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Report

The HCR Database – Its Potential for use at Above Ground Gas Facilities

RIVM

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MANAGING RISK

The HCR Database - Its Potential for use at Above Ground Gas Facilities	DET NORSKE VERITAS LTD, UK Highbank House Exchange Street Stockport, SK3 0ET United Kingdom Tel: +44 161 477 3818 Fax: +44 161 477 3819 http://www.dnv.com Org. No: GB 440 6013 95
For: RIVM	
Account Ref.:	

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Summary:

A summary of the HCRD is given together with some frequencies derived from the data that may be used for other applications.
RIVM is considering different ways to establish release frequencies for high pressure above ground gas piping in the Netherlands for external land use planning purposes. The frequencies are restricted to piping and flanges. One of the sources being considered is the use of the HCRD (offshore release data gathered by the UK Health and Safety Executive). This report examines the derivation of release frequencies from this source. The conclusion is that HCRD could be used to derive frequencies for hole sizes up to 100mm diameter, but would not provide a robust basis for hole sizes above this size.

Prepared by:	*Name and Position* Phil Crossthwaite Chief Specialist	*Signature* P J Crossthwaite
Verified by:	*Name and Position* B Bain Principal Specialist	*Signature* Brian Bain
Approved by:	*Name and Position* Phil Crossthwaite Chief Specialist	*Signature* P J Crossthwaite

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3	Amendments, further comments from RIVM and reviewer.	PXC	BB	JT	PXC

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CONCLUSIVE SUMMARY

The Hydrocarbon Releases Database (HCRD) contains detailed information on offshore hydrocarbon release incidents in the UK Continental Shelf from 1992. The data in HCRD are considered to be of high quality because of the detail in the reporting form, although doubts in the accuracy of the population data have been expressed. Reporting, although voluntary, is considered to be largely complete; under reporting is likely to be restricted to small releases or releases through small holes, and as such is not particularly relevant to the present work. Although the releases in HCRD are from equipment offshore, the definition of the system where the release occurred and the mode of failure enable the selection of both systems (equipment) and failures that are likely to occur onshore. Indeed, failure modes which might be regarded as 'offshore only' are relatively minor in number and tend to give small rather than large holes. On this basis it is considered that HCRD can be used as a basis to derive leak frequencies for piping and flanges on onshore plant including gas treatment plants and compressor stations.

Three different approaches have been considered in this work to derive release frequencies from HCRD:

- Frequencies given in the standard reports produced by HCRD.
- Frequencies calculated by DNV's current interpretation of HCRD.
- Frequencies calculated following extraction and use of relevant gas releases from HCRD.

The frequency given in the standard report from HCRD is a simple division of the number of recorded releases for a specified system by the experience with that system (population). All releases, including very small releases which are not relevant for this study are included in the frequency derivation. The number of releases in one of the three defined severities of release is given and a separate report gives the number of releases in pre specified hole size ranges; it is not possible to derive frequencies for user specified hole size ranges from the standard reports.

DNV's current interpretation of the HCRD to derive release frequencies was carried out recently for Statoil in order to determine a consistent set of frequencies for use in their offshore QRAs. The release frequencies for different types of equipment in the database were derived by the use of a standard shaped curve which was fitted to the data, so that frequencies for specified hole size ranges can be determined. It is always assumed that a full bore failure is possible for equipment such as piping or flanges.

If the data in HCRD that DNV considered relevant for gas piping onshore (i.e. data which are specific for 'gas' releases from 'piping' and 'flanges' and which exclude data from systems that are either not considered relevant (e.g. drains, vents etc) or do not contain population data, e.g. pipelines), frequencies can be derived for holes (and any range of holes) up to 100mm diameter as the hole size is recorded in HCRD. Hole sizes above this are not recorded in HCRD, entries are merely '>100mm', so direct determination of a frequency and an associated hole size is not possible. A calculation for hole size can be carried out from other entries in HCRD. This indicates a different hole size distribution from that derived from the hole sizes recorded in HCRD. This difference reduces the confidence in the accuracy of the hole size distribution, but in the equipment considered for this study is relatively minor because of the concentration of hole sizes in the range less than 75mm diameter.

A comparison of the release frequencies derived from (a) the standard HCRD reports, (b) DNV's interpretation of HCRD and (c) release frequencies derived for relevant data with certain exclusions, is given in the table below. Comparison of the predicted frequencies using the different interpretations confirms the need to carefully specify the interpretation of the data as it can be seen that different interpretations give considerably different predictions for release frequencies.

Equipment	Size Range	Leak frequency from HCRD Average	Leak frequency from HCRD 95% confidence	Leak frequency from DNV Interpretation	Leak frequency from HCRD Average (10mm dia or more)	Leak frequency from HCRD 95% confidence (10mm dia or more)	Leak frequency from HCRD Average (75mm dia or more)	Leak frequency from HCRD 95% confidence (75mm dia or more)
Flanged Joint	D>11"	2.16E-04	2.99E-04	2.1E-04	1.7E-05	2.5E-05	No releases	1.24E-05
	3"<D<11"	1.77E-04	2.10E-04	1.0E-04	9.5E-06	3.8E-06	3.8E-06	5.98E-06
	D<3"	1.33E-04	1.52E-04	6.9E-05	9.9E-06	1.8E-06	1.8E-06	2.83E-06
Steel piping	D>11"	1.52E-05	2.65E-05	1.5E-05	3.4E-06	3.4E-06	3.4E-06	2.48E-05
	3"<D<11"	3.70E-05	4.69E-05	1.8E-05	5.3E-06	1.5E-06	1.5E-06	1.2E-05
	D<3"	1.28E-04	1.47E-04	4.3E-05	1.8E-05	3.3E-06	No releases	5.65E-06

Because of the lack of data for releases from large holes, (>100mm), use of HCRD to derive frequencies for hole sizes in excess of 100mm diameter (including full bore ruptures, for which there are no recorded releases) would require some form of statistical method or judgement. Consequently HCRD does not contain appropriate data to derive leak frequencies for hole sizes in excess of 100mm for piping and flanges on onshore plant including gas treatment plants and compressor stations.

1 INTRODUCTION

The Hydrocarbon Releases Database (HCRD) contains detailed information on offshore hydrocarbon release incidents in the UK Continental Shelf (UKCS) which is supplementary to that required under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR). The HCRD reporting scheme is voluntary, is based on the OIR/12 reporting form (see Appendix 1), and was set up by the UK Health and Safety Executive (HSE) in 1992 in consultation with industry in response to one of the recommendations made by Lord Cullen in his report on the Piper Alpha disaster. The data are stored on a web based system which became operational in 2003. Prior to that date statistical reports were produced annually by the HSE. Now, standard reports can be generated by duty holders and other authorised users.

1.1 Purpose.

The purpose of this report is to:
1. Give an overview of the HCRD, with a survey of the content that could be relevant for above ground gas facilities.
2. Examine the data to consider whether they may be used for the derivation of frequencies for pipelines and flanges on gas treatment plants and compressor stations.

1.2 Structure of the Report.

The HCR database is described in Section 2 and a brief overview of the facilities that will report leaks is given in Section 3. Three potential ways to derive frequencies are given in Section 4, with a brief conclusion in Section 5. Technical and other details are presented in the Appendices.

2 THE HYDROCARBON RELEASE DATABASE (HCRD)

HCRD contains details of reportable releases from quarter 4 1992 to 2010. The data after March 2008 is provisional due to late submissions and amendments. Reports are available for data from 1992/1993 to 2008/2009 and this period has been used in this report[1]. There are 4014 recorded releases in this period. The raw data comprises up to 75 information entries for each recorded release (see headings in Appendix 3). The data are entered following the completion of the reporting form (OIR/12 as given in Appendix 1). A summary of the database form etc that are relevant for the purposes of this study is given below.

2.1 Reportable Releases

A gas release is reportable if it is:

- A continuous release at a rate greater than 1 kg/h, nominally 20% lower flammable limit at 0.1m, or
- A discrete release with a total mass of greater than 0.1kg, or
- Ignition of the gas occurred, or
- Emergency action was required to prevent escalation.

The system is voluntary but it is considered that all releases which, if ignited, would have the potential to cause injury or damage outwith the immediate vicinity of the release would be included.

2.2 Severity Classification

Each release is categorised as either Major, Minor or Significant:

MAJOR: "Has the potential to quickly impact out with the local area e.g. affect the temporary refuge (TR), escape routes, escalate to other areas of the installation or cause serious injury or fatalities." A major leak, if ignited, would be likely to cause a "major accident", i.e. it would be of a size capable of causing multiple casualties or rapid escalation affecting the temporary refuge (TR), escape routes, etc.

Major gas releases are either a release of more than 300 kg, or the mass release rate is more than 1kg/s and the duration is more than 5 minutes. A major release could result in a jet fire of over 10 metres length (>1kg/s) capable of causing significant escalation after 5 minutes duration, or a flash fire/explosion on reaching LFL. 300 kg equates to approximately 3000 m^3 of explosive cloud at NTP, which is enough to fill an entire module or deck area, and to cause serious escalation if ignited.

MINOR: "Has the potential to cause serious injury to personnel in the immediate vicinity, but no potential to escalate or cause multiple fatalities." A minor leak, even if ignited, would not be expected to result in a multiple fatality event or significant escalation, but could cause serious injuries or a fatality local to the leak site or within that module only.

[1] From August 2010 data are available for 2009/2010, but this has not been included in this analysis.

Minor gas releases are either a release of less than 1 kg, or the mass release rate is less than 0.1kg/s and the duration is less than 2 minutes. A minor release could result in a jet fire of less than 5 metres length (<1kg/s) which is unstable and therefore unlikely to cause significant escalation, or a flash fire/explosion on reaching LFL. 1 kg equates to less than 10 m^3 of explosive cloud at NTP, probably insufficient to cause a significant hazard if ignited.

SIGNIFICANT: "Has the potential to cause serious injury or fatality to personnel within the local area and to escalate within that local area e.g. by causing structural damage, secondary leaks or damage to safety systems." A significant leak, if ignited, might have the potential to cause an event severe enough to be viewed as a "major accident" or be of a size leading to significant escalation within the immediate area or module.

Significant gas releases are capable of jet fires of 5 to 10 metres lasting for between 2-5 minutes, or release rates between 0.1 to 1.0 kg/s lasting 2-5 minutes giving explosive clouds of between 10 and 3000 m^3 in size. Significant gas releases are greater than minor releases but less than major releases.

2.3 Population Data

The successful operation of the HCR system depends not only on the correct submission of reportable hydrocarbon releases, but also on the retention of an accurate record of all operators/owners together with full details of all hydrocarbon carrying installations on the UKCS. HSE maintains lists of offshore duty holders and their installations, and these are updated using the submission of safety cases as the basis for change. Normally at the time of receipt of the safety case, HSE will request the duty holder to supply details of the hydrocarbon carrying systems and equipment on board the installation, via a population data questionnaire. However, with the provision of the on-line population data notification facility duty holders can now supply the required information, in advance, direct into HCRD.

The required population data are in three parts:
Part 1: Installation details
Part 2: Systems details
Part 3: Details of equipment contained in the systems listed in Part 2

Population data are recorded for most but not all equipment types.

2.3.1 Installation Data

NAME: This is used as a primary reference in the HCR system, and is referenced on all other pages of the questionnaire. This is the name or other designation given on the installation documentation.

TYPE: FIXED, MOBILE or SUBSEA and also what type of facilities are involved e.g. Production - Utility - Quarters - Subsea Satellite, or Wellhead - Riser, etc. FLOATING PRODUCTION SYSTEMS (FPS) are classed as FIXED Installations.

Location Details : These apply to both Fixed and Subsea Installations. The Quadrant and Block No. are stated on the registration documents, and are needed to categorise the general location of the Installation, i.e.. Northern, Central or Southern North Sea.

PERSONNEL: Attended or not normally attended (i.e. NUI) respectively.

Start-up DATE: This will indicate the operational age of the installation. For FIXED and SUBSEA installations and new-build FPS, this is the First Oil/Gas date (the date when hydrocarbons are used on board for the first time, for example for commissioning purposes).

2.3.2 Systems Data

GENERAL Temporary systems and/or equipment (i.e. items that are not permanently a part of the installation) are not included in the population count. Most systems consist of major equipment items (vessels, turbines, pumps, compressors) arranged in trains, with several stages interconnected with piping, valves, instruments, etc. Each train is normally isolated from the other by ESDV or other means.

01 DRILLING A drilling system (rig) would normally comprise mud, shale, kill, de-gasser, diverter, and other permanent associated equipment, but excludes BOPs, xmas trees, and wells. This is the number of rigs carried on the Installation. For platforms carrying one drilling rig and one workover rig, the total will be 2. For those with (permanent) workover capability only, from one independent source (i.e. not requiring a MODU) the total will be 1.

02 WELL CONTROL Comprises all BOP stacks, but not the piping, valves, flanges, etc. connected to them.

03 WELL Consists of the xmas tree, wellhead and well itself. Note that a gas injection well means one where gas is injected into the reservoir. A gas lifted well is one where lift gas is employed to assist flow, and is counted as a production well. "Surface" means with the wellhead and xmas tree, etc. are above water, "Subsea" means on the seabed, including subsea satellite wells.

04 FLOWLINE Comprises the piping, flanges, valves and instrumentation between the wing valve (or the annulus valve for lift gas) and the relevant manifold (or pipeline isolation valve in the case of a single satellite well). Includes all hydrocarbon carrying flowlines, both topsides and subsea (out to 500 metres zone). The lines between the 500 metres safety zone and the parent installation are counted as pipelines. The flowlines involved with the wells (03 above) are included, together with any lift gas and other hydrocarbon carrying lines. Choke and kill lines associated with drilling and well control are also included.

05 MANIFOLD The common gathering or distribution header for all flowlines of a particular type e.g. gas lift manifold, oil production manifold, gas injection manifold, etc. It includes piping, valves, flanges and instrumentation forming the manifold. All manifolds involving hydrocarbons are included under the appropriate category, including choke and kill.

<u>06 SEPARATION</u> This section covers all vessels, valves, piping etc. associated with product separation (either OIL or GAS) as distinct from other "downstream" processes that are covered under 07 Processing systems. Test separation is a separate system from production separation. Each train is a separate system with one or more stages. If some equipment is shared between trains, then it is counted in only one equipment list in part three. Gas and condensate lines etc. associated with oil separation are part of oil separation, and not gas separation. The total number of distinct, isolatable trains in each given category are included.

