# Guidance on assigning ignition probabilities in onshore and offshore quantitative risk assessments

# GUIDANCE ON ASSIGNING IGNITION PROBABILITIES IN ONSHORE AND OFFSHORE QUANTITATIVE RISK ASSESSMENTS

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# FOREWORD

This report is based on research which was conducted in the period 2002–04 on behalf of the sponsors Oil and Gas UK (formerly UKOOA), the Health and Safety Executive (HSE) and the Energy Institute (EI) (formerly Institute of Petroleum (IP)). The original project, to develop IP *Research report: Ignition probability review, model development and look-up correlations,* had the aim of providing a technical review of ignition data and methods to develop improved models and guidance for the estimation of ignition probabilities for use in quantitative risk assessment (QRA). It was recognised that the methods available at that time could be very simplistic and not take account of the latest leak and ignition data, which were showing a reduced trend in ignition probabilities. Also, the models available at that time mainly did not take into account other factors known to be important such as vapour dispersion and the concentration of ignition sources. The study reviewed the data and models available and went on to develop a detailed ignition probability model. A series of look-up correlations were then developed for a range of representative onshore and offshore release scenarios to provide a simple and consistent means to apply the model covering most QRA situations.

The look-up correlations have now become the primary method for assigning ignition probabilities in both offshore and onshore QRAs and are quoted in the OGP *Risk assessment data directory*, which is widely adopted as the basis for offshore installation QRAs.

In 2012, the EI conducted an internal review of its 2006 publication and as a result of this decided to undertake a wider survey on the use of the EI/UKOOA ignition probability model and look-up correlations. The aim of this survey was to better understand the extent of use of these models and the situations they were being applied to, and to seek users' feedback on what, if any, improvements were worthwhile in terms of changes to the model, look-up correlations or associated guidance.

The survey was conducted in late summer 2012 and its findings were then presented at a workshop in September 2012 where further discussion between model users, including operators, consultants and QRA technical specialists, was used to identify what improvements were considered worthwhile.

The workshop, as described in EI *Technical workshop proceedings: Leak frequency and EI UKOOA Ignition probability model review,* concluded that there was no need to improve the detailed model or look-up correlations themselves. However, the guidance should be improved in the following areas:

- Its application to liquefied natural gas (LNG) – the correlations are not appropriate to larger releases of LNG, particularly refrigerated LNG, owing to differences in dispersion characteristics.
- The selection of suitable correlations, particularly with regard to floating production/ storage units (FPUs/FPSOs) with or without weather-vaning capability.
- Changing the format of the report to make it more user-friendly, as it was originally presented as a Research Report.

The findings from the survey and workshop have been the primary driver behind this update of the 2006 research report to develop this publication.

The information contained in this publication is provided as guidance only and while every reasonable care has been taken to ensure the accuracy of its contents, the Energy Institute, the project co-sponsors, the developer and the technical representatives listed in the acknowledgements, cannot accept any responsibility for any action taken, or not taken, on the basis of this information. The Energy Institute shall not be liable to any person for any loss or damage which may arise from the use of any of the information contained in any of its publications.

The information contained in this publication may be reviewed from time to time. It would be of considerable assistance in any future revision if users would send comments (e.g. on the performance of the model and the look-up correlations) or suggestions for improvement to:

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# ACKNOWLEDGEMENTS

This project was undertaken by David Mansfield of ESR Technology[1] with the original analysis and modelling work conducted in 2002–2004 and published by the EI in January 2006. David Mansfield also acted as primary author for this update of the publication and contributed to the workshop and surveys in mid 2012 which form the basis of this update.

The EI wishes to record its appreciation of the work carried out by the steering group for the original work and others who participated during the technical review. Significant contributions were made by:

| | |
|---|---|
| David Aberdeen | BP (Chairperson) |
| Brian Bain | DNV |
| Gerry Burke | WS Atkins |
| Stephen Connolly | Health and Safety Executive |
| Howard Crowther | Consultant |
| Tim Davenport | Shell |
| Alastair Gunn | ExxonMobil |
| Richard Jones | Acona |
| Robert Kyle | United Kingdom Offshore Operators Association |
| Colin Morgan | ESR Technology |
| Mark Scanlon | Energy Institute |
| Chris Venn | WS Atkins |

Affiliations refer to the time of preparation.

The EI also wishes to record its appreciation to those EI members and other invited operator and consultant representatives, including David Mansfield of ESR Technology, for their preparation, organisation and participation in the EI *Leak frequency and EI UKOOA ignition probability model review workshop*, held in Aberdeen on 18 September 2012 and the associated surveys used to inform the workshop. These surveys and the workshop provided the impetus to update this guidance, highlighting those specific areas where additional guidance or clarification was considered worthwhile.

