

**Title:**  
**UKOPA Pipeline Product Loss  
Incidents and Faults Report  
(1962-2015)**

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UKOPA

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**UKOPA PIPELINE FAULT DATABASE**



**Pipeline Product Loss Incidents and Faults Report**

(1962 - 2015)

Report of the UKOPA **F**ault **A**nd **R**isk **W**ork **G**roup

Comprising data from:

National Grid  
Scotia Gas Networks  
Northern Gas Networks  
Wales & West Utilities  
BP  
INEOS  
Sabic  
Essar Oil (UK) Limited  
Shell  
E-ON UK  
BPA

Report prepared by Dr C J Lyons & Dr J V Haswell for FARWG

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## Summary

This report presents the 2015 pipeline product loss and incidents results from the UKOPA Pipeline Fault Database, which records pipeline population, and product loss incidents and faults on onshore Major Accident Hazard Pipelines (MAHPs) operated by National Grid, Scotia Gas Networks, Northern Gas Networks, Wales & West Utilities, BP, INEOS, SABIC, Essar Oil (UK) Ltd, Shell, E-ON UK and BPA, covering operating experience up to the end of 2015.

MAHPs are defined by the UK statutory legislation – The Pipelines Safety Regulations 1996 [PSR96] as amended.

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 2015 is 0.218 incidents per 1000 km.yr, whilst in the previous report this figure was 0.219 incidents per 1000 km.yr (covering the period from 1962 to 2014). The overall trend continues to show a reduction in failure frequency.

The failure frequency over the last 20 years is 0.082 incidents per 1000 km.yr, compared to 0.074 incidents per 1000 km.yr in the previous report.

For the last 5 years the failure frequency is 0.108 incidents per 1000 km.year, whilst in the previous report this figure was 0.078 incidents per 1000 km.year (covering the 5 year period up to the end of 2014). The most recent 5 year failure frequency shows an increase on the previous rate.

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.

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## 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, and operational ALARP assessments on, major hazard pipelines. The main multiplier in pipeline risk assessments is the per unit length failure rate, which directly influences the extent of the risk zones adjacent to the pipelines.

UKOPA published the first report in November 2000, presenting the first set of data for pipeline incidents resulting in the unintentional release of product up to the end of 1998.

### 1.2 Purpose of the UKOPA Pipeline Fault Database

The purpose of the UKOPA Pipeline Fault database is to:

- Record leak and fault data for UK MAHPs
- 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 on failure 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 population is extensive and the data covers over 50 years of operation, there are pipeline groups (e.g. large diameter, recently constructed pipelines) on which no faults or failures have occurred, or for which failure data is not statistically significant; however it is unreasonable to assume that the failure frequency for these pipelines is zero.

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 insufficient failure data exist.

Using Structural Reliability Analysis and fracture mechanics 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 external interference failures to be calculated.

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

## 2 Product System Data

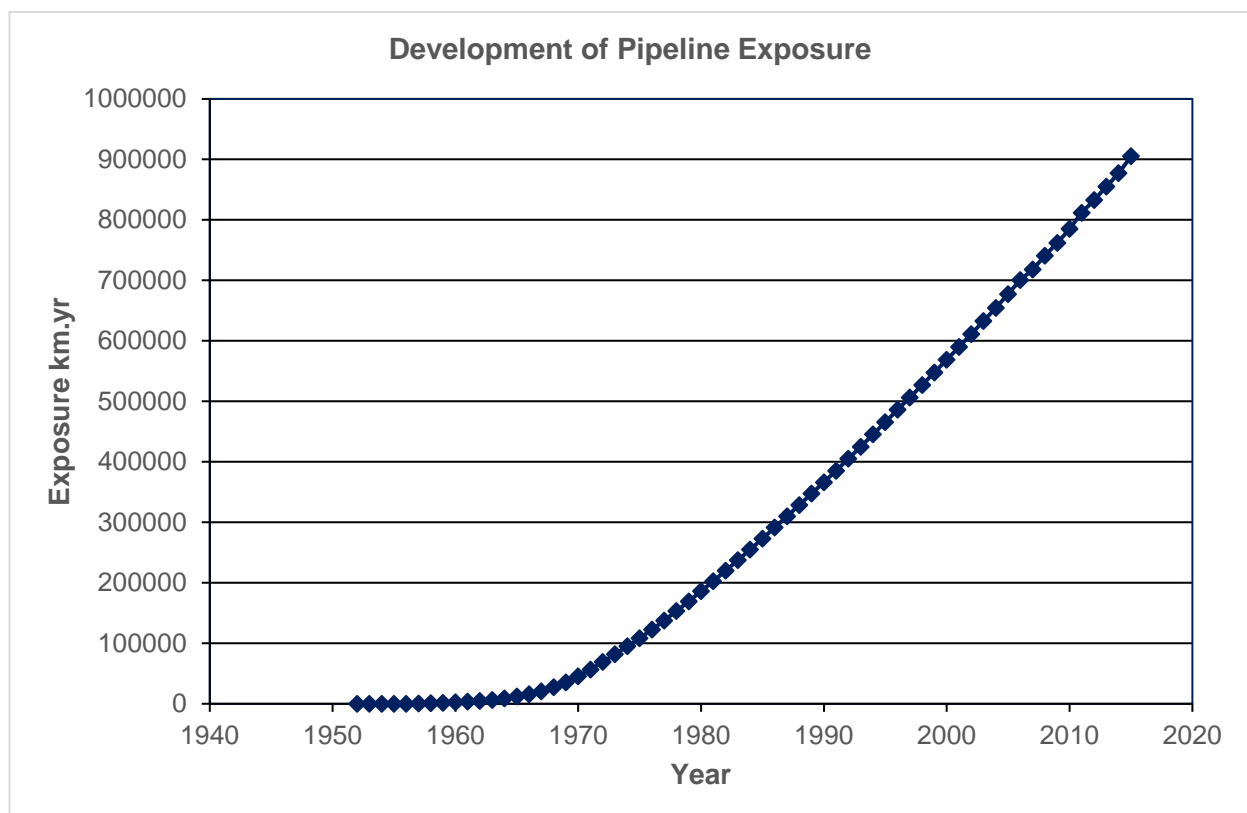
### 2.1 Exposure

The total length of MAHPs\* in operation at the end of 2015 for all participating companies (National Grid, Scotia Gas Networks, Wales & West Utilities, Northern Gas Networks, BP, Essar Oil (UK) Ltd, Shell, INEOS, Sabc, E-ON UK and BPA) was 22,553 km. The total exposure in the period 1952 to the end of 2015 was 900,151 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 sections of cross-country pipelines are included in totals.*

**Figure 1**



\*For definition of MAHPs – see UK statutory legislation – The Pipelines Safety Regulations 1996 [PSR96] as amended, for the full definition – for natural gas the classification is above 8 bar absolute.



## 2.2 Transported Products

The lengths (in km) of pipeline in operation at the end of 2014, by transported product, are shown in Table 1 below.

**Table 1 - Lengths of Pipeline in Operation**

Natural Gas (Dry)	20,783	Propylene	36
Ethylene	1142	Condensate	24
Natural Gas Liquids	251	Propane	21
Crude Oil (Spiked)	224	Butane	20
Ethane	38	<b>TOTAL</b>	<b>22,553</b>
Hydrogen	14		<b>Kilometres</b>

Note: The database includes 543 km of decommissioned pipeline (440 km previously used to transport natural gas, 56 km to transport ethylene, 37 km to transport carbon monoxide, 5 km to transport propane and 5 km to transport butane).

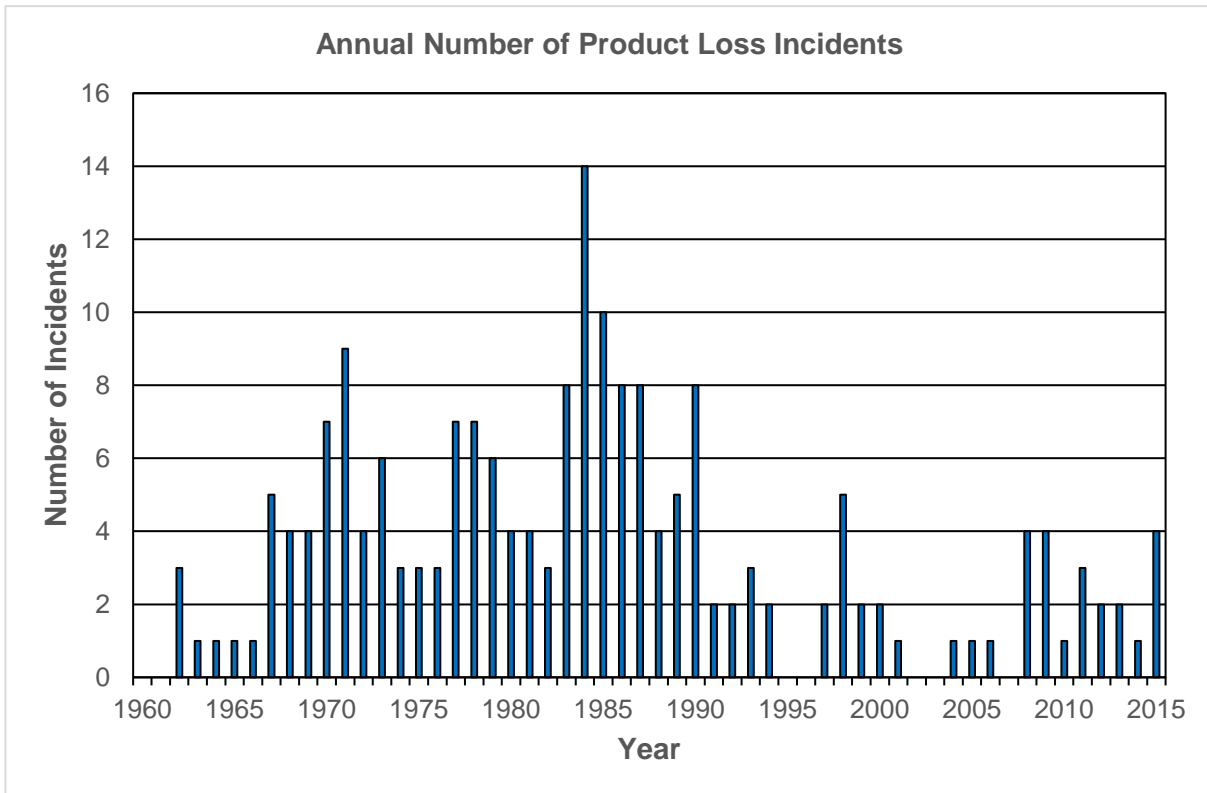
## 3 Product Loss Incident Data

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 196 product loss incidents were recorded over the period between 1962 and 2015 compared with 192 product loss incidents documented in the report covering the period to 2014. No product loss incidents were recorded prior to 1962. An annual breakdown of incidents is illustrated in Figure 2.

