Best Practice Facility Parts Count Determination

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Abstract

The HSE’s hydrocarbon release database (HCRD) is the world’s most comprehensive list of offshore process leaks in terms of number of data entries, years covered and level of detail. Despite this, it has become apparent that the quality of the data, in terms of both incidents and equipment populations, is not as good as is generally perceived. Joint industry initiatives involving operators, HSE, Oil and Gas UK (OGUK), and safety consultants have been underway during 2018 to improve the data set held in the HCRD. This work builds on previous work performed by DNV GL and ESR [1][2]. The aim of these initiatives is to improve the database population information (past and present), i.e. the number of equipment years held in the database for each item, and liaison with HSE to improve the reporting of incidents.

One of the prime purposes of the HCRD is to determine the frequency of leaks occurring from various types of process equipment. These frequencies can then be applied to a facility as a whole by multiplying the total number of pieces of equipment (from a ‘parts count’) by their specific leak frequency. One conclusion of the initiatives is that there is an element of subjectivity in determining the total parts count for each installation and thereby the total population against which the incident data can be compared in deriving frequencies. If this is under or overestimated, the leak frequency and thus the entire risk profile of the facility will be less accurate. This potentially impacts any frequency-based assessments using this data, and may lead to incorrect prioritisation of safety resources. While there is some guidance on how to count equipment [3][4], this is not always clear and can lead to inconsistencies.

The original HCRD equipment population database was established more than 20 years ago in an extensive and resource intensive exercise. However, this population database has not been adequately maintained over the years and although a population review and ‘back fill’ exercise was undertaken in 2016 to fill some of the main gaps, a new exercise is required to re-establish its accuracy. To reduce the burden on industry, it is being proposed by the Oil & Gas UK Accident & Failure Frequency Data Work Group (AFFD WG) that a simpler approach is taken to re-assess the population data and how it is changing with time by using the data from parts count data in existing Quantitative Risk Assessments (QRAs). This is similar to the approach used in the PLOFAM2 [5] database (Process Leaks for Offshore Installations Frequency Assessment Model) which involves estimating the equipment population for process equipment on Norwegian installations. This approach should provide a practical means of updating the equipment counts in the future as installations are commissioned, modified and decommissioned. Since this exercise will involve combining population data from a number of different sources, a consistent approach is to be encouraged.

The following paper gives a short introduction to the HSE HCRD and a summary of current industry initiatives. The main content of the paper however is to provide a pragmatic and consistent methodology for counting equipment parts on an installation for use in the HCRD population updates and by risk assessment practitioners when undertaking QRAs. The intention of this paper is to serve as a road map that can be adopted across industry and form the background for an official OGUK publication guideline. The methodology proposed has been agreed as a good starting position on which to base a more formal project aimed at obtaining acceptance from all interested parties. This paper has been prepared by representatives from MMI Thornton Tomasetti, DNV GL, ESR Technology, and Atkins.

1. Introduction

1.1. Summary of the current industry initiatives

The Oil & Gas UK Accident & Failure Frequency Data Work Group (AFFD WG) was first established in 2013, under the then Major Hazard Management Forum, to review the future of the HCRD and address emerging issues, including the population data. This coincided with implementation of the EU Directive on offshore safety [6] and the introduction of the ROGI (Report of an Oil and Gas Incident) form [7] for reporting. The overall aim of the working group was to ensure all historical accident and failure frequency data feeding into QRA and other assessments remains fit for purpose and to facilitate better decision making with regards to risk management.

With regard to the population data, it had been noted that no changes had been made to the data for more than ten years. In particular:

- There were a large number of installations where the equipment counts were not completed for all identified systems;
- There were a large number of installations for which no data was ever recorded (none after around 2002).

