DNV·GL

OIL & GAS

Existing Leak Frequency Model Experiences, Possibilities, Challenges

ERSA Norge Seminar , Ingeniørenes hus

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26. Mars 2014

Content of presentation

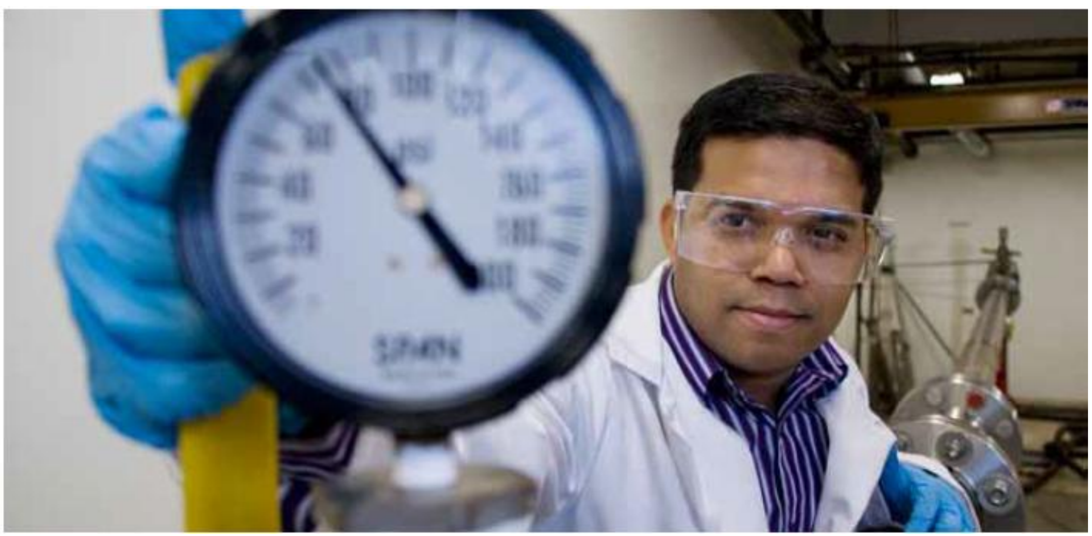
- Background
- HRCD data
- How does the model work
- Uncertainties
- Experiences
- Focus ahead

Current Leak frequency Model

- The work initiated in 2003 resulted in a JIP report issued in its final version in 2005

- During autumn 2008 the frame agreement contractors were invited to complete this work and agree on a common technical basis.
  - A final report was delivered in Mai 2009
  - Involvement from Statoil, DNV, Scandpower, Safetec and Lilleaker

