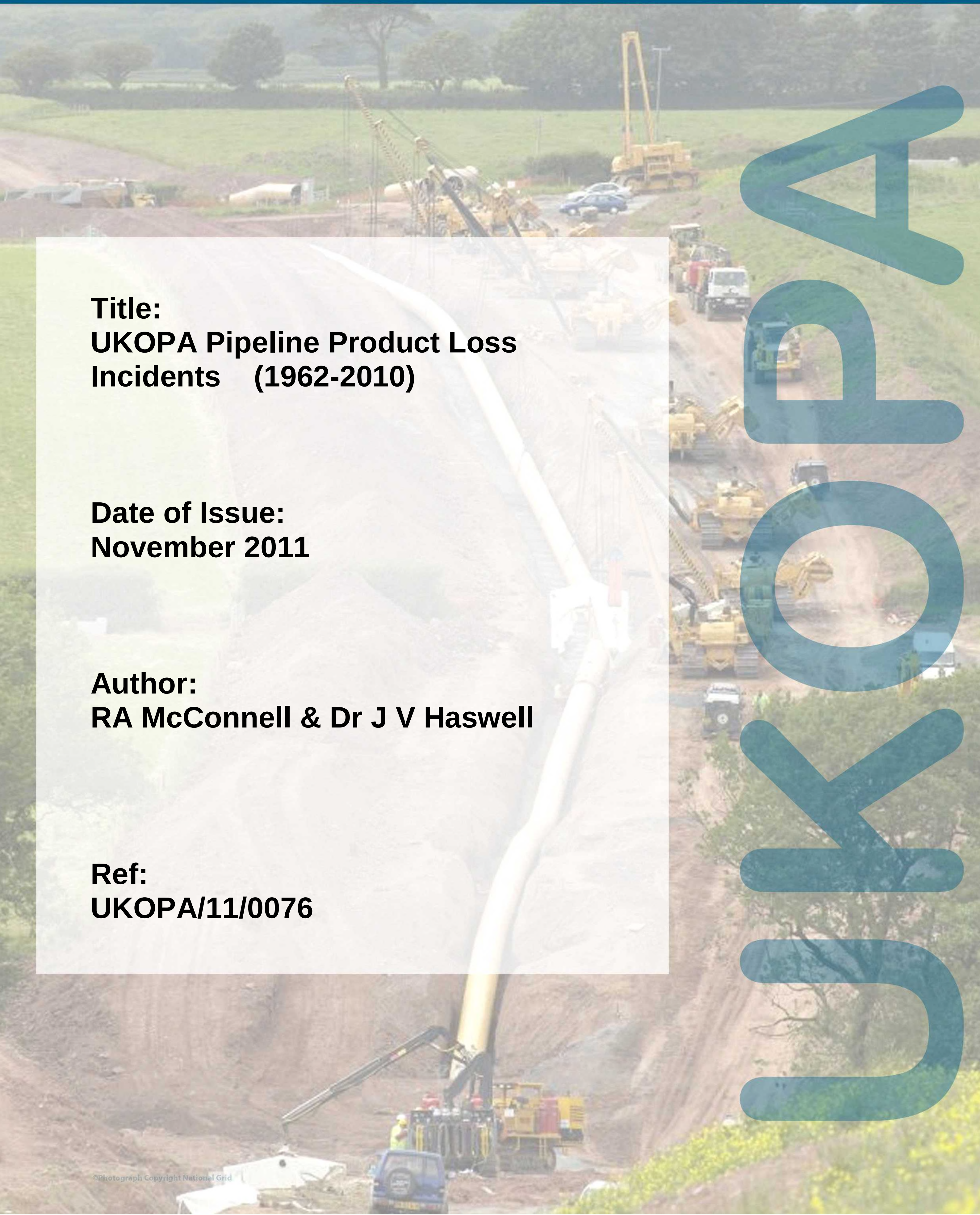
UKOPA

United Kingdom Onshore Pipeline Operators' Association



Title:
UKOPA Pipeline Product Loss Incidents (1962-2010)

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Author:
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UKOPA/11/0076

UKOPA PIPELINE FAULT DATABASE

Pipeline Product Loss Incidents

(1962 - 2010)

8th Report of the UKOPA **F**ault **D**atabase **M**anagement **G**roup

Comprising:

National Grid
BP
Ineos
Sabic
Shell UK Limited
Shell EPE
E-ON UK
Wales & West Utilities
Scotia Gas Networks
Northern Gas Networks
Health and Safety Executive

Report prepared by R A McConnell & Dr J V Haswell for FDMG

Report Reference: UKOPA/11/0076
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Summary

This report presents collaborative pipeline and product loss incident data from onshore Major Accident Hazard Pipelines (MAHPs) operated by National Grid, Scotia Gas Networks, Northern Gas Networks, Wales & West Utilities, Shell UK Limited (now Essar Oil (UK) Ltd), Shell EPE, BP, Ineos, SABIC and E-ON UK, covering operating experience up to the end of 2010.

The data presented here covers reported incidents where there was an unintentional loss of product from a pipeline within the public domain, and not within a compound or other operational area.

The overall failure frequency over the period 1962 to 2010 is 0.234 incidents per 1000 km.year, whilst in the previous (Formal 6th) report this figure was 0.242 incidents per 1000 km.year (covering the period from 1962 to 2008).

The failure frequency over the last 20 years is 0.079 incidents per 1000 km.year.

For the last 5 years the failure frequency is 0.093 incidents per 1000 km.year, whilst in the previous report this figure was 0.064 incidents per 1000 km.year (covering the 5 year period up to the end of 2008).

This report also presents data for part-wall damage and defects known as fault data, and the statistical distributions derived for estimating pipeline failure probabilities due to external interference events.

Contents

1 Introduction

1.1 Background

One of the key objectives of UKOPA is to develop a comprehensive view on risk assessment and risk criteria as they affect Land Use Planning aspects adjacent to high hazard pipelines. The main multiplier in pipeline risk assessments is the per unit length failure rate which directly relates to the extent of risk zones adjacent to the pipelines.

Regulators and consultants who carry out risk assessments for UK pipelines have generally relied on US and European data to provide the basis for deriving failure rates due to the shortage of verified published data relating to UK pipelines. UKOPA published the first report in November 2000, presenting the first set of incident data for pipeline incidents resulting in the unintentional release of product up to the end of 1998.

A full list of published reports is listed in the table below.

Report Date	Type of Report	Covering Incidents to end of	Report Number	Reference
2000	Formal	1998	1	R 4092
2002	Formal	2000	2	R 4798
2003	Formal	2002	3	R 6575
2005	Formal	2004	4	R 8099
2007	Formal	2006	5	6957
2009	Formal	2008	6	9046
2010	Interim	2009	7	UKOPA/2010/0074
2011	Formal	2010	8	UKOPA/2011/0076

1.2 Purpose of the Database

The purpose of the database is to:

- record leak and fault data for UK Major Accident Hazard Pipelines
- estimate leak and pipeline rupture frequencies for UK pipelines, based directly on historical failure rate data for UK pipelines
- provide the means to estimate failure rates for UK pipelines for risk assessment purposes based on analysis of damage data for UK pipelines
- provide the means to test design intentions and determine the effect of engineering changes (e.g. wall thickness of pipe, depth of burial, diameter, protection measures, inspection methods and frequencies, design factor etc.)

1.3 Key Advantages

The database is designed to reflect the ways in which the UKOPA operators design, build, operate, inspect and maintain their pipeline systems. Although the pipeline and failure data are extensive, there are pipeline groups (e.g. large diameter, recently constructed pipelines) on which no failures have occurred; however, it is unreasonable to assume that the failure frequency for these pipelines is zero. Similarly, further pipeline groups exist for which the historical failure data are not statistically significant.

Unlike its Europe-wide EGIG***** counterpart, this UKOPA database contains extensive data on pipeline failures and on part-wall damage known as fault data, allowing prediction of failure frequencies for pipelines for which inadequate failure data exist.

Using Structural Reliability Analysis techniques it is possible to determine the range of defect dimensions that will cause a specific pipeline to fail; analysis of the statistical distributions of actual defect dimensions from the part-wall defect data allows the probability of a critical defect to be determined and failure frequencies for any credible failure mechanism to be calculated.

This approach has been used extensively and successfully by contributing companies in pipeline uprating projects and assessing failure rates for quantified risk assessments.

*European Gas Pipeline Incident Data Group (Gas loss incidents in gas transmission pipelines operating above 15 bar).

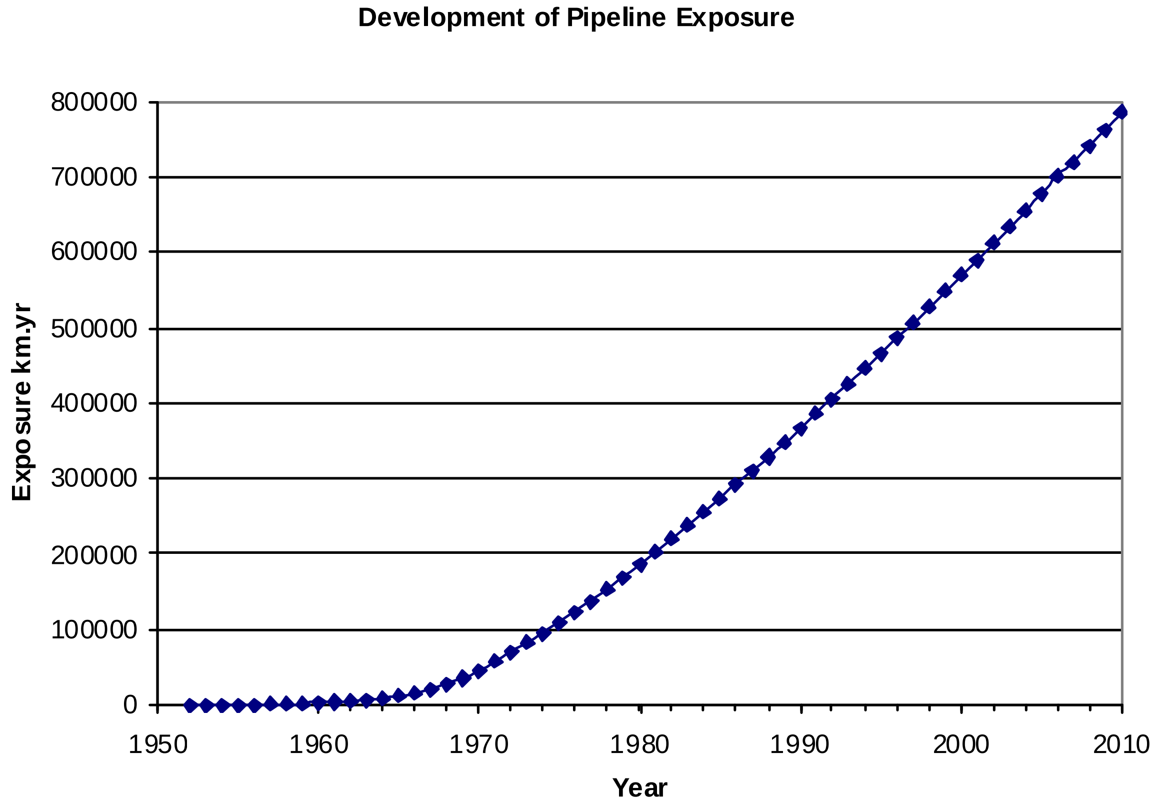
2 Product System Data

2.1 Exposure

The total length of Major Accident Hazard Pipelines* in operation at the end of 2010 for all participating companies (National Grid, Scotia Gas Networks, Wales & West Utilities, Northern Gas Networks, BP, Shell UK Limited [now Essar UK Ltd], Shell EPE, Ineos, Sabic and E-ON UK) was 22,370 km. The total exposure in the period 1952 to the end of 2010 was 785,385 km.yr; the development of this exposure is illustrated in Figure 1.

