EGIG PIPELINE INCIDENT DATABASE

SAFETY PERFORMANCES DETERMINES THE ACCEPTABILITY OF CROSS COUNTRY GAS TRANSMISSION SYSTEMS

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SUMMARY

The use of pipelines for the transport of large quantities of natural gas to industry and to commercial and domestic consumers represents a safe mode of transport in terms of the impact on the environment and human health. The safe transportation of product by pipeline is vital to meeting the energy needs in the future.As a general policy the natural gas industry strives to design, construct and maintain pipelines in a safe manor to prevent any damage in order to protect the public, public health and the environment and to assure an undisturbed supply of natural gas to customers. This business principle aims to secure the confidence of authorities and of consumers as well as continuity of supply.

Although legal approaches may differ across Europe, and be influenced by cultural, historical and geographical factors, the gas industry conducts similar basic safety practices across Europe since the overall objective is to construct, operate and maintain safe pipeline systems. In 1982 six European gas transmission system operators took the initiative to gather data on the unintentional releases of gas in their pipeline transmission systems. This co-operation was formalised by the setting up of EGIG (European Gas pipeline Incident data Group). Now EGIG is a co-operation between a group of nine major gas transmission system operators in Western Europe and is the owner of an extensive gas pipeline-incident database.

The objective of this initiative was to provide a broad basis for statistical use, giving a more realistic picture of the frequencies and probabilities of incidents than would be possible with the independent data of each company considered separately. The collection of safety related data has grown in significance as a result of increasing interest shown by local, national and international responsible authorities for safe gas transmission.

The creation of this extensive pipeline-incident database (1982) has helped pipeline operators to demonstrate the safety performances of their pipeline systems. 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 are not taken into account so that the result of the database presents an average of all participating companies.

Uniform definitions have in a consistent way been used over the entire period. The database gives useful information about trends which have been developed over the years (1970-2001).

This paper gives the highlights of the 5th report of EGIG covering the period 1970-2001 and has been presented recently during the 22nd World Gas Conference of IGU (International Gas Union) in Tokyo Japan.

Notwithstanding the fact that only major gas releases can cause a potential danger for the public and the environment, all unintentional gas releases are reported into the EGIG database. The total safety performance of a high pressure gas transmission pipeline can be expressed in the failure frequency of the failure mode “loss of containment”. This parameter can be considered as a total measure of the

effectiveness of all the pipeline processes (i.e. design, construction, maintenance and operation). More extensive analyses are given in the 5th report of EGIG.

The main conclusions of the 5th EGIG report are:

- Nine major European gas transmission companies, participating in EGIG (European Gas Pipeline Incident Data Group), now have an accumulative exposure of their pipeline system of 2.41 million kilometres-years and 1060 incidents.

- From 1970 to 2001 no incident on a high pressure transmission steel pipeline has caused fatalities or injuries to inhabitants.

- The overall incident frequency with an unintentional gas release over the period 1970 to 2001 is 0.44 incidents per year per 1000 km pipeline. However, the figure over the past 5 years is significantly lower: 0.20 incidents per year per 1000 km pipeline.

- Over the last decade the overall frequency of incidents causing an unintentional gas release has gradually reduced thus demonstrating the success of an increasing integration of safety in the total pipeline process; i.e. proper design and construction (including pipe manufacture), adequate maintenance, and safe operation. Due to information technology, it is now possible to get quicker information about the effectiveness of measures to increase the safety performances of gas transmission systems.

- External interference remains the main cause of gas pipeline incidents involving gas leakage; an average of 0.22 incidents per year per 1000 km pipeline for the period 1970 to 2001. An improvement in the incident frequency has been observed in recent years; over the past 5 years the figure is 0.10 incidents per year per 1000 km pipeline.

- When an incident with a gas escape occurs, in 40% of the cases the incident will be detected and reported to the pipeline owner/operator by the public. The second most common way is by patrol survey.

- For the incident causes 'corrosion' and 'construction defects/material failures' no ageing could be demonstrated.

- Furthermore, the overall ignition probability is low; according to the EGIG database, the gas has ignited in 4.0% of all incidents and from 1970 to 2001. However, the ignition probability differs significantly per diameter and type of leak; the ignition probability for a small pipeline (≤16 inch) with a rupture is 9.5% and for a large pipeline (>16 inch) 25%.

1. INTRODUCTION

In 1982 six European gas transmission system operators took the initiative to gather data on the unintentional release of gas in their pipeline transmission systems. This co-operation 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 statistical use, giving a more realistic picture of the frequencies and probabilities of incidents than would be possible with the independent data of each company considered separately. The collection of safety related data has grown in significance as a result of increasing interest shown by local, national and international responsible authorities for safe gas transmission.

In 2001 a total of nine companies were participating, comprising all of the major gas transmission system operators in Western Europe. The participating companies were:
-Dansk Gasteknisk Center a/s, represented by DONG Energi-Service;
-ENAGAS, S.A.;
-FLUXYS;
-Gaz de France;
-Gastransport Services (part of N.V. Nederlandse Gasunie);
-Ruhrgas AG;
-SNAM RETE GAS;
-SWISSGAS AG;
-Transco, represented by Advantica.

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 are not taken into account so that the result of the database presents an average of all participating companies. Uniform definitions have been used consistently over the entire period. Consequently, the database gives useful information about trends which have developed over the years.

In this paper, information is given on the development of the database and results of some analyses. Accumulated frequencies are given over the entire period. However, since the exposure time of the pipeline system increases, each new year added has a smaller effect on the accumulated frequencies. Therefore occasionally a separate presentation of the most recent period is also given. This has been done by using the 5-year moving average or by comparison of only the past five years with the accumulated frequency.

