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# Investigations into the immediate and underlying causes of failures of offshore riser emergency shutdown valves

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Research Report

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# Investigations into the immediate and underlying causes of failures of offshore riser emergency shutdown valves

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Riser emergency shutdown valves (RESDVs) are an essential risk reduction measure for offshore installations and are a legal requirement under the Pipelines Safety Regulations 1996. RESDV failures, whether arising from a test or a real demand, are reportable to HSE under RIDDOR and a preliminary survey found approximately 180 cases of failure. Given the criticality of RESDVs to offshore safety, it was determined that the reasons for these occurrences should be investigated with a view to focussing inspection topics and identifying areas for future improvement across the industry.

Two themes have emerged from the causal analysis of RESDV failures: the age of the valves that failed, and the failure to learn and implement lessons from previous incidents.

The three most common immediate causes were stated by dutyholders to be corrosion, the age of the RESDV and seizure/sticking.

Nearly half of failed RESDVs have had a previous failure, and over a quarter of failed RESDVs were brought back into service after cycling and/or lubricating the valves. The root cause of the failure needs to be determined and acted upon so that it does not recur, rather than just bringing the RESDV back into service.

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# EXECUTIVE SUMMARY

Riser emergency shutdown valves (RESDVs) are an essential risk reduction measure for offshore installations and are a legal requirement under the Pipelines Safety Regulations 1996. The RESDV should isolate the topsides from the well and subsea pipeline in the event of an emergency shutdown, to reduce the inventory for loss of containment or when required for maintenance. RESDV failures, whether arising from a test or a real demand, are reportable to HSE under RIDDOR and a preliminary survey found approximately 180 cases of failure. Given the criticality of RESDVs to offshore safety, it was determined that the reasons for these occurrences should be investigated with a view to focussing inspection topics and identifying areas for future improvement across the industry.

It is important to determine the underlying causes of incidents as this information can help to prevent future undesirable events. Dangerous occurrences (such as failures of RESDVs) reported to HSE through RIDDOR provide an opportunity for such lessons to be learned. Some dangerous occurrences have been identified as potential precursors to major accidents, and because of the relatively greater numbers of dangerous occurrences compared to major accidents, a greater number of events may be studied.

Two themes have emerged from the causal analysis of RESDV failures: the age of the valves that failed, and the failure to learn and implement lessons from previous incidents (including bringing valves back into service after cycling and/or lubricating).

Nearly half of the RESDVs that failed were over 20 years of age. The three most common immediate causes were stated by dutyholders to be corrosion, the age of the RESDV and seizure/sticking. As well as the age of the RESDV being directly stated as responsible for the failure, some of the corrosion incidents will also be related to age; however there will be some overlap between these two immediate causes as some incidents had more than one immediate cause.

Nearly half of failed RESDVs have had a previous failure, and over a quarter of failed RESDVs were brought back into service after cycling and/or lubricating the valves. The root cause of the failure needs to be determined and acted upon so that it does not recur, rather than just bringing the RESDV back into service. A significant number of incidents had organisational culture as an underlying cause; in most of these cases there was evidence or a strong reason to believe that the dutyholder had not learned lessons from previous failures.

Overarching the causes of failure are the underlying causes of maintenance and plant integrity, i.e. a failure to maintain and monitor equipment. This reflects the findings from HSE's KP4 inspections where "fix on fail" was routinely found. To improve performance, failures need to be anticipated so that preventative maintenance can occur, whether that is replacement or servicing. Trending of data will help anticipate failures, and to do this dutyholders need to record measurable quantities such as closure time and internal leakage rate rather than just pass or fail (another common finding during KP4). Thus, using such data it can be anticipated when an RESDV will fall below a dutyholder's defined performance standards.

# 1 INTRODUCTION

Riser emergency shutdown valves (RESDVs) are an essential risk reduction measure for offshore installations and are a legal requirement under the Pipelines Safety Regulations 1996 (PSR). Regulation 19 (Schedule 3) of PSR states:

> *1. An emergency shut-down valve shall be incorporated in the riser of a pipeline -*
>
> > *(a) in a position in which it can be safety inspected, maintained and tested; and*
> >
> > *(b) so far as is consistent with sub-paragraph (a), as far down the riser as is reasonably practicable;*
>
> *and such valve shall comply with the remaining paragraphs of this Schedule.*
>
> *6. An emergency shut-down valve shall be maintained in an efficient state, in efficient working order and in good repair.*

PSR requires that every riser with an internal diameter of 40 mm or more, which forms part of a major accident hazard pipeline, be fitted with an emergency shutdown valve and that the valve is maintained in good working order.

The RESDV should be located so that the distance along the riser between the valve and the base of the riser is as short as reasonably practicable, in order that the most vulnerable section of the riser can be isolated from the majority of the pipeline inventory. However, it is equally important that the RESDV can be safely maintained and tested so that it can function properly.

Guidance on operational practice for RESDV testing and reporting is available in PD 8010-5:2013[1].

The RESDV should isolate the topsides from the well and subsea pipeline in the event of an emergency shutdown, to reduce the inventory for loss of containment or when required for maintenance.

Failure of an RESDV can consist of:

- failure to close on demand;
- an excessive leak rate once closed;
- excessive closure time; or,
- other conditions such as leaks to atmosphere.

Such failures, whether arising from a test or a real demand, are reportable to HSE under RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrence Regulations, 2013). HSE has compiled a database of reported incidents, and a preliminary survey (see Section 2) found approximately 180 cases of failure in seven years. Given the criticality of RESDVs to offshore safety, it was determined that the reasons for these occurrences should be investigated with a view to focussing inspection topics and identifying areas for future improvement across the industry.

The project initially involved a search of the HSE COIN database, but it was found that there was insufficient information to draw firm conclusions and so a dutyholder questionnaire was devised; this forms the basis of the analysis in this report.

# 2 HSE COIN DATABASE SEARCH

## 2.1 COIN CASE RETRIEVAL AND FILTERING

A search of the HSE COIN database was carried out by the HSE Data Mining team to find records relating to failures of RESDVs. 179 cases were identified, although a small number were duplicates or may have been related to subsea isolation valves or other shutdown valves. The 179 cases were read through and, where possible, immediate or underlying causes were identified.

## 2.2 REPORTING HISTORY

Relevant COIN cases were found dating back to 2006, which is the limit of cases that would be found in COIN because data are only kept for 7 years. It appears that reporting was sparse until mid-2009. There would also appear to be significant gaps when no or few cases were entered – particularly February 2008 to February 2009. Figure 2.1 gives an indication of the reporting frequency over the years covered. It should be noted that some of the cases were reported retrospectively.

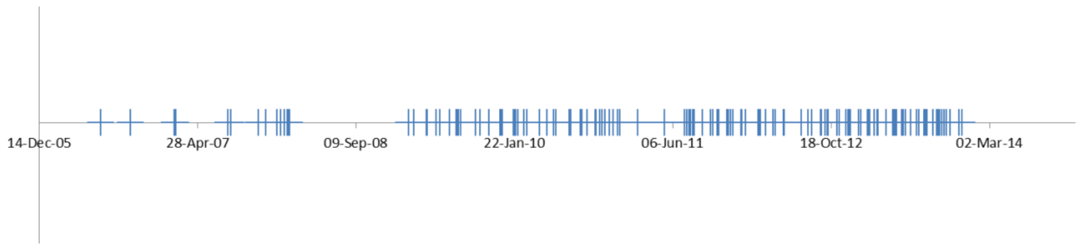


**Figure 2.1:** Clustering of COIN case entry dates

## 2.3 FAILURE IDENTIFICATION

The failure, i.e. whether the valve had failed to close or had too great a leakage rate etc., was identified, where possible, from the case descriptions. Figure 2.2 gives the distribution of failures.

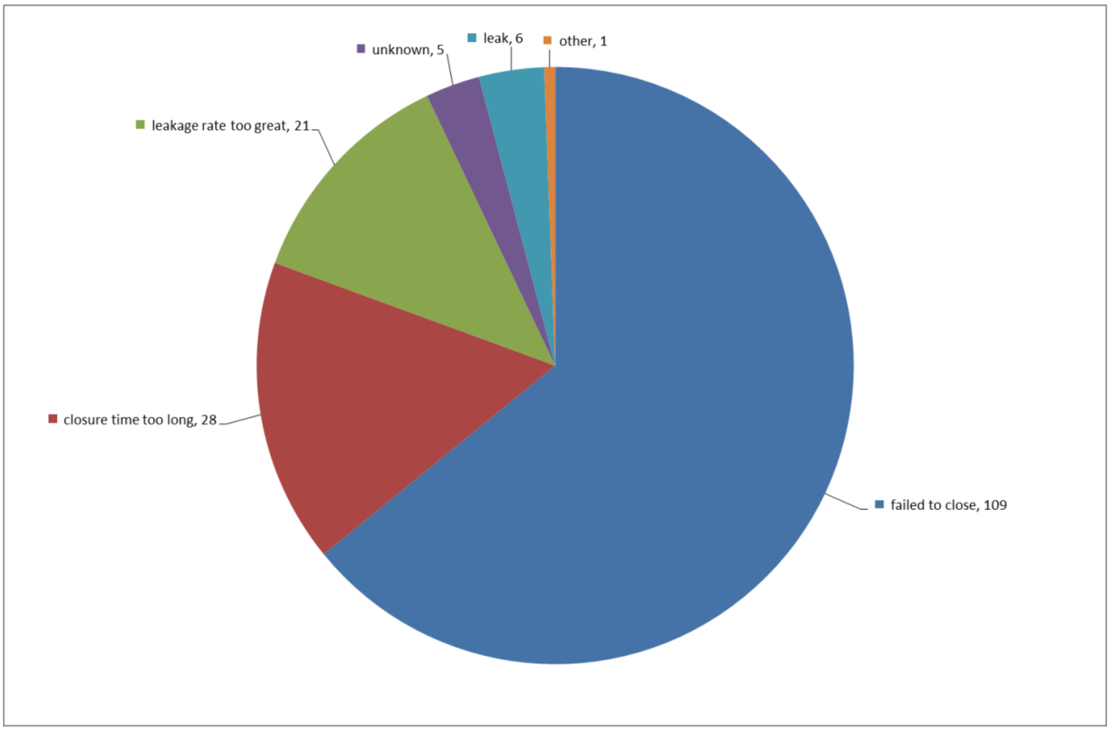


**Figure 2.2:** Distribution of failure types as found from the COIN survey

## 2.4 IMMEDIATE CAUSE IDENTIFICATION

During reading of the case descriptions, various immediate cause tags or categories were developed and, where possible, one or more of these were assigned to each case. In a large number of cases, it was not possible to identify the immediate cause from the case description, or the cause was given as unknown. Table 2.1 lists the immediate cause tags that were identified. These were then grouped more broadly to reduce the number of categories. Figure 2.3 shows the distribution of immediate causes categorised in this way.

**Table 2.1** Immediate cause tags and number of cases

| Cause tag | Number |
|---|---|
| unknown or unidentifiable | 66 |
| closed - on cycling | 25 |
| closed - after lubrication | 13 |
| closed - after intervention | 9 |
| closed - after flushing | 1 |
| pneumatics / hydraulics - solenoid | 24 |
| pneumatics / hydraulics - hydraulics | 6 |
| pneumatics / hydraulics - pneumatics | 5 |
| pneumatics / hydraulics - pilot valve | 3 |
| pneumatics / hydraulics - incorrect configuration | 1 |
| pneumatics / hydraulics - other | 1 |
| valve - valve replacement | 6 |
| valve - valve repair | 1 |
| actuator | 4 |
| performance standard being reviewed | 4 |
| other - air vent blocked | 1 |
| other - air vent water ingress | 1 |
| other - salt deposition | 2 |
| other - grit blast on actuator | 1 |
| other - swarf on internals | 1 |
| actuator - ice on collar | 1 |
| other - ice build up on stem | 1 |
| other - stem seal | 1 |
| other - temporary hydraulic pump | 1 |

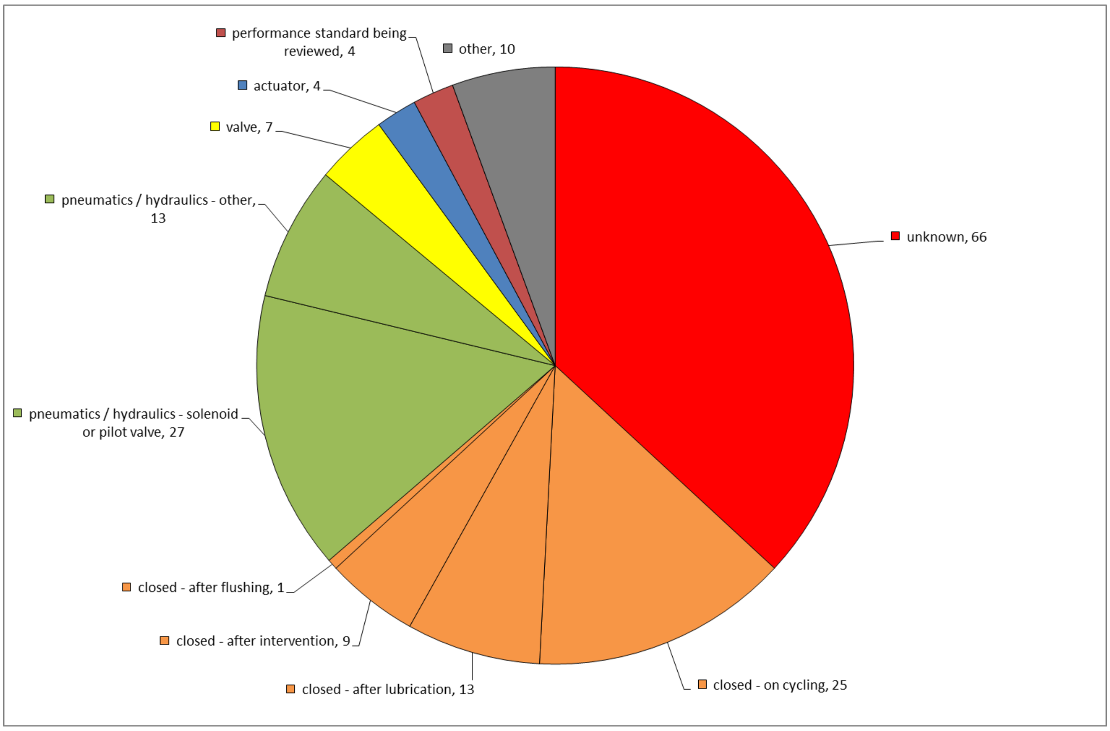


**Figure 2.3:** Distribution of causes

It was apparent from the COIN search that, in a large number of cases, the valve was being cycled or some intervention had been carried out until closure occurred or the performance criteria were met, but with little further investigation. It was also apparent that, for a large number of cases, there was insufficient information in the COIN description to determine the cause of the failure. Additionally, in only two of the cases was there information relating to underlying causes. On this basis, it was decided that a dutyholder survey would be more fruitful.

