5th EGIG-report
1970-2001

Dear Ms./Mr.

Please find enclosed the 5th EGIG report you have requested.

The aim of the EGIG group is to maintain a database with information of pipeline incidents to get more insight into the hazards of gas transmission.

In this report statistics and analyses are given on the gas pipeline incidents of 9 European gas transmission companies. The report covers the period 1970 - 2001.

At the time the report was issued no incidents with fatalities or injuries had occurred to inhabitants. Unfortunately this conclusion no longer holds. The next (6th) EGIG report, foreseen to be issued in December 2005, will be updated with the most recent available data.

If you have any questions on the report, please contact the Project Manager of EGIG. You may use this information for publications under the restriction that EGIG is mentioned as source of information.

Yours faithfully,

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5th EGIG-report 1970-2001

GAS PIPELINE INCIDENTS

5th Report of the *E*uropean *G*as Pipeline *I*ncident Data *G*roup

Comprising:

Dansk Gasteknisk Center a/s, represented by DONG Energi-Service
ENAGAS, S.A.
FLUXYS
Gaz de France
Gastransmission Services (part of N.V. Nederlandse Gasunie)
Ruhrgas AG
SNAM RETE GAS
SWISSGAS AG
Transco, represented by Advantica

Doc. number: EGIG 02.R.0058
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The next (6th) EGIG report will be issued in December 2005. An annual update (in 2003 and 2004) can be found on the EGIG website.

Comments or questions to this publication can be directed to Secretariat EGIG:

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Contents

SUMMARY

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 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.

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 kilometres-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.

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 (**E**uropean **G**as pipeline **I**ncident data **G**roup).

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. Collection of safety related data has become more important as a result of increasing interest shown by local, national and international authorities responsible 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;
- Gasunie Technology & Assets;
- E.ON 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.

This is the fifth report of EGIG covering the period 1970-2001. The first of the preceding four reports appeared in 1988 (data from 1970-1987), the second in 1993 (data from 1970-1992), the third in 1998 (data from 1970-1997) and the fourth in 1999 (data from 1970 – 1998). This fifth report will be presented during the 22nd IGU (**I**nternational **G**as **U**nion) World Gas Conference. Future reports will be issued every 3 years after 2002 to coincide with the frequency of the IGU World Gas Conferences.

In this report, information is given on the development of the database and on the results of some analyses. Accumulated frequencies are given over the entire period. As the exposure time over 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 in this report. This has been done by using the 5-years moving average or by comparison of only the past five years with the accumulated frequency.

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 always related to an onshore gas transmission steel pipeline (this does not apply to production pipelines):
    - ♦ 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 pipe;
- RUPTURES: diameter of defect more than the pipe diameter.

2.2 Type of incidents

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 secondary 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 [SCC], 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);
- Other information (free text).

2.3 Failure frequency calculation

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

3. DATABASE CONTENT

3.1 System data

3.1.1 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 million kilometres-years, while in the period 1970-1998 the exposure was 2.09 million kilometres-years. The development of the exposure, from 1970 to 2001, is given in Figure 1.

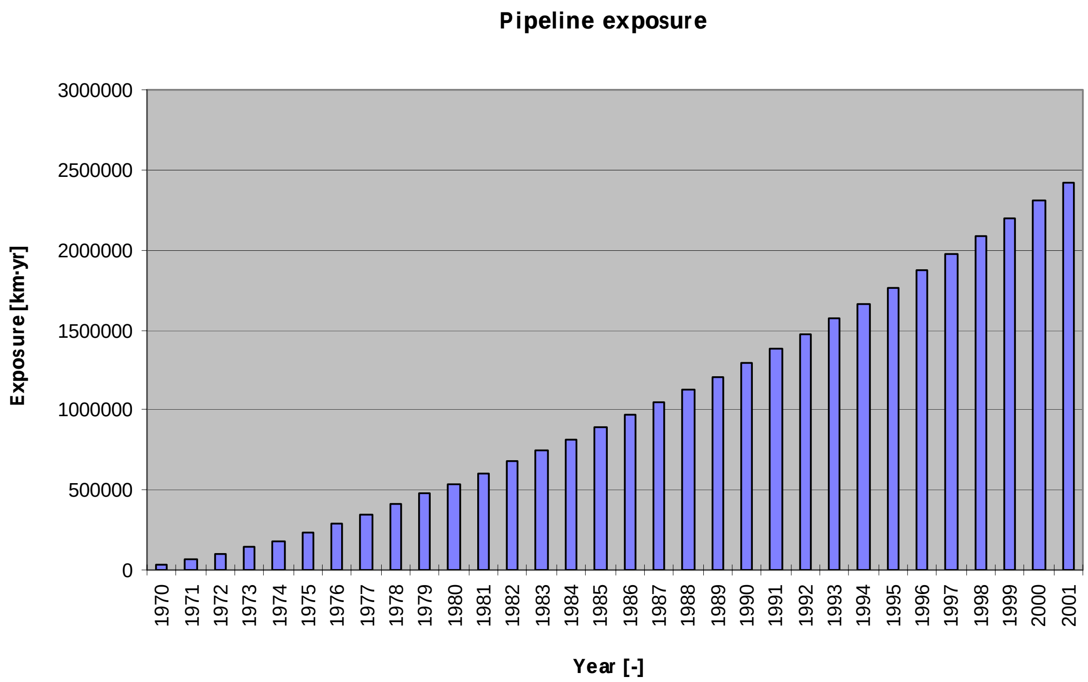

Figure 1

The annual length is presented in Figures 2 and 4.

3.1.2 Diameter range

The annual increase in length per "diameter class" is given in Figure 2. In Appendix 1 the same figure is given on a larger scale.

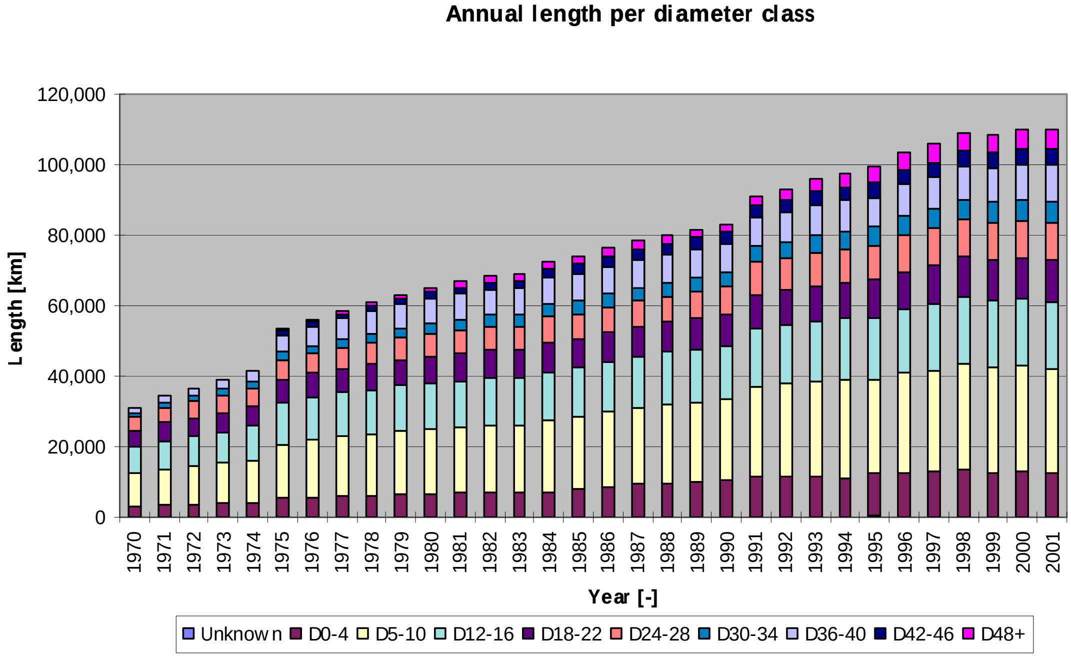

Figure 2

In this graph there are different patterns in the annual kilometres in the years 1975, 1991 and 1996. The main reason for this is the participation of new members. It should be observed that from 1998 and onwards the annual length remains more or less constant. The experience however still improves (compare Figure 1).

3.1.3 Year of construction

The total exposure (1970-2001) “per year of construction” is given in Figure 3.

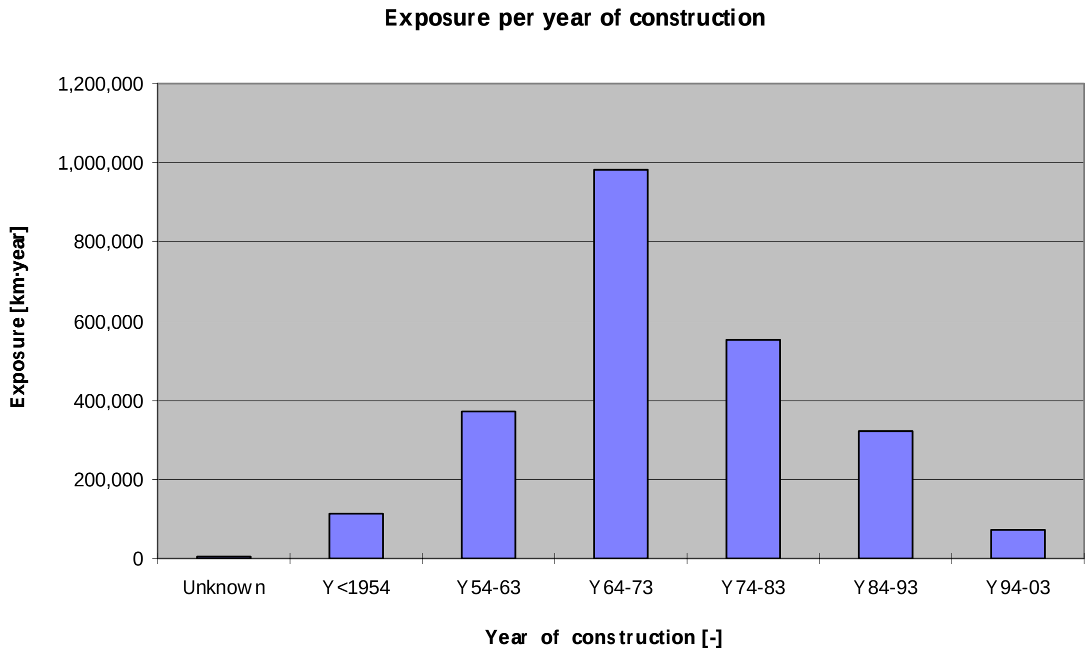

Figure 3

3.1.4 Grade of material

The annual increase of the database per “grade of material” is given in Figure 4. In Appendix 2 the same figure is given on a larger scale.

