PRACTICAL APPLICATION OF THE UKOOA IGNITION MODEL

Brian Bain, Matthew Celnik and Geir Korneliussen
Det Norske Veritas Limited, UK

The UKOOA ignition model [Ignition Probability Review, Model Development and Look-up Correlations; The Energy Institute, London; 2006] is the UK offshore industry standard for determining the ignition probability of flammable releases on offshore installations. As the model is dependent on a large number of parameters, several look-up correlations were developed for typical onshore and offshore modules, to reduce the model to a limited set of parameters. There remains some debate about how these look-up correlations can best be applied in order to describe all conditions satisfactorily.

A number of enhancements and clarification to the existing look-up correlations for offshore installations are proposed. The hot-work hours for a typical offshore module was defined in the original model as 15 hours/year, however, this may be considered very low if substantial works are undertaken. Therefore, an enhancement to the look-up correlations is proposed to account for increased hot-work hours. A change to the model to allow users to specify different splits between immediate and delayed ignition is also proposed.

INTRODUCTION

In the field of QRA there are many areas where both the methodology and specific data to be applied to a problem have a degree of uncertainty. Of these various areas, the topic of ignition probability perhaps has the greatest level of uncertainty. Various formulations have been proposed and practitioners have been aware that these can lead to a wide range of calculated probabilities for the same situation. This is significant since a large proportion of the risks to both onshore and offshore installations and persons working in them come from ignited hydrocarbon and chemical releases, and the ignition probability is a direct multiplier for these. Consequently, the accuracy of the ignition probability has a large effect on the overall calculated risk figures and therefore on the assessment of measures which may be deemed necessary to reduce these risks.

In the UK an attempt to address this situation was made in a project undertaken by ESR Technology, co-sponsored by the United Kingdom Offshore Operators Association (UKOOA) (now Oil & Gas UK), the Health and Safety Executive (HSE) and the Energy Institute (EI) and with contributions from operators and other technical consultancies. The work culminated in the issue of the report published by the Energy Institute entitled "Ignition Probability Review, Model Development and Look-Up Correlations" in January 2006 [1]. The review element of the work concluded that the commonly applied approach, up to that point, of adopting generic correlation based on mass release rates was overly simplistic and lead to overly conservative estimates in some situations. A new model was developed which drew largely on the work of DNV [2], WS Atkins [3] and the "Gas Build-up JIP Workbook" [4]. The new model was implemented within an Excel workbook distributed with the EI report [1].

It was recognised that the work involved in collecting a large amount of data for the full model may be too onerous for some risk assessments. Consequently, the EI report [1] also describes a second phase of the work in which the full model was used to develop a series of correlations based on the mass release rate. Although it was intended that the look-up correlation version be used in certain circumstances, such as concept studies or where there was insufficient data to populate the full model, it has become common practice to use the correlations in all QRA work because of the relative ease of implementation.

The model has become generally referred to as the "UKOOA Ignition Model" despite the fact that the United Kingdom Offshore Operators Association "UKOOA" effectively became Oil and Gas UK in 2007. This name is given to both the full model and the simplified look-up correlation version. However, the predominant use of the latter means that it is this version which practitioners normally mean when referring to the "UKOOA ignition Model". The curves are illustrated in the OGP Risk Assessment data Directory [5].

This paper looks at five topics associated with the use of the model which may improve its ease of use or its accuracy. These are presented in summarised form to provide an overview.

CHANGED TABULATION

The data underlying the lookup correlations is presented in a table within the report [1] and replicated in Table 1.

In essence the data describes a number of release rate/ignition probability pairs between which the ignition probability for the required release rate can be obtained by logarithmic interpolation but subject to remaining within defined limits, that is the "Maximum Prob" and "Minimum Prob" columns in Table 1. However, in this format the shape of the correlation is difficult to visualise and the equations for calculating the ignition probability for a given release rate is more complex than it needs to be.

An alternative tabulation is presented below in which the co-ordinates of the points between which logarithmic interpolation can take place are given explicitly. This is presented in Table 2.

Table 1. Lookup Correlation Data For Ignition Probabilities, reproduced from [1].