# 3 DUTYHOLDER SURVEY

## 3.1 INTRODUCTION

A dutyholder survey was designed so that clearer information could be obtained relating to RESDV failures, with the intention that the collated data could be readily tabulated and analysed for immediate/underlying causes. The questionnaire template that was sent out is reproduced in Appendix A, with its supporting guidance document reproduced in Appendix B. The questionnaire was sent out in mid-March 2014 with a 6 week response deadline. However, most dutyholders did not meet this deadline and reminders were sent by both HSL and HSE, with a deadline of 3rd September 2014. The questionnaires were sent by individual emails to relevant dutyholder personnel. Each dutyholder was sent an Excel spreadsheet containing the COIN RESDV failure cases relevant to that company – this was to encourage responses whilst maintaining confidentiality.

Twenty-nine (29) dutyholders were contacted with surveys on RESDV failures, of these 22 responded covering 117 of the 179 identified incidents. One hundred and four (104) reports were provided by dutyholders in total, some of the incidents initially identified were not due to failure of RESDVs.

## 3.2 ANALYSIS

The surveys received from the dutyholders were analysed to obtain causal information of the RESDV failures. This was done in two parts: firstly information supplied on details of the valve by the dutyholder in the table in part 1 of the survey (sometimes this information needed to be grouped into ranges), and secondly, by assigning key words or phrases to the textual information supplied in part 2. The categories of information obtained were:

- Was there a previous failure of the valve?
- The valve type
- The age of the valve
- The test frequency
- The performance standard for closure time
- The actuation method
- The valve size
- The valve manufacturer
- The typical line pressure
- The fluid in the line
- The time from the previous test to failure
- The reason for the valve operation
- The site of failure
- The immediate causes
- The underlying causes
- Whether the valve was brought back into service after cycling and/or lubrication

The categories used for the underlying causes, with associated descriptions/examples, are given in Appendix C. These have been used by HSL in other causal analysis studies and are based upon the HID issues types used to record information in COIN (Organisational Culture was added by HSL). For some surveys the underlying causes identified by the dutyholders were used, and for others judgement was used to identify the underlying causes.

### 3.3 RESULTS

The graphs generated from the causal analysis results are located in Appendix D, Figures AD.1 to AD.18. Some graphs are reproduced in the main body of the report for clarity. The words 'failure' or 'failed' are used in a broad sense to describe all failure modes of the RESDV including failing to close, failing to meet the performance standards, internal leaking, etc. unless otherwise stated.

Nearly half (45%) of the RESDVs that failed had had a previous failure (see Figure AD.1), and most of these RESDVs had had one previous failure but a significant number had had two or more.

Most of the failures were of ball valves (Figure AD.2) and involved valves between 20 and 24 years of age (Figure AD.3). To put this into context, information on the age of the RESDVs in service on the UK Continental Shelf (UKCS) is needed. Virtually all of the installations on the UKCS are over 20 years of age, so any valves that have not been replaced will also be over 20 years of age. It would be useful to compare this with the typical design life of an RESDV.

Many different inspection/testing regimes are in place for RESDVs, some of which have simple repeat patterns of, for example, three or 12 months. Others, however, are more complicated with different tests occurring with different repeat periods.

Figure AD.4 shows the closure time performance standards of ESDVs that failed. The most common performance standard is for a closure time within 60 s. The closure times have not been grouped, and show the number of different standards on closure times that dutyholders on the UKCS apply to their RESDVs.

It was not possible to analyse the performance standard for leakage rate due to the range of units used to measure the leakage (and inability to convert because the density of the fluid was not supplied). There were also relatively few failures due to too high a leakage rate, so this was not studied further. Approximately half of the failures were of pneumatic RESDVs and one third due to hydraulic valves (Figure AD.5).

The sizes of RESDVs that failed are presented in Figure AD.6. This has been normalised in two ways (see Figure AD.7): firstly, it was normalised using the number of pipeline ESDV valves (grouped into size ranges) that are in the population section of the Hydrocarbon Release Database (HCRD)[2]; and, secondly, by the number of pipelines entered into the OGUK Pipelines Database[3] (using the same size ranges as the HCRD for ease of comparison). There are problems with both of these population sets; the populations of equipment in the HCRD have not been updated since 2003 and the OGUK data does not specify how many of the pipelines have RESDVs attached. However, both population sets give similar results; it is clear that smaller valves (less than 12") tend to have more failures (it is likely that the HCRD

underestimates the population of RESDVs of less than 4”, giving an anomalously large number of failures per unit population).

The typical line pressure for approximately half of the failures was between 0 and 49 barg (Figure AD.8), with the highest typical pressure being 170 barg. The OGUK data[3] does not contain any information on the typical pressures in the pipelines to normalise this finding.

Lines containing gas had the most failures for RESDVs followed by lines containing oil, with a small number containing condensate or multiple phases (Figure AD.9). The number of failures for RESDVs on pipelines containing gas and oil is very similar if normalised using the populations from OGUK data[3]. Mixed hydrocarbons and condensate seem to have relatively high failure rates but this could be anomalous due to the low numbers of pipelines containing these fluids (see Figure AD.10).

Most failures occurred within one year of the last performance test of the RESDV (Figure AD.11); however some valves had not been tested for three, four, seven and eight years despite this being longer than the dutyholders’ stated inspection intervals. The time from the previous test to failure was unknown in 21 cases; in some cases this will have been due to the dutyholder not supplying the information, and in others the dutyholder not knowing the information, perhaps because the failure was an old one and records were no longer available.

Most failures occurred during testing; however, in approximately a third of cases the RESDV failed on demand (Figure 3.1/AD.12). The fact that approximately two-thirds of RESDV failures occur during testing shows the value of the tests. It was found from the HCRD[2] that there were 396 pipeline ESDVs on the UKCS in 2003. On average there are two tests per year, meaning that there would have been approximately 5500 tests in the seven years corresponding to this study. Figure AD.12 states that 68 tests were failures through testing, giving a failure rate of 1.2% for the period of the study. This is broadly in line with that found from the Norwegian sector, where in 2013 1.8% of RESDVs failed their tests (with a mean failure rate of 2.0% from 2002-13)[4]. The industry standard is 1%[4].

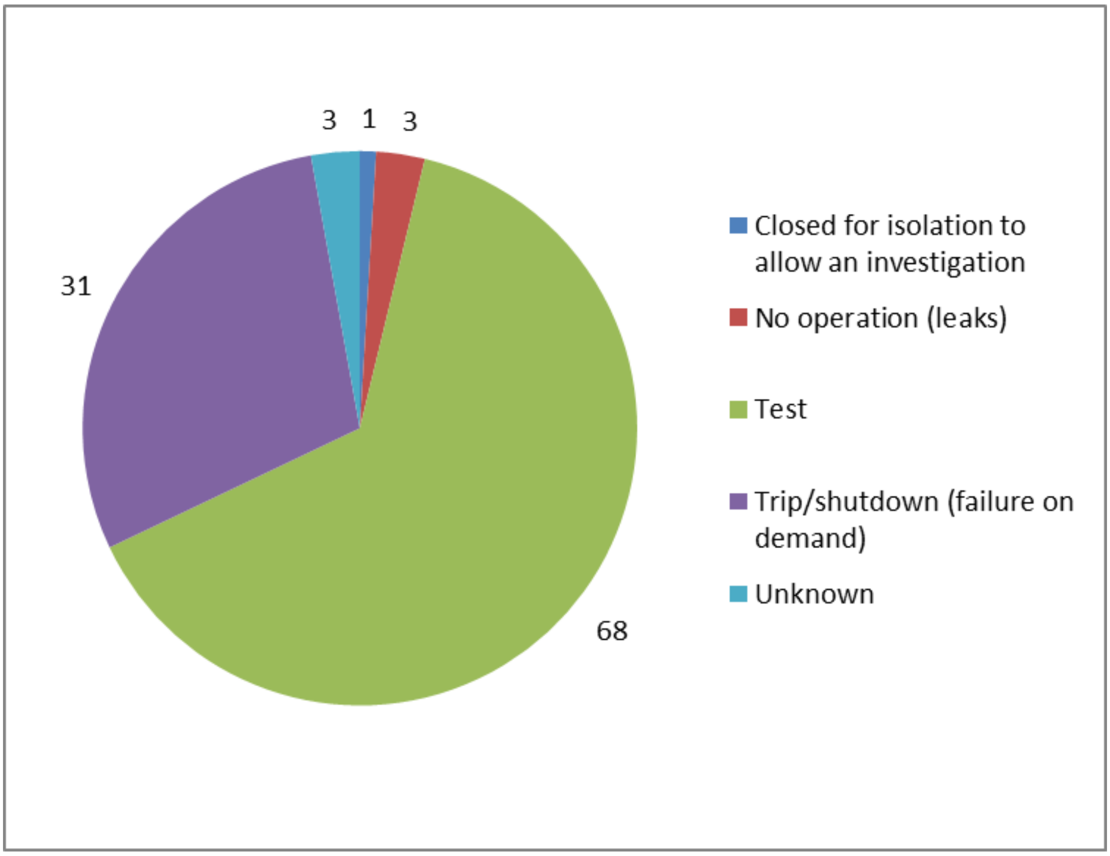


**Figure 3.1:** A pie chart showing the reason for valve operation of RESDVs that failed.

Over three-quarters of failures were due to failure to close (68 due to failing to close and 14 due to failing to close within the time specified in the performance standard); the other significant failure was the valve internally leaking at too high a rate (Figure 3.2/AD.13). A Norwegian study[4] on the failing of tests on safety barriers found more failures for RESDV riser leak tests than closure tests. This suggests that there may be an under-reporting of failed tests due to internal leaking in valves on the UKCS, or that valves which have failed those tests have been stated to have failed to close when reported.

It is difficult to find patterns in the site of failure; however, multiple failures were recorded for actuators, hydraulics, pilot/shuttle valves, pneumatics, seals/seats and solenoids (Figure AD.14).

The most important causal information obtained from the dutyholder surveys is the immediate (Figures AD.15 and 3.3/AD.16) and underlying causes (Figure 3.4/AD.17). The immediate causes in Figure AD.17 were summarised into the groups shown in Figure 3.3/AD.16.

