PARLOC 2001:

The Update of Loss of Containment Data for Offshore Pipelines

Prepared by Mott MacDonald Ltd. for:

The Health and Safety Executive, The UK Offshore Operators Association and The Institute of Petroleum.

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EXECUTIVE SUMMARY

This report describes studies performed for the United Kingdom Offshore Operators Association (UKOOA), the Institute of Petroleum (IP) and the UK Health and Safety Executive (HSE) regarding loss of containment from offshore pipelines operated in the North Sea and supersedes the last loss of containment study published as PARLOC 96. The databases compiled during earlier studies – Parloc '90, '92, '94 & '96 [Refs. 1-4] - have been updated to include information collected up to the end of 2000. These databases are:

- A **Pipeline Database,** which contains details of all the pipelines installed in the North Sea. A *pipeline*, as defined in this study, *extends along the riser from the pig trap and associated pipework and valves, and includes all pipework and fittings on the main flow path and all branches on the main flow path up to and including the first valve on each branch.* Where a pipeline does not have a pig trap the first valve above water level is the termination point.

- An **Incident Database,** which contains a description of each reported incident and data on the pipeline(s) affected. For this study an *incident* has been defined as an *occurrence which directly results or threatens to result in loss of containment of a pipeline.*

The contents of the incident database are summarised below:

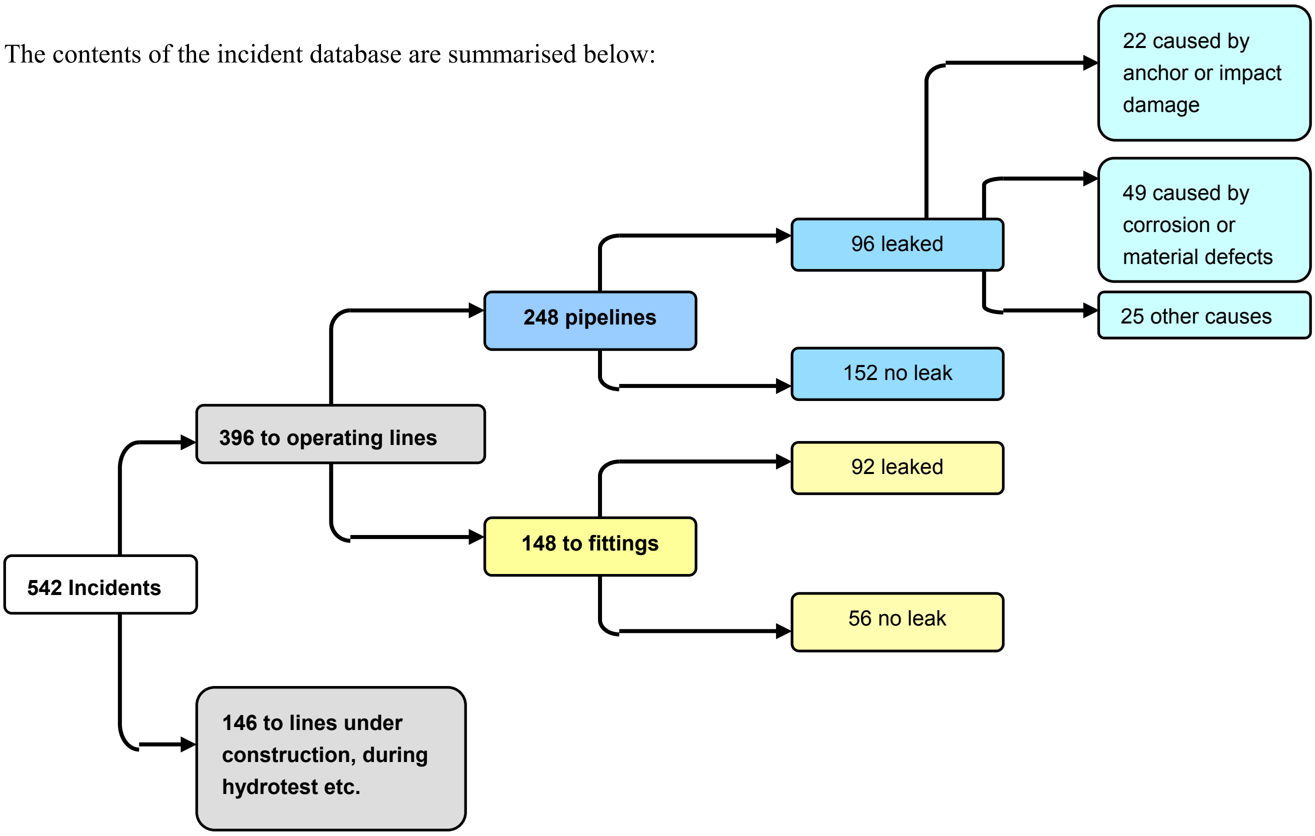


Figure 0-1 - Summary of the contents of the PARLOC 2001 Incidents Database

By comparison, the contents of the PARLOC 96 report are summarised below:

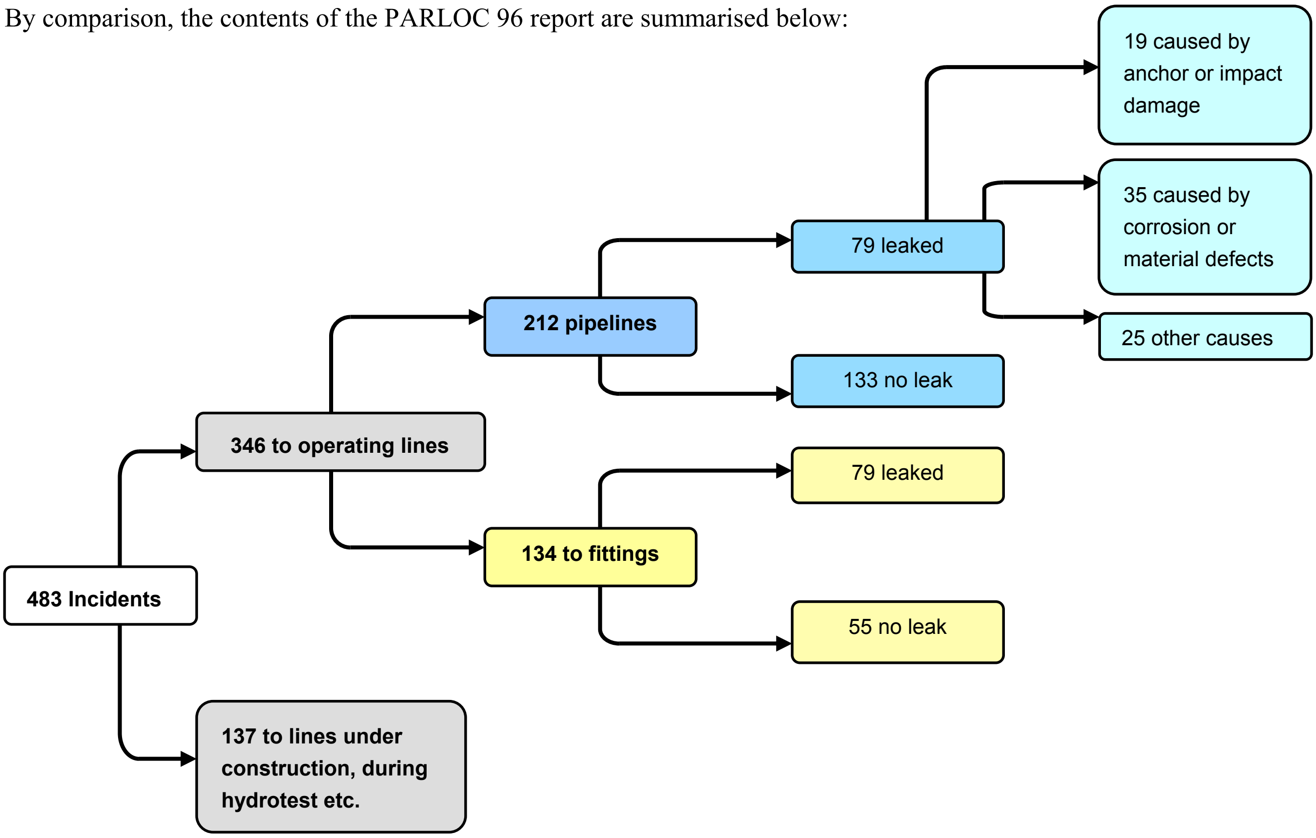


Figure 0-2 – Summary of the contents of the PARLOC 96 Incidents Database

The total number of pipelines, including both steel and flexible lines, listed in the pipeline database is 1567 at the end of 2000. The total length installed to the end of 2000 calculated from the pipeline database, is 24,837 km and the operating experience 328,858 km-years. This compares with PARLOC 96 the number of pipelines were 1003, the total pipeline length was 19,770 km and a total operating experience of 195,690 km-years to the end of 1995.

The data contained in this report can be considered as a starting point in the identification of potential hazards and provide initial indications of the likely levels of the loss of containment frequency for an individual pipeline. They also provide indications of the level of reliability achieved in the operation of North Sea pipelines, which can be used in the context of quantified risk assessment.

It should however be noted that individual pipelines have histories, different properties, characteristics and functions, many of which have not been considered in the analysis presented in this report. Such attributes as steel type or grade, the service of the pipeline, the nature of the field joints, whether or not the pipeline is part of a bundle, the routing of the pipeline and any protection afforded to it, and the inspection and maintenance regime for the pipeline might be included for consideration.

In so far as it has been possible, the influence of these factors on the failure rates of pipelines has been determined, however, the databases contain insufficient information for substantive conclusions to be drawn in all cases. It is therefore recommended that in hazard and risk analysis each pipeline should be individually assessed.

A number of limitations of the PARLOC study are acknowledged. While, the database is over 99% complete regarding information on Diameter, length, contents and installation dates, it is acknowledged that other information such as wall thickness, burial conditions and steel riser type is only 70-90% complete. Overall the relatively small number of loss of containment incidents to date means that clear statistical trends are more difficult to identify. Furthermore there are known to be areas in which the data that could permit a more detailed analysis are not currently recorded, for example corrosion protection data.

1 INTRODUCTION

This report has been prepared by **Mott Macdonald Ltd (MML)** following the award of a Joint Industry Funded Project contract by the **United Kingdom Health & Safety Executive (HSE), The Institute of Petroleum (IP) and the UK Offshore Operators Association (UKOOA).** The study involves updating the database of pipelines and incidents involving North Sea offshore pipelines in which containment was lost or jeopardised to include incidents occurring up to the end of 2000 and to revise the published report PARLOC 96. The main objective of this continuing study is to update and improve confidence in the statistical information available to assess the generic frequency of loss of containment associated with the operation of North Sea pipelines.

The basis of the study has been a review of information held by Regulatory Authorities and pipeline operators. In compiling previous PARLOC reports, the incident data held by the HSE have been collated and released to MML. In previous PARLOC reports the Norwegian Petroleum Directorate (NPD) have provided information from their pipeline and incident databases, as has information and contacts with pipeline operators been made available by Energistyrelsen and Staatstoezicht op de Mijnen, the Danish and Dutch Authorities respectively. For the publication of this report, a major collection exercise was also undertaken through the United Kingdom Offshore Operators Association (UKOOA) and individual operators to obtain further details and clarification of incidents that have occurred.

MML have been given access to the data from earlier studies in this area. Also a literature review has been undertaken, which included Trade Journals, Lloyd's List and published papers and reports.

This report describes the work involved in the collation of data and the compilation of two databases, one covering all North Sea pipelines and one listing the incidents. This new revision of the study reports on the extended databases that have now been updated to cover the period up to the end of 2000. The information available to the study team and the methods by which data were checked and evaluated are described.

The report also describes the re-analysis of the extended databases to develop incident frequencies appropriate to pipelines in the North Sea, concentrating on incidents which gave rise to loss of containment. A *pipeline,* as defined in this study, *extends along the riser from the pig trap and associated pipework and valves, and includes all pipework and fittings on the main flow path and all branches on the main flow path up to and including the first valve on each branch.* Where a pipeline does not have a pig trap the first valve above water level is the termination point.

The pipelines database is over 99% complete regarding information on diameter, contents, length and installation date, however, for other information such as wall thickness, pipeline burial conditions or steel riser type, the information is only 70 - 90% complete. This limits the extent to which clear trends of failure rate against these parameters can be deduced. Moreover some information that might be expected to permit a more in depth assessment of pipeline failure rates is not currently recorded. The implications of such limitations are discussed in the report.

Trends in the recorded data have also been investigated and the report indicates how incident frequencies vary with location, cause of failure, line type, line size and contents. This re-analysis includes all the data contained within the extended databases and not just the data collected since the last update of the study. Consequently this report supersedes all PARLOC reports published previously.

2 SUMMARY AND RESULTS

2.1 INTRODUCTION

The purpose of this study is to update and improve confidence in the statistical information available to assess the generic loss of containment frequencies from operating North Sea pipelines. In order to achieve this two databases have been compiled:

- A **Pipeline Database,** which contains details of pipelines installed in the North Sea.

- An **Incident Database,** which contains a description of reported incidents and data on the pipeline(s) affected.

During this latest revision of the loss of containment study these databases have been extended to contain information collected up to the end of 2000. The collation and contents of the complete databases are discussed in this Section and are described in detail in Section Three.

The extended databases have been used to perform assessments of factors affecting the frequency of incidents. These assessments are discussed in this Section and described in detail in Sections Four and Five. The important results are presented in the conclusions.

The definition of key terms and the symbols used in the Figures are presented in the Glossary.

2.2 SUMMARY

Information for this study has been obtained from:

- Regulatory Authorities
- Operators in the UK, Dutch, Norwegian and Danish sectors
- PARLOC 96

MML contacted the regulatory authorities concerned with North Sea pipelines and 54 UK, Dutch and Danish operators while compiling the database. The Norwegian sector data were obtained through NPD and individual operators.

The availability of these data has enabled generic incident frequencies for loss of containment from North Sea pipelines to be calculated.

The influences of a number of factors on the loss of containment frequency have also been examined based upon the reported number of incidents and the corresponding confidence interval calculated from the databases assembled in this study.

It has been concluded from the analysis performed on the databases that there are five significant factors that are important in considering loss of containment frequency. These are:

- Incident cause
- Location on the pipeline affected (riser, safety zone or mid line)
- Diameter of pipeline
- Length of pipeline
- Contents of pipeline

The most important are the first two factors, while the significance of the other factors depends upon the location of the pipeline affected and the incident cause.

The data contained in this report may be considered as a 'starting point' in the identification of potential hazards and provide initial indications of the likely loss of containment frequency for an individual pipeline. They also provide indications of the level of reliability achieved in the operation of North Sea pipelines, which can be used in the context of a quantified risk assessment. However, it should be noted that individual pipelines have different histories, properties, characteristics and functions many of which have not been considered in the analysis presented in this Report. Therefore, it is recommended that in performing any hazard and risk analyses each pipeline should be individually assessed.

2.3 LIMITATIONS OF THE PARLOC STUDY

2.3.1 Completeness of Pipeline Database

It has been possible to create a pipeline database that is over 99% complete in respect of primary information (diameter, contents, length and installation date). The database has therefore provided a reliable basis for the estimation of the cumulative experience used to derive the quoted failure rates.

Secondary information in the database such as pipeline burial conditions or steel riser type, is only 70 - 90% complete. The database contains no information relating to corrosion protection, routing or fittings. This naturally limits the extent to which it is possible to discern trends of failure rates against the less recorded, or unrecorded, parameters. Some of these issues are discussed further below.

2.3.2 Completeness of Incident Database

The Incident database includes every known loss of containment incident. However, it is currently not possible to differentiate the effects of all pipeline characteristics when undertaking a frequency analysis since the relatively small number of loss of containment incidents to date means that overlaps in confidence intervals preclude clear effects and trends in nearly all cases. The incorporation of damage reports and / or inspection and maintenance report data would be expected to provide an avenue through which the data used to generate leak frequency calculations could be supplemented. It should, however, be recognised that the use of such data might give rise to debate about its interpretation, its validity, and its reliability as well as about the methodology used for any supplementary analyses.

2.3.3 Loss of Containment Volumes

The Incident database does not provide precise information with respect to either the location, or the duration, of loss of containment incidents although the time to locate and register the leak and the time to effect repair is of importance. This lack of information means that an accurate determination of the volume of product lost in each recorded loss of containment incident cannot be reliably estimated. While this may be regarded as being a limitation of the study it is the opinion of the authors that it will generally be more appropriate to develop an estimate of the loss of containment volume from a knowledge of the pipeline operating conditions at the time of a failure and the equivalent hole size rather than on the basis of direct historical data.

2.3.4 Reduced Relevance of Historic Failure Data

PARLOC currently contains all incidents on flexible lines including those due to early materials development problems. Since these problems have largely been overcome it may be argued that the derived incident frequencies may be pessimistic. It has often been proposed that before a failure frequency, either for a riser or pipeline, is developed it is appropriate for the incidents that are being used to establish the failure rate to be filtered to exclude any incidents that are considered to be unrepresentative of the installation being considered.

It is true that some of the incidents that have occurred in the past can be attributed to a lack of industry experience in a particular area, and that with the passage of time and increased experience the likelihood of such failures has declined. Care should always be exercised when making or attempting such judgements. Only those failures that can be directly attributed to a specific cause should be excluded in this way and even then only if it is known with certainty that the cause will not be relevant in the future. While it is true that certain causes of failure may become less likely due to a better understanding of the mechanisms giving rise to them, it is by no means definite that overall failure rates will reduce with time. It should be noted that in an area in which innovative solutions to problems are continually being introduced, there is a tendency for new causes of failure to replace the old. However, and taking these factors into consideration, with much longer experience than that afforded to earlier PARLOC studies, the authors have noticed a drop in incident frequency such as would have been observed if causes of failure were being excluded and not replaced. This suggests that failure mitigation measures introduced by operators are successfully reducing failure rates.

2.3.5 Corrosion Protection

Corrosion has been identified as one of the major causes of loss of containment, however, no corrosion protection data is currently recorded in the pipeline database. It is not therefore possible to derive failure rates for specific types of corrosion prevention.

2.3.6 Incidents to Fittings

Although over half the loss of containment incidents that have been recorded for pipeline systems have occurred to fittings, it has not been possible to establish corresponding frequency rates. This is because the required experience data is not available in the documentation and databases made available to the study. This information could be extracted through operator supplied data, Process and Instrument Diagram (P&ID) drawings or listings of equipment. In order to be compatible with the incident database all fittings on the pipeline should be assessed up to and including the pig trap and flanges on valves, including those on branch lines. Given the large number of incidents to fittings this would be a useful development that would assist in the proper treatment of fittings in safety studies. Since the changes in safety legislation Offshore (Emergency Pipeline Valves) Regulations, 1989, S1 1029, subsequently subsumed in Regulation 19 and Schedule 3 of SI 1996 NO. 825 0 – The Pipeline Safety Regulations 1996, there has been an increase in the number of reported incidents (not loss of containment) involving platform emergency shutdown valves (ESDVs) and subsea isolation valves (SSIVs) on UK operated pipelines. No differentiation has been made between ESD and SSI valves, which are reported within the 'Fittings' category in the Incident Database.

2.3.7 Pipeline Routing and Protection

In the Study, the pipeline database has been used to calculate the population data associated with a selected group of incidents in terms of the total number, length and operating experience (in years or km-years) of installed pipelines satisfying certain specified criteria.

Since individual pipelines have unique histories and properties, many of which have not been considered fully in the PARLOC study, generic loss of containment frequencies can only provide average data for input into a risk assessment exercise. A discussion is included in Section 3 of the types of information collected for each pipeline within the database. However, available data are not sufficient to allow the full use of the incident data in the assessment of design options, such as pipeline routing and protection near platforms. Further information would need to be collected to enable these to be evaluated.

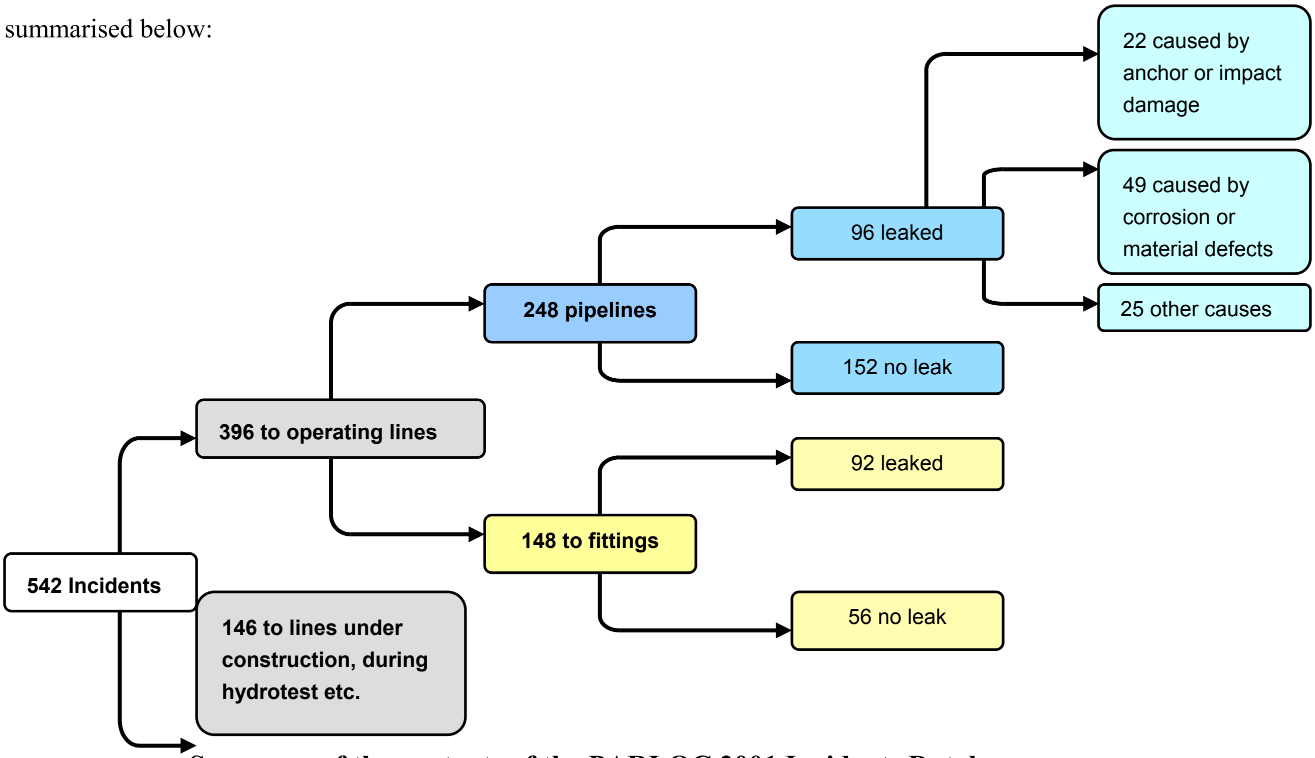
The applicability of this approach in a design context is limited. For example, it can be used to calculate failure rates for a gas pipeline of given diameter adjacent to the platform in the safety zone. However, an approach predicted solely on the historical data contained in the databases cannot account for different routing options, since the pipeline is treated as an independent component in isolation from its surroundings. Hazards external to a pipeline do of course represent significant causes of damage to that pipeline. Therefore the relative position of the pipeline and risers with respect to cranes, platform activities, supply boat anchoring zones or construction activities would be expected to have been significant in cases where incidents have occurred. If this information were collated it could be combined with the available historical incident data to provide more comprehensive and appropriate models for use in safety assessments.

Similarly, it is perceived that protection to pipelines and risers assists in reducing their exposure to risks, thereby increasing safety and reducing probabilities of damage. However, the effectiveness of protection systems cannot be evaluated. While there is information to indicate whether the riser or line had any protection where incidents have occurred, since the corresponding experience data is not always complete, it is therefore not possible to evaluate frequencies. Comparing lines protected by mattresses or rock dump near platforms would be a possible approach to this problem.

2.4 RESULTS

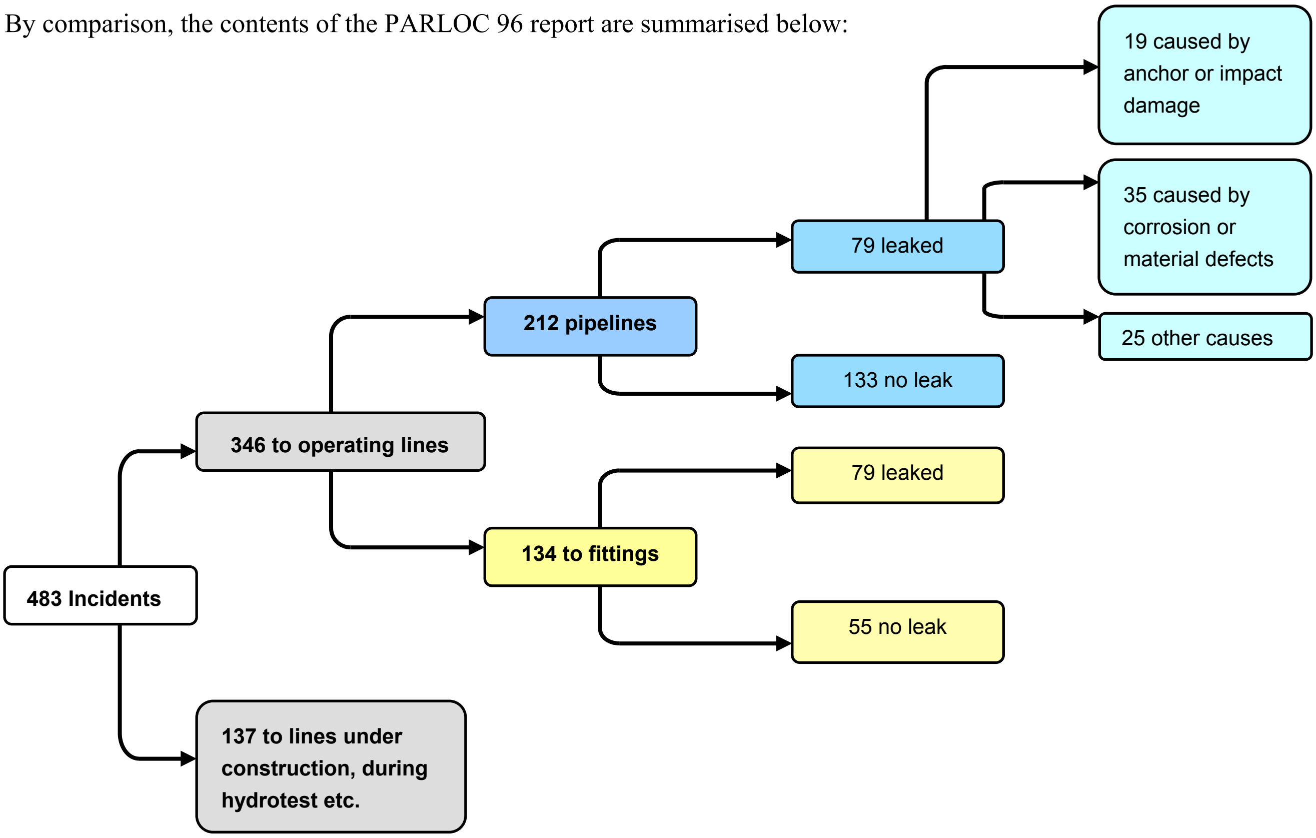
Incident Database

The contents of the incident database assembled during this revision of the PARLOC 2001 study are summarised below:



Summary of the contents of the PARLOC 2001 Incidents Database

By comparison, the contents of the PARLOC 96 report are summarised below:



Summary of the contents of the PARLOC 96 Incidents Database

Of the 248 incidents to operating pipelines that are contained in the updated database, 209 were associated with steel pipelines, the remaining 39 were incidents to flexible lines. A summary of the 209 incidents associated with operating steel pipelines is presented in Table 2.1 by cause and location along the pipeline.

The causes of the 188 incidents that resulted in leakage are summarised in Tables 2.2 to 2.6 by location of the pipeline where the leak occurred and the Diameter of the pipeline affected. Of the incidents, 96 resulted in a loss of containment from steel and flexible pipelines and 92 of the leaking incidents was from a fitting associated with the pipeline.

In the database, the size of damage has been classified according to equivalent hole Diameter based on details in the description of the incident or an interpretation of the incident record. The equivalent hole size in the 65 incidents which resulted in loss of containment from operating steel pipelines is presented in Table 2.7. The equivalent hole size is presented by pipeline Diameter and the location of the incident:

- 16 incidents resulted in damage with an equivalent hole size greater than 80mm.
- 12 resulted in damage with an equivalent hole size of 20 -80 mm
- 37 resulted in damage with an equivalent hole size of less than 20 mm or is unknown

The equivalent hole size in the 31 incidents which resulted in loss of containment from operating flexible pipelines is presented in Table 2.8, and the associated equivalent hole size is summarised below:

- 5 incidents resulted in damage with an equivalent hole size greater than 80mm.
- 4 resulted in damage with an equivalent hole size of 20 -80 mm
- 19 resulted in damage with an equivalent hole size of less than 20 mm

3 reported incidents associated with flexible lines have no data relating to equivalent hole size. Most of the flexible pipelines damaged were in the Diameter range of 2 to 8 inches. 1 riser of 12 inch Diameter was damaged.

Table 2.9 shows the equivalent hole size for incidents to fittings associated with operating pipelines.

- 7 incidents resulted in damage with an equivalent hole size greater than 80mm.
- 13 resulted in damage with an equivalent hole size of 20 -80 mm
- 72 resulted in damage with an equivalent hole size of less than 20 mm (includes 5 leakage incidents from unknown pipeline diameters)

67 of the leaks from fittings associated with operating pipelines of known pipeline diameter were described as having an equivalent hole size of less than 20 mm. In 13 incidents the leaks were described sufficiently to determine that the equivalent hole size was 20-80 mm and in 7 incidents it was possible to determine that the

equivalent hole size was greater than 80 mm. There were a further 5 incidents of leakage with an equivalent hole size less than 20 mm, where no information about the pipeline Diameter was available.

Pipeline Database

A number of sources of information have been used to assemble and verify the pipeline database, these include:

- UKOOA Catalogue, 1995
- UK Health and Safety Executive (HSE) pipeline database, 1992
- UK Department of Energy (DEn) pipeline records to 1984
- Norwegian Petroleum Directorate (NPD) pipeline database
- Subsea Guide and 6th Edition Field Development Guide, published by OPL
- Pipeline Operators

The total number of pipelines listed to the end of 2000 is 1567. Of these 134 are short spools, less than 100 m in length. The previous update of the database contained information on 1003 pipelines. The total length installed to the end of 2000 calculated from the extended pipeline database is 24,837 km and the operating experience 328,858 km-years. This compares with 19,770 km and 195,690 km-years to the end of 1995 as contained in the previous update of the database.

Analysis of Databases

The databases have been used to assess factors affecting the frequency of incidents. The following factors have been investigated:

- Incident cause
- Part of pipeline affected
- Pipeline Diameter
- Pipeline length
- Pipeline contents
- Whether the line is trenched or buried
- Piggy-backed pipelines
- Bundled pipelines
- Pipeline age
- Type of line
- Hydrotest pressure
- Location of pipeline in the North Sea
- Location of riser
- Pipeline steel grade

These assessments were performed on the extended databases and therefore are concerned with the information collected up to the end of 2000 and not solely that collected during this update.

The generic loss of containment frequency is presented in Figures 2.1 to 2.6 for riser incidents, for anchoring and impact incidents and for corrosion and material defect incidents considering the factors found to be significant in the analysis. The reported number of incidents in each category and the associated pipeline operating experience are tabulated in Section 5.3. The best estimate has been calculated on the basis of actual numbers of reported incidents divided by the appropriate operating experience. The upper 95 per cent and lower 5 per cent confidence limits have also been calculated. The upper 95 per cent limit has been calculated for the special case where no loss of containment incidents have been reported for pipelines in that particular group. In this special case the best estimate that has been presented is the value calculated assuming 0.7 incidents had occurred (corresponding to a 50% confidence on Poisson distribution for zero incidents occurring). Confidence limits are discussed in Section 4.3.1. The symbols and terms used in the figures are defined in Appendix D of this report.

Figure 2.1 presents the frequency of loss of containment for risers by pipeline material and diameter; Figures 2.2 to 2.4 present the frequency of loss of containment for anchoring and impact damage for various sections of a pipeline; Figures 2.5 and 2.6 present the frequency of loss of containment for corrosion and material defects (including incidents classed as other, for reasons given in Section 5.2.4) for varying lengths of pipelines.

Tables 2.1, 2.2 and 2.4 present a more detailed breakdown of the location of the pipeline affected for different causes of incidents; Tables 2.3 and 2.5 indicate the size of the pipeline affected by incidents which resulted in a loss of containment, Table 2.6 presents details of the location on the pipeline of the fitting affected; Tables 2.7 to 2.9 present a breakdown of the size of the leak for loss of containment incidents for operating steel pipelines by diameter and location of the pipeline affected; for operating steel pipelines, operating flexible pipelines and fittings associated with operating pipelines respectively.

Section 5 presents tabulated failure rate data.

		Total	Platform	Riser					Safety Zone				Mid Line	Well	Shore Zone	Land	SPM
				Total	Piping	Splash Zone	Subsea	Unkown	Total	Near	Far	Unknown					
Anchor	Ship / Supply Boat	18		0					11	1	6	4	6		1		
	Rig or Construction	11		0					8	5	1	2	3				
	Other/Unknown	11		1			1		0				10				
	Total	40	0	1	0	0	1	0	19	6	7	6	19	0	1	0	0
Impact	Ship on Riser	8		8		7		1	0								
	Trawl	27		0					1			1	23	3			
	Dropped Object	2		1			1		1	1							
	Wreck	1		0					0				1				
	Construction	2		1			1		1	1							
	Other/Unknown	16		2		1		1	4	1	2	1	9			1	
	Total	56	0	12	0	8	2	2	7	3	2	2	33	3	0	1	0
Corrosion	Internal	24	1	3				3	8	2	4	2	8	4			
	External	22		19	2	8	2	7	1			1	2				
	Unknown	6		3	1			2	1	1			2				
	Total	52	1	25	3	8	2	12	10	3	4	3	12	4	0	0	0
Structural	Expansion	6		5				5	1	1							
	Clamp Failure	1		1			1		0								
	Buckling	5		0					1		1		4				
	Total	12	0	6	0	0	1	5	2	1	1	0	4	0	0	0	0
Material	Weld Defect	8		4				4	2	1	1		1				1
	Steel Defect	10		5			1	4	2	1		1	2	1			
	Total	18	0	9	0	0	1	8	4	2	1	1	3	1	0	0	1
Nat. Hazard	Vibration	10		1			1		2		1	1	5		2		
	Storm	1		0					0						1		
	Scour	1		0					1			1					
	Subsidence	1		1			1		0								
	Total	13	0	2	0	0	2	0	3	0	1	2	5	0	3	0	0
Fire/Explosion	Total	0		0					0								
Construction	Total	2		0					0				1	1			
Maintenance	Total	1		1	1				0								
Human Error	Total	2		2	2				0								
Op. Problems	Total	1		0					0				1				
Other	Total	12		2				2	2	2			6	1			1
	Total	209	1	60	6	16	9	29	47	17	16	14	84	10	4	1	2

Table 2-1 - Causes of Incidents to Operating Steel Pipelines

				Riser					Safety Zone								
		Total	Platform	Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown	Mid Line	Well	Shore Zone	Land	SPM
Anchor	Ship / Supply Boat	6		0					6	1	4	1					
	Rig or Construction	0		0					0								
	Other/Unknown	2		0					0				2				
	Total	8	0	0	0	0	0	0	6	1	4	1	2	0	0	0	0
Impact	Ship on Riser	0		0					0								
	Trawl	6		0					0				6				
	Dropped Object	0		0					0								
	Wreck	1		0					0				1				
	Construction	1		0					1	1							
	Other/Unknown	1		0					0				1				
	Total	9	0	0	0	0	0	0	1	1	0	0	8	0	0	0	0
Corrosion	Internal	14		0					3	2	1		7	4			
	External	7		4		4			1			1	2				
	Unknown	5	1	1	1				1	1			2				
	Total	26	1	5	1	4	0	0	5	3	1	1	11	4	0	0	0
Structural	Expansion	0		0					0								
	Clamp Failure	1		1			1		0								
	Buckling	0		0					0								
	Total	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Material	Weld Defect	4		0					2	1	1		1				1
	Steel Defect	6		2				2	2	1		1	1	1			
	Total	10	0	2	0	0	0	2	4	2	1	1	2	1	0	0	1
Nat. Hazard	Vibration	0		0					0								
	Storm	0		0					0								
	Scour	0		0					0								
	Subsidence	0		0					0								
	Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire/Explosion	Total	0		0					0								
Construction	Total	0		0					0								
Maintenance	Total	0		0					0								
Other	Total	11		4			1	3	2	2			4	1			
	Total	65	1	12	1	4	2	5	18	9	6	3	27	6	0	0	1

Table 2-2 - Causes of Incidents to Operating Steel Pipelines which Resulted in a Loss of Containment

Location on Pipeline	Cause of Incident	Pipeline Diameter (inches)
Mid Line	Impact-trawl	2.375
Mid Line	Other-unknown.	4.5
Mid Line	Impact.	34
Mid Line	Internal corrosion	10.75
Mid Line	Other-unknown.	6.625
Mid Line	Other-unknown.	2
Mid Line	Internal corrosion	12.75
Mid Line	Corrosion-unknown.	4.5
Mid Line	Impact-wreck	20
Mid Line	Material-weld defect	30
Mid Line	Impact-trawl	2.375
Mid Line	Impact-trawl	3.5
Mid Line	Internal corrosion	6.625
Mid Line	Internal corrosion	9.13
Mid Line	Internal corrosion	6.625
Mid Line	Internal corrosion	6.625
Mid Line	Material-steel defect	24
Mid Line	Anchor-ship/supply boat	3
Mid Line	External corrosion	5
Mid Line	Anchor-ship/supply boat	2.375
Mid Line	External corrosion	5
Mid Line	Internal corrosion	6.625
Mid Line	Corrosion-unknown.	6.625
Mid Line	Impact-trawl	2
Mid Line	Impact-trawl	2
Mid Line	Other-unknown.	2.375
Mid Line	Impact-trawl	10.75
Plat	Other-unknown	30
Riser	Other-unknown	16
Riser	Other-unknown.	10.75
Riser	Material-unknown	8
Riser	Other-unknown	20
Riser	Material-steel defect	12.75
Riser Piping	Corrosion-unknown.	6
Riser Splash Zone	External corrosion.	6.625
Riser Splash Zone	External corrosion.	10.75
Riser Splash Zone	External corrosion.	6.625
Riser Splash Zone	External corrosion	12.75
Riser Subsea	Corrosion-unknown.	10.75
Riser Subsea	Structural-clamp failure.	16
SPM	Material-weld defect.	36
Safety Zone	Anchor-ship/supply boat	16
Safety Zone	External corrosion.	3.5
Safety Zone	Material-steel defect	11.4
Safety Zone Far	Internal corrosion	8.625
Safety Zone Far	Anchor-ship/supply boat	16
Safety Zone Far	Anchor-wreck	12.75
Safety Zone Far	Anchor-ship/supply boat	10
Safety Zone Far	Anchor-ship/supply boat	10
Safety Zone Far	Material-weld defect	24
Safety Zone Near	Internal corrosion	4
Safety Zone Near	Anchor-ship/supply boat.	4.5

Diameter Range of Operating Steel Pipelines Affected by Incidents which Resulted in a Loss of Containment

Cont'd…

Location on Pipeline	Cause of Incident	Pipeline Diameter (inches)
Safety Zone Near	Internal corrosion	4.5
Safety Zone Near	Impact-construction vessel	2.375
Safety Zone Near	Material-weld defect.	4.5
Safety Zone Near	Corrosion-unknown.	4.5
Safety Zone Near	Other-unknown.	6.625
Safety Zone Near	Corrosion-unknown.	6.625
Safety Zone Near	Structural-unknown	5.37
Well	Internal corrosion	4.5
Well	Internal corrosion	10.75
Well	Internal corrosion	6.625
Well	Internal corrosion	6.625
Well	Material-steel defect	6.625
Well	Other-unknown.	6.625

Table 2-3 - Diameter Range of Operating Steel Pipelines Affected by Incidents which Resulted in a Loss of Containment

		Total	Platform	Riser					Safety Zone				Mid Line	Well	Shore Zone	Land	SPM	Unknown
				Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown						
Anchor	Ship / Supply Boat	1		0					0					1				
	Rig or Construction	0		0					0									
	Other/Unknown	0		0					0									
	Total	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Impact	Ship on Riser	0		0					0									
	Trawl	3		0					0				1	2				
	Dropped Object	1		0					0					1				
	Wreck	0		0					0									
	Construction	0		0					0									
	Other/Unknown	0		0					0									
	Total	4	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0
Corrosion	Internal	1	1	0					0									
	External	0		0					0									
	Unknown	0		0					0									
	Total	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Structural	Expansion	0		0					0									
	Clamp Failure	1		0					0				1					
	Buckling	1		0					0					1				
	Total	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Material	Weld Defect	0		0					0									
	Steel Defect	0		0					0									
	Flexible Defect	12		2			1	1	3	2		1	4	3				
	Total	12	0	2	0	0	1	1	3	2	0	1	4	3	0	0	0	0
Nat. Hazard	Vibration	0		0					0									
	Storm	0		0					0									
	Scour	0		0					0									
	Subsidence	0		0					0									
	Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire/Explosion	Total	0		0					0									
Construction	Total	2		0					0					2				
Maintenance	Total	1		0					0				1					
Other	Total	8		3				3	0				2					3
	Total	31	1	5	0	0	1	4	3	2	0	1	9	10	0	0	0	3