This paper is based on the official EGIG report [1] covering the period 1970-2001. The most important information will be updated annually and is available at the internet site of EGIG (http://www.gastransportservices.nl/EGIG/).

2. DEFINITIONS AND DESCRIPTIONS

2.1. Classification of damage

The criteria for the incidents in the database are:
-There is an unintentional release of gas;
-The incidents are related to an onshore gas transmission steel pipeline (this does not applies to production lines)
 -with a design pressure greater than 15 bar;
 -outside the fences of installations;
 -excluding associated equipment (e.g. valves, compressors) or parts other than the pipeline itself.

Damages are recorded in classes, depending on the leak size:
-PINHOLE/CRACK: diameter of defect equal to or less than 2 cm;
-HOLES: diameter of defect more than 2 cm and equal to or less than the diameter of the pipeline;

-RUPTURES: diameter of defect more than the pipeline diameter.

2.2. Type of incident

The incidents are divided according to the initial cause into the following types:

-External interference;
-Corrosion;
-Construction defect/material failure;
-Hot-tap made by error;
-Ground movement;
-Other and unknown causes.

Depending on the type of the incident, the following information is recorded (only to explain possible differences in performances):

-External interference:
    -Activity causing the incident (e.g. digging, piling, ground works);
    -Equipment causing the incident (e.g. anchor, bulldozer, excavator, plough);
    -Installed protective measures (e.g. slabbing, casing, sleeves).
-Corrosion:
    -Location (external, internal or unknown);
    -Corrosion type (galvanic, pitting, stress corrosion cracking, unknown).
-Construction defect/material failure:
    -Type of defect (construction or material);
    -Defect specification (hardspot, lamination, material, field weld, unknown);
    -Pipeline type (straight, field bend, factory bend).
-Ground movement:
    -The type of ground movement (dike break, erosion, flood, landslide, mining, river, unknown).
-Other and unknown:
    -Causes are also subdivided into a number of predefined sub-causes (e.g. design error, erosion, lightning, maintenance, other weld, repair clamp, other/unknown).

For all incidents other information is also recorded, some examples are:

-Depth of cover;
-Size of leak (pinhole-crack, hole, rupture, unknown);
-Ignition (yes/no);
-Detection (e.g. client, contractor, landowner, patrol);
-Diameter;
-Wall thickness;
-Grade of material;
-Construction year;
-Design pressure;
-Type of coating (e.g. asphalt, bitumen, coal tar, epoxy, polyethylene).

2.3. Failure frequency calculation

The failure frequency is calculated by dividing the number of incidents by the "kilometer-years", i.e. the exposed length for the pipeline category under consideration and its exposure duration. All the frequency figures are given per 1000 kilometer-years (km·yr).

3. DATABASE CONTENT

3.1. Development database

The total length of the pipeline system of all the participating companies is still increasing: in 2001 the annual length is 110,236 km, while in 1998 the annual length was 109,188 km. The total exposure in the period 1970-2001 is $2.41 \cdot 10^6$ kilometer-years, while in the period 1970-1998 the exposure was $2.09 \cdot 10^6$ kilometer-years. The development of the exposure, from 1970 to 2001, is given in Figure 1.

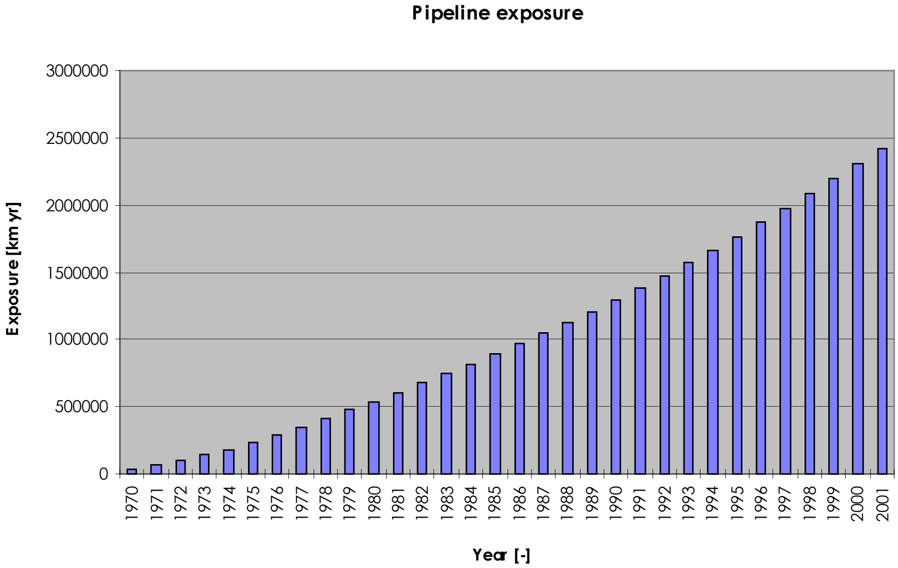

Figure 1. *Exposure length*

3.2. Incident data

The total number of incidents in the EGIG database up to the end of 2001 is equal to 1060. The annual number of incidents in the database is given in Figure 2.