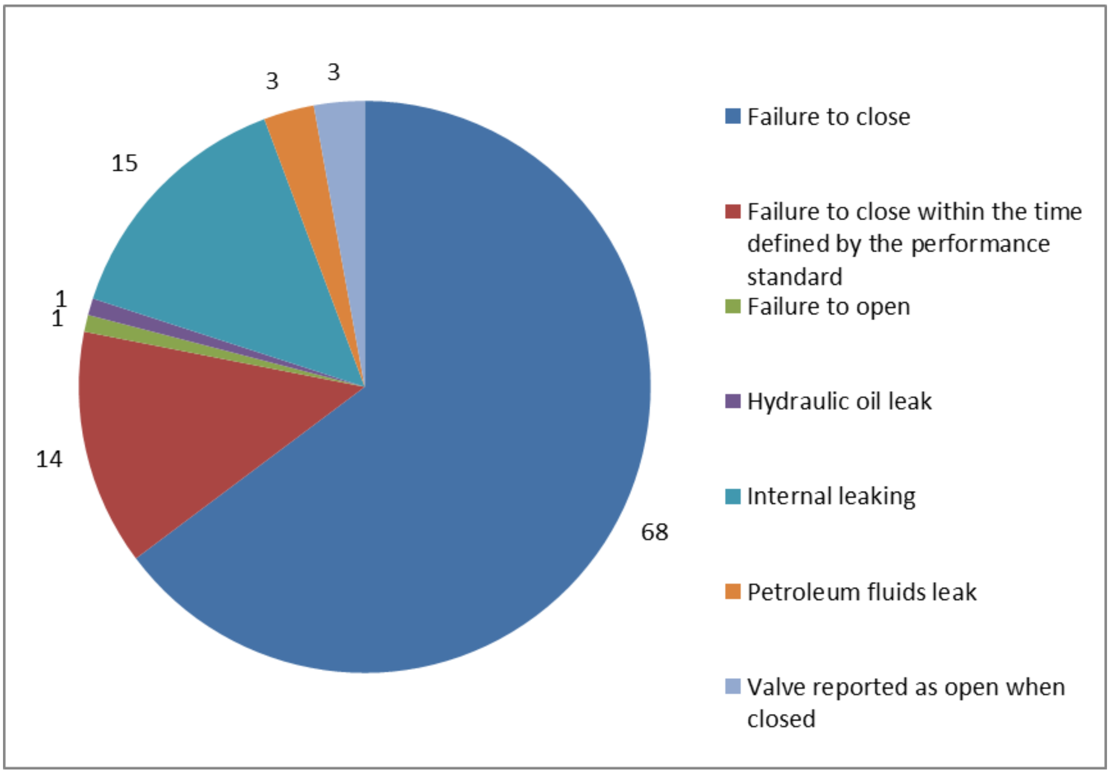


**Figure 3.2:** A pie chart showing the RESDV failure types.

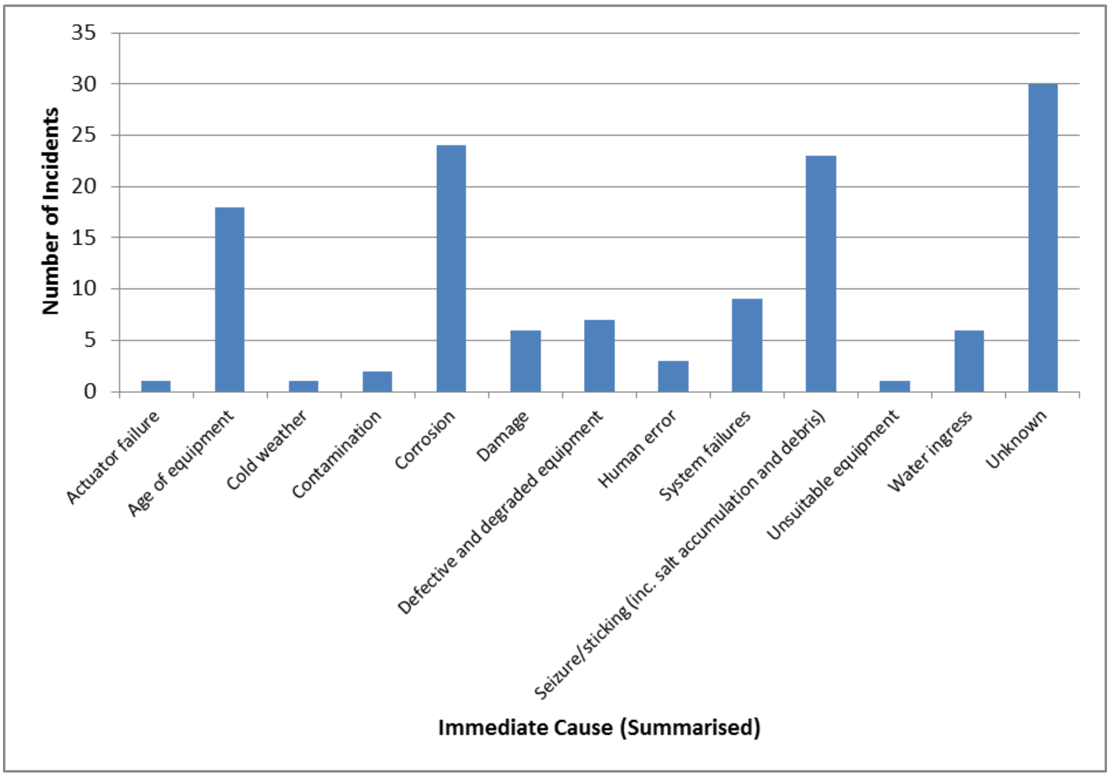


**Figure 3.3:** A graph showing the immediate cause of RESDV failures summarised into groups.

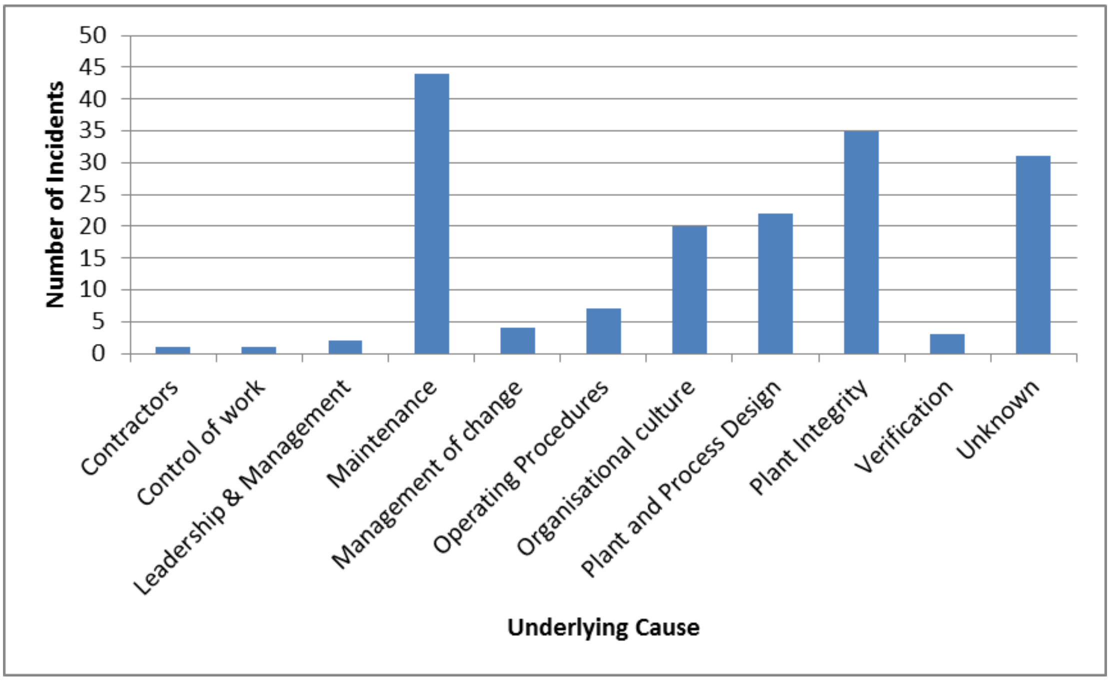


**Figure 3.4:** A graph showing the underlying cause of RESDV failures.

Corrosion is the largest immediate cause of RESDV failures (24 incidents), followed by seizure/sticking (including salt accumulation and debris) (23 incidents) and the age of the equipment (18 incidents). However, age is not strictly a failure mode or cause of failure as a well maintained valve could last indefinitely. In eight of the 18 incidents attributed to age by dutyholders, corrosion was also cited as a factor. It is not possible to attribute the cause of failure of the other 10 age-related failures.

Maintenance is the primary underlying cause of failures, followed by plant integrity, plant and process design and organisational culture (see Appendix C for information on these underlying causes). The underlying cause of organisational culture (20 incidents) is mostly associated with the dutyholder failing to learn lessons from previous failures.

Risk profiling was not identified as an underlying cause in any failures. HSL's previous experience of causal analysis suggests that risk profiling is an important factor in accidents. Failures of risk profiling include failing to identify hazards, to assess risks adequately and to identify risk control measures. However, the regular performance testing of the RESDVs shows that risks associated with them have been recognised. No additional information was provided to conclude otherwise.

The immediate and underlying causes contain a large number of incidents where the causes were unknown. It is impossible to know for most cases if the causes were unknown to the dutyholder or if the dutyholder did not supply enough information to HSL for the causes to be identified.

Over a quarter of failed RESDVs (29) were brought back into service after cycling and/or lubricating to get them to function (Figure 3.5/AD.18) suggesting dutyholders are not maintaining the RESDVs.

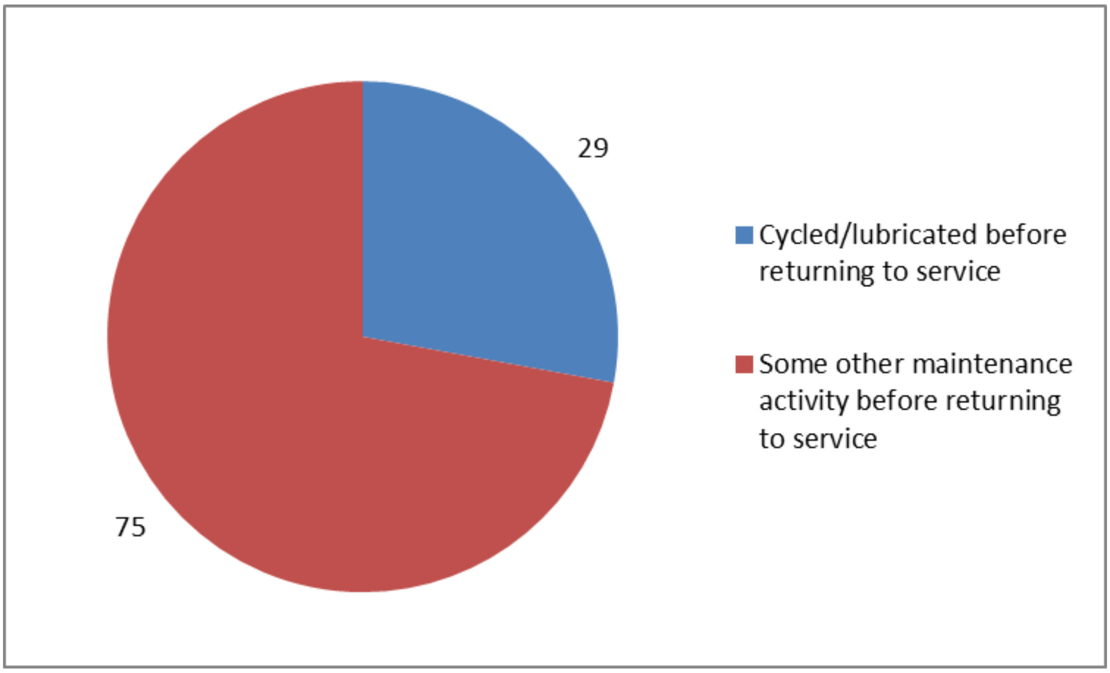


**Figure 3.5:** A graph showing how many failed RESDVs were brought back into service after cycling and/or lubricating.

# 4 DISCUSSION AND CONCLUSIONS

It is important to determine the underlying causes of incidents as this information can help to prevent future undesirable events. Dangerous occurrences (such as failures of RESDVs) reported to HSE through RIDDOR provide an opportunity for such lessons to be learned. Some dangerous occurrences have been identified as potential precursors to major accidents, and because of the relatively greater numbers of dangerous occurrences compared to major accidents, a greater number of events may be studied. The importance of getting at root causes is underlined by the following quotations:

> *"From a prevention point of view it is better to focus on factors further along the causal chains* [underlying causes] *which put operators in a position where it is possible for them to make critical errors"* – Andrew Hopkins, *Lessons from Longford: The Esso Gas Plant Explosion*[5]
>
> Incidents are '*a useful way of revealing the far-reaching causal chains that combine to breach a system's defences, barriers and safeguards'* – James Reason and Alan Hobbs: *Managing Maintenance Error*[6]
>
> It is important that investigation reports determine 'why' something happened not just 'what' happened e.g. *'it is not enough to know that people made mistakes; we need to know why they made these mistakes'* in order for the appropriate and most effective preventative measures to be taken – Andrew Hopkins, *Disastrous Decisions: The Human and Organisational Causes of the Gulf of Mexico Blowout*[7]

Two themes have emerged from the causal analysis of RESDV failures: the age of the valves that failed and the failure to learn and implement lessons from previous incidents (including bringing valves back into service after cycling and/or lubricating).

Nearly half of the RESDVs that failed were over 20 years of age. The three most common immediate causes were stated by dutyholders to be corrosion, the age of the RESDV and seizure/sticking. As well as the age of the RESDV being directly stated as responsible for the failure, some of the corrosion incidents will also be related to age; however there will be some overlap between these two immediate causes as some incidents had more than one immediate cause. Some of the less common immediate causes, such as degradation, are also related to the age of the equipment.

Nearly half of failed RESDVs had had a previous failure, and over a quarter of failed RESDVs were brought back into service after cycling and/or lubricating the valves. The root cause of the failure needs to be determined and acted upon so that it does not recur, rather than just bringing the RESDV back into service. Although operational guidance is available to the industry on RESDV testing and reporting (PD 8010-5:2013[1]), the analysis of the collected data in this study indicates that industry best practice is not being communicated and implemented offshore. For example, 20 incidents had organisational culture as an underlying cause (see Appendix C for further information about this category); in most of these incidents there was evidence or a reason to believe that the dutyholder had not learned lessons from previous failures. Poor

design of plant and process was also a factor in 22 incidents; dutyholders need to learn lessons from any failures that result from design so that they are not repeated.

Overarching these causes of failure are the underlying causes of maintenance and plant integrity (see Appendix C), i.e. a failure to maintain and monitor equipment. This reflects the findings from HSE's KP4 inspections[8] where "fix on fail" was routinely found. To improve performance, failures need to be anticipated so that preventative maintenance can occur, whether that is replacement or servicing. Trending of data will help anticipate failures, and to do this dutyholders need to record measurable quantities such as closure time and internal leakage rate rather than just pass or fail (another common finding during KP4). Thus, using these data it can be anticipated when an RESDV will fall below a dutyholder's defined performance standards.

# 5 RECOMMENDATIONS

- Dutyholders need to fully investigate failures of RESDVs to learn why they failed, rather than perform simple maintenance such as lubricating and cycling to bring the valve back into service.

- These lessons learned from previous failures need to be acted upon to prevent future failures.

- Dutyholders need to move towards preventative maintenance of RESDVs and away from "fix on fail". One possible method would be to trend performance data to predict when RESDVs will fail their performance criteria, and for maintenance to be undertaken before the failure.

# 6 APPENDIX A: DUTYHOLDER QUESTIONNAIRE TEMPLATE

The questionnaire sent out to dutyholders is reproduced below:

## Immediate and underlying causes of Riser Emergency Shutdown Valve (RESDV) failures

## Survey

**Questionnaire**

The questionnaire consists of two parts – a table (below) for basic information relating to the valve failure, and space for a textual description of the event, on the following page. The textual description of the event is perhaps the most important as it will reveal any trends and common issues. Please read the accompanying information document e-mailed with this questionnaire for background and guidance.

