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UKOPA Pipeline Fault Database – Application to All Pipelines

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Executive Summary

The UKOPA pipeline fault database has been established to provide recognised failure and fault data for onshore UK major accident hazard pipelines (MAHPs). The database contains operational fault and failure data for 99% of the total population of UK MAHPs. High pressure natural gas pipelines represent 88% of the MAHP population in terms of length, and 93% in terms of operational exposure in kilometre years (kmy). This report details the findings of an assessment of the validity of the application of the data to the other pipeline populations which make up the remaining 12% of the total MAHP pipeline population in terms of length and 7% in operational exposure.

The report draws the following conclusions:

1. Failure (ie leak and rupture) data in the UKOPA database is sparse, so data trends must be considered using fault data.

2. Detailed comparison and assessment of failure and fault trends has shown that, with the exception of internal corrosion, fault and failure data for the total pipeline population is representative of the non-natural gas pipeline population.

3. Although the database is dominated by natural gas pipeline fault and failure data, assessment has shown the data is relevant to all non-natural gas as well as natural gas pipelines.

In addition, the work carried out shows that:

4. Construction codes/standards have no apparent influence on the pipeline failure or fault rates.

5. The database confirms that changes in operation and maintenance procedures and especially tools used for inspection and frequency of inspection affect the recorded fault rates.

6. Actions taken to inspect for, detect and assess geometrically ‘small’ features is likely to affect and bias the apparent fault rate for affected populations of pipelines

7. UKOPA data indicates lower or equivalent numbers of leaks per population for all key leak categories when compared to CONCAWE and EGIG data.

8. Reporting level and criteria could have a significant effect on the indicated fault rate.

This report is endorsed by the UKOPA Fault Data Management Group.

1.0 Introduction

Major Accident Hazard Pipelines (MAHPs) in the UK are operated in accordance with the requirements of the Pipelines Safety Regulations 1996 (PSR 96). UK pipelines have a high safety record, and the prime pipeline codes in use within the UK (ie BSi/PD 8010 and IGE TD/1) have converged in requirements. UKOPA considers that the operational regime applied by UK operators is consistent, and therefore that this record applies to all pipelines. The UKOPA pipeline fault database contains data for 99% of all UK MAHPs, and is therefore considered to provide the most accurate representation of pipeline operational performance of all UK onshore MAHPs. The database is dominated by natural gas pipelines so a study has been carried out to assess any differences which may exist between the natural gas and other sectors of the population, and to assess whether these differences affect the operational failure and fault data.

Potential sources of differences between the natural gas and other pipeline populations are:-

- Design codes and construction standards
- Inspection and maintenance procedures
- Geometric parameters (ie diameter and wall thickness).

A programme of work to assess these issues has been carried out.

2.0 Scope of Assessment

The scope of the assessment was defined to investigate the above by comparing data extracted for pipeline populations defined in Table 1. As the purpose of the assessment was to investigate the validity of applying the database dominated by gas pipeline data to all pipelines, the ranges of pipeline parameters were selected to represent non-natural gas pipeline population, which comprises of pipelines less than or equal to a diameter of 325 mm and wall thickness 12mm.

Table 1 – Population Categories and Parameter Ranges Considered

Pipeline Population	Parameter Range	
	Diameter (mm)	Wall Thickness (mm)
All Products	All, 0-220, 225-274, 275 – 325 and > 326	All, 0-9.5, 9.51 – 12 and > 12
Natural Gas		
Non-Natural Gas		

Failure (ie loss of product or leak and rupture) data and fault (ie part wall damage) data and rates estimated per 1000 km years has been considered. Comparisons and trends have been based on fault data.

3.0 Methodology

The methodology involved detailed comparison of selected datasets, commencing on the basis that there were no significant differences between the pipeline populations. The assessment and comparison of leak and fault rates was then carried out in stages, and any differences were investigated in further detail.

The approach applied is summarised as follows:

i) Failure and fault numbers and rates per 1000 km years operation for all, natural gas only and non-natural gas pipeline populations were compared.

ii) Actual fault rates for natural gas, and non-natural gas populations were compared with expected fault rates for these populations estimated from the fault rate of the total population.

iii) Proportional differences between populations were investigated in detail.

iv) Trends in UKOPA leak data were compared with equivalent trends from CONCAWE and EGIG data.

4.0 Results

The results of the dataset comparisons are summarised below.

4.1 Failure and Fault Data

The comparison of the numbers and rates per 1000 kmys of leaks and ruptures for natural gas and non-natural gas pipelines with that of the total population is given in Table 2.

Table 2 Pipeline Operational Exposure and Failure Data

	All	**Nat Gas**	**Non Nat Gas**
Operational Exposure (kmy)	614023	571374	42648
Leaks	165	163	2
Leak Rate (per 1000 kmy)	0.269	0.285	0.0469
	7	7	0

Ruptures			
Rupture Rate (per 1000 kmy)	0.011	0.012	0

This table shows that:

i) The operational exposure of the non-natural gas population is less than 10% of the exposure of the total pipeline population.

ii) The leak rate for non-natural gas pipelines is less than 20% of the rate for the total pipeline population.

iii) There is no rupture data for non-natural gas pipelines.

The data shown in Table 2 indicates that non-natural gas pipelines have a significantly lower leak rate than natural gas pipelines. It must be noted however that as the data is very sparse (ie only two recorded leaks for all damage modes in non-natural gas pipelines), detailed comparison or assessment is difficult.

Fault data for the total, natural gas and non-natural gas pipeline populations is given in Table 3.

Table 3 – Summary of Fault Data

	All	**Nat Gas**	**Non Nat Gas**
Part-Wall Faults:			
Damage During Original Construction	184	146	38
External Corrosion	679	543	136
External Interference	562	540	22
Girth Weld Defect	58	56	2
Ground Movement	14	12	2
Internal Corrosion	21	1	20
Other	212	185	27
Pipe Defect	225	220	5
Pipe Mill Damage	99	84	15
Seam Weld Defect	13	13	0
	65	56	9

Unknown			
Total	**2132**	**1856**	**276**
Fault Rate per 1000 kmy	**3.472**	**3.248**	**6.472**

This table shows that:

i) The volume of fault data is ten times the volume of failure data.

ii) The fault rate for non-natural gas pipelines is approximately twice that of the total population.

The greater volume of fault data shown in Table 3 enables a more detailed comparison and assessment of the non-natural gas pipeline population in relation to the total population.

4.2 Comparison of Natural Gas and Non-Natural Gas Faults for all Pipelines

Figures 1 and 2 compare the number and rate of faults for the total pipeline population with those for natural gas and non-natural gas pipeline populations. These figures give an apparent indication that the level of construction defects, external corrosion and internal corrosion are proportionally higher for the non-natural gas population.

