Trends in Offshore Process Equipment Leak Frequencies

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The HSE's Hydrocarbon Release Database (HCRD) has become recognised as the main source of information for collating data on accidental process releases. Information derived from the HCRD is used in many parts of the world and for risk assessments of onshore sites as well as offshore installations.

Graphs of number of incidents by year show that there has been a general downward trend in the frequency of leaks from process equipment over the period in which data has been collected. The question arises as to whether the trend is similar for all equipment types or whether there are distinct differences. This paper reports the results of a study into the variation of frequencies with time for different equipment types to examine the relative rates of reduction and to establish if there are any equipment types where frequencies are now increasing.

The study is based on data from around 2500 incidents reported in the period October 1992 to December 2019 which meet current reporting criteria for fixed production installations. The analysis considers 19 equipment types; pressurised vessels, valves, pipework, flanges etc., and examines how the number of incidents and the frequency of occurrence has changed over this period using 5 year and 10 year rolling averages.

The results demonstrate that, for all equipment types, the average frequency over the last 10 years analysed (2010-2019) is lower than the average over the whole period (1992-2019). However, the overall frequency across all equipment types has plateaued in recent years and results for some equipment types now indicate an upward trend.

It is concluded that it is now appropriate to use lower leak frequencies for current offshore risk assessments than was the case in the past and that this may have a bearing on risk-based decisions, such as provision of safety barriers. The quality and completeness of reporting and collation of the data has declined since 2015. This has a bearing on uncertainty of the leak frequencies and it will be important to address issues in the collation of data for incidents and equipment populations

Keywords

Leak Frequency, Offshore, Hydrocarbon Release Database

Introduction

As a result of a recommendation of the Cullen enquiry into the Piper Alpha Disaster, the UK offshore industry has, since October 1992, been submitting reports of hydrocarbon loss of containment incidents to the UK HSE. Guidance on the submission of data is provided in /1/ and /2/. Data gathered is stored in the UK HSE's Hydrocarbon Release Database (HCRD) and DNV has previously carried out detailed analysis of this for a number of purposes;

1. Derivation of leak frequency correlations for process equipment types /3/, /4/
2. Derivation of leak frequency correlations for systems /5/
3. Incident Data Tables /6/, /7/
4. Causal Analysis of trends and hole size distributions /8/

The first two of these required examination of specific data fields, together with population data to develop leak frequency models for use in risk assessments. The third produced information on almost all the data fields in the HCRD but at a high level. The fourth looked at the relative proportion of causes, how they have changed with time and how hole size distribution changes with cause.

The purpose of this study is to examine the variation over time in the number of incidents per year and the frequency per equipment-year (or per pipework-metre-year) to determine the general trends. In particular, whether the frequencies of some types of equipment are changing faster than other types and if any are now increasing.

The information available for the leak frequency studies (/3/and /4/) was limited to incidents occurring up until December 2015 and the incident tables /6/, /7/ on data up to December 2017. Further information was released by the HSE in June 2020 which enabled the analysis of incidents up until December 2019, albeit the data for 2019 is classed as provisional. This comprised a total of 5101 incidents. While the quality and completeness of the reporting and collation of the data has declined since 2015, it is believed that the incident data for 2016-2019 can provide useful information and has been included in this study to provide trending information for the most recent period.

Study Basis

The incident data used as a basis for the study is the information contained in two Excel Workbooks available from the HSE statistics web page. The information is contained in;

1) Workbook obtained through the link “Offshore Hydrocarbon Releases 1992-2016” /9/ which accesses the file “hsr 1992-2014”. This includes data for the period 1992-2015.

2) Workbook obtained through the link “Offshore Hydrocarbon Releases 2015-2019” /10/ which accesses the file “hsr 2015-2019”. This includes “final” data for 2016-2018 and provisional data for 2019.

Note that data for 2015 is contained in both data sets but in different formats and that these are not in complete agreement with each other. In this study the data for 2015 in /10/ has been used.

The combined data sets contain details of 5101 incidents in the UKCS in the period October 1992 to December 2019. These do not reflect all the data fields in the HCRD. Some fields have been omitted, such as the names of installations and their ID numbers in order to maintain a degree on anonymity. Also, some fields which were made available in the 1992-2015 data set are omitted from the 2016-2019 data set. However, these fields do not significantly affect the analysis carried out in this study. In the period from 2016, coinciding with the introduction of the ROGI form /11/, the quality of the data in terms of completeness and quality has decreased meaning that some judgement is required in assigning categories. In particular, there is a significant number of incidents where the equipment type has not been specified or does not comply with the intended taxonomy. The result is that it is not possible to assign the incident to a given equipment type with certainty. To account for this, the “BLANK” and “Not Taxonomy Compliant” incidents have been redistributed among the equipment types in the same proportion as the incidents where the equipment type was known. The effect of this is to increase the estimated number of incidents and frequencies for that category. Without this correction it would have appeared that the number of incidents and frequencies for some equipment types were decreasing at a greater rate than is likely to have been the case in practice, or could mask increases in frequency.

Figure 1 shows the number of incidents in the HCRD for each year[1] which clearly shows the general reduction in incidents over the period. The graph also shows the number of incidents where the equipment type was not recorded or where the recorded information did not comply with the equipment taxonomy (“BLANK” entries). Figure 2 shows the equivalent graph for incidents selected in this analysis (see section below for selection criteria).

