Trends in Offshore Process Equipment Leak Frequencies

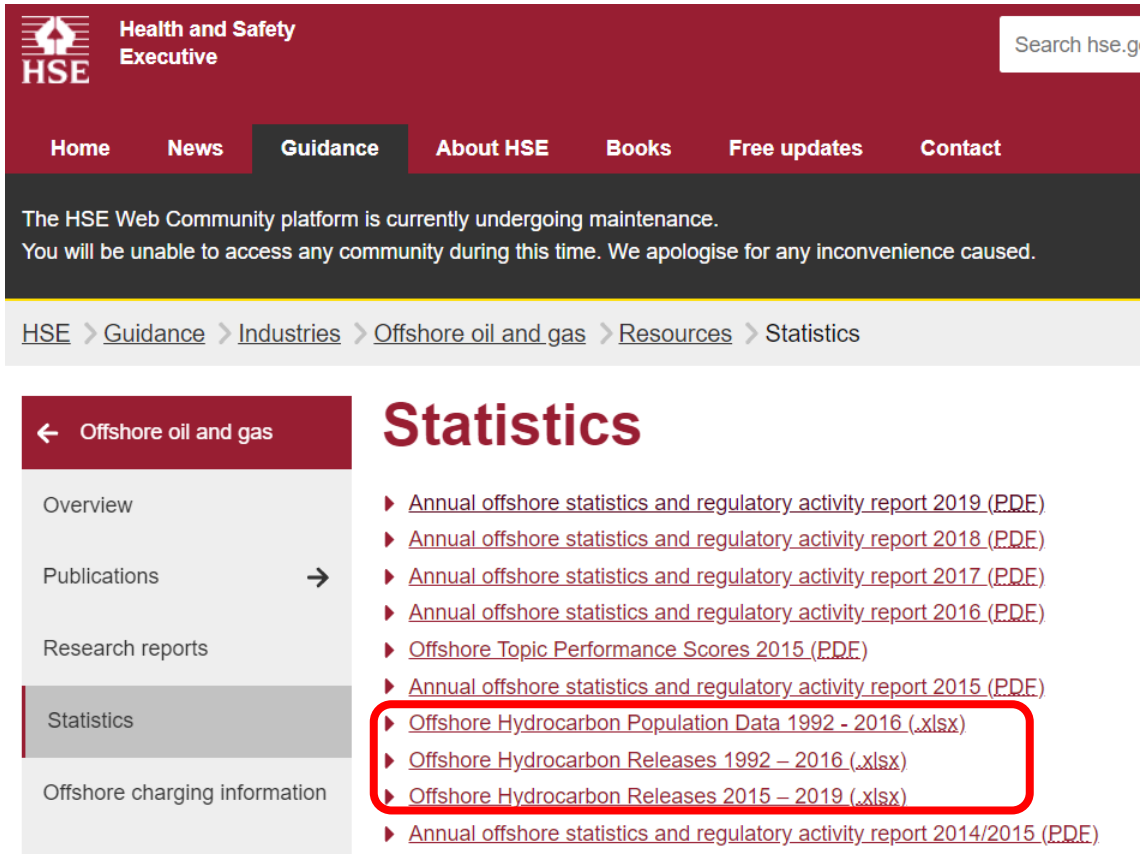
Based on Experience in the UKCS

Introduction

- The UK HSE's Hydrocarbon Release Database (HCRD) has been collecting information of process releases in the UKCS since October 1992.
- Currently in excess of 5000 incidents.
- Used as the basis for leak frequency calculations.
- Process leak frequency is a primary input to risk analysis of offshore installations.
- Data derived from the HCRD is used worldwide including for onshore sites.
- Evidence is that the frequency of incidents has been decreasing over the past 20 years.
- Is this the case for all equipment types?
- Is this trend true for recent years?

Available Data

- The data used in this study was taken from spreadsheets downloaded from the HSE's Offshore Statistics web page at https://www.hse.gov.uk/offshore/statistics/index.htm
- This provides information on incidents (2 spreadsheets) and equipment populations.
- Incident data covers the period October 1992 to December 2019.
- Population data covers the period 1992 to 2016 – populations for 2017-2019 assumed to be the same as for 2016.



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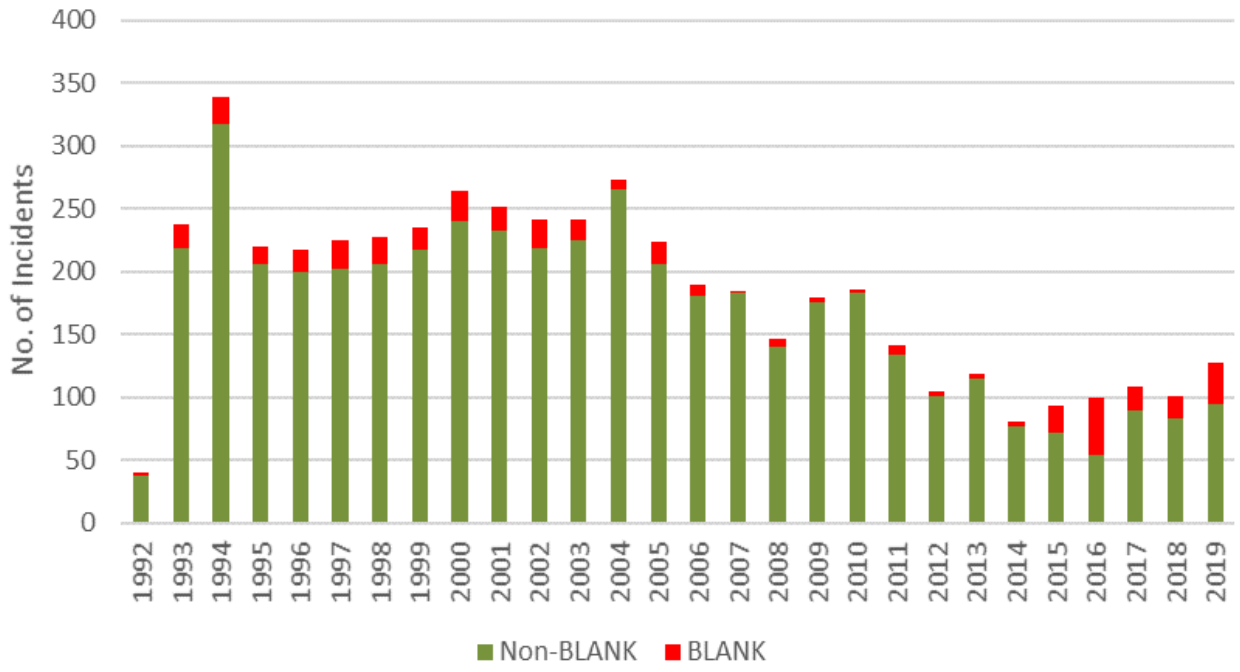
Number of Incidents

- A graph of number of incidents by year shows that there has been a marked decrease in the number of reported incidents in the last 20 years.
- Roughly 250/year decreasing to 100/year.
- Not all incidents recorded the type of equipment involved. Particularly in the years following the introduction of the ROGI form in 2015.
- The frequency of events is also influenced by the equipment populations.