To provide a short-term temporary solution for the above two concerns, a population ‘back-fill’ exercise was carried out in 2016, using (a) average data for systems where equipment data was missing, and (b) ‘surrogate’ data from similar installations for those where no data existed.
In order to focus on a more permanent solution for the population data going forward, the AFFD WG Terms of Reference were modified in 2017, with the following revised objectives:

1. To identify a fit for purpose, sustainable process for maintaining and updating population data previously kept within the HSE HCR database, appropriate to industry resources / requirements, and acceptable to industry and the regulator, for recommendation to the O&G UK Board;
2. Identify potential future improvements for QRA failure frequency data quality, to be reviewed once the HCR database population data process is completed;
3. To provide oversight to the development of a JIP scope and proposal for development of a standard methodology for use of HCR data in QRA to be presented to the Major Hazards Management (MHM) Technical Group.

A proposal is being submitted to Duty Holders from the AFFD WG to address the first of the objectives above. Duty holders are being asked to provide equipment population data to the HSE, from “parts count” data routinely collected / counted as an input to quantitative risk assessments (QRAs). This paper supports that proposal and suggests a method to ensure a consistent approach across industry is taken.

1.2. The importance of Establishing Leak Frequencies

Risk is a combination of frequency and consequence. Improvements in computing power, coupled with increased experimental data and validation mean that consequence modelling is much improved from that performed only a short time ago. Computational Fluid Dynamics has become much more widespread, and the use and development of commercial phenomenological software has become standard good practice for all safety assessments. For example, HSE would expect some modelling of hazards to be performed no matter the ‘tier’ in COMAH safety reports. However, there still exists more uncertainty in hazard modelling than is often realised. For example, releases are often modelled as originating from circular orifices in one direction, when in reality the hole may be from a crack or break in a seal, such as between two flange faces and the release direction may be more diffuse. Release modelling may also be performed for a single steady state scenario, and rarely captures the transient nature of a release, or the escalation consequences that may follow the initial event.

Frequency prediction is also subject to uncertainties. There are many factors which are very difficult to account for including installation specific conditions and different operating environments. This is particularly pronounced when trying to predict failure frequencies for individual components or systems. However, given the reasonably robust collation of leak and population data underpinning the HCRD, it is considered that this represents a good basis for leak frequency estimation for oil & gas facilities, and any uncertainties in a risk assessment are likely to be dominated by other aspects of the modelling and risk assessment methodology. So, in overall risk assessment terms for the average leak frequency estimation of process equipment, the consensus view of these authors is that the HCRD, and frequency data derived from it, is the most robust single source available, albeit noting the shortcomings that this paper is trying to improve regarding the population counts.

One factor that may be worth considering, especially on installations that are not fully attended, is the extent to which the presence of personnel affects the leak frequency. Many of the reported leak events occur during intervention activities. This is considered further in Section 2.4. There may be a case for applying a modification factor to leak frequencies for periods when interventions are ongoing on Normally Unattended Installations (NUIs). In essence, the leak frequencies would increase when personnel are present, and decrease when they are absent, but give the average leak frequency when considered across a full year. The QRA would then take account of the higher exposed population when leaks are more likely to occur.

As industries become more mature and hazards are better understood, performance based solutions are becoming the norm. Rather than designing prescriptively to a design code, operators are, for example, instead asking whether the design code load is credible. Where an existing asset can no longer achieve its performance standard, risk practitioners are being asked to design to an accepted failure frequency such as $10^{-4}$ or $10^{-5}$ per year. By maintaining the HCRD to a good standard and ensuring that the data contained is comprehensive and consistent, confidence can be preserved in its use for such performance based applications.

1.3. Minor and Significant leaks

The following section explains the criteria of defining the magnitude of a hydrocarbon release.

