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11 April 2005

Review of CONCAWE Data for Product Pipelines

Part 1 – W S Atkins 1997 Report for HSE

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. HSE use a database in the computer program PIPIN which is based on analysis carried out by W S Atkins in 1997 [Ref.1]. Anomalies in the failure rates with different pipeline diameters gave some unexpected results, with intermediate diameter pipelines having greater risk distances than smaller or larger pipelines.

W S Atkins based their data on an analysis of CONCAWE published reports since 1971, covering the period 1971 to 1994 inclusive. Their analysis covered crude oil and product oil pipelines, and resulted in separate failure rates for each.

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.

2 Conclusions

The 1997 Atkins report [Ref. 1] has been closely examined to identify the methodology used to obtain the failure rates that are believed to be used in by HSE in the PIPIN computer program for product pipelines.

The 1997 study appears to have over-estimated the risks from product pipelines, mainly because:-

(i) 130 pipeline failures derived by Atkins include several hot fuel oil corrosion failure cases, which should be excluded from Clean Product pipeline failures. "Clean product" is defined as white oils excluding fuel oils. Atkins also under-reported some other cases, but the final total is 113 rather than 130 for the period 1971-1994.

(ii) The pipeline exposure (number of pipeline operating years) may have been under-estimated. The figure is not given by Atkins but has been derived as 221,800 kilometre years. A better estimate may have been closer to 320,000 kilometre-years.

(iii) The overall product pipeline failure rate was 0.586 per 1000 kilometre-years (although not explicitly stated in the report). This is significantly lower that reported a later Atkins 1998 report which states that the CONCAWE data shows product pipelines failure rate 0.29 per 1000 km-years. Between 1997 and 1998, Atkins must therefore have reviewed the 1997 analysis and revised the exposure and number of failure based on further data from CONCAWE.

(iv) The strange results for failure rates, presented for the different diameter classes in Table 13 of the Atkins report, may explain the anomalies obtained by HSE when using PIPIN to calculate Land Use Planning zones for gasoline pipelines in 2004. The failure rate for the intermediate diameter class 202 – 304 mm shows a higher failure rate than either the smaller pipeline diameter < 202 mm, and also the larger diameter class 304 - 405 mm.

(v) Full presentation of the failure holes sizes, and explanation of the calculation methods is not given in the Atkins report, so full verification and confirmation of their results is not possible. However, the calculation methods appear suspect. The overall failure rate for the 202 - 304 mm diameter pipeline class from Tables 13-16 is 1.175 per 1000 km-years which is much higher than the overall failure rate of 0.586 per 1000 kilometre-years as calculated above. If this data has indeed been entered into the HSE's PIPIN model, it should be discarded. Part 2 of this study will review and re-calculate product pipeline failure rates based on CONCAWE data for the years 1971 to 2003 inclusive.

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 crude and product oil pipelines in Europe. As part of its regulatory function, the UK Health & Safety Executive (HSE) use established failure databases to carry out risk-based calculations to set Land Use Planning zones adjacent to Major Accident Hazard (MAH) pipelines in the UK. Crude oil and product oils are not currently classified as MAH pipelines, although there were plans to include gasoline in the 2004 revision of the Pipeline Safety Regulations, but these were abandoned in July 2004. It is possible that a future European Directive may include gasoline pipelines.

HSE commissioned W S Atkins to carry out a detailed review of pipeline failures recorded in the annual CONCAWE reports in order to synthesise a failure rate. This was carried out and a report "Pipeline Failure Model" Issue 01, was delivered to HSE in August 1997. This report describes in detail the methodology used to derive the failure rates for crude oil and product pipelines.

Subsequently, W S Atkins issued a further report [Ref. 2], also commissioned by HSE, in July 1998 called "Assessing the Risk from Gasoline Pipelines in the UK Based on a Review of Historical Experience". This contains a summary of the results from the CONCAWE data for the period 1971-1996. This second report has different result from the first report, but no derivation of the second set of results is available.