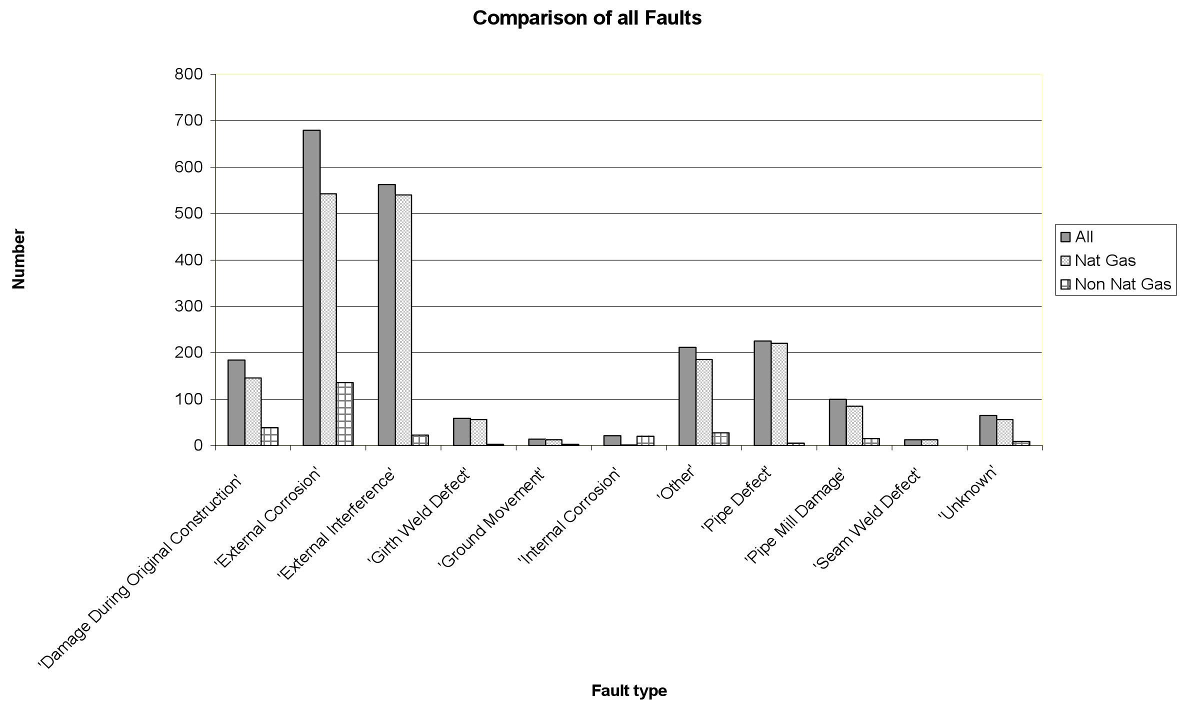

Figure 1 – Comparisons of Numbers of Faults

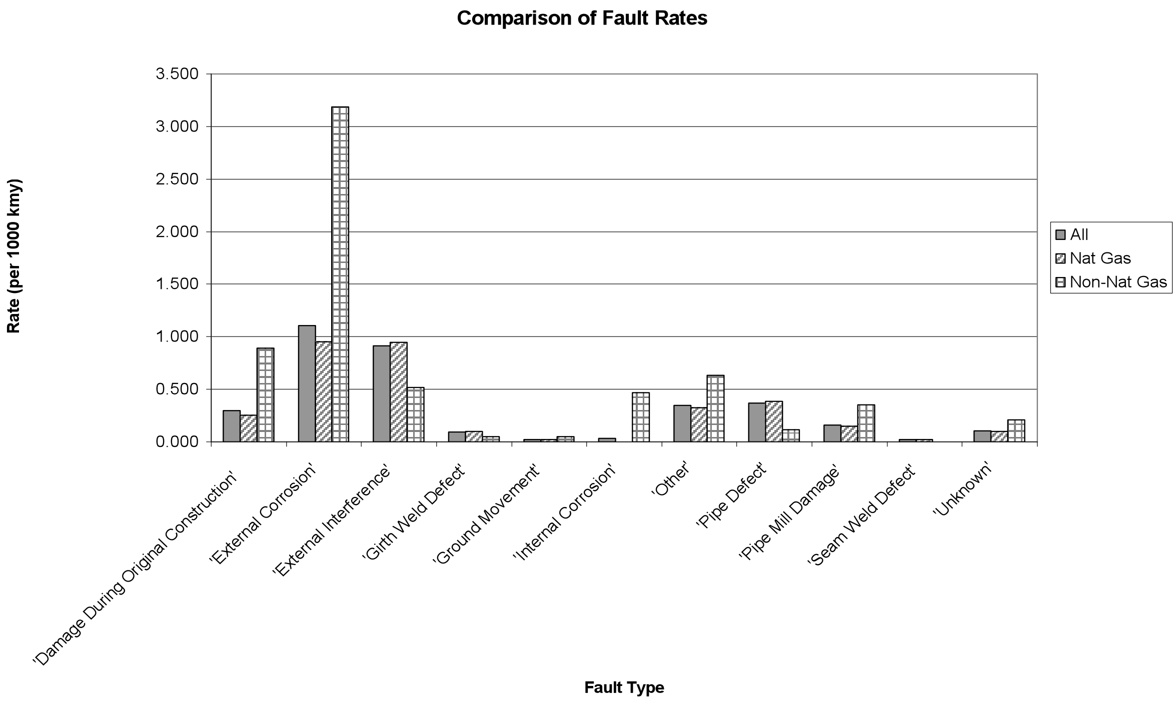

Figure 2 Comparison of Fault Rates

Figures 3 and 4 compare the actual numbers of faults for the natural gas and non-natural gas populations with an 'expected' number of faults estimated from the total population figures. The expected numbers were estimated as follows:-

$$N_{ex}(P_s) = N_a(P_t)*E(P_s)/E(P_t)$$

Where:

N_{ex}	=	Expected number of faults
N_a	=	Actual number of faults
P_t	=	Total population
P_s	=	Sample population (ie natural gas or non-natural gas)

Figure 3 shows that the actual number of faults for natural gas pipelines is very similar to the 'expected' number estimated from total pipeline population. This is as anticipated, as the gas pipeline population dominates the total pipeline population.

