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Review of unidentified ignition sources of unplanned flammable releases - Comparison of Offshore and Onshore data

Report Number

HSL/2006/09

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ACKNOWLEDGEMENTS

The data used in the preparation of this report was abstracted from the MHIDAS database by Andrew Lelland of AEA Technology, and his contribution is acknowledged.

FOREWORD

This Report was prepared to compare the frequency of ignition of unplanned and uncontrolled releases of flammable gases, liquids and vapours from onshore sources, with those from offshore releases, and to estimate the proportion of undefined ignition sources from major accidents. The offshore releases were analysed in previous Report FS/04/13 *Offshore ignition probability arguments* by Dr. AM Thyer of Fire Section at HSL Buxton. The probability of ignition has also been modelled by an spreadsheet, prepared by AEA Technology Ltd at the request of the U.K. Offshore Operators Association (UKOOA). This has been reported elsewhere as the Ignition Probability Review and Model Development Report (2003). This model has a quite extensive interaction between contributing factors which demonstrates the difficulty in clearly identifying ignition sources from incidents which have occurred.

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EXECUTIVE SUMMARY

The Major Hazard Incident Database (MHIDAS) was searched to provide data on the probability of ignition of accidental releases of flammable gases, liquids and vapours. The data was of 4343 major incidents involving fires or explosions and/or releases of flammable materials. The data was sorted between the U.K., the U.S.A. and the Rest of the World. There is an insignificant difference between the data sets, as the overall frequency of ignition is very high with more than 95% of all recorded incidents involving an ignition or explosion.

The review of the on-shore Major Accidents UK, USA and throughout the world involving releases of flammable liquids and vapours, indicates that the source of ignition is often not found. Many of the references reviewed indicated that an investigation into the initiator of the incident was underway, but it was not uncommon for the investigation report not to be published in the public domain. Overall, following investigations into major accidents that had a release and an ignition, about 60% of those incidents did not have an ignition source identified by the investigation.

The implications for enforcement by HSE are significant. The main defence argument in many cases involving a release of flammable material that did not ignite is that since an ignition source was not found there was no or little risk[1] to persons. The defence arguments are aimed at dismissing the potential for harm[2] to persons because of a lack of ignition; but ignition sources do exist and as this report shows, are very difficult to identify.

Whilst the data is not particularly focussed on any particular industry, there is a subset of data which is attributed to "Process" situations. This has been assumed to refer to incidents which have occurred on an oil refinery or chemical plant. Even though these would be expected to have a lower incidence of ignitions than the general environment due to the stricter controls typically in force in such areas, there is a trivial difference in ignition probability which remains higher than 95%

The major finding from the database is that of all the incidents where ignition occurred, approximately two-thirds of them had no identified ignition source. Of the approximate one third where an ignition source was identified, the sources were fairly evenly distributed in that there was no obviously dominant ignition source. However, there was a significant reduction in ignition frequency from electrical sources and flames, and a significant increase in ignitions from hot surfaces and auto-ignition, in process areas compared with non-process areas. This indicates that the controls used for electrical equipment and hot working (flames) used in process areas do reduce frequency of ignitions from these sources.

Of the releases, again about one third were classified as "gas" and the remaining about two-thirds were classified as "liquid". There was no obvious difference in the frequency of ignition of these, in that "gas" releases appeared to be no more likely to be ignited than "liquid" releases.

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[1] *risk* is defined here as the combination of consequence and likelihood. See Glossary on page 20.

[2] *harm* is defined here as the consequence of a hazard being realised. See Glossary on page 20.

1 INTRODUCTION

In a previous Report, *Offshore ignition probability arguments* by Dr. AM Thyer of Fire Section at HSL Buxton, referenced FS/04/13, the probability of ignition of a release of flammable material on an offshore oil platform was investigated from data abstracted from the OIR/12 database[3]. In that report, the probability of ignition was found to be low in areas classified as hazardous (i.e. Zone 1 or Zone 2), but significantly higher in areas not classified as hazardous. Even so, in non-hazardous areas, the number of ignitions of releases was significantly low at about 16% based on a sample of 132.