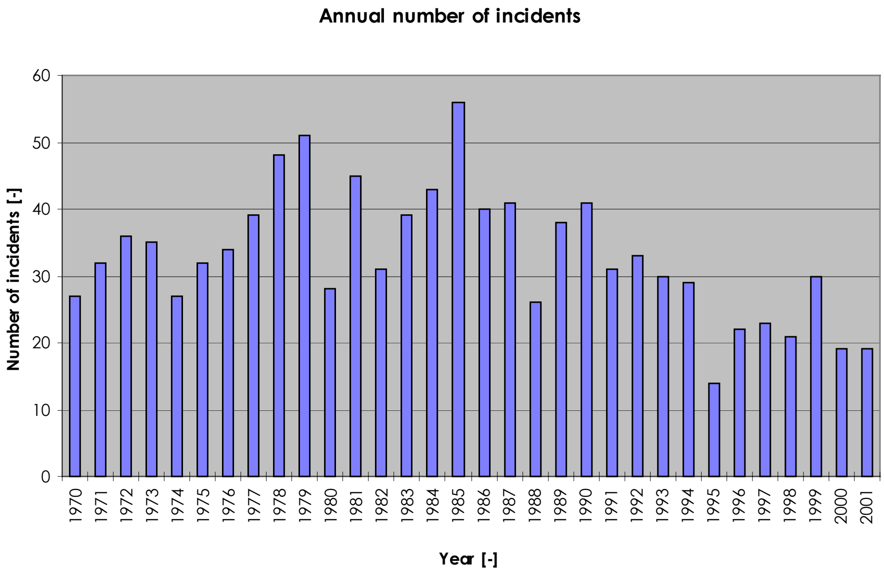

Figure 2. *Annual number of incidents*

4. RESULTS

4.1. Overall incident frequencies

The development of the overall incident frequency is given in Table 1.

Timescale		Number of incidents [-]	Total exposure [km·yr]	Frequency [per 1000 km·yr]
1970-1999	4th EGIG report	1000	$2.09 \cdot 10^6$	0.48
1970-2001	total period	1060	$2.41 \cdot 10^6$	0.44
1997-2001	last 5 years	112	$0.54 \cdot 10^6$	0.21
2001	last year	19	$0.11 \cdot 10^6$	0.17

Table 1. *Development incident frequencies*

An overview of the development of the average overall failure frequency over the total period 1970 to 2001 is given in Figure 3. This figure shows the gradual reduction in the overall incident frequency in each year which is the cumulative total from 1970 onwards. In order to see the results over the last period, without the influence of the past, the moving average is calculated only over the past 5 years (1970-1974, 1971-1975, 1972-1976 etc). These results are also given in Figure 3.

The main conclusions of the development are:

- The average failure frequency over the period 1970-2001 is 0.44 per year per 1000 km pipeline with a 95% confidence interval of ± 0.03;
- The failure rate per year has decreased a factor 5 over the past 32 years.

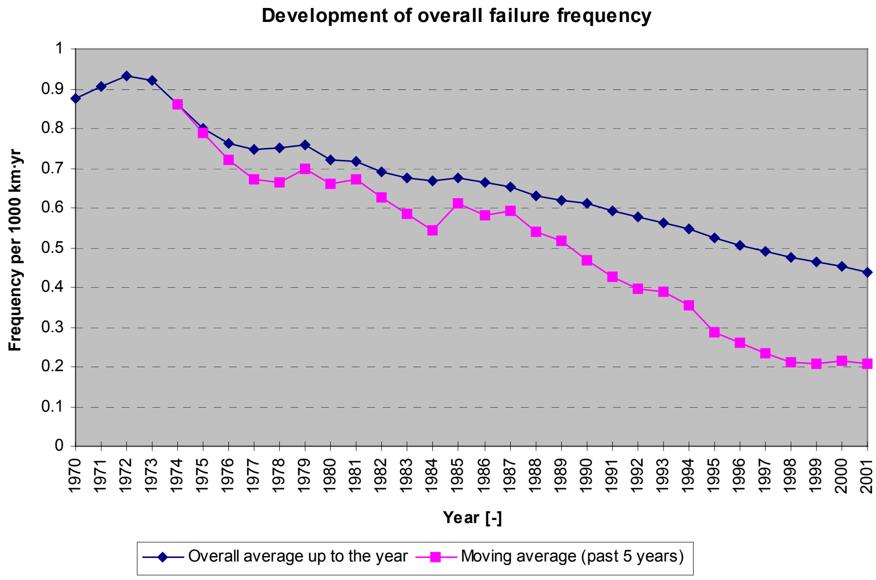

Figure 3. *Development safety performances*

4.2. Frequency per type of incident

The distribution of the incident cause for the entire period (1970-2001) is given in Table 2.

Incident cause	1970-2001 [%]
External Interference	50
Construction defects/Material failure	17
Corrosion	15
Ground movement	7
Hot-tap med by error	5
Other	6

Table 2. *Distribution of the incident causes*

The average failure frequency per type of incident is given in Figure 4. The moving average per incident cause over the five past years is given in Figure 5.