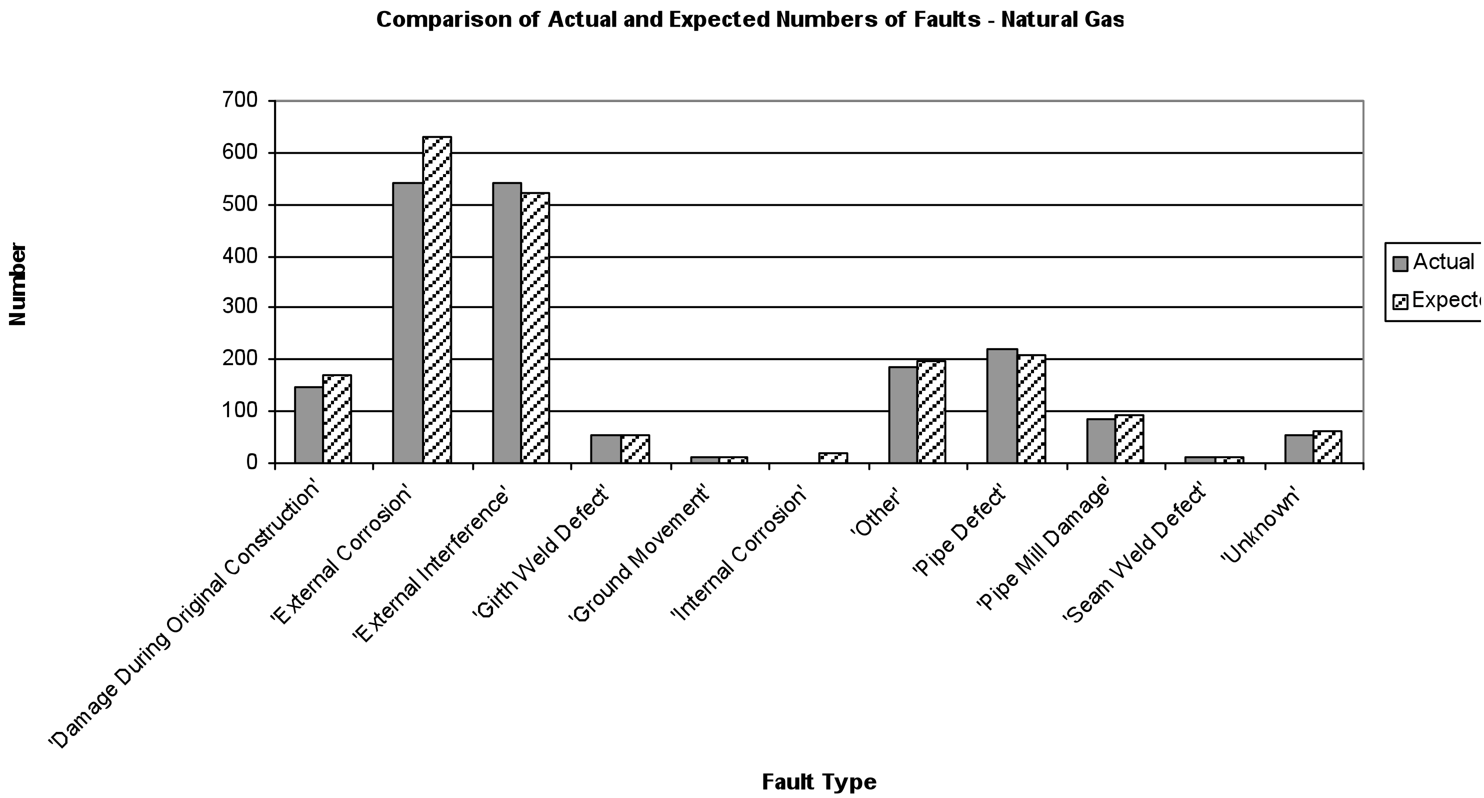

Figure 3 –
Comparison of Actual and Expected Numbers of Faults for Natural Gas Pipelines

Figure 4 shows that the actual numbers of construction, external corrosion and internal corrosion faults in the non-natural gas pipeline population are higher than the ‘expected’ number estimated from the total pipeline population. This difference in trends is considered further in order to determine whether it is significant, ie whether the non-natural gas population differs from the total population.

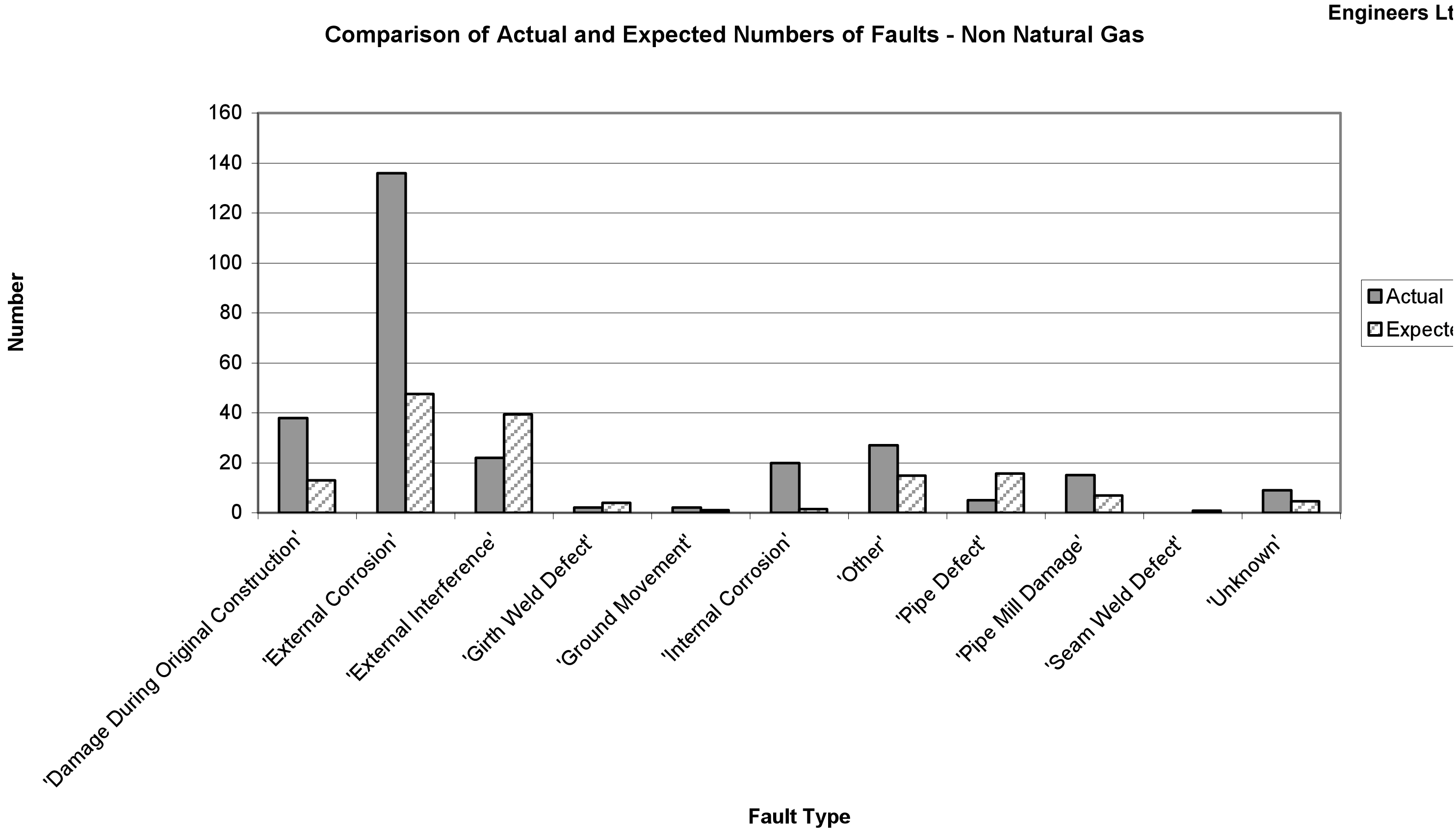

Figure 4 –
Comparison of Actual and Expected Numbers of Faults for Non-Natural Gas Pipelines

4.3 Comparison of Natural Gas and Non-Natural Gas Faults for Pipelines <= 12.00 mm wt.

Over 99% of the non-natural gas pipeline population is comprised of pipelines with wall thickness less than or equal to 12.00mm. A detailed comparison of the faults reported in the non-natural gas pipeline population with faults reported in all pipelines with wall thicknesses less than or equal to 12.00 mm was carried out in order to determine whether a higher number of construction, external and internal corrosion faults occurs in the total pipeline population.