1. **Basic data table**

| | | |
|---|---|---|
| 1 | Date of 'fail': | |
| 2 | Dutyholder: | |
| 3 | Installation: | |
| 4 | Pipeline/riser number: | |
| 5 | Pipeline/riser name/description: | |
| 6 | Valve number: | |
| 7 | Valve name/description: | |
| 8 | Cross-reference to previous failure of same valve: | |
| 9 | Other valves involved (if common mode failure): | |
| 10 | Valve type: | |
| 11 | Valve manufacturer: | |
| 12 | Age of valve: | |
| 13 | Test frequency: | |
| 14 | Performance standard - closure time: | |
| 15 | Performance standard - maximum leakage rate: | |
| 16 | Describe maintenance regime: | |
| 17 | Actuation method (hydraulic / pneumatic etc): | |
| 18 | Actuator manufacturer | |
| 19 | Actuator age | |
| 20 | Valve size: | |
| 21 | Typical line pressure: | |
| 22 | Unit (pressure) | |
| 23 | Fluid (crude / gas / water cut etc): | |
| 24 | Time from previous test to failure: | |

## 2. Description of incident / valve failure

Please include:

- reason for valve operation  (e.g. scheduled test;  emergency shutdown ..)
-  'occurrence' i.e. failed to close; outwith performance standard …
- description of immediate causes
- description of investigations undertaken and indications of underlying causes .

# 7 APPENDIX B: ACCOMPANYING INFORMATION FOR QUESTIONNAIRE

The following was sent out to the dutyholders as accompanying information for the questionnaire:

## Immediate and underlying causes of Riser Emergency Shutdown Valve (RESDV) failures

## Guidance and background information for survey

1. **Background**
2. **Findings of preliminary search of HSE COIN database**
3. **Present Survey**

**Annex: 'Occurrence', immediate cause and underlying cause tags**

### 1. Background

HSL has been commissioned by HSE Energy Division to carry out a survey of the failure of riser ESD valves to close on demand or to meet performance criteria. The main aims of the survey are to identify the immediate and underlying causes of the failures.

Failure of a riser ESD valve to meet performance standards, particularly failure to close on demand, is RIDDOR reportable and a preliminary survey of cases held on HSE's 'COIN' database has been carried out. The results of this preliminary survey are described more fully in Section 2. This wider questionnaire-based survey intends to provide deeper information on the causes of failures with the aim of identifying areas of focus for future improvement.

### 2. Preliminary search of HSE COIN database

A search of HSE's COIN database from 2006 onwards found approximately 170 relevant cases (i.e. RESDV failures). Reporting was sparse up until spring 2009 whereon there was an increase in the number of reports (although some of the reports are retrospective).

Of the reported failures, some were failures on test, some on accidental or real demand, or some for planned shutdown etc.

Figure AB.1[a] shows the distribution of 'occurrence', i.e., whether the valve failed to close, failed to meet the performance standard for leakage rate or closure time, or otherwise – e.g. hydrocarbon leak, passing or other fault related to valve.

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[a] *The numbering of the figures in this appendix has been amended from those in the information that was sent to dutyholders.*

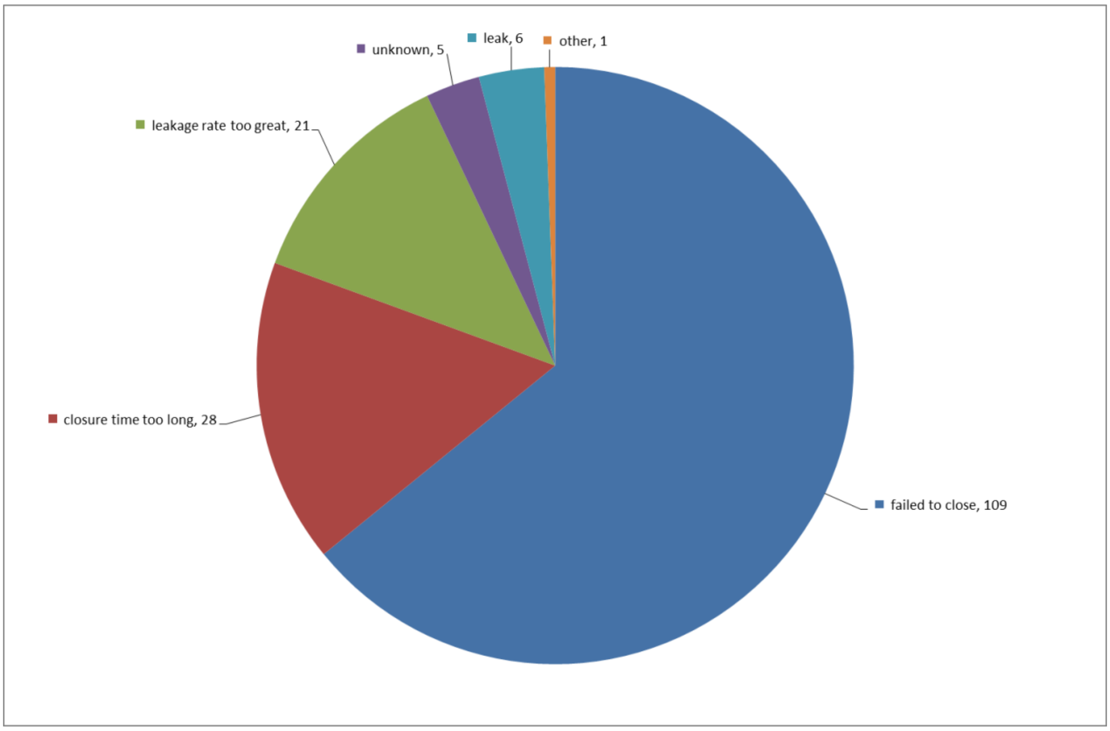


**Figure AB.1 Distribution of 'occurrence' (numbers are approximate)**

Figure AB.2 shows the distribution of the immediate cause of the failure. In many cases, it was not possible to identify the immediate cause from the case description (categorised as unknown), and in a number of cases all that was identifiable was that the valve had closed upon cycling, after lubrication or after 'intervention'. Other than these instances, the most prevalent cause was problems with solenoids or other pneumatic/hydraulic problems.

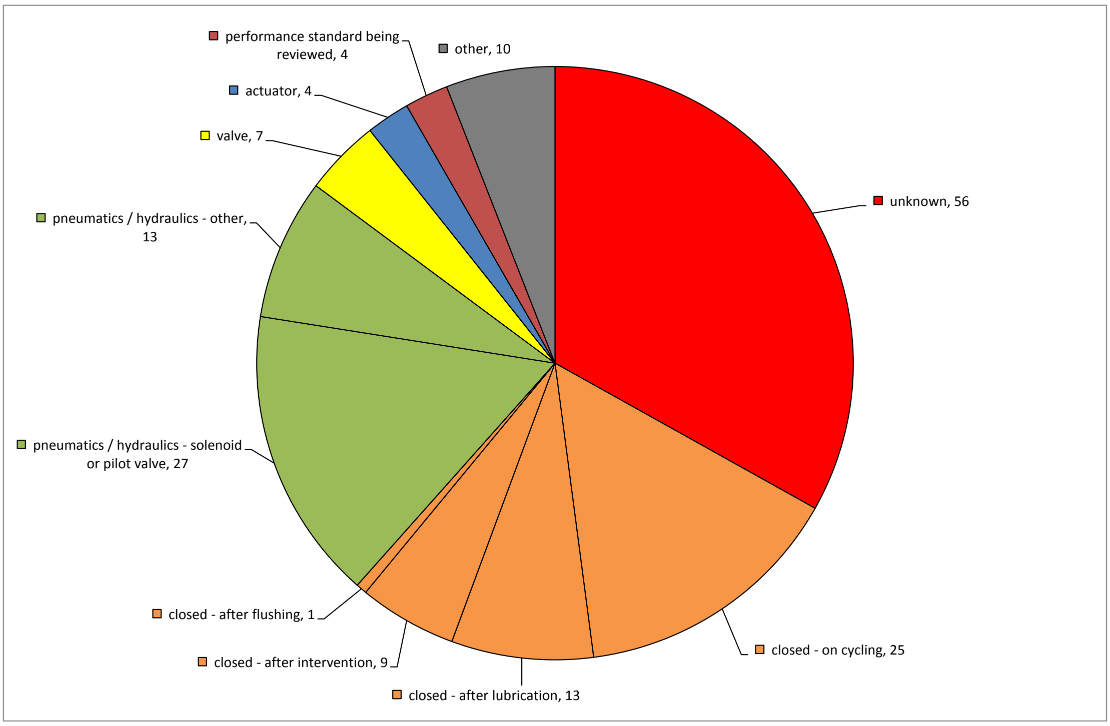


**Figure AB.2 Immediate causes as identified from RIDDOR report (numbers are approximate)**

## 3. Present survey – aims and guidance on questionnaire completion

This survey aims to gather more information relating to:

- immediate cause of valve failure
- underlying cause of valve failure

The general purpose of the survey is to identify trends and common issues regarding performance and upkeep of RESDVs.

The questionnaire consists of two parts – a table for basic data and a blank page for a textual description of the event. In the description of the event, as much detail as possible is preferable, but the main elements that are required are:

- what occurred ('occurrence' – e.g. failed to close, closure time too long)
- what were the immediate causes
- an indication of the underlying cause(s)

*Immediate causes*

In terms of immediate causes 'the deeper, the better' should be the guiding phrase, although the failures will ultimately be categorised and therefore the broad cause of failure should be readily identifiable. Lists of 'occurrence' and immediate cause, as categorised following the preliminary COIN search are given in the Annex to this document, below.

Often there may be more than one immediate cause – for example there was a problem with an actuator and a solenoid valve (independent), or, for example the air supply was contaminated and this had caused the solenoid valve to fail (dependent). All relevant immediate causes should be identified.

*Underlying causes*

Identifying underlying causes requires somewhat deeper investigation, and, as above, 'the deeper the better' should be the guiding phrase, but as a minimum an indication should be given - e.g. 'maintenance backlogs', 'inadequate records', 'test frequency insufficient', 'design problem'. Broad headings of underlying cause categories used by HSL for incident investigation are given in the annex.

*Response length*

The responses to the questionnaires will be human-read and then collated/categorised, therefore a concise answer is preferred but not to the detriment of the information provided. Responses will preferably be between a paragraph and a page in length.

For some cases detailed reports may have already been submitted as part of the RIDDOR case, but for ease of data collation and so that this survey can be a stand-alone study, completion of the questionnaire is appreciated.

**Annex: 'Occurrence', immediate cause tags and underlying cause headings**

Below are listed the category 'tags' used in the preliminary survey. These are for guidance only, detailed textual information is preferred.

**'Occurrence'**

Failure to close
Closure time too long
Leakage rate too great
Leak (i.e. hydrocarbon release)
Other

**Immediate cause tags**

unknown – closed after cycling
unknown – closed after lubrication
pneumatics - solenoid replacement
pneumatics - air contamination
pneumatics - incorrect valve positioning
pneumatics - incorrect configuration
pneumatics - pilot valve
pneumatics - other
hydraulics - solenoid replacement
hydraulics - air contamination
hydraulics - incorrect valve positioning
hydraulics - incorrect configuration
hydraulics - pilot valve
hydraulics - other
actuator
valve
other

**HSL Underlying Cause Headings**

These broad headings are taken from an underlying causes guidance sheet that HSL uses when identifying underlying causes of incidents. These are included for guidance purposes. 'Maintenance' is likely to be a common theme for RESDV failures, therefore some more detail than this will be necessary.