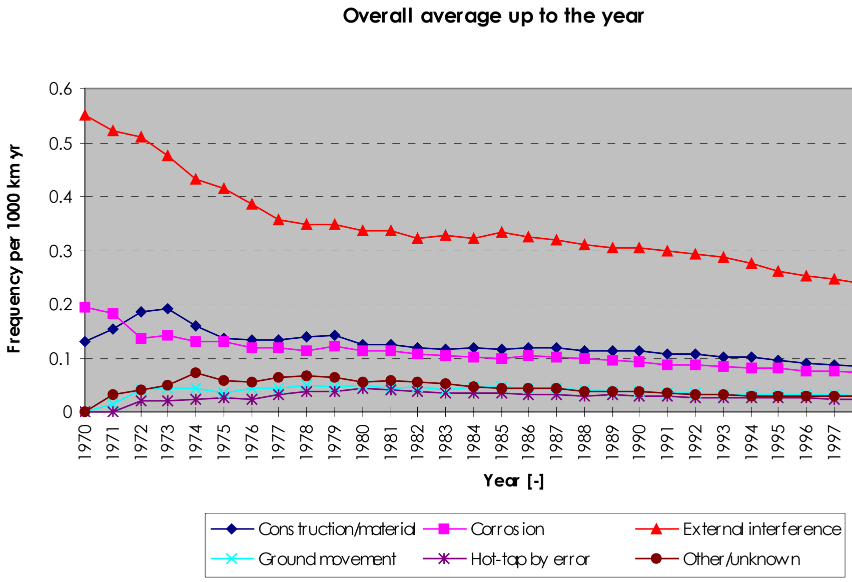

Figure 4. *Development overall frequency per incident cause*

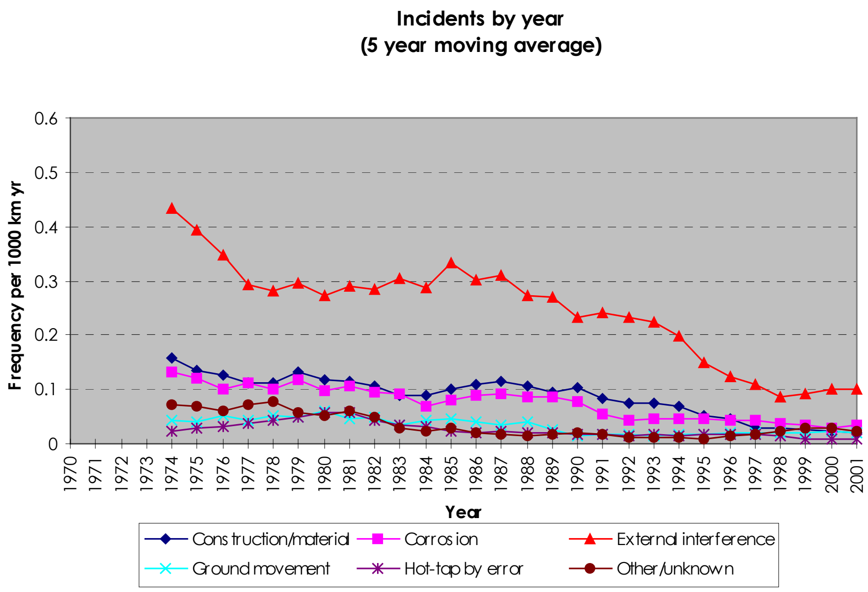

Figure 5. *Development moving average frequency per incident cause*

Figure 6 summarizes Figure 4 and Figure 5. It shows the frequency per type of incident (initiating cause) over the total period (1970-2001) and the performance only over the last 5 years (1997-2001).

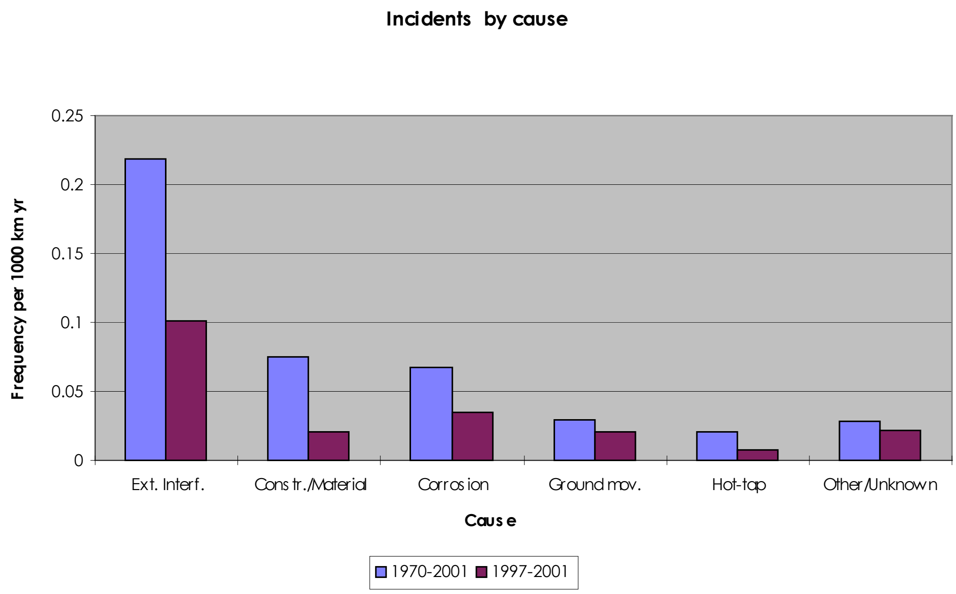

Figure 6. *Development by cause*

From this Figure it can be concluded that external interference remains the main cause of incidents with gas leakage: an average of 0.22 incidents per 1000 km·yr over the period 1970 to 2001. However, an improvement in the incident frequency has been observed in recent years: 0.10 incidents per 1000 km·yr over the period 1997 to 2001.

4.3. Ageing analysis

Pipeline ageing could be a significant factor in terms of likelihood of failure if a set of preventive measures were not taken (technical and/or organisational measures). The effectiveness of these measures can be assessed by analysing the historical data: to consider whether there is an increase in the failure frequencies of the failure modes which are subject to ageing or not.