Figure 5 compares the number of faults for the total pipeline population with wall thickness less than or equal to 12.00 mm with those for natural gas and non-natural gas pipeline populations with the same wall thickness range. The specific comparions for pipelines with wall thicknesses less than 12.00mm in Figure 5 shows a similar trend to that shown by the total population (including all wall thicknesses) in Figure 1. That is, the numbers of faults in pipelines with wall thicknesses less than or equal to 12.00mm is similar to that of the total population, indicating there is no significant differences between the total data and the data set relevant to non-natural gas pipelines. It therefore indicates there is an apparent increase in construction, external and internal corrosion faults in the non-natural gas population. This difference requires further consideration.

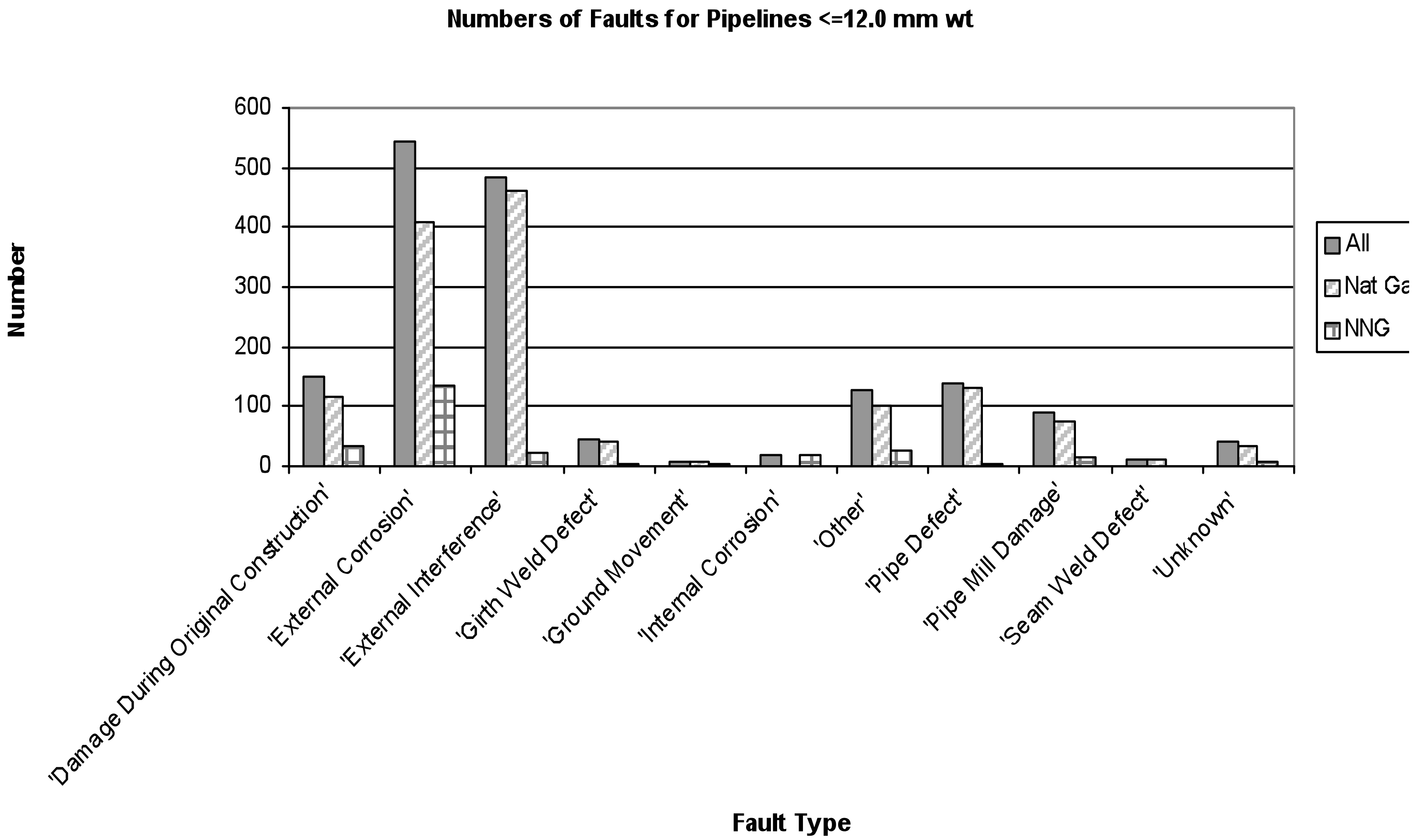

Figure 5 –
Comparison of Numbers of Faults for Pipelines with Wall Thickness <= 12.00 mm

The fault rate (per 1000 kmy) was then calculated and compared for these pipelines, this is shown in Figure 6. Figure 6 clearly demonstrates that in non-natural gas pipelines, the fault rate for internal corrosion is approximately ten times, external corrosion is approximately three times and construction damage approximately twice the rate in the total pipeline population.