Leadership and management
Risk profiling
Competence
Plant and process design
Management of change
Plant integrity
Safety critical systems
Control of work

Operating procedures
Contractors
Maintenance
Emergency arrangements
Verification
Organisational culture

# 8 APPENDIX C: UNDERLYING CAUSES USED FOR HSL ANALYSIS OF INCIDENTS

| Issue | Includes: |
|---|---|
| **Leadership & Management** | • Board members, senior executives and managers not accountable for major hazard safety leadership and performance.<br>• Appropriate resources not made available to ensure a high standard of major hazard safety management throughout the organisation.<br>• Information on major hazard safety performance not routinely reviewed at Board level.<br>• No systems and arrangements in place to ensure the active involvement of the workforce in the design of major hazard safety controls and/or in the review of major hazard safety performance.<br>• Lack of Board level involvement and/or competence.<br>• Inadequate monitoring of compliance with procedures<br>• Wider concerns over the: Safety Case/ Safety Report/Major Accident Prevention Policy/Major Hazard Management System. |
| **Risk profiling** | Dutyholder arrangements inadequate to understand the risk profile of their business; major hazard scenarios not identified, risks not evaluated.<br>• Key elements of a risk assessment system missing or inadequate<br>• Risk assessment methodology inadequate to address risk profile.<br>• Risk assessment failed to identify important risk control measure(s)<br>• Risk assessment failed to include life cycle of the activity e.g. normal operating, non-routine operations, and maintenance.<br>• Risk assessment documentation inadequate.<br>• Failure to review and revise risk assessment following a material change in operating conditions.<br>• Human factors not taken into account in the risk assessment<br>• Inadequate hazard studies |
| **Competence** | • Inadequate major hazard awareness; gaps in skills knowledge or experience, etc.<br>• Recruitment criteria; Staff selection; staff assessment; competency assurance systems do not adequately address health and safety, including major hazards.<br>• Inadequate training, including failure to ensure adequate training of operators in operating procedures or safety critical tasks. |

| | |
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| **Plant & Process design** | Issues concerning the development, implementation and application of safety engineering codes, standards and procedures to the design of new plant. It covers both the design of safety devices, such as PRVs and emergency shutdown systems, and the correct design of piping and vessels in terms of materials, process parameters and control systems to prevent and control hazards such as overpressure, corrosion and erosion.<br>• Unclear policy and management arrangements for plant and process design leading to actual or potential inadequate risk control.<br>• Unsuitable / inadequate vessels, pipework, valves, instrumentation, software and/or safety devices to control e.g. corrosion, overpressure & erosion.<br>• Vessels, pipework, safety systems etc. not designed, constructed, installed or maintained in accordance with relevant legal and other standards.<br>• Absent / inadequate P&I diagrams.<br>• Inadequate / unsafe plant commissioning / decommissioning. |
| **Management of Change**<br>Includes plant, process and organisational change This may be permanent, temporary or urgent changes throughout the life-cycle. | Change can be addition, replacement, removal or modification, covering:<br>**Plant:** Design, equipment, software, layout, location, instrumentation, set points of critical alarms, relief systems or trip settings, materials, specifications, plant status.<br>**Process changes:** raw materials, suppliers, process steps, process parameters, scale.<br>**Procedural change:** operational procedural steps, computer controlled software; maintenance procedures.<br>**Organisational change**: staffing levels; organisational restructuring; management arrangements; methods of work; shift patterns, contractorisation.<br>• Change Management system missing key elements.<br>• Poorly documented change system indicating ineffective control.<br>• Inadequate safety, engineering and technical reviews prior to change.<br>• Poorly planned change<br>• Scope of change system inadequate in terms of scope and life cycle.<br>• Failure to consider human factors in change system.<br>• Depth and quality of risk assessment process in relation to change fails to meet standards.<br>• Inadequate management of plant / process modifications. |

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| **Plant Integrity** | • Inadequate management arrangements for ensuring plant integrity.<br>• Inadequate recognition of risks from ageing plant leading to actual or potential failure to manage major hazards.<br>• Inadequate life extension policy in respect of plans to operate assets beyond design life leading to actual or potential failure to manage major hazards.<br>• Inadequate systems to monitor integrity, e.g. vibration monitoring, etc.<br>• Significant signs of plant ageing: creep, cracking, corrosion and changes in corrosion rates.<br>• Recurring defects, and/or increasing trends of unplanned maintenance and breakdowns.<br>• Unclear policy on temporary repairs. |
| **Safety Critical Systems**<br>As defined in the relevant sector legislation, authoritative sector guidance and safety case/report manuals. | Control and instrumentation systems for minimising major hazard risks, protective systems for ensuring safe operation of plant (e.g. pressure control and relief systems such as HIPPs), alarm and trip systems, associated computer software, mitigation systems.<br>• Safety critical systems not designed to relevant standards.<br>• Integrity of the safety related system adequate to meet required risk reduction.<br>• Failure of safety critical system leading to loss of control.<br>• Failure to identify and assess adequacy of safety critical systems.<br>• Gap analysis on the adequacy of legacy systems compared with good practice guidance not carried out.<br>• System for managing the examination and testing of safety critical systems inadequate.<br>• Documentation and records relating to safety critical systems inadequate.<br>• Inadequate arrangements for protecting safety critical software.<br>• Arrangements for addressing safety critical defects inadequate.<br>• Integrity of alarm systems, including human interface, inadequate. |
| **Control of work** | • Unclear policy and management arrangements for control of work including permit-to-work systems leading to actual or potential inadequate risk control.<br>• Unsuitability of permits; permits not addressing hazard profile (e.g. major hazards v other H&S hazards).<br>• Failure of management system; non-compliance with procedures; communication failure e.g. at handover; poor auditing/monitoring of system.<br>• Supervision issues; failure of Area Authorities to visit sites, no or poor toolbox talks, poor or no auditing arrangements. |

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| **Operating procedures** | Procedures required to operate the plant; arrived at by consideration of the task and hazard analysis of the process and should identify safety critical operations. Hazards may include chemical reactivity, sampling procedures, inerting requirements for flammable liquid storage tanks, purging procedures such as double block and bleed as well as general process operating hazards. The scope should cover plant start-up, shut-down, normal process operations, loading, purging, inerting, storage and transport. Ergonomic principles and potential for human error are included.<br>• Unclear policy and management arrangements for operating procedures to actual or potential inadequate risk control.<br>• Scope of operating procedures inadequate and fail to cover hazard profile.<br>• Documented procedures absent, inadequate, out-of-date.<br>• Non-competent and/or unauthorised persons carrying out procedures against policy.<br>• Plant / equipment not operated in accordance procedures. |
| **Contractors** | • Deficiencies in arrangements for selecting and managing contractors leading to actual or potential inadequate risk control<br>• Deficiencies in selection procedures and contactors lacking sufficient competence<br>• Unclear understanding of the scope of responsibility<br>• Poor communication<br>• Supervision fatigue<br>• Lack of familiarity with local plant/procedures,<br>• Lack of verification/certification of contractor plant |
| **Maintenance** | Procedures required to define maintenance work including the (task) analysis of the maintenance process.<br>• Inadequate maintenance policy and arrangements.<br>• Inadequate records.<br>• Inadequate routine testing and examination, including non-destructive testing.<br>• Maintenance backlogs on safety critical elements undermining risk control.<br>• Non-compliance with statutory schemes of inspection (e.g. pressure systems).<br>• Poorly maintained plant and protective systems. |

| | |
|---|---|
| **Emergency arrangements** | Off-shore; on-site, and off-site emergency planning.<br>• Emergency plans not prepared, inadequate, and/or not implemented.<br>• Emergency plant and equipment not sufficient to deliver emergency plan.<br>• Consultation on emergency plans fails to meet legal requirements.<br>• Plan not tested or reviewed to meet legal requirements.<br>• Inadequate information to members of the public sufficient to meet legal requirements.<br>• Inadequate arrangements for evacuation. Mustering, temporary refuges. |
| **Verification** | • Verification scheme for safety critical elements inadequate and/or not implemented.<br>• Inadequate performance standards.<br>• Out of date certification.<br>• Use of third party verification, including independent competent person. |
| **Organisational Culture** | Organisational culture influences human behaviour, performance and practices.<br>• Culture is simply viewed as employees following rules. Does the organisation have policies, principles, processes and documentation in place to control major accident hazards.<br>• There is evidence of a 'blame culture' as opposed to a 'just culture'.<br>• There is a weak, invisible leadership and an ambiguous commitment to actively manage major hazards (i.e. a lack of mindful and process safety leadership) including; a focus on personal injury instead of major accident hazards, bias of production over safety, normalisation of deviance and emphasis on reactive measures to manage major hazards at the expense of proactive measures).<br>• Employees and contractors are not actively involved in task analysis, major hazard risk assessment, development of procedures, design for usability and maintainability, incident investigations, etc.<br>• There are no arrangements in place to empower employees (e.g. to stop work if it is not safe to continue), little deference to expertise on site (particularly for safety critical decision making and action in an emergency).<br>• Failure to learn; mechanisms are not in place to learn from the findings of incident and near miss investigations, underlying root causes have not been uncovered, human factors have not been fully integrated into the investigation and the lessons learnt have not been communicated clearly across the organisation (including lessons learnt from the company's incidents, other incidents within the industry and those from other industries). |