Exposure of Pipeline before first recorded incident in 1962 = 3740 km.yr (included in exposure and incident frequency calculations)
Above Ground Pipelines are included in totals.

Figure 1



*For definition of Major Accident Hazard Pipelines (MAHPs) - see UK statutory legislation - The Pipelines Safety Regulations 1996 [PSR96], for the full definition – for natural gas the classification is above 8 bar absolute.

2.2 Transported Products

The lengths of pipeline in operation at the end of 2010, by transported product, are (in km):

Table 1

Natural Gas (Dry)	21,053	Propylene	36.3
Ethylene	1,153	Condensate	24.0
Natural Gas Liquids	225.8	Propane	19.5
Crude Oil (Spiked)	212.6	Butane	19.5
Ethane	38.1	**TOTAL**	**22,370**

Note:- The database includes 550 km of decommissioned pipeline, 412 km that used to transport natural gas, 92.4 km that used to transport ethylene, 36.3 km that used to transport carbon monoxide, 4.8 km that used to transport propane and 4.8 km that used to transport butane.

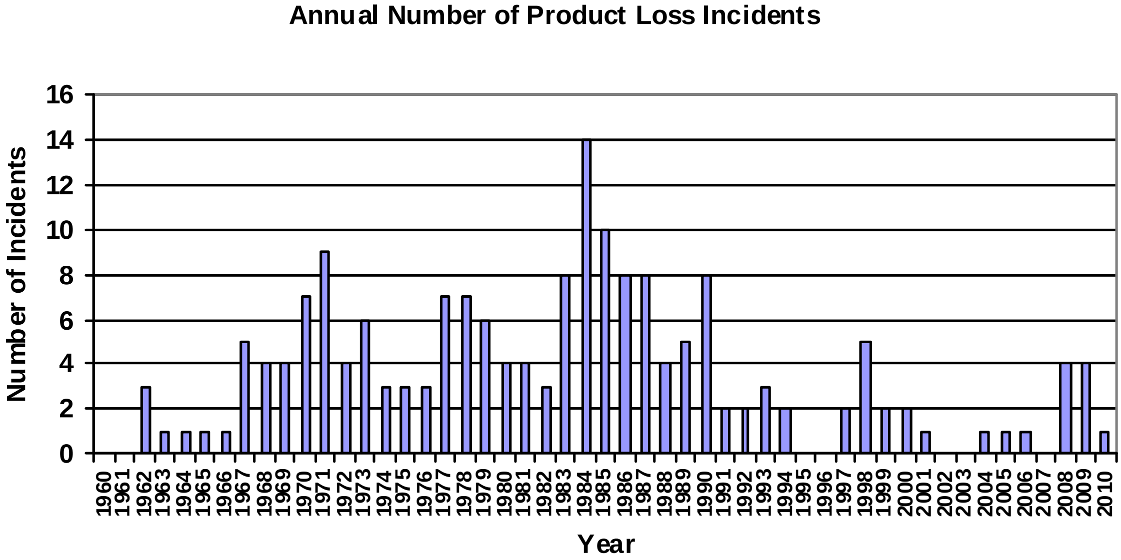
3 Product Loss Incident Data

A product loss incident is defined in the context of this report as:

- an unintentional loss of product from the pipeline
- within the public domain and outside the fences of installations
- excluding associated equipment (e.g. valves, compressors) or parts other than the pipeline itself

A total of 184 product loss incidents were recorded over the period between 1962 and 2010 compared with 179 product loss incidents documented in the report covering the period to 2008. No product loss incidents were recorded prior to 1962. An annual breakdown of incidents is illustrated in Figure 2.

Figure 2

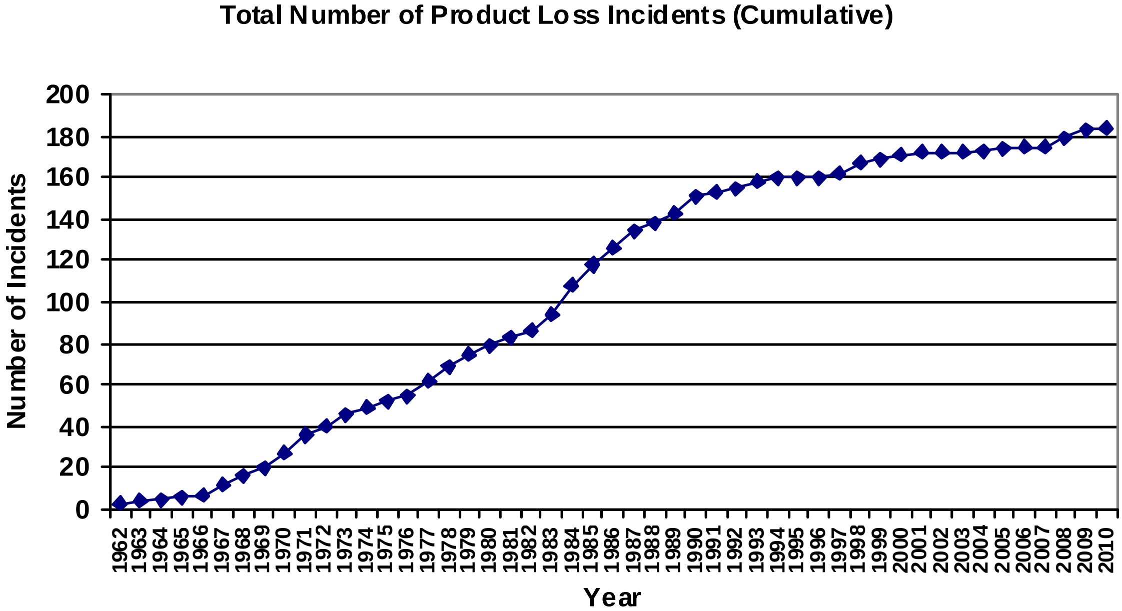


Differences between 2008 and 2010 product loss statistics

Five product loss incidents were recorded in the last two years, two due to minor external corrosion leaks, two leaks due to external interference, and one classified as “other”

The cumulative number of incidents over the period 1962 to 2010 is shown in Figure 3.

Figure 3



3.1 Incident Ignition

There were 9 out of 184 (4.9%) product loss incidents that resulted in ignition. Table 2 below provides more detail:

Table 2 – Incidents that Resulted in Ignition

Affected Component	Cause Of Fault	Hole Diameter Class
Pipe	Seam Weld Defect	0-6 mm
Pipe	Ground Movement	Full Bore and Above (18" Diameter Pipe)
Pipe	Girth Weld Defect	6-20 mm
Pipe	Unknown	6-20 mm
Pipe	Pipe Defect	0 – 6 mm
Pipe	Unknown	40 – 110 mm
Pipe	Lightning Strike	0-6 mm
Bend	Internal Corrosion	0-6 mm
Bend	Pipe Defect	6-20 mm

3.2 Incident Frequency

3.2.1 Trends over the Past 5, 20 and 48 Years

The incident frequency over eight consecutive 5-year periods up to the end of 2010 is shown in Table 3.

Table 3

Period	Number of Incidents	Total Exposure [km.yr]	Frequency [Incidents per 1000 km.yr]
1966 - 1970	21	33,306	0.631
1971 – 1975	25	63,035	0.397
1976 - 1980	27	77,627	0.348
1981 - 1985	39	87,166	0.447
1986 - 1990	33	93,202	0.354
1991 - 1995	9	99,233	0.091
1996 - 2000	11	103,121	0.107
2001 - 2005	3	108,742	0.028
2006 – 2010	10	107,691	0.093

The overall incident frequency by hole size over the period 1962 - 2010 is shown in Table 4.

Table 4

Hole Size Class	Number of Incidents	Frequency [Incidents per 1000 km.yr]
Full Bore* and Above	7	0.009
110mm – Full Bore*	3	0.004
40mm – 110mm	7	0.009
20mm – 40mm	23	0.029
6mm – 20mm	29	0.037
0 – 6mm	113	0.144
Unknown	2	0.005
Total	184	0.234

* Full Bore ≡ diameter of pipeline

The total exposure for the last 20 years 1991-2010 is 418,717 km.years and the resulting incident frequency is shown in Table 5.