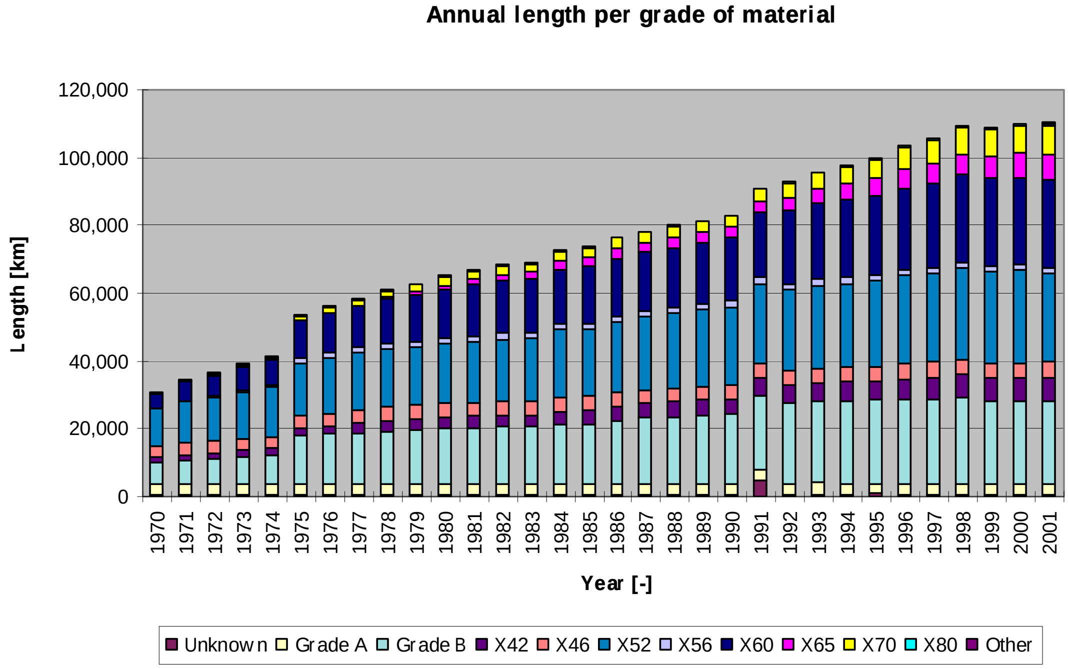

Figure 4

The majority of the grades are Grade B, X52 and X60. Again there are different patterns in length in the years 1975, 1991 and 1996, due to the participation of new members.

3.2 Incident data

In the third EGIG report 945 incidents were reported up to the end of 1997. However, a review of the EGIG database and a quality check whether the EGIG database is consistent with the internal database of the individual companies, resulted in 34 additional incidents. Therefore the total number of reported incidents for the period 1970-1997 was 979.

In 1998, all companies reported a total of 21 incidents. So the total number of incidents up to the end of 1998 was 1000, as reported in the fourth EGIG report. A review of those incidents then finally resulted in a total of 992 incidents at the end of 1998. In the last three years a total of 68 incidents were reported by all companies. Hence the database now consists of 1060 incidents. The development of the number of incidents in the database is given in Figure 5.

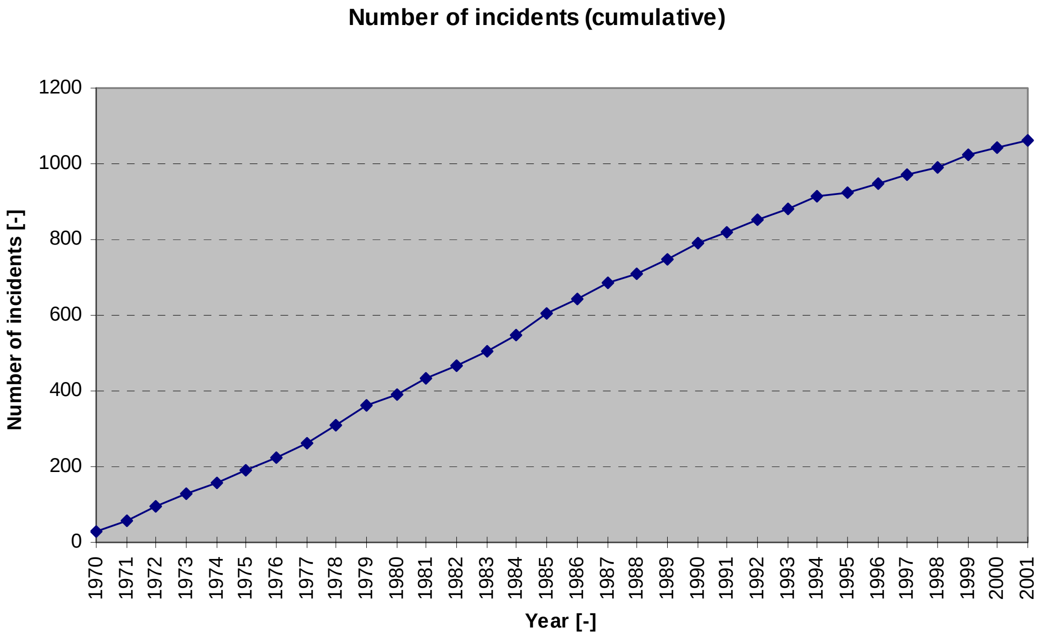

Figure 5

The annual number of incidents in the database is given in Figure 6.

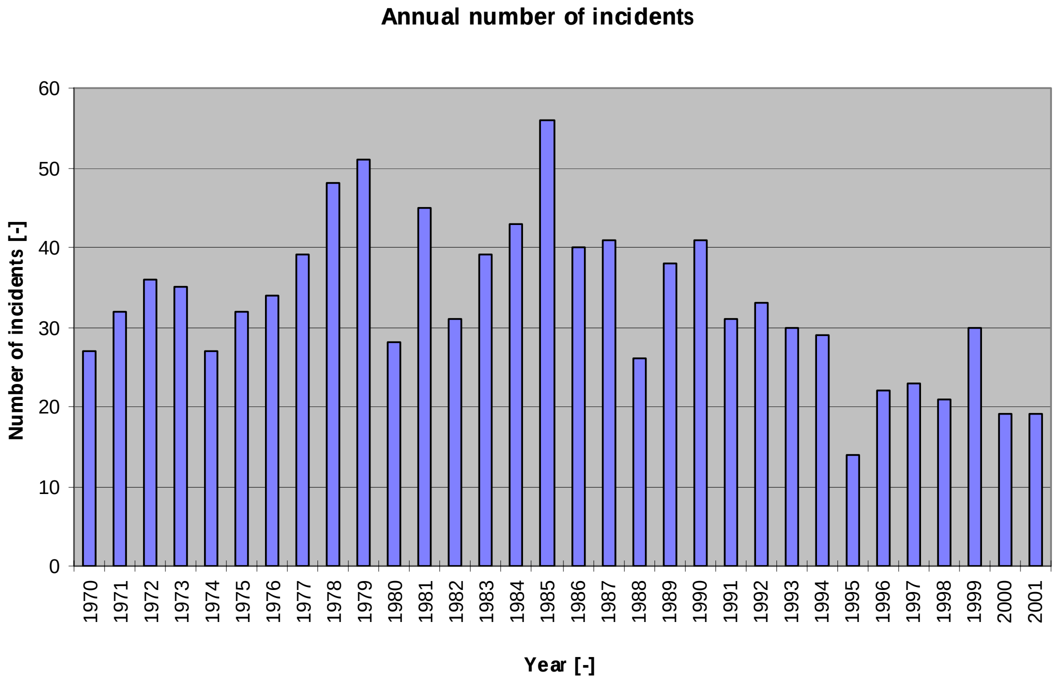

Figure 6

4. RESULTS

4.1 Failure frequencies

In this section two types of calculated failure frequencies are given. The results are split-up into primary and secondary failure frequencies. The primary frequencies are based on the number of incidents divided by the total system exposure. Secondary frequencies are based on the number of incidents divided by partial system exposures (e.g. per diameter class, per wall thickness class, depth of cover class).

4.1.1 Primary failure frequencies

4.1.1.1 Overall incident frequency

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

Timescale		**Number of incidents [-]**	**Total exposure [km·yr]**	**Frequency [incidents 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

An overview of the development of the overall average failure frequency over the total period 1970 to 2001 is given in Figure 7. 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 7. In Appendix 3, Figure 7 is given on a larger scale.