In view of the apparently low probability of ignition, a search was undertaken on the MHIDAS[4] database to determine the number of accidental, unplanned or uncontrolled releases of flammable materials and to determine the probability of ignition occurring from onshore releases. This would allow some correlation to determine the validity of the assumption that the low probability of ignition is correct for offshore installations.

This Report details the data abstracted; the way the data was sorted, collated and analysed, and the overall results. All the data sorting is contained in the Appendix on page 12

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[3] The OIR/12 database is a record of all OIR/12 forms (Offshore Installation Hydrocarbon Release Report) voluntarily completed and submitted to the HSE Offshore Safety Division.

[4] Major Hazard Incident DAta Service.

2 DATA ABSTRACTION FROM MHIDAS

The MHIDAS Database stores public domain information gleaned from a wide variety of sources, and the data is stored as individual records. The original request for data searching asked for the following criteria to be used:

- Incident date
- Materials released
- Form of release (gas, liquid, vapour, spray)
- Whether ignition occurred or not
- When ignition occurred (instantaneously or delayed)
- Identified ignition source
- Zoning of release location
- Extent of damage
- Number of deaths
- Number and extent of injuries

In the event, the data records actually selected were as follows:

- ID
- Record
- Record Char
- Date sign
- Year
- Month
- Day
- Country
- Material Name
- Material Code
- Incident Type
- Incident Type
- Primary origin
- Secondary origin
- Kill Sign
- Number killed
- Injsign
- Number injured
- Number evacuated
- DamSign
- Cost of damage, million US$
- General ignition source
- Specific ignition source
- Abstract

The total number of records retrieved was 6578. The "record" column is a specific entry to an incident. However, where more than one material can be identified, a subsequent entry is made with the same record number and an entry in the "record char" column. In order to avoid duplication of the data, each record where a "record char" exists was examined, and the entry with the most relevant material has been retained, and the others deleted. Relevance here includes the first material to ignite, or the major material, if involved. Hence this ensures that there is only one entry for each record. Where materials are not precisely identified or are produced by the fire (for example, "chemicals" igniting and producing "toxic fumes") then the entire entry is deleted.

Of all the remaining columns, those which are not directly relevant to ignition sources and materials were deleted, and two extra columns were inserted. The two extra columns were to make sorting of the fluids released easier, in that each material was assigned a phase as "gas", "liquid" or "vapour", giving the following columns:

- Record
- Material name
- Phase
- Incident Type
- Incident Type
- Primary origin
- Secondary origin
- General ignition source
- Specific ignition source
- Abstract

The data was refined by removing all reference to fires or explosions involving solid material or non-flammable materials, such as oxygen or hydrogen peroxide. This was stored as an Excel spreadsheet file "Filtered Data.xls". This left a total of 4343 records.

All General Ignition Sources were refined by using the existing valid field entries. Where data had not been entered in a field, the abstract was consulted and sometimes it was possible to identify the probable ignition source or material. Where there was arson or suspicious circumstances, then the general ignition source was entered as being arson. If it was not possible to identify any type of material involved, such as gas, liquid, vapour or solid, then the entry was deleted as this probably referred to non-process material related fire. The file was stored as "Filtered Data_1.XLS" The final data entries were:

- Arson
- Autoignition
- Collision
- Electric source
- Flame
- Friction spark
- Hot surface
- Non ignition
- Unknown

Where no ignition source was identified, then "unknown" was entered. The specific ignition source was further refined by determining a subsidiary specific item. The general ignition sources listed above were subdivided as follows:

- Arson
- Autoignition
    - non-specific autoignition
    - chemical reaction
- Electric source
    - non-specific
    - domestic
    - instrument

- lightning
    - motor/generator
    - static
    - vehicle
    - welding
- Flame
    - non-specific
    - domestic
    - flare
    - furnace
    - grassfire
    - match
    - welding
- Friction spark
    - non-specific
    - compressor
    - pump
    - sparking tool
    - welding
- Hot surface
    - non-specific
    - chemical reaction
    - cigarette
    - flame
    - friction surface
    - incandescent
    - lagging
    - steam pipe
    - stove
    - vehicle exhausts
    - welding
- Non ignition
    - non-specific
    - compressor
    - chemical reaction
- Unknown