<u>07 PROCESSING</u> These are the downstream processes associated with gas and/or oil treatment, but exclude all other systems stated elsewhere in the questionnaire (e.g. separation, compression, utilities, etc.). Equipment is counted under each of the sub-systems for oil and gas processing respectively, except for Methanol and Chemical Injection which are on a "systems only" basis.

<u>08 UTILITIES</u> These are mainly the non-process systems which involve hydrocarbons. These are all on a "systems only" basis except for Fuel Gas systems.

<u>09 GAS COMPRESSION</u> This includes turbines and all interstage scrubbing/cooling equipment associated with the compression process, as well as the compressors themselves. "Gas" means product gas compression for export, injection, or gas lift purposes. The total number of distinct, isolatable trains are recorded. Each separate stage of gas compression is not counted separately unless these are on different drives and employ different methods of compression. Multi-stage compressors are counted as one compressor.

<u>10 METERING</u> Includes prover loops, densitometers and other equipment specifically supplied as part of the metering package. All meter runs are counted as piping within the metering system. All turbine meters and/or fixed orifices located in other processes are counted as instruments in those processes.

<u>11 EXPORT</u> A pipeline is designated as OIL/GAS/CONDENSATE according to the main contributor of the pipeline. Includes all export pipeline/risers and associated equipment (such as pig traps, ESD valves, swivels, riser release connectors, SSIVs) out to the 500-metre limit, plus export/booster pumps and all piping etc. down to the recognised pipeline (valved) interfaces. In the case of crossovers between export and import systems, there would normally be an agreed interface between the systems (usually at a common isolation valve), which should be adhered to for reporting purposes. Pipelines to and from a separate SUBSEA or other Installation (e.g. CALM/SALM, etc.) are included up to the 500-metre zone.

<u>12 IMPORT</u> A pipeline is designated as OIL/GAS/CONDENSATE according to the main contributor of the pipeline. Includes all import pipelines/risers and associated equipment (such as pig traps, ESD valves, swivels, riser release connectors, SSIVs) within the 500 metre limit, plus all piping etc. from the recognised pipeline (valved) interfaces up to the interfaces with the systems being served which may include crossovers to export (see 11 above). Pipelines to and from a separate SUBSEA or other Installation (e.g. CALM/SALM, etc.) are also included up to the 500-metre zone.

13 DRAINS A typical drain system includes transfer pumps and de-gasser vessels, with caissons included in drains piping. Oil and condensate are assumed to share common drains. Open and closed systems are counted separately, and that these are both on a "systems only" basis.

14 VENT The LP vent is also known as the atmospheric vent, and a HP vent is any system working at higher than atmospheric.

15 FLARE LP flare is usually that system handling all (low pressure) process effluent gases. HP flare is for handling all (high pressure) process upset releases from blowdown.

16 BLOWDOWN Process blowdown and depressurisation systems are situated between the process itself and the respective vent/flare system.

2.3.3 Equipment Data

The number of pieces of equipment in each individual system identified above is aggregated onto a list. For example, there may be a total of 3 "Oil Flowlines" (item 04 above), but for the equipment data there should be a single list of all of the valves, flanges, piping etc. for all 3 flowlines. The following definitions are used (note that not all numbers are used).

01 BOP STACK The entire unit including valves, flanges, rams etc. down to the wellhead connection and up to the first flange, but excluding all piping, valves and fittings beyond the first flange (e.g. flowline or choke/kill connection) and excluding the flange itself.

02 WELLHEAD The joint between the xmas tree/BOP stack and the well itself.

03 XMAS TREE The entire unit including valves, flanges, rams etc. down to the wellhead connection and up to the first flange, but excluding all piping, valves and fittings beyond the first flange (e.g. flowline or choke/kill connection) and excluding the flange itself.

09 FLANGES **A f**langed joint comprises 2 flanges normally; spectacle blinds and orifice plates are counted as 3. Screwed joints are counted as 2 flanges. Clamp (Grayloc) and Hammer union (Chicksan) joints also count as 2 flanges. Swivel joints, as employed in FPSO Turrets are included as a special type of flange.

11 INSTRUMENTS One instrument could comprise the instrument itself, plus up to 2 valves, up to 4 flanges, 1 fitting, and associated small bore piping (1"or less). Corrosion coupons are treated as flanged, valved connections with instrument (probe & cap) attached.

18 PIPELINES A pipeline is considered as that part from the seabed RISER connection out to the 500-metre radius of the safety zone. Pipelines are measured in length (metres) per size category, for both material types (steel or flexible) excluding valves, flange, and instrument fittings.

19 RISERS A riser is that part of the pipeline from the pig trap and/or the ESDV down to the seabed connection. Risers are measured in length (metres) per size category, for both material types (steel or flexible) excluding valves, flanges, and instrument fittings. Riser release connectors are broken down into their individual component valves, flanges, piping, and instruments for inclusion in the count.

20 PIPING Piping is measured in length (metres) per size category for both material types (steel or flexible) excluding valves, flanges, and instrument fittings. Redundant piping is not included if completely separated and isolated. However, locked closed lines, although infrequently used, are included as likely leak sources.

25 VALVES The number of valves in each size range is included for both manual and actuated, and for each valve category. The "block valve" category includes kill, shut-off, and isolation. A pipeline SSIV assembly counts as one item. Riser release connector valves are included as block valves. Each valve consists of the body, stem and packer, but excludes flanges, controls, and instrumentation. Interfaces for valves are at valve connections according to normal specification break conventions, and only whole numbers of components are counted. (It is not allowable to count $^{1}/_{2}$ valves).

MAJOR EQUIPMENT ITEMS: These include compressors (04), (note that one compressor comprises all stages on the same shaft), heat exchangers (10), mud/shale equipment (12), degassers (13), pig launchers (16), pig receivers (17), pressure vessels (21), pumps (22), storage tanks (23) and turbines (24). Each item comprises the item of equipment itself, but excludes all valves, piping, flanges, instruments and fittings beyond the first flange and excludes the first flange itself. The items need to be identified together with the total number within the system(s)

OTHER EQUIPMENT ITEMS: These include filters (05), expanders (06), recompressors (07), fin fan coolers (08) and diverters (14). The items need to be identified together with the total number within the system(s).

2.3.4 Equipment Data Estimation[2]

The following methods are given for the estimation of equipment, in descending order of preference:

1) Physically counting the equipment on the installation by walking around the facility.
2) CAD system counting. The CAD system involved must have been recently audited. This should be followed by a physical offshore check of a representative sample to establish/confirm accuracy.
3) Counts determined from paper drawings (e.g. P&IDs, isometrics etc.). The drawings must be up to date and as built. This should be followed by a physical offshore check of a representative sample to establish/confirm accuracy.
4) Generic estimate using a valid method, together with a physical offshore check of a representative sample to establish/confirm accuracy.
5) Generic estimate using a valid method, together with an engineering drawing check of a representative sample to establish/confirm accuracy.
6) A basic generic estimate, provided that a degree of accuracy can be stated.

[2] Note that in DNV's experience parts counts are not usually available nor are physical checks (3) carried out.

It is recognised that generic estimation methods introduce inaccuracies and it is therefore preferable that sampling checks are carried out to establish and/or confirm the degree of accuracy for 4-6 above. The expected degree of accuracy should be stated by the duty holder but this, nor the method used for equipment counting, is given in the data that are visible to authorised users.

2.4 Causes of Release

The entries for the cause of a release include design (yes or no) together with three other causes each with pre specified sub groups as given in Table 1.

Table 1 Causes of Releases

Equipment	**Operational**	**Procedural**
Internal corrosion	Incorrectly fitted	Non-compliance with a procedure
External corrosion	Improper maintenance	Non-compliance with a Permit to Work (PTW)
Mechanical Failure, other than fatigue or wearout	Improper inspection	Deficient procedure
Fatigue e.g. due to vibration effects	Improper testing	Quality control failure, e.g. poor inspection of incoming goods, usually linked with manufacturing failure
Wearout of component	Improper operation	None (No procedural failure involved)
Erosion	Dropped object	
Material defects, e.g. metallurgical deficiencies	Impact other than a dropped object e.g. struck by something or someone	
Defects due to manufacture, e.g. welding defects	Left open whilst containing hydrocarbons	
None (No equipment failure involved)	Opened up whilst containing hydrocarbons	
	Struck by lightning	
	Incorrectly specified (but <u>not</u> defective) e.g. inappropriate rating or material	
	None (No operational cause involved)	

2.5 Mode of Operation

This is recoded as one of the following:

- Drilling an oil well
- Drilling a gas well
- Carrying out a Well Operation with the xmas tree in place
- Carrying out a Well Operation with the xmas tree removed
- Normal production
- During pipeline pigging
- In the process of shutting down
- During shutdown
- When blowing or blown down
- In the process of flushing out
- In the process of cleaning
- In the process of inspection
- Carrying out hot work during maintenance
- Carrying out cold maintenance work not otherwise specified
- Draining for maintenance activities
- Replenishing of stocks (e.g. of fuel oil, etc.)
- Replacing equipment during maintenance
- Routine or planned maintenance not otherwise specified
- Servicing or maintaining well equipment
- Carrying out hot work during construction
- Cold construction work not otherwise specified
- Carrying out draining for construction activities
- Carrying out the commissioning of newly installed equipment
- Installing equipment during construction
- Removing equipment during construction
- Using temporary equipment
- Construction work on wells not otherwise specified under well operations
- Testing equipment
- Sampling fluids, etc
- Reinstatement of equipment after maintenance
- Initial start-up of equipment after commissioning or shutdown.

2.6 Data Recording

The object of the current work is to examine the data in HCRD for piping and flanges only; other equipment items have been excluded from the scope of the work. Releases from both steel piping and flanged joints are recorded in one of the following three size groupings:

- Line diameter (D) less than or equal to 3”
- D greater than 3” but less than or equal to 11”
- D greater than 11”

Information is given (see Appendix 2) to assist in the determination of the hole size. Further it is recommended that the "equivalent hole diameter" is determined as the hydraulic equivalent (round) hole diameter. This may be calculated from the actual hole geometry as 4A/P, where A = cross-sectional area, and P= wetted perimeter (if the hole is not round (e.g. crack, split). Some releases are not associated with a 'hole' (e.g. release from an open topped vessel such as shale shakers, or where carry-over of hydrocarbons from one system to another was involved). These are labelled N/A, and are classified (severity) by inspection of the amount released only. Hole diameters are recorded in mm, except where the hole size is greater than 100mm diameter where the entry is '>100'.

2.7 Reports

Standard reports are available to authorised users. These are given under the following standard headings:

- Leak Frequency & Hole Size Distribution
- Installation Leak Frequency
- Quarterly Report by Severity
- Graphs
- Tables

Examples of these reports are given in Appendix 4.

3 THE NORTH SEA ENVIRONMENT

For the purposes of data recording, the NSCS is split into three sections; Southern, Central and Northern[3]. Facilities in the Northern and Central sections process oil, gas and condensate whereas facilities in the Southern section largely process gas with small amounts of entrained condensate. Approximately 14% of the platforms in the N Sea are in the northern section, with some 18% in the central and 68% in the southern section.

Facilities in the Northern and Central sections comprise a mixture of medium to large, mainly manned installations of steel jacket construction. Most process gas, oil and condensate. The majority of the installations are now in excess of their original designed life of 25years. The size and extent of the facilities are dependent on the nature of the reservoir (e.g. whether artificial lift is required) and the depth of the sea. Some reservoirs are at pressures in excess of 600 barg and at temperatures of 150°C. The processing facilities normally run to dual trains comprising 1st and 2nd stage oil and gas separation; the three phases of crude oil, produced water and gas are separated to meet the crude oil export specification. Pressures are typically 20 barg to 80 barg but some gas systems are higher (e.g. 175 barg). There is an extensive system of pipelines to convey materials to the shore.

Facilities in the Southern section comprise a few large old manned platforms (generally more than 30-40 years old) supplemented by a large number of NUI's and subsea wells. NUI's have little processing facilities, being normally limited to produced water separation, corrosion

[3] Although the data are recorded by the split into NCSC sections, the population data are not specified per sector, so frequencies for each sector cannot be determined.

inhibitor injection, metering and pigging. Processing on the manned platforms is similar to NUIs but also includes gas compression. Pressures are typically in the range from less than 40barg for mature fields to around 100barg for newer fields. Gas and condensate are normally combined before being transported to shore in subsea pipelines at pressures which are dependent on the receiving pressure at the land based terminal. Typical codes for the pipelines include PD8010-2:2004, Norwegian Offshore Standard (DNV-OS-F101) and IP Code Part 6.

4 DERIVATION OF RELEASE FREQUENCIES FROM THE DATA

In this section three different ways are given to develop failure frequencies from the HCRD:

- Directly from the standard reports produced by HCRD.
- Using DNV's current interpretation of release frequencies using HCRD.
- By interpretation of gas data extracted from HCRD for this project.

4.1 Frequencies from Standard Reports

Frequencies are given in the standard leak frequency reports that are available to authorised users. An example of the report format and output is given in Appendix 4. The leak frequency inputs allow the selection of a particular system and equipment, in terms of a primary, secondary and tertiary equipment/system and the dates over which the data are to be considered. The report gives the total number of leaks in both the selected time period, the specified input system and equipment, a leak frequency, and the number of minor, significant and major releases. The leak frequency is the number of leaks divided by the number of system/equipment years. Data were extracted for (a) 'gas' releases (b) equipment types 'flanges' and 'steel piping' and (c) systems for which there were population data (as without a population a leak frequency cannot be established). The systems and frequencies derived from the extracted data are given in Appendix 5. If all the systems are combined together, further release frequencies may be derived. These frequencies for all the systems together are given in Table 2.

Table 2 Release Frequencies from HCRD Standard Reports for Gas Systems.

Equipment	Size Range	System/Equipment Years	No of Releases	Leak frequency from HCRD Average	Leak frequency from HCRD 95% confidence (1)
Flanged Face	D>11"	241214	26	1.08E-04	1.50E-04
	3"<D<11"	1052698	93	8.83E-05	1.05E-04
	D<3"	2227910	148	6.64E-05	7.61E-05
Flanged Joint	D>11"	120607	26	2.16E-04	2.99E-04
	3"<D<11"	526349	93	1.77E-04	2.10E-04
	D<3"	1113955	148	1.33E-04	1.52E-04
Steel piping	D>11"	592765	9	1.52E-05	2.65E-05
	3"<D<11"	1325582	49	3.70E-05	4.69E-05
	D<3"	1132544	145	1.28E-04	1.47E-04

Allgasdata//Population

(1) The 95% upper confidence values were determined using an excel spreadsheet (CI of binominal fraction.xls) provided by RIVM.