Table 5

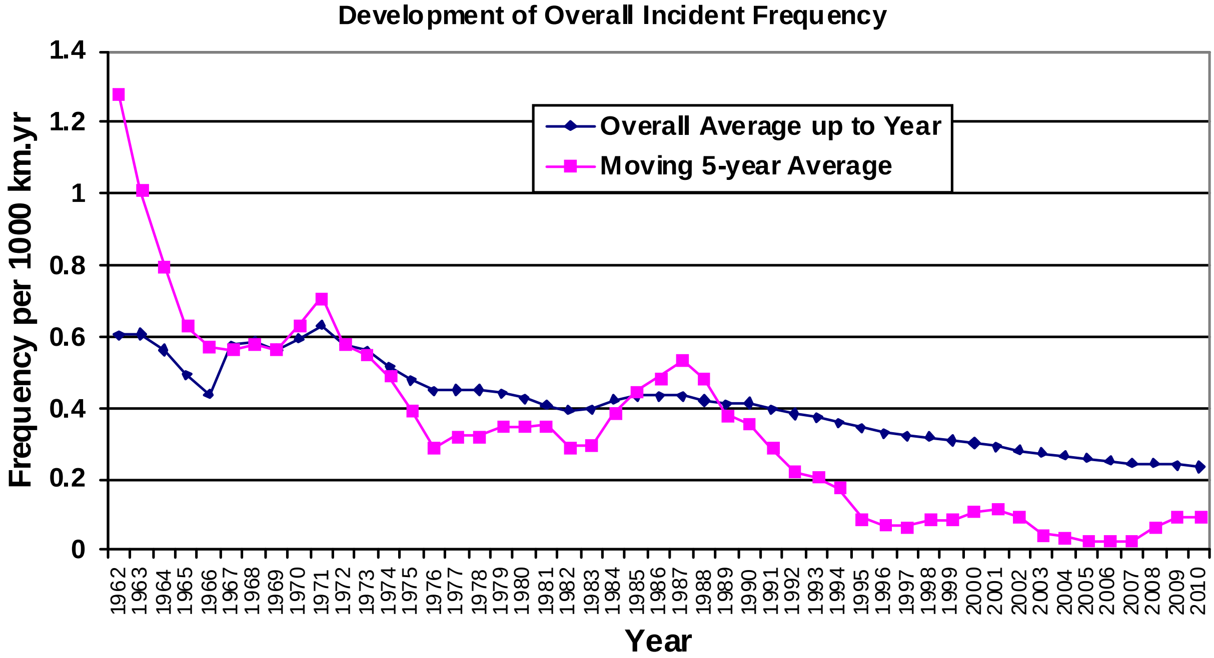
Hole Size Class	Number of Incidents	Frequency [Incidents per 1000 km.yr]
Exposure	**1991-2010**	**418787**
Full Bore* and Above	0	0.000
110mm – Full Bore*	1	0.002
40mm – 110mm	1	0.002
20mm – 40mm	6	0.014
6mm – 20mm	4	0.010
0 – 6mm	21	0.050
Unknown	0	0.000
Total	33	0.079

The failure frequency over the last 20 years is therefore 0.079 incidents per 1000 km.years and for the last 5 years (2006-2010) is 0.093 incidents per 1000 km.yr.

These compare with the failure frequency during the period 1962-2010 of 0.234 incidents per year per 1000 km.yr. An overview of the development of this failure frequency over the period 1962 to 2010 is shown in Figure 3.

In order to see the results over recent periods, the moving average for each year is calculated with reference to the incidents from the previous 5 years (2006-2010, 2005-2009, 2004-2008 etc.).

Figure 3



3.2.2 Confidence Intervals

Confidence intervals take uncertainty into account. The greater the exposure, the smaller the confidence interval which shows that uncertainty decreases as more operating experience is gained. To calculate the confidence intervals, the population is assumed to have a known distribution.

Failure events generally follow a random distribution so it is assumed that a Poisson distribution can be applied. The 95% confidence intervals for the overall average failure frequency is shown in Figure 4 and for the 5-year average in Figure 5.

Figure 4

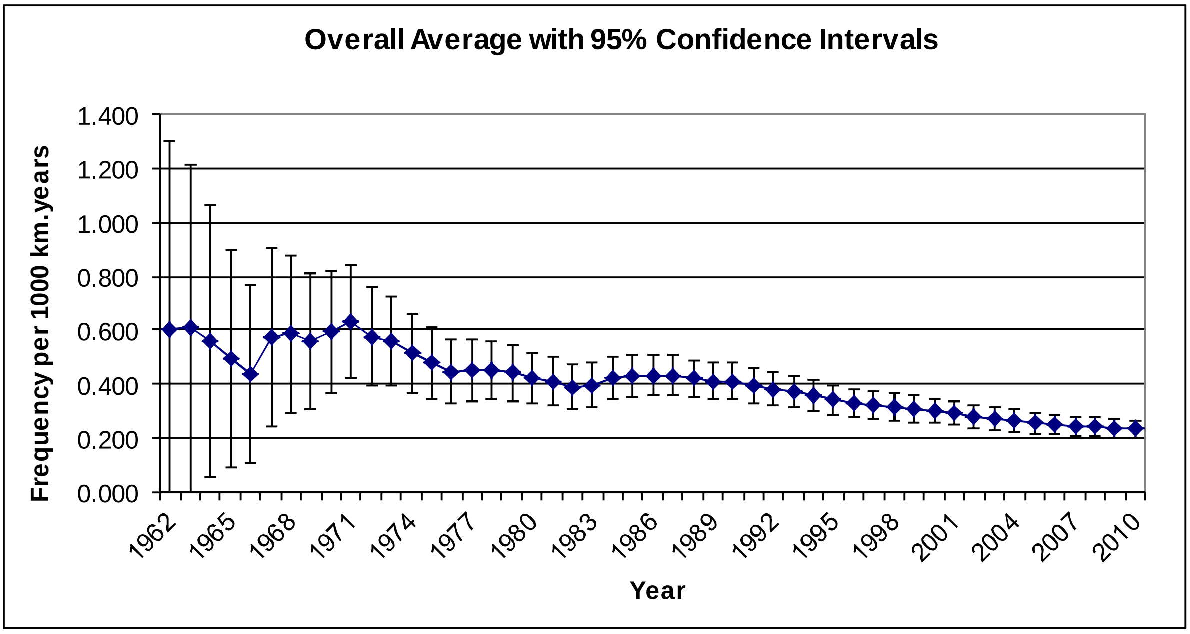


Figure 4 shows that the overall frequency for the whole period is 0.234 per 1000 km.years +/- 0.035.

Figure 5

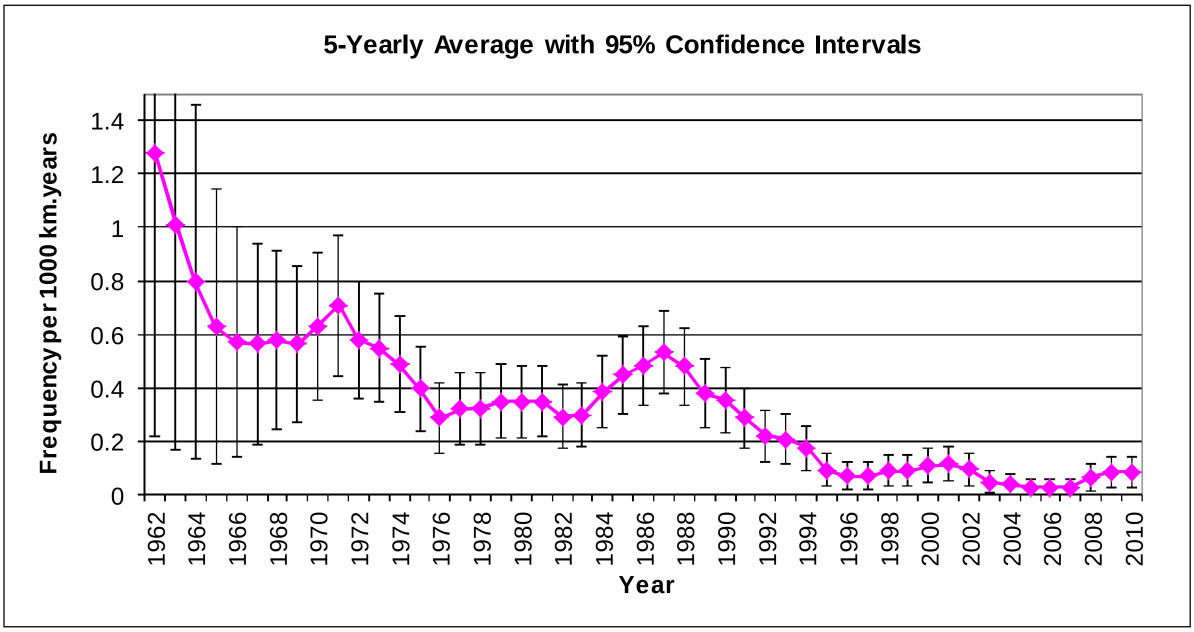


Figure 5 shows that the 5-year average failure frequency for 2006-2010 is 0.093 per 1000 km.years +/- 0.059.

3.3 Incident Frequency by Cause

The development of product loss incident frequency by cause is shown in Figure 6.