**Figure 2**

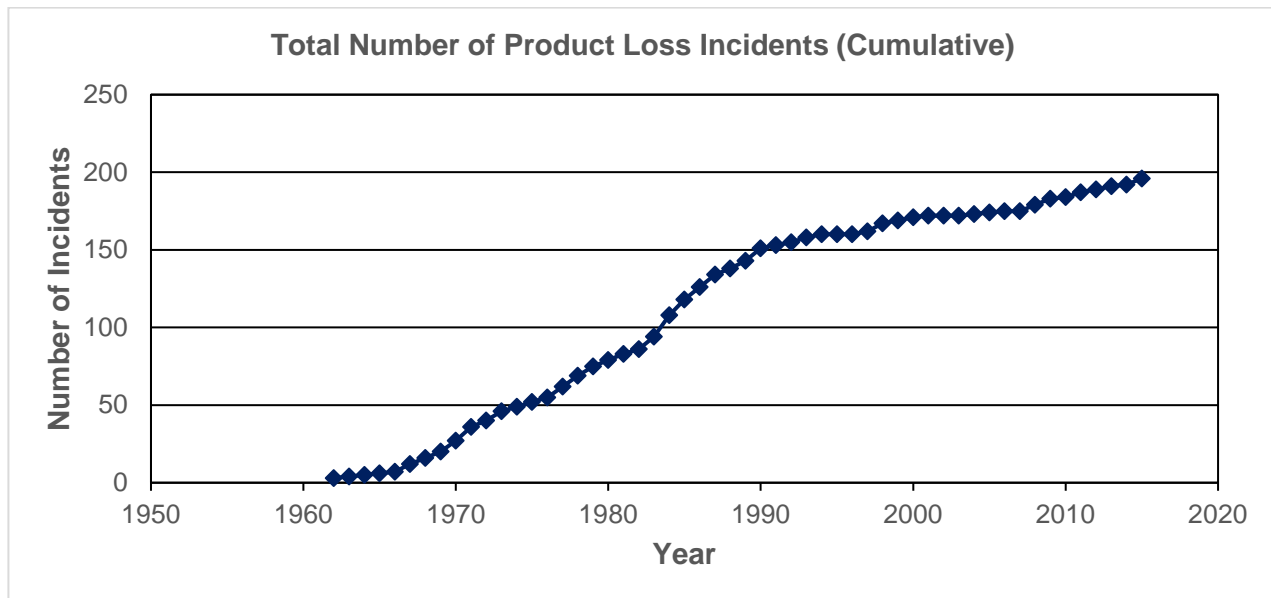


**Differences between 2014 and 2015 product loss statistics**

Four product loss incidents were recorded in 2015. One incident was due to external interference, one due to external corrosion, two are recorded as other (one was a leak at a socket and spigot weld, the other at a syphon flange<sup>1</sup>). In comparison, in 2014 there was one product loss recorded, due to external interference. The cumulative number of incidents over the period 1962 to 2015 is shown in Figure 3.

<sup>1</sup> The socket and spigot weld and syphon flange are historic and uncommon details

**Figure 3**



### 3.1 Incident Ignition

There were 9 out of 196 (4.6%) 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	Date
Pipe	Unknown	0 – 6 mm	1963
Pipe	Internal Corrosion	0 - 6 mm	1969
Pipe	Girth weld	6 – 20 mm	1970
Pipe	Pipe Defect	6 – 20 mm	1971
Pipe	Unknown	6 – 20 mm	1972
Pipe	Ground Movement	Full Bore	1984
Pipe	Other	40 - 110 mm	1991
Pipe	Pipe Defect	0 – 6 mm	1994
Pipe	Lightning Strike	0 – 6 mm	1998

### 3.2 Incident Frequency

#### 3.2.1 Trends over the Past 5, 20 and 49 Years

The incident frequency over eight consecutive 5-year periods up to the end of 2015 is shown in Table 3.



**Table 3 - 5 Year Incident Frequency**

<b>Period</b>	<b>Number of Incidents</b>	<b>Total Exposure [km.yr]</b>	<b>Frequency [Incidents per 1000 km.yr]</b>
1966 - 1970	21	33306	0.631
1971 - 1975	25	63036	0.397
1976 - 1980	27	77627	0.348
1981 - 1985	39	87167	0.447
1986 - 1990	33	93202	0.354
1991 - 1995	9	99233	0.091
1996 - 2000	11	103122	0.107
2001 - 2005	3	108742	0.028
2006 - 2010	10	107787	0.093
2011 - 2015	12	111390	0.108

The overall incident frequency by hole size over the period 1962 - 2015 is shown in Table 4.

**Table 4**

<b>Equivalent Hole<sup>#</sup> Size Class</b>	<b>Number of Incidents</b>	<b>Frequency [Incidents per 1000 km.yr]</b>
Full Bore* and Above	8	0.009
110mm – Full Bore*	3	0.003
40mm – 110mm	7	0.008
20mm – 40mm	24	0.027
6mm – 20mm	32	0.035
0 – 6mm	120	0.133
Unknown	2	0.002
Total	196	0.218

\* Full Bore<sup>2</sup> = diameter of pipeline

# Equivalent hole size quoted in this report is the circular hole diameter in mm with an area equivalent to the observed (usually non-circular) hole size.

The total exposure for the last 20 years 1995-2015 is 439704 km.yrs and the resulting incident frequency is shown in Table 5.

**Table 5**

<b>Hole Size Class</b>	<b>Number of Incidents</b>	<b>Frequency [Incidents per 1000 km.yr]</b>
Full Bore* and Above	1	0.002
110mm – Full Bore*	0	0.000
40mm – 110mm	0	0.000
20mm – 40mm	6	0.014
6mm – 20mm	6	0.014
0 – 6mm	23	0.052
Unknown	0	0.000
Total	36	0.082

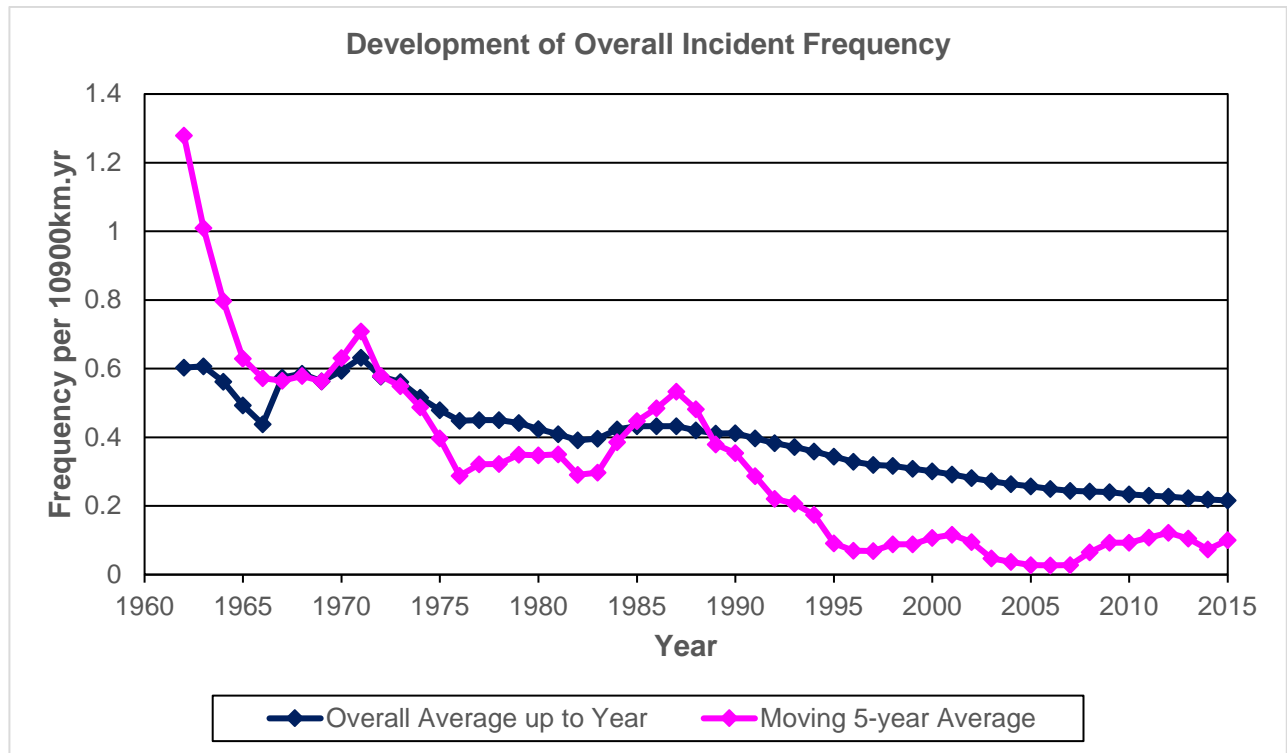
The failure frequency over the last 20 years is therefore 0.082 incidents per 1000 km.yrs and for the last 5 years (2011-2015) is 0.108 incidents per 1000 km.yr.