Approximately 50% of leaks in the HCRD are defined as ‘Minor Leaks’. The HSE states that ‘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’ [8]. Different consultants use varying criteria and schemes to establish which leaks to consider to generate a set of generic component leak frequencies for use in risk assessment. One approach is to neglect ‘minor’ severity events. A ‘minor’ severity event is further defined as per Table 1 below:
Table 1: Criteria for Minor Releases From [8]. Either criteria 1 or criteria 2 must be met for a leak to be defined as Minor

<table>
<thead>
<tr>
<th>Fluid Type</th>
<th>Criteria 1 - Quantity Released</th>
<th>Criteria 2 - Flowrate &amp; Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Less than 1 kg</td>
<td>Less than 0.1 kg/s and 2 minutes duration</td>
</tr>
<tr>
<td>Liquid</td>
<td>Less than 60 kg</td>
<td>Less than 0.2 kg/s and 5 minutes duration</td>
</tr>
<tr>
<td>Two Phase</td>
<td>Less than 1 kg</td>
<td>Less than 0.2 kg/s (liquid) and 2 minutes duration</td>
</tr>
</tbody>
</table>

For a gas and two phase release, the flowrate would either have to be very small initially (of the order of 0.02 kg/s), or decay very quickly such that less than 1 kg of material was released. The liquid release criterion appears more onerous, analogous to the flowrate from a fully open domestic tap, however this is still not assumed to be capable of major harm under this definition.

It is common to disregard ‘minor’ leaks from the database when calculating leak frequency for the estimation of the occurrence of Major Accident Hazard events. For this reason, data extracted from the HCRD [9] is quoted in this paper with and without ‘minor’ leaks.

2. Leak Frequency Determination in QRA

There are a number of ways of estimating the leak frequency from a system, varying from simple qualitative approaches to complicated component failure mode analysis and failure rate data. The preferred approach to estimate leak frequency for quantitative risk assessments (QRA) is to count the number of main equipment items, valves, flanges, instruments and length of pipe (all herein described as ‘equipment items’). The number of equipment items multiplied by their respective component leak frequency gives the overall leak frequency for the section of the process being represented by a given loss of containment scenario. There are therefore 2 key parameters required to define the leak frequency from a system namely:

1: Individual component leak frequency;

2: The number of equipment items in a system.

These two parameters are discussed in the following sections.

2.1. Component Leak Frequency

A component leak frequency takes the units of ‘number of leaks per unit of time’, and is typically based on an analysis of historical data. The number of leaks recorded is divided by the number of component years in the database. This may be subdivided into categories defining the size of the release and this can be performed to varying degrees of complexity. The key factors in the analysis, however, are the number of leaks recorded and the number of component-years in the database.

A simple example of how a component leak frequency may be calculated is given in the following text. Consider a hypothetical situation where an operator has 100 valves in operation for 20 years. This gives a population history of 20 x 100 = 2,000 component years. Consider also that over the 20 years of experience, there has been 2 leaks. The component leak frequency may be estimated as 2 / 2,000 = 0.001 leaks per year per valve.

2.2. Number of Equipment Items in a System

The number of equipment items (i.e. valves, flanges, instruments, equipment, and lengths of pipe) is typically estimated using a desktop exercise based on a ‘parts count’ of relevant P&IDs. Site walkarounds and line walkdowns can be used where P&IDs are not available but very good access is required to ensure a line can be traced accurately and all parts seen, and this may not be practical offshore.

Continuing from the previous example, consider the operator above is to bring a new system online which contains 10 of the previously mentioned valves. The leak frequency from the new system could be estimated as 10 x 0.001 = 0.01 leaks per year per valve.

2.3. Identifying the Boundary of where to Stop Counting Equipment Items

As mentioned above, a proposal has been submitted to Duty Holders to provide equipment population data to the HSE, from “parts count” data routinely collected/counted as an input to quantitative risk assessment (QRA). The issue of which parts of the overall process system should be counted is not clear and could cause inconsistency in population data from operators if not properly addressed. Problems with the population data will affect the calculation of component leak frequencies, and inconsistencies in subsequent parts counting will lead to inconsistent leak frequency estimation. Parts counted within HCRD should ideally be same as those counted in a QRA.
This issue is described in the example below and illustrated in Figure 1. Consider a hypothetical scenario where there are 100 instances where two valves separate the process and drain systems. There would be 200 valves in a process system and over a 10 year period there is one leak. The leak frequency per valve is calculated as 1 / (200 x 10) = 0.0005 per valve per year. However, as the second valve is behind a normally closed valve, it should have a very much lower exposure to process fluids, so should it be included in the count?