In Table 2, frequencies for flanges are in terms of per flanged face (as reported in HCRD) and per flanged joint per year, which is the value normally used for QRAs. Piping frequencies are in terms of per m per year. D is the diameter of the equipment. A further report gives information on the number of releases in pre specified hole size ranges, but it is not possible to derive frequencies for user specified hole size ranges from the standard reports.

4.2 Frequencies from DNV's Interpretation of HCRD

DNV has been deriving release frequencies from HCRD for use in both onshore and offshore QRAs for a number of years. The current interpretation of the data to give release frequencies is given by Falck et al. This interpretation was carried out for Statoil with cooperation and input by Scandpower and Safetec. One of the main reasons for the work was that Statoil had observed that although analyses of their facilities by different organisations were all based on HCRD, there was considerable inconsistency in the leak frequencies actually used in these analyses. Further, doubts had been expressed regarding the accuracy of some of the population data. This work was intended to standardise the leak frequencies used for their offshore facilities.

It has been recognised for many years that direct use of the frequency values from HCRD into QRAs gives release frequencies which are higher than experience for the system being analysed. Different analysts have used different approaches and assumptions in the modification of the data in HCRD and this leads to inconsistent leak frequencies despite them being based on the same HCRD dataset. The methodology used in DNV's current interpretation comprised the following main steps:

- Data for different types and sizes of equipment were grouped where there was insufficient experience to show significant differences between them.
- Leak frequencies were split into different leak scenarios in order to promote compatibility with different approaches to outflow modelling in the QRA.
- Analytical leak frequency functions were fitted to the data to obtain a smooth variation of leak frequency with equipment and hole size.

The data used for this interpretation included all systems (i.e. oil, gas, condensate etc) which had population data.
The leak frequency function took the following form:

$$F(d) = f(D)\, d^{m} + F_{rup} \quad \text{for } d = 1\text{mm to } D.$$

Where:

$F(d)$	= frequency (per year) of holes exceeding size d
$f(D)$	= function representing the variation of leak frequency with D
D	= equipment diameter (mm)
d	= hole diameter (mm)
m	= slope parameter
F_{rup}	= additional rupture frequency (per year).

Hence the frequency of holes within any range d_1 to d_2 is:

$$F(d_1) - F(d_2) = f(D)\,(d_1^{\,m} - d_2^{\,m}) \quad \text{for } d = 1\text{mm to } D$$

The frequency for full bore ruptures, i.e. holes with diameter D, is:

$$F(D) = f(D)\ D^{m} + F_{rup}$$

As there are considerable data for piping and flanges, and the data are recoded in terms of ranges of D, the size dependence was represented by the following general term:

$$f(D) = C\,(1 + a\,D^{n})$$

Where C, a and n are constants for each equipment type.

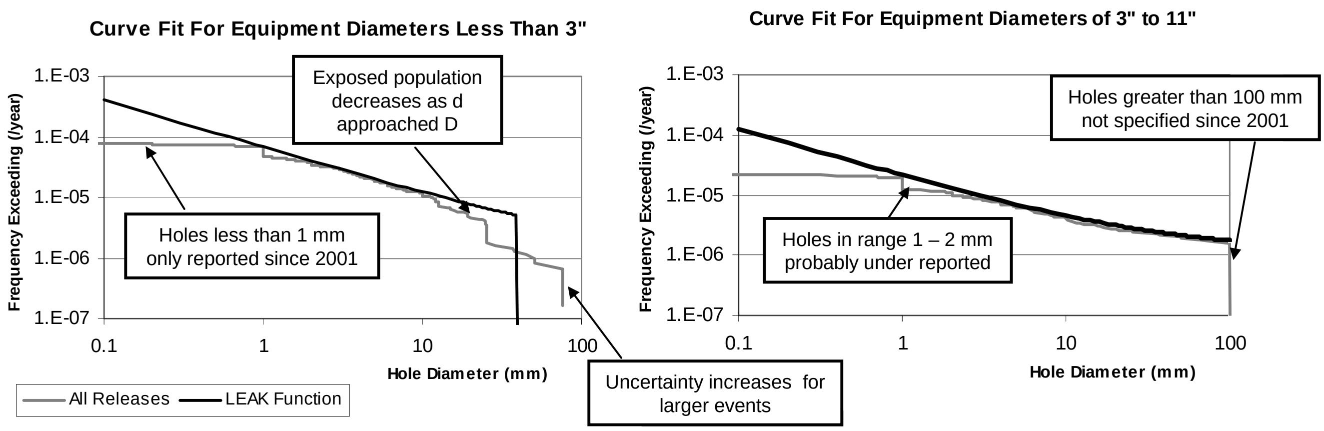
Note that m and F_{rup} are not dependent on size.

In the consideration of the data, the following were excluded:

- Leaks from certain types of equipment and systems (e.g. wellhead equipment, drilling equipment, pipelines and risers) which reduced the number of records by 755 (out of 3644 records).
- Leaks where the hole size was not recorded.
- Leaks where the estimated initial rate was less than 0.1 kg/s.

The curve fitting and derivation of leak frequencies for large diameter equipment is indicated in Figure 1.

Figure 1 Typical Characteristics of Historic Exceedance Curves



The data exclusions gave 892 records then exclusion of the low pressure releases reduced the set by a further 53 records. For the offshore application there was further separation into ESD isolation or late isolation and limited leaks (leaks that may have potential to give personnel risks but are unlikely to lead to evacuation or escalation or affect structural integrity).

Predictions for leak frequencies for a range of piping diameters using this methodology are given in Table 3, Table 4 and Appendix 6.

Table 3 Full pressure leak frequencies for piping (per metre year)

HOLE DIA RANGE (mm)	2" DIA (50 mm)	12" DIA (300 mm)	18" DIA (450 mm)	24" DIA (600 mm)
1-3	2.7E-05	9.4E-06	9.0E-06	8.9E-06
3-10	1.1E-05	3.9E-06	3.8E-06	3.7E-06
10-50	4.7E-06	1.6E-06	1.6E-06	1.6E-06
50-150	0.0E+00	3.5E-07	3.3E-07	3.3E-07
>150	0.0E+00	6.7E-07	6.6E-07	6.6E-07
TOTAL	4.3E-05	1.6E-05	1.5E-05	1.5E-05

TN 14

Table 4 Full pressure leak frequencies for flanges (per flanged joint year)

HOLE DIA RANGE (mm)	2" DIA (50 mm)	12" DIA (300 mm)	18" DIA (450 mm)	24" DIA (600 mm)
1-3	4.5E-05	9.8E-05	1.3E-04	1.6E-04
3-10	1.7E-05	3.7E-05	4.9E-05	6.1E-05
10-50	6.5E-06	1.4E-05	1.9E-05	2.3E-05
50-150	0.0E+00	2.6E-06	3.5E-06	4.3E-06
>150	0.0E+00	6.5E-06	6.9E-06	7.4E-06
TOTAL	6.9E-05	1.6E-04	2.1E-04	2.6E-04

TN 14

4.3 Frequencies Derived from Data for Relevant Gas Systems

The full data in HCRD may be extracted for each year. If these are combined then data for ‘gas’, ‘steel piping’, ‘flanges’ and hole diameters 10mm or more (minimum hole size specified by RIVM) may be extracted. The dataset for these selections comprises 116 records. The breakdown of this dataset in terms of cause and mode is given in Table 5. Although all the failures are on equipment which is located offshore, with some being subsea, virtually all the failure modes would be applicable to equipment onshore (erosion and internal corrosion are examples of failure modes that would not be applicable to treated natural gas). If the dataset is further reduced to take out systems that were not included in the dataset used above in Section 4.1 and Appendix 5, for example drains, flares, vents, etc the number of releases is reduced to 47. This dataset is considered to be the most appropriate to examine to derive leak frequencies for onshore gas equipment[4]. Some details for the dataset are presented in Appendix 7 (reported in decreasing hole size). Frequencies based on these releases are derived in Table 6. These may be compared with the frequencies given in Table 2, except that the latter are for all hole sizes.

4.3.1 Hole Sizes

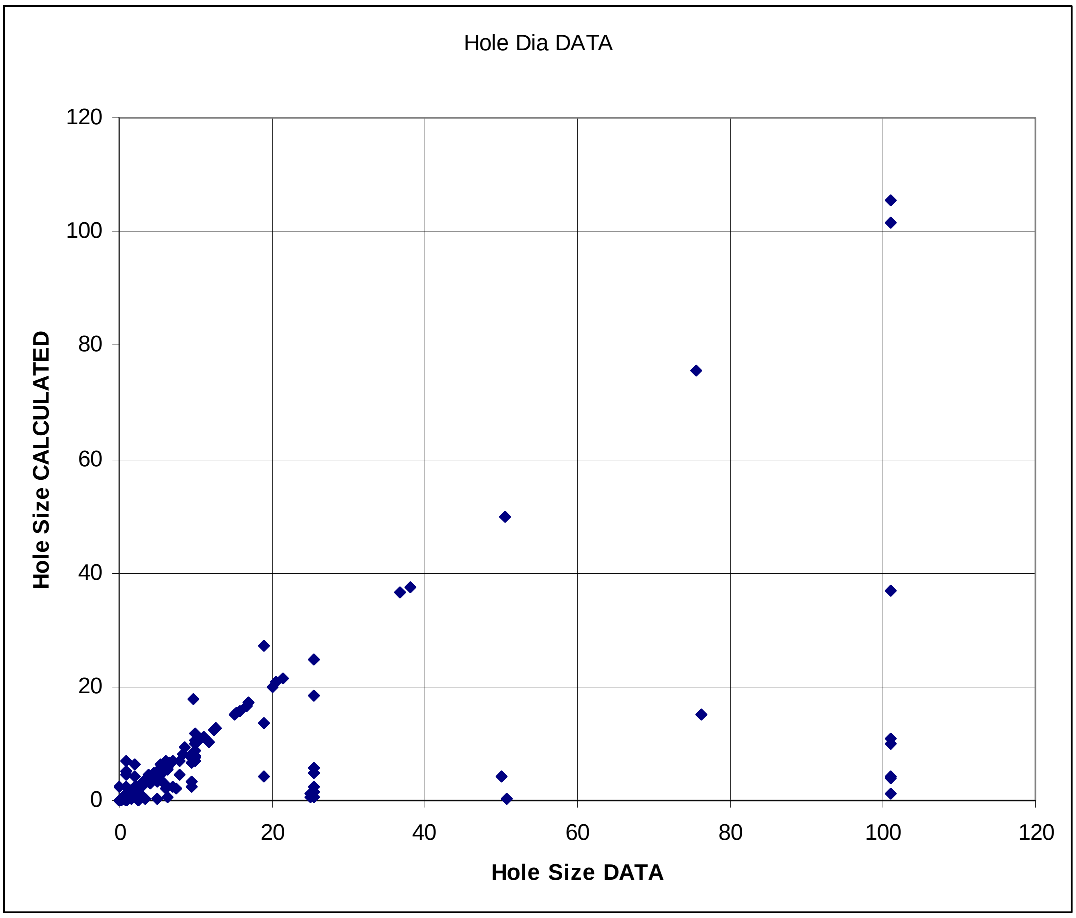
HCRD records a hole size for most of the releases in the database; releases with a hole size in excess of 100mm are recorded as ‘>100mm’ and some entries do not contain a hole size entry or are designated N/A. To determine an approximate average hole size for the releases in section 4.3 above, the entries for a hole size >100mm were replaced by 150mm. With this modification the average hole size for each equipment type can be determined (see Table 6); for releases with a

[4] Note that Flowlines are included in this dataset. Although much of the lengths of the Flowlines are likely to be subsea, the failure modes indicated that failures were on the platform rather than subsea. Also low pressure releases are retained.

hole size of 10mm or more, the average size ranges from 31-79mm diameter for flanges and 20-150mm diameter for piping. The average for all the entries in Appendix 7 is 39mm diameter.

The data also contain entries for the quantity of material released, the duration of release, the pressure at the time of the release and the density. Using these entries it is possible to calculate a hole size (calculated assuming a discharge coefficient of 0.8) which gives a slightly different hole size distribution to that from the hole sizes recorded in HCRD. A comparison of the hole size in HCRD and the calculated hole size is shown in Figure 2 (including hole sizes less than 10mm diameter). This possibly indicates that a calculation method was used to determine many of the hole sizes, but also indicates that some of the entries '>100mm' may be conservative.

Figure 2 Comparison of Hole Size in HCRD with Calculated Hole Size



Allgasdata19922008Allrelevant sorted

Note that hole sizes in HCRD '>100mm' have been given a hole size of 101mm (x axis) for the plot.