An analysis on the EGIG dataset has been carried out to examine whether ageing could be demonstrated (see Figure 7). The main conclusions from this analysis are:

- For the possible age related failure causes (corrosion and material defects/construction failures) no ageing could be demonstrated;
- The observed failure frequencies for pipelines constructed before 1964 are significantly higher than pipelines constructed after 1964.

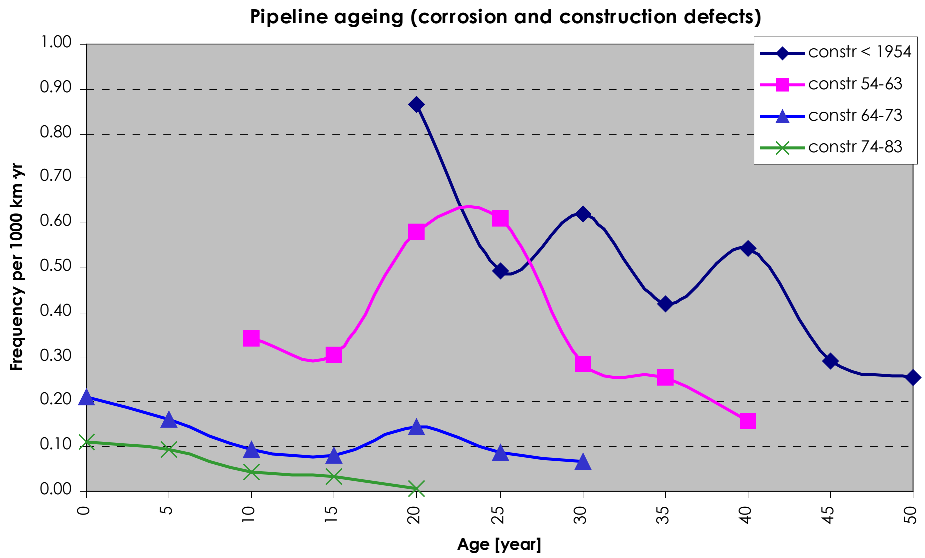

Figure 7. *Ageing analysis*

4.4. Frequency by cause and size of leak

An overview of the incident frequencies by cause and size of leak in the period 1970 to 2001 is given in Figure 8.

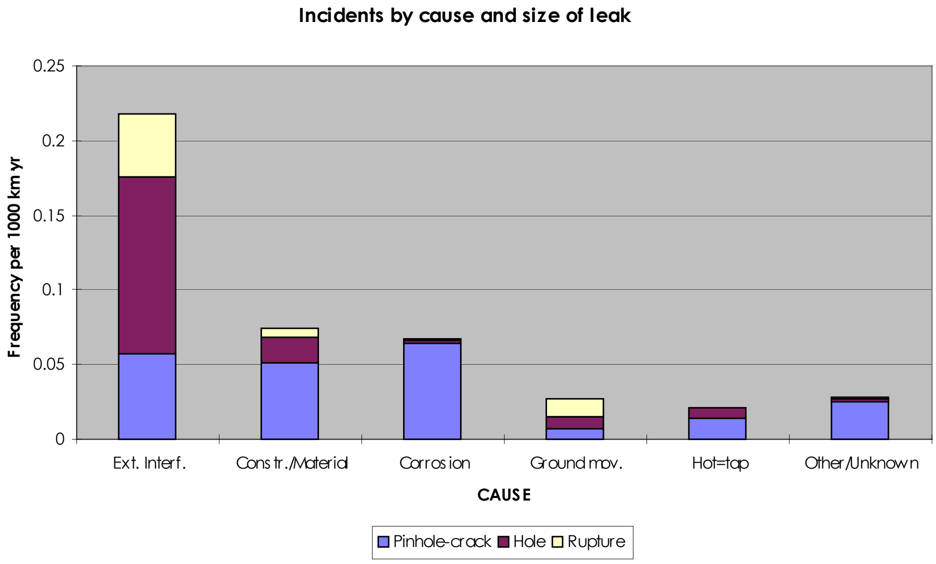

Figure 8. *Incidents by cause and size of leak*

From this Figure it can be concluded that when a pipeline is damaged by external interference there is a higher probability for getting a hole than for a pinhole-crack or a rupture. For external interference the most dangerous activities are digging the ground by excavators (over 50%), followed by ground works carried out by drainage machines and ploughs (both around 10%). The most significant size of leak for construction defects/material failures and corrosion is a pinhole-crack.

4.5. External interference failure frequencies: enter into details

From Figure 6 it can be seen that external interference remains the main cause for gas leakage incidents. In Figure 9 the frequencies caused by external interference are given per diameter class and size of leak.