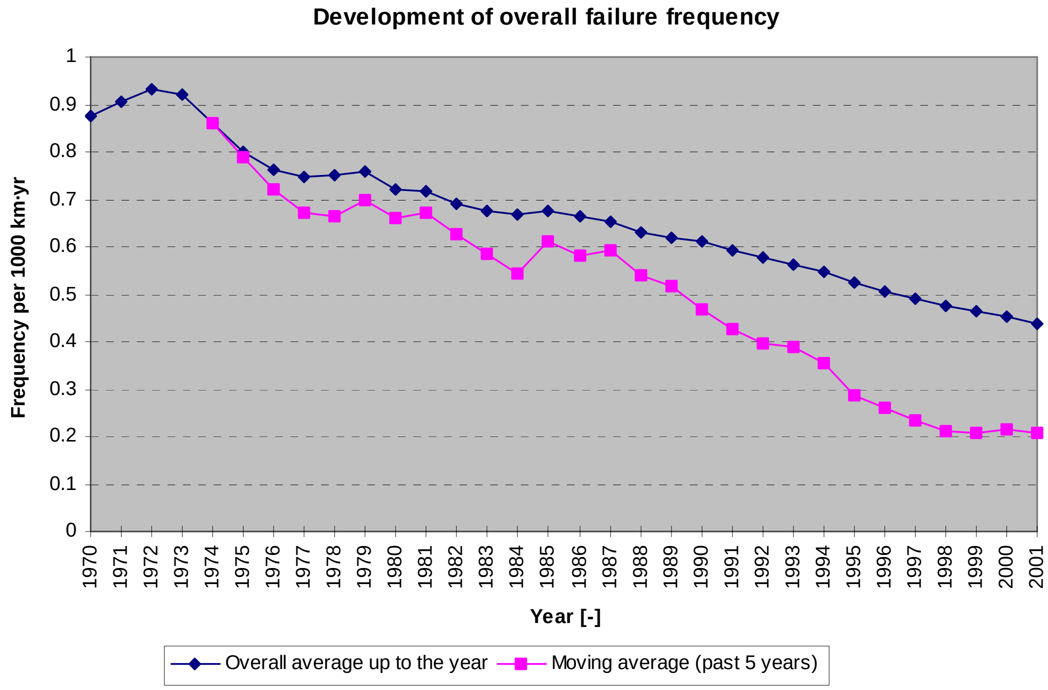

Figure 7

In Appendix 5 information is given on confidence intervals and a failure frequency trend analysis. The main conclusions are:

- the average 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.

4.1.1.2 Frequency per type of incident

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

Incident cause	1970-2001 [%]
External interference	50
Construction defect/material failure	17
Corrosion	15
Ground movements	7
Hot-tap made by error	5
Other	6

Table 2

External interference remains a main cause of incidents with gas leakage: an average of 0.22 incidents per 1000 km·yr over the period 1970 to 2001.

In Figure 8 the development of the average failure frequency is given per incident cause over the total period 1970-2001. In Appendix 4, the same figure is given on a larger scale. The moving average per incident cause over the past five years is given in Figure 9.

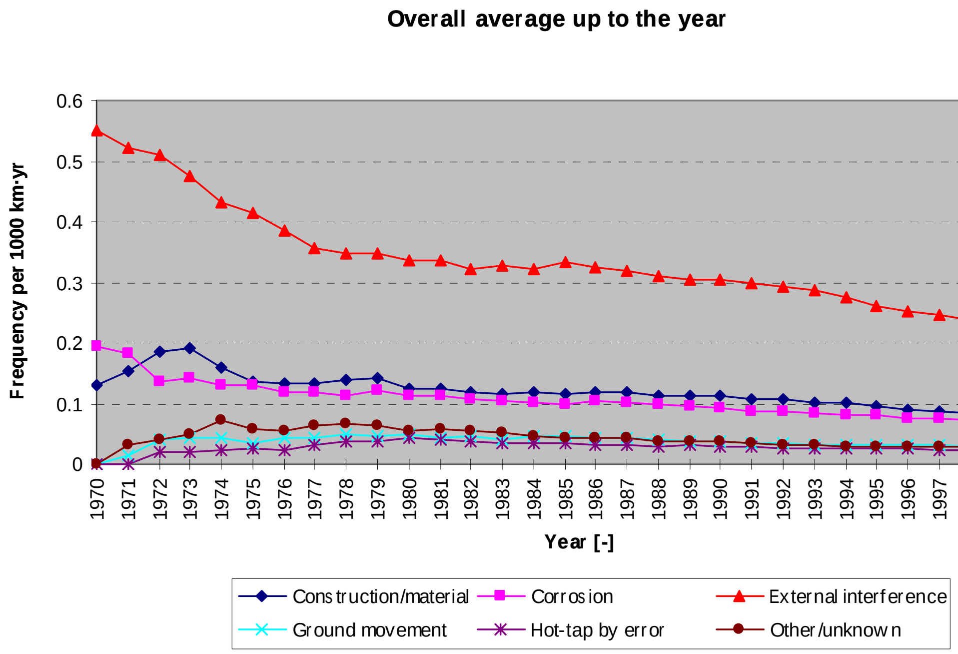

Figure 8

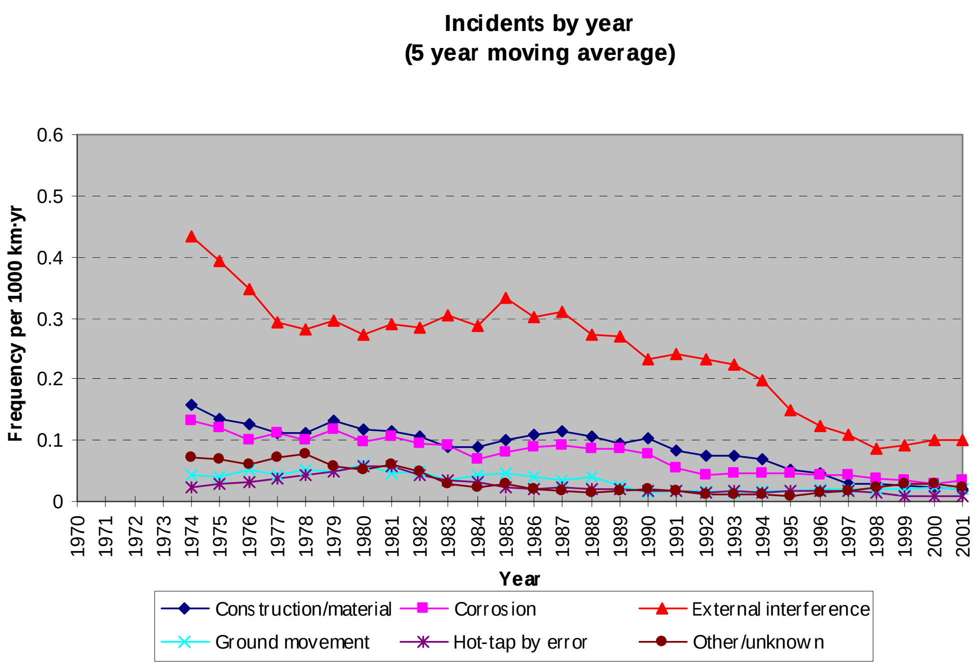

Figure 9

With regard to the main cause (external interference), an improvement in the incident frequency has been observed in recent years with respect to the overall frequency: from 0.22 (in the period 1970-2001) to 0.10 (in the period 1997-2001) incidents per 1000 km·yr. However, the moving average flattens in the last few years. Figure 10 summarizes the above two figures: it shows the frequency per type of incident over the total period (1970-2001) and the performance only over the last 5 years (1997-2001).

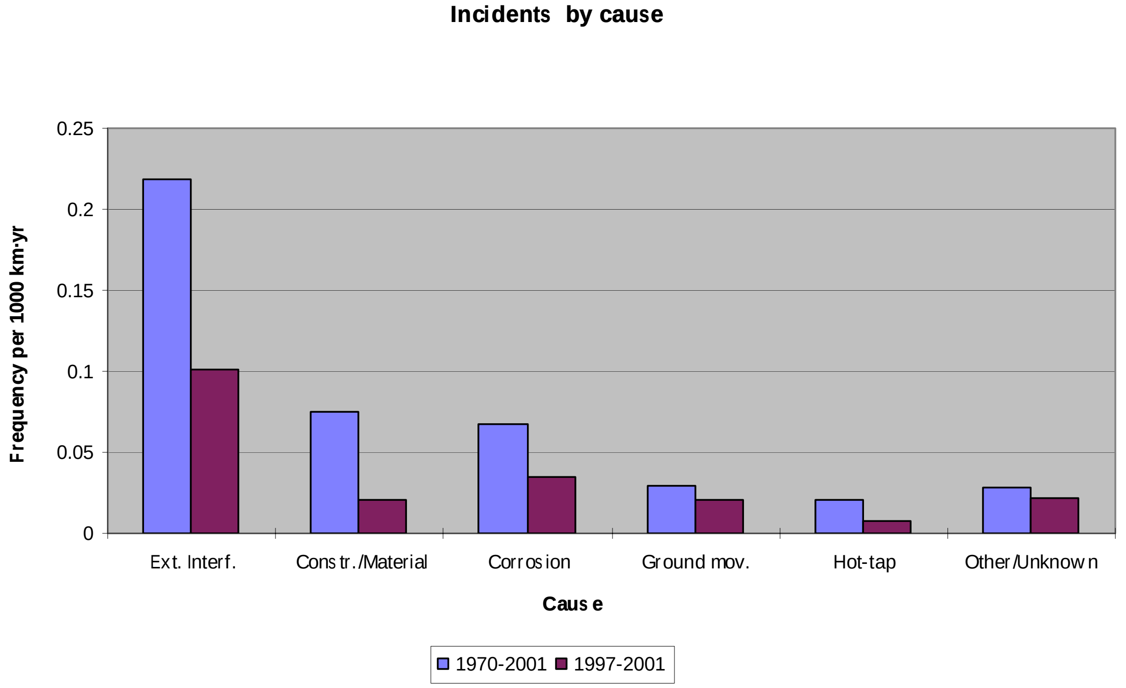

Figure 10

4.1.1.3 Ageing analysis

Pipeline ageing could be a significant factor in terms of likelihood of failures 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. In Appendix 6 the analysis has been carried out to examine whether ageing can be demonstrated or not. The main conclusions from this analysis are:

- for the possible age related failure causes (corrosion and material defects/construction failures) it can be concluded that ageing does not occur in the time window of the EGIG data collection;
- the observed failure frequencies for pipelines constructed before 1964 are significantly higher than pipelines constructed after 1964.

4.1.1.4 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 11.