Figure 6

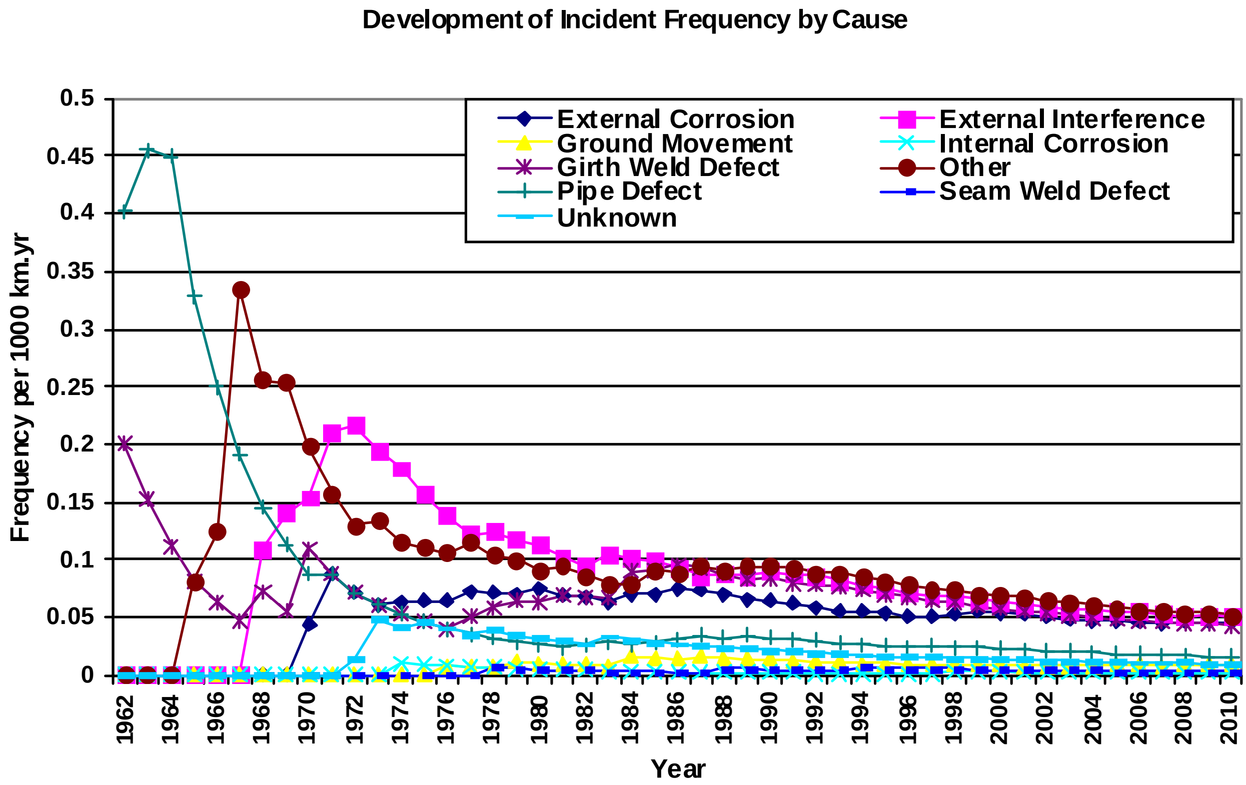


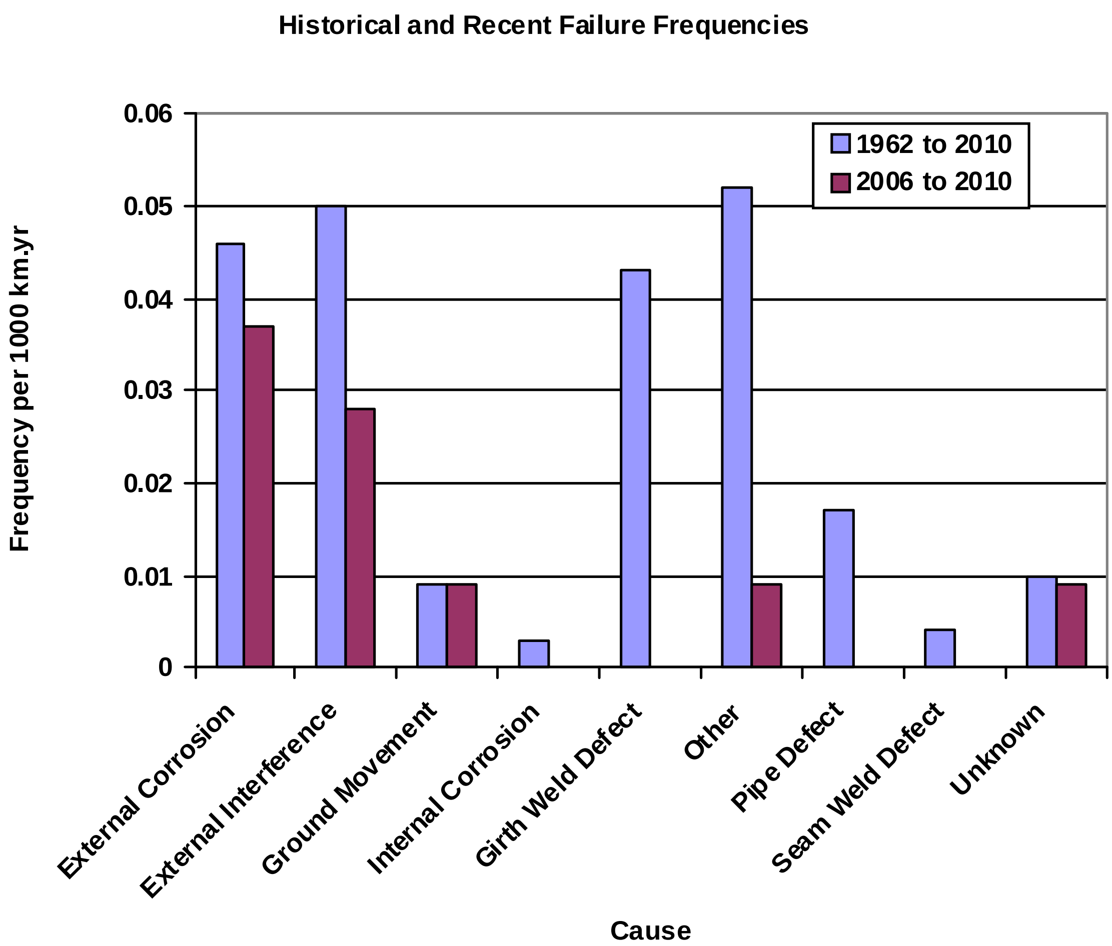
Table 6 – Product Loss Incidents by Cause

Product Loss Cause	No. of Incidents
Girth Weld Defect	34
External Interference	40
Internal Corrosion	2
External Corrosion	37
Unknown	7
Other	41
Pipe Defect	13
Ground Movement	7
Seam Weld Defect	3
Total	**184**

Other Cause	Incidents
Internal cracking due to wet town gas	30
Pipe-Fitting Welds	4
Leaking Clamps	3
Lightning	1
Soil stress	1
Threaded Joint	1
Electric Cable Arc Strike	1
Total	**41**

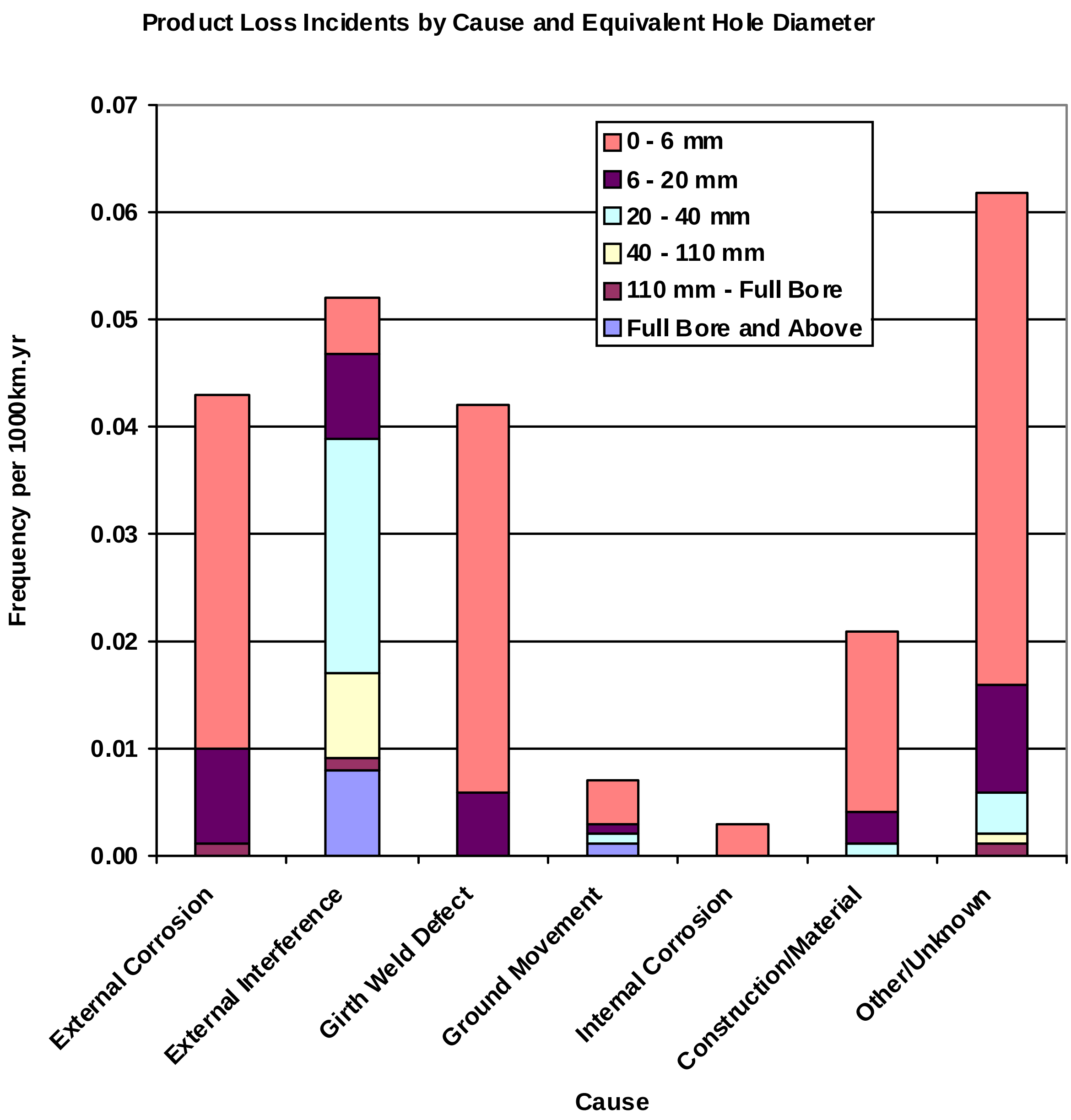
Figure 7 shows the product loss incident frequency by cause over the period 1962-2010 compared with the frequency over only the last 5 years (2006-2010).

Figure 7



An overview of the product loss incident frequency by cause and size of leak in the period 1962 to 2010 is shown in Figure 8.

