UKOPA

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13 April 2005

Review of CONCAWE Data for Product Pipelines
Part 3 – UK Product Pipeline Failure Rates

1   Summary

This review has been carried out following use of pipeline failure rate data by the UK Health & Safety Executive (HSE) during 2004 to assess the risks from gasoline pipelines. The data was based on an analysis carried out by W S Atkins in 1997 [Ref.1]. Part 1 of this study examined the Atkins analysis, but found several aspects which require updating. A study has therefore been commissioned to examine the following aspects to enable an up-to-date failure rate to be applied to product oil pipelines in the UK.

The study is in three parts:-

- Part 1 reviews the original W S Atkins work based on published CONCAWE data.

- Part 2 carries out a detailed analysis of failure rates based on CONCAWE data, extending the analysis to cover years 1971 through to 2003.

- Part 3 examines the UK pipeline failures to assess significance of the data and possible adjustments that could be applied to UK product oil pipeline failure rates.

Part 2 re-examined the CONCAWE data from 1971 through to 2003 and synthesised new failure rates for product pipelines in Europe. This part of the study reviews those factors that apply to the UK system to evaluate how European data could be adapted to UK conditions.

2 Results and Conclusions

The failure rate of clean oil Product Pipelines for CONCAWE for the period 1971 to 2003 inclusive was re-assessed in Part 2 of the study as follows:-

Failure Rates per 1000 kilometre-years - CONCAWE

Spillage Cause	Pinhole	Hole	Rupture	Total
Mechanical	0.025	0.022	0.012	0.059
Corrosion	0.012	0.049	0.002	0.063
Natural	0.002	0.008	0.004	0.014
Third Party	0.051	0.108	0.045	0.204
Total	0.090	0.188	0.063	0.341

An analysis of UK product oil pipeline spillages indicates that the observed failure rate is about half the expected rate compared to the European average from CONCAWE statistics. An analysis of failure modes indicates that the number of corrosion failures is similar to what might be expected, but that other failure rates are lower in the UK.

This observation is supported by comparison of similar database results for gas pipelines, where the UKOPA database shows an overall failure rate 58% of the European average failure rate from the EGIG database. The most significant difference is the 3rd party (or External Interference) failure rate, where the UKOPA rate is only 25% of the average European EGIG rate. There are several substantial reasons for the lower 3rd party failure rate in the UK, and these apply equally to clean product oil pipelines as to gas pipelines.

The UK 3rd Party failure rate is therefore half that observed in Europe, so the recommended failure rates for product oil pipelines in the UK is as follows:-

Failure Rates per 1000 kilometre-years – Product Oil Pipelines in the UK

Spillage Cause	Pinhole	Hole	Rupture	Total
Mechanical	0.025	0.022	0.012	0.059
Corrosion	0.012	0.049	0.002	0.063
Natural	0.002	0.008	0.004	0.014
Third Party	0.026	0.054	0.022	0.102
Total	0.064	0.134	0.041	0.239

Further reduction in failure rate depends on individual pipeline aspects such as intelligent pigging to reduce Mechanical and Corrosion failure rates, and leak detection to reduce the size of releases.

3   Introduction

CONCAWE Oil Pipelines Management Group's Special Task Force on Oil Pipeline Spillages publishes an annual report reviewing the performance of cross-country pipelines in Western Europe. Based on the statistics given in these reports it has been possible to synthesise the characteristic pipeline failure rate for product oil pipelines in Europe. Results were presented in Part 2 of this study.

In the UK there is an extensive network of clean product oil pipelines. Data from the Linewatch UK publication "Special requirements for safe working in close proximity to high pressure pipelines" dated June 2004 [further pipelines have since been included] indicates that there are 7 major Companies operating around 43 separate product pipeline systems in the UK.

UK Companies contribute to the CONCAWE database, so any product spillages which have occurred in the UK are recorded in the CONCAWE database. However, detailed data from each country is not available in CONCAWE reports (although a comparison of 3rd party spillage rates for various countries in shown in Figure 25 of the CONCAWE report [Ref. 2] in 2002) so this analysis is based on data obtained directly from CONCAWE.