As an explanation, the source welding appears in three different groups - electric; friction spark, and hot surface. This is because the first is specifically arc-welding, the second is associated with hot cutting and grinding, and the last with gas welding. During the refining, some occurrences of explosions were found when there was no ignition. These were typically refrigeration installations which burst, probably due to excessive internal pressure or over-temperature, or chemical reactions either releasing gas or having excessive vapour pressures due to overheating ruptured vessels without any vapour cloud explosion or fire. In transport accidents, for example where a road or rail tanker has been involved in an impact which resulted in an ignition, this is attributed to a collision or derailment unless other more specific details are available. This latter category includes inshore marine incidents involving barges and ships in and around ports and on rivers (particularly in the United States), and the accidental cutting or severing of pipes etc.

For the purposes of determining the probability of ignition, the number of ignitions and non-ignitions has been evaluated. The ignitions were then broken down into identified ignition sources and unknown ignition sources. This was repeated for the USA and the Rest of the World data, to see if there were any significant differences.

The materials involved have been classified on a simple basis to attempt to correlate with those of the offshore report. The categories chosen in the offshore report are "oil", "gas", and "two-phase". No further details were available as to the flammability, boiling point or state of these categories. Thus any release has to be broadly categorised, and the three categories above seem to be as good as any other. In this report, if the material is liquid at ambient temperature, it is deemed to be "oil". If it is a gas at atmospheric pressure and ambient temperature, then it is deemed to be "gas". The term "two-phase" has been reserved for liquefied natural gas, chemical reactions and aerosols, for want of a more specific and accurate definition. This method of classification clearly has some disadvantages, in that petrol and bitumen are both classed as "oil" and there is no discrimination between them. Under the circumstances, this is the best attempt that can be made to compare two different datasets with different criteria.

All the summarised data is shown in the Appendix on page 12.

3 OVERALL IGNITION PROBABILITY

The data has been sifted to determine the overall probability of ignition occurring from an unplanned release of flammable material. The data are obtained from a wide variety of sources, and since there is no obligation to report incidents where ignition does not occur, then it is highly likely that the non-ignitions are grossly under-reported. On a world-wide basis for all reported incidents, totalling 4343, the probability of ignition appears very high at 98.4%, with few releases not involving ignition, as detailed in Table 1. This appears to be exceptionally high, and is in marked contrast to the information presented in the previous Report "*Offshore ignition probability arguments*", where the probability of ignition is seen to be very much lower, in the order of 16%. For the North Sea Offshore Industry, reporting of all incidents is obligatory, so the reporting is almost 100% even for releases which do not ignite.

Table 1 World-wide Overall Probability of Ignition

Ignition did not occur:	1.6%
Ignition occurred from an identified ignition source:	37.4%
Ignition occurred from an unidentified ignition source:	61.0%

The world-wide data includes all forms of release, so includes transport, domestic fire and explosion incidents, and those not specifically in areas routinely handling flammable materials. Therefore this is likely to include many incidents which are routinely handling flammable materials in situations not specifically designed to handle them. For example, many incidents occur during transport away from the dedicated filling or emptying situation, so it is likely that the area has not been designed to minimise the risk of ignition.

Since the number of incidents world-wide is for all categories, particularly involving transport etc, the data was then sifted to take into account only those incidents which were categorised as "process". This is the best that can be done for the coarse categorisation of the available data. The overall probability of ignition in 185 U.K. "process" incidents has been determined as 97.3%, as detailed in Table 2.

Table 2 Overall Probability of Ignition in Process Areas

Ignition did not occur:	2.7%
Ignition occurred from an identified ignition source:	35.7%
Ignition occurred from an unidentified ignition source:	61.6%

This compares well with the figures for the U.S.A. and the rest of the world, giving ignition probabilities of 98.1% and 99.4% respectively. It is worth noting that the frequency of non-ignition is very low compared with that from the Offshore Report. The possible reasons for this are discussed later.