Figure 1: Simplified Example P&ID of an Existing and New Process system

Now imagine a new plant opens, with only one valve separating the process and drain systems. The calculated leak frequency for the plant is 0.0005 per year, but should it be 0.0010 per year? The second valve (V2) in the existing system could be considered to have artificially increased the population database. If V2 had been discounted from the database, a valve would take a leak frequency of 0.001 per year, and the new plant leak frequency would also be 0.001 per year. This highlights the need for consistent rules for equipment counting and deciding which equipment within the process should be counted: this is discussed in the next section.

2.4. When & Where does the Leak Occur?

Data from the HCRD between 1992 and 2015 has been analysed and is presented below in Table 2 and 3, and Figure 2 (data on incidents past 2015 have yet to be issued as final). The HCRD records the cause of a leak, which can be reported as one or more of: a design failure, an equipment failure, an operational failure or procedural failure. The table shows that approximately 50% of leaks occur during normal operation, whereas approximately 50% occur while other operations are ongoing in the area. These causes are recorded in the database if the operation ‘was being carried out on or around the equipment when it leaked’ [8].

This finding highlights the fact that when leaks occur, there is a good chance that the related system is not being operated in its normal mode. The leaks could occur from drain valves, or downstream of normally closed valves, or through isolated equipment. This data suggests that these items should not therefore be ignored when counting the number of equipment items as they all add to the complexity of the system. In the majority of cases however, it is assumed by these authors that leaks from the other side of normally closed valves would not be significant in terms of a risk assessment if associated inventory was small or the fluid which would leak from it was non-flammable.

An additional finding from this data, but not specifically relevant to the topic of this paper, is the fact that leaks may be the result of human interference, and not simply a random occurrence that can be assumed to happen at any time. Implicit in the calculation of leak frequency is that failures are random, and that the probability of an operator being present and potentially harmed, or offering an ignition source, is simply proportional to the time that person spends in the area. This data is supported by the fact that of 227 ignited events in the HCRD, only 87 occurred during ‘normal operations’. A modification factor for interventions may be appropriate for leak frequency determination.

Table 2: HCRD data summary 1992 to 2015
Table 3: Operational Mode at Time of Incident (HCRD, 1992 – 2015).

<table>
<thead>
<tr>
<th>Operational Mode</th>
<th>All Leaks</th>
<th>Significant and Major Leaks Only</th>
<th>Proportion (Significant and Major only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Production</td>
<td>2538</td>
<td>1244</td>
<td>53.0%</td>
</tr>
<tr>
<td>Reinstatement / Startup</td>
<td>797</td>
<td>413</td>
<td>17.6%</td>
</tr>
<tr>
<td>Maintenance / Hotwork/Other</td>
<td>296</td>
<td>143</td>
<td>6.1%</td>
</tr>
<tr>
<td>Shutting Down / Shutdown / Blowdown</td>
<td>262</td>
<td>160</td>
<td>6.8%</td>
</tr>
<tr>
<td>Wellops</td>
<td>195</td>
<td>102</td>
<td>4.3%</td>
</tr>
<tr>
<td>Drilling Operations</td>
<td>127</td>
<td>73</td>
<td>3.1%</td>
</tr>
<tr>
<td>Testing / Sampling</td>
<td>147</td>
<td>69</td>
<td>2.9%</td>
</tr>
<tr>
<td>Flushing/Cleaning/Inspection</td>
<td>101</td>
<td>55</td>
<td>2.3%</td>
</tr>
<tr>
<td>Construction</td>
<td>68</td>
<td>29</td>
<td>1.2%</td>
</tr>
<tr>
<td>Pigging</td>
<td>44</td>
<td>22</td>
<td>0.9%</td>
</tr>
<tr>
<td>Well Operation</td>
<td>36</td>
<td>20</td>
<td>0.9%</td>
</tr>
<tr>
<td>Flushing/Cleaning/Inspection</td>
<td>24</td>
<td>9</td>
<td>0.4%</td>
</tr>
<tr>
<td>Shutting Down / Shutdown / Blowdown</td>
<td>5</td>
<td>2</td>
<td>0.1%</td>
</tr>
<tr>
<td>N/A and Blank</td>
<td>16</td>
<td>8</td>
<td>0.3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4656</strong></td>
<td><strong>2349</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