# 9 APPENDIX D: CAUSAL ANALYSIS RESULTS

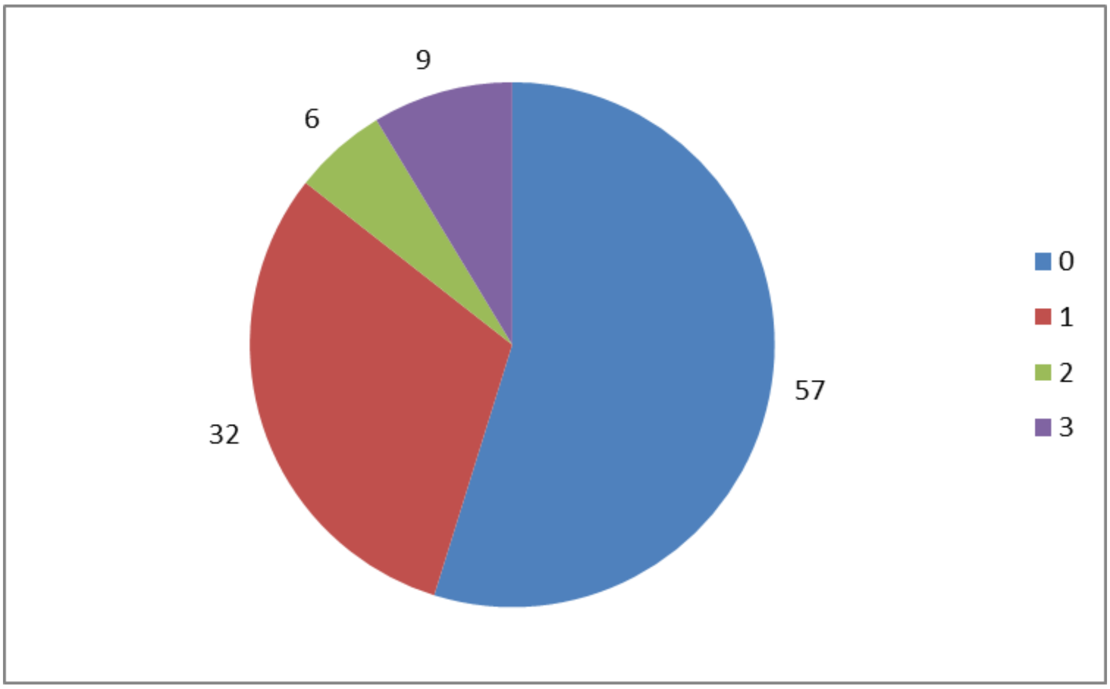


**Figure AD.1:** A pie chart showing the number of failed RESDVs that have had previous failures.

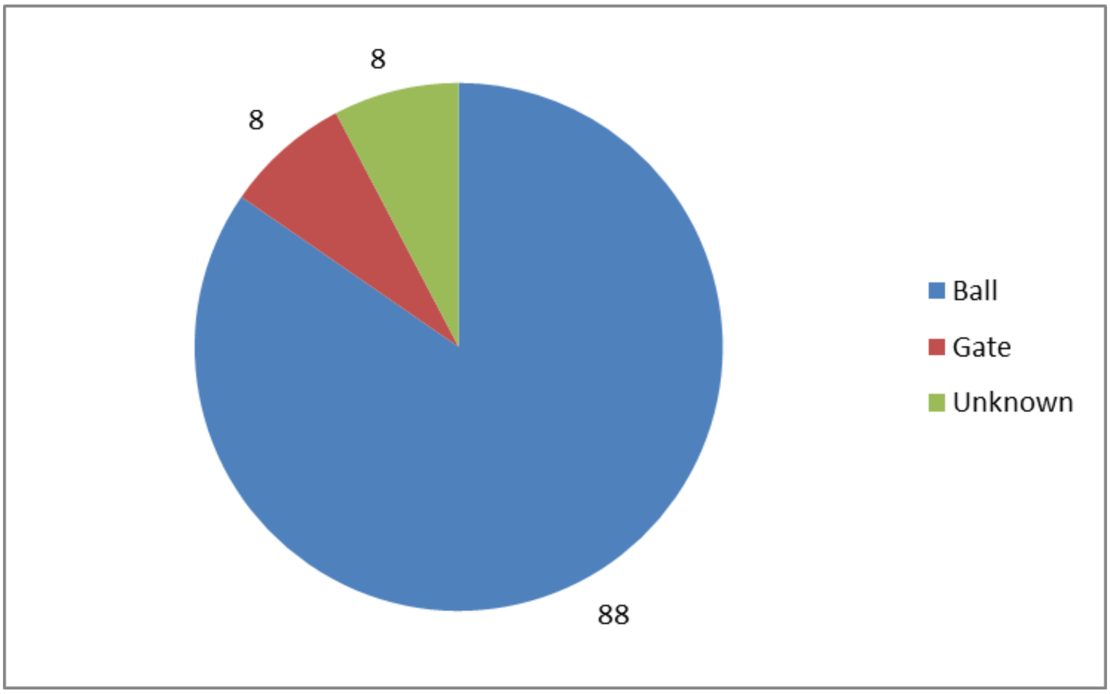


**Figure AD.2:** A pie chart showing the types of RESDV that failed.

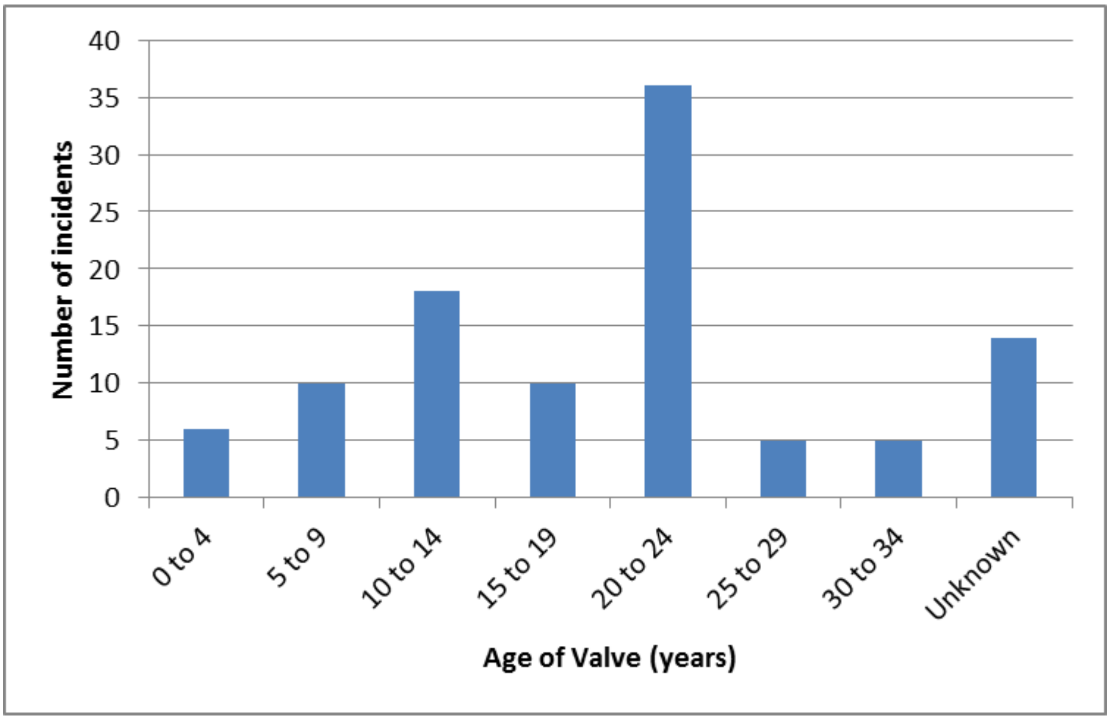


**Figure AD.3:** A graph showing the age of RESDVs that failed.

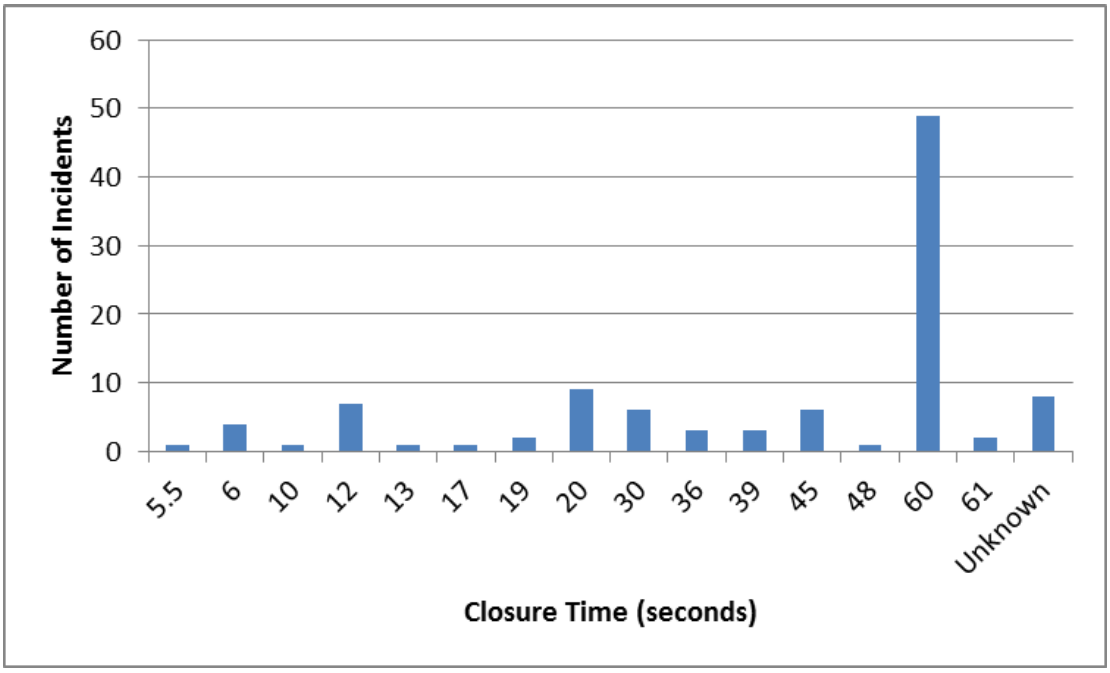


**Figure AD.4:** A graph showing the performance standard for closure time of RESDVs that failed.

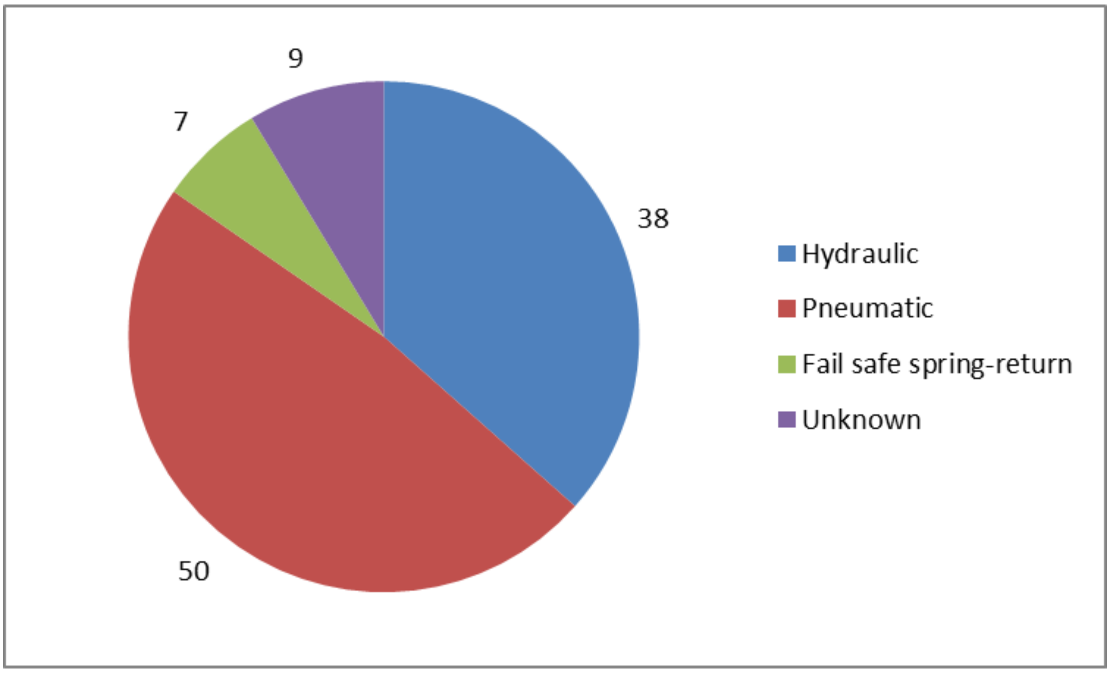


**Figure AD.5:** A pie chart showing the actuation method of RESDVs that failed.

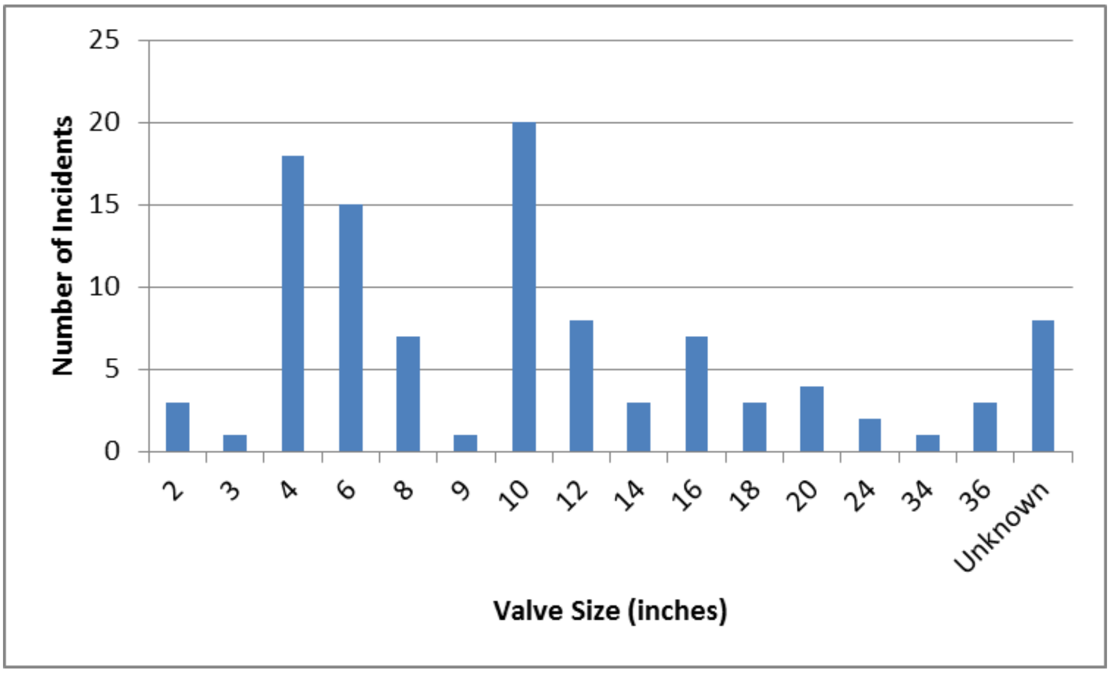


**Figure AD.6:** A graph showing the size of RESDVs that failed.

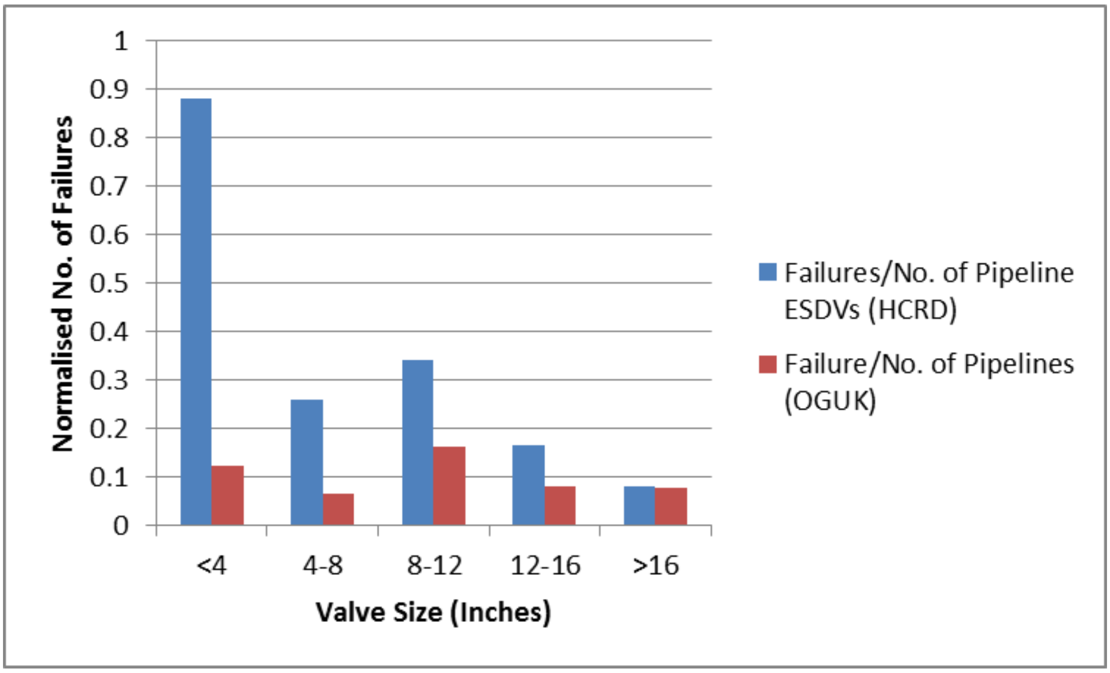


**Figure AD.7:** The number of failures normalised by the number of RESDVs of the different sizes. There are problems with both of these population sets; the populations of equipment in the HCRD have not been updated since 2003 and the OGUK data does not specify how many of the pipelines have RESDVs attached.