This report examines UK product pipeline failures to see if there is any statistical difference between expected and actual failure rates. Recognising that the population and failure data is relatively sparse, a comparison with other similar data-sets is also made. Product pipelines in the UK are laid at a similar depth and have similar standards applied for regular surveillance to prevent 3rd Party failures occurring, so a similarity with other, larger, pipeline systems such as the UK Natural Gas Transmission system (NTS) would be expected.

A brief review has therefore been carried out to consider the changes seen from the UKOPA (mainly UK gas industry NTS) Leak Database compared to the European Gas Industry Group (EGIG) database. This is then compared with the observed difference in 3rd party failure rate for product pipelines.

4 UK Clean Product Pipeline Spillage Rates

The following data has been obtained directly from CONCAWE.

During the period 1971 to 2003, a total of 21 clean product spillages in the UK have been recorded in the CONCAWE database. This compares with the total of 220 for all European pipelines recorded in CONCAWE.

Of these 21 spillages, 5 were at pumping stations, 1 was above ground, and 2 were on associated fittings and equipment, so the total line-based clean product spillages was 13.

Using the spill size categorisation used in Parts 1 and 2 of this study, the pipeline holes recorded for these 13 spillages were as follows:- 5 Pinholes, 7 Holes, and 1 Rupture.

The total average clean product pipeline length in the UK during the period 1971-2003 was 2905 kilometres, so the total exposure (kilometre-years of operation) during this 33 year period was 33 x 2905 = 95,865 kilometre-years

Failure rates for the UK system compared to the whole of Europe is therefore:-

	UK Data		European Data	
Exposure	95,865 kilometre-years		489,456 kilometre-years	
	Number	Failure Rate per 1000 km-yrs	Number	Failure Rate per 1000 km-yrs
Pinhole	5	0.052	44	0.090
Hole	7	0.073	92	0.188
Rupture	1	0.010	31	0.063
Total	13	0.135	167	0.341

Applying the Chi^2 statistical analysis to this data indicates that the observed number of failures for the UK system shows a "poor fit"*[*] with the CONCAWE population and statistically, does not represent the same data-set. Chi^2 is 12.5 which is outside the "good fit"* range (5% to 95%) of 1 to 7.8. If the expected number of UK failures is doubled, Chi^2 becomes 4 showing a better degree of fit to the European data.

It therefore appears that the observed number of UK spillages is approximately half the number expected from European CONCAWE data.

The Chi^2 analysis is shown below

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[*] "poor fit" and "good fit" in this context are terms used to describe the statistical characteristics of a population of data when applying the Chi^2 test

Chi-squared test applied to CONCAWE UK Data

Hypothesis 1   UK Data = European

	European	Expected UK failures	Actual UK Failures	Chi^2
Exposure	489456	95865		
Pinhole	44	9	5	1.52
Hole	92	18	7	6.74
Rupture	31	6	1	4.24

Degrees of Freedom   3   TOTAL Chi^2 12.5

"Good fit" 5% to 95% Chi2 =   1 to 7.8

"Bad Fit"

Hypothesis 2   2 x UK data = European

	European	Expected UK failures	Actual UK Failures	Chi^2
Exposure	489456	95865	(times two)	
Pinhole	44	9	10	0
Hole	92	18	14	1
Rupture	31	6	2	3

Degrees of Freedom   3   TOTAL Chi^2 4

"Good fit" 5% to 95% Chi2 =   1 to 7.8

"Good fit"

A similar analysis has been applied to the causes of spillages in the UK. An analysis of UK spillages shows the following:-

Spillage Cause	Number of spillages - UK	Percentage UK	Number of spillages - Europe	Percentage Europe
Mechanical	2	15.3%	29	17.4%
Corrosion	5	38.5%	31	18.6%
Natural	0	0%	7	4.2%
Third Party	6	46.2%	100	59.9%

When the Chi^2 test is applied to this data, again the UK data shows a "bad fit" when compared to European data. However, if the number of failures in each category is doubled the UK data becomes a "good fit" with European data, apart from corrosion. This suggests that the number of corrosion failures in the UK is consistent with the European average, but other failure categories show a significantly lower failure frequency.