3. Proposed Methodology for Consistent Equipment Parts Counting

Guidance on what equipment items should be considered for equipment parts counting purposes is limited. The HSE published some guidelines in 1996 which can be found online, but only gives very brief definitions [3]. The authors have identified a 1994 DNV report [10] for the Oil & Gas Exploration and Production (E&P) Forum, now the International Association of Oil & Gas Producers (IOGP), which contained diagrams showing system boundaries on simplified P&IDs. This document could only be found in an incomplete pdf format, however there are plans by the AFFD WG to re-issue this in an updated format. A key phrase used in the document to show the boundaries to be used when counting equipment, and shown in diagrams, is ‘FSV’ or ‘First Shut-off Valve’. With reference to the example in Section 2.3, this indicates that the original parts count data obtained from operators for the HCRD only counted parts up to ‘V1’ (The FSV), and didn’t count V2.

The following Sections give examples of where the consensus view of these authors think the boundaries for counting equipment items should be.

3.1. Normally Closed Valves and Double Block and Bleed Arrangements

There are normally closed valves, double block and bleed arrangements, or simply double block arrangements throughout process plants. These should be counted as shown in the example in Figure 3 for a process system normally isolated from a
3.2. Process System into Vent System

Vent systems typically have 3 inputs: pressure relief valves, automatic blowdown / emergency depressurisation valves, and manual venting. Typical piping layouts for these systems are shown below in Figure 4.

For blowdown and manual venting it is thought appropriate to stop the count at the ‘first closed valve’, consistent with E&P forum document. The pressure relief valve (PRV) is a more complicated case, however it is still proposed that the equipment count stop at the ‘first closed valve’. For the example below, 6.5 valves (3 full + 7 halves) would be counted (including the PRV), and potentially 13 flanged joints if the valves are flanged.

This decision to stop counting equipment parts at the first closed valve for the PRVs is debatable in the sense that the leak frequency for a system without a spare PRV, and only a single operational PRV would be the same as if there were a spare available. The spare PRV allows maintenance of the operational PRV without a full system shutdown, but adds to the complexity. As discussed in Section 2.3, leaks during non-normal operation are possible so it could be argued that valves V8, 9, 10 & 11 should be included.

3.3. Duty and Standby Equipment

Having equipment on duty and standby is common in processing industries to ensure productivity in the event of equipment malfunction. Operators have different philosophies as to the level of isolation of the standby equipment depending on the process, however it is common for a piece of equipment to be left ‘cold’, depressurised and physically isolated from the process by closed valves. This is illustrated below in Figure 5 for a pump system, but this could equally apply to a whole compression train or separation system. It is the consensus view of these authors that the pump, and all other equipment between the closed isolation valves are not counted if depressurised and physically isolated. The same argument made in Section 3.2 about the increase in complexity not leading to a calculated increase in risk could, however, be applied to this type of arrangement. For the example below, 3 valves, one pump, and 8 flange joints would be counted (if the valves and pumps have flanged connections)

If the standby system is kept pressurised but physically isolated, the parts should still be counted. Any leak from the system would be short-lived as it is essentially already isolated and this should be taken account of in the consequence modelling. If the standby system is not physical isolated (e.g. valve V3 could be left open), the standby equipment should be counted as though it is one continuous system with the duty system.
3.4. Heat Exchangers
A generic heat exchanger P&ID layout is shown below in Figure 6. A question may be asked as to whether to count equipment items on the heating medium side of the heat exchanger. A case may be made that a tube rupture, or other failures of the heat exchanger, may lead to a release by pressurising the heating fluid side and causing a secondary failure. These authors do not think this is appropriate as the design of the vessel should prevent this.

