# CDOIF

Chemical and Downstream Oil Industry Forum

Guideline

Process Safety Leadership Group – Other Products in Scope

## Foreword

In promoting and leading on key sector process safety initiatives, CDOIF has developed through its members a guideline and screening methodology for assessing the risk from other products within the scope of the Process Safety Leadership group (PSLG) final report.

It is not the intention of this document to specify the risk assessment process, nor replace any existing corporate policies or processes. The intent is to provide a reference for those organisations storing the products defined within the scope of appendix 1 of the final PSLG report, and provide the means by which effective and efficient risk assessment can be performed.

There are no limitations on further distribution of this guideline to other organisations outside of CDOIF membership, provided that:

1. It is understood that this report represents CDOIF's view of common guidelines as applied to the risk assessment of other products defined within the scope of the PSLG final report.
2. CDOIF accepts no responsibility in terms of the use or misuse of this document.
3. The report is distributed in a read only format, such that the name and content is not changed and that it is consistently referred to as "CDOIF Guideline – PSLG Other Products in Scope".
4. It is understood that no warranty is given in relation to the accuracy or completeness of information contained in the report except that it is believed to be substantially correct at the time of publication.

This guidance is not intended to be an authoritative interpretation of the law; however Competent Authority (CA) inspectors may refer to it in making judgements about a duty holder's compliance with the law. This will be done in accordance with the CA's published enforcement policies (refer to www.hse.gov.uk/pubns/hse41.pdf) and it is anticipated that this document will facilitate a consistent national approach.

It should be understood however that this document does not explore all possible options for the risk assessment of other products within the scope of the final PSLG report, nor does it consider individual site requirements – Following the guidance is not compulsory and duty holders are free to take other action.

## Contents

## 1 Executive summary

The final report of the Process Safety Leadership Groups (PSLG) safety and environmental standards for fuel storage sites was published in December 2009.

Since publication, duty holders have been completing detailed risk quantification against the guidance provided in Appendix 2 of the report, for the scenario of over topping a finished gasoline tank which has the same or similar characteristics as tank 912 at Buncefield (as defined in paragraph 24 of the PSLG report):

- those storing gasoline (petrol) as defined in Directive 94/63/EC European Parliament and Council Directive 94/63/EC of 20 December 1994 on the control of volatile organic compound emissions resulting from the storage of petrol and its distribution from terminals to service stations;
- vertical, cylindrical, non-refrigerated, above-ground storage tanks typically designed to standards BS 2654,3 BS EN 14015,4 API 620,5 API 6506 (or equivalent codes at the time of construction);
- with side walls greater than 5 m in height; and
- filled at rates greater than 100 m3/hour (this is approximately 75 tonnes/hour of gasoline).

The Competent Authority (CA) has reviewed the risk assessments, and in the vast majority of cases these have been agreed, Safety Integrity Levels (SIL) identified, and implementation plans submitted. In many instances the overfill protection systems have already been installed.

The purpose of this guidance is to draw on the experience of both the CA and Duty Holders in completing risk assessments for finished gasoline storage tanks, and propose a screening methodology that can be adopted to simplify and expedite the assessment of other products (as defined in appendix 1 of the final PSLG report) which may give rise to the formation of a flammable vapour cloud.

It is not the intention of this document to replace the guidance provided in the final PSLG report, but instead provide a methodology for simplifying the risk assessment process for ‘other products’ based on the knowledge and feedback from the assessment of finished gasoline. The CA and Duty Holder should continue to reference the guidance provided by the final PSLG report when determining what measures may be required to reduce the risk of an overfill from other product tanks.

This guidance also takes into account the research report published by the Health and Safety Laboratory (HSL) ‘RR908 Vapour cloud formation: Experiments and modelling’, which has the potential to influence the other products in scope, and the parameters considered when performing a risk assessment.

## 2 Scope

This document provides guidance and a screening methodology to assist duty holders and the CA in the risk assessment of other products in scope of the final PSLG report.

Other products are identified as follows:

| Substances considered likely to form a large vapour cloud |
|---|
| Acetone |
| Benzene |
| Crude Oils[1] |
| Raw Gasoline |
| Methyl ethyl ketone |
| Naphthas |
| Reformate (worse case – light) |
| Natural gas liquids (condensate) |
| Methyl tert-butyl ether |
| Iso Pentane |
| Special boiling point solvent 2 |
| Toluene |

All tanks storing the products identified above are subject to the scope criteria as defined in paragraph 24 of the final PSLG report.