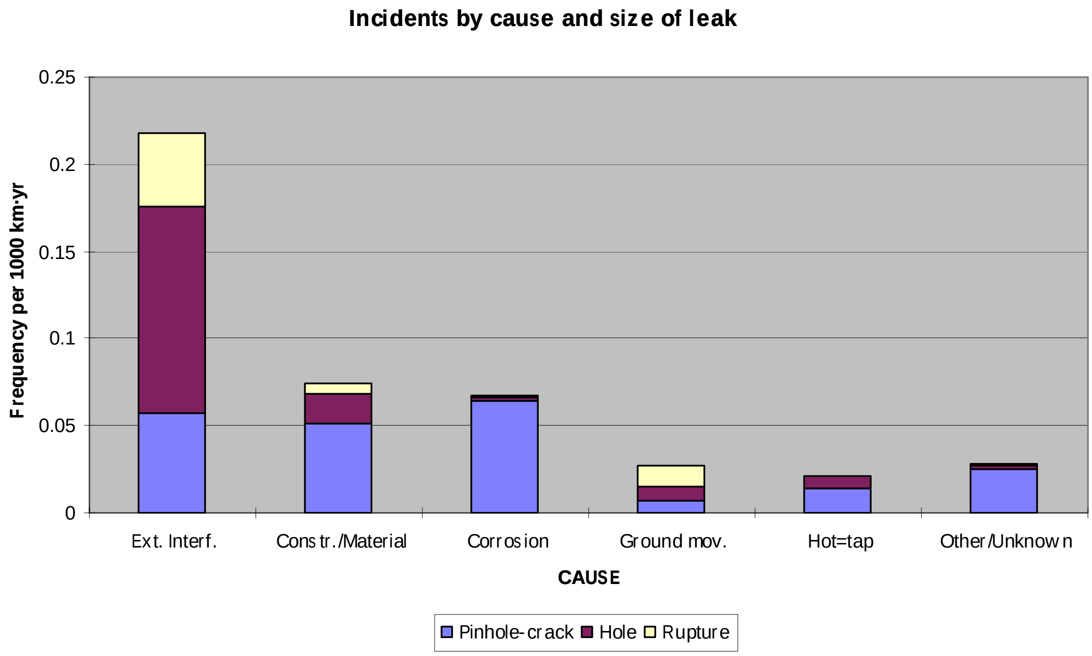

Figure 11

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 getting 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.

4.1.2 Secondary failure frequencies

4.1.2.1 External interference

From Figures 10 and 11 it can be seen that external interference remains the main cause for gas leakage incidents. In Figure 12 the frequencies caused by “external interference” are given per “diameter class” and “type of leak”.

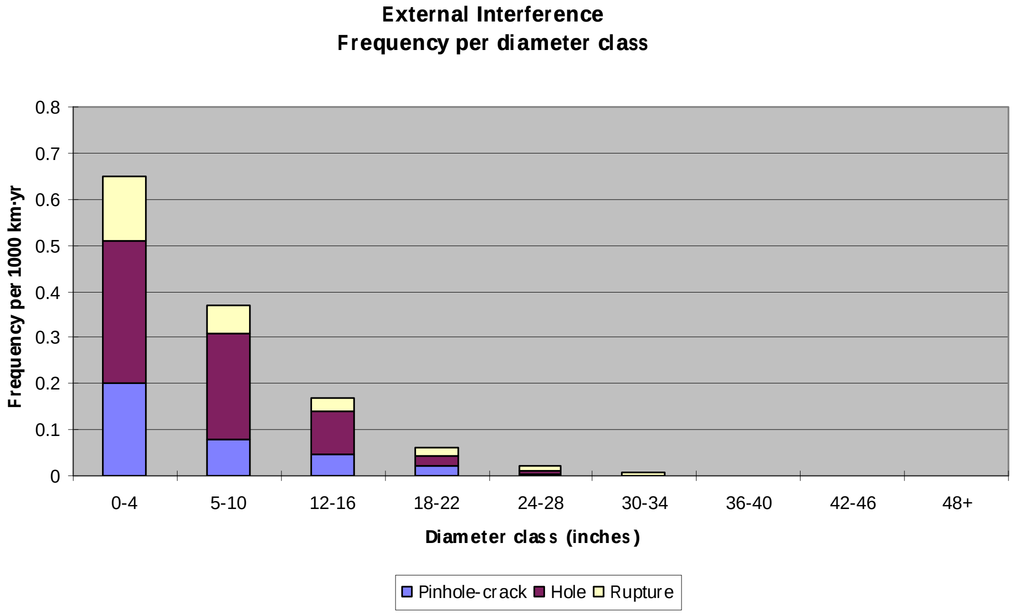

Figure 12

From this figure it could be concluded that there is a sort of proportional relationship between the diameter class and the failure frequency due to external interference. However, there is no direct relationship, but possible relationships are:

- smaller diameter pipelines are in areas with more activity;
- smaller diameter pipelines in general are buried shallower than larger diameter pipelines;
- smaller diameter pipelines can easy be hooked up during ground works;
- smaller diameter pipelines have, in general, thinner wall thickness than larger diameter pipelines and
- smaller diameter pipelines have, in general, a lower grade of material than larger diameter pipelines.

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 13 the frequencies caused by “external interference” are given per “wall thickness” and “size of leak”.

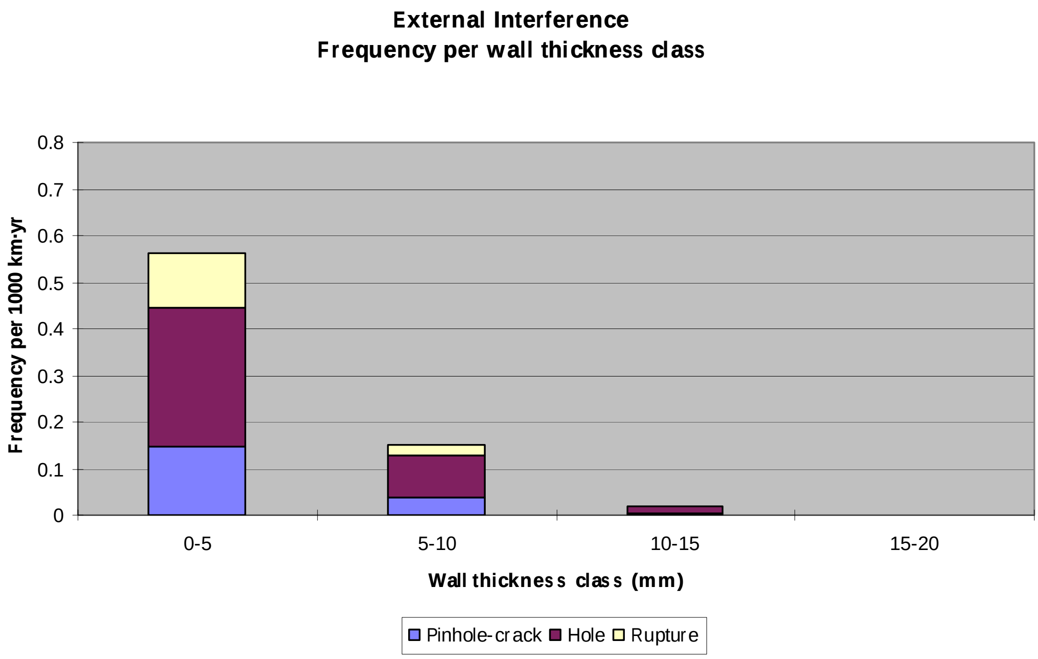

Figure 13

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

4.1.2.2 Construction defects and material failures

Incidents caused by construction defects and material failures have a relatively high frequency in pipelines constructed before 1963. The distribution is given in Figure 14.

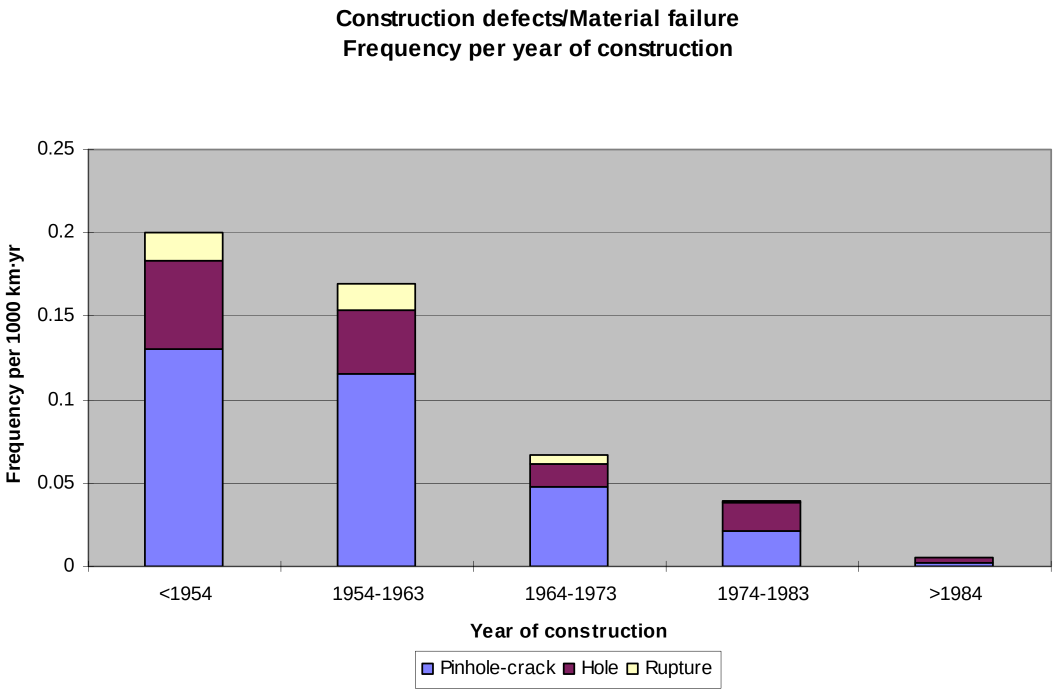

Figure 14

4.1.2.3 Corrosion

Corrosion is the third highest cause of gas leakage and occurs mainly in thin-walled pipelines (pipelines with wall thickness less than 10 mm). The distribution is shown in Figure 15. 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.