Data in the HCRD does not support this hypothesis however as shown in Table 4 and 5. Approximately 10% of leaks in the database are classified as ‘Non-Process’, and approximately 50% of these are diesel. Only 1% are associated with Heat Transfer Oil. For this reason, equipment on the utility heating (or cooling) medium side of the process should not be counted, unless the heat exchanger has process fluids on both sides. This is illustrated in Figure 6 below. For the example shown, only the shell side of the exchanger would be counted (plus 2 valves and potentially 6 flange joints). If the heat exchanger below was a plate exchanger, a whole exchanger should be counted. Kettle type boilers / reboilers, and fired heaters should be considered the same as shell and tube exchangers.

Table 4: Split of Process and Non Process Leaks in the HCRD, 1992-2015

<table>
<thead>
<tr>
<th>Type of Leak</th>
<th>All Leaks</th>
<th>All leaks, excluding minors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Proportion</td>
</tr>
<tr>
<td>Process Leak</td>
<td>4085</td>
<td>88%</td>
</tr>
<tr>
<td>Non-Process Leak</td>
<td>571</td>
<td>12%</td>
</tr>
<tr>
<td>All Leaks</td>
<td>4656</td>
<td>100%</td>
</tr>
</tbody>
</table>
Table 5: Contributors to Non Process Leaks in the HCRD, 1992-2015

<table>
<thead>
<tr>
<th>Fluid Type</th>
<th>Number of Leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Leaks</td>
</tr>
<tr>
<td>Diesel</td>
<td>258</td>
</tr>
<tr>
<td>Lube Oil</td>
<td>106</td>
</tr>
<tr>
<td>Oil Based Mud</td>
<td>27</td>
</tr>
<tr>
<td>Methanol</td>
<td>51</td>
</tr>
<tr>
<td>Hydraulic Oil</td>
<td>52</td>
</tr>
<tr>
<td>Glycol</td>
<td>26</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>20</td>
</tr>
<tr>
<td>Helifuel</td>
<td>9</td>
</tr>
<tr>
<td>Seal Oil</td>
<td>7</td>
</tr>
<tr>
<td>Heat Transfer Oil</td>
<td>7</td>
</tr>
<tr>
<td>Bottled Gas</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>571</td>
</tr>
</tbody>
</table>

3.5. Instruments / Instrument Connections

The 1996 HSE guidelines on reporting hydrocarbon releases [3] and IOGP guidelines [4] defined an instrument as ‘...itself, plus up to 2 valves, up to 4 flanges, 1 fitting, and associated small bore piping (usually 1” diameter or less)’, however the terms ‘Instrument’, ‘instrument connection’ and ‘small bore fitting’ are used interchangeably. The requirement of the maximum number of valves and flanges that can be included within an ‘instrument’ can cause complications. P&IDs often show very simplified representations of instruments but give the impression of completeness. Some operators have a specific instrument legend sheet showing the actual instrument arrangement verses what is shown on a P&ID but these are uncommon.

It is not clear how instruments were counted in the past so there is some uncertainty in the existing HCRD. It is suggested therefore for clarity that the number of instrument connections is used as the basis for performing these counts in the future. This does necessarily mean a change to data in the HCRD.

Using instrument connections as the definition of an ‘instrument’ would define the majority of pressure and temperature instruments as one instrument, but flow meters and level indicators relying on pressure differential would be counted as 2. Flow and level transmitters do tend to be much more complicated than pressure and temperature indicators which would support this method. The methodology is illustrated in Figure 7 where 10 ‘Instruments’ would be counted. Note that flanges associated with the flow orifice or other device installed in the main process pipe would be counted in addition to the flow instrument. Typically, 2 flanged joints (4 flange faces) should be considered for a flow orifice. For Instrument I10, an additional flanged joint would be added to the equipment count where an actual piping tee has been added to the process line to allow the use of the temperature probe.