Note[1] – the crude oils considered in scope are subject to paragraph 6 of the PSLG final report appendix 1

*Note: Some of these products may be screened out of scope, following an assessment using the Health and Safety Laboratory (HSL) research report RR908, 'Vapour cloud formation: Experiments and modelling'. Refer to section 3.2 and Appendix 1 for further information.*

# 3 Reference documents and key guidance

## 3.1 PSLG final report

In the first instance, reference should be made to the PSLG final report appendix 2 for guidance on completing risk assessments for the scenario of overfilling a PSLG in-scope tank.

## 3.2 Health and Safety Laboratory (HSL) Research Report 'RR908 Vapour cloud formation: Experiments and modelling'

This research report focuses mainly on what happens at the base of a tank during a cascade, the predictive methods that can be adopted for calculating evaporation of the material, and recommending dilution factors that can be applied.

In support of the research report, a simple calculation methodology has been developed to help to determine the range and nature of a flammable vapour cloud over time. This has an influencing factor over the risk assessments that need to be performed; some products may no longer be in scope (for example Toluene and some grades of crude oil).

Reference should be made to Appendix 1 for a simple evaluation tool to help in determining the properties of vapour cloud formation for in-scope products.

## 3.3 Explosion mechanism phase 2

There is an on-going project which is looking at the explosion mechanism from Buncefield. Those completing risk assessments should pay close attention to the results of this work as it may influence any assessments that are performed, specifically:

- The actual explosion mechanism, for example whether this is from flame acceleration through trees and undergrowth, or acceleration due to leaf and other debris at the front of the flame

- The distances that should be considered when performing a risk assessment (PSLG states two zones at a radius of 250m and 400m from the base of the tank)

## 3.4 Containment Policy (CP)

Those products within scope of the PSLG are defined in Appendix 1 of the final report. The scope of the Containment Policy is defined in part 2 of the policy. These may not include the same products, for example crude oil is in scope for PSLG and out of scope for containment policy. Implementation of the PSLG scope does not bring those products into the scope of the containment policy, unless they are already included.

## 3.5 CA agreement on the nature and architectures of overfill prevention systems

Following completion of the risk assessment, when considering the installation of overfill protection to other products and the architecture and nature of these systems, reference should be made to the alternative measures cited in the report, particularly in relation to the use of operators:

'Those that include an operator(s) as part of the overfill prevention system must demonstrate that the reliability and availability of that operator(s) can be adequately supported to undertake the necessary control actions to prevent an overfill without compromising the ALARP outcome. Operator involvement should be properly managed, monitored, audited and reviewed on an on-going basis. The CA is unlikely to accept that an operator can be included in a system rated above Safety Integrity Level (SIL) 1 within BS EN 61511-1'

UKPIA has published guidance and an assessment methodology to help duty holders in reviewing the requirements and minimum standards for the use of operators as part of a SIL1 Safety Instrumented System (SIS). More information can be found here: http://www.ukpia.com/process-safety/tools/self-assessment-tools.aspx in the section "Understand Hazards and Risks".

### 3.6 Chemical and Downstream Oil Industry Forum (CDOIF)

There are three projects that are currently under consideration by CDOIF which may influence the outcome of the risk assessments, or design of overfill prevention systems. These are:

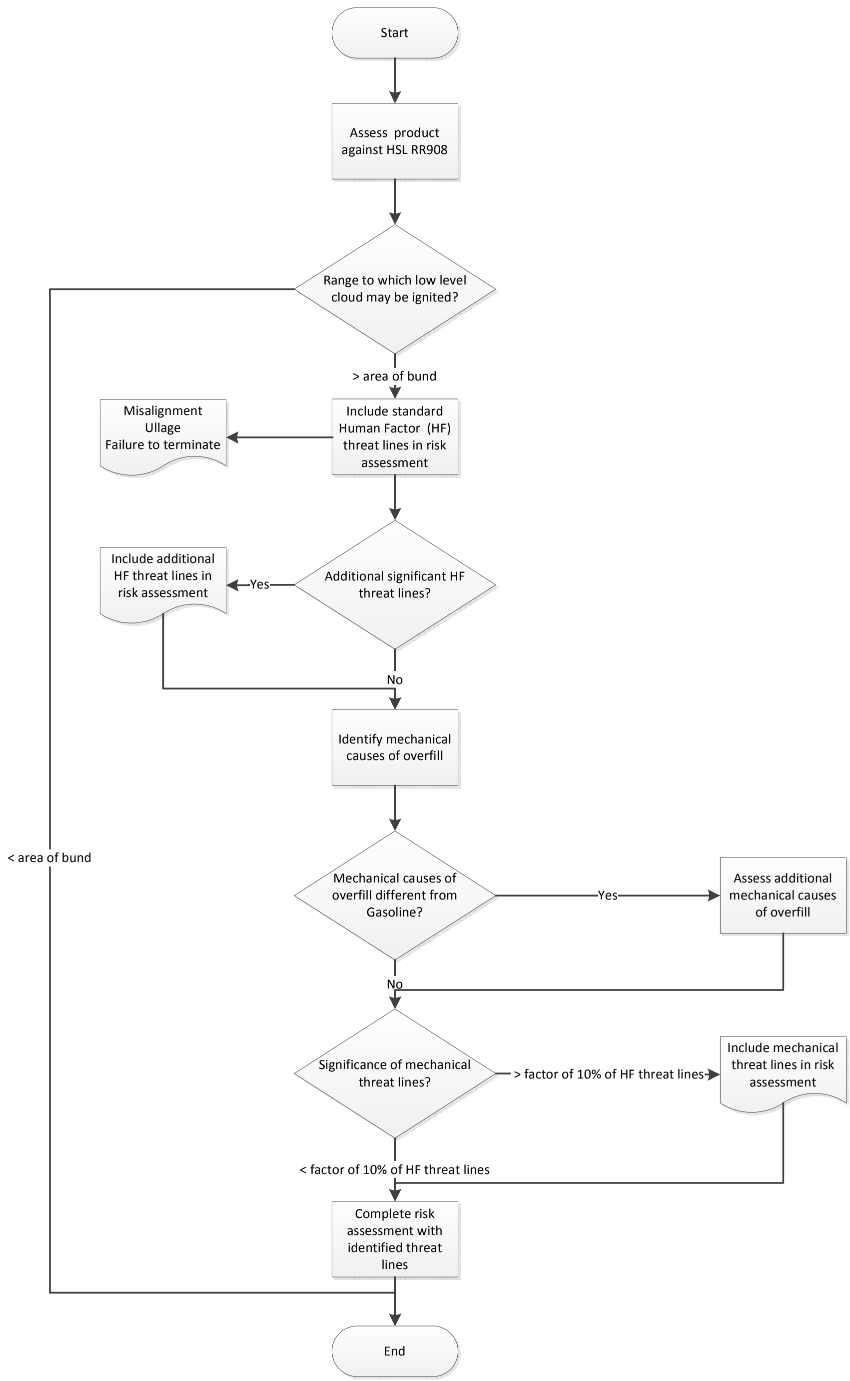
- Environmental Risk Assessment
- Leak Detection
- Prior Use – suitability of existing equipment to form part of the Safety Instrumented Function

The output of the environmental risk assessment working group may influence the need for, and target SIL levels of overfill protection systems. The leak detection work group may provide alternative means (or mitigation layer) that could be employed to reduce the risk of a vapour cloud explosion to a tolerable level, thus also influencing the need for, and target SIL levels of overfill protection systems.

Where the need for a SIL rated overfill protection system has been identified, the Prior Use guidance can be adopted when determining the suitability of existing equipment to form part of the Safety Instrumented Function.

# 4 Screening methodology

The following flowchart provides a simple screening methodology to assist in the development of risk assessments for other products within the scope of the final PSLG report. Reference should be made to section 5 of this guidance where additional information is provided on the selection of generic data which may be applied to relevant threat lines and barriers.



# 5 Generic parameters and data

## 5.1 Threat lines

To justify the Human Error Probabilities (HEP)'s for operators performing critical tasks during the transfer of other in scope substances as described in this guidance, it is expected that good practice be implemented. Good practice with regard to sites that come under the scope of this guidance is described in the PSLG report, 'Safety and environmental standards for fuel storage sites'. Specific guidance on incorporating human error in initiating events is given in appendix 2; annex 7 of the PSLG report.