Figure 8

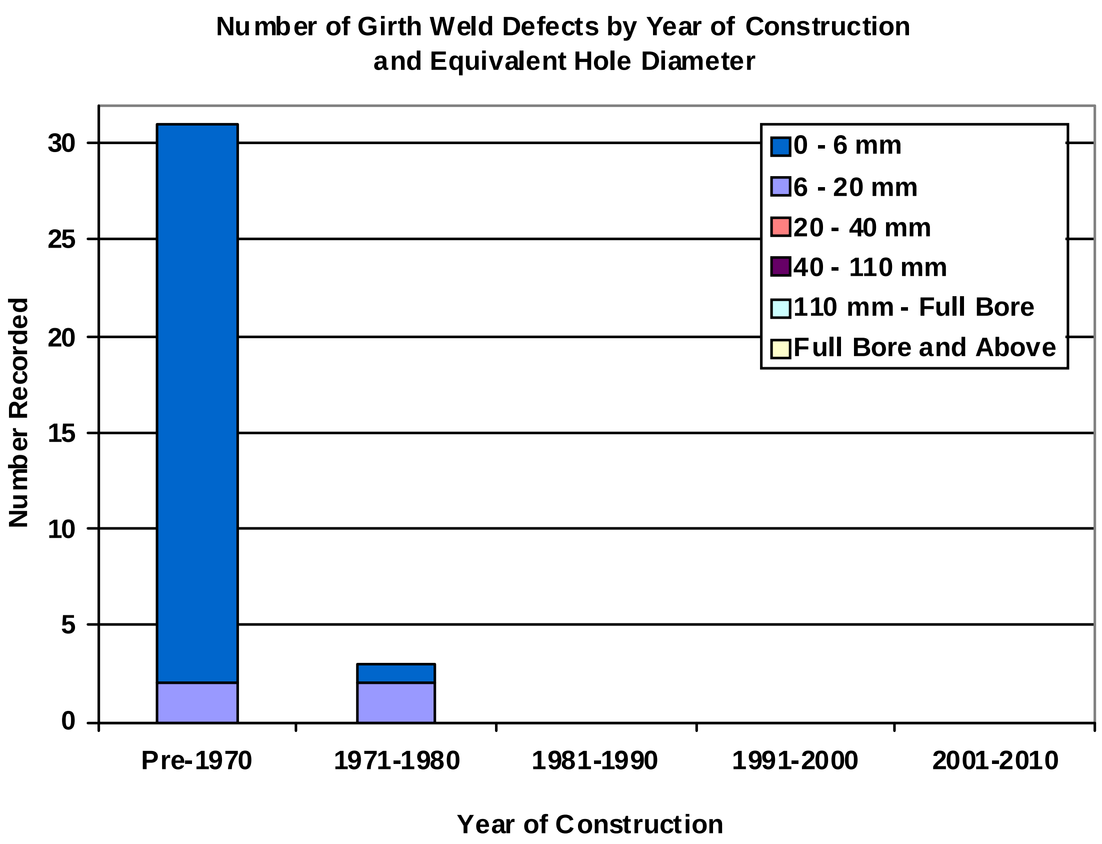


Construction/Material = Seam Weld Defect + Pipe Defect + Pipe Mill Defect + Damage During Original Construction

3.4 Girth Weld Defects

Figure 9 shows that 34 leaks due to girth weld defects were recorded in pipelines constructed before 1980, 31 of which were before 1970. No further leaks due to this cause have been observed since 1980.

Figure 9



The reduction in the number of girth weld defects in pipelines constructed after 1970 is associated with the improvements in field weld inspection and quality control procedures, and the increasing capability of in line inspection tools to detect girth weld anomalies.

3.5 External Interference

External interference is one of the main causes of product loss incident data with 40 recorded failures attributable to this cause.

3.5.1 External Interference by Diameter Class

Figure 10 shows the product loss incident frequencies associated with external interference by diameter class and by hole size.

Figure 10

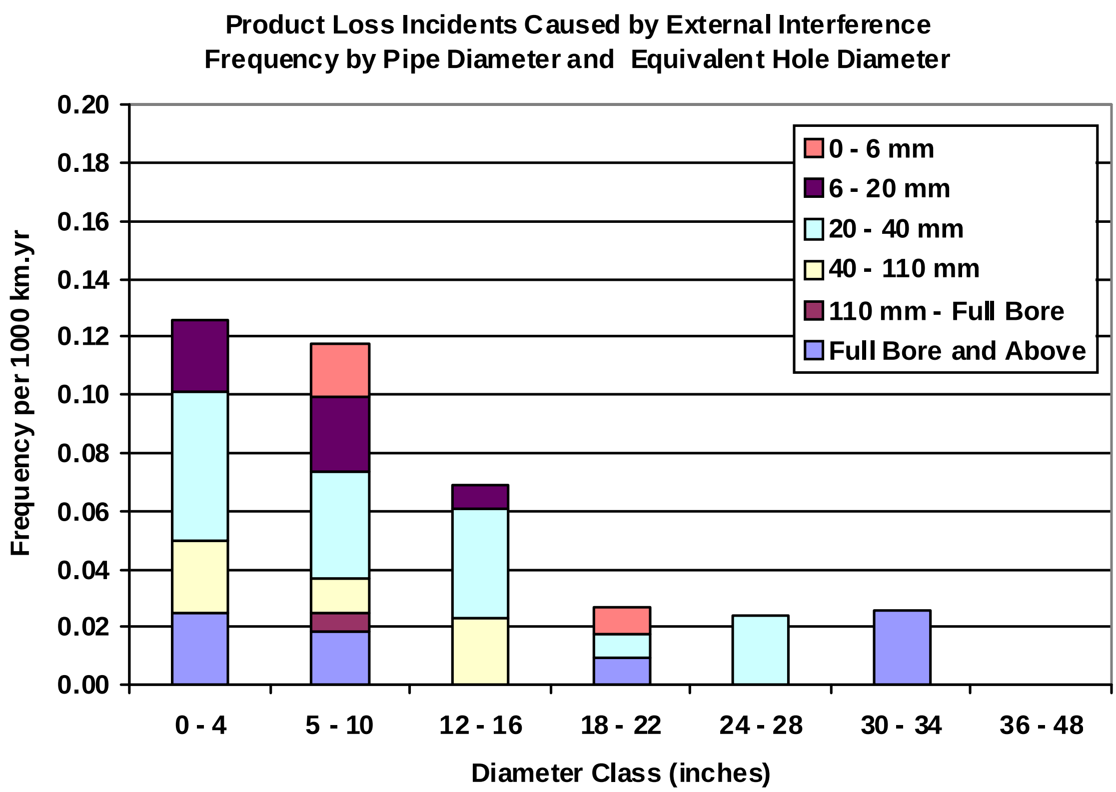


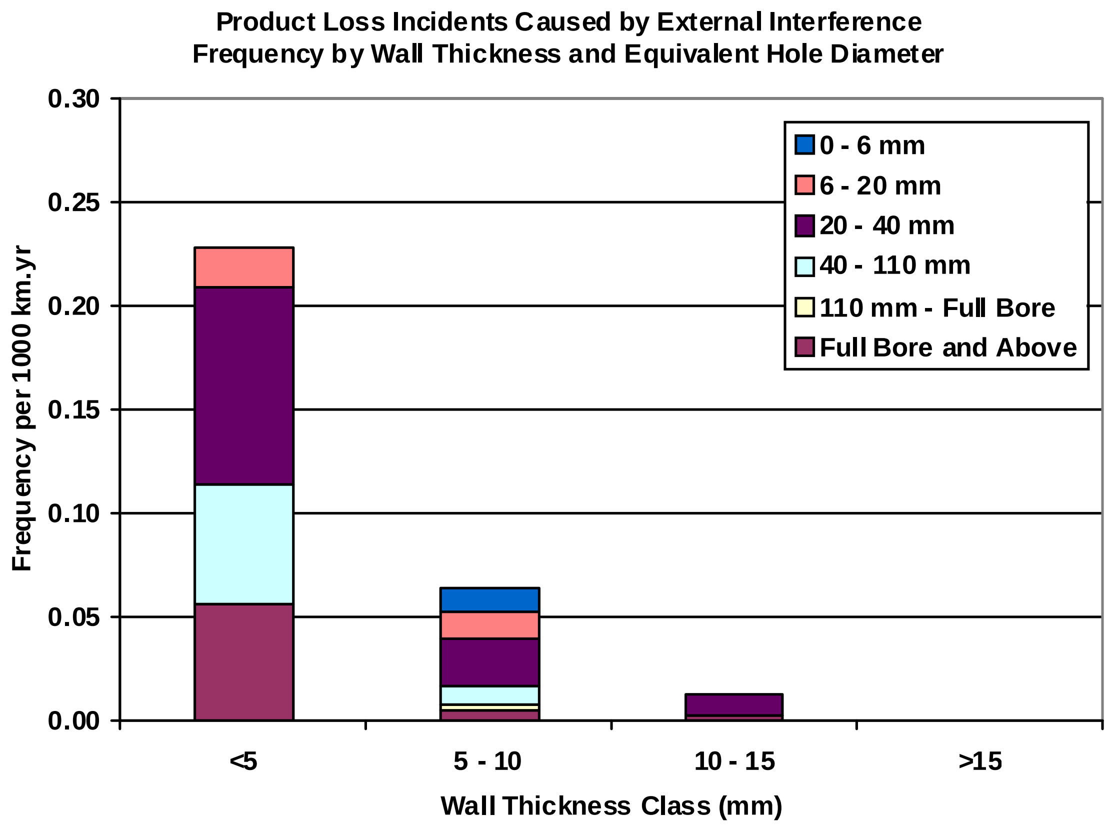
Table 7 – Exposure by Diameter Class

Diameter inches	Exposure km.yr	Incidents	Frequency /1000km.yr
0-4	39239	5	0.127
5-10	161610	19	0.118
12-16	131519	9	0.068
18-22	115165	3	0.026
24-28	127103	3	0.024
30-34	37942	1	0.026
36-48	172806	0	0.000
Total	**785350**	**40**	**0.051**

3.5.2 External Interference by Measured Wall Thickness Class

The relationship between product loss incidents caused by third party interference and wall thickness is shown in Figure 11.

Figure 11



Note: Largest wall thickness for loss of product incident caused by external interference to date is 12.7mm.

Table 8 – Exposure by Wall Thickness Class

Wall Thickness mm	Exposure km.yr	Incidents	Frequency /1000 km.yr
<5	52576	12	0.228
5-10	378151	24	0.063
10-15	297274	4	0.013
>15	57384	0	0.000
Total	**785385**	**40**	**0.051**