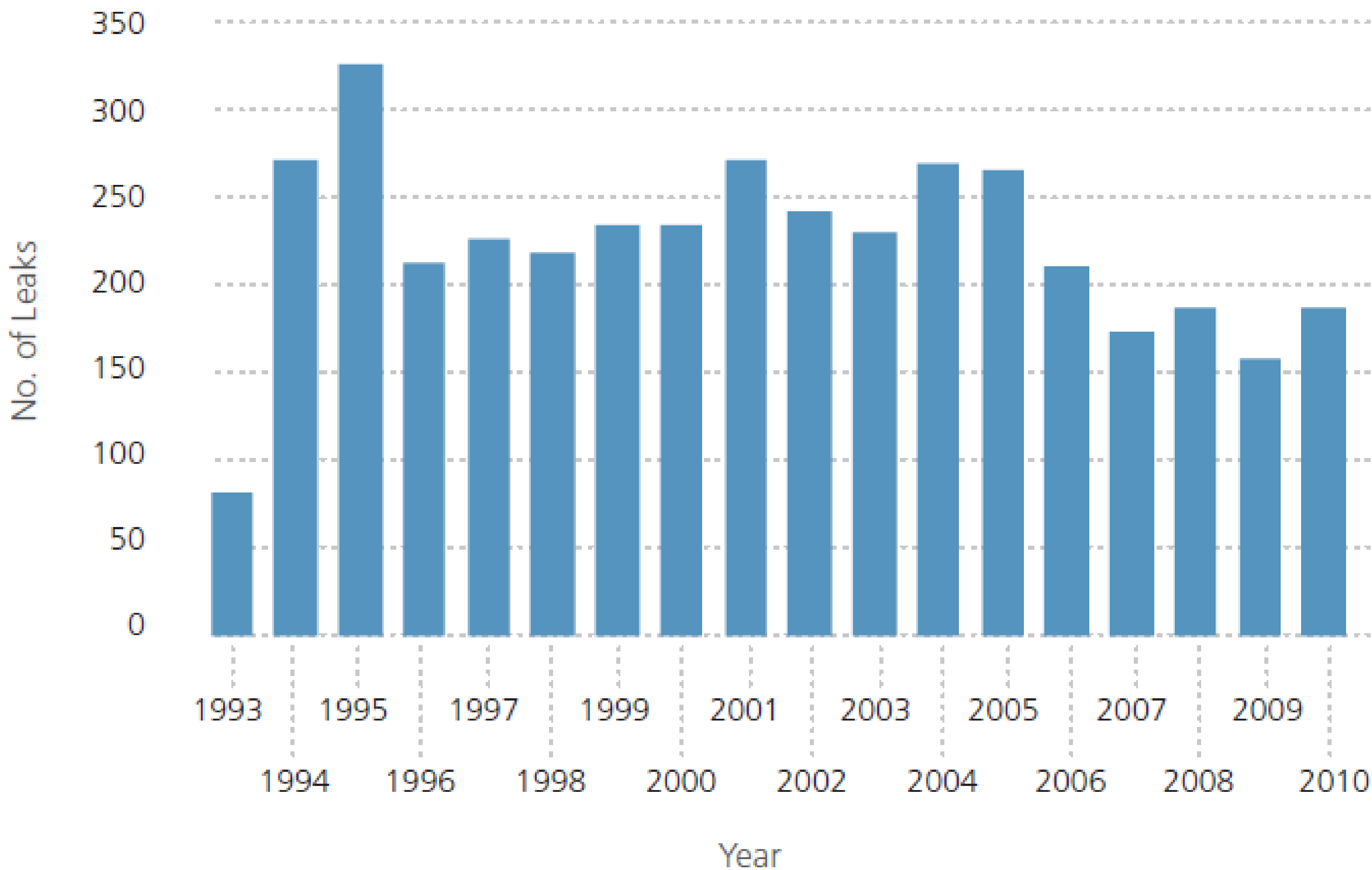
- The report was updated in Dec. 2010



HCRD

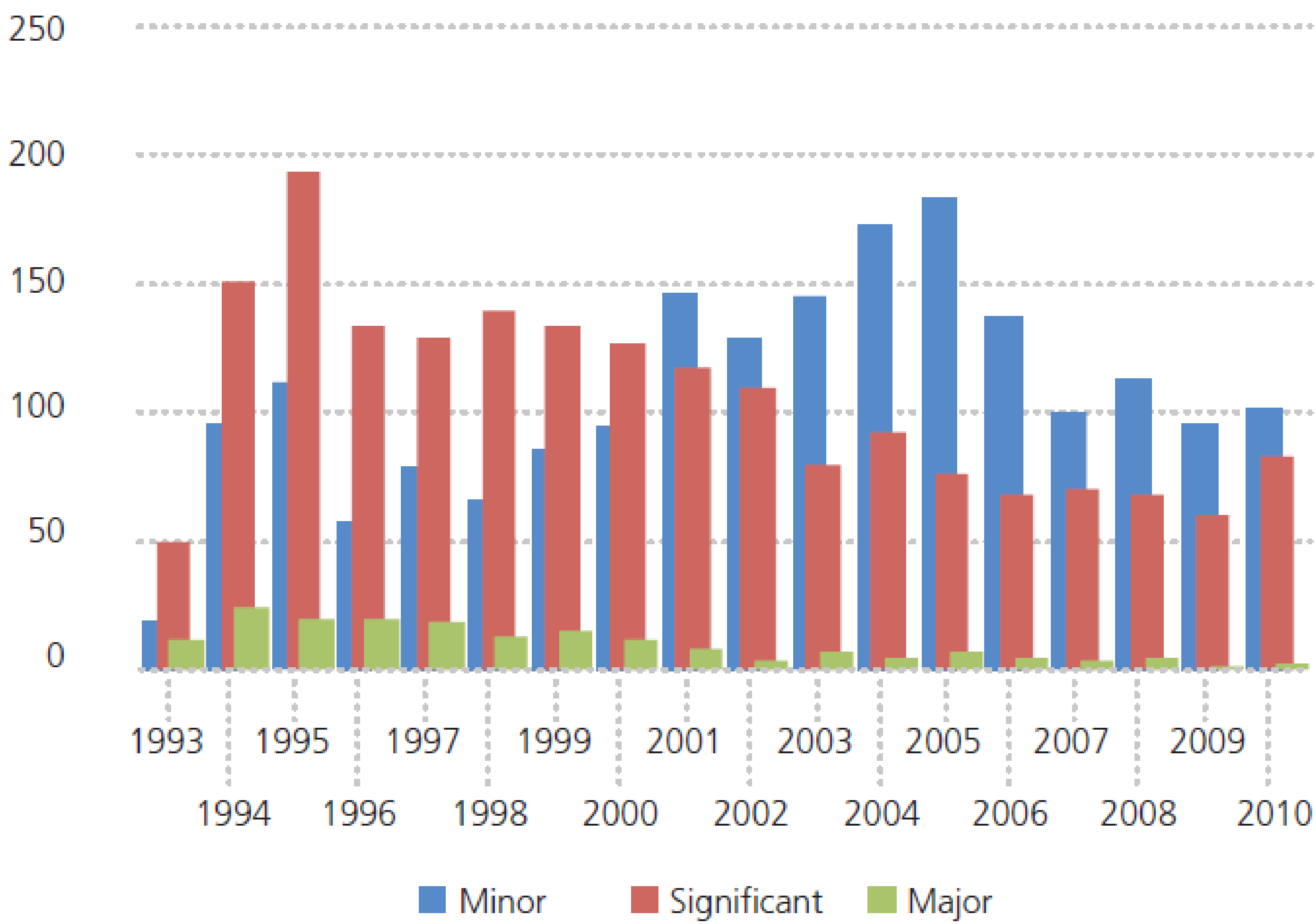
- HCRD
  - Database of all offshore hydrocarbon leaks reported to UK Health and Safety Executive (HSE) since 1992.
  - Complete reporting – regulatory requirement
  - More than 4000 leak events covering
  - 100 equipment types.
  - Supported by equipment population database
- Wide recognition of HCRD
  - Used for analysis of installations around the world
  - Regarded as the most complete source of historical leak frequency data.

Number of Leaks per year, HCRD 1992-2010



Source: Hydrocarbon release reporting and statistics, 2012

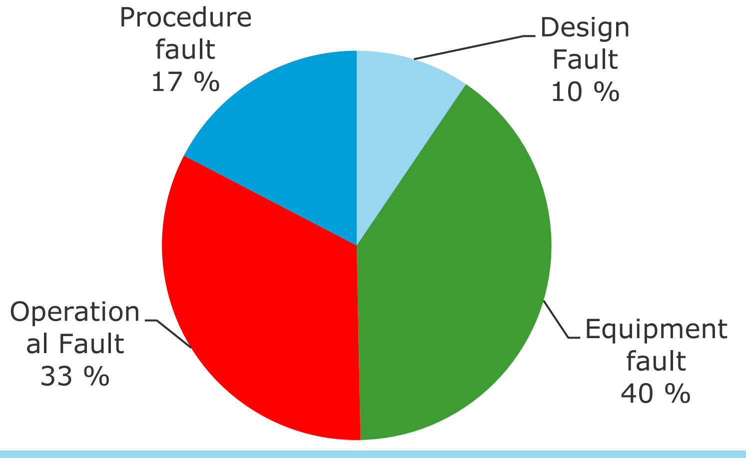
Number of Leaks per year, HCRD 1992-2010