Table 2-4 – Causes of Incidents to Operating Flexible Pipelines which Resulted in a Loss of Containment

Location on Pipeline	Cause of Incident	Pipeline Diameter (inches)
Mid Line	Repair	3
Mid Line	Material-flexible defect	Unknown
Mid Line	Material-flexible defect	Unknown
Mid Line	Other-unknown	Unknown
Mid Line	Impact-trawl	6
Mid Line	Other-unknown	Unknown
Mid Line	Material-flexible defect	4
Mid Line	Material-flexible defect	4
Mid Line	Structural-clamp failure	10
Safety Zone Near	Material-flexible defect	4
Safety Zone Near	Material-flexible defect	8
Plat	Internal corrosion.	16
Riser	Other-unknown	12
Riser	Material-flexible defect	Unknown
Riser	Other-unknown	8
Riser	Other	Unknown
Riser Subsea	Material-flexible defect	8.625
Unknown	Other	Unknown
Unknown	Other	Unknown
Unknown	Other	6
Well	Construction	6
Well	Construction	6
Well	Impact-trawl	6
Well	Impact-dropped object	6
Well	Impact-trawl	6
Well	Material-flexible defect	4.5
Well	Material	4
Well	Material-flexible defect	4
Well	Anchor-ship/supply boat	6
Well	Structural	6
Well	Material-flexible defect	4

Table 2-5 – Diameter Range of Operating Flexible Pipelines Affected by Incidents Which Resulted in a Loss of Containment

a) Incidents to Fittings Associated with Operating Steel Lines

				Riser					Safety Zone									
		Total	Platform	Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown	Mid Line	Well	Shore Zone	Land	SPM	Unknown
Anchor	Other/Unknown	2							1			1		1				
Impact	Trawl	2							0				1	1				
Corrosion	Internal	4	1	1				1	2	1		1						
Structural	Buckling	1							0				1					
Material	Weld Defect	1	1						0									
	Steel Defect	2	2						0									
	Total	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nat. Hazard		3		2			1	1	0								1	
Other		1							0				1					
Fitting	Flange Leak	10	2	5	1		2	2	1			1		1				1
	Seal leak	2	1	1				1	0									
	Valve Leak	13	7	0					3		1	2	2	1				
	Connector Lead	6		0					0				4	1			1	
	Hydrocouple Leak	6		1				1	4	1		3	1					
	Load Limit Connector Leak	3		0					0					3				
	Insulation Joint Leak	1		1		1			0									
	Nipple Leak	4	1	0					1			1	1	1				
	Pig Trap	11	10	1	1				0									
	Human Error	6	4	0					0				1				1	
	Unknown Fitting Leak	2	0	1				1	0				1					
	ESDV Leak	3	3	0					0									
	SSIV Leak	2		0					2	2								
	Total	69	28	10	2	1	2	5	11	3	1	7	10	7	0	0	2	1

b) Incidents to Fittings Associated with Operating Flexible Lines

Material	Weld Defect	1	1	0					0									
Fitting	Connector Leak	1		1				1	0									
	ESDV	1	1	0					0									
	Flange Leak	1		0					1	1								
	Load Limit Connector Leak	2		0					1	1				1				
	Seal Failure	1		1			1		0									
	Total	92	34	15	2	1	4	8	16	6	1	9	13	10	0	0	3	1

Table 2-6 – Causes of Incidents to Fittings Associated with Operating Pipelines which Resulted in Loss of Containment

Location of Incident		Pipeline Diameter Range (in)																		
		0 to 9						10 to 16						>16						All Diameter
		Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						Ranges
		0-20	Rupture?	20-80	Rupture?	>80	Rupture?	0-20	Rupture?	20-80	Rupture?	>80	Rupture?	0-20	Rupture?	20-80	Rupture?	>80	Rupture?	Unknown
Platform	Total													1						
Riser	Piping	1																		
	Splash Zone	1				1	1	1				1	1							
	Subsea							1		1										
	Unknown					1	1	2				1	1			1				
	Total	2	0	0	0	2	2	4	0	1	0	2	2	0	0	1	0	0	0	
Safety Zone	Near	5		3	1	1														
	Far	1						1		1		2	2	1						
	Unknown					1						2	1							
	Total	6	0	3	1	2	0	1	0	1	0	4	3	1	0	0	0	0	0	
Mid Line	Total	14		4	2	1	1	1				3		2				2	2	
Subsea Well	Total	4		1				1												
Shore	Total																			
Land	Total																			
SPM	Total															1				
Total	65	26	0	8	3	5	3	7	0	2	0	9	5	4	0	2	0	2	2	

Table 2-7 – Size of Damage Expressed as an Equivalent Hole Diameter to Operating Steel Pipelines

Location of Incident		Pipeline Diameter Range (in)												
		2 to 9						10 to 16						All Diameter Ranges
		Equivalent Hole Diameter (mm)						Equivalent Hold Diameter (mm)						
		0-20	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**0-20**	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**Unknown**
Platform	Total									1				
Riser	Piping													
	Splash Zone													
	Subsea					1	1							
	Unknown	3						1						
	Total	3	0	0	0	1	1	1	0	0	0	0	0	0
Safety Zone	Near	1		1										
	Far													
	Unknown											1	1	
	Total	1	0	1	0	0	0	0	0	0	0	1	1	0
Mid Line	Total	7		1	1	1	1							
Subsea Well	Total	7		1		2	2							
Shore	Total													
Land	Total													
Unknown	Total													3
Total	31	18	0	3	1	4	4	1	0	1	0	1	1	3

Table 2-8 – Size of Damage, Expressed as an Equivalent Hole Diameter, to Operating Flexible Pipelines

Location of Incident		Pipeline Diameter Range (in)																		
		0 to 9						10 to 16						>16						All Diameter Ranges
		Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						
		0-20	Rupture?	20-80	Rupture?	>80	Rupture?	0-20	Rupture?	20-80	Rupture?	>80	Rupture?	0-20	Rupture?	20-80	Rupture?	>80	Rupture?	Unknown
Platform	Total	6		1				6		1		1	1	11		7		1		
Riser	Piping							1						1						1
	Splash Zone													1						
	Subsea	2												2						
	Unknown					1		2						3						1
	Total	2	0	0	0	1	0	3	0	0	0	0	0	7	0	0	0	0	0	2
Safety Zone	Near	2				1	1			1				2						
	Far													1						
	Unknown	3						1						5						
	Total	5	0	0	0	1	1	1	0	1	0	0	0	8	0	0	0	0	0	0
Mid Line	Total	4						4				1	1	2		3				
Subsea Well	Total	8				2	2													
Shore	Total																			
Land	Total																			
Unknown	Total																			3
Total	92	25	0	1	0	4	3	14	0	2	0	2	2	28	0	10	0	1	0	5

Table 2-9 – Size of Damage, Expressed as an Equivalent Hole Diameter, to Fittings associated with Operating Pipelines

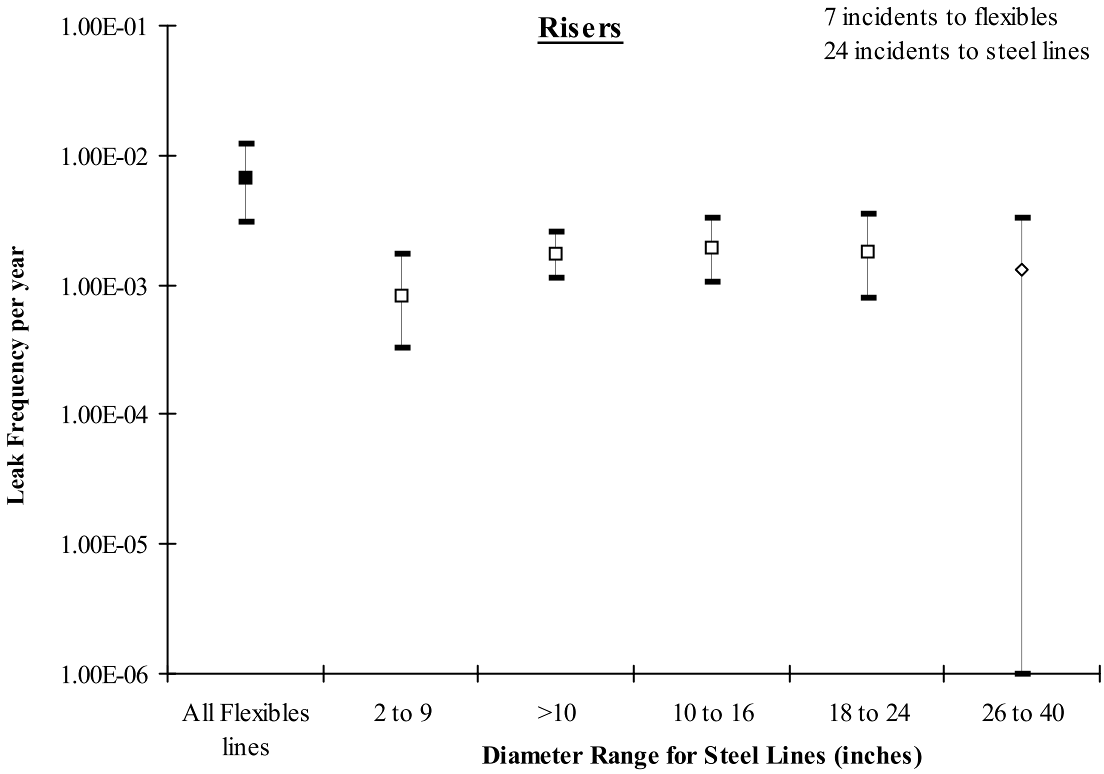


Figure 2-1– Variation of Frequency of Loss of Containment Incidents from Risers by Pipeline Material and Diameter of Line

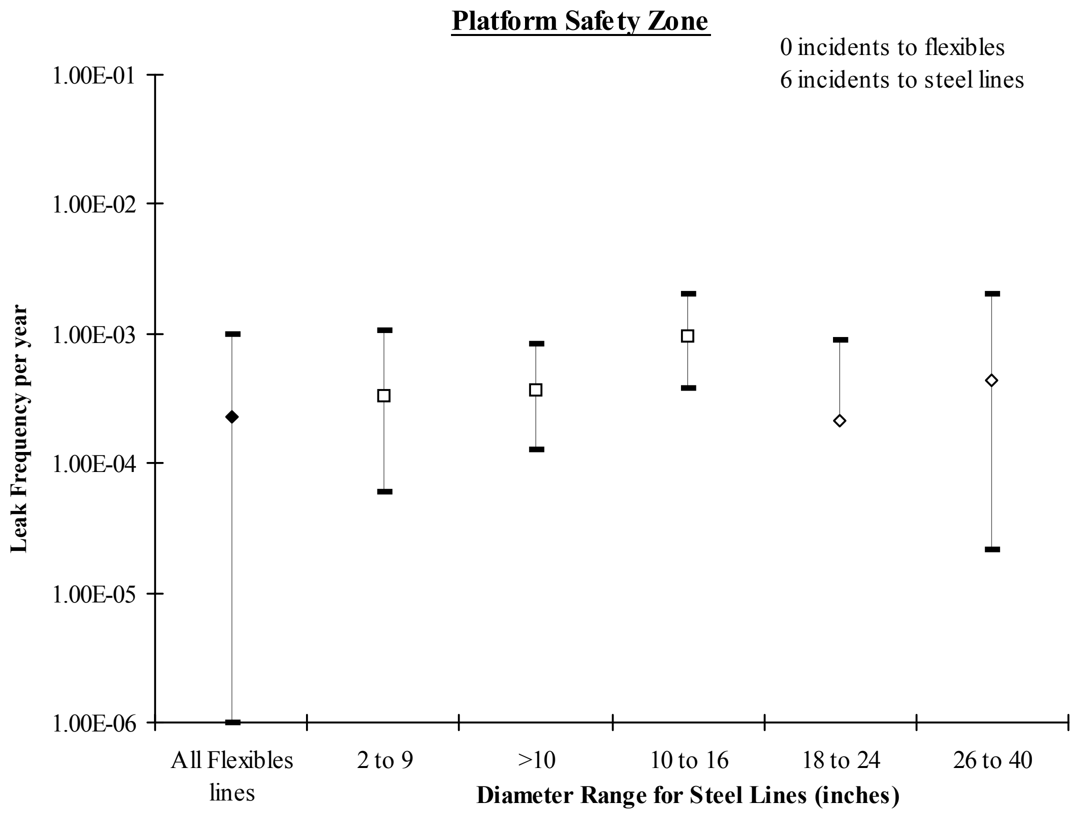


Figure 2-2 - Variation of Frequency of Loss of Containment Incidents by Pipeline Material and Diameter for All Anchoring and Impact Incidents Occurring in the Platform Safety Zone

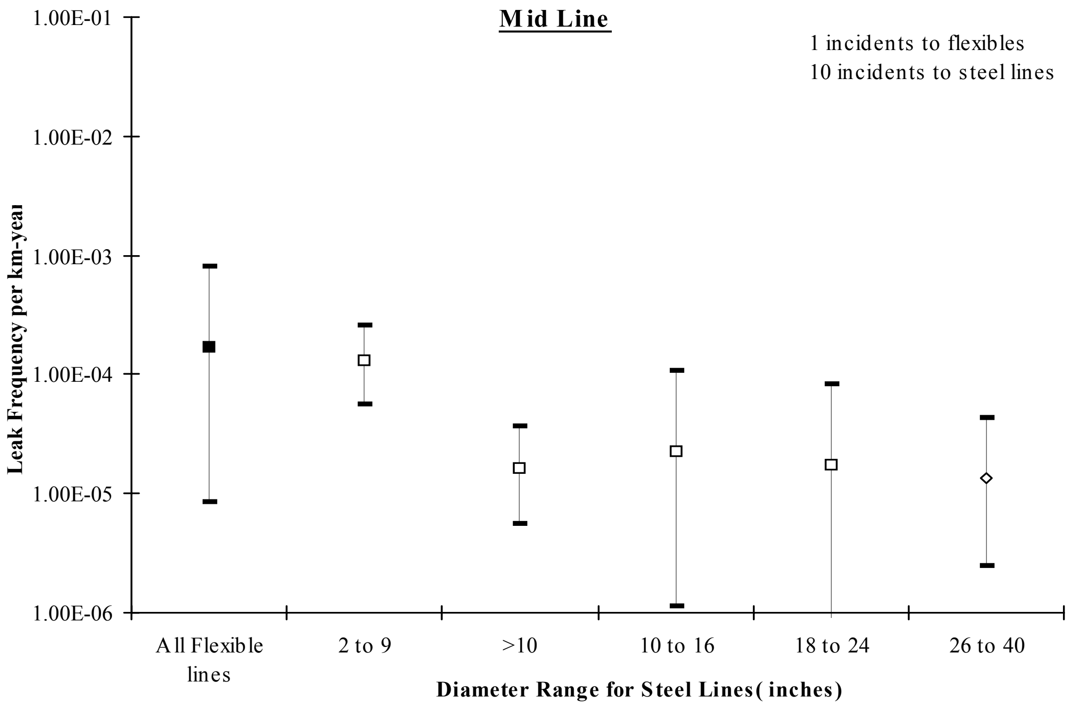


Figure 2-3 – Variation of Frequency of Loss of Containment Incidents by Pipeline Material and Diameter for All Anchoring and Impact Incidents Occurring in the Mid Line of Pipelines

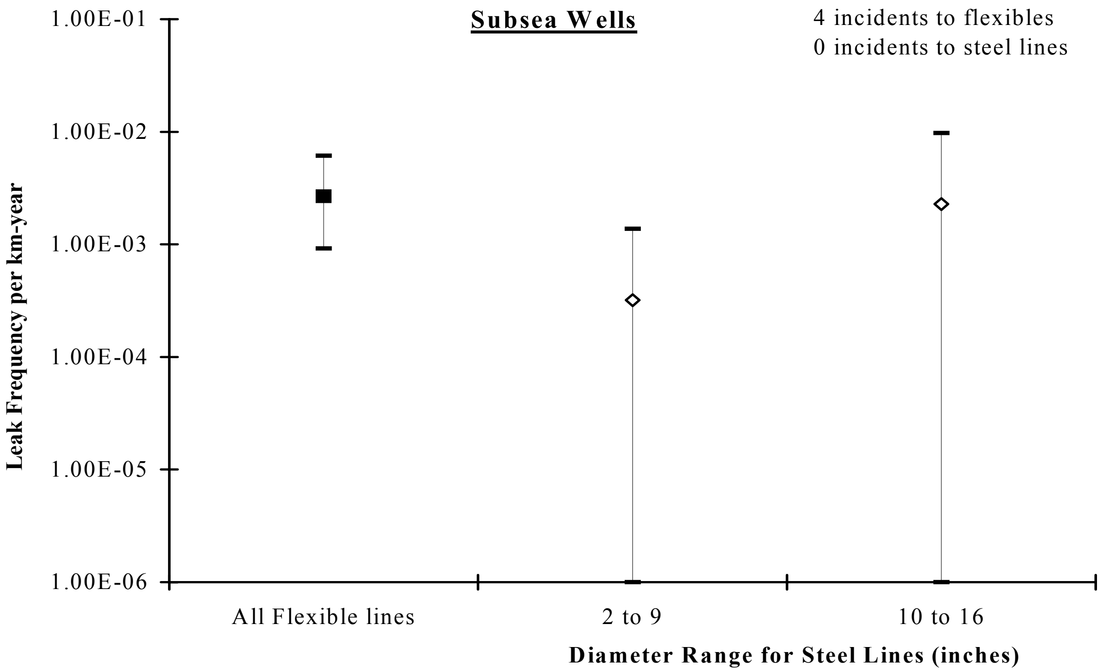


Figure 2-4 – Variation of Frequency of Loss of Containment Incidents by Pipeline Material and Diameter for All Anchoring and Impact Incidents Occurring in the Safety Zone associated with Subsea Wells

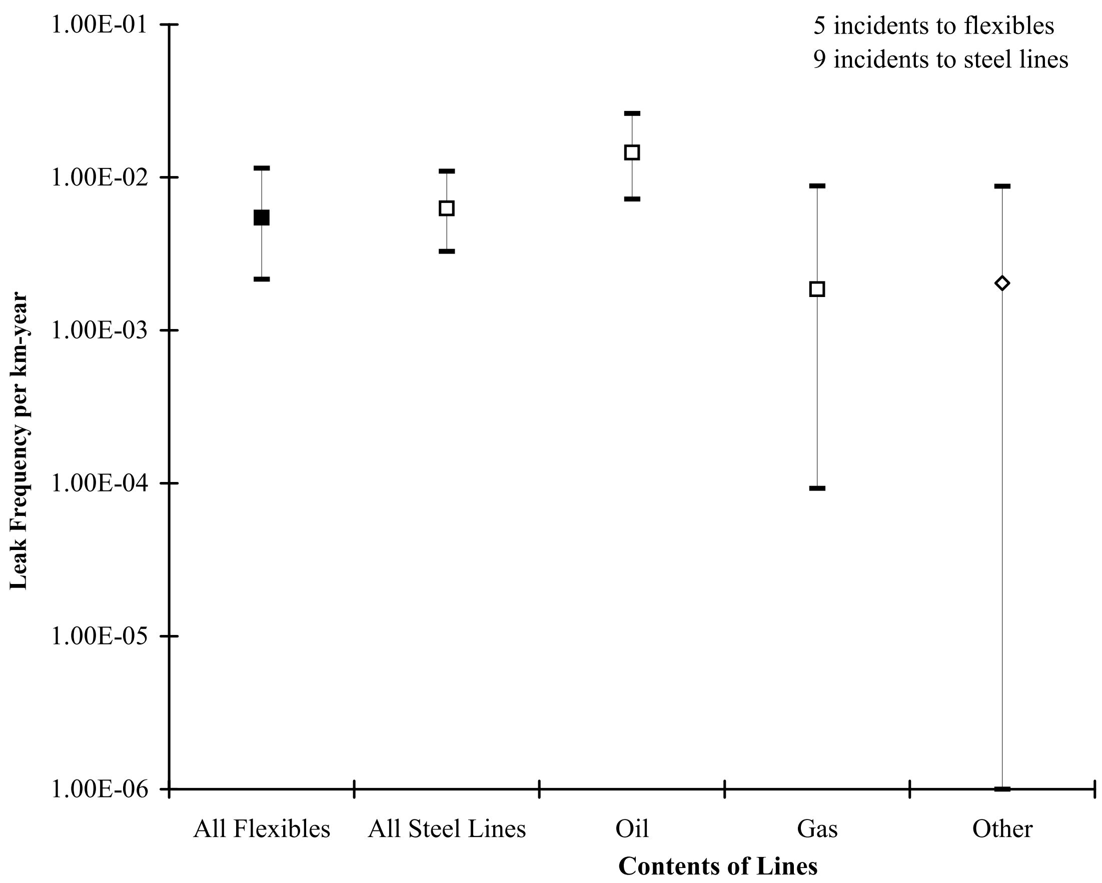


Figure 2-5 – Variation of Frequency of Loss of Containment Incidents for Lines less than 2km Long by Pipe Material and by Contents of Line for All Corrosion and Material Incidents

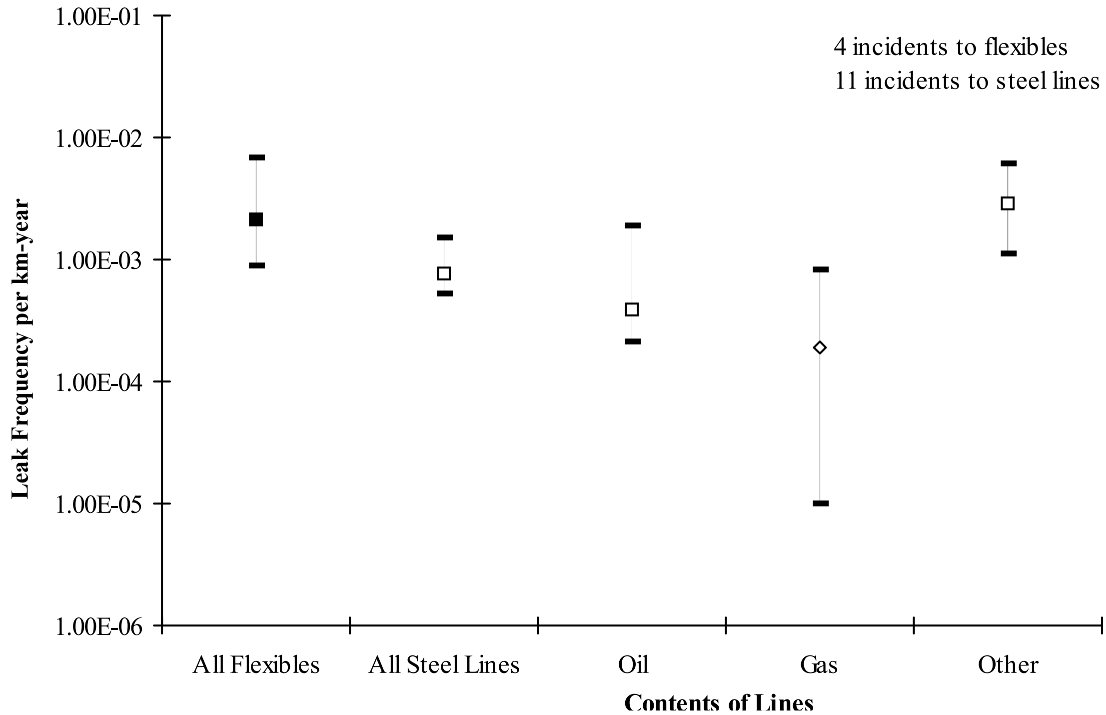


Figure 2-6 – Variation of Frequency of Loss of Containment Incidents for Lines 2-5km Long by Pipe Material and by Contents of Line for All Corrosion and Material Incidents

3 COMPILATION OF DATABASES

3.1 INTRODUCTION

The purpose of this study was to update and improve confidence in the statistical information available to assess the frequency of loss of containment associated with operation of North Sea pipelines. In order to achieve this, two databases have been compiled:

A **Pipeline Database,** which contains details of all the pipelines installed in the North Sea.

An **incident Database,** which contains a description of each reported incident and data on the pipeline or lines affected.

During this latest revision to the loss of containment study these databases have been extended to contain information collected until the end of 2000. The collation and contents of the complete databases is discussed in this Section.

Combining the information from both extended pipeline and incident databases enables the frequency of incidents to be related to the pipeline population as a whole in terms of incidents per year or per km-year, as appropriate.

Throughout the study, considerable care has been taken to ensure the data collected are as accurate and complete as possible, in order that the frequencies derived are representative of actual North Sea conditions. Extensive cross-checking and verification of records from different sources has been carried out and wherever discrepancies were identified careful engineering judgement was used to determine which source is most likely to be correct. This is discussed for both databases in the remainder of this Section.

3.2 PIPELINE DATABASE

3.2.1 Introduction

A *pipeline,* as defined in this study, *extends along the riser from the pig trap and associated pipework and valves, and includes all pipework and fittings on the main flow path and all branches on the main flow path up to and including the first valve on each branch.* Where a pipeline does not have a pig trap the first valve above water level is the termination point.

The pipeline database is used to calculate the population data associated with a selected group of incidents in terms of the total number, length and operating experience (in years or km-years) of installed pipelines satisfying certain specified criteria. The criteria by which the Incident database will be searched must also be contained in the pipeline database. It is, therefore, important that the database is as accurate and complete as possible with regard to these criteria to ensure that the frequencies calculated are representative. The most important of these criteria are pipe Diameter and contents, the pipe length and year of installation.

3.2.2 Contents of Database

The pipeline database contains information on the pipelines in the North Sea UK, Norwegian, Danish, German and Dutch sectors which have been installed to the end of 2000. In addition to pipelines and flowlines, details of some short lines, mostly less than 100 m, from manifold to manifold or from a template to a well just off the template, have been included. Umbilicals, lines separately identified but less than 1.5 inches in Diameter and very short jumper lines associated with subsea completions have also been included.

Tables 3.1 and 3.2 summarise the North Sea pipeline population and the associated operating experience to the end of 2000. Pipelines with contents in the "Other" category transport fluids such as water and chemicals.

The total number of pipelines listed to the end of 2000 is 1567. Of these 134 are short spools, less than 100 m in length. The last update of the database contained information on 1003 pipelines. The total length installed to the end of 2000 calculated from the extended pipeline database is 24,837 km and the operating experience 328,858 km year. This compares with 19,770 km and 195,690 km-years to the end of 1995 as contained in the last update of the database.

Most pipelines have been installed in one of the two main stages of North Sea development, from 1971-75 and later from 1981-85. Prior to 1971, very few lines were installed. There are approximately the same number of gas and oil pipelines overall, but the gas lines are longer, so that the total length installed is approximately twice that for oil lines. Between 1995 and 2000, 564 pipelines were installed.

Certain pipeline sizes have been used more often than others. Steel lines of 16 inch Diameter and less have been used equally often. However, of the larger sizes those commonly used have Diameters which are 16, 18, 20, 24, 30 and 36 inch. There are only two 22 inch, six 26 inch, five 28 inch, eight 32 inch, one 34 inch, one 35 inch and three 40 inch Diameter pipelines used in the North Sea. Therefore, in order to balance out this effect the population has been grouped into four categories, 0-9, 10-16, 18-24 and 26-40 inch, for analysis purposes.

Line Type		Contents of Pipeline			
Diameter (in)		Oil	Gas	Other	Total
Flexible lines		181	105	212	498
Steel Lines		319	451	299	1069
	0 to 9	161	142	249	552
	10 to 16	79	145	42	266
	18 to 24	37	84	5	126
	26 to 40	25	57	2	84
Unknown		17	23	1	41
Total		500	556	511	1567

Number of Pipelines in Database

Line Type		Contents of Pipeline			
Diameter (in)		Oil	Gas	Other	Total
Flexible lines		2576.0	1959.0	3620.0	8155.0
Steel Lines		79380.0	188194.0	39672.0	307246.0
	0 to 9	10364.0	8907.0	33702.0	52973.0
	10 to 16	16566.0	27861.0	3109.0	47536.0
	18 to 24	20292.0	37989.0	562.0	58843.0
	26 to 40	31862.0	113412.0	2297.0	147571.0
Unknown		296	24	2	322
Total		81956.0	190153.0	43292.0	315401.0

Operating Experience in km-Years to end of 2000

Line Type		Contents of Pipeline			
Diameter (in)		Oil	Gas	Other	Total
Flexible lines		365.0	600.0	1024.0	1989.0
Steel Lines		5388.0	13866.0	3594.0	22848.0
	0 to 9	925.0	1085.0	3024.0	5034.0
	10 to 16	1217.0	2274.0	398.0	3889.0
	18 to 24	1419.0	2880.0	53.0	4352.0
	26 to 40	1725.0	6598.0	118.0	8441.0
Unknown		102	1029	0	1131.0
Total		5753.0	14466.0	4618.0	24837.0

Installed Length to end of 2000 (km)

Line Type		Contents of Pipeline			
Diameter (in)		Oil	Gas	Other	Total
Flexible lines		275.0	229.0	548.0	1052.0
Steel Lines		4449.0	8432.0	3924.0	16776.0
	0 to 9	1244.0	1240.0	3506.0	5990.0
	10 to 16	1530.0	3243.0	385.0	5158.0
	18 to 24	780.0	2497.0	27.0	3304.0
	26 to 40	878.0	1441.0	5.0	2324.0
Unknown		17	11	1	29
Total		4724.0	8661.0	4472.0	17857.0

Riser Operating Experience in Riser-Years to end of 2000

Table 3-1 - Summary of Pipeline Database by Pipeline Diameter and Contents

Diameter (inches)	No. of pipelines	Total length (km)	Operating Experience (km Years)	No. of Risers	Riser Years
0 to 2	51	419.0	3757.0	63	665.0
>2 to 4	174	2166.0	23468.0	193	2261.0
>4 to 6	109	612.0	7078.0	72	842.0
>6 to 9	224	1856.0	18670.0	207	2223.0
>9 to 12	135	1395.0	13756.0	177	2209.0
>12 to 16	149	2820.0	33955.0	219	2946.0
>16 to 20	74	2145.0	30098.0	118	2064.0
>20 to 24	56	2120.0	27713.0	90	1768.0
>24 to 30	45	3447.0	52699.0	56	1100.0
>30 to 40	42	5849.0	95996.0	53	1006.0
Unknown	10	18	53	8	25
Total	1069	22847	307243.0	1256	17109.0

Table 3-2 - Summary of Steel Pipelines in Database by Pipeline Diameter

3.2.3 Sources of Data

A number of sources of information were used to assemble and verify the original and the revised versions of the pipeline database, these include:

- UKOOA Catalogue, 1988, 1991 and 1995 editions
- UK Health and Safety Executive (HSE) pipeline database, 1992
- UK Department of Energy (DEn) pipeline records to 1984
- Norwegian Petroleum Directorate (NPD) pipeline database
- Subsea Guide and 6th Edition Field Development Guide, published by OPL
- Pipeline Operators
- Journal articles, published papers etc.
- PARLOC 90 [Ref. 1]
- PARLOC 92 [Ref. 2]
- PARLOC 94 [Ref. 3]
- PARLOC 96 [Ref. 4]

For the UK sector in previous PARLOC reports, the basis for the database were the 1989, 1991, and 1995 editions of the catalogue compiled from information supplied by most operators to UKOOA. The basis for other sectors and areas where there were gaps in the UKOOA catalogue were the Guides published by OPL. In some cases pipeline operators supplied specific details of their pipelines, mostly relating to risers and flexible lines. For the current (2000) update information was obtained directly from the operators.

Other important confirmatory sources of pipeline details were Health and Safety Executive (HSE) pipeline database, the 1984 report prepared by SRS which gave the DEn (HSE) pipeline records until that date, an NPD database of Norwegian sector lines which correlated well with the existing records in the database, journal articles and papers which contain data on the main North Sea trunk lines and a database of subsea completions which was useful in establishing installation and abandonment dates for flowlines.

3.2.4 Data Collection

The type of information that has been collected for each pipeline and the codings used in the database are listed in Appendices A and B. The basic information recorded is the start and end points of the line, the operator, whether it is gas or oil service, the date it was installed and details such as Diameter, wall thickness, type of coating and specification. The specification is used to identify the grade of carbon steel, any special steels and the make of flexibles. The degree of protection given to the pipeline is recorded, such as whether it is trenched or buried, whether it is part of a bundle or it is piggy-backed onto a larger line. Other data which may be useful for the purpose of checking incident records such as commissioning date, notes on whether the pipeline was ever replaced and water depth are also recorded. The identification number which the relevant regulatory authorities assign to the pipeline is recorded where appropriate.

The database also includes data which allow the pipeline involved in a given incident to be identified in an unattributable way. These data fields include a pipeline number unrelated to the HSE or NPD identification number, the type of line, e.g. trunk or flowline, and whether it is in the northern, central or southern North Sea.

Where the data was available from the operator, the number of risers associated with the pipeline are also recorded. An assessment of whether the riser is internal or external was made from the available data sources. Confirmation of the assessment was obtained from the operator, where possible.

Additional attempts were made to include information relating to the type and numbers of fittings along the pipelines, the type of end connections employed (i.e. hyperbarically welded, flanged etc.) and the nature of the start and end points (i.e. shore, tee piece, FPF riser etc.). The nature of the start and end points of the pipeline was recorded for every pipeline, however, source information relating to fittings and end connections was very limited. It was possible to record the type of end connections for only a third of the lines within the database. Details relating to fittings were even more scarce with published sources generally only commenting on the presence of SSIVs (subsea isolation valves) or ESDVs (emergency shut down valves). The general opinion from the operators was that this information was likely to be available within their organisation but the data collection would be extremely time consuming. Therefore for this revision of the study the pipeline database has only been updated to reflect the information held in published sources.

3.2.5 Data Collation and Verification

Where information could be verified by comparison of two or more sources the accuracy in the most important fields is good. Pipeline Diameters are rarely different, however, pipeline lengths differ by as much as 10-20%

at times, which may be 0.5-1 km on the shorter lines and 10 km on the long trunk lines. Reported installation dates generally agree to within a year.

Not all the information about a particular pipeline could be found in all cases. Most sources identify the Diameter, contents, length and installation date but only some provide secondary information such as wall thickness or burial conditions. It has therefore been possible to create a database which is over 99% complete in the four main fields but in others it is typically 70-90% complete.

3.3 INCIDENT DATABASE

3.3.1 Introduction

The main sources of incident data that were used in the original study and during this update are operator incident reports and regulatory authority incident records.

The information held by the UK Health and Safety Executive (UK Department of Energy until 1990) included "reportable occurrences" as defined in Schedule I of the Submarine Pipelines (Inspectors etc.) Regulations 1977. These include near misses such as wrecks or mines discovered in the vicinity of a pipeline, as well as the events which result in damage to lines. This information has been collected, collated and assessed. However, in this report only occurrences from verifiable sources which directly resulted or threatened to result in loss of containment of a pipeline have been considered. Occurrences which could not be confirmed by one of the main sources or did not actually affect the line have been excluded from the analysis.

3.3.2 Contents of Database

The revised database now contains the following details:

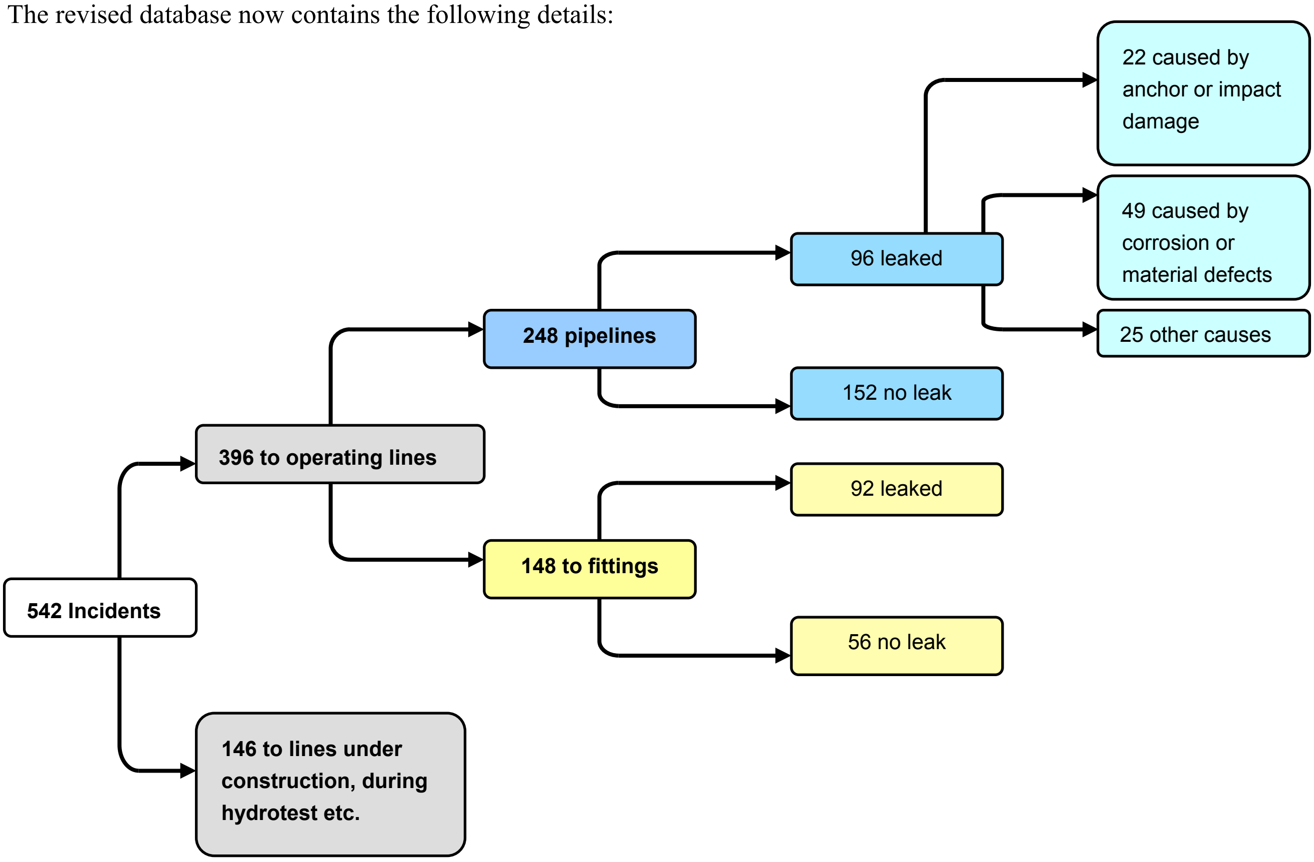


Figure 3-1 Summary of the contents of the PARLOC 2001 Incidents Database

A further 13 incidents related to oil loading structures and equipment have not been included in the main database since they are not directly concerned with pipelines.