Table 5 Breakdown in terms of cause and mode of operation (10mm or more - gas)

Equipment Cause	%	Operating Cause	%	Mode of Operation	%
Piping					
External Corrosion	13	Improper inspection	8	Blowdown	5
Internal corrosion	10	Improper maintenance	8	Flushing	5
Erosion	13	Improper operation	19	Inspection	5
Mechanical Failure	11	Improper testing	1	Maintenance	11
Fatigue	6	Incorrect Fitting	9	Normal Production	30
Mechanical Wear	1	Left open whilst containing hydrocarbons	9	Reinstatement	8
None	45	Opened up whilst containing hydrocarbons	6	Start up/Shutdown	21
Other	1	None	40	None	1
		Other	1	Other	14
Flanges					
External Corrosion	0	Improper inspection	0	Blowdown	3
Internal corrosion	0	Improper maintenance	0	Flushing	3
Erosion	3	Improper operation	14	Inspection	0
Mechanical Failure	11	Improper testing	3	Maintenance	17
Fatigue	3	Incorrect Fitting	19	Normal Production	17
Mechanical Wear	6	Left open whilst containing hydrocarbons	8	Reinstatement	22
None	78	Opened up whilst containing hydrocarbons	39	Start up/Shutdown	11
Other	0	None	14	None	6
		Other	3	Other	22

Allgasdata/19922008Gas10mmormore

Table 6 Frequencies Derived from Gas Data (hole size 10mm or greater)

Equipment	Size Range mm	System/Equipment Years	No of Releases (10mm or more)	Leak frequency from HCRD Average	Leak frequency from HCRD 95% confidence	Average hole dia mm
Flanged Face	D>11"	241214	2	8.29E-06	2.61E-05	31
	3"<D<11"	1052698	5	4.75E-06	9.99E-06	79
	D<3"	2227910	11	4.94E-06	8.17E-06	37
Flanged Joint	D>11"	120607	2	1.66E-05	5.22E-05	31
	3"<D<11"	526349	5	9.50E-06	2.00E-05	79
	D<3"	1113955	11	9.87E-06	1.63E-05	37
Steel piping	D>11"	592765	2	3.4E-06	1.06E-05	150
	3"<D<11"	1325582	7	5.3E-06	9.92E-06	41
	D<3"	1132544	20	1.8E-05	2.57E-05	20

Allgasdata//Population

4.3.2 Hole Sizes 75mm or more

For the purposes of land use planning, only releases of gas through large holes are likely to be of interest. Further reduction of the data (to include only holes that are listed in HCRD as 75mm diameter or more) gives eight releases. Of these:

- Four releases were from flanges (50%) and four releases were from piping (50%)
- Two out of four of the releases from flanges were as a result of improper operation or procedure (generally opening).
- Two out of four of the releases from piping were as a result of mechanical failure, one from mechanical fatigue and one from external corrosion.
- Only two of the six holes reported as >100mm were calculated to be >100mm; both of these were for piping.
- The maximum calculated hole size for piping above 11” diameter is 122mm. For flanges, the maximum calculated hole size was 58mm. Although this was for flanges in the range above 11” diameter the hole size in HCRD was 50mm, so it was not included in the data for holes of 75mm and above.
- Four releases (50%) occurred during normal production.

Frequencies for holes 75mm and above based on both the hole size reported in HCRD and the hole size calculated as above are given in Table 7. If the >100mm entries are replaced by 150mm, the average hole size (HCRD) is 131mm, or 125mm (for the calculated hole size). There are no full bore releases recorded for equipment with diameter more than 75mm (but it is possible that the smaller diameter range has full bore releases).

Table 7 Frequencies Derived from Gas Data (hole size 75mm or greater)

Equipment	Size Range mm	Population	Releases in HCRD (Calculated)	Leak frequency from HCRD Average (1)	Leak frequency from HCRD 95% confidence (1)	Average hole dia mm in HCRD	Leak frequency from Calculated hole Average (2)	Leak frequency from Calculated hole 95% confidence (2)	Average hole dia mm (Calculated)
Flanged Face	D>11"	241214	0 (0)		1.24E-05	N/A		1.24E-05	N/A
	3"<D<11"	1052698	2 (0)	3.8E-06	5.98E-06	150		2.85E-06	24
	D<3"	2227910	2 (0)	1.8E-06	2.83E-06	113		1.34E-06	11
Flanged Joint	D>11"	120607	0 (0)		2.48E-05	N/A		2.48E-05	N/A
	3"<D<11"	526349	2 (0)	3.8E-06	1.2E-05	150		5.69E-06	24
	D<3"	1113955	2 (0)	1.8E-06	5.65E-06	113		2.69E-06	11
Steel piping	D>11"	592765	2 (2)	3.4E-06	1.2E-05	150	3.4E-06	1.1E-05	119
	3"<D<11"	1325582	2 (1)	1.5E-06	5.5E-06	113	7.5E-07	3.6E-06	50
	D<3"	1132544	0 (0)		3.26E-06	N/A		3.26E-06	11

Allgasdata//Population

(1). Based on hole sizes recorded in HCRD.

(2) Based on calculated hole sizes.

4.4 Methodology used in the Netherlands for QRAs

Information on the methodology for QRAs in the Netherlands is given in Bevi. Some relevant extracts that might be useful for readers who are not resident in the Netherlands are given in Appendix 8.

4.5 Applicability of the HCRD for Failure Frequencies for Onshore above ground High Pressure Gas Piping.

The equipment used offshore has a similar function to that used for onshore gas piping (i.e. containment and control of hydrocarbon). For the third method of analysis in the report, only data from equipment containing gas was used, which is the same as the onshore piping (although operating pressures offshore will not necessarily match those onshore). For the first and second methods of analysis (standard reports and DNV interpretation of HCRD) there was no exclusion of equipment based on the material within the equipment, so these data sources were not as specific and would include oil containing lines which would have different properties to onshore gas piping. Equipment offshore is constructed to recognised codes of practice (as would be the case for onshore gas piping), however because of the different designs, functions, pressures, operating regimes, ages etc of the offshore equipment the standards would probably be more variable than the onshore gas piping standards in the Netherlands. Maintenance and inspection regimes offshore would be tailored to the specific operators' requirements (and in accordance with the agreed verification scheme) but should result in a similar standard of containment to the onshore gas piping. The conditions offshore can be severe, probably more severe than conditions onshore even in exposed locations, but the design should incorporate appropriate protection. Failures due to the external environment are not specified in HCRD so it is not possible to identify whether the external conditions give failures directly that would not be expected onshore. One failure mode that is recorded and which might be regarded as offshore specific is erosion. This mode however is not significant to this study as all reported failures give small holes. Failure modes that would be regarded as onshore specific (e.g. impact by motor vehicle) are obviously not included in the offshore data. Onshore equipment and offshore equipment would be expected to be in use for similar percentage of the time so time of use would not be expected to be an important difference. Overall, there is considerable uncertainty regarding the application of the HCRD to onshore facilities, but the lack of specific publicly available good quality onshore failure data means that the use of the offshore data is generally preferable to the use of either limited onshore data or frequencies purported to be derived from data that are no longer available for review.

5 CONCLUSIONS

DNV and other organisations use HCRD as the basis for release frequencies in onshore and offshore QRAs, but although the same base data are used as a starting point, the frequencies derived for use in QRAs can vary widely because of different interpretations of the data. The data in HCRD are considered to be of high quality because of the detail in the reporting form, although doubts in the accuracy of the population data have been expressed. Reporting, although voluntary, is considered to be largely complete; under reporting is likely to be restricted to small releases or releases through small holes, and as such is not particularly relevant to this work. Although the equipment is offshore, with some being subsea, the definition of the system where the release occurred and the mode of failure enable the selection of both systems and failures that are likely to occur onshore. Indeed, what might be regarded as 'offshore only' failure modes are relatively minor in number and tend to give small rather than large holes. On this basis it is considered that HCRD can be used as a basis to derive leak frequencies for onshore equipment, although it must be borne in mind that onshore specific failure modes are not included.

Three different approaches to determine leak frequencies from HCRD have been considered in this study. The use of standard reports from HCRD gives a frequency which is a simple division of the number of recorded releases for a specified system by the experience with that system. All release sizes, including very small releases which are not relevant for this study, are included in the frequency derivation.

DNV's current interpretation of the HCRD was carried out for Statoil in order to determine a consistent set of release frequencies for use in their offshore QRAs. The release frequencies for different types of equipment in the database were derived by the use of a standard shaped curve which was fitted to the data, so that frequencies for user specified hole size ranges can be determined. It is always assumed that a full bore failure is possible for equipment such as piping or flanges.

If the data in HCRD that DNV considered relevant for gas piping onshore (i.e. data which are specific for 'gas' releases from 'piping' and 'flanges' and which exclude data from systems that are either not considered relevant (e.g. drains, vents etc) or do not contain population data, e.g. pipelines), frequencies can be derived for holes (and ranges of holes) up to 100mm diameter as the hole size is recorded in HCRD. Hole sizes above this are not recorded in HCRD, entries are merely '>100mm', so direct determination of a frequency and an associated hole size is not possible. A calculation for hole size can be carried out from other entries in HCRD. This indicates a different hole size distribution from that derived from the hole sizes recorded in HCRD. This reduces the confidence in the accuracy of the hole size distribution, but in the equipment considered for this study is relatively minor because of the concentration of hole sizes in the range less than 75mm diameter.

A comparison of the release frequencies derived from (a) the standard HCRD reports, (b) DNV's interpretation of HCRD and (c) release frequencies derived for relevant data with certain exclusions, is given in Table 8. Comparison of the predicted frequencies confirms the need to carefully specify the interpretation of the data as it can be seen that different interpretations give considerably different predictions for release frequencies.

Table 8 Comparison of Predicted release Frequencies

Equipment	Size Range	Leak frequency from HCRD Average	Leak frequency from HCRD 95% confidence	Leak frequency from DNV Interpretation	Leak frequency from HCRD Average (10mm dia or more)	Leak frequency from HCRD 95% confidence (10mm dia or more)	Leak frequency from HCRD Average (75mm dia or more)	Leak frequency from HCRD 95% confidence (75mm dia or more)
Flanged Joint	D>11"	2.16E-04	2.99E-04	2.1E-04	1.7E-05	2.5E-05	No releases	1.24E-05
	3"<D<11"	1.77E-04	2.10E-04	1.0E-04	9.5E-06	3.8E-06	3.8E-06	5.98E-06
	D<3"	1.33E-04	1.52E-04	6.9E-05	9.9E-06	1.8E-06	1.8E-06	2.83E-06
Steel piping	D>11"	1.52E-05	2.65E-05	1.5E-05	3.4E-06	3.4E-06	3.4E-06	2.48E-05
	3"<D<11"	3.70E-05	4.69E-05	1.8E-05	5.3E-06	1.5E-06	1.5E-06	1.2E-05
	D<3"	1.28E-04	1.47E-04	4.3E-05	1.8E-05	3.3E-06	No releases	5.65E-06

Because of the lack of data for releases from large holes, (>100mm), use of HCRD to derive frequencies for hole sizes in excess of 100mm diameter (including full bore ruptures, for which there are no recorded releases) would require some form of statistical method or judgement. Consequently HCRD does not contain appropriate data to derive leak frequencies for hole sizes in excess of 100mm for piping and flanges on onshore plant including gas treatment plants and compressor stations.

6 REFERENCES

Bevi. Reference Manual Bevi Risk Assessments version 3.1. RIVM. Jan 2009

Falck A, Bain B and Rødsætre L. Leak Frequency Modelling for Offshore QRA Based on the Hydrocarbon Release Database. Paper for the Hazards XXI Process Safety & Environmental Protection Symposium IChemE Nov 2009

APPENDIX
1
OIR/12 REPORTING FORM

- o0o -

?

Click here for guidance RESET

HSE
Health & Safety Executive

Incident Serial No.
(HSE use only)

HYDROCARBON RELEASE REPORT
SUPPLEMENTARY INFORMATION

This form should be used to impart supplementary information on Hydrocarbon Releases which are reported on OIR/9B forms under RIDDOR 95, Dangerous Occurrences 13, 14, 73, or 74 per ON 30 (revised) available at http://www.hse.gov.uk/offshore/notices/on_30.htm

OFFSHORE INSTALLATION DETAILS:

NAME (or other designation)

Registration No. *(for HSE use only)*

DATE: (of incident)

TIME: (of incident) (24 hours)

Location at time of Incident:

Quadrant

Block

Latitude

Longitude

Water Depth metres

GUIDANCE NOTES :

This form should be completed as soon as possible, but in any case within 4 weeks following the incident.
Guidance on how to complete the form is contained on page 6 at the back of the form, and detailed guidance on reporting of Hydrocarbon Releases is given in booklet ref. OTO96956 available at http://www.hse.gov.uk/research/otopdf/1996/oto96956.pdf

Next Page

Please return completed form to:

Health and Safety Executive
Offshore Division
HCR Admin (OSD3.1)
5N.2 Redgrave Court
Merton Road
Bootle
L20 7HS

For official use only

OIR / 9B REF:

CHECKED: **DATE:**

INPUT: **DATE:**

INPUT AUDIT: **DATE:**

TECH AUDIT: **DATE:**

OIR / 12 *(text rev 05.10)* 1

1. HYDROCARBON (HC) RELEASED: *(Tick appropriate box)*

NON PROCESS ☐ (Specify) ______

PROCESS: OIL ☐ CONDENSATE ☐ GAS ☐ 2-PHASE ☐

FOR GAS, DENSITY ______ FOR LIQUIDS, GRAVITY ______

IF 2- PHASE, STATE GOR: ______ (*) = Specify GOR units, e.g. scf / bbl

FOR GAS or 2-PHASE, STATE LEVEL OF H2S: ______ p.p.m.

2. ESTIMATED QUANTITY RELEASED: ______ (*)
(*) = Specify units e.g. Tonnes, Kgs, m^3

3. DURATION OF LEAK: ______ (MINS)
(Estimated time from discovery, e.g. alarm, to termination of leak)

4. LOCATION OF LEAK: *(Please complete checklist on Page 4)*

5. HAZARDOUS AREA CLASSIFICATION: (i.e. zone at location of incident)
(Tick appropriate box) 1 ☐ 2 ☐ UNCLASSIFIED ☐

6. EQUIVALENT HOLE DIAMETER: ______ (*)
(*) = Specify units e.g. inches or mm.

7. MODULE VENTILATION? NATURAL ☐ FORCED ☐

HOW MANY SIDES ENCLOSED? ______
(Insert the number of walls, including floor and ceiling)

MODULE VOLUME ______ m^3

ESTIMATED No. OF AIR CHANGES (if known) ______ (*)
(*) = Specify hourly or daily rate

8. WEATHER CONDITIONS:

WIND: SPEED ______ DIRECTION ______ (*)
(*) = Specify units, e.g. mph, m/s, ft/s (*) = Specify heading in degrees

OTHER CONDITIONS: (Describe)

9. SYSTEM PRESSURE:
MAXIMUM ALLOWABLE OPERATING ______ ACTUAL ______ (*)

(*) = Specify units e.g. bara, psig or other (i.e. at time of release)

10. TOTAL HC INVENTORY IN SYSTEM ______ (*)

(i.e. isolatable between ESD valves) (*) = Specify units e.g. Tonnes, Kgs, m^3

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11. MEANS OF DETECTION: *(Please tick type of detector or specify as appropriate)*

HEAT ☐ SMOKE ☐ FLAME ☐ GAS ☐ OTHER ☐ (specify) ☐

12. EXTENT OF DISPERSION? (Please describe)

13. CAUSE OF LEAK? (Please complete checklist on page 5)

14. DID IGNITION OCCUR? *(Please tick appropriate box)* Yes ☐ No ☐

If Yes, was it: IMMEDIATE ☐ DELAYED ☐ DELAY TIME ☐ (secs)

Was there: (add sequence of events by numbering appropriate boxes in order of occurrence)