Source: Hydrocarbon release reporting and statistics, 2012

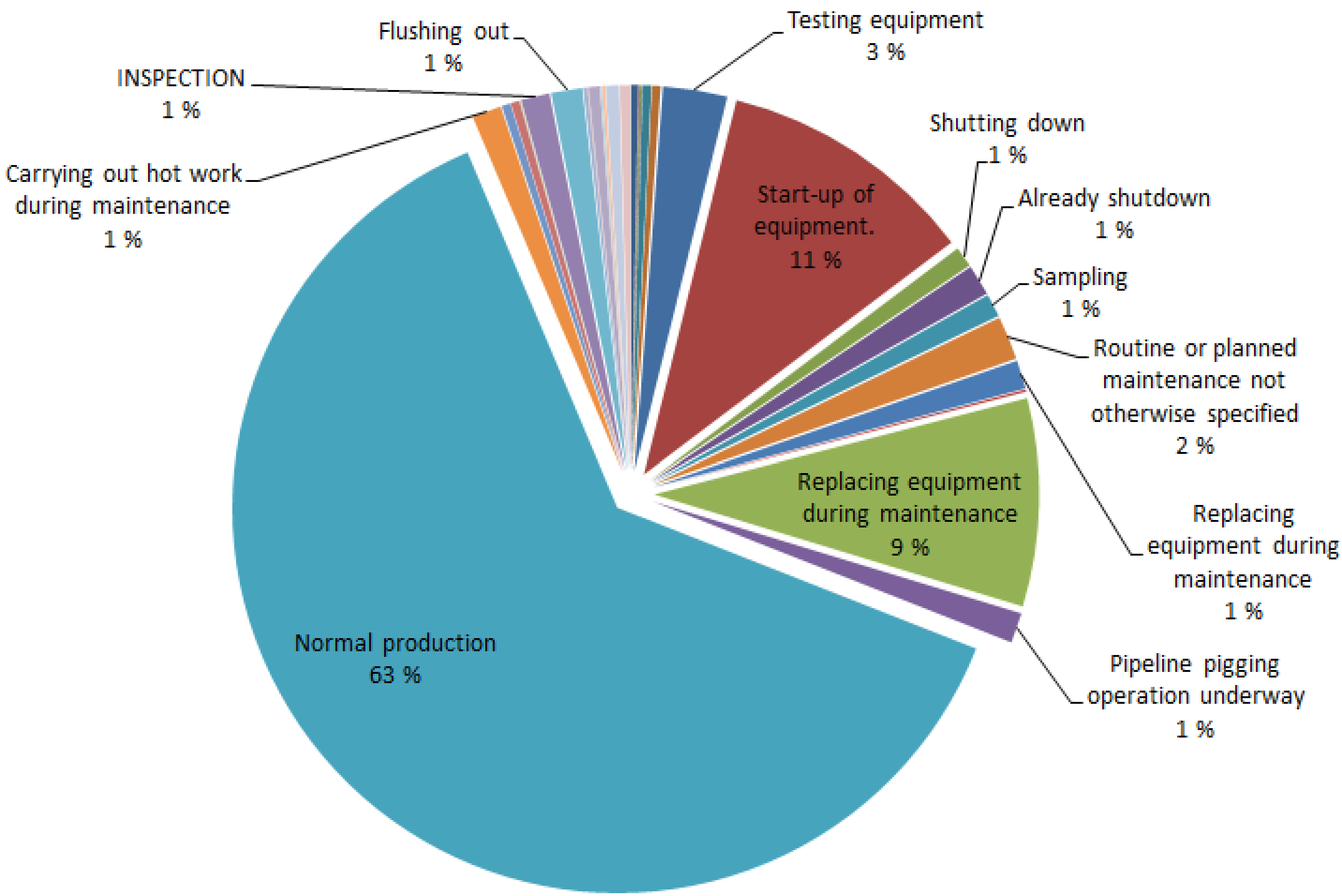
Causation factors in HSE offshore data

Category	Causation Factor	Instances	Category Totals
Design fault	–	321	321
Equipment Fault	Corrosion/Erosion	277	
	Mechanical Defect	920	
	Material Defect	76	
	Other	89	1362
Operational Fault	Incorrectly fitted	267	
	Improper Operation	495	
	Dropped/Impact	36	
	Left Open/Opened	237	
	Other	81	1116
Procedural Fault	Noncompliance	231	
	Deficient Procedure	323	
	Other	34	588



Source: Hydrocarbon release reporting and statistics, 2012

Operational Mode



Source: HCRD Database 1992-2010,

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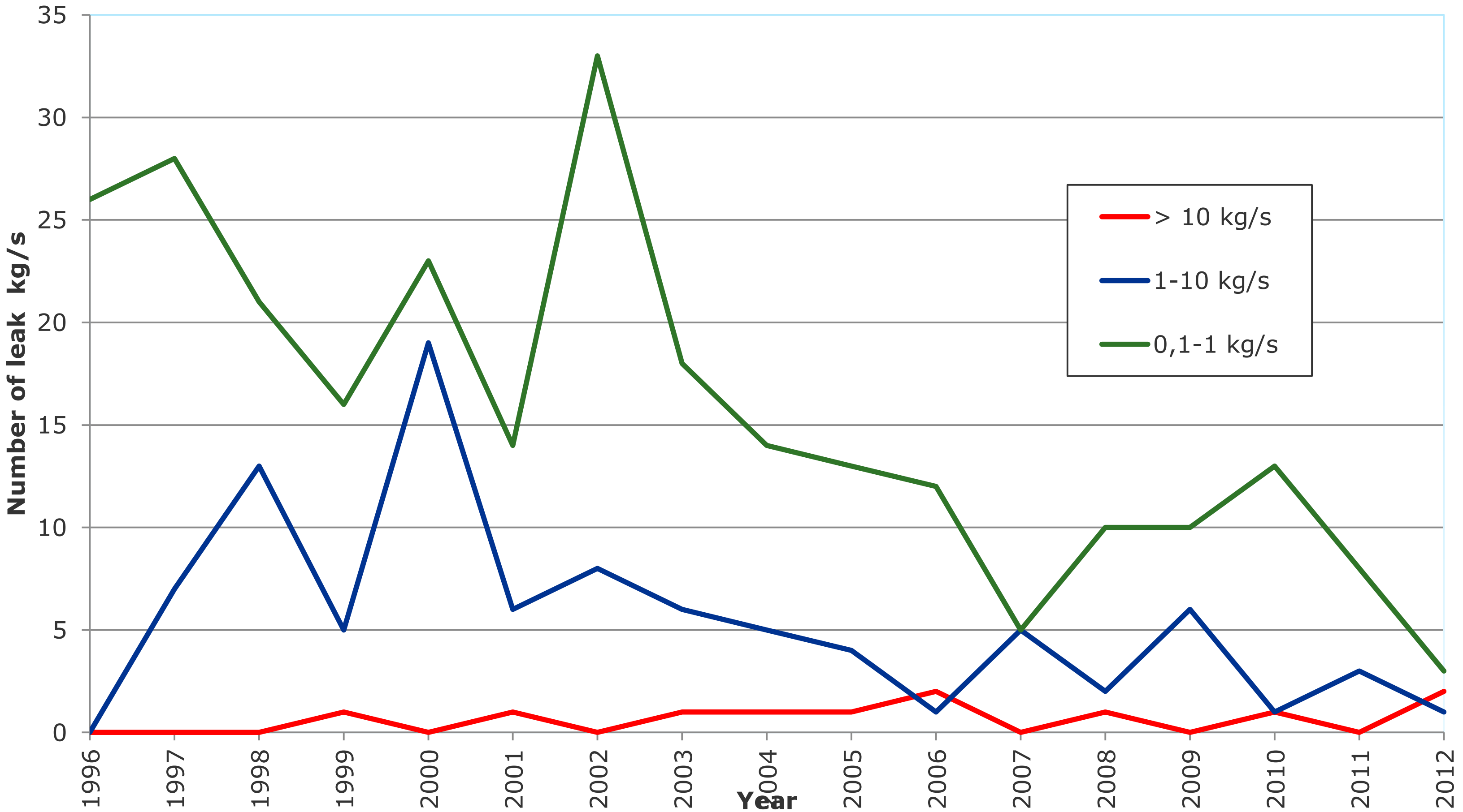
North Sea Hydrocarbon leak Trends