3.5.3 External Interference by Area Classification

Figure 12

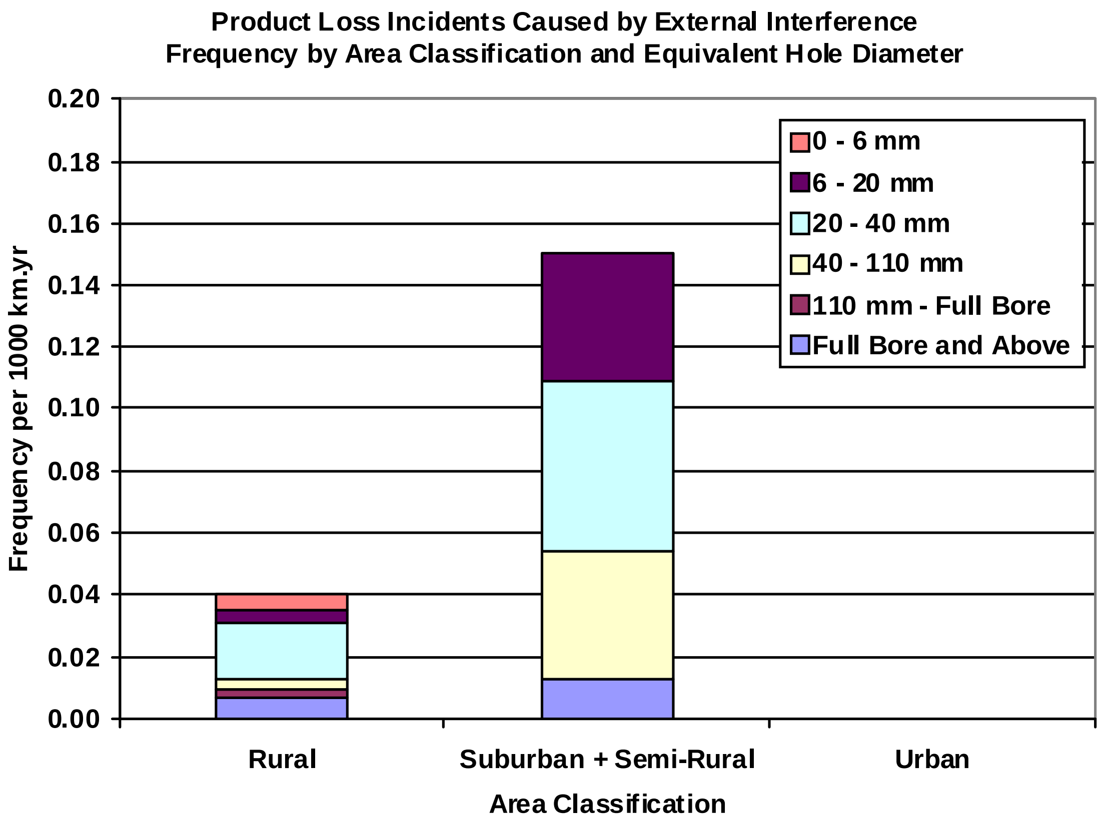


Table 9 – Exposure by Area Classification in km.yr

Area Classification	Exposure km.yr	Incidents	Frequency /1000 km.yr
Rural	711658	29	0.041
Suburban	72722	11	0.151
Urban	1005	0	0.000
Total	**785385**	**40**	**0.051**

Note:
Rural = population density < 2.5 persons per hectare
Suburban = population density > 2.5 persons per hectare and which may be extensively developed with residential properties, and includes data classed as semi-rural
Urban = Central areas of towns or cities with a high population density

3.6 External Corrosion

3.6.1 External Corrosion by Wall Thickness Class

Figure 13

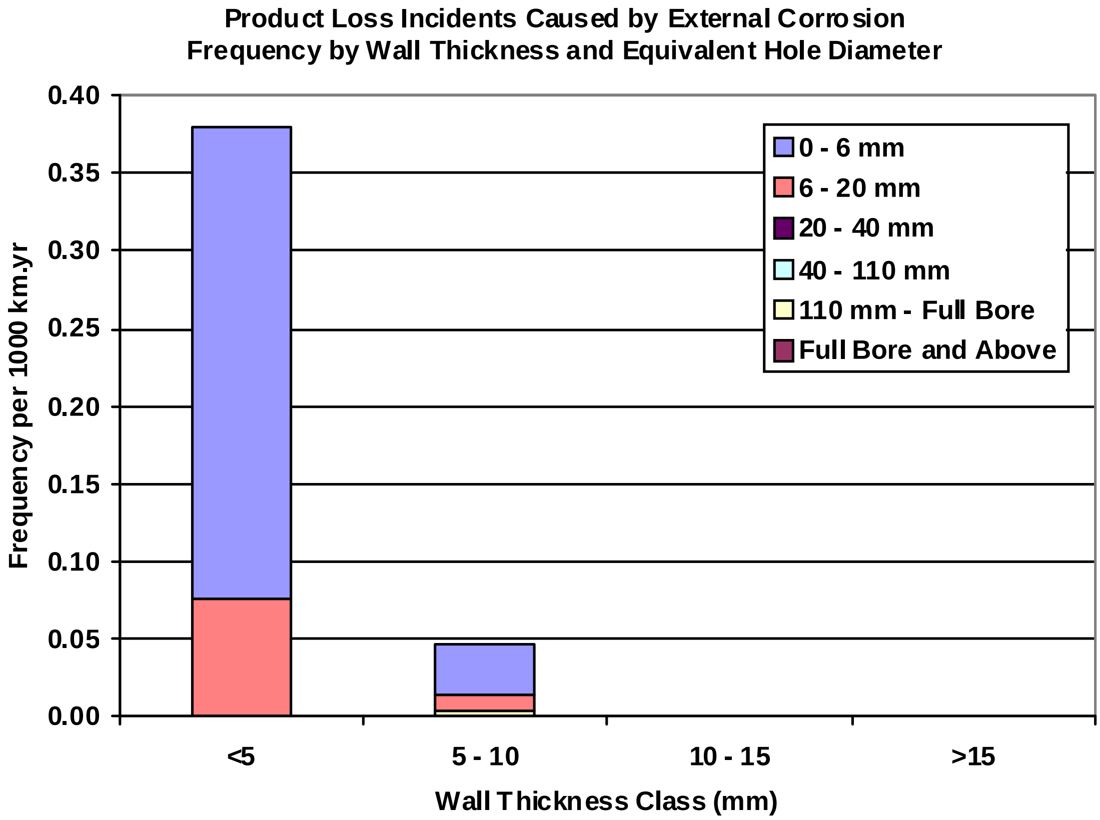


Table 10 – Exposure by Wall Thickness Class

Wall Thickness mm	Exposure km.yr	Incidents	Frequency /1000 km.yr
<5	52576	20	0.380
5-10	378151	17	0.045
10-15	297274	0	0.000
>15	57382	0	0.000
Total	**785385**	**37**	**0.047**

3.6.2 External Corrosion by Year of Construction

Figure 14

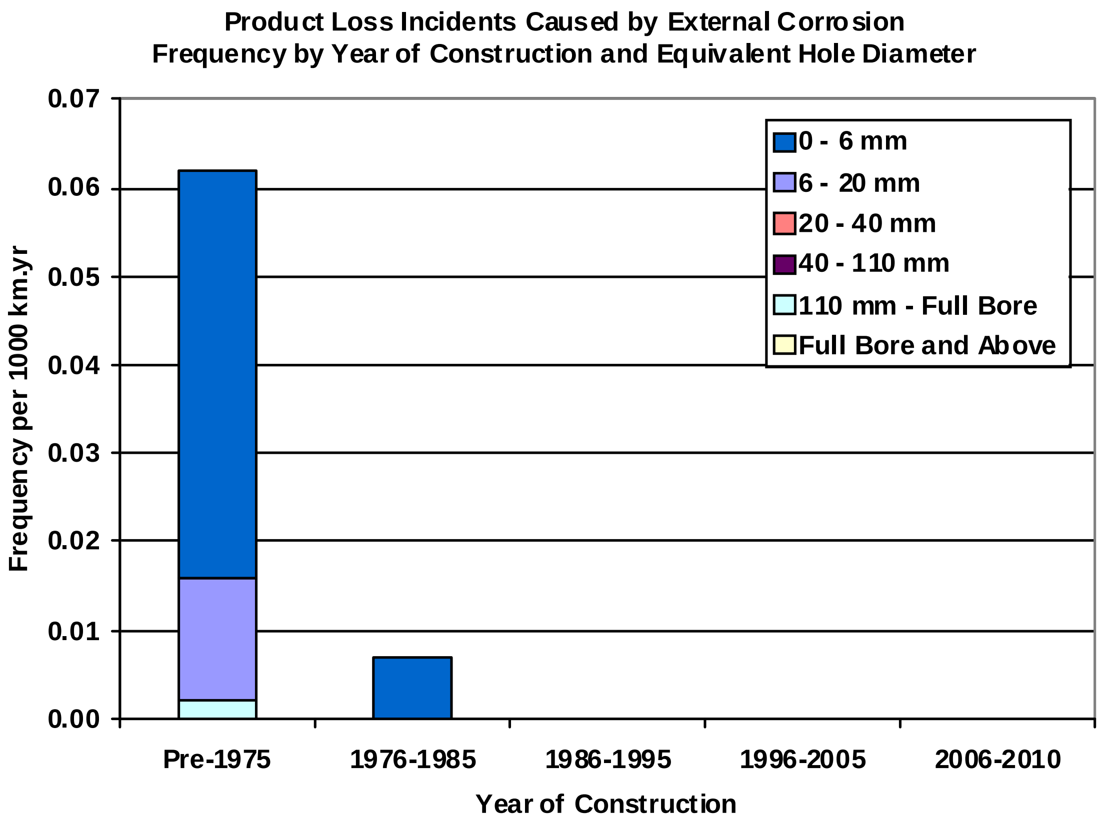


Table 11 – Exposure by Year of Construction

Construction Year	Exposure km.yr	Incidents	Frequency /1000 km.yr
Pre-1975	583858	36	0.062
1976-1985	142457	1	0.007
1986-1995	41115	0	0.000
1996-2005	15610	0	0.000
2000-2004	2345	0	0.000
Total	**785385**	**37**	**0.047**

The reduction in the number of incidents due to external corrosion for pipelines constructed after 1976 is predominantly associated with the introduction of in line inspection, which together with appropriate defect acceptance criteria, means that metal loss defect are detected and repaired before developing to through wall.

