

Model code of safe practice

Part 15

Area classification for installations handling flammable fluids

4th edition



MODEL CODE OF SAFE PRACTICE PART 15
AREA CLASSIFICATION FOR INSTALLATIONS HANDLING FLAMMABLE FLUIDS

4th edition

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FOREWORD

El *Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids* (EI15, formerly referred to as IP15) is a well-established Model Code for area classification in the petroleum industry. It provides a demonstrable methodology for determining hazard radii, applicable to installations handling flammable fluids. Identifying and designating areas in which there is a risk of a flammable (explosive) atmosphere occurring is a legal duty under the Dangerous Substances and Explosives Atmospheres Regulations 2002, (DSEAR) [which implement ATEX Directive 99/92/EC setting minimum requirements for improving the safety & health of workers potentially at risk from explosive atmospheres], and the Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations, 1995, (PFEER).

The fourth edition of this Model Code provides clarification on issues that have been raised by users of the third edition since its publication in 2005 and also incorporates key findings from a number of research studies commissioned by the EI. In addition, further editorial changes have been made.

The Model Code applies dispersion modelling to the calculation of hazard radii, taking into account variables such as pressure of release and the effect of mist or spray formation. The current methodology takes account of both the composition of the material released and its release conditions including the release pressure, together with sensitivity to various operating parameters.

The Model Code also provides a risk-based approach for specifying hazardous areas from secondary grade sources of release, allowing further flexibility in specifying hazard radii. Whilst the Model Code includes the basis of the risk-based approach, the full methodology is provided in the publication EI *A risk-based approach to hazardous area classification*, 2nd edition, 2015.

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Suggested revisions are invited and should be submitted to the Technical Department, Energy Institute, 61 New Cavendish Street, LONDON W1G 7AR.

KEY TECHNICAL CHANGES

This section sets out in a generalised form, a summary of the key technical changes between the third and fourth editions of EI15.

The key technical changes comprise:

1. Emphasis being placed on the use of the point source approach for area classification and relocation of direct examples to Annex D.
2. Amendments to the point source approach – amended hazard radii for secondary grade releases from pumps, compressors, flanges and valves (based upon revised equivalent hole sizes); along with amended hazard radii from pool spills.
3. Annex C, calculation of hazard radii, has been reordered and restructured to aid user understanding.
4. Examples on how to assess whether ventilation is ‘adequate’ are provided.
5. Expansion of Annex F on ventilation and releases within enclosed areas to include pertinent findings in HSE Research Report: *Technical input on ventilation effectiveness for area classification guidance EI15*.
6. Amendments to guidance on ventilation of hazardous areas. Amended definition of ‘adequate ventilation’ and other key findings from HSE Research Report *Technical Input on ventilation effectiveness for area classification guidance EI15*. Based on this work some sections have been restructured and sections which are no longer technically valid have been deleted.
7. Incorporation of conclusions in *EI Research Report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*, including a sensitivity analysis to various parameters.
8. Incorporation of further background technical information on hazard radii from pool spills.
9. Incorporation of hazard radii and background information for LNG releases.
10. Revised ‘equivalent hole sizes’ for frequency bands (LEVEL I – III), based on analysis of the HSE Hydrocarbon Release Database (HCR).
11. Amplification of the discussion of the limits of applicability of the Model Code.
12. Amplification of the discussion of grades of release, particularly with reference to detection times.
13. Revision of the guidance on the formation of flammable mists, noting further research into this subject is ongoing.
14. Guidance and recommendations on equipment design, information on protection concepts and fired process heaters and guidance on equipment selection and non-electrical sources of ignition have been removed and incorporated into *EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas*.

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It also wishes to recognise the contribution made by those individuals, companies and organisations that provided comments since publication of the 3rd edition which have resulted in this revised edition.

OVERVIEW

GENERAL: This Model Code presents approaches to be used in area classification: the point source approach, where release rates are dependent on process conditions, and the direct example approach, which is limited to common facilities. The risk-based approach is included within the point source approach for a risk-based methodology for determining unknown release hole sizes for secondary grade releases, where actual hole size is not available.

CHAPTER 1: Establishes the scope of the Model Code and defines key terms. It indicates a means of defining flammable fluids for area classification purposes by their flash points and, where extremes of volatility, temperature and pressure occur, by fluid category. Figure 1.1 provides a guide to applying the Model Code and selecting the appropriate approach to be used.

CHAPTER 2: Identifies the information required to classify a hazardous area and explains the technique of area classification by use of either the point source or direct example approach. It also describes the area classification drawing.

CHAPTER 3: Describes the point source approach and provides the basis for the hazard radii specified throughout the Model Code. These are based on the results of dispersion modelling published in *El Research report: Dispersion modelling and calculations in support of El Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*, which allows for variations in release rates and operational pressures. A risk-based approach is also provided for determining the extent of Zone 2 hazardous areas where release hole sizes are not specified.

CHAPTER 4: Provides guidance on the effect of ventilation on hazard radii and zone classification in non-open areas. The different degrees of ventilation are described and Figure 4.1 provides a procedure for assessing the type and degree of ventilation for given situations. Open areas, sheltered areas and enclosed areas are defined and the application of area classification to each situation is described. Methods of artificial ventilation and the effect of loss of ventilation on the area classification are discussed.

ANNEX A: Provides background information on EI classes of petroleum, and their relationship to the fluid categories used in this Model Code. Implications of flammable fluids being released as a mist or spray are discussed.

ANNEX B: Summarises work done on assessing the area classification of hydrogen and hydrogen-containing streams.

ANNEX C: Presents the background to the calculation of hazard radii for release rates used in Chapter 3, based on dispersion modelling in *El Research report: Dispersion modelling and calculations in support of El Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*. Also, for use with the risk-based approach, Annex C describes the procedure for determining appropriate release frequency for release rates, to be used in conjunction with Chapter 3 and describes the background to the risk-based approach and how risk tolerability criteria are related to release frequencies and corresponding release hole sizes.

ANNEX D: Provides direct examples, with diagrams, which can be used to classify common facilities; distances are valid for the conditions given. However, the Annex also refers to the point source approach in Chapter 3 for variable releases (e.g. releases from tank vents).

ANNEX E: Presents a discussion on small scale operations including research and development installations (e.g. pilot plants, laboratories, etc.) where special features will need to be considered in assessing the fire and explosion risk, and the approach to area classification.

ANNEX F: Provides background information and examples on the assessment of ventilation of enclosed areas. Releases within enclosed areas, such as buildings, and associated external hazardous areas are also discussed.

ANNEX G: Glossary of terms used in this Model Code.

ANNEX H: List of references cited in this Model Code.

1 INTRODUCTION

1.1 SCOPE

This Model Code gives guidance on the classification of areas around equipment handling or storing flammable fluids, and provides a basis for both the correct selection of fixed electrical equipment and the location of other sources of ignition in those areas. An 'area' in this context is always taken to be three-dimensional. Area classification zoning restrictions should be considered when introducing and using any temporary electrical equipment or mobile equipment capable of generating a source of ignition, to a facility.

It is intended that the guidance given in this Model Code is applicable internationally to installations in processing, distribution, production and retail sectors. The application of this Model Code is limited to flammable fluids similar in physical characteristics to those occurring in the petroleum, petrochemical and allied industries. It does not cover ignitable dusts or the assessment of health risks due to the handling of flammable fluids.

It does not comprehensively address the releases of flammable refrigerated or cryogenic liquids, for which the dispersion characteristics are markedly different from those of fluids at higher temperatures. The general approach presented in the Model Code may be applied to such releases if specific dispersion modelling, using the appropriate dispersion characteristics, is performed. For this purpose, a limited amount of information and guidance on the hazardous areas generated by those fluids is given. It can, however, be used for situations where vented boil-off vapour is released at around ambient temperatures. If it is desired to consider area classification for the liquids, it will be necessary to carry out specific calculations using suitable dispersion models, e.g. those applied in the calculation of radii provided in Annex C Part 1, published in *EI Research report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*.

General guidance as to the main principles, definitions and explanations of terms relating to area classification has also been set out internationally by the International Electrotechnical Commission (IEC) and in Europe by the European Committee for Standardization (CEN), followed nationally by bodies such as, in the United Kingdom, the British Standards Institution (BSI). References to standards and guidance issued by these bodies are provided throughout this Model Code.

1.2 LIMITS OF APPLICABILITY

1.2.1 General

The area classification techniques described in this Model Code assume that the facilities to which they are applied are designed, constructed, maintained and operated in accordance with industry good practice so as to reduce the frequency of releases. The guidance contained in a number of EI publications (cited in Annex H) covering good operational and maintenance practice should also be followed.

Area classification should not be used as a prime tool in determining layout. However, aspects of area classification may be considered in determining separation distances. Guidance as to

the recommended spacings between equipment and public boundaries and to other facilities, including sources of ignition, can be found in other industry guidance, Codes of Practice, etc.

In the UK, there are many criteria used for classifying the severity of release e.g. those used in RIDDOR and the HSE Hydrocarbon Release System (HCR). Generally, these regimes classify the severity of a release based on the quantity and duration of a release and are not related to the failure mode of equipment. This Model Code seeks to evaluate equipment failure cases, on which area classification is based.

The aim of area classification is to avoid ignition of those releases that may occur from time to time in the normal operation of facilities handling flammable fluids. The approach is to reduce the probability of coincidence of a flammable atmosphere and an electrical or other source of ignition.

It is not the aim of area classification to prevent the ignition of major accidental releases of flammable materials that could extend to large distances from the release source. These larger accidental releases, which may result from major or catastrophic failure of process or storage equipment, should be dealt with by risk assessment and other procedures or processes including the requirements of relevant legislation.

1.2.2 Extent of hazardous area

The design intent should always be to minimise the extent of the hazard radii. It is not good practice to classify hazardous zones that would reach uncontrolled sources of ignition, such as site roads, occupied buildings and off-site populations. For typical sites these distances can be between 15 m and 30 m.

In the majority of cases, it is expected that the release rates will result in hazard radii significantly less than 30 m, although releases resulting in potential hazard radii greater than 30 m which occur due to design intent, e.g. discharges from a relief valve, vent or high pressure source, should be included in the area classification review. Arrangements should be made if practical to route the discharge to a flare or to discharge at an appropriate location subject to a risk assessment.

If a hazard radius calculated using the point source method is greater than 30 m, then the size of the release is generally larger than that considered for area classification purposes and measures should be taken where practical to eliminate the source or reduce the size of the release.

1.2.3 Small scale operations

As guidance, Table 1.1 details capacity thresholds above which area classification is typically required. However, it would be incorrect to assume that operations involving smaller quantities than these thresholds do not require area classification. Such operations should be separately assessed to determine the size of release that may occur during normal operation (continuous/primary grade release), or foreseeable equipment failure or operator error (secondary grade release) and the risk of harm to an individual should this ignite. Where there is risk of injury, appropriate control and mitigation measures should be taken to protect the health and safety of the individual. Such precautionary measures can include area classification, but this may not always be necessary. For example, in locations handling only small quantities of flammable fluids, such as a laboratory, the control measures taken to minimise releases and limit vapour concentrations to provide a safe atmosphere for the occupants to breathe may remove the

need to designate any area classification. Further guidance may be found in the HSE document *Hazardous area classification and laboratory operations*, available at the UK Health and Safety Executive website.

Further information on the application of area classification to small-scale operations is given in Annex E.

Table 1.1: Capacity thresholds above which area classification is required

	Gas: volume corrected to 1 bar(a) pressure	Liquefied flammable gas	Flammable liquid at a temperature above its flash point
Inside	50 litres	5 litres	25 litres
Outdoors	1 000 litres	100 litres	200 litres

Whilst these figures are only guides, for inventories below these values, it is up to the user to determine the extent of hazards and necessary safe distances. These figures rely on the use of good practice. It is up to the user to determine the extent of hazard for the materials being stored and handled on the premises.

1.3 APPLICATION OF THIS MODEL CODE

The application of this Model Code and the relevance of each chapter are shown in Figure 1.1 which summarises the area classification procedure.

1.3.1 Other facilities

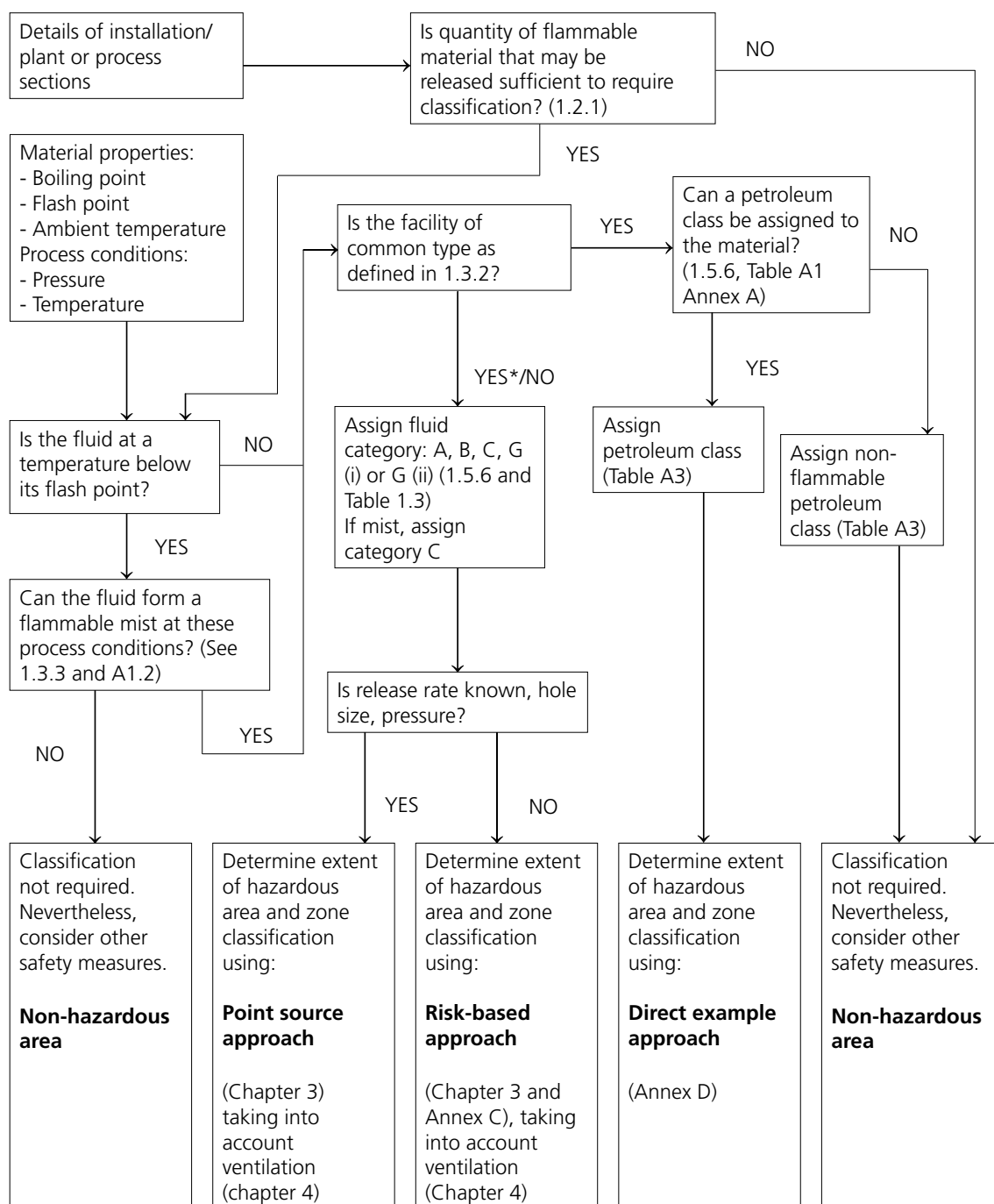
For process streams of less uniform volatility and where there are extremes in temperature and pressure, as in processing plant, a more rigorous calculation methodology should be used, referred to as the 'point source approach'. This methodology is presented in Chapter 3. An optional 'risk-based approach', covered in Annex C, may be used in conjunction with the point source approach when the release rate (hole size, pressure) is unknown. This approach may also be used to revise the extent of hazard radii.

1.3.2 Facilities of common type

Certain facilities of standard layout and design, handling flammable fluids, can be classified directly from typical examples. This is referred to as the 'direct example approach' and is presented in Annex D. These facilities may also be classified using the point source approach.

1.3.3 Mists and sprays

Flammable atmospheres may also be formed if flammable fluids are handled below their flash points. Although such fluids are normally regarded as non-hazardous, if released through a small hole under pressure they are capable of producing a mist or spray. They should be regarded as a category C fluid (see Table 1.3) generating a hazardous area as appropriate. (See Annex A.1.2).



* The point source/risk-based approach can be applied.

Figure 1.1: Application of Code

1.4 AREA CLASSIFICATION MANAGEMENT

Area classification should be incorporated into a company's Safety, Health, and Environmental (SHE) Management System. The person responsible for the coordination of the area classification should be identified and be competent in this field. The work, which requires an interdisciplinary approach, should be carried out by persons who have full knowledge of the process systems and equipment, in consultation with process safety, loss prevention and electrical engineering personnel, as appropriate. Agreements reached on the area classification should be formally recorded, regularly reviewed and kept updated. Records, such as drawings and/or tabulated data sheets, should include details as to the type of protection selected to meet the zone requirements and the apparatus sub-group and temperature class (T class) of the equipment.

In principle, the classification of an area entails consideration of all the actual sources and potential sources of release of flammable fluid present. The procedure of considering individual point sources will be necessary, and this approach is detailed in Chapter 3. In some cases, as shown in Chapter 2, the procedure can be simplified by adopting a standardised area classification diagram (Annex D).

In classifying a new facility or a modification to an existing facility, the area classification should be carried out before the design and layout of equipment are finalised. At this stage, it may be possible to make considerable improvements at little cost. The area classification should always be reviewed and drawings modified, if necessary, on completion of design and before any change is made to existing plants handling flammable fluids.

The company operating a facility has the prime responsibility to ensure that area classification has been carried out on installations handling flammable fluids. This is, within the European Union, a specific legal requirement under the ATEX directive (99/92/EC). Where a facility has been designed and built on a turnkey basis, the plant designers should have carried out an area classification study, and should have passed it over with other documentation to the operating company at the end of commissioning.

1.5 KEY TERMS

1.5.1 Flammable atmosphere

A flammable atmosphere means a mixture, under atmospheric conditions, of air and one or more flammable substances in the form of gases, dusts, vapours or mists in which, after ignition has occurred, combustion spreads to the entire unburned mixture. As the term 'flammable' atmosphere is traditionally used and is familiar to the petroleum industry, it is used throughout this Model Code instead of the term 'explosive' atmosphere that is employed in the ATEX directive. The two terms may be taken to be equivalent and therefore interchangeable.

This Model Code does not apply to:

- Flammable atmospheres outside normal atmospheric conditions or where the oxidant is not air.
- Mixtures of air and combustible dusts.

1.5.2 Area classification

Area classification is the assessed division of a facility into hazardous areas and non-hazardous areas, and the subdivision of the hazardous areas into zones. A hazardous area is defined as a three-dimensional space in which a flammable atmosphere may be expected to be present at such frequencies as to require special precautions for the design and construction of equipment, and the control of other potential ignition sources. All other areas are non-hazardous in this context, though they may, in part or whole, form part of a wider restricted area within the facility in which all work is carried out under special controls.

1.5.3 Zone classification

Hazardous areas are divided into zones based on the likelihood of occurrence and duration of a flammable atmosphere.

Zone 0: That part of a hazardous area in which a flammable atmosphere is continuously present or present for long periods.

Zone 1: That part of a hazardous area in which a flammable atmosphere is likely to occur in normal operation.

Zone 2: That part of a hazardous area in which a flammable atmosphere is not likely to occur in normal operation and, if it occurs, will exist only for a short period.

Non-hazardous areas: Areas that do not fall into any of the above.

Note: The concept of a negligible extent (NE) has been applied by various codes including The Institution of Gas Engineers and Managers. However, this concept is only applied to scenarios of small, low pressure gas releases, where the consequences of ignition have been shown to be negligible. Further guidance on the concept can be found in their guide, IGEM/SR/25 2nd. Ed, *Hazardous area classification of natural gas installations*. The guidance provided by EI 15 for anticipated small flammable releases is either to suggest the use of the small nominal hazardous areas, or that a specific hazardous area is calculated from the release hole size and the release conditions, using the Point Source Methodology.

1.5.4 Source and grade of release

For the purpose of area classification a source of release is defined as a point from which a flammable gas, vapour or liquid may be released into the atmosphere. Three grades of release are defined in terms of their likely frequency and duration:

- Continuous grade release: A release that is continuous or nearly so, or that occurs frequently and for short periods.
- Primary grade release: A release that is likely to occur periodically or occasionally in normal operation i.e. a release which, in operating procedures, is anticipated to occur.
- Secondary grade release: A release that is unlikely to occur in normal operation and, in any event, will do so only infrequently and for short periods, for example as might result from operator error or foreseeable equipment failure, such as a leak resulting from failure of flange gasket, or seal on a pump or valve etc.

The grade of release is dependent solely on the frequency and duration of the release. It is completely independent of the rate and quantity of the release, the degree of ventilation, or the characteristics of the fluid, although these factors determine the extent of vapour travel and, in consequence, the dimensional limits of the hazardous area.

To assist understanding of the boundaries of the definitions of the different grades of release, the following quantities are suggested. A release should be regarded as continuous grade if it is likely to be present for more than 1 000 hours per year and primary grade if it is likely to be present for between 10 and 1 000 hours per year. A release which is not anticipated in normal operation, likely to be present for up to 10 hours per year and for short periods only should be regarded as secondary grade. This assessment should take account of any likelihood of leaks remaining undetected. Where releases are likely to be present for up to 10 hours per year but are anticipated in normal operation (e.g. routine sampling points) they should be regarded as primary grade releases.

Note that the time for which a leak may be present depends on the time taken to detect and isolate the leak. On facilities where operations personnel patrol the plant, the time to detect and isolate a leak may be taken to be, at most, the time interval between patrols (which is typically less than 10 hours). With the continuing trend for de-manning, the patrol interval may increase to greater than 10 hours. This will change the grade of release, unless other measures such as gas detection and remote isolation are provided to reduce the time to detect and isolate leaks.

Multiple secondary grade releases are not considered to constitute primary grade release. This is based on work by Quantra, *Analysis of the HSE hydrocarbon release database for use in EI15*, that shows for typical secondary grade releases, a frequency of approximately one release per year would require approximately 1 000 secondary grade release sources within a hazard radius. Even with this high release frequency, it is unlikely that the duration of release would be in excess of 10 hours without detection.

The allocation of the grade of release should be reviewed in the course of the design stages to determine if practicable and economical design or engineering improvements can be made to reduce the number of continuous and primary grade releases.

Assessment of the grade of release is not always obvious and will require experienced engineering and operational judgement. Examples where continuous, primary and secondary grade sources normally occur on common facilities may be found in Annex D. It should be noted that the respective grades of release, and thereby zonal identification, have already been taken into account.

1.5.5 Relationship between grade of release and zone classification

In most cases, under unrestricted 'open air' conditions there is a direct relationship between the grade of release and the zone classification to which it gives rise, i.e.

- Continuous grade normally leads to Zone 0.
- Primary grade normally leads to Zone 1.
- Secondary grade normally leads to Zone 2.

However, it should be noted that the terms 'grade of release' and 'zone' are **not** synonymous. Although continuous, primary and secondary grade releases will normally result in Zones 0, 1 and 2 respectively, this may not always be true.

Table 1.2 shows the relationship between grade of release and zone for releases in open areas.

Table 1.2: Relationship of grade of release to zone for an open area

Grade of release	Likely to occur in normal operation	Presence of flammable atmosphere hours/yr in open area	Zone
Continuous	Yes	Greater than 1 000	Zone 0
Primary	Yes	1 000 – 10	Zone 1
Primary	Yes	Fewer than 10	Zone 2
Secondary	No	Greater than 10	Zone 1
Secondary	No	Fewer than 10	Zone 2

In a congested, stagnant or enclosed area, a more stringent zone may apply (see Chapter 4).

Some sources may be considered to have a dual grade of release with a small continuous or primary grade and a larger secondary grade (see 3.6.2). Examples of this are a vent with dual-purpose process requirements or a pump seal.

It should also be noted that, whilst a Zone 1 area will often be surrounded by a larger Zone 2 area, there is no specific requirement for this. Where a Zone 1 area is not surrounded by a larger Zone 2 area then the possibility of any large but infrequent release, which would require a larger Zone 2 area, should be considered.

1.5.6 Categorisation of petroleum and flammable fluids

Where the flammable fluid is a liquid, its volatility is a key property, since it will determine the extent of vapour formation from any release. In typical processing units there are variations in temperature, pressure and fluid composition that affect the volatility of material released. The point source approach in Chapter 3 uses five categories of fluids (three liquid and two gas). These fluid categories are defined in Table 1.3, and the determination of category is described in 3.3.3.

Table 1.3: Fluid categories

Fluid category	Description
A	A flammable liquid that, on release, would vaporise rapidly and substantially. This category includes: (a) Any liquefied petroleum gas or lighter flammable liquid. (b) Any flammable liquid at a temperature sufficient to produce, on release, more than about 40 % vol. vaporisation with no heat input other than from the surroundings.
B	A flammable liquid, not in category A, but at a temperature sufficient for boiling to occur on release.
C	A flammable liquid, not in categories A or B, but which can, on release, be at a temperature above its flash point, or form a flammable mist or spray.
G(i)	A typical methane-rich natural gas.
G(ii)	Refinery hydrogen.

In some of the commonly encountered types of facilities, such as those referred to in 2.4.3, the IP Petroleum Class based on flash point is used directly in the area classification process. This approach is used throughout the direct examples in Annex D.

1.5.7 Special terminology – hazard radius

In addition to the standard terminology used throughout this Model Code, presentation of many cases of point source release covered in Chapter 3 uses a base parameter designated the 'hazard radius' which is defined as 'the extent at which the concentration of flammable vapour in air has fallen to the lower flammable limit'. This distance may be increased due to ground effect (see 3.9)

Throughout the guidance, the terms R_1 and R_2 are used to denote the hazard radius. The following convention is adopted:

- In situations where the Zone is defined by a single parameter, the term R_1 is used. This is applied to pressurised releases that do not touch the ground and to liquid pools.
- In situations where the Zone is defined by two parameters, the terms R_1 and R_2 are used. This is applied to pressurised releases that touch the ground resulting in the 'ground effect'. The R_1 is the hazard radius in free air and R_2 is the hazard radius resulting from the ground effect.

For very low vapour release rates, e.g. the breathing from open road tanker hatches due only to ambient temperature variations or evaporation of liquids from small drain channels, the rate of vapour flow may be too low for dispersion modelling to predict the hazard radius accurately. In such cases, a nominal value, based on experience and engineering judgement is suggested.

1.5.8 Other terms

The Glossary at the end of this Model Code should be consulted for the definitions of other terms (see Annex G).

1.6 VENTILATION

Ventilation comprises the movement of air within and through a volume to achieve the introduction of fresh air into, and removal of contaminated air from, the volume and the mixing of air and contaminants within the volume. Chapter 4 provides guidance on how the effect of ventilation is included in area classification.

1.7 BUOYANCY OF RELEASE

Previous editions of this and other area classification publications have made a distinction between heavier-than-air and lighter-than-air gases/vapour, in determining the shape profile of a hazardous region in open areas. However, work contained in EI Research report: *Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids* has shown that, for the majority of releases from pressurised sources in open air, the shape of the jet is not dominated by the relative density of the fluid. This is because a turbulent jet dispersion mechanism prevails and the angle of release and the jet momentum determine the initial direction of the flammable cloud. Furthermore, the diluting mixture in air attains a density very similar

to that of air within a very short distance of the release point, so that buoyancy effects are not a significant factor. Similar considerations apply to fluids which are released at high temperatures and would be buoyant by virtue of their corresponding low densities. Where the release is within an enclosed area, special reference should be made to the conditions in Chapter 4, since lighter-than-air releases may accumulate at high level.

Some common situations where the releases are not pressurised are given in the direct examples in Annex D, but these are all heavier-than-air vapour releases (e.g. from open road-tanker fill covers, sumps and pools etc.). If a lighter-than-air gas or vapour such as hydrogen or methane were released as a non-pressurised cloud or 'bubble', its dispersion would need to be specifically assessed.

In addition, special considerations apply to hydrogen because of its low minimum ignition energy and these are discussed in Annex B.

2 THE TECHNIQUE OF AREA CLASSIFICATION

2.1 INTRODUCTION

The object of the area classification approach is to reduce the probability of coincidence of a flammable atmosphere and an ignition source.

It requires delineation of the facility into hazardous areas and non-hazardous areas. Hazardous areas are further divided into zones which are graded according to the estimated probability of the presence of a flammable atmosphere. There are restrictions within these areas and zones on the use of equipment with the potential to cause ignition. Guidance as to the correct selection of equipment is provided in *EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas* and in fuller detail by the various parts of IEC 60079 series of standards. **In these documents the term 'explosive atmosphere' is used as a synonym for 'flammable atmosphere'.**

The area classification, based on the process fluids and conditions and the type and location of equipment, must be carried out **before** the choice of appropriately certified electrical equipment can be made.

2.2 DATA REQUIRED FOR THE ASSESSMENT

Information must first be assembled which, according to the complexity of the installation, can include:

- (a) A process flow diagram showing flows, temperatures and pressures.
- (b) The material properties (e.g. diesel and its flash point, gas group and T class – see 2.6) and process conditions (temperature and pressure).
- (c) Flash points or, where more complex conditions requiring a point-source release approach apply, the boiling ranges or other relevant physical characteristics of the fluids handled that will enable the fluid category, as defined in 1.5.6 and Annex A, to be determined. These data will also be required to determine the apparatus sub-group and T class (see *EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas*).
- (d) Where relevant, a piping and instrumentation diagram would also indicate drain/sample points etc. and line/valve sizes (for example for processing plant).
- (e) A layout drawing with typical plans and elevations showing the position of all equipment, including operational vents to atmosphere, drain/surface water systems, storage areas and tanker loading areas. In addition, this should show sources of ignition such as heaters, roadways with unrestricted access, flares, workshops, hot work areas etc.
- (f) Knowledge of the equipment features and the mode of operation.
- (g) Ventilation details, considering whether open, congested, stagnant or enclosed area(s) (see Chapter 4). For congested or enclosed areas, the positions of openings such as doors, windows and inlets/outlets will be needed. The location of below-grade areas, such as pits and pipe-trenches, should also be specified.

2.3 APPLICATION

Given the imprecision inherent in area classification it is not considered good practice, even in an open area, to denote small pockets of non-hazardous areas within a general hazardous area unless these are a special feature of the design, e.g. a ventilation protected enclosure, or unless such a release has different flammability characteristics e.g. in terms of gas group or T class (see 2.6). Likewise, it is normally not necessary to determine the hazardous area that would arise from each individual source of release when this would not influence the overall zone boundary.

In carrying out such a hazardous area assessment, by either the point source approach (2.4.1), or the direct example approach (2.4.3) the following basic principles should be considered:

- (a) When classifying a new facility or modifying an existing one, the area classification should be carried out **before** the design and layout of equipment is finalised, as at this stage it may be possible to make considerable improvements at little cost and even some saving.
- (b) The area classification should be reviewed, and modified if necessary, on completion of design or before any significant change is made to an existing plant or to the category of flammable fluids that are to be handled.
- (c) Vents and drain points from vessels and instruments can influence the boundary of the overall Zone 2 hazardous area. As the exact locations of these may not be known when the initial hazardous area drawing was prepared, the hazardous areas as derived should be drawn from the extremities of the equipment or pipework containing the vent or drain point.
- (d) Where facilities such as storage, pumps or loading and discharge facilities, handle a number of materials, the area classification should be based on the most volatile anticipated.
- (e) The basic guidance set out in Chapter 3 and Annex D, except where otherwise stated, relates to open area conditions with good ventilation that ensures natural dispersion of releases to atmosphere. These correspond to typical onshore facilities consisting of structures located in the open, and should be applicable to some offshore facilities.
- (f) Where less well ventilated or enclosed situations occur, typically in offshore installations and in certain onshore situations, guidance on the relevant ventilation condition should be obtained from Chapter 4.
Good practice is to consider whether it is possible to avoid continuous or primary grade releases in reduced ventilation locations such as sheltered or enclosed areas. Likewise, the area classification will be simplified if it is possible to avoid a layout that, by obstruction, would create a sheltered area within a nominal open hazardous area.
- (g) In some cases where a sufficient 'straight line' separation distance cannot be achieved between the potential sources of release and ignition source, the inter-positioning of a suitably dimensioned imperforate firewall may be practical (see 4.2.4.1). Alternatively, it may be possible to enclose the potential sources of release and/or ignition sources. However, the effects of reduced ventilation on the zone classification will need to be considered (see 4.5).
- (h) The relevance of the risk-based approach when the release rate is unknown (see 2.4.2).