Source: PSA Trends I Risk level summary report 2012

General Approach

The methodology for obtaining leak frequencies from HCRD consists of three main steps:

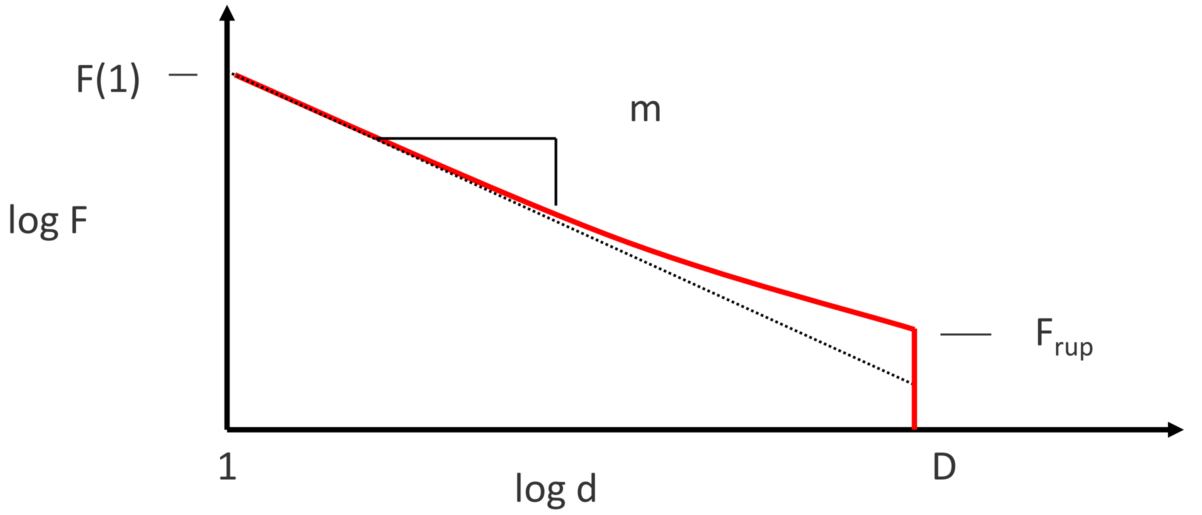
- ***Grouping data*** for different types and sizes of equipment, where there is insufficient experience to show significant differences between them.
- ***Fitting analytical leak frequency functions*** to the data, in order to obtain a smooth variation of leak frequency with equipment and hole size.
- ***Splitting the leak frequencies into different leak scenarios***, in order to promote compatibility with different approaches to outflow modelling in the QRA.

Grouping of Data

- HCRD allow 78 separate types and sizes of process equipment to be distinguished
- In some cases, there is relatively little leak experience,
- No statistical significance in leak frequencies between certain types and sizes of process equipment
- Such results may be misleading
- To avoid this, it is desirable to combine equipment types and sizes with relatively little leak experience.

DNV equipment type	HCRD equipment types
Steel pipes	Piping, steel (3 sizes)
Flanged joints	Flanges (3 sizes)
Manual valves	Valve, manual (10 types & sizes)
Actuated valves	Valve, actuated (18 types & sizes)
Instruments	Instruments (including connect-ing tubing, valves and flanges)
Process vessels	Pressure vessel (14 types)
Atmospheric vessels	Vessels at atmospheric pressure
Centrifugal pumps	Pumps, centrifugal (2 seal types)
Reciprocating pumps	Pumps, reciprocating (2 seal types)
Centrifugal compressors	Compressors, centrifugal
Reciprocating compressors	Compressors, reciprocating
Shell side heat exchangers	Heat exchangers, HC in shell
Tube side heat exchangers	Heat exchangers, HC in tube
Plate heat exchangers	Heat exchangers, plate
Air cooled heat exchangers	Fin fan coolers
Filters	Filters
Pig traps	Pig launchers & pig receivers (4 sizes)

Leak frequency function.