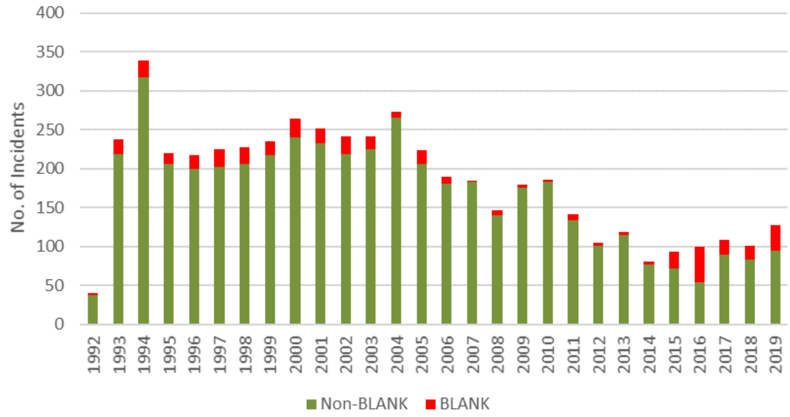


Figure 1: Incidents Recorded in the HCRD by Year

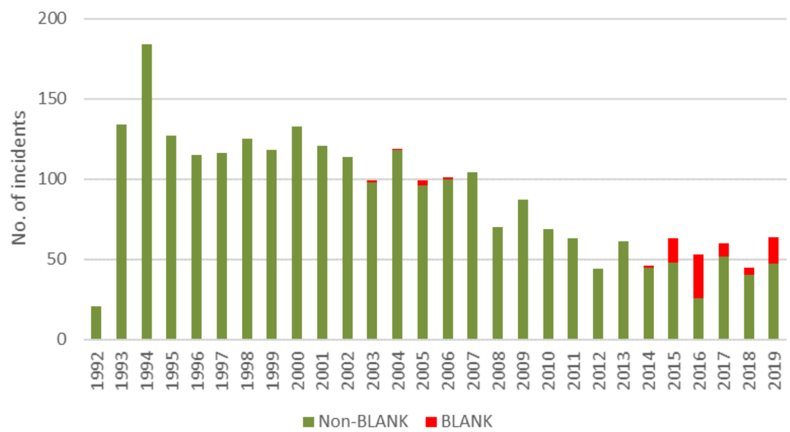


Figure 2: Selected Incidents From the HCRD by Year

[1] The number of incidents in 1992 relates only to the 3-month period October-December.

It can be seen that until 2015 almost all of the “BLANK” entries were eliminated by the selection process. Since 2015 there have been a substantial number of entries which still fell within the selection criteria but where either no equipment was recorded, or the recorded value did not comply with the taxonomy specified in the ROGI form /11/. This is symptomatic of the reduction in quality of the information recorded since the introduction of the ROGI form. The estimated number of incidents for each equipment type was adjusted by redistributing the “BLANK” entries to the equipment types in the same proportion as incidents where the equipment type was specified.

The population data used to calculate frequencies is also obtained from the HSE’s statistics web page /12/.

Selection of Incidents

Both the number of incidents and the population, in terms of equipment-years, for the same period are required to calculate the leak frequency for a given equipment type. While all the incidents within an installation’s safety zone which meet the reporting criteria are required to be recorded, the same is not true for the corresponding equipment populations. For example, population data is not available for mobile drilling units. In order to match the data, and for consistency over time, some criteria were applied to select the incidents of relevance. It should be noted that the criteria used here differ from those used in the derivation of the leak frequency correlations presented in the International Association of Oil and Gas Producers (IOGP) process leak frequency guidance /3/. In addition to the extra four years of data, the study has included hole sizes of less than 1 mm and releases at near atmospheric pressure. These were excluded from the frequency correlation analysis on the basis of them having limited consequences.

The selection criteria are described below.

Installation Type

The equipment population data /12/ relates only to fixed production installations. The incomplete information on mobile units and non-production installations was removed from the equipment counts. These mostly relate to mobile units where it is difficult to determine the amount of time that was spent in UK waters during which a leak would have been reported. Installations where the type of installation was not available were retained.

System Types

Not all process systems have their equipment counted. Equipment counts are generally not available for systems associated with flaring and venting, nor are they available for utility systems. An equipment populations study carried out by DNV /13/ identified 35 system types which were normally counted and 17 which were not normally counted. Incidents in the uncounted system types were omitted from the analysis.

Equipment Type

There are two types of equipment which have no associated population counts. These are “Drain Openings” and “Drain Plugs” and have been omitted.

Operation Releases Accidently Ignited

All ignited events are required to be reported. In a few cases these may be incidents where a non-accidental release, for example from a vent, was ignited. Such incidents have been deselected in this study

Reporting Limits

Reporting criteria have changed over the period that the HCRD has been operating. Some incidents which were previously reported may not comply with the latest guidance (as given in /2/). To ensure a more consistent basis for examining trends, those incidents which are below the current criteria have been omitted.

Time Period

The HCRD started on 1st October 1992 so only incidents in the last quarter of that year were recorded. Incidents have not been excluded because of their date and are included in the overall average number of incidents and frequency per year. However, in order to compare complete years of data, they have not been included in the 5-year or 10-year rolling averages.

Overall Selection

When all the above were taken into consideration, 2555 out of the overall 5101 events were included in the study. A breakdown by criteria is presented in Table 1.

Table 1: Numbers of Incidents Removed or Retained in the Selection Process

Criteria	Retained	Removed	Proportion Retained
Date	5101	0	100.0%
Installation Type	4704	397	92.2%
System Type	3696	1405	72.5%
Equipment Type	5001	100	98.0%
Ignited Events Discounted	4096	5	99.9%
Reportability	3772	1329	73.9%
Overall	2555	2546	50.1%

Trends Over Time

It is well established that the number of incidents per year has progressively fallen over the time span of the HCRD, albeit it has plateaued in recent years. However, the trends are different for different levels of severity and may also be so for different causes. This has been reported in previous studies /14/ and /15/ for the period up to 2015 and more recently in /8/. This study is similar to the previous work but also includes the incidents in the period 2016-2019. To investigate this, and to provide a degree of smoothing of the values, the data was analysed to produce 5 year rolling averages of the number of incidents by severity.

e.g. $N_{ave-5}(2001) = (N_{1999} + N_{2000} + N_{2001} + N_{2002} + N_{2003})/5$

Where N_{1999}, N_{2000}, etc. is the number of incidents in the relevant year and $N_{ave-5}(2001)$ is the average over the 5-year period 1999-2003.

The graphs in Figure 3 present all incidents in the HCRD, i.e., not only the selected incidents described above. In this graph the values on the year axis are the mid-year of the range, e.g., the values for 1995 are the averages over the period 1993-1997 inclusive. Separate curves are presented for the different severity classes of “Major”, “Significant” and “Minor”. It is notable that the annual number of minor incidents that were reported increased up until 2003 although the combined value for Minor + Significant was relatively constant. This may be partly due to differences in judgement in the classification process. The number of major incidents declined over this period. Between 2003 and 2014 there was a steady decrease on all severity categories. However, in the period since 2014 the number of reported incidents has been broadly similar.