No.	Type	Maximum Prob	Minimum Prob	Point a	Gradient a	Offset a	Point b	Gradient b	Offset b	Point c	Gradient c	Offset c	Point d
1	Pipe Liquid Industrial	0.07	0.001	0.1	0.558795	−2.18593	70	N	N	0	N	N	0
2	Pipe Liquid Rural	0.007	0.001	0.1	0.605288	−2.13944	0.3	0.127125	−2.38946	70	N	N	0
3	Pipe Gas LPG Industrial	1	0.001	0.1	0.739652	−2.21896	1000	N	N	0	N	N	0
4	Pipe Gas LPG Rural	1	0.001	0.1	0.129819	−2.82879	10	0.80103	−3.5	1000	N	N	0
5	Small Plant Gas LPG	0.6	0.001	0.1	0.356547	−2.60206	1	1.56813	−2.60206	3	0.734824	−2.20447	1000
6	Small Plant Liquid	0.1	0.001	0.1	0.338819	−2.61979	1	0.809894	−2.61979	100	N	N	0
7	Small Plant Liquid Bund	0.013	0.001	0.1	0.338819	−2.61979	1	0.809894	−2.61979	100	N	N	0
8	Large Plant Gas LPG	0.65	0.001	0.1	0.356547	−2.60206	1	1	−2.60206	100	N	N	0
9	Large Plant Liquid	0.13	0.001	0.1	0.356547	−2.60206	1	0.840621	−2.60206	100	N	N	0
10	Large Plant Liquid Bund	0.05	0.001	0.1	0.338819	−2.61979	1	0.809894	−2.61979	100	N	N	0
11	Large Plant Confined Gas LPG	0.7	0.001	0.1	0.356547	−2.60206	1	1.211604	−2.60206	70	0.31737	−0.95211	1000
12	Tank Liquid 300 × 300 m Bund	0.12	0.001	0.1	0.075721	−2.90309	1	0.395757	−2.90309	7	0.88091	−3.31309	500
13	Tank Liquid 100 × 100 m Bund	0.015	0.001	0.1	0.075721	−2.90309	1	0.395757	−2.90309	7	0.88091	−3.31309	500
14	Tank Gas LPG Storage Plant	1	0.001	0.1	0.023065	−2.93554	1	1.458907	−2.93554	100	N	N	0
15	Tank Gas LPG Storage Industrial	1	0.001	0.1	0.023065	−2.93554	1	1.145784	−2.93554	100	0.647338	−1.93865	700
16	Tank Gas LPG Storage Rural	0.5	0.001	0.1	0.023065	−2.93554	1	1.123063	−2.93554	10	0.40624	−2.21872	1000
17	Offshore Process Liquid	0.0175	0.001	0.1	0.400548	−2.55806	100	N	N	0	N	N	0
18	Offshore Process Liquid NUI	0.01	0.001	0.1	0.400548	−2.55806	100	N	N	0	N	N	0
19	Offshore Process Gas Opendeck NUI	0.025	0.001	0.1	0.037789	−2.92082	1	0.880788	−2.92082	30	N	N	0
20	Offshore Process Gas Typical	0.04	0.001	0.1	0.768182	−2.19042	3	0.390377	−2.01017	10	N	N	0
21	Offshore Process Gas Large Module	0.05	0.001	0.1	0.845058	−2.11355	5	0.285097	−1.72215	30	N	N	0
22	Offshore Process Gas Congested_Mech Vented Module	0.04	0.001	0.1	1.134699	−1.82391	1	0.216588	−1.82391	50	N	N	0
23	Offshore Riser	0.025	0.001	0.1	0.525219	−2.43339	30	N	N	0	N	N	0
24	Offshore FPSO Gas	0.15	0.001	0.1	0.072551	−2.88606	1	1.213764	−2.88606	50	N	N	0
25	Offshore FPSO Gas Wall	0.15	0.001	0.1	0.544175	−2.41443	0.3	1.231261	−2.05517	10	N	N	0
26	Offshore FPSO Liquid	0.028	0.001	0.1	0.468588	−2.49002	100	N	N	0	N	N	0
27	Offshore Engulf_blowout_riser	0.1	0.001	0.1	0.652869	−2.30574	100	N	N	0	N	N	0
28	Cox, Lees, Ang – Gas	0.3	0	0.5	0.641939	−1.80676	100	N	N	0	N	N	0
29	Cox, Lees, Ang – Liquid	0.08	0	0.5	0.392472	−1.88185	100	N	N	0	N	N	0
30	Tank Liquid – diesel, fuel oil	0.0024	0.001	0.1	0.010724	−2.98928	1	0.067994	−2.98928	7	0.554906	−3.40076	500