$$F_d = Cd^m\left(1 + aD^n\right) + F_{rup}$$

F(d) = frequency (per year) for holes larger than d

D = Equipment diameter

m = Slope parameter

F_{rup} = Additional frequency for rupture

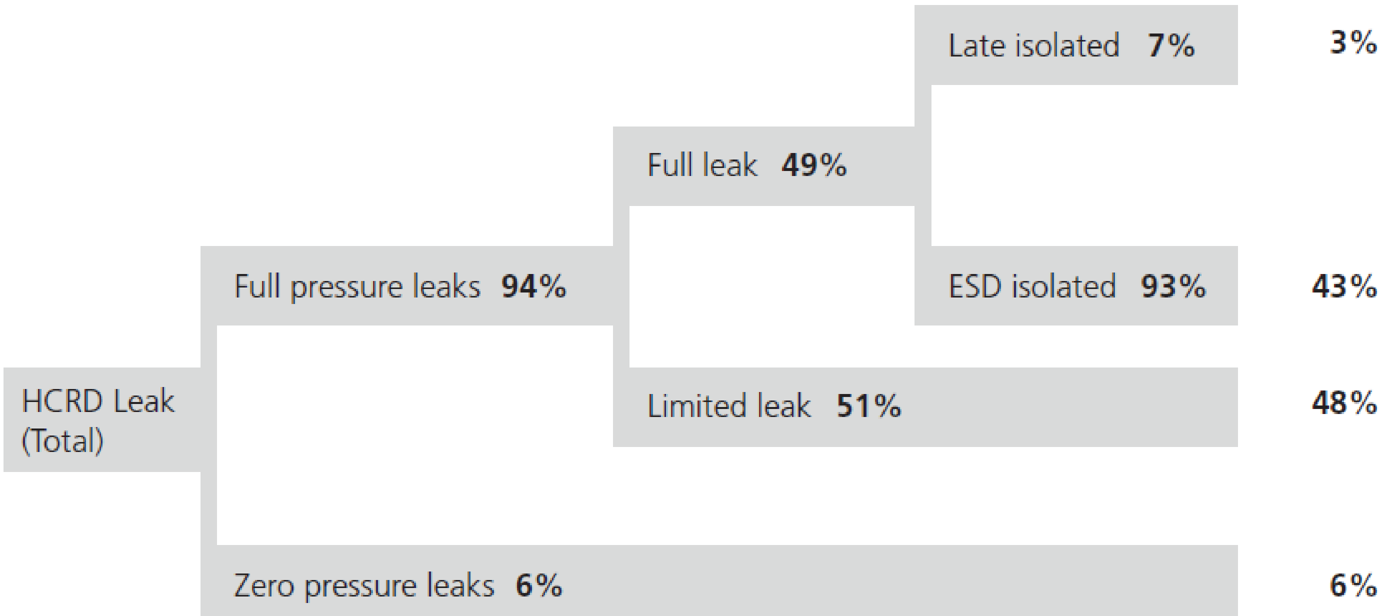
C,a,n = Constants for each leak type leak type

Uncertainties in applying curve to data

Leak Scenarios

- Experience shows that when using all data from the HCRD to establish leak frequencies, the calculated leak frequencies of released quantities above a given magnitude are found to be higher than actually experienced.
- An examination of the data shows that some of the leaks have occurded when the pressure in the systems is virtually zero
- Thus, in order to promote compatibility with different approaches to leak outflow modelling in the QRA, the existing method divides the leaks in HCRD several scenarios divided into 2 main scenarios;
  - **Full pressure leaks**
  - **Zero pressure leaks.**

Leak Scenarios



Release Type			Total	GAS LEAK	OIL LEAK	CONDEN-SATE LEAK	2-PHASE LEAK	NON-PROCESS
Zero Pressure leak			6%	6%	7%	7%	2%	8%
Full pressure leak	Limited leak		48%	33%	75%	64%	67%	53%
	Full leaks	ESD isolated	43%	57%	16%	27%	30%	36%
		Late Isolated	3%	4%	2%	2%	1%	3%
Total			100%	100%	100%	100%	100%	100%

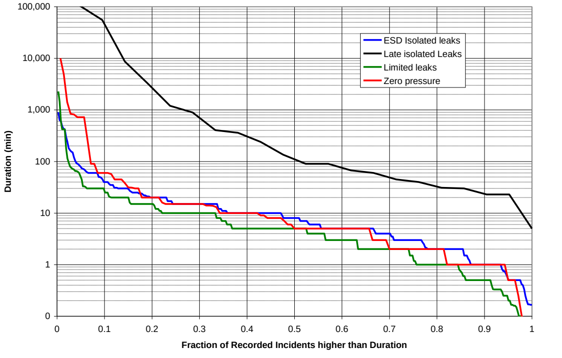
Full pressure leaks

- *Full leaks* :
  - consistent with QRA models beginning at the normal operating pressure, until controlled by ESD and blowdown, with a small probability of ESD/blowdown failure.
- *Limited leaks,*
  - cases where the outflow is less than from a leak at the operational pressure controlled by the quickest credible ESD (after 30 seconds) and blowdown (according to API) initiated 60 seconds later.
  - This is presumed to be cases where there exist restrictions in the flow from the system inventory, as a result of local isolation valves initiated by human intervention or process safety systems other that ESD and blowdown

Estimation of Reduced Leak Duration for Limited Leaks

- Given the above conclusion, the reduced leak duration for limited leaks is estimated based upon the differences between the curves in the normalised duration