2.4 AREA CLASSIFICATION APPROACHES

This Model Code presents methodologies to be used in area classification. The point source approach can be used for all situations:

- Where the release hole size is known, the hazard radius can be read from tables within the Model Code.
- Where the secondary grade release rate is unknown, the release rate and hazard radii are calculated using the risk-based approach.
- The direct example approach, which can be used in limited cases for common facilities.

Figure 1.1 illustrates how to select the appropriate approach to be used.

2.4.1 Point source approach

For installations or processes (due to variabilities of temperature, pressure, equipment and the degree and type of ventilation) the extent of flammable release that would occur may vary greatly making individual assessment necessary. This is known as the 'point source approach'. The release rate of a flammable fluid is required in order to apply this methodology. A step-by-step procedure is provided in Chapter 3.

2.4.2 Risk-based approach

For systems where the release rate is of an unknown, unspecified and variable quantity, the risk-based approach is proposed to determine the hole size to be used for a secondary grade release. A secondary grade release, as defined in 1.5.4, is one which would not be anticipated to occur during normal operation. Examples include failure of pump/compressor seals, leaks from valves and flanges, or operational error (see Annex C – Part 2).

2.4.3 Direct example approach

Some arrangements of generic industrial equipment handling common flammable materials may be classified directly from typical examples. Such arrangements include drilling, workover and wellhead sites, tank storage (both upstream and downstream), road and rail car loading and unloading, container filling and filling station forecourts. Typical classification should follow the approach in 2.2. Direct examples for these arrangements are presented in Annex D.

However, this approach should only be applied when the facility under consideration does not differ significantly from the direct example in terms of layout, type of equipment, class of flammable fluid or the pertinent temperature, pressure or ventilation state.

Individual ancillary items (e.g. pump sets, vents, sampling and drainage points, pig launchers and traps, sumps, interceptors and separators and surface drainage) associated with generic facilities covered in Annex D, but not shown in the diagrammatic examples, should be assessed according to the point source approach (see 2.4.1).

2.5 THE AREA CLASSIFICATION DRAWING

Area classification records can comprise detailed drawings with notes and/or can be in the form of tabulations. The area classification drawings should be in sufficient scale to show all the main items of equipment and all the buildings in both plan and elevation. The positions of all openings such as doors, windows and ventilation inlets and outlets, and utility entries if not sealed vapour-tight should be included, as the careful positioning of these openings can affect the sizing of related external hazardous areas.

Records should be marked up to show the boundaries of all hazardous areas and zones present using the shading convention adopted in IEC 60079-10-1, shown in Figure 2.1. It is acceptable to indicate any requirement for small local zones/areas, e.g. around pumps and control valves, in a note on the drawing. The final area classification should include a record of all additional supporting details as outlined in 2.2.

Note: It is necessary to clearly distinguish regions on the drawing where different gas properties prevail (e.g. hydrogen with a gas group IIC) on part of a drawing where mainly hydrocarbons are present. This may be illustrated using half-width hatching for the 'hydrogen' region although individual operators may have a different approach.

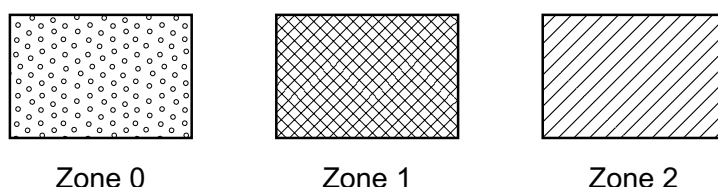


Figure 2.1: Hazardous area zone classification shading convention

The drawings and/or notes should indicate where the classification depends on the correct operation of a dedicated ventilation arrangement. It should consider and indicate the effect of failure of such an arrangement.

The preparation of the area classification drawing provides an opportunity to verify that the coverage of all sources of release has been comprehensive. It also provides an opportunity for smoothing zone boundaries to remove unmanageable detail. For example, it is not good practice to denote small pockets of non-hazardous areas within a general hazardous area. It may be desirable to adopt physical plant features, e.g. roads or access ways, as a readily defined zone boundary line, provided the zone boundary from any source is within these limits.

The drawings should be kept up-to-date to take account of:

- new or modified equipment;
- changes in installation protection;
- experience in operation of the installation;
- changes in method or frequency of operations, and
- reclassification as a result of measurements in and around hazardous areas.

2.6 APPARATUS SUB-GROUP AND TEMPERATURE CLASS (T CLASS)

To select equipment appropriate to the zone classification, the apparatus sub-group and T class should be determined during the area classification, based on the flammable substances that can be released, and this information added to the drawing and/or records.

When applying this, the effect of abnormal operations, for example startup and shutdown, should be considered, since such operations may affect the composition of any substances released and hence their flash points and/or auto-ignition temperatures. However, it may be reasonable to ignore any such abnormal composition if it is expected to exist within the

plant for less than 1 % of the time, say 100 hours per year, and provided that there is no continuous or primary grade release during this period. Secondary grade sources are not likely to release during such a period.

When a release is a mixture of substances, the most restrictive apparatus sub-group and T class should be specified. If gases belonging to more than one electrical apparatus sub-group and T class are present in non-overlapping areas then it is acceptable to show different groups and classes.

In considering wide boiling range mixtures or mixtures of gas and liquid, the apparatus sub-group should be based on the properties of the gas or vapour that would be released. For example, in the case of a gas oil hydro-treating process unit in a refinery, it should be based on the hydrogen-rich recycle gas. In areas where hydrogen may be present, such as battery rooms, the classification should be gas group IIC and T class Tl. See Annex B for a discussion of hydrogen-containing releases.

Further guidance, including the apparatus sub-group and T class appropriate to particular flammable fluids, can be found in *EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas*.

3 THE POINT SOURCE APPROACH FOR CLASSIFICATION OF INDIVIDUAL SOURCES OF RELEASE

3.1 SCOPE

This chapter covers all facilities. Typical hazard radii are provided, using the results of dispersion modelling published in *EI Research report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*. The direct examples in Annex D may refer to this section for vents, spills etc. and where conditions at sites do not meet those stated in the direct examples, hazard radii used should be consistent with this chapter.

The area classification of point sources is determined using calculated hazard radii together with either the physical geometry (e.g. a pit) or the shape factors shown in Figure 3.6 to form a three-dimensional envelope of the hazardous area. The hazard radii in this Chapter are for the condition of open area natural ventilation and are valid within the process conditions given.

Generally, process plant will constitute a Zone 2 area inside plant boundaries, within which there may be local Zone 1 and, more rarely, Zone 0 areas. Zone 2 areas inside plant boundaries will generally be made up of zones associated with flanges and valves, with larger zones associated with other process equipment (e.g. pumps and compressors).

Where a release rate (hole size and pressure) is unknown, a risk-based approach may be used, as outlined in Annex C Part 2. The risk-based approach provides a means of adjusting release frequency and hence hazard radii, to fit specific process scenarios.

It should be noted that where a hazard radius is greater than 30 m, the size of the release is generally larger than that considered for area classification purposes, and consideration should be given to measures to minimise the size of release (see 1.2)

3.2 EXPLANATION OF THE 'POINT SOURCE' CONCEPT AS USED IN THIS MODEL CODE

Release sources evaluated under this category are referred to as 'point sources'. Some are true point sources such as with flanges, vents, drains, sample points, pool spills; other equipment items, such as pump units, are composed of an assembly of several individual point sources. Determination of hazard radii using the 'point source' approach entails consideration of each individual point source.

3.3 METHODOLOGY

The factors determining the extent of the hazardous area from a point source include the vaporising potential of the fluid release, the degree of ventilation and the rate or volume of the release.

The methodology involves the following steps:

- identify point sources and associated release conditions;
- determine grade of release;
- determine fluid category;

- establish zone classification;
- determine hazard radii;
- determine hazardous area, and
- where appropriate, combine the hazardous areas from different point sources.

3.3.1 Identify point sources

The first stage in the area classification of a plant or facility is the identification of the point sources, which typically include valves, flanges, vents, sampling and drainage points, instrument connections, releases from rotating machinery such as pumps and compressors, and any areas where spillage from these sources could collect.

In well designed, operated and maintained facilities, such point sources are usually secondary grade releases with a limited number of primary and continuous grade releases.

3.3.2 Determine grade of release

In principle, the classification procedure entails the consideration of all actual and potential sources of flammable release. All continuous and primary grade sources of release should be identified and assessed to determine the extent of the resulting Zone 0 and Zone 1 hazardous areas; wherever possible by design, they should be reduced both in number and extent.

The extent of vapour travel, and hence the hazard radii for each point source to be assessed, will be a function of the fluid characteristics and vapour-forming conditions during release, including mass or mass rate and the rate of vaporisation.

3.3.2.1 Determination of the grade of release

The definitions of continuous, primary or secondary grades of release in 1.5.4 and Annex G align with other codes of practice and standards. They are independent of the degree of ventilation or the nature and volatility (vaporising potential) of the fluid, the rate/volume of the release, or any other physical aspects.

In assessing the grade of a release the following points are pertinent:

- (a) In the case of operationally controlled releases e.g. sampling and drain points, most (if not all) vents, filter cleaning and pig receiving operations, no one grade of release is applicable since the operational frequency chosen will determine whether the equipment release should be graded as primary or continuous. Such a decision can usually be made at the planning stage.
- (b) For releases that are not operationally controlled (e.g. accidental leakage from equipment) a secondary grade of release is applicable. An assessment of hole sizes from equipment (e.g. pumps, compressors, piping systems, etc.) has been undertaken (see Annex C Part 2, Table C13) and incorporated in specific subsections of 3.7. As an alternative, equipment-specific hole sizes based on manufacturer, industry or company specific data may be used.

3.3.3 Determine fluid category

The fluid category for each point source may be determined using Tables 1.3 (Chapter 1) and Annex A.

3.3.4 Establish zone classification

The zone classification (i.e. Zone 0, 1 or 2) is a function of the grade of release, duration of flammable atmosphere and the degree of ventilation. See 1.5.3 to 1.5.5 and Chapter 4.

3.3.5 Determine hazard radii

The procedure for determining the hazard radii is dependent upon the grade of release (whether primary, continuous or secondary) due to the difference in the nature of the releases. Whereas continuous and primary grade releases are releases at known rates because they have been anticipated and designed for, secondary grade releases are typically leaks due to equipment failure and the hole size has to be estimated by e.g. using a risk-based approach.

Having determined the grade of release, Figures 3.1 and 3.2 should be used to determine the procedure for establishing the hazard radii. R_1 and where applicable R_2 .

3.3.6 Determine hazardous area

Having determined the hazard radii, they are then used to obtain the three-dimensional form and extent of the hazardous area envelope (see 3.9 and Figure 3.6), taking into account the various ventilation situations described in Chapter 4.

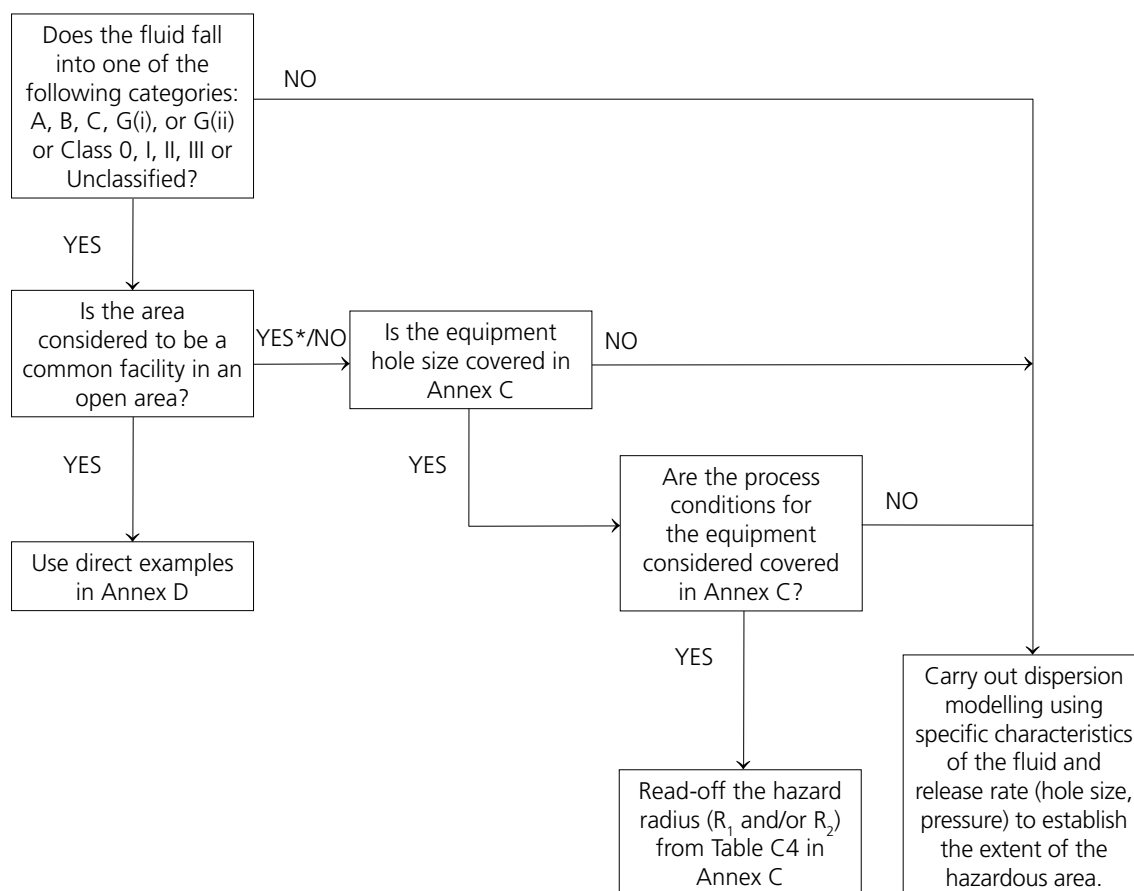
3.3.7 Combine, where appropriate, the hazardous area from all point sources

In cases where there may be multiple point source releases in close proximity e.g. within the battery limits of a refinery process unit, consideration should be given to combining the hazardous areas from individual point sources, which could increase the release grade applicable to the common area. For secondary grade sources of release, it is often only necessary to consider those sources located towards the periphery of a plant to determine the outer boundary of the overall Zone 2 area since the area inside the battery limits is taken to constitute a general Zone 2. If individual potential release sources extend the boundary to the extent that it causes a problem, consideration should be given to redesign to reduce the hazard radius.

Should the equipment layout be such that it is not possible to assign a general Zone 2 area, then the hazardous area provided by each secondary grade release source or group of release sources should be determined.

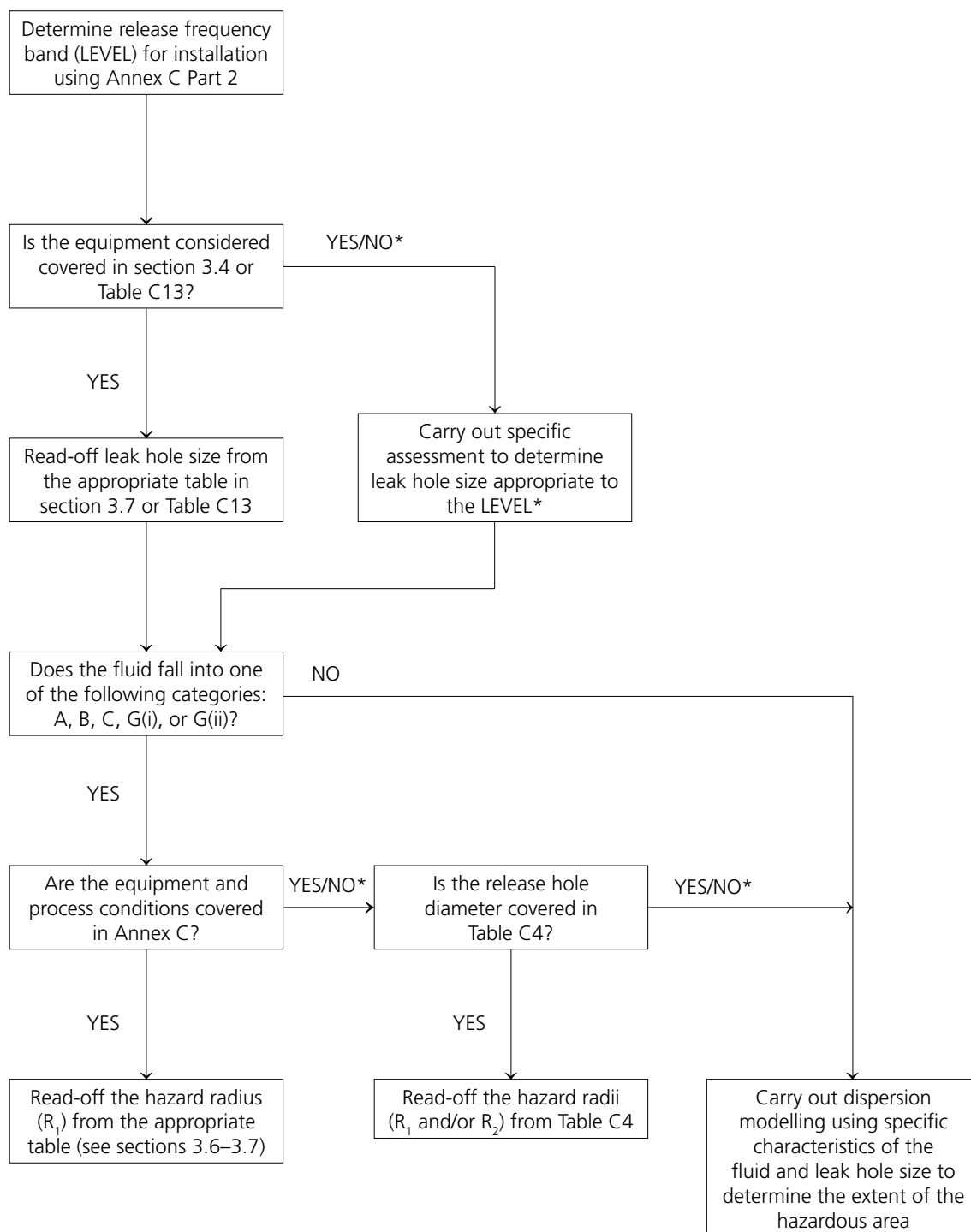
Subject to any restrictions caused by reduced ventilation within enclosed areas (see Chapter 4), the hazardous areas will mainly therefore be Zone 2 with several smaller Zone 1 areas.

Zone 0 areas will normally be restricted to the interior of equipment containing both flammable fluids and air, e.g. vapour collection lines, tank interiors, open sumps and any substantially continuous vents.



* The point source/risk-based approach can be applied

Figure 3.1: Procedure for determining the hazard radii for primary and continuous grade releases



* Optional, irrespective of whether covered in 3.6; modelling may always be used to determine frequency of leak hole size and hazard radius.

Figure 3.2: Procedure for determining the hazard radii for secondary grade releases

3.4 POINT SOURCES

The following section provides typical hazard radii (R_1) for the following standard equipment/arrangements:

- equipment drains and liquid sample points;
- vents;
- piping systems;
- pig receivers and launchers;
- liquid pools due to spillage;
- sumps, interceptors and separators;
- pits or depressions;
- surface water drainage systems;
- pumps, and
- compressors.

Hazard radii (R_1 and, where appropriate, R_2) for process conditions different to those given here may be determined by calculation or by reference to Table C4 in Annex C Part 1. Shape factors for the hazardous areas are determined using 3.9 and Figure 3.6.

3.5 APPLICATION OF THE POINT SOURCE APPROACH TO DIRECT EXAMPLES

If direct examples of area classification of common facilities in open areas, provided in Annex D of this Model Code are being used then, where required, these should be supplemented by use of the point source approach, where appropriate for equipment not specifically covered by the direct example approach.

3.6 EQUIPMENT WHERE RELEASE HOLE SIZE IS KNOWN AND INDEPENDENT OF RELEASE FREQUENCY

3.6.1 Equipment drains and liquid sample points

Gaseous sample points or drain points from gas systems should be considered as vents. Good practice is to prevent abnormal release following a failure of the sampling system. For example, double valving would prevent a loss of containment from a single sample valve being accidentally knocked, jamming or frozen open. For other release points not individually covered (e.g. cleaning or filter changing openings), the classification approach should follow the principles outlined, noting the comparability of the release quantity and fluid category with those of other listed examples and whether the equipment is to be drained to an open or closed system.

Systems should be designed to avoid draining or sampling of category A or B liquids direct to atmosphere. Where possible, such liquids should be cooled before draining or sampling to avoid the release of vapour. Where this is not feasible (e.g. with LPG), equipment drains should be connected to a closed system. Samples should be taken in a closed container such as a sample bomb. When the lines and bomb are not purged to a closed system there should be an additional hazardous area extending from the point of purging.

On some process drains the fluid normally drained is non-flammable, but flammable material could ultimately be drained. A typical example is water draining from a process vessel. The hazardous area should be based on the flammable liquid unless measures are in place to eliminate release of flammable liquid.

3.6.1.1 Point sources

The point sources are equipment and instrument drains, and liquid sample points which release flammable fluids direct to atmosphere.

3.6.1.2 Grade of release

Drains and sample points should be regarded as primary grade release sources in normal operation. Situations where there is potential for a larger secondary grade of release due to an accidental occurrence e.g. the valve remaining open, or the container being overfilled, should also be assessed.

When classifying a drain point used only at shutdown, the fluid category should be based on the material at shutdown and the drain should be regarded as a secondary grade source of release.

3.6.1.3 Determination of hazard radii

The primary grade of release from a sample point in an outdoor area will be dependent on the type of sample point being used and the sampling procedure.

If a sample point handling a category B or C fluid is allowed to run to grade before and after the sample is taken, a pool may form and so the zone extent should be determined as per 3.8.1. It is assumed that this type of sample point would not be used for a category A fluid.

To determine the extent of the primary hazardous zone, use Tables C3 and C4 where the flow rate of material is the key factor rather than the hole size in determining the hazardous radii. The reason for this is that a quarter turn valve on a sample point is likely to be cracked open rather than opened fully to take the sample so that the pipe bore is not relevant in determining the rate of release. Some proprietary sampling systems have restrictions to limit this release rate.

For a sample point where the sample container is connected to the system, such as a bomb or enclosed sampler, a primary release should not occur.

For all sample systems, the release size for a secondary release should be determined by identifying the likely failure modes. These include a passing valve, the valve sticking or freezing open, a valve being knocked open, a sample bomb connection leaking or a sample container being spilled. It is recommended that as many of these failure modes are mitigated against as possible through the use of sprung valve handles, double valves and the positioning of sample points above appropriate drains.

The secondary hazard radii may be determined using Tables C3 and C4 in Annex C Part 1. However, more accurate hazard radii may be determined using dispersion models which take into account the actual characteristics of the process fluid and the physical characteristics of the drain/sample point.

3.6.2 Vents to atmosphere

3.6.2.1 Determination of hazardous area

It is recommended that specific dispersion modelling of actual process fluids and venting conditions is used to determine the vertical and horizontal extent of the hazardous area.

For some vents there may be a continuous or primary grade release during normal operation, with a larger, secondary grade release during abnormal or emergency operations. The hazardous area for such a vent is defined by a Zone 0 or 1 hazardous area corresponding to the continuous or primary grade release, surrounded by a larger Zone 2 hazardous area corresponding to the secondary grade release. The following sections give the hazard radii for unimpeded vents for specific conditions based on the results of dispersion modelling published in *EI Research report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*, (see also Annex C Part 1). Where any impedance to venting exists (e.g. weather plates) the hazard radius is likely to be greater.

It is assumed that the vents provided are remote from or elevated sufficiently above any structure such that the dispersion regime is not affected by interaction with structures.

If the calculated hazard radius is greater than 30 m, then the size of release is greater than that normally considered for area classification purposes (see 1.2)

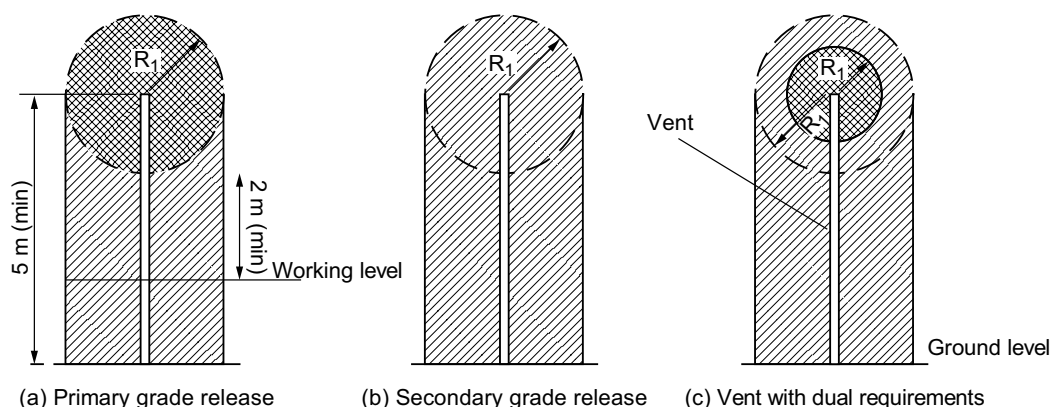
3.6.2.2 Low pressure tank vents

Freely vented tanks will allow vapour/air mixtures to be released in normal operation. The pressure within the tank fluctuates slightly above and below atmospheric due to changes in temperature or during tank filling. Such vents from tankage vapour space should be regarded as primary grade sources of release with the extent of the Zone 1 hazardous area dependent on the vapour emission rate (or filling rate). For low venting rates under very low or zero wind conditions, material may flow down the outside of the vent pipe. It is therefore appropriate to extend the hazardous area beneath the Zone 1 area down to ground level. However, due to the low frequency of such conditions occurring, this need only be classified as Zone 2. Table 3.1 together with Figure 3.3 gives the hazardous area around the vent from the storage of a typical category C fluid.

Table 3.1: Hazard radius (R_1) from tank vent for category C fluid

Vent rate (Nm ³ /hr.)	Vent diameter (mm)			
	50	80	100	250
250	2	2	2	3
500	3	3	3	4
1 000	3	4	4	6
2 500	4	5	5	6

(Based on Table 10(b) in Addendum 1 of *EI Research report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*.)



Notes:

1. Vent pipe opening should have at least R_1 metres of free space around it in all directions to allow dispersal of vapour, and be away from open windows, doors etc.
2. For road tanker delivery systems the height of a vent should be greater than the possible liquid level in the road tanker to prevent overspill, and in no case less than 5 m above ground level.
3. To avoid a Zone 1 area affecting personnel, the height of the vent should be at least $R_1 + 2$ m measured from any working level within R_1 metres of the vent stack.
4. In (c), R_1 for Zone 1 is for the primary grade release and R_2 for Zone 2 is for the secondary grade release.
5. Where vents are not routed to the atmosphere, or discharge at an angle, the user should model the discharge from the specific vent configuration.

Figure 3.3: Typical hazardous areas around tank vents**3.6.2.3 Low pressure process vents**

Process vents may release mixtures of hydrocarbons undiluted with air, or gas/vapour mixtures with air of any composition. The hazard radii for process vents have been calculated for a matrix of venting rates and vent diameters for both a lighter and a heavier-than-air release and are given in Table 3.2 to be used in conjunction with 3.9 and Figure 3.6. The zone classification will depend on the grade of release. To avoid ground effects (R_2) and effects on personnel, it is recommended that process vents discharge at a height greater than $R_1 + 2$ m from ground or the nearest working level. For specific vent conditions not given in Table 3.2, actual hazard radii may either be calculated or, for a conservative hazard radius, the hazard radius for the next greater vent size may be used.

Table 3.2: Hazard radius (R_1) for process vents

Vapour emission rate (Nm ³ /h)	Category Gi (19g/mol)			Category Gii (7g/mol)			Category A (48g/mol)		
	Vent diameter (mm)			Vent diameter (mm)			Vent diameter (mm)		
	50	100	250	50	100	250	50	100	250
10	1	2	4	2	3	5	3	5	6
100	1	2	4	2	3	5	3	5	6
250	2	2	4	2	3	5	3	6	6
500	2	2	4	2	3	5	4	5	7
1 000	3	3	4	3	4	5	5	5	9
2 500	4	4	5	5	5	6	7	7	13
(Based on Tables 13 and 15 in Addendum 1 of EI Research report: <i>Dispersion modelling and calculations in support of EI code of safe practice – Part 15: Area classification code for installations handling flammable fluids.</i>)									
Note: High pressure (sonic (>0,8Barg)) vents will require the user to carry out specific modelling.									

3.6.2.4 Instrument vents

The diameter of the smallest item on the vent line (e.g. the line, vent or restriction orifice) should be used to determine the hazard radius.

Gaseous sample points should be designed so that the flow rate is less than 10 m³/hr under ambient conditions. It may be necessary to fit a flow restrictor on high pressure systems.

Hazard radii may be determined using data given in Table C4 in Annex C Part 1.

3.6.2.5 Pressure relief valves

Pressure relief valves lifting at their design condition are covered under area classification, with any discharge being a secondary grade of release. However, the design of relief valve vents should ensure they are discharged at an appropriate location. To cover any fugitive emissions that may occur, a Zone 1 of nominal 1 m radius should be placed around the end of any discharge point. Where a process relief valve lifts at its design intent the extent of the resultant Zone 2 should be determined.

3.6.3 Pig receivers and launchers

Operating procedures should ensure that pig receivers and launchers are isolated from the line and vented down to atmospheric pressure and drained before they are opened. Therefore, the design of the pig receiver and launcher closure should be such that it cannot be opened while under pressure; this may be achieved by an interlock with the vent and drain system, and the provision of properly maintained pressure gauge(s). Doors on traps and launchers require a stringent inspection and maintenance regime to ensure they remain leak-tight under pressure.

Vents and drains should discharge to an appropriate location and the hazard radii from any vents, equipment drains or open sumps should be estimated using the appropriate section of this chapter.

3.6.3.1 *Grade of release*

Releases from pig receiver and launcher doors during pigging operations should normally be regarded as primary grade release. The hazardous area should be classified in accordance with 1.5.5.

3.6.3.2 *Determination of hazard radii*

With an interlock system as recommended here, the openings on the receiver and launcher should be regarded as minor release sources and it is suggested that a nominal hazard radius of 3 m is assigned. This distance may be reduced to 1,5 m if the equipment is purged with nitrogen or water washed through before opening.

On pig receivers and launchers without an interlock system on drains, vents and the door, there should be an additional Zone 2 from the equipment door. The hazard radii should be determined; Table C4 in Annex C Part 1 may be referred to as a guide to the hazard radii depending on the possible release size, process conditions and release height. However, note that for equipment on large and/or high pressure lines the resulting hazard radius may well be much larger than that generally considered for area classification.

3.6.4 **Pits or depressions**

Where a pit or depression exists in a hazardous area or adjacent to it, without itself containing a source of release, it should be regarded as inadequately ventilated and therefore classified as Zone 1.

3.6.5 **Surface water drainage systems**

Oily water and chemical sewers can become contaminated with flammable fluids during normal operations, and openings to atmosphere should therefore be regarded as sources of primary grade release.

Normal open surface liquid drain channels, typically not more than 0,5 m wide, handling flammable materials should have a nominal hazardous area of 1 m horizontal radius each side and 1 m radius vertically above them. Where there is a possibility that a hot material (e.g. category C fluid above 50 °C or steam condensate) could enter the drain in sufficient quantities to produce an appreciable flammable vapour, or that category A or B materials could inadvertently enter, these distances should be extended to 3 m.

The vaporisation rate from any vents on drain systems should normally be low and a Zone 1 hazardous area should be drawn in accordance with Table 3.2 assuming a vent rate of not more than 10 m³/hr at ambient conditions.

The possibility of abnormal releases (e.g. hot water) entering the drains and the vaporisation of volatile liquids should be considered. Based on this it may be appropriate to define a larger Zone 2 area for the vent using dimensions given in Table 3.2 consistent with the higher vapour emission rate.

The possibility of vapour release should always be considered when access chamber covers are lifted or temporarily removed.