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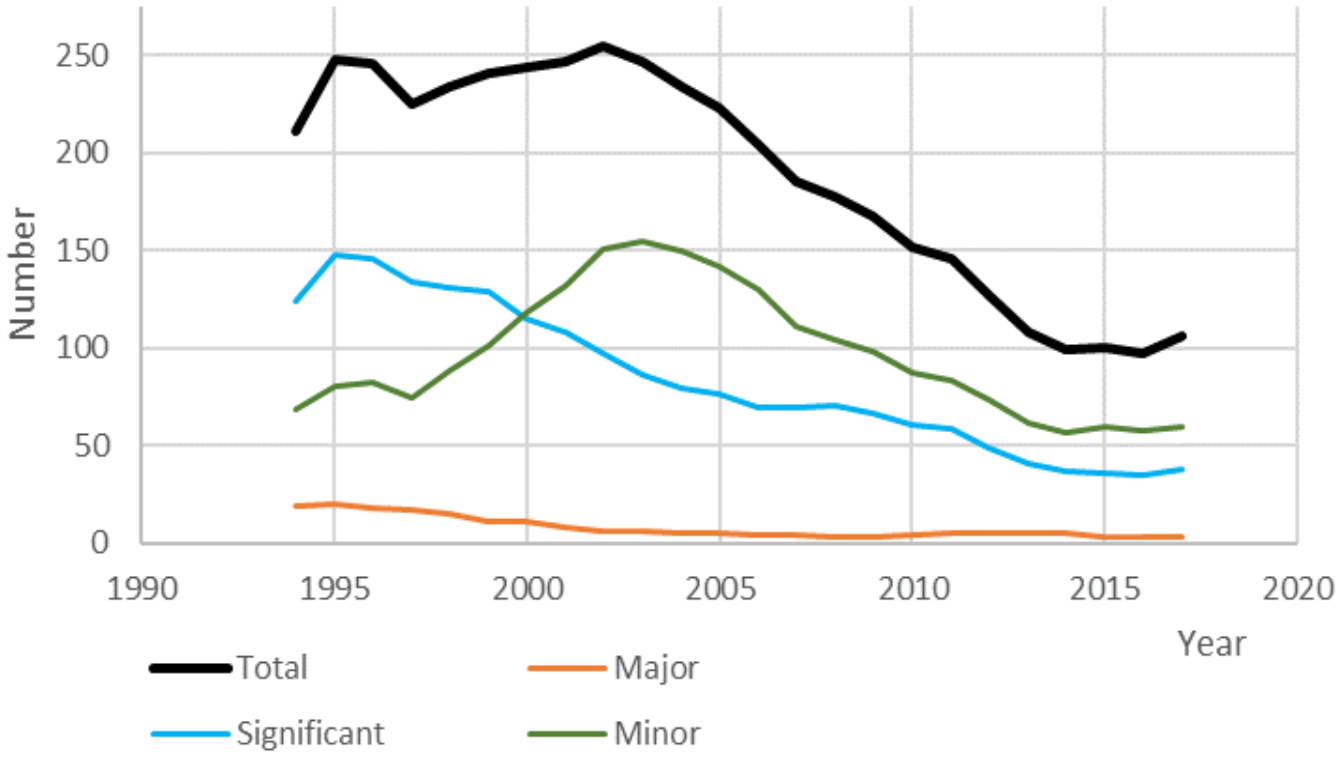
Severity Classification

- Incidents are classified by severity, which is primarily based on the fluid type, inventory released and the release rate.
- 5-year rolling average shows a significant downward trend for “Total” but plateauing in recent years.
- Significant change in proportions of “Minor” and “Significant” in the period up to 2003. This may be partly a reporting issue.
- Large reduction in number of “Major” incidents in period 1992-2010 but an increase in the period 2010-2015.



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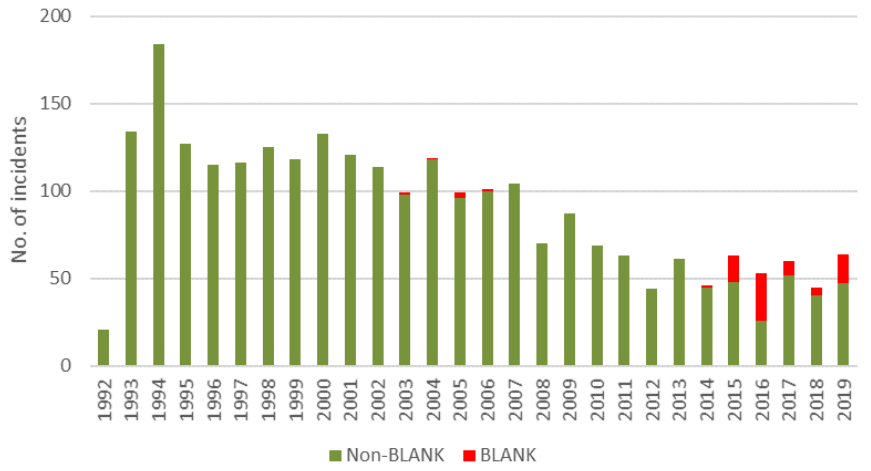
Selection of Incidents

- The population data relates to most (but not all) process systems of fixed production platforms.
- The incident data relates to all leaks within the 500 metre safety zone from all installation types.
- Hence the incident and population data are not consistent.
- Reporting criteria have changed or been clarified over the years.
- In order to have a consistent basis for comparison, the data used in this study is a sub-set of the total reported.
- Selection process removes almost all the incidents with no recorded equipment type prior to 2015.
- “BLANK” entries were redistributed among the population in the ratio of their historic occurrence – introduces some uncertainty.

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%



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Leak Frequency Correlations

- Leak Frequency correlations have been derived from HCRD.
- Correlations are provided in the IOGP in their guidance published in September 2019.
- 24 equipment types
- Correlations based on frequencies over the full period (1992-2015) and alternatively the most recent 10 year period (2006-2015).
- Hole size distributions based on the full period in both cases.

Flanges per year by diameter (based on 2006-2015 data)

General equation $F(d) = Cd^m + B, \quad 1\ mm < d \leq D$

$F(d) = 0, \quad d > D$

Where the parameters C, m and B are dependent on the equipment size (D) as given in by interpolation from the following table

	Equipment Diameter (mm)		
Parameter	**0**	**174**	**508**
C	5.37×10^{-6}	1.31×10^{-5}	3.10×10^{-5}
m	-0.775	-0.790	-1.071
B	-1.40×10^{-7}	4.00×10^{-7}	2.05×10^{-6}

Values greater than 508 mm use the same value as for 508 mm

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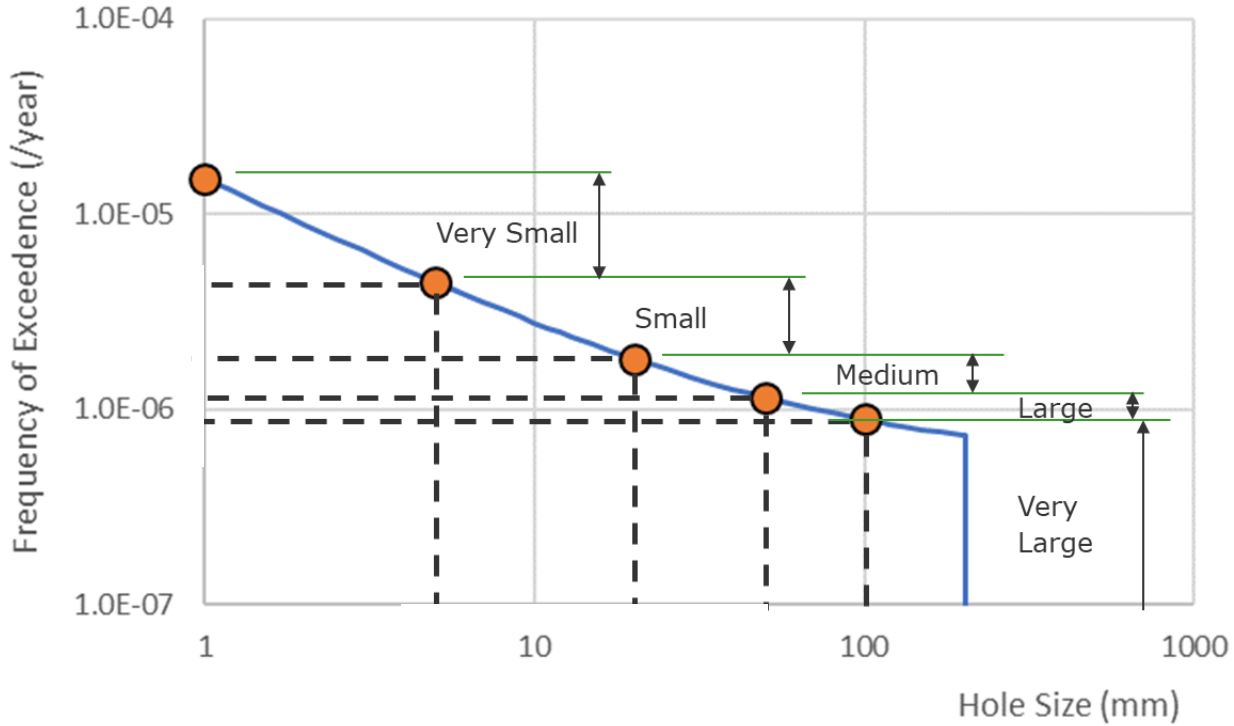
Leak Frequency Calculation