These compare with the failure frequency during the period 1962-2015 of 0.218 incidents per year per 1000 km.yr. An overview of the development of this failure frequency over the period 1962 to 2015 is shown in Figure 4 below.

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 (2011-2015, 2010-2014, 2009-2013 etc.).

<sup>2</sup> Full bore releases include large holes in small diameter pipelines

Figure 4



### 3.2.2 Confidence Intervals

Confidence intervals take uncertainty into account. For a specified confidence level (e.g. 95%), the greater the exposure, the narrower the confidence interval. In other words, the uncertainty decreases as more operating experience is gained.

Pipeline failures are discrete events, that tend to occur randomly, and are independent of each other. To calculate the confidence intervals, it is therefore assumed that the failure data will follow a Poisson distribution. The 95% confidence intervals for the overall average failure frequency are shown in Figure 5, and for the 5-year average in Figure 6.

Figure 5

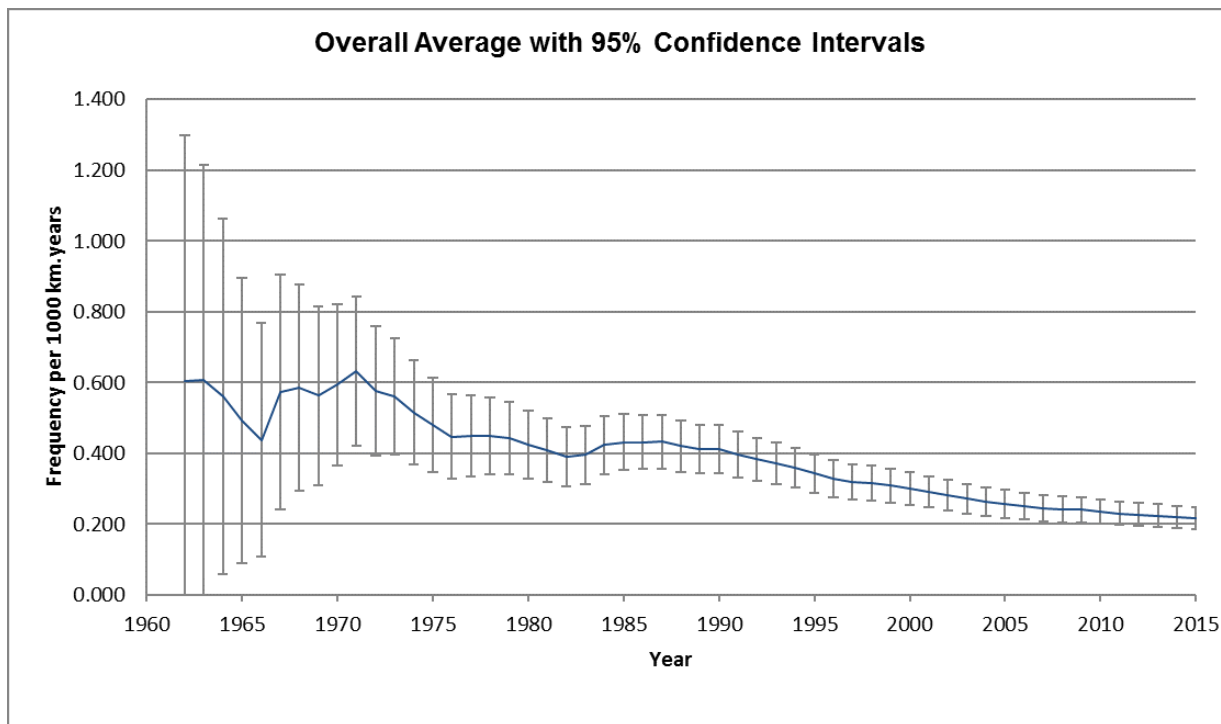


Figure 5 shows that the overall frequency for the whole period is 0.216 per 1000 km.yrs +/- 0.031.

Figure 6

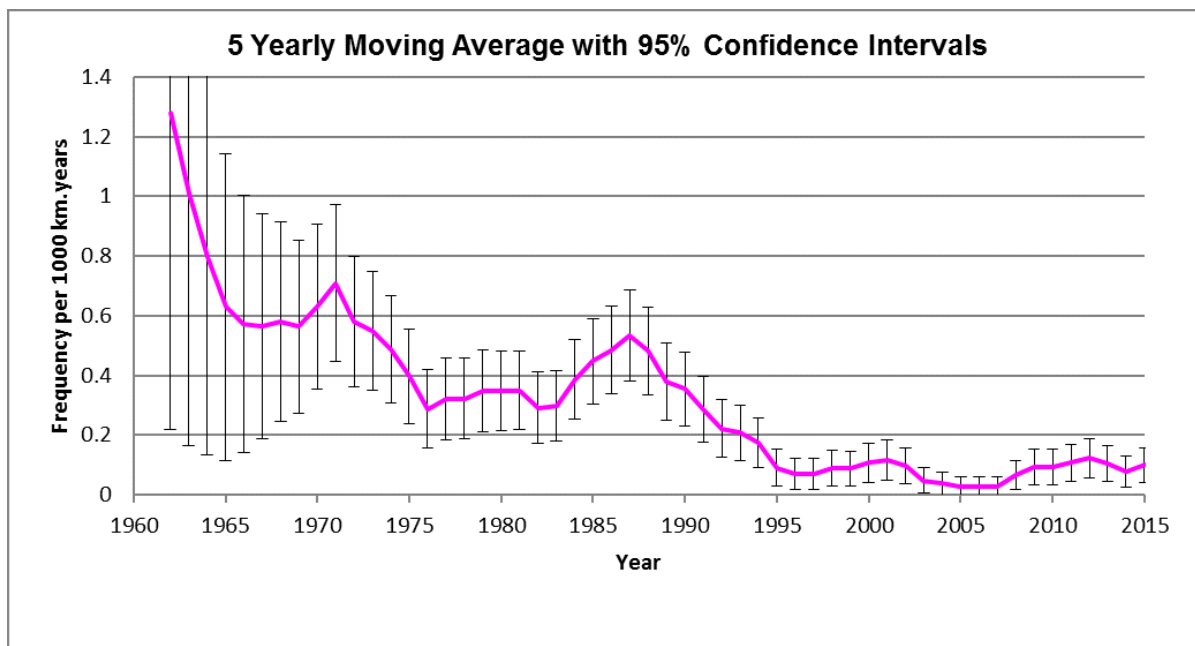
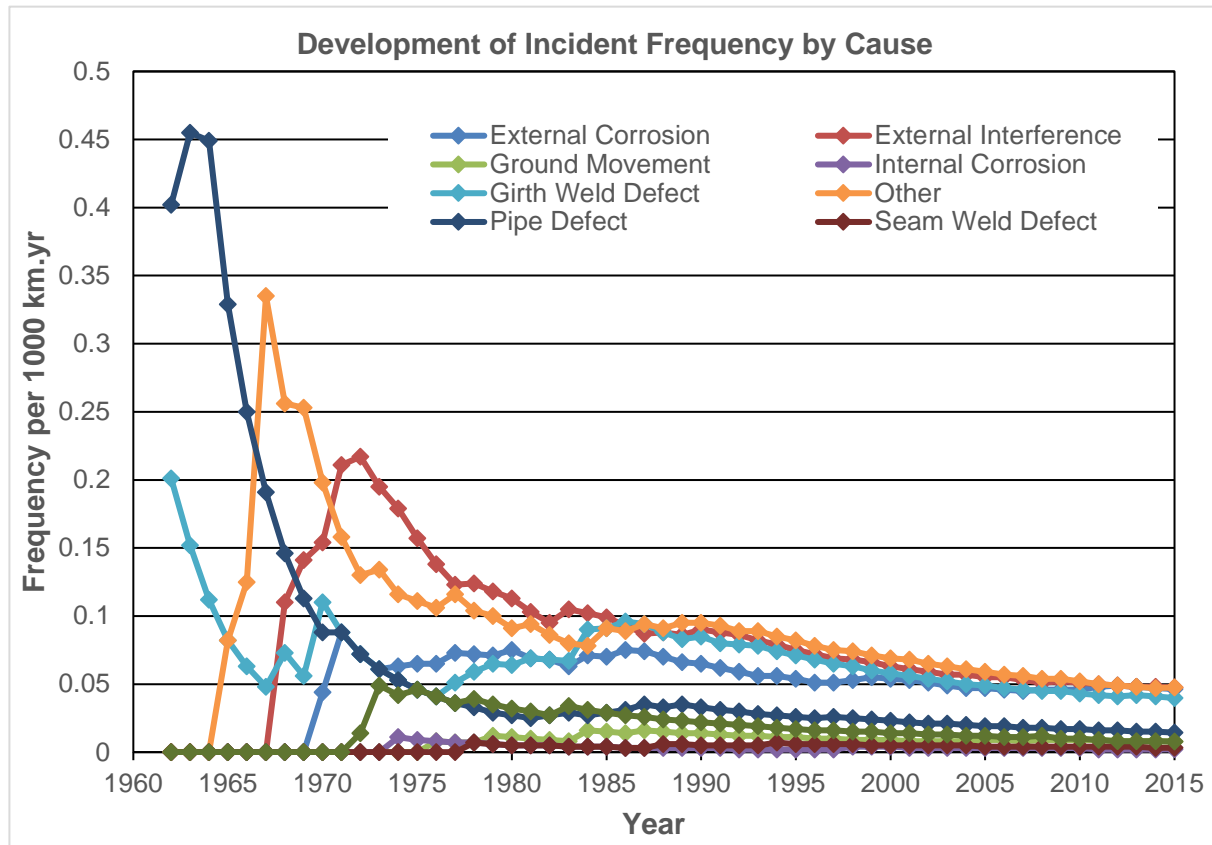


Figure 6 shows that the 5-year average failure frequency for 2010-2015 is 0.100 per 1000 km.yrs +/- 0.058.