Note: Drainage systems for distribution installations should be designed with consideration given to the principles detailed in *EI Model code of safe practice – Part 2: Design, construction and operation of petroleum distribution installations* and *EI Environmental guidelines for petroleum distribution installations*. In the case of filling stations, the design should give consideration to the principles detailed in *APEA/EI Design, construction, modification, maintenance and decommissioning of filling stations*.

3.7 EQUIPMENT WHERE HOLE SIZE IS FREQUENCY DEPENDENT

3.7.1 Pumps

The two considerations when determining hazard radii for rotary e.g. centrifugal, gear, lobe etc. pump seals releases are (a) fugitive emissions in normal operation and (b) larger releases as a result of seal failure.

All types of single seal and dual seals without barrier fluids or interspace leak detection can give rise to fugitive emissions which should be regarded as primary grade release sources associated with a Zone 1 hazard radius of 0,3 m when pumping a category A or B fluid. Dual seals with either a monitored barrier fluid system or interspace leak detection system should not give rise to fugitive emissions and so Zone 1 need not be specified. If a packed gland pump seal is being used, the Zone 1 sphere of radius 0,3 m should apply regardless of fluid category to account for the design of the packing to require more lubrication from the process media. It is recommended that packed gland pumps are not used on category A or B fluids.

The larger releases which may occur due to seal failure are covered by the hazard radii based on the secondary grade releases as shown in Table C13 in Annex C Part 2. Single seal pumps should have an external throttle bush which is designed to limit the release rate in the event of seal failure.

For packed gland sealed reciprocating pumps, a 0,3 m radius Zone 1 should be placed around the packing gland to account for fugitive emissions during normal operation. Any secondary release resulting from a failure of the gland packing seal should be determined from the hazard radii based on the secondary grade releases as shown in Table C13 in Annex C Part 2.

For seal-less units, such as magnetic drive, canned or piston-diaphragm pumps which have double diaphragms with interspace leak detection, the equivalent hole size for the flange leak should be used.

Where adequate ventilation is necessary to gain the Zone 2 classification for seal failure it is recommended that pumps should have high integrity seals (dual seals and throttle bush or better).

3.7.1.1 Point sources and grades of release

Point sources on pumps include their seals, vents, drains, valves, piping flanges and filters/strainers. They are normally all secondary grade release sources because flanges are broken, filters opened and vents and drains are operated infrequently. Seal failure resulting in appreciable release of liquid is also unlikely. Should any of these operations be carried out frequently then the item should be regarded as an individual primary grade release source.

3.7.1.2 Estimation of leak hole size and determination of hazard radii

In the absence of manufacturer data, hazard radii may be calculated using the hole diameters given in Table C13 in Annex C Part 2. These values are based on failure data of single seal pumps with throttle bushes and high integrity type pumps.

Secondary grade releases from single seal pumps without throttle bushes are generally greater than from single seal pumps fitted with throttle bushes or from high integrity type pumps. Also, single seal pumps without throttle bushes will generally have a larger hole size should the seal fail. Consequently, at the LEVEL I release frequency, the LEVEL II equivalent hole size should be used to represent a leak from a single seal pump without a throttle bush.

3.7.2 Compressors

Piping on compressor systems may be subject to vibration. The hazard radii recommended in this section assume that failure of joints and nozzles due to vibration are considered to be catastrophic failures, and hence outside the scope of this Model Code.

3.7.2.1 Point sources and grades of release

Point sources on compressors include glands, seals and flanged joints, which should all be regarded as giving rise to secondary grade releases.

3.7.2.2 Estimation of leak hole size and determination of hazard radii

If available, manufacturer data for seal failure leak rates should be used to establish the hazard radii equivalent to a LEVEL I release. If manufacturer data are not available, Table C13 in Annex C part 2 should be used.

Having determined the hole size, the hazard radius (R_1) (and, where required, R_2) may be determined using Table C4 in Annex C Part 1. Any vents or relief valves on flammable material duty, including vents from the seal and lube oil system, should discharge to a closed system or to atmosphere at an appropriate location. The hazardous area around the vent should be based on 3.6.2. Similarly, liquid from knock-out drums or pulsation dampers should preferably drain through a vented degassing pot to a closed drain system.

The hazard radii for drains and vents should be determined independently of the compressor, based on 3.6.1 and 3.6.2 respectively.

3.7.3 Piping systems

Pipework designed and constructed to ISO 15649 *Petroleum and natural gas industries – Piping*, ANSI/ASME B31.3 *Process piping*, or equivalent that is fully welded should not be considered as a source of release.

Small bore pipework is particularly prone to accidental damage and possible release to atmosphere, and therefore support and bracing of small bore connections should be considered to ensure area classification is not required.

3.7.3.1 Point sources and grades of release

Joints are regarded as primary grade releases when they are broken during normal operation (e.g. for spade changing). The area classification should be determined based on guidance in 1.5.5.

Leakage is unlikely on infrequently used valves and these should therefore be regarded as sources of secondary grade releases. On frequently used valves (including control valves) with packed glands, where leakage is more likely due to wear on the packing, these should be regarded as producing an additional primary grade release with a nominal radius of 0,3 m.

3.7.3.2 Estimation of leak hole size and determination of hazard radii

Hole sizes for flanges and valves are given in Table C13 in Annex C Part 2. Having determined the hole size, the hazard radius (R_1) may be determined using Table C4 in Annex C Part 1.

3.8 LIQUID POOLS, SUMPS, INTERCEPTORS, SEPARATORS

3.8.1 Liquid pools due to spillage

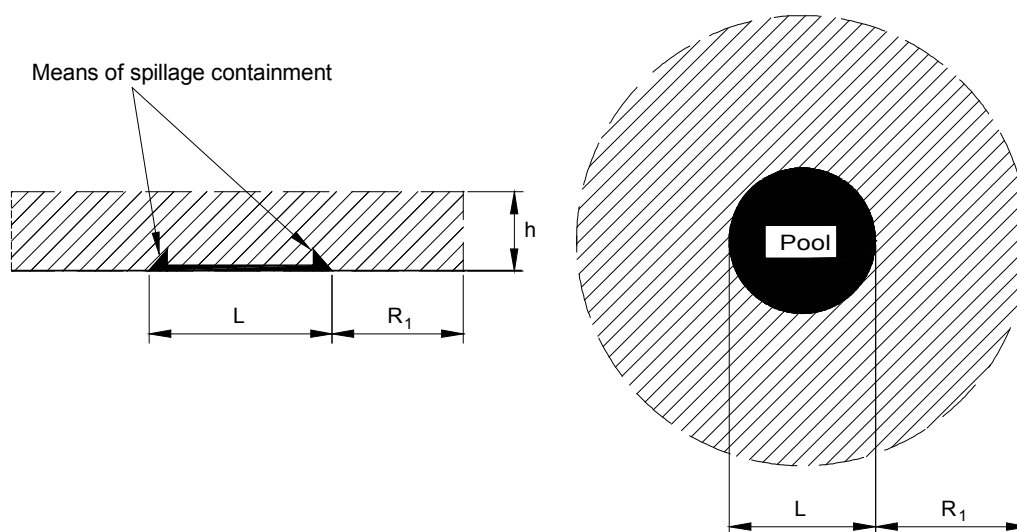
Plant design should minimise any liquid spills. However, inadvertent spills can occur, and this may influence the size and area of an overall Zone 2 boundary.

On each facility the positions at which a spillage is credible should be identified. If they cannot be eliminated by reasonably practicable changes to plant design, then the size and position of the likely pool should be estimated.

In an open area the resulting hazardous area should normally be classified as Zone 2 because plant design should prevent spillage in normal operation.

The size of the hazardous area should be determined from data in Table C6 and Figure 3.4. These distances are based upon calculations in *EI Research report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*.

For category A and B liquids the size of the hazardous area will often be determined by the initial flash vapour release rather than the evaporation from the on-ground accumulation. In normal circumstances pool size will be constrained by physical barriers e.g. bunds, kerbs and drainage channels etc. In the absence of any physical constraint, the user should model the pool to the maximum spread size, although it is likely that the size of the pool will be very transient and of a shrinking pool diameter. It is suggested a pool depth of 0,1 m is used, particularly for sumps and interceptors.



Notes:

R_1 is the extent of the hazard radius from the edge of the pool in the same direction.

L is the equivalent diameter of the pool.

h depends on the temperature of release and the volatility of the material released. For category C fluids up to 50 °C, h is nominally 1 m; for volatile fluids or at elevated temperatures, a nominal height, h , of at least 3 m should be applied.

Figure 3.4: Liquid pool due to spillage

3.8.2 Sumps, interceptors and separators

For the purposes of this Model Code a sump means a vessel or pit, open or vented to atmosphere, used to collect flammable liquid, usually as a result of deliberate draining. Other liquids, e.g. water, may enter the sump but the flammable liquid is normally an appreciable part of the total liquid entering. A sump is usually below ground level.

In contrast, interceptors and separators are vessels or pits open or vented to atmosphere, used to separate flammable liquids from other non-flammable liquids (typically water) in which the flammable liquids are not present in appreciable quantity. Typically, they are found on the main oil/water effluent system from a facility.

Open sumps, interceptors and separators should preferably be located in an open area. For vented sealed sumps, interceptors and separators the hazardous area should be drawn from the vent in accordance with 3.6.2, based on the expected flow-rate.

Sumps and vessels covered with e.g. ventilated concrete slabs or metal grills should not be regarded as sealed vessels but should be treated as open sumps.

3.8.2.1 *Grade of release*

Where sumps, interceptors or separators are intended to contain flammable liquids they should be considered as continuous or primary grade sources depending on the frequency with which flammable material is expected to enter.

They may be regarded as a secondary grade source when flammable material enters infrequently e.g. during major maintenance at intervals of about two years or longer, or as a result of equipment failure e.g. tube failure in a cooling water system or in a major spillage.

The possibility of more frequent, unplanned maintenance should always be considered.

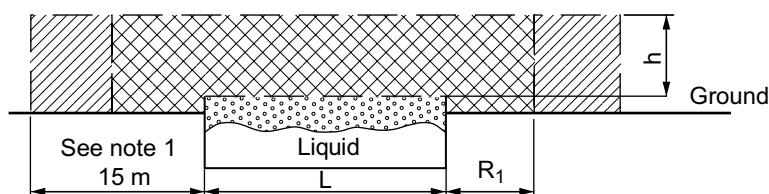
Where there is a possibility that, in normal operation, appreciable quantities of flammable gas or materials in fluid categories A or B can enter, a degasser installed upstream of the sump or a sealed but vented sump is recommended. Otherwise the system should be designed so that normally category C fluids only (below 50 °C) can enter.

3.8.2.2 *Determination of hazardous area*

The typical layout of sumps, interceptors and separators is shown in Figure 3.5. The space within the walls of an open sump or to ground level, whichever is higher, should be regarded as an enclosed area. For a primary grade source of release it should be classified as Zone 0 and for a secondary grade source of release as Zone 1.

The hazardous area above ground and outside the sump walls should be drawn as shown from the periphery of the sump using the appropriate hazard radius (R_1) obtained from Table C6 for the sump equivalent diameter, using a depth of 0,1 m, where it can be assumed that entry of category C fluids only (at temperatures substantially below their boiling point) can occur. Generally, this assumption can be made only in the case of installations such as storage and tankage areas. This area should be classified as Zone 1 or Zone 2 depending on whether the source is primary or secondary grade.

Where there is a possibility that a hot material (e.g. category C fluid above 50 °C or steam condensate) could enter the sump in sufficient quantity to produce an appreciable flammable vapour, or category A or B fluids could inadvertently enter, a hazard radius (R_1) of at least 15 m should be used with an increased vertical distance of 3 m.



Notes:

1. Zone 2 is applicable where there is a possibility of a secondary grade release and the hazard radius R_1 for the primary grade release is less than 15 m.
2. Dimensions from Table C6. h depends on the temperature of release and the volatility of the material released. For category C fluids up to 50 °C, h is nominally 1 m; for volatile fluids or at elevated temperatures, a nominal height, h , of at least 3 m should be applied.
3. For a secondary grade release, the areas shown as Zones 0 and 1 would be Zones 1 and 2 respectively.

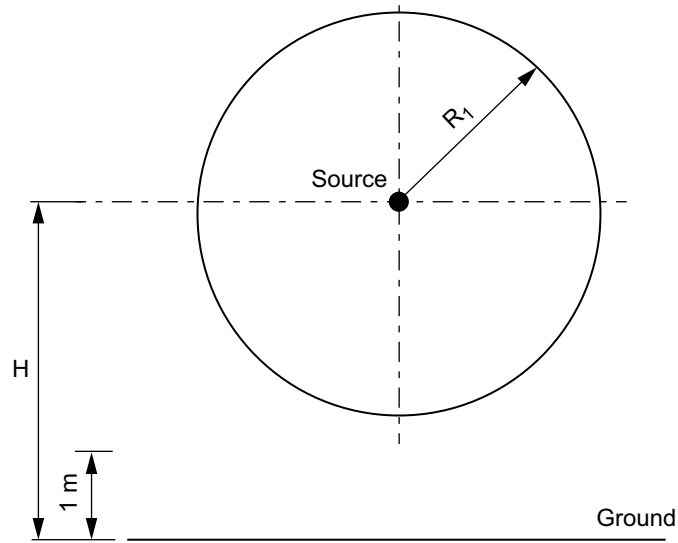
Figure 3.5: Open sump – zoning for primary grade release

3.9 SHAPE FACTORS AND HAZARD RADII FOR PRESSURISED RELEASES

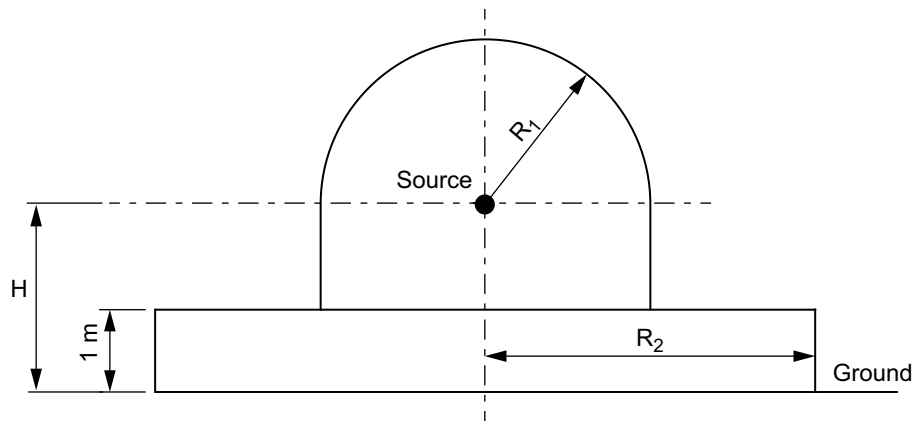
The relationship between the hazard radius R_1 (as determined in the preceding sections) and the full three-dimensional envelope of the hazardous area is determined using Figure 3.6. The shape factor depends upon the height and orientation of the release and the hazard radius. The key features are:

- Releases below a height (H) of 1 m are influenced by the ground and have a hazard radius R_2 .
- Releases above 1 m, but at heights below the hazard radius $R_1 + 1$ m are influenced by the ground if the release is directed downward and passes below 1 m.
- Releases at a height above the hazard radius $R_1 + 1$ m are independent of the ground.

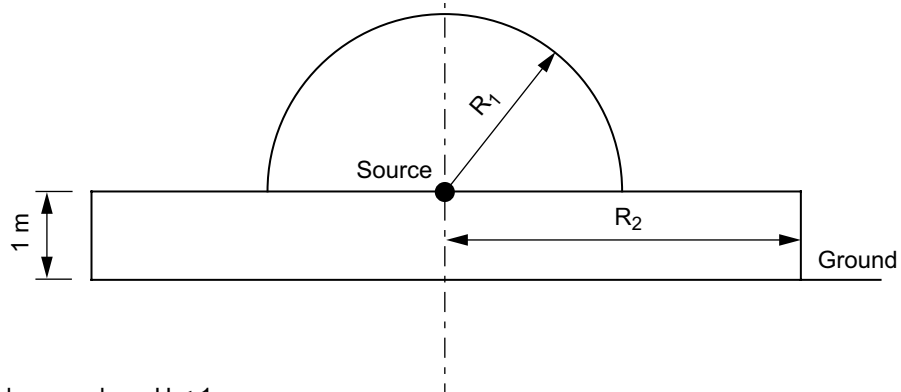
The ground effect radius R_2 can be determined using Table C4 in Annex C Part 1. The ratio R_2/R_1 decreases as release pressure increases due to improved mixing.



(a) Releases where $H > R_1 + 1\text{ m}$



(b) Releases where $1\text{ m} < H < R_1 + 1\text{ m}$



(c) Releases where $H < 1\text{ m}$

Figure 3.6: Shape factors for pressurised releases

4 EFFECT OF VENTILATION ON AREA CLASSIFICATION

4.1 INTRODUCTION

Ventilation comprises the movement of air within and through a volume to achieve the introduction of fresh¹ air into, and removal of contaminated air from, the volume, and the mixing of air and contaminants within the volume.

Gas or vapour released to the atmosphere will eventually be diluted by dispersion in free air until its concentration is at a safe limit (below the lower flammable limit (LFL)). The time taken for this to occur and the size and spatial location of the gas cloud depends upon the nature of the release, the vapour properties such as density relative to air, the movement of the air and the presence of turbulence to promote mixing. Where the release is not into completely free air (i.e. not into an open area) then the air flow, or ventilation, is also a factor in determining the rate of gas or vapour dispersion. However, it is important to also consider, in a sheltered or obstructed open area or enclosed area, whether any recirculating motions may lead to a gradual accumulation of gas or vapour over time (which may impact upon the zone classification (see 1.5.3)).

The processes of movement of air and removal of contaminated air occur, to differing degrees, in any ventilation process. The limiting cases are:

- Efficient displacement without mixing. Here a contaminant is swept out of a volume without much mixing. This is sometimes referred to as 'displacement ventilation'. By inference, high concentrations of contaminant may exist within the volume and be emitted from it.
- Gradual displacement with good mixing. Here any contaminant is well-mixed through the volume. A large part or all of the volume can become contaminated, while displacement removes the mixture of air and contaminant. A special case of this is sometimes referred to as 'dilution ventilation'.

The ventilation of an enclosed space was typically quantified by a single parameter – the number of air volume changes per hour. However, ventilation is a complex subject and in carrying out an assessment it is necessary to consider both the type (natural or artificial) of ventilation and, within the type, the degree of ventilation to be provided, its reliability and the consequences of its failure. These considerations need to take account of the potential size of release and the affected volume which may be a subdivision of a larger volume, for example a bay in a large warehouse.

The main disadvantage of using a method based on number of air changes per hour (acph) is that the requirement is not related to the size of the release and therefore the same level of ventilation is required for an enclosure containing potentially large releases as for one that may contain very small releases. Also, a definition of adequate ventilation in terms of an air change rate will require huge volumes of air to be moved to achieve the criterion in large enclosures. However, in practice, the dispersion of releases which are small relative to the size of the enclosure will behave in a similar manner to a release outdoors and therefore the air change rate is not critical to the gas dispersion.

Ventilation effectiveness for the purposes of area classification has been assessed by the Health & Safety Laboratory (HSL), with the results of this investigation contained in HSE

¹ 'Fresh' implies free from flammable contaminants.

Research report RR993 *Technical input on ventilation effectiveness for area classification guidance E115*. The revision of this Chapter has been informed by the findings contained in this publication.

It shows that providing sufficient ventilation to limit the average concentration to 25 % LFL for a specified release in an enclosed area generally achieves the objective of adequate ventilation for a Zone 2. Although this demonstrates that the overall level of ventilation is sufficient, it does not demonstrate that the local ventilation is adequate.

It is the local ventilation effectiveness that will determine how the release disperses. Therefore, it is important that the 25 % LFL criterion should be a minimum requirement, as other factors need to be taken into account. If such a criterion is only just met then this indicates further effort may be required to ensure that the ventilation local to the release point is adequate.

While use of the 25 % LFL criterion does achieve this objective, large gas clouds may still occur, particularly in large enclosures. In these cases consideration should be given to measures to reduce the potential leak size through e.g. use of alternative equipment or improved maintenance regimes.

In this chapter, the classification of ventilated enclosed spaces and outdoor areas, including open, congested and stagnant areas, is discussed. For further background information on ventilation in enclosed areas containing sources of release, and examples on how to determine adequate ventilation rates (for a number of example scenarios), see Annex F.

Figure 4.1 can also be used to determine how to assess the degree of ventilation for any given situation.

4.2 OUTDOOR AREAS

An outdoor area can be considered as an area which may have regions of varying levels of congestion, but where vapour is dispersed by wind and natural convection. There are three categories of outdoor area: open area, congested area and stagnant area.

The area classification exercise is simplified if all continuous and primary grade sources of release can be located within open areas. However, congested and stagnant areas cannot always be avoided in the layout of facilities, particularly where there are space limitations.

4.2.1 Open area

An open area can be considered as those outdoor areas where the degree of congestion does not restrict the effects of the wind or natural convection and the air speed through the area is the same as that away from all obstructions. Obstructions such as dense pipework, other buildings, natural obstructions, e.g. trees and cliffs, may preclude an area being considered 'open' unless it can be shown that air speeds through the area are not significantly affected by the obstructions.

In open areas, the point source hazard radii (Table C.4) apply from the point of release.

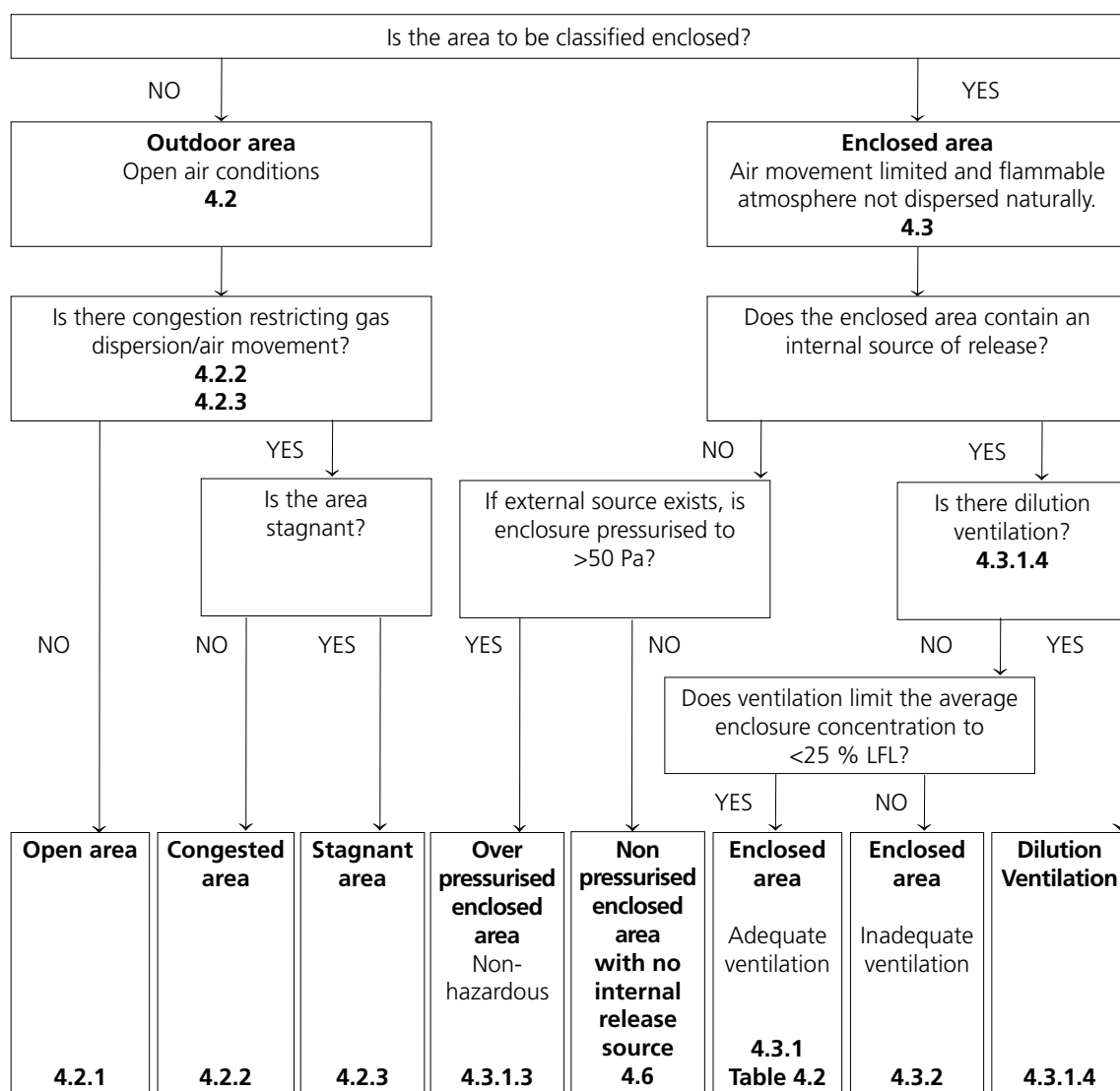


Figure 4.1: Procedure for assessing type and degree of ventilation

4.2.2 Congested areas

A congested area can be considered as an outdoor area, where owing to the degree of congestion, diluting effects of the wind can be considered restricted and less than that in an open area. Typical examples of congested areas include:

- Closely spaced pipework and/or equipment within 'open' plant; the extent of the congested area is defined by:
 - (a) the footprint of the equipment at ground level, and
 - (b) the maximum height of the equipment and pipework, but excluding any individual isolated items such as process columns or stacks.
- Process structures having a roof but only partial walls (e.g. compressor houses, road tanker loading areas).

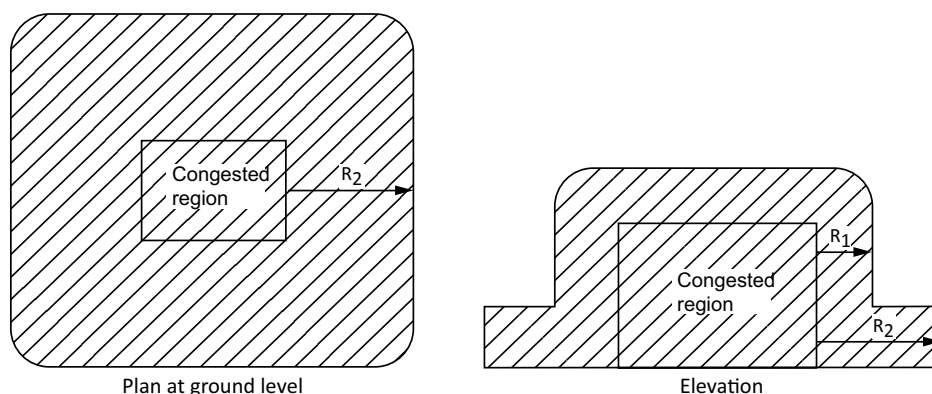
- Storage areas where air movement is obstructed by the tankage walls or bunds etc. See Figure D4.

The degree of congestion will restrict air speeds through that area to below the unobstructed wind speed at that height, but typically air speeds are greater than 0,5 m/s. The reduced air speeds will potentially slow the dispersion of flammable releases and the flammable material could fill the congested volume.

In such cases the whole of the congested area should be zoned based on the category of release plus an area outside the congested area defined using the point source hazard radii (Table C.4) around the congested region, see Figure 4.2.

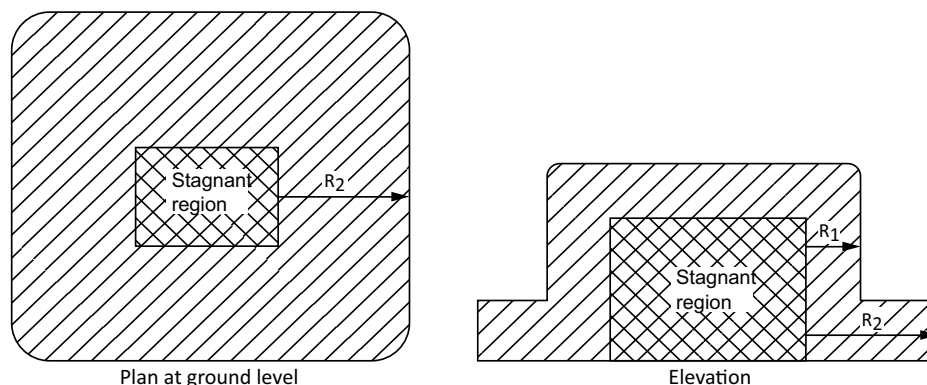
4.2.3 Stagnant areas

When the level of congestion severely limits the air speed through the area such that the air speeds are not typically greater than 0,5 m/s, the area should be considered as a stagnant area and zone classification should be determined using a similar approach to an inadequately ventilated enclosed area (see 4.3.2). The stagnant area itself should therefore be zoned using a more severe classification than would be the case for an open or congested area, and a Zone 2 should be applied outside of the stagnant area defined by the point source hazard radii (Table C4) see Figure 4.2. Stagnant areas may include below grade areas, pits, pipe trenches and the annular space between the tank wall and the outer protective wall as shown in Figure D5.



- (a) Congested region as given in 4.2.2
- Assuming secondary grade release within the congested region.
 - R is for maximum release case.

Figure 4.2: Zoning of congested and stagnant regions

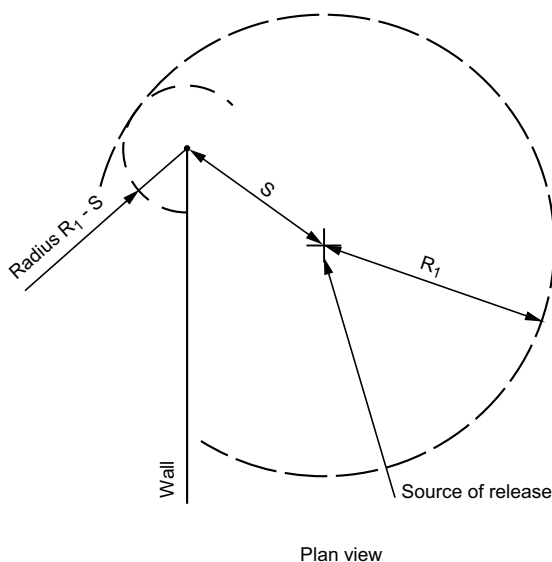


- (b) Regions deemed to be stagnant as given in 4.2.3.
- i) Assuming secondary grade release within the stagnant region.
 - ii) Use of R_1 & R_2 will depend on height above ground level.

Figure 4.2: Zoning of congested and stagnant regions (continued)

4.2.4 Obstacles to free air movement

Obstacles may impede local air movement, and this may enlarge the extent of the hazardous area and possibly increase the severity of the zone classification. However, it is also noted that some obstacles such as dykes, walls and ceilings may limit the movement of a gaseous release, reducing the extent of the hazardous area. Examples of this use of a 'deflection wall' are provided in 4.2.4.1.



Notes:

1. R_1 is the hazard radius obtained from Chapter 3, see Fig. 3.6 for any ground effects.
2. The wall should extend to at least the full vertical height of the hazardous area if it is to be used as a deflection wall.
3. S is the shortest distance from the source to the edge of the retaining wall.

Figure 4.3: Extent of hazardous area around wall producing sheltered area

4.2.4.1 *Effect of a fire or deflection wall on hazardous area*

Where limitation of space will not allow a source of ignition (electrical or otherwise) to be located outside a hazardous area, the alternative may be to separate them with an impermeable deflection wall. This would be sized so that the equivalent vapour travel distance around the ends of or above the wall will be at least equal to the straight line distances derived from the standard assessment of the hazardous area dimensions. This widely used rule of thumb is illustrated in Figure 4.3. It has no formal technical basis, and its adoption depends on engineering judgement and past experience.

Such a deflection wall should be constructed to an adequate fire resistance standard and be located so as to minimise the flame engulfment of facilities containing a significant quantity of flammable material, and may form part of the site boundary or the wall of a building. The wall should be on one side only of the facilities containing the source(s) of release, allowing free ventilation in all other directions.

Examples of this application include the bund wall around a tank compound (see Annex D), the reduction of separation distances as in LPG facilities, the separation between power-driven equipment and process equipment by a gas-tight wall with a drive shaft seal, and numerous cases in the compact circumstances of an offshore platform.

4.3 **ENCLOSED AREAS**

An enclosed area can be considered as any building, room or enclosed space within which ventilation, either mechanical or natural, is required to dilute releases of flammable gas. The adequacy of this ventilation needs to be assessed to ensure that it is appropriate for the releases that may occur within the space and the zone that is applied within the enclosed area. This excludes enclosed spaces within process plants such as storage tanks, interceptors etc.