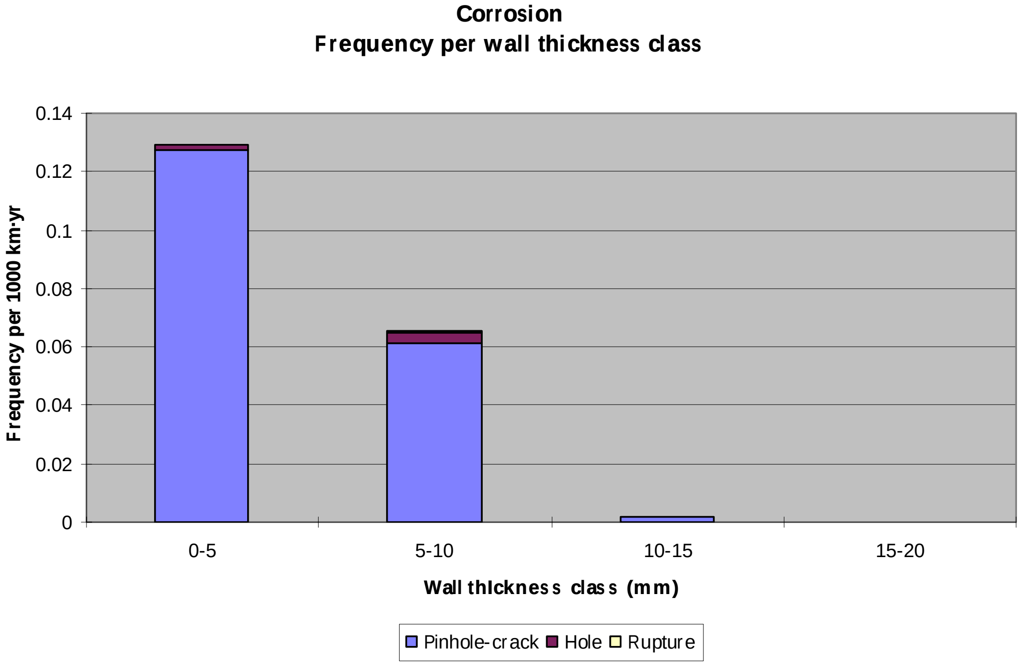

Figure 15

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 of corrosion

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

Table 3

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%) are caused by manufactured gas.

In Figure 16 the frequency caused by "corrosion" is given per "year of construction" and "size of leak" is presented.

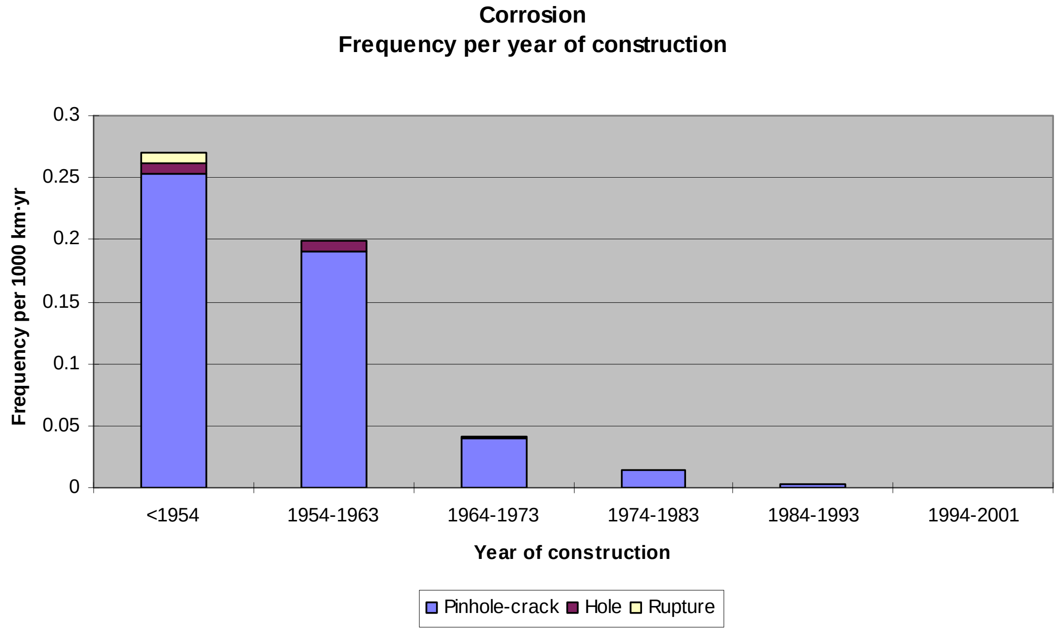

Figure 16

An incident caused by corrosion will normally result in a pinhole. However, there was one internal 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.

4.1.2.4 *Frequency per depth of cover*

As expected a greater depth of cover will reduce the occurrence of incidents caused by external interference. The variation with the depth of cover is given in Figure 17.

In Figure 17 only the information is given for the cover classes 80-100 cm and 100+ cm. The reason for this is the relative low number of incidents and the small proportion of exposure for the other depths of covers.

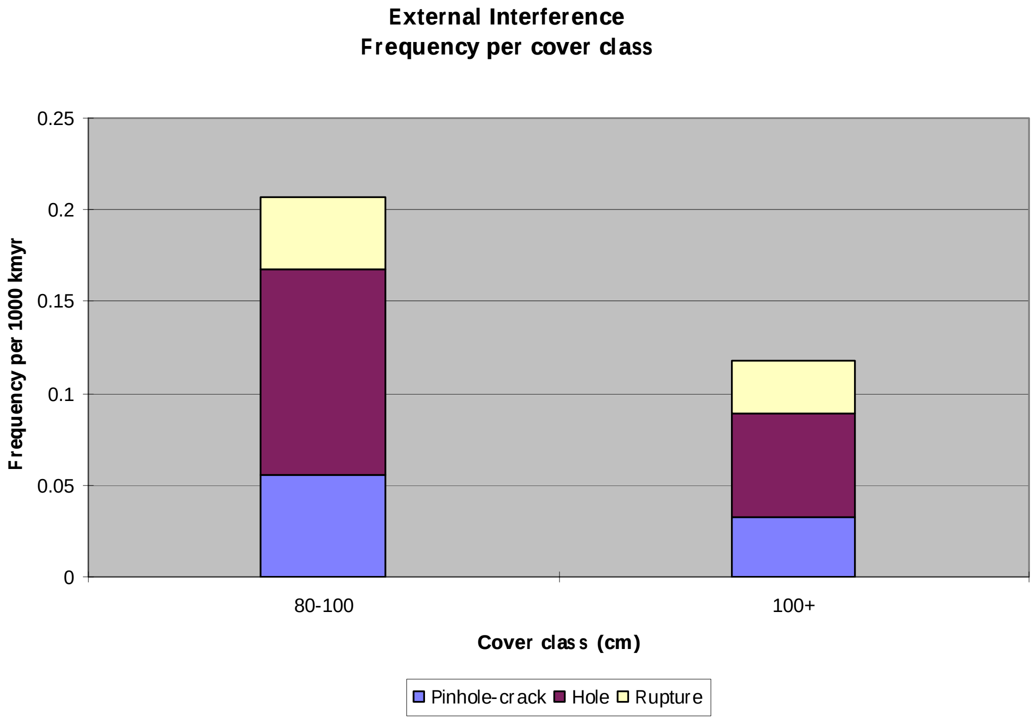

Figure 17

To see whether a change has occurred in the depth of cover in recent years, the distribution of the depth of cover in the last five years of the pipeline population is compared to the distribution over the entire period since 1970 (see Table 4).

Depth of cover [cm]	Exposure [%]	
	1970 to 2001	1997 to 2001
Unknown	2	1
0-80	4	3
80-100	52	42
100+	42	54

Table 4

It may be concluded that pipelines now are buried deeper than in the past. This may partly influence the failure frequency (due to external interference), and may be one of the reasons that the failure frequency decreases over time.

4.1.2.5 Hot-tap made by error

The term “Hot-tap made by error” means that a connection has been made, in error, to a high pressure gas transmission pipeline due to it being incorrectly identified as, say a low pressure distribution pipeline or water pipeline. This type of incident mainly occurs in pipeline diameters up to 16 inches. The variation per “diameter class” is given in Figure 18.

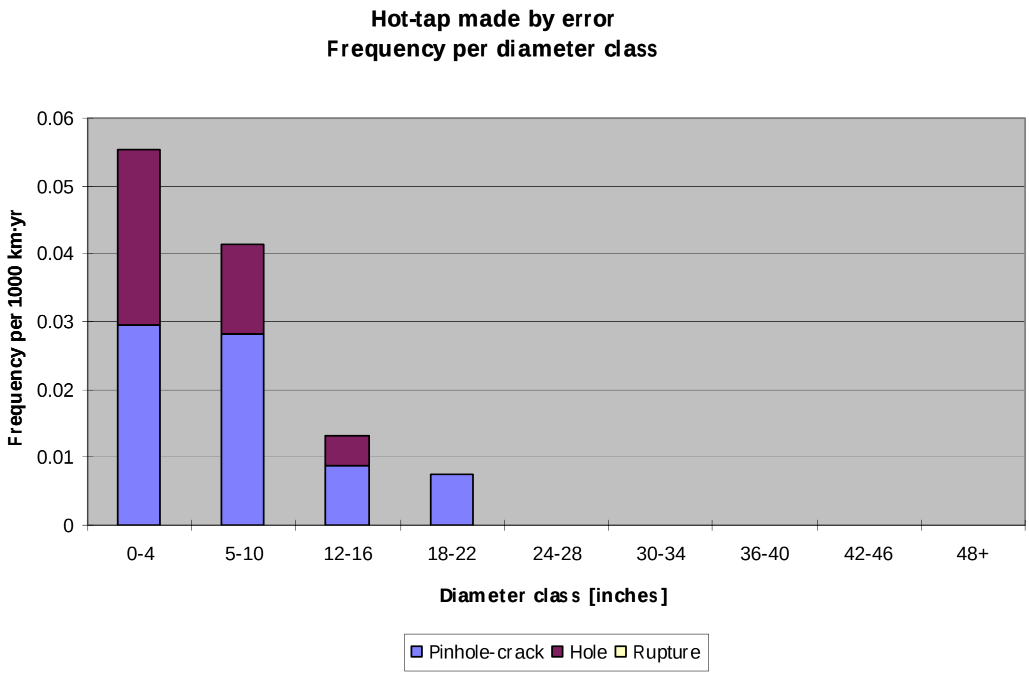

Figure 18

In the diameter class up to 4 inches, the ratio of pinhole-crack / hole is about 50%. In the larger diameters (5-10 inches and 12-16 inches), the probability of a hole is much lower.