Project coordination and technical editing was carried out by Lee Allford (Energy Institute).

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# OVERVIEW

The probability of ignition of flammable releases from onshore and offshore installations is a key factor in determining the risks such installations present to people, assets and the environment, yet data and practical models available to enable assessors to assign suitable ignition probability distributions in QRA have been lacking.

This publication presents the findings of a project to improve the modelling of ignition probabilities in onshore and offshore installation QRAs. Specifically, the project reviewed current data and models, developed an ignition probability model for assigning ignition probabilities in QRA, and developed a simple basis and guidance for assigning ignition probabilities to generic scenarios.

The project reviewed knowledge and research in the field of ignition probability estimation in support of QRA. This was evaluated, together with the usefulness of the UK offshore industry hydrocarbon release data, as a basis for developing an improved ignition probability model. The review concluded that the commonly applied approach of adopting generic correlations based on the mass release rate for the probability of ignition was overly simplistic and may lead to unrealistic and very conservative estimates in some situations. Further, some of the correlations in use do not reflect recent ignition probability data and knowledge.

An ignition probability model was developed that combined work on the dispersion of flammable vapours in process areas with the identification of ignition characteristics in offshore and onshore plant areas and other relevant onsite and offsite land use types. It has been benchmarked against historical ignition probability data.

The model – made available as a functional workbook – provides a means to estimate the overall ignition probability and an approximate time/location distribution for specific release scenarios. It can also provide an insight into the main ignition factors and allows sensitivity analysis and 'what-if' analysis, which may help designers to change the plant layout or process conditions to reduce the ignition potential.

Recognising that the number of factors taken into account by the model means it may be too onerous to apply for some risk assessments, the project developed a series of simple, mass release rate based, ignition probability look-up correlations for a selected range of representative onshore and offshore plant and storage release scenarios. These correlations – made available as a functional workbook – provide users with a simple and convenient introductory means to incorporate more appropriate ignition probability data in many typical QRAs. Their scope includes liquid and vapour release correlations; in addition, two-phase releases can be assessed by combining the liquid and vapour results. The look-up correlations are supported by guidance on selecting the appropriate correlation to use in a given situation, and details of the underlying basis and assumptions used in deriving them. Note that the full model should be run for complex scenarios or where additional detail is required.

Some guidance is provided on ignition timing and estimating the likelihood of an explosion, given ignition.

This publication comprises the following:

– The published report: *Guidance on assigning ignition probabilities in onshore and offshore quantitative risk assessments*.

- Ignition model spreadsheets (Version D1) in single scenario and multirun formats (provided as Microsoft Excel ® spreadsheets).
- Look-up correlations workbook (Version D2) (provided as Microsoft Excel ® spreadsheet) including the updated guidance on their application.

The report adopts the following structure:

**1.0 Introduction:**
This provides an overview of background to the project and the project scope and application.

**2.0 Look-up correlations user guide:**
This section presents guidance for users on the selection and application of the look-up correlations for assigning ignition probabilities within QRAs.

**3.0 Full model user guide:**
This section presents guidance for users wishing to use the full ignition model to estimate ignition probabilities for specific scenarios.

**4.0 Ignition timing and ignited outcomes:**
This section provides general guidance on using ignition timing, etc. to determine the split of probabilities between different ignited outcomes, including the probability of an explosion, given ignition.

**Annex A Full ignition model description:**
This section describes the basis of the full ignition model and is provided for those wishing to understand the basis of the model and how it works. It provides a useful source of information on the model for advanced users wishing to exploit the full potential of the full ignition model.

**Annex B Modelling basis of look-up correlations:**
This section describes the basis of the look-up correlations and is provided for those wishing to gain a fuller understanding of the basis of these to help with selecting, using or adapting the correlations.

**Annex C Ignition data and methods literature review:**
This section presents the review of ignition data and models undertaken as part of the original work and published in the 2006 research report. Whilst some of these data may now be superseded, it still provides a useful overview of the data available and a historical perspective on the modelling and assigning of ignition probabilities in QRA.

**Annex D Glossary**
This section contains a list of abbreviations and definitions referred to in the publication.

**Annex E References**
The section contains the list of references quoted in the publication.

**Annex F Ignition model spreadsheets**
This section contains the ignition model (single scenario, multirun version) and look-up correlations workbooks.

# 1 INTRODUCTION

## 1.1 INTRODUCTION

Ignition probabilities are key inputs in QRA that can have a major influence on the estimated risks. In the past, the ignition probabilities adopted for offshore and many onshore QRAs were drawn from relatively few sources and data points, many of which may not be appropriate to the modern design and operation of oil and gas installations.