This section applies to buildings, rooms or enclosed spaces where there are potential sources of release of flammable vapour or gases. In most cases there will also be openings in the walls, through which flammable gases or vapour may migrate as a result of draughts, convection currents, or disturbance caused by equipment within the enclosed area.

It is generally easier to ensure that flammable gases removed from an enclosed area are diluted and released safely if the ventilation system is designed to extract air from the building. In this case, it is also possible to monitor the air exhaust from the building, and to take additional precautions if flammable gases or vapours are detected. Special precautions are also necessary if the ventilation system fails, e.g. all unsuitably certified electrical equipment may be automatically isolated.

The extent of any classified area beyond the openings in a building containing release sources is effectively a function of the dilution of the release within the building. The extent of the classified area beyond the building need not be greater than the hazard radius equivalent to the release in open air as calculated using the methodology in Chapter 3. A reduction in the hazard radius may be estimated based on the anticipated level of dilution of the release within the building.

Continuous or primary grade releases should not be discharged within enclosed areas, but should be piped directly to an external safe location through ducting. With suitable ventilation design, any Zone 1 areas should be of very limited extent. However, where continuous primary releases are unavoidable, reference should be made to 4.2.

Gas detection or other means of prompt identification of releases of flammable materials should be considered. No general guidance can be given about the size of buildings or structures that suit these options, as other factors such as the prevailing wind conditions at the site and whether the building is heated also need to be considered.

In a building with a well-mixed atmosphere, into which a constant flow of flammable gas or vapours is released, a simple calculation allows the steady state concentration of gas to be calculated. If the release is intermittent, or controlled before the steady state concentration is reached, the maximum gas concentration will be less. A worst case scenario is for the whole building containing release sources to reach a hazardous concentration. There may then be the potential for ignition to occur externally to the building, producing a flame that burns back into the building, creating a confined explosion within the building. It is therefore essential that the potential for gas build-up to concentrations above 25 % of LFL be avoided within the bulk atmosphere in the building.

Enclosed areas are further qualified by the degree of ventilation, i.e. adequate or inadequate.

4.3.1 Adequate ventilation

The objective of adequate ventilation is to ensure that the zonal classification can be maintained throughout the building, i.e. a building containing secondary grade releases can be properly classified as Zone 2. If there were primary grade releases then adequate ventilation would maintain the building as a Zone 1.

In a large building it may be possible to classify some parts as non-hazardous while other parts may be classed as Zone 1 or Zone 2. The extent of the 'local zones' should be determined since the background concentration may be higher than outdoors. As a rule of thumb (where the average concentration is maintained at less than 25 % LFL) the extent of the hazardous area given in C4 should be multiplied by a factor of 2, unless other precise methodologies are used.

4.3.1.1 Ventilation flow rates

It has been shown that limiting the average concentration to 25 % LFL in the enclosure generally achieves the objective of the ventilation for a Zone 2, as defined in 4.3.1. The ventilation rates provided in Table 4.1 are the minimum levels of ventilation required to ensure that the average concentration stays below 25 % LFL. However, this only demonstrates that the overall level of ventilation is sufficient and it does not demonstrate that the *local ventilation* is adequate. It is the local ventilation effectiveness that will determine how the release disperses. The 25 % LFL criterion should be regarded as a minimum requirement as other factors need to be taken into account. If such a criterion is only just met, then this is a good indication that further measures may be required to ensure that the ventilation local to the release point can be considered adequate.

For examples on how to determine adequate ventilation flow rates see Annex F.

Table 4.1: Ventilation flow rates required to dilute average gas concentrations to 25 % LFL

Fluid category	Release pressure (bar(a))	Ventilation flow rate to dilute to 25% LFL (m³/s)			
		Release hole diameter			
		1 mm	2 mm	5 mm	10 mm
A	6,8	1,2	4,6	29	(120)
	10	1,5	5,9	37	(150)
	50	3,4	14	86	(340)
	100	4,9	20	130	(490)
B	5	1,0	4,0	25	(99)
	10	1,5	5,9	37	(150)
	50	3,5	14	86	(350)
	100	4,9	20	130	(490)
C	5	1,0	3,8	24	(94)
	10	1,4	5,7	36	(140)
	50	3,3	14	82	(330)
	100	4,7	19	120	(470)
G(i)	5	0,1	0,3	1,7	6,8
	10	0,2	0,6	3,5	14
	50	0,8	3,0	19	(75)
	100	1,7	6,6	41	(170)
G(ii)	5	0,2	0,6	3,3	13
	10	0,3	1,1	6,6	27
	50	1,4	5,4	34	(140)
	100	2,7	11	67	(270)
Notes 1. The cases in brackets are those for which area classification may not be appropriate for outdoor releases. The hazard radii of these releases may exceed 30 m and therefore are by default also inappropriate for area classification indoors. This should be avoided. The data are provided for information only. 2. At the fluid storage temperature of 20 °C the nominal discharge pressure of 5 bar(a) is below the saturated vapour pressure of Fluid category A. The saturated vapour pressure (6,8 bar(a)) was used to calculate the discharge rate and dispersion. 3. The required ventilation flow rate should take account of any primary release within the enclosure.					

4.3.1.2 Effect of obstructions on dispersion

The build-up of flammable gas or vapour following a release of a pressurised fluid can be strongly affected by local obstructions to the resulting jet and to the ventilation flow. The presence of objects near to the point of release can lead to local confinement or congestion that can lead to dissipation of the momentum of the release or recirculation leading to less rapid dilution compared to a release in an unobstructed location within the enclosure.

In addition to increasing the gas cloud volume, local confinement and congestion are likely to increase the persistence time of a release and increase the chances of flammable gas leaving the zoned area. In such cases, it may not be possible to describe the space as adequately ventilated based solely on the overall ventilation rate of the enclosure.

An initial assessment of the effects of congestion and confinement can be made by using a factor to take into account the efficiency of mixing (ϵ). This factor is effectively applied as a safety factor to the required ventilation rate to demonstrate adequate ventilation. In cases where the release is small relative to the enclosure volume, e.g. for large enclosures, then the gas cloud build-up only depends weakly on the overall ventilation rate and the efficiency of mixing factor cannot be used to highlight cases where the local ventilation is not adequate.

For assessing the adequacy of the ventilation for releases in confined or congested areas, the measured ventilation rate should be multiplied by ϵ and an assessment made as to whether this ventilation rate still meets the 25 % LFL average concentration criterion in Table 4.1. For designing the required ventilation for a new process, the ventilation flow rate from Table 4.1 should be divided by ϵ and this value should be the target ventilation rate. For unconfined/non congested enclosures $\epsilon = 1$. As a rule of thumb for a moderate level of confinement/congestion a factor of $\epsilon = 0,5$ should be used and for higher levels of confinement/congestion a value of $\epsilon = 0,3$ should be used. If the 25 % LFL criteria are met taking into account the efficiency of the mixing factor, then this indicates that the global ventilation rate is adequate. The adequacy of the local ventilation should then be checked, for example by carrying out smoke tests.

4.3.1.3 *Over-pressurisation*

Over-pressurisation is a ventilation system for a room or other enclosed area. It may allow a room that contains no sources of release to be classed as non-hazardous although it is connected to another room classified as Zone 1 or Zone 2 or, in conjunction with adequate ventilation, allow a room surrounded by a Zone 1 to be classified as Zone 2, if it contains only secondary grade sources of release.

Applied to an enclosed area it is a form of artificial ventilation and should be designed so that a pressure differential of at least 50 Pa (5 mm WG) is maintained between the enclosed area and any hazardous area. In the event of loss of pressure differential, a warning, both audible and visual, should be provided. If direct access is provided between the pressurised area and a Zone 1 area, air lock doors should be installed between the areas and the space between them classified as a Zone 1.

As air locks may allow pressure differentials to be briefly lost, some delay on the activation of any shutdown of electrical equipment may be considered. Such a delay following an audible alarm should not normally exceed 30 seconds.

4.3.1.4 *Dilution ventilation*

In some restricted circumstances, a very high flow of air applied to a space, perhaps within some larger enclosed area, may be used to dilute and remove much larger releases than those controlled by local exhaust ventilation (LEV). A forced draught fan may be used in conjunction with an extractor fan. This arrangement has been used inside the acoustic enclosures for gas turbines, where the complex pipework provides many potential sources of release, but the source of ignition created by the hot surface of the turbine cannot be prevented. The objective is to dilute even quite large releases very close to the source, so that the consequences of ignition are acceptable. The maximum size of release to be controlled needs to be carefully assessed and each installation will be different, so generalised advice on ventilation rates cannot be given. Further guidance is available in ISO21789 for gas turbine enclosures.

4.3.1.5 Local exhaust ventilation (LEV)

LEV systems may be used for controlling the release of flammable gases where there are a small number of readily identifiable release sources.

With a suitable design, LEV should prevent any flammable atmosphere forming except in the immediate vicinity of the release source. An enclosed area may then remain classified non-hazardous, even though primary grade releases are present. More commonly, the enclosed area will be classified as Zone 2, to allow for various possible secondary grade releases. Where primary grade release sources are present, an audible or visual warning should be provided if the LEV system is not functioning correctly.

LEV may also be provided to control releases that are generated by operator action, e.g. sample points. In this case, the extraction may only need to operate during the sampling operation.

4.3.2 Inadequate ventilation

Where adequate ventilation cannot be achieved, then the enclosure should be considered as having inadequate ventilation. Continuous and primary grade sources of release should be avoided in such an area. Inadequately ventilated areas should be classified as Zone 1 since a secondary grade release source may form a localised flammable atmosphere and persist for long periods.

Inadequately ventilated areas should be avoided, particularly where personnel access is required, subject to the Confined Spaces Regulations 1997 (as amended). These require, in addition to the controls on entry, the provision of arrangements for dealing with emergencies including rescue from a confined space. If the ventilation cannot be improved, the use of gas detectors should be considered. When these are installed it should not be possible for any substantial volume of flammable atmosphere to form and persist undetected, allowing safety measures to be taken, as ignition would be very hazardous. If fixed gas detectors are not provided, access should be controlled, and testing of the atmosphere before entry should be required.

4.4 DESIGN CONSIDERATIONS

The recommended design target should be to ensure that the average concentration of a flammable atmosphere within an enclosed area does not exceed 25 % LFL in the event of a prolonged release.

In cases where the release impinges internally within the enclosed area, specialist guidance should be sought because the outcome may be an enclosed area, release and material-specific. It is possible that, in certain circumstances, there is no need to assign a hazardous area beyond any openings in the enclosed area, unless the opening is within the zone immediately surrounding the release location. However, it is recommended that specialist guidance is sought before this is confirmed as the case.

High ventilation rates are likely to cause discomfort to operators dressed for indoor conditions.

The area classification external to an enclosed area should take account of the location of release points relative to openings. Where it is possible for a release to be directed through an opening the hazard radius should be at least R_1 as determined by Table C4, and may extend to R_2 in the event of interaction with the ground.

It should be noted that large gas clouds may still occur, particularly in large enclosed areas. In these cases consideration should be given to measures to reduce the potential leak size.

In some cases, depending on the size of the leak relative to the enclosed area and taking into account the average concentration throughout the enclosure, it may only be necessary to classify part of the enclosed area as Zone 2. In other cases it may be more appropriate to classify the whole enclosure. If exhaust ventilation is used, the outlet should normally be at high level (depending on density of gas released), and in particular it is important that it is sited so that recirculation of flammable gases back into any other building or structure is not possible, even under very still air conditions. Any ventilation system should be designed to be reliable, with, e.g. automatic start-up of a standby fan in the event of primary fan failure, or a means to isolate ignition sources in the enclosed area. Power for the main and standby fans should not be from a common supply unless there is a back-up supply. However, whilst total failure of the ventilation system is unlikely, it is foreseeable and therefore consideration should be given to the actions described in 4.4.1 – 3.

4.4.1 Provisions for loss of adequate ventilation

An enclosed area classified by virtue of having adequate ventilation normally contains only secondary grade sources of release and/or openings into Zone 2 areas. It may sometimes contain small primary grade release sources. On loss of adequate ventilation there will not necessarily be an immediate development of a flammable atmosphere and it may be considered acceptable, subject to monitoring of the atmosphere and of plant conditions, to continue for a short period to operate equipment suitable for the Zone indicated in Table 4.2. Nevertheless, there should be an audible and visible alarm to indicate ventilation loss and a written procedure to cover both the degree of monitoring necessary and the action to be taken if mechanical ventilation fails.

4.4.2 Provision for loss of over-pressure ventilation

An enclosed area with over-pressure ventilation should normally be separated by vapour-tight barriers from adjacent hazardous areas and contain no continuous or primary grade sources of release. Therefore, on loss of over-pressure ventilation the development of flammable atmospheres within the enclosed area is likely to be slow and it is not normally necessary immediately to isolate electrical equipment. Nevertheless, there should be an audible and visible alarm to indicate ventilation loss and a written procedure to cover the electrical isolation that would be required if the ventilation loss persisted. Where necessary, a master switch should be provided to facilitate the isolation of electrical equipment. In general this should be applied to any equipment not of a type of protection suitable for use in the adjacent hazardous area. Fixed gas detectors should normally be provided. Equipment not suitable for use in a Zone 1 area should be electrically isolated automatically if gas is detected.

4.4.3 Provisions for loss of dilution ventilation

An enclosed area classified as non-hazardous by virtue of dilution ventilation may contain primary grade sources of release and small continuous grade sources of release. If dilution ventilation is the basis of safety, an automatic switch-over to a back-up power supply must be provided. The back-up supply must, as a minimum, operate for sufficient time to enable the plant to be shut down. An audible and visible alarm should be provided.

4.5 EFFECT OF VENTILATION ON CLASSIFICATION OF ENCLOSED AREAS

The classification of enclosed areas is dependent upon the degree of ventilation and the grade and location of the release. Table 4.2 considers the zone classification within enclosures containing sources of release. Figure 4.4 considers the zone classification within enclosures that do not have internal sources of release but that are adjacent to other hazardous areas, arising from external sources.

Table 4.2: Effect of ventilation on zone classification for enclosures with an internal source of release

Grade of internal release source	Ventilation			Over-pressure
	Inadequate ⁽¹⁾	Adequate ⁽¹⁾		
		Zoning local to source ⁽³⁾	Zoning of remaining enclosed area ⁽³⁾	
Continuous	Avoid ⁽²⁾	Zone 0	Zone 1	Not applicable where there is an internal primary or continuous grade of release, but may be applicable in conjunction with adequate ventilation to maintain an enclosed area containing only secondary grade releases as Zone 2 when surrounded by a Zone 0 or 1 hazardous area.
Primary	Avoid ⁽²⁾	Zone 1	Zone 2	
Secondary	Zone 1	Zone 2	none	

Notes:
1. Adequate ventilation means that the ventilation rate as given in section 4.3.1.1 is sufficient to apply the zone classification appropriate for that grade of release.
2. Location of continuous or primary grade sources within an inadequately ventilated enclosed area should be avoided. If it is unavoidable, engineering controls such as local exhaust ventilation must be provided.
3. With a source of small hazard radius, e.g. a sample point, the ventilation locally can sometimes be high enough to prevent the source influencing the classification of the enclosure as a whole. The extent of the zones around sources of release should be determined taking into account the background concentration within the enclosure. As a rule of thumb (when maintaining <25 % LFL) the extent of the hazardous area given in Table C4 for an outdoor release should be multiplied by a factor of 2, unless other precise methodologies are used.

4.6 ENCLOSED AREAS WITH NO SOURCE OF INTERNAL RELEASE WITHIN OR ADJACENT TO A HAZARDOUS AREA

The classification of such enclosed areas will depend on their location and ventilation.

Enclosed areas within a classified area should be given the same zone classification as the external zone (Location A in Figure 4.4).

If a portion of the perimeter of an enclosed area with openings is overlapped by a hazardous area (Location B in Figure 4.4) the following options are listed in order of preference;

1. Remove or reduce the source(s) of release such that the hazardous area does not reach the enclosed area. In this case the enclosed area is designated non hazardous (refer to Location D in Figure 4.4).
2. Seal or move openings such that there are no openings within the hazardous area. In this case the enclosed area is designated non hazardous (refer to Location C in Figure 4.4).
3. Classify the entire enclosed area as per the external zone (refer to Location A in Figure 4.4).
4. Classify the portion of the building within the hazardous area (Location B in Figure 4.4).

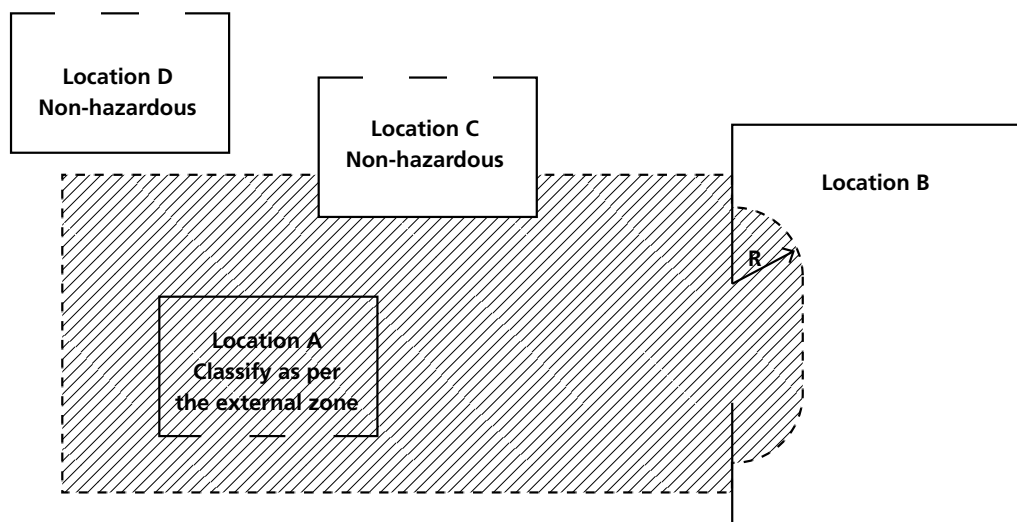
If option four is chosen, the hazard radius R should extend as a minimum into the enclosed area to the extent to which it would do so in the absence of the enclosed area. If sources of release are located in the proximity of openings into the enclosed area (taking into account the dispersion characteristics of the flammable gas/vapour) it may be appropriate to use judgement to extend the zone further into the enclosed area. This may be informed by sections 3.4 and 4.3. If option four is chosen management processes and procedures are required to ensure that the boundary between hazardous and non-hazardous areas is clearly demarcated within the enclosed area (see section 2.5).

If there are no openings within the classified area and the enclosed area is gas tight, the enclosed area is designated non-hazardous (Location C in Figure 4.4).

Enclosed areas adjacent to the classified area are designated non-hazardous but should be located as far as possible from the classified area. (Location D in Figure 4.4)

Note: The air change rate that is required to dilute the gas/vapour concentration down to a safe level within 10 hours to prevent a requirement for a higher zone classification for enclosed areas without an internal source of release located within a classified area (e.g. Location A in Figure 4.4), is approximately one air change per hour (independent of the enclosed area volume). The one air change per hour rate indicates that it is unlikely in most practical situations that gas/vapour would persist for long enough inside the enclosed area to affect the classification. The enclosed area is therefore assigned the same classification as the zone in which it is located.

Enclosed areas located within a classified area, having an internal release source, should be classified as per Table 4.2.



Notes:

Location A	Enclosed area within hazardous area.	Classify enclosed area as per the external zone.
Location B	Enclosed area with a portion of the perimeter with openings within a hazardous area.	See four options described in 4.6.
Location C	Enclosed area with no openings within the hazardous area and the portion of the enclosed area within the hazardous area is gas tight.	Classify as non-hazardous.
Location D	Enclosed area located in a non-hazardous area.	Classify as non-hazardous.

Figure 4.4: Enclosed areas without an internal source of release located within or adjacent to classified areas

ANNEX A

CLASSIFICATION AND CATEGORISATION OF PETROLEUM AND FLAMMABLE FLUIDS

A1 EI CLASSIFICATION OF PETROLEUM, BASED (EXCEPT FOR LIQUEFIED PETROLEUM GASES, LPG) ON CLOSED CUP FLASH POINTS

The EI classes of petroleum (formerly IP classes of petroleum), including the subdivision of Classes II and III products, have been standardised by the EI to govern the handling of petroleum materials throughout the fuels supply chain, covering bulk storage, loading, conveyance, discharge and distribution (see Table A1).

It should, however, be recognised that there is an upper temperature limit, though unlikely to be encountered, in the Class I, II(2) and III(2) classification applications in Annex D, above which they should not be extended; this upper limit is the temperature at which the liquid would boil.

Table A1: EI Petroleum classes

Class 0	Liquefied petroleum gases (LPG)
Class I	Liquids that have flash points below 21 °C
Class II(1)	Liquids that have flash points from 21 °C up to and including 55 °C, handled below flash point
Class II(2)	Liquids that have flash points from 21 °C up to and including 55 °C, handled at or above flash point
Class III(1)	Liquids that have flash points above 55 °C up to and including 100 °C, handled below flash point
Class III(2)	Liquids that have flash points above 55 °C up to and including 100 °C, handled at or above flash point
Unclassified	Liquids that have flash points above 100 °C

Typical examples of petroleum fluids are shown in Table A2.

Table A2: Typical commonly encountered petroleum materials

Petroleum Class and flash point range	Typical examples	Typical flash point (°C)	Typical boiling range (°C)
0	LPGs, ethylene, propylene	Not applicable	Propane -42 Butane -1 Isobutane -12
I <21°C	Gasoline (petrol) Stabilised crude oil Avtag wide cut jet fuel (JP4; Jet B) Benzene Toluene Naphtha Methanol	-45 <21 -25 -11 4 -2 to 10 11	ca. 20 – 205 ca. -1 to 380 + ca. 0 – 220 80 110 30 – 177 65
II 21 – 55 °C	Avtur/Jet A/Turbofuel Kerosine (a) premium grade (b) regular	38 minimum 43 minimum 38 minimum	150 – 240 160 – 280 150 – 280
III >55 – 100 °C	Gas oil/distillate heating oil Automotive diesel fuel	55 + 55 +	250 – 360 180 – 360
Unclassified >100 °C	Atmosphere residues Heavy fuel oils	>100	>350

A1.1 FLASH POINT

The definition of flash point as given in the Glossary (Annex G) is taken as the indicator of the lowest temperature at which, in the presence of air at atmospheric pressure, a flammable liquid will give off a sufficiently rich vapour for ignition to occur in the presence of a source of ignition.

The EI classification system, as in A1, and its subdivision of Classes II and III according to whether the condition of handling is at a temperature below or above the flash point, is in accord with the principle expressed in IEC 60079–10–1 that an explosive gas (vapour) atmosphere generally cannot exist if the flash point is significantly above the relevant maximum temperature of that fluid. However, where materials are released under pressure forming mist or spray, a flammable liquid can be ignited at temperatures far below the flash point.

A1.2 MISTS OR SPRAYS

There is little knowledge on the formation of flammable mists and the appropriate extents of associated hazardous areas. Some of the issues related to the formation and the hazard

of flammable mists are addressed in *Pressurised atomisation of high flash point liquids - Implications for hazardous area classification*, by P.J. Bowen and L.C. Shirvill.

It is important to realise that not every release will form a mist. Secondary grades of release resulting from e.g. leaking flanges, failure of packed glands, etc. will in most cases result in the formation of liquid pools, rather than mists. In these cases, a flammable atmosphere would not form directly from the release unless it impacted upon a hot surface.

This paper concludes that pressure differentials of only a few bars are sufficient to atomise commonly encountered liquids. Generation of mists created by the impact of liquid streams on a surface close to the point of release also appears to be possible. However, it does not make any recommendations for the extents of flammable mists and sprays.

For liquids handled above their flash point the degree of vapour, aerosol, and liquid rain-out is already accounted for within the specific release source term in the dispersion modelling in *EI Research report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*. These have been used to validate the calculation methods described in this Model Code. Thus, where hazard radii have been determined using the point source, or risk-based approach, area classification techniques may be applied normally. Similarly, the hazard radii in direct examples in Annex D incorporate the same calculated mist/rain-out fractions used in the dispersion modelling.

Where flammable liquids are handled under pressure any release will be a mixture of vapour, very small droplets (below 50 microns diameter) that form an aerosol, and more sizable droplets that typically coalesce and rain out as a fluid.

The fraction that exists as an aerosol, or rains out of any release, will be a function of the physical and chemical properties of the fluid (for area classification purposes defined as one of the fluid categories in Table 1.3) and the physical source terms (e.g. pressure, hole size, temperature etc).

Flammable liquids handled below their flash point may be classified non-flammable dependent upon the flash point values set in legislation. When under pressure these liquids may present a flammable hazard due to the potential for formation of a mist or spray. When this is the case, for the purposes of area classification the liquid should be regarded as fluid category C.

The likelihood of flammable mist formation in normal operation, or as a consequence of foreseeable malfunction, should be assessed. The complexity of the factors involved in mist formation make dispersion modelling very difficult and in most cases a qualitative approach based on operational experience and engineering judgement would be appropriate. The flammability of a mist will depend on the amount of vapour present and the aerosol droplet quantity and size; in many cases this will represent only a small amount of the total release. Factors that impact upon the quantity of aerosol droplets, such as release hole diameter, pressure, etc. will impact upon the ignition potential of the mist.

Continuous and primary grade mist releases should normally only be associated with processes where a liquid is being deliberately sprayed e.g. spray painting. Mists require a minimum concentration to be flammable; these concentrations would typically be associated with a cloud that reduces visibility (and is clearly visible), hence releases can be easily identified and may be mitigated.

It is not normally appropriate to classify the inside of a plant designed for controlled combustion of mists (e.g. oil fire boilers) as a hazardous area. The risks of fuel leakage, flame failure, etc. are controlled by the application of relevant design standards.

Where an assessment leads to the conclusion that flammable mist formation is possible, then the source of the release should be contained, vented to a safe location, or managed to reduce the hazard. For example, the fitting of flange guards or demister pads to vents can promote the coalescing of any mist formed, limiting the potential extent of any hazardous area. However, these measures are only practicable in a few specialised applications, and require rigorous control over maintenance activities to ensure that the guards are replaced afterwards.

It is suggested that, where a fluid is more than 5 °C below its flash point, and at atmospheric pressure or under only a few metres, head in a storage tank, it can be treated as non-hazardous; where it is pumped and under pressure, it should be regarded as a category C fluid (see A2), generating a hazardous area appropriate to the type of equipment installed, because of the possibility of mist or spray formation from a small hole or a flange leak.

In applying the EI flash point classification in those cases where it is used with the approach in Chapter 3, and in Annex D, the principles outlined above will take effect.

Further research on mists and sprays is currently being undertaken by an ongoing joint industry project (JIP) administered by the Health and Safety Executive (HSE), but at the time of issuing this Model Code, this research is only in its development stages; however, work completed to date indicates that flammable mists of kerosine are produced at low pressures, circa 1 barg. Further types of materials are under investigation. A literature review RR980 has been completed as part of the JIP and is available from the HSE website.

A1.3 CLASS I PRODUCT

A Class I product such as gasoline, or a gasoline type component or a stabilised crude oil, with a low flash point, will always produce a vapour in the flammable range in air even at temperatures below ambient. Facilities handling Class I products will always require to be area classified.

A1.4 CLASS II AND III PRODUCTS AND THE DISTINCTION BETWEEN SUBDIVISIONS (1) AND (2)

In the case of materials whose flash point places them in Class II or III these will often be stored or handled at temperatures below the flash point – i.e. at temperatures which do not give rise to generation of flammable vapours. When a Class II or III product cannot be raised to the flash point (i.e. Class II(1) or III(1)), nor can its release be in the form of a flammable mist or spray, then for the purposes of area classification such a liquid may be considered not to give rise to a hazardous area, so that hazard zoning is not necessary for the surrounding plant.

In such a case it must be confirmed that the liquid temperature cannot be raised by any means in the event of release, e.g. by contact with a hot surface or proximity to an adjacent non-electrical source of ignition.

However, where a material is held under pressure and there is a possibility of mist or spray formation on release, that material may produce a flammable atmosphere regardless of the storage conditions and flash point. In such circumstances, therefore, those materials classified as Class II(1) or III(1) (i.e. non-hazardous) should be classed as II(2) or III(2) respectively are categorised as fluid category C for the purposes of area classification.

As a typical example, within the UK mainland a maximum ambient temperature of 30 °C can be assumed, while typically offshore in the North Sea a maximum would be 24 °C. Aviation fuels such as Jet A-1 (flash point 38 °C minimum) may therefore, under these conditions, be classed as non-hazardous when stored away from processing areas and hot lines and vessels.

Because of the greater variability in temperature Class II liquids should, however, be regarded as hazardous, i.e. Class II(2), in processing areas and should be individually assessed in climatic regions other than the UK (see Annex D1.1).

When products are to be stored or handled that are in the Class II(2) or III(2) condition, or are likely to be exposed to conditions of temperature above the flash point, the facilities should be classified as laid down for Class I. It will be seen that this is the procedure that has been applied in Annex D. For the alternative cases the procedure of the point source approach of Chapter 3 is to be applied to facilities in the Class II(2) or III(2) condition.

A1.5 UNCLASSIFIED

Petroleum products having a flash point above 100 °C can be given the subdivision accorded to Class III and should be regarded as Class III(2) when handled at or above their flash points.

A distinction, however, should be made between distillates in this unclassified range and products such as bitumens. When such materials are stored in heated fixed roof tankage (wherein the ullage space is essentially unventilated), the flash point as sampled or recorded will not be indicative of the presence or absence of a flammable atmosphere that may have accumulated in the ullage space. In common with the ullage space of fixed roof tanks or road or rail tank vehicles containing all classes of petroleum, the ullage space should be classified Zone 0, with a 1,5 m Zone 1 surrounding vents and other roof openings (see note 2 to Figure D4).

It should also be recognised in respect of heated petroleum of high flash point that although flash point and auto-ignition temperature (AIT) are different characteristics, at very high temperatures the effects can converge, i.e. the high temperatures, for example, of a hot surface can create a flammable condition locally which may be ignited by auto-ignition by that hot surface, as well as by an alternative ignition source.

With this criterion, the 'class of petroleum' should not be used in the classification, for example, of hot processing conditions under which the temperature of release would be above the boiling level. For these conditions, one of the additional categorisations of vaporising potential (supplemental to the flash point class) for use with the point source approach of Chapter 3 should be applied and the appropriate fluid category A, B, C or G (gas) selected (see Annex A2).

A2 RELATIONSHIP BETWEEN PETROLEUM CLASS AND FLUID CATEGORY

Where flammable fluids are handled under a variety of temperatures, pressures, and composition, the classification by means of the above EI system for petroleum fluids is inadequate and the concept of 'fluid category' has been introduced (see 1.5.6). This enables the determination of hazardous areas by use of the point source (Chapter 3) or risk-based (Chapter 3 and Annex C) approaches.

A2.1 SIMPLE RELATIONSHIP BETWEEN PETROLEUM CLASS AND FLUID CATEGORY

For simple situations Table A3 may be used to convert EI classification to fluid category.

It will be noted that the degree of vaporisation that will occur on release to atmosphere reduces in going from category A to category C, i.e. category C is least volatile.

From the definitions it will be clear that for the same flammable fluid, at various stages of its processing or handling, there can be a different fluid category depending upon temperature and pressure at the specific points of release. Each situation at a point of release should be separately evaluated.

Table A3: Relationship between EI petroleum class and fluid category

IP Petroleum class, based (except for LPG) on closed cup flash points			Fluid category		
Class	Description	Handled above flash point	Handled above boiling point	Can be released as mist	Handled below boiling point and cannot be released as mist ³
0	Liquefied petroleum gases (LPG)	Yes	A	A	A²
I	Flash point less than 21 °C	Yes	B	C	C
II(1)	Flash point 21 – 55 °C	No	N/A¹	C	N/A¹
II(2)	Flash point 21 – 55 °C	Yes	B	C	C
III(1)	Flash point 55 – 100 °C	No	N/A¹	C	N/A¹
III(2)	Flash point 55 – 100 °C	Yes	B	C	C
Unclassified(1)	Flash point greater than 100 °C	No	N/A¹	C	N/A¹
Unclassified(2)	Flash point greater than 100 °C	Yes	B	C	C
Notes 1. Not applicable (N/A) because liquids not handled above their flash point cannot be above their boiling point. 2. Cryogenic fluids need special consideration. 3. See A1.2 for mists and sprays.					

