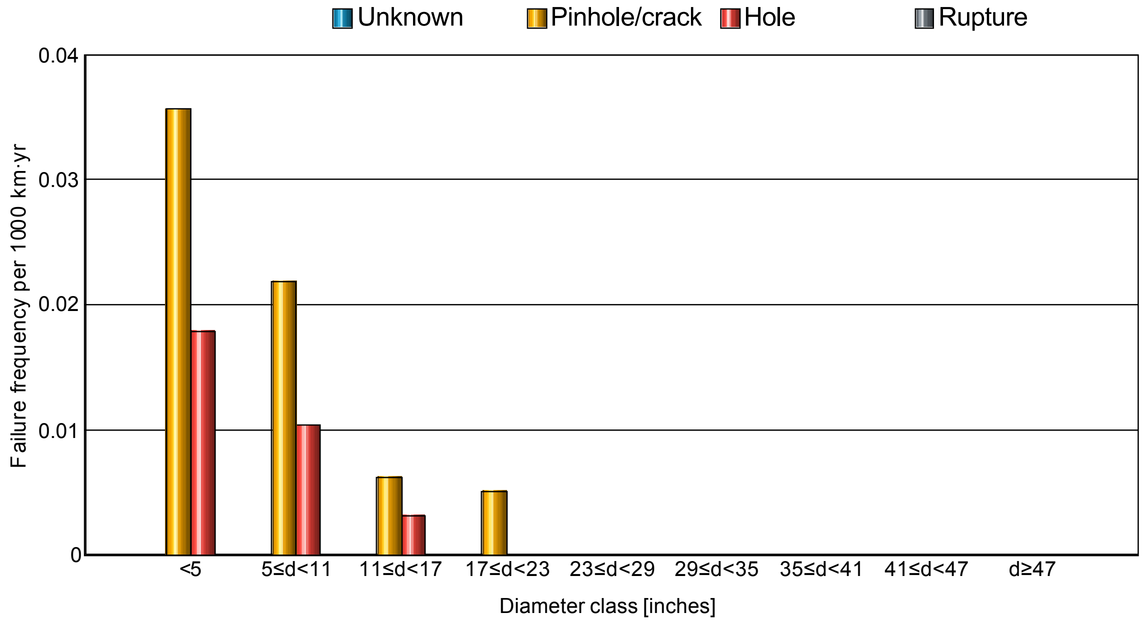

Figure 22: Relation hot tap made by error, size of leak and diameter class

3.3.3.5 Ground movement

Ground movement is responsible for 7.5% of the total incidents of the database.
Figure 23 and Figure 24 depicts the relation between ground movement, size of leak and diameter class. Ground movement incidents can cause serious leak sizes, however, it also can be concluded that smaller diameters are more vulnerable for ground movement than larger diameters. The bar at the diameter ≥ 47'' is caused by one ground movement incident. This demonstrates that even large diameter pipelines can be affected by the enormous forces accompanied by ground movement incidents.