### 3.3 Incident Frequency by Cause

The development of product loss incident frequency by cause is shown in Figure 7, and the number of incidents due to each cause is listed in Table 6.

**Figure 7**



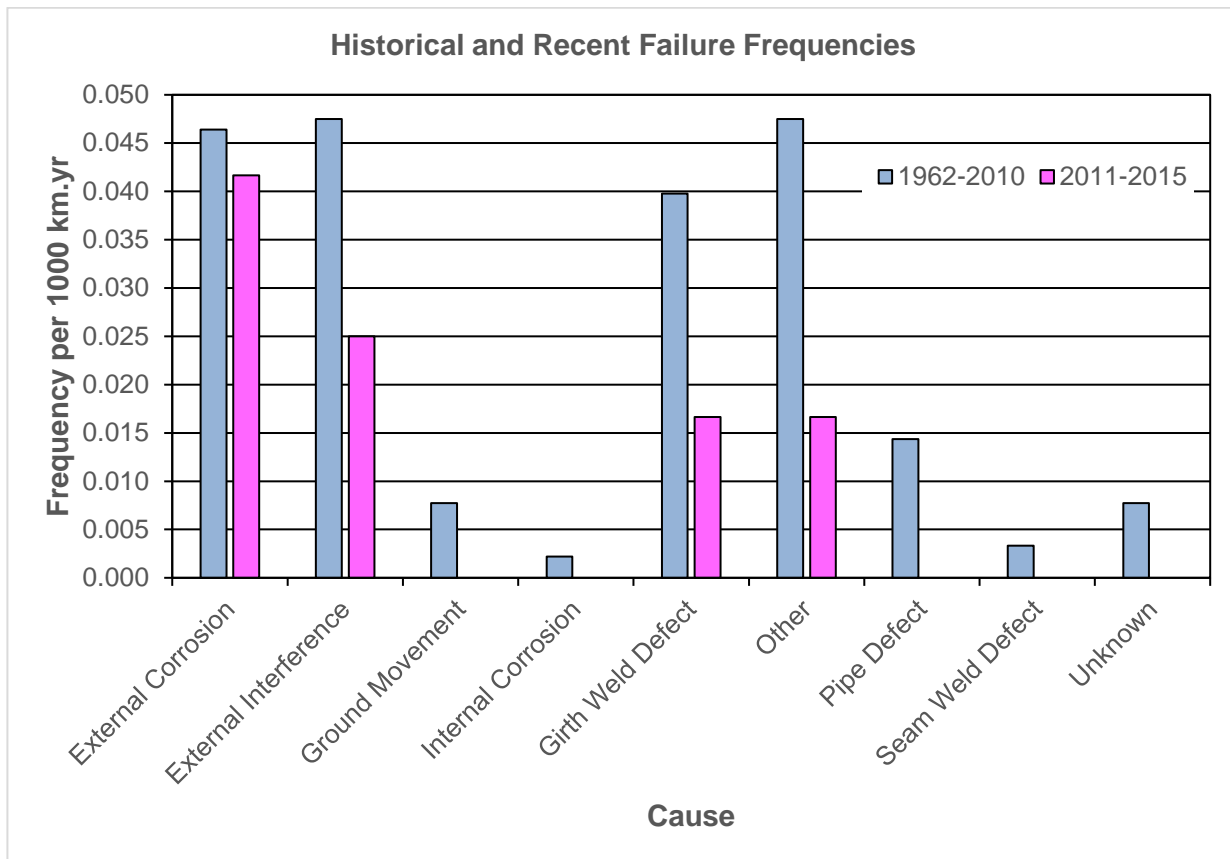
**Table 6 – Product Loss Incidents by Cause**

Product Loss Cause	No. of Incidents
Girth Weld Defect	36
External Interference	43
Internal Corrosion	2
External Corrosion	42
Unknown	7
Other	43
Pipe Defect	13
Ground Movement	7
Seam Weld Defect	3
<b>Total</b>	<b>196</b>



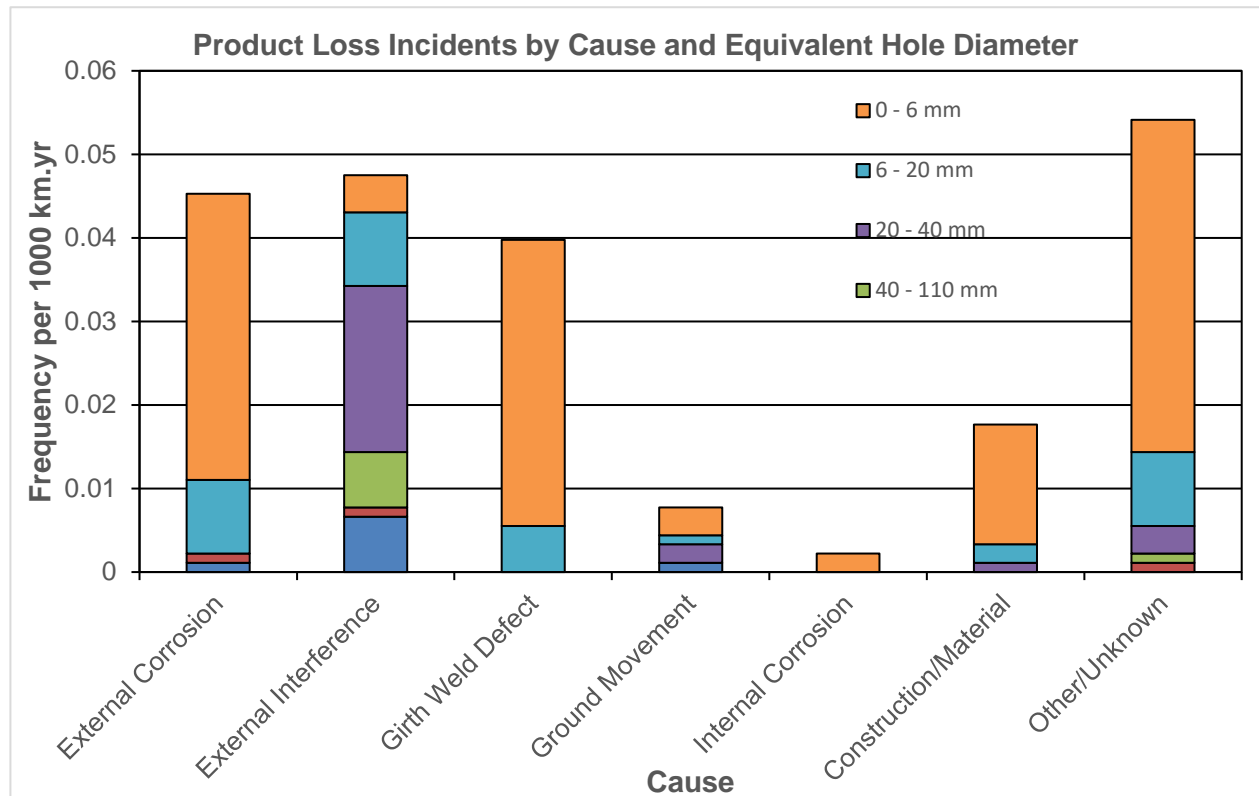
Figure 8 shows the product loss incident frequency by cause over the period 1962- 2015 compared with the frequency over the last 5 years (2011-2015).

**Figure 8**



An overview of the product loss incident frequency by cause and size of leak in the period 1962 to 2015 is shown in Figure 9.

**Figure 9**



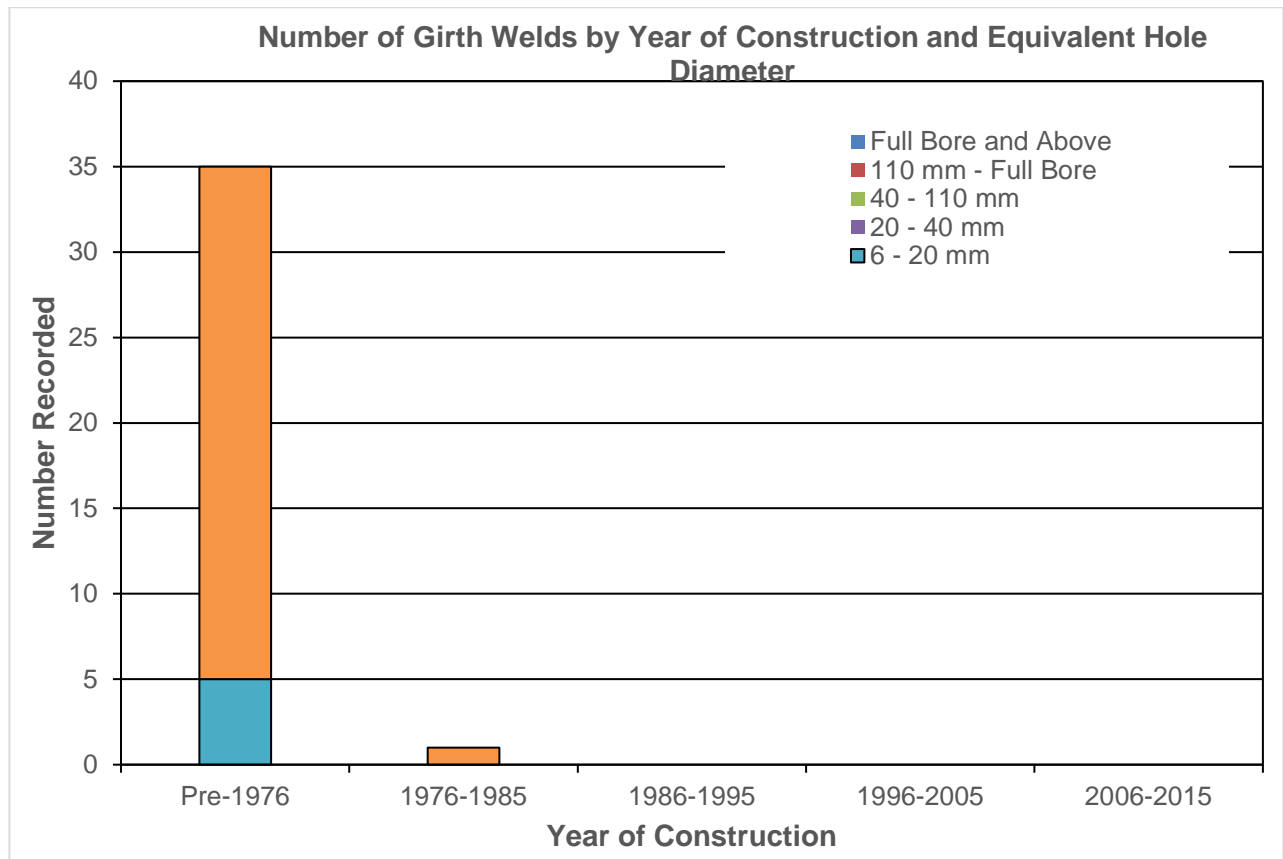
*Construction/Material = Seam Weld Defect + Pipe Defect + Pipe Mill Defect + Damage during Original Construction*

*\* Full Bore ≡ diameter of pipeline*

### 3.4 Girth Weld Defects

Figure 10 shows that 36 leaks due to girth weld defects were recorded in pipelines constructed before 1985, 35 of which were in pipelines constructed before 1972.