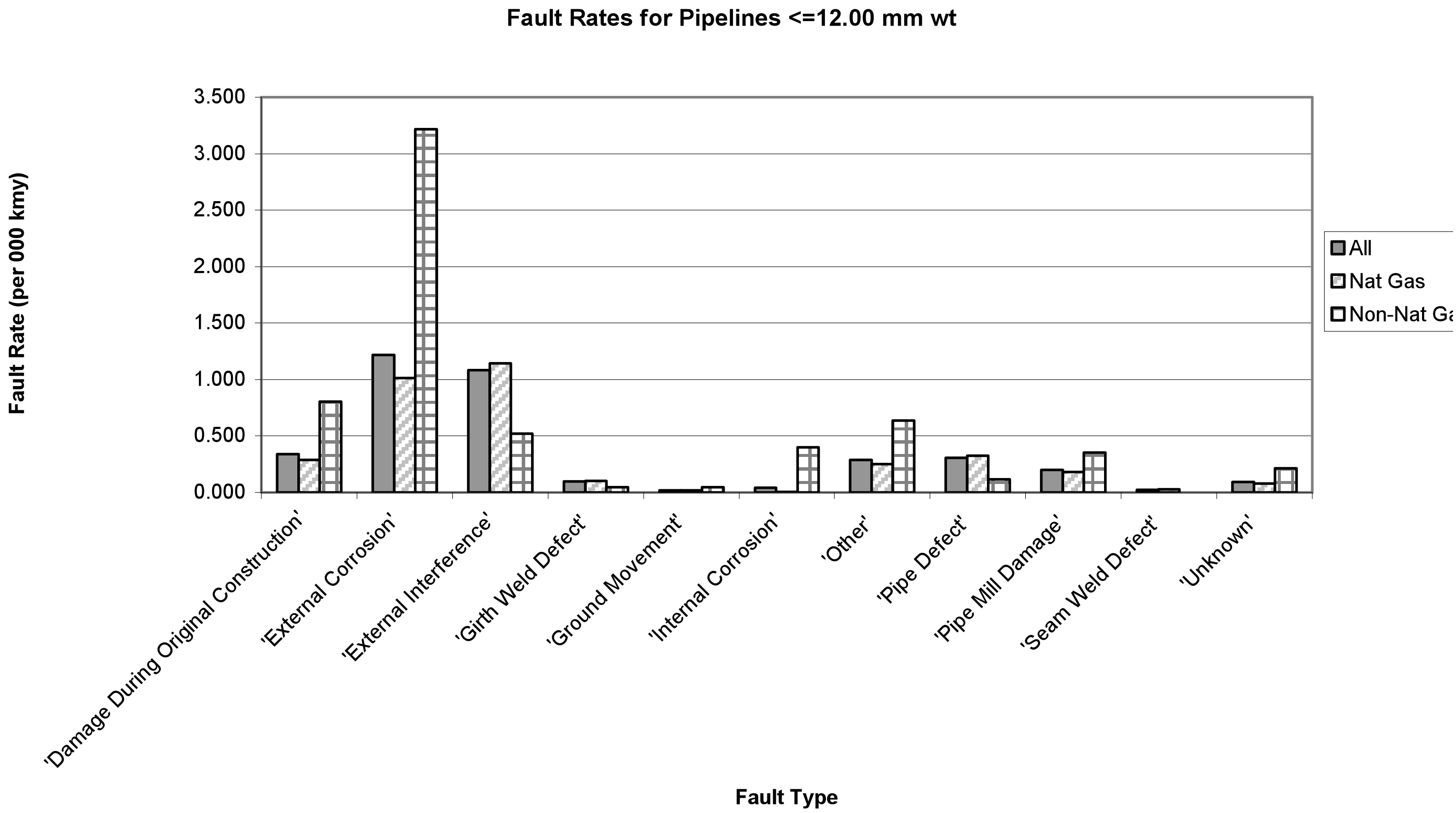

Figure 6 –
Comparison of Fault Rates for Pipelines with Wall Thickness <= 12.00 mm

4.4 Assessment of Non-Natural Gas Pipeline Fault Data

Comparisons reported in Sections 4.1 – 4.3 indicate that the fault rate for non-natural gas pipelines is approximately twice that of the total population, and that the actual numbers of construction, external and internal corrosion faults for the non-natural gas population are higher than the 'expected' numbers estimated from the total pipeline population.

To assess the information in and sensitivity of the fault data, the non-natural gas population was considered in greater detail. The number of faults in the total non-natural gas population was compared with that of its largest component, the ethylene pipeline population, which comprises 52%. This comparison, shown in Figure 7, indicates that while the numbers of construction faults in the non-natural gas population occurs predominantly in the ethylene population, the occurrence of external corrosion is in proportion to the percentage population and is therefore approximately similar and internal corrosion occurs predominantly in 'other' ie non-ethylene pipelines.

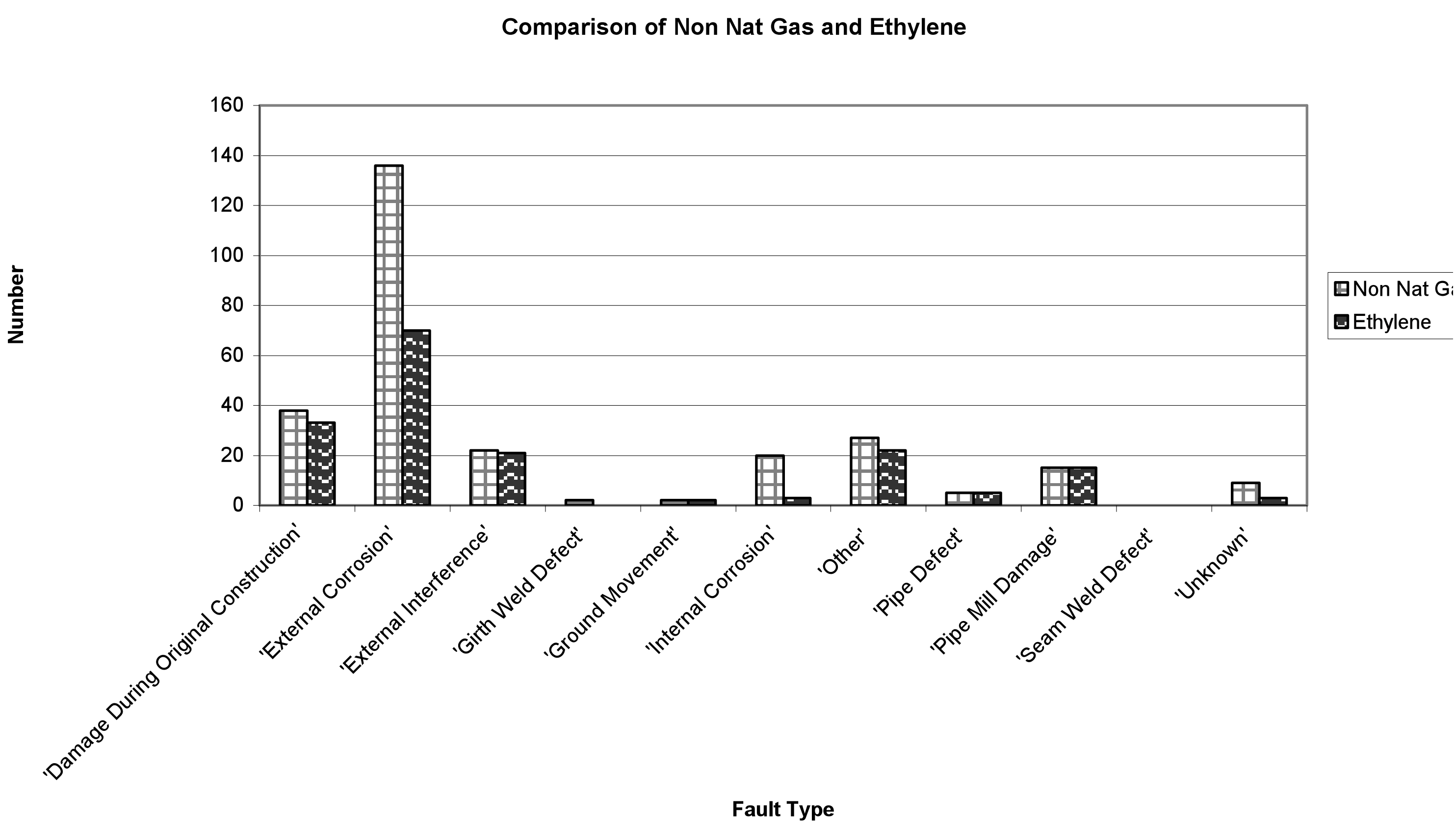

Figure 7 –
Comparison of Numbers of Faults for Non-Natural Gas and Ethylene Pipelines

This assessment indicates that there is sufficient fault data to enable qualitative consideration of fault trends in small sections (ie < 5%) of the total pipeline population.