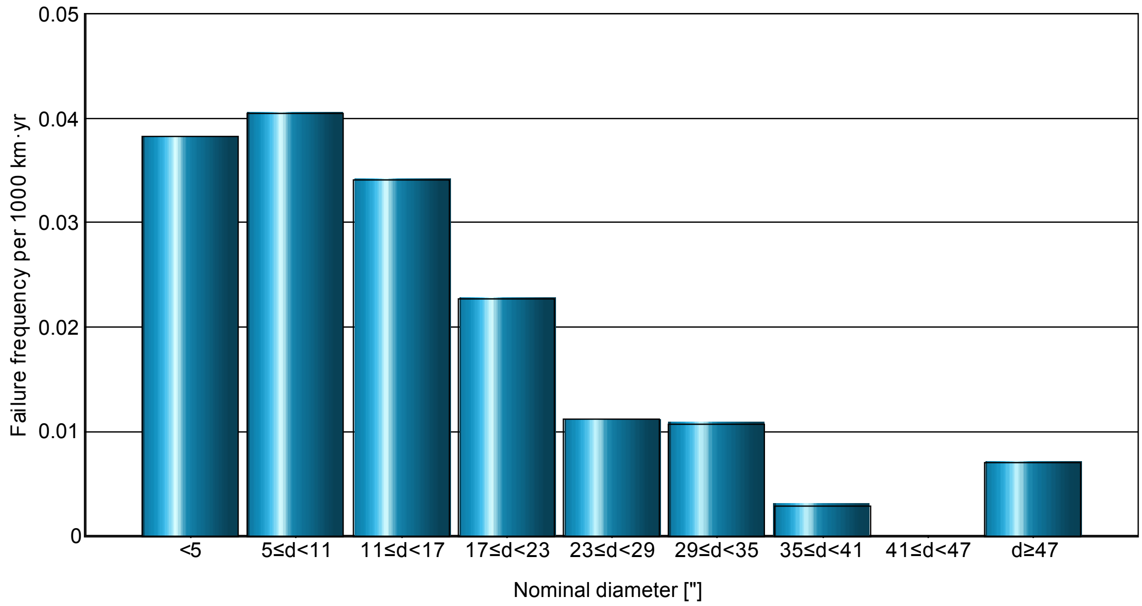

Figure 23: Relation ground movement and diameter class

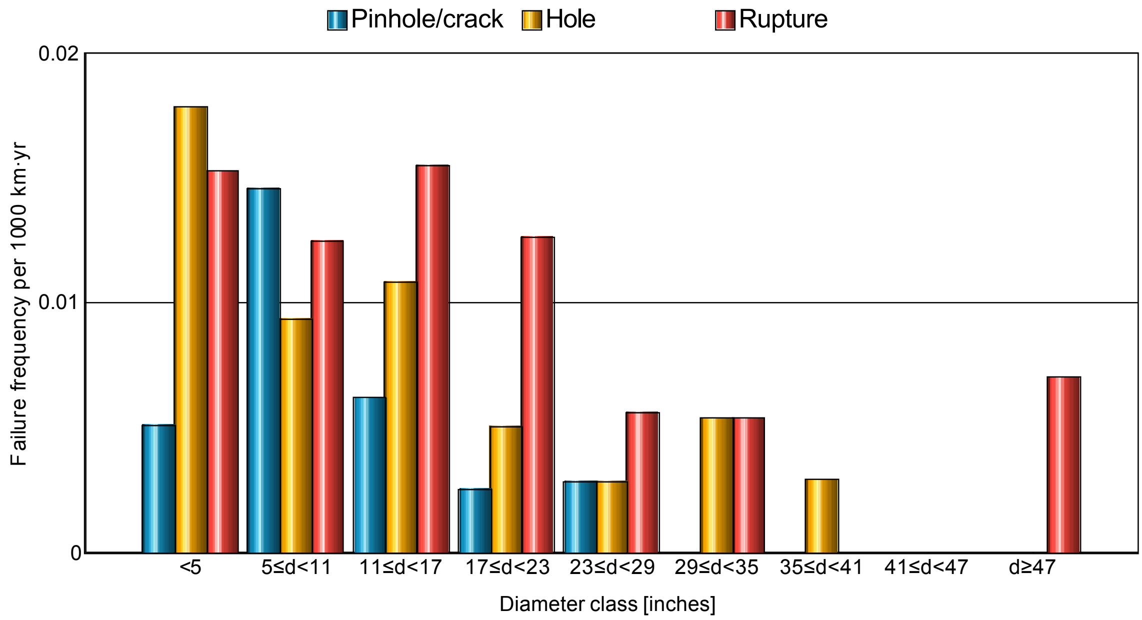

Figure 24: Relation ground movement, size of leak and diameter class

Analysing the information recorded about these failure causes, it is possible to highlight some important elements, which are divided into "Ground Movement". Figure 25 shows the distribution of the sub-causes in the category ground movement.