3.6.3 External Corrosion by External Coating Type

Figure 15

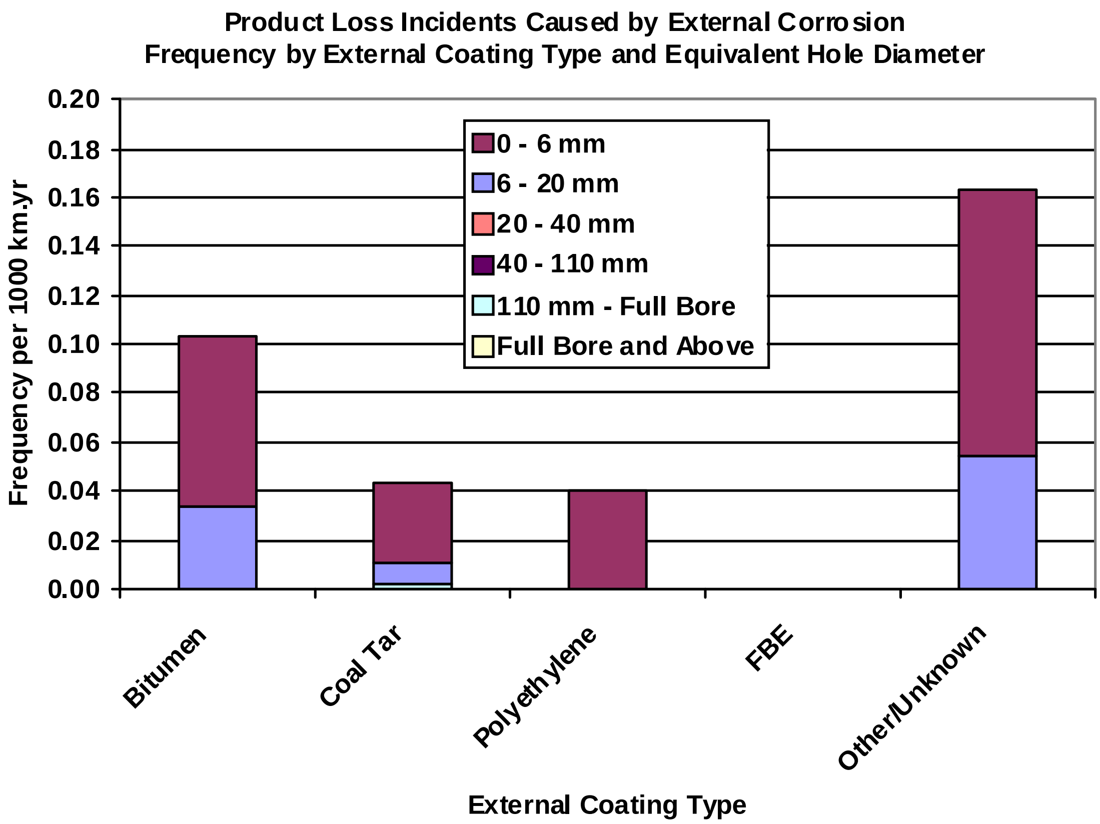
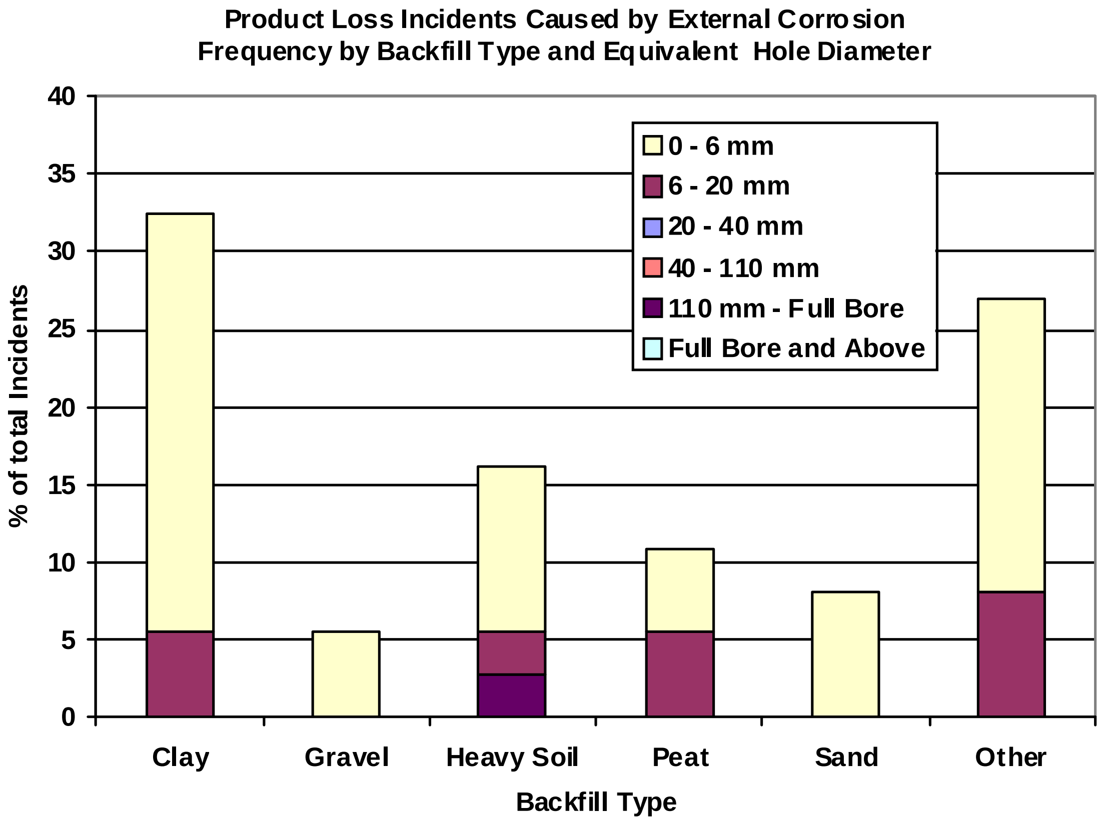


Table 12 – Exposure by External Coating Type

External Coating	Exposure km.yr	Incidents	Frequency /1000 km.yr
Bitumen	29090	3	0.103
Coal Tar	569393	25	0.044
Polyethylene	75292	3	0.047
FBE	74829	0	0.000
Other/Unknown	36780	6	0.163
Total	**785385**	**37**	**0.047**

3.6.4 External Corrosion by Type of Backfill

Figure 16



3.7 Pipeline Failure Classified as "Other"

Pipeline failure rates due to causes other than those defined as

- External interference
- Corrosion
- Material and construction
- Ground movement (or other environmental load)

are generally classified as "Other".

The UKOPA product loss data contains the following incidents under this category:-

Table 13 – Pipeline Failures Classified as "Other"

Other Cause	Incidents
Internal cracking due to wet town gas	30
Pipe-Fitting Welds	4
Leaking Clamps	3
Lightning	1
Soil stress	1
Threaded Joint	1
Electric Cable Arc Strike	1
Total	**41**

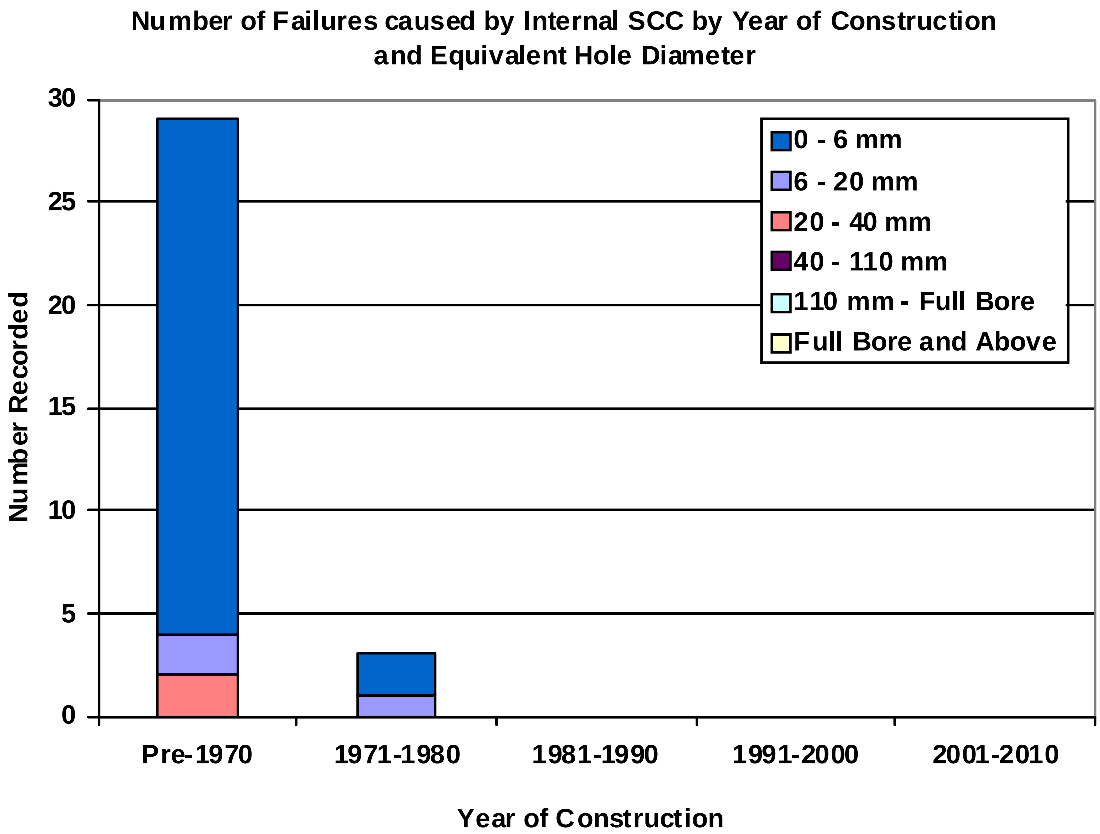
The UKOPA product loss data indicates that "Other" causes account for approximately 28% of the total failure rate.

88% (36 out of 41) of the incidents recorded in this category relate to pipelines constructed before 1970, and are not relevant to pipelines designed, constructed and operated in accordance with current pipeline standards.

3.8 Pipeline Failures Caused by Internal Cracking

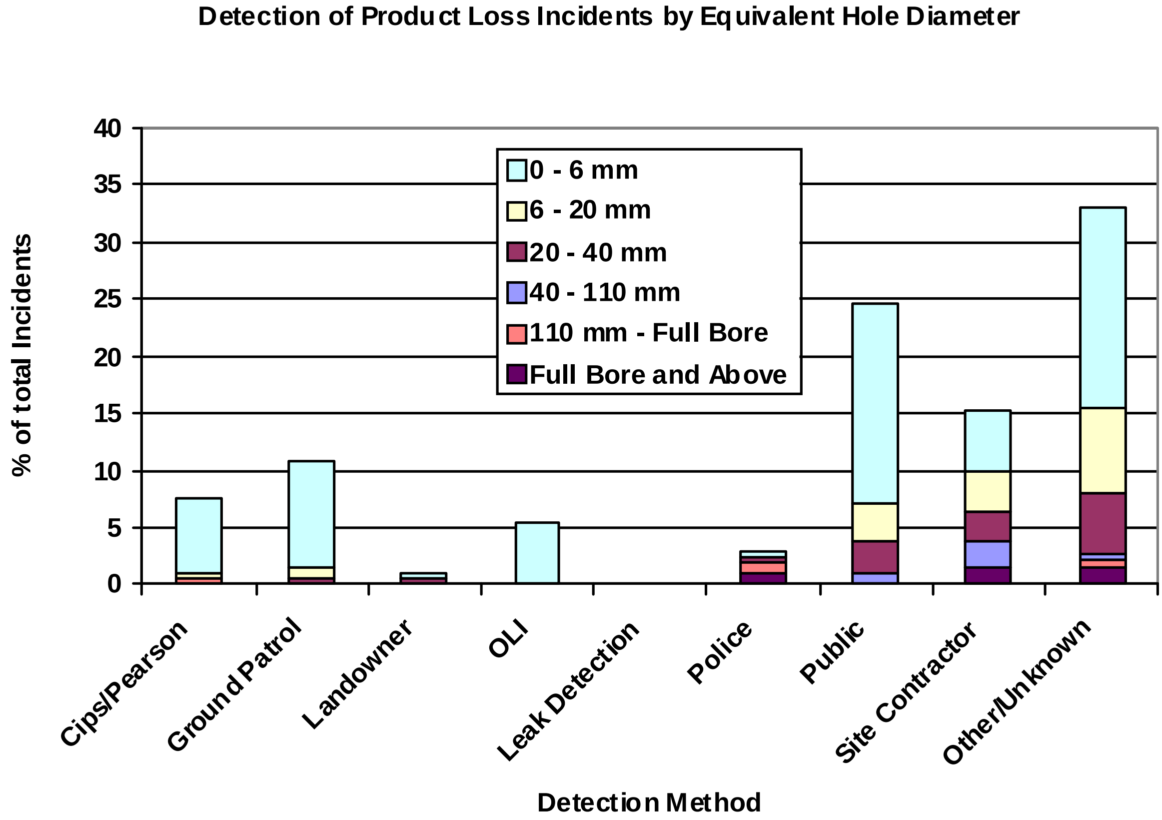
A significant proportion of the failures classified as "Other" (30 out of 41 = 73%) were caused by internal cracking (stress corrosion cracking [SCC]) in pipelines which had seen wet towns gas (pre-natural gas) service. 90% of these failures (27 out of 30) were in pipelines constructed before 1970.