A FLASH FIRE ☐ AN EXPLOSION ☐
A JET FIRE ☐ A POOL FIRE ☐

15. IGNITION SOURCE (IF KNOWN) (please describe)

16. WHAT EMERGENCY ACTION WAS TAKEN? *(tick appropriate box(es))*

SHUTDOWN	☐	AUTOMATIC	☐	MANUAL	☐
BLOWDOWN	☐	AUTOMATIC	☐	MANUAL	☐
DELUGE	☐	AUTOMATIC	☐	MANUAL	☐
CO2 / HALON	☐	AUTOMATIC	☐	MANUAL	☐
CALL TO MUSTER	☐	AT STATIONS	☐	AT LIFEBOATS	☐
OTHER	☐	(specify)			

17. ANY ADDITIONAL COMMENTS:

CONTACT (In case of queries) *(block capitals, please)*

NAME: POSITION:

SIGNATURE: DATE:

3

Next Page

LOCATION CHECK LIST (SEE 'LOCATION OF LEAK' ITEM 4. ON PAGE 2)

(Please indicate those items which come nearest to pinpointing the location of the leak)

(a) MODULE/AREA NAME: ☐

(Please state the name in common use on the installation, inc. subsea if appropriate)

(b) SYSTEM: (please tick one box per category and also tick equipment details as appropriate)

☐ **DRILLING:** Well Control ☐ Exploration ☐ Appraisal ☐ Development ☐ Completion ☐

☐ **WELL:** Oil production ☐ Gas Production ☐ Gas Injection ☐ Surface ☐ Subsea ☐

☐ **FLOWLINES:** Oil ☐ Gas ☐ Other ☐ *(specify)* ☐

☐ **MANIFOLD:** Oil ☐ Gas ☐ Other ☐ *(specify)* ☐

☐ **SEPARATION:** Oil ☐ Gas ☐ Test ☐ Production ☐ Train No ☐ of ☐ Stage ☐

☐ **PROCESSING:** Oil ☐ Gas ☐ (Specify system) ☐

☐ **UTILITIES:** Oil ☐ Gas ☐ (Specify system) ☐

☐ **GAS COMPRESSION:**

☐ **METERING:** Oil ☐ Gas ☐ Condensate ☐

☐ **EXPORT/IMPORT** Oil ☐ Gas ☐ Condensate ☐

☐ **DRAINS:** Open ☐ Closed ☐

☐ **VENT/FLARE:** HP ☐ LP ☐

☐ **BLOW-DOWN:**

(c) EQUIPMENT: *(Please tick **one** box per category and also tick equipment details as appropriate)*

☐ **BOP** Wellhead ☐ Xmas Tree ☐ Surface ☐ Subsea ☐ Rating: ☐

☐ **COMPRESSOR** Centrif ☐ Recip ☐

☐ **FILTER** Drain Opening ☐ Plug ☐

☐ **EXPANDER** Recompressor ☐

☐ **FIN FAN COOLER**

☐ **FLANGE:** Type ☐ Rating ☐ Size ☐ (*)

(*) Specify e.g. RTJ, RF, ANSI 900#, API nom, bore ins/mm, etc.

☐ **HEAT EXCHANGER:** HC in Shell ☐ Tube ☐ Plate ☐

☐ **INSTRUMENT** (incl. piping, valves and tappings)

☐ **MUD** Shale ☐ Drilling ☐ (please specify) ☐

☐ **PIG LAUNCHER/ RECIEVER:** Horiz/Vert, Length/Dia ☐ (ins/mm)

☐ **PIPELINE** Riser ☐ Material ☐ Rating ☐ Size ☐ (*)

☐ **PIPING:** Material ☐ Rating ☐ Size ☐ (*)

(*) Specify e.g. API 5LX52, pressure in psig/barg, nom. bore in ins/mm, etc.

☐ **PRESSURE VESSEL:** Horiz/Vert Type ☐ Length/Dia ☐ (ins/mm)

(*) Specify e.g. separator, contactor, length tan to tan and diameter in ins/mm

☐ **PUMP:** Centrif ☐ Recip ☐ Single ☐ Double Seal ☐

☐ **STORAGE TANK:** Capacity ☐ (Specify units e.g. bbls, gall. m^3)

☐ **TURBINE:** Gas ☐ Dual Fuel ☐

☐ **VALVE:** Manual/Actuated Function ☐ Type ☐ Size ☐ (*)

(*) Specify e.g. Relief, ESDV, PCV, gate, ball, globe, diameter in ins/mm, etc.

Next Page

CAUSE OF LEAK CHECK LIST (SEE "CAUSE OF LEAK". ITEM 13. ON PAGE 3)

(Please indicate those items which come nearest to identifying the cause of the leak)
(Choose one parameter from each of the following categories, and tick appropriate boxes)

(a) DESIGN:

- ☐ FAILURE RELATED TO DESIGN
- ☐ NO DESIGN FAILURE

(b) EQUIPMENT:

- ☐ CORROSION: INTERNAL ☐ EXTERNAL ☐
- ☐ MECHANICAL FAILURE FATIGUE ☐ WEAROUT ☐
- ☐ EROSION
- ☐ MATERIAL DEFECTS
- ☐ OTHER (Specify) ________
- ☐ NO FAILURE IN THE EQUIPMENT ITSELF

(c) OPERATION:

- ☐ INCORRECTLY FITTED
- ☐ IMPROPER MAINTENANCE INSPECTION ☐ TESTING ☐ OPERATION ☐
- ☐ DROPPED OBJECT OTHER IMPACT ☐
- ☐ LEFT OPEN
- ☐ OPENED WHEN CONTAINING HC
- ☐ OTHER (Specify) ________
- ☐ NO OPERATIONAL FAILURE

(d) PROCEDURAL:

- ☐ NON - COMPLIANCE WITH PROCEDURE PERMIT TO WORK ☐
- ☐ DEFICIENT PROCEDURE
- ☐ OTHER (Specify) ________
- ☐ NO PROCEDURAL FAILURE

(e) OPERATIONAL MODE IN AREA AT TIME OF RELEASE:

- ☐ DRILLING WELL OPERATION ☐ WITH TREE ☐ TREE ☐ OIL ☐ GAS ☐
  (please specify actual operation e.g. wireline, well test etc.) ________
- ☐ NORMAL PRODUCTION
- ☐ PIGGING
- ☐ SHUTTING DOWN SHUTDOWN ☐ BLOW - DOWN ☐
- ☐ FLUSHING CLEANING ☐ INSPECTION ☐
- ☐ MAINTENANCE: HOT WORK ☐ OTHER (Specify) ________
- ☐ CONSTRUCTION: HOT WORK ☐ OTHER (Specify) ________
- ☐ TESTING SAMPLING ☐
- ☐ REINSTATEMENT START - UP ☐

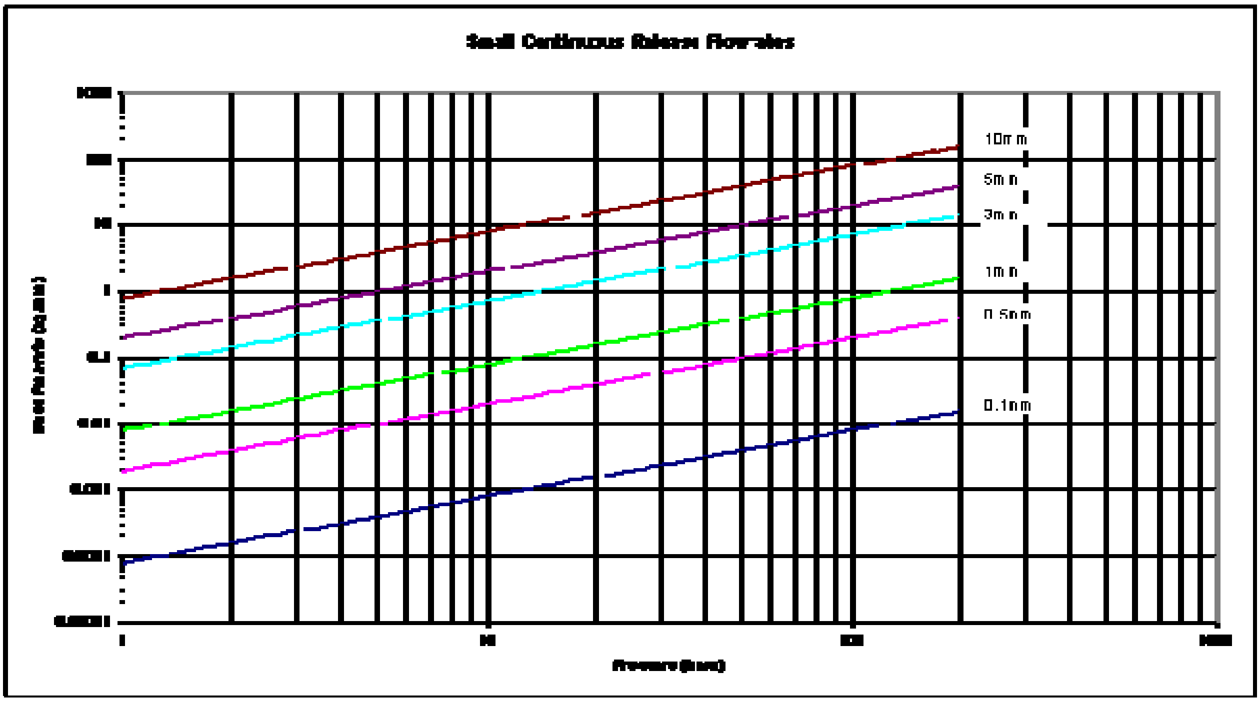
Continue

5

APPENDIX
2
ESTIMATION OF GAS RELEASES

- o0o -

The following graphs and table are provided (in the Help document) to give help and guidance on estimating the mass of gas released for different leak hole sizes, pressures, pipe system inventories etc.



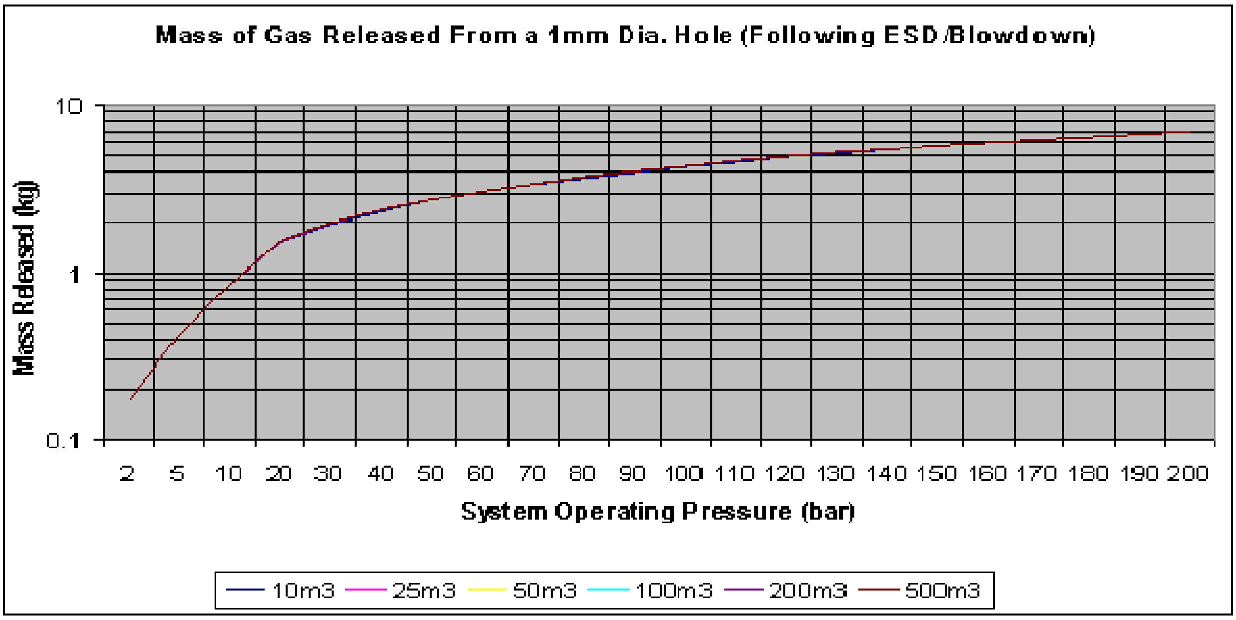
Graph shows the mass flow rates in kg/minute for a small continuous gas release

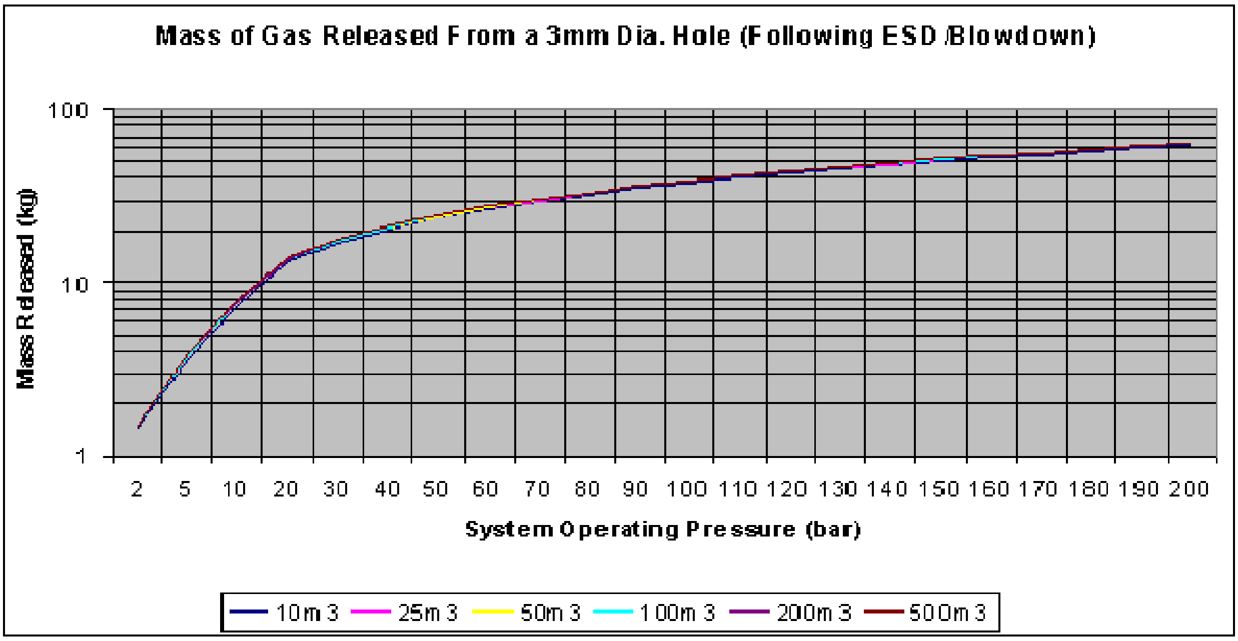
Pressure	Nominal Pipe Diameter (inch)						
Bara							
	3”	4”	6”	8”	10”	11”	12”
1	0.0045	0.0079	0.0178	0.0317	0.0495	0.0599	0.0713
5	0.0223	0.0396	0.0891	0.1585	0.2476	0.2996	0.3565
10	0.0446	0.0792	0.1783	0.3169	0.4952	0.5992	0.7131
15	0.0699	0.1188	0.2674	0.4754	0.7428	0.8988	1.0696
20	0.0891	0.1585	0.3565	0.6338	0.9904	1.1984	1.4261
25	0.1114	0.1981	0.4457	0.7923	1.238	1.4979	1.7827
50	0.2228	0.3962	0.8913	1.5846	2.4759	2.9959	3.5654
100	0.4457	0.7923	1.7827	3.1692	4.9519	5.9918	7.1307
150	0.6685	1.1885	2.674	4.7538	7.4278	8.9877	10.6961
200	0.8913	1.5846	3.5654	6.3384	9.9038	11.9836	14.2614
250	1.1142	1.9808	4.4567	7.923	12.3797	14.9795	17.8268