The Chi^2 analysis is shown below

Chi-squared test applied to CONCAWE UK Data

Hypothesis 1   UK Data = European

		Expected	Actual	
	European	UK failures	UK Failures	Chi^2
Exposure	489456	95865		
Mechanical	29	6	2	2.38
Corrosion	31	6	5	0.19
Natural	7	1	0	1.37
3rd Party	100	20	6	9.42
Degrees of Freedom		4	TOTAL Chi^2	13.4

"Good fit" 5% to 95% Chi2 1 .1 to 9.5
"Bad Fit"

Hypothesis 2   2 x UK data = European (except corrosion)

		Expected	Actual	
	European	UK failures	UK Failures	Chi^2
Exposure	489456	95865	(times two)	
Mechanical	29	6	4	0
Corrosion	31	6	5	0
Natural	7	1	1	0
3rd Party	100	20	12	3
Degrees of Freedom		4	TOTAL Chi^2	4

"Good fit" 5% to 95% Chi2 1.1 to 9.5
"Good fit"

5   Comparison with Other UK and European Pipeline Database Results

The 5th EGIG (European Gas Incident Group) report was issued in 2004 and contains statistics of gas leak incident from European pipelines for the period 1970 to 2001.

The total exposure for this period was 2,410,000 kilometre-years, and the overall leak rate was 0.44 per 1000 kilometre-years, which represents 1060 gas leakage events. Half of these were due to External Interference, giving a leak rate of 0.22 per 1000 km-years.

The latest version of the UKOPA Leak Database is due to be issued later in 2005, covering gas leak data in the UK from the period 1962 to 2004. Total reported exposure is 663,146 kilometre-years, and the total number of recorded leaks is 169 giving an overall leak rate of 0.255 per 1000 kilometre-years. Of this total 37 were External Interference events giving a leak rate of 0.056 per 1000 km-years.

The overall UK leak rate is therefore 58% of the European average rate, and the External Interference leak rate is 25% of the European average.

Reasons for this reduction in External interference events include:-

(a)   Greater efforts by pipeline operators to inform and warn landowners, services and utility companies of the dangers of excavations near their pipelines.

(b)   Extensive surveillance programs to detect and stop unauthorised excavations, as required by UK Pipeline Codes.

(c)   Extensive efforts to route pipelines away from population areas in the UK, required by UK Pipeline Codes.

(d)   Strong regulatory controls and an effective safety regulation organisation in the UK.

6   Application of CONCAWE Results to UK Pipelines

As recorded when analysing the CONCAWE clean product oil failures, 69.5% of all failure were in the pipeline diameter range 8 to 12 inches, and 13.8% were less than 8 inches.

The UK clean product pipeline network has 77% of its length in the 8 to 12 inch diameter range and 9% less than 8 inches. Therefore there appears to be direct applicability of the CONCAWE failure data to UK pipelines, without having to make complex adjustments for pipeline diameter.

The analysis carried out above indicates that there is a significantly lower 3rd party failure rate in the UK, and from two separate sources (statistical analysis of UK failures and comparison with parallel databases) the reduction appears to be a factor of at least 2. Therefore 3rd party failure rates should be at least halved for UK clean product pipelines. The overall pipeline failure rates then become:-

Failure Rates per 1000 kilometre-years – Clean Product Oil Pipelines in the UK

Spillage Cause	Pinhole	Hole	Rupture	Total
Mechanical	0.025	0.022	0.012	0.059
Corrosion	0.012	0.049	0.002	0.063
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References

1   "Pipeline Failure Model", A Report prepared by W S Atkins Safety & Reliability for and on behalf of The Health & Safety Executive, Report Number AM5099 /430 / R8000 / WP1.00, Issue 01, dated August 1997

2   "Western European Cross-Country Oil Pipelines 30-year Performance Statistics", prepared on behalf of CONCAWE oil pipelines Management Group (OPMG) by D. Lyons (Consultant), CONCAWE Report No 1/02