4.5 Consideration of Fault Number and Type

In order to consider in more detail the significance of the numbers of faults of specific types occurring in different populations, a 'leak:fault detection rate' was defined. This ratio was defined simply as the ratio of the number of detected leaks to the total number of detected leaks + faults for specific damage categories. In this assessment, construction damage is defined as the sum of 'damage during construction', 'girth weld', 'pipe' and 'seam weld' categories. To ensure the ratio is as meaningful as possible, the number of faults in all categories was defined as leaks + faults.

This data derived for the total pipeline population is given in Table 4.

Table 4 Leak:Fault Data for All Pipelines

Category:	Leaks	Faults	Leak:Fault Rate
Construction	49	579	0.078
External Interference	36	562	0.060
Internal Corrosion	2	21	0.087
External Corrosion	32	679	0.045
Natural Causes	5	14	0.263
Unknown	8	65	0.110
'Other'	39	212	0.155

Table 4 shows that the leak rate for all faults categorised as, for example, external interference, is 0.06 or 6%. Assuming the dataset for the total pipeline population demonstrates consistent trends, the above leak:fault rate ratios can be used to estimate the number of leaks expected from a recorded number of faults.

Assuming therefore that the trends obtained for the total population in Table 4 can be applied to the non-natural gas pipeline population, the ratios of the number of leaks to the number of faults for each type of damage given in Table 4 were used to estimate an ‘expected’ numbers of leaks generated by each type of fault in the non-natural gas population. The estimated ‘expected’ numbers of leaks are compared with the actual number of leaks for each type of fault for the non-natural gas pipeline population and the ethylene pipeline population in Table 5.

Table 5 – Expected Numbers of Leaks Estimated for Non-Natural Gas and Ethylene Pipeline Populations

	Non-Natural Gas		Ethylene	
Type:	**Faults**	**Expected No Leaks**	**Faults**	**Expected No Leaks**
Construction	60	5	53	4
External Interference	22	1	21	1
Internal Corrosion	20	2	3	0
External Corrosion	136	6	70	3
Natural Causes	2	0	2	0
Unknown	9	1	3	0
Other	27	7	5	1
Total Expected:		**23**		**11**
Actual:		**2**		**1**

Table 5 shows the estimated number of 'expected' leaks for all non-natural gas and ethylene pipelines calculated the actual number of faults multiplied by the relevant leak:fault ratio for the total pipeline population.

The expected numbers of leaks estimated in Table 5 are then compared with the total number of actual leaks. This indicates that the actual numbers of leaks in both the total non-natural gas pipeline and the ethylene pipeline populations are an order of magnitude lower than the estimated expected numbers.

4.6 Comparison of UKOPA, CONCAWE and EGIG Pipeline Failure Rates

The leak rate recorded in the UKOPA database was compared with rates recorded in the CONCAWE and EGIG databases in Figure 8. Equivalent CONCAWE and EGIG leak rates were calculated as follows:

$$N_{C(U)} = N_C * P_U / P_C$$

And

$$N_{E(U)} = N_E * P_U / P_E$$

Where:

N_C = Number of leaks in CONCAWE database
$N_{C(U)}$ = Number of leaks in CONCAWE database for UKOPA Operational exposure
P_U = Operational exposure of UKOPA population
P_C = Operational exposure of CONCAWE population

and

N_E = Number of leaks in EGIG database
$N_{E(U)}$ = Number of leakss in EGIG database for UKOPA Operational exposure
P_U = Operational exposure of UKOPA population
P_E = Operational exposure of EGIG population

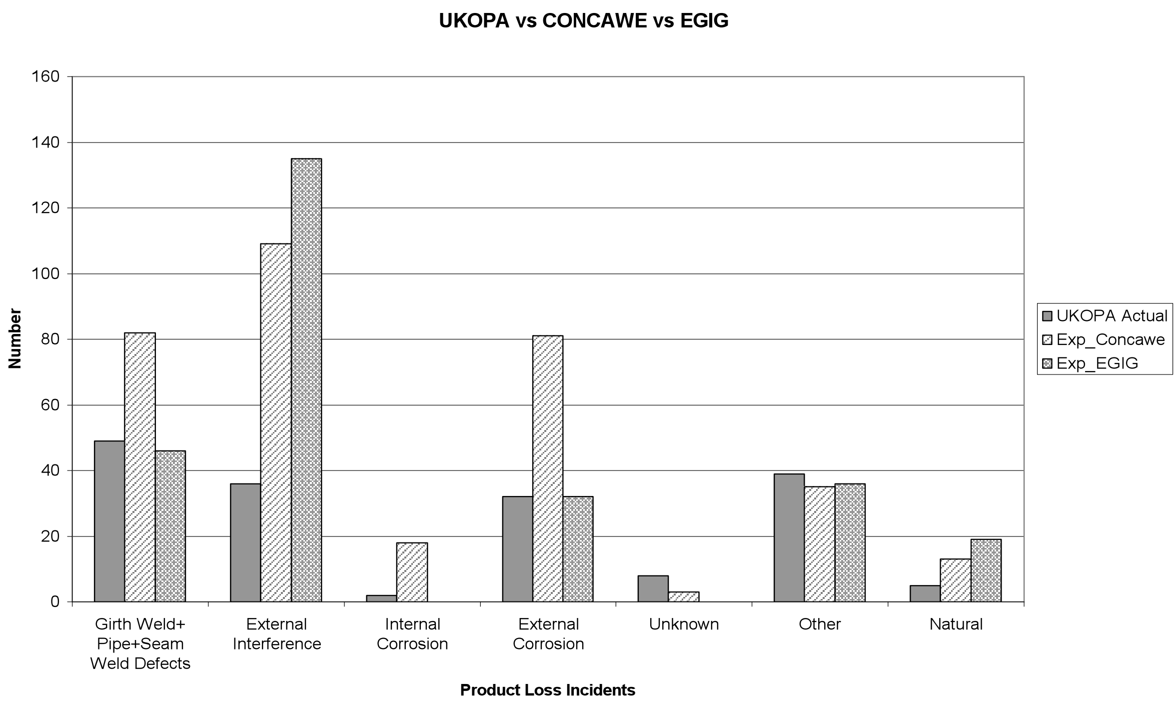

Figure 8 – Comparison of Numbers of Leaks for UKOPA with Equivalent CONCAWE and EGIG Populations

Figure 8 shows that the UKOPA pipeline data indicates lower or equivalent numbers of leaks per population for all key leak causes than CONCAWE and EGIG data.