$$D_L = \frac{D_F}{R}$$



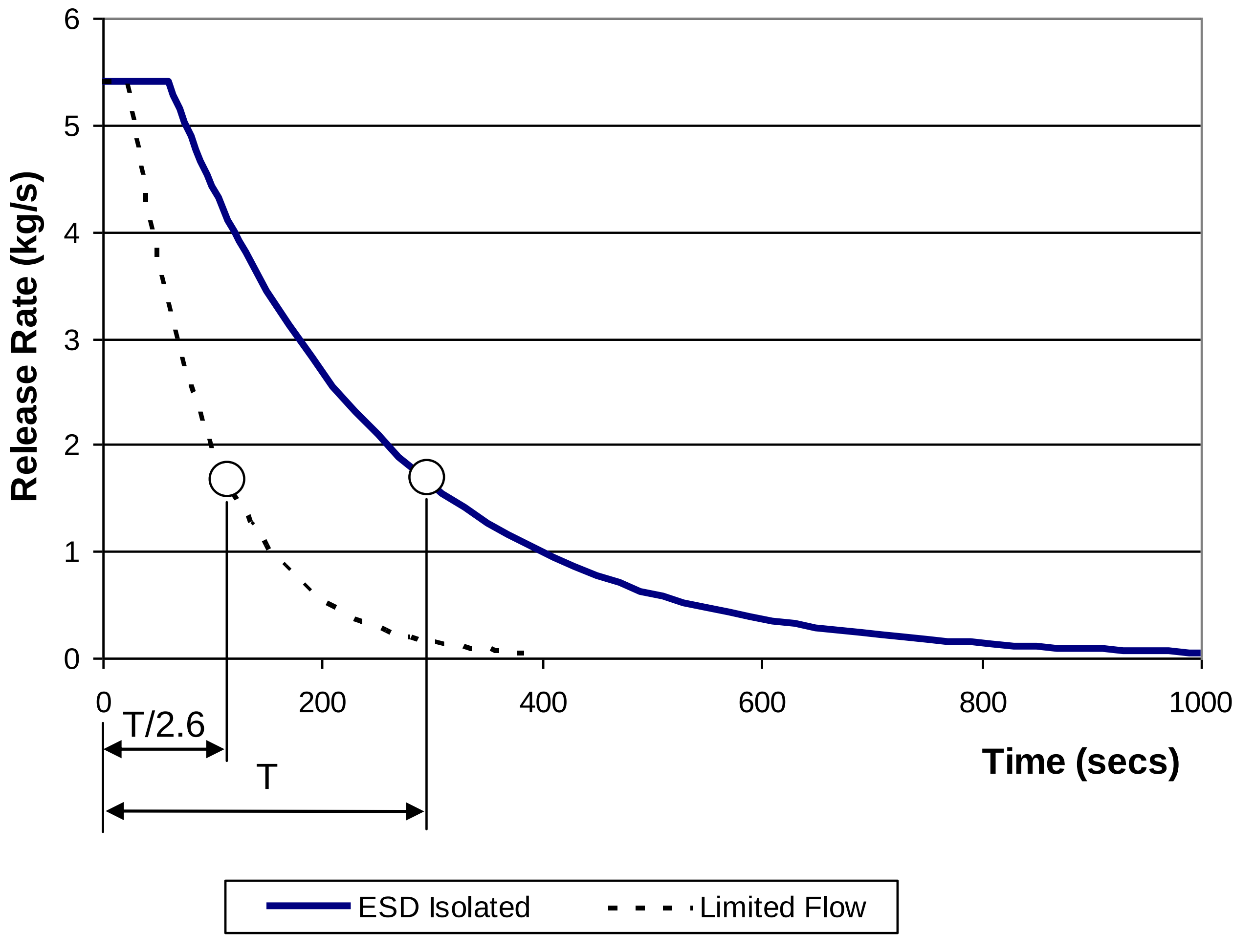
Where

DL	=	Leak duration Limited leaks
DF	=	Leak duration full leaks
R	=	Time reduction factor

Time reduction factor

Leak duration	Gas	Oil	Condensate	2-Phase	Non-Process
Time Factor	2.6	1.7	2.6	7.1	2.3

Application of Time Reduction Factor for a Gas Leak



Zero pressure leaks

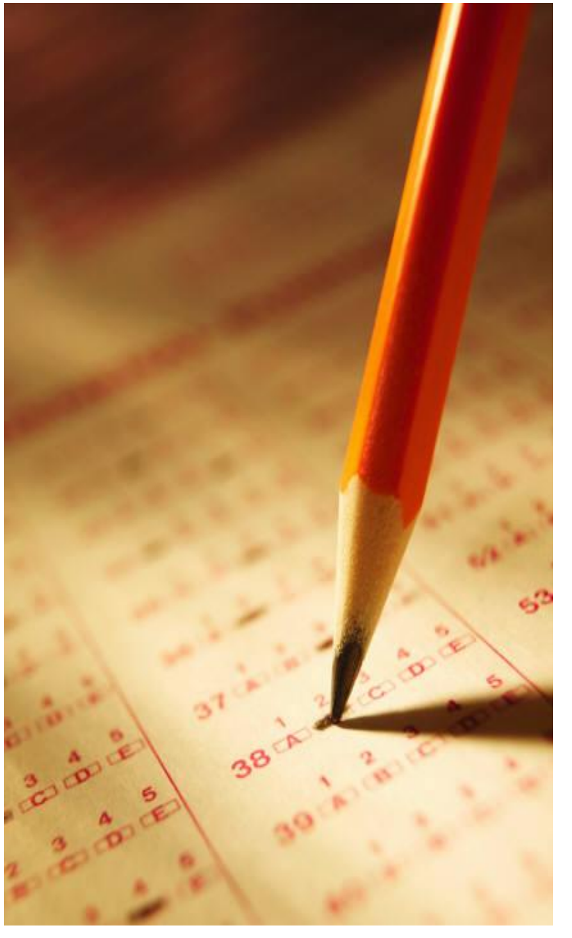
- This scenario includes all leaks where the pressure inside the leaking equipment is virtually zero (0.01 barg or less).
- This may be because the equipment has a normal operating pressure of zero (e.g. open drains), or because the equipment has been depressurised for maintenance.
- These leaks may typically be very small gas releases, short lasting oil spills, or liquid releases from atmospheric tanks.
- These leaks should be modelled separately,