As the original Report categorised the materials involved ("oil", "gas" and "two-phase"), a similar categorisation has been carried out and, as might be expected, there is a marginally greater probability of non-ignition is associated with "oil" rather than gas, as shown in Table 3. However, due to the very low probability of non-ignition, it is likely that this is statistically insignificant. This may also be attributable to the way that materials were classified, with bitumen being classed as "oil", even though it is only mobile when hot. Two-phase materials have been excluded from this table as there were only three incidents, which make the data inappropriate.

Table 3 Ignition Probability by Fluid Type

	Oil	Gas
Ignition did not occur:	1.6%	0.9%
Ignition occurred from an identified ignition source:	19.6%	26.8%
Ignition occurred from an unidentified ignition source:	78.8%	72.3%

4 IDENTIFICATION OF IGNITION SOURCES

The data detailed above shows that in a majority of cases, no ignition source was specifically identified. This may be for a variety of reasons. In some cases, the data indicates that "...an inquiry is to be undertaken...", showing that although an investigation is to take place, no details are yet available. In the case of non-U.K. incidents, it is unlikely that any future report describing the cause will be tied up to the data stored in the database. Even so, the discrepancy between U.K., U.S.A., and the rest of the world data is small, and Table 8 on page 14 shows that only in about one third of cases is the ignition source identified. Table 8 can be summarised as below:

Primary ignition source	U.K. Process	U.K. Non-process	U.K. Total
Arson	-	5.4%	3.6%
Autoignition	8.7%	5.6%	6.6%
Collision	-	7.0%	4.7%
Electric	9.7%	10.8%	10.4%
Flame	7.0%	9.4%	8.6%
Friction spark	1.6%	1.9%	1.8%
Hot surface	8.7%	4.0%	5.6%
Non-ignition	2.7%	3.2%	3.0%
Unknown	61.6%	52.7%	55.7%
TOTAL	100%	100%	100%

These can be further collated for the U.K. for the identified ignition sources, and the frequency of ignition by Primary Ignition Source for U.K. Process Areas is summarised in Table 4. The definition of "process area" is a site at which processes are carried out, so it will not necessarily have a Hazardous Area Classification, and hence electrical equipment may not necessarily be of an adequate standard of protection. This is in marked contrast to the off-shore case where the entire structure has been subjected to a hazardous area classification exercise.

Table 4 Distribution of Ignition Source in U.K. On-Shore Process Areas

Autoignition	16	24.2%
Electric	18	27.3%
Flame	13	19.7%
Friction spark	3	4.6%
Hot surface	16	24.2%

This shows that apart from friction sparks, the frequency of other sources igniting a flammable atmosphere are fairly evenly distributed. The highest source is ignition by electrical means. In some way this is a surprising conclusion, as process areas within the U.K. require an area classification exercise to be carried out, which provides information for the selection of electrical equipment appropriate to the Zone in which it is to be installed. Thus for areas where a flammable atmosphere could be foreseen to occur, the electrical equipment will be of a suitable design, be it non-sparking, enhanced safety or flameproof. Hence the occurrence of ignition from electrical equipment in process areas is surprising. It can be contrasted with the same data for non-process areas which is given below in Table 5. Note that for this table, only the same ignition sources have been compared, in that arson and collisions have been taken out

Table 5 Distribution of Ignition Source in U.K. On-Shore Non-Process Areas

Autoignition	21	17.8%
Electric	40	33.9%
Flame	35	29.7%
Friction spark	7	5.9%
Hot surface	15	12.7%

From this, it can be seen that friction sparks contribute very little to ignition sources, either in process areas or non-process areas. Of the rest, the process areas seem to have lower frequencies for both electrical ignition sources and flames, but higher frequencies in autoignition and hot surfaces. This does seem to confirm an intuitive conclusion that in process areas, both electrical equipment and flames are subjected to control, and hot surfaces are probably more common due to high temperature processes. Another factor is that process areas are likely to have more electrical equipment present than non-process areas. Although there is no data to support this view, intuitively it can be seen that large numbers of electric drives and instruments in process areas are likely, whereas in the non-process areas (i.e. everywhere else), the occurrence of electrical equipment is probably lower. This would show that the controls for the use of hazardous area classifications applied to electrical equipment do reduce the number of ignitions from electrical sources. It is noteworthy that in the U.K., there were no ignitions due to lightning (contrasting with 9 and 13 for the U.S.A. and the RoW respectively), so this is not problematic in the U.K.