By comparison, PARLOC 96 contained the following details:

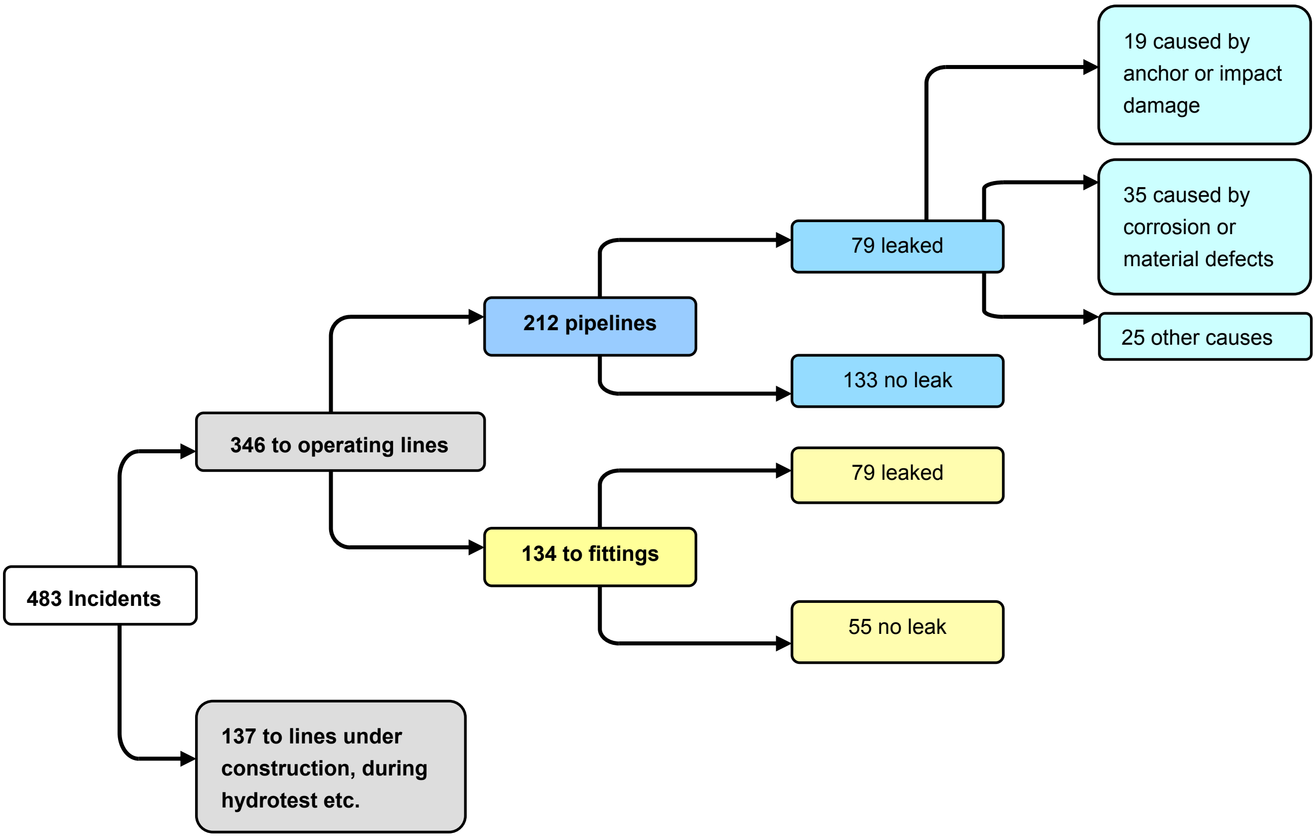


Figure 3-2 Summary of the contents of the PARLOC 96 Incidents Database

In this study incidents to fittings and pipelines have been identified separately; whereas the population of North Sea pipelines is known so that incident frequencies can be determined, the number and distribution of fittings on North Sea pipelines could not be determined from the information made available to the study.

Table 3.3 summarises the records in the incident database. There are 3 incidents involving pipelines not listed in the table due to unknown status at the time of incident. The incidents which resulted in loss of containment from operating pipelines are discussed in detail in Section 4. Incidents which directly resulted or threatened to result in loss of containment of an operating pipeline are considered in Section 5.

The database of pipeline incidents has been compiled so that it contains all relevant details available on a particular incident. It can also be used to identify the separate information contributed to any one incident record from various individual sources.

The important factors contributing to the achievement of completeness in database information are

- Data Sources
- Data Collection
- Data Collation and Verification.

These are discussed in the remainder of this Section.

Status of Pipeline at Incident	Number of Incidents	CONSEQUENCE OF INCIDENT					
		No Leak	Leak	0-20mm	20-80mm	80mm and above	Unknown
Operating	248	152	96	56	16	21	3
Shut Down	17	15	2	0	1	1	0
Under Construction	66	47	19	2	0	16	1
Before Commissioning	12	11	1	1	0	0	
Hydrotest	20	4	16	7	1	7	1
Commissioning	3	1	2	0	1	1	0
Total	366	230	136	66	19	46	5

a) Incidents involving Pipelines

Status of Pipeline at Incident	Number of Incidents	CONSEQUENCE OF INCIDENT					
		No Leak	Leak	0-20mm	20-80mm	80mm and above	Unknown
Operating	148	56	92	67	13	7	5
Shut Down	11	5	6	5	0	1	0
Under Construction	4	1	3	0	0	0	3
Before Commissioning	2	1	1	1	0	0	0
Hydrotest	8	4	4	4	0	0	0
Commissioning	3	1	2	1	0	1	0
Total	176	68	108	78	13	9	8

b) Incidents involving Fittings

Table 3-3 – Summary of the Contents of the Incident Database

3.3.3 Sources of Data

The incident database has been compiled from information supplied by:

- UK, Norwegian, Dutch, Danish and German Regulatory Authorities
- Operators in the UK, Dutch and Danish sectors
- Reports from previous studies made available to the project
- Other published sources.

Table 3.4 lists the number of incidents derived from each source for incidents involving operating pipelines. The sources are discussed in detail in the rest of this Section.

Primary Source of Incident Information	All Incidents	Loss of Containment Incidents
Operator	120	63
UK DEn	28	17
UK HSE	134	60
UK DEn/SRS	49	25
NPD	44	18
Protech	10	0
Veritec	3	2
Journal	7	3
Battelle	1	0
TOTAL	**396**	**188**

Table 3-4 - Sources of Data on Incidents to Operating Pipelines, Including Fittings

Regulatory Authorities

During the compilation of the database, MML contacted all regulatory authorities concerned with North Sea pipelines and all UK operators were contacted to obtain details of incidents.

The Norwegian Petroleum Directorate supplied information relating to the incident details held in their databases. The Dutch Staatstoezickt op de Mijnen supplied a listing of incidents and contacts within the relevant operators. The Danish Energy Agency provided a list of contacts within the pipeline operators. Similar to the study in Parloc 96, no incidents have been reported for the small number of pipelines within the German Sector. The response and co-operation of all these organisations during all phases of the study has been excellent and assisted in ensuring completeness of the revised database over the whole of the North Sea for incidents up to the end of 2000.

Operator Supplied Information

During the study, roughly 54 operators in the UK, Dutch, Norwegian and Danish sectors were contacted directly for assistance in compiling the database. During the update, 23 operators provided detailed responses containing information relating to incidents that were not reported on in the earlier phases of the study or confirmed that there had been no new incidents.

3.3.4 Data Collection

The first stage in assembling the database involved recording as much information as possible about each incident given by a particular data source onto a standard form. The incident form used during the original study was based on that used in the SRS 1984 study, in response to a request made by the UK Department of Energy, when collating their information. During the original study this format was maintained for all data sources, which ensured that all data was recorded in a consistent manner. The incident form used in this update of the database is a slightly expanded version of that used in the original study. An example of the incident form is presented in Appendix F.

The information supplied on each form was transferred to the database and identified by a unique source reference number, which was also recorded on the corresponding form. If there was insufficient information to identify the pipeline from the source alone, such as was the case for the Battelle incidents collated in the original study, then the pipeline database was used as the starting point in establishing its identity, or possible alternatives, so that cross referencing with other sources could be performed.

The incident database contains fields identifying the following:

- source of information;
- date either of the incident or of when the damage was discovered (since it is rare to know both);
- pipeline status at the time of the incident;
- location of the incident along the pipeline;
- text description of the cause;
- any details or contributing factors;

Further fields in the incident database identify the following:
- damage incurred;
- the extent of leakage in terms of equivalent hole size;
- actions taken to correct the problem.

Other data fields contain the details of the pipeline involved in the incident, i.e. the pipeline operator, start point, end point, Diameter, thickness, material specification, contents, installation date as in the pipeline database.

The incident record is mainly descriptive because this is the most effective way to describe fully the causes of a particular type of incident and, should additions be made at a later date, the possibility of duplicated records is minimised if detailed entries exist.

In reporting pipeline incidents the location has normally been given as one of six zones:

- platform;
- riser;
- safety zone (≤ 500 m from the platform);
- mid line (>500 m from the platform);
- within 500 m of a subsea well;
- shore approach.

Using the information presented in the incident records it has been possible to further subdivide the location for some incidents to include:

- pipeline 100-500 m from the platform;
- subsea pipeline to 100 m from the platform;
- submerged riser;
- riser in the splash zone.
- riser piping from the splash zone to pig trap or first valve above sea level.

Based on details in the description of the incident or a qualitative interpretation of the incident record, the size of the damage has been classified by hole size as follows:

- 0 to 20 mm;
- 20 to 80 mm;
- 80 mm and above

Note that these definitions are based on the size of damage to the pipeline rather than the volume of product lost. The volume lost will be a function of hole size, operating conditions and time taken to locate and shut down the leak. The data fields and coding used for the incidents database are presented in Appendix A.

3.3.5 Data Collation and Verification

Data collation was performed using the following main steps:

i) Assess each data source and assign a confidence rating for the information presented in it.
ii) Check that data in the database has been correctly extracted from the original sources.
iii) Compare the information held in the original sources about the same incident and resolve the differences using the results of (i).
iv) Review of database to verify that no duplicate data has been included, which may contain slight but sometimes significant differences.
v) Supplement the information given for each incident or data entry with other details known about the system.
vi) Produce database entry.

It was found that information supplied directly from the operators agreed in the most part with information obtained from the regulatory authorities. Therefore, these sources were assigned a high confidence rating. The only information supplied by these sources which was not included in the final analysis was that corresponding to records in which the integrity of the pipeline was not affected; for example, wreck found near the line.

The Protech report was also considered reliable because it involved discussions with operators.

Journal articles were found to be fairly reliable and provided a useful confirmation, and sometimes additional details, of incidents reported officially.

The Battelle database was confirmed as being the least accurate because it was based on pipelines which could only be identified indirectly and contained very brief descriptions of incidents and consequences. In addition, a number of inconsistencies were found. Therefore, the general philosophy in assessing the Battelle database has been to request confirmation from operators and not use those incidents which were stated not to have occurred. Battelle data do, in the main part, seem to be confirmed by operators and by other reports in Protech, published papers and SRS.

Where more than one record existed for a particular incident containing differences in some of the details, the confidence ratings of the individual records were used to assess whether these were duplicate sets and decide between alternative versions. An overall incident record was established combining the verified information from the different sources. A unique project incident number was then assigned to the record and the remaining, duplicate, sets were marked as such and cross-referenced to the same incident number.

4 LOSS OF CONTAINMENT INCIDENTS

4.1 INTRODUCTION

In this Section, the causes and consequences of the incidents which resulted in loss of containment from operating pipelines contained in the incident database are described and the results of an analysis of these incidents are presented. In the database there are details of 188 incidents associated with operating steel and flexible pipelines which resulted in leaks. 96 of these incidents resulted in loss of containment from the pipeline whereas for the remaining 92 incidents the leak was from a fitting associated with the pipeline. In the analysis the estimate of the loss of containment frequency based upon the reported number of incidents and the appropriate confidence interval are used to determine the influence of contributory factors.

In Section 5 an assessment of all incidents involving operating pipelines is presented and the loss of containment and repair frequencies are tabulated.

The data contained in this Section and in Section 5 can be considered as a starting point in the identification of potential hazards and provide initial indications of the likely levels of the loss of containment frequency for an individual pipeline. However, it should be noted that individual pipelines may have very different histories, properties, characteristics and functions, many of which may not have been considered to the required detail in the analysis presented in this Section. Therefore it is recommended that each pipeline should be individually assessed.

4.2 CAUSES AND CONSEQUENCES OF INCIDENTS

4.2.1 Causes of Incidents

The causes of the 188 incidents that resulted in leakage are summarised in Tables 4.1, 4.4 and 4.5 by location on the pipeline where the leak occurred.

Operating Steel Lines

The causes of the 65 leaks involving steel line are summarised in Table 4.1. Table 4.2 gives an indication of the range of pipeline Diameters affected by these incidents.

17 of the 65 incidents were due to external forces, either anchoring or impact from other sources. Supply boats were responsible for 6 leakages caused by anchoring vessels, and all of these occurred in the platform safety zone. A further 3 with unknown causes of which 2 are thought due to trawling or anchoring. Trawls are known to have been responsible for 6. Another 2 impact incidents were caused by a sinking vessel landing on a line and a dredger working on the construction of an adjacent line.

36 of the 65 incidents were due to corrosion or material defects in the pipeline. Of the 26 corrosion incidents which resulted in leaks, 14 were caused by internal corrosion. 1 of the external corrosion incidents was the Ekofisk 2/4A riser failure which occurred in 1975. There are 5 corrosion incidents with insufficient details to determine if they are of external or internal nature. 10 leaks were attributed to defects in the weld or steel, including 2 cases of brittle fracture. 2 of the 11 incidents, the cause of which is given as ‘other’ in Table 4.1, were either material or corrosion failures. However, from the information available from the relevant regulatory authority and the operator it was not possible to determine which.

The structural failure was a riser clamp failure which resulted in the riser being dropped and the leak occurred from a buckle in the riser.

The 11 other incidents of leaks from operating steel lines resulted from unknown causes.

		Total	Platform	Riser					Safety Zone				Mid Line	Well	Shore Zone	Land	SPM
				Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown					
Anchor	Ship / Supply Boat	6		0					6	1	4	1					
	Rig or Construction	0		0					0								
	Other/Unknown	2		0					0				2				
	Total	8	0	0	0	0	0	0	6	1	4	1	2	0	0	0	0
Impact	Ship on Riser	0		0					0								
	Trawl	6		0					0				6				
	Dropped Object	0		0					0								
	Wreck	1		0					0				1				
	Construction	1		0					1	1							
	Other/Unknown	1		0					0				1				
	Total	9	0	0	0	0	0	0	1	1	0	0	8	0	0	0	0
Corrosion	Internal	14		0					3	2	1		7	4			
	External	7		4		4			1			1	2				
	Unknown	5	1	1	1				1	1			2				
	Total	26	1	5	1	4	0	0	5	3	1	1	11	4	0	0	0
Structural	Expansion	0		0					0								
	Clamp Failure	1		1			1		0								
	Buckling	0		0					0								
	Total	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Material	Weld Defect	4		0					2	1	1		1				1
	Steel Defect	6		2				2	2	1		1	1	1			
	Total	10	0	2	0	0	0	2	4	2	1	1	2	1	0	0	1
Nat. Hazard	Vibration	0		0					0								
	Storm	0		0					0								
	Scour	0		0					0								
	Subsidence	0		0					0								
	Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire/Explosion	Total	0		0					0								
Construction	Total	0		0					0								
Maintenance	Total	0		0					0								
Other	Total	11		4			1	3	2	2			4	1			
	Total	65	1	12	1	4	2	5	18	9	6	3	27	6	0	0	1

Table 4-1 – Causes of Incidents to Operating Steel Pipelines which Resulted in a Loss of Containment

Location on Pipeline	Cause of Incident	Pipeline Diameter (inches)
Mid Line	Impact-trawl	2.375
Mid Line	Other-unknown.	4.5
Mid Line	Impact.	34
Mid Line	Internal corrosion	10.75
Mid Line	Other-unknown.	6.625
Mid Line	Other-unknown.	2
Mid Line	Internal corrosion	12.75
Mid Line	Corrosion-unknown.	4.5
Mid Line	Impact-wreck	20
Mid Line	Material-weld defect	30
Mid Line	Impact-trawl	2.375
Mid Line	Impact-trawl	3.5
Mid Line	Internal corrosion	6.625
Mid Line	Internal corrosion	9.13
Mid Line	Internal corrosion	6.625
Mid Line	Internal corrosion	6.625
Mid Line	Material-steel defect	24
Mid Line	Anchor-ship/supply boat	3
Mid Line	External corrosion	5
Mid Line	Anchor-ship/supply boat	2.375
Mid Line	External corrosion	5
Mid Line	Internal corrosion	6.625
Mid Line	Corrosion-unknown.	6.625
Mid Line	Impact-trawl	2
Mid Line	Impact-trawl	2
Mid Line	Other-unknown.	2.375
Mid Line	Impact-trawl	10.75
Platform	Other-unknown	30
Riser	Other-unknown	16
Riser	Other-unknown.	10.75
Riser	Material-unknown	8
Riser	Other-unknown	20
Riser	Material-steel defect	12.75
Riser Piping	Corrosion-unknown.	6
Riser Splash Zone	External corrosion.	6.625
Riser Splash Zone	External corrosion.	10.75
Riser Splash Zone	External corrosion.	6.625
Riser Splash Zone	External corrosion	12.75
Riser Subsea	Corrosion-unknown.	10.75
Riser Subsea	Structural-clamp failure.	16
SPM	Material-weld defect.	36
Safety Zone	Anchor-ship/supply boat	16
Safety Zone	External corrosion.	3.5
Safety Zone	Material-steel defect	11.4
Safety Zone Far	Internal corrosion	8.625
Safety Zone Far	Anchor-ship/supply boat	16
Safety Zone Far	Anchor-wreck	12.75
Safety Zone Far	Anchor-ship/supply boat	10
Safety Zone Far	Anchor-ship/supply boat	10
Safety Zone Far	Material-weld defect	24
Safety Zone Near	Internal corrosion	4
Safety Zone Near	Anchor-ship/supply boat.	4.5
Safety Zone Near	Internal corrosion	4.5

Table 4.2 - Diameter Range of Operating Steel Pipelines Affected by Incidents Which Resulted in a Loss of Containment

Cont'd…….

Location on Pipeline	Cause of Incident	Pipeline Diameter (inches)
Safety Zone Near	Impact-construction vessel	2.375
Safety Zone Near	Material-weld defect.	4.5
Safety Zone Near	Corrosion-unknown.	4.5
Safety Zone Near	Other-unknown.	6.625
Safety Zone Near	Corrosion-unknown.	6.625
Safety Zone Near	Structural-unknown	5.37
Well	Internal corrosion	4.5
Well	Internal corrosion	10.75
Well	Internal corrosion	6.625
Well	Internal corrosion	6.625
Well	Material-steel defect	6.625
Well	Other-unknown.	6.625

Table 4-2 - Diameter Range of Operating Steel Pipelines Affected by Incidents Which Resulted in a Loss of Containment

Flexible Lines

The causes of incidents to operating flexible pipelines that resulted in loss of containment are presented in Table 4.4. Table 4.3 gives an indication of the range of pipeline Diameters affected by these incidents. 12 of the 31 leaks in flexible flowlines were due to material problems. 5 of these incidents were due to embrittlement of the liner due to inappropriate operating conditions for the available liners. Higher specification liners are now available. The remaining 19 incidents were due to external damage and internal corrosion (1 No.). 3 incidents were due to trawl gear, 1 was due to damage caused by an anchor and another was caused by an object dropped on the line. Of the other incidents, 3 were caused by damage incurred during installation or aggravation of earlier damage during maintenance operations, 1 was caused by a line buckling, 1 was caused by a supply boat, 2 were incidents associated with structural problems and the remaining 8 were due to unknown causes.

Location on Pipeline	Cause of Incident	Pipeline Diameter (inches)
Mid Line	Repair	3
Mid Line	Material-flexible defect	Unknown
Mid Line	Material-flexible defect	Unknown
Mid Line	Other-unknown	Unknown
Mid Line	Impact-trawl	6
Mid Line	Other-unknown	Unknown
Mid Line	Material-flexible defect	4
Mid Line	Material-flexible defect	4
Mid Line	Structural-clamp failure	10
Safety Zone Near	Material-flexible defect	4
Safety Zone Near	Material-flexible defect	8
Platform	Internal corrosion.	16
Riser	Other-unknown	12
Riser	Material-flexible defect	Unknown
Riser	Other-unknown	8
Riser	Other	Unknown
Riser Subsea	Material-flexible defect	8.625
Unknown	Other	Unknown
Unknown	Other	Unknown
Unknown	Other	6
Well	Construction	6
Well	Construction	6
Well	Impact-trawl	6
Well	Impact-dropped object	6
Well	Impact-trawl	6
Well	Material-flexible defect	4.5
Well	Material	4
Well	Material-flexible defect	4
Well	Anchor-ship/supply boat	6
Well	Structural	6
Well	Material-flexible defect	4

Table 4-3 - Diameter Range of Operating Flexible Pipelines Affected by Incidents Which Resulted in a Loss of Containment

		Total	Platform	Riser					Safety Zone				Mid Line	Well	Shore Zone	Land	SPM	Unknown
				Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown						
Anchor	Ship / Supply Boat	1		0					0					1				
	Rig or Construction	0		0					0									
	Other/Unknown	0		0					0									
	Total	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Impact	Ship on Riser	0		0					0									
	Trawl	3		0					0				1	2				
	Dropped Object	1		0					0					1				
	Wreck	0		0					0									
	Construction	0		0					0									
	Other/Unknown	0		0					0									
	Total	4	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0
Corrosion	Internal	1	1	0					0									
	External	0		0					0									
	Unknown	0		0					0									
	Total	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Structural	Expansion	0		0					0									
	Clamp Failure	1		0					0				1					
	Buckling	1		0					0					1				
	Total	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Material	Weld Defect	0		0					0									
	Steel Defect	0		0					0									
	Flexible Defect	12		2			1	1	3	2		1	4	3				
	Total	12	0	2	0	0	1	1	3	2	0	1	4	3	0	0	0	0
Nat. Hazard	Vibration	0		0					0									
	Storm	0		0					0									
	Scour	0		0					0									
	Subsidence	0		0					0									
	Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire/Explosion	Total	0		0					0									
Construction	Total	2		0					0					2				
Maintenance	Total	1		0					0				1					
Other	Total	8		3				3	0				2					3
	Total	31	1	5	0	0	1	4	3	2	0	1	9	10	0	0	0	3

Table 4-4 – Causes of Incidents to Operating Flexible Pipelines which Resulted in a Loss of Containment

Fittings

75 of the 92 leaks which were associated with fittings were caused by failure of the fitting itself, as indicated in Table 4.5. Flanges, valves, pig trap components and connectors, such as hydrocouples, were affected in roughly equal numbers with the greatest number, 15, occurring to connectors. 6 further leaks were caused by human error in that valves were wrongly operated. 3 leaks were associated with ESDVs, of which in 1 incident an ESDV leaked through a stem seal and 1 was due to fatigue. Of the 2 SSIV leaks one was through a nipple and the other through a stem seal. Of the other 17 incidents, 2 were due to anchors damaging valves, 2 occurred through trawl damage, 1 was cause by buckling, 2 were caused by risers moving during a storm and 1 was caused by a single-point mooring (SPM) moving during a storm, 4 were due to defects in the welds or material failures, 4 were due to rapid corrosion or erosion and the other 1 was of unknown cause.

85 of the leaks were from fittings associated with steel lines, 7 were from fittings associated with flexible lines.

Of the 92 fitting leaks, 50 were gas leaks, 32 were oil leaks, 4 involved methanol lines, 5 were water lines and the contents of the remaining line was unknown.

Although over half the loss of containment incidents that have been recorded for pipeline systems have occurred to fittings, it has not been possible to establish corresponding frequency rates. As discussed in PARLOC 96, this is because the required experience data is not available in the documentation and databases made available to the study. This information could be extracted through operator supplied data, Process and Instrument Diagram (P&ID) drawings or listings of equipment. In order to be compatible with the incident database all fittings on the pipeline should be assessed up to and including the pig trap. Given the large number of incidents to fittings this would be a useful development which would assist in the proper treatment of fittings in safety studies.

a) Incidents to Fittings Associated with Operating Steel Lines

				Riser					Safety Zone									
		Total	Platform	Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown	Mid Line	Well	Shore Zone	Land	SPM	Unknown
Anchor	Other/Unknown	2							1			1		1				
Impact	Trawl	2							0				1	1				
Corrosion	Internal	4	1	1				1	2	1		1						
Structural	Buckling	1							0				1					
Material	Weld Defect	1	1						0									
	Steel Defect	2	2						0									
	Total	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nat. Hazard		3		2			1	1	0								1	
Other		1							0				1					
Fitting	Flange Leak	10	2	5	1		2	2	1			1		1				1
	Seal leak	2	1	1				1	0									
	Valve Leak	13	7	0					3		1	2	2	1				
	Connector Lead	6		0					0				4	1			1	
	Hydrocouple Leak	6		1				1	4	1		3	1					
	Load Limit Connector Leak	3		0					0					3				
	Insulation Joint Leak	1		1		1			0									
	Nipple Leak	4	1	0					1			1	1	1				
	Pig Trap	11	10	1	1				0									
	Human Error	6	4	0					0				1				1	
	Unknown Fitting Leak	2	0	1				1	0				1					
	ESDV Leak	3	3	0					0									
	SSIV Leak	2		0					2	2								
	Total	69	28	10	2	1	2	5	11	3	1	7	10	7	0	0	2	1

b) Incidents to Fittings Associated with Operating Flexible Lines

Material	Weld Defect	1	1	0					0									
Fitting	Connector Leak	1		1				1	0									
	ESDV	1	1	0					0									
	Flange Leak	1		0					1	1								
	Load Limit Connector Leak	2		0					1	1				1				
	Seal Failure	1		1			1		0									
	Total	92	34	15	2	1	4	8	16	6	1	9	13	10	0	0	3	1

Table 4-5 – Causes of Incidents to Fittings Associated with Operating Pipelines which Resulted in a Loss of Containment

4.2.2 Region of Pipeline Affected by Incidents

Tables 4.1 to 4.5 also indicate the region along the pipeline where the 188 incidents that resulted in leakage occurred. In all these Tables the number of incidents which have occurred on or near to a platform, including the platform safety zone, exceed the number that have occurred away from it, although the operating experience measured in km-years is much larger away from platforms. Therefore the frequency of leaks is much greater near to platforms than away from them.

Platform

36 leaks occurred on platforms, 34 of which were associated with the fittings associated with operating pipelines. Of the remaining 2, one was associated with a steel pipeline, the other with a flexible line.

Riser

Of the 32 riser leaks only 5 were definitely reported to have occurred in the splash zone, 3 in the piping above sea level and 7 subsea. The exact locations of the other 17 were unknown. A breakdown of the factors involved in the riser leaks follows:

- 25 involved steel lines.
- 7 involved flexible risers.
- 17 were pipeline incidents.
- 15 involved fittings.

Safety Zone

37 leaks occurred within the 500 m platform safety zone:

- 32 involved steel lines.
- 5 involved flexible lines.
- 21 were pipeline incidents.
- 16 were fittings incidents.

Of these 37 leaks, 17 definitely occurred within 100 m of the platform and 7 definitely occurred within the safety zone but more than 100 m from the platform. The exact location of the other 13 incidents was not reported.

A total of 75 leaks were reported outside platform safety zones, either in the mid line of operating pipelines or within 500 m of subsea wells.

Mid Line

49 incidents occurred in the mid line of the pipelines, away from platforms or subsea wells.

- 40 involved loss of containment from steel pipelines.
- 13 involved fittings associated with operating pipelines.
- 9 involved flexible lines.

Subsea Well

27 of the incidents were reported to have occurred within 500 m of subsea wells.

- 10 involved fittings associated with operating pipelines.
- 6 involved steel lines.
- 11 involved flexible lines.

SPM

4 incidents involved Single Point Moorings.

Other

The location of the remaining 4 incidents remains unknown. This is due to a lack of information in the database from either Operators or Regulatory Authorities. 3 of these unknown incidents occurred on operating flexible pipelines and 1 was a fitting incident associated with an operating steel pipeline. These unknown incidents are included in the overall total of 188 incidents.

No loss of containment incidents were reported in the shore zone or on the land sections of offshore pipelines.

4.2.3 Consequences

Equivalent Hole Size

The size of damage has been classified according to equivalent hole Diameter based on details in the description of the incident or an interpretation of the incident record.

The equivalent hole size in the 65 incidents which resulted in loss of containment from operating steel pipelines is shown in Table 4.6. The equivalent hole size is presented by pipeline Diameter and the location of the incident.

- 16 incidents resulted in damage with an equivalent hole size greater than 80 mm
- 12 resulted in damage with an equivalent hole size of 20 - 80 mm
- 37 resulted in damage with an equivalent hole size of less than 20 mm

Also indicated in Table 4.6 is whether the pipeline involved was ruptured or not. In total 13 lines were described as being severed or ruptured; in 3 cases the lines were less than 80 mm in Diameter and so these appear as 20-80 mm equivalent hole size in the category 0 to 9 inch Diameter.

Similar information for the 31 incidents that resulted in loss of containment from operating flexible pipelines is presented in Table 4.7. 6 flexible line incidents resulted in rupture of the line, 1 in damage with an equivalent hole size of 20 - 80 mm and 5 greater than 80mm. 19 incidents resulted in small damage with an equivalent hole size of less than 20 mm and 4 fell in the 20-80mm category. 3 incidents associated with flexible lines are reported, however no data relating to equivalent hole size could be obtained from operators. Most of the flexible pipelines damaged were in the Diameter range of 2 to 8 inches. 1 riser of 12 inch Diameter was damaged.

Leaks Associated with Fittings

Table 4.8 shows the equivalent hole size for incidents to fittings associated with operating pipelines. 67 of the leaks from fittings associated with operating pipelines were described as having an equivalent hole size of less than 20 mm. There were 5 incidents of leakage with an equivalent hole size less than 20 mm, where no information about the pipeline diameter was available. In 13 incidents the leaks were described sufficiently to determine that the equivalent hole size was greater than 20 mm and in 7 incidents it was possible to determine that the equivalent hole size was greater than 80 mm.

Hydrocarbon Release

In the Incident Database, there are 96 reported incidences resulting in a loss of containment from steel and flexible pipelines and 92 from a fitting associated with the pipeline. For the leaking incidents to fittings, there are 4 incidents where there are quantitative data concerning the leakage per minute, per hour or per day. More information regarding the statistical analysis of hydrocarbon release data can be found in the Offshore Technology Report 2000/073 Development of Statistical Models for Data Analysis. Of the 96 reported leaks to steel and flexible lines, 65 leaks were reported as hydrocarbons. Of these approximate volumes were reported for only 5 of the 92 loss of containment incidents.

Location of Incident		Pipeline Diameter Range (in)																		
		0 to 9						10 to 16						>16						All Diameter Ranges
		Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						
		0-20	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**0-20**	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**0-20**	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**Unknown**
Platform	Total													1						
Riser	Piping	1																		
	Splash Zone	1				1	1	1				1	1							
	Subsea							1		1										
	Unknown					1	1	2				1	1			1				
	Total	2	0	0	0	2	2	4	0	1	0	2	2	0	0	1	0	0	0	0
Safety Zone	Near	5		3	1	1														
	Far	1						1		1		2	2	1		1				
	Unknown	0				1						2	1							
	Total	6	0	3	1	2	0	1	0	1	0	4	3	1	0	1	0	0	0	0
Mid Line	Total	14		4	2	1	1	1				3		2				2	2	
Subsea Well	Total	4		1				1												
Shore	Total																			
Land	Total																			
Unknown	Total																			
Total	65	26	0	8	3	5	3	7	0	2	0	9	5	4	0	2	0	2	2	0

Table 4-6 – Size of Damage, Expressed as an Equivalent Hole Diameter to Operating Steel Pipelines

Location of Incident		Pipeline Diameter Range (in): 2 to 9 — Equivalent Hole Diameter (mm): 0-20	Rupture?	20-80	Rupture?	>80	Rupture?	10 to 16 — Equivalent Hold Diameter (mm): 0-20	Rupture?	20-80	Rupture?	>80	Rupture?	All Diameter Ranges: Unknown
Platform	Total									1				
Riser	Piping													
	Splash Zone													
	Subsea					1	1							
	Unknown	3						1						
	Total	3	0	0	0	1	1	1	0	0	0	0	0	0
Safety Zone	Near	1												
	Far													
	Unknown			1								1	1	
	Total	1	0	1	0	0	0	0	0	0	0	1	1	0
Mid Line	Total	6		1	1	1	1							
Subsea Well	Total	8		1		2	2							
Shore	Total													
Land	Total													
Unknown	Total													3
Total	31	18	0	3	1	4	4	1	0	1	0	1	1	3

Table 4-7 – Size of Damage, Expressed as an Equivalent Hole Diameter, to Operating Flexible Pipelines

Location of Incident		Pipeline Diameter Range (in)																		
		0 to 9						10 to 16						>16						All Diameter Ranges
		Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						Equivalent Hole Diameter (mm)						
		0-20	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**0-20**	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**0-20**	Rupture?	**20-80**	Rupture?	**>80**	Rupture?	**Unknown**
Platform	Total	6		1				6		1		1	1	11		7		1		
Riser	Piping							1						1						1
	Splash Zone													1						
	Subsea	2												2						
	Unknown					1		2						3						1
	Total	2	0	0	0	1	0	3	0	0	0	0	0	7	0	0	0	0	0	2
Safety Zone	Near	2				1	1			1				2						
	Far													1						
	Unknown	3						1						5						
	Total	5	0	0	0	1	1	1	0	1	0	0	0	8	0	0	0	0	0	0
Mid Line	Total	4						4				1	1	2		3				
Subsea Well	Total	8				2	2													
Shore	Total																			
Land	Total																			
Unknown	Total																			3
Total	92	25	0	1	0	4	3	14	0	2	0	2	2	28	0	10	0	1	0	5

Table 4-8 – Size of Damage, Expressed as an Equivalent Hole Diameter, to Fittings associated with Operating Pipelines

4.3 ANALYSIS OF LOSS OF CONTAINMENT INCIDENTS

4.3.1 Introduction

Earlier phases of the study and other work referenced in Section 3.2.3 have identified that the likelihood of damage to a pipeline in the safety zone near to a platform is significantly higher than in the open sea. The same trend has again been confirmed in this study for the number of loss of containment incidents, as was discussed in Section 4.2.2. This Section and Section 4.4 examine the influences of these and other factors on the estimate of the loss of containment frequency based upon the reported number of incidents and the corresponding confidence interval calculated from the databases assembled in this study. In this Section the incident cause, location of pipeline affected and pipeline Diameter, length and contents are considered. The effect of other factors identified in earlier studies is considered in Section 4.4. The factors considered are:

- Bundled Lines
- *Changes in Pipeline Service*
- *Field Joints*
- Hydrotest Pressure
- *Inspection and Maintenance*
- Location of Risers
- Piggybacked Lines
- Pipeline Age
- Pipeline Location in the North Sea
- Pipeline Protection and Burial
- *Pipeline Routeing*
- Pipeline Steel Grade
- *Subsea Systems*
- Type of Line

In the preceding list the use of italic script identifies those factors for which insufficient information was available for any reliable conclusions to be drawn. These are nonetheless factors which are considered to have the potential to influence the failure rates of the pipelines. No information has for example been collated on failure incidents associated with subsea systems although subsea systems are becoming more common.

In all of the calculations the frequencies are given in terms of per km-year for mid-line incidents and per year of operational experience for subsea well, platform safety zone, shore zone and riser incidents. The estimate of loss of containment frequency has been calculated on the basis of actual numbers of reported incidents divided by the appropriate operating experience. This is shown on the Figures using open square symbols for steel lines and filled square symbols for flexible lines.

In common with other studies [5-7], it has been assumed that the likelihood of loss of containment incidents in a specific group is constant, i.e. the number of incidents follows a Poisson distribution. To validate this assumption the variation of leak frequency with age of the pipeline at the time of the incident has been considered and is presented in Section 4.4.3.

Based on this assumption the upper 95 per cent and lower 5 per cent confidence limits for each group have been calculated and are also shown on the Figures. The interval between the limits reflects the number of incidents in each group; for cases where the number of incidents is small the lines connecting the upper and lower confidence limits in the Figures are long in comparison to the cases where the number of incidents is larger.

The upper 95 per cent limit is calculated for the special case where no loss of containment incidents have been reported for pipelines in that particular group. This is the accepted method for analysing failure data [5,7]. The diamond on this line indicates the position where the estimate of loss of containment frequency would be if 0.7 (corresponding to 50% confidence on Poisson distribution [5] for zero incidents occurring) incidents had occurred. An open diamond represents steel lines and a filled diamond flexible lines.

36 of the 65 loss of containment incidents involving steel pipelines were due to corrosion or material defects in the pipeline. 17 of the 65 incidents were due to external forces, involving either anchoring or impact from other sources. All loss of containment incidents which occurred to steel pipelines, excluding risers, were caused by corrosion, material defect, impact or anchoring, except the 7 cases in which the causes were unknown. There is a difference in the importance of various factors between these incidents and therefore they are considered separately in this analysis.

Of the other 12 loss of containment incidents 5 occurred to risers (i.e. 1 was due to failed riser clamps, another was the Piper Alpha incident and the other 3 were reported as leaks). The other 7 incidents were of unknown cause, 4 of which occurred in the mid line, 1 at a well and the other 2 in the safety zone.

No anchoring or impact incident caused loss of containment from a riser. For this reason, risers have been examined as a special case, but the same factors are considered as have been used in the rest of the Section so that the results can be compared.

4.3.2 Risers

There have been only 12 cases of loss of containment from steel risers and 5 from flexible risers; there are insufficient data to determine the importance of different parameters. The 15 1oss of containment incidents that occurred to fittings associated with risers and the 34 associated with fittings that occurred on the platform are not included in this analysis.

Figure 4.1 illustrates the dependence of the frequency of loss of containment from a steel riser on the length of the pipeline associated with the riser. There may be a trend with length but there is a considerable overlap of the confidence intervals. This Figure does not show any clear variation of frequency with length as is the case for loss of containment due to corrosion or material defects, as described in Section 4.3.3. One incident has been omitted from Figure 4.1 as no data concerning the length of the pipeline was available.

Figure 4.2 illustrates the relationship between the frequency of loss of containment from a riser and the riser Diameter. The majority of flexible risers are 2 to 9 inches in Diameter and therefore they have not been grouped by Diameter. There does appear to be a trend in the estimates based upon reported incidents; however, the overlap in the confidence intervals suggests that the dependence of loss of containment frequency on Diameter is not pronounced for risers.

Figure 4.3 illustrates the dependence of the frequency of loss of containment on pipeline contents. Contents classified as 'other' include lines transporting methanol, water, chemicals, etc. Again the overlap in the confidence intervals suggests that the dependence of loss of containment frequency on contents is not pronounced.