This report examines the original detailed analysis by W S Atkins to assess and comments on its validity.

4 W S Atkins 1997 Analysis

4.1 Summary of method

In the Atkins 1997 report [Ref. 1], they have reviewed each annual CONCAWE report and extracted those failure which they identified as involving product oils including:-

fuel oil, kerosene, gas oil, petrol, aviation fuel, light fuel oil, naphtha, hot fuel oil, diesel, light petroleum products, gasoline and lubricating distillates.

In Appendix IV, for each of the years 1971-1994, each failure is tabulated along with Monthly pipeline exposure (kilometre-years operation that year),

Pipeline diameter, pipeline wall thickness, failure mode divided into:-

- Corrosion divided into internal corrosion and external corrosion,
- Mechanical defect divided into construction defect and material defect,
- Natural failure divided into flood, land and other
- Third Party Activity divided into Accidental, Malevolent, and Incidental

Design specification, Notes, Hole size, Product, construction year, and Location.

However, the hole size column is not filled in, so the derivation of the failure rate for each hole size is not available from this table. It has subsequently been derived using the full CONCAWE listing of failures published in the 2002 CONCAWE publication "Western Europe cross-country oil pipelines 30-year performance statistics" [Ref.3].

A total of 131 failures are identified in the tables in Atkins Appendix IV, although only 130 have identified causes so the subsequent analysis is based on 130. The total exposure (i.e. number of kilometre-years of pipeline operation) is given for crude oil and product oil, but the split into crude oil and product oil has not been given in the Atkins report. This has been derived from the final failure rates obtained for product pipelines and appears to be 221,823 kilometre years.

The overall product pipeline failure rate is therefore

$$130 / 221.823 = 0.586 \text{ per } 1000 \text{ km-years}$$

This is considerably higher than the later 1998 Atkins report which records 0.29 per 1000 km-years as the overall CONCAWE product pipeline failure rate based on failure rate data from 1971 to 1996.

The method for analysis of the CONCAWE data was as follows:-

(i) identify key parameters for each product loss / pipeline failure Several product failure events were not included because they did not apply to line pipe. Failures excluded from the CONCAWE data-sets were defined in Section 8. The following were excluded:- Valve equipment, Flanges, bolts etc, Gaskets / O-ring materials, Instrument fittings, Couplings / branches, and Pumping stations etc.

(ii) analyse hole size category based on amount of product lost

(iii) calculate failure rates in each diameter class, wall thickness class, and depth of cover category, covering holes sizes for rupture, puncture and pinhole, for relevant failure mechanisms (third party activity, corrosion, mechanical failure, and natural failures).

(iv) for zero failure cases, assume a single failure has occurred, apart from corrosion, where a failure rates cannot be worse than previous cases, so same results are assumed.

Criteria for assigning hole sizes was based on the following:-

Failure Mechanism	Rupture	Puncture	Pinhole
Third party activity	> 250 m3	11 to 250 m3	10 m3 or less
Corrosion	> 500 m3	11 to 500 m3	10 m3 or less
Mechanical	> 200 m3	11 to 200 m3	10 m3 or less
Natural	> 200 m3	11 to 200 m3	10 m3 or less

4.2 Detailed Review year-by-year

For each year analysed, a comparison has been made between the failures recorded in the 1997 Atkins report [Ref. 1], and the 2002 report from CONCAWE [Ref. 3]. Where possible, the failures have been matched between the reports, so that the relevant amount spilled can be identified. This task has been made more difficult because the Atkins report lists the failures by the numbers in the original annual CONCAWE report, whereas the CONCAWE report lists the failure by failure mechanisms.

In addition, access is not available to the detailed year-by-year CONCAWE reports for 1971 through to 1993. This would have made the comparison easier because each entry in the Atkins table has the associated reference number within the annual CONCAWE report.