Therefore it can be seen that overall, the controls for installation of electrical equipment and the use of flames in process areas do seem to reduce the frequency of ignitions, yet hot surfaces and auto-ignition seem to be an area where more control or awareness is required. In contrast, the frequency of ignition by friction sparks is very low, and hence the requirement to certify mechanical equipment under the ATEX directive would seem to be simply a formalisation of what appears to be already well under control.

5 DISCUSSION

From the above tables, probabilities of ignition are seen to be extremely high. The MHIDAS database uses public-domain information gleaned from a variety of sources, so includes all those incidents which are readily available. Due to the way that the media report incidents, it is possible that incidents which are simply releases and do not ignite are not reported, as there is no "newsworthiness" in their being reported. However, the fact that some incidents are reported as not igniting does suggest that the incident was reported for some other reason, for example it may be that there were several deaths or a lucky escape. Consequently it is difficult to assess whether the probability of ignition is a true reflection, or whether the probability is over-estimated because of under-reporting of the non-ignitions. This cannot be determined from the data available.

Direct comparisons between the U.K., the U.S.A. and the Rest of the World may also be invalid. This is because of the societal differences between the three zones. For example, in the U.K. there is a relatively low rate of reporting arson, compared with the Rest of the World. Searching the data reveals that in Colombia, the summary of one report states

> "Pumping operations were suspended after the pressure dropped due to a bomb attack on the pipeline. 57th disruption this year".

It is not clear from the database how many of these previous disruptions resulted in a release, a fire or an explosion, and whether they are included or not. Consequently, the accuracy of the data may not be good and cannot be verified.

Similarly, in the U.S.A., the main source of domestic heating fuel is gas oil or propane, so the quantities of propane transported in the U.S.A. is far larger per capita than in the U.K. where the major domestic heating fuel is natural gas piped to the users direct. Also the vast majority of vehicles (including heavy goods vehicles) within the U.S.A. use gasoline, whereas in the U.K., almost all heavy goods vehicles are diesel-fuelled, as are an increasing proportion of private cars. Hence the per capita consumption of gasoline is far higher in the U.S.A., so fires and explosions involving transport fuels are more likely where the fuel forms flammable vapours at ambient temperatures.

From the above, it can be seen that the probability of ignition is high, and roughly two-thirds of all ignition sources are not identified. Thus it is important to minimise releases, as ignition sources have a high probability of existing wherever flammables are released. This echoes the sentiments of Trevor Kletz (1999) who says "...any flammable atmosphere will inevitably find a source of ignition...", and so it can be inferred that it is not the actual ignition which is the hazard, but the release. The ignition is simply the consequence of the hazard arising.

In this report, the definitions of *hazard*, *harm*, *likelihood* and *risk* have specific meanings which are given in the glossary on page 20.

6 CONCLUSIONS

The Major Hazard Incident Database has been interrogated for releases, fires and explosions of flammable substances.

Over 6500 separate incidents were scrutinised, and 4343 of those were involved with flammable gases or liquids. The remainder were solids and were not included in the analysis.

The apparent overall frequency of ignition onshore is very high at 98.4%, probably due to under reporting of incidents.

Of the ignitions that did occur, the ignition source was not identified for more than 61% of the incidents.

In on-shore "process areas" in the U.K., the proportion of unidentified ignition sources is 61.6%, compared with 52.7% for non-process areas.

Of the identified ignition sources of electrical and flame, the frequency of these two occurring in on-shore "process areas" was lower than on non-process areas (47.0% compared with 63.6%).

Of the identified ignition sources of hot surfaces and auto-ignition, the frequency of these two occurring in on-shore "process areas" was higher than on non-process areas (48.4% compared with 30.5%).