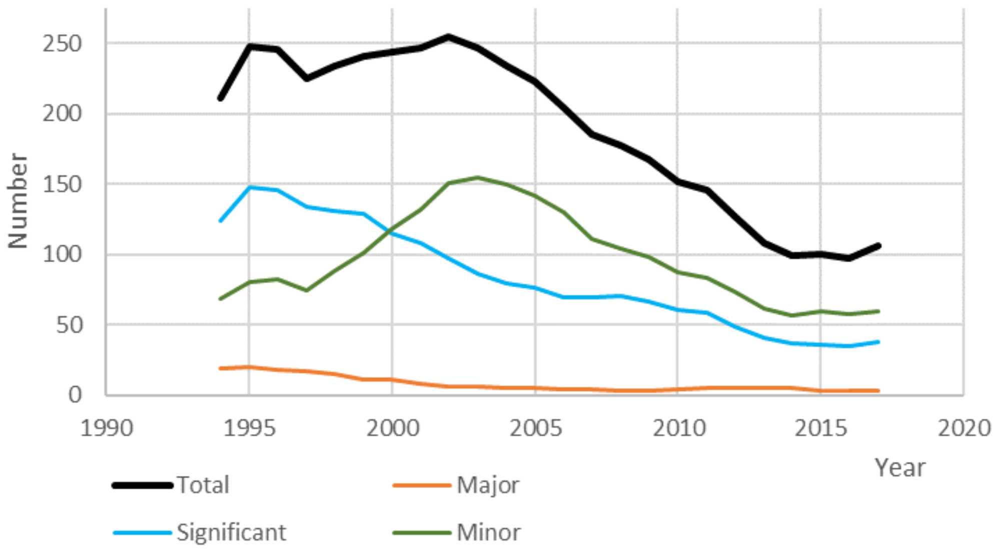


Figure 3: 5-Year Rolling Average – All Incidents By Severity Classification

The different equipment types will have their own variations over time with some declining more rapidly than others and some increasing in recent years. To examine this, the 19 main equipment type groups have been analysed separately. The trends are depicted graphically in the Results section using six lines as follows;

1) The average number of incidents per year over the period 1/10/1992 to 31/12/2019.

2) The rolling average of the number of incidents over a 10 year period

3) The rolling average of the number of incidents over a 5 year period

4) The average frequency per year over the period 1/10/1992 to 31/12/2019

5) The rolling average frequency over a 10 year period

6) The rolling average frequency over a 5 year period

The population of equipment has varied over this time period so an increase or decrease in the number of incidents may be a reflection of the increase or decrease in the population, rather than because the leak frequency per equipment item has changed. Hence, the trend lines for frequencies are not scaled equivalents of the incident number trends.

Results

This section presents results for various equipment groups which have sufficient number of incidents to make the results meaningful. For each equipment type the following results are presented;

1) A graph of overall average, 5-year running average and 10-year running average for the number of incidents per year and frequency (per equipment-year). See section above for further details.

2) The average number of incidents and the average leak frequency over the 27¼ year period 1/10/1992 to 31/12/2019. This is independent of the hole size or severity classification.

3) Tables showing the ratio in percent of values, at five year intervals, of the trend lines compared with the overall averages. For example, in the case of steel piping the number of relevant incidents over the period 1/1/2005 to 31/12/2009 (mid-point 30/6/2007) was 7.69 which is 69.3% of the average value of 11.1. Similarly, the average frequency for that period was 2.60×10^{-5} which is 66.4% of the overall average of 3.91×10^{-5}.

Since the hole sizes are recorded for the majority of cases, it is also possible to produce scatter diagrams indicating the hole size and date of incident. For some equipment types, such as pipes valves and flanges, there is information on the size of the equipment which leaked. This enables an assessment of whether a loss of containment was a rupture (taken as a hole greater than or equal to 90% of the equipment size) or not. Incidents for which no hole size was recorded are shown with a red marker on the 1 mm line to indicate the date but not the actual hole size. Figure 4 shows an example of such a plot for flanged joints. Equivalent plots for other equipment types are provided in /16/ which also contains results for relative incident numbers and frequencies for 10 year running averages.

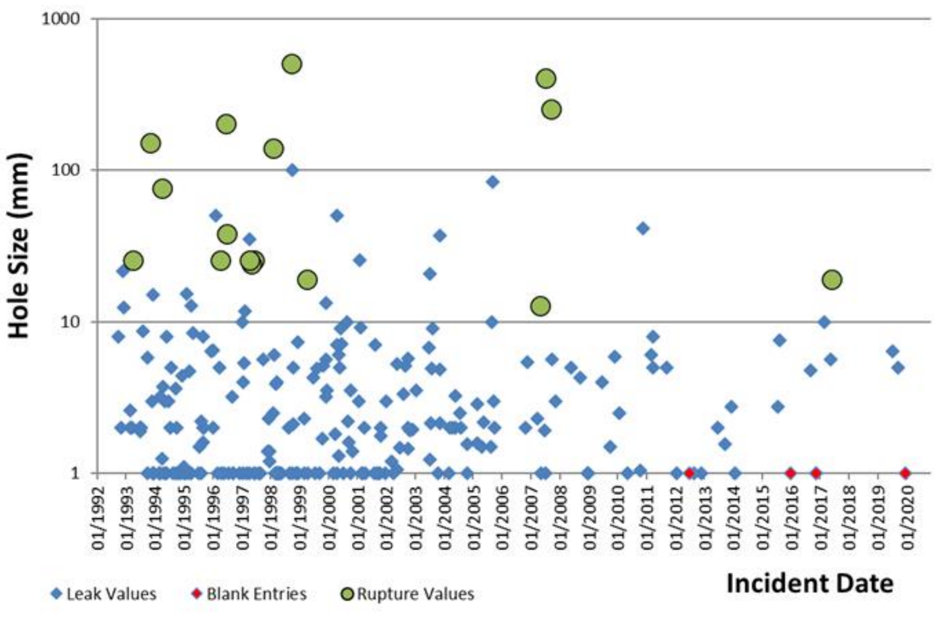


Figure 4: Scatter Diagram of Hole Size at Date of Incident for Flanged Joints

Note that in the graphs presented below, the values on the "Year" axis are the mid-year of the range, e.g. the 5-year average shown for 1995 is the value at 30/6/1995 and covers the period 1/1/1993 to 31/12/1997. Similarly, the 10-year average for 1998 is the value at 30/6/1998 and covers the period 1/7/1993 to 30/6/2003 albeit this is an average for the values at 1/1/1998 (1993-2002) and 1/1/1999 (1994-2003).