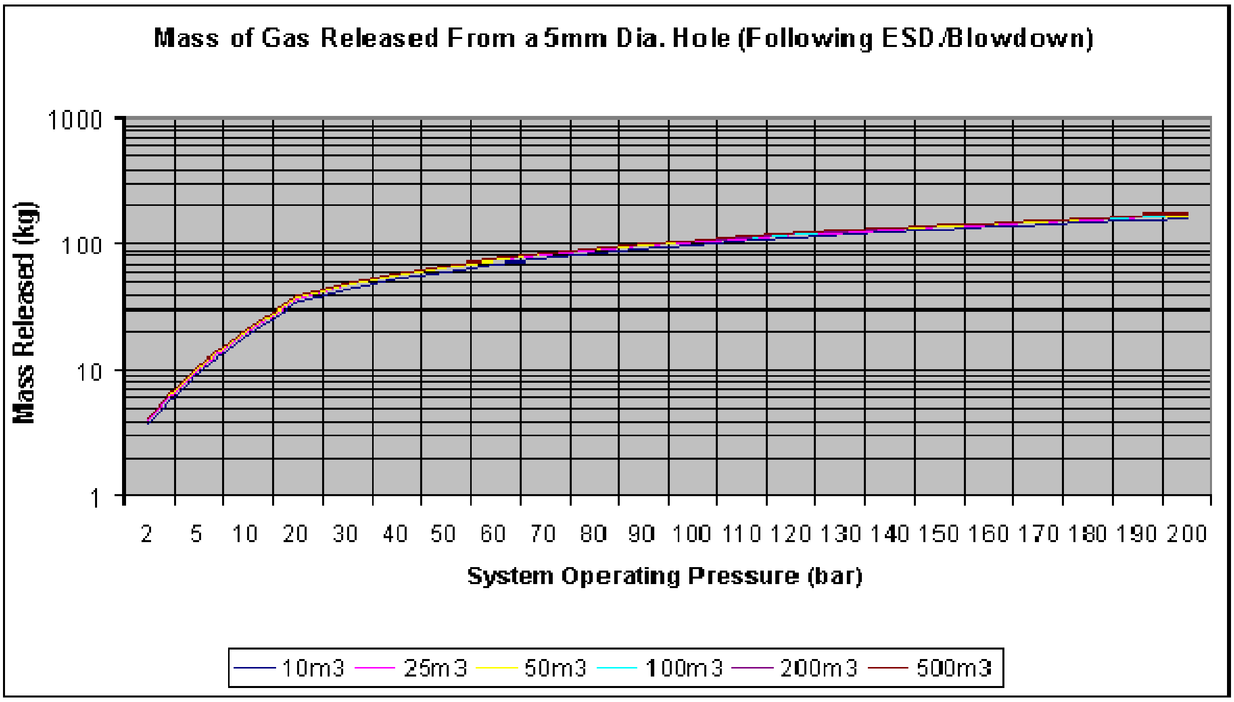
The table shows the mass of gas per metre length of piping (kg/m)

The following graphs are based on the assumptions:

- Gas molecular weight 26 kg/kmole
- Blowdown rate as per API 521 (blowdown from operating pressure to half the original or 8 bara, whichever is the lower, within 15 minutes of blowdown operation.






Mass of Gas Released From a 5mm Dia. Hole (Following ESD/Blowdown)
1000
100
10
1
Mass Released (kg)
2
5
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
System Operating Pressure (bar)
10m3
25m3
50m3
100m3
200m3
500m3

APPENDIX 3
HEADINGS IN THE DATABASE

- o0o -

The following are the headings in HCRD

Heading	Explanation
Reporting Year	Calendar year in which incident occurred. However, the spreadsheet relates to fiscal years, i.e. incidents occurring between the period 1 April to 31 March,
IDENTIFIER	Unique identifier for each incident/record
Duty Holder	
YEARQ	This gives the time of year at which the incident occurred as follows: 1Q = 1st Quarter i.e. 1 January to 31 March of the incident year etc
TIMEQ	This gives the time of day at which the incident occurred as follows:
Time in Quarter	1Q = 1st Quarter (00:01 to 06:00) etc
LOCATION	The location of the Installation at the time of the incident has been translated into one of three areas of the UKCS, namely N = Northern Area (590 N Latitude and above) including West of Shetland C = Central Area (between 590 N and 560 N) S = Southern Area (560 N and below) including Irish Sea and English Channel
WATER_RANGE (metres)	The actual reported Water Depth at the location has been translated into one of four Water Depth Ranges, i.e. less than 100 metres, 100 to less than 700 metres, 700 to less than 1000 metres, 1000 metres and upwards
AGE_RANGE (years)	The age of the Installation, at the time of the incident, is the period between the start-up date (from population data) and the time of the incident. This age has then been translated into one of five Age Ranges, i.e. less than 5 years old, between 5 and 10 years old, between 10 and 15 years old, between 15 and 20 years old, over 20 years old
CATEGORY	This is the type of Installation, i.e. F = Fixed, M = Mobile, S = Subsea.
MANNED?	If the installation is normally manned, this column will show a 'Y', if it is normally unattended (NUI) there will be an 'N' in this field.
PRODUCTION?	Y' if production facilities exist on the installation, 'N' if not.
WELLHEAD?	Y' if wellhead facilities exist on the installation, 'N' if not.
UTILITY?	Y' if utilities exist on the installation, 'N' if not
QUARTERS?	Y' if accommodation exists on the installation, 'N' if not.
RISER?	Y' if pipeline riser facilities exist on the installation, 'N' if not.
SUBSEA?	Y' if subsea satellite wells exist and are tied-back to the installation, 'N' if not.
FPS?	'Y' if the installation is a Floating Production System (including FSU, FPSO, etc.) and 'N' if not.
MOBILE_TYPE	For Mobile Installations, the rig type is given, i.e. S = Semi-submersible, J = Jack-up, D = Drill-ship
PROCESS	This is the type of Hydrocarbon released, i.e.NON-PROCESS, OIL, CONDENSATE, GAS, 2-PHASE
NON_PROCESS	The type of non-process hydrocarbon involved if 'NON-PROCESS' appears in the previous column e.g. diesel, helifuel, lubricating (lube) oil, hydraulic oil, seal oil, glycol, methanol, oil-based mud etc.
SEVERITY	The severity of the release as either 'MAJOR', 'SIGNIFICANT', or 'MINOR'.

DENSITY (kg/m3)	the density of Gas involved, in kg/m^3, for all records showing GAS in the 'PROCESS' column. For 2-PHASE releases, there will be a value in both this field and the 'GRAVITY' field.
GRAVITY (kg/m3)	This shows the gravity of liquid involved, in kg/m^3
GOR	For 2-PHASE releases only, this shows the Gas-to-Oil Ratio (GOR) as a fraction (kg Gas : kg Oil ratio).
H2S (ppm)	This is the reported level of H_2S present in ppm weight
QUANTITY (kg)	Amount of Hydrocarbon released in kgs
DURATION (mins)	Duration of leak in minutes
SYSTEM	A full description of the system involved, or a Drilling or Well Operation activity description
SEP_TRAIN No	If System above involves 'Separation', this is the train number of the particular separation train involved
SEP_TRAINS	If above is filled, this is the total number of separation trains on the Installation
SEP_STAGE	If above is filled, this is the stage of separation within the train
EQUIPMENT	The full equipment item description
FLANGE_TYPE	If equipment was flange, this is the type of joint involved, selected from Ring type (RTJ), Compressed, Spiral Wound, Clamp (Grayloc or similar), or Hammer Union (Chicksan), Other or Not Known
FLANGE_RATING (barg)	For those incidents involving flanges, this field contains the rating of the flange in barg
HORIZ/VERT	For those incidents involving Pig Launchers or Pig Receivers, this field will contain either 'Horizontal' or 'Vertical' to describe the orientation of the equipment
PTRAP_LENGTH (mm)	For those incidents involving Pig Launchers or Pig Receivers, this field will contain the length of the Pig trap, in mm.
PIPLNE_RATING (barg)	For those incidents involving Pipeline or Risers, this field will contain the rating of the Pipeline/Riser in barg
PIPING_RATING (barg)	For those incidents involving Piping, this field will contain the rating of the Piping in barg. This figure is not necessarily related to ANSI or API values
VESSEL_LENGTH (mm)	For those incidents involving Pressure Vessel, this field will contain the length of the vessel, in mm
VESSEL_DIA (mm)	For those incidents involving Pressure Vessel, this field will contain the diameter of the vessel, in mm.
STOR_CAPACITY (m3)	For those incidents involving Storage Tanks, this field will contain the tank capacity in m^3.
VALVE_TYPE	For those incidents involving valves, this field will contain the type of valve involved, i.e. gate, ball, plug, globe, needle, etc. NOT KNOWN has been inserted where a type was not reported
HAZ_CLASS	This field contains the Hazardous Area Classification for the location of the incident, where 1 and 2 represent areas 1 and 2 respectively, and 3 represents unclassified

HOLE_DIAM (mm)	This is the hydraulic equivalent hole size, deduced from d = 4A/p, in mm. Where d is the diameter of the hydraulic equivalent hole, A is the cross-sectional area of the actual hole in mm^2, and p is the wetted perimeter of the actual hole in mm. It is important to note that N/A in this field indicates that hole size is not applicable to the mode of release involved.
VENTILATION TYPE	The mode of module ventilation will be shown as 'NATURAL', ' FORCED', or 'NOT KNOWN' (where no ventilation type was reported).
NO_OF_SIDES	This will range from 0.5 (grated floor only) to 6 (all sides fully enclosed), and will show 'NOT KNOWN' where not reported.
MOD_VOLUME (m3)	This contains the volume of the module involved, in m^3, and will show 'NOT KNOWN' where not reported
AIR_CHANGES (perday)	This is the number of air changes per 24 hour day, and will show 'NOT KNOWN' where not reported.
WIND_SPEED (m/s)	This is the wind speed converted to m/s, and will show 'NOT KNOWN' where not reported.
WIND_DIRECTION (deg)	This is the heading with respect to platform North, in degrees, and will show 'NOT KNOWN' where not reported.
MAX_PRESSURE (barg)	This is the maximum allowable pressure of the system, in barg.
ACT_PRESSURE (barg)	The actual (working) pressure at time of incident, in barg.
INVENTORY (kg)	This is the isolatable hydrocarbon inventory contained in the system, in kgs. and will show 'NOT KNOWN' where not reported
HEAT	This shows whether a HEAT detector was activated 'YES, or not 'NO'.
SMOKE	This shows whether a SMOKE detector was activated 'YES, or not 'NO'.
FLAME	This shows whether a FLAME detector was activated 'YES, or not 'NO'.
GAS	This shows whether a GAS detector was activated 'YES, or not 'NO'.
DETECTION_OTHER	Where the release was detected by other means, either in addition to or instead of the conventional means of detection shown in the four fields above, this field will show what method was involved, e.g. visual, sound, smell, etc. Otherwise, 'NONE' will appear here,
DESIGN_CAUSE	YES' means that the failure was related to design, and 'NO' means no design failure was involved.
EQT_CAUSE	Equipment causation is sorted in the database into 6 primary categories, 2 secondary categories, and keywords to further describe 'other' categories
OP_CAUSE	Operational causation is sorted into 7 primary categories, 2 secondary categories, and keywords to further describe 'other' categories.
PRO_CAUSE	Procedural causation is sorted into 4 primary categories, 1 secondary category, and keywords to further describe 'other' categories.
OP_MODE	The operational mode in the area at the time of release is sorted into 9 primary categories, 7 secondary categories, 2 tertiary categories, and keywords to further describe 'other' categories.
IGNITION	'YES' in this field signifies that ignition took place

IGN_TYPE	If ignition took place (i.e. a 'YES' appears in the previous field) then this column will carry 'IMMEDIATE' for immediate ignition , 'DELAYED' for a delayed ignition, or 'NONE' for not applicable
DELAY_TIME (s)	If delayed ignition occurred (i.e 'DELAYED' appears in the previous field) then the estimated delay time between start of release and actual ignition, in seconds, will appear here.
FLASH EXPLOSION JET POOL	These four fields designate the sequence of events during the ignition. A '1' will appear in the field appropriate to the primary ignition event, a '2' will appear in the second, etc. For example, a Flash fire followed by an Explosion and then a Jet fire would show as 1 2 3 in the 'FLASH', 'EXPLOSION', and 'JET' fields respectively, with 'POOL' left blank A pool fire on its own would appear as '1' in the 'POOL' field only.
SHUTDOWN	AUTO' in this field signifies that automatic shutdown took place, and 'MANUAL' indicates that there was a manual shutdown.
BLOWDOWN	AUTO' in this field signifies that automatic blowdown took place, and 'MANUAL' indicates that there was a manual blowdown.
DELUGE	AUTO' in this field signifies that automatic deluge took place, and 'MANUAL' indicates that the deluge system was manually operated
CO2_HALON	AUTO' in this field signifies that automatic operation of the CO_2/Halon system took place, and 'MANUAL' indicates that the CO_2/Halon system was manually operated.
MUSTER	ATSTATIONS' in this field signifies that a muster took place at stations, whereas 'ATLIFEBOATS' indicates that the muster took place at the lifeboats.
EMERACT_OTHER	If any other emergency action was taken during the incident, but was not adequately covered by any of the previous fields, then a 'YES' will appear in this field.