There was little difference in the frequency of friction sparks igniting flammable atmospheres between on-shore "process" and non-process areas (4.6% compared with 5.9%).

7 APPENDIX

Table 6 Summary data of all incidents sorted by Primary Ignition Source:

Primary ignition source	U.K.	U.K. %	U.S.A.	U.S.A. %	RoW	RoW %	Total	Total %
Arson	20	3.6	8	0.5	133	6.4	161	3.7
Autoignition	37	6.6	49	2.9	50	2.4	136	3.1
Collision	26	4.7	223	13.2	166	7.9	415	9.5
Electrical	58	10.4	162	9.6	148	7.1	368	8.5
Flame	48	8.6	124	7.3	97	4.6	269	6.2
Friction spark	10	1.8	39	2.3	36	1.7	85	2.0
Hot surface	31	5.6	81	4.7	80	3.8	192	4.4
Non-ignition	17	3.1	23	1.4	29	1.4	69	1.6
Unknown source	310	55.6	984	58.1	1354	64.7	2648	61.0
TOTAL	557	100.0	1693	100.0	2093	100.0	4343	100.0

Table 7 Summary of incidents sorted by
Primary Ignition Source and Secondary Ignition Source:

Primary ignition source	Secondary ignition source	U.K.	U.S.A.	RoW	Total
Arson		20	8	133	161
Total		20	8	133	161
Autoignition	Chemical reaction	15	20	23	58
	Non-specific	22	29	27	68
Total		37	49	50	126
Collision		26	223	166	415
Total		26	223	166	415
Electrical	Domestic	7	4	4	15
	Instrument	14	9	8	31
	Lightning		9	13	22
	Motor/generator	9	20	11	40
	Non-specific	14	17	31	62
	Static	7	66	49	122
	Vehicle	7	37	29	73
	Welding			3	3
Total		58	162	148	368
Flame	Boiler	4	19	4	27
	Domestic	5	2	2	9
	Flare	5	20	22	47
	Furnace	7	24	17	48
	Grassfire		1	4	5
	Incandescent			1	1
	Match	4	6	9	19
	Non-specific	17	31	30	78
	Sparking tool		1	2	3
	Stove		13		13
	Welding	6	7	6	19
Total		48	124	97	269
Friction Spark	Compressor	1	11	3	15
	Friction surface		1		1
	Incandescent		2	3	5
	Machinery			4	4
	Non-specific	6	15	18	39
	Pump		7	2	9
	Sparking tool	3	3	6	12
Total		10	39	36	85

Primary ignition source	Secondary ignition source	U.K.	U.S.A.	RoW	Total
Hot surface	Chemical reaction	1			1
	Cigarette	4	5	17	26
	Compressor		1		1
	Friction surface	5	6	3	14
	Furnace			1	1
	Incandescent	4	21	24	49
	Lagging	1		3	4
	Non-specific	7	21	25	53
	Steam Pipe	6	3	4	13
	Vehicle exhaust	3	24	2	29
	Welding			1	1
Total		31	81	80	192
Total of Identified sources		230	686	710	1626
Non-ignition		17	23	29	69
Unknown source		310	984	1354	2648
TOTAL		557	1693	2093	4343

Table 8 Breakdown of Identification of Ignition Source

	U.K.	U.S.A.	RoW	Total
Total of Identified sources	41.3%	40.5%	33.9%	37.4%
Non-ignition	3.1%	1.4%	1.4%	1.6%
Unknown source	55.6%	58.1%	64.7%	61.0%
TOTAL	100.0%	100.0%	100.0%	100.0%

Table 9 Summary data for Process incidents, sorted by Primary Ignition Source.