Table 2. Lookup Correlation Data Presented in Alternative Form

Case No.	Case Description	Point 1		Point 2		Point 3		Point 4		Point 5		Point 6		Point 7	
		Q (kg/s)	P_{ign}	Q (kg/s)	P_{ign}	Q (kg/s)	P_{ign}	Q (kg/s)	P_{ign}	Q (kg/s)	P_{ign}	Q (kg/s)	P_{ign}	Q (kg/s)	P_{ign}
1	Pipe Liquid Industrial	0.01	0.00100	0.03493	0.00100	0.100	0.00180	70.000	0.07000	100000	0.07000				
2	Pipe Liquid Rural	0.01	0.00100	0.03787	0.00100	0.100	0.00180	0.300	0.00350	70.000	0.00700	70.000	0.00700	100000	0.00700
3	Pipe Gas LPG Industrial	0.01	0.00100	0.08791	0.00100	0.100	0.00110	1000	1.00000	100000	1.00000				
4	Pipe Gas LPG Rural	0.01	0.00100	0.04799	0.00100	0.100	0.00110	10.000	0.00200	1000.000	0.08000	23408.547	1.00000	100000	1.00000
5	Small Plant Gas LPG	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	3.000	0.01400	498.991	0.60000	100000	0.60000
6	Small Plant Liquid	0.01	0.00100	0.07548	0.00100	0.100	0.00110	1.000	0.00240	100.000	0.10000	100000	0.10000		
7	Small Plant Liquid Bund	0.01	0.00100	0.07548	0.00100	0.100	0.00110	1.000	0.00240	8.053	0.01300	100.000	0.01300	100000	0.01300
8	Large Plant Gas LPG	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	100.000	0.25000	260.000	0.65000	100000	0.65000
9	Large Plant Liquid	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	100.000	0.12000	109.990	0.13000	100000	0.13000
10	Large Plant Liquid Bund	0.01	0.00100	0.07548	0.00100	0.100	0.00110	1.000	0.00240	42.492	0.05000	100.000	0.05000	100000	0.05000
11	Large Plant Confined Gas LPG	0.01	0.00100	0.07654	0.00100	0.100	0.00110	1.000	0.00250	70.000	0.43000	325.028	0.70000	100000	0.70000
12	Tank Liquid 300 × 300 m Bund	0.01	0.00100	0.05250	0.00100	0.100	0.00105	1.000	0.00125	7.000	0.00270	519.617	0.12000	100000	0.12000
13	Tank Liquid 100 × 100 m Bund	0.01	0.00100	0.05250	0.00100	0.100	0.00105	1.000	0.00125	7.000	0.00270	49.035	0.01500	100000	0.01500
14	Tank Gas LPG Storage Plant	0.01	0.00104	0.00160	0.00100	0.100	0.00110	1.000	0.00116	100.000	0.96000	102.838	1.00000	100000	1.00000
15	Tank Gas LPG Storage Industrial	0.01	0.00104	0.00160	0.00100	0.100	0.00110	1.000	0.00116	100.000	0.22700	988.106	1.00000	100000	1.00000
16	Tank Gas LPG Storage Rural	0.01	0.00104	0.00160	0.00100	0.100	0.00110	1.000	0.00116	10.000	0.01540	52551.538	0.50000	100000	0.50000
17	Offshore Process Liquid	0.01	0.00100	0.07882	0.00100	0.100	0.00110	100.000	0.01750	100000	0.01750				
18	Offshore Process Liquid NUI	0.01	0.00100	0.07882	0.00100	0.100	0.00110	24.731	0.01000	100.000	0.01000	100000	0.01000		
19	Offshore Process Gas Opendeck NUI	0.01	0.00101	0.00803	0.00100	0.100	0.00110	1.000	0.00120	30.000	0.02400	31.423	0.02500	100000	0.02500
20	Offshore Process Gas Typical	0.01	0.00100	0.08833	0.00100	0.100	0.00110	3.000	0.01500	10.000	0.02400	37.008	0.04000	100000	0.04000
21	Offshore Process Gas Large Module	0.01	0.00100	0.08933	0.00100	0.100	0.00110	5.000	0.03000	30.000	0.05000	100000	0.05000		
22	Offshore Process Gas Congested_Mech Vented Module	0.01	0.00100	0.09194	0.00100	0.100	0.00110	1.000	0.01500	50.000	0.03500	92.624	0.04000	100000	0.04000
23	Offshore Riser	0.01	0.00100	0.08340	0.00100	0.100	0.00110	30.000	0.02200	38.267	0.02500	100000	0.02500		
24	Offshore FPSO Gas	0.01	0.00100	0.02688	0.00100	0.100	0.00110	1.000	0.00130	50.000	0.15000	100000	0.15000		
25	Offshore FPSO Gas Wall	0.01	0.00100	0.08393	0.00100	0.100	0.00110	0.300	0.00200	10.000	0.15000	100000	0.15000		
26	Offshore FPSO Liquid	0.01	0.00100	0.08160	0.00100	0.100	0.00110	100.000	0.02800	100000	0.02800				
27	Offshore Engulf_blowout_riser	0.01	0.00100	0.08642	0.00100	0.100	0.00110	100.000	0.10000	100000	0.10000				
28	Cox, Lees, Ang – Gas	0.01	0.00081	0.50000	0.01000	100.000	0.30000	100000	0.30000						
29	Cox, Lees, Ang – Liquid	0.01	0.00215	0.50000	0.01000	100.000	0.08000	100000	0.08000						
30	Tank Liquid – diesel, fuel oil	0.01	0.00100	0.10000	0.00100	1.000	0.00103	7.000	0.00117	25.551	0.00240	100000	0.00240		

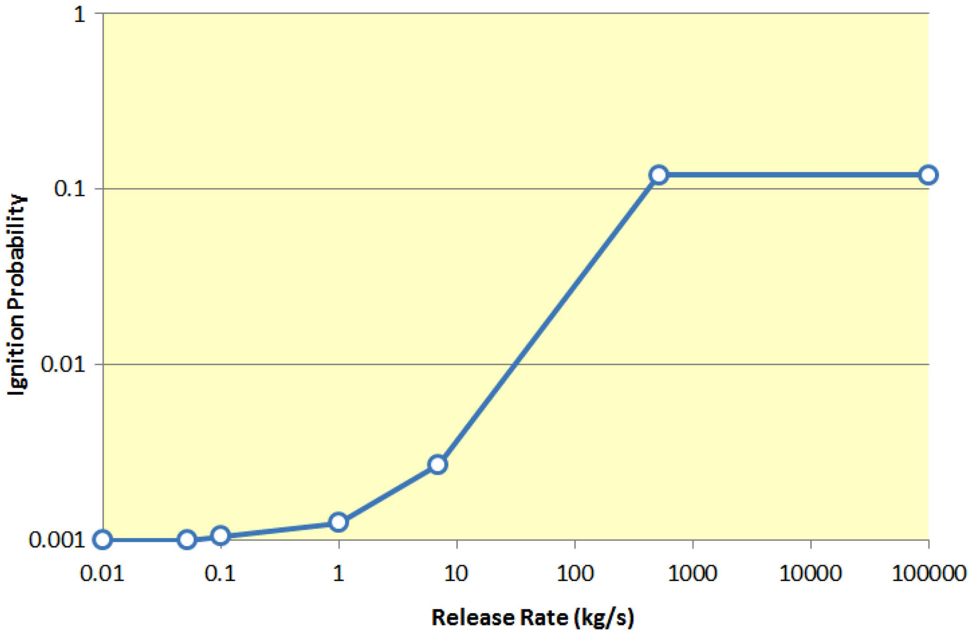

Figure 1. Example Look-up Curve (Tank Liquid 300 × 300 m Bund)

This table defines each of the curves using between 4 and 7 points. As an example, the curve for "Offshore Process Gas Typical" is shown in Figure 1.