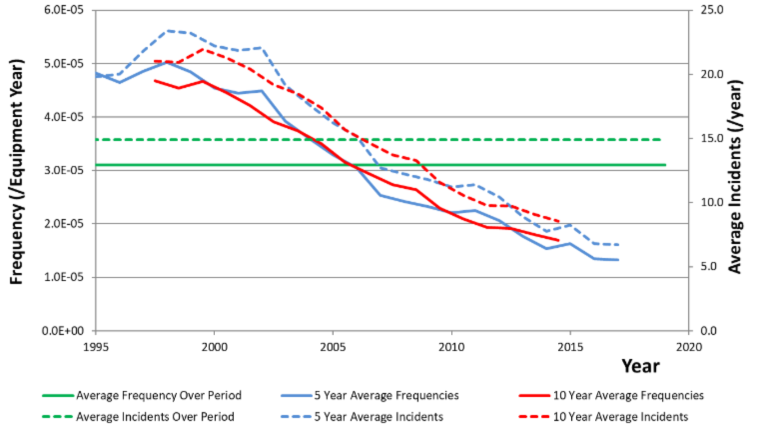
Steel Piping

Overall Average Incidents:
14.88/year

Average Frequency:
3.10×10^{-5}/metre-year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	146.6%	156.9%
30/06/02	148.3%	145.0%
30/06/07	85.6%	81.8%
30/06/12	70.1%	66.5%
30/06/17	45.0%	42.9%



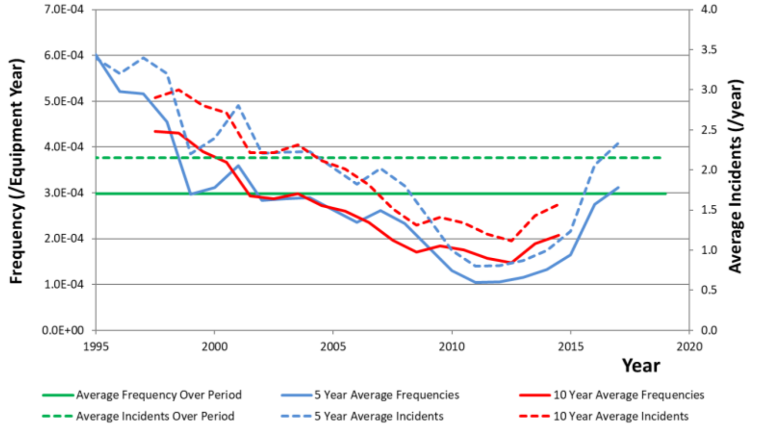
Flexible Piping

Overall Average Incidents:
2.15/year

Average Frequency:
2.98×10^{-4}/metre-year

Averages Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	158.0%	173.3%
30/06/02	102.7%	95.1%
30/06/07	93.8%	87.6%
30/06/12	37.4%	35.5%
30/06/17	108.3%	104.7%



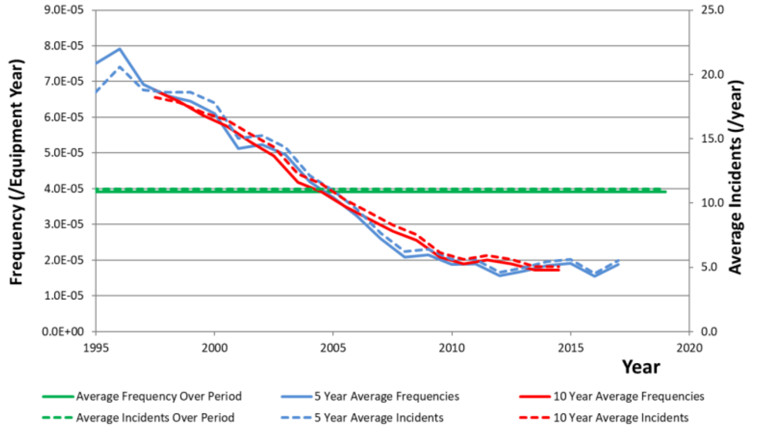
Flange Joints

Overall Average Incidents:
11.1/year

Average Frequency:
3.91×10^{-5}/year

Averages Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	169.4%	176.9%
30/06/02	137.4%	133.7%
30/06/07	69.3%	66.4%
30/06/12	41.7%	40.1%
30/06/17	49.6%	48.1%



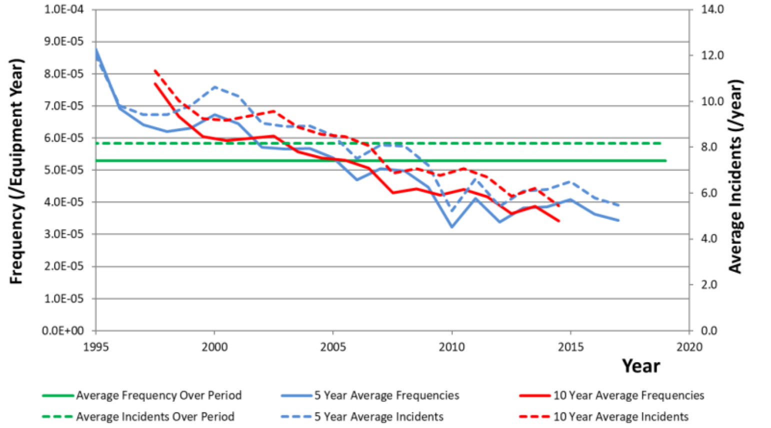
Manual Values

Overall Average Incidents:
8.17/year

Average Frequency:
5.29×10^{-5}/year

Averages Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	115.2%	121.1%
30/06/02	110.8%	108.2%
30/06/07	99.0%	95.3%
30/06/12	66.5%	64.1%
30/06/17	67.0%	64.9%



Actuated Valves

Overall Average Incidents:

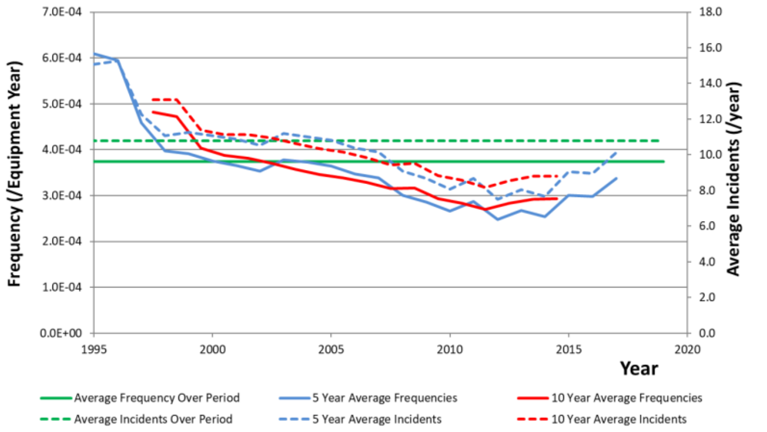
10.8/year

Average Frequency:

3.75×10^{-4}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	113.7%	122.5%
30/06/02	97.4%	94.3%
30/06/07	94.2%	90.3%
30/06/12	69.4%	66.3%
30/06/17	93.8%	90.1%



Instrument Connections

Overall Average Incidents:

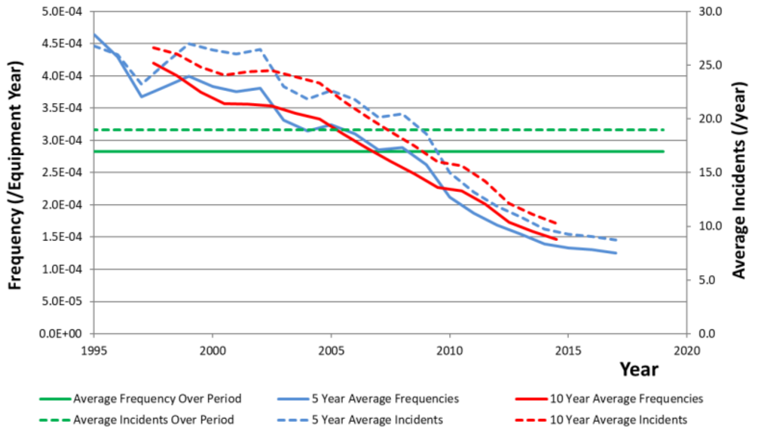
18.99/year

Average Frequency:

2.82×10^{-4}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	122.2%	130.1%
30/06/02	139.4%	135.0%
30/06/07	106.2%	101.2%
30/06/12	62.4%	59.7%
30/06/17	45.9%	44.3%



Process Vessels (Excluding "Other")

Overall Average Incidents:

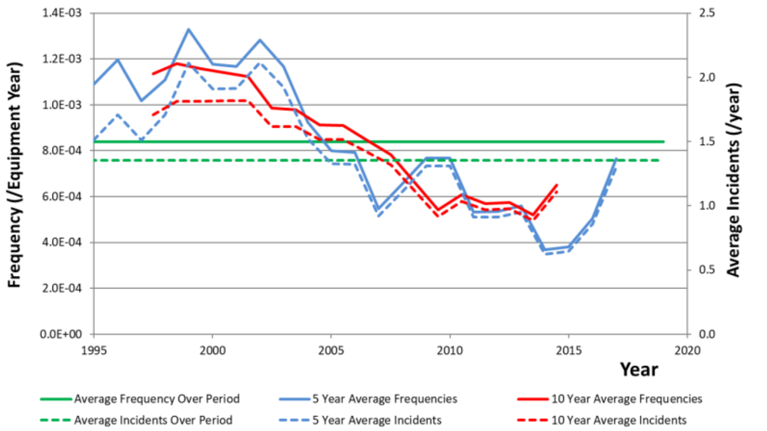
1.36/year

Average Frequency:

8.38×10^{-4}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	111.4%	121.3%
30/06/02	156.0%	153.1%
30/06/07	67.9%	65.3%
30/06/12	67.3%	63.9%
30/06/17	96.0%	91.3%



Process Vessels (Other)

Overall Average Incidents:

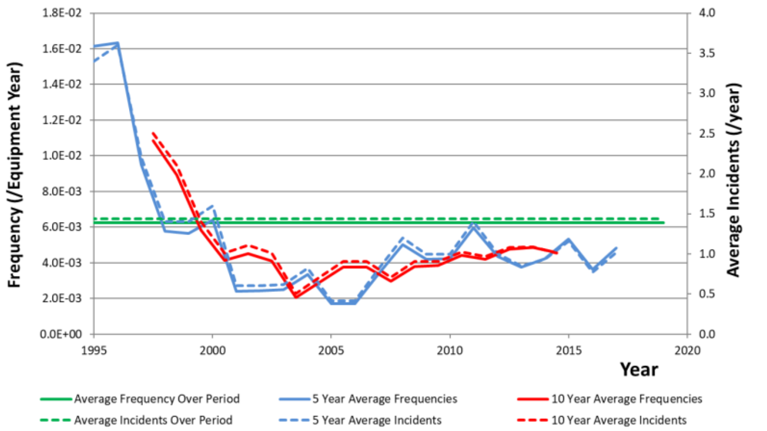
1.43/year

Average Frequency:

6.26×10^{-3}/year

Relative Value by 5 Year Time Band

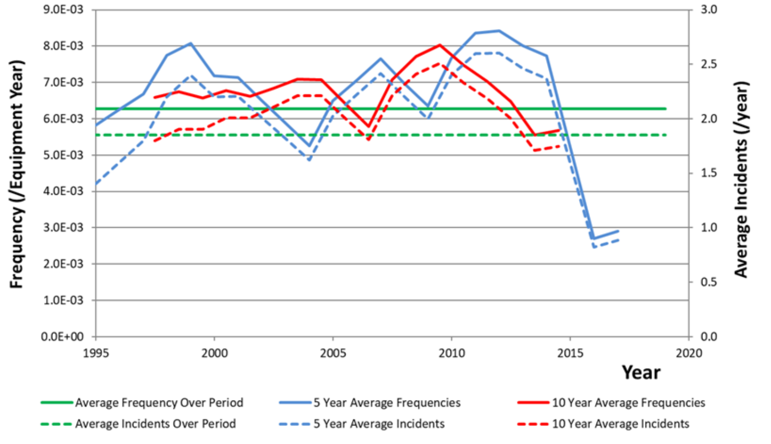
Mid-Point	Incidents	Frequency
30/06/97	153.3%	151.6%
30/06/02	42.2%	38.9%
30/06/07	56.6%	53.8%
30/06/12	69.9%	69.6%
30/06/17	71.2%	77.2%



Centrifugal Compressors

Overall Average Incidents:
1.85/year
Average Frequency:
6.28×10^{-3}/year
Relative Value by 5 Year Time Band