- For a given equipment type and size a frequency of hole size exceedance curve can be drawn.
- The frequency of leaks in given hole size range can then be calculated.
- For example

$$f_{5\text{-}20} = F_5 - F_{20}$$

- Results presented here are for frequency of holes of 1 mm or greater.



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Equipment Types

- 24 Equipment types in the IOGP guidance.
- Some of these are based on very few incidents and have been excluded from this study
- 19 types included in this study
- Many are grouped from the original taxonomy which has 120 equipment types. E.g. Manual valves are a combination of 10 types and size categories.

VALVEMANUAL_BLEED	VALVEMANUAL_BLOCK_D3 VALVEMANUAL_BLOCK_3D11 VALVEMANUAL_BLOCK_D11
VALVEMANUAL_CHECK_D3 VALVEMANUAL_CHECK_3D11 VALVEMANUAL_CHECK_D11	VALVEMANUAL_CHOKE_D3 VALVEMANUAL_CHOKE_D11 VALVEMANUAL_CHOKE_3D11

- Steel Piping
- Flexible Piping
- Flanged Joints
- Manual Valves
- Actuated Valves
- Instrument Connections
- Process Vessels
- Process Vessels (Other)
- Centrifugal Compressors
- Reciprocating Compressors
- Centrifugal Pumps
- Reciprocating Pumps
- Heat Exchangers (HC inside shell)
- Heat Exchangers (HC inside tube)
- Plate Heat Exchangers
- Pig Traps
- Filters
- Turbines
- Xmas Trees

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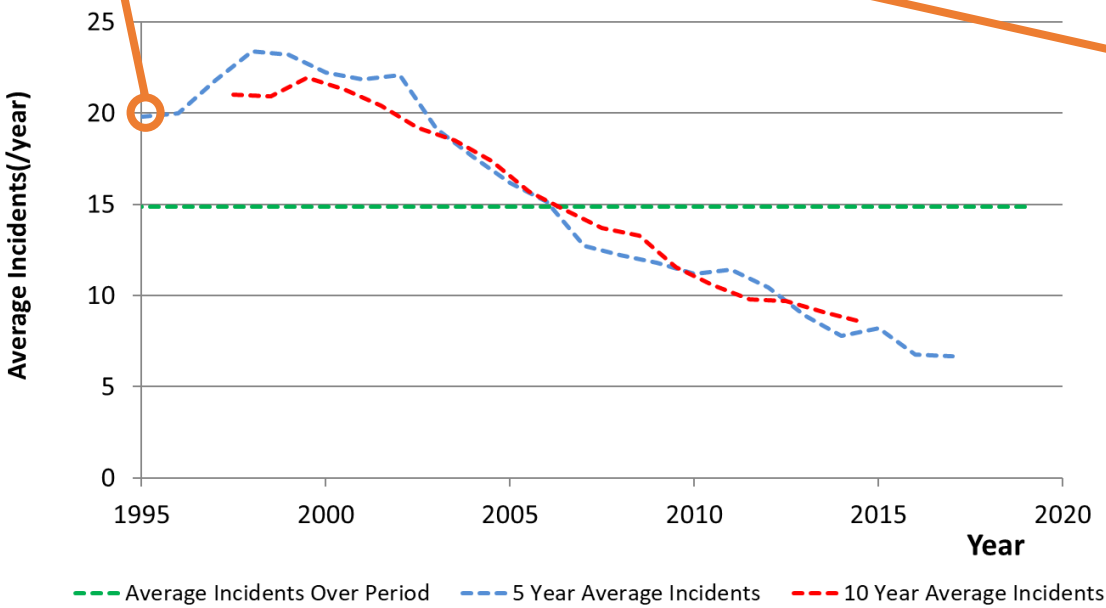
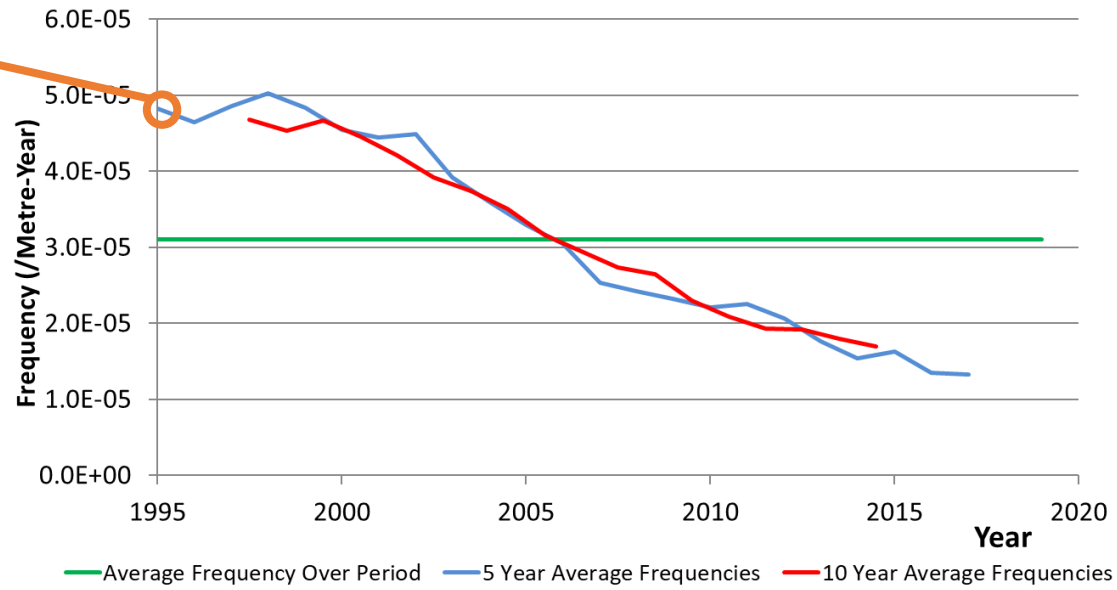
Trending Analysis (Steel Pipework Example)

- In the 5 year period 1992-1997 there were 99 recorded leaks from steel pipework with a hole size of 1 mm or more.
- 19.8 leaks per year
- Population in that period is 2,051,014 metre-years
- Frequency = 99/2051014 = 4.82×10^{-5} per metre-year