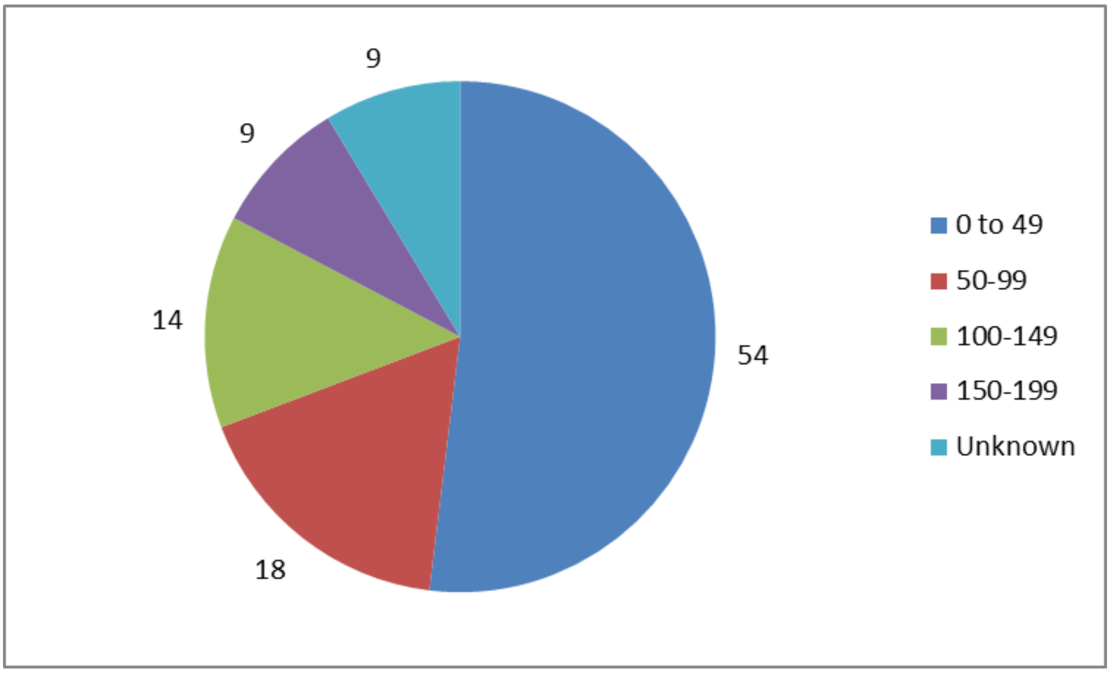


**Figure AD.8:** A pie chart showing the typical line pressure (in barg) of RESDVs that failed.

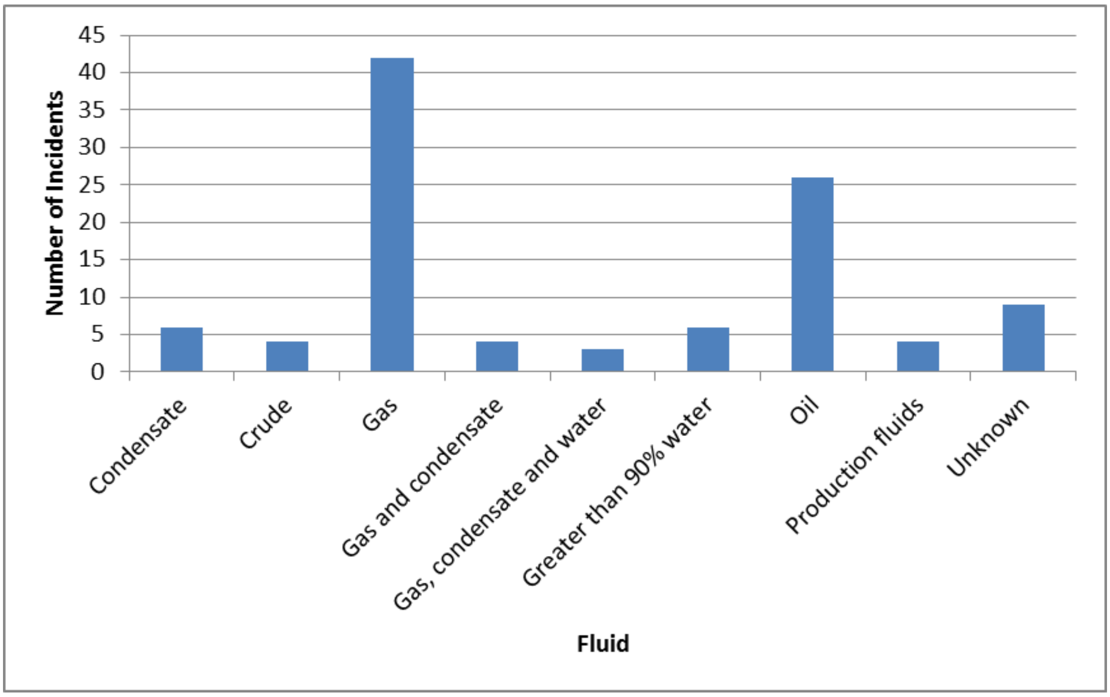


**Figure AD.9:** A graph showing the type of fluid in the lines for RESDVs that failed.

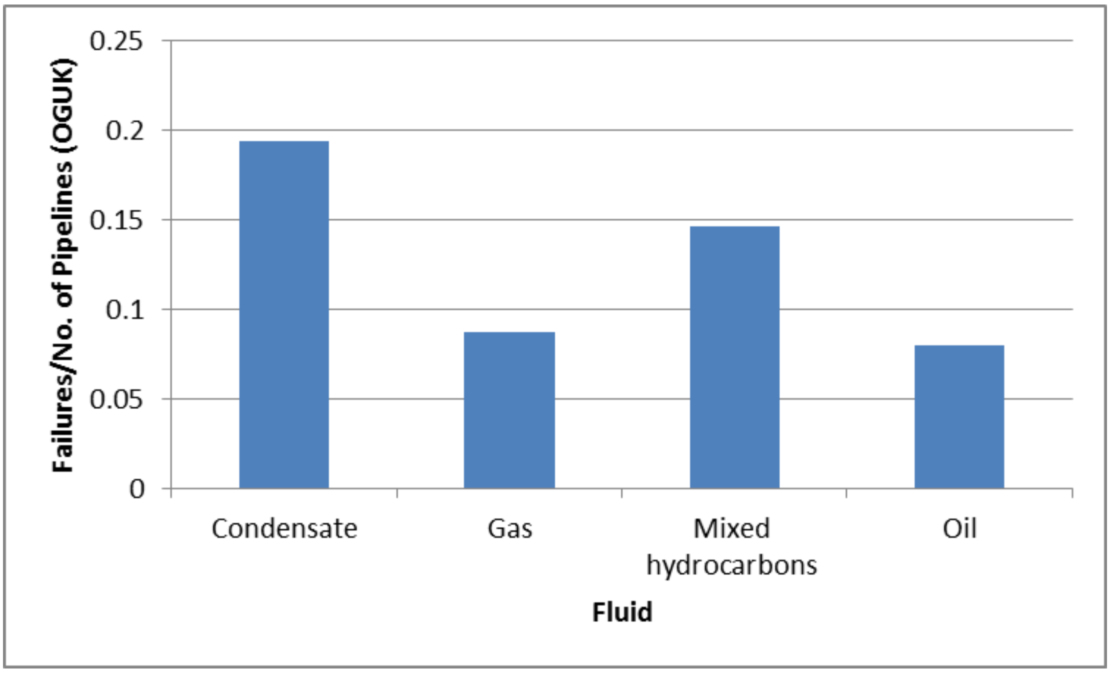


**Figure AD.10:** A graph showing the normalised number of failures by the fluid type in the lines for RESDVs that failed.