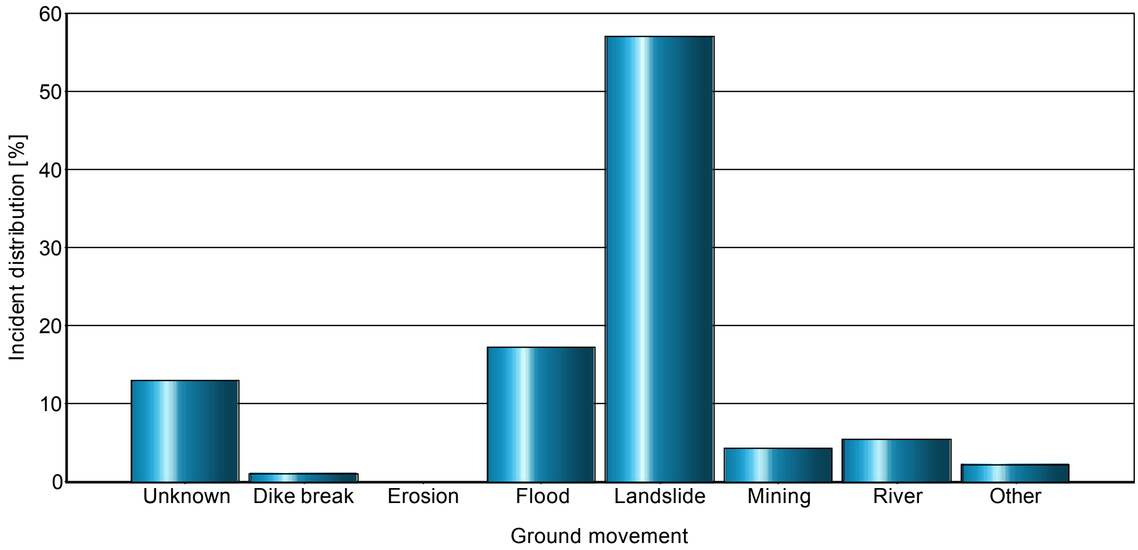

Figure 25: Distribution of the sub-causes of ground movement

3.3.3.6 Other and unknown

The main cause for the category “Other and unknown” is lightning.
The sub-cause lightning represents almost 26% of the incidents within this category.

Within the period 1970-2010, 21 incidents due to lightning have been recorded in the EGIG database, which represents a failure frequency due to lightning equal to 0.0059 per 1,000 km·yr.
The EGIG examined the distribution of the consequences of lightning in terms of leak sizes. Out of 21 incidents, 19 were small leaks (pinholes and cracks) and only 2 resulted in a large leak (hole). As lightning is a huge source of energy, ignition is very likely.

3.4 Other analysis

3.4.1 Ageing

The influence of the age of the pipelines on their failure frequencies has been studied in the ageing analysis presented.

In this ageing analysis, the failure frequency of corrosion incidents has been studied as a function of construction year.