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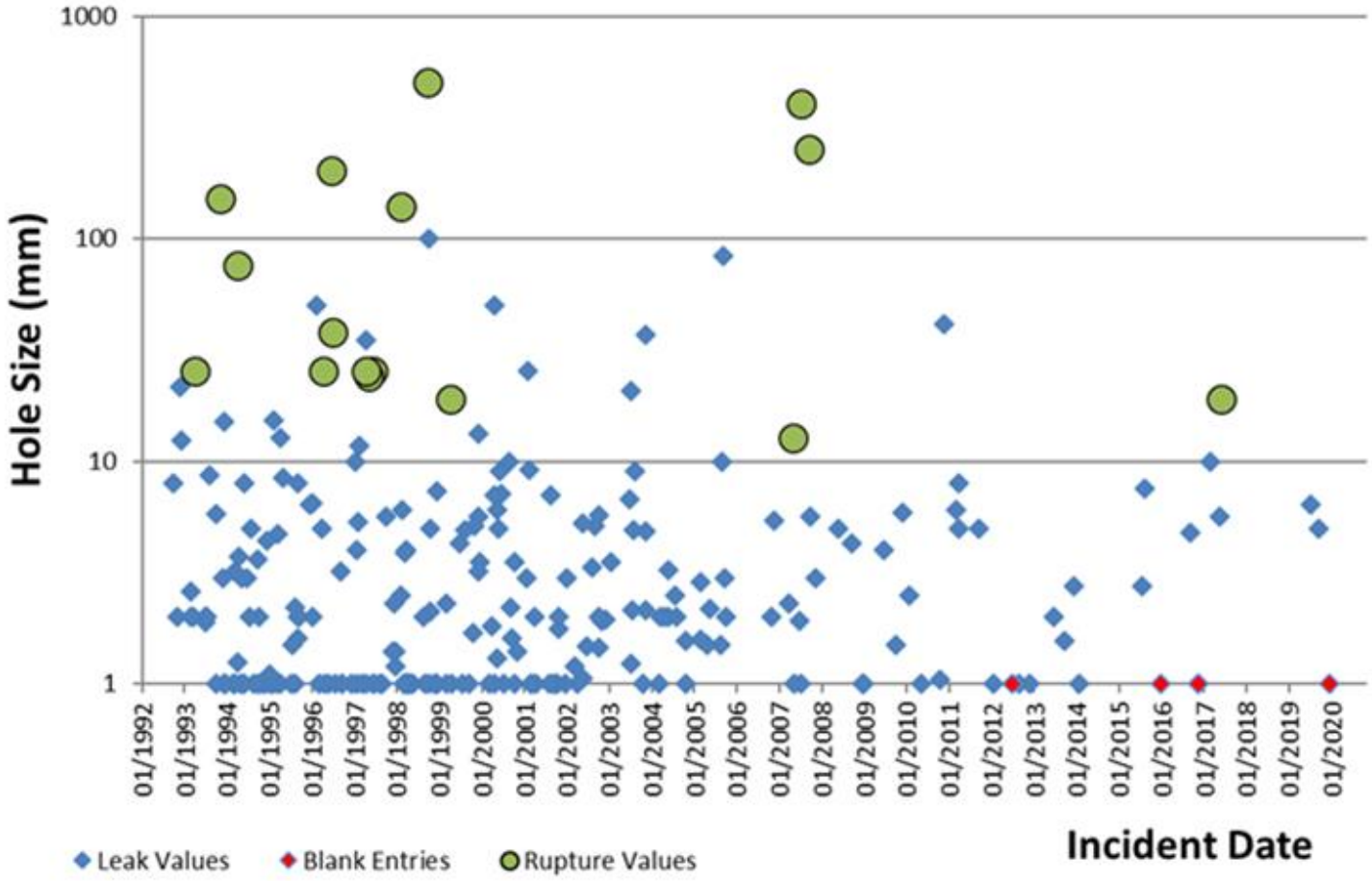
Scatter Plots

- The full study report provides additional plots showing the dates and sizes of releases.
- “Rupture” cases are those where the reported hole size is >90% of the equipment size.
- Example shown is for flanged joints



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Typical Results – Steel Piping

Steel Piping

Overall Average Incidents:

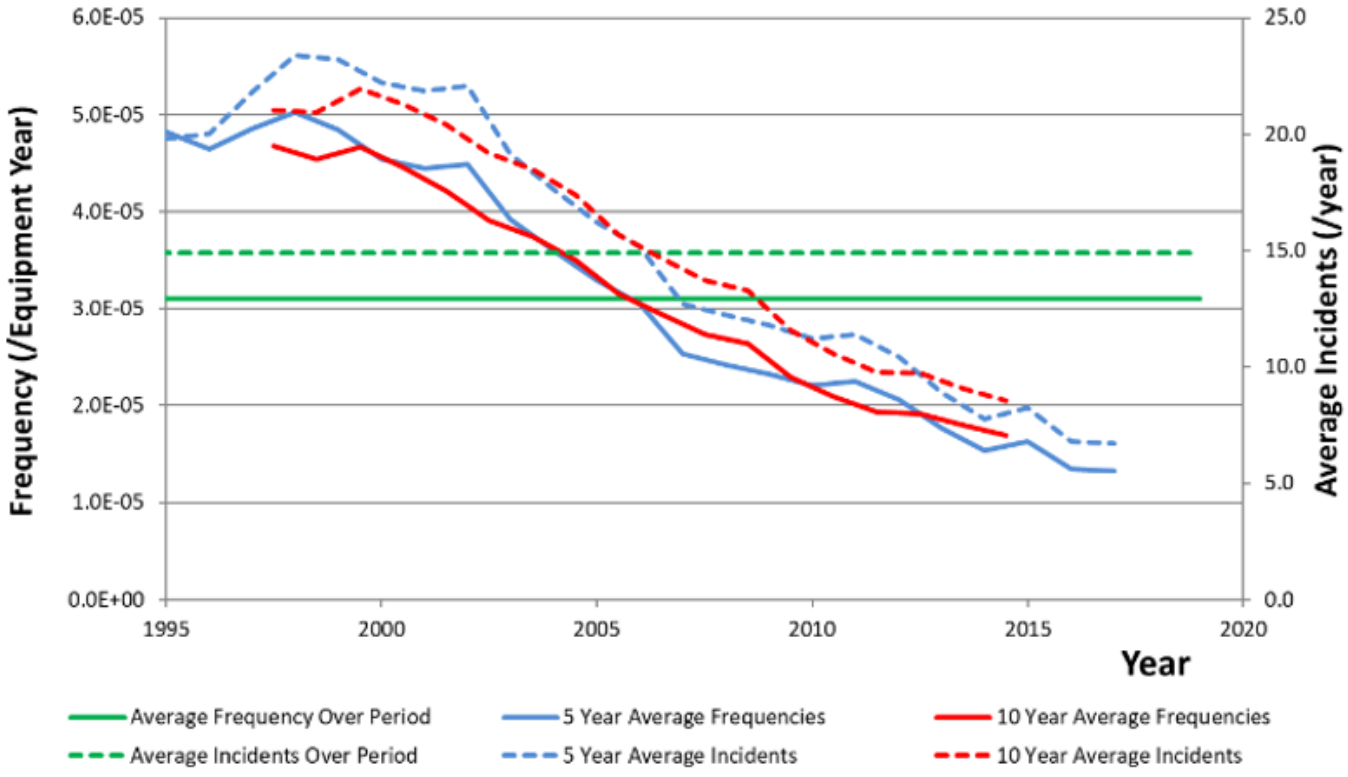
14.88/year

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%



Lines for incidents and frequencies follow similar trends but are not scaled versions of each other because of the effect of varying populations.