This approach would create a consistent method for counting instruments across users and provide a pragmatic and easily verifiable approach. Multiple occurrences where parts counts have become confused where, for example, analysts have tried to associate valves on the instrument bridle with those of the ‘2’ allocated to an instrument, have been witnessed by the authors. It is also believed that this definition falls in line with the original intent of the HSE definition so will not lead to a disparity between previous and new population data.
3.6. MEG / TEG, units

Monoethylene glycol (MEG), and triethylene glycol (TEG) are often used in offshore processing to remove water from wet gas in a ‘contactor’ column. Wet gas enters the bottom of the column and is brought into contact with MEG or TEG which absorbs the water. Glycol systems can be extensive and require multiple unit operations to strip the water out, regenerate and re-inject the glycol.

Leaks of glycol, and the associated pools or mists that may ensue, are practically non-flammable [11] and are therefore unable to lead to fatalities (ignoring toxic effects). In the event of an undetected leak from this system however, there would be the possibility of hydrocarbon gas breakthrough with the resultant fire and explosion hazard. An undetected leak is credible as glycol is non-volatile so conventional gas detectors would not register the leak.

The question arises as to whether all equipment within the entire glycol system should be counted or not? As the glycol systems become more removed from the process hydrocarbon containing systems, the quantity of hydrocarbon present and the potential for gas breakthrough reduces significantly; further, the chance of process control or shutdown preventing the release increases. In addition, frictional losses through piping increases meaning any gas breakthrough that may occur would most likely be limited. It is the consensus view of these authors that the following items of equipment should serve to sufficiently limit flow of gas through the glycol system, and should therefore act as the limits applied to the equipment count:

- Any ESD valve;
- Any process control valve that would act to close in the event of gas breakthrough – e.g. level control from a vessel, pressure control on gas breakthrough into a vessel;
- Any check valve orientated to prevent gas flow into the system;
- Any non-centrifugal pump;
- A flow orifice.

Note that the entire glycol contactor should be included in the equipment count.

Flash-gas or off-gas lines may be taken from the glycol as part of the regeneration process. Equipment parts associated with flash gas below 2 barg in normal operation or directed directly to a vent or flare system should not be counted. Where flash gas is produced at a pressure greater than 2 barg, equipment parts should be counted with the same boundary conditions as those listed in the bullet points above.

3.7. Chemical Injection,

Chemical injection fluids are typically non-hazardous and a leak of such fluids is unlikely to lead to multiple fatalities or a major escalation event. In the event of a leak from the chemical injection system however, there is potential for backflow of process gas or liquid into the injection system and breakthrough out of the hole. The boundaries for counting equipment items for these systems should be defined by the same bullet points listed for glycol above.

Methanol injection is a common operation offshore. While methanol is hazardous, the same counting criteria as for other chemical injection fluids should apply,
3.8. Produced water
All equipment located on separators and scrubbers should be counted where these contain significant hydrocarbon. However, the downstream produced water treatment equipment is typically not counted due to the small quantities or concentrations of hydrocarbon present. For separators or coalescers creating produced water there is the potential, in the event of a leak, for the flow of process gas or liquid into the produced water system and breakthrough out of the hole. The boundaries for counting equipment items for the produced water systems should be defined by the same bullet points listed for glycol above.

3.9. Fuel Gas Systems
Fuel gas systems typically extract gas from the export gas system and reduce the pressure before routing to consumers. Equipment counting for fuel gas systems should adopt the following boundaries:

- The final pressure reduction valve before being routed to its final user. This does not include any pressure reduction integrated into the piece of equipment, for example within the turbine, or at a burner tip;
- Where lines reduce to 1” or less. The pressure loss in a 1” line are significant meaning a significant flow of fuel gas could not be maintained;
- Where the fuel gas operating pressure drops below 2 barg.

3.10. Compressor Systems
Where a multistage compression system is powered by the same mechanical drive mechanism, separate ‘compressor’ equipment items should be counted. This definition is not consistent with previous parts count guidance [10], however it is considered a more logical approach. For the example shown below in Figure 8, there is three times the complexity of a single stage compression unit leading to the conclusion that it would leak more often, therefore 3 ‘compressors’ should be counted. Essentially, the number of compressor stages shown on the P&IDs should equal the number of compressors counted. To enable comparison with previous data in the HCRD, a note should be added stating that the three compressors are on a single shaft.