APPENDIX
4
EXAMPLES OF REPORTS

- o0o -

Leak Frequency

Select Criteria

Systems	○	Start Year	1992/1993
Equipment	○	End Year	2008/2009
Systems & Equipment	◉		
Drilling & Well Operations	○		

Systems

Primary	Secondary	Tertiary	Quaternary
GAS COMPRESSION			

Equipment

Primary	Secondary	Tertiary	Quaternary
PIPING	STEEL	D > 11"	

Results

Total system / equipment years	251905	Leak frequency	1.5879E-5
Total releases found:		Total releases in database	4014
Minor	1		
Significant	2		
Major	1		
Total	4		

Hole Size Distribution

Selected Criteria

System GAS COMPRESSION **Equipment** PIPING, STEEL, D > 11" **From** 1992/1993 T

Results

Size Band (mm)

Year	<10	10 < 25	25 < 50	50 < 75	75 < 100	>=100	N/A
1992/1993	0	0	0	0	0	0	0
1993/1994	0	0	0	0	0	1	0
1994/1995	0	0	0	0	0	0	0
1995/1996	0	0	0	0	0	0	0
1996/1997	0	0	0	0	0	0	0
1997/1998	0	0	0	0	0	0	0
1998/1999	1	0	0	0	0	0	0
1999/2000	0	0	0	0	0	0	0
2000/2001	0	0	0	0	0	0	0
2001/2002	0	0	0	0	0	0	0
2002/2003	0	0	0	0	0	0	0
2003/2004	1	0	0	0	0	0	0
2004/2005	1	0	0	0	0	0	0
2005/2006	0	0	0	0	0	0	0
2006/2007	0	0	0	0	0	0	0
2007/2008	0	0	0	0	0	0	0
2008/2009	0	0	0	0	0	0	0
Distribution	0.7500	0.0000	0.0000	0.0000	0.0000	0.2500	0.0000

Installation Frequency

Select Criteria

Location	North UKCS				
Type	Fixed	Manned	Yes	Years From	1992/1993

Results

	Total releases found	Frequency
Minor	685	1.2298
Significant	599	1.0754
Major	48	0.0862
Total	1332	2.3914
Total Installations	557	

Year	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	0
No. of Installations	28	31	32	31	32	32	34	34	34	34	33	33	33	

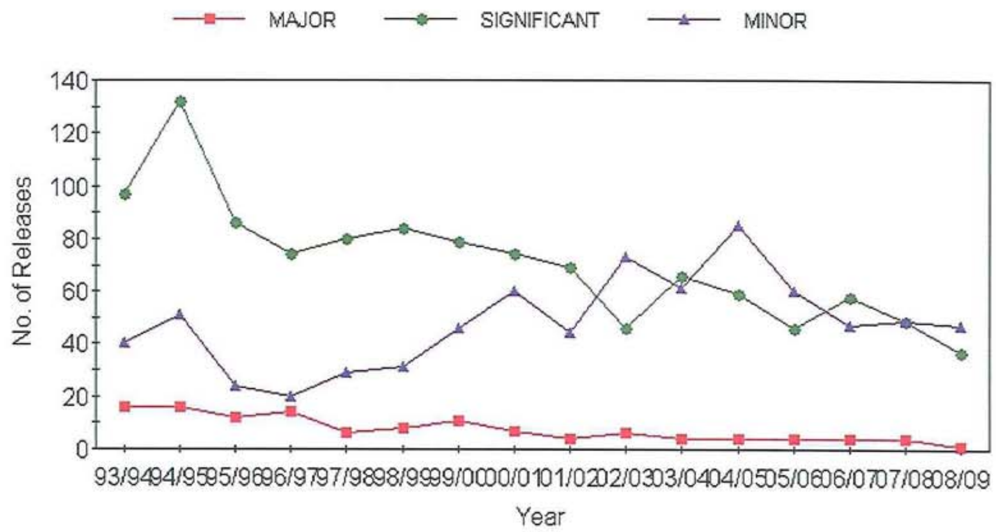
Quarterly Report

Select Criteria

Quarter From September Enter Year 2000

September 2000				
Hydrocarbon Type		**Severity**		**Total**
	Minor	Significant	Major	
Non-Process	3	1	0	4
Oil	3	2	0	5
Condensate	1	0	0	1
Gas	9	8	0	17
2-Phase	1	1	0	2
Total	17	12	0	29
October 2000				
Hydrocarbon Type		**Severity**		**Total**
	Minor	Significant	Major	
Non-Process	5	0	0	5
Oil	7	1	0	8
Condensate	2	0	0	2
Gas	6	8	1	15
2-Phase	0	2	0	2
Total	20	11	1	32
November 2000				
Hydrocarbon Type		**Severity**		**Total**
	Minor	Significant	Major	
Non-Process	3	0	0	3
Oil	4	4	0	8
Condensate	1	0	0	1
Gas	5	7	0	12
2-Phase	0	4	0	4
Total	13	15	0	28
Quarter (September 2000 - November 2000)				
Hydrocarbon Type		**Severity**		**Total**
	Minor	Significant	Major	
Non-Process	11	1	0	12
Oil	14	7	0	21
Condensate	4	0	0	4
Gas	20	23	1	44
2-Phase	1	7	0	8
Total	50	38	1	89

Severity analysis, gas releases.



1: Gas releases reported from 1 April 1993 to 31 March 2009.

2: The reducing trend in significant gas releases since 1998/99, showed an upsurge in 2003/04, but resumed in 2004/05 and 2005/06. A rise occurred in 2006/07 since when it has shown further decline.

3: Note that a PRINT of this graph requires landscape orientation

Please read notes at the end of this report

ALL OFFSHORE HYDROCARBON RELEASES

Reported Releases by Year - 1996/1997 to 2010/2011

Severity	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011
Minor	78	66	85	95	145	128	144	172	182	136	99	114	96	100	13
Significant	129	140	133	127	117	109	79	92	76	68	70	69	60	81	8
Major	19	13	15	12	8	4	7	5	7	5	4	5	1	2	1
Total	226	219	233	234	270	241	230	269	265	209	173	188	157	183	22

Notes:

1: Click on a year hyperlink to view the monthly trend for that year.
2: The data for 2008/09 is subject to change.
3: Latest information for 2009/10 (i.e. 1 April 2009 onwards) is provisional due to variable lead-in times for receiving, checking and inputting data, and hence will not be included until finalised.
5: A print of this table requires landscape orientation

APPENDIX 5
FREQUENCIES PREDICTED FROM STANDARD REPORTS

- o0o -

Years	System	Primary	Secondary	System/Equipment Years	Number of Releases	Leak frequency from HCRD Average	Leak frequency from HCRD 95% Upper
1992-2009	Gas Compression	Flanges	D>11"	79906	16	2.00E-04	3.04E+04
			3"<D<11"	216310	41	1.90E-04	2.46E-04
			D<3"	561400	48	8.55E-05	1.09E-04
		Steel piping	D>11"	251905	4	1.59E-05	3.63E-05
			3"<D<11"	344815	20	5.80E-05	8.43E-05
			D<3"	265697	64	2.41E-04	2.97E-04
1992-2009	Export/Gas	Flanges	D>11"	32152	3	9.33E-05	2.41E-04
			3"<D<11"	67594	1	1.48E-05	7.02E-05
			D<3"	178108	7	3.93E-05	7.38E-05
		Steel piping	D>11"	69130	1	1.45E-05	6.86E-05
			3"<D<11"	105985	3	2.83E-05	7.32E-05
			D<3"	53545	6	1.12E-04	2.21E-04
1992-2009	Flowlines/Gas	Flanges	D>11"	53	1	1.89E-02	8.64E-02
			3"<D<11"	48024	22	4.58E-04	6.54E-04
			D<3"	48692	15	3.08E-04	4.74E-04
		Steel piping	D>11"	1066	2	1.88E-03	5.89E-03
			3"<D<11"	103520	7	6.76E-05	1.27E-04
			D<3"	13278	7	5.27E-04	9.90E-04
1992-2009	Import/Gas	Flanges	D>11"	19510	1	5.13E-05	2.43E-04
			3"<D<11"	135156	1	7.40E-06	3.51E-05
			D<3"	180605	0		1.66E-05
		Steel piping	D>11"	50166	0		5.97E-05
			3"<D<11"	289830	0		1.03E-05
			D<3"	54742	1	1.83E-05	8.67E-05
1992-2009	Manifold/Gas	Flanges	D>11"	12794			2.34E-04
			3"<D<11"	98455	5	5.08E-05	1.07E-04
			D<3"	84527	3	3.55E-05	9.17E-05
		Steel piping	D>11"	72448	0		4.13E-05
			3"<D<11"	107081	0		2.80E-05
			D<3"	34872	3	8.60E-05	2.22E-04
1992-2009	Metering/Gas	Flanges	D>11"	13043	0		2.30E-04
			3"<D<11"	33659	5	1.49E-04	3.12E-04
			D<3"	70068	2	2.85E-05	8.98E-05
		Steel piping	D>11"	37035	2	5.40E-05	1.70E-04
			3"<D<11"	49942	0		6.00E-05
			D<3"	43180	2	4.63E-05	1.46E-04
1992-	Process	Flanges	D>11"	17322	2	1.15E-04	3.63E-04

2009	Dehydration/Gas						
			3"<D<11"	73835	9	1.22E-04	2.13E-04
			D<3"	254033	4	1.57E-05	3.60E-05
		Steel piping	D>11"	30899	0		9.69E-05
			3"<D<11"	74503	2	2.68E-05	8.45E-05
			D<3"	92422	14	1.51E-04	2.37E-04
1992-2009	Process Prod Water Treatment/Gas	Flanges	D>11"	1509	0		1.98E-03
			3"<D<11"	14621	0		2.05E-04
			D<3"	101339	0		2.96E-05
		Steel piping	D>11"	1040	0		2.88E-03
			3"<D<11"	12244	2	1.63E-04	5.14E-04
			D<3"	47838	4	8.36E-05	1.91E-04
1992-2009	Process LPG Condensate/Gas	Flanges	D>11"	6550	1	1.53E-04	7.24E-04
			3"<D<11"	57981	1	1.72E-05	8.18E-05
			D<3"	216306	3	1.39E-05	3.58E-05
		Steel piping	D>11"	14251	0		2.10E-04
			3"<D<11"	84767	6	7.08E-05	1.40E-04
			D<3"	127616	22	1.73E-03	2.46E-04
1992-2009	Process Sour/Gas	Flanges	D>11"	31	0		9.21E-02
			3"<D<11"	9176	0		3.26E-04
			D<3"	25546	1	3.91E-05	1.86E-04
		Steel piping	D>11"	77	0		3.82E-02
			3"<D<11"	7198	1	1.39E-04	6.59E-04
			D<3"	7807	1	1.28E-04	6.07E-04
1992-2009	Separation/Gas Production	Flanges	D>11"	21428	0		1.40E-04
			3"<D<11"	41586	0		7.20E-05
			D<3"	165600	0		1.81E-05
		Steel piping	D>11"	63175	0		4.74E-05
			3"<D<11"	45195	4	8.85E-05	2.03E-04
			D<3"	42722	2	4.68E-05	1.47E-04
1992-2009	Utitities/ Gas/Fuel Gas	Flanges	D>11"	36916	2	5.42E-05	1.71E-04
			3"<D<11"	256301	8	3.12E-05	5.63E-05
			D<3"	341686	65	1.90E-04	2.34E-04
		Steel piping	D>11"	1573	0		1.90E-03
			3"<D<11"	100502	4	3.98E-05	9.11E-05

			D<3"	348825	19	5.45E-05	7.99E-05

Allgasdata//Population

Frequencies for flanges are in terms of per **flange face** per year (as defined in section 2.3.3), and for piping are in terms of per m per year. The frequency for a **flange joint** is taken as twice the frequency in the table. Screwed joints also count as two flanges. The 95% upper confidence values were determined using an excel spreadsheet (CI of binominal fraction.xls) provided by RIVM.

It was noticed during the investigation that in a small number of cases the number of leaks in the table above does not correspond with the number of leaks in the detailed data that can be extracted from HCRD (by selecting year on year data). The reason for this discrepancy is not known and has not been investigated further.

Data on pipelines are included in HCRD. These were not included in the table above because most of the pipelines are subsea, where the conditions and therefore failure modes are considerably different from the failure modes on land, and as pipelines are not a defined 'system', the population for data for gas pipelines (alone) cannot be determined.

If all the data in the table above are combined, (i.e. to give overall release frequencies for gas systems) the following may be derived.

Primary	**Secondary**	**System/Equipment Years**	**Number of Releases**	**Leak frequency from HCRD Average**	**Leak frequency from HCRD 95% Upper**
Flanged Face	D>11"	241214	26	1.08E-04	1.50E-04
	3"<D<11"	1052698	93	8.83E-05	1.05E-04
	D<3"	2227910	148	6.64E-05	7.61E-05
Steel piping	D>11"	592765	9	1.52E-05	2.65E-05
	3"<D<11"	1325582	49	3.70E-05	4.69E-05
	D<3"	1132544	145	1.28E-04	1.47E-04

Allgasdata//Population

Frequencies for flanges are in terms of per flange face per year, and for piping are in terms of per m per year.

APPENDIX

6

FREQUENCIES PREDICTED FROM DNV'S INTERPRETATION OF HCRD

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The following frequencies are derived from HCRD using DNV's current interpretation of the data.