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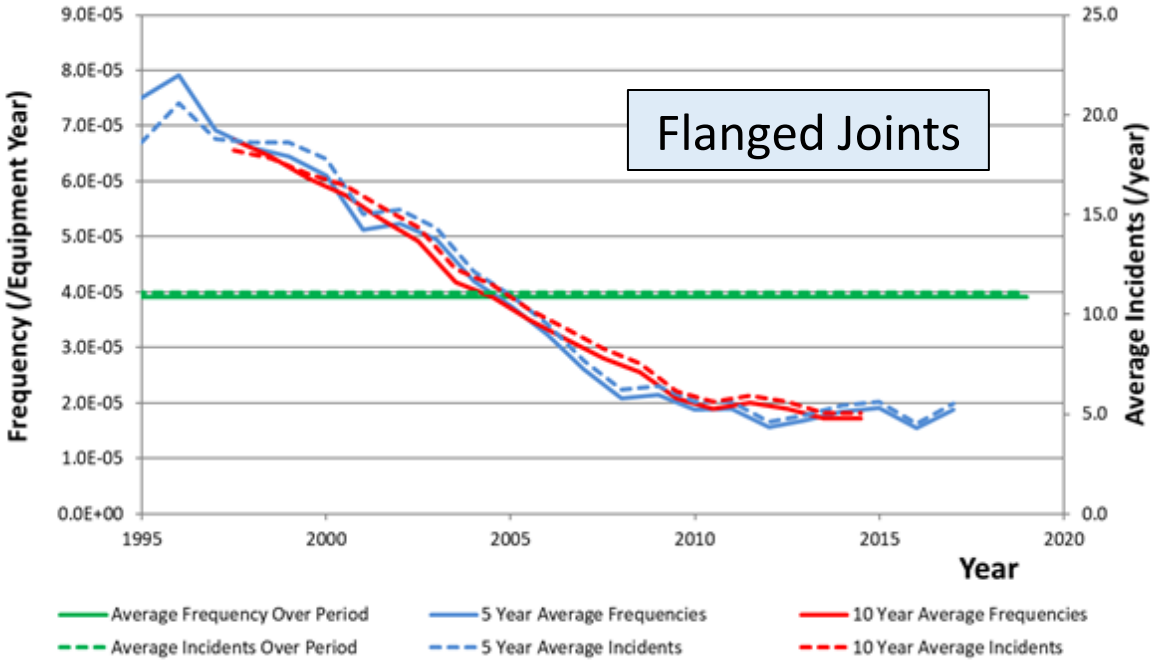
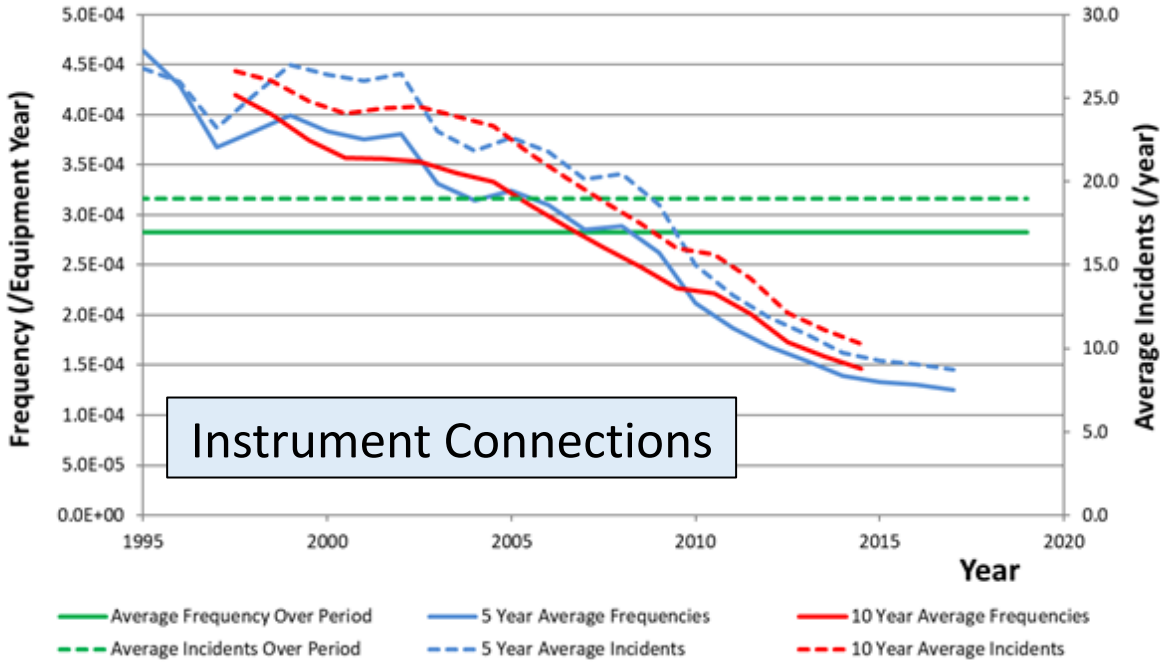
Flanges and Instrument Connections

- Flanged joints and instrument connections are also significant contributors to the overall leak frequency on offshore installations.
- They exhibit similar downward trends