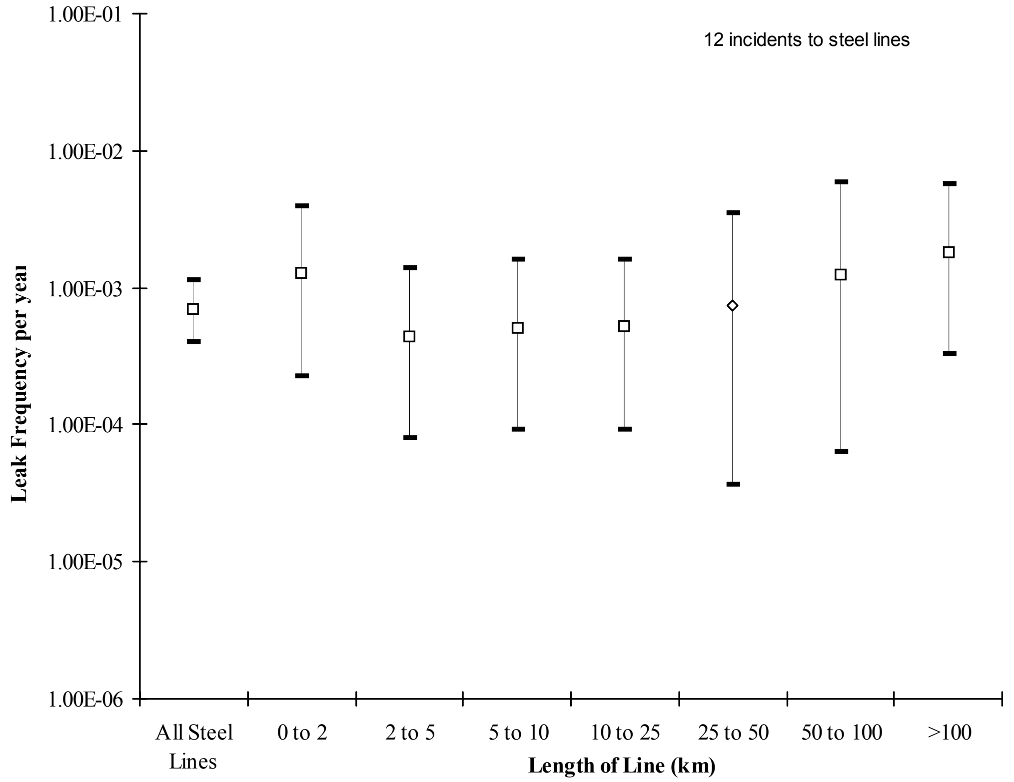


Figure 4-1 – Variation of Frequency of Loss of Containment Incidents from Steel Risers by Length of Line Associated with the Riser

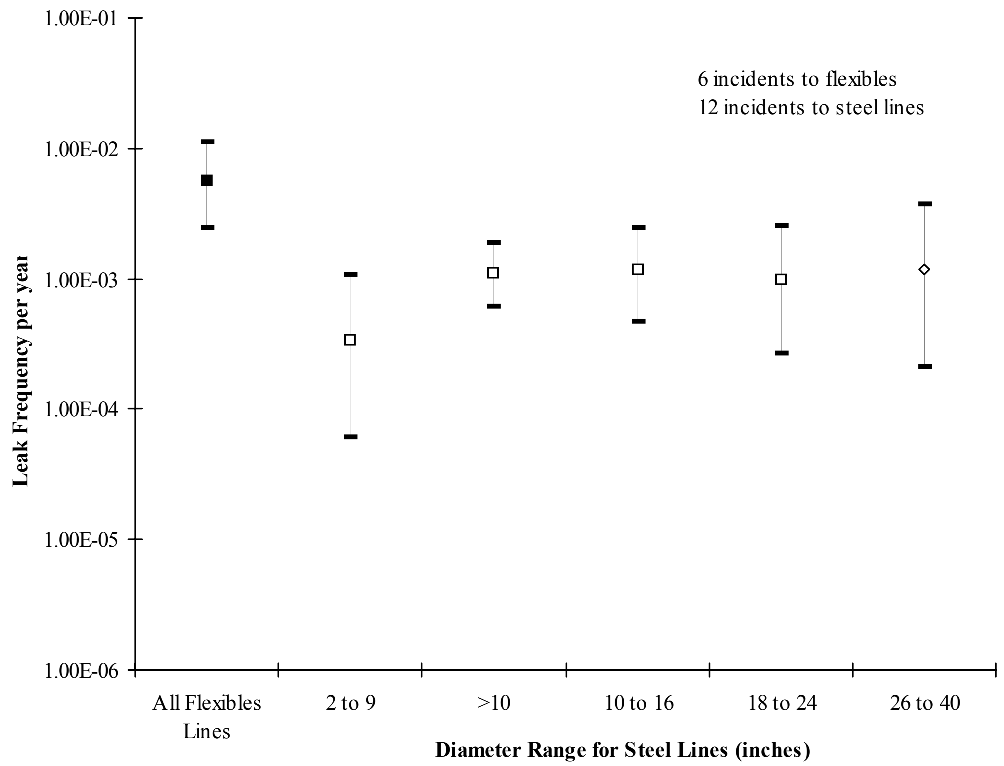


Figure 4-2 – Variation of Frequency of Loss of Containment Incidents from Risers by Pipeline Material and Diameter

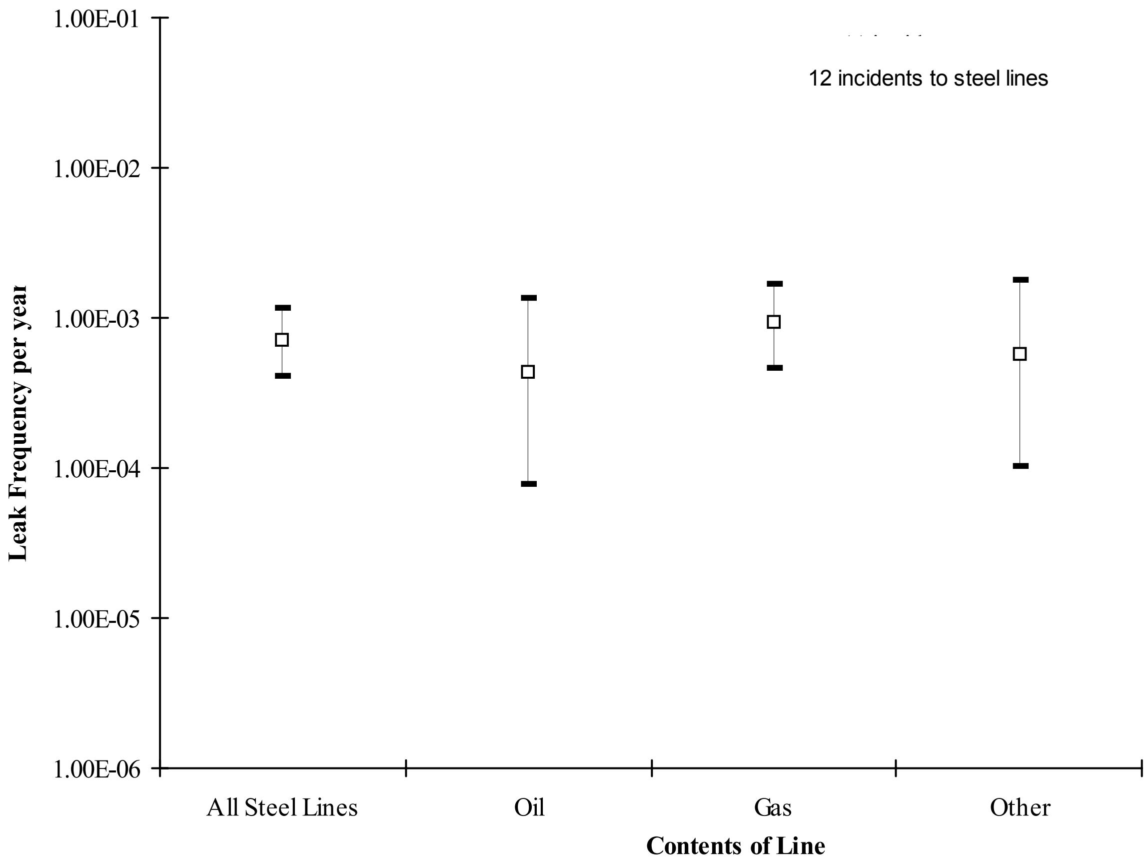


Figure 4-3 – Variation of Frequency of Loss of Containment Incidents from Steel Risers by Contents of Line

4.3.3 Corrosion and Material Defect Incidents

29 of the 56 corrosion and material defect incidents that resulted in loss of containment occurred to pipelines of less than 5 km in length. Considering the platform safety zone, mid line and subsea well zone, 8 of the 43 corrosion and material defect loss of containment incidents which affected steel lines occurred to lines less than 2 km in length, 12 to those between 2 and 5km and 23 to those greater than 5km.

Figure 4.4 shows the variation of the frequency of all the loss of containment corrosion and material defect incidents with the length of pipeline. Because of the importance of very short pipelines, all corrosion and material defect incidents are included in this Figure, whether they occurred in the platform safety zone, the mid line region or the subsea well zone. The number of incidents have been divided by the appropriate pipeline operating experience in km-years. It can be seen that there is a significant dependence of the loss of containment frequency on pipeline length. Considering all steel lines the best estimate based upon reported incidents is 1.3 x 10^{-4} per km-year, whereas considering steel lines of less than 2 km in length it is 5.7 x 10^{3} per km-year.

Figure 4.4 also shows the loss of containment frequency for flexible lines due to material defect incidents, which are mostly due to embrittlement of the rilsan liner. Comparison of all flexible and all steel incidents shows a trend of reducing frequency of leaks with length of pipeline.

In Figure 4.5 (a) the loss of containment frequency is presented by location of the pipeline affected, for lines less than 2 km long. For the safety zone and subsea well zone there is no obvious trend in the estimates based upon reported incidents and there is overlap in the confidence intervals. In previous studies, there was an apparent trend in the estimates based upon reporting incidents in the mid line of pipelines (per km-year) and platform safety zone and subsea well zone (per year or per 0.5 km-year). Figure 4.5 (a) shows that the confidence intervals for the mid line of pipelines and platform safety zone and subsea well zone totally overlap and that this trend is no longer visible. It should be noted that there are no lines less than 2 km long with a shore zone.

Figure 4.5 (b) is a similar plot for lines of 2 to 5 km in length. There have been insufficient incidents to draw definitive conclusions, but for flexible lines the confidence intervals overlap while for steel lines there appears to be a difference between the frequency within the subsea well zone and outside it, although there is a slight overlap between the confidence intervals. Additionally, the operating experience for shore zones is too small to draw any conclusions.

Figure 4.5 (c) is a plot for lines greater 5 km in length. Again there have been insufficient incidents to draw definitive conclusions. There have been no incidents to flexible pipelines in this category. For the different regions of the steel lines there appears to be a trend of increasing incident frequency within the safety zone and well zone compared to the pipeline midline.

Figures 4.6 (a), (b) and (c) show the variation of loss of containment frequency by Diameter of the pipeline affected for lines less than 2 km long, 2 to 5 km long and greater than 5 km long respectively. There does not appear to be any significant trend by Diameter in any of the length categories. There does seem to be a slight trend in the estimates based upon reported incidents for lines greater than 5 km long however all the confidence intervals overlap.

Figures 4.7 (a), (b) and (c) show the variation of loss of containment frequency by contents of the pipeline affected for lines less than 2 km long, 2 to 5 km long and greater than 5 km long respectively. In all the plots there is a trend in the estimates based upon reported incidents with gas lines showing lower frequencies, however the confidence intervals overlap.

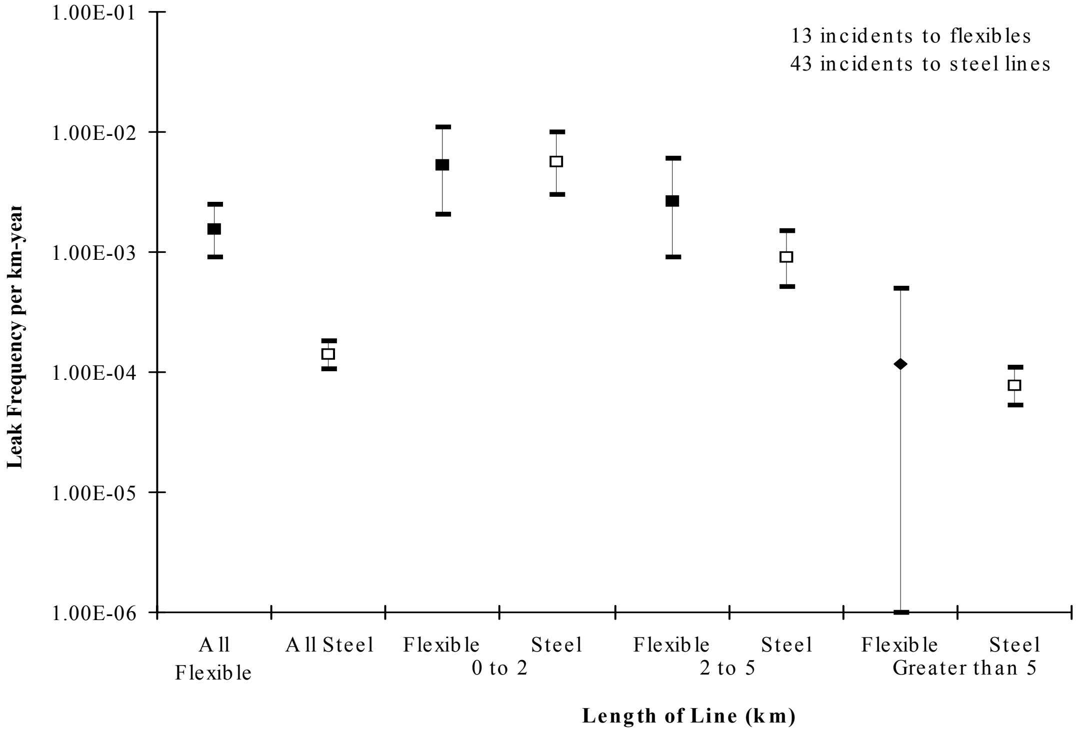
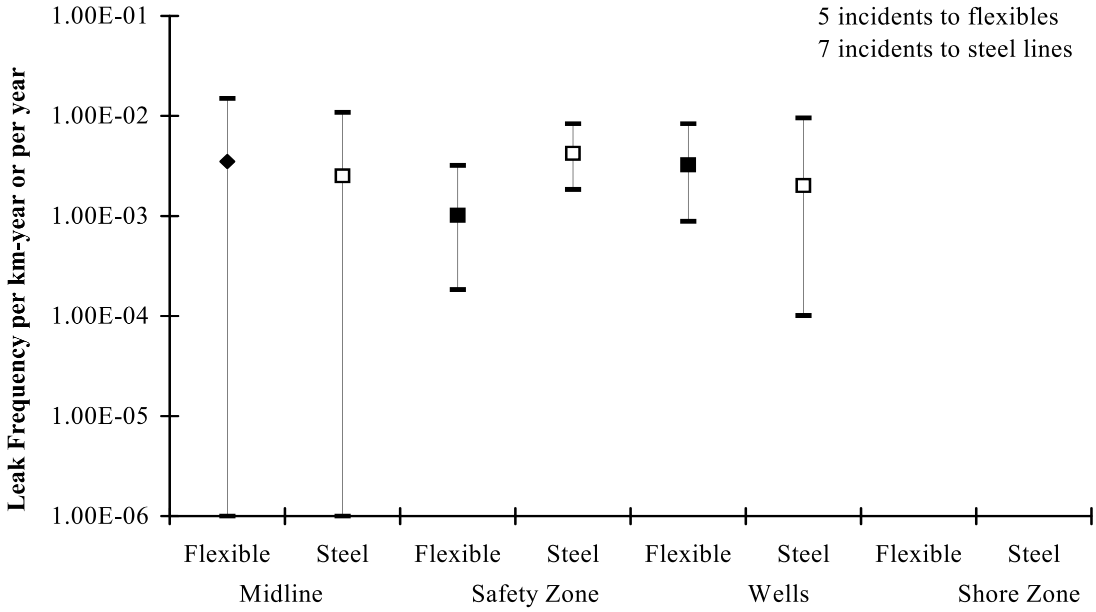
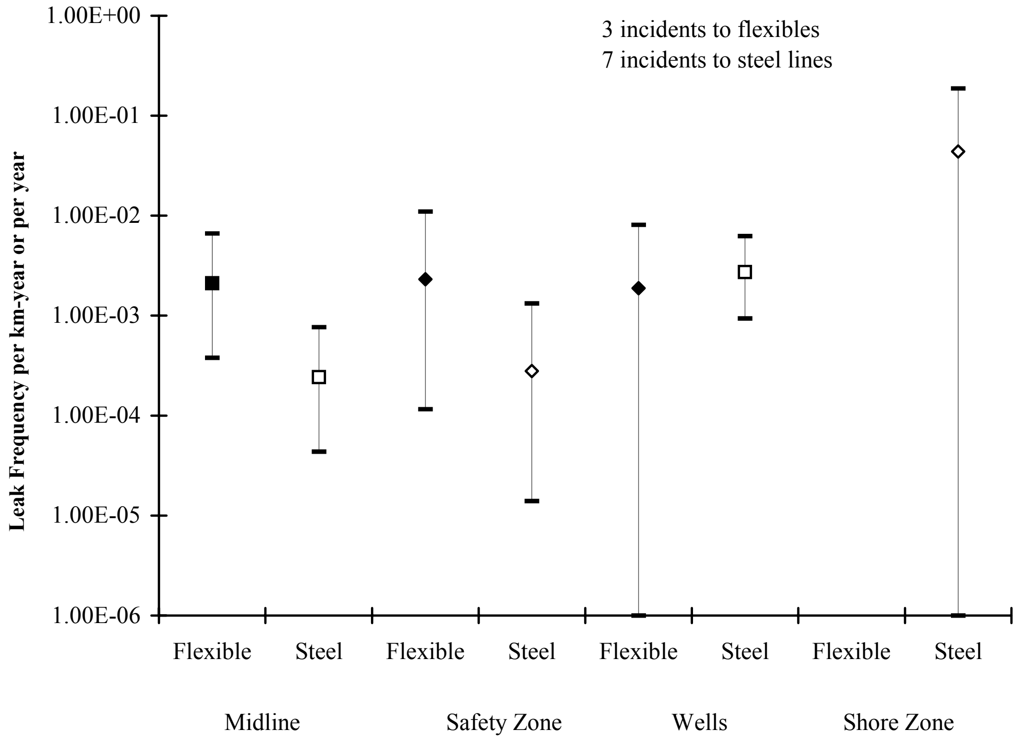


Figure 4-4 – Variation of Frequency of Loss of Containment Incidents by Length of Line for All Corrosion and Material Incidents

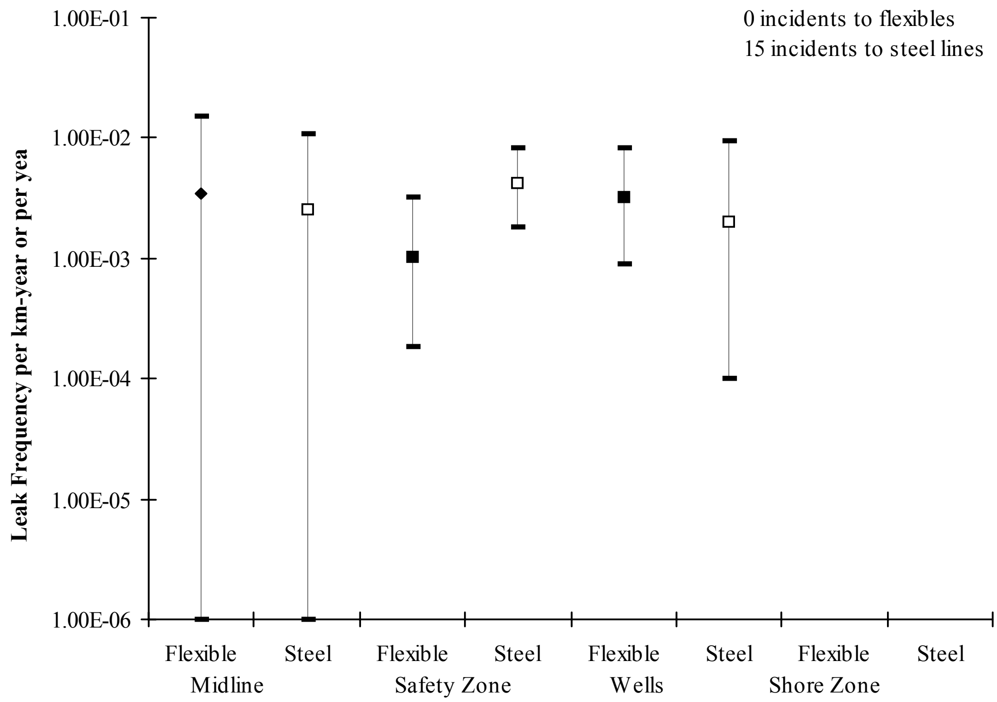


(a) Steel and Flexible Lines Less Than 2km Long

Figure 4-5 - Variation of Frequency of Loss of Containment Incidents by Region of Pipeline Affected for All Corrosion and Material Incidents

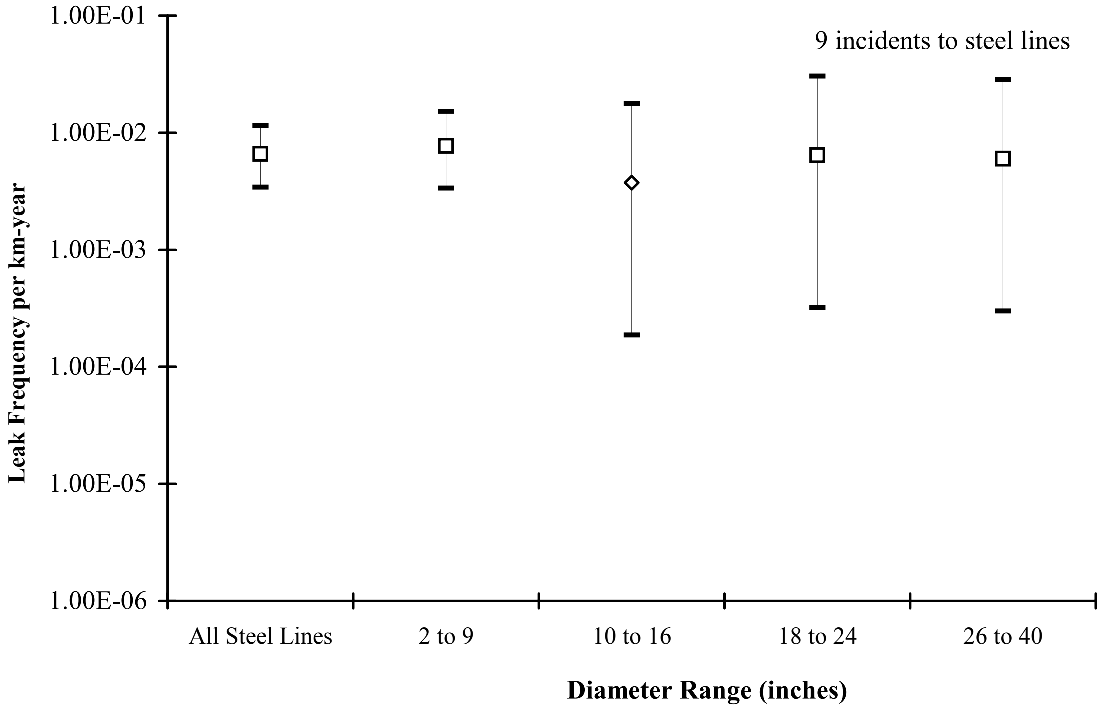


(b) **Steel and Flexible Lines 2-5 km Long**

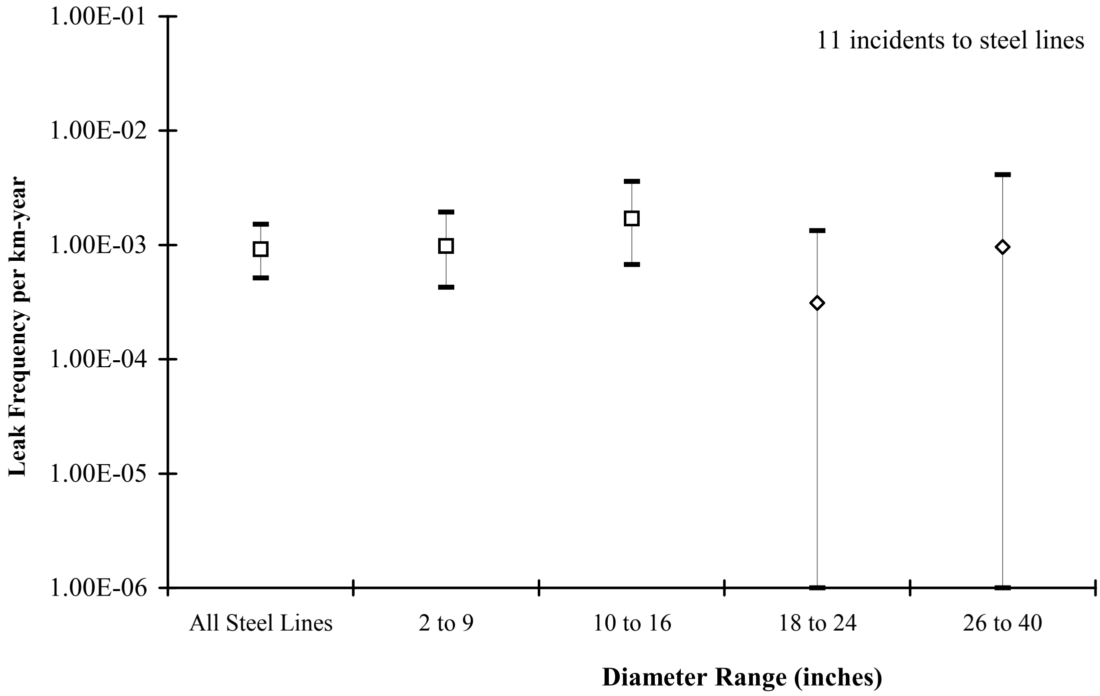


(a) **Steel and Flexible Lines Less Than 2km Long**

Figure 4-5– Variation of Frequency of Loss of Containment Incidents by Region of Pipeline Affected for All Corrosion and Material Incidents

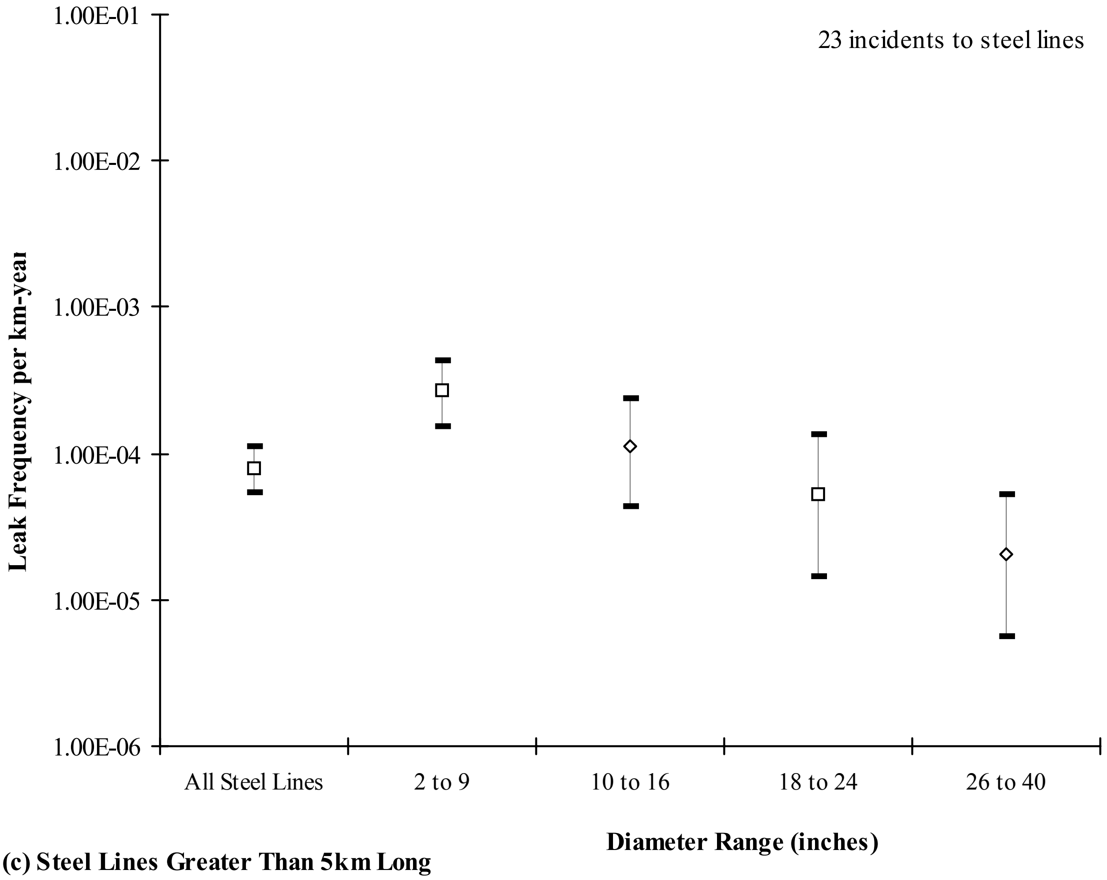


(a) Steel Lines Less Than 2 km Long



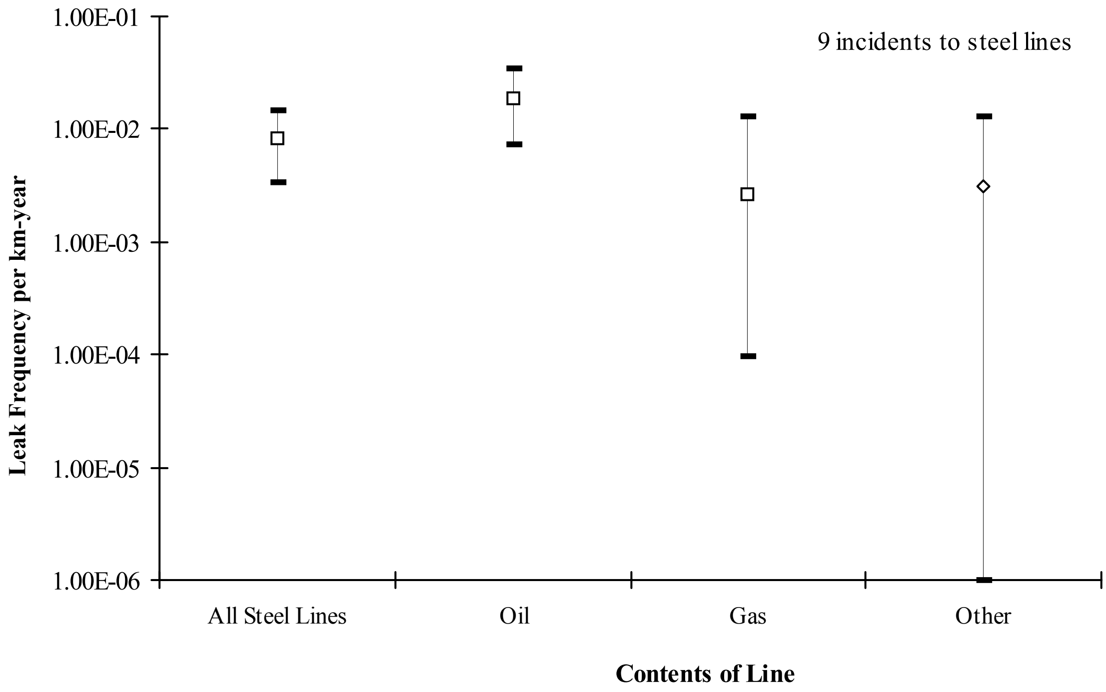
(b) Steel Lines 2-5km Long

Figure 4-6 – Variation of Frequency of Loss of Containment Incidents by Diameter of Steel Line for All Corrosion and Material Incidents

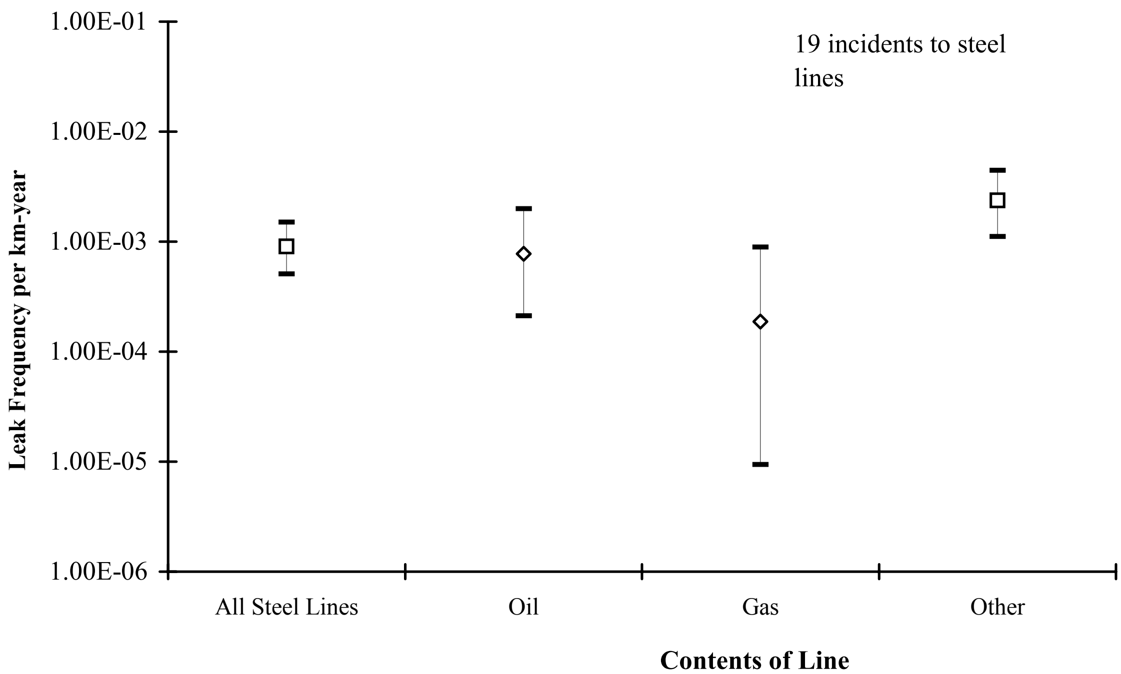


(c) Steel Lines Greater Than 5km Long

Figure 4-6 – Variation of Frequency of Loss of Containment Incidents by Diameter of Steel Line for All Corrosion and Material Incidents

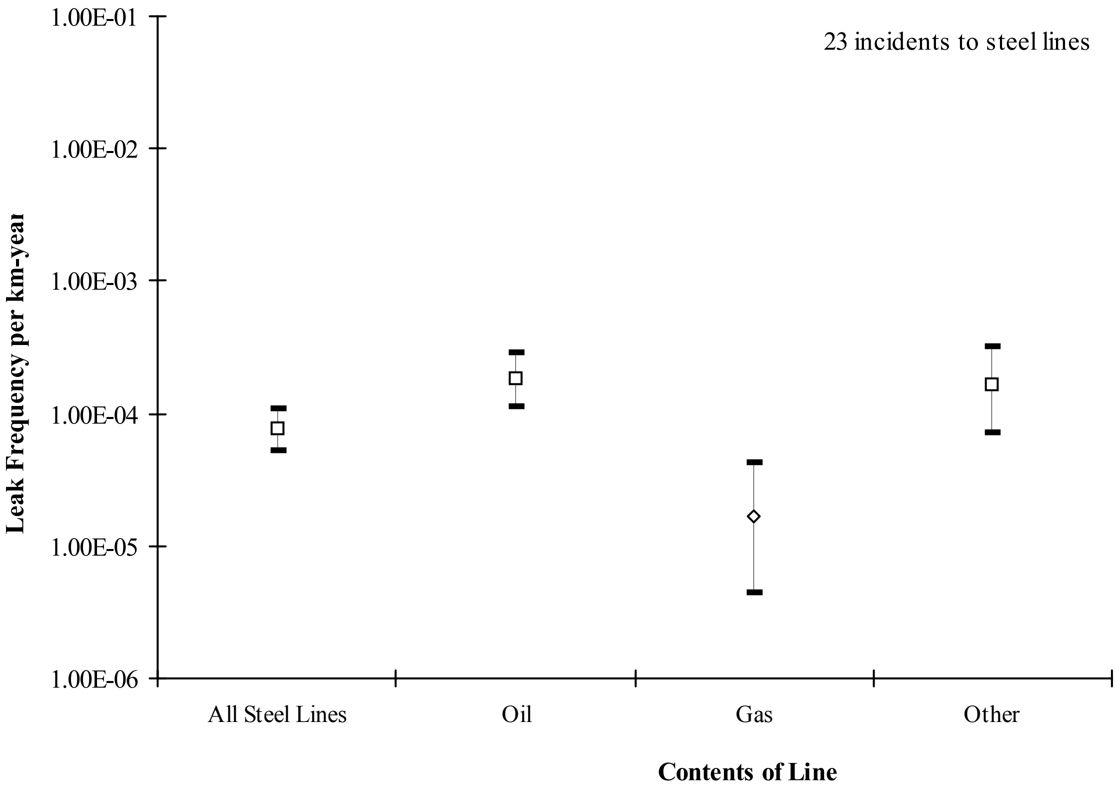


(a) Steel Lines Less Than 2 km Long



(b) Steel Lines 2-5km Long

Figure 4-7 -Variation of Frequency of Loss of Containment Incidents by Contents of Steel Lines for All Corrosion and Material Incidents



(c) Steel Lines Greater Than 5km Long

Figure 4-7 - Variation of Frequency of Loss of Containment Incidents by Contents of Steel Lines for All Corrosion and Material Incidents

4.3.4 Anchoring and Impact Incidents

Figure 4.8 (a) presents the variation of the frequency of all the loss of containment anchoring and impact incidents that have occurred in the mid line of pipelines by the length of line. There is a trend in the estimates based upon reported incidents, with shorter lines characterised by higher frequencies. However, the confidence interval for all lines does overlap with the confidence interval for each length group. Figure 4.8 (b) presents the same plot for incidents which have occurred in the platform safety zone by the length of line. This again shows that impact incidents have occurred to lines of all lengths. However, there is no trend in the estimates based upon reported incidents and the confidence intervals overlap implying that length of line is not significant for impact incidents in this region.

Figure 4.9 illustrates the relationship between the frequency of loss of containment from the mid line of pipelines and pipeline Diameter. The majority of the flexibles are of 2 to 9 inches in Diameter and therefore they have not been grouped by Diameter. The confidence interval of flexible lines has some overlap with that for steel lines and totally overlaps that for steel lines of 2 to 9 inch Diameter. However, there is a significant difference in the frequencies for steel lines of 2 to 9 inch Diameter and larger Diameter lines.

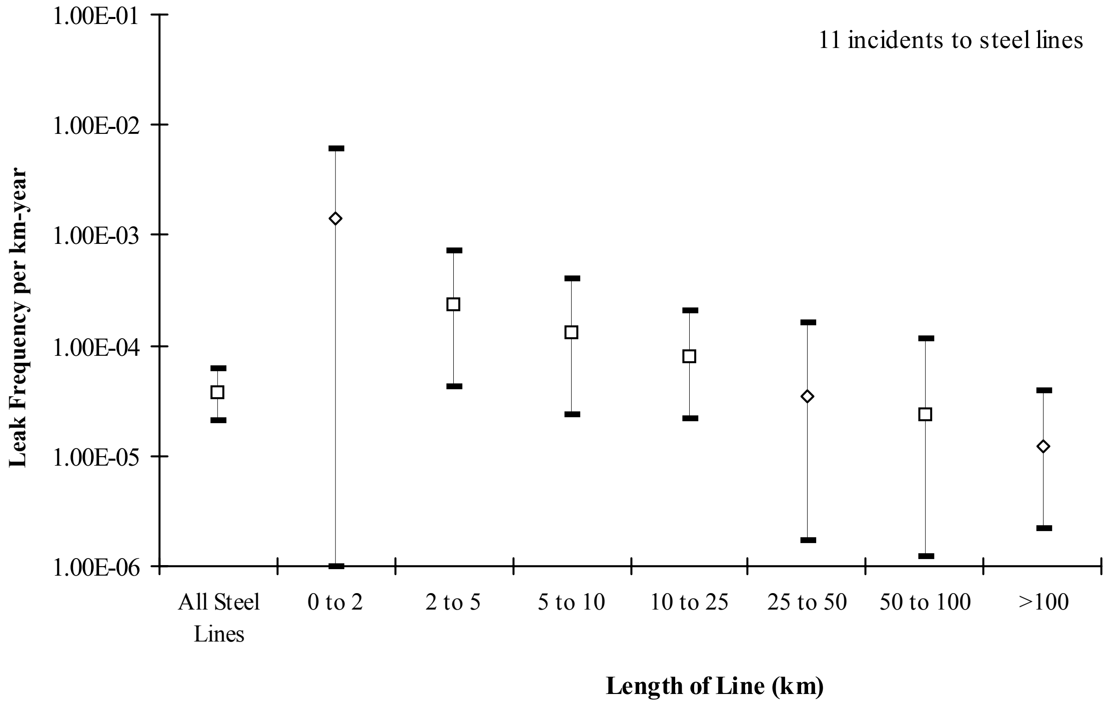
Figure 4.10 illustrates the same type of plot for impact incidents which occurred within the platform safety zone. It can be seen that there is no trend by Diameter, comparing the frequencies for steel lines of 2 to 9 inch Diameter and larger lines.

Figure 4.11 (a) presents the variation of frequency of loss of containment incidents for lines of Diameter 2 to 8 inches by pipeline material and location on pipeline affected. A slight trend in the estimates based upon reported incidents in the mid line of pipelines (per km-year) and platform safety zone (per year or per 0.5 km-year) can be seen, however, the confidence intervals overlap. The difference between platform safety zone and mid line is much greater for the larger steel lines, as can be seen in Figure 4.11 (b).

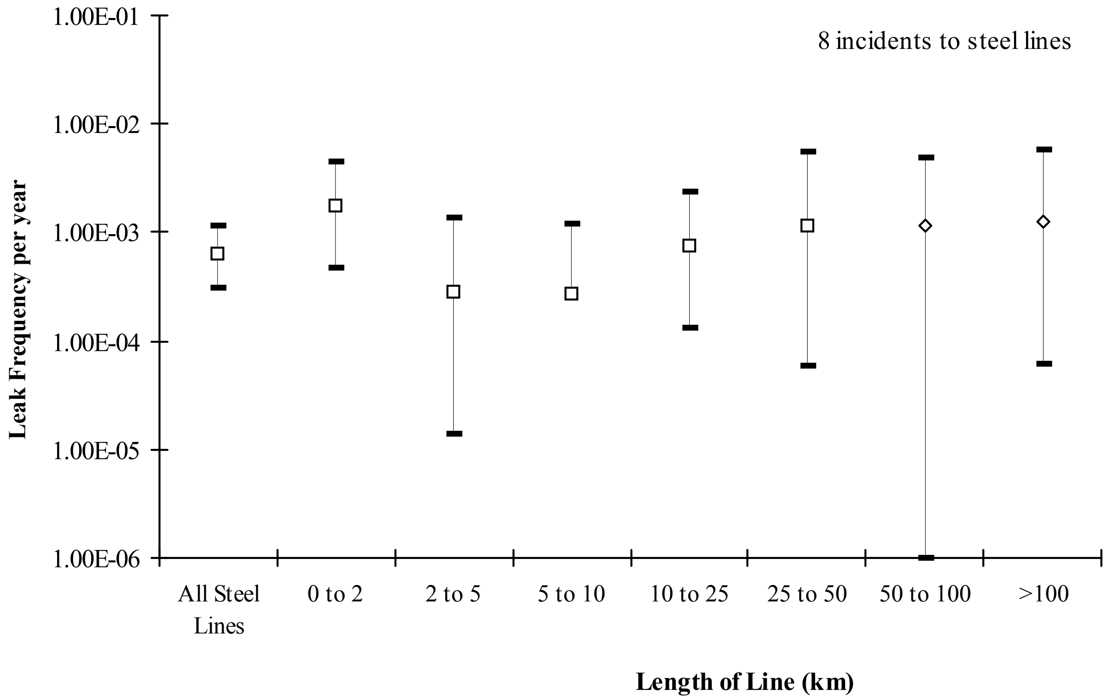
Figure 4.12 (a) presents the variation of frequency of loss of containment impact incidents for steel lines of Diameter 2 to 8 inches by line contents. There have been insufficient incidents to determine the trend in this case, however, the confidence intervals overlap.