![Figure 8: 3 Stage Compressor System. 3 compressors would be counted in this instance](image)

3.11. Flanges
Available P&IDs should be used as the basis for counting flanges in a system. Process engineering disciplines should be consulted as to whether equipment parts are welded or flanged as this may not be clear from the drawings. It should also be determined whether flanges connecting sections of piping together are shown on P&IDs, and if not, an appropriate factor should be applied specific to the facility.

It should be noted that the HCRD population data counts flange faces: a flanged joint would consist of two flanges faces (and by inference the interspatial gasket or equivalent).

3.12. Length of Piping
Establishing the length of piping in a process can take an equivalent amount of time to that of counting all the other equipment items. Rule sets are used to estimate the length of pipe for each section on a P&ID, assuming, for example, that all vent lines are 10 m to the vent or boundary valve, or simply assigning a stock of piping lengths for each major equipment item. Alternatively, piping isometrics can be employed but this is an even more onerous task.

It is interesting to note that in some of these authors’ experience, where what seem like sensible rule sets on piping lengths are employed, the contribution to leak frequency from piping calculated in QRA often turns out to be between 40% and 50%, not 22-25% as reported in the HCRD. This could be due to an over conservative estimation of piping length in the QRA, or an under reporting of piping length in the HCRD leading to an overestimation of the piping component leak frequency. It is the consensus view of these authors that the latter is the cause as numerous sources [4, 12] conclude that 1 m of process piping has a comparable leak frequency to that of a flange which intuitively feels wrong.

The methodology of estimating piping length in a plant could follow the following method. Operators and equipment count practitioners should treat these as guidance, and not hard and fast rules, as there are several approaches that could be used, and appropriate method should be selected:

- The length of main process piping between equipment should be estimated as double the straight line distance (not accounting for the orthogonal layout) between the two when located in the same module / area;
- Piping length through modules or decks should be estimated as the straight line length + 50%;
• Piping length on bridges should be estimated as the bridge length + 10%;
• Vent lines should be estimated to be 5 m to the boundary valve;
• Drain lines should be estimated to be 2 m to the boundary valve;
• Valve bypass lines should be estimated to be 5 m;
• Flowline lengths should be estimated as 10 m;
• Manifold length should be estimated as the wellbay width;
• Instrument bridle length should be estimated as the diameter of the vessel, plus 2 m to account for the piping to the bridle. Bridles are considered to be a separate piece of pipe, and not part of an ‘instrument’;
• Riser lengths should be estimated from layout and elevation drawings.

The above rule set is proposed as a best current methodology, but validation of this rule set against a number of actual installations is recommended. This could be funded by a JIP and give increased confidence in the methodology employed. The outcome of such a study could be a rule set for lengths of piping associated with specific pieces of equipment, or a refinement of the methodology presented above.

4. Conclusions
For QRA parts count data to be used as the input for future HCRD population data, a detailed methodology is required to ensure consistency across assessors. This paper has indicated areas where there is some uncertainty and inconsistencies in current practices. It has presented a road map for producing a pragmatic methodology for counting equipment parts that can adopted across industry and form the background for an official OGUK publication guideline.

5. Recommendations
A cross party JIP is recommended to agree a consolidated parts count methodology for the purposes of updating and maintaining the HCRD population data, and to encourage a more consistent approach across QRAs. This would be used by duty holders to ensure consistent population data is submitted to the HCRD, which will lead to improvements in the accuracy of the HCRD database for leak frequency analysis and other risk related activities. The JIP would look at:

• How were the number of equipment parts associated with an installation calculated previously, especially for the original 1992 data;
• How can existing database records, in particular population data, be reconciled with the population data that will be extracted;
• Produce specific illustrated examples on how to count equipment to help remove some of the inconsistencies in parts counting;
• Establishing a rule set for piping length determination;
• Establishing whether a leak frequency modification factor for interventions is appropriate and, if so, what it should be.

6. References