ANNEX B

AREA CLASSIFICATION FOR HYDROGEN

Hydrogen and hydrogen-containing streams occur widely in refineries and chemical plants e.g. in platformers, hydrotreaters, refinery fuel gas, synthesis gas units (which produce a mixture of hydrogen and carbon monoxide). Hydrogen may also be present in battery rooms and analyser houses. Such situations present special problems for area classification and electrical equipment selection because of their gas group categorisation as IIC, related to the very low ignition energy of hydrogen.

Further guidance on flammable gas mixtures containing hydrogen is given in EI *Predictions of minimum spark ignition energy and quenching distances for CH₄/H₂ and C₃H₈/H₂ mixtures with air*. This work was commissioned to determine at what hydrogen content a gas mixture containing hydrogen should be designated as hydrogen. This work has shown that mixtures containing hydrogen in excess of 30 % volume should be regarded as hydrogen, unless a specific assessment is undertaken to justify a higher limit.

Annex C Part 1 gives the composition used to represent a typical refinery hydrogen stream (i.e. G(ii)) together with hazard radii over a range of process conditions.

ANNEX C

CALCULATION OF HAZARD RADII

Secondary grade releases are accidental in nature and therefore the extent of the flammable atmosphere will vary depending on the size of the leak. Where release rates are unknown, this Annex provides a procedure for determining an appropriate leak rate. This Annex is split into three parts:

- Part 1: Presents the background to the calculation of hazard radii for release rates used in Chapter 3 and is based on dispersion modelling in *EI Research report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*.
- Part 2: Describes the procedure for determining appropriate release frequency band (LEVEL) for release rates, to be used in conjunction with Chapter 3, and is taken from the methodology detailed in *EI A risk-based approach to hazardous area classification*.
- Part 3: Describes the background to the risk-based approach and how risk tolerability criteria are related to release frequency bands (LEVELs) and corresponding release hole sizes.

ANNEX C – PART 1

BACKGROUND TO THE CALCULATION OF HAZARD RADII IN CHAPTER 3

C1 INTRODUCTION

This Annex provides extracts from *EI Research Report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids* as background to the calculation of hazard radii based on dispersion modelling. Dispersion modelling was used to determine the hazard radius, R_h , for each release source in 3.4. The tables in this Annex use the same approach and process fluids. However, they cover a much wider range of process conditions and may therefore be used to obtain a more accurate estimate of hazard radii if required.

The dispersion modelling contained in *EI Research Report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids* was carried out using DNV PHAST. The results were sufficiently consistent with those in the previous edition of this Model Code² to support using DNV PHAST without modifying the standard approach to modelling these releases.

C1.1 BASIS FOR DISPERSION MODELLING

Dispersion modelling was carried out for representative fluids for categories A, B, C, G(i) and G(ii). The compositions used are shown in Table C1. In addition, the physical parameters used during modelling are shown in Table C2. If actual compositions of flammable fluids or dispersion parameters vary widely from those used here, specific dispersion modelling should be carried out to verify hazard radii.

Table C1: Fluid compositions and LFLs

Stream component (mol %)	Fluid category					LFL (vol %)	Molecular weight (g/mol)	Boiling point (°C)
	A	B	C	G(i)	G(ii)			
N ₂ Nitrogen	0,00	0,00	0,00	2,00	2,00	–	28,01	-196
C ₁ Methane	0,00	4,00	0,00	88,45	10,00	5,00	16,04	-161
C ₂ Ethane	0,00	0,00	0,00	4,50	3,00	3,00	30,07	-87
C ₃ Propane	70,00	6,00	1,00	3,00	3,00	2,10	44,09	-42
C ₄ Butane	30,00	7,00	1,00	1,00	1,00	1,80	58,12	-1
C ₅ Pentane	0,00	9,00	2,00	1,00	0,00	1,40	72,15	36
C ₆ Hexane	0,00	11,00	3,00	0,00	0,00	1,20	86,17	69
C ₇ Heptane	0,00	16,00	3,00	0,00	0,00	1,05	100,20	98

² Dispersion modelling was carried out using Shell Global Solutions' (SGS) HGSYSTEM package.

Table C1: Fluid compositions and LFLs (continued)

Stream component (mol %)	Fluid category					LFL (vol %)	Molecular weight (g/mol)	Boiling point (°C)
	A	B	C	G(i)	G(ii)			
C ₈ Octane	0,00	22,00	27,00	0,00	0,00	0,95	114,23	126
C ₉ Nonane	0,00	0,00	25,00	0,00	0,00	0,85	128,26	151
C ₁₀ Decane	0,00	25,00	38,00	0,00	0,00	0,75	142,28	173
H ₂ O Water	0,00	0,00	0,00	0,05	0,00	–	18,02	100
Carbon dioxide	0,00	0,00	0,00	0,00	1,00	–	44,01	-78
Hydrogen	0,00	0,00	0,00	0,00	80,00	4,00	2,02	-253
Average MW (g/mol)	48,30	100,06	125,03	18,74	7,03			
LFL (vol %)	2,00	1,05	0,86	4,6	4,00			
LFL (kg/m ³)	0,039	0,042	0,043	0,034	0,011			

Table C2: Physical parameters used in dispersion modelling

Parameter	Value used in EI15
Ambient temperature	30 °C
Storage/process temperature	20 °C
Relative humidity	70 %
Wind speed	2 m/s
Stability class	D
Surface roughness length	0,03 m
Release direction	Horizontal
Release height	For R ₁ : 5 m For R ₂ : 1 m
Release angle	For R ₁ : horizontal For R ₂ : unknown
Sample time	18,75 s
Reference height	10 m
Hazard distances	To LFL

C1.2 HAZARD RADIUS 'LOOK-UP' TABLES BASED ON DISPERSION MODELLING

Hazard radii appropriate to the release hole sizes quoted for items of equipment in 3.4 may be directly read off Table C4. Where the equipment is not covered by 3.4, hole sizes may be determined by historical data or synthesis techniques.

The numerical values given in Table C4 are specific to the example fluids. The release rates for these fluids (Table C3) are only weakly dependent upon small variations in the ambient temperature of about 30 °C, which is chosen to reflect a UK summer temperature. Other fluids may be more sensitive to temperature changes.

The ground effect radius (R_2) should be used in conjunction with 3.9 and Figure 3.6 to determine the shape of a hazardous area.

Typical hazard radii from Table C4 are presented in tabular form in the relevant sections of Chapter 3.

Table C3: Release flow rate (kg/s)

Fluid Category	Release pressure see note 2 (bar(a))	Release flow rate (kg/s)			
		Release hole diameter			
		1 mm	2 mm	5 mm	10 mm
A	5 ¹	0,01	0,04	0,3	1
	10	0,01	0,06	0,4	1,5
	50	0,03	0,14	0,9	3,5
	100	0,05	0,2	1,2	5
B	5	0,01	0,04	0,3	1
	10	0,02	0,07	0,4	1,7
	50	0,04	0,15	1	4
	100	0,06	0,2	1,4	5,5
C	5	0,01	0,06	0,3	1,1
	10	0,02	0,1	0,4	1,7
	50	0,04	0,2	1	4
	100	0,06	0,25	1,4	6
G(i)	5	0,001	0,002	0,02	0,06
	10	0,001	0,005	0,03	0,1
	50	0,007	0,03	0,2	0,7
	100	0,015	0,06	0,4	1,5
G(ii)	5	0,0004	0,001	0,01	0,04
	10	0,001	0,003	0,02	0,07
	50	0,004	0,02	0,1	0,4
	100	0,007	0,03	0,2	0,7
LNG	1,5	0,003	0,012	0,077	0,31
	5	0,009	0,035	0,22	0,87
	10	0,013	0,052	0,33	1,3
Notes					
1. At the fluid storage temperature of 20 °C the nominal discharge pressure of 5 bar(a) is below the saturated vapour pressure of Fluid category A. The saturated vapour pressure (6,8 bar(a)) was used to calculate the discharge rate and dispersion.					
2. Release pressure should be taken as the maximum allowable operating pressure.					

Table C4: Hazard radii R_1 and R_2 for pressurised releases

Fluid category	Release pressure see note 4 (bar(a))	Hazard radius R_1 (m)				Hazard radius R_2 (m)			
		Release hole diameter				Release hole diameter			
		1 mm	2 mm	5 mm	10 mm	1 mm	2 mm	5 mm	10 mm
A	5	2	4	8	14	2	4	16	40
	10	2,5	4	9	16	2,5	4,5	20	50
	50	2,5	5	11	20	3	5,5	20	50
	100	2,5	5	11	22	3	6	20	50
B	5	2	4	8	14	2	4	14	40
	10	2	4	9	16	2,5	4	16	40
	50	2	4	10	19	2,5	5	17	40
	100	2	4	10	20	3	5	17	40
C	5	2	4	8	14	2,5	4	20	50
	10	2,5	4,5	9	17	2,5	4,5	21	50
	50	2,5	5	11	21	3	5,5	21	50
	100	2,5	5	12	22	3	6	21	50
G(i)	5	< 1	< 1	< 1	1,5	< 1	< 1	1	2
	10	< 1	< 1	1	2	< 1	< 1	1,5	3
	50	< 1	1	2,5	5	< 1	1,5	3,5	7
	100	< 1	1,5	4	7	1	2	5	11
G(ii)	5	< 1	< 1	1,5	3	< 1	< 1	2	4
	10	< 1	1	2	4	< 1	1	2,5	5
	50	< 1	2	4	8	1	2	6	11
	100	1	2	6	11	2	3	8	14
LNG	1,5	2,5	3	6	10	2	3	7	30
	5	3	5	10	17	2	4	11	40
	10	3	5,5	10	20	2,5	4,5	13	37,5

Notes

1. At the fluid storage temperature of 20 °C the nominal discharge pressure of 5 bar(a) is below the saturated vapour pressure of Fluid category A. The saturated vapour pressure (6,8 bar(a)) was used to calculate the discharge rate and dispersion.
2. Distances to LFL for LNG releases at 5 m height. These distances have been modelled as methane, with typical LNG compositions varying between 93 % – 90 %. Typical rundown, storage and loading temperatures for LNG are in the range -170 °C to -160 °C; therefore releases from a storage temperature of -165 °C have been modelled.
3. No data are available for gasoline blends with ethanol; however, for blends with small quantities of ethanol, these could be treated as category C. It is recommended that modelling is carried out.
4. Release pressure should be taken as the maximum allowable operating pressure.

C1.3 LIQUID POOLS DUE TO SPILLAGE

C1.3.1 Spill volumes

In *El Research report: Dispersion modelling and calculations in support of Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*, results for modelled spill volumes for pool sizes and spill conditions were given: these are provided in Table C5. These spills are modelled on flat and level concrete surfaces.

The spill volume has been modelled as being released instantaneously onto the ground and allowed to spread until it reaches the pool diameter shown in Table C5. Evaporation and dispersion will take place as soon as the pool starts spreading outwards.

However, for the purposes of area classification, only spills onto concrete have been considered. Spill sizes for pools given in Table C5 in some cases give loss of containment greater than that considered for area classification purposes based on the size of spill and duration of release required for such a spill.

Actual calculated data for selected release scenarios from *El Research report: Dispersion modelling and calculations in support of Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids* are given in Table C6. Hazard radii for liquid pools due to spillage have been developed from these calculations, and are given in 3.8.

There is no distinction between R_1 and R_2 for liquid pools, since all releases are at ground level.

Distances to LFL are from the edge of the liquid pool and are for releases on to concrete, into ambient (air) and ground temperature of 20 °C.

Table C6 provides distances to LFL for fluid category A (at -40 °C) and fluid categories B and C at ambient temperature.

Table C5: Spill volumes modelled (m³)

Pool diameter (m)	Pool depth			
	Minimum: concrete (0,005 m)	Minimum: dry soil (0,02 m)	0,1 m	1 m
1	0,0039	0,015	(not modelled)	(not modelled)
3	0,035	0,14	0,71	(not modelled)
10	0,39	1,6	7,9 ⁽¹⁾	79 ⁽¹⁾
30	(not modelled)	(not modelled)	70 ⁽¹⁾	707 ⁽¹⁾
100	(not modelled)	(not modelled)	(not modelled)	7 854 ⁽¹⁾
Notes				
1 Releases of this magnitude for fluid category A material are too large for area classification purposes resulting in hazard radius exceeding 30 m.				
2 Releases of this magnitude for all fluid categories are too large for area classification purposes resulting in hazard radius exceeding 30 m.				

Table C6: Hazard radius R_1 for pool spills

Fluid category	Pool diameter (m) x depth (m)	Distance (m) to LFL (R_1) Concrete
A	1 * 0,005	8
	3 * 0,005	17
	10 * 0,005	58 ⁽¹⁾
	3 * 0,1	15
	10 * 0,1	76 ⁽¹⁾
B	1 * 0,005	3
	3 * 0,005	14
	10 * 0,005	18
	3 * 0,1	15
	10 * 0,1	28
C	1 * 0,005	2,6
	3 * 0,005	5,5
	10 * 0,005	15
	3 * 0,1	7,5
	10 * 0,1	24
	10 * 1	19
Based on EI <i>Research report: Dispersion modelling and calculations in support of Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids</i> for categories A and B. Additional work from HSL was carried out for category C and this was modelled as pentane to represent the worst case. Note 1: For this liquid pool the hazard radius exceeds 30 m. The size of the potential release is greater than normally considered for area classification and should be avoided.		

C1.4 SENSITIVITY OF DISTANCES TO LFL TO PARAMETER VARIATIONS

An analysis was undertaken to assess the impacts of variations to atmospheric temperature, relative humidity, wind speed, reference height, stability, reservoir temperature and surface roughness on hazard radii for fluid categories A to G(ii). The parameters investigated are presented in Table C7:

Table C7: Parameter values used in sensitivity analysis

Parameter	Value used in EI15	Range of values modelled			
Ambient temperature	30 °C	-20 °C, 0 °C, 20 °C, 40 °C			
Storage/process temperature	20 °C	Same as ambient and fluid category A (liquefied petroleum gas (LPG)-like) at -40 °C			
Relative humidity	70 %	50 %, 90 %			
Wind speed	2 m/s	1,5 m/s	2 m/s	5 m/s	9 m/s
Stability class	D	F	D	D	D
Surface roughness length	0,03 m	0,1 m, 0,3 m, 1,0 m			
Release direction	Horizontal	Horizontal			
Release height	For R ₁ : 5 m For R ₂ : 1 m	For R ₁ : 5 m For R ₂ : 1 m			
Release angle	For R ₁ : horizontal. For R ₂ : unknown	For R ₁ : horizontal. For R ₂ : -30°, -45°, -60°			
Sample time	18,75 s	No variation (Note 1)			
Reference height	10 m	No variation (Note 2)			
Hazard distances	To LFL	To LFL and 0,5 LFL			
Notes:					
1 This is a standard value derived from CCPS <i>Guidelines for use of vapor cloud dispersion models</i> and TNO <i>Yellow book</i> .					
2 This is the standard height for wind speed measurements, e.g. HMSO <i>Meteorological glossary</i> .					

The conclusions of the analysis are presented in sections C1.4.1 – C1.4.4. The conclusions and recommendations focus on the hazard distances as defined in EI15, i.e. to LFL and not to 0,5 LFL.

A full investigation of the effects of varied parameters used in this Annex is presented in *EI Research Report: Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids*.

C1.4.1 Fluid category A

For fluid category A under pressure:

- The variation in hazard distance with weather category compared with the base case (2D) is mostly less than +/-20 %, whereas for higher windspeeds and larger hole sizes the reduction in hazard distance compared with base case reaches 27 %. Given the uncertainties in dispersion modelling, this is not considered significant.
- The variation of hazard distance with relative humidity is negligible.

- The reduction in hazard distance with increasing surface roughness (up to 1 m) is less than 20 %. Given the uncertainties in dispersion modelling, this is not considered significant.

For fluid category A, refrigerated at -40 °C and stored at atmospheric pressure:

- The hazard distances are up to 80 % higher than for the same fluid stored under pressure at ambient temperature.
- **Higher wind speeds give longer dispersion distances than for the same fluid stored under pressure at ambient temperature. This should be taken account of for installations storing refrigerated LPG.**
- The variation of hazard distance with relative humidity is negligible.
- The reduction in hazard distance with increasing surface roughness (up to 1 m) is up to 31 %; however, in most cases the surface roughness will be significantly less than this.

C1.4.2 Other fluid categories

For fluid categories B, C, G(i) and G(ii):

- For lower storage/process pressures, the weather category has no discernible impact on the hazard distances for the gases G(i) and G(ii). For fluid category G(ii), high windspeeds give the longest hazard distances. Higher windspeeds also lead, at all release pressures, to shorter hazard distances for fluid categories B and C (as well as fluid category A).
- The variation of hazard distance with ambient temperature is less than 20 % over the range modelled. Given the uncertainties in dispersion modelling, this is not considered significant.
- The variation of hazard distance with relative humidity is negligible.
- The reduction in hazard distance with increasing surface roughness (up to 1 m) is less than 20 %. Given the uncertainties in dispersion modelling, this is not considered significant.

C1.4.3 Liquid pools

- **For fluid category A there is significant variation with increasing ambient temperature.**
- For fluid category B the variation for a higher ambient temperature than base case (20 °C) is less than 10 %. Given the uncertainties in dispersion modelling, this is not considered significant and no variation from the hazard distances shown is recommended. For lower temperatures the hazard distances are significantly shorter.
- For fluid category C the variations of hazard distance with ambient temperature are mostly small.
- For all fluid categories A, B and C the variation of hazard distance with relative humidity is negligible.
- For all fluid categories A, B and C the variation of hazard distance with surface roughness is significant.

C1.4.4 LNG

- Except for very small releases (i.e. 1 mm hole size), the hazard distances for releases initially horizontal at 0.1 m height are mostly longer than for the corresponding releases at 1 m height due to rain-out, liquid pool formation and re-evaporation occurring.

- The variation in hazard distance with relative humidity is less than 10 %. Although not negligible, this is insufficient to justify any variation from the hazard distances.
- The reduction in hazard distance with increasing surface roughness (up to 1 m) is less than 25 %. However, in most cases the surface roughness will be significantly less than this and it would be prudent to retain the hazard distances shown.
- For spills onto water, the phenomenon of rapid phase transition (RPT) has not been considered. The modelling results show that, for releases resulting in significant rain-out (those at 0,1 m height and 1,5 bar(a) release pressure), the hazard distances are significantly increased at low windspeed compared with releases onto land.

ANNEX C – PART 2

RISK-BASED APPROACH TO AREA CLASSIFICATION

C2 INTRODUCTION

This Annex presents a risk-based approach which may be applied to the classification of an upstream or downstream petroleum sector facility by consideration of the point source approach. The criterion which has been adopted is that the total individual risk due to an ignited release should not exceed $1.0\text{E-}5/\text{yr}$. For continuous and primary releases the extent of the associated hazardous area is not affected by the amount of time a flammable atmosphere is present. For secondary releases, however, the extent of the hazardous area generally varies with the frequency of release.

For continuous and primary releases the extent of the hazardous area (Zones 0 and 1) may be determined using dispersion models which reflect the nature of the release source and the environmental conditions. The probability of a flammable atmosphere being present can also be readily determined. The only unknowns are the amount of time an operator spends within the hazardous area (occupancy) and the frequency of ignition.

Secondary releases are accidental in nature and therefore the extent of the flammable atmosphere will vary depending on the size of the leak. The objective of the risk-based approach is to establish the outer boundary of Zone 2, i.e. the minimum distance at which unclassified ignition sources may be located. Historical data have been used to develop a 'leak size vs. frequency' relationship. By setting values for ignition probability, individuals' exposure to Zone 2 release sources, and vulnerability to ignited releases, the leak size corresponding to the maximum frequency of release which determines the Zone 2 boundary may be established.

The risk-based approach procedure for secondary grade releases is shown in Fig. C1.

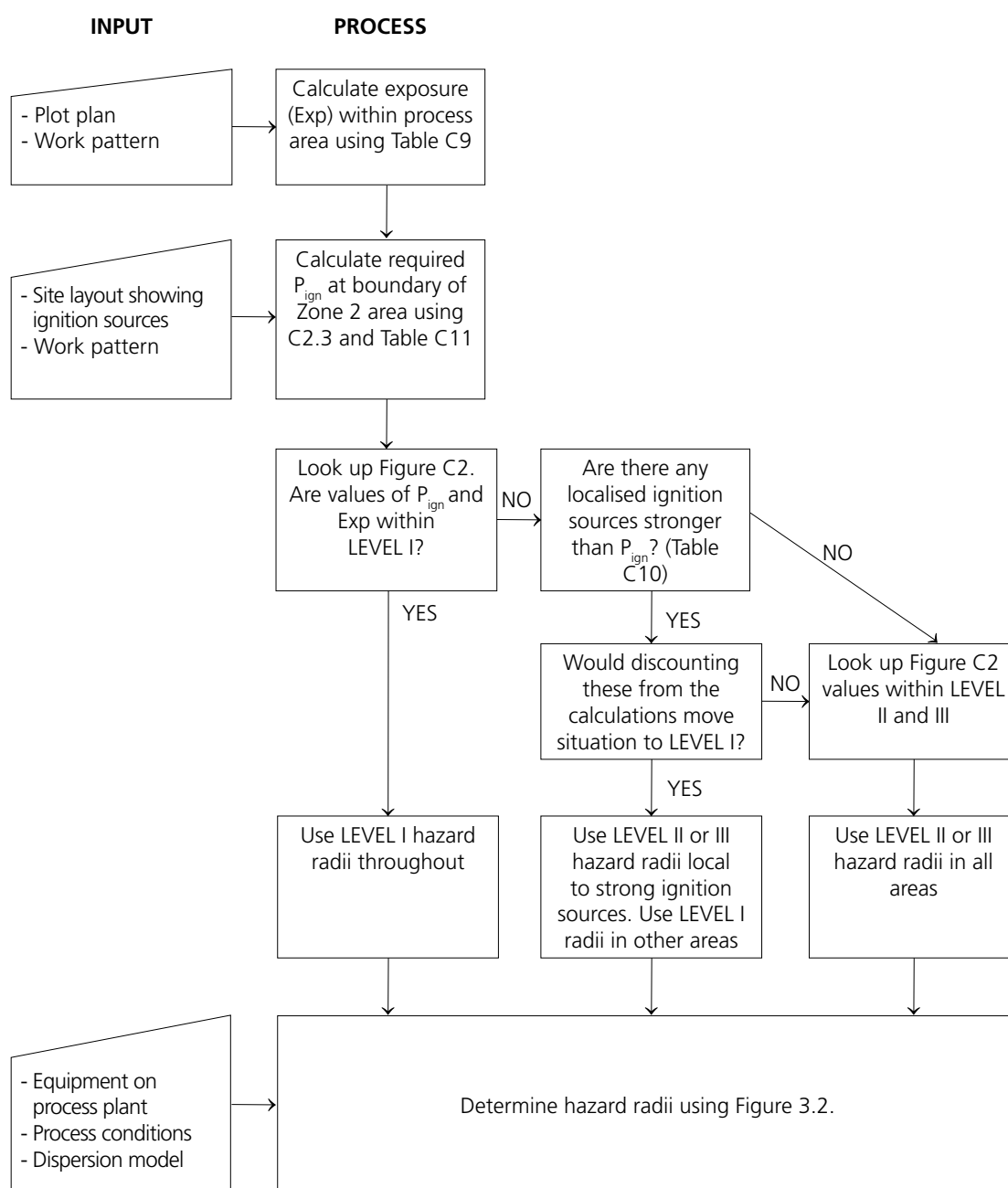


Figure C1: Risk-based procedure for calculation of hazard radii for secondary grade releases

C2.1 PROCEDURE TO DETERMINE SECONDARY GRADE RELEASE FREQUENCIES

C2.1.1 Determine exposure

Workers within Zone 2 hazardous areas are exposed to multiple sources of release. In order to take multiple sources into account a parameter called exposure (Exp) is used as follows:

$$\text{Exp} = P_{\text{occ}} * N_{\text{range}}$$

Where:

P_{occ} Probability the worker is on site within the hazardous area (occupancy).

N_{range} The time weighted average number of release sources which can affect the individual during their time within the hazardous area.

Table C9 gives various input values of P_{occ} and N_{range} for determining exposure in this expression.

C2.1.1.1 Probability of occupancy (P_{occ})

P_{occ} is calculated by estimating the proportion of time the most vulnerable individual spends on site exposed to at least one potential release source (i.e. within a hazardous area).

This is the number of hours the individual spends in the hazardous area per year divided by the number of hours in a year. A maximum number of working hours of 1 920 hr/yr (i.e. 40 hours * 48 weeks) is taken; this corresponds to a maximum P_{occ} of 0,22 (i.e. 1 920/8 760).

Four values of P_{occ} are selected for Zone 2:

- 100 % of time on all shifts in a hazardous area ($P_{\text{occ}} = 0,22$).
- An average of approximately five hr/day in a hazardous area ($P_{\text{occ}} = 0,13$).
- An average of two hr/day in a hazardous area ($P_{\text{occ}} = 0,055$).
- An average of one hr/day in a hazardous area ($P_{\text{occ}} = 0,028$).

C2.1.1.2 Calculation of number of secondary grade release sources within range (N_{range})

Plant workers will be exposed to a wide variety of potential secondary grade release sources depending on the type of plant and their working schedule. At one extreme there may be workers who spend very short periods of time near hazardous release sources (e.g. engineering/planning/laboratory staff who make occasional visits to process units) and at the other extreme there will be workers permanently stationed within the hazard ranges of multiple release sources (e.g. workers in an LPG bottling plant, or compressor house).

To take account of these situations it is necessary to calculate the average number of release sources which could affect the individual (taken as the average number of Zone 2 hazard radii which the individual is within during their time in the hazardous area). The following values for the average number of release sources are proposed for various process plant activities based on observation of typical onshore process units. For operators who spend all of their working time in a single location (e.g. drilling operators) an exact count of the number of release sources may be made.

Table C8 presents suggested values for the average number of secondary grade release sources within range (N_{range}) for a number of example activities.

Table C8: Average number of release sources in range (N_{range})

Activity	Description	Average no. of release sources in range
General patrol in 'open' plant	Hazard radius from flanges/valves is typically 1,5 – 3,0 m and therefore only large radius release sources (e.g. standard pumps) will affect worker for large proportion of time.	1
General patrol in 'congested' plant	As above, however allows for congestion and proximity to multiple release sources.	5
Inspection of areas with many release sources	Inspection of items of equipment such as pumps, compressors, manifolds etc. Observation of typical onshore plant shows groups of 30 release sources (within 3 m range) to be typical.	30

Table C9: Exposure calculation for plant area*

Work pattern				No. of release sources within range			Exposure (Exp)	
				% of time			N_{range}	
Average hours/yr spent on site	Fraction of time on site spent within plant area*	Hours/yr spent on site within radius of plant area	P_{occ} Fraction of total time per yr spent within plant area	Open plant one source	Congested plant five sources	Many release sources 30 sources	Average number of sources in range during time on site	$P_{\text{occ}}^* N_{\text{range}}$
1 920	1	1 920	0,220	0 %	0 %	100 %	30	6,6
1 920	1	1 920	0,220	20 %	30 %	50 %	16,7	3,7
1 920	1	1 920	0,220	20 %	50 %	30 %	11,7	2,6
1 920	1	1 920	0,220	50 %	30 %	20 %	8	1,8
1 920	1	1 920	0,220	100 %	0 %	0 %	1	0,2
1 920	0,6	1 152	0,130	0 %	0 %	100 %	30	3,9
1 920	0,6	1 152	0,130	20 %	30 %	50 %	16,7	2,2
1 920	0,6	1 152	0,130	20 %	50 %	30 %	11,7	1,5
1 920	0,6	1 152	0,130	50 %	30 %	20 %	8	1,0
1 920	0,6	1 152	0,130	100 %	0 %	0 %	1	0,13
1 920	0,25	480	0,055	0 %	0 %	100 %	30	1,65
1 920	0,25	480	0,055	20 %	30 %	50 %	16,7	0,92
1 920	0,25	480	0,055	20 %	50 %	30 %	11,7	0,64
1 920	0,25	480	0,055	50 %	30 %	20 %	8	0,44

Table C9: Exposure calculation for plant area* (continued)

Work pattern				No. of release sources within range				Exposure (Exp)
				% of time			N _{range}	
Average hours/yr spent on site	Fraction of time on site spent within plant area*	Hours/yr spent on site within radius of plant area	P _{occ} Fraction of total time per yr spent within plant area	Open plant one source	Congested plant five sources	Many release sources 30 sources	Average number of sources in range during time on site	P _{occ} * N _{range}
1 920	0,25	480	0,055	100 %	0 %	0 %	1	0,06
1 920	0,125	240	0,028	0 %	0 %	100 %	30	0,8
1 920	0,125	240	0,028	20 %	30 %	50 %	16,7	0,5
1 920	0,125	240	0,028	20 %	50 %	30 %	11,7	0,3
1 920	0,125	240	0,028	50 %	30 %	20 %	8	0,2
1 920	0,125	240	0,028	100 %	0 %	0 %	1	0,03

* Note, the 'plant area' refers to the potential Zone 2 area

C2.1.2 Determine probability of ignition (P_{ign})

Sources of ignition are controlled within Zone 2 hazardous areas. However, it is acceptable to locate any sources of ignition on the Zone 2/unclassified boundary e.g. fire heaters, transformers, plant roads, etc.

The probability of ignition for a given release rate is plotted graphically in Cox, Lees and Ang, *Classification of hazardous areas*, and contained in Annex B of *EI A risk-based approach to hazardous area classification*. Releases with low release rates (i.e. less than 1 kg/s) will typically have dispersion distances within the Zone 2 boundary and a probability of ignition (P_{ign}) of 0,01 is quoted in Cox, Lees and Ang, *Classification of hazardous areas*. The probability of ignition (from all causes) given release in Zone 2 may, therefore, be taken as 0,01 (ignitions/release into a Zone 2 area). E&P Forum *Hydrocarbon leak and ignition database* contains a similar ignition model for releases on offshore platforms.

Outside hazardous areas there is no control over sources of ignition and continuous sources of ignition may be present at the Zone 2 outer boundary. Where there is a strong and continuous source of ignition (e.g. flare, hot exhaust etc.) at a Zone 2 outer boundary, an ignition probability of 1,0 may be taken for the portion of the Zone 2 outer boundary which is adjacent to the source of ignition. For less strong or intermittent sources of ignition a probability of ignition of 0,1 is taken which corresponds to the average ignition probability for medium/large releases quoted in Cox, Lees and Ang, *Classification of hazardous areas*. As an alternative to the values quoted in Table C10, the methodology contained in the EI publication, *Research Report: Ignition probability review, model development and look-up correlations*, may be used to determine probability of ignition.

These values are summarised in Table C10.

Table C10: Probability of ignition (P_{ign}) for varying sources of ignition strengths

Source of ignition	Description	(P_{ign})
Controlled	Where control of sources of ignition extends beyond Zone 2 (e.g. on offshore facilities where ignition sources are linked to fire and gas detection systems).	0,003
Weak	Typical sources of ignition within a Zone 2 area.	0,01
Medium	Ignition due to road traffic, substations, buildings, unclassified electrical equipment, engines, hot surfaces etc.	0,1
Strong	Continuous strong sources of ignition such as fired heaters, flares etc.	1

For a given secondary grade release source, strong, medium and weak sources of ignition may be located on the Zone 2 boundary. The appropriate value of P_{ign} to use in calculating the individual risk (IR) of the most exposed worker is a function of the proportion of time the worker spends in areas of various ignition source strengths.

If, for example, the most exposed worker spends 100 % of time in areas of strong ignition (e.g. operating a fired heater) then a value of 1,0 should be taken for P_{ign} . For situations where the work pattern is relatively random within the process area, P_{ign} may be calculated by estimating the proportion of the Zone 2 boundary which contains controlled, weak, medium and strong sources of ignition.

The maximum value of P_{ign} is 1,0. However, this would only be achieved if the Zone 2 hazardous area were surrounded by strong continuous sources of ignition. Values of P_{ign} which do not contain 'strong' and/or 'medium' components are mainly applicable to offshore facilities.

Typical cases are given in Table C11.

Table C11: Calculation of P_{ign}

Percentage of time worker spends in areas with following ignition sources at the plant* boundary				P_{ign}
Strong (%)	Medium (%)	Weak (%)	Controlled (%)	
100	0	0	0	1,000
40	40	20	0	0,442
20	40	40	0	0,244
10	50	40	0	0,154
0	100	0	0	0,100
0	60	40	0	0,064
0	50	50	0	0,055

Table C11: Calculation of P_{ign} (continued)

Percentage of time worker spends in areas with following ignition sources at the plant* boundary				P_{ign}
Strong (%)	Medium (%)	Weak (%)	Controlled (%)	
0	40	60	0	0,046
0	10	90	0	0,019
0	0	100	0	0,010
0	0	90	10	0,009
0	0	50	50	0,007
0	0	0	100	0,003

* Note, the 'plant' is the potential Zone 2 area

C2.2 DETERMINATION OF RELEASE FREQUENCY (LEVEL)

The release frequency, i.e. LEVEL to be used on a specific plant is based on the exposure of the most exposed individual to flammable releases (Exp) and the probability of ignition of those releases (P_{ign}). The release frequency (LEVEL) is then used to determine hole sizes for secondary grade releases.