Figure 4.12 (b) presents the variation of frequency of loss of containment impact incidents for steel lines greater than 8 inches in Diameter by line contents. Again, there have been insufficient incidents to determine the trend in this case, however, the confidence intervals overlap.

Figure 4.13 presents the same plot for incidents which occurred to lines of all Diameters in the safety zone. Again the confidence intervals overlap, however, there is a trend in the estimates based upon reported incidents which implies that gas lines have a lower loss of containment frequency for impact incidents.



(a) Mid Line Incidents



(b) Safety Zone Incidents

Figure 4-8 – Variation of Frequency of Loss of Containment Incidents by Region of Pipeline Affected and Length of Line for All Anchoring and Impact Incidents

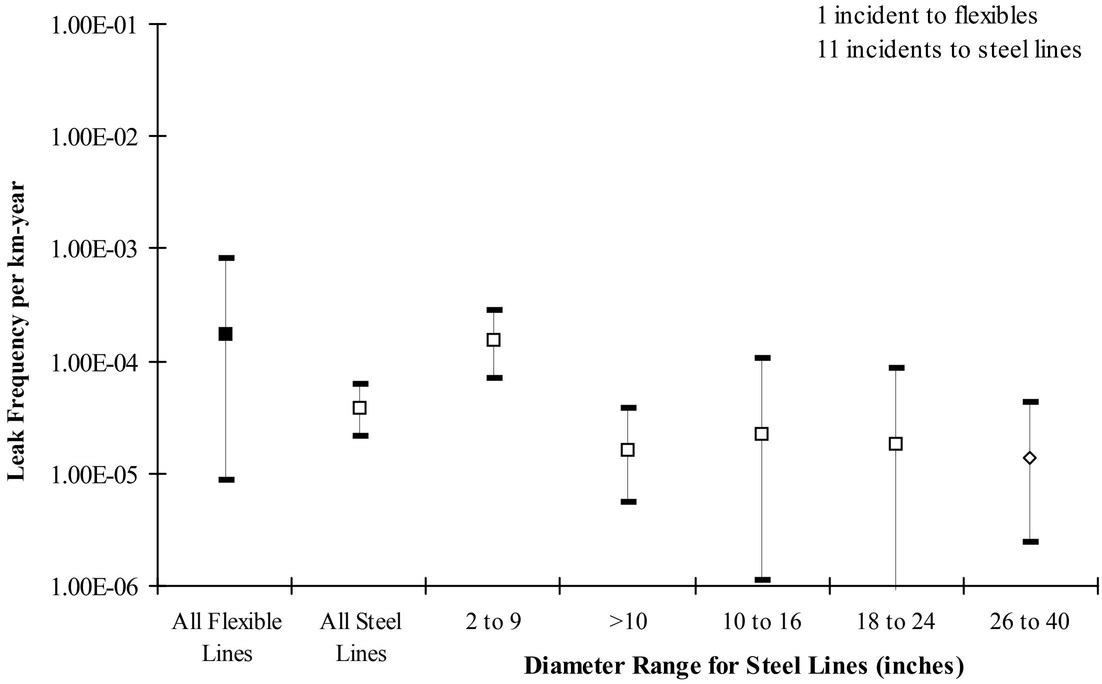


Figure 4-9 – Variation of Frequency of Loss of Containment Incidents by Pipeline Material and Diameter for All Anchoring and Impact Incidents Occurring in the Mid Line of Pipelines

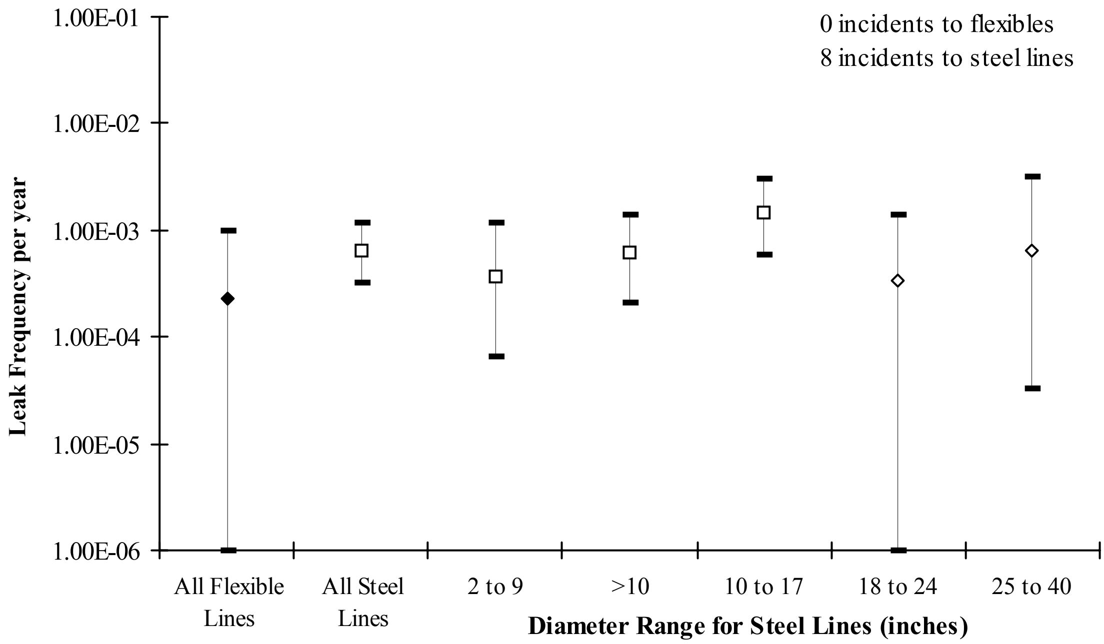
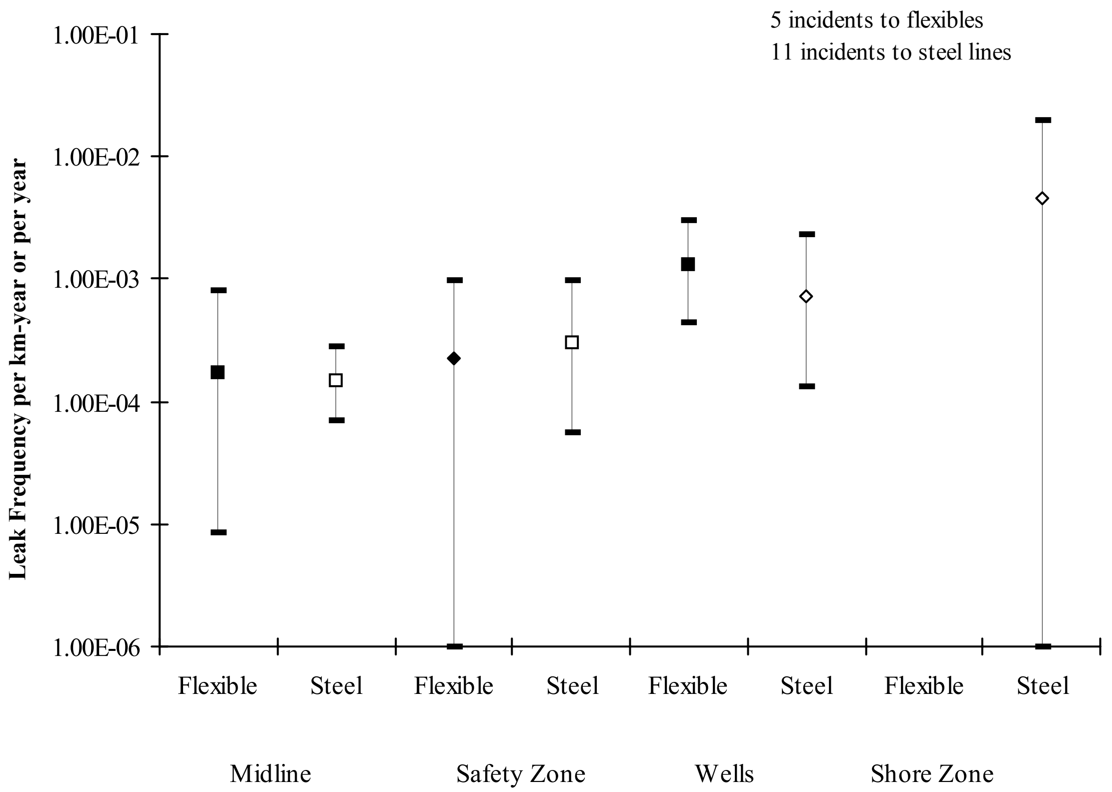
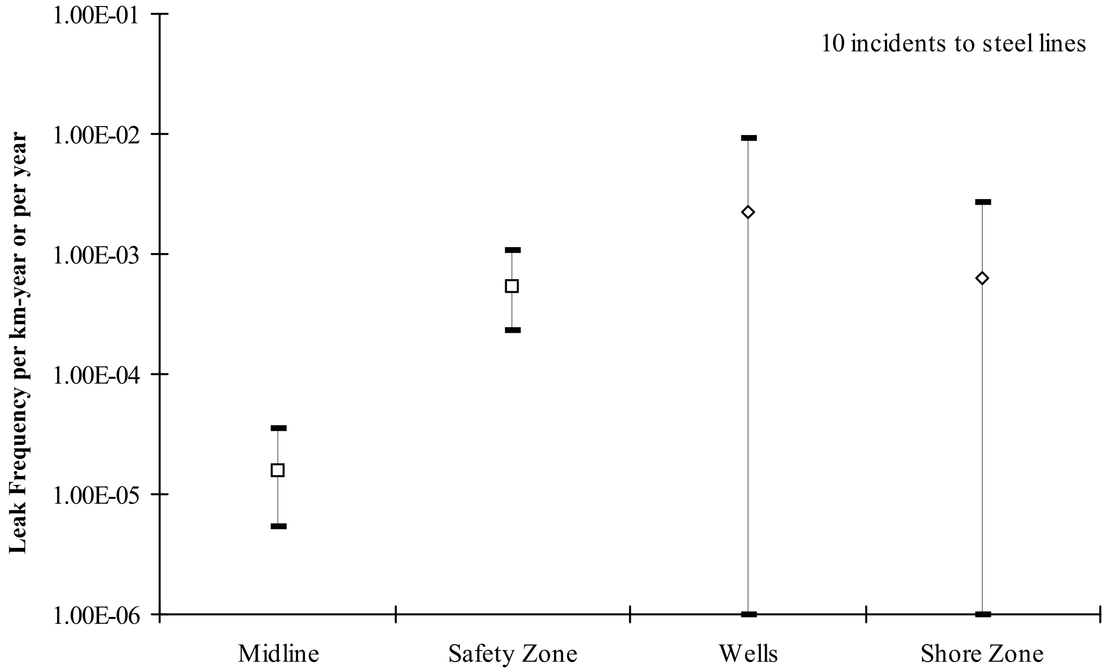


Figure 4-10 – Variation of Frequency of Loss of Containment Incidents by Pipeline Material and Diameter for All Anchoring and Impact Incidents Occurring in the Platform Safety Zone

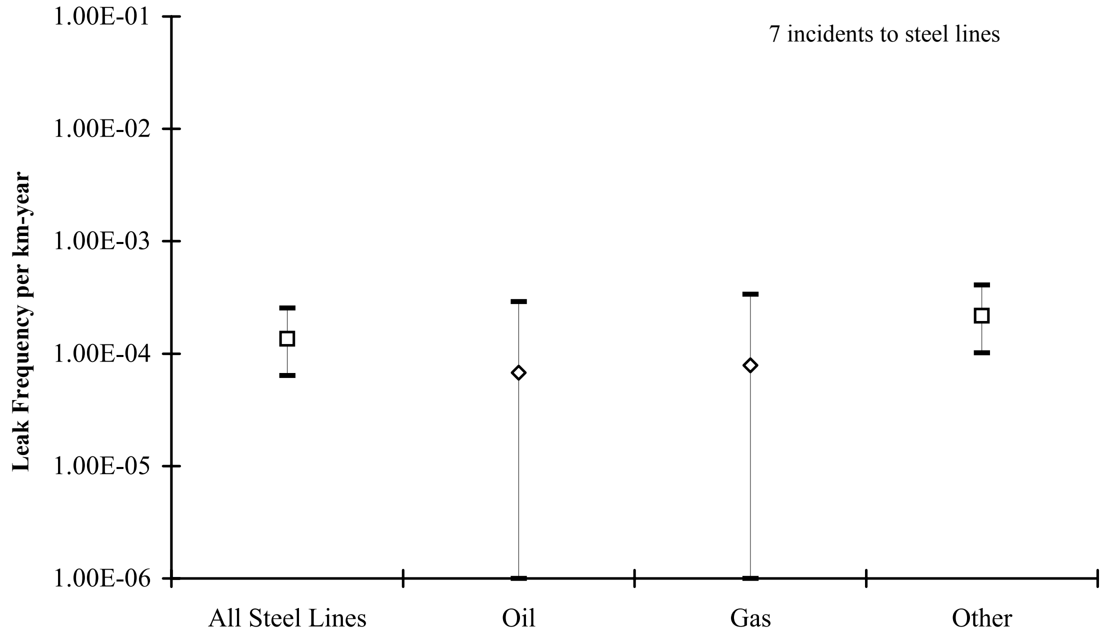


(a) Steel and Flexible Lines 2 to 8 inches in Diameter

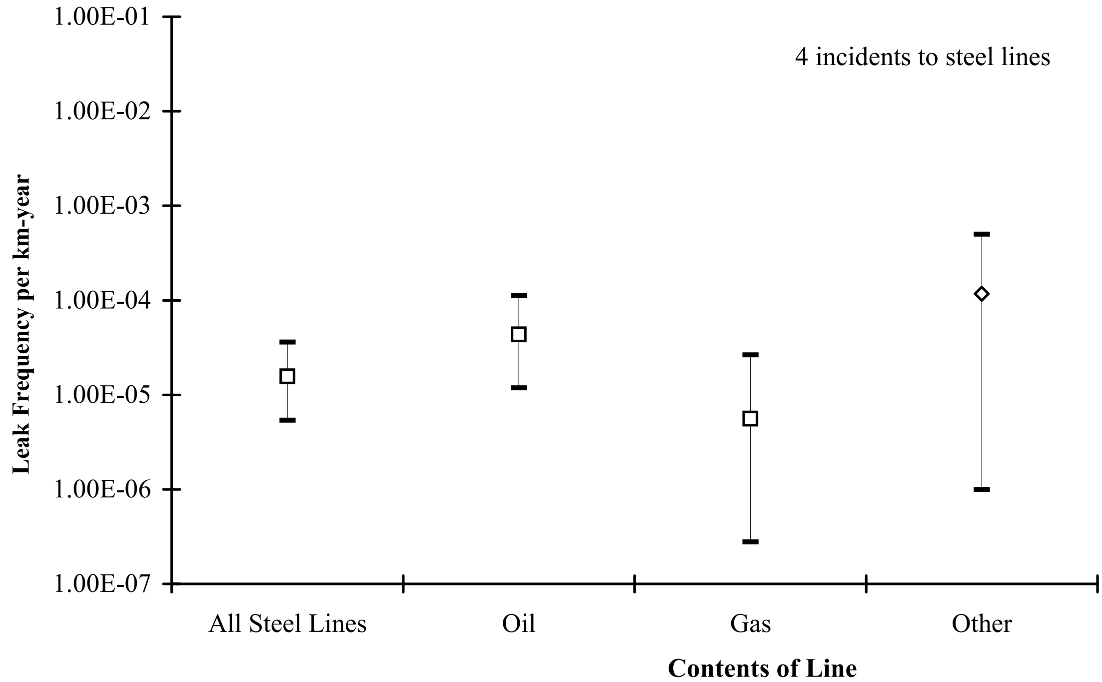


(b) Steel Lines Greater Than 8 inches In Diameter

Figure 4-11 – Variation of Frequency of Loss of Containment Incidents by Pipeline Material for All Anchoring and Impact Incidents by Location on Pipeline



(a) Steel Lines 2 to 9 inches in Diameter



(b) Steel Lines Greater Than 9 inches In Diameter

Figure 4-12 – Variation of Frequency of Loss of Containment Incidents by Contents for All Anchoring and Impact Incidents Occurring in the Mid Line of Steel Pipelines

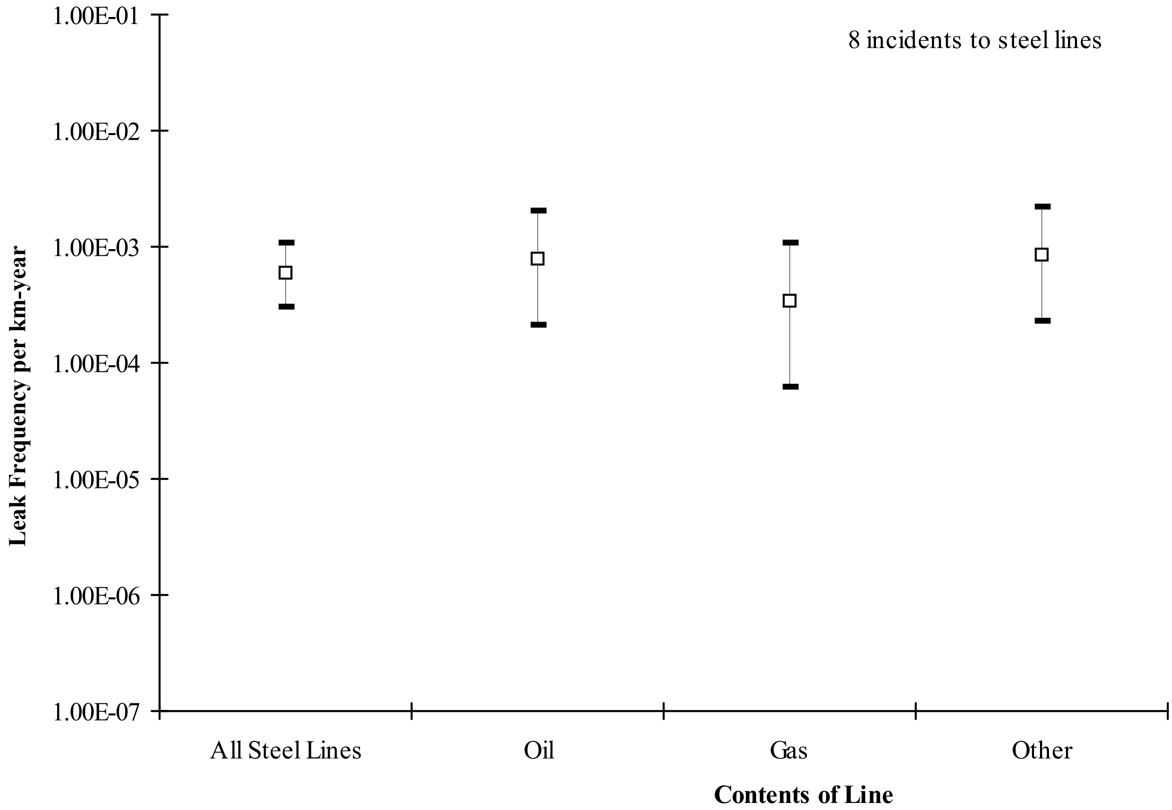


Figure 4-13 – Variation of Frequency of Loss of Containment Incidents by Contents for All Anchoring and Impact Incidents Occurring to Steel Lines in the Platform Safety Zone

4.4 INFLUENCE OF OTHER FACTORS UPON LEAK FREQUENCIES

4.4.1 Introduction

In Section 4.3 the dependence of the estimate of the loss of containment frequency was examined by incident cause, location of pipeline affected and pipeline Diameter, length and contents. It was found that for riser incidents there were no parameters that had a significant effect upon loss of containment frequency. For corrosion and material defects, line length was the most significant parameter. For anchoring and impact, the incident location on the pipeline was the most significant parameter, with pipeline Diameter significant for incidents which occurred in the mid line of pipelines.

This Section investigates the effect on the estimate of the loss of containment frequency of other factors, which were not considered in the original studies. The factors investigated include pipeline protection, location in the North Sea, age, type of line, hydrotest pressure, riser location, piggybacked lines, bundled line and grade of steel.

4.4.2 Protection and Burial

Many pipelines are trenched to protect them from trawling damage or to enhance stability. In the pipeline database compiled during this study 57% by length of all lines have some degree of protection, either trenching (lowering) or burial (covering) over part or all of their length. Considering large and small Diameter lines the proportions of lines with some degree of protection are 59% by length for lines 16 inch and under and 68% for larger Diameter lines.

Figure 4.14 (a) illustrates the dependence of the frequency of loss of containment from the mid line of steel pipelines due to impact and anchoring incidents on the type of pipeline protection. The three categories used are:

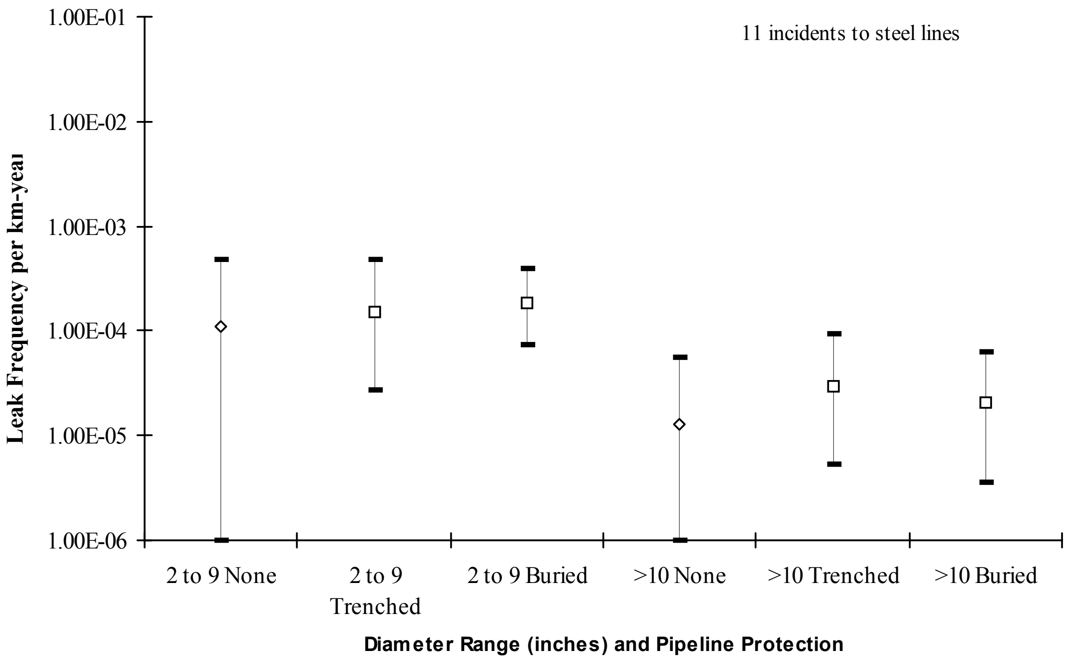
- no protection;
- trenching (lowering);
- burial (covering) or trenching and burial, over part or all of the pipeline length.

The pipelines have been grouped by Diameter since this was shown in Section 4.3.4 to be significant for impact incidents.

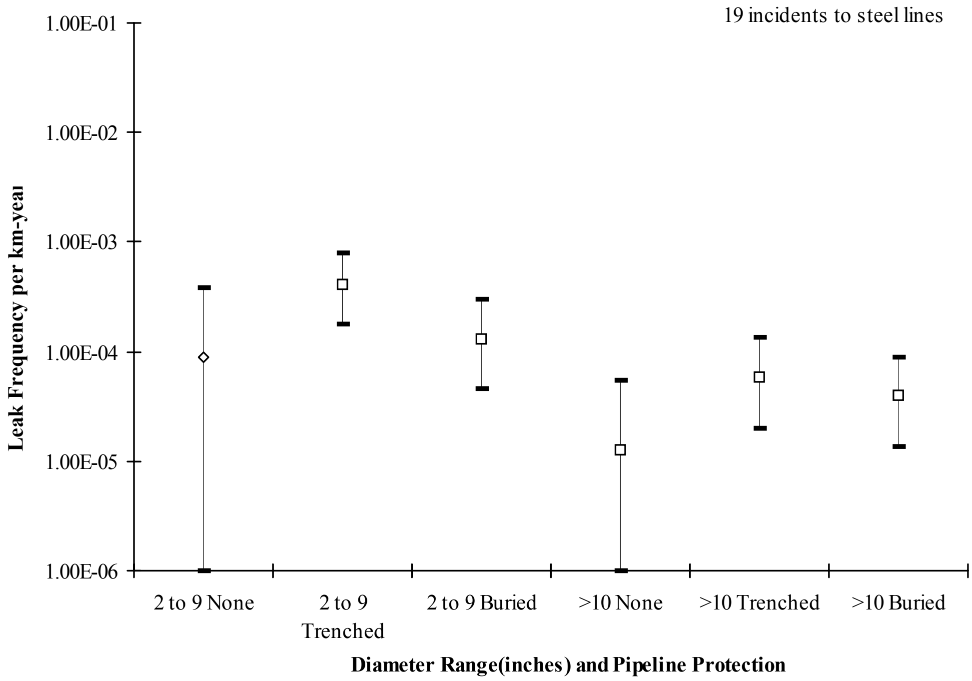
There is considerable overlap in the confidence intervals in Figure 4.14 (a) and there have been insufficient incidents to determine a clear trend in the estimate based upon the reported number of incidents, other than the smallest Diameter pipelines are subject to a higher failure rate.

Figure 4.14 (b) is a similar plot but also includes loss of containment incidents that occurred in the subsea well zone and in the platform safety zone further than 100 m from the platform. Again there is considerable overlap in the confidence intervals. No discernible difference is evident between trenched only or buried and part buried pipelines for frequencies calculated upon reported number of incidents. However, in general there is a more marked difference between unprotected and protected pipelines, with the latter characterised by higher leak frequencies.

It has not been possible to determine the influence of protection of lines close to (i.e. <100 m) the platform.



(a) Mid Line Incidents



b) Mid Line, Subsea Well Zone and Safety Zone Incidents which occurred >100m from the Platform

Figure 4-14 – Variation of Frequency of Loss of Containment Incidents by Contents for All Anchoring and Impact Incidents Occurring in the Mid Line of Steel Pipelines

4.4.3 Pipeline Age

It is generally accepted, and it has been assumed in previous studies, that incident frequencies are higher in the early years and towards the end of a pipeline's life. This has been attributed to higher vessel activity during the early years of field development or early appearance of defects in materials, corrosion inhibition systems or structural design. Increasing deterioration with age is also expected to lead to higher leak probabilities and the possibility of a wear-out phase for corrosion incidents has been proposed.

These potential relationships are examined in Figures 4.15 to 4.18 grouped by the parameters found to be significant in Section 4.3. In Figure 4.15 the variation of loss of containment frequency with pipeline age is presented for steel risers. All reported incidents have occurred to risers less than 25 years old. There have been insufficient incidents to determine clear trends in the frequencies calculated from the reported number of incidents and the confidence intervals show considerable overlap. However, the frequency does imply that steel risers with age less than 8 years old have a much higher loss of containment frequency. Two steel riser incidents have been excluded from the graph due to lack of details regarding the installation age.

Figure 4.16 presents the variation of loss of containment frequency with age for all corrosion and material defect incidents, which have occurred to steel pipelines less than 2 km in length. There are no discernible trends in this Figure.

Figure 4.17 presents the variation of frequency of loss of containment due to impact incidents occurring in the mid line of (a) steel lines of Diameter 2 to 9 inches and (b) steel lines greater than 10 inches in Diameter, by age. Figure 4.18 presents the variation by age of line for loss of containment due to impact incidents that occurred within the safety zone. There is a considerable overlap in the confidence intervals for both graphs.

The number of incidents that have occurred to newer pipelines is greater than for the older pipelines. The operating experience associated with pipelines of age 0-4 years is nearly 7087 km-years, while for the age range 16-20 years it is 62600 km-years. No pipeline line is older than 35 years. Due to this very large difference in operating experience between younger and older pipelines, it is difficult to draw firm conclusions on trends in loss of containment frequency with age.

4.4.4 Pipeline Location in the North Sea

Conditions in the northern central and southern North Sea differ in terms of water depth, product carried, average age of installations and activities of other seabed users. All of these factors could be expected to have an influence on pipeline performance, for example the geographical location may influence both the environmental conditions and the extent of fishing activity. This is examined in Figures 4.19 to 4.22 grouped by the parameters found to be significant in Section 4.3.

Figure 4.19 presents the variation of loss of containment frequency for steel risers by location in the North Sea. Even though the confidence intervals overlap, there is a trend in the estimates based upon reported incidents indicating that risers in the Central North Sea have a somewhat higher loss of containment frequency than elsewhere.

Figure 4.20 presents the loss of containment frequency associated with all material and corrosion incidents which occurred to lines less than 2 km long by contents and location in the North Sea. The confidence intervals overlap in all cases. Again there is a slight trend in the estimates based upon reported incidents which implies that pipelines in the Central North Sea have a higher loss of containment frequency than elsewhere.

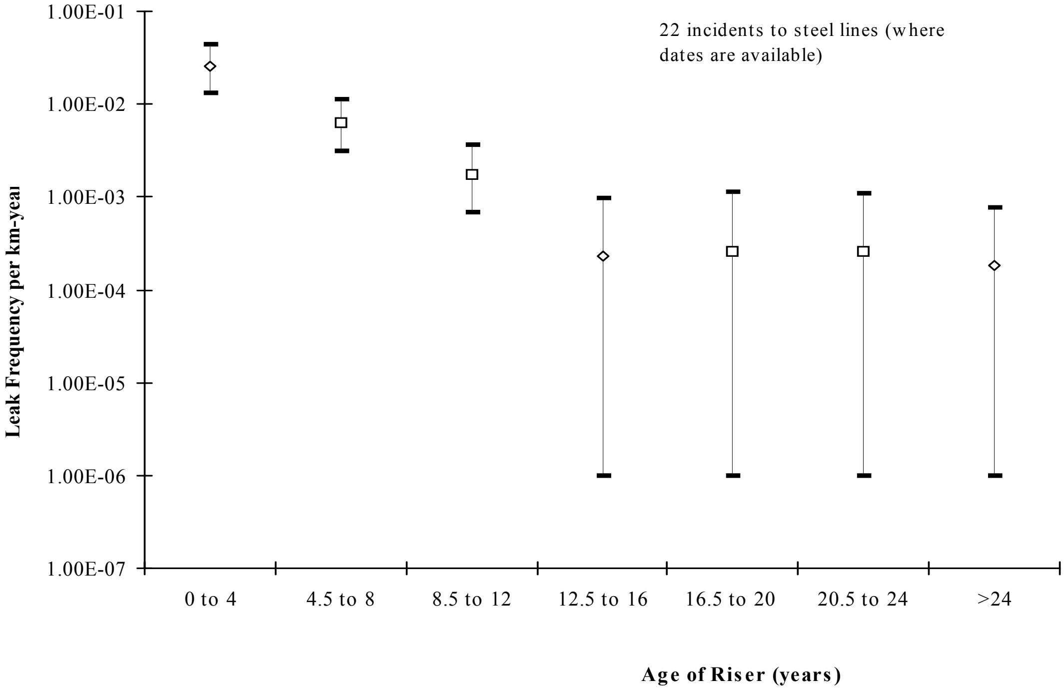


Figure 4-15 – Variation of Frequency of Loss of Containment Incidents by Age of Riser at Time of Incident for All Incidents Occurring to Steel Risers

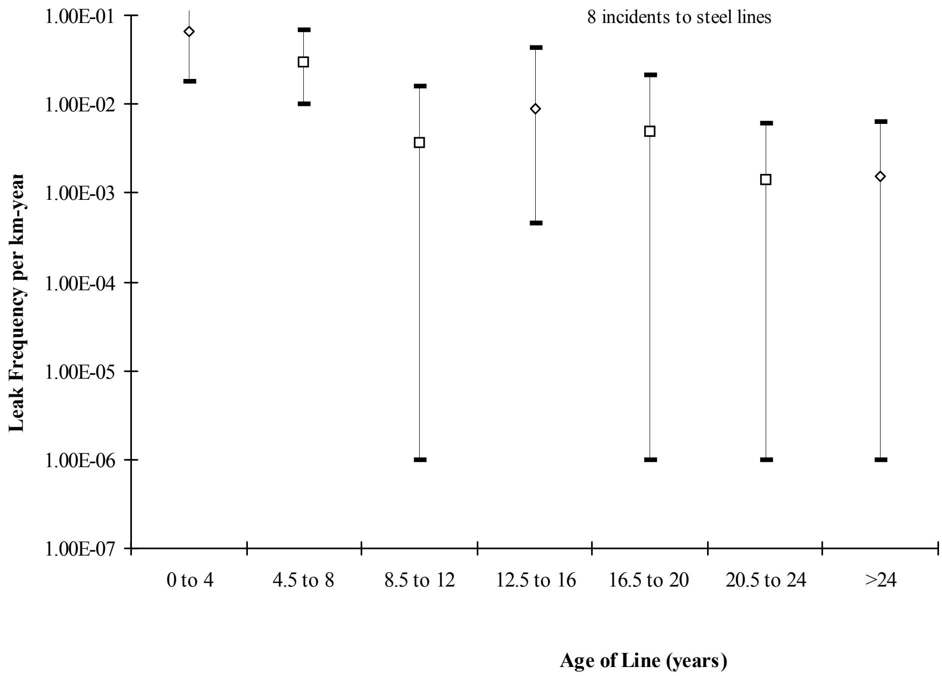
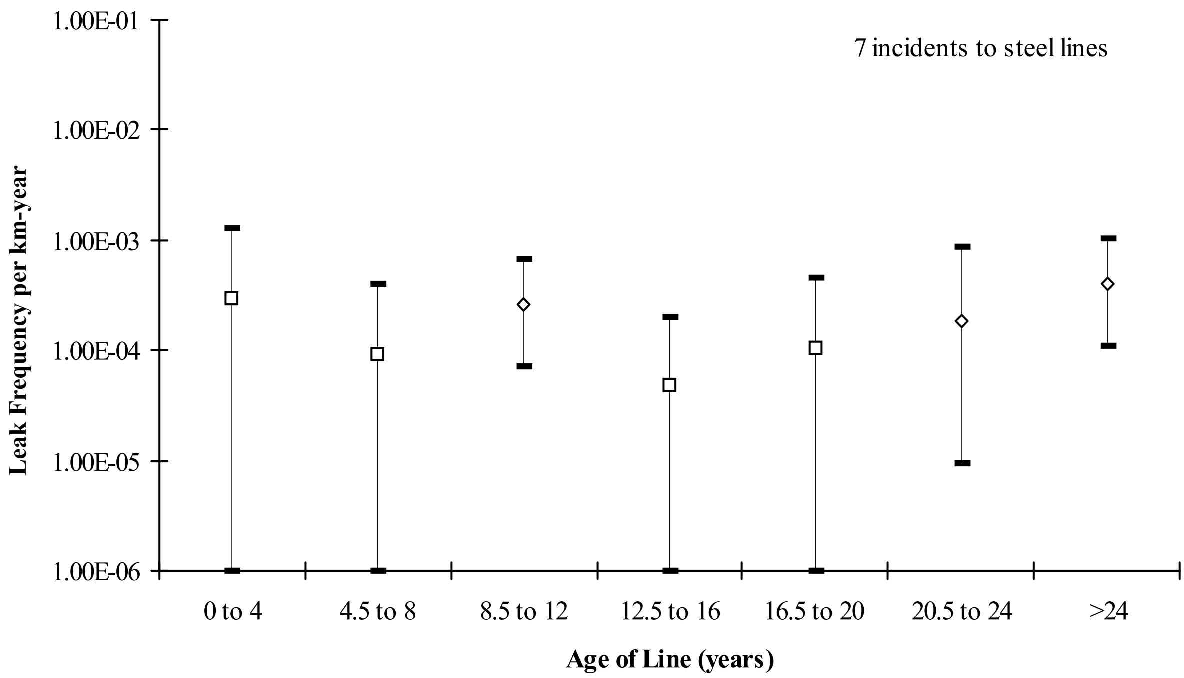
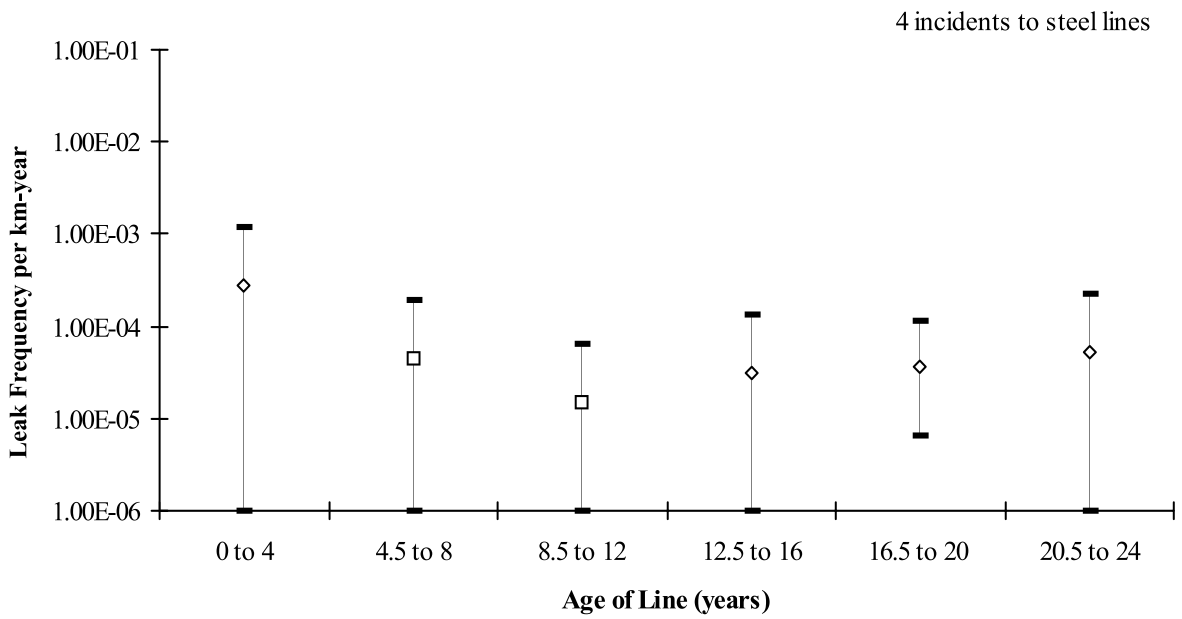


Figure 4-16 – Variation of Frequency of Loss of Containment Incidents by Age of Line at Time of Incident for All Corrosion and Material Incidents Occurring to Steel Lines less than 2km Long



(a) Diameter Range 2 to 9 inches



(b) Diameter Range greater than 10 inches

Figure 4-17 – Variation of Frequency of Loss of Containment Incidents by Age of Line at Time of Incident for All Anchoring and Impact Incidents Occurring to the Mid Line of Pipelines

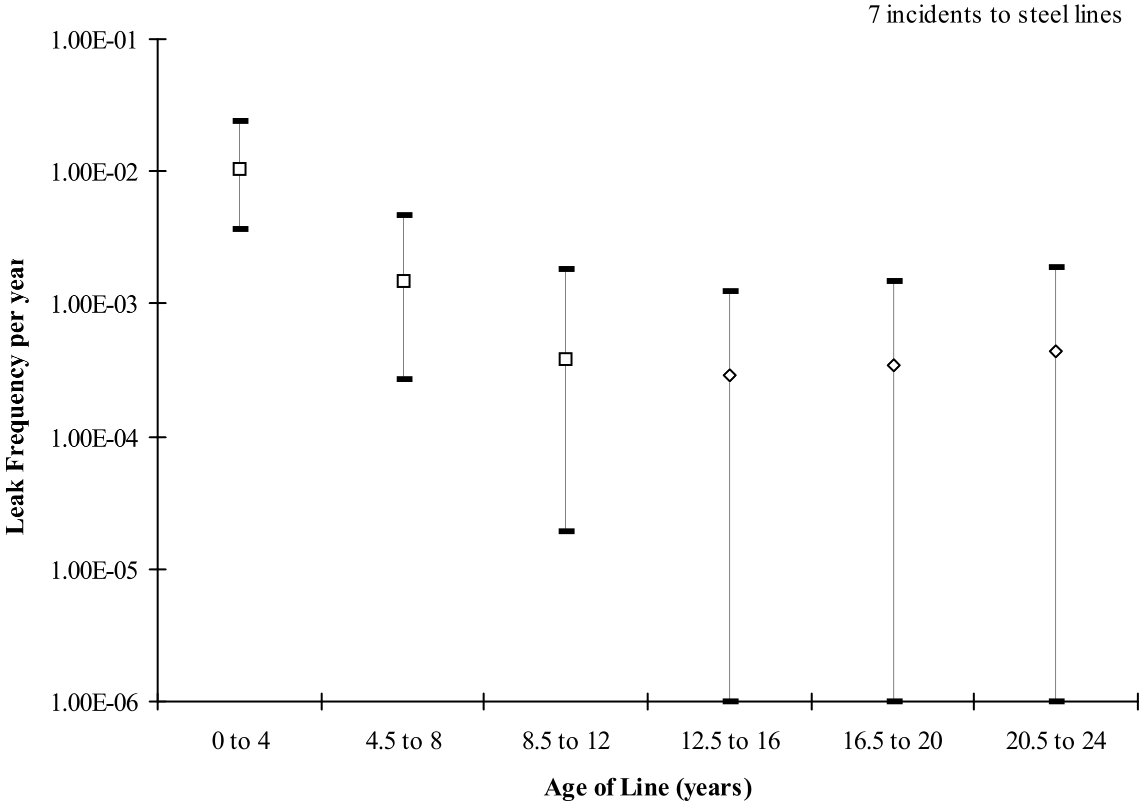


Figure 4-18 – Variation of Frequency of Loss of Containment Incidents by Age of Line at Time of Incident for All Anchoring and Impact Incidents Occurring in the Platform Safety Zone for Steel Pipelines Only