4.2 Detection of incidents

About 40% of all incidents in the EGIG database are detected by the public. The second highest “detector” is detection by patrol surveys and the third is detection by contractors. A complete overview is given in Figure 19.

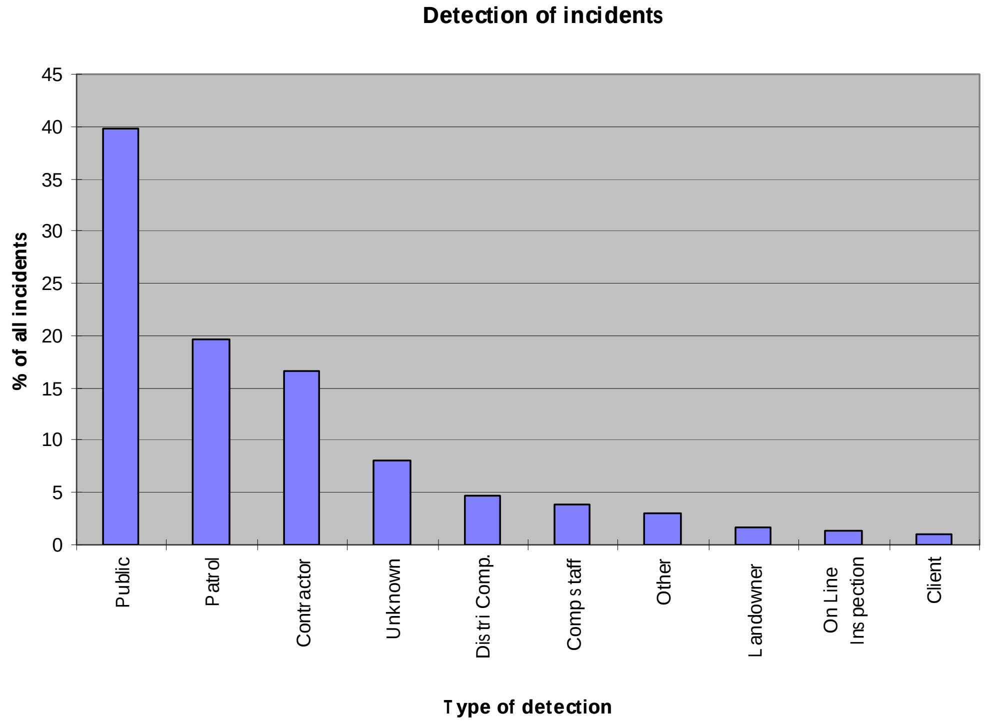

Figure 19

4.3 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 1970-1997 (which was 3.9%) and 1970-1998 (which was 3.8%).

The ignition probability is related to the size of leak classification as presented in Table 5:

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

Table 5

4.4 Injuries/fatalities

From 1970 to 2001 no incident on a natural gas transmission pipeline has caused fatalities or injuries to inhabitants. An inhabitant is defined as a person who is living in the vicinity of the pipeline and who is neither directly nor indirectly involved with activities related to gas transmission nor the activity causing the incident.

5. DISCUSSION 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 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.

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 kilometres-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;
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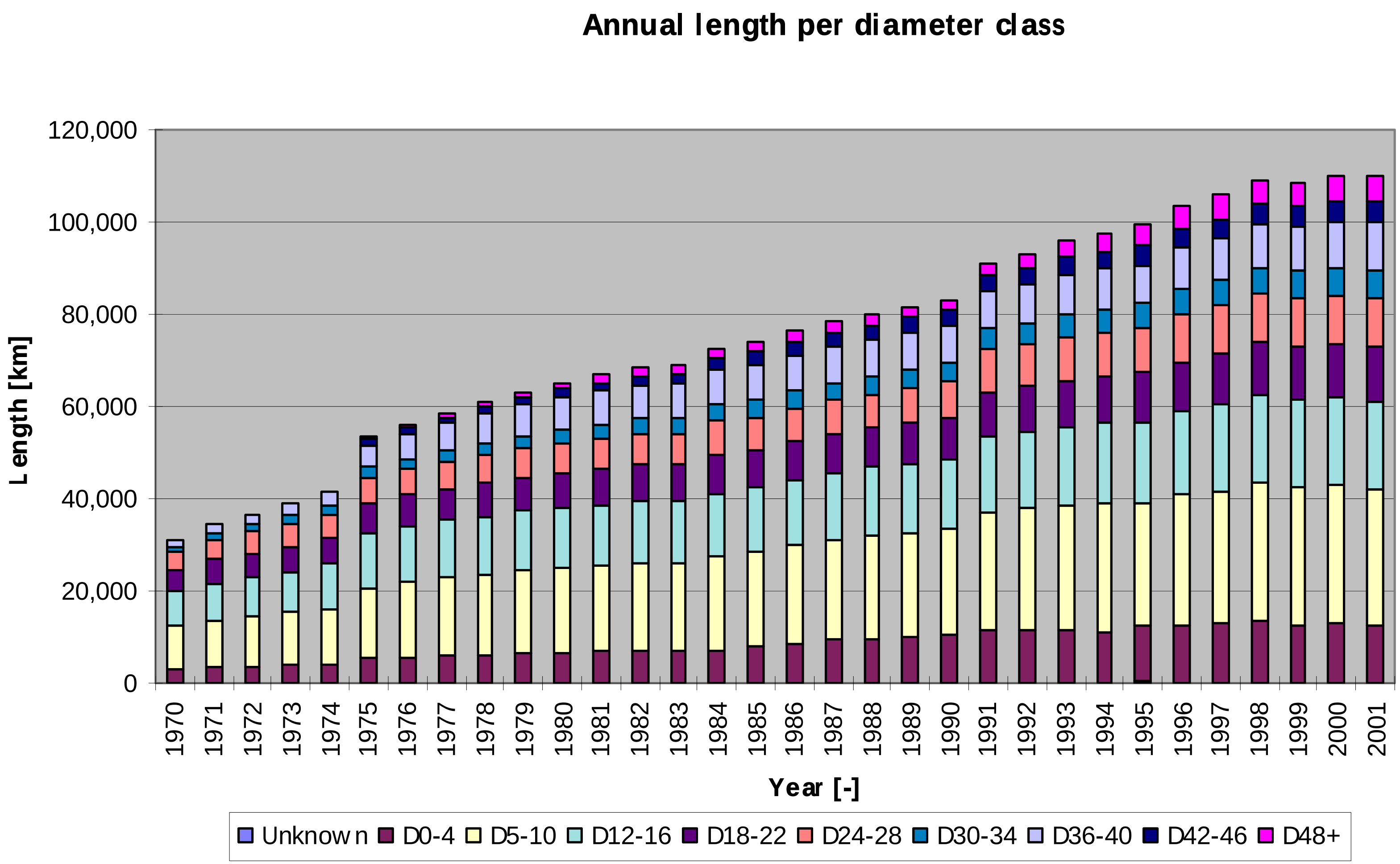
- The failure rate has decreased by a factor 5 over the past 32 years.
- For the incident causes corrosion and construction defects/material failures no ageing could be demonstrated;
- There is a trend to use large diameter pipelines (> 42 inch) in combination with a higher grade of material (X65 and 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.