This Model Code suggests three LEVELS (LEVELS I, II and III, see Table C12) which are based on achieving an overall value of individual risk of less than $1,0E-5$ /yr. Hence, as the combination of occupancy and the probability of ignition increases, the corresponding LEVEL will increase, which will result in larger failure scenarios.

Note: LEVEL I is highest frequency ($1,0E-2$) and LEVEL III is lowest frequency ($1,0E-4$).

It is the general intent to assign the frequency of release (LEVEL) to an installation as a whole rather than determine the LEVEL for each individual point source.

Table C12: Categorisation of release frequency

LEVEL	Frequency of release/release source yr
LEVEL I	Greater than $1,0E-2$ /release source yr
LEVEL II	$1,0E-2$ to $1,0E-3$ /release source yr
LEVEL III	$1,0E-3$ to $1,0E-4$ /release source yr

To select the appropriate release frequency (LEVEL I, II or III) to use for a given exposure of an individual to secondary grade release sources (Exp), and a given probability of ignition (P_{ign}), Figure C2 should be used.

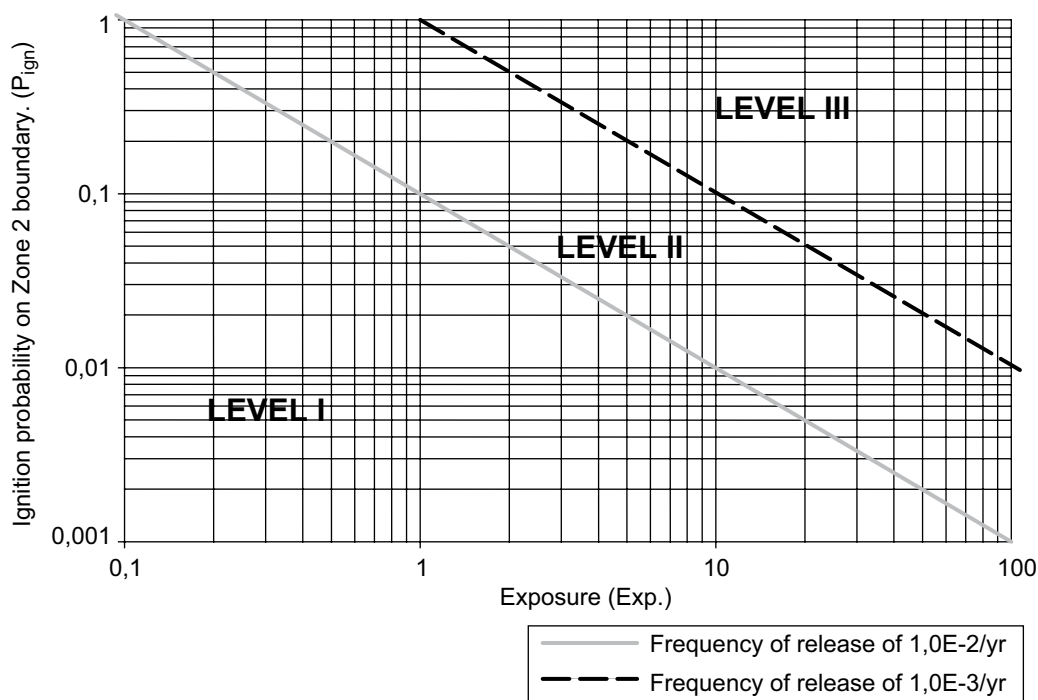


Figure C2: Release frequency (LEVEL) to achieve an Individual Risk (IR) criterion of 1,0E-5 (or lower) given Exp and P_{ign} .

Notes

1. In the extreme case of high exposure and a concentration of strong ignition sources, a frequency of LEVEL III (1,0E-4/release source-yr) should be used. However, it may be preferable to carry out measures to reduce the risk.

C2.3 SELECTION OF EQUIVALENT HOLE SIZE FOR CALCULATED RELEASE FREQUENCY (LEVEL)

The frequency of a flammable release due to secondary grade release sources may be estimated by examining failure data for various items of equipment considered to be point source releases in this Model Code. The size and extent of the flammable atmosphere depends on the hole size (diameter) in the equipment, and the characteristics of the process fluid.

El A *risk-based approach to hazardous area classification* contains a detailed description of how the release frequency (LEVEL) vs. hole size relationship was determined for items of equipment considered to be point source releases. It also provides a methodology which allows hazard radii to be calculated given a hole size and process conditions.

After publication of El A *risk based approach to hazardous area classification*, an analysis of the HSE *Hydrocarbon release system* (HCR) database was undertaken, as it contained more accurate failure data for various items of equipment considered to be point source releases. These data were used to develop revised equivalent hole sizes for the release frequencies (LEVELs) adopted in this Model Code Table C13 summarises the equivalent hole size distribution for secondary grade releases at various release frequency bands (LEVELs) from the items of equipment covered in 3.4.

Table C13: Equivalent hole sizes for a range of release frequencies

Equipment type	Hole size (mm)		
	LEVEL I Greater than 1,0E-2/ release source-yr	LEVEL II 1,0E-2–1,0E-3/ release source-yr	LEVEL III 1,0E-3–1,0E-4/ release source-yr
Single seal with throttle bush	2	5	10
Double seal	1	2	10
Reciprocating pump	2	10	20
Centrifugal compressor	1	5	30
Reciprocating compressor	2	10	30
Flanges	1	1	5
Valves	1	2	10
Notes 1. At the LEVEL I release frequency, for single seal centrifugal pumps without a throttle bush, use LEVEL II equivalent hole size. 2. It is assumed that the smaller equivalent hole sizes for valves > 80 mm diameter (when compared to valves < 80 mm diameter) are due to a higher mechanical integrity of the piping system, which will result in a lower failure frequency. 3. Assumed level III failures are mainly due to the pump/compressor sets and are generally independent of sealing arrangements.			

ANNEX C – PART 3

BACKGROUND TO RISK-BASED APPROACH

C3 INTRODUCTION

This Annex provides extracts from EI *A risk-based approach to hazardous area classification, 2nd edition* as background to the determination of release frequency bands (LEVELs) and hole sizes used for secondary grade releases in 3.7.

C3.1 SELECTION OF RISK ACCEPTABILITY CRITERIA

In order to use a risk-based approach, the units in which risk is measured and criteria deemed to be acceptable must be established. The measures of risk contained in Table C14 were considered.

In the UK, only individual risk (IR) has quoted acceptability criteria. HSE *The tolerability of risk from nuclear power stations*, suggests that 'a risk of death of around one in 1 000 per annum is the most that is ordinarily accepted by a substantial group of workers in any industry in the UK and therefore it seems reasonable to adopt this as the dividing line of what is just about tolerable as a risk and what is unacceptable'. Fatalities due to accidental ignited releases represent only one contribution to IR and therefore the acceptability criterion for this contributor should be set at a lower level.

Table C14: Suggested risk criteria

Measure of risk (units)	Criteria
Individual risk (fatality/yr.)	Numerical criteria available in the UK which could be adapted to this situation
Societal risk (Frequency of number of simultaneous fatalities/yr.)	No hard numerical criterion available in the UK
Economic risk (\$/yr.)	None
Environmental risk	As low as reasonably practicable (ALARP) principle applies
Fire risk (fires/yr.)	No criteria available

The IR for a typical (onshore) petrochemical plant worker in the UK is of the order of 1,0E-4/yr. (British Medical Association *Living with risk*) and is built up from a number of contributions. The two principal categories are:

- Major hazard risk from hydrocarbon processing activities.
- Non-hydrocarbon processing related risk such as occupational risk (trips, falls etc.). In the case of offshore workers there is also a significant contribution from transportation risks (e.g. helicopter, ship etc.).

The major hazard hydrocarbon processing risk is generally due to release of hydrocarbons. The mechanisms of release fall into four categories:

- Generic (leaks from pipework, vessels and 'point sources' such as pumps, compressors, valves, flanges etc.).
- Process specific events (sampling, draining etc.).
- External events (extreme weather, seismic, vehicle/ship/aircraft impact).
- Escalation and knock-on.

The consequences of a hydrocarbon release will depend on the process fluid, processing conditions and release rate. Consequences which have the potential to cause a fatality include explosions, fires, toxic releases, missiles etc.

In this Model Code, zoning guidance for secondary grade releases is intended to manage the risk associated with accidental ignition of hydrocarbon releases. Fatalities due to ignited releases represent one component of one category of major hazard hydrocarbon processing risk. To establish a robust criterion for this contributor it is proposed to set the IR acceptability level for fatality due to accidental ignited releases to 10 % of the total IR for a typical onshore plant worker (i.e. $0,1 \times 1,0E-4 = 1,0E-5/\text{yr}$).

The value of $1,0E-5/\text{yr}$ compares well with work carried out by the HSE, (internal report, unpublished) which calculates the actual Fatal Accident Rate (FAR) of 0,56 fatalities/1,0E8 exposure hours due to accidental ignition of flammable substances. This is equivalent to an IR of $1,07E-5/\text{yr}$.

An upper bound IR acceptability criterion of $1,0E-5/\text{yr}$ due to accidental ignition of flammable substances is therefore adopted.

C3.2 RELATIONSHIP OF INDIVIDUAL RISK (IR) TO RELEASE FREQUENCY (LEVEL)

Individual Risk (/yr) from a single ignited secondary grade release source is defined as:

$$IR_{\text{ignited release}} \text{ (/release source-yr)} = F_{\text{release}} \text{ (/release source-yr)} * P_{\text{ign}} * P_{\text{occ}} * V$$

where:

$IR_{\text{ignited release}}$	Maximum acceptable IR due to ignited releases. As described in C3.1, this is taken to be $1,0E-5/\text{yr}$.
F_{flam}	Frequency of a flammable atmosphere at the Zone 2 boundary from each release source.
P_{ign}	Probability of ignition at the Zone 2 outer boundary.
P_{occ}	Occupancy: probability that the individual is within the effect distance (hazardous area).
V	Vulnerability: probability of fatality per exposure to an ignited release (see Note).
N_{range}	Number of release sources within range of the individual.

Note: EI *A risk-based approach to hazardous area classification* describes two approaches, (a) analysis of historical data, and (b) synthesis using conditional probabilities. Both approaches give broadly similar results, and a vulnerability value (V) of 0,01 fatalities per accidental ignited release within the Zone 2 area is used in the calculations.

Within a Zone 2 boundary, there will usually be a multiplicity of release sources, so that as one moves further away from one particular release source other release sources will come within range. The frequency of a flammable atmosphere within a Zone 2 area will therefore vary from location to location within the Zone 2 depending on how many secondary grade release sources are within range of the individual. This effect is quantified by the term N_{range} . Individual Risk (/yr) from a number of ignited secondary grade release sources is defined as:

$$IR_{\text{ignited release}} \text{ (/yr)} = F_{\text{flam}} \text{ (/release source-yr)} * P_{\text{ign}} * P_{\text{occ}} * V * N_{\text{range}}$$

where:

$IR_{\text{ignited release}}$ Maximum acceptable IR due to ignited releases. As described in C3.1, this is taken to be 1,0E-5/yr.

F_{flam} Frequency of a flammable atmosphere at the Zone 2 boundary from each release source.

P_{ign} Probability of ignition at the Zone 2 outer boundary.

P_{occ} Occupancy: probability that the individual is within the effect distance (hazardous area).

V Vulnerability: probability of fatality per exposure to an ignited release.

N_{range} Number of release sources within range of the individual.

Note: EI *A risk-based approach to hazardous area classification* describes two approaches, (a) analysis of historical data, and (b) synthesis using conditional probabilities. Both approaches give broadly similar results, and a vulnerability value (V) of 0,01 fatalities per accidental ignited release within the Zone 2 area is used in the calculations.

This equation may be further simplified by:

- Substituting the values of 0,01 for V , and 1,0E-5/yr for the maximum value of IR.
- Combining N_{range} and P_{occ} as one variable called Exposure (Exp). $\text{Exp} = P_{\text{occ}} * N_{\text{range}}$.

Giving:

$$F_{\text{flam}} \text{ (/release source-yr)} = (1,0\text{E-}5/\text{yr}) / (P_{\text{ign}} * 0,01 * \text{Exp})$$

Figures C3 and C4 show the relationship of $IR_{\text{ignited release}} \text{ (/release source-yr)}$ vs. exposure with fixed values for F_{flam} and $V = 0,01$, and for various values of P_{ign} .

For simplicity, the release frequencies of flammable releases are banded into three LEVELs.

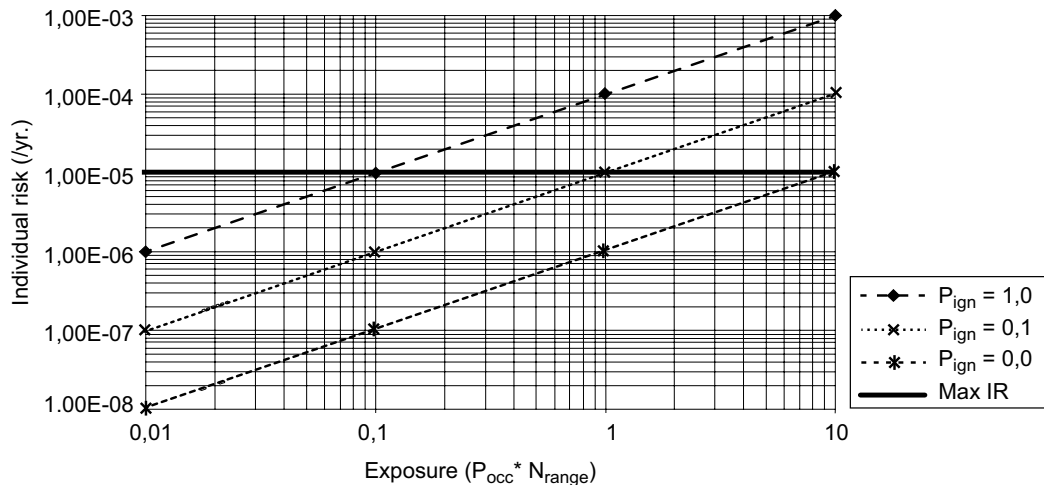


Figure C3: Individual risk (/yr) vs. exposure (release frequency = 1,0E-2/release source-yr)

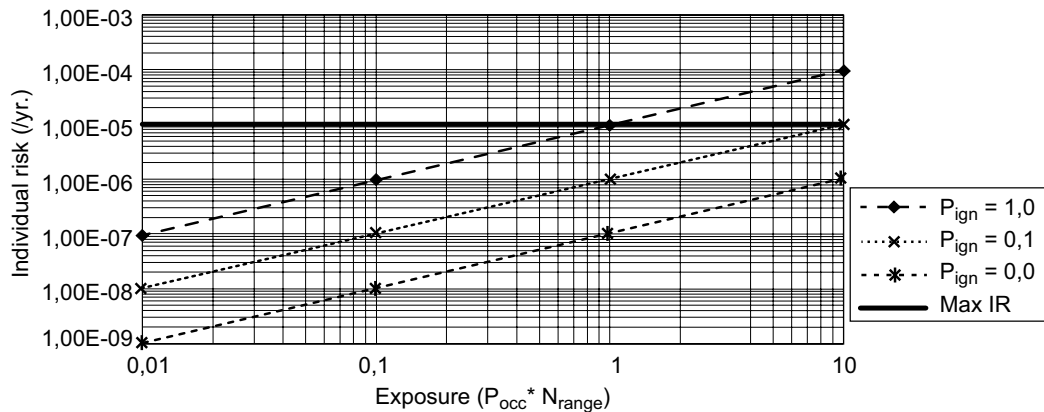


Figure C4: Individual risk (/yr) vs. exposure (release frequency = 1,0E-3/release source-yr)

C3.3 EFFECT OF INDIVIDUAL RISK (IR) CRITERION ON DETERMINING HOLE SIZES

This Model Code bases the hazard radii derived using the risk-based approach on an individual risk of 1,0E-5/yr as justified in C3.1. Whilst there is no intention that this should be changed, it is not the purpose of this Code to impose IR criteria on individual companies. The use of a higher or lower level of IR impacts on the derived release frequency (LEVEL) and hence the actual size of the hazard radius.

For a given set of mitigating probabilities for ignition, occupancy and vulnerability of say 1,0E-2 at the standard IR of 1,0E-5/yr the event frequency would be 1,0E-3/yr and therefore LEVEL II would be used. However, if the IR was based on 1,0E-4/yr, for the same set of mitigating probabilities, the event frequency is increased to 1,0E-2/yr and hence LEVEL I will be specified, giving smaller hazard radii. If an IR 1,0E-3/yr was the chosen criteria, the event frequency would be further reduced to 1,0E-1/yr which, using historic data for release frequencies would result in hole sizes even smaller than those set at LEVEL I, reducing still further the hazard radii.

ANNEX D

THE DIRECT EXAMPLE APPROACH FOR CLASSIFICATION OF COMMON FACILITIES IN OPEN AREAS

D1 SCOPE

The approach detailed in this Annex can be used as the basis for classification of those petroleum industry operations that are carried out in an open area, unless otherwise noted, in facilities similar in layout and material handled so that they can be classified directly from typical examples. For facilities in congested, stagnant and enclosed areas, guidance is given in Chapter 4.

The direct examples in this Annex are based on engineering judgement. However, the notes associated with the diagrams should always be reviewed and, where necessary, consideration given to any circumstances departing from these general design criteria. The distances shown may be modified by use of the point source methodology used in Chapter 3.

Whilst every effort has been made to keep hazard radii in proportion, it should be noted that the figures are NOT drawn to scale.

The following sections give guidance on the area classification applicable to some typical facilities. When using this approach, the facility being assessed must not differ significantly from the example in layout, equipment size or degree of ventilation.

Where there are significant differences the point source methodology should be applied.

D1.1 CLIMATE VARIATIONS

For the purposes of this Model Code, a maximum ambient temperature of 30 °C has been assumed. The hazardous area zone dimensions in the following diagrams are therefore based on this condition unless stated otherwise.

For products handled above a temperature of 30 °C, the extent of the hazardous area may be greater than the recommendations given in this Annex.

In more pronounced cases, e.g. high vapour pressure condensates, very light hydrocarbon petrochemical feedstock, or blending components, the appropriate fluid category should be used and the point source approach outlined in Chapter 3 should be followed.

The division between the Class II and III subdivisions (1) and (2) will also depend upon ambient temperature and, in areas outside the UK, it will be necessary to determine the maximum ambient temperature levels and the influence they may have on handling temperatures.

D1.2 FLUIDS HANDLED BELOW FLASH POINT

Certain flammable fluids when handled under pressure and at a temperature below their flash point, may form a flammable mist. For further details see A.1.2. and Chapter 3.

Fluids which can be released onto a hot surface such as a steam pipe or engine exhaust, may form a flammable vapour and area classification may be required see Chapter 3.

D1.3 'UNCLASSIFIED' FLAMMABLE FLUIDS

Flammable fluids falling into the 'Unclassified' Class, i.e. flash point $>100^{\circ}\text{C}$, may, according to the temperature of handling, either be considered as non-hazardous or, at temperatures in excess of the flash point, be considered as Class III(2) liquids.

D2 PETROLEUM CLASS 0 (LPG OR SIMILAR)

D2.1 BULK PRESSURISED LPG INSTALLATIONS (CLASS 0 PRODUCT)

This section applies to bulk storage of LPG and to above ground storage tanks at filling stations. It does not apply to domestic LPG installations.

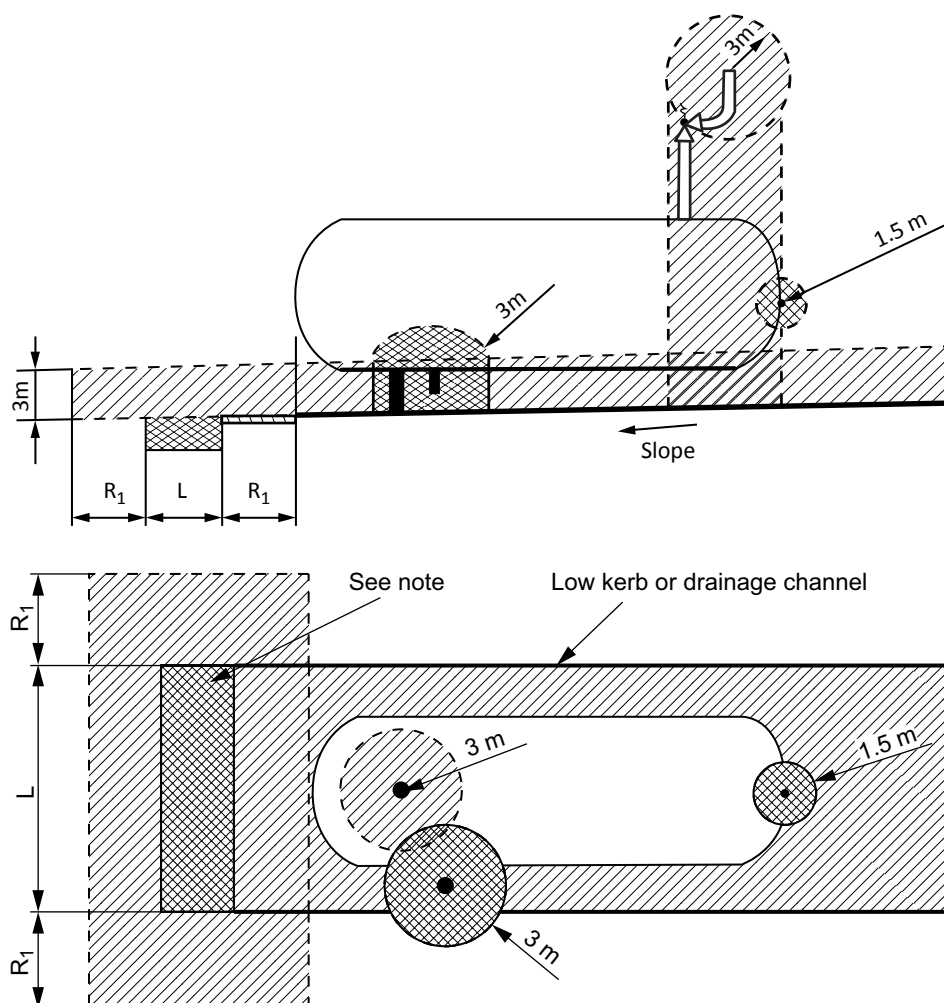
The main sources of release are considered to be ullage level indicators and loading/unloading connections which are provided with self-sealing valves. These points should have nominal Zone 1 areas of radius 1,5 m and 3 m respectively, which correspond to the loss of materials from a nominal 1 mm diameter hole. For coupling sizes used on filling stations, the hazard radius around the connection point may be reduced to 1,5 m.

Relief valves which are regularly maintained and tested, and flanges, including access chamber covers, should have a nominal 3 m radius Zone 2 hazardous area. Where a soft seat relief valve is used, the Zone 2 hazard radius may be reduced to 0,5 m.

Any spill catchment area provided to retain liquid LPG spillages should be classified as described in Figure D1 and in accordance with 3.8.1. This transient spill area is classified as Zone 2.

Any ancillary equipment associated with the storage area, e.g. pump sets, should be classified a Zone 2 area dependent on the type of pump and seal system. The extent of the hazardous area should be determined in accordance with the point source approach in Chapter 3.

A typical example is shown in Figure D1. Classification of buried/mounded LPG storage is covered in D2.3.1.



Note: See 3.8.1.

Figure D1: LPG storage facilities (Class 0 product)

D2.2 UNLOADING OF CLASS 0 PRODUCTS i.e. LPG AND SIMILAR FLAMMABLE FLUIDS

D2.2.1 Road tanker classification

Road tankers delivering LPG to filling stations should be assessed for area classification together with the provisions of safe entry of vehicles covered in D3.3.3 (e.g. in the event of a spillage of flammable materials at the site).

Whilst road tankers delivering liquid fuels are discharged under gravity at ambient conditions, LPG will be at its vapour pressure at ambient temperature and will therefore have to be pumped into the storage vessel but without the need for vapour recovery and without creating vapour discharges to atmosphere.

Delivery of LPG is typically from a rigid tanker with an onboard discharge pump. Providing the pump is of a high integrity type, this will give rise to a Zone 2 hazardous area around the

pump. In cases where an external pump is used for delivery, a Zone 2 hazardous area will be present around any hose connection points around the tanker and the pump will require classification at its fixed location. Further details of pump classification can be found in 3.7.1. Road tankers used for LPG are highly variable in design and the site operator should ensure they are advised of the type of tanker likely to deliver to their site and be provided with an area classification drawing of the tanker which may be used. Area classification of the site will be incomplete without this.

The hazardous areas around the delivery area will need to take account of the hazardous areas created during unloading of LPG. This includes (but is not limited to) hazardous areas around hose reels, gauges, pumps and relief valves on the tanker. The integrity level of these fittings and components will impact upon any associated hazardous area.

D2.3 LOADING OF CLASS 0 i.e. LPG AND SIMILAR PRODUCTS

Area classification around an LPG tanker during loading should be carried out using the guidance in D2.2.1 and Figure D2. In addition, because the loading from bulk storage will be carried out using an external pump connected to the road tanker via flexible hoses of up to 80 mm diameter. Loss of LPG on disconnection will generate a Zone 1 of nominal hazard radius 3 m around these hose connection points. This compares to a loss of LPG at 10 bar(a) through a 1 mm hole giving a hazard radius of 2,5 m (see Table C4 in Annex C Part 1). If smaller hoses are used, which limit the loss of LPG on disconnection to less than 100 ml, the hazard radius may be reduced to 1,5 m. The hazardous areas around the relief valve and level indicators will be as detailed in Figure D2.

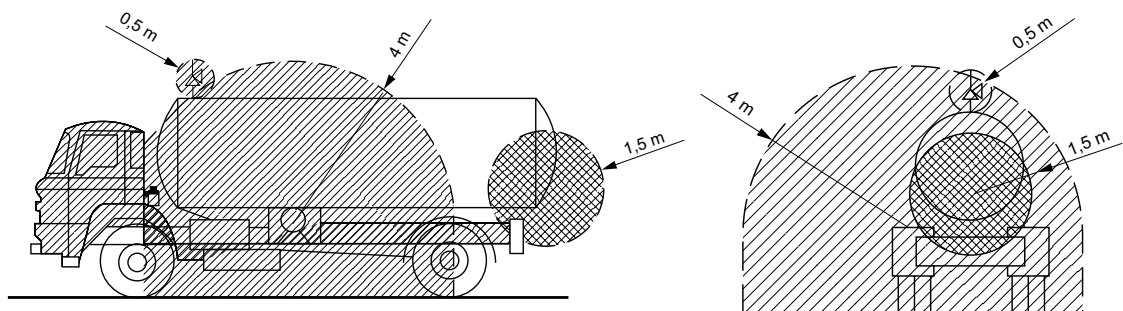


Figure D2: Typical composite hazardous area zone classification around LPG road tanker during loading and unloading

D2.3.1 Unloading to underground storage tanks^{3 4}

For LPG storage in buried storage vessels, typical classification is given in Figures D3(a) and (b). Buried storage vessels will have vessel access chambers which should be classified as Zone 1 hazardous areas. Where connections are made (e.g. fill point or ullage level indicator operation), this will create a transient Zone 2 hazardous area of 1,5 m above ground around

³ In addition to hazardous areas there is also a 'separation distance' around the storage vessel and the main components. For further information see UKLPG CoP 1 and 20.

⁴ Area classification is typical only. Site-specific conditions may lead to changes in the size and extent of hazardous areas.

the access chamber during the unloading operation. Where fill points and ullage level indicators are offset (above ground), these will give rise to Zone 2 and Zone 1 hazardous areas respectively of 1,5 m⁵ radius, see Figure D3(b).

Relief valves with a soft seat, which are regularly maintained and tested, are not considered under the design relief condition for area classification purposes; however, fixed electrical equipment should not be installed within the direct path of discharge. To allow for small, infrequent leakages they should be classified with a Zone 2 hazardous area of 0,5 m radius. Where other types of relief valves are fitted, this hazard radius should be increased to 2,5 m.

Provided LPG storage facilities are purged with nitrogen prior to initial filling and final emptying e.g. for inspection or maintenance purposes, the ullage should never contain a flammable atmosphere, and therefore the ullage space can be considered as non-hazardous. However, if nitrogen purging is not used, the ullage space within the vessel should be classified as Zone 0 due to the presence of air in the vessel.

Where it is necessary to classify single flanges they should have a Zone 2 hazardous area of extent appropriate to the integrity of the flange and process conditions encountered in the pipework, the extent of which should be at least 1 m.

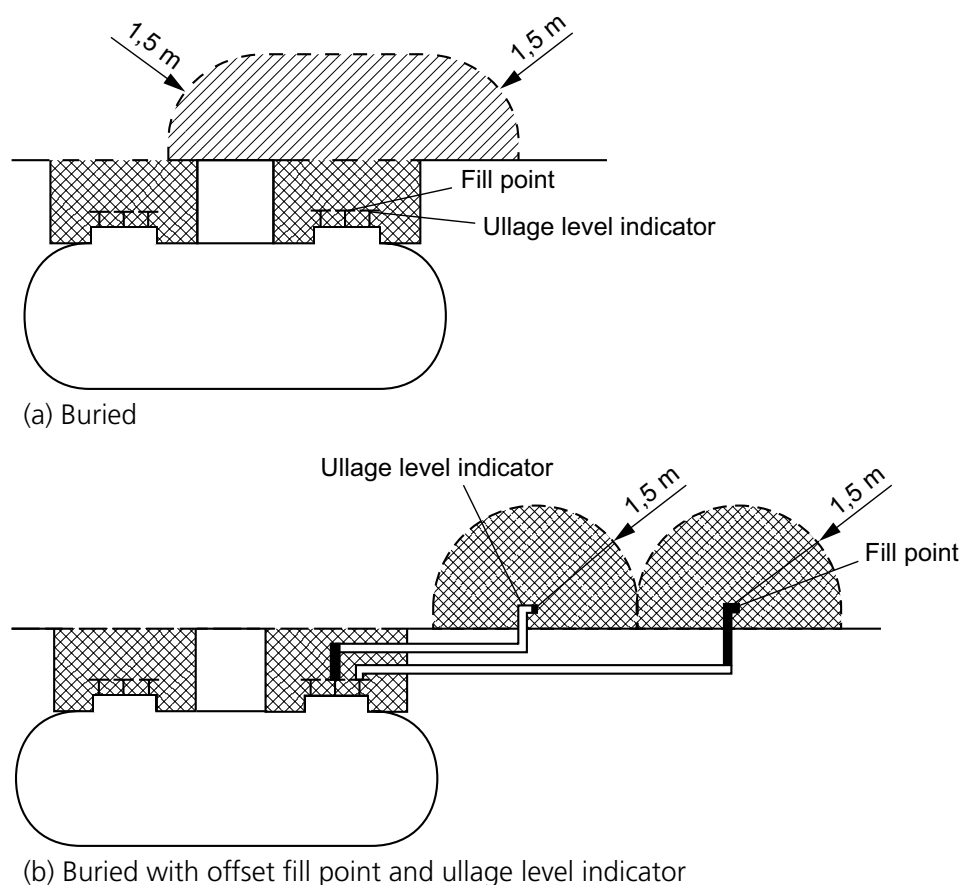


Figure D3: Typical hazardous area zone classification for underground LPG storage tanks

⁵ Valid for losses up to 100 ml

D2.3.2 Unloading to above ground storage tanks

Where the tanker is unloaded to above ground storage tanks, these should be classified using the guidance in section D2.1.

D3 PETROLEUM CLASSES I, II, III AND UNCLASSIFIED

D3.1 INTRODUCTION

This chapter covers storage tanks, bulk road and rail transfer and storage, and marine transfers of petroleum classes I, II, III and unclassified products.

Products handled below their flash point do not generally give rise to a flammable atmosphere unless they are released under pressure and form a flammable mist. Flammable mist formation may occur if transfer is under pump pressure; however, it is considered unlikely in situations when transferred under gravity e.g. at retail filling stations. Further information on flammable mists is given in Annex A.