Primary ignition source	U.K.	U.K. %	U.S.A.	U.S.A. %	RoW	RoW %	Total	Total %
Arson			1	0.2	6	0.9	7	0.5
Autoignition	16	8.7	22	4.2	25	3.8	63	4.6
Collision			2	0.4	2	0.3	4	0.3
Electric	18	9.7	21	4.0	20	3.0	59	4.3
Flame	13	7.0	33	6.4	28	4.2	74	5.4
Friction spark	3	1.6	16	3.1	11	1.7	30	2.2
Hot surface	16	8.7	16	3.1	31	4.7	63	4.6
Non-ignition	5	2.7	10	1.9	4	0.6	19	1.4
Unknown	114	61.6	399	76.7	534	80.8	1047	76.7
TOTAL	185	100.0	520	100.0	661	100.0	1366	100.0

Probability of Ignition

From the data above, the probability of ignition can be estimated from U.K. data for process areas as follows:

Table 10 U.K. Process Areas Probability of Ignition

Ignition did not occur:	2.7%
Ignition occurred from an identified ignition source:	35.7%
Ignition occurred from an unidentified ignition source:	61.6%

Types of Release

Table 11 Breakdown of data for all oil/gas and two-phase releases

Phase	U.K.	U.K. %	U.S.	U.S. %	RoW	RoW %	Total	Total %
Gas	163	29.3	674	39.8	681	32.5	1518	35.0
Oil	389	69.8	1017	60.1	1409	67.3	2815	64.8
Two-phase	5	0.9	2	0.1	3	0.2	10	0.2
Total	557	100.0	1693	100.0	2093	100.0	4343	100.0

Table 12 Breakdown of data for non-process oil/gas and two-phase releases

Phase	U.K.	U.K. %	U.S.	U.S. %	RoW	RoW %	Total	Total %
Gas	102	27.4	515	43.9	460	32.1	1077	36.2
Oil	266	71.5	656	55.9	971	67.8	1893	63.6
Two-phase	4	1.1	2	0.2	1	0.1	7	0.2
Total	372	100	1173	100	1432	100	2977	100

Table 13 Breakdown of data for process oil/gas and two-phase releases

Phase	U.K.	U.K. %	U.S.	U.S. %	RoW	RoW %	Total	Total %
Gas	61	33.0	159	30.6	221	33.4	441	32.3
Oil	123	66.5	361	69.4	438	66.3	922	67.5
Two-phase	1	0.5	0	0.0	2	0.3	3	0.2
Total	185	100.0	520	100.0	661	100.0	1366	100.0

Table 14 Breakdown of ignition by phase:

UK	Identified ignition source	Unidentified ignition source	Non-ignition
Gas	22	37	2
Oil	44	76	3
Two-phase	0	1	0

USA	Identified ignition source	Unidentified ignition source	Non-ignition
Gas	49	110	0
Oil	62	289	10
Two-phase	0	0	0

RoW	Identified ignition source	Unidentified ignition source	Non-ignition
Gas	47	172	2
Oil	75	361	2
Two-phase	1	1	0

Total	Identified ignition source		Unidentified ignition source		Non-ignition	
Gas	118	39.3%	319	30.5%	4	21.0%
Oil	181	60.4%	726	69.3%	15	79.0%
Two-phase	1	0.3%	2	0.2%	0	0.0%

8 REFERENCES

EN 60079-10:2003	*Electrical apparatus for explosive gas atmospheres* - *Part 10: Classification of hazardous areas*.
Kletz, Trevor (1999)	*What went wrong?*, Gulf Publishing Co. (1999)
AEA Technology (2003)	Ignition Probability Review and Model Development, January 2003

9 GLOSSARY

harm	the consequence of the hazard being realised
hazard	something with the ability to cause harm
Hazardous Area	An area where flammable atmospheres may occur. See BS EN 60079-10
HSE	Health and Safety Executive
likelihood	the chance (probability or frequency) of harm arising from the hazard
MHIDAS	**M**ajor **H**azard **I**ncident **DA**ta **S**ervice
OIR/12	**O**ffshore **I**ncident **R**eport No.12 (HSE Form for voluntarily reporting a hydrocarbon release on an offshore installation)
risk	the combination of consequence and likelihood
Zone 1	A hazardous area where a flammable atmosphere may form frequently and when it does, may persist for long periods of time
Zone 2	A hazardous area where a flammable atmosphere, if formed, will rapidly disperse, and will not be present for more than typically 10 hours per year