A specific ignition probability is then obtained from the equation.

$$P_{ign} = e^{\log p_n + \frac{(\log Q - \log Q_n)(\log P_{n+1} - \log P_n)}{\log Q_{n+1} - \log Q_n}}$$

Where

P_{ign} is the Ignition probability at release rate Q

P_n is the ignition probability at release rate Q_n, and

P_{n+1} is the ignition probability at release rate Q_{n+1}

and where the points (Q_n, P_n) and (Q_{n+1}, P_{n+1}) are adjacent points in Table 2 between which the value of Q lies.

INTERPOLATED IGNITION PROBABILITIES

It is usual for analysts to utilise a single look-up correlation in determining an ignition probability. In this case the analyst selects the correlation they consider to be the best representation of the situation they are dealing with. However, there are many situations where none of the correlations are strictly appropriate. One scenario described in the reporting of the use of the correlations [1] is the case of flashing releases. Correlations are provided for gas/LPG (full flash) releases and for liquid releases where the flash fraction is less than 10%. This does not cover 2-phase releases or liquid releases with a flash fraction between 10% and 100%. It is suggested that an ignition probability can be calculated by combining the results from two different but appropriate correlations. For example, if we consider a 10 kg/s release of well fluids release with liquid hydrocarbon (80%) and gas (20%) fractions on an offshore installation then this could be considered as an 8 kg/s release of liquid occurring simultaneously with a 2 kg/s release of gas. The EI Report [1] suggests that the ignition probabilities for these could be calculated separately using their appropriate correlations and then combined by calculating the overall probability of non-ignition. This approach recognises that the leak would be simultaneously producing a gas cloud and liquid pool which could be susceptible to different ignition sources. The two are combined in the equation.

$$P_{ign-overall} = 1 - [(1 - P_{ign-gas}) \times (1 - P_{ign}-liquid)]$$

This can result in the overall probability being somewhere between the ignition probability for the two look-up correlations or higher. The results are shown in Figure 2.

However, it may be considered inappropriate to combine the two probabilities in this way, given that the areas covered by the gas and liquid are likely to overlap so that the two are not additive. In this case, it may be more appropriate to use the higher of the two ignition probabilities based on the total release rate (10 kg/s in this case).

A further alternative could be to evaluate the ignition probability at the full release rate on both correlations and obtain an estimate for the 2-phase release using a linear interpolation. This is shown in Figure 3 and indicates a rather different result for the same scenario (1.04% compared with 1.73%).

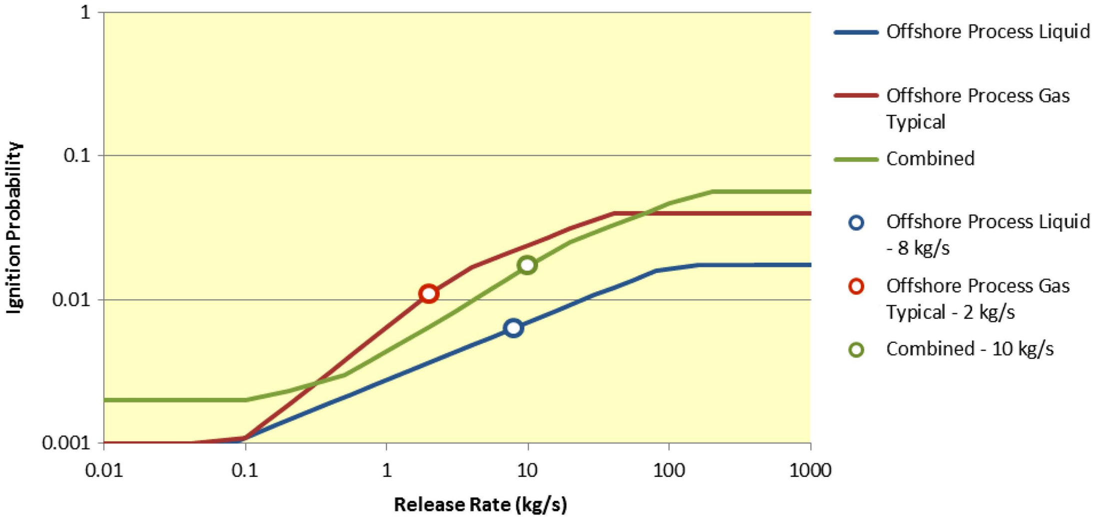

Figure 2. Calculation of Ignition Probability for a 2-Phase Release

The same techniques could also be used for gas or liquid releases if an analyst considers that a situation is somewhere between two of the standard cases. For example if the size of the module is considered to be greater than "typical" but not sufficient to be classed as "large". Figure 4 shows an example of a case of a 10 kg/s gas release considered to be mid-way between the two standard cases.

FRACTION OF IMMEDIATE RELEASES

The use of the look-up correlations has been generally accepted and implemented by risk analysts and a consistent evaluation of the "total" ignition probability has been achieved. However, there remain differences in approach as to how this probability should be apportioned between "immediate" and "delayed" ignitions.

For much of the time during the development of the UKOOA model only the total ignition probability was considered. However, the steering group also acknowledged that typical QRA studies split the overall value between "immediate" ignitions in which ignition occurs at the point of release and "delayed" ignitions requiring the build-up of a vapour cloud which is ignited by a remote source. These two scenarios may be treated differently in terms of consequences and therefore of overall risk. There is insufficient reliable information from historical records to determine the fraction in overall terms, let alone to determine the dependence on release rate.