Flammable atmospheres may occur if a product handled below its flash point is released onto a surface that is at a temperature that is above the product flash point.

D3.2 STORAGE TANKS

The following direct examples apply to storage tanks. The examples apply directly to the storage of Class I liquids, for which there should always be such a zoning. This guidance may be applied, where such conditions arise, to the storage of Class II(2) and III(2) liquids.

As indicated in Chapter 2, Annex A Table A3 and A1.3, liquids that are stored under Class II(1) or III(1) conditions will not normally require external area classification; however, when such fluids are pumped at a pressure that may form a flammable mist or may be released onto a hot surface, reference should be made to D1.3.

It is considered good practice to restrict electrical apparatus within bunds to the minimum necessary. Pumps and their drives should not be sited within tank bunds.

The zoning in D3.2.1 and D3.2.2 will normally be adequate for the fittings on the tank shell, but it should be confirmed that there is no equipment or release within the tank bund which would extend the hazardous area. If this cannot be confirmed, the point source approach in Chapter 3 should be applied.

D3.2.1 Fixed roof and horizontal cylindrical tankage – Classes I, II(2) III(2) and Unclassified products

For fixed (cone or dome) roof and horizontal cylindrical tanks the ullage space should be classified as Zone 0 (see Figure D4(a)). This applies also to tanks fitted with internal floating covers.

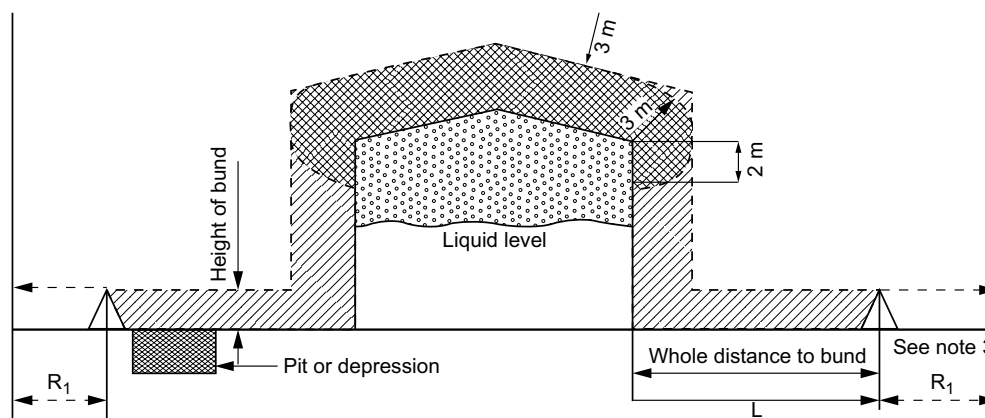
The vent system on the tank roof should be considered a primary grade source of release. Vapour will travel along the surface of the roof and flow downwards, close to the tank shell. It is assumed that the bund wall will contain the spread of vapour due to venting. The area extending 3 m upwards at right angles to the roof surface, 3 m horizontally from the roof edge and 2 m

vertically down the shell from the roof edge should therefore be classified as Zone 1. These hazard distances from the vent are obtained from Table 3.1 and apply to liquid filling rates of:

- up to 250 m³/h equivalent to venting rates of 250Nm³/hr and vent diameter of 250 mm, for the fixed roof tank, and
- up to 250 m³/h equivalent to venting rates of 250Nm³/hr and vent diameter of 100 mm for the small horizontal cylindrical tank see Table 3.1.

Additional information and for filling rates greater than 250 m³/h can be found in Table 3.1.

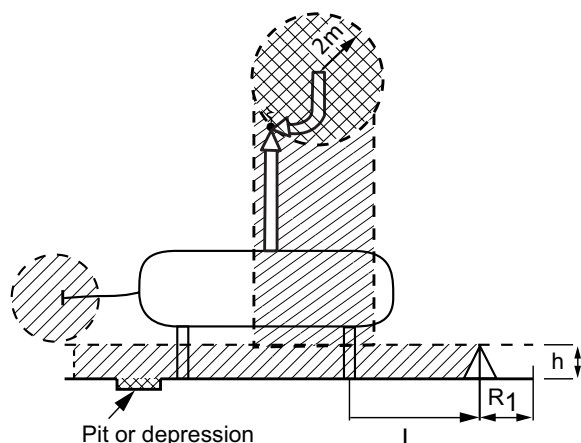
The area within the tank bund up to a height equal to the top of the bund or up to 1 m, whichever is the greater, should be classified as Zone 2, and any pits or depressions Zone 1, because of the greater tendency of heavier-than-air vapour to persist. Where bund walls are 1 m or greater it is assumed that the vapour is contained within the bund wall. For bund walls less than 1 m height it is anticipated that the flammable vapour will extend beyond the bund wall. The extent of the flammable atmosphere beyond the bund wall should be based on the pool spill data given in Chapter 3. At a distance of 3 m from the shell, the Zone 2 should be extended upwards to meet the Zone 1 area. This is shown in Figure D4(a). If the bund wall is less than 3 m from the tank shell, the zoned area extends a minimum of 3 m from the tank shell.



Notes:

1. If engineering measures to eliminate mist or spray formation are not in place then the ullage space of Class II(1) and III(1) tanks should also be regarded as Zone 0.
2. If the ullage space is categorised as Zone 0, it is recommended that the area surrounding any vents or openings on the roof of such a tank be regarded as Zone 1 to a radius determined using information in 3.6.2.2.
3. The distance of R_1 from the bund is to be determined based on the information provided in 3.8.1.
4. For unclassified products such as bitumens and heavy residual and bunker fuels stored under confined heated conditions in fixed roof tanks (i.e. unventilated ullage space), the flash point of the product is not a reliable guide to the presence or absence of a flammable atmosphere that may have built up in the tank vapour space. For this reason it is prudent, in common with the ullage space of road or rail tank vehicles containing all classes of flammable fluids, to classify the ullage space of all such tanks as Zone 0, with a 1,5 m Zone 1 hazardous area around roof vents and other openings. For further information see *El Model code of safe practice – Part 11: Bitumen safety code*.

Figure D4(a): Bunded tanks – cone or dome



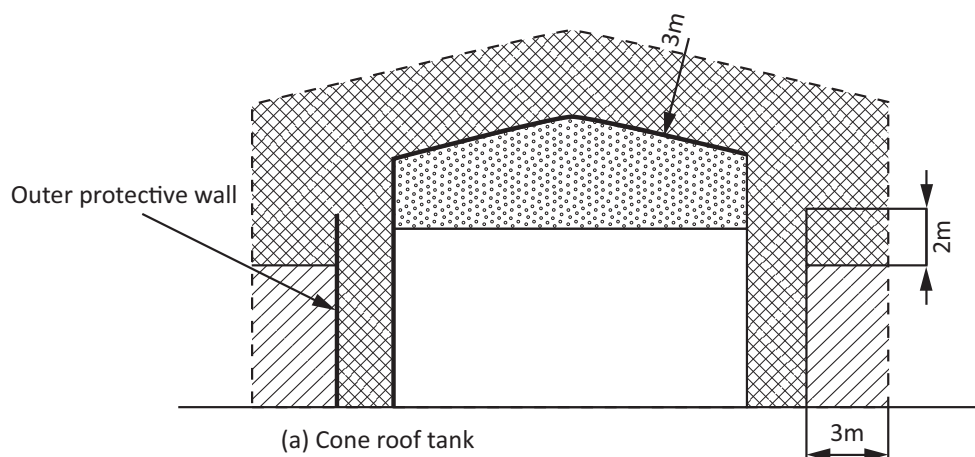
Notes:

1. If engineering measures to eliminate mist or spray formation are not in place then the ullage space of Class II(1) and III(1) tanks should also be regarded as Zone 0.
2. If the ullage space is categorised as Zone 0, it is recommended that the area surrounding any vents or openings on the roof of such a tank be regarded as Zone 1 to a radius determined using information in 3.6.2.2.
3. For unclassified products such as bitumens and heavy residual and bunker fuels stored under confined heated conditions in tanks of this type (i.e. unventilated ullage space), the flash point of the product is not a reliable guide to the presence or absence of a flammable atmosphere that may have built up in the tank vapour space. For this reason it is prudent, in common with the ullage space of road or rail tank vehicles containing all classes of flammable fluids, to classify the ullage space of all such tanks as Zone 0, with a 1,5 m Zone 1 hazardous area around roof vents and other openings. For further information see *EI Model code of safe practice – Part 11: Bitumen safety code*.
4. The distance of R_1 from the bund is to be determined based on the information provided in 3.8.1.

Figure D4(b): Small bunded horizontal storage tank**D3.2.2 Floating roof tankage – Classes I, II(2) and III(2) products**

The area classification around a floating roof tank should be as described in Figure D4(c). The space within the tank shell above the roof should be classified as Zone 1.

The area above and around the tank shell for a distance of 2 m should be classified as Zone 2 and should extend, at the height of the bund, to the bund wall. Any pits or depressions within this Zone 2 should be classified as Zone 1.



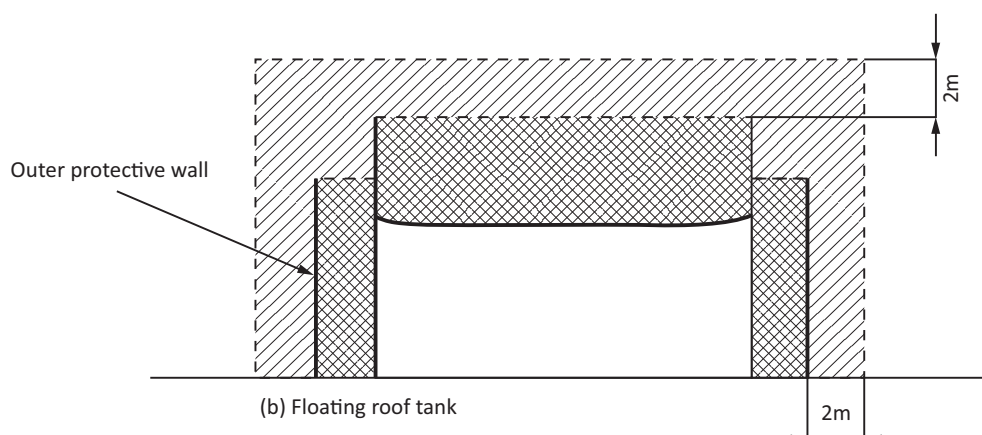


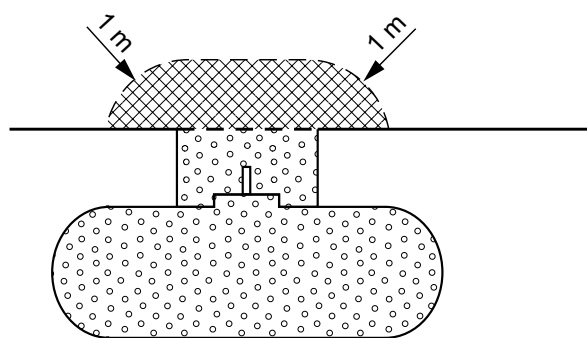
Figure D5: Tanks with outer protective wall (continued)

D3.2.4 Underground tanks

Underground tanks are normally located at filling stations, or small industrial or domestic premises. Guidance on their area classification is covered in D3.3.3, and in Figure D6 for the tank access chamber and offset fill pipe chamber.

If there is a tank tunnel providing access to an underground or mounded tank, it will normally be an enclosed area and should be classified in accordance with Chapter 4, after considering the effect of any artificial ventilation system.

- (a) Fill point/vapour connection in access chamber
- (b) Offset fill point/vapour connection in access chamber
- (c) Above ground offset fill point and vapour connection



(a) Fill point/vapour connection in access chamber

Figure D6: Typical hazardous area zone classification for underground gasoline storage tanks and fill points during road tanker connection, unloading and disconnection

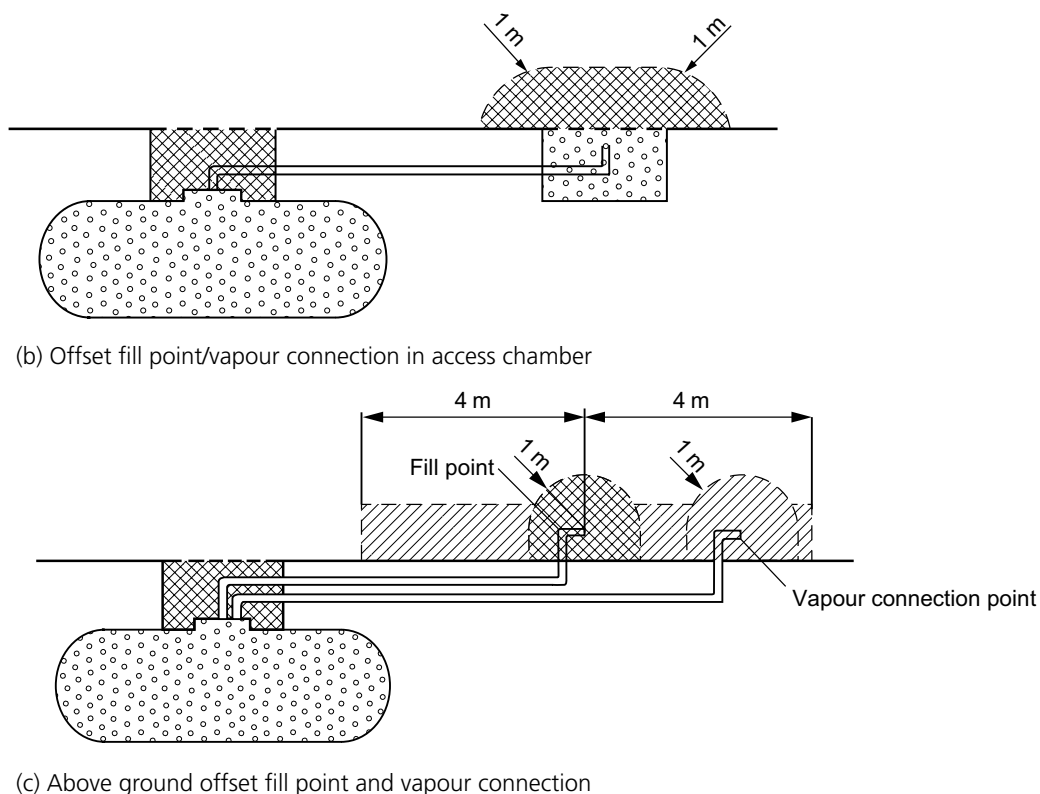


Figure D6: Typical hazardous area zone classification for underground gasoline storage tanks and fill points during road tanker connection, unloading and disconnection (continued)

D3.2.5 Vent stacks

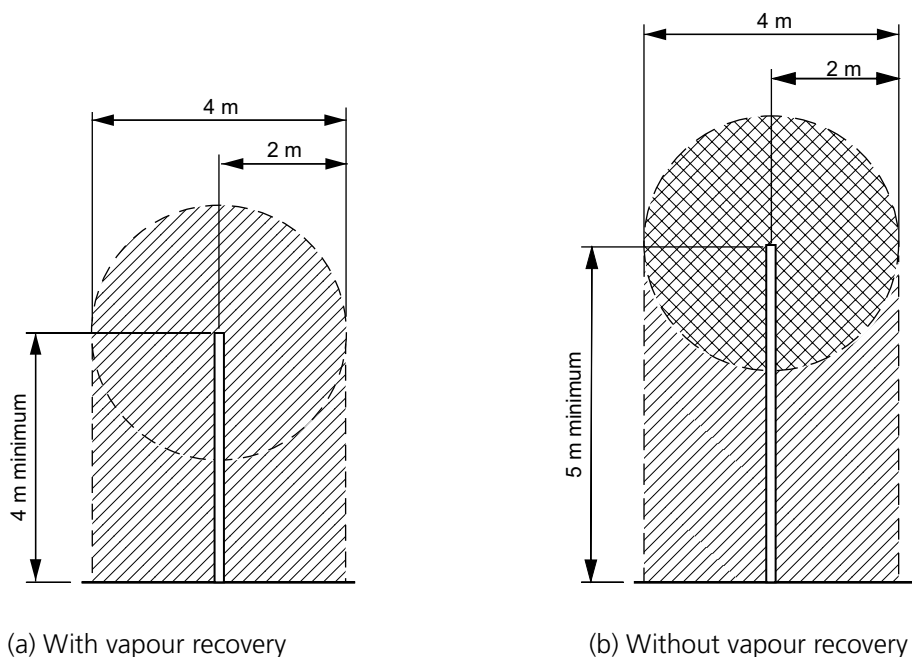
High level vents e.g. from underground or mounded tanks should be regarded as primary grade release sources with the extent of the Zone 1 hazardous area dependent on the vapour emissions rate (or filling rate), as described in 3.6.2.

D3.2.5.1 Venting from storage tanks

Care should be taken to ensure that the hose connection point from the tank vent(s) remains securely closed in the event that vapour recovery is not undertaken. Failure to observe this precaution will likely lead to the discharge of flammable vapour at low level, bypassing the normal tank vent outlets.

The area classification around vents from underground storage tanks will be dependent on whether there is a vapour recovery system in place or whether tanks are vented directly to atmosphere.

Systems with vapour recovery fitted will give rise to a Zone 2 hazardous area of radius 2 m around the top of the vent from the system, extending down to ground level. Vent pipes venting directly to atmosphere will give rise to a Zone 1 of radius 2 m around the top of the vent, extending down to ground level, classified as Zone 2. See Figure D7.



Note:

The above hazard radii in these diagrams are applicable for vent pipes up to 80 mm in diameter and tanker unloading rates up to 250 000 litres/hr (equivalent to a vent rate of 250 Nm³/hr). For larger vent pipes and faster filling rates, see 3.6.2.

Figure D7: Typical hazardous area zone classification around a storage tank vent pipe at retail facilities

D3.3 ROAD TANKER LOADING

This covers both bottom and top loading of Classes I, II, III products and similar flammable fluids in the normal case where such facilities are located in an open area.

If materials that are below their flash point are loaded into a tanker compartment that is not connected to a vapour recovery system and which has previously contained a high vapour pressure product such as gasoline, (i.e. switch-loaded), they may displace flammable vapours from the tanker vent. In such cases the vent should be classified as for a Class I, II(2) or III(2) product.

Before loading or unloading, all vehicle electrics, other than ATEX certified protected electrical equipment, should be isolated.

As depicted in the following direct examples, loading facilities should normally be located in an open area (see *EI Model code of safe practice – Part 2: Design, construction and operation of petroleum distribution installations*). A roof for weather protection is acceptable but any sides should not unduly restrict natural ventilation. Also, the space below the roof should be regarded as a sheltered area, and classified as Zone 2 as depicted in Figure D8. Turbulent airflow above a ventilated roof makes it impossible to calculate a specific hazardous area around roof vents. Therefore, it is recommended that electrical equipment should not be located near to roof vents.

The approach to the classification for both bottom and top loading of road tankers should take account of the following situations:

- (a) The loading island and bay area with no vehicle present.
- (b) The loading island and bay area with vehicle present, including during filling.
- (c) Any spillage of flammable materials.

These direct examples are only valid providing the design of the road tanker is in accordance with relevant national and international statutory requirements (see *El Petroleum road tanker design and construction*), and suitable safety and operating procedures are followed (see *El Model code of safe practice – Part 2: Design, construction and operation of petroleum distribution installations*). Unless these are met, the movement of vehicles to and from a loading position, (which must take place with the loading island, bay area and vehicle in a flammable hazard-free state) and the occupation of a loading position adjacent to a road tanker that is filling, may be potentially hazardous.

Loss of containment on one loading island which spreads to an adjacent vacant loading island, e.g. vapour spread, spillage during filling, breaking of flanges or leakage from maintenance, renders the entry or departure of vehicles potentially hazardous. It should be noted that certain hazardous areas are transient and only exist whilst loading is being carried out.

D3.3.1 Road tanker bottom loading

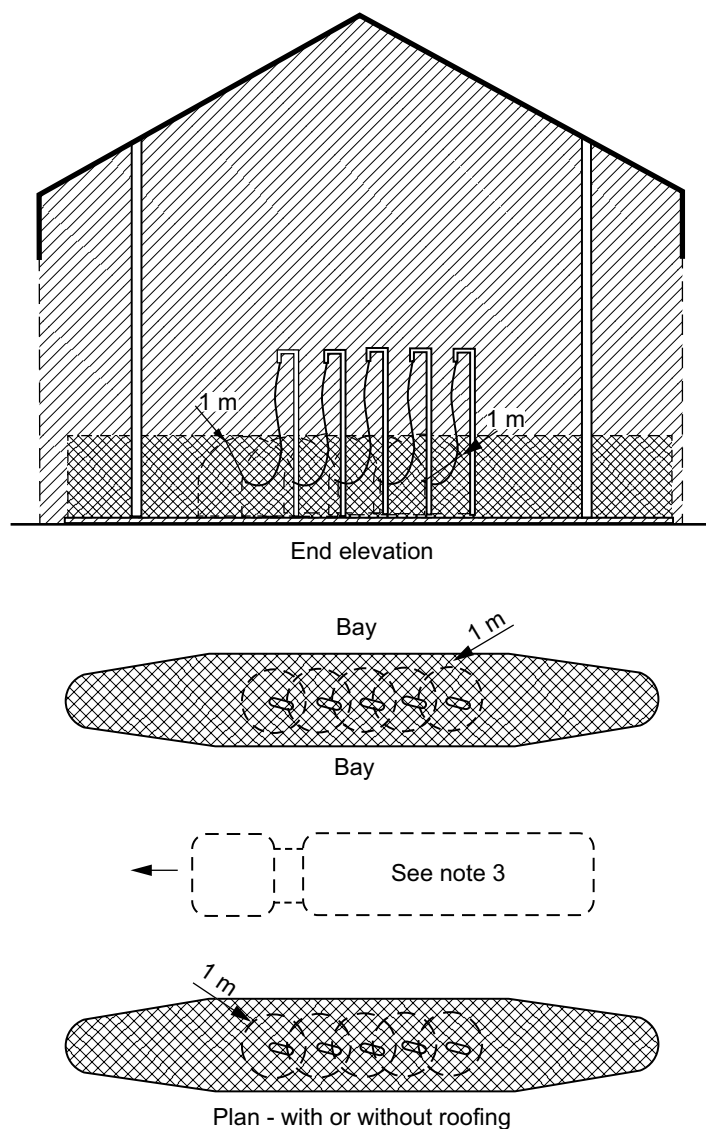
The hazardous areas around all possible sources of release which could arise from the installed loading equipment and slop facilities, in the absence of a vehicle, should be assessed and a practical envelope devised. This should include hazardous areas arising from routine operations such as filter cleaning.

The additional hazardous areas which arise whilst vehicles are being filled should be determined. These hazardous areas are transient and will not exist when the couplers/ adaptors are closed and the loading arms have been returned to the parked position. Spillages arising during vehicle filling should, however, be considered.

Following the steps in D3.3 the analysis should be carried out in stages as detailed in D3.3.1.1.1 – D3.3.1.6.

D3.3.1.1 Classification of loading island and bay area – no vehicle present

For the purposes of this Model Code, it is assumed that the fixed loading connections are equipped with self-sealing couplings. Due to the frequency with which the connections are made and broken, causing a small release of liquid or vapour to occur, they should be regarded as primary grade release sources, giving rise to a Zone 1 hazardous area around the couplings in the parked position of the loading arms, down to ground level. For releases of up to 10 ml (anticipated release from coupling) a nominal 1 m hazard radius should be assigned around the end of each hose. However, it is recommended that the entire loading island is classified as a Zone 1 area to ensure equipment located on the island is specified accordingly, as shown in Figure D8.



Notes:

1. The bay area between loading islands and beyond the hazardous area associated with the loading arms can be considered non-hazardous in the absence of spillage.
2. In order that the bay is not assigned as a Zone 1 area, the loading arms should be parked in the vertical position when not in use.
3. Illustration of entry into empty bay in safe condition if no spillage present and all fill covers closed.

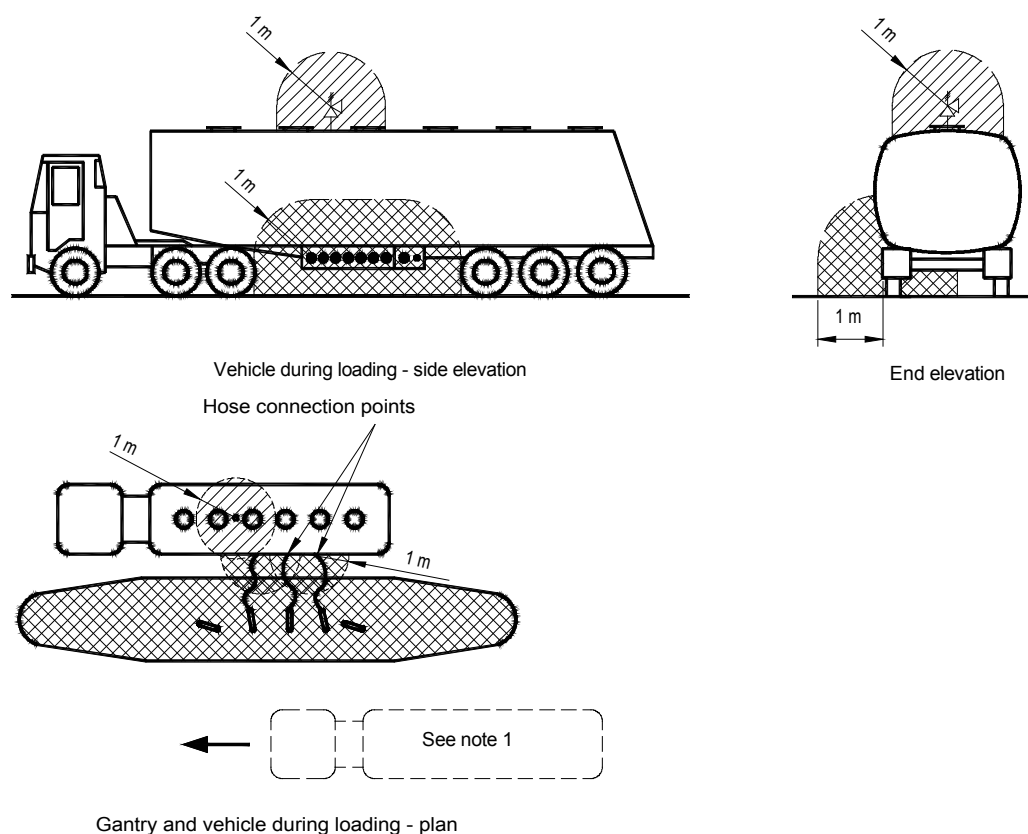
Figure D8: Bottom loading island, no vehicle present

D3.3.1.2 Classification of loading island and bay area during loading – vehicle present

The vehicle equipment is classified according to the requirements of ADR.

Vapour is piped from the vapour manifold on the vehicle to a low-level connection on the loading island, through a self-sealing coupling. From this connection, the vapour is routed to a vapour recovery unit or, when this is not provided, to a vent direct to atmosphere

(see D3.3.1.6). There is, therefore, no free venting in the loading area from compartment adaptors. However, a small leakage could result from the hose connection point on the tanker during coupling and uncoupling. Due to the frequency of operation, this gives rise to a Zone 1 area of radius 1 m (see Figure D9). This distance assumes that the self-sealing couplings normally used for bottom loading limit the normal release. If vapour recovery is employed, the only circumstance in which discharge to the open air can occur is where failure of the overfill prevention system leads to the emergency venting of a compartment. This possibility is remote since the design of the overfill prevention system should be both self-checking and fail-safe. Accordingly it can be designated a secondary grade release, resulting in a Zone 2 area of 1 m radius around each relief valve, as shown in Figure D9.



Notes:

1. In this diagram the road tanker is not shown as a hazardous zone because there are no sources of hydrocarbon in the cab but the electrical equipment is required to comply with ADR regulations.
2. Empty bay with no spillage present is in safe condition for vehicle entry/departure, with vents and all connections closed.
3. When bottom loading tankers are being filled with open fill covers (without vapour recovery), the hazardous area due to vapour emission from vents during loading at a filling rate of 2,5 m³/min extends in all directions from each open fill cover for less than 1 m radius. This distance should be increased to 1,5 m to allow for the possible release of product from draw-off valves when used for adjustment of load.
4. The ullage space in the tank should be classified as Zone 0.

Figure D9: Road tanker equipped for bottom loading with vapour collection, during loading

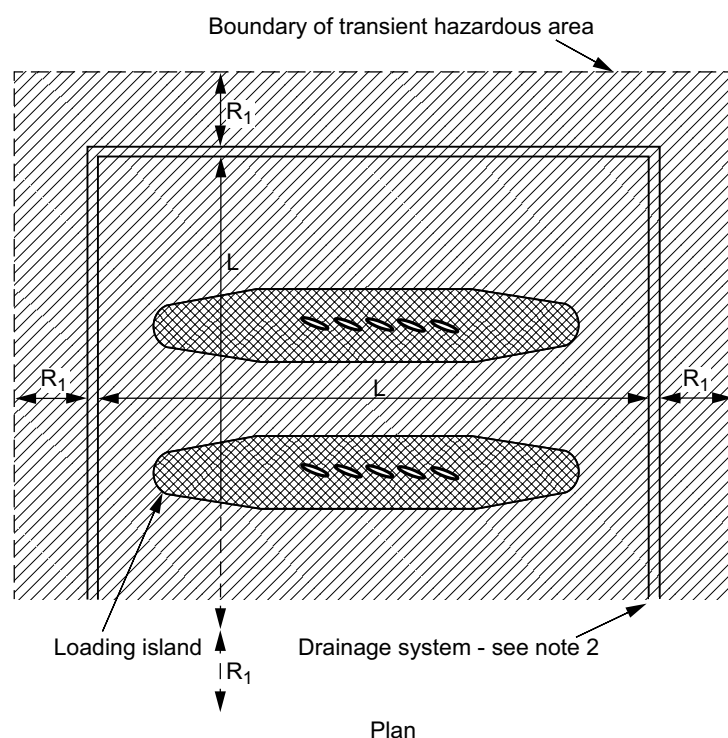
D3.3.1.3 Provision for spillage

In addition to the Zone 1 areas in Figures D8 and D9 during the loading operation, transient Zone 2 areas should be recorded where spillages of Class I, II(2) or III(2) materials could occur.

Spillages in the loading area should be considered as secondary grade releases. Spillages can occur from filters during routine servicing, from the failure of pipework system components and, despite the provision of overfill prevention devices, from overfilling of tanker compartments at flow rates up to the maximum loading rate. The extent of a spillage should be assessed according to the expected duration of release and with due regard to surface grading and drainage systems. Overfilling a tanker compartment is likely to result in the formation of the largest wetted area or pool.

Details of the surface area drainage (i.e. the grading of the paved area and positions of collecting points, ducts and channels) will determine the size of pool likely to be formed for a given combination of spillage rate and duration.

In Figure D10, the spillage is assumed to be of a category C fluid and the size of the hazardous area (Zone 2) from these secondary grade release sources is based on the means of spillage containment as recommended in 3.8.1. The height of the Zone 2 area should therefore be 1 m. Where there is a drainage channel, kerb or other means of containment around the loading area, then no flow of spillage outside the channel or containment area need be considered, but the further extent of vapour travel should be taken into account. The total hazardous area will therefore normally be greater than that within the containment area (see Figure D10 for typical zoning). If a means of containment is not provided around the loading facility the likely extent of a spillage must be assessed by considering the surface grading.