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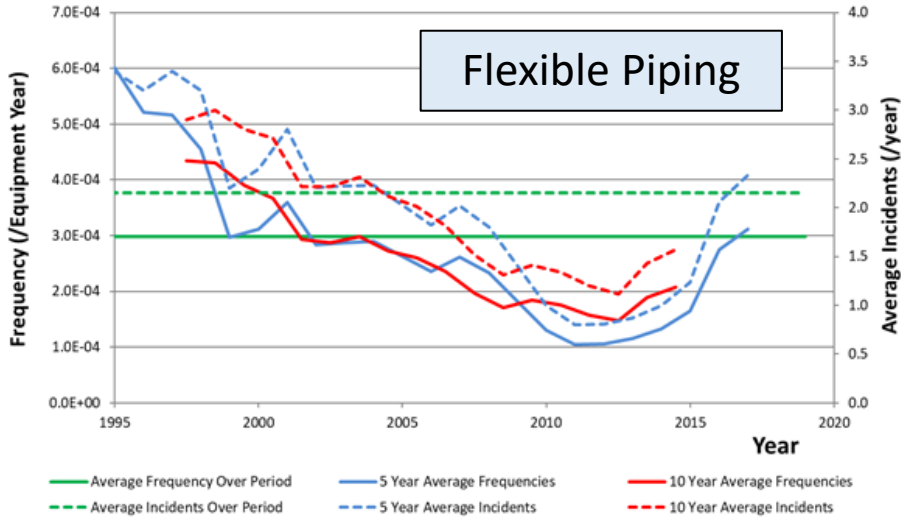
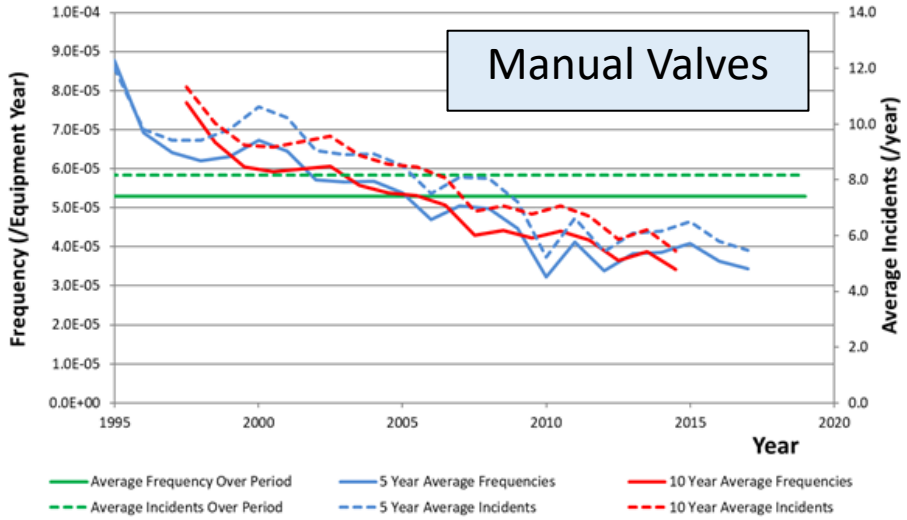
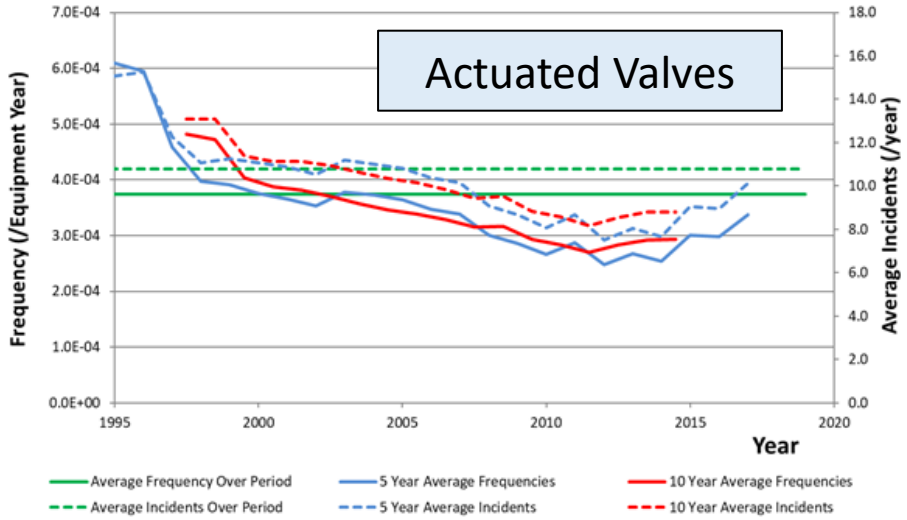
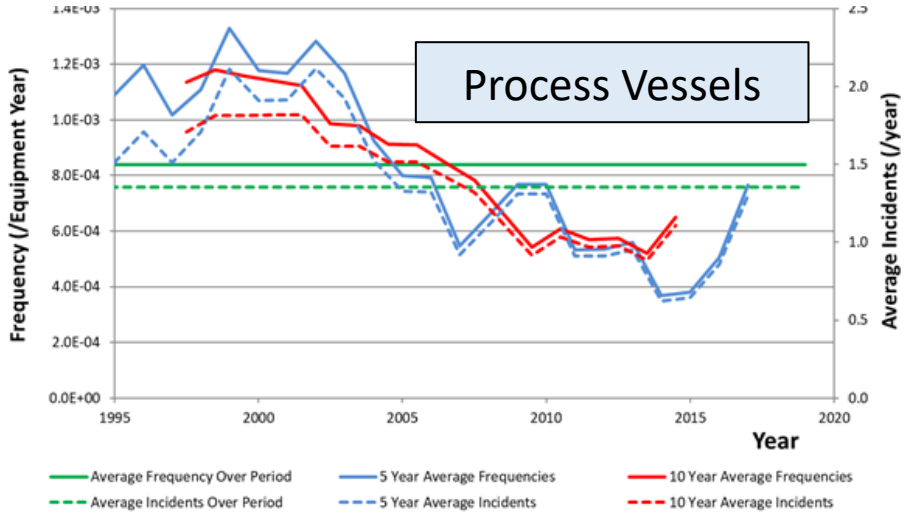
Other Equipment Types#1









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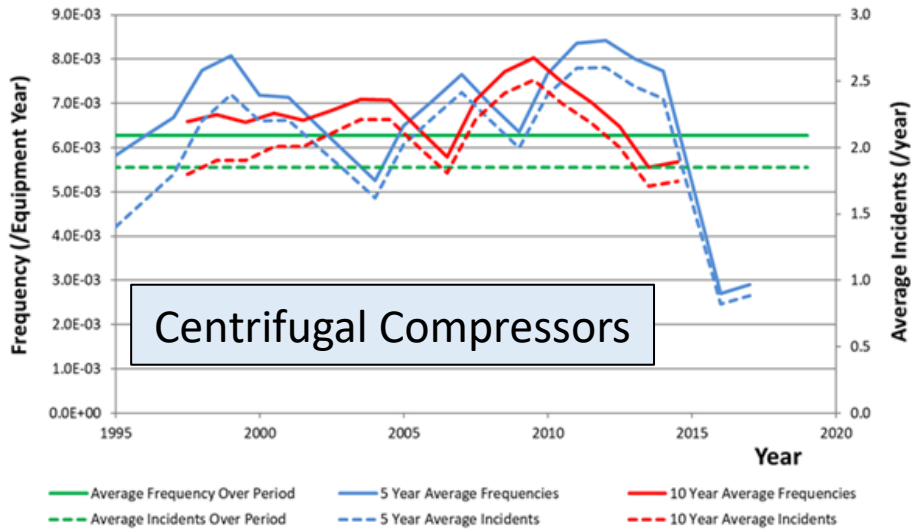
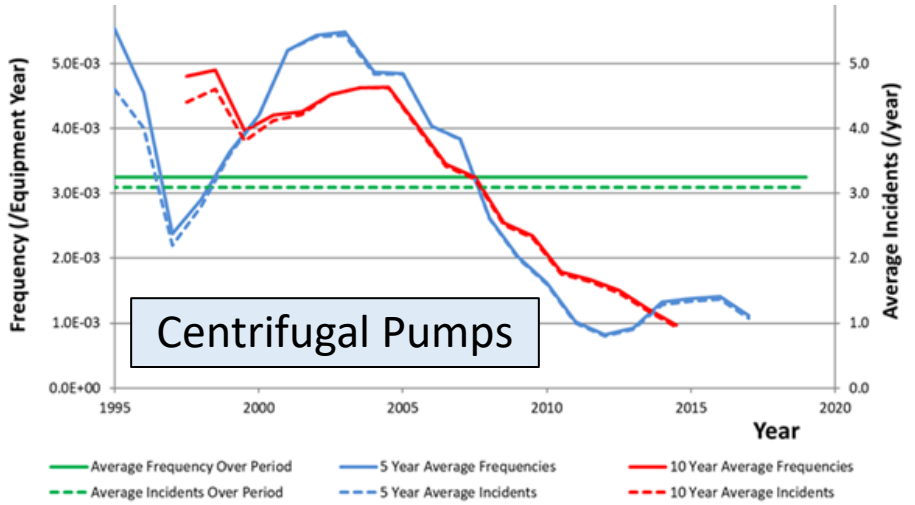
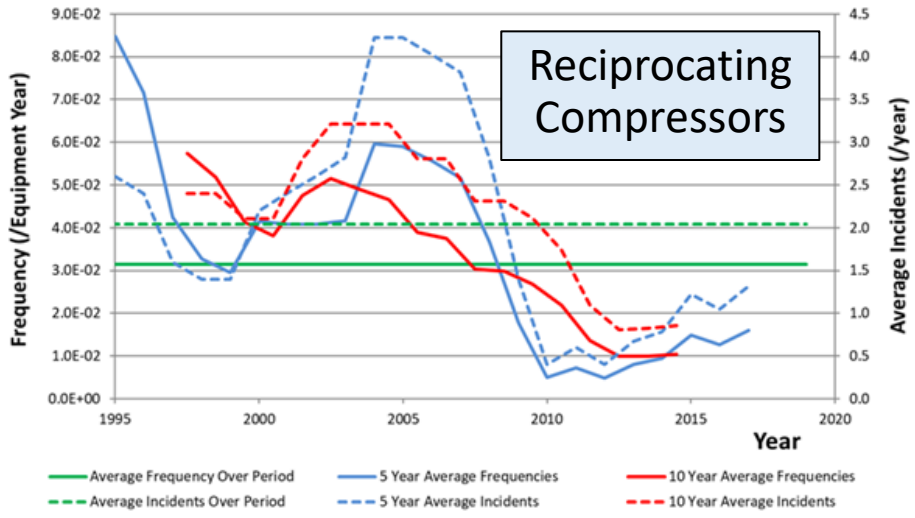
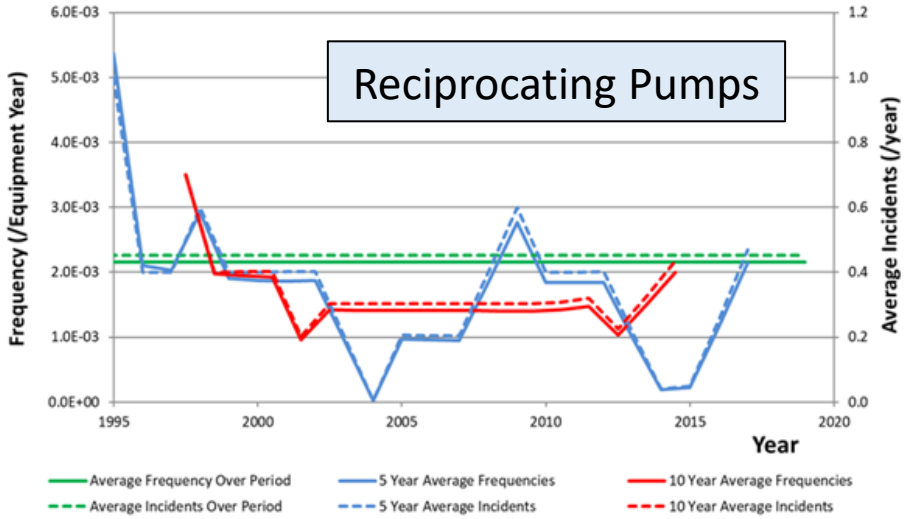
Other Equipment Types #2