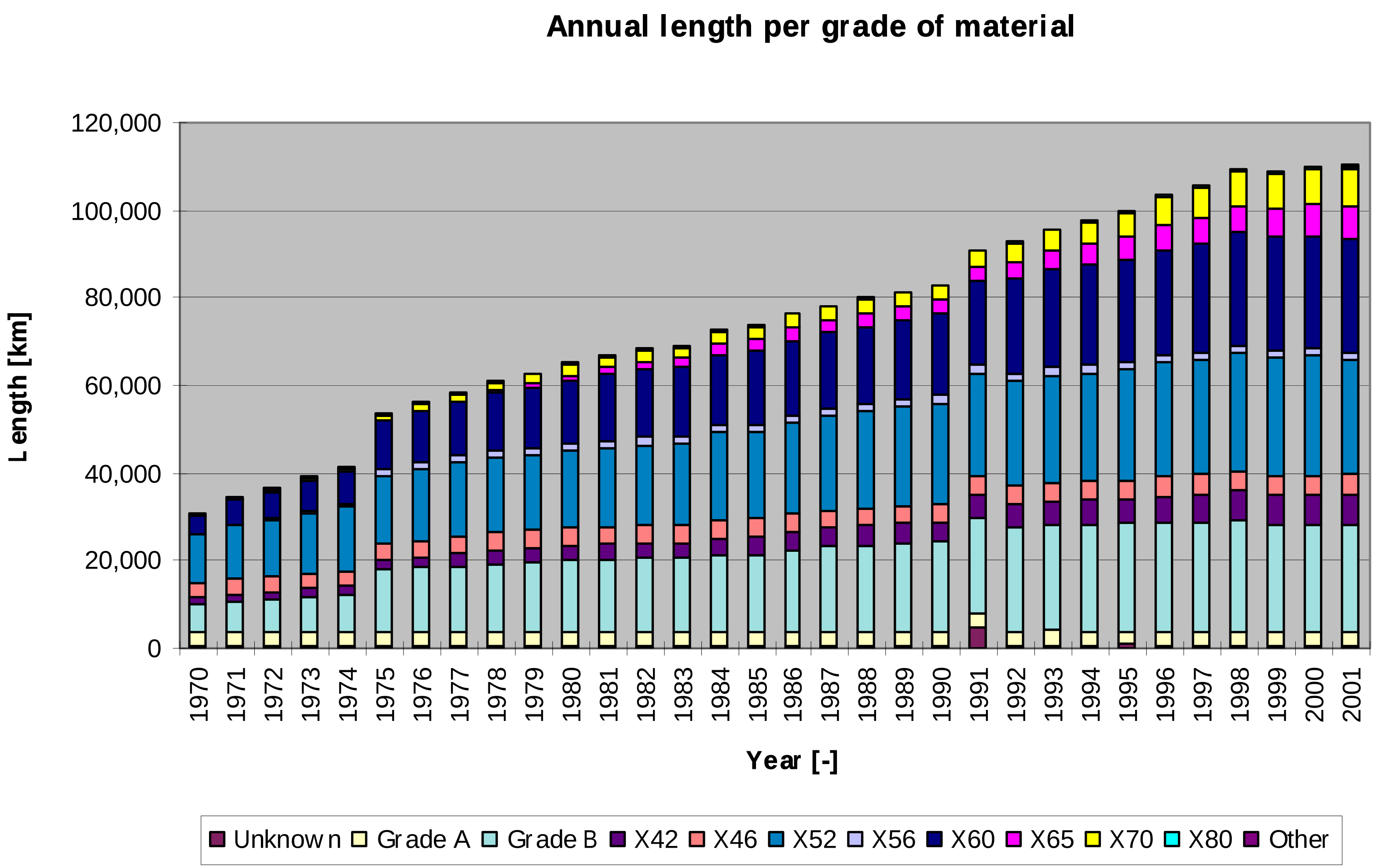
Discussion

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.

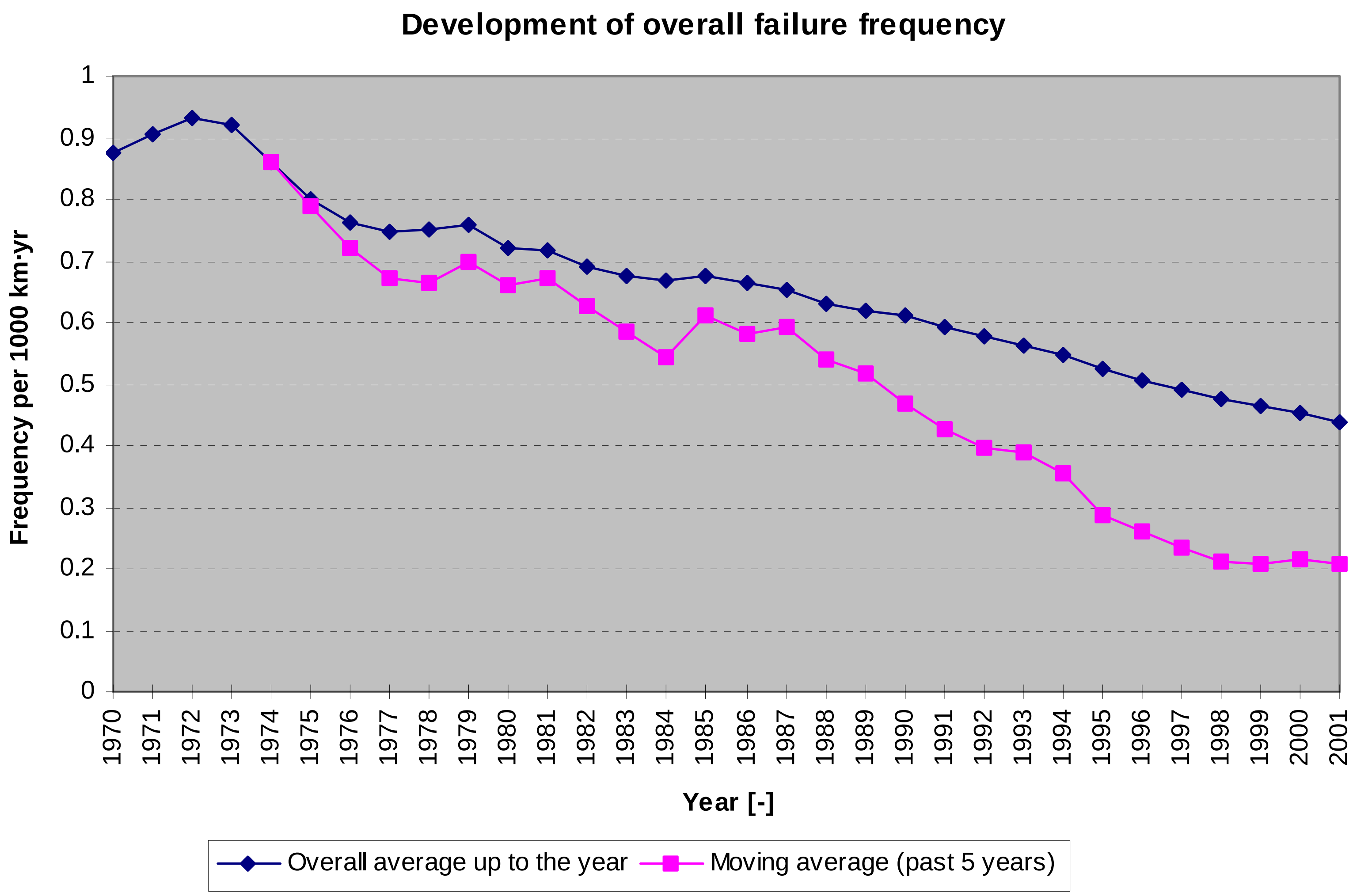
APPENDIX 1 (FIGURE 2)



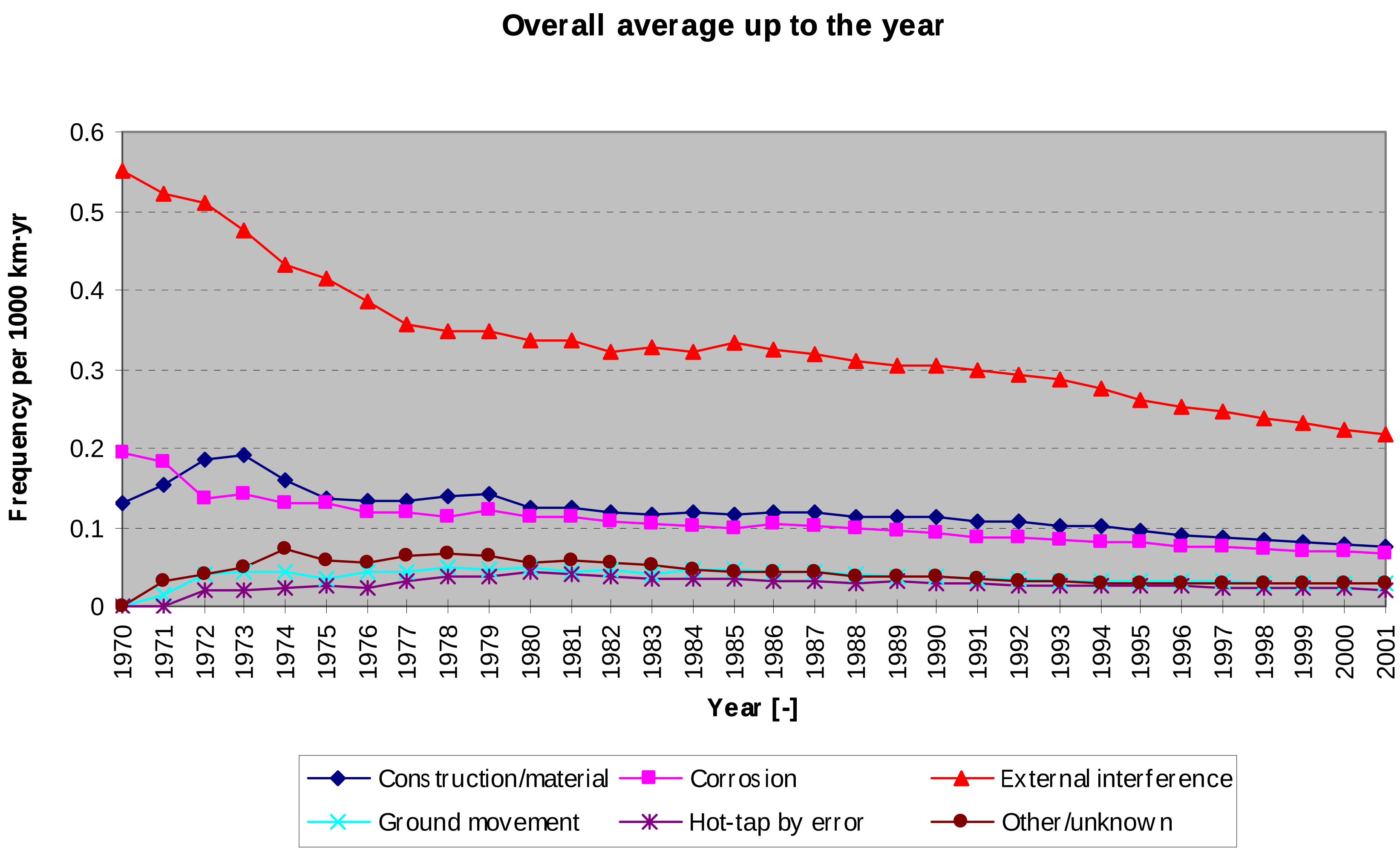
APPENDIX 2 (FIGURE 4)



APPENDIX 3 (FIGURE 7)



APPENDIX 4 (Figure 8)



APPENDIX 5 (CONFIDENCE ANALYSIS)

Confidence intervals

In Figure 20 the overall failure frequency up to the year given on the horizontal axis is presented and the 95% confidence interval of the EGIG pipeline system is shown. The confidence intervals are based upon the number of observed failures up to that year.