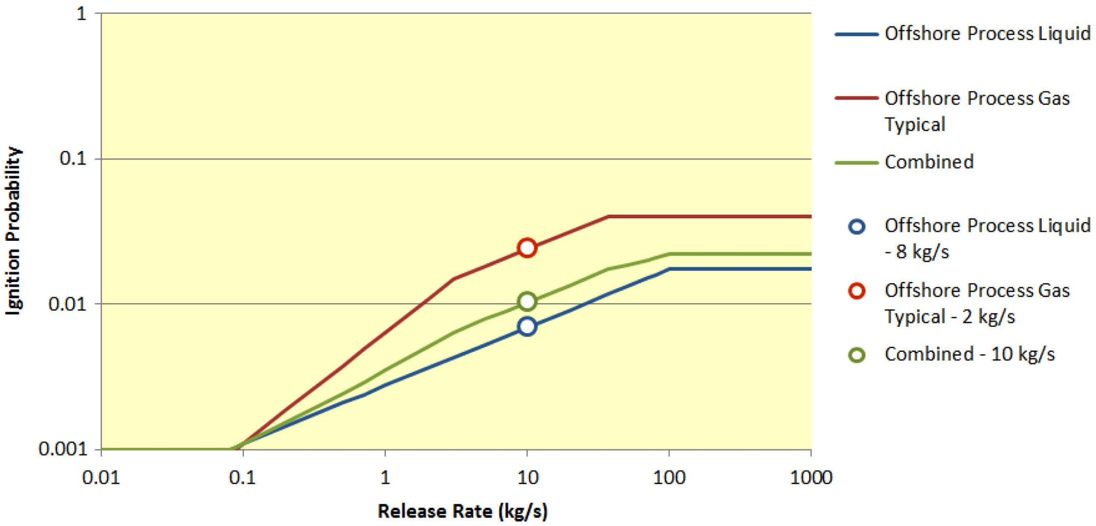

Figure 3. Calculation of Ignition Probability for a 2-Phase Release Using Interpolation

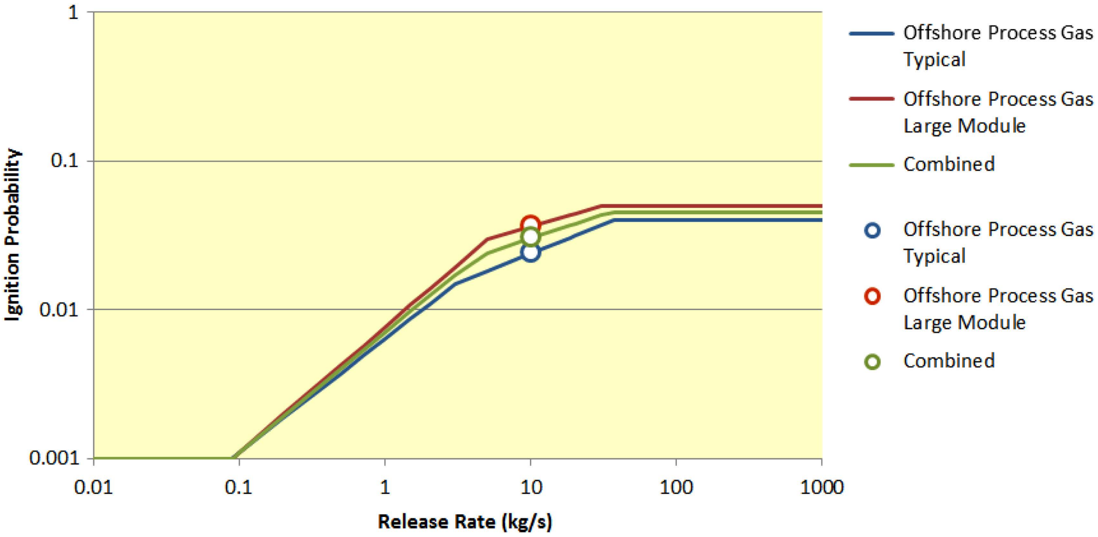

Figure 4. Calculation Using Interpolation for a Gas Release

The EI report concluded the following;

"The DNV TDIM Project also analysed ignition events to estimate the occurrence of self-ignition (i.e. where the leak and ignition had a common cause/dependancy). This concluded that a common leak and ignition effect may only be present in ~0.1% of releases, giving a probability of ignition due to this mechanism of approximately 0.001. This is in reasonable agreement with the values suggested in Table 1.32, and has been adopted within the ignition model"

The table referred to essentially provided values derived from the correlation $P_{ign,imm} = 0.0001\ Q$, where the mass release rate, Q, is measured in kg/s. This would give the value for immediate ignition of 0.001 for a 10 kg/s release. Inspection of the "full" UKOOA spreadsheet model confirms that this is the value calculated and that there is no dependence on the release rate.

An examination of the use of the look-up correlations by different practitioners suggest that many, perhaps the majority, do not follow this practice but instead employ a proportional split between the "immediate" and "delayed" cases. The origins of this approach are based partly on practice employed prior to the development of the model and partly from text contained in a later section of the report [1] dealing with ignition timing and which states the following;

"Assuming early ignition relates to ignition within one minute or so of the leak commencing, then the typical QRA practice to assume a 50:50 or 30:70 distribution between early and delayed ignition appears to be reasonable given the data available. Based on the data available in Table 2.11, a 30:70 (early: delayed) distribution may be representative of early ignition within 30 s, whereas a 50:50 distribution may be representative of early ignition within 60 s."