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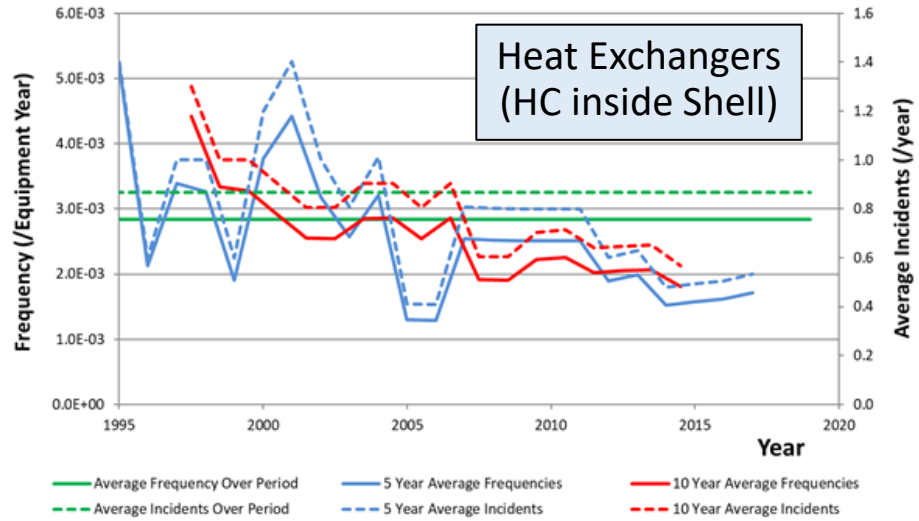
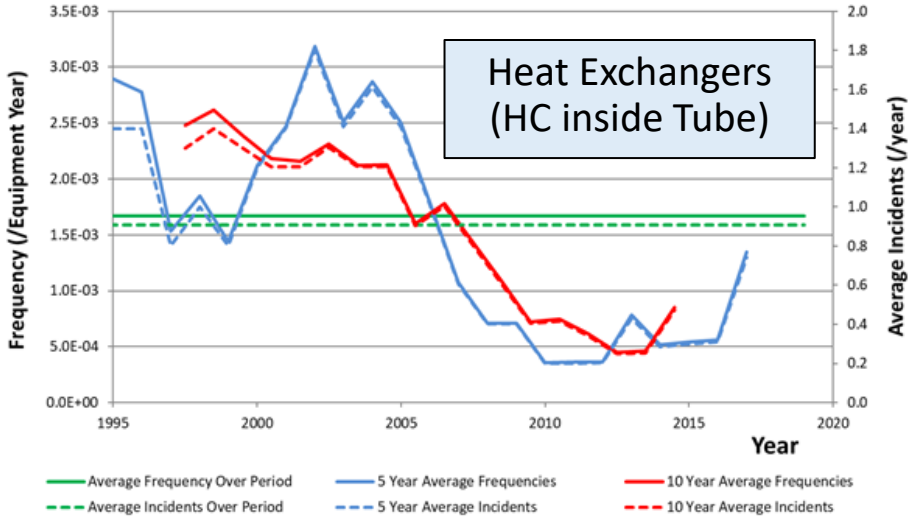
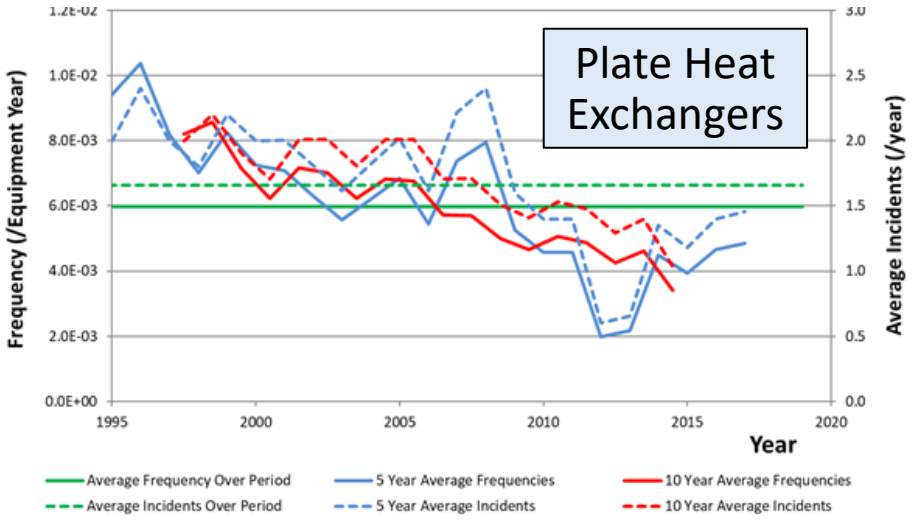
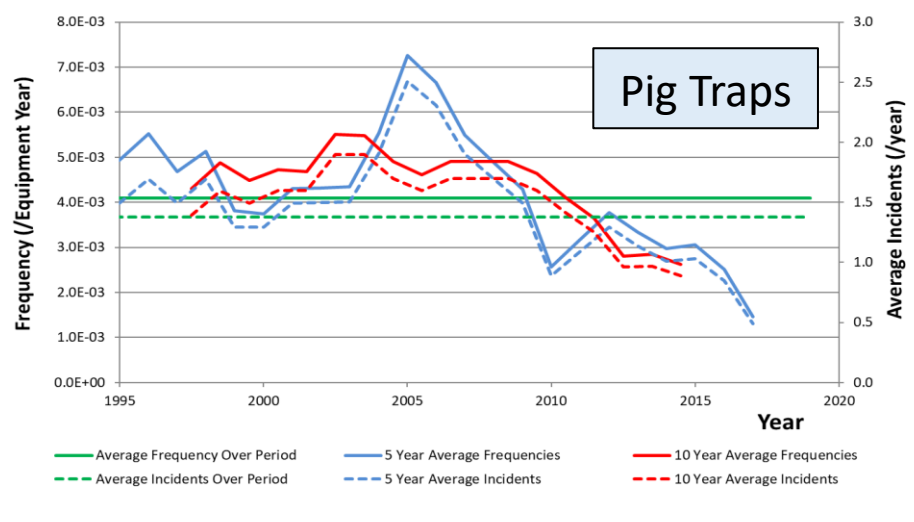
Other Equipment Types #3