For those processes that are similar to those for finished gasoline (for example the same operators carrying out the same type of basic activities, who are suitably trained and have the necessary operational experience and are familiar with the process) then the error probabilities suggested in the following sections may be used, as task analysis has already been completed for finished gasoline. Where different HEPs are used, these should be justified.

For those processes that are not similar to finished gasoline, it is suggested that the following risk controls contribute towards good practice and should be in place as a minimum before the human error probabilities suggested in the following sections can be applied.

- Perform a task analysis of all relevant critical tasks relating to an overflow event.
- Perform human error analysis to identify what could go wrong with each critical task and how to detect and deal with this.
- Have sufficiently detailed procedures covering all relevant aspects of the transfer of other in-scope substances.
- Perform training in the task(s) to be performed, including refresher training.
- Demonstrate, periodically, operator competence in the tasks to be performed.
- Determine that the operator has no other demands on their time that could limit their ability to safely perform the required tasks.
- Perform periodic operational audit (functional test) for critical tasks.
- Monitor critical operator tasks over time (trending).
- Provide an audit trail / records for all of the above.

Note: When completing risk assessments, consideration can be given to operational cross-checks of the tank levels which may provide an additional layer of protection thus further reducing the risk of an overfill. See PSLG final report, appendix 2, annex 6 for further guidance on cross-checks.

## 5.2 Misalignment

Misalignment refers to the threat that an operator has incorrectly lined up the receiving tank with the discharging tank – the wrong tank will be filled.

Alignment of sending and receiving tanks can be carried out by either a control room operator via the control system, or by a local operator via local control panel or manual valve(s).

The following logic can be used when selecting the number of failures of tank alignments (or critical step).

| | |
|---|---|
| IF | The control room or local operator carries out the operation (or critical step) on a routine basis (it is a regular task), and the operator can be demonstrated to be competent in carrying out that task<br><br>OR<br><br>The task (or critical step) is not routine, but there is a detailed procedure in place (requiring confirmation of steps completed), and the operator can be demonstrated to be competent in carrying out the task |
| THEN | Assume a failure of 1/1000 tank alignment operations |
| OTHERWISE | Assume a failure of 1/100 tank alignments operations[1] |

Note[1] – further detailed analysis of the critical step may be required where tasks are not routine, and where there are specific and unusual site requirements for carrying out the task.

### 5.3 Failure to terminate

Failure to terminate refers to the threat that an operator fails to terminate a transfer of product, resulting in overfill.

This threat line applies to any tank (containing product within the scope of the PSLG final report) which goes through a fill and empty cycle. It may not apply to tanks which are continuously fed (for example run-down tanks).

The following logic can be used when selecting the number of failures to terminate a transfer (or critical step)[1].

| | |
|---|---|
| IF | The control room or local operator carries out the operation (or critical step) on a routine basis (it is a regular task), and the operator can be demonstrated to be competent in carrying out that task<br><br>OR<br><br>The task (or critical step) is not routine, but there is a detailed procedure in place (requiring confirmation of steps completed), and the operator can be demonstrated to be competent in carrying out the task |
| THEN | Assume a failure to terminate the transfer of 1/1000 tank fill cycles |
| OTHERWISE | Assume a failure to terminate the transfer of 1/100 tank fill cycles [2] |

Note[1] – Consideration should be given to ship-fed transfers, which may require more than one action to terminate the transfer.

Note[2] – further detailed analysis of the critical step may be required where tasks are not routine, and where there are specific and unusual site requirements for carrying out the task.

## 5.4 Ullage

Ullage refers to the threat that an operator incorrectly specifies the flow rate or 'fill' time of the transfer, or the operator incorrectly determines the Ullage, resulting in the potential over-filling of the receiving tank.

*Note: this threat line may not be relevant where Ullage calculations are performed in conjunction with other departments, such as planning, accounts.*

Ullage calculations can be performed for either batch transfers of product, or where a continuous flow of product is required to maintain the level in a receiving tank.