Piping

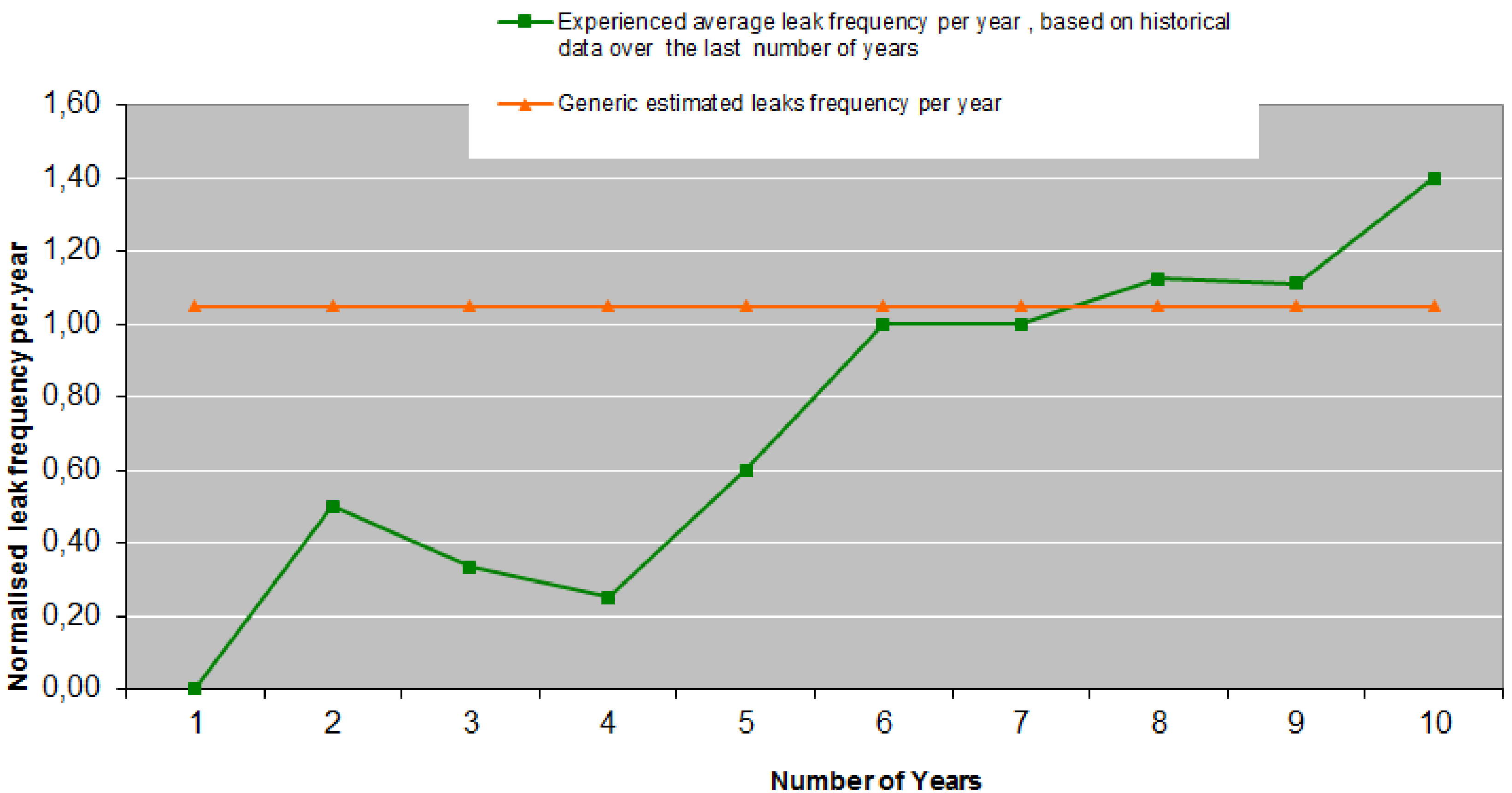
- The generated leak frequency from piping is high compared to other equipment.
- The fraction of piping leaks recorded in the HCRD and from Norwegian sources was found not to be significantly different.
- A comparison of the number of meters of piping per flange recorded in the HCRD database was compared to a count on three FLACS models representing installations on the Norwegian continental shelf.
- It was concluded that the recorded number of leaks was reasonable, while the recorded exposure data was underestimated.
- **it was therefore concluded to give a specific guidelines for obtaining the leak frequency from process piping until the above issues has been resolved.**

Uncertainties

- Incorrect or lacking information in HCRD.
  – # Leaks > 100 mm hole size
- Inaccurate exposure data registered by HCRD
  – Specially piping is a concern
- Inappropriate categorisation of the leaks into the different scenarios.
- Inappropriate representation of the leak frequency distributions by the fitted leak frequency distributions.
- Phase transition of the medium during a leak. There is uncertainty about how this is handled in the HCRD database