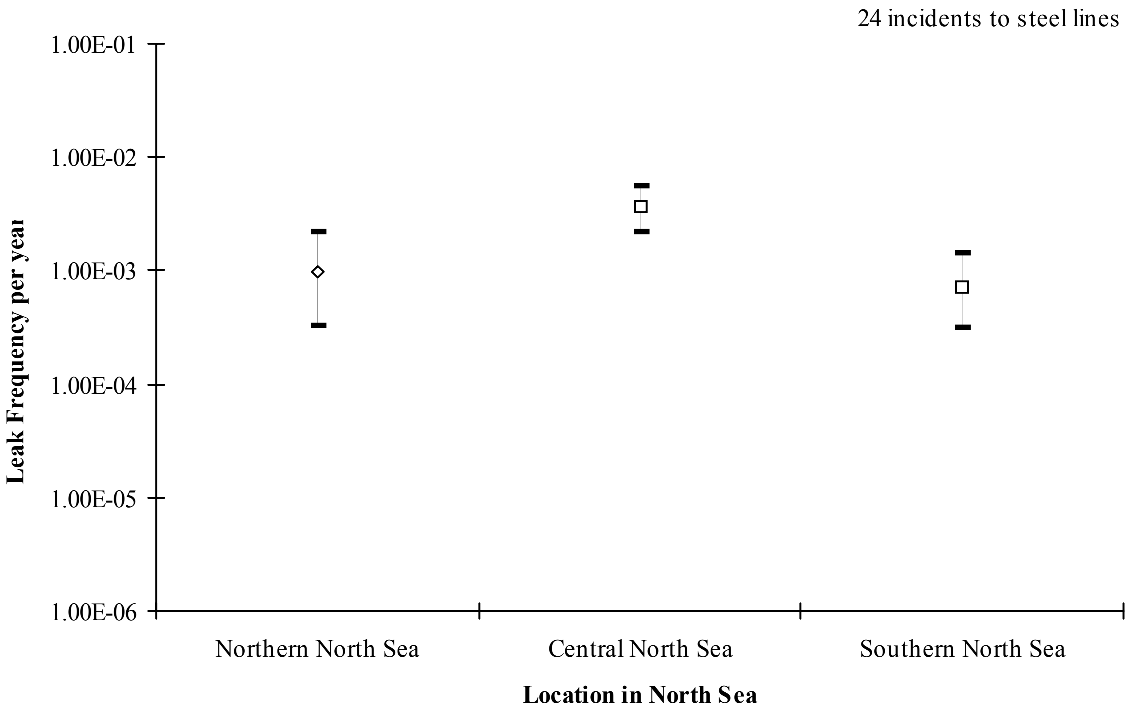


Figure 4-19 – Variation of Frequency of Loss of Containment Incidents by Location in the North Sea for All Riser Incidents Occurring to Steel Lines

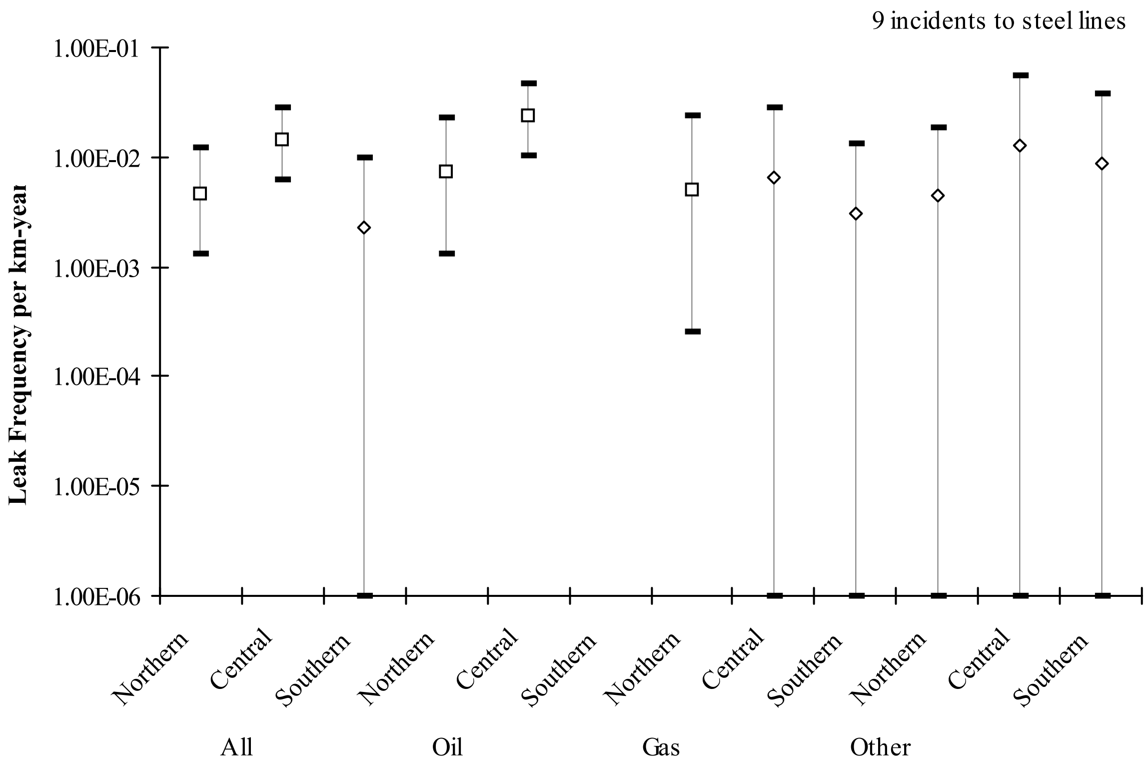


Figure 4-20 – Variation of Frequency of Loss of Containment Incidents by Location in the North Sea and Pipeline Contents for All Corrosion and Material Incidents Occurring to Steel Lines Less than 2km Long

Figure 4.21 presents the variation of frequency of loss of containment due to impact incidents to the mid line of steel lines of Diameter 2 to 9 inches and greater than 10 inches in Diameter by location in the North Sea. Figure 4.22 presents the variation by location in the North Sea for loss of containment impact incidents that occurred within the safety zone. These figures do not show any clear and consistent dependence of loss of containment incidents with location in the North Sea.

4.4.5 Type of Line

Each pipeline has been classified as one of a number of types. For the purposes of this analysis the types considered were trunk line, interfield line, infield line, flowline and other (e.g. loading lines, spur lines). The loss of containment frequencies are presented in Figures 4.23 to 4.25 grouped by the parameters found to be significant in Section 4.3.

Figure 4.23 presents the loss of containment frequency associated with all material and corrosion incidents which occurred to lines less than 2 km long by contents and either flowline, infield line or other. Note, there are no lines less than 2 km in length which are classified as interfield or trunk lines. There have been insufficient reported incidents to determine consistent trends in the frequencies calculated from the reported number of incidents in this case and the confidence intervals overlap.

Figure 4.24 presents the variation of frequency of loss of containment for impact and anchoring incidents which occurred within the platform safety zone. There are no clear trends in the frequencies for trunk, interfield and infield lines. The estimates based upon reported incidents indicate that 'other' lines have a higher loss of containment frequency, however, the confidence intervals overlap for all line types. No incidents have been reported to flowlines.

Figure 4.25 (a) and (b) present the variation of frequency of loss of containment due to anchoring and impact incidents for steel lines of Diameter 2 to 9 inches and for steel lines greater than 10 inches in Diameter by line type. This figures do not show any clear and consistent trends.

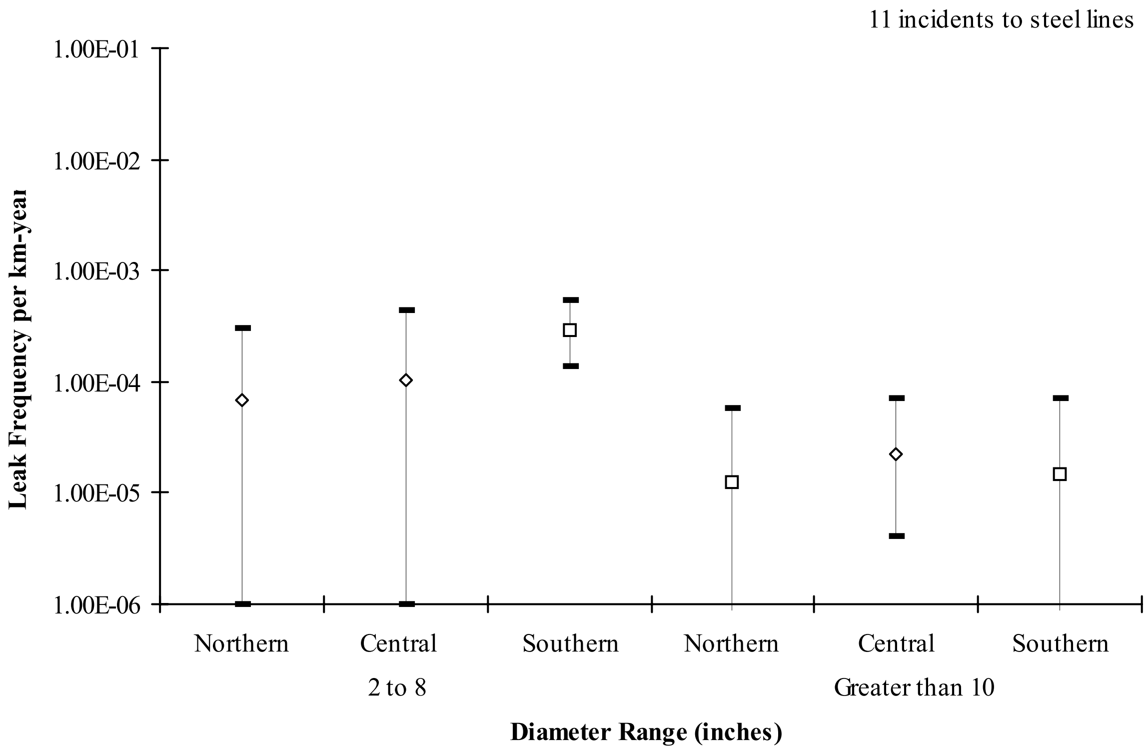


Figure 4-21 – Variation of Frequency of Loss of Containment Incidents by Location in the North Sea and Pipe Diameter for All Anchoring and Impact Incidents Occurring to the Mid Line of Steel Lines

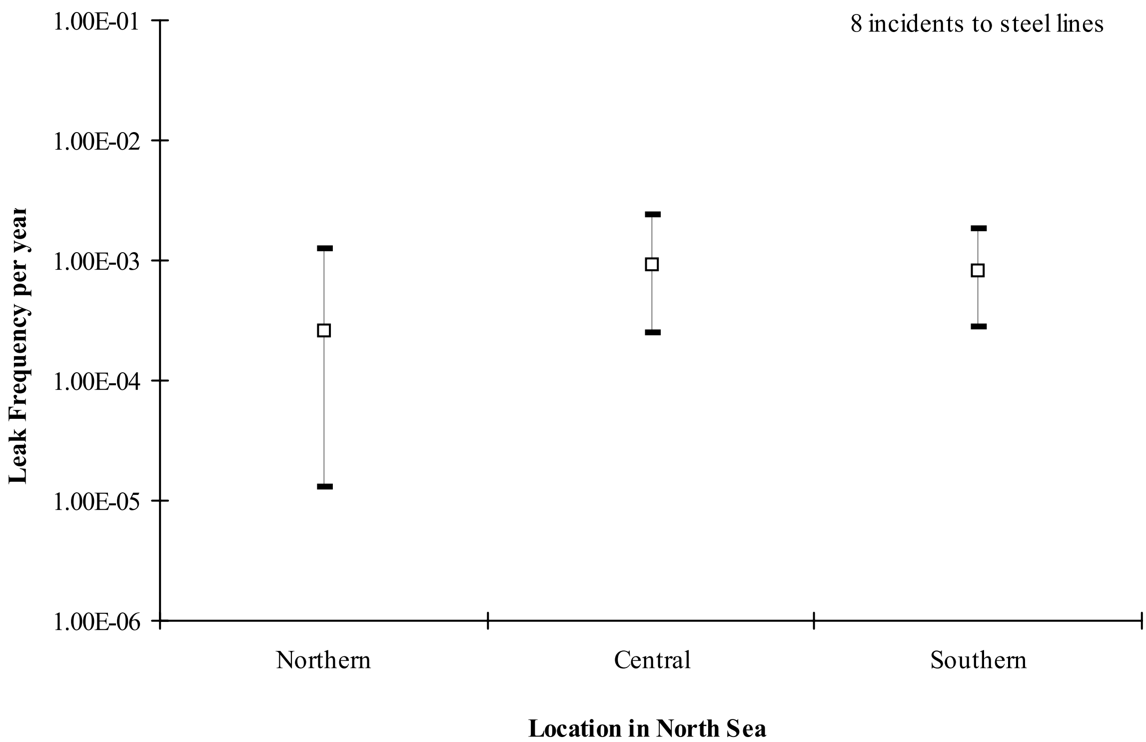


Figure 4-22 – Variation of Frequency of Loss of Containment Incidents by Location in the North Sea for All Anchoring and Impact Incidents Occurring in the Platform Safety Zone of Steel Lines

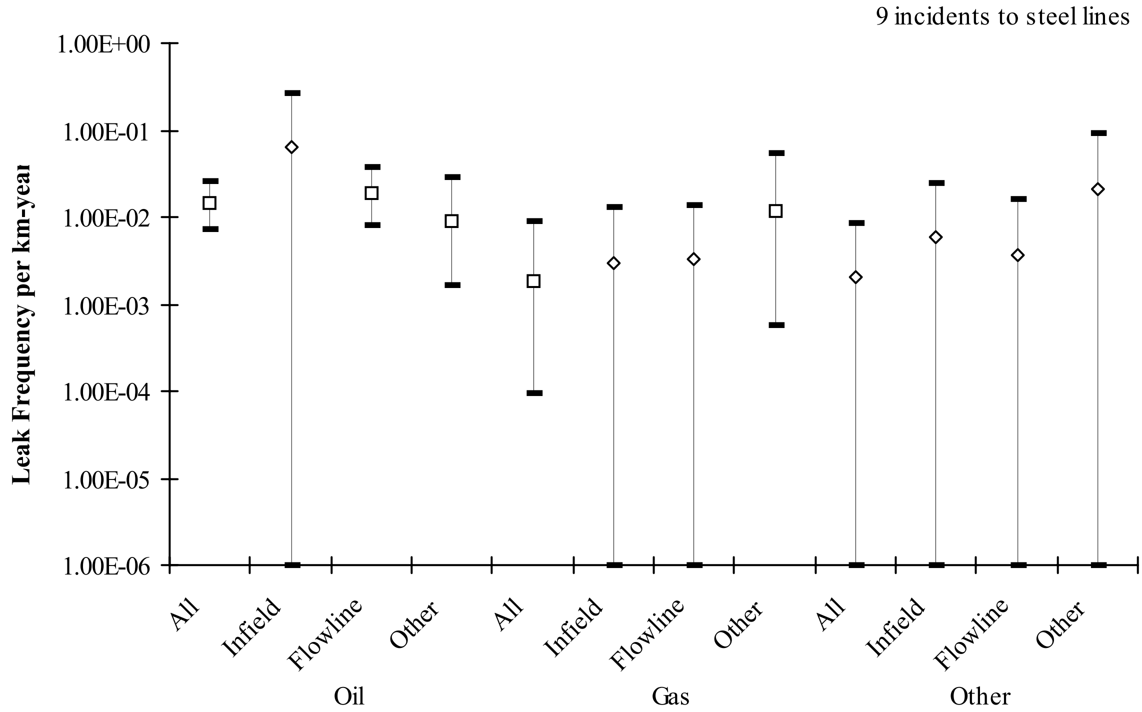


Figure 4-23 – Variation of Frequency of Loss of Containment Incidents by Line Type and Pipe Contents for All Corrosion and Material Incidents Occurring to Steel Lines less than 2km Long

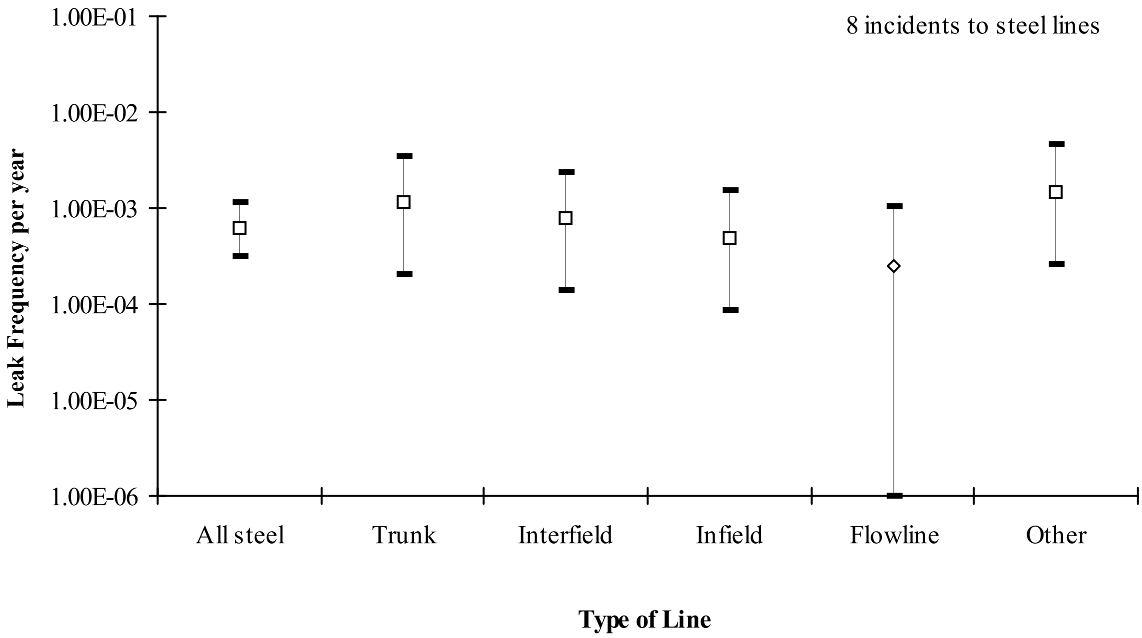
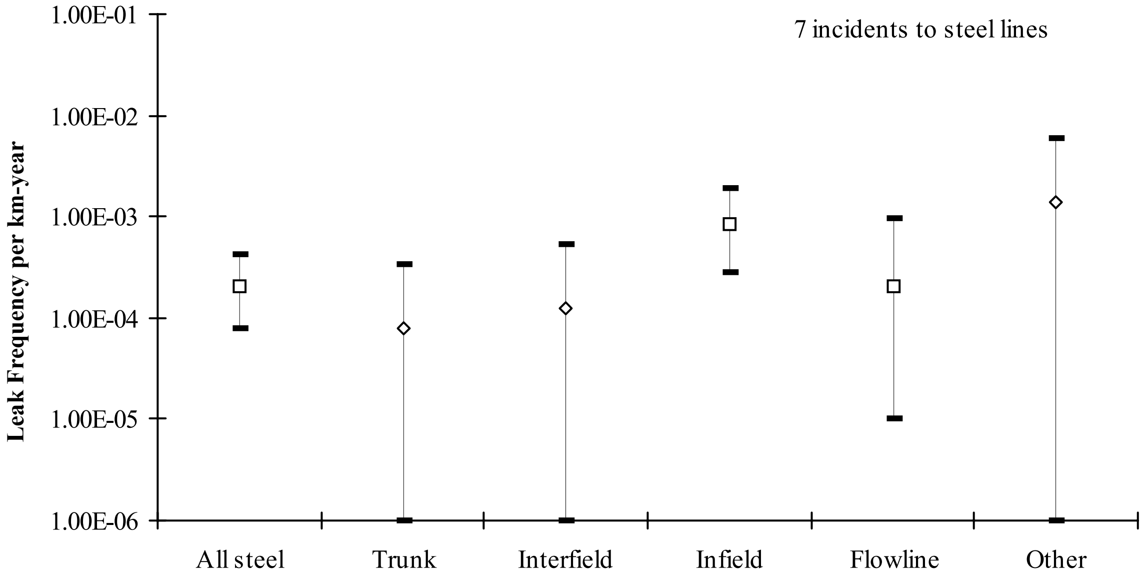
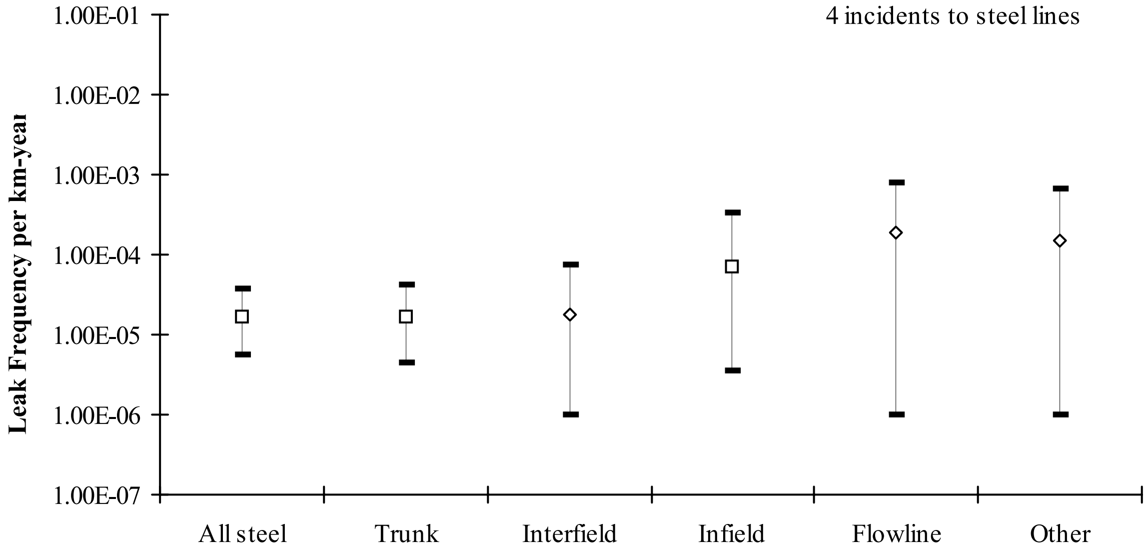


Figure 4-24 – Variation of Frequency of Loss of Containment Incidents by Line Type for All Anchoring and Impact Incidents Occurring to Steel Lines in the Platform Safety Zone



(a) Diameter Range 2 to 9 inches



(b) Diameter Range greater than 10 inches

Figure 4-25 – Variation of Frequency of Loss of Containment Incidents by Line Type for All Anchoring and Impact Incidents Occurring to the Mid Line of Steel Lines

4.4.6 Hydrotest Pressure

For some of the pipelines the hydrotest pressure was recorded in the data sources identified in Section 3.3. The variation of the frequency of loss of containment for these steel pipelines as a function of the ratio of hydrotest pressure to MAOP is presented in Figures 4.26 to 4.28 for material and corrosion defect incidents and impact anchoring and impact incidents grouped by the parameters found to be significant in Section 4.3. In general, there are no trends in the estimates based upon reported incidents. It is apparent that this is on the whole true and the confidence intervals overlap in most of the Figures. However, in Figure 4.27 it would appear that when considering anchoring and impact incidents to all lines, those lines with a ratio of hydrotest pressure to MAOP greater than 2 have a high leak frequency. This, however, is likely to be a result of the low incident frequency as it is extremely unlikely that the ratio of hydrotest pressure to MAOP would result generically in a higher occurrence of such frequncies. There are 4 cases where the hydrotest pressure associated with the pipelines are not known and thus these incidents have been omitted from both figures, all 4 cases in Figure 4.26.

4.4.7 Position of Risers

In previous studies (Ref. [3] and Ref. [4]), an assessment of whether the risers associated with steel jacket platforms were internal or external was made using the available data sources on pipelines, as was discussed in Section 3.3. Certain operators were able to provide confirmation of this assessment. The incident frequency for internal and external steel risers is examined in Figure 4.29 as a function of the damage consequences, such as loss of containment and requirement for repairs.

Considering loss of containment incidents, there is overlap in the confidence intervals but the loss of containment frequency calculated using the reported number of incidents for internal risers is greater than the best estimate for external risers. However, considering incidents where repair was required, there is no significant dependence with riser location. This is because all boat impact incidents occurred to external risers, even though none of these led to leaks. Incidents which required repair are discussed further in Section Five.

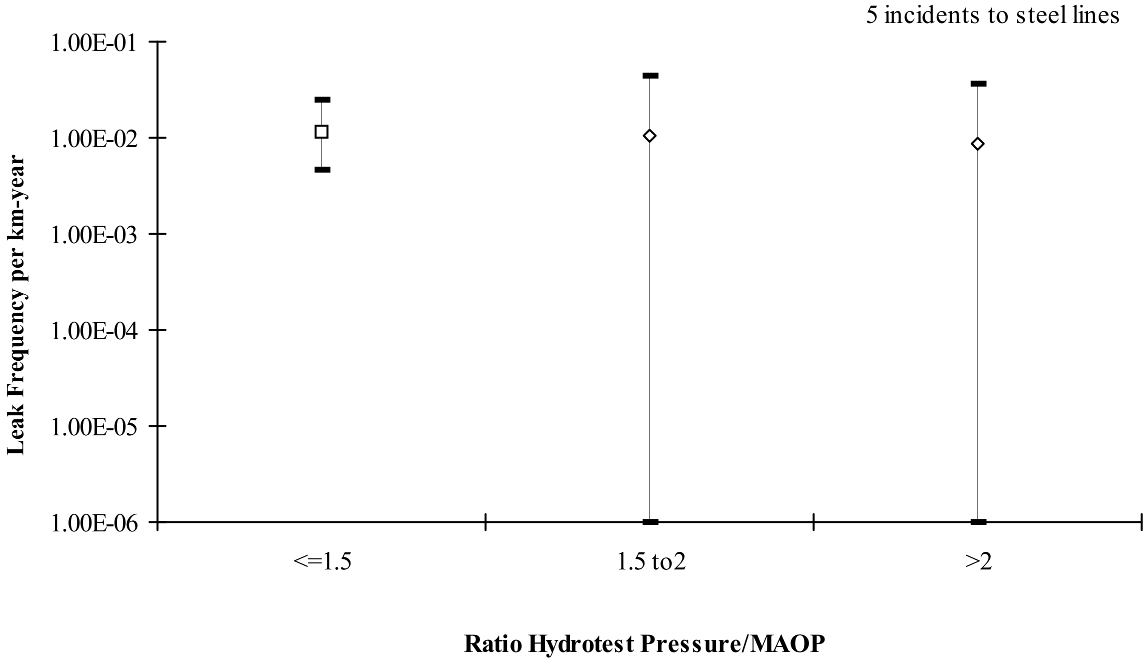


Figure 4-26 – Variation of Frequency of Loss of Containment Incidents by the Ratio of Hydrotest Pressure to MAOP for All Corrosion and Material Incidents Occurring to Steel Lines less than 2km Long

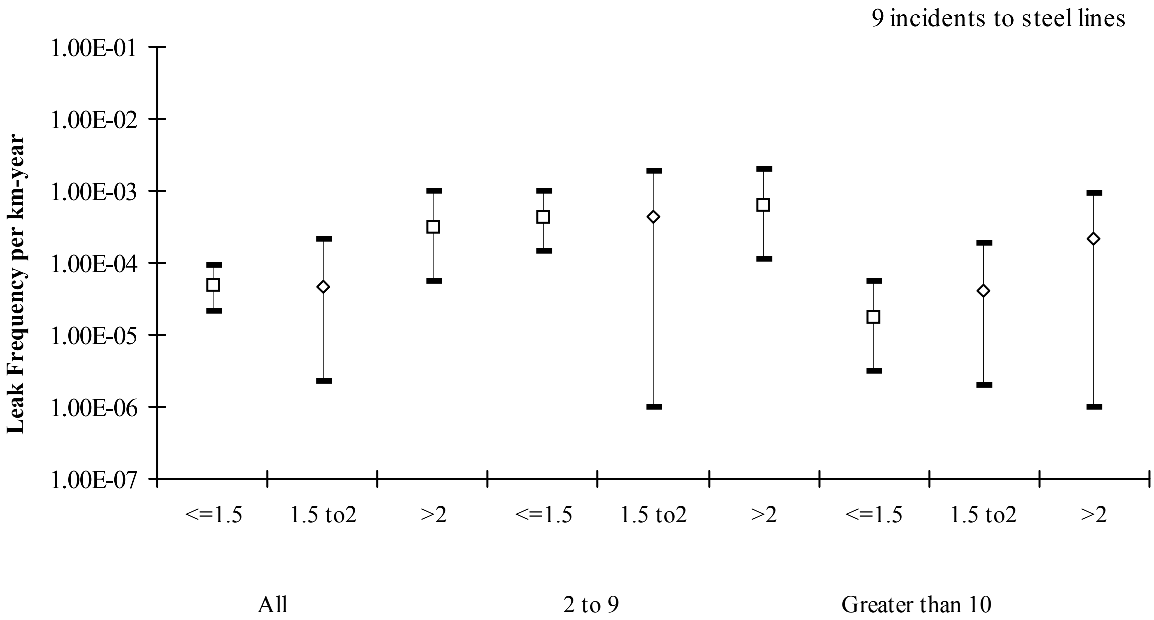


Figure 4-27 – Variation of Frequency of Loss of Containment Incidents by Diameter and the Ratio of Hydrotest Pressure to MAOP for All Anchoring and Impact Incidents Occurring to the Mid Line of Steel Lines

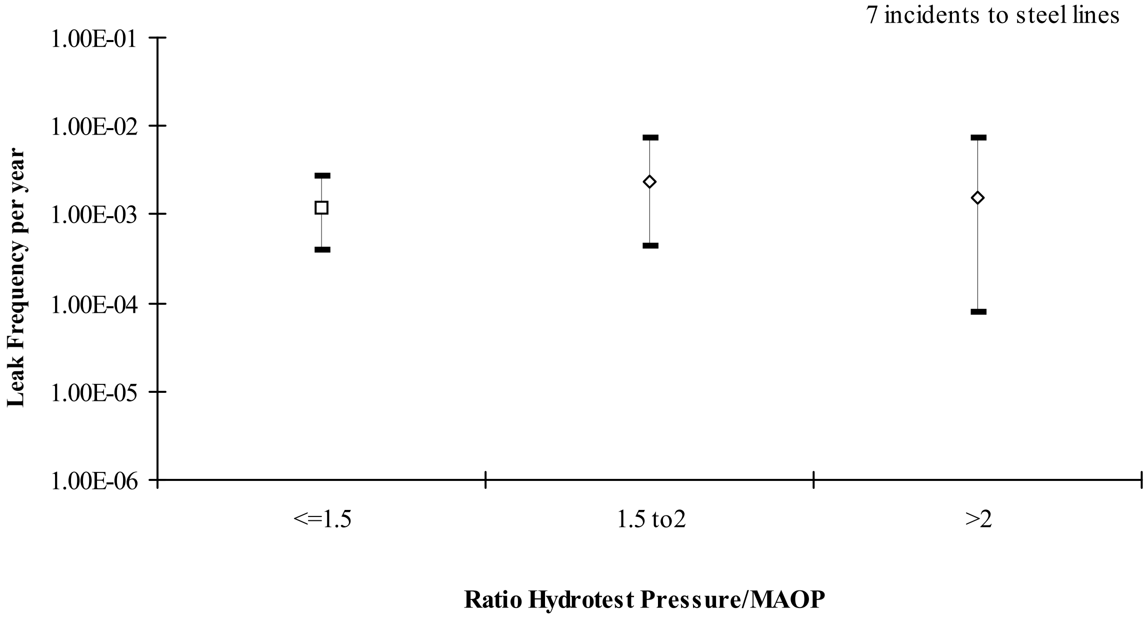


Figure 4-28 – Variation of Frequency of Loss of Containment Incidents by the Ratio of Hydrotest Pressure to MAOP for All Anchoring and Impact Incidents Occurring in the Platform Safety Zone to Steel Pipelines

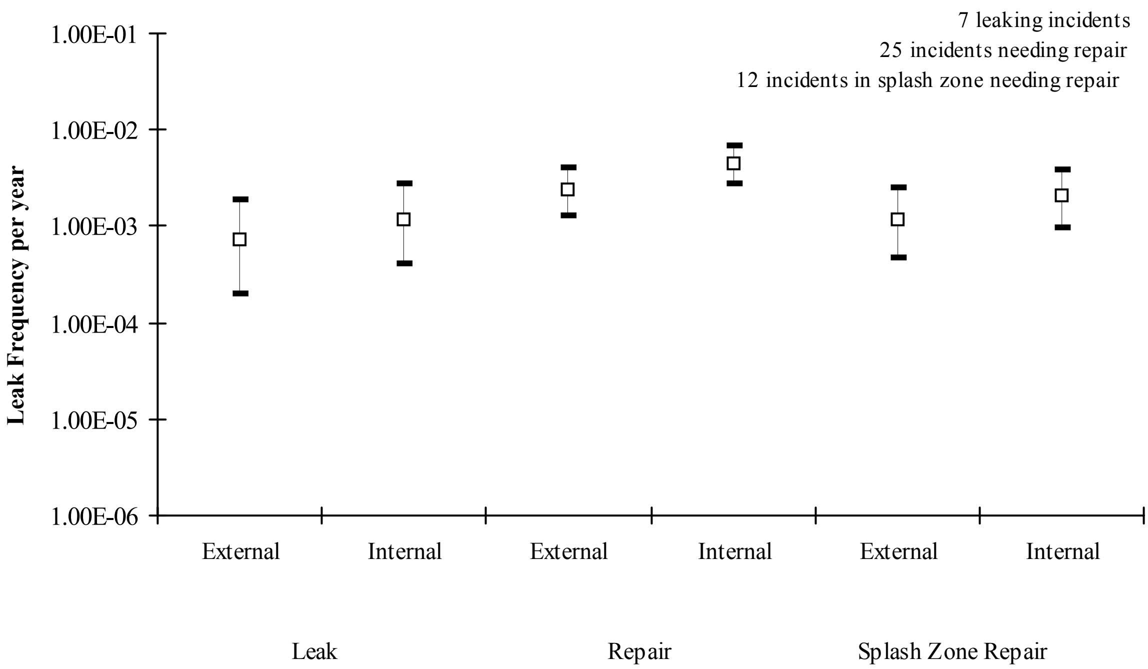


Figure 4-29 – Variation of Frequency of Various Consequences of Incidents by Position of Riser

4.4.8 Piggybacked Lines

Of the 1069 steel pipelines that have been installed in the North Sea, 164 of them have been piggybacked to larger Diameter lines. The operating experience of the total piggybacked pipeline population is 30062 km years compared to the operating experience of steel pipelines of 304212 km years.

Comparing the population of piggybacked lines to an equivalent group of steel lines in the Diameter range 0 to 4.5 inches that are not piggybacked, Figure 4.30 illustrates the frequency of loss of containment from these pipeline populations due to anchoring and impact incidents.

The estimates based upon reported incidents indicate that piggybacked lines have a higher loss of containment frequency, however, there is a degree of overlap in the confidence intervals.

4.4.9 Bundled Lines

Within the pipelines database there are details of 119 pipelines contained within 27 bundles. All of these bundled lines are in the Diameter range 2 to 16 inches and are contained in carrier pipes in the Diameter range 12 to 40 inches. The operating experience of this subset of the total pipeline population is about 2570 km years.

Figure 4.31 compares the frequency of loss of containment from this pipeline population with an equivalent group of steel lines in the Diameter range 12 to 40 inches due to anchoring and impact incidents.

As there have not been any incidents to bundled lines causing loss of containment and the operating experience of these lines is small no firm conclusions can be drawn.

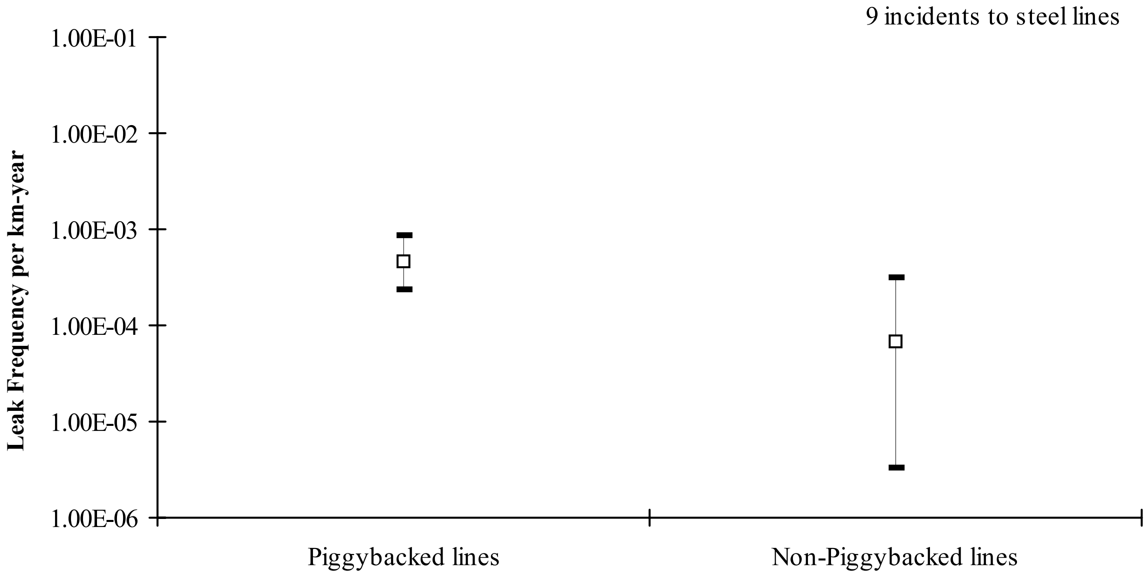


Figure 4-30 – Variation of Frequency of Loss of Containment Incidents for All Anchoring and Impact Incidents Occurring to Piggybacked and Non-Piggybacked Steel Pipelines 0 to 4.5 inches in Diameter

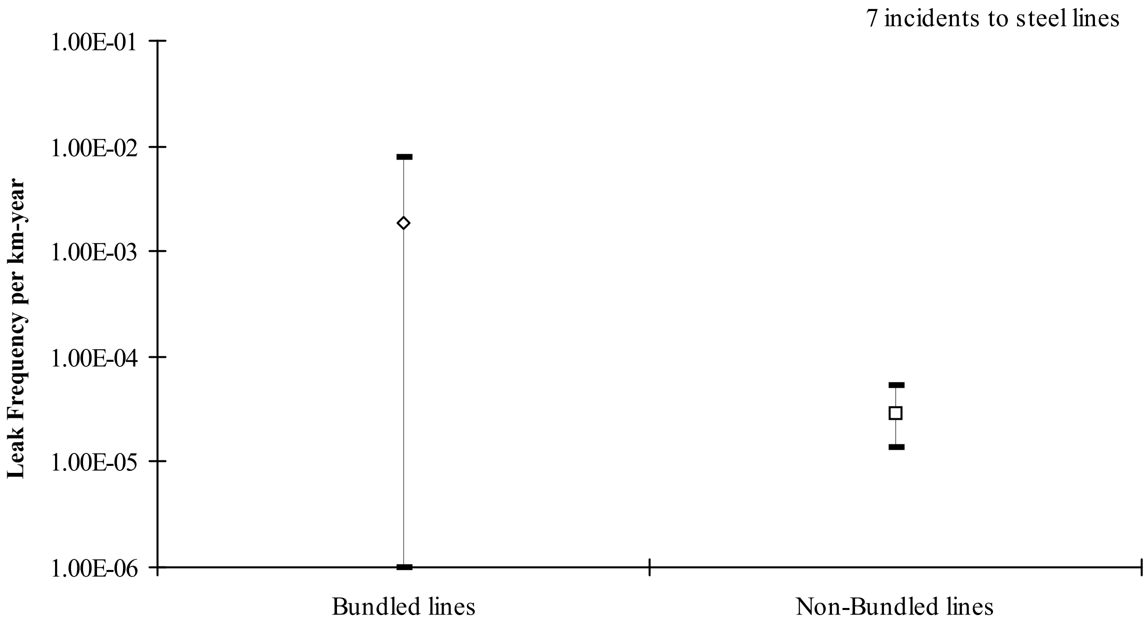


Figure 4-31 – Variation of Frequency of Loss of Containment Incidents for All Anchoring and Impact Incidents Occurring to Bundled and Non-Bundled Steel Pipelines 12 to 40 inches in Diameter

4.4.10 Grade Of Steel Pipelines

Within the pipelines database each steel pipeline has been categorised as 'high' or 'low' grade steel. API Steel grades from up to X48 have been classified as low grade steels and grades X52 to X80 plus duplex steel as high grades.