It should be noted in the above that the term used is "early" rather than "immediate" and can be applied to ignitions occurring up to 60 seconds after the start of the release. The term "delayed" in this sense is used to denote ignitions after this time, whereas, in this paper, "delayed" refers to those ignition cases which aren't immediate. During this "early" period a substantial vapour cloud can form which, if ignited, would give rise to an explosion with large overpressure. Given that the split between "immediate" and "delayed" is primarily intended to distinguish between "fire only" and "explosion plus fire" cases, it is considered that the use of a 30:70 or 50:50 split does comply with the true implementation of the UKOOA model. There are also cases where 70% of the total ignition have been taken as immediate.

Figure 5 shows the difference between the use of a $P_{ign} = 0.001$ approach and a 30:70 split approach.

As can be seen from figure 5, the two approaches can give very different results. This difference may be reflected in the overall results of the QRA. It is not clear whether a proportional split is appropriate or not and the correct approach may be dependent on the approach taken in the corresponding explosion analysis. However, a proportional split does not comply with the intent of the UKOOA model.

In order to allow a convenient means of apportioning the total ignition probability it is proposed that the immediate ignition probability can be calculated as

$$P_{ign-imml} = a + bP_{ign}$$

where the parameters a and b are selected by the analyst.

Consequently the delayed ignition probability would be calculated as

$$P_{ign-del} = P_{ign} - P_{ign-imm} = (1 - b)P_{ign} - a$$

In the examples shown in Figure 5, the first graph uses $a = 0.001, b = 0$. In the second graph, $a = 0, b = 0.3$.

The variation in approaches can be more significant if more than one analyst is involved in the overall work and

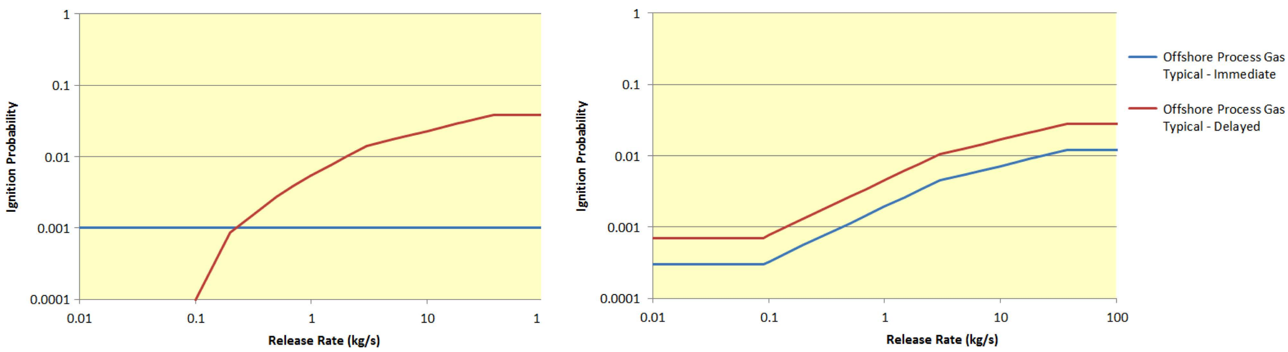

Figure 5. Alternative Approaches in Splitting Total Ignition Probability

are adopting different approaches. One example of this is where one consultant is responsible for explosion analysis and another is responsible for incorporating the results of these into the overall QRA. If the two consultants are using different approaches, it may be possible for part of the true risk to be omitted or for it to be double counted.

SINGLE PARAMETER MODIFICATION

The look-up correlations were derived from running a series of representative cases through the full UKOOA model and fitting a simplified curve to achieve the correlations tabulated above. There may be scenarios when it is known that one of the parameters is significantly different from the value assumed in the derivation of the correlation. As an example, if the number of hot-work hours is significantly higher than what was assumed in the initial derivation, there may be concerns that use of the correlation will underestimate the true value.

The EI report [1] provides some information on the inputs required for some of the runs of the full model which were used to derive the correlations.

To develop a simple model to account for a single additional parameter, for example hot-work hours, the following procedure was used for each scenario and release-rate point Q in Table 2:

1. Run the full UKOOA model with default hot-work hours (HW_0) to get the base ignition probability, $P_{ign,0}$.
2. Run the full UKOOA model with a range of hot-work hours, h_i to get a set of ignition probabilities, p_i. Sufficient points in log-space were used to cover the applicable range of hot-work hours per year.
3. Fit a straight line to the (h_i, p_i) points to determine a gradient, k.
4. For the actual number of hot-work hours, calculate ignition probability:

$$P_{ign} = P_{ign,0} + k \cdot (HW - HW_0)$$

Table 3 gives values of k calculated for offshore scenarios, and also lists the basis hot-work hours for each scenario. These new (Q, P_{ign}) points then replace those in Table 2, and the subsequent methodology for calculation of ignition probability is identical to that discussed previously. This method assumes that the ignition probability is approximately linearly dependent (in log-space) on the parameter of interest. For the case of hot-work, this is

Table 3. Default Hot-Work Hours for Offshore Correlation Scenarios

UKOOA Correlation	Basis Hot-work (hrs/yr)	Hot-work P_{ign} Gradients, k			
		Point a	Point b	Point c	Point d
Offshore Process Liquid	15	1.14E-07	1.73E-05	N/A	N/A
Offshore Process Liquid NUI	0	1.18E-07	1.74E-05	N/A	N/A
Offshore Process Gas Opendeck NUI	0	5.09E-09	1.61E-07	8.07E-07	N/A
Offshore Process Gas Typical	15	2.88E-06	3.72E-05	3.69E-05	N/A
Offshore Process Gas Large Module	15	1.32E-06	4.37E-05	4.31E-05	N/A
Offshore Process Gas Congested_Mech Vented Module	15	1.03E-06	2.83E-05	3.65E-05	N/A
Offshore Riser	0	2.36E-09	1.17E-06	—	N/A
Offshore FPSO Gas	0	7.93E-09	2.50E-07	5.19E-05	N/A
Offshore FPSO Gas Wall	0	7.93E-09	4.12E-08	7.57E-06	N/A
Offshore FPSO Liquid	0	1.94E-08	1.47E-05	N/A	N/A
Offshore Engulf_blowout_riser	15	1.41E-08	3.54E-05	N/A	N/A