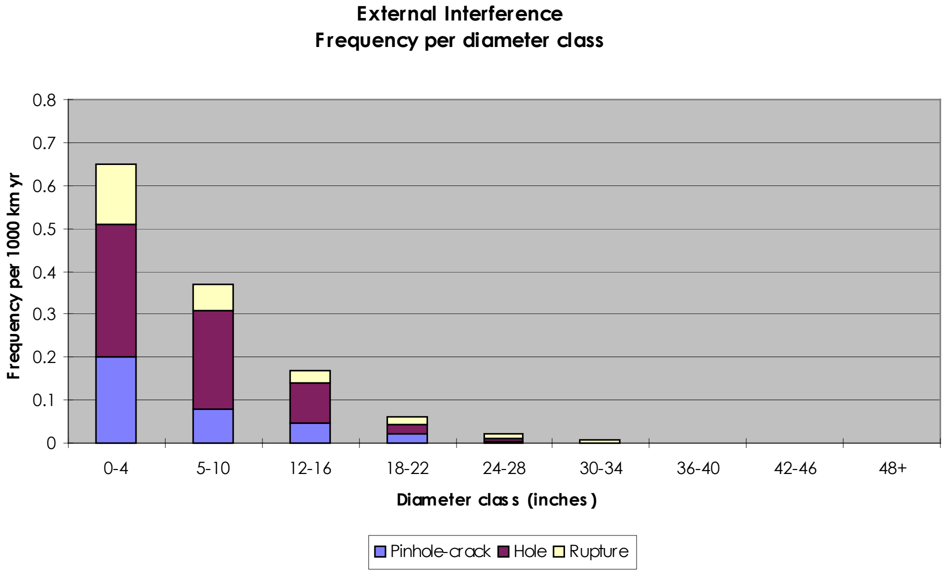

Figure 9. *External interference failure frequencies per diameter class and size of leak*

It is expected that there is a direct positive relationship between pipeline incidents with gas leakage caused by third party interference (outside mechanical forces on the pipeline) and the wall thickness. In Figure 10 the frequencies caused by external interference are given per wall thickness class and size of leak.

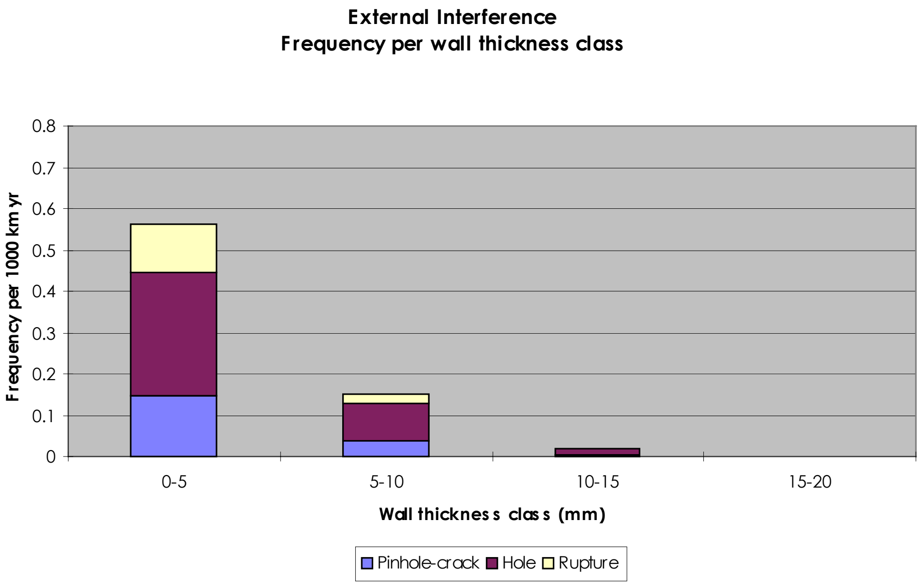

Figure 10. *External interference failure frequencies per wall thickness class and size of leak*

It is worth noting that no incidents due to external interference were observed on pipelines with a wall thickness of more than 15 mm.

As expected a greater depth of cover will reduce the occurrence of external interference faults. The variation with the depth of cover is given in Figure 11.

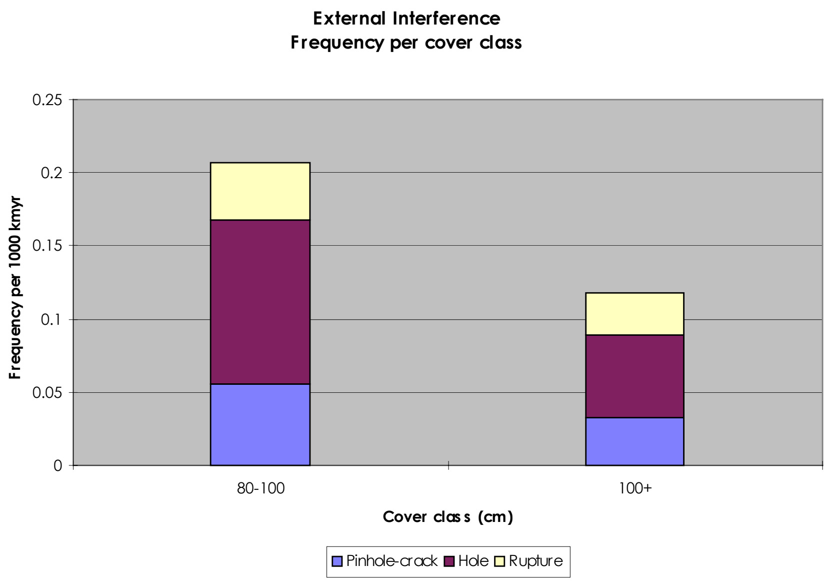

Figure 11. *External interference failure frequencies per depth of cover class and size of leak*

4.6. Material and construction defects: enter into details

Incidents caused by construction defects and material failures have a relatively high frequency in pipelines constructed before 1963. The distribution per year of construction class is given in Figure 12.