Figure 17



3.9 Detection of Pipeline Failures

Figure 18



Note: Leak detection and On-Line Inspection (OLI) are not applicable to all pipelines.

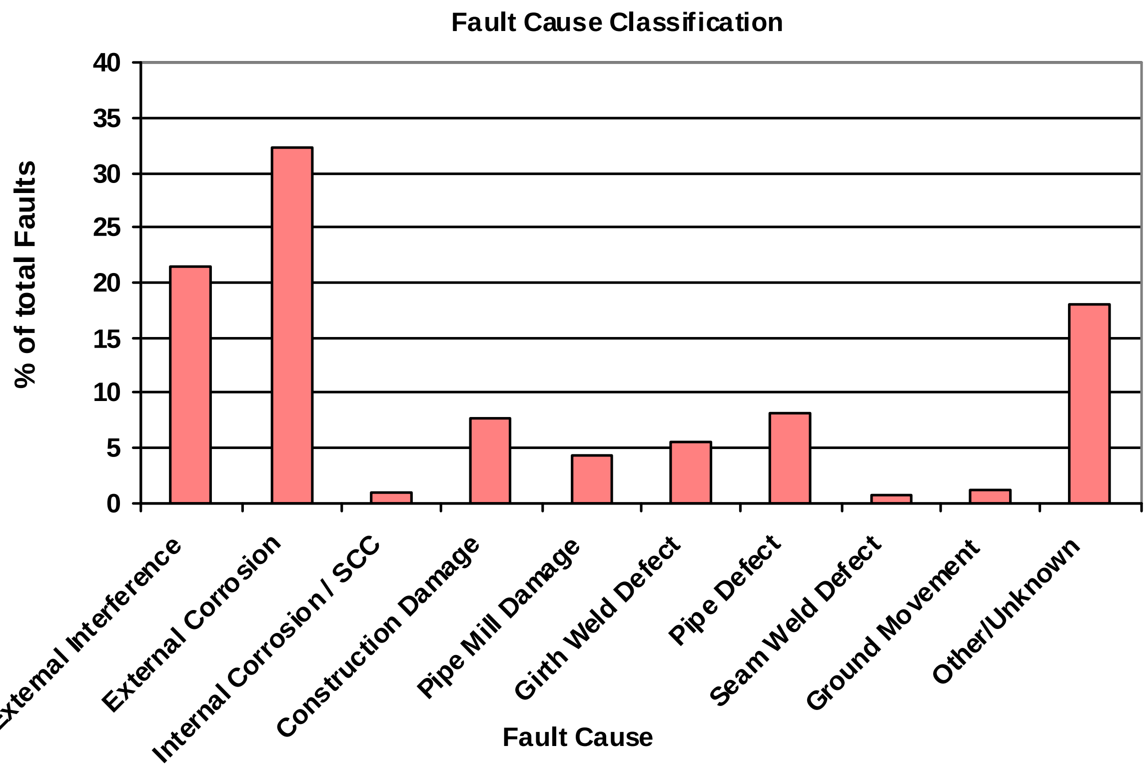
4 Fault Data

4.1 Pipeline Damage Data

A Fault is a feature that has been confirmed by field investigation, excavation and measurement. Any features that are inferred by other measurements such an intelligent pig in line inspections, CIPS, etc. and have not been verified in the field are not included in the UKOPA database. However pipeline defects comprising of coating damage or grinding marks confirmed by field inspection are included.

The total number Faults recorded at the end of 2010 was 3080. The main causes of the Faults are shown in Figure 19.

Figure 19

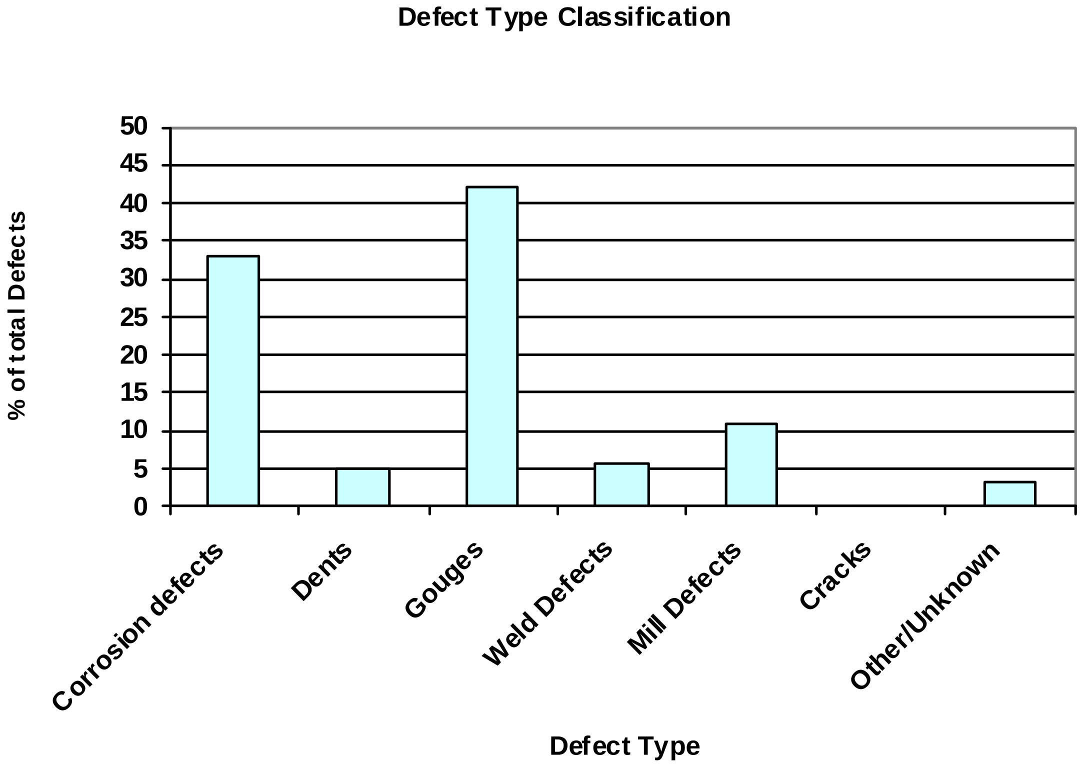


4.2 Part-Wall Defect Data

One of the main benefits of collecting Fault data is to record of the size of part-wall defects which are measured and recorded in the database. Many faults have several defects and as a result the database contained 5087 defects at the end of 2010.

Classification of defect data is shown in Figure 20.

Figure 20



4.3 Statistical Distributions of Defect Dimensions

Pipeline damage due to external interference occurs in the form of gouges, dents or combinations of these. This type of damage is random in nature, and as operational failure data are sparse, recognized engineering practice requires that a predictive model is used to calculate leak and rupture failure frequencies for specific pipelines. Predictive models such as those described in references (1,2,3) use dent-gouge fracture mechanics models to predict the pipeline probability of failure, which is dependent upon the pipeline geometry, material properties and operating pressure.

The UKOPA database includes reports of external interference incidents, including the type of damage (dent, gouge and combinations of these), the size of the damage and the number and location of the incidents. The external interference damage data recorded up to and including 2010 in the UKOPA database has been analyzed to determine the best fit Weibull distribution parameters for gouge length, gouge depth and dent depth. The Weibull distribution parameters for the data are given in Table 14.

Table 14

Distribution Parameters	Gouge Length	Gouge Depth	Dent Depth
Weibull Shape (α)	0.575	0.666	1.028
Weibull Scale (β) mm	127.3	0.846	9.930

These parameters allow pipeline failure probabilities to be derived for external interference events. An estimate of "hit rate" (i.e. frequency of damage incidents) is also required to obtain pipeline frequencies to be calculated. "Hit rate" is dependent on specific pipeline parameters including location (rural-suburban), depth of cover, and frequency of external interference events for the pipeline population.

Note: Weibull distributions were identified as appropriate distributions in work carried out to develop the FFREQ predictive model, which is recommended by UKOPA.

1 A Methodology for the prediction of Pipeline Failure Frequency Due to External Interference. C Lyons, J V Haswell, P Hopkins, R Ellis, N Jackson. IPC 2008-64375, 7th International Pipeline Conference, Calgary 2008.

2 Reduction Factors for Estimating the Probability of failure of Mechanical Damage Due to External Interference. A Cosham, J V Haswell, N Jackson. IPC 2008-64345, 7th International Pipeline Conference, Calgary 2008.

3 Modelling of Dent and Gouges, and the Effect on the Failure Probability of Pipelines. P Seevam, C Lyons, P Hopkins, M Toft. IPC 2008-64061, 7th International Pipeline Conference, Calgary 2008.

4 The Application of Risk Techniques to the Design and Operation of Pipelines. I Corder. C502/016/95, Proceedings of International Conference on Pressure Systems: Operation and Risk Management, Institution of Mechanical Engineers, London, UK, p. 113-125. 1995.