**Figure 10**



The reduction in the number of girth weld defects in pipelines constructed after 1972 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.

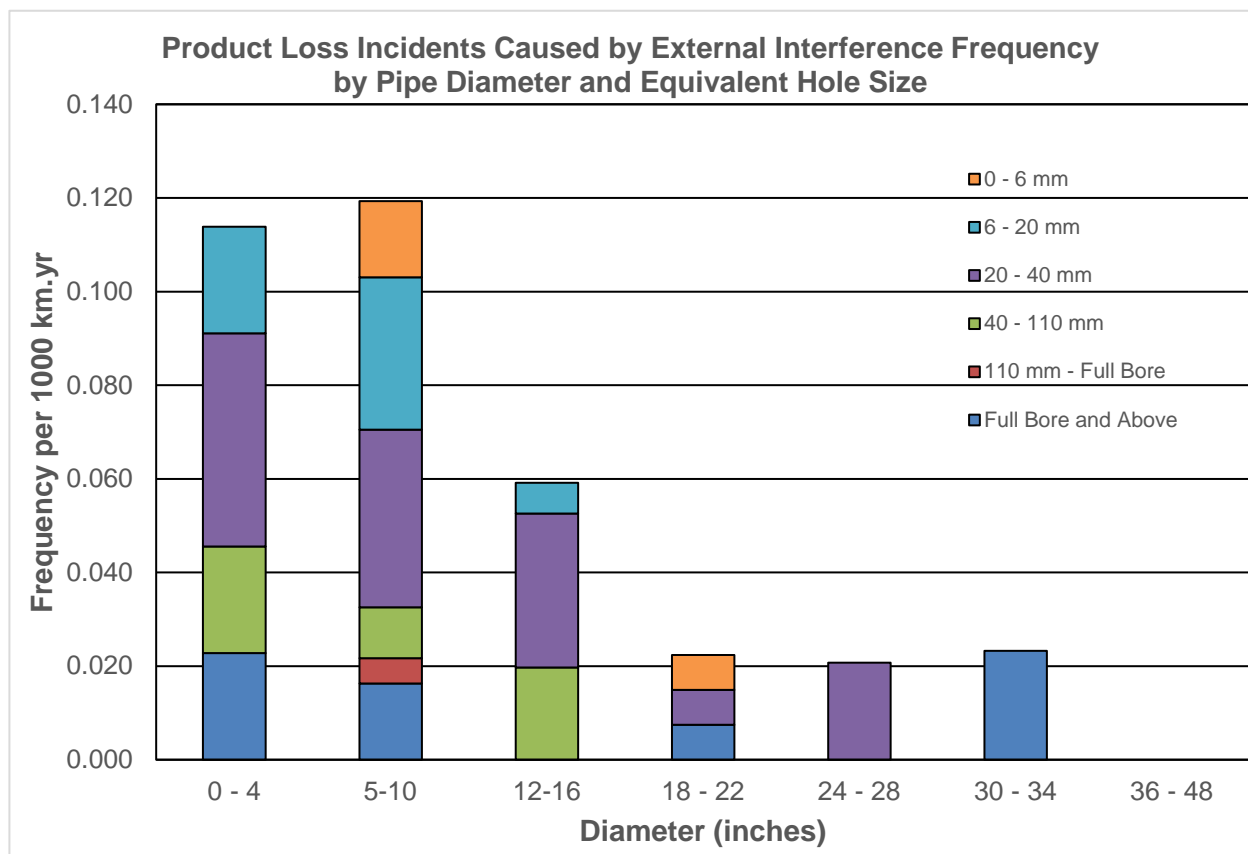
### 3.5 External Interference

External interference is one of the main causes of product loss incidents with 42 recorded failures attributable to this cause.

#### 3.5.1 External Interference by Diameter Class

Figure 11 shows the product loss incident frequencies associated with external interference by diameter class and by hole size.

**Figure 11**



**Table 7 – Exposure by Diameter Class**

Diameter [inches]	Exposure [km.yrs]	External Interference Incidents	Frequency [per 1000 km.yr]
0-4	43699	5	0.114
5-10	183316	22	0.120
12-16	151190	9	0.060
18-22	133330	3	0.023
24-28	143785	3	0.021
30-34	42718	1	0.023
36-48	202113	0	0.000
<b>Total</b>	<b>900151</b>	<b>43</b>	<b>0.048</b>

### 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 12.

**Figure 12**



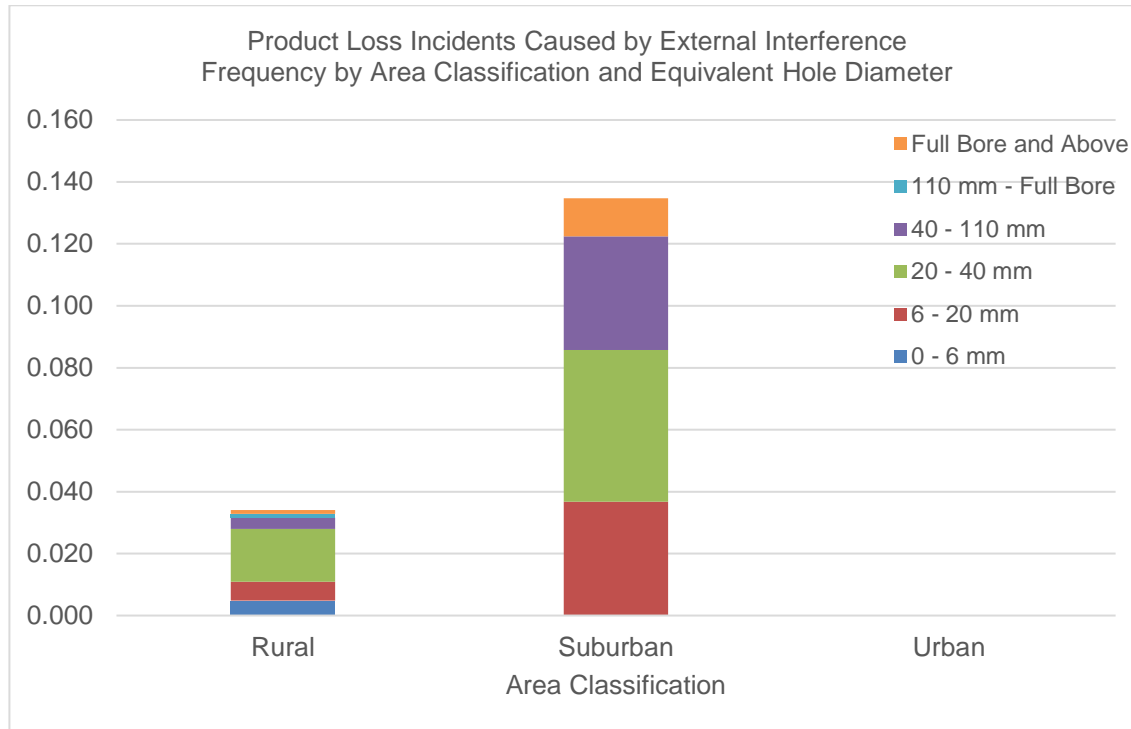
*Note: Largest wall thickness for loss of product incident caused by external interference to date is 12.7mm.*

**Table 8 – Exposure by Wall Thickness Class**

Wall Thickness [mm]	Exposure [km.yr]	External Interference Incidents	Frequency [per 1000 km.yr]
<5mm	58254	13	0.223
6-10mm	424077	26	0.061
11-15mm	343891	4	0.012
>15mm	73929	0	0.000
<b>Total</b>	<b>900151</b>	<b>43</b>	<b>0.048</b>

### 3.5.3 External Interference by Area Classification

**Figure 13**



**Table 9 – Exposure by Area Classification in km.yr**

Area Classification	Exposure [km.yr]	External Interference Incidents	Frequency [per 1000 km.yr]
Rural	817751	32	0.039
Suburban	81220	11	0.135
Urban	1180	0	0.000
<b>Total</b>	<b>900151</b>	<b>43</b>	<b>0.048</b>