The following conclusions are drawn from this comparison:-

1 In general the entries in the Atkins and CONCAWE reports cross-reference fairly well.

2 Atkins have included hot fuel oil pipeline failures – therefore the number of failures recorded by Atkins is significantly higher than the clean product failures recorded by CONCAWE. In CONCAWE reports, hot fuel oil is treated as a separate substance and not included in clean product oil statistics.

3 Some years, Atkins do not seem to have recorded all the relevant product pipeline failures – e.g. no entries for 1973, 1 entry instead of 3 for 1990, 7 for 1991 instead of 12, 3 for 1992 instead of 6, 7 instead of 8 in 1993.

Overall, the number of pipeline failures recorded by Atkins was 130, whereas a detailed re-assessment suggests that the number is 113.

4.3 Result of the Atkins 1997 Analysis

The results from the Atkins analysis are presented in terms of overall failure rate tables. The analysis leading to the split between pinhole, hole and rupture is not given in the report, so the overall validity of the work cannot fully be verified.

The main table showing the result is Table 31, reproduced below, showing the failure mode failure rate for different diameter ranges. The numbers have been re-stated in 1000 km-year units:-

Diameter	Third party	Mechanical material defect	Mechanical construction	Natural Landslide	Natural Floods
>762 mm	0	0	0	0	0
608-762 mm	1.37	1.37	0	1.37	0
405-608 mm	0.13	0.0325	0.0487	0	0
304-405 mm	0.139	0.0154	0.0154	0.0563	0.0154
202-304 mm	0.4	0.05	0.025	0.025	0
<202 mm	0.273	0.0684	0.0684	0	0

Subsequently, the zero lines have been filled in using single case failures, resulting in a somewhat lopsided set of failure rates, with high failure rates for large and small pipelines, due to the lack of a significant number of failures in some pipeline diameter classes.

This table also enabled the pipeline exposure (number of kilometre-years op operation) to be back-calculated. Knowing that there was only one flood data-point, it was possible to work back from the total number of failures of each type to obtain the exposure in each diameter class as follows:-

	TPA	Mech Mat	Mech Con	Nat Land	Nat Flood	Exposure
Dia range	number of failures					x 1000 km-years
>762	0	0	0	0	0	
608-762	1	1	0	1	0	0.730
405-608	8	2	3	0	0	61.538
304-405	9	1	1	3	1	64.935
202-304	32	4	2	2	0	80.000
<202	4	1	1	0	0	14.620
total	54	9	7	6	1	221.823

NOTE: pipe diameters >608 mm is statistically irrelevant due to its low exposure rate