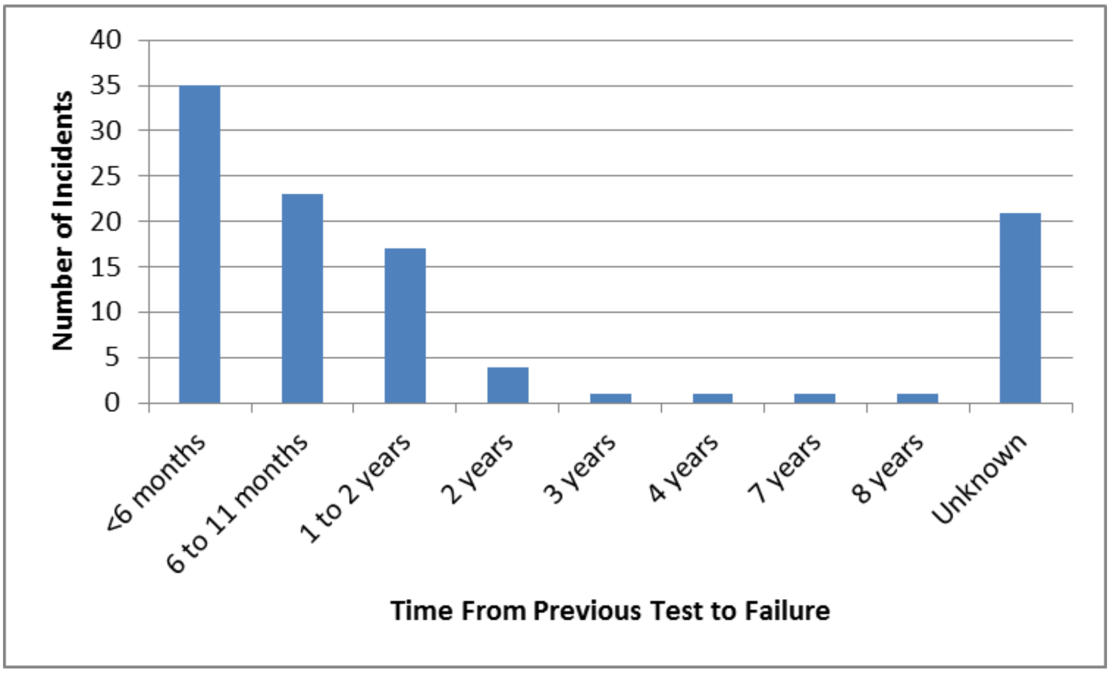


**Figure AD.11:** A graph showing the time from the previous performance test to failure for RESDVs.

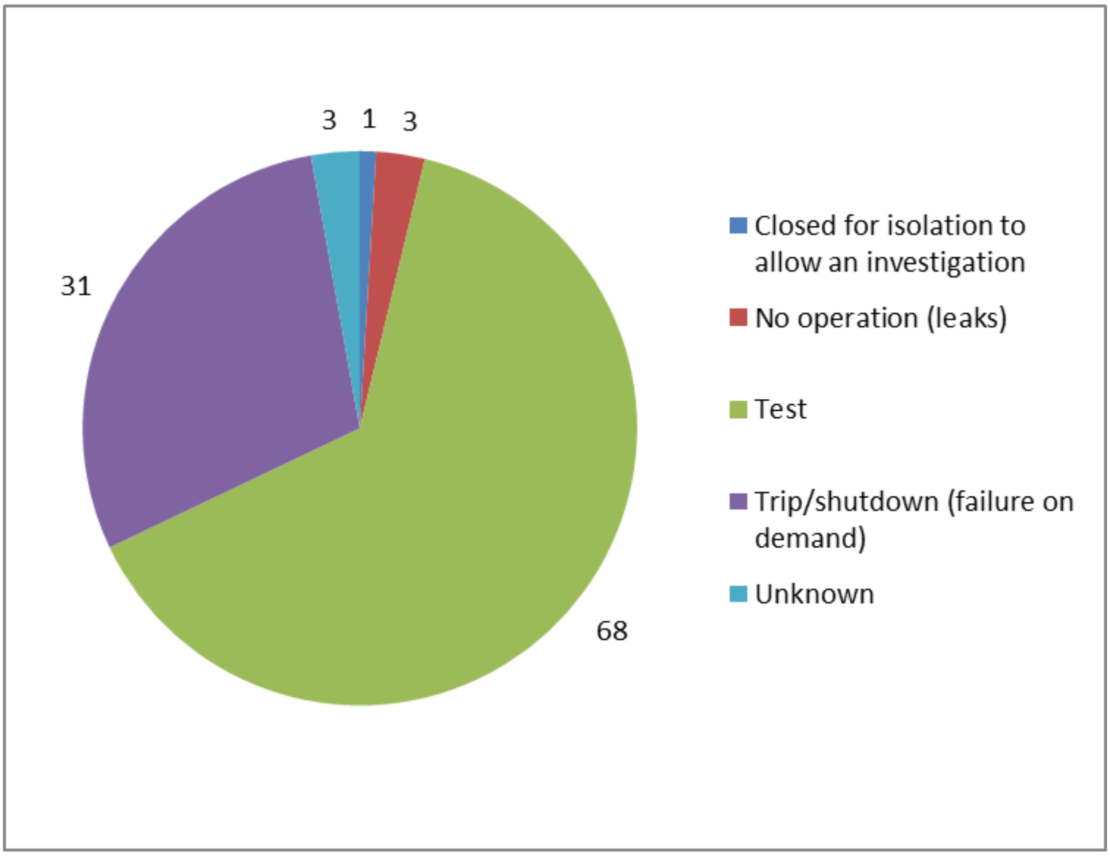


**Figure AD.12:** A pie chart showing the reason for valve operation when the RESDVs failed.

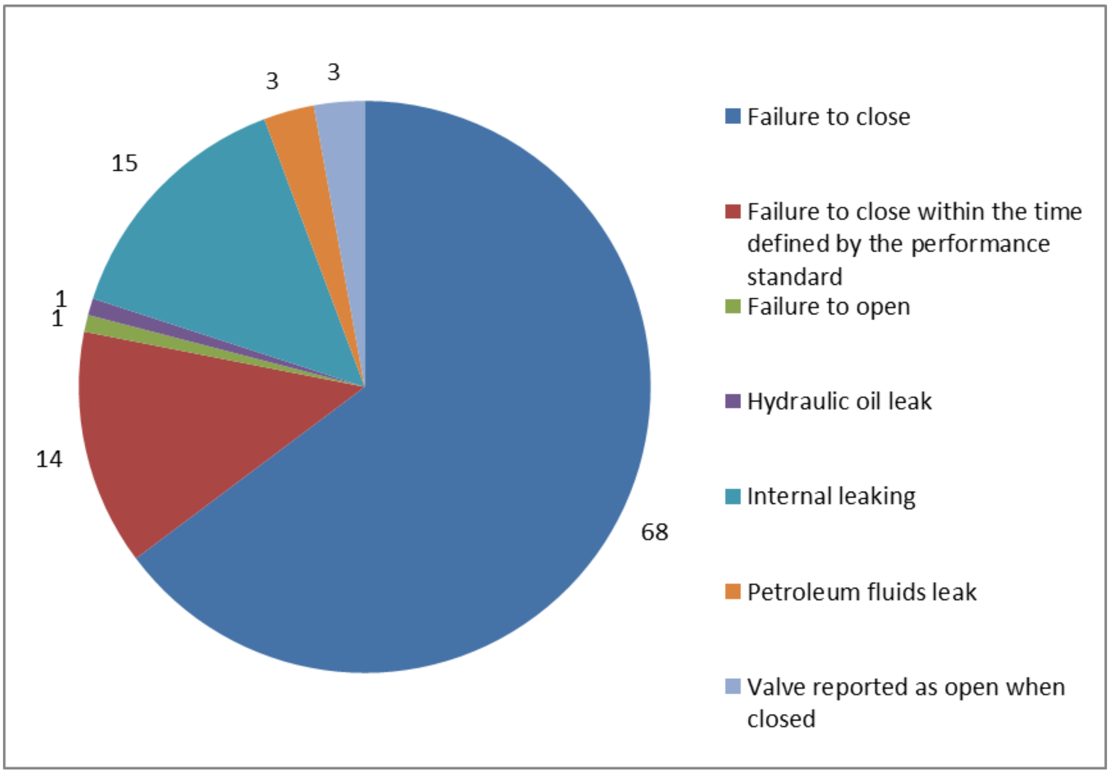


**Figure AD.13:** A pie chart showing the RESDV failure types.

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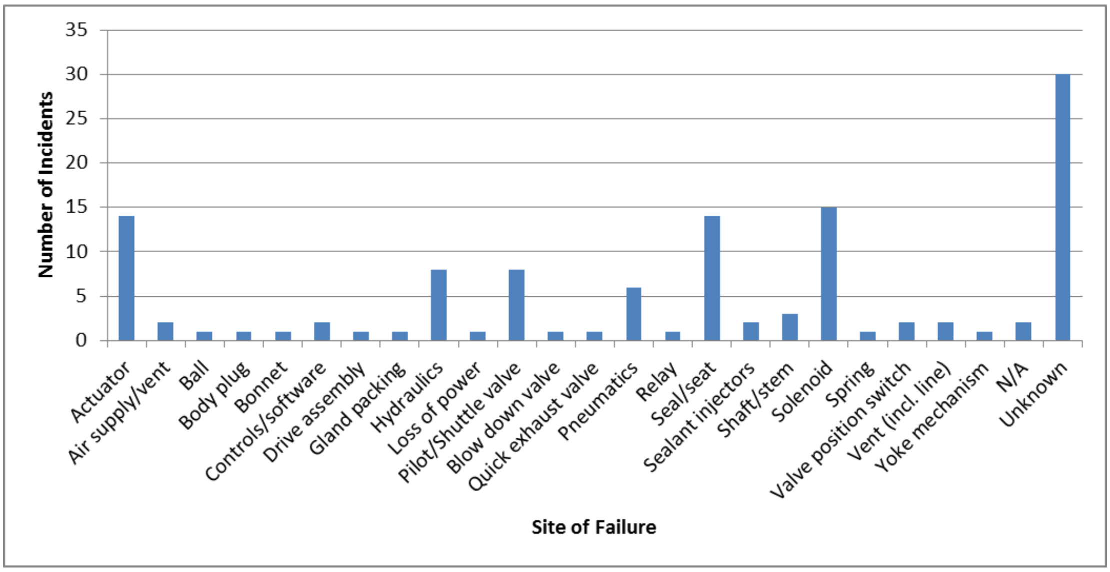


**Figure AD.14:** A graph showing the site of failure of RESDVs.

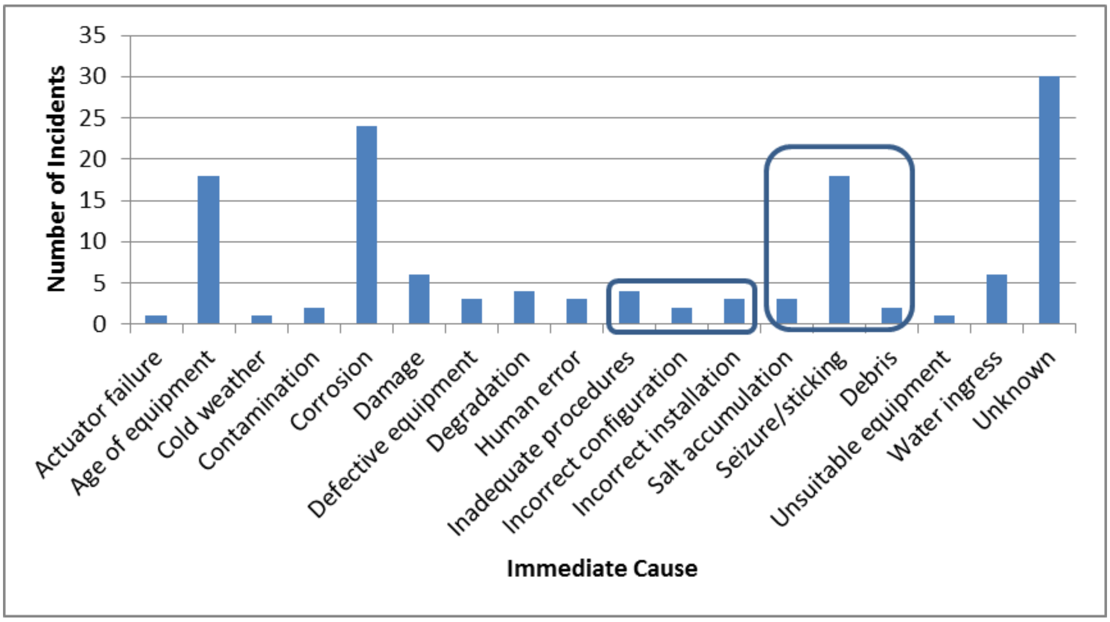


**Figure AD.15:** A graph showing the immediate cause of RESDV failures (circled caused grouped together in Figure AD.16).

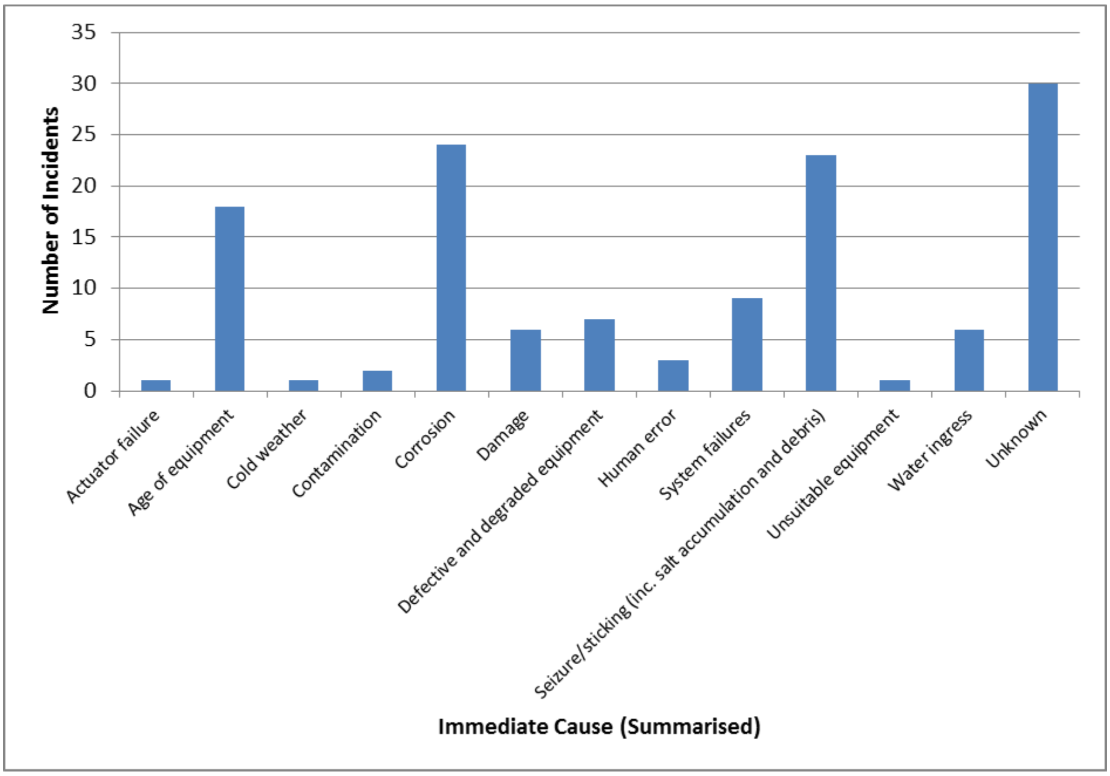


**Figure AD.16:** A graph showing the immediate cause of RESDV failures summarised into groups.

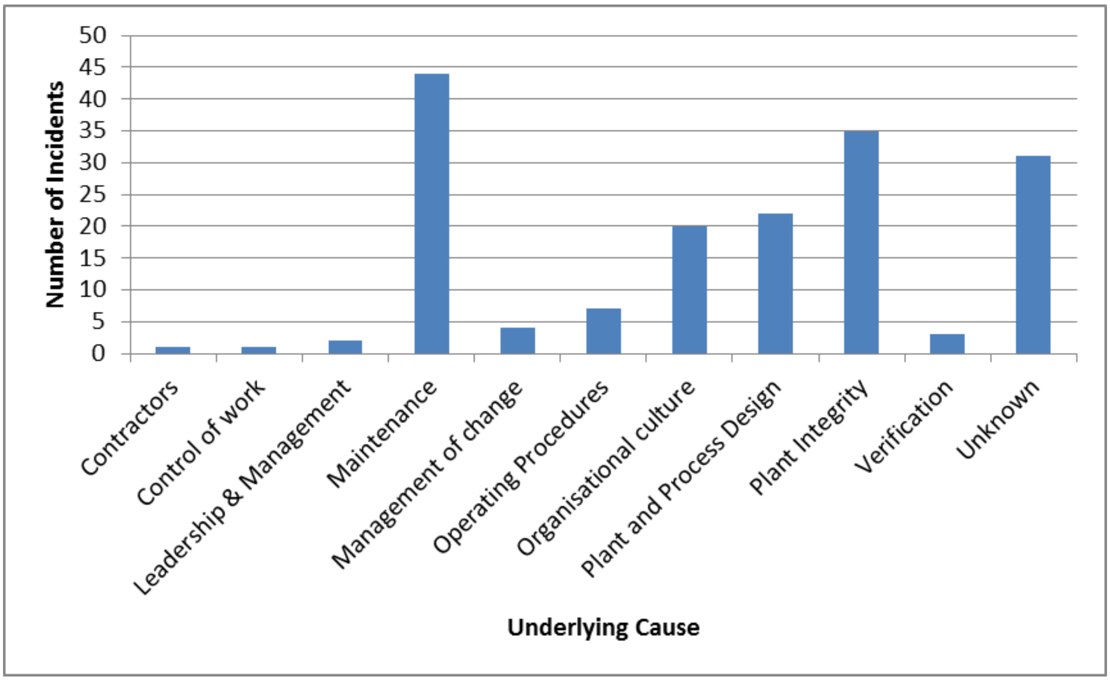


**Figure AD.17:** A graph showing the underlying cause of RESDV failures.

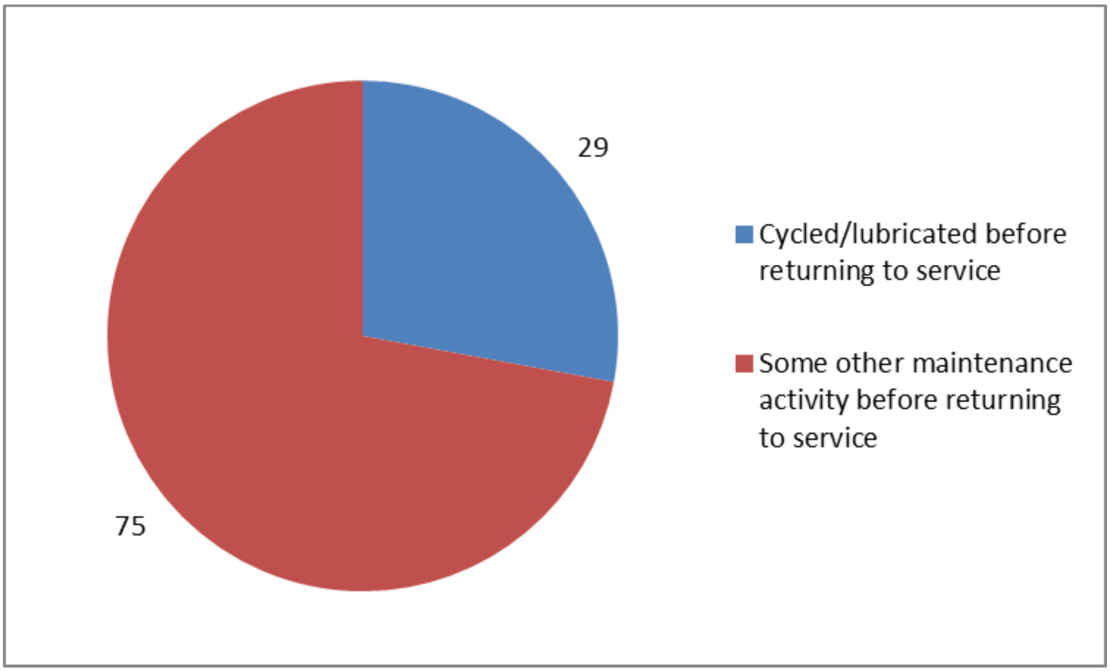


**Figure AD.18:** A graph showing the number of failed RESDVs that were brought back into service after cycling and/or lubricating.

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HSE

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# Investigations into the immediate and underlying causes of failures of offshore riser emergency shutdown valves

Riser emergency shutdown valves (RESDVs) are an essential risk reduction measure for offshore installations and are a legal requirement under the Pipelines Safety Regulations 1996. RESDV failures, whether arising from a test or a real demand, are reportable to HSE under RIDDOR and a preliminary survey found approximately 180 cases of failure. Given the criticality of RESDVs to offshore safety, it was determined that the reasons for these occurrences should be investigated with a view to focussing inspection topics and identifying areas for future improvement across the industry.

Two themes have emerged from the causal analysis of RESDV failures: the age of the valves that failed, and the failure to learn and implement lessons from previous incidents.

The three most common immediate causes were stated by dutyholders to be corrosion, the age of the RESDV and seizure/sticking.

Nearly half of failed RESDVs have had a previous failure, and over a quarter of failed RESDVs were brought back into service after cycling and/or lubricating the valves. The root cause of the failure needs to be determined and acted upon so that it does not recur, rather than just bringing the RESDV back into service.

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