*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 14

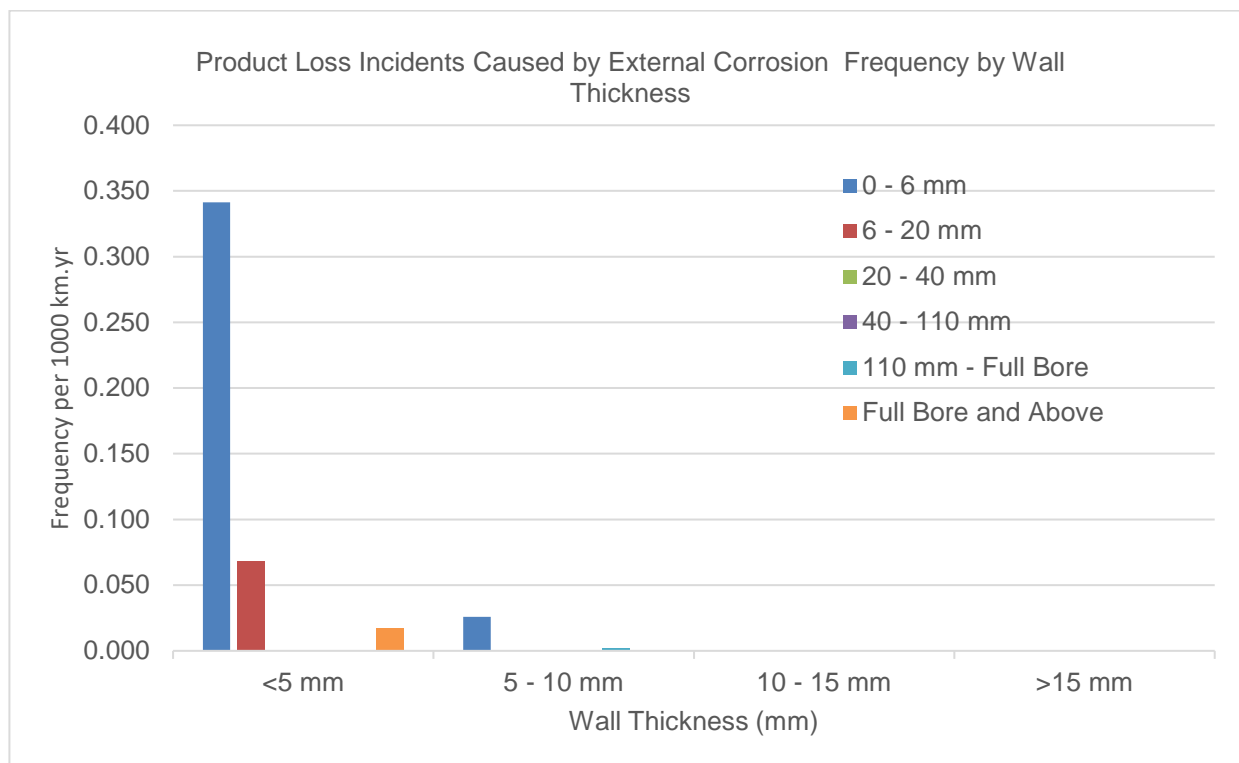


Table 10 – Exposure by Wall Thickness Class

Wall Thickness [mm]	Exposure [km.yr]	External Corrosion Incidents	Frequency [per 1000 km.yr]
<5 mm	58254	25	0.429
6-10mm	424077	16	0.038
11-15mm	343891	0	0.000
>15mm	73929	0	0.000
<b>Total</b>	900151	41	0.046

Note – one corrosion leak wall thickness size is unknown.

### 3.6.2 External Corrosion by Year of Construction

Figure 15

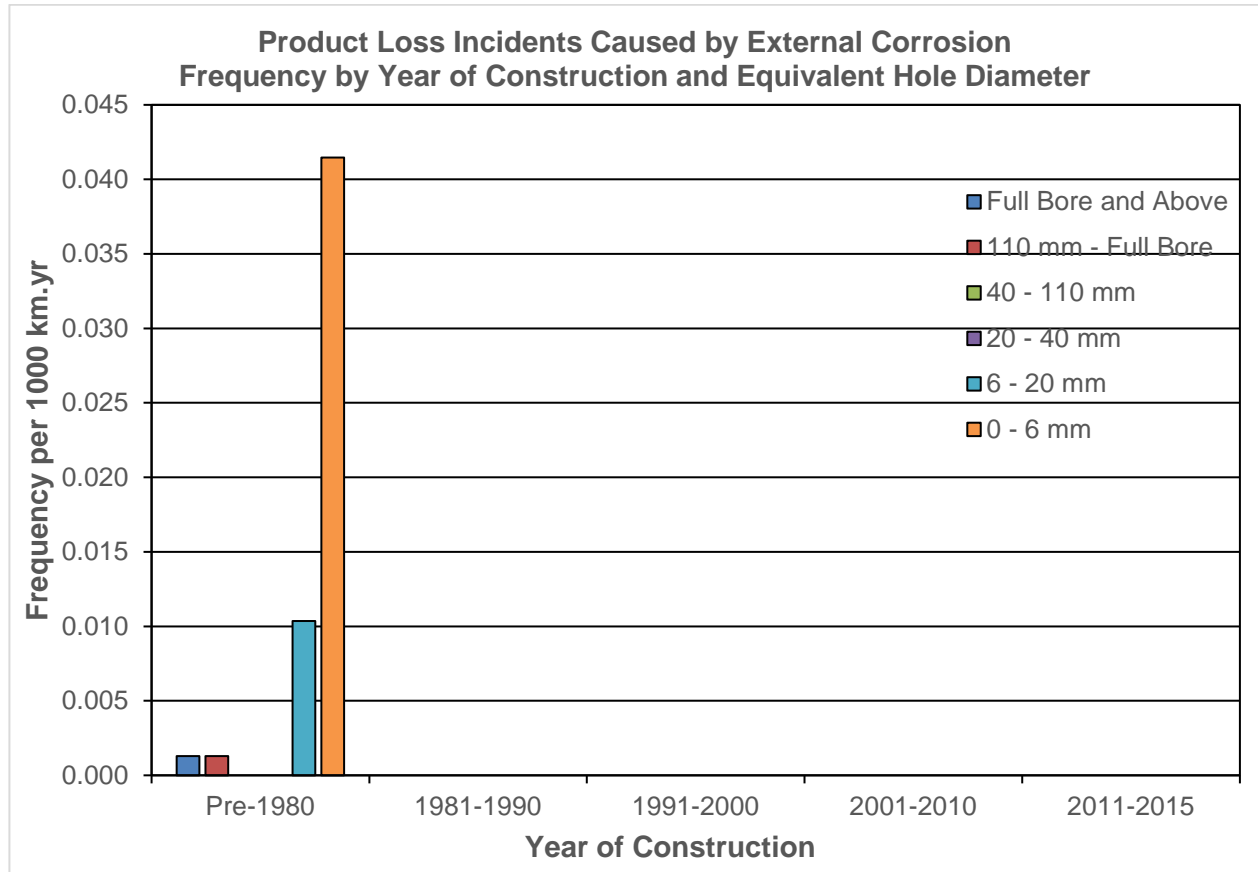


Table 11 – Exposure by Year of Construction

Construction Year	Exposure [km.yr]	External corrosion Incidents	Frequency [per 000 km.yr]
Pre-1980	767161	42	0.055
1980-1989	71080	0	0.000
1990-1999	43820	0	0.000
2000-2009	18001	0	0.000
2010-2014	89	0	0.000
<b>Total</b>	<b>900150</b>	<b>42</b>	<b>0.047</b>

The reduction in the number of incidents due to external corrosion for pipelines constructed after 1980 is partly associated with the introduction of in line inspection, which together with appropriate defect acceptance criteria and improved cathodic protection monitoring systems, means that metal loss defects are detected and repaired before developing to through-wall product loss incidents.