Full pressure leak frequencies for piping (per metre year)

HOLE DIA RANGE (mm)	2" DIA (50 mm)	12" DIA (300 mm)	18" DIA (450 mm)	24" DIA (600 mm)
1-3	2.7E-05	9.4E-06	9.0E-06	8.9E-06
3-10	1.1E-05	3.9E-06	3.8E-06	3.7E-06
10-50	4.7E-06	1.6E-06	1.6E-06	1.6E-06
50-150	0.0E+00	3.5E-07	3.3E-07	3.3E-07
>150	0.0E+00	6.7E-07	6.6E-07	6.6E-07
TOTAL	4.3E-05	1.6E-05	1.5E-05	1.5E-05

TN 14

A comparison of the number of meters of piping per flange recorded in the HCRD to a count performed on three FLACS models representing installations on the Norwegian continental shelf found that the HCRD gave less than two meters of piping per flange joint, while counting on the FLACS models gave a number of around seven. It was concluded that this indicated that the recorded number of leaks was reasonable, while the recorded exposure data was underestimated. Analyses for Statoil would therefore use frequencies that were a factor of three less than the above derived frequencies.
The frequency of a full bore rupture ranges from 6.5E-07 per m per year for 150mm diameter piping to 5E-07 per m per year for 1200mm diameter piping.

Full pressure leak frequencies for flanges (per flanged joint year)

HOLE DIA RANGE (mm)	2" DIA (50 mm)	12" DIA (300 mm)	18" DIA (450 mm)	24" DIA (600 mm)
1-3	4.5E-05	9.8E-05	1.3E-04	1.6E-04
3-10	1.7E-05	3.7E-05	4.9E-05	6.1E-05
10-50	6.5E-06	1.4E-05	1.9E-05	2.3E-05
50-150	0.0E+00	2.6E-06	3.5E-06	4.3E-06
>150	0.0E+00	6.5E-06	6.9E-06	7.4E-06
TOTAL	6.9E-05	1.6E-04	2.1E-04	2.6E-04

TN 14

The frequency of a full bore rupture for flanges 150mm and above is 6E-06 per year.

APPENDIX 7
DETAILS OF RELEASES FROM GAS SYSTEMS WITH A HOLE DIAMETER 10MM OR MORE

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Approximate Year of construction	Reported hole dia	Severity	System	Equipment	Flange type	Actual pressure	Design cause	Equipment cause	Operating cause	Procedural cause	Operating mode
	mm					Barg					
'2007'	>100	'MAJOR'	'FLOWLINES / GAS'	'FLANGES / 3? < D < = 11?'	'(GRAYLOC) CLAMP'	'10'	'NO'	NONE	OPENED	NONCOMPTW	NONE
'1998'	>100	'MINOR'	'GAS COMPRESSION'	'FLANGES / 3? < D < = 11?'	'COMPRESSED JOINT'	'5'	'NO'	NONE	LEFTOPEN	NONCOMPTW	REINSTATEMENT
'1993'	>100	'SIGNIFICANT'	'UTILITIES / GAS / FUEL GAS'	'FLANGES / D < = 3?'	'RTJ'	'15.86207'	'NO'	MECHWEAR	NONE	NONCOMPROC	NORMPROD
'1997'	>100	'SIGNIFICANT'	'GAS COMPRESSION'	'PIPING / STEEL / 3? < D < = 11?'	''	'110'	'NO'	MECHFAIL	IMPROPOP	NONE	NORMPROD
'2008'	>100	'MINOR'	'FLOWLINES / GAS'	'PIPING / STEEL / D > 11?'	''	'0.2'	'NO'	MECHFAIL	NONE	NONCOMPROC	SHUTTINGDN
'1994'	>100	'MAJOR'	'GAS COMPRESSION'	'PIPING / STEEL / D > 11?'	''	'16'	'YES'	MECHFAT	NONE	NONE	STARTUP
'1994'	76	'MAJOR'	'GAS COMPRESSION'	'FLANGES / D < = 3?'	'(GRAYLOC) CLAMP'	'352'	'NO'	MECHFAT	NONE	NONE	NORMPROD
'2002'	76	'MAJOR'	'PROCESSING / GAS / LPG/ CONDENSATE'	'PIPING / STEEL / 3? < D < = 11?'	''	'38'	'NO'	CORREXT	NONE	NONE	NORMPROD
'1994'	51	'MINOR'	'PROCESSING / GAS / DEHYDRATION'	'FLANGES / D < = 3?'	'COMPRESSED JOINT'	'0'	'NO'	NONE	LEFTOPEN	NONCOMPROC	SHUTDOWN
'2000'	51	'MAJOR'	'GAS COMPRESSION'	'FLANGES / D > 11?'	'COMPRESSED JOINT'	'54'	'NO'	NONE	IMPROPOP	NONCOMPROC	REINSTATEMENT
'1996'	50	'SIGNIFICANT'	'UTILITIES / GAS / FUEL GAS'	'FLANGES / 3? < D < = 11?'	'COMPRESSED JOINT'	'1.5'	'NO'	NONE	OPENED	NONCOMPTW	ROUTINEMAINT
'1998'	38	'MINOR'	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D < = 3?'	''	'0'	'NO'	NONE	LEFTOPEN	NONE	ROUTINEMAINT
'2003'	37	'MINOR'	'GAS COMPRESSION'	'PIPING / STEEL / D < = 3?'	''	'9.9999998E-3'	'NO'	NONE	IMPROPOP	NONCOMPROC	MAINTHOTWK

'2001'	25	'SIGNIFICANT '	'GAS COMPRESSION'	'FLANGES / 3? < D <= 11?'	'COMPRESSED JOINT'	'28'	'NO'	NONE	IMPROPOP	DEFPROC	NORMPROD
'1997'	25	'SIGNIFICANT '	'GAS COMPRESSION'	'FLANGES / D <= 3?'	'RTJ'	'12'	'NO'	NONE	INCORRFIT	NONCOMPROC	REINSTATEMENT
'1997'	25	'MINOR'	'PROCESSING / GAS / DEHYDRATION'	'FLANGES / D <= 3?'	'COMPRESSED JOINT'	'1.144409E-8'	'NO'	NONE	OPENED	DEFPROC	REPLACEMENT
'1997'	25	'SIGNIFICANT '	'GAS COMPRESSION'	'PIPING / STEEL / D <= 3?'	''	'0'	'NO'	NONE	IMPROPOP	DEFPROC	REPLACEMENT
'1997'	25	'SIGNIFICANT '	'GAS COMPRESSION'	'PIPING / STEEL / D <= 3?'	''	'26'	'NO'	NONE	INCORRFIT	NONE	STARTUP
'1998'	25	'SIGNIFICANT '	'GAS COMPRESSION'	'PIPING / STEEL / D <= 3?'	''	'74'	'NO'	MECHFAIL	INCORRFIT	NONE	STARTUP
'1995'	25	'MINOR'	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D <= 3?'	''	'0'	'YES'	NONE	IMPROPOP	NONE	NORMPROD
'1998'	25	'MINOR'	'FLOWLINES / GAS'	'PIPING / STEEL / D <= 3?'	''	'122'	'YES'	NONE	IMPROPOP	DEFPROC	NORMPROD
'1998'	25	'MINOR'	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D <= 3?'	''	'10.34483'	'YES'	CORRINT	NONE	NONE	REINSTATEMENT
'1992'	22	'SIGNIFICANT '	'GAS COMPRESSION'	'FLANGES / D <= 3?'	'RTJ'	'2'	'NO'	NONE	IMPROPTEST	DEFPROC	REINSTATEMENT
'2003'	21	'SIGNIFICANT '	'GAS COMPRESSION'	'FLANGES / 3? < D <= 11?'	'COMPRESSED JOINT'	'13'	'NO'	MECHFAIL	AWAITING INVESTIGATION	AWAITING INVESTIGATION	FLUSHING
'1998'	20	'SIGNIFICANT '	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D <= 3?'	''	'34'	'NO'	MECHFAIL	INCORRFIT	NONE	STARTUP
'1996'	19	'MAJOR'	'GAS COMPRESSION'	'PIPING / STEEL / D <= 3?'	''	'55.172409'	'NO'	NONE	INCORRFIT	NONE	STARTUP
'1996'	19	'MAJOR'	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D <= 3?'	''	'30'	'NO'	MECHFAIL	NONE	NONE	STARTUP
'1998'	19	'SIGNIFICANT '	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D <= 3?'	''	'11'	'NO'	NONE	OPENED	NONCOMPROC	INSPECTION
'2008'	17	'SIGNIFICANT	'FLOWLINES /	'PIPING /	''	'27.58621'	'NO'	EROSION	NONE	NONCOMPROC	CLEANING

		'	GAS'	STEEL / 3? < D < = 11?'							
'1996'	17	'SIGNIFICANT '	'PROCESSING / GAS / SOUR (H2S/CO2) TREATMENT'	'PIPING / STEEL / 3? < D < = 11?'	''	'0.013'	'NO'	NONE	IMPROPOP	NONCOMPROC	MAINTHOTWK
'1993'	15	'SIGNIFICANT '	'EXPORT / GAS'	'PIPING / STEEL / D < = 3?'	''	'158.6207'	'NO'	CORRINT	NONE	NONE	REINSTATEMENT
'1995'	13	'SIGNIFICANT '	'PROCESSING / GAS / LPG/ CONDENSATE'	'FLANGES / D < = 3?'	'COMPRESS ED JOINT'	'0.689655 18'	'NO'	NONE	OPENED	NONCOMPROC	CONSTHOTWK
'2001'	13	'SIGNIFICANT '	'FLOWLINES / GAS'	'PIPING / STEEL / D < = 3?'	''	'9.999999 8E-3'	'YES'	MECHFAT	NONE	NONE	SHUTDOWN
'1993'	13	'SIGNIFICANT '	'GAS COMPRESSION'	'PIPING / STEEL / D < = 3?'	''	'15.17241'	'NO'	MECHFAIL	INCORRFIT	NONCOMPROC	NORMPROD
'1996'	13	'SIGNIFICANT '	'PROCESSING / GAS / PROD. WATER TREATMENT'	'PIPING / STEEL / D < = 3?'	''	'7.586206 9'	'NO'	EROSION	IMPROPINSP	NONE	NORMPROD
'1992'	12	'SIGNIFICANT '	'GAS COMPRESSION'	'FLANGES / D > 11?'	'COMPRESS ED JOINT'	'12.41379'	'NO'	NONE	IMPROPOP	DEFPROC	REINSTATEMENT
'1997'	12	'SIGNIFICANT '	'UTILITIES / GAS / FUEL GAS'	'FLANGES / D < = 3?'	'COMPRESS ED JOINT'	'15'	'NO'	NONE	INCORRFIT	NONCOMPROC	REINSTATEMENT
'2001'	11	'MAJOR'	'MANIFOLD / GAS'	'PIPING / STEEL / D < = 3?'	''	'25'	'YES'	EROSION	IMPROPINSP	NONE	PIGGING
'1993'	10	'SIGNIFICANT '	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / 3? < D < = 11?'	''	'35'	'NO'	NONE	IMPROPTES T	NONCOMPROC	STARTUP
'1995'	10	'SIGNIFICANT '	'PROCESSING / GAS / LPG/ CONDENSATE'	'PIPING / STEEL / D < = 3?'	''	'1.37931'	'NO'	CORREXT	NONE	NONE	NORMPROD
'2000'	10	'MINOR'	'GAS COMPRESSION'	'FLANGES / D < = 3?'	'COMPRESS ED JOINT'	'0.5'	'NO'	NONE	OPENED	NONE	REMOVAL
'2005'	10	'MINOR'	'GAS COMPRESSION'	'FLANGES / D < = 3?'	'RTJ'	'1'	'NO'	NONE	OPENED	NONE	TESTING
'1997'	10	'SIGNIFICANT '	'UTILITIES / GAS / FUEL GAS'	'FLANGES / D < = 3?'	'COMPRESS ED JOINT'	'6'	'NO'	MECHFAIL	NONE	NONE	NORMPROD
'1997'	10	'SIGNIFICANT	'EXPORT / GAS'	'PIPING /	''	'1.144409	'NO'	NONE	IMPROPMAI	NONE	REPLACEMENT

		'		STEEL / 3? < D < = 11?'		E-8'			NT		
'2008'	10	'MINOR'	'PROCESSING / GAS / PROD. WATER TREATMENT'	'PIPING / STEEL / 3? < D < = 11?'	"	'6.987'	'NO'	CORRINT	NONE	NONE	REINSTATEMENT
'1999'	10	'SIGNIFICANT '	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D < = 3?'	"	'32'	'NO'	MECHFAIL	NONE	NONE	SHUTDOWN
'2004'	10	'SIGNIFICANT '	'UTILITIES / GAS / FUEL GAS'	'PIPING / STEEL / D < = 3?'	"	'20'	'YES'	SPECIFICATIO N	INCORRFIT	NONE	NORMPROD

Allgasdata19922008/ 19922008Gas10mmormore reduced

APPENDIX
8
EXTRACTS FROM BEVI - METHODOLOGY USED IN THE NETHERLANDS FOR QRA

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Information on the methodology for QRAs in the Netherlands is given in Bevi. The following extracts are considered relevant for the current considerations and are included mainly for readers who are not resident in the Netherlands:

- For scenarios and failure frequencies no distinction is made between process pipes or transport pipes, the materials from which a pipeline is made, the presence of cladding, the design pressure of a pipeline or its location on a pipe bridge. A distinction is made between aboveground pipes and underground pipes.
- The frequencies for aboveground pipes are as given in the following table;

	Frequency (per meter per annum) **nominal diameter < 75 mm**	**Frequency (per meter per annum)** **75 mm ≤ nominal diameter ≤ 150 mm**	**Frequency (per meter per annum)** **nominal diameter > 150 mm**
1. Rupture in the pipeline	1×10^{-6}	3×10^{-7}	1×10^{-7}
2. Leak with an effective diameter of 10% of the nominal diameter, up to a maximum of 50 mm	5×10^{-6}	2×10^{-6}	5×10^{-7}

- These frequencies include failures due to flanges (and valves).
- In very specific situations the use of a lower failure frequency for transport pipes aboveground can be justified, such as the failure frequency of (underground) pipes in a pipe bay. Lower failure frequencies are used in specific situations, particularly for natural gas pipes. The use of failure frequencies for transport pipes aboveground that are lower than the values in the table above must be submitted and approved on a case-by-case basis by the competent authority
- In the case of a line rupture, outflow occurs from both ends of the rupture. There are several possibilities:
  a If the outflow mainly takes place from one end, the scenario can be modelled as a rupture of one pipeline (‘line rupture’).
  b If the rupture occurs in a long transport pipeline, the various contributions from both ends of the rupture are included in the calculation of the outflow.
  c If the contributions from both ends of the line rupture are relevant to the outflow, one effective pipeline diameter must be used in the calculation, for which the outflow rate matches the outflow rate from both ends added together (given for input into SAFETI NL).

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