The following logic can be used when selecting the number of failures to correctly enter either a flow rate or 'fill' time as part of a transfer (or critical step)[1].

| | |
|---|---|
| IF | The control room or local operator carries out the operation (or critical step) on a routine basis (it is a regular task), and the operator can be demonstrated to be competent in carrying out that task<br><br>OR<br><br>The task (or critical step) is not routine, but there is a detailed procedure in place (requiring confirmation of steps completed), and the operator can be demonstrated to be competent in carrying out the task |
| THEN | Assume a failure to correctly enter flow rate or 'fill' time of 1/1000 tank fill cycles |
| OTHERWISE | Assume a failure to correctly enter flow rate or 'fill' time of 1/100 tank fill cycles [2] |

Note[1] – Where the receiving tank level is maintained under service, particular attention should be drawn to the integrity of the level gauge (which can highlight unexpected variations in level). Further additional analysis may be required based on the fill rate, for example identification of what could cause overfill, and over what duration this could occur.

Note[2] – further detailed analysis of the critical step may be required where tasks are not routine, and where there are specific and unusual site requirements for carrying out the task.

## 5.5 Mechanical failures

Mechanical failures can occur to such equipment as Automatic Tank Gauging (ATG) systems, flow-meters, pumps or Remotely Operated Solenoid Valves (ROSV's).

With reference to the screening methodology in section 4, where this equipment is considered to contribute significantly to the threat of overfill (greater than a factor 10% of the human factors related initiating event frequency, which was not the case for any of the PSLG LOPAs on Finished Gasoline which were filled via a batch process),

OR

Where the mechanical failures of equipment is considered to be different to that assessed for finished gasoline (for example, the equipment, architecture or service is significantly different), then any additional mechanical causes of overfill should be assessed, in accordance with the guidance provided by the final PSLG report.

For equipment that is not considered to contribute significantly to the threat of overfill (less than a factor 10% of the human factors related initiating event frequency), and where the equipment is not significantly different from that used for finished gasoline, no further detailed assessment should be required.

When considering the failure rate data for the equipment installed, this should be obtained from appropriate sources.

The best and most appropriate information comes from the operational experience of the end user.

Where an end user has no operational experience of a new item of equipment, there are other sources of failure data that might be considered. These may include:

- Manufacturers failure rate data
- Generic failure rate data, from sources such as EEMUA, FARADIP, OREDA etc.

However, great care should be taken when using either of these alternative sources to gain failure rate information for *existing* equipment. Firstly, manufacturers will almost certainly have no direct experience of the use of the items under conditions similar to those of the end user. Furthermore, the data provided by manufacturers is often simply a synthesised prediction of performance that they are hoping for from the product.

Secondly, with the generic failure rates to be found in databases, there is no guarantee that the component that the end user is considering will be similar in performance to the database figure. Any use of generic data should have appropriate justification for its appropriateness and should be regarded as a provisional figure until real experience is available to support or reject the figure.

Preferentially end users own failure data should be used to calculate failure rates. Further information can be found in Appendix 1 of the CDOIF guideline 'Demonstrating prior use'.

Note that for new installations of equipment, it is likely that manufacturer's failure rate data will be used; this should be analysed as part of the design process, to ensure that required risk reduction (for the layer of protection in question) has been achieved.

## 5.6 Barriers and probability of failure on demand (PFD)

Based on the risk assessments completed and accepted by the CA for finished gasoline, the following typical data may be adopted when completing risk assessments for other products within the scope of the PSLG final report.

| Parameter | Value | Comments |
|---|---|---|
| CM1 | - | Probability of ignition, based on site (and off-site where relevant) specific data |
| CM2 | 1 | Probability of explosion after ignition, however this will be influenced by the HSL research report RR908 which may screen out some products, and the work of the Phase 2 explosion mechanism (refer to section 3.3). |
| CM3 | - | Weather conditions, based on site specific data, but may be re-used from the calculations performed for finished gasoline |
| CM4 | - | Probability that a person(s) in the explosion zone, based on site specific data |
| CM5 | 1 | Probability of fatality in the explosion zone |
| IPL1 – Operator Cross-checks | 0.1 | Operational cross-checks of the tank levels, see below for definition. |
| IPL2 – Alarm & Operator Response | 0.1 | The barrier is “Alarm and Operator Response”, i.e. an alarm in a manned location and an operator responding to the alarm. See below regarding assurance required for the operator to have a PFD of 0.07.<br>The PFD of the rest of the system (i.e. field instrument, data processing and transfer and the audible/visual alarm) is assumed to be less than 0.03 provided that good management control and maintenance of the system can be demonstrated |
| IPL3 - IHHA | 0.1 | Independent Protection Layer (IPL) provided by an independent high high alarm system. If a Safety Related SIL 1 system is used as this IPL using an operator, then the system should conform to the UKPIA SIL1 Human Factors criteria. |