5.0 Statistical Analysis

A simple statistical assessment of the average annual leak rate per 1000 kmy for the total, natural gas, non-natural gas and ethylene pipeline populations has been carried out. The leak data is given in Appendix 1, and the results of statistical analysis are given in Appendix 2.

Results obtained for the total pipeline population are compared with EGIG data in Table 6

Table 6– Comparison of UKOPA and EGIG Leak Rate Statistics

Data Source	Average Leak Rate (per 1000 kmy)	95% Confidence Interval
UKOPA	0.408	+/- 0.029
EGIG	0.44	+/- 0.03

Table 6 shows that the average leak data statistics for UKOPA are lower than EGIG, while the confidence interval for the data is equivalent.

The results in Appendix 2 show that the statistics of the natural gas pipeline population are very similar to those for the total population.

An assessment of the data in Appendix 1 confirms that the data for non-natural gas pipeline populations is very sparse compared to the total and natural gas populations. The sparseness of the data prevents the generation of meaningful statistical results for the small population.

6.0 Data Sensitivity

As noted in Section 4, the failure for all pipelines is sparse, so comparisons have been made using the fault data. This offers two advantages; i) the volume of fault data is more than ten times the volume of failure data, and ii) fault data is recorded in terms of type of damage.

While this enables more detailed assessment of trends, the volume of data is generally low, so the sensitivity of the trends indicated by simple comparisons of data sets must be considered.

A qualitative view can be obtained through consideration of the comparisons made in Section 4. In terms of operational exposure, the natural gas pipeline population represents 93% of the total pipeline population data. This means that the non-natural gas population represents less than 10% of the total data, and therefore is ten times more sensitive to the rate of occurrence of faults and failures.

The number of failures (leaks) recorded for the non-natural gas pipeline population is 10 times less than the expected number of failures estimated from the total pipeline population, and the number of faults is approximately twice the expected number. Based on the fact that the operational exposure for non-natural gas pipelines is less than 10% of the total, a sensitivity level of an order of magnitude should be expected.

The leak data is very sparse, so it is considered reasonable to assume that the leak rate for non-natural gas pipelines is represented by that of the total pipeline population (ie it is not considered to be an order of magnitude lower). As a corollary to this, the fault rate for non-natural gas pipelines is twice that of the total pipeline population. The volume of fault data is ten times that of leak data, and so is considered to be more representative measure. The increase in fault rate is much lower than the expected order of magnitude sensitivity level, and so it is considered reasonable to assume that the fault rate for non-natural gas pipelines is similar to that of the total pipeline population.

It is therefore concluded that the fault and failure data for the total pipeline population data can be assumed to represent faults and failures in the non-natural gas pipeline population.

7.0 Discussion

Consideration of the failure and fault data has shown that while leak data is sparse, indications can be drawn from detailed comparisons of fault data. A simple qualitative sensitivity assessment of the data has shown it is reasonable to assume that the faults and failure data for the total pipeline population is representative of faults and failures occurring in the non-natural gas pipeline population. However, detailed comparisons have shown that numbers of construction damage, external corrosion and internal corrosion faults occurring in non-natural gas pipelines, are higher than would be expected from the UKOPA total population, but equivalent to CONCAWE and EGIG rates. Issues considered to be worth further consideration are therefore:

i) Pipeline Geometry.

ii) Construction standard.

iii) Operations and maintenance procedures.

iv) Remedial action policy.

v) Reporting practice .

7.1 Pipeline Geometry

In Section 4.3, it is noted that over 99% of the non-natural gas pipeline population is comprised of pipelines with wall thickness less than 12.00mm, and a comparison of the non-natural gas pipelines fault data with fault data from the total population of pipelines with wall thickness less than or equal to 12.00mm is considered. This showed that when the comparison was based on equivalent wall thickness, the non-natural pipeline population is apparently similar to the total pipeline population. However in addition, it is noted that the non-natural gas pipeline population is of smaller diameter (< 325mm diameter) as well as smaller wall thickness, and therefore these pipelines are more sensitive to "small damage". This means that a greater proportion of damage is likely to be detected and reported on these pipelines in comparison with the greater proportion of pipelines in the total population with an equivalent design factor (or operating stress).

This may explain the apparently higher fault trend noted in Section 4.1.

7.2 Construction Standards

Construction standards applied to the UKOPA pipeline population have developed and improved, so it is considered reasonable to assume that the more rigorous requirements of later codes result in fewer construction damage faults.

The majority of the construction damage faults recorded in the UKOPA database (ie >90%) have been detected post commissioning and have survived the hydrotest, and their detection is a function of improvements in operational inspection tools. In addition it must be noted that while construction inspection level (specifically level of radiography) varies with the code applied, the population of defects detected depends largely upon workmanship standards, which operational experience has shown to be largely acceptable. It is also noted that, taking the sensitivity of the non-natural gas population size to fault incidence rate into account, the level of construction damage faults is broadly similar to that of the total population.

The fault incident rate in the total population is similar to that of the EGIG population, analysis of the EGIG data reported in the 5th (2002) EGIG report has confirmed that aging effects (ie increasing fault and failure rates) based on pipeline commissioning date (and therefore code applied) are not indicated.

It is therefore concluded that the construction fault rate in non-natural gas pipelines is similar to that in the total pipeline population.

7.3 Operations and Maintenance

Operations and maintenance procedures relating to the incidence of external and internal corrosion fault rates have been reviewed. This review indicates that the introduction of internal in-line inspection and external survey techniques for metal loss due to corrosion resulted in peaks of detected damage data for natural gas pipelines in the early and late 1980s respectively. Equivalent peaks for non-natural gas pipelines are evident, but occur slightly later (ref UKOPA Fault Data Report). These peaks are the result of new technology and techniques detecting and reporting accumulated historical data. Following their recording of accumulated historical data, the annual data trend reduces to a level which represents the actual rate of occurrence. This observation is confirmed by the fault detection vs leak occurrence ratio, which shows that based on the performance of the total population, the leak rate expected for these damage mechanisms in the non-natural gas pipeline populations would be expected to be significantly higher than the actual recorded. The actual fault rates for external and internal corrosion are three and ten times respectively those for the total pipeline population.

The rate for external corrosion is well within the data sensitivity level of an order of magnitude, and therefore it is concluded that the external corrosion rate for the non-natural gas pipeline population is similar to that in the total pipeline population.

The rate for internal corrosion for non-natural gas pipelines is ten times that in the total population, which is equivalent to the data sensitivity level of an order of magnitude and therefore may represent a significant difference between the populations. The high internal corrosion rate in non-natural gas pipelines does not occur in ethylene pipelines which comprise the largest component of this population, so it is reasonable to assume the high rate is significant and is the result of a specific cause. Further investigation is required to understand this data trend.