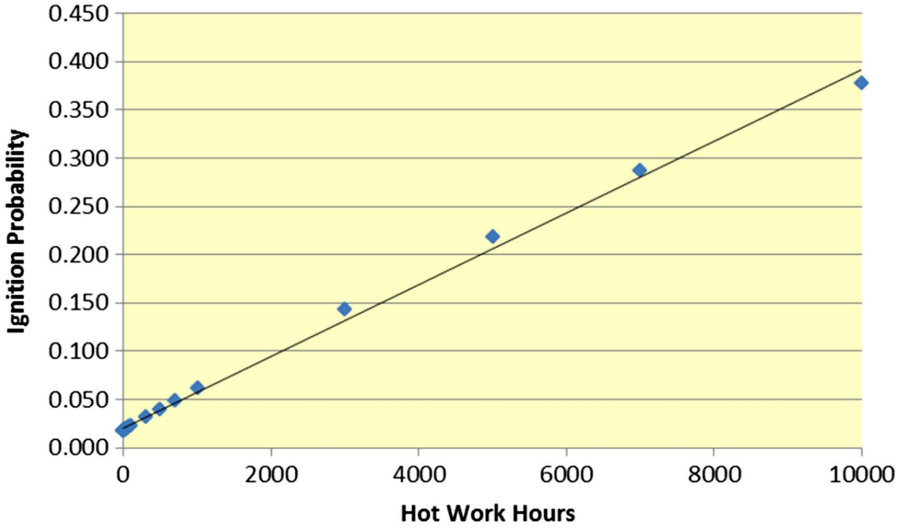

Figure 6. Ignition Probability vs. Hot-Work Hours for "UKOOA Proc Gas" Scenario at a Release Rate of 3 kg/s

indeed the case, as can be seen in Figure 6, which shows the (h_i, p_i) points for the "*UKOOA Proc Gas*" scenario for a release rate of 3 kg/s.

Figure 7 shows the change to the ignition probability for the "*UKOOA – Proc Gas*" scenario when the number of hot-work hours are increased from the base (15 hours/year) to 2000 hours/year.

IMPLEMENTATION IN SAFETI OFFSHORE

The UKOOA ignition modelling methodology is being incorporated into the Offshore QRA software currently being developed by DNV Software so that it can be used as one of a number of alternatives. This implementation also aims to improve the usability of the full model so that less reliance is placed on the more approximate look-up correlation approach.

One key element of an offshore QRA is to assess the likelihood of getting an explosion overpressure above tolerance limits for barriers, equipment and personnel:

$$f_{\text{pressure}>\text{limit}} = f_{\text{release}} \cdot P_{\text{ignition|release}} \cdot P_{\text{pressure}>\text{limit|ignition}}$$

where f is frequency and P is conditional probability.