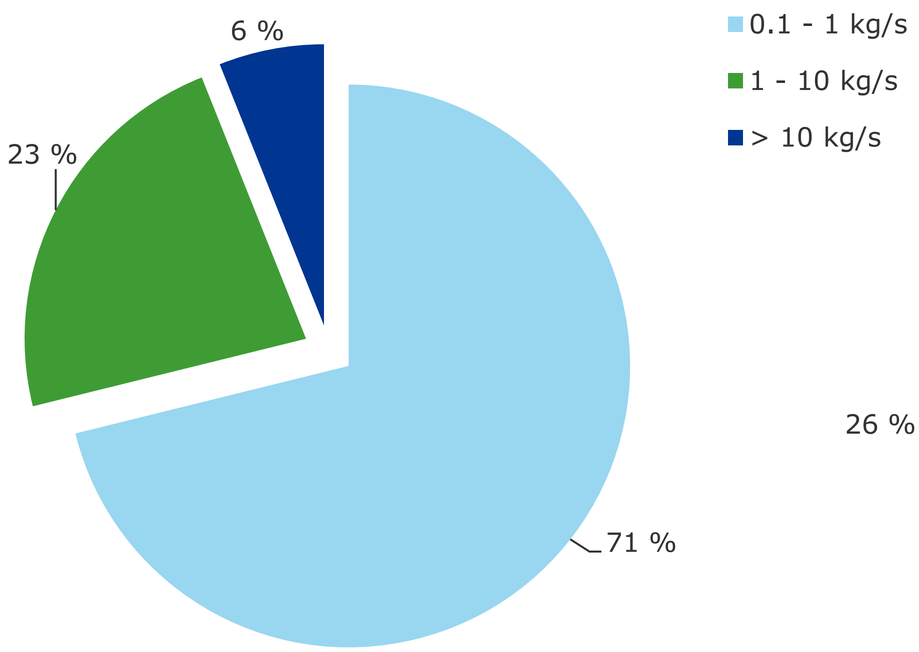


How well do does the Model predict the leak frequency

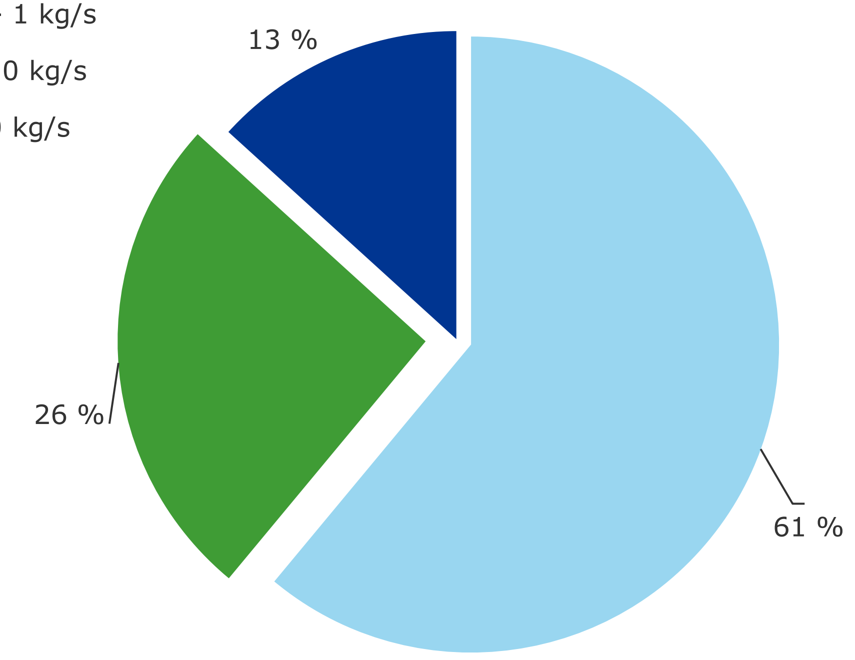


Example of results DNV GL project work

Distribution of leaks between leak sizes



NCS Leaks 2003-2012



Typical estimated distribution

Modelling of Large leaks

- Higher focus on modelling of high consequence low frequent events
- NORSOK Z013 annex F suggest leak rates up to 2000 kg/s
- Challenging to modell consequences for these leaks due to high transients
- The frequency function seems to give too high frequencies for rupture cases with impact on
  - Fire & Explosion risk
  - Design Accidental Loads
  - Safety functions

Summary of Experience

- The general picture is that in a 7-10 year perspective, the estimated number of leaks > 0.1 kg/s fits well with the experienced level.
- The RNNP report from PSA shows however that the number of leaks on the NCS the last years has stabilised on a level which is lower than the previous years
- In addition, the RNNP report shows that the number of leaks on the NCS is somewhat lower that the corresponding number of leaks at the UKCS
- By using UK data on NCS you should therefore expect an overestimation of the leak frequencies, but DNV GL has not seen such a pronounced trend. This may be due to uncertainty in the exposure data
- The uncertainty in the piping frequencies for “Large leak” has a significant impact on the risk results.
- The model seems to over predict the number of large leaks

Focus ahead #1

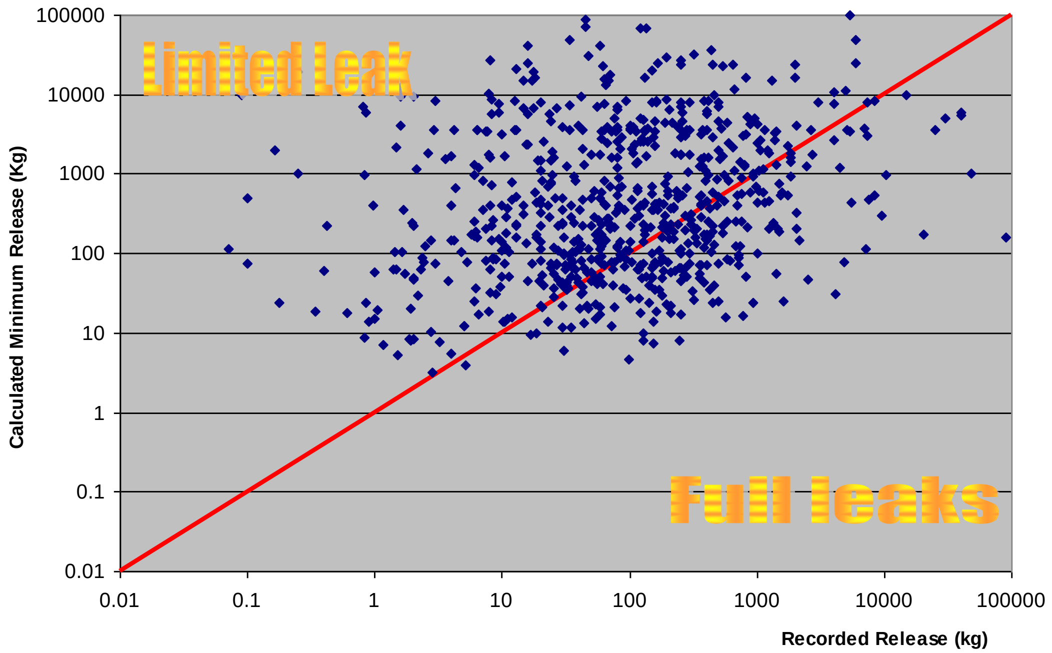
- In general, DNV GL believes that the best solution and approach is to continue the previous work, and improve/update the methodology in areas expected to have an improvement potential.
- Focus should be set on issues where the uncertainty is largest
  - Fraction of Large Leaks
  - Limited and full pressure leaks
  - Leak frequency of process piping
- HSE have more data which we do not have access to through the database

Focus ahead #2

- Data
  - The current model uses data from 1992-2010. Expanding up to 2014 it will cover more than 4000 leaks
  - The number of leaks has however decreased and by using average leak rates from the last 22 years we may overestimate the leak frequency
  - By decrease the number of years, we get challenges related to number of leaks per equipment type
  - We should therefore discuss how many years to use as basis for the data and whether there should be introduced any trending
- Fraction of Large leaks
  - We should discuss changes to the leak functions in order to predict more correct number of large leaks. DNV GL is however in the opinion that the functions is rather good in the areas of which we have data, meaning between hole sizes 2-100 mm
- Piping
  - The uncertainty related to the piping has previously been assessed as high and an update should therefore include a discussion related to this issue

Focus ahead #3

- One of the main issues with the model and the area which has been most discussed is the split between Limited and Full leaks
- The update should include a discussion related to potential improvement.



Calculated minimum release volume compared with recorded reduced number of incidents. Reduced number of incidents (892)

What about operational issues

- DNV GL is of the opinion that models such as the OMT model will provide added value to specific analyses or where detailed information of the operational impact is important or needed.
- DNV GL is however concerned whether integrating the OMT model is suitable in proportion to the effort required and whether the QRA as a decision support tool, will benefit from this.
- QRA's are complex models with challenges with respect to traceability. DNV GL are concerned that adding even more complexity to the process will reinforce the challenges related to traceability.

Thanks !

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