Attempts were made to develop simple models or relationships to assign ignition probabilities in QRAs. A common approach to assigning ignition probability is to relate this to the media and release flow rate. Such an approach is proposed in the *E&P Forum leak and ignition data report* and in the Cox, Lees and Ang formulae found in IChemE *Classification of hazardous locations* which were developed in 1990.

These formulae typically assign a minimum ignition probability of 1 % for small releases, rising to a maximum of 30 % for 100 kg/s releases. The upper limits have generally been derived from offshore blowout ignition data. This assumes that the maximum ignition probability for any offshore release would be no greater than the average ignition probability from a range of blowouts on drilling units; an assumption that does not stand up to detailed interrogation.

Models and simple fractions have also been suggested to estimate what proportion of ignitions are early or delayed and which may result in explosions (an example is given in *Classification of hazardous locations*). These probabilities determine the hazardous outcome from any ignited event (e.g. jet fire, flash fire or explosion followed by a jet fire), and so can be critical in determining the risk characteristics.

Given the greater attention to major hazard safety, and the need for ignition control highlighted by the current safety regimes in the UK North Sea and the worldwide oil and gas industry in general, it could be expected that current ignition probabilities might be less than those from past experience. This may be being reflected in some of the latest ignition data.

The objective of the research originally reported in 2006 and updated here as guidance was to provide a current and informed view on ignition probabilities for use in QRA and develop a simple model to assist practitioners in assigning ignition probabilities for use in QRA, together with guidance on the model and its application. The guidance also addresses the timing of ignition and methods for estimating the likelihood of an explosion, given ignition.

The model development considered both offshore and onshore situations and addressed the key differences between the onshore and offshore environments, including the confined layout of most offshore installations as opposed to the relatively open nature of many onshore facilities. The model takes account of large leaks that could spread to adjacent areas and reach external sources of ignition and recognises that the leak size needed to spread from one offshore module to the next would be smaller than ones capable of drifting between onshore plant areas.

The model – made available as a functional spreadsheet – provides a means to estimate the overall ignition probability and an approximate time/location distribution for specific release scenarios. It can also provide an insight into the main ignition factors and allows sensitivity analysis and 'what-if' analysis, which may help designers to change the plant layout or process conditions to reduce the ignition potential.

Recognising that the number of factors taken into account by the model means it may be too onerous to apply for some risk assessments, a series of simple, mass release rate based, ignition probability look-up correlations was developed for a selected range of representative onshore and offshore plant and storage release scenarios. These correlations – made available as a functional spreadsheet – provide users with a simple and convenient introductory means to incorporate more appropriate ignition probability data in many typical QRAs.

## 1.2 APPLICATION

This guidance should be drawn to the attention of safety practitioners, risk analysts and designers who need to determine or evaluate ignition probabilities in QRA, such as where required for safety cases or safety reports.

The project sponsors believe that the model and look-up correlations provide a more appropriate means for assigning ignition probabilities in QRAs, as they take better account of the release type and plant characteristics, and results better align with historical data including the UK offshore industry hydrocarbon release data. However, their use requires expert judgement and results should be used and interpreted with a degree of caution, in particular where they are less conservative than former approaches. In addition, those preparing or revising safety cases or safety reports should include details of pertinent assumptions and input data that support the derived ignition probabilities.

## 1.3 SCOPE

The scope of application of the model and look-up correlations is to assess the ignition potential of momentum driven releases of hydrocarbons; however, these are not suited to the ignition probability assessment of:

– refrigerated liquefied gases e.g. LNG;
– vaporising liquid pools;
– subsonic gas releases, or
– other non-momentum driven releases, such as those following catastrophic storage vessel failure.

This is due to the limits of the simple dispersions models used within the ignition model, see Note 6 in Table 1. The full ignition model does have the option to manually enter the volume/area of the flammable clouds in each assessment area, so can be used in this manual mode to address situations such as those previously mentioned in combination with suitable external dispersion models.

The scope of application of the look-up correlations includes liquid and vapour release correlations. In addition, two-phase releases can be assessed by combining the liquid and vapour results. The look-up correlations are supported by guidance on selecting the appropriate correlation to use in a given situation, and details of the underlying basis and assumptions used in deriving them. Note that the full model should be run for complex scenarios or where additional detail is required.

The ignition model uses a series of annular areas to represent the plant configuration and does not take elevations into account. The model is, therefore, not directly able to address modules at different levels (heights). However, the model can be configured to approximate some vertical configurations. Guidance on these aspects is given in 3.7.