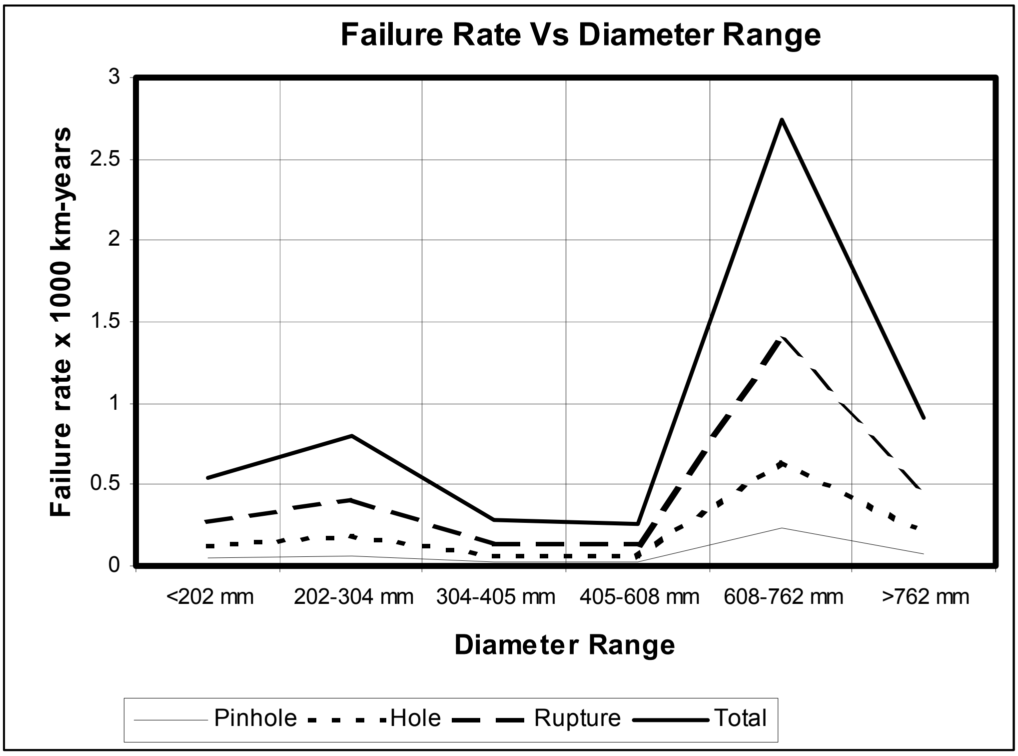
This exposure was then cross-correlated with the failure rates given for corrosion and the number of corrosion failures in each wall thickness class to give the same exposure:-

Corrosion	RATE	NUMBER	EXPOSURE
<5.9mm	0.653	19	29.096
6-10.9	0.187	36	192.513
11-15.9	0		
>16	0		
		Total	221.610

The 3rd Party results for the diameter classes are presented in the Atkins report Table 13, re-stated as per 1000 km-years:-

Diameter	Pinhole	Hole	Rupture	Total
>762 mm	0.0757	0.134	0.244	0.454
608-762 mm	0.229	0.406	0.736	1.371
405-608 mm	0.0217	0.0385	0.0698	0.130
304-405 mm	0.0232	0.0411	0.0746	0.139
202-304 mm	0.0668	0.118	0.215	0.400
<202 mm	0.0456	0.0808	0.147	0.273

This table shows the strange effect of taking a few data-points to try and obtain a range of failure rates for different diameter pipelines. Conventional database results show that large pipelines have lower failure rates, whereas this table shows the failure rate varying between different diameter ranges:-



This is an unusual trend for pipeline failures – normally larger diameter pipelines show lower failure rates than smaller diameter pipelines. Also, pipeline rupture is the smallest contribution to failure rates, whereas in the Atkins analysis, it appears to be the largest contribution.

This table explains HSE's difficulties in attempting to carry out a risk assessment using this data in PIPIN, for Land Use Planning zones for gasoline pipelines. The failure rate for the intermediate diameter class 202 – 304 mm shows a higher failure rate than either the smaller pipeline diameter < 202 mm, and also the larger diameter class 304 - 405 mm.

Atkins appear to have obtained failure rates for each diameter class by considering the number of failures and the pipeline exposure in each diameter class. This gives a very pessimistic result for failure rate. Taking the Diameter range results for just the 202-304 mm diameter class from tables 13,14,15 and 16 for all failure mechanisms of their report gives an overall failure rate of 1.175 per 1000 kilometre years. Yet the overall failure rate from all the data for what is the predominant pipeline size is only 0.586 per 1000 kilometre-years.

The calculation method they used therefore appears suspect, and if this data has indeed been entered into the HSE's PIPIN model, it should be discarded.

Part 2 of this study re-evaluates the failure rate using better data for clean Product pipeline exposure, and failures up to, and including, 2003.

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11 April 2005

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 "Assessing the Risk from Gasoline Pipelines in the UK Based on a Review of Historical Experience", A Report Prepared by W S Atkins Safety & reliability for and on behalf of The Health & Safety Executive, Report Number AM5121, Issue No 01, dated July 1998.

3` "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