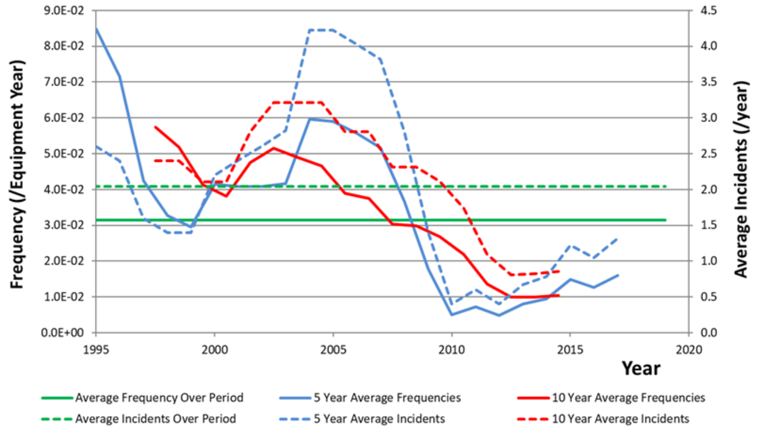
Mid-Point	Incidents	Frequency
30/06/97	97.3%	106.3%
30/06/02	108.5%	103.3%
30/06/07	130.6%	122.0%
30/06/12	140.8%	134.1%
30/06/17	47.8%	46.3%



Reciprocating Compressors

Overall Average Incidents:
2.04/year
Average Frequency:
3.15×10^{-2}/year
Relative Value by 5 Year Time Band

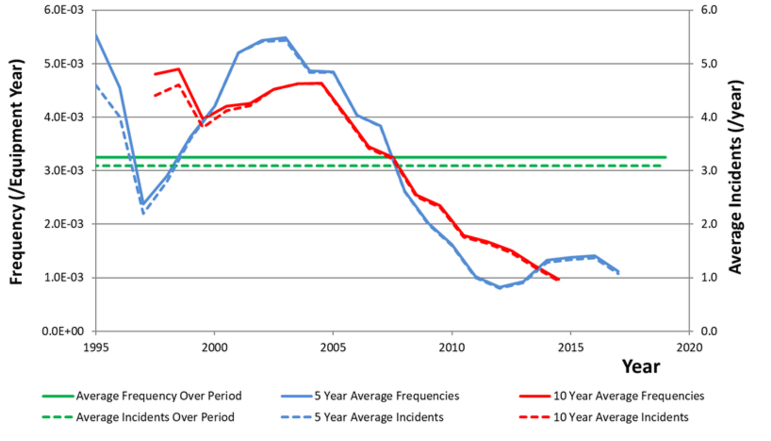
Mid-Point	Incidents	Frequency
30/06/97	78.5%	134.6%
30/06/02	128.0%	129.5%
30/06/07	187.2%	163.8%
30/06/12	19.8%	15.5%
30/06/17	64.5%	50.6%



Centrifugal Pumps

Overall Average Incidents:
3.10/year
Average Frequency:
3.25×10^{-3}/year
Relative Value by 5 Year Time Band

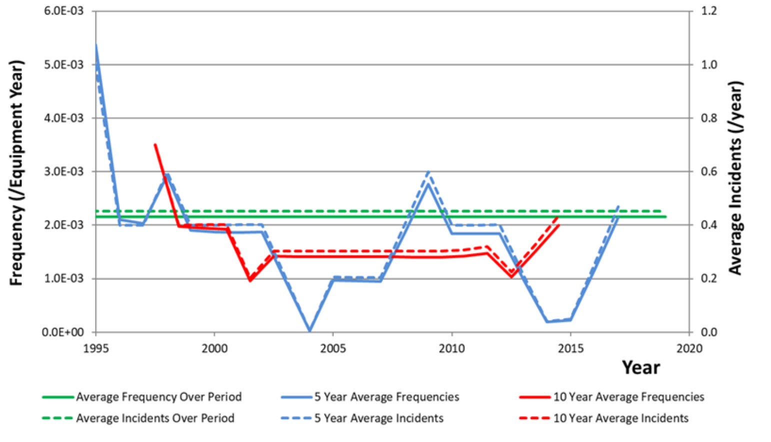
Mid-Point	Incidents	Frequency
30/06/97	71.1%	73.3%
30/06/02	174.9%	167.4%
30/06/07	123.6%	118.1%
30/06/12	26.1%	25.4%
30/06/17	34.8%	34.3%



Reciprocating Pumps

Overall Average Incidents:
0.45/year
Average Frequency:
2.16×10^{-3}/year
Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	88.3%	94.0%
30/06/02	88.7%	86.6%
30/06/07	45.0%	43.9%
30/06/12	88.5%	85.4%
30/06/17	103.7%	99.7%



Heat Exchangers (Hydrocarbon inside Shell)

Overall Average Incidents:

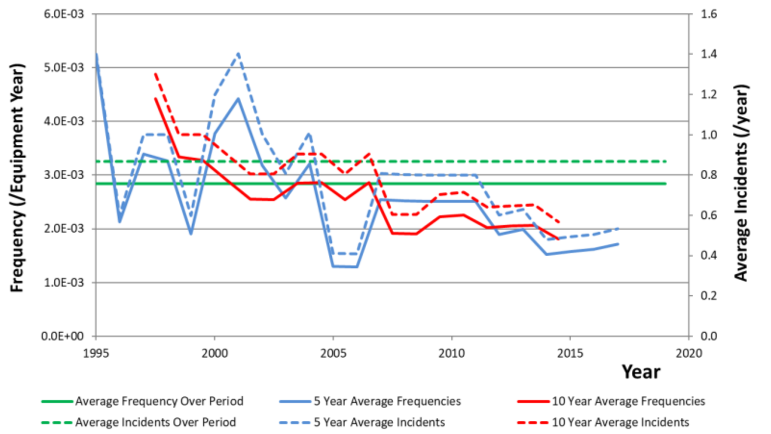
0.87/year

Average Frequency:

2.83×10^{-3}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	115.2%	119.5%
30/06/02	115.6%	112.2%
30/06/07	93.0%	89.8%
30/06/12	69.3%	66.8%
30/06/17	61.5%	60.5%



Heat Exchangers (Hydrocarbon inside Tube)

Overall Average Incidents:

0.91/year

Average Frequency:

1.67×10^{-3}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	88.3%	91.7%
30/06/02	199.1%	190.8%
30/06/07	67.1%	64.3%
30/06/12	22.3%	21.8%
30/06/17	81.6%	80.8%