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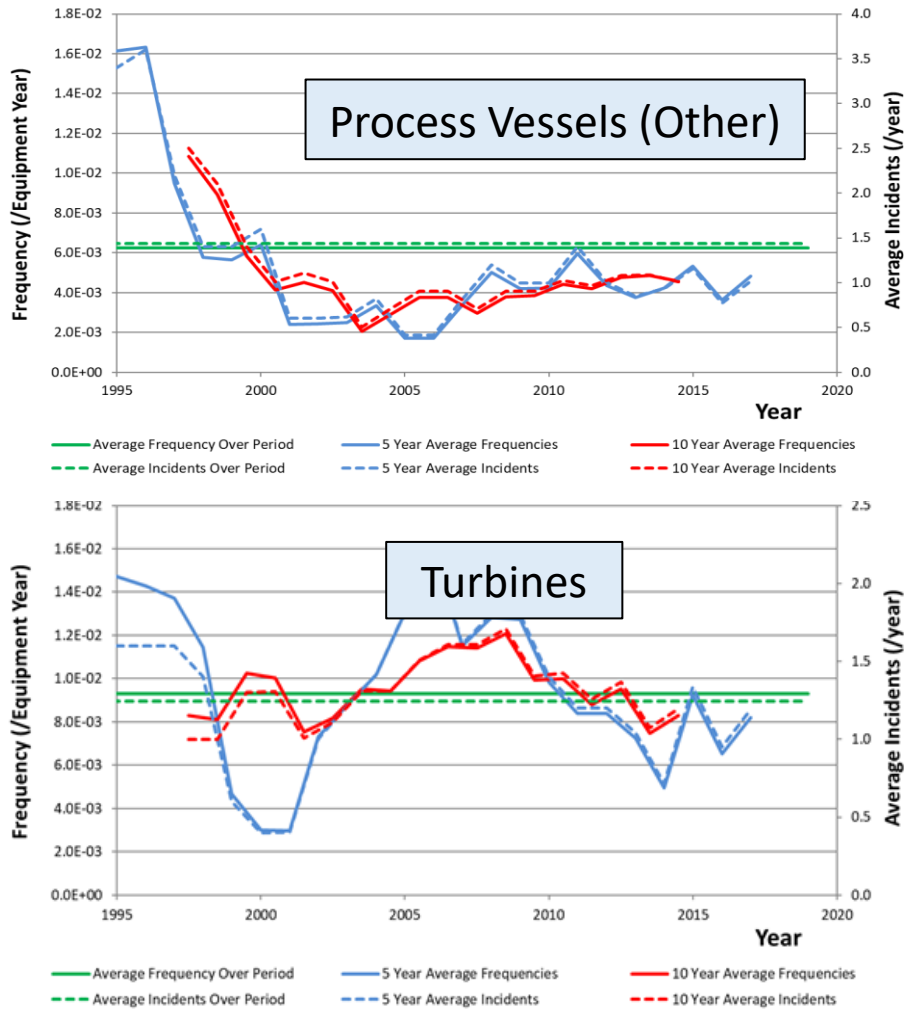
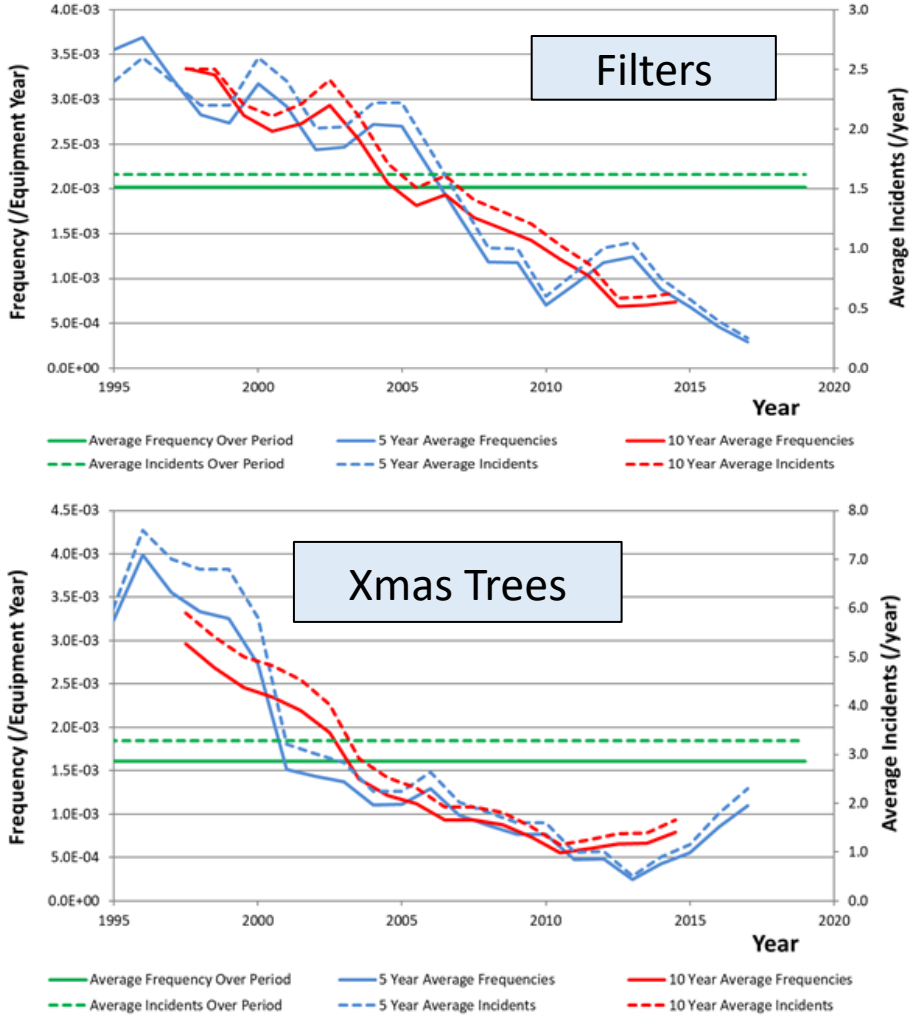
Other Equipment Types #4





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Relative Reductions

- As a single value representative measure to describe the overall trend, the ratio of the most recent 10-year running average frequency compared with the overall frequency was calculated.
- Results are shown ranked in order of the greatest reductions.
- "Recent Trend" is categorised by subjective judgement of the last part of the trend lines;
  - Continuing Decrease
  - Recent Decrease
  - Level
  - Increasing
  - Significantly Increasing

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

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Conclusions & Recommendations#1

- 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.
- Frequencies for equipment items with few incidents will tend to fluctuate more but this is likely to be the result of stochastic variation.
- There is greater uncertainty in the overall reduction value for equipment types with low populations and/or number of incidents.
- 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.

Conclusions & Recommendations#2

- 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.
- The overall frequency across all equipment types has plateaued in recent years and results for some equipment types indicate an increasing frequency.
- The population data on which the analysis is based only extends up to 2015. It has been assumed that the population has remained constant for all equipment types in the period 2016–2019 inclusive. If the population has actually decreased this could be masking increases in failure frequencies of more types of equipment.
- 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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For further discussion on the results of the study please contact Brian Bain (brian.bain@dnv.com)

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