In comparing the frequency of loss of containment from high and low grade steel lines by length as a result of corrosion and material defect incidents no trend was observed between the two categories. However, the analysis did confirm the observed trend by length for corrosion and material defect incidents discussed in Section 4 3.3.

No trend in the frequency of loss of containment by Diameter was observed between the two categories of steel lines as a result of anchoring and impact incidents in the mid-line. This analysis also re-emphasised the observed trend by Diameter for anchoring and impact incidents in the mid line discussed in Section 4.3.4.

Figure 4.32 shows the frequency of loss of containment from high and low grade steel lines by Diameter as a result of anchoring and impact incidents in the platform safety zone. There appears to be a trend of higher frequency of loss of containment for low grade steels, particularly in lines above 10 inches in Diameter, however, the confidence limits between the two steel grades overlap.

4.4.11 High Pressure Lines

Within the pipeline database there are details of 314 pipelines with a maximum operating pressure (MAOP) greater than 5000 psi. Of these, 57 are unknown, 88 are flexible and 169 are steel lines. 131 are steel pipelines of diameter 2 to 9 inches and 27 are steel lines of diameter 10 to 16 inches. The operating experience of this subset of the total pipeline population is about 12,415 km years.

Figure 4.33 illustrates the frequency of loss of containment from this pipeline population due to anchoring and impact incidents.

The estimates based upon reported incidents suggest that high pressure flexible lines have a higher loss of containment frequency, however, there is a degree of overlap in the confidence intervals.

4.4.12 Other Factors

Other factors reviewed for their influence on failure rates have included changes in pipeline service, effects of field joints, influence of inspection and maintenance regime, pipeline routeing and subsea systems. All of these are believed to influence the failure rate of pipelines, or, in the case of subsea systems, to have an associated failure rate. Insufficient information is available in the databases for any trends associated with these factors to be identified, however it is considered that it would be advisable to supplement and/or extend the existing database in these areas at some time in the future.

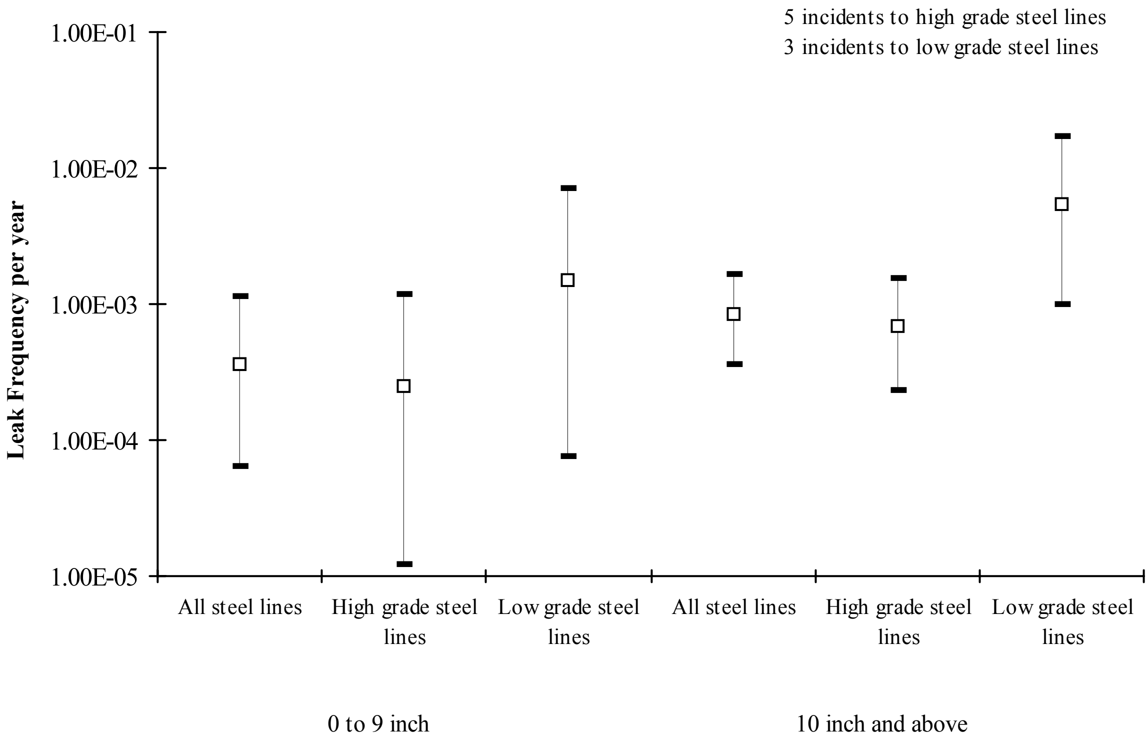


Figure 4-32 – Variation of Frequency of Loss of Containment Incidents by Diameter and Steel Grade for All Anchoring and Impact Incidents in the Platform Safety Zone

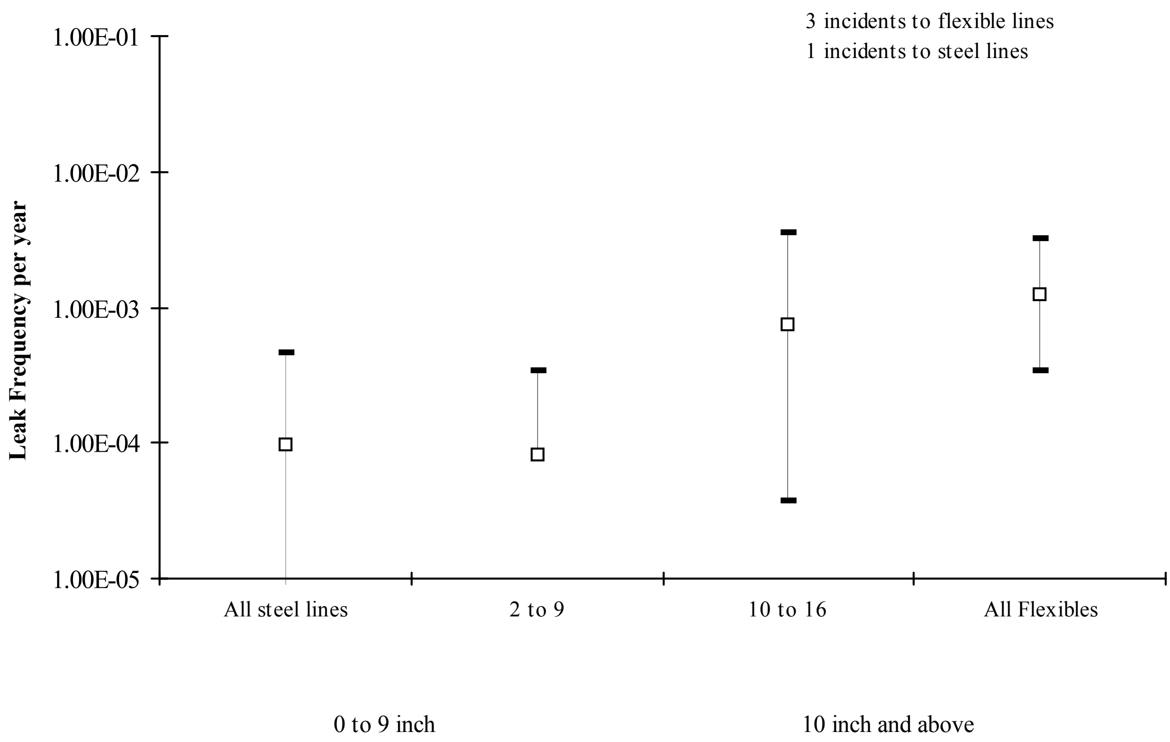


Figure 4-33 – Variation of Frequency of Loss of Containment Incidents by Pipeline Diameter for All Anchoring and Impact Incidents Occurring to Flexible Lines and Steel Pipelines of Maximum Operating Pressure Greater than 5000 psi

4.5 INCIDENTS TO FLEXIBLE PIPELINES AND RISERS

Within the PARLOC database, 31 of the 96 incidents to operating pipelines that resulted in leaks were associated with flexible lines. These 31 incidents span the period of time over which flexible pipelines have been manufactured and operated within the North Sea, and some are due to developmental problems associated with early variants of flexible pipeline products which are now no longer in production.

A review of these 31 incidents indicated that 3 incidents occurred to products which are no longer manufactured or operated in the North Sea. Of these 3 incidents, 2 occurred as a result of design limitations in the product which have now been improved upon to a degree where it can be considered that this type of failure has been designed out. The third incident was caused by trawl damage, and cannot therefore be excluded as a valid incident. 5 of the other 28 1oss of containment incidents from flexible pipelines occurred due to material defect incidents relating to the embrittlement of the rilsan liner, (see Section 4.3.3).

Figure 4.34 compares the frequency of loss of containment for flexible pipelines according to location. Figure 4.35 compares the frequency of loss of containment of flexible incidents with those of steel lines for the riser and safety zones.

Figure 4.4 illustrates that for corrosion and material defect incidents the leak frequencies for flexible and steel pipelines have a degree of overlap when considering the effect of pipeline length. Furthermore, it should be noted that the leak frequencies for flexible pipelines are influenced by the incidents relating to rilsan liner ageing.

Figure 4.11(a) illustrates that the calculated leak frequencies resulting from impact are similar for flexible and steel lines.

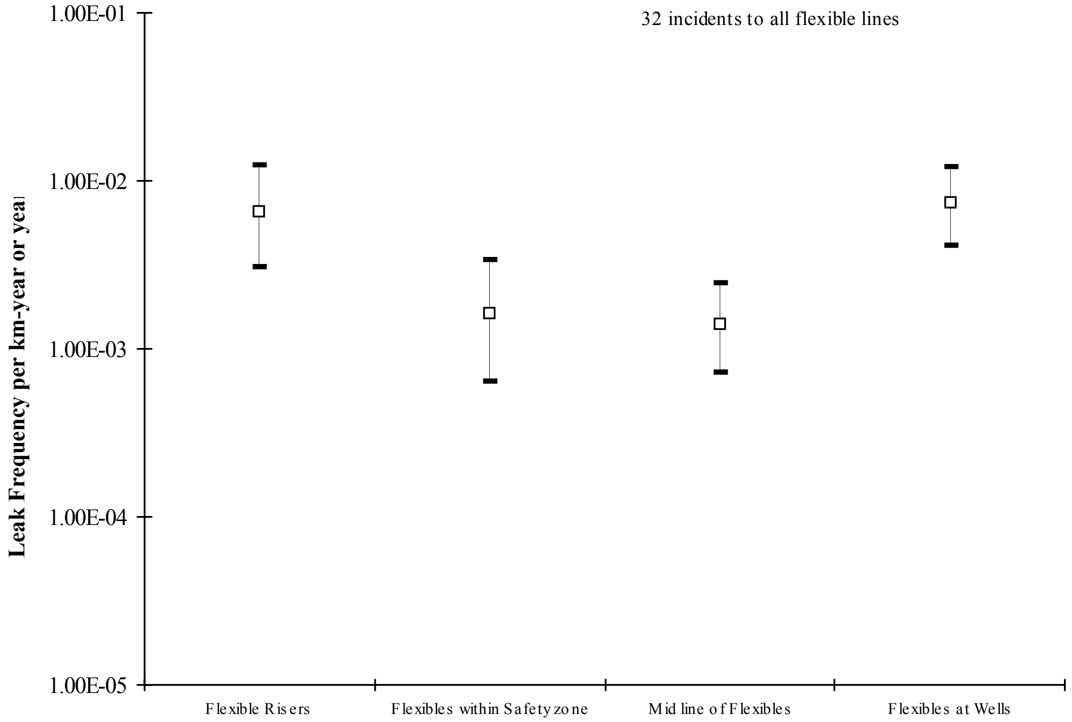


Figure 4-34 – Variation of Frequency of Loss of Containment Incidents for All Incidents to Flexible Lines and Incidents to Flexible Lines in Current Manufacture

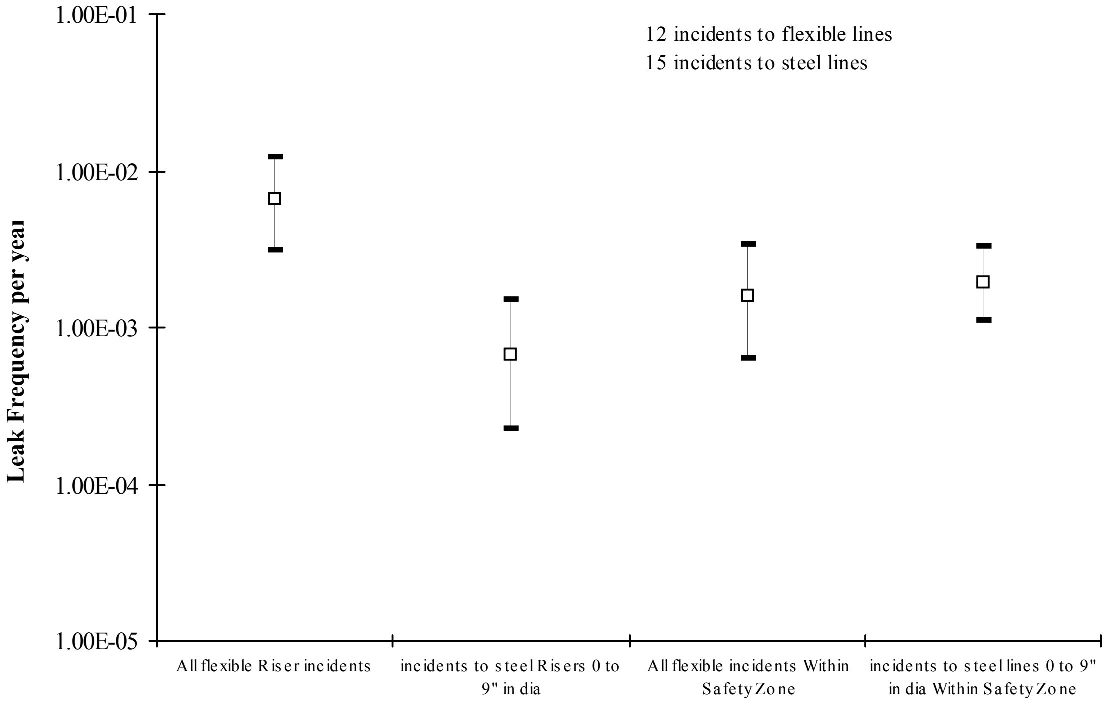


Figure 4-35 – Variation of Frequency of Loss of Containment for Incidents to Flexible Lines and Steel Pipelines 0 to 9 inches in Diameter

4.6 INCIDENTS TO SAFETY VALVES

Since the SI No.1029 1989-The Offshore (Emergency Pipeline Valves) Regulations 1989 (subsequently subsumed in SI 825 1996- The Pipeline Safety Regulations 1996), there has been an increase in the number of reported incidents involving platform emergency shutdown valves (ESDVs) and subsea isolation valves (SSIVs) on UK operated pipelines.

In this revision to the study there are 148 reported incidents to fittings compared with 134 in PARLOC 96. Of these 14 newly reported incidents, 6 resulted in leaks, 4 more were associated with ESDVs. 4 leaks occurred in the safety zone, one of which occurred topside.

35 of the 148 incidents were due to platform ESDV failure. 1 of these incidents led to a minor external leak while 2 others led to medium leaks, All 3 occurred to steel lines. 27 of the 35 incidents required repair to the ESDV.

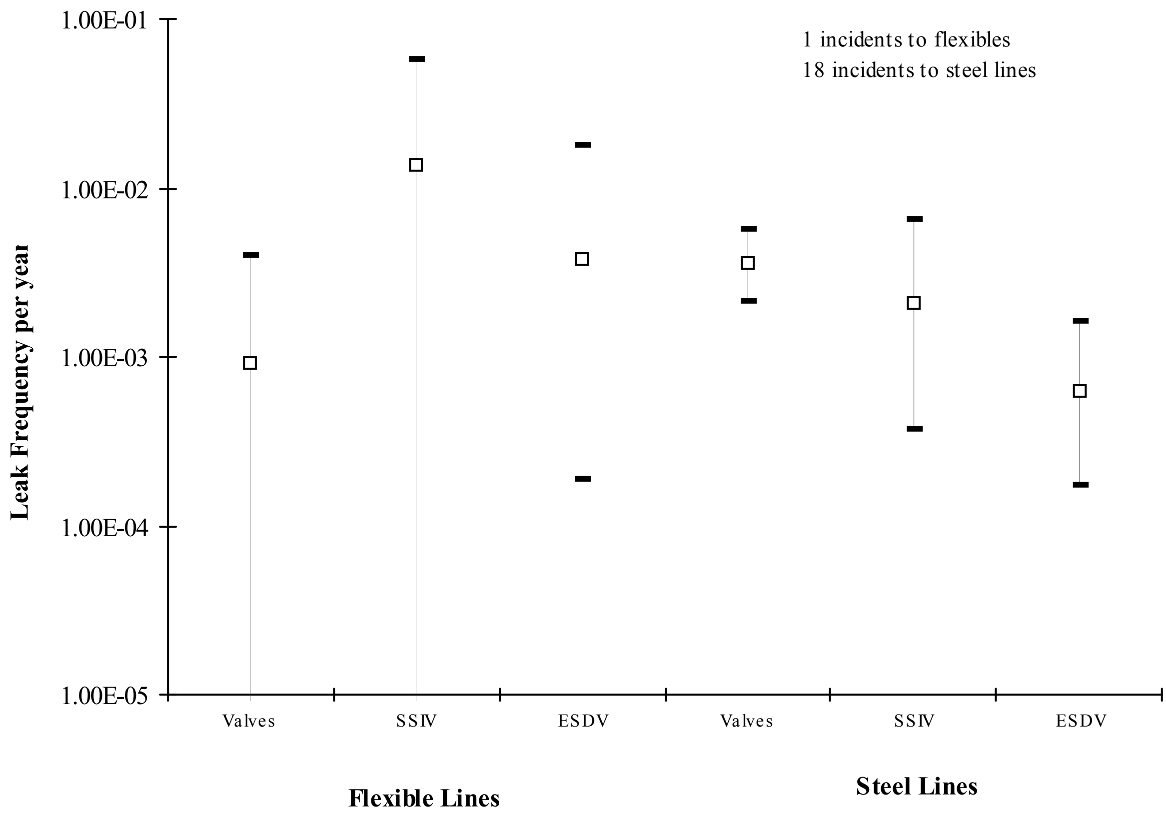


Figure 4-36 Variation of Frequency of Loss of Containment Incidents by type of Valves to Steel and Flexible Lines

4.7 INCIDENTS TO UMBILICALS, JUMPERS AND HOSES

Contained within the incident database are a growing number of reports involving umbilicals, flexible jumpers and flexible hoses. However, reporting of these incidents is not considered to be comprehensive and so those details contained in the database are assumed, at present, to be only a subset of the total number of incidents.

Discussion of these reported incidents is included in the following to raise awareness.

Incidents to Umbilicals

There have been 10 reported incidents involving small Diameter chemical injection umbilical lines, 8 associated with operating lines, 1 with a line undergoing hydrotest and the tenth with a line which was shut down.

7 of the 10 incidents resulted in loss of containment. In 1 incident a small leak occurred in a riser during hydrotest and in another a small leak occurred in a shut down line where a valve was not sealing correctly with

the other 5 incidents occurring to operating lines that resulted in a loss of containment. 3 of these leaks occurred from fittings at subsea wells, 1 being of medium size the cause of which was unknown, and the other 2 being caused by impacts of unknown origin, 1 at a well and 1 in the safety zone within l00 m of the platform.

Of the 3 incidents to operating lines which did not result in a loss of containment, 2 occurred to risers due to wave action and 1 was caused by installation damage at a well. All the umbilicals involved in these incidents required some degree of repair.

Incidents to Flexible Jumpers

The database contains details of 4 incidents to flexible jumpers, 3 of which were to operating lines and 1 to a line undergoing hydrotest. All the incidents were at wells and resulted in loss of containment. The resulting leak sizes were small in 3 of the cases with 1 jumper rupturing during hydrotest. Of the 3 incidents to operating lines 2 were caused by material failures and 1 due to an impact possibly caused by trawl gear.

Incidents to Flexible Hoses

There have been 6 reported incidents to flexible hoses, all of which involved operating risers. All the incidents were due to material failure, 5 of them being attributed to fatigue failure. 3 of the incidents resulted in a loss of containment while in all 6 incidents the hoses effected needed to be replaced.

5 ASSESSMENT OF INCIDENTS TO PIPELINES

5.1 INTRODUCTION

In this Section all the incidents collected during the study which involved operating pipelines are considered. An incident is defined as an event which directly results or threatens to result in loss of containment of a pipeline. An incident can affect more than one pipeline. For example, more than one riser was affected in the Piper Alpha incident of 1988, however, in this study this is recorded as a single incident. As a result, there is only one incident recorded which involves riser failure due to fire or explosion impinging on the pipeline.

In the database there are details of 396 incidents that were associated with operating pipelines. 209 of these incidents were associated with steel pipelines, whilst in a further 148 incidents fittings associated with pipelines were affected and the remaining 39 were incidents to flexible lines. These are presented in Tables 5.1 to 5.3.

The consequences of the incidents have been considered to be of three main types:

- loss of containment;
- no loss of containment but repair of the line required;
- no loss of containment and no repair of the line required.

There have been incidents in which the pipe has been damaged and no repair of the line has been required; these, for example, included minor localised concrete coating loss or small defects. There have also been incidents where no visible damage was reported. In some of these cases remedial action was taken to protect the line. Incidents which directly resulted or threatened to result in loss of containment of a pipeline are those of most interest to the study and where most effort has been put to obtain information. Other incidents have only been included in the database when they formed part of a regulatory authority accident database.

The causes of incidents are summarised in Tables 5.1 to 5.3. Table 5.1 considers the cause of incidents that affected steel pipelines. The largest number of incidents is associated with impact, anchoring and corrosion. Between them these account for 148 of the 209 incidents to steel operating pipelines. They also account for 43 of the 65 incidents, which resulted in loss of containment from steel pipelines. The loss of containment incidents have been discussed in detail in Section Four.

Table 5.2 considers the causes of incidents which affected fittings associated with operating pipelines. Of the 148 incidents 92 resulted in leaks. These have also been discussed in Section Four.

Table 5.3 presents the cause of incidents which involved flexible pipelines. Of the 39 cases 31 resulted in loss of containment and these have been discussed in Section Four.

The causes of incidents which affected operating pipelines are described in detail in Section 5.2. The calculated loss of containment and repair frequencies based upon Section 4 and 5.2 are presented in Section 5.3.

				Riser					Safety Zone								
		Total	Platform	Total	Piping	Splash Zone	Subsea	Unkown	Total	Near	Far	Unknown	Mid Line	Well	Shore Zone	Land	SPM
Anchor	Ship / Supply Boat	18		0					11	1	6	4	6		1		
	Rig or Construction	11		0					8	5	1	2	3				
	Other/Unknown	11		1			1		0				10				
	Total	40	0	1	0	0	1	0	19	6	7	6	19	0	1	0	0
Impact	Ship on Riser	8		8		7		1	0								
	Trawl	27		0					1			1	23	3			
	Dropped Object	2		1			1		1	1							
	Wreck	1		0					0				1				
	Construction	2		1			1		1	1							
	Other/Unknown	16		2		1		1	4	1	2	1	9			1	
	Total	56	0	12	0	8	2	2	7	3	2	2	33	3	0	1	0
Corrosion	Internal	24	1	3				3	8	2	4	2	8	4			
	External	22		19	2	8	2	7	1			1	2				
	Unknown	6		3	1			2	1	1			2				
	Total	52	1	25	3	8	2	12	10	3	4	3	12	4	0	0	0
Structural	Expansion	6		5				5	1	1							
	Clamp Failure	1		1			1		0								
	Buckling	5		0					1		1		4				
	Total	12	0	6	0	0	1	5	2	1	1	0	4	0	0	0	0
Material	Weld Defect	8		4				4	2	1	1		1				1
	Steel Defect	10		5			1	4	2	1		1	2	1			
	Total	18	0	9	0	0	1	8	4	2	1	1	3	1	0	0	1
Nat. Hazard	Vibration	10		1			1		2		1	1	5		2		
	Storm	1		0					0						1		
	Scour	1		0					1			1					
	Subsidence	1		1			1		0								
	Total	13	0	2	0	0	2	0	3	0	1	2	5	0	3	0	0
Fire/Explosion	Total	0		0					0								
Construction	Total	2		0					0				1	1			
Maintenance	Total	1		1	1				0								
Human Error	Total	2		2	2				0								
Op. Problems	Total	1		0					0				1				
Other	Total	12		2				2	2	2			6	1			1
	Total	209	1	60	6	16	9	29	47	17	16	14	84	10	4	1	2

Table 5-1 – Causes of Incidents to Operating Steel Pipelines

				Riser					Safety Zone								
		Total	Platform	Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown	Mid Line	Well	Shore Zone	Land	SPM
Anchor	Other/Unknown	2		0					1			1		1			
	Total	2	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0
Impact	Trawl	4		0					0				3	1			
	Unknown	2		0					0				1	1			
	Total	6	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0
Corrosion	Internal	4	1	1	1				2	1		1					
Structural	Clamp Failure	2		2				2	0								
	Buckling	1		0					0				1				
	Total	3	0	2	0	0	0	2	0	0	0	0	1	0	0	0	0
Material	Weld Defect	2	2	0					0								
	Steel Defect	2	2	0					0								
	Total	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nat. Hazard	Storm	4		3			1	2	0								1
Other	Total	2		1				1	0				1				
Fitting	Flange	11	2	5	1		2	2	3	1		2		1			
	Valve	15	8	0					3		1	2	3	1			
	Connector	7		1				1	0				4	1			1
	Hydrocouple	7		1				1	5	1		4	1				
	Load Limit Connector	5		0					1	1				4			
	Insulation Joint	1		1		1			0								
	Seal Failure	4	1	2			1	1	1	1							
	Nipple	4	1	0					1			1	1	1			
	ESDV Leak *	0		0					0								
	SSIV Leak	2		0					2	2							
	Pig Trap	18	14	1	1				1			1				2	
	Human Error	6	4	0					0				1				1
	Unknown Fitting	3	1	1				1	0				1				
	ESDV Mechanical Failure	35	35	0					0								
	SSIV Mechanical Failure	2		0					2	2							
	Valve Mechanical Failure	3	3	0					0								
	Total	123	69	12	2	1	3	6	19	8	1	10	11	8	0	2	2
	Total	148	74	19	3	1	4	11	22	9	1	12	17	11	0	2	3

Table 5-2 – Causes of Incidents to Fittings Associated with Operating Pipelines

* Incidents included under ESDV mechanical failure

		Total	Platform	Riser					Safety Zone				Mid Line	Well	Shore Zone	Land	SPM	Unknown
				Total	Piping	Splash Zone	Subsea	Unknown	Total	Near	Far	Unknown						
Anchor	Rig or Construction	1		0					0				1					
	Other/Unknown	1		0					0					1				
	Total	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Impact	Trawl	6		0					0				3	3				
	Dropped Object	1		0					0					1				
	Other/Unknown	2		0					0				2					
	Total	9	0	0	0	0	0	0	0	0	0	0	5	4	0	0	0	0
Structural	Buckling	2		0					0				1	1				
Material	Flexible Defect	12		2			1	1	2	1		1	5	3				
Construction	Total	2		0					0					2				
Repair	Total	1		0					0				1					
Other	Total	11	2	3				3	0				2	1				3
	Total	39	2	5	0	0	1	4	2	1	0	1	15	12	0	0	0	3

Table 5-3 – Causes of Incidents to Operating Flexible Pipelines

5.2 CAUSES OF INCIDENTS

5.2.1 Anchoring

Summary of Consequences of Anchoring Incidents

There were a total of 44 incidents involving anchoring. 2 of these incidents occurred to operating flexible lines, 2 to fittings associated with operating steel lines and 40 of these incidents are among the 209 recorded incidents associated with operating steel pipelines. Of these incidents:

- 18 did not require repair.
- 11 resulted in loss of containment.
- In addition to the loss of containment incidents, in 22 incidents the pipeline needed some degree of repair; in 5 of these cases the pipeline had been moved by the anchor and damage to the pipe body was reported in 8 incidents.
- In 6 incidents the pipelines affected sustained dents, but repair was only required in 1 incident.
- In 4 incidents only the concrete coating was damaged.
- In 6 cases, no visible damage was reported.

2 anchoring incidents affected flexible lines. In one incident the flexible was torn and leaked. In the other there was external damage, but not severe enough to warrant repair.

2 anchoring incidents involved fittings associated with operating lines and resulted in damage to valves, both of which led to leakage.

Causes of Anchoring Incidents

11 incidents to operating steel pipelines (excluding fittings and flexibles) were caused by construction vessels, 8 occurred within platform safety zones, of which 5 were within 100 m of the platform. The remaining 3 incidents occurred to the mid line of the pipeline. None of these incidents resulted in pipe leakage, and only 1 of the affected pipelines needed repair.

l incident was to a flexible line in the mid line of the pipeline which did not result in a leak.

A further 18 anchoring incidents were caused by supply boats, 11 occurring in the safety zone, 6 to the mid line of the pipeline and 1 in the shore zone. The exact location of 7 of these incidents was reported, only 1 occurred within 100m of the platform; the other 6 occurred further than l00m from the platform. Of the 11 incidents 6 resulted in loss of containment. Of the lines that did not leak as a result of the anchor impact, one was dented and the other sustained damage to the coating but no repair was necessary in either incident. All of the supply boat incidents were to steel pipelines.

5.2.2 Impacts

Consequences of Incidents Involving Impact

Incidents attributed to impact damage represent the largest number of incidents associated with operating steel pipelines, accounting for 56 of the 209 recorded. Of these incidents, 9 resulted in loss of containment. 24 incidents required some degree of repair and in 32 incidents no repair was required. The damage sustained by pipelines in the 56 incidents which did not result in leakage was 13 by denting, with 14 others being gouged or having their coating damaged, 3 being severed, 4 being buckled and a further 9 being moved off line. In 16 incidents no damage was reported or the type of damage sustained was not defined. The total number of damage types exceeds the number of incidents since some incidents resulting in more that one type of damage being reported.

Of the 9 incidents to operating flexible lines there were 6 cases of trawl damage, 3 of which resulted in a loss of containment, 1 incident occurred when an object was dropped on a line causing it to leak. The cause of one incident was unknown while the remaining incident occurred when a trencher crossed the path of a flexible line, however, there was no loss of containment.

There were 6 reported incidents to fittings involving impacts. 4 of these were reported as trawl damage, of which 2 involving connectors, 1 a grout plug and 1 damage to a gearbox assembly, while the cause of the other two were unknown. Only 1 of the trawl incidents resulted in a loss of containment whilst 2 other incidents required replacement of the component. The fifth impact incident to a fitting, was caused by a marker buoy chain snagging a wellhead and causing the springing of two flanges, with a subsequent leak. The final impact was due to an anchor chain being dropped near a subsea well zone.

Causes of Impact Incidents

8 incidents involved ships impacting risers, all of which were known to involve external risers. None of these cases resulted in loss of containment from the riser, however, 6 of the incidents resulted in dents, with 5 needing repair or added protection. 5 of these ship impacts were caused by supply boats.

There was 1 incident in which a boat sunk onto a pipeline.

37 incidents were reported to have been caused by trawl gear damaging pipelines. 27 were to steel lines, 4 were to fittings associated with lines and the remaining 6 were to flexible lines. Of the 27 incidents involving steel lines, 1 occurred in the platform safety zone, 23 in the mid line of the pipeline and 3 incidents occurred near to a subsea well. The 3 flexible line incidents resulted in loss of containment; 1 occurred in the mid line of the pipeline and 2 occurred near to a subsea well. 4 fitting incidents occurred in the mid line of the pipeline and 2 near to a subsea well.

The exact cause of 20 impact incidents was uncertain. 16 of these incidents occurred to steel lines, 2 to flexible lines and 2 to fittings, with 4 occurring in the platform safety zone, 2 in the riser, 1 on land, 12 in the mid line of the pipelines (one at a tee). The 1 line that leaked was a 34" oil pipeline. Of the 15 steel pipelines which did not leak, 5 had no damage reported, 1 was gouged, 3 had coating damage and 7 were dented or ovalised; however, only 2 lines needed repairing. The Diameter range of the lines affected was 2 to 24 inches.

Construction vessel activity was responsible for 2 incidents. In 1 incident two lines were affected, a methanol line was severed and a larger line was damaged. In the other incident a riser was buckled.

Slight denting from dropped objects was reported three times, with one dropped object causing a small leak in a flexible line.

1 incident occurred when a trencher crossed the path of a flexible line in the mid line. No loss of containment resulted.

3 incidents were attributed to chain damage. 2 occurred to steel lines neither of which leaked but gouging resulted in one line; the other was unaffected. 1 incident occurred to a fitting at a well which leaked. In another incident a mechanical digger damaged the coating of a pipeline on land.

5.2.3 Corrosion

Summary of Consequences of Incidents

Incidents attributed to corrosion account for 52 of the 209 recorded incidents associated with operating steel pipelines. 46 of these required repair, abandonment or replacement (or intended replacement) of the line. 3 required the MAOP to be reduced and in 3 a corrosion inhibition programme was implemented. For steel pipelines, there have been 26 corrosion incidents which resulted in leaks; 7 were due to external corrosion and 14 were due to internal corrosion, while in 5 incidents, the information given was insufficient to decide whether the corrosion was internal or external.

There have been 4 incidents of corrosion in fittings, all of which resulted in a loss of containment.

These incidents represent a small subset of corrosion reports in the North Sea, for example, in the NPD database there are numerous reported cases of external corrosion and internal corrosion. However, only very few had consequences which were significant and only these cases are classified as incidents and are recorded in this database. A similar situation exists with other incident categories, notably material defects, natural hazards and riser clamp problems.

Causes of Corrosion Incidents

Of the 22 cases of external corrosion 14 were of a serious nature. 2 resulted in major leaks, 2 in a minor leak and repair was required in 15 cases. The MAOP was reduced in 3 of the other incidents. No repair was required in the other incident. 19 of the external corrosion cases recorded in the study database occurred to risers, 1 in the safety zone and two in the mid line region. The affected lines were of various Diameters and wall thicknesses. All were either oil or gas lines. With regard to the age of the riser at the time of occurrence of the 18 incidents which required repair or MAOP reduction, 5 were 3 years old or less, 5 were between 8 and 11 years old and the remaining 8 were 15 years or older.

Of the 28 cases involving internal corrosion recorded in the study database, 4 occurred to fittings. 16 of these occurred in oil lines, 5 in gas lines and 7 in water lines. 18 of the 28 resulted in leaks with all 4 of the fittings leaking. 4 of the pipeline leak incidents occurred at welds, 1 occurred at a screwed joint and 10 in the pipe. 1 of these pipeline incidents was attributed to anaerobic corrosion due to sulphide reducing bacteria. The 18 lines that leaked were all short; 7 transported water and 9 oil and 2 gas. Of the non-leaking incidents 2 lines were replaced, 1 had a 6.4m section replaced and 3 had inhibitor programmes implemented.

There were altogether 6 corrosion incidents with insufficient details to decide if they were due to internal or external corrosion. These all occurred to steel lines, 5 of the 6 steel line incidents resulted in leakage.

5.2.4 Material Defects

Summary of Consequences of Incidents

Incidents involving material defects to lines account for 18 of the 209 recorded incidents associated with operating steel pipelines, for 4 of the 148 incidents involving fittings and for 12 of the 39 recorded incidents associated with operating flexible pipelines.

Of the 18 cases involving steel pipelines, 10 resulted in loss of containment. In addition to the lines which leaked, 2 incidents required some degree of repair. 3 of the incidents involving fittings on pipelines and the 12 incidents to flexible lines, that were attributed to material defects, resulted in line leakage.

Causes of Material Incidents

Of the 18 cases involving steel pipelines, 8 were due to a defect in a weld. The remaining 10 incidents were attributed to defects in the steel. 9 of these incidents occurred to risers, 4 occurred in the platform safety zone, 3 in the mid line, 1 at an SPM and 1 at a subsea well.

5 of the 12 material defect incidents involving flexibles involved ageing and embrittlement of the liner due to the operating conditions. 4 incidents occurred in the mid-line of pipes, 3 were near wells, 3 occurred in the platform safety zone and 2 to riserS. All of the incidents occurred when the lines were less than 12 years old.

All 4 of the incidents involving fittings on pipelines occurred on platforms and concerned small branch tappings from the main line; 2 were due to a weld failure and 1 a crack in a 2 inch branch off of a 16 inch line.

2 of the 25 incidents the cause of which is given as "other", were either material or corrosion failures; however, from the information available from the appropriate regulatory authority and the operator it was not possible to determine which. 1 of these incidents occurred in the safety zone and the other in the subsea section of a riser.

5.2.5 Fire

There were no incidents caused by a fire and explosion. Piper Alpha is listed as a fitting incident which resulted in a fire and explosion.

5.2.6 Repair and Maintenance

There were 2 incidents that resulted due to damage during maintenance, 1 where a TFL tool aggravated earlier damage and caused a flexible line to rupture in the mid line and 1 where a riser was gouged when the monel cladding was being ground off to facilitate inspection.

5.2.7 Natural Hazards

Summary of Consequences of Incidents

Incidents resulting from natural hazards account for 13 of the 209 recorded incidents associated with operating steel pipelines and 4 of the 148 incidents resulting in damage to a valve or fitting on a line.

None of the 13 incidents associated with operating steel pipelines leaked, however, additional protection of the line was required in all cases. Only 3 lines sustained damage, this being to their coating.

3 of the 4 fitting incidents resulted in loss of containment through damage to a flange.

Causes of Incidents

Of the 13 recorded cases of damage to steel lines from natural hazards, 10 were due to current and wave action, 1 resulted from storm damage, 1 was due to scouring and 1 was due to subsidence. 5 of the incidents occurred in the mid line of pipelines, 3 occurred in the shore zone, 3 in the platform safety zone and 2 to a subsea riser.

All incidents to fittings associated with a line, which resulted in a leak, occurred when bad weather failed clamps and caused a leak at a flange.

5.2.8 Structural Damage

Summary of Consequences of Incidents

Incidents involving structural damage to lines account for 12 of the 209 recorded incidents associated with operating steel pipelines, 3 of the 148 incidents resulting in damage to a valve or fitting associated with a line and 2 of the 39 incidents to operating flexible pipelines.

Only 1 of the 12 cases of structural damage to steel lines recorded in the extended database resulted in a loss of containment. In all the other incidents, the pipelines were moved, but only 3 required repair as a result.

1 of the 3 fitting incidents resulted in a leak and the other 2 incidents required component replacement.

The 2 incidents to flexible lines both resulted in a loss of containment. 1 was due to buckling and one to clamp failure.

Causes of Structural Incidents

Of the 12 recorded cases of damage to steel lines, 6 occurred as a result of thermal expansion, 5 by upheaval buckling, with the remaining incident caused by clamp failure. 6 of the incidents occurred to risers, 4 occurred in the mid line and the other 3 occurred in the platform safety zone. The only leak was due to clamp failure which resulted in the riser being dropped and the leak then resulted from a buckle in the riser.

Only 1 of the incidents involving fittings associated with a line resulted in leakage. This was due to thermal expansion which caused a crack in a valve at a tee. 2 further cases were reported involving problems with clamps

Of the 2 incidents to flexible lines which resulted in a loss of containment, 1 was due to buckling and one to clamp failure.

5.2.9 Construction Faults

Incidents to Operating Pipelines

There were only 4 reported instances of damage to operational pipelines as a result of faults produced during construction. The incidents happened two to three years after installation of the pipe. 2 cases involved steel pipelines and were due to damage incurred during pipelay and trenching. In both cases coating damage occurred. The other 2 cases affected flexible lines, 1 suffered a slight leak and in the other the line ruptured. Both occurred at wells and resulted from installation damage.

Incidents during Hydrotest and Commissioning

There are details of 34 incidents which were reported to have occurred during hydrotest or commissioning of the pipeline. 11 incidents involved fittings, of which 10 were on a platform and 1 in a platform safety zone. 20 of the other 23 incidents involved steel lines. In the remaining 3 incidents a flexible line ruptured due to incorrect sequencing of valve operations during commissioning an end fitting failed and the cause of the third incident is given as unknown. 6 of the 20 incidents to steel lines involved damage incurred during trenching, of which 5 resulted in leakage and the other in denting. 5 failures during hydrotest were due to weld defects, 3 in the mid line of a pipeline 1 in the subsea riser and 1 in a platform safety zone. 2 failures were due to anchoring and impact damage both in the mid line of a pipeline. There was a further incident involving an impact in the safety zone which resulted in damage to the pipeline. There was 1 hydrotest failure due to corrosion in a line being tested after repair. 2 other incidents involved a riser during hydrotest, the cause of which is not known. There were 3 other hydrotest failures, 2 occurred in the mid line and 1 in the platform, the causes of which were unknown.