### 3.6.3 External Corrosion by External Coating Type

Figure 16

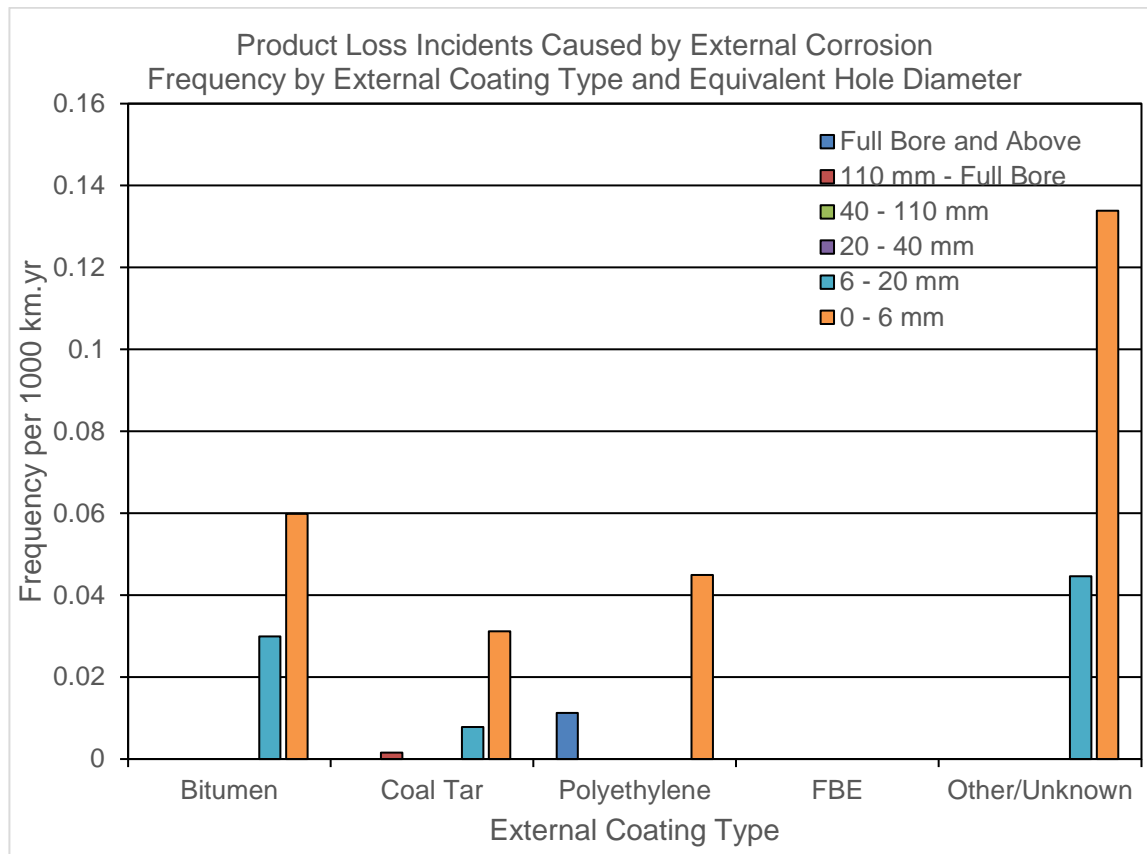
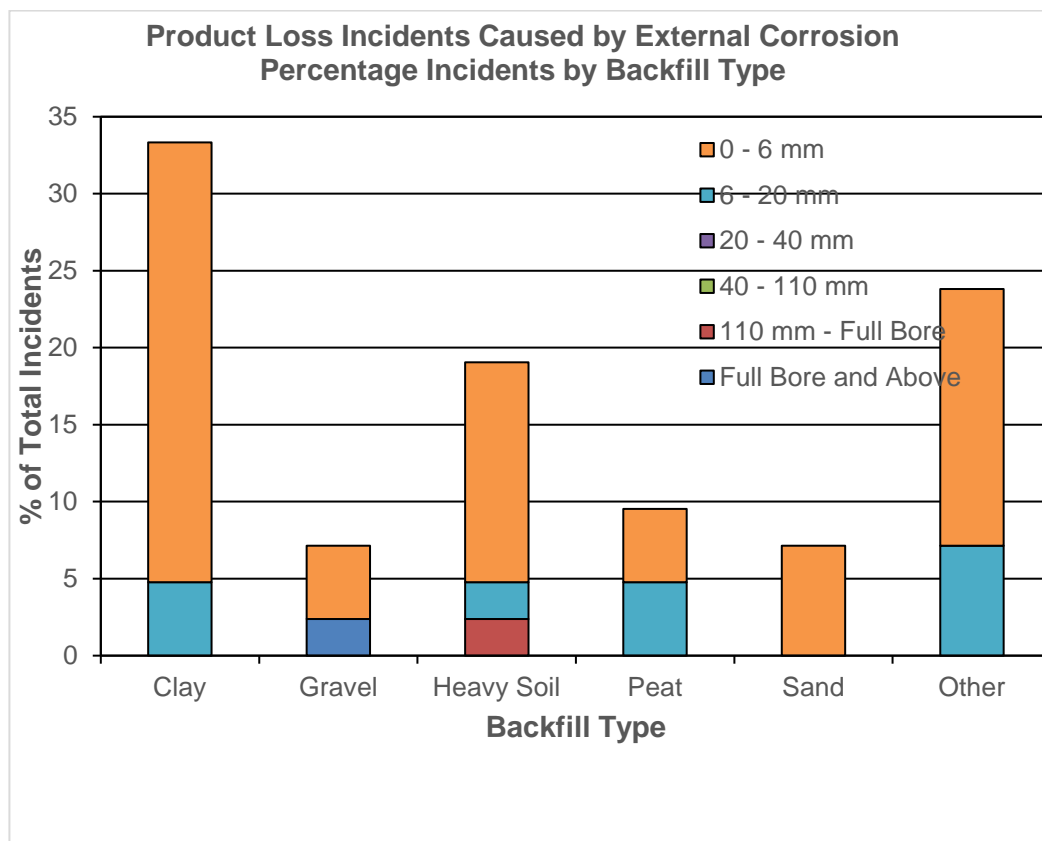


Table 12 – Exposure by External Coating Type

External Coating	Exposure [km.yr]	External corrosion Incidents	Frequency [per 1000 km.yr]
Bitumen	33176	3	0.090
Coal Tar	637282	26	0.041
Polyethylene	88437	5	0.057
FBE	96637	0	0.000
Other/Unknown	44619	8	0.179
<b>Total</b>	<b>900151</b>	<b>42</b>	<b>0.047</b>

## 3.6.4 External Corrosion by Type of Backfill

Figure 17



## 3.6 Pipeline Failures 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
Socket & Spigot weld	1
Syphon Flange	1
<b>Total</b>	<b>43</b>

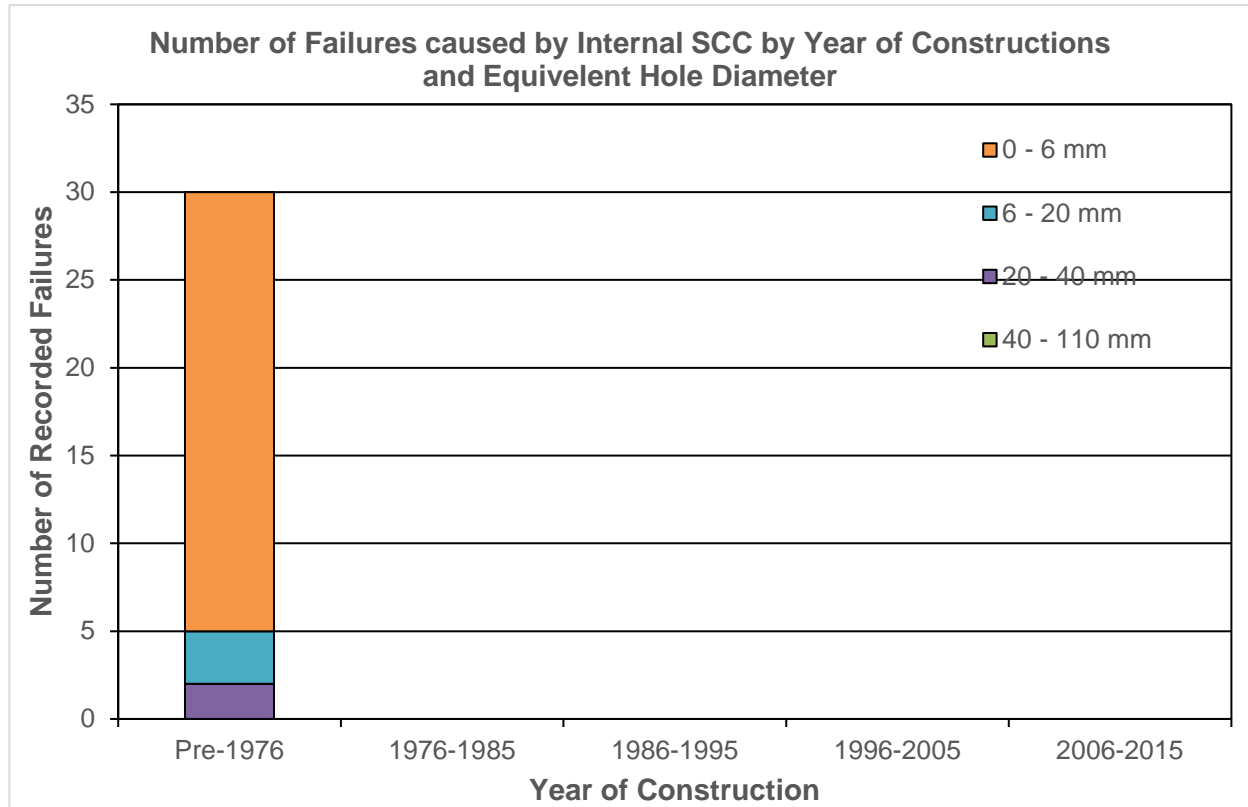
The UKOPA product loss data indicates that “Other” causes account for approximately 21% of the total failure rate.

88% (36 out of 43) 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.

### 3.7 Pipeline Failures Caused by Internal Cracking

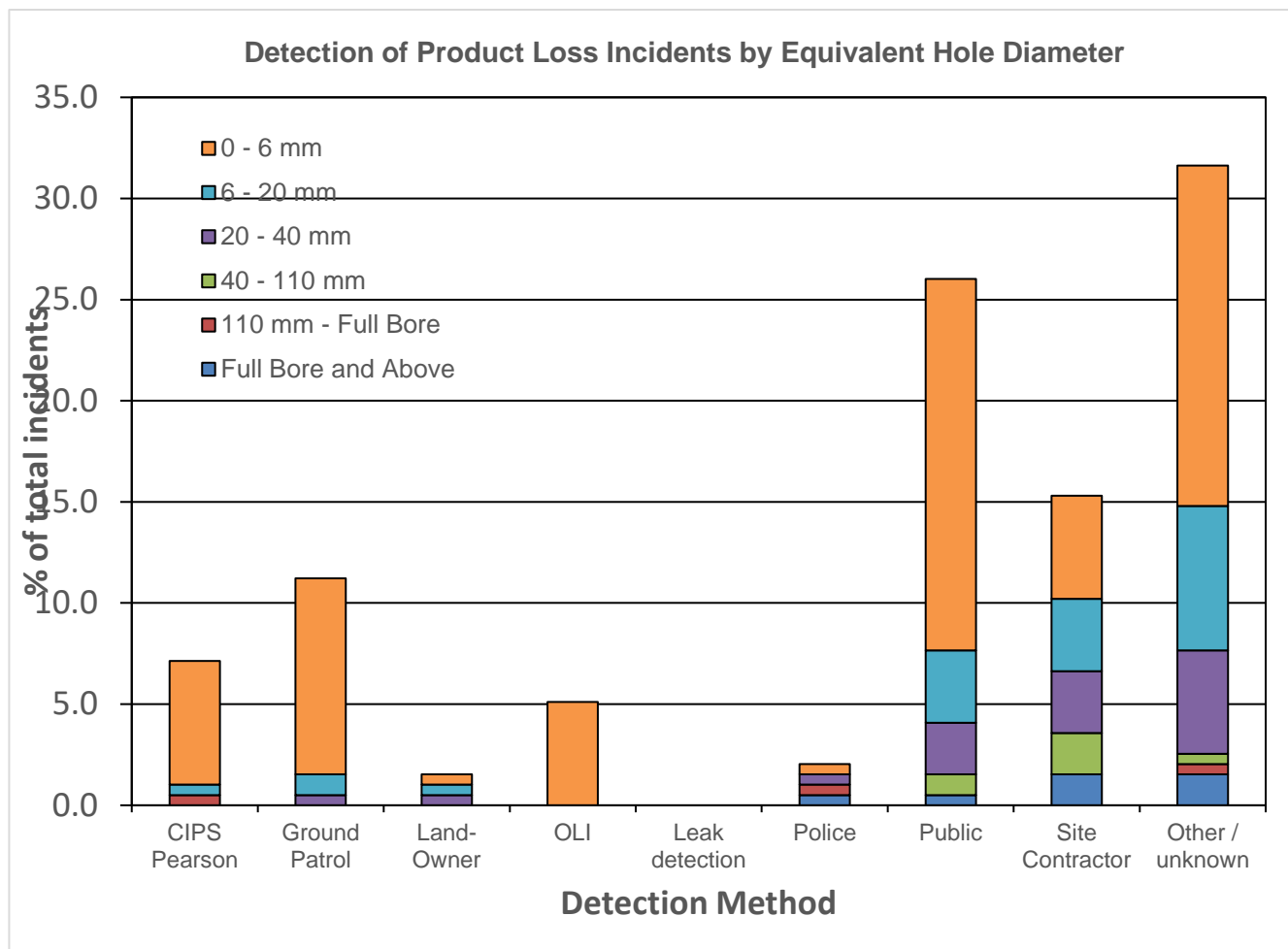
A significant proportion of the failures classified as “Other” (30 out of 41 = 73%) were caused by internal cracking (stress corrosion cracking [SCC]) in pipelines which had seen wet towns gas (pre-natural gas) service. 93% of these failures (28 out of 30) were in pipelines constructed before 1972.