| Parameter | Value | Comments |
|---|---|---|
| IML1 | - | Consideration may be given to an additional Independent Mitigation Layer (IML) such as leak detection. Further reference should be made to the CDOIF guideline 'Leak detection' |

### 5.6.1 Operating Procedures used as Barriers

The "Operational Cross-Check" procedure involves the expected level being manually calculated on a regular basis using the feed rate and/or monitoring the level in another tank going down. This calculated value is cross-checked against the level indication of the tank being filled. If the anticipated change in level is not in line with the level indication of the tank that is filling then predefined and specific actions shall be undertaken (e.g. checking the level indication by measurements in the field or redirecting the rundown to an alternative tank with sufficient ullage). This system allows for both a faulty instrument and for errors in the original line-up to be detected. The checks of the level indication with the calculated level need to be performed at regular intervals (e.g. an hour after the start of the tank filling and every 3-4 hours thereafter).

The "**Alarm and Operator Response**" barrier involves a well defined response to a maintained tank level alarm (i.e. a high level alarm).

To ensure these operational barriers are effective, there should be in place tank operating procedures which include the following elements (or similar):

a. Be clearly written, kept current and required to be used by the operator.

b. Set requirements for periodic maintenance and validation to confirm correct tank guage operation.

c. Require a start of shift orientation (which may be part of the shift handover) where the tank levels are assessed and a search for abnormal tank levels, fill rates or line-ups is made. This should include re-evaluating each filling tank's "time to fill" and predicted "time at full."

d. Require periodic verbal interaction or supervision of the operator to sustain their continuous vigilance.

e. Provide a step-by-step tank management procedures that include:

   i. Tank valve line up instructions with check off provisions for each different tank transfer configuration.

   ii. Standard form (i.e. a manual calculation carried out by competent personnel), software program, or DCS based tank inventory management system that can be used to estimate the fill rate and ultimate level in the tank during the transfer.

iii. Proactive monitoring of the tank level as the transfer occurs such as a standard transfer form or software program that requires the operator to log initial tank level from the tank gauging system, direction of level change (increasing or decreasing) and periodic tank levels throughout the transfer.

In addition to these specific elements the duty holder should also conform to the guidance provided in Section 5.1 Threat Lines, i.e. training, competence, demands on operator time, audits, etc. See PSLG final report, appendix 2; annex 6 for further guidance on cross-checks.

## Abbreviations

| Abbreviation | Description |
|---|---|
| ALARP | As Low as is Reasonably Practicable |
| ATG | Automatic Tank Gauging |
| BPCS | Basic Process Control System |
| CA | Competent Authority |
| CDOIF | Chemical and Downstream Oil Industry Forum |
| CM | Conditional Modifier |
| CP | Containment Policy |
| HEP | Human Error Probability |
| HF | Human Factors |
| IHHA | Independent High High Alarm |
| HSE | Health and Safety Executive |
| HSL | Health and Safety Laboratory |
| IML | Independent Mitigation Layer |
| IPL | Independent Protection Layer |
| PFD | Probability of Failure on Demand |
| PSLG | Process Safety Leadership Group |
| ROSOV | Remotely Operated Solenoid Valve |
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| | |

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CDOIF wish to record their appreciation to the working group members who were responsible for creating this guideline:

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| 0 | All | First Issue | 14-May-2012 | Peter Davidson |
| 1 | All | Updated to include working group comments | 19-June-2012 | Peter Davidson |
| 2 | All | Updated to include further working group comments | 02-Aug-2012 | Peter Davidson |
| 3 | All | Updated to include CA comments | 12-Nov-2012 | Peter Davidson,<br>Mark Manton,<br>Neil Macnaughton |
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| 5 | All | Updated to include final UKPIA comments | 03-Dec-2012 | Peter Davidson |
| | | | | |

## Appendix 1 – Vapour cloud formation calculation