It is therefore concluded that the database confirms that changes in operation and maintenance procedures and especially tools used for inspection and frequency of inspection affects the recorded fault rates. Reports on other pipeline failure databases (refs) conclude that the rate and level of change in fault rate depend upon the change implemented, but the underlying rate is expected to return to a stable level.

7.4 Remedial Action Policy

In the case of smaller diameter pipelines in which the wall thickness for equivalent design factors is lower that that in the larger diameter pipelines which dominate the total population data, the application of similar procedures for detecting and assessing damage will result in a larger number of recorded faults. Historical practice has been to investigate and carry out remedial action on all faults with depths reported as greater than 20% wall thickness. Faults are only recorded in the database if they are verified (ie confirmed through a dig and measurement). In the case of say a 2mm depth defect, when detected on a small diameter pipeline, such a defect would be reported by in-line inspection, investigated and may warrant structural repair, whereas if detected on a larger diameter pipeline, would not be reported. This means that the fault rate for smaller diameter and wall thickness non-natural gas pipelines, for example for external corrosion, is likely be higher (as a greater number of smaller defects are subject to remedial action).

This explains the higher fault rates for non-natural gas pipelines in terms of the pipeline characteristics, but as the argument applies also to all small diameter pipelines within the total population, it supports the conclusion that, taking these factors into account, the rates for non-natural gas pipelines are similar to those for the total pipeline population.

7.5 Reporting Level

Consistency in reporting level is a management issue for all databases. It is of particular importance when operational data is recorded. Variation in reporting level and criteria between operators is expected, and for this reason considerable effort has been invested in the format, control and criteria applied to data input to the UKOPA database. It is possible that a more detailed reporting level may be reflected in the non-natural gas pipeline population, due to the difference in population size, the scale of organisation in place to manage activities associated with the pipeline and the associated time period required to finalise and validate entry of a complete dataset.

It is concluded that reporting level and criteria could have a significant effect on the indicated fault rate. Further consideration of this issue is outside the scope of the current study.

8.0 Conclusions

The following conclusions are drawn from the work reported:

1 Failure (ie leak and rupture) data in the UKOPA database is sparse, so data trends must be considered using fault data.

2 Detailed comparison and assessment of failure and fault trends has shown that, with the exception of internal corrosion, fault and failure data for the total pipeline population is representative of the non-natural gas pipeline population.

3 Although the database is dominated by natural gas pipeline fault and failure data, assessment has shown the data is relevant to all non-natural gas as well as natural gas pipelines.

4 Construction codes/standards have no apparent influence on the pipeline failure or fault rates.

5 The database confirms that changes in operation and maintenance procedures and especially tools used for inspection and frequency of inspection affect the recorded fault rates.

6 Actions taken to inspect for, detect and assess geometrically ‘small’ features is likely to affect and bias the apparent fault rate for affected populations of pipelines.

7 UKOPA data indicates lower or equivalent numbers of leaks per population for all key leak categories when compared to CONCAWE and EGIG data.

8 Reporting level and criteria could have a significant effect on the indicated fault rate.

9.0 References

1 Pipeline Product Loss Incidents (1961 – 2001). "001 Interim Report of the UKOPA Fault Database Management Group. R Greenwood. Advantica Jan 2003.

2 5th EGIG Report 1970 – 2001 Gas Pipleine Incidents. Doc No EGIG 02.R.0058 Dec 2002.

3 Performance of Cross-Country Pipelines in Western Europe. Statistical Summary of Reported Spillages – 2000. CONCAWE Report No 4/01.

Appendix 1 Leak Rate Data for All, Natural Gas, Non-Natural Gas and Ethylene Pipeline Populations

	All	Nat Gas	Non-Nat Gas	Ethylene
Year	Ave to Yr	Ave to Yr	Ave to Yr	Ave to Yr
1960	0.00000	0.00000	0.00000	0.00000
1961	0.00000	0.00000	0.00000	0.00000
1962	0.56190	0.56190	0.00000	0.00000
1963	0.56349	0.56349	0.00000	0.00000
1964	0.52057	0.52057	0.00000	0.00000
1965	0.45762	0.45762	0.00000	0.00000
1966	0.40720	0.40720	0.00000	0.00000
1967	0.53566	0.53566	0.00000	0.00000
1968	0.54794	0.54794	0.00000	0.00000
1969	0.52899	0.52899	0.00000	0.00000
1970	0.56091	0.56091	0.00000	0.00000
1971	0.59978	0.59978	0.00000	0.00000
1972	0.54930	0.54930	0.00000	0.00000
1973	0.53497	0.52334	0.01163	0.01163
1974	0.49187	0.48183	0.01004	0.01004
1975	0.45824	0.44943	0.00881	0.00881
1976	0.42846	0.42067	0.00779	0.00779
1977	0.43137	0.42441	0.00696	0.00696
1978	0.43163	0.42537	0.00626	0.00626
1979	0.42461	0.41894	0.00566	0.00566
1980	0.40778	0.40262	0.00516	0.00516
1981	0.39304	0.38831	0.00474	0.00474
1982	0.37557	0.37120	0.00437	0.00437
1983	0.38467	0.38062	0.00405	0.00405
1984	0.41076	0.40700	0.00377	0.00377
1985	0.41879	0.41175	0.00704	0.00352
1986	0.41894	0.41234	0.00660	0.00330
1987	0.41890	0.41269	0.00621	0.00310
1988	0.40689	0.40104	0.00585	0.00293
1989	0.39882	0.39328	0.00554	0.00277
1990	0.39915	0.39390	0.00525	0.00263
1991	0.38428	0.37929	0.00499	0.00250
1992	0.37034	0.36559	0.00475	0.00237
1993	0.35963	0.35511	0.00452	0.00226
1994	0.34758	0.34326	0.00432	0.00216
1995	0.33237	0.32824	0.00413	0.00206
1996	0.31836	0.31441	0.00395	0.00198
1997	0.30928	0.30549	0.00379	0.00190
1998	0.30632	0.30267	0.00365	0.00182
1999	0.29819	0.29468	0.00351	0.00175
2000	0.28888	0.28551	0.00338	0.00169
2001	0.28015	0.27689	0.00326	0.00163

NB Ave to year data in rate/1000 kmy

Appendix 2 Results of Statistical Analysis

All Pipelines	
	Statistics
Mean	0.4081461
Standard Error	0.0140681
Median	0.4068903
Standard Deviation	0.080815
Sample Variance	0.0065311
Kurtosis	0.0195211
Skewness	0.5807186
Range	0.319631
Minimum	0.2801476
Maximum	0.5997786
Sum	13.46882
Count	33
Confidence Level(95.0%)	0.0286557
Natural Gas Pipelines	
	Statistics
Mean	0.4032987
Standard Error	0.0140942
Median	0.4010357
Standard Deviation	0.0809652
Sample Variance	0.0065554
Kurtosis	0.1707558
Skewness	0.6569014
Range	0.3228885
Minimum	0.2768901
Maximum	0.5997786
Sum	13.308856
Count	33
Confidence Level(95.0%)	0.028709