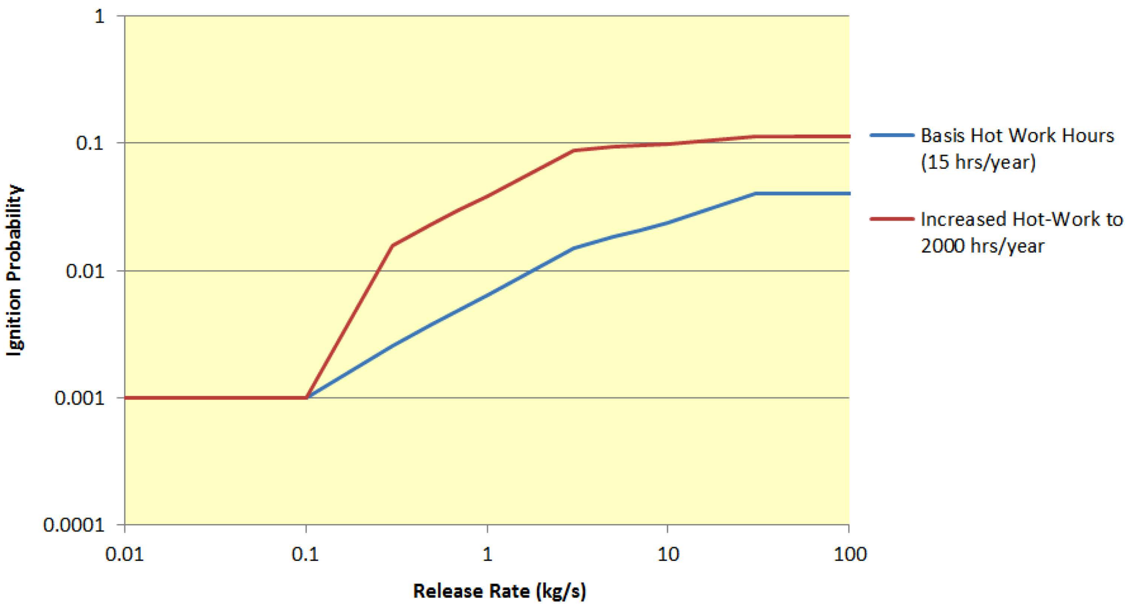

Figure 7. Effect of Increase in Hot-Work Hours on Ignition Probability

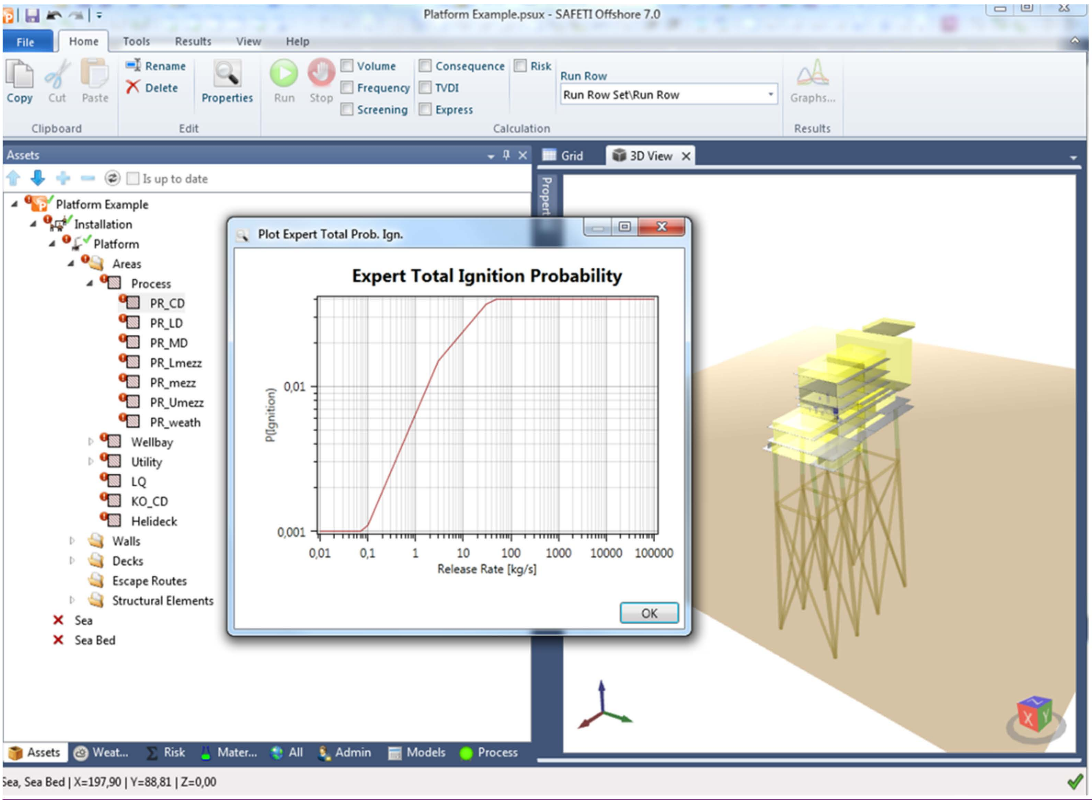

Figure 8. Incorporation of the Look–up Correlation Approach Into Integrated Offshore QRA

Whereas, it is generally more convenient to modularise a QRA study in models dealing with aspects of the overall problem, it is found that the interaction of the ignition timing and the explosion analysis is such that it necessary to treat the two methodologies together in the same piece of analysis.

The worst case overpressure is typically higher than what is possible to design barriers to withstand. Since the overpressure is sensitive to the size of the ignited flammable cloud it is important to be able to model the probability of ignition vs. time and not only the total ignition probability. Safeti Offshore models the uncertainty in release rate, cloud build up, detection, ignition, etc. The reliability of safety systems such as automatic (and manual) detection, isolation & blowdown and shutdown of ignition sources are included.

The full UKOOA model has a built in dispersion model and can predict the probability of ignition versus time. It also allows site specific parameters such as released material, process conditions, hotwork, module dimensions, weather/ventilation, etc. to be incorporated. This can also be applied to the look–up correlation approach.

Both the full UKOOA ignition model and the look-up correlations are implemented in Safeti Offshore. Default data is provided in accordance with the values provided in the full spreadsheet model to overcome the complexity of having to enter all the detailed information that the full model needs.

In the ignition modelling part of Safeti Offshore the analyst can select from the following options:

- Use the full UKOOA cloud build up and ignition model
- Use the UKOOA look-up correlation with UKOOA cloud build up model
- Use the UKOOA look-up correlation with the more detailed cloud build up model available in Safeti Offshore
- Use TDIIM [2]
- Use an Expert correlation (total ignition probability vs. release rate).

CONCLUSIONS

The "UKOOA Ignition Model" has become the standard approach for calculating the ignition probability of offshore hydrocarbon releases for offshore platforms in the United Kingdom continental shelf. If is also used for QRA studies of offshore installations in other parts of the world and in onshore studies. Typically, the look-up correlation form of the method has been adopted and this has brought benefits in terms of ease of use and consistency among practitioners.

Despite this, there are some areas where the approach could be amended to make it easier to use or adapted it to allow for the effects of variation of some key parameters. These include;

- Retabulation of the data defining the curves in order to make its meaning more obvious.
- Interpolation of new look-up correlations to address situations which are intermediate between the standard curves.
- A consistent treatment of the division of the overall ignition probability into its "immediate" and "delayed" constituents.
- A means of incorporating changes in a single parameter to produce a more accurate result or to examine the sensitivity of the results to that parameter.
- Incorporation of the methodology into QRA studies and in particular its integration with explosion overpressure exceedence analysis where the distribution of ignition times are important.

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