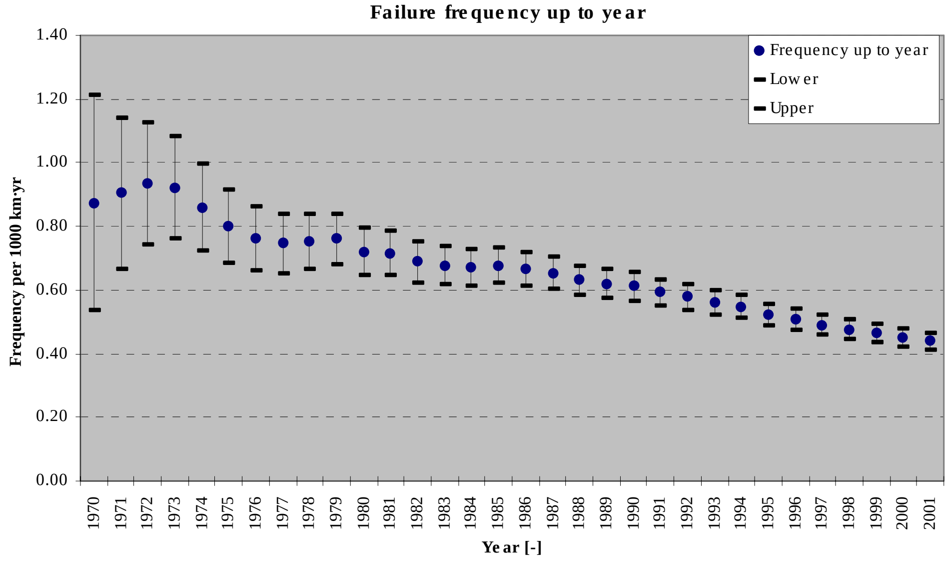


Figure 20

In Figure 21 the 5-year moving average, together with 95% confidence interval is presented. These confidence intervals are based upon the number of observed failures in the corresponding five years.

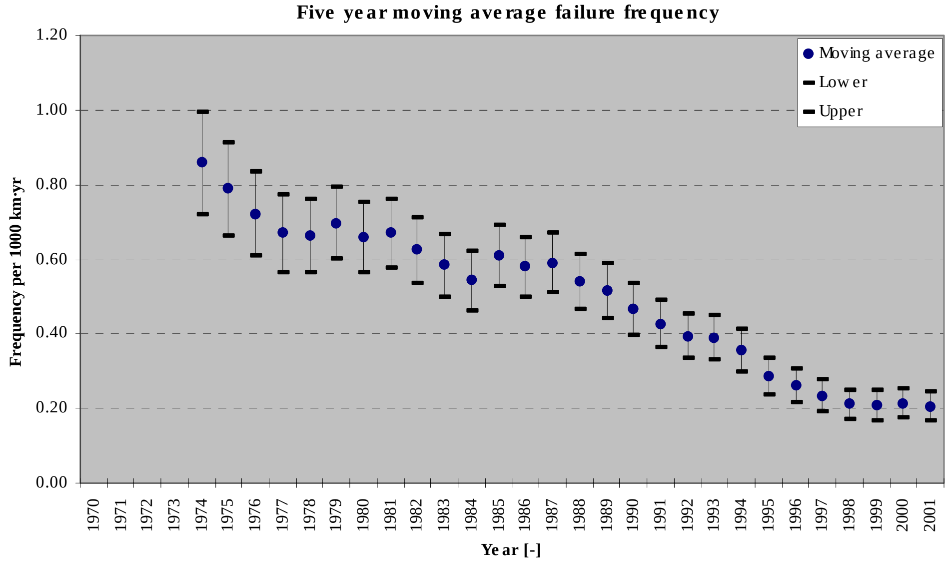


Figure 21

Failure frequency trend analysis

In Figure 22 the observed failure frequency is plotted over the years. The plotted uncertainty interval is the 95% confidence interval for the true underlying failure frequency per year based upon the observed number of failures in that year.

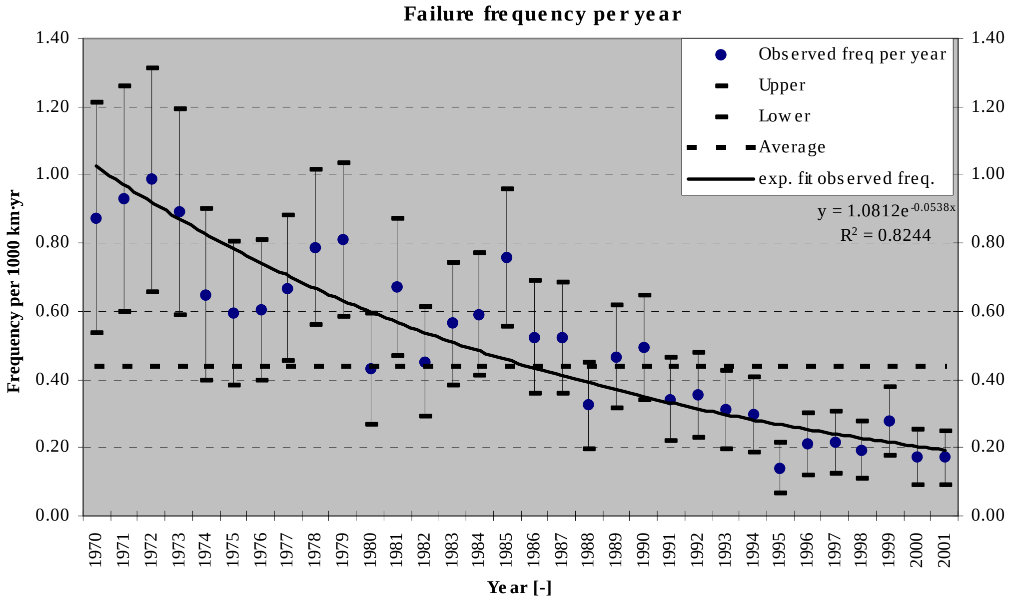


Figure 22

The average failure frequency is 0.44 per year per 1000 km pipeline with a 95% confidence interval of ± 0.03. This number is the same as the 1998 value in Figure 20. Clearly, the observed frequencies in the early years are significantly higher than the average and the recent years show a significantly lower frequency. An exponential fit has been plotted through the data.

From the exponential fit the EGIG group concludes that the failure rate has been decreased by a factor 5 over the past 32 years.

APPENDIX 6 (AGEING ANALYSIS)

Approximately one third of the incidents in the EGIG database are related to construction defects and corrosion (categories CD and CO). In table 4 the construction year classes, the system lengths and number of incidents can be found. Only 3 incidents have occurred on pipelines built after 1984.

Construction period	Exposure [km·year]	# CO/CD incidents	Av freq [$km^{-1}\cdot yr^{-1}$]
unknown	3459	12	$3.5\cdot 10^{-3}$
before 1954	114723	54	$4.7\cdot 10^{-4}$
1954-1963	371635	137	$3.7\cdot 10^{-4}$
1964-1973	980498	106	$1.1\cdot 10^{-4}$
1974-1983	553892	30	$5.4\cdot 10^{-5}$
1984-2001	390111	3	$7.7\cdot 10^{-6}$
total	2414318	342	$1.4\cdot 10^{-4}$

Table 4

From the data it is clear that newer pipelines experience a lower failure frequency for corrosion and material defects.

Further, the incidents have been analysed versus pipeline age. It was assumed that all pipelines were built halfway within the construction period class. So for example a pipeline built in the period 1954 to 1963 was assumed to be built in 1959. The pipelines before 1954 were assumed to be built in 1949.

The age of a pipeline for each incident was then rounded to the nearest 5 years. In Figure 23 the frequencies per kilometre year for corrosion or construction defects are shown.

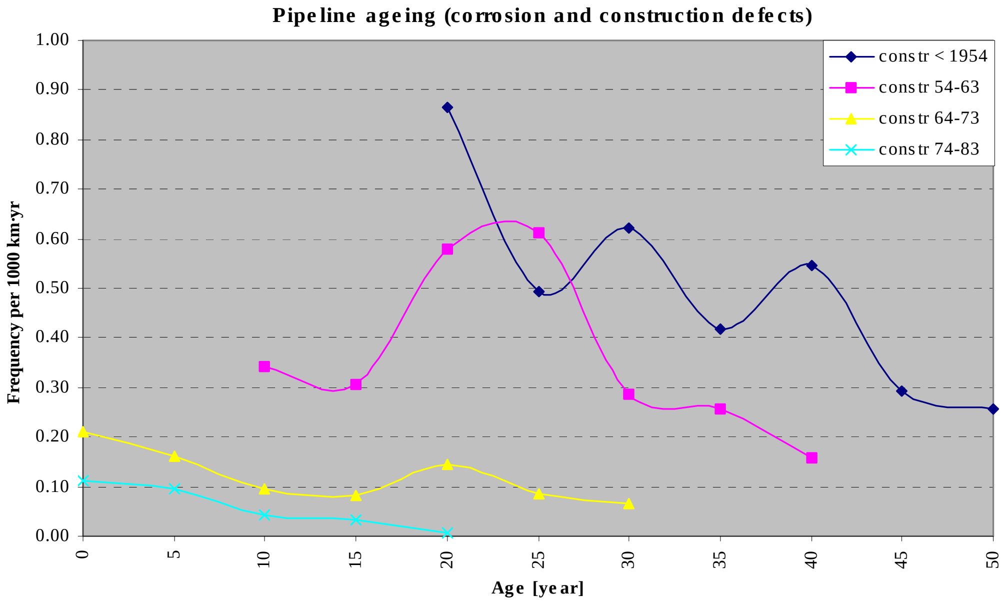


Figure 23

From the graph it can be seen that newer pipelines have lower failure frequencies than older pipelines, but also that the frequencies tend to decrease slightly in time. This means that ageing does not occur in the time window of the EGIG data collection.