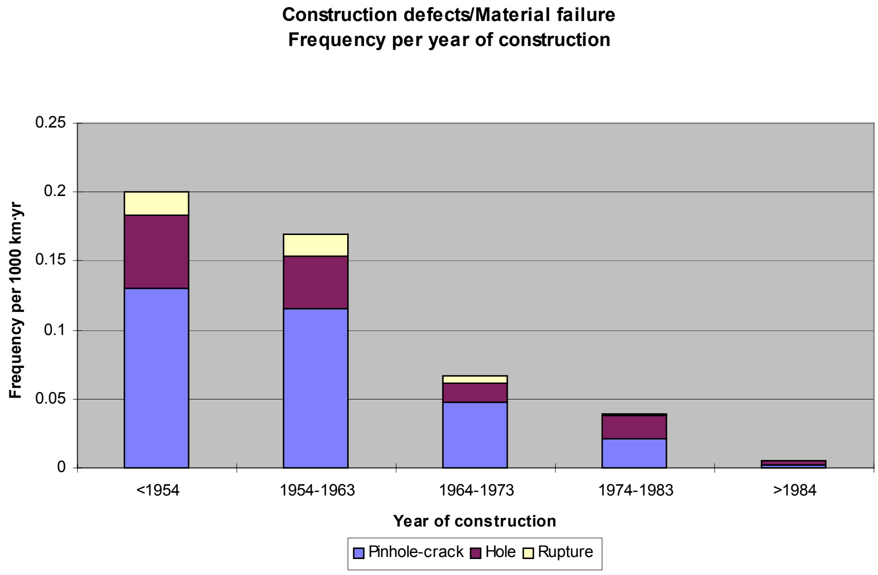

Figure 12. *Failure frequency due to material and construction defects per year of construction*

4.7. Corrosion failure frequencies: enter into details

Corrosion is the third highest cause of gas leakage and occurs mainly in thin-walled pipelines (less than 10 mm). The distribution is shown in Figure 13. The frequencies for the wall thickness classes up to 5 and 5-10 mm are caused by 48% and 47% of all corrosion incidents and have an exposure of 25% and 47% of the total exposure. It is worth noting that no corrosion incidents were observed on pipelines with a wall thickness of more than 15 mm.

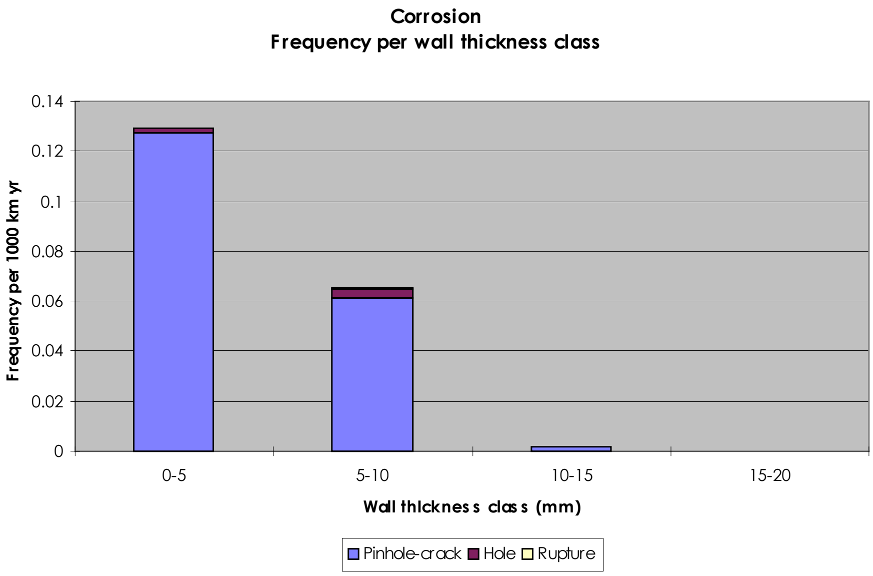

Figure 13. *Corrosion failure frequencies per wall thickness class and size of leak*

Of all corrosion incidents 79% were caused by external corrosion, 17% by internal corrosion and 4% was unknown. External corrosion is subdivided into the following types (see Table 3):

Type	% of total
Galvanic	12%
Pitting	**74%**
Stress Corrosion Cracking	1%
Unknown	13%

Table 3. *Corrosion types*

With regard to external corrosion, pitting is the major contributor. Internal corrosion was not due to natural gas, as all the incidents with internal corrosion (17%) were caused by manufactured gas. In Figure 14 the frequency caused by corrosion is given per year of construction and size of leak.

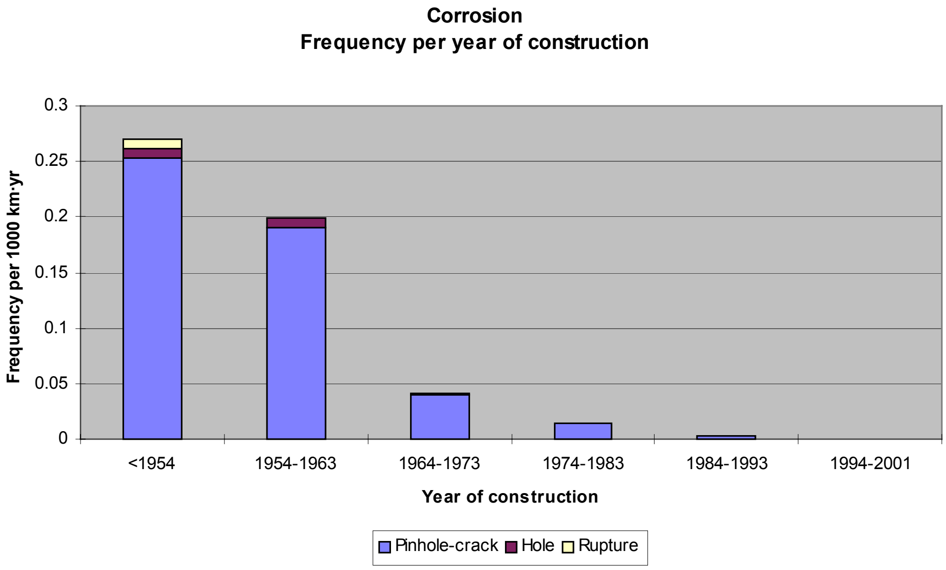

Figure 14. *Corrosion failure frequencies per year of construction and size of leak*

An incident caused by corrosion will normally result in a pinhole. However, there was one corrosion incident observed by the EGIG members which resulted in a rupture of the pipeline. The pipeline was constructed before 1954, the material was grade A and the diameter was between 6 and 10 inches. From this incident the type of corrosion was unknown and the fractured length was some metres.