Incidents to Shut Down Pipelines

PARLOC contains details of 17 incidents to pipelines which had been operating but had been shut down when the incident occurred. 7 of these involved anchoring and impact resulting in damage to 5 flexible lines and 2 steel line. In 3 of these incidents a flexible line had to be repaired and in one steel line incident where the pipewall was damaged, a hyperbaric tie-in was completed successfully; no repair was reported for the other 3 incidents. All but one occurred outside the platform safety zone. Of those that occurred outside the platform safety zone 2 occurred within 500 m of a subsea well and the rest within 1.2 km of a subsea well. 4 incidents involved risers, 2 of which were buckled. 1 was being used as an anchor for pullin of a flexible and in the other case tension was lost during re-connection. In the third riser incident, a swivel was disconnected and a blind flange installed and for the fouth a repaired riser was installed. 3 incidents involved internal corrosion with one occurring on the platform at a pig tee and the other 2 in the mid line in one of which the steel line was replaced by a flexible. 2 incidents were attributed to material fatigue where decisions were made to redesign and produce new flowline pipe assemblies. One incident was reported as leak due to fracture near the well.

11 incidents occurred to fittings whilst the line was shut down. 3 occurred in the mid line, 1 in the safety zone, 6 in the platform and 1 at the riser. 1 incident was due to an accumulation of hydrates in a valve cavity at a tee stopping operation of the valve, 1 was a leak from pig trap valving, 1 was an incident involving a poorly fitted valve body bleed plug on an SSIV allowing water ingress to the line, 1 was due to anchor dragging and the riser incident was caused by the outer coflon layer bursting when circulating water to empty the riser. The causes of the other 5 incidents were not well documented.

5.2.10 Fitting Faults

Summary of Consequences of Incidents

123 of the 148 incidents resulting in damage to a valve or fitting associated with a pipeline were attributed to defects in fittings or in the operation of valves. The other 25 have been discussed in the preceding Sections.

Of these 123 fitting failure incidents, 69 resulted in a loss of containment from the pipeline 4 of these were known to be of a large size.

Since the changes in Offshore (Emergency Pipeline Valves) Regulations, 1989, SI 1029 there has been an increase in the number of reported incidents involving platform emergency shutdown (ESD) valves and subsea isolation valves (SSIV's) on UK operated pipelines. The Incident Database does not differentiate between these and other fittings, and this is considered to have contributed to the increase in Fittings Incidents since PARLOC 92.

Causes of Fitting Incidents

In this revision to the study there are 148 reported incidents to fittings compared with 134 in PARLOC 96. Of these 14 newly reported incidents 3 were flange leaks, 2 were associated with emergency shut down valves, 5 were valve leaks, 3 were associated with pig traps and 1with couples.

Of the 123 fitting failures, 19 incidents were caused by connectors failing; 7 were hydrocouples, 5 were load limiting connectors and the others were other couplings. Of these 19 incidents, 6 connectors were located in platform safety zones, 2 of which were definitely within 100 m of the platform, 5 were in the mid line of the pipeline, 5 at wells, 1 at an SPM and 2 were on a riser. All resulted in leakage, except 1 of the safety zone incidents. 16 of the incidents involved fittings associated with steel pipelines with the remaining 3 being associated with flexible lines.

11 failure incidents involved leakage from a flange. 1 was of a serious size with the remainder being small. The serious incident occurred to a flexible line with the other incidents being to steel lines. 5 of these incidents occurred to flanges in risers, of which 2 were in the subsea section of the riser, 1 incident was to a flange at a well, 3 to a flange in the safety zone and the other 2 on the platform itself.

15 of the fitting incidents were attributed to failures of valves, 13 of which resulted in a loss of containment. Of the incidents involving valves, 8 occurred on platforms, 3 were in the mid line of a pipeline, 3 was in the safety zone and 1 was at a subsea well.

A further 18 incidents were caused by failures of pig traps. Of these cases, 14 occurred on platforms and 2 onshore. 11 of these cases resulted in pipe leakage, 10 of which occurred on platforms and the other in the riser piping. 3 of the non-leaking incidents involved cracks which required repair, of which 1 involved damage to a pig trap valve seat and the other 2 involved failure of the door mechanism.

6 incidents occurred due to human error in operating valves. 4 of the incidents occurred on platforms and resulted in a loss of containment the other 1 occurred in the mid line and also resulted in a loss of containment. 1 was at an single point mooring. All resulted in loss of containment.

Of the remaining incidents, 1 occurred to an insulation joint on a riser in the splash zone which leaked. 4 occurred to nipples on pipelines, 1 of which was in the safety zone, 1 at a well, 1 on the platform and 1 at a mid line tee; all leaked. A further 4 incidents occurred due to seal failures, of which 1 was on the platform, 1 to the subsea riser, and another to an unknown section of a riser and 1 in the safety zone within 100m of the platform. The platform and riser incidents resulted in leakage.

Incidents to Emergency Shut Down Valves and Subsea Isolation Valves

With changes in Government legislation over the last few years requiring the periodic function testing of emergency shut down valves there has been a corresponding increase in the reporting of incidents associated with these special fittings.

35 of the 148 incidents were due to platform ESDV failure. 4 of these incidents led to a minor external leak, with all the other incidents requiring repair to the ESDV.

20 of the 35 incidents occurred as a result of the ESDV failing to close on demand. In 3 cases the ESDV failed to re-open fully after closing as required and in a further 9 incidents the ESDV failed to seal correctly due to seal failure. In 1 incident the ESDV could not be held open and during inspection the internals of a further valve were found to be badly scored. In 1 incident the cause was due to failure in the flexible spool connecting the riser base to the seabed flowline. In the remaining 6 incidents the incident details were too vague to ascertain the cause of the failure.

There have been 4 incidents reported to SSIVs in the safety zone within l00m of the platform. 2 of these incidents resulted in external leakage, 1 leaked from an incorrectly installed vent plug and the other through the valve stem seal. Of the other 2 incidents, 1 occurred due to failure of the hydraulic circuit preventing the SSIV from closing on demand and the other showed the SSIV to be in poor condition during a routine inspection. Both incidents required the units to be repaired or replaced.

5.2.11 Other Incidents

A total of 25 incidents occurring to steel pipelines, flexible lines and fittings are classified in the database as ‘other’. These can be broken down into:

- 12 for steel lines, of which 11 leaked.
- 11 for flexible lines, of which 9 leaked.
- 2 for fittings associated with operating pipelines of which 1 leaked.

Amongst these, there was 1 reported incident where a line became blocked due to a build up of wax or hydrates. No leakage occurred but a section of the line had to be replaced. In another incident, the topside section of a riser was damaged due to fretting by wire identification tag which resulted in loss of wall thickness.

2 incidents occurred due to procedural error where risers were displaced from their supports due to a pressure surge when full line pressure was experienced against closed ESDVs.

5.3 TABULATIONS OF THE FREQUENCY OF LOSS OF CONTAINMENT INCIDENTS AND REPAIRS

It was found in Section Four, which considered the loss of containment incidents, that there are five main factors which are important in considering loss of containment frequency. These are:

- Incident cause
- Location of the pipeline affected (riser, safety zone or mid line)
- Diameter of pipeline
- Length of pipeline
- Contents of pipeline

The most important are the first two factors. The significance of the other factors depends upon the location of the pipeline affected and the incident cause.

In this Section the loss of containment frequency and the repair frequency are tabulated for riser incidents, anchoring and impact incidents and corrosion and material defect incidents, considering the factors found to be significant in Section 4.3. The reported number of incidents in each category and the associated pipeline operating experience are presented in each of the Tables. The best estimate presented in the Tables is based on the actual number of incidents, except where no incidents have been reported where 0.7 has been used in the calculations. The upper 95 per cent and lower 5 per cent confidence limits have been calculated for each group and are also presented in the Tables. The upper 95 per cent limit is calculated for the special case where no loss of containment incidents have been reported for pipelines in that particular group. Confidence limits are discussed in Section 4.3.1.

Table 5.4 presents the frequency of loss of containment and repair for risers; Table 5.5 presents the frequency of loss of containment and repair for anchoring and impact damage occurring within the platform safety zone; Table 5.6 presents the frequency of loss of containment and repair for anchoring and impact damage occurring within the subsea well safety zone, Table 5.7 presents the frequency of loss of containment and repair for anchoring and impact damage occurring within the mid line section of pipelines and Table 5.8 presents the frequency of loss of containment and repair for corrosion and material defects (including incidents classed as 'other', for reasons given in Section 5.2.4).

Tables 4.1 to 4.4 present a more detailed breakdown of the location of the pipeline affected for different causes of incidents and present the Diameter of the lines affected. Tables 4.6 and 4.7 present a more detailed breakdown of the size of the leak for loss of containment incidents by Diameter and location of the pipeline affected.

Loss of Containment Incidents

RISER			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	5990.0	5	1.97	5	10.51	3.29E-04	8.35E-04	1.75E-03
	>10	10786.0	20	13.25	20	29.05	1.23E-03	1.85E-03	2.69E-03
	10 to 16	5158.0	11	6.17	11	18.21	1.20E-03	2.13E-03	3.53E-03
	18 to 24	3304.0	6	2.61	6	11.84	7.90E-04	1.82E-03	3.58E-03
	25 to 40	2324.0	3	0.82	3	7.75	3.53E-04	1.29E-03	3.33E-03
All Flexibles	All Diameters	1052.0	7	3.29	7	13.15	3.13E-03	6.65E-03	1.25E-02

Incidents which Required Repair

RISER			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	5990.0	8	3.98	8	14.43	6.64E-04	1.34E-03	2.41E-03
	>10	10786.0	44	1.37	44	56.57	3.12E-03	4.08E-03	5.24E-03
	10 to 16	5158.0	19	12.45	19	27.88	2.41E-03	3.68E-03	5.41E-03
	18 to 24	3304.0	16	10.05	16	24.28	3.04E-03	4.84E-03	7.35E-03
	25 to 40	2324.0	9	4.7	9	15.71	2.02E-03	3.87E-03	6.76E-03
All Flexibles	All Diameters	1052.0	7	3.29	7	13.15	3.13E-03	6.65E-03	1.25E-02

Table 5-4 – Frequency of Loss of Containment Incidents and Repair Incidents for Risers

Loss of containment incidents that occurred in the platform safety zone

SAFETY ZONE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	5990.0	2	0.36	2	6.3	6.01E-05	3.34E-04	1.05E-03
	>10	10786.0	4	1.37	4	9.15	1.27E-04	3.71E-04	8.48E-04
	10 to 16	5158.0	5	1.97	5	10.51	3.82E-04	9.69E-04	2.04E-03
	18 to 24	3304.0	0	0	0.7	3	1.00E-06	2.12E-04	9.08E-04
	25 to 40	2324.0	1	0.05	1	4.74	2.15E-05	4.30E-04	2.04E-03
All Flexibles	All Diameters	3068.0	0	0	0.7	3	1.00E-06	2.28E-04	9.78E-04

Incidents which required repair that occurred in the platform safety zone

SAFETY ZONE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	5990.0	3	0.82	3	7.75	1.37E-04	5.01E-04	1.29E-03
	>10	10786.0	8	3.98	8	14.43	3.69E-04	7.42E-04	1.34E-03
	10 to 16	5158.0	7	3.29	7	13.15	6.38E-04	1.36E-03	2.55E-03
	18 to 24	3304.0	0	0	0.7	3	1.00E-06	2.12E-04	9.08E-04
	25 to 40	2324.0	3	0.82	3	7.75	3.53E-04	1.29E-03	3.33E-03
All Flexibles	All Diameters	3068.0	0	0	0.7	3	1.00E-06	2.28E-04	9.78E-04

Table 5-5 – Frequency of Loss of Containment Incidents and Repair Incidents for all Anchoring and Impact Incidents Occurring in the Platform Safety Zones

Loss of containment incidents that occurred in the subsea well safety zone

SUBSEA WELL S/ZONE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	2185.0	2	0.36	2	6.3	1.65E-04	9.15E-04	2.88E-03
	>10	401.0	0	0	0.7	3	1.00E-06	1.75E-03	7.48E-03
	10 to 16	307.0	0	0	0.7	3	1.00E-06	2.28E-03	9.77E-03
	18 to 24	11.0	0	0	0.7	3	1.00E-06	6.36E-02	2.73E-01
	25 to 40	0.0	0	0	0.7	3	1.00E-06	7.00E-03	3.00E-04
All Flexibles	All Diameters	1493.0	4	1.37	4	9.15	9.18E-04	2.68E-03	6.13E-03

Incidents which required repair that occurred in the subsea well safety zone

SUBSEA WELL S/ZONE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	2185.0	4	1.37	4	9.15	6.27E-04	1.83E-03	4.19E-03
	>10	401.0	0	0	0.7	3	1.00E-06	1.75E-03	7.48E-03
	10 to 16	307.0	1	0.05	1	4.74	1.63E-04	3.26E-03	1.54E-02
	18 to 24	11.0	0	0	0.7	3	1.00E-06	6.36E-02	2.73E-01
	25 to 40	0.0	0	0	0.7	3	1.00E-06	7.00E-03	3.00E-04
All Flexibles	All Diameters	1493.0	5	1.97	5	10.51	1.32E-03	3.35E-03	7.04E-03

Table 5-6 – Frequency of Loss of Containment Incidents and Repair Incidents for all Anchoring and Impact Incidents Occurring in the Subsea Well Safety Zones

Loss of containment incidents that occurred in the mid line of pipelines

MID LINE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	45679.0	7	3.29	7	13.15	7.20E-05	1.53E-04	2.88E-04
	>10	243843.0	4	1.37	4	9.15	5.62E-06	1.64E-05	3.75E-05
	10 to 16	44286.0	1	0.05	1	4.74	1.13E-06	2.26E-05	1.07E-04
	18 to 24	56728.0	1	0.05	1	4.74	8.81E-07	1.76E-05	8.36E-05
	25 to 40	146052.0	2	0.36	2	6.3	2.46E-06	1.37E-05	4.31E-05
All Flexibles	All Diameters	5895.0	1	0.05	1	4.74	8.48E-06	1.70E-04	8.04E-04

Incidents which required repair that occurred in the mid line of pipelines

MID LINE			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Diameter (inches)	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	0 to 9	45679.0	11	6.17	11	18.21	1.35E-04	2.41E-04	3.99E-04
	>=10	243843.0	15	9.25	15	23.09	3.79E-05	6.15E-05	9.47E-05
	10 to 16	44286.0	11	6.17	11	18.21	1.39E-04	2.48E-04	4.11E-04
	18 to 24	56728.0	1	0.05	1	4.74	8.81E-07	1.76E-05	8.36E-05
	25 to 40	146052.0	4	1.37	4	9.15	9.38E-06	2.74E-05	6.26E-05
All Flexibles	All Diameters	5895.0	2	0.36	2	6.3	6.11E-05	3.39E-04	1.07E-03

Table 5-7 – Frequency of Loss of Containment Incidents and Repair Incidents for all Anchoring and Impact Incidents Occurring in the Mid Line of Pipelines

Loss of containment incidents for pipelines less than 2km in length

			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Contents	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	All	1434.0	9	4.7	9	15.71	3.28E-03	6.28E-03	1.10E-02
	Oil	551.0	8	3.98	8	14.43	7.22E-03	1.45E-02	2.62E-02
	Gas	539.0	1	0.05	1	4.74	9.28E-05	1.86E-03	8.79E-03
	Other	344.0	0	0	0.7	3	1.00E-06	2.03E-03	8.72E-03
All Flexibles	All Contents	915.0	5	1.97	5	10.51	2.15E-03	5.46E-03	1.15E-02

Loss of containment incidents for pipelines 2 to 5km in length

			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Contents	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	All	11850.0	11	6.17	11	18.21	5.21E-04	9.28E-04	1.54E-03
	Oil	3878.0	3	0.82	3	7.75	2.11E-04	7.74E-04	2.00E-03
	Gas	5017.0	2	0.05	1	4.74	9.97E-06	1.99E-04	9.45E-04
	Other	2955.0	7	3.29	7	13.15	1.11E-03	2.37E-03	4.45E-03
All Flexibles	All Contents	1533.0	4	1.37	4	9.15	8.94E-04	2.61E-03	5.97E-03

Loss of containment incidents for pipelines greater than 5km in length

			NUMBER OF INCIDENTS				FREQUENCY PER YEAR		
	Contents	Experience (years)	Number Reported	Lower Bound	Best Estimate	Upper Bound	Lower Bound	Best Estimate	Upper Bound
Steel Lines	All	456814.0	19	12.45	19	27.88	2.73E-05	4.16E-05	6.10E-05
	Oil	74950.0	12	6.92	12	19.44	9.23E-05	1.60E-04	2.59E-04
	Gas	182272.0	2	0.36	2	6.3	1.98E-06	1.10E-05	3.46E-05
	Other	199592.0	5	1.97	5	10.51	9.87E-06	2.51E-05	5.27E-05
All Flexibles	All Contents	5925.0	0	0	0.7	3	1.00E-06	1.18E-04	5.06E-04

Table 5-8 – Frequency of Loss of Containment Caused by Corrosion and Material Defects

6 LIST OF REFERENCES

1. PARLOC 90: Pipeline and Riser Loss of Containment Study, Authors: Advanced Mechanics & Engineering Ltd., OTH 91 337 ISPN 011 4133468
2. PARLOC 92: The Update of Loss of Containment Data for Offshore Pipelines, Authors: Advanced Mechanics & Engineering Ltd., OTH 93 424 ISBN 0 7176 0769 0
3. PARLOC 94: The Update of Loss of Containment Data for Offshore Pipelines, Authors: Advanced Mechanics & Engineering Ltd., OTH 95 468 ISBN 0 7176 1109
4. PARLOC 96: The Update of Loss of Containment Data for Offshore Pipelines, Authors: Advanced Mechanics & Engineering Ltd., OTH 951 ISBN 0 7176 1606 1
5. Methods for Determining and Processing Probabilities (the Red Book), CPR 12E, Committee for the Prevention of Disasters caused by Dangerous Substances, First Edition 1988, pp 10.87 - 10.89.
6. de la Mare, R.F. and Andersen, O., "Pipeline Reliability", Veritas Report 80-0572, Oslo, 1980 pp 51 -52.
7. F.P. Lees, Loss Prevention in the Process Industries, Butterworths, 1983, pp 119-120.

APPENDIX A - CODING RULES FOR INCIDENT DATABASE

Database Title	Description	Coding Type	Code
ID	Access Database Unique Reference Number	Numeric	Number
project no	Project Number	Numeric	Number
PARLOC	Reference to PARLOC Reports	Numeric	1990 1992 1994 1996 2001
src no	Source Number	Numeric	Number
duplicate	Duplicate Incidents	Alpha-Numeric	Reference to texts, sources etc.
den plno	Old Department of Energy Pipeline Coding Number. Now HSE Number.	Alpha-numeric	Number
plno	Operator's Pipeline Number.	Alpha-numeric	Number unique to Operator
source date	Source Date	Numeric	Number
incdt date	Incident Date	Date	dd-mm-yy

Database Title	Description	Coding Type	Code	
date no	Date Number	Numeric	Number	
Pipeloc	Incident Location	Text	**Main Classification**	**More Specific Details**
			PLAT	-
			RISER	PIP SPLASH SUB UNK
			SZ	N F UNK
			SPM	-
			MID	-
			WELL	-
			SHORE	-
			LAND	-
			OTH	-
Details	Incident Location	Text	**Main Classification**	**More Specific Details**
			Platform	-
			Riser	Piping Splash Zone Subsea Unknown
			Safety Zone	Near Far Unknown
			Single Point Mooring	-
			Midline	-
			Well	-
			Shore Zone	-
			Land	-
			Other	-
depth	Water Depth (m) at Incident	Numeric	Number	

Database Title	Description	Coding Type	Code
categ	Incident Category	Text	<table><tr><th>Main Classification</th><th>More Specific Details</th></tr><tr><td>SSIV</td><td>-</td></tr><tr><td>ESDV</td><td>-</td></tr><tr><td>FAIL</td><td>COR FTG STR</td></tr><tr><td>HIT</td><td>-</td></tr><tr><td>REST</td><td>FTG</td></tr></table>
code	Incident Cause	Text	<table><tr><th>Main Classification</th><th>More Specific Details</th><th>Fine Details</th></tr><tr><td rowspan="2">FITTING (FTG)</td><td>Mechanical Failure (MECH)</td><td>End Fitting (END) Connector (CNT) Valve (VLV) Hydrocouple (HYC) ESDV (ESDV) SSIV (SSIV) Seal (SEAL)</td></tr><tr><td>Leak (LK)</td><td>Flange (FLG) Valve (VLV) ESDV (ESDV) Hydrocouple (HYC) Connector (CNT) Tee (TEE) Insulation Joint (INJ) Load Limit Connector (LLC) Nipple (NPL) SSIV (SSIV) Seal (SEAL)</td></tr></table>

Database Title	Description	Coding Type	Code		
code Cont'd	Incident Cause	Text	**Main Classification**	**More Specific Details**	**Fine Details**
			FITTINGS (FTG)	Pig Trap (PIG)	Human Error (HUM) Mech. Failure (MECH) Material Failure (MAT) Valve Failure (VLV) Flange (FLG)
				Human Error (HUM)	Maintenance/Repair (REP) Leak (LK)
				Other (OTH)	
			CORROSION (COR)	Internal (INT)	Erosion (ERO) At weld (WLD)
				External (EXT)	Anode Failure (ANO) Coating Failure (COAT) On Clamp (CLP) On Sleeve (SLV) On Support (SPT)
			IMPACT(IMP)	Ship on riser (SHP)	Supply Boat (SUP) Standby Vessel (SBY) DSV (DSV) Construction Vessel(CV) Drill/Workover Rig (RIG) Other (OTH)

Database Title	Description	Coding Type	Code		
code Cont'd	Incident Cause	Text	**Main Classification**	**More Specific Details**	**Fine Details**
				on Pipeline (PIP)	Trawl (TWL) Wreck (WRK) Dropped Object (OBJ) Anchor/Trawl Suspected (AT) Construction Vessel(CV) Trencher (TREN) Chain (CHN) Hooked (HOOK) Other (OTH) Cable / Wire Wear (WR)
			ANCHORING (ANC)	Supply Boat (SUP) Standby Boat(SBY) DSV(DSV) Construction Vessel(CV) Drill/Workover Rig(RIG) Ship(SHP) Trencher (TREN) Unknown (UNK)	Dropped Anchor (DROP) Hook/Dragged Anchor (HOOK) Grappling/Recovery (REC) Cable/Wire Wear (WR) Other (OTH)
			NAT. HAZARD (ENV)	Storm (ST)	Mech. Failure (MECH) Fatigue Failure (FAT) Clamp Failure (CLP)
				Scouring (SCR)	
				Vibration in Current (VBR) Subsidence (SUB)	
			FIRE/EXPLOSION (FIR)	Escalation (EXP)	Structural (STR)

Database Title	Description	Coding Type	Code		
			Main Classification	**More Specific Details**	**Fine Details**
code Cont'd	Incident Cause	Text	MAINTENANCE/ REPAIR (REP)		
			HUMAN ERROR (HUM)	Lifting & Handling (HAND) Maintenance/ Repair (REP) Procedural Error (PROC)	
			STRUCTURAL (STR)	Upheaval Buckling (BUC) Expansion of Pipe (EXP) Clamp Failure (CLP) Single Buoy Marker (SBM)	Bolts Sheared (BLT)
			MATERIAL (MAT)	Weld Defect (WLD)	Fatigue (FAT) Girth (GRTH) Anode Attachment (ANO) Longitudinal (LONG) Crack (CRK)
				Steel Defect (STD)	Out of Spec (SPC) Brittle Fracture (BRT) Fatigue Failure (FAT)
				Defect in Flexible Pipe (FLX)	Split (SPT) Aged (AGD) Fabrication Fault (FAB)
				Unknown (UNK)	

Database Title	Description	Coding Type	Code		
code Cont'd	Incident Cause	Text	**Main Classification**	**More Specific Details**	**Fine Details**
			CONSTRUCTION (CON)	Buckle (BUC) Pipelaying Control (LAY) Towing Speed (TOW) Trenching (TREN) Lifting & Handling (HAND) Repair (REP) Human Error (HUM) Mech. Failure (MECH) Hooked / Dragged Anchor (HOOK)	
			OTHER (OTH)	Material (MAT) Corrosion (COR) Mine Nearby (MINE) Wreck Nearby (WRK) False Alarm (FALSE) Not an Incident (NINCDT) Diver (DIVE) Explosion (XPL) Unknown (UNK) Bomb (BOMB) Operational (OP)	
cause	Incident Cause	Text	Textual Description		
remarks	Source / Operator Remarks	Text	Textual Description		
damage	Incident Damage	Text	Textual Description		

Database Title	Description	Coding Type	Code
consequence	Consequences of Incident	Text	Textual Description
leak	Pipeline leak status	Text	**Main Classification** / **More Specific Details** NO (pipeline did not leak) / LK. (pipeline leaked) / SML (small), MED (medium), RUP (rupture), UNK (unknown)
repaired?	Was the leak repaired?	Text	YES NO
repair	Repair works carried out	Text	Textual Description
hole size	Approximate dimensions of hole (mm)	Numeric	Number
Rupture?	Was the line ruptured?	Text	YES NO
rpr tm	Approximate Repair Time (days)	Numeric	Number
L (km)	Length of Line (km)	Numeric	Number

Database Title	Description	Coding Type	Code
DIAM	Diameter of Line (in)	Numeric	Number
THICK	Thickness of Line (in)	Numeric	Number
SPEC	Material Specification of line	Numeric	**Steel Grades** Low Grade Steel: 5 LB to X48 High Grade Steel: X52 to X80, Duplex **Flexible Lines** FLEX: COF (Coflexip) PAG (Pagoflex) DUN (Dunlop) HOSE (Hose) DUP (Duplex)
CONT	Contents of Line	Text	**Code** – **Description** GAS – Gas OIL – Oil COND – Condensate PROD – Produced oil/gas mix GASLIFT – Gas for gas lift METH – Methanol GLY – Glycol CHEM – Other chemicals WATER – Injection water O/W – Oil then water service G/W – Gas then water service PILOT, others such as – AIR, N2
COATING	Coating on line	Text	**Code** – **Description** CONC – Concrete outer coating Fusion FBE – bonded epoxy Polyethylene PE – Coal tar enamel CTE – Neoprene NEO – Insulated coat INSL

Database Title	Description	Coding Type	Code
PROTECTION	Line Protection	Text	**Code** / **Description** TRCH — Lowered (trenched) BURY — Covered (buried) T&B — Both NONE — none
PGGY/BNDL/ PinP	Details of whether pipe is piggy-backed, a part of a bundle or a pipe-in-pipe	Text	**Code** / **Description** PGGY BNDL — Piggy-backed line or line with piggy-back attached. Pipeline to which it is attached is noted Line is part of a bundle. Case size and an ID number is given for each bundle.
MAOP	Maximum Operating Pressure (Bar)	Numeric	Number
HYDRO	Hydrotest Pressure (Bar)	Numeric	Number
max DPTH	Depth (m) Max. value. Incident water depth in incident file.	Numeric	Number
TRCH/BURY	Trench/burial depth (m)	Numeric	Number

Database Title	Description	Coding Type	Code
LTYPE	Line Type	Text	**Code** / **Description** TR — Trunk export INT — Interfield line SP — Spur to tee in export IF — Infield line FL — Flowline LO — Loading FR — Flare Line SRS — Steel Riser FRS — Flexible Riser
INSTALL	Date of Installation	Date	dd-mm-yy
RISR	Number of Risers	Numeric	Number
Lookup to Location	Location of Incident including Block from: and Block to:	Text	UKN, UK, UKS, NOR, DAN, OUT etc. Of use in making data unattributable.
Lookup to Status	Status of line at time of Incident	Text	**Code** / **Description** Bc — Before Commissioning Com — During Commissioning Hyd — During Hydrotest Op — Operational Sd — Shut Down Uc — Under Construction
Lookup to Type	Type of Incident	Text	**Code** / **Description** UNK — Unknown A — Pipeline F — Fitting X — Not a pipeline D — Duplicate HOSE — Hose JUMP — Jumper UMB — Umbilical

Database Title	Description	Coding Type	Code
Lookup to Source	Source of data	Text	**Code** / **Description** BAT – Batelle DEN – Department of Energy HSE – UK Health and Safety Executive JUR – Journal NPD – Norwegan Petroleum Direc OP – Operator PRO – Protec SRS – SRS Study for UK Department of Energy UKOOA – UK Offshore Operators Association VER – Veritec Database
Coordinates	UTM or Geographical Coordinates of Incident Location (confidential)	Numeric	Degrees and Minutes

APPENDIX B - CODING RULES FOR PIPELINE DATABASE

Database Title	Description	Coding Type	Code
ID	Access Database Unique Reference Number	Numeric	Number
DEN PLNO	Old Department of Energy Pipeline Coding Number. Now HSE Number.	Alpha-numeric	Number
L (km)	Length of Line (km)	Numeric	Number
Diameter:	Diameter of Line (in)	Numeric	Number
Thickness:	Thickness of Line (in)	Numeric	Number
PIGGY/BND	Details of whether pipe is piggy-backed or a part of a bundle	Text	**Code**: PGGY BNDL — **Description**: Piggy-backed line or line with piggy-back attached. Pipeline to which it is attached is noted Line is part of a bundle. Case size and an ID number is given for each bundle.
MAOP	Maximum Operating Pressure (Bar)	Numeric	Number
HYDRO	Hydrotest Pressure (Bar)	Numeric	Number

Database Title	Description	Coding Type	Code
MAX DEPTH	Depth (m) Max. value. Incident water depth in incident file.	Numeric	Number
TRCH/BURY	Trench/burial depth: (m)	Numeric	Number
COMMISS	Date Line Commissioned	Date	dd-mm-yy
DECOMMIS	Date Line Decommissioned	Date	dd-mm-yy
DATE INSTALL	Date Line Installed	Date	dd-mm-yy
REMARKS	Operator's Remarks	Text	Textual Description
HYPERBARIC	Number of hyperbaric welds on Line	Numeric	Number
FLANGCON	Number of flanged Connections	Numeric	Number
HYDROBALL/ CPLE	Number of Mechanical Connectors	Numeric	Number
SSIV	Number of SSIVs	Numeric	Number
ESDV	Number of ESDVs	Numeric	Number
TEES	Number of Tees	Numeric	Number

Database Title	Description	Coding Type	Code
CROSSINGS	Number of Crossings	Numeric	Number
SPAN SUPPORT	Description of any Span support on line	Text	Textual Description
ROCK DUMP	Description of any Rock Dump on line	Text	Textual Description
SHORE	Number of Shore approaches	Numeric	Number
TEE/Y	Number of Tee/Y pieces	Numeric	Number
SPOOL	Number of Spools	Numeric	Number
TEMPLATES	Number of Templates	Numeric	Number
WELLS	Number of Wells	Numeric	Number
DYNAMICRISR	Number of Dynamic Risers	Numeric	Number
FPFRISR	Number of Floating Production Facility Risers	Numeric	Number
RISER	Number of Risers	Numeric	Number
FLARE	Number of Flares	Numeric	Number

Database Title	Description	Coding Type	Code
SPM	Number of SPMs	Numeric	Number
3 rd OPL PG	Report Page Number	Numeric	Number
4 rd OPL PG	Report Page Number	Numeric	Number
5 rd OPL PG	Report Page Number	Numeric	Number
Lookup to Material:	Material Specification of line	Numeric	**Steel Grades** Low Grade Steel: 5 LB to X48 High Grade Steel: X52 to X80, Duplex **Flexible Lines** FLEX: COF (Coflexip), PAG (Pagoflex), DUN (Dunlop), HOSE (Hose), DUP (Duplex)
Lookup to Contents:	Contents of Line	Text	**Code** – **Description** GAS – Gas OIL – Oil COND – Condensate PROD – Produced oil/gas mix GASLIFT – Gas for gas lift METH – Methanol GLY – Glycol CHEM – Other chemicals WATER – Injection water O/W – Oil then water service G/W – Gas then water service others such as – PILOT, AIR, N2

Database Title	Description	Coding Type	Code
Lookup to Coating:	Coating on line	Text	**Code** / **Description** CONC – Concrete outer coating FBE – Fusion bonded epoxy PE – Polyethylene CTE – Coal tar enamel NEO – Neoprene INSL – Insulated coat
Lookup to Location:	Location of Line	Text	**Code** / **Description** UKN – UK Northern UKC – UK Central UKS – UK Southern NOR – Norwegian DAN – Danish
Lookup to Protection:	Line Protection	Text	**Code** / **Description** TRCH – Lowered (trenched) BURY – Covered (buried) T&B – Both NONE – None
Lookup to Line Type:	Line Type	Text	**Code** / **Description** TR – Trunk Export INT – Interfield line SP – Spur to tee in Export IF – Infield Line FL – Flowline LO – Loading FR – Flare Line SRS – Steel Riser FRS – Flexible Riser

APPENDIX C - GLOSSARY OF TERMS

Term	Definition
Best Estimate	This is the estimate of loss of containment frequency, calculated as described above, except in the case of no reported incidents when it has been taken to be 0.7 divided by the appropriate operating experience.
Confidence interval	The interval between the upper and lower bounds.
DSV	Diving Support Vessel.
ESDV	Emergency Shut-down Valve.
Estimate of loss of containment frequency	The estimate of loss of containment frequency has been calculated on the basis of actual numbers of reported incidents divided by the appropriate operating experience.
- Upper Bound	The upper 95 per cent confidence limit, calculated as described in the Chart Glossary.
- Lower Bound	The lower 5 per cent confidence limit, calculated as described in the Chart Glossary.
Fitting	By fitting it is meant items integrated in the pipeline such as flanges, connectors and valves and instrument lappings and pig traps.
Hydrotest pressure	The hydrostatic internal pressure to which the pipeline was tested prior to installation.
Incident	An occurrence which directly resulted or threatened to result in loss of containment of a pipeline.

Term	Definition
Incident database	This contains a description of each reported incident and data on the pipeline or lines affected.
MAOP	Maximum operating pressure of a pipeline.
Mid Line	The pipeline on the seabed outside the subsea well and platform safety zones and not in the shore approach.
NIFO	Norwegian Industry Association for Oil Companies.
Occurrence	Reportable occurrences are defined in Schedule 1 of the Submarine Pipelines (Inspectors etc.) Regulations 1977. These include near misses such as wrecks or mines discovered in the vicinity of a pipeline, as well as the events which resulted in damage to lines.
OPL	Publishers of the Subsea Guide and 3rd Edition Field Development Guide, used to identify Pipelines.
Pipeline	A pipeline, as defined in this study, extends from the pig trap and associated pipework and valves, and includes all pipework and fittings on the main flow path and all branches on the main flow path up to and including the first valve on each branch. Where a pipeline does not have a pig trap the first valve above water level is the termination point.
Pipeline database	This contains details of all the pipelines installed in the North Sea.

Term	Definition
Pipeline status	The pipeline status at the time of the incident was classified as one of six categories: • Under Construction • During Hydrotest • Before Commissioning • During Commissioning • Operational • Shut Down.
Platform	A fixed or permanently anchored offshore installation onto which the riser is mounted.
Platform Safety Zone	The part of the seabed within 500 m of the platform. Where possible it has been considered as two regions: Near - within 100 m of the platform Far - 100 to 500 m from the platform.
Regulatory Authority	UK Health and Safety Executive (UK HSE) UIC Department of Energy (UB DEn) Norwegian Petroleum Directorate (NPD) Dutch Staatstoezicht op de Mijnen Danish Energy Agency.
Riser	The connecting piping between the pipeline on the sea floor and the termination point of the Pipeline. It consists of three regions: • Splash zone • Subsea riser - Riser below splash zone • Piping - Riser above splash zone.
Shore Approach	The length of the pipeline close to the shore.

Term	Definition
Sources of Incident Data	SRS Study for the UK Department of Energy Protech E & P Forum Battelle databases from the Battelle economic study Technical work based on Battelle Veritec Database DnV reports Lloyds List Operators Oil Companies
SPM	Single point mooring.
SSIV	Subsea Isolation Valve.
Subsea Well Safety Zone (Well)	The part of the seabed within 500m of a subsea facility not associated with a platform.
TFL	A flow metering system.
UKOOA	United Kingdom Offshore Operators Association.

APPENDIX D - CHART GLOSSARY OF TERMS

Symbol	Definition
-	Confidence Limit
□	The estimate *of loss* of containment frequency for steel lines calculated on the basis of actual numbers of reported incidents divided by the appropriate operating experience.
■	As above but for flexible lines.
◊	0.7 divided by the appropriate operating experience for the case of no reported incidents.
♦	As above but for flexible lines.
|	Confidence interval for corresponding groups

In all of the calculations, the frequencies are given per km-year for mid line incidents and per year of operational experience for subsea well and platform safety zone and riser incidents. The estimate of loss of containment frequency has been calculated on the basis of actual numbers of reported incidents divided by the appropriate operating experience. This is shown on the Figures using open square symbols for steel lines and filled square symbols for flexible lines.

In common with other studies [5-33], it has been assumed that the likelihood of loss of containment incidents in a specific group is constant, that is the number of incidents follows a Poisson distribution. Based on this assumption be upper 95 per cent and lower 5 per cent confidence limits for each group have been calculated and are also shown on the Figures. The interval between the limits indicates the number of incidents in each group; for cases where the number of incidents is small the lines connecting the upper and lower confidence limits in the Figures are long in comparison to the cases where the number of incidents is larger.

The upper 95 per cent limit is calculated for the special case where no loss of containment incidents have been reported for pipelines in that particular group. This is the accepted method for analysing failure data [5,7]. The one-sided confidence interval is indicated by the dashed line. The diamond on this line indicates the position where the estimate of loss of containment frequency would be if 0.7 incident had occurred (50% confidence on Poisson distribution [5] for zero incidents occurring). An open diamond represents steel lines and a filled diamond flexible lines.

APPENDIX E - PIPELINE QUESTIONNAIRE

Questionnaire 2 - Pipeline Database

Record of Pipeline Systems Installed, Abandoned or Subject to Change(s) in service between January 1996 and December 2000

	Information Description	Supplied Information
1	Name of source (Operator, regulator etc.)	
2	Project pipeline system No.	
3	DEn No. (if known)	
4	From (Facility/Field/Block/Sector)	
5	To (Facility/Field/Block/Sector)	
6	Pipeline Operator	
7	Pipeline function (export, flowline, loading line etc.)	
8	Length	
9	Diameter (OD for steel, ID for flexibles)	
10	Thickness (for steel lines)	
11	Line pipe specification (eg API X52, Coflexip, Dunlop, etc)	

12	Contents (including details of any change of service)	
13	Maximum allowable operating pressure & class rating	
14	Maximum allowable operating temperature	
15	Coatings (internal, external, insulation, concrete, etc)	
16	Field joint coating details	
17	Protection measures (rockdump, burial, matresses etc. along pipeline, tie-in spool, riser)	
18	Trench/burial depth (to top of pipe)	
19	Piggy-backed (Details of pipeline to which it is attached)	
20	Bundled/Pipe-in-pipe (Details of bundle or pipe-in-pipe system)	
21	Subsea crossings (description of utility crossed)	
22	No of subsea tee/Y-connections	
23	Water depth (maximum)	
24	Date installed	
25	Date commissioned	
26	Date abandoned (where applicable)	

27	Number of risers	
28	Riser details (Type steel, flexible, caisson etc.)	
29	Pig traps (horizontal, vertical, purpose ie sphering, intelligent pigging etc.)	
30	Location of main line flanges (topside, subsea, riser etc.)	
31	Main line valves (details of type i.e. SSIV, ESDV, manual, full bore, reduced bore, flanged, welded etc.)	

APPENDIX F - INCIDENTS QUESTIONNAIRE

Questionnaire 1 - Pipeline Incidents

Record of Pipeline System Incidents between January 1996 and December 2000

	Information Description	Supplied Information
1	Name of source (Operator, regulator etc.)	
2	Project pipeline system No.	
3	DEn No. (if known)	
4	Source incident number	
5	Pipeline type (steel, flexible, piggy-back, bundle, pipe-in-pipe, jumper, umbilical, hoses)	
6	Diameter (OD for steel, ID for others)	
7	From (Facility/Field/Block/Sector)	
8	To (Facility/Field/Block/Sector)	
9	Location on pipeline system where incident occurred (riser, safety zone, mid line, shore approach etc..)	
10	Location on pipeline system where incident occurred (Geographical or UTM co-ordinates)	
11	Identify where incident occurred at fitting (isolation flange, flanges, SSIV'S Riser ESDV's etc..)	

12	Water depth at incident location	
13	Cause of damage (detailed description)	
14	Consequences (detailed description)	
15	Extent of Damage (detailed description)	
16	Dimensions of rupture (e.g estimated equivalent diameter)	
17	Pipeline status at time of incident (i.e. construction, commissioning, testing, operating etc.)	
18	Repair works required	
19	Time to repair	