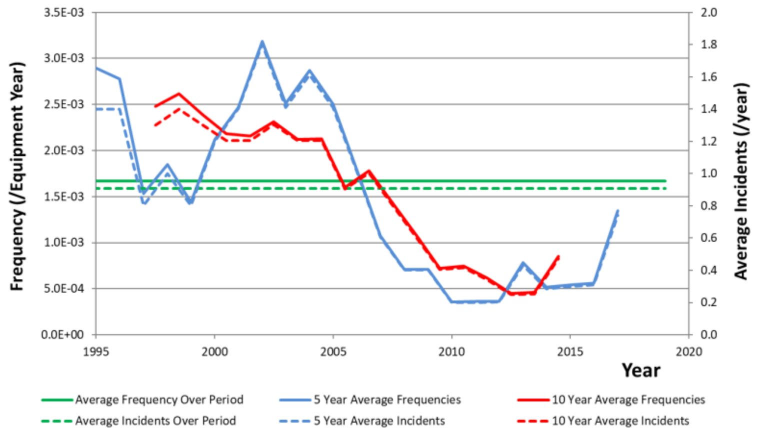


Plate Heat Exchanger

Overall Average Incidents:

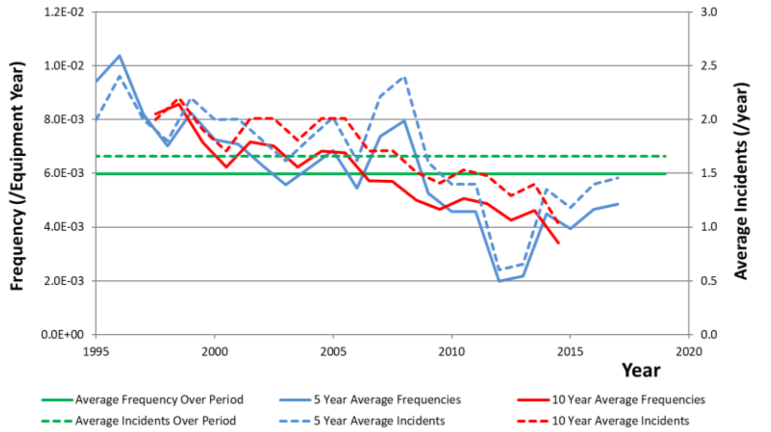
1.66/year

Average Frequency:

5.98×10^{-3}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	120.4%	136.8%
30/06/02	108.8%	105.1%
30/06/07	133.3%	123.4%
30/06/12	36.3%	33.2%
30/06/17	87.6%	81.2%



Pig Traps

Overall Average Incidents:

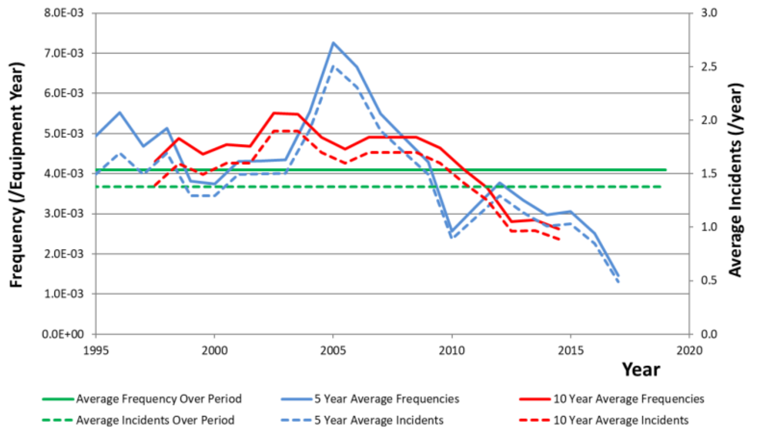
1.38year

Average Frequency:

4.10×10^{-3}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	108.5%	114.3%
30/06/02	108.9%	105.2%
30/06/07	138.3%	133.9%
30/06/12	94.1%	92.0%
30/06/17	35.6%	35.5%



Filters

Overall Average Incidents:

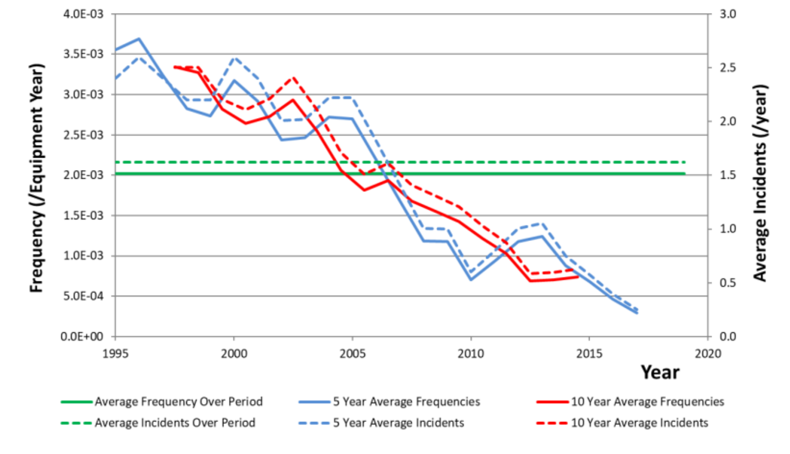
1.62/year

Average Frequency:

2.02×10^{-3}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	147.8%	160.3%
30/06/02	123.6%	120.8%
30/06/07	87.1%	83.7%
30/06/12	61.8%	58.2%
30/06/17	15.4%	14.6%



Turbines

Overall Average Incidents:

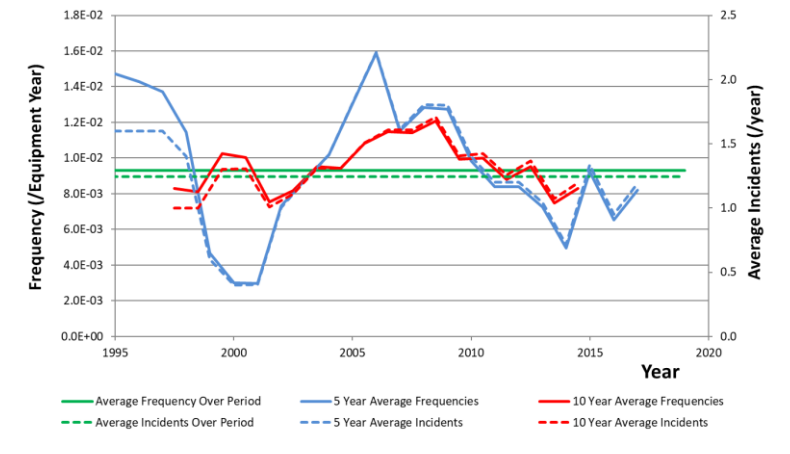
1.25/year

Average Frequency:

9.31×10^{-3}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	128.4%	147.3%
30/06/02	80.7%	78.6%
30/06/07	129.3%	123.7%
30/06/12	96.5%	90.1%
30/06/17	95.7%	88.2%



Xmas Trees

Overall Average Incidents:

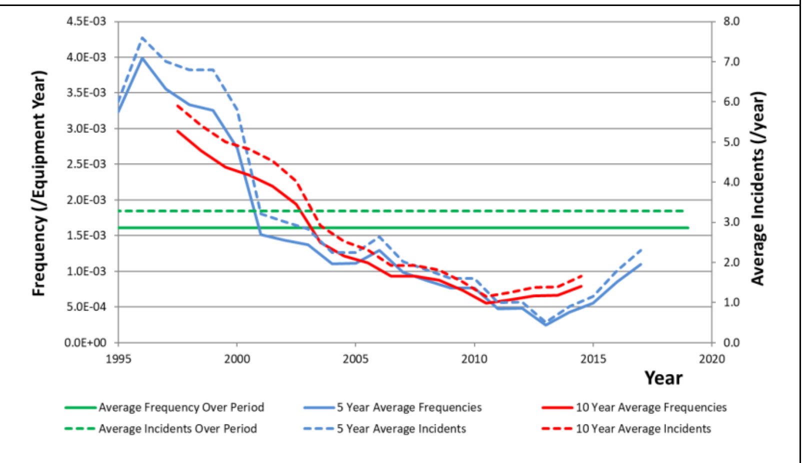
3.28/year

Average Frequency:

1.61×10^{-3}/year

Relative Value by 5 Year Time Band

Mid-Point	Incidents	Frequency
30/06/97	213.1%	220.3%
30/06/02	91.8%	89.2%
30/06/07	61.7%	61.3%
30/06/12	30.7%	29.8%
30/06/17	70.2%	68.0%



Conclusions and Recommendations

The general trend of reductions in leak frequency is seen in most types of equipment. The trending graphs for equipment types with larger numbers of incidents will tend to be smoother and more statistically significant. Correspondingly, frequencies for equipment items with few incidents will tend to fluctuate more but this is likely to be the result of stochastic variation.

As a single value representative measure to describe the overall trend, the ratio of the 10-year running average frequency compared with the overall frequency was calculated. These values are given in Table 2 which has been arranged in decreasing order of reduction. All types of equipment show a decrease, but some changes are relatively small. The table also indicates the most recent trends based on the 5-year rolling average frequency curves and broadly categorised by judgment as follows;

- Continuing Decrease: equipment with frequencies showing a long term downward trend, e.g. filters, instrument connections and steel pipe.

- Recent Decrease: Equipment types where the frequency has been generally level over the duration of the records but has decreased significantly in recent years. Only one equipment type, centrifugal compressors, comes into this category
- Level: Equipment type where the frequencies have declined in the past but have been broadly consistent in recent years, e.g. centrifugal pumps and reciprocating compressors.
- Increasing: Equipment types where the frequencies have declined in the past but are now showing evidence of increasing, e.g. xmas trees and process vessels.
- Significantly Increasing: Equipment Types where the five-year running average is trending upwards at a greater rate. Only flexible piping comes into this category.

The basis on which category to assign a given equipment type to is relatively subjective and not based on a mathematical analysis. It is influenced by the absolute number of incidents since, as noted above, equipment types with smaller numbers of incidents will exhibit greater stochastic variation. Further work could include a more detailed examination of this aspect to place it on a more robust mathematical footing.

Table 2: Comparison of Recent 10-Year Average and Overall Average Frequency

Rank	Equipment Type	Comparison of 10-year Average With Overall Average		Recent Trend
		Percentage of Overall Average	Percentage Reduction	
1	Centrifugal Pumps	29.8%	70.2%	Level
2	Reciprocating Compressors	33.0%	67.0%	Level
3	Filters	36.5%	63.5%	Continuing Decrease
4	Flanged Joints	44.1%	55.9%	Level
5	Xmas Trees	48.9%	51.1%	Increasing
6	Heat Exchanger (HC in Tube)	51.2%	48.8%	Level
7	Instrument Connections	52.0%	48.0%	Continuing Decrease
8	Steel Pipe	54.7%	45.3%	Continuing Decrease
9	Plate Heat Exchangers	57.0%	43.0%	Level
10	Heat Exchanger (HC in Shell)	60.5%	39.5%	Level
11	Pig Traps	64.1%	35.9%	Continuing Decrease
12	Manual Valves	64.5%	35.5%	Level
13	Flexible Piping	69.8%	30.2%	Significantly Increasing
14	Other Vessels	73.2%	26.8%	Level
15	Process Vessels	77.6%	22.4%	Increasing
16	Actuated Valves	78.2%	21.8%	Increasing
17	Turbines	89.1%	10.9%	Level
18	Centrifugal Compressors	90.6%	9.4%	Recent Decrease
19	Reciprocating Pumps	99.7%	0.3%	Level

The equipment items listed at the top of the table are the ones which have shown the biggest reduction in frequencies. For example, the overall average frequency for centrifugal pumps is 3.25×10^{-3}/equipment-year but the average frequency for the period 2010-2019 inclusive is 9.69×10^{-4}/equipment-year which is 29.8% of the overall average, i.e., a 70.2% reduction. This also compares with the average for 1993-2002 which was 4.81×10^{-3}/equipment-year.

Nine of the equipment types show a greater than 40% reduction using this metric and a further seven show a reduction in the range 20-40%. Only three equipment types show a reduction of less than 20%.

Given the large number of flanged joints on offshore installations, the significant decrease in their leak frequency since 2004 has a large effect on the overall number of incidents per year. Anecdotal information from the industry is that this is likely to be due to improvements in the procedures for tightening flanges and increased adherence to those procedures.

The population data on which the analysis is based only extends up to 2015. In the absence of more information. it has been assumed that the population has remained constant for all equipment types in the period 2016–2019 inclusive. If the population has been decreasing as decommissioning starts to more than offset new platforms, this could be masking increases in more equipment types. Operators of platforms in UK waters are currently being asked to provide estimates of the population of equipment in order to provide a more accurate assessment of the historic variation. It may be a number of years before this exercise is completed. Retaining the completeness and robustness of input data in the HCRD is critical in order for future analysis to retain statistical value.

The overall conclusion is that the majority of equipment types have shown an overall decrease relative to 20 and 10 years ago. It is now appropriate to use lower frequencies in risk assessments than those from correlations based on previous analysis which excludes more recent experience. However, the overall frequency across all equipment types has plateaued in recent years and results for some equipment types indicate an increasing frequency.

It is recommended that incident data continues to be recorded and reported in a timely and accurate manner and that steps are taken to conclude the population collection exercise in a short time period.

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