4.8. Detection of incidents

About 40% of all incidents in the EGIG database are detected by the public. Second highest “detector” is detection by patrol surveys and the third is detection by the contractors. A complete overview is given in Figure 15.

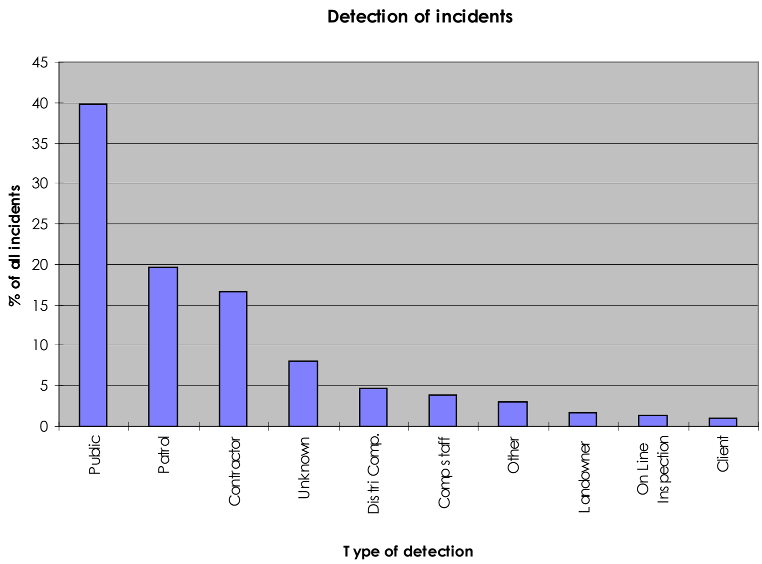

Figure 15. *Detection of incidents*

4.9. Ignition probability

On average 4% of all the incidents result in an ignition. This is in the same order of magnitude as reported in EGIG over the years 1970-1998 (which was 3.8%). The ignition probability is related to the size of leak classification in the next table:

Size of leak	Ignition prob.
Pinhole-crack	3.2%
Hole	2.1%
Rupture <= 16 inches	9.5%
Rupture > 16 inches	25.0%

Table 4. *Ignition probabilities*

4.10. Injuries/fatalities

From 1970 to 2001 no incident on a transmission pipeline of natural gas caused fatalities or injuries on inhabitants (or residents).

5. DISCUSSIONS AND CONCLUSIONS

In order to demonstrate the continuing safety level of natural gas onshore transmission pipelines, there has been close co-operation, for many years, between a group of nine major gas transmission system operators in Western Europe. In 1982, this co-operation was formalised by the setting up of EGIG (**E**uropean **G**as pipeline **I**ncident data **G**roup).

Pipeline incident data between 1970 and 2001 (involving an unintentional release of gas) have been collected by the gas transmission system operators from their pipeline systems. These data form an extensive database and are of direct relevance to pipeline design, operating and maintenance practices in Europe. In the light of this broad experience and degree of participation, the database can be used to monitor the safety record of gas transmission systems.

5.1. Conclusions from the fifth EGIG report

- In the period 1970 to 2001 no incident on a natural gas transmission pipeline caused fatalities or injuries to inhabitants.
- The participating companies now have an accumulative exposure of their pipeline system of 2.41 million kilometer-years.
- The overall incident frequency with an unintentional gas release over the period 1970 to 2001 is 0.44 incidents per year per 1000 km pipeline. However, the figure over the past 5 years is significantly lower: 0.21 incidents per year per 1000 km pipeline;
- The overall failure frequency is 0.44 per year per 1000 km pipeline with a 95% confidence interval of ± 0.03;
- The failure rate has decreased by a factor 5 over the past 32 years.
- For the incident causes corrosion and construction defects/material failures no ageing could be demonstrated;
- There is a trend to use large diameter pipelines (> 42 inch) in combination with a higher grade of material (X65 and X70);
- The major cause of incidents is still external interference (50%), followed by construction defects/material failures (17%) and corrosion (15%);
- A greater depth of cover gives a significantly lower frequency for failures caused by external interference;
- A larger proportion of the incidents is detected by the public, the second highest detector is patrol survey;
- In only a small minority of the incidents did the leaked gas lead to ignition (4% on average), but one should notice that this number depends on many parameters.

5.2. Discussion

Over the last decade the overall frequency of incidents causing an unintentional gas release has gradually reduced demonstrating the success of an increasing integration of safety in the total pipeline process; i.e. proper design and construction (including pipe manufacture), adequate maintenance, and safe operation. Due to information technology, it is now possible to get quicker information about the effectiveness of measures to increase the safety performances of gas transmission systems.

REFERENCES

1. EGIG-group (2001). Gas Pipeline Incidents, 5th Report of the European Pipeline Incident Data Group (document number EGIG 02.R.0058).