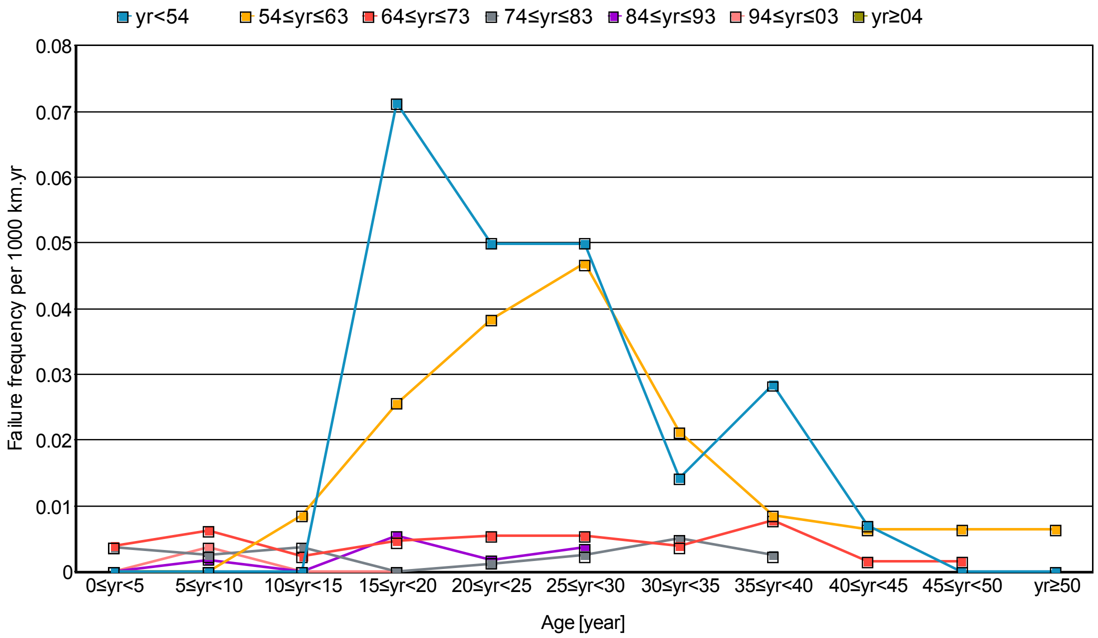

Figure 26: Ageing analysis (corrosion)

Explanation Figure 26.

Taking for instance a pipeline constructed before 1954, the failure frequency 25 to 30 years after the construction year is equal 0.050 whereas it will equal 0.014 after 35-40 years.

The first conclusion of Figure 26 is that early constructed pipelines (before 1964) have a higher failure frequency than recently constructed pipelines. However a second important conclusion is that all failure frequencies irrespective of the age category are slightly decreasing in time.

Pipelines constructed, commissioned and operated before 1960s appear to be subject to failure due to corrosion. When technology became available during the 1960s, it appears that pipelines operated afterwards have not had a history of failures due to corrosion. Pipelines constructed from the 1964-1973 construction classs do not show ageing. Operational measures for older pipelines have tended to reduce the failure frequency of the older pipelines.

3.4.2 Ignition probability

Fortunately not every gas release ignites, which limits the consequences of the incidents. In the period 1970-2010, only 4.5% of the gas releases recorded as incidents in the EGIG database ignited.

Ignition depends on the existence of random ignition sources. The EGIG database gives the possibility to evaluate the link between ignition and leak size.
Table 3 gives the ignition probabilities per size of leak.

Size of leak	Ignition probabilities [%]
Pinhole-crack	4
Hole	2
Rupture	13

Table 3: Ignition probabilities per leak type

4 Conclusions and facts

- EGIG has maintained and expanded the European Gas pipeline incident database. Transmission companies of fifteen European countries now collect incident data on more than 135,000 km of pipelines every year. The total exposure, which expresses the length of a pipeline and its period of operation, is 3.55 million km·yr.
- The statistics of incidents collected in the database give reliable failure frequencies. The overall incident frequency is equal to 0.35 incidents per year per 1,000 km over the period 1970 to 2010.
- The 5 year moving average failure frequency in 2010, which represents the average incident frequency over the past 5 years, equals 0.16 per year per 1,000 km.
- The five year moving average and overall failure frequency has reduced consistently over the years, although it has tended to stabilise.
- The high contribution of external inference emphasises its importance to pipeline operators and authorities.
- External interference incidents are characterised by potentially severe consequences.
- External interference incidents have reduced over the years so that they are now of a similar order to that of corrosion and construction/material defects.

5 Reference

- 7th Report of the **E**uropean **G**as Pipeline **I**ncident Data **G**roup, 1970-2007, December 2008.