**Figure 18**



## 3.8 Detection of Pipeline Failures

Figure 19



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

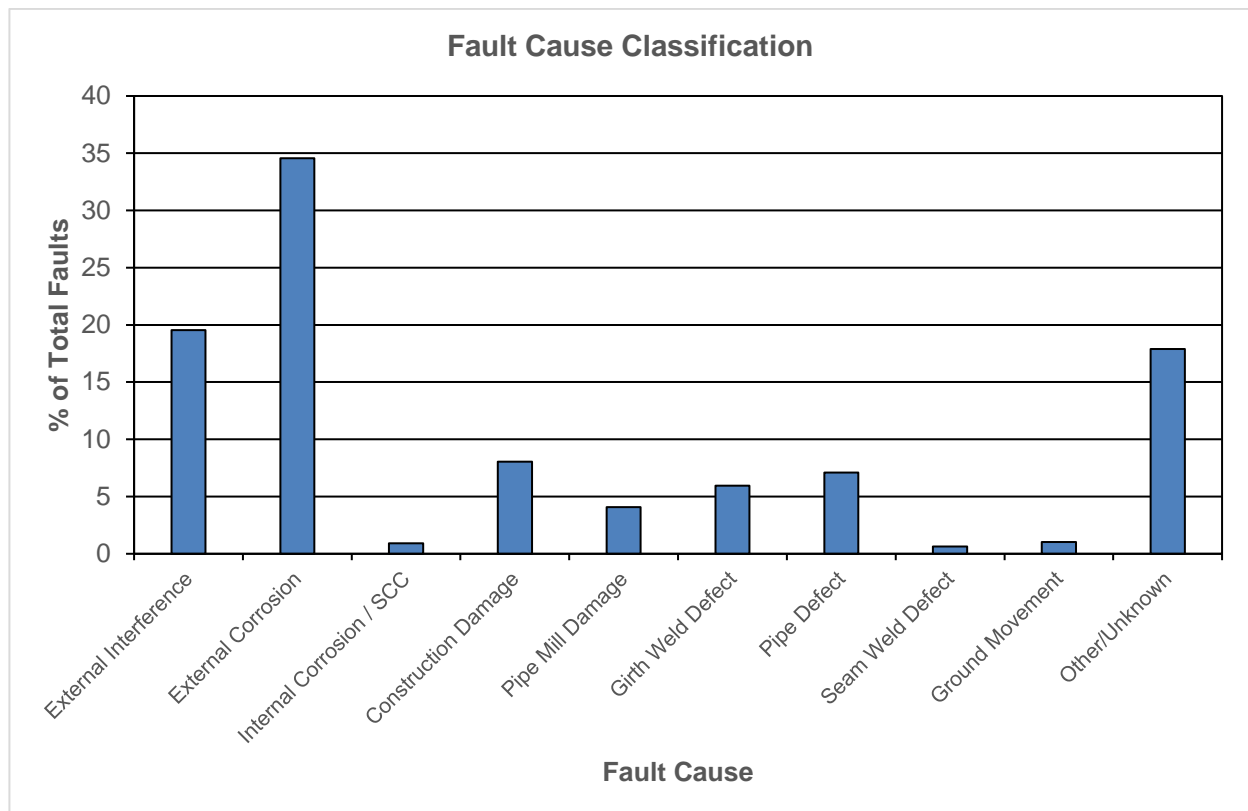
## 4 Fault Data

### 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 as intelligent pig in-line inspections, monitoring the performance of cathodic protection systems, 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 for the period 1962 - 2015 was 3640. The main causes of the Faults are shown in Figure 20.

Figure 20

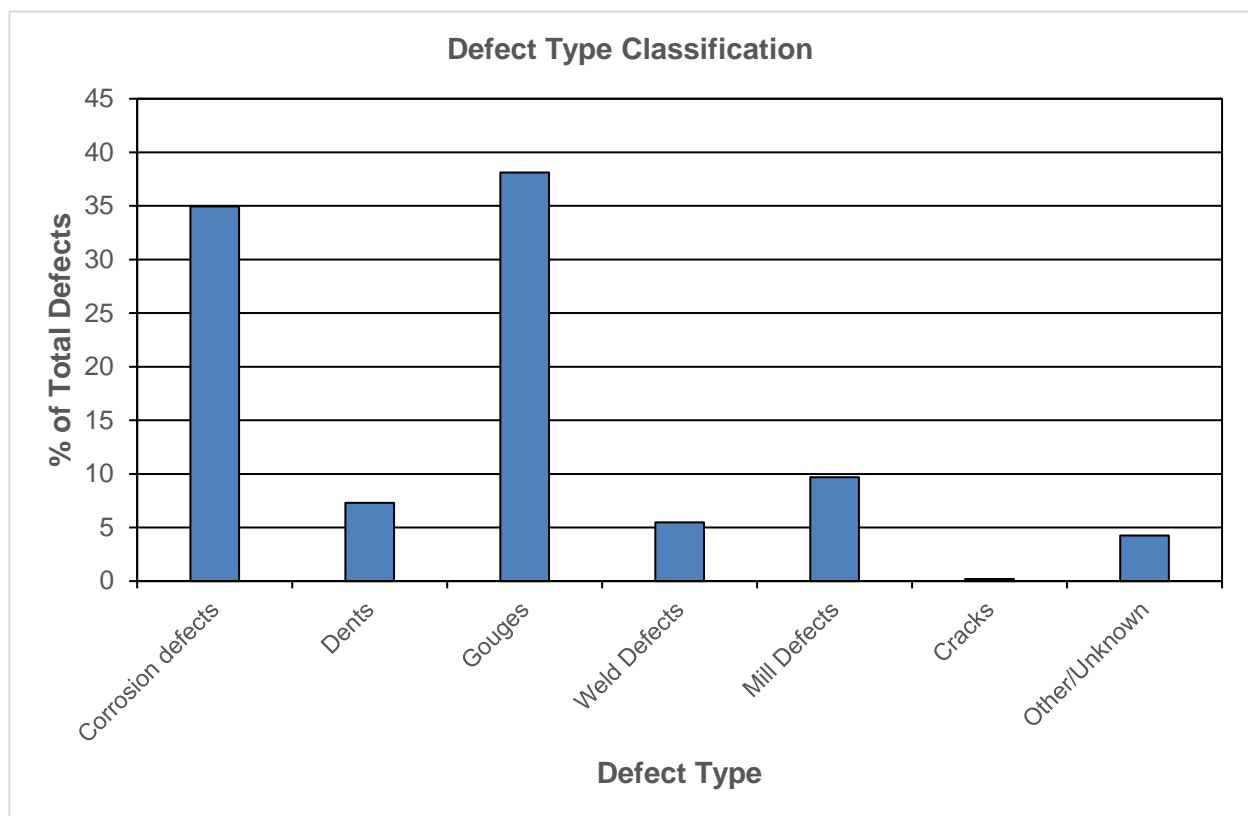


## 4.2 Part-Wall Defect Data

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 contains 5838 defects recorded in the period 1962 - 2015.

Classification of defect data is shown in Figure 21.

**Figure 21**



### 4.3 Statistical Distributions of Defect Dimensions

Pipeline damage due to external interference occurs in the form of gouges, dents or dent-gouge combinations. 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 [1,2,3,4] use dent-gouge fracture mechanics models to predict the pipeline probability of failure, which is also 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 dent-gouge combinations), 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 [5]. The parameters have not yet been updated to include the 2011 – 2015 data.

The Weibull distribution parameters for the data up to and including 2010 are given in Table 14.

**Table 14**

Distribution Parameters	Gouge Length	Gouge Depth	Dent Depth
Weibull Shape ( $\alpha$ )	0.573	0.674	1.018
Weibull Scale ( $\beta$ ) mm	125.4	0.916	9.382

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 failure frequencies. “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. The hit rate in rural areas associated with the above damage distribution parameters is 1.255 per 1000 km.yrs.

*Note: Weibull distributions were identified as appropriate distributions in historic work carried out to develop the FFREQ predictive model.*

- 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, 7<sup>th</sup> 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, 7<sup>th</sup> 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, 7<sup>th</sup> 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.
- 5 An Update to the UKOPA Pipeline Damage Distributions, G Goodfellow, S Turner, J Haswell and R Espiner, IPC2012-90247, 9<sup>th</sup> International Pipeline Conference, Calgary 2012.