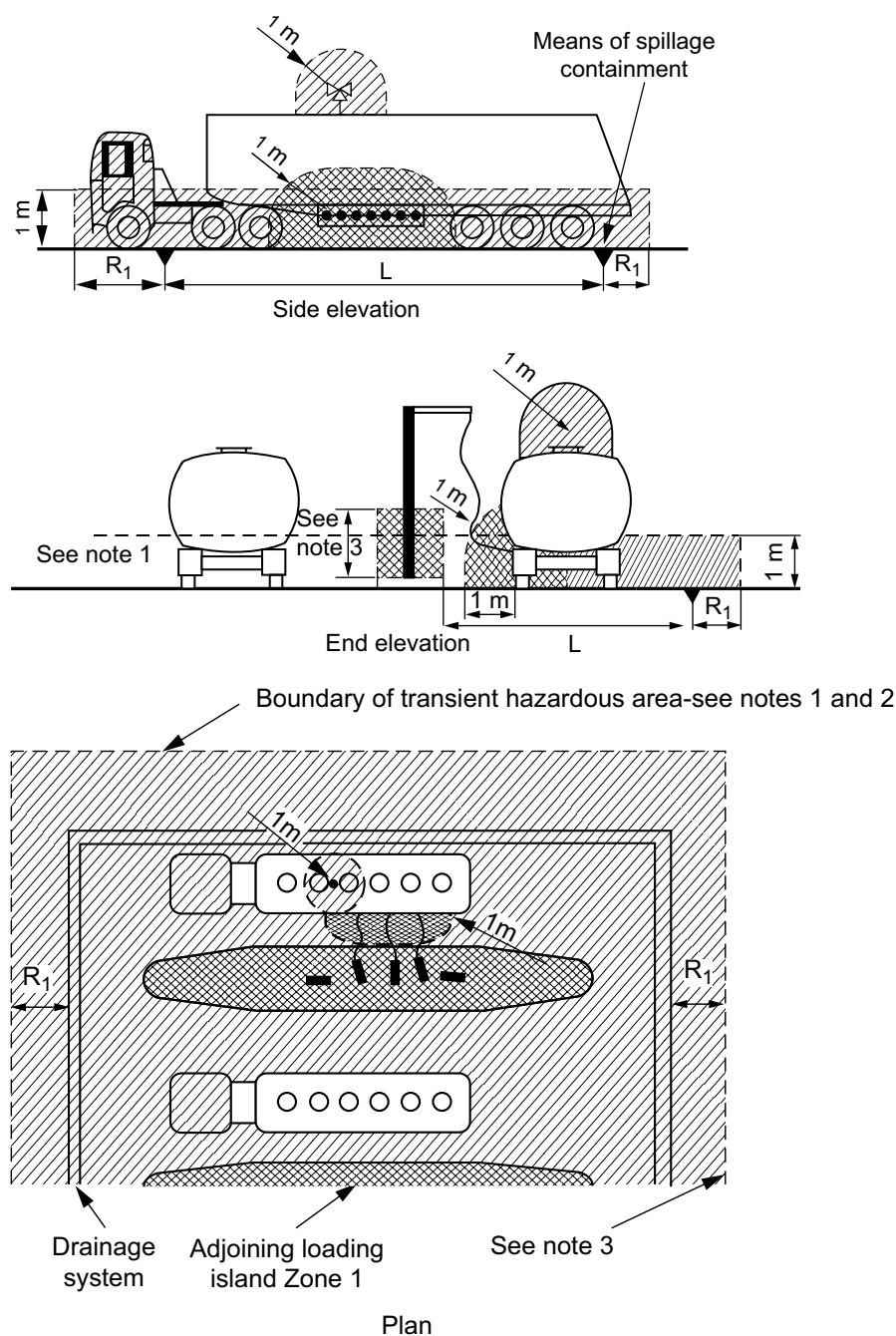
Notes:

1. For determination of extent of Zone 2 spillage area (R_1), see 3.8.1.
2. The dimensions of 'L' are determined by the means of spillage containment such as ground contours, kerbs, drainage gulleys or cut-off drains (as shown). 'L' shown here is not necessarily the same dimension in both directions.
3. If weather roofing is provided, the space above the Zone 1 area will be Zone 2 up to the roof.

Figure D10: Area classification in event of spillage

D3.3.1.4 The composite classification drawing

From the analysis carried out in the previous sections it is possible to assemble a composite of Figures D8 to D10, resulting in a final, composite drawing (see Figure D11). The whole arrangement should permit the movement of vehicles to and from the loading positions, with the loading island, bay area and vehicle in a flammable hazard-free state.



Notes:

1. Transient hazardous areas normally free from hazard when no spillage is present, or for Class II(1) and III(1) materials.
2. If weather roofing is provided, all space above the Zone 1 area will be Zone 2 up to the roof (see D3.3.1.5).
3. For height of Zone 1 area see D3.3.1.1.

Figure D11: Composite area classification drawing for bottom loading road tanker during loading in the event of a spillage

D3.3.1.5 Weather protection – bottom loading

In the case of bottom loading, overhead protection against weather can be dispensed with, as fill covers are not open for loading purposes. Where, however, extremes of climate make weather roofing desirable, irrespective of whether or not pipework is installed in the roof space, it is recommended that the whole of the roof space, other than that which may already be within the above-defined Zone 1 area, should be classified as Zone 2 (see Figure D8).

D3.3.1.6 Safe disposal of vented vapour

Where the vapour emitted from vehicle loading is returned to a vapour recovery system, any emissions should be lean in hydrocarbon levels. However, to allow for process malfunction and operational issues the vent should be regarded as a secondary grade source of release, and its hazardous area should be assessed in accordance with 3.6.2.

Where a vapour recovery system is not provided, facilities should be available to enable the road tanker's vapour manifold to be connected to a discharge system which will ensure that vapour displaced during loading is vented safely away from the immediate loading area. The hazardous area from such a vent should be assessed in accordance with 3.6.2. Given the frequency of most loading operations, the classification should be Zone 1.

D3.3.2 Top loading of road tankers

A detailed analysis should be carried out to produce a composite area classification diagram.

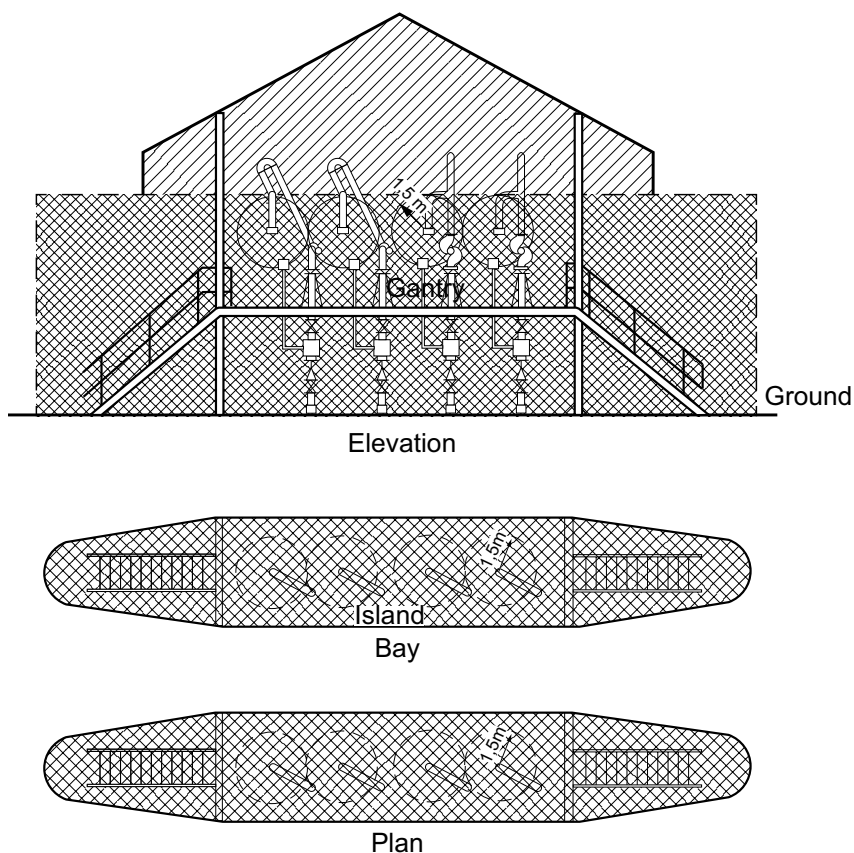
As in D3.3.1, the hazardous areas around all possible sources of release, which could arise from the installed loading equipment and product disposal facilities in the absence of a road tanker, should be assessed and a practical envelope devised. This should include hazardous areas arising from other routine operations such as filter cleaning.

Additional hazardous areas which arise whilst vehicles are being loaded should then be determined. These hazardous areas are transient and will not exist when the fill covers are closed and the loading arms have been returned to the parked position. Spillages, which could arise during road tanker loading should also be considered.

Following the principles established in D3.3, the analysis should be carried out as detailed in D3.3.2.1 – D3.3.2.4.

D3.3.2.1 Classification of loading island and bay area – no vehicle present

For this condition the loading island should be classified with the loading arms in the parked position to permit movement of a vehicle to and from the loading position which must take place with the loading island, bay area and vehicle in a flammable hazard-free state. The lower part of the loading arms after use will have internal and external wetted areas and evaporation and drainage can take place. Therefore, a nominal 1,5 m Zone 1 area should be assigned around the end of each loading arm. Due to the frequency of operation they should be regarded as primary grade release sources. The Zone 1 area should be extended vertically down to ground level. However, it is recommended that the entire loading island is classified as a Zone 1 area to ensure equipment located on it is specified accordingly, as shown in Figure D12.



Note: The above zoning applies to all fixed equipment. The bay areas between loading islands can be considered non-hazardous in the absence of spillage and with loading arms in the parked position in readiness for the entry or departure of the road tanker with its fill covers closed.

Figure D12 Top loading island and bay area – no vehicle present

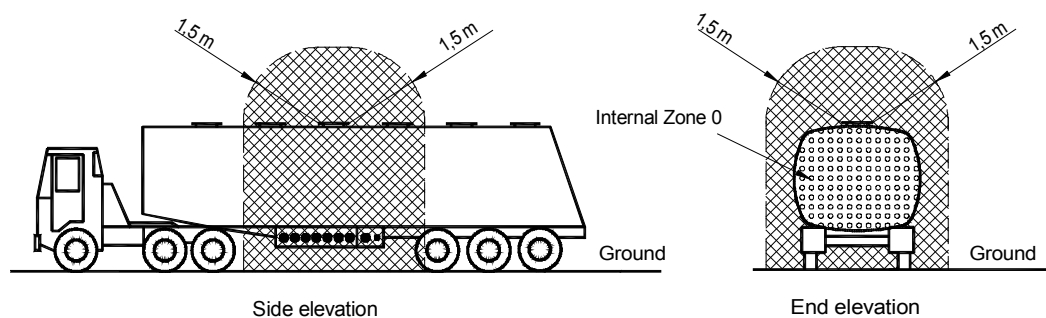
D3.3.2.2 Classification of loading island and bay area during loading – vehicle present

When all the tanker compartments are closed, the unoccupied space of an empty bay between the Zone 1 areas of adjacent loading islands permits the entry of the road tanker and its departure when loaded, subject in both cases to there being no spillage and loading arms being in the parked position.

When a road tanker is at the loading position, a further Zone 1 area is generated when vents and fill covers are opened.

Whilst the hazardous area due to vapour emission from vents during loading at a filling rate of 2,5 m³/min extends in all directions to less than 1 m (for Class I product), it is recommended that the Zone 1 is 1,5 m to allow for the possible release of product from draw-off valves when used for adjustment of load.

The extent of the Zone 1 area is shown in Figure D13.



Note: Zone 0 inside compartments applies for all classes of flammable fluids.

Figure D13: Top loading of road tanker through open or vent fill covers

D3.3.2.3 Provision for spillage

This will apply only for Class I, II(2) and III(2) products (See D3.4.3 and Figure D14).

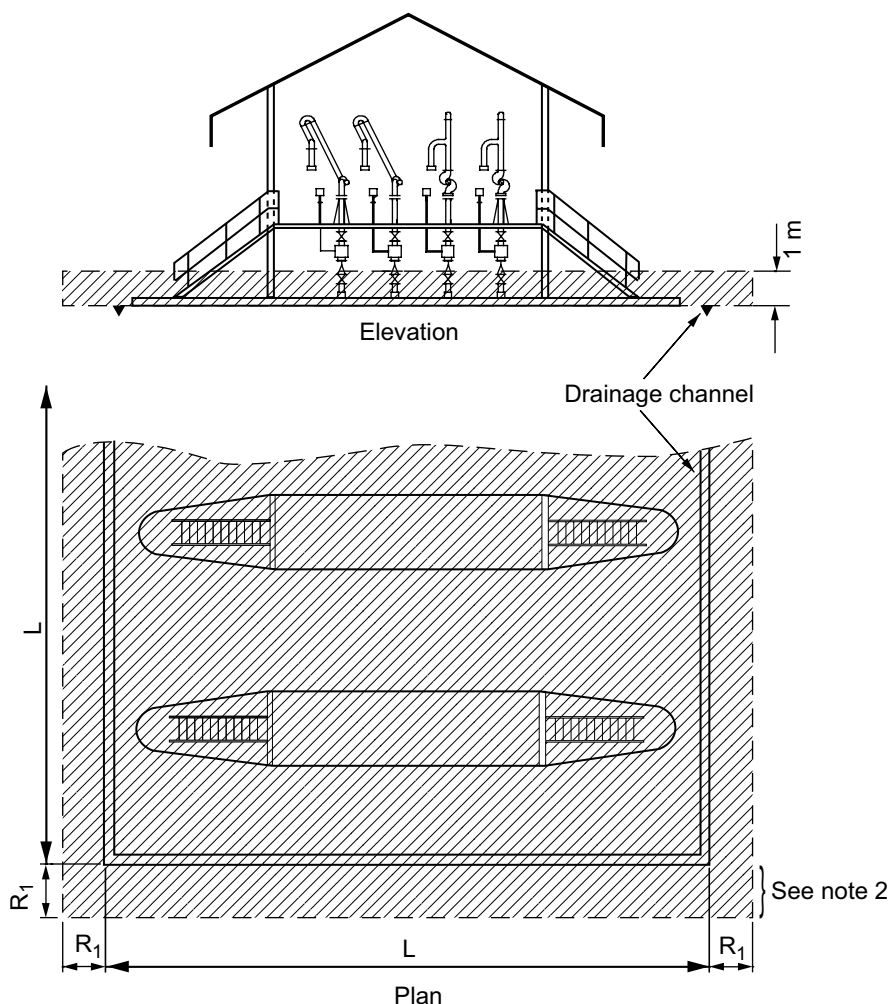


Figure D14: Typical Zone 2 provision for spillage area with drainage

Notes: See next page

Notes:

1. For determination of the Zone 2 hazardous area resulting from spillage, for Class I, II(2) and III(2) products, see D3.3.1.3 and 3.8.1.
2. The dimensions of L and R_1 are controlled by means of spillage containment such as ground contours, kerbs, drainage gulleys and cut-off drains (as shown). L shown here is not necessarily the same dimension in both directions.

Figure D14: Typical Zone 2 provision for spillage area with drainage (continued)

D3.3.2.4 The composite classification drawing

From the analysis carried out and using Figures D8 - D10, it is possible to assemble a composite area classification drawing (see Figure D15).

The whole arrangement should permit the movement of vehicles to and from the loading positions, with the loading island, bay area and vehicle in a flammable hazard-free state.

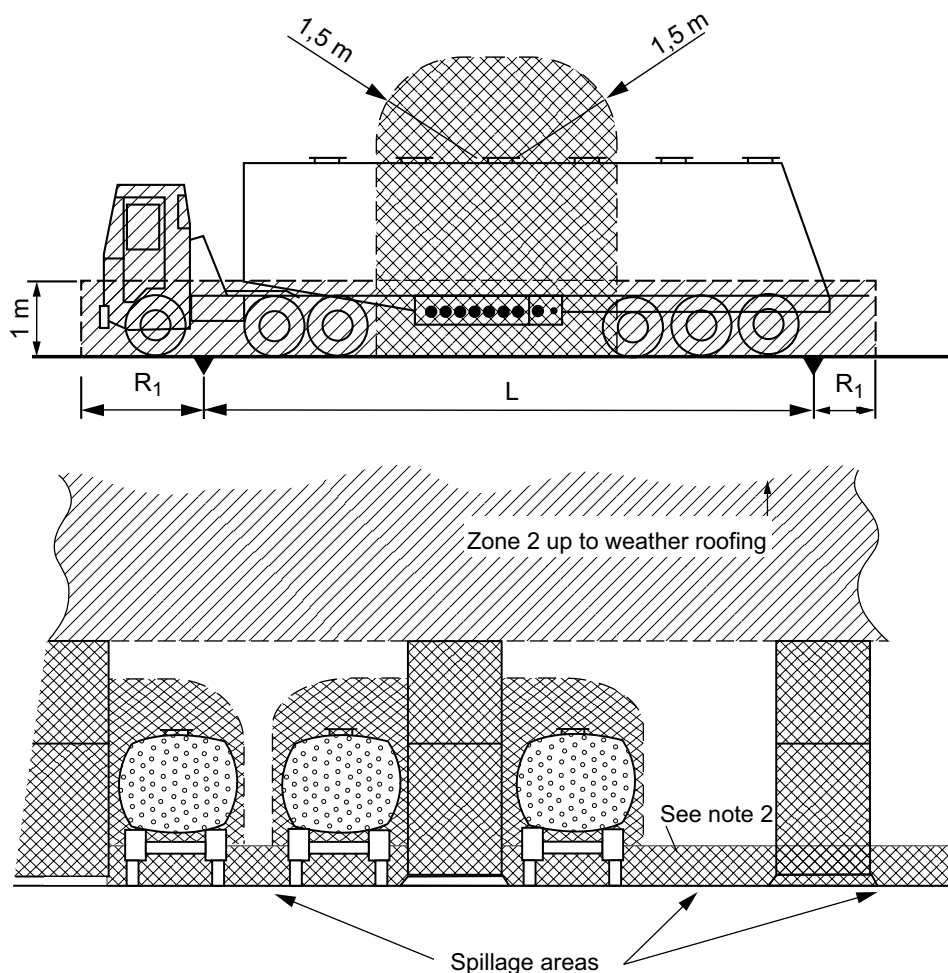
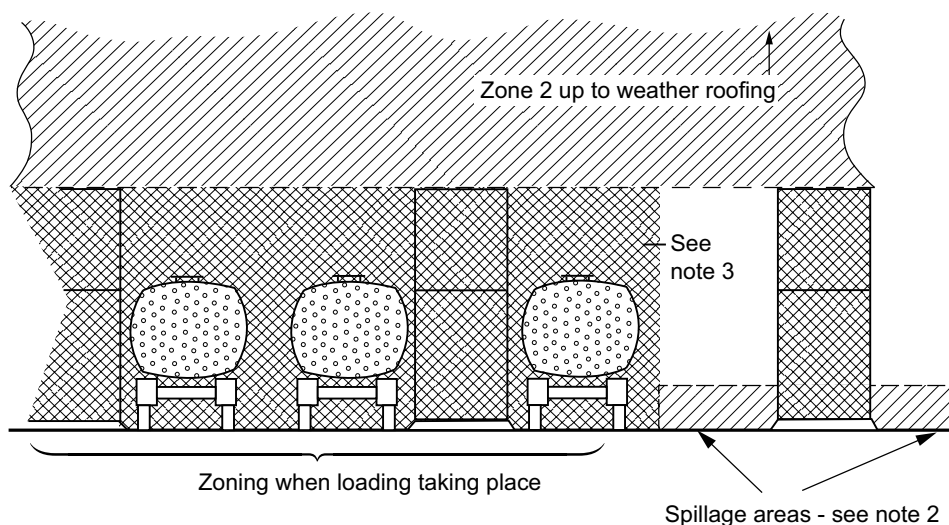


Figure D15: Composite area classification drawing for top loading road tankers during loading, in the event of a spillage – Classes I, II and III products. For treatment of unoccupied bay on right hand side in condition to receive a road tanker (see note 2)



Notes:

1. If weather roofing is provided, all space above the Zone 1 area will be Zone 2 up to the roof.
2. Transient hazardous areas normally free from flammable hazard when no spillage present, or for Class II(1) and III(1) products.
3. Areas filled-in, as shown.

Figure D15: Composite area classification drawing for top loading road tankers during loading, in the event of a spillage – Classes I, II and III products. For treatment of unoccupied bay on right hand side in condition to receive a road tanker (continued)

D3.3.3 Road tanker unloading at retail service stations

This section applies to delivery of ground fuels at retail service stations; however, it may be used for delivery to industrial sites provided the facilities are similar to retail sites.

D3.3.3.1 Entry and departure of road tankers

The area may be considered suitable for entry and exit of tankers as long as fill point sealing caps are in position, the access chamber covers are closed (for underground fill points) and providing no spillage has occurred. In the event that any spillage has occurred, this will create a transient hazardous area and the road tanker should not enter the area until the spillage has been cleaned up. If the spillage occurs while the road tanker is parked for unloading, it should remain isolated and not depart until the spillage has been cleaned up.

The extent of the hazardous area due to a spillage will be determined by the area of containment and should be classified using 3.8.1.

D3.3.3.2 Connection, unloading and disconnection of delivery hoses for flammable materials

The releases outlined in this section may occur during connection, unloading and disconnection.

Connection of dry hose couplings to road tanker is not anticipated to give rise to any flammable releases; the only anticipated release will take place on disconnection of a wetted hose.

Disconnection of the hose from the road tanker, which should precede disconnection from the receiving tank, will expose internal wetted areas of both the hose coupling and bottom loading adaptor on the tanker, and drips may also occur. As the hose is lifted and product is drained to the receiving tank, the hose may be moved sideways and/or towards the tank. These sources of release, which are likely to occur during normal operation, give rise to the following hazardous areas (see also Figure D16):

- Zone 1 of nominal 1 m radius around the road tanker bottom loading adaptors, which extends down to ground level.
- Zone 1 of nominal 1 m height above ground and 1 m radius either side of the hose 'corridor' required from the tanker unloading position to the storage tanks.
- Zone 2 of 4 m radius from the tanker unloading connections, to a height of 1 m to cover any small spillages of up to circa 2,5 litres that may occur during the disconnection of hoses.

Note: These hazardous areas are considered to be transient in the sense that they only exist during and shortly after the unloading process. The zoning is based on retail service stations. For deliveries to industrial sites the frequency of delivery may be used to determine zone categorisations.

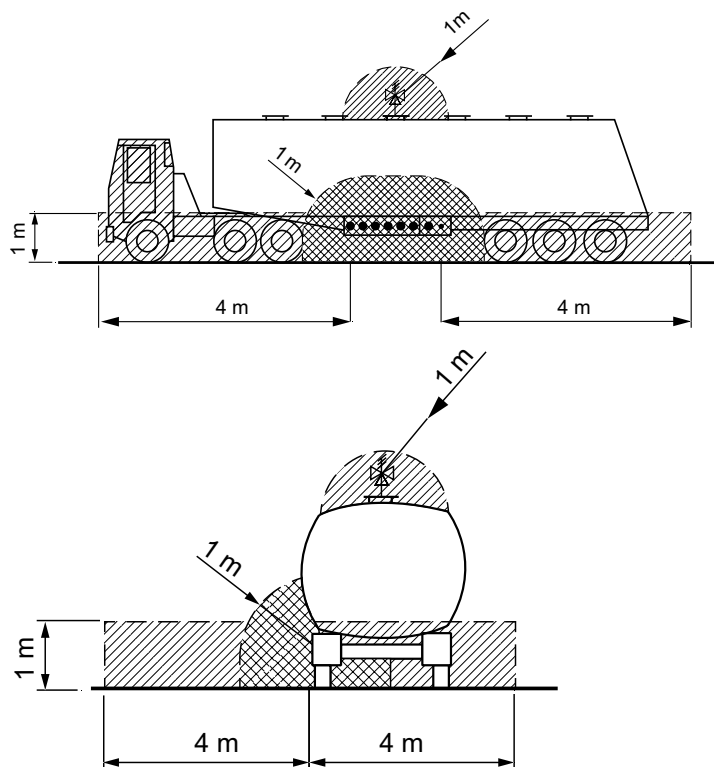
The hazardous areas shown in Figure D16 are based on:

- A road tanker being parked in a designated location as close as reasonably practicable to the tank fill points, which are installed in adequately ventilated positions in open areas, and
- Hose runs being confined to a designated 'corridor', with the minimum number of hoses used, to reduce the couplings required.

At service station sites where the road tanker is connected to a vapour recovery system and stage 1b vapour recovery⁶ operates, external breathing of the road tanker should not occur. However, under certain conditions e.g. leaving the road tanker standing boxed-in under strong sunlight, this could cause the tanker to emit vapour through its pressure/vacuum (P/V) breather vent. At the frequency that this is likely to occur, this may be considered to generate a Zone 2 hazardous area of 1 m radius.

In the event of manual measurement of the tanker compartment contents (e.g. dipping or sampling), there should be a Zone 1 area of radius 1 m in all directions from the centre of any tank top opening, extending 2 m above the tank shell. Where hatches are open but no manual measurement is taking place, this vertical extent may be reduced to 1 m.

⁶ Stage 1b vapour recovery is defined as 'the control of emissions during the off-loading of road tankers into service station storage tanks' in *EI Guidelines for the design and operation of petrol vapour emission controls at distribution terminals* 4th Edition.



Note: Ullage space in the road tanker should be classified as Zone 0.

Figure D16: Typical hazardous area zone classification of a road tanker during unloading

D3.3.3.3 Underground storage tanks and fill points

Removal of the sealing cap from the tank fill point prior to hose connection may give rise to a small release of flammable vapour around the fill point.

Unless leakage occurs from the hose couplings or connection points, the completed hose connection between the delivery road tanker and receiving tank comprises a closed system, so that during the period of delivery there is no source of release.

When the hose is disconnected, the wetted surface area of the tank fill pipe will be exposed until the sealing cap is replaced, hence there will be a small release of flammable vapour for a very short duration. In addition, there will be some drainage on disconnection of the hose.

The above sources of release will give rise to the following hazardous areas (see also Figure D6):

- Zone 0 within the tank itself and within any access chamber or pit in which there are tanker delivery hose connection points.
- Zone 1 of nominal 1 m radius from the tank fill point. Where the fill point is located in a pit or access chamber, the radius should be extended from the edge of the sump as shown in Figures D6(a) and (b). The above ground hazardous area for below ground connection points is determined by the dimensions of the sump containing the connection points.

- Zone 2 with a horizontal radius of 4 m⁷ from any above ground offset tank fill points where spillages will not be caught in an enclosure, 1 m above forecourt level, as shown in Figure D6(c).

Additionally, covered tank access chambers not containing tanker delivery hose connection points used in normal operation should be classified as Zone 1 due to the possibility of leakage from fittings within the chamber.

The delivery point area may also be treated as non-hazardous. However where diesel tanks are manifolded with gasoline tanks, or filled from multi-compartmented tankers containing gasoline, there may be vapour carry-over. In these cases, fill points, and tank ullage spaces should be classified as if they contain gasoline.

D3.3.3.4 Vapour connection point

Pressure build-up in the vapour recovery system can bypass the poppet valve and cause small releases of vapour when the cap is removed prior to connecting the hose. Small releases may also occur during hose disconnection procedures. These releases will give rise to a Zone 2 hazardous area of nominal 1 m radius around the vapour connection point. Part of this area may already be covered by the Zone 1 area relating to the fill point.

D3.3.3.5 Unloading to above ground storage tanks

A different situation to that described in D3.3.3.3 arises when a road tanker has to be unloaded into an above ground tank, and a pump is necessary to provide the required pressure. The area classification is determined by the location of the unloading point and whether the pump is provided on the vehicle or at the installation.

- The preferred method of unloading is by using a fixed pump on the installation, fed by gravity from the road tanker. This has the advantages that the equipment on the vehicle is de-energised during unloading and the vehicle hoses and couplings are not subject to pump discharge pressures. In this case, the area classification should be correctly designated for the coupling points and hose draining. There will be an additional Zone 2 around the pump, the radius of which will depend on the type of pump installed. Further guidance on the area classification of pumps may be found in 3.7.1.
- Where a static pump is not available and a vehicle-mounted cargo pump is to be used (requiring the engine to be run in order to power the pump and therefore with the road tanker's electrical system live), area classification will be necessary for both gasoline and diesel unloading (due to the possibility of mist or spray formation from leakage points). The operation itself will give rise to a Zone 2 hazardous area, with the radius depending on the type of pump used. Refer to 3.7.1 for the area classification. For the hazardous area around any coupling point, see Figure D16.

D3.4 RAIL CAR LOADING AND UNLOADING

D3.4.1 General

Rail car loading facilities vary in design. They may consist of a loading siding provided with a number of loading points spaced at intervals to suit rail car dimensions. An alternative to this multi-point system is a single-point installation in which the loading arms are grouped in

⁷ Radius of 4 m is suitable for spills of up to 2,5 litres on unrestricted level surfaces.

one position and the train of rail cars is moved so that each car is brought into the loading position successively. In either case the installations are similar to the road tanker loading facilities considered in D3.3 and should be analysed in the same way.

The area classification guidance given in D3.4.2 to D3.4.5 for the loading and discharge of rail tank cars should be read in conjunction with the design and operational guidance in *EI Model code of safe practice – Part 2: Design, construction and operation of petroleum distribution installations*.

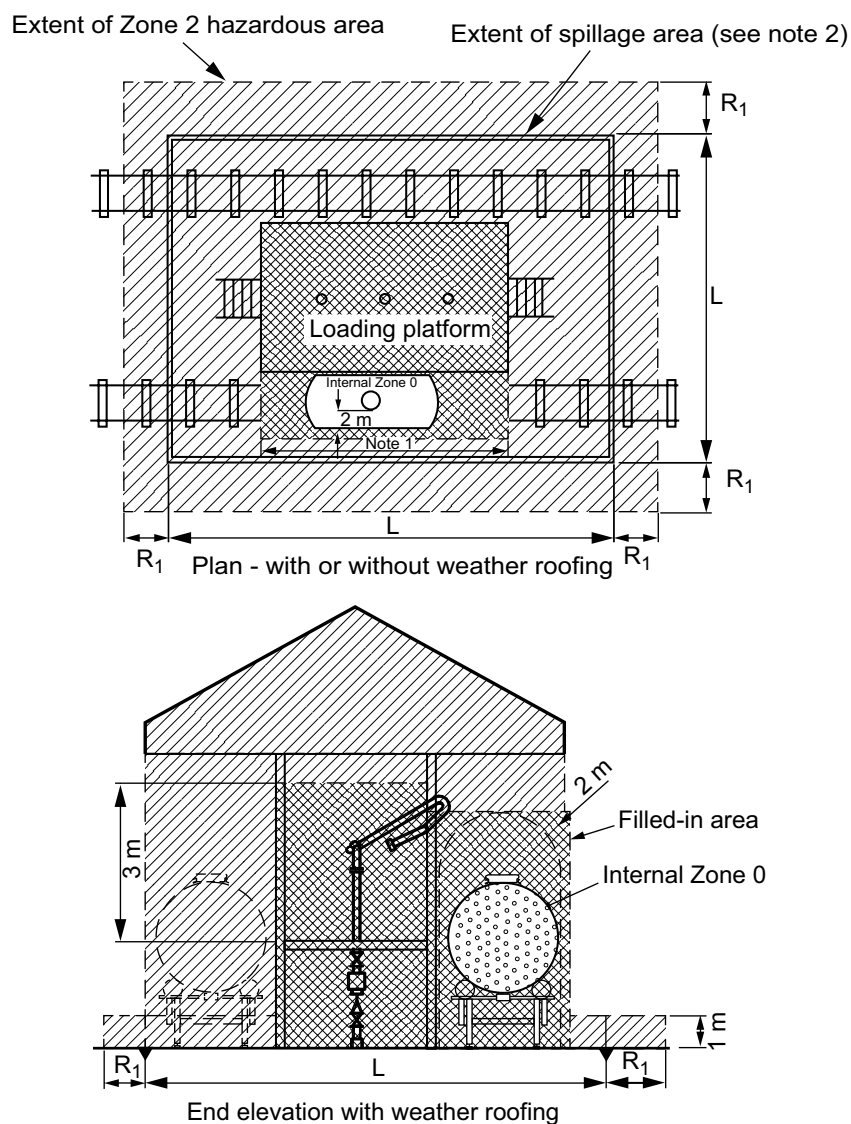
D3.4.2 Top loading of rail cars with vapour recovery

Loading of rail cars with vapour recovery should eliminate routine emissions of flammable vapours from the fill covers. If rail cars are fitted with permanent filling and vapour recovery connections, there should be no release of vapour except where failure leads to emergency venting of the compartment. Accordingly, this should be designated a secondary grade release allowing the Zone 1 area above the fill covers in Figure D17 to be classified as a Zone 2 area.

However, where loading facilities require removal of the fill covers prior to loading and closure on completion of loading, this will allow a release of flammable vapour which could extend over the full length of the loading gantry (i.e. while the rail car is moved along the track). Due to the frequency of operation this should be designated a primary grade release creating a 2 m radius Zone 1 area around the fill cover extending to ground level (see Figure D17).

The possible losses of vapour from the loading arm itself will give rise to a nominal 1,5 m radius from the outlets of the loading arm. Due to the variable location of the loading arm, the Zone 1 area should be extended 3 m above the working level of the gantry.

The interior of the rail car will, as in the case of a road car, be classified Zone 0 at all times. Figure D17 shows the individual aspects which should be combined to produce the overall composite hazardous area zone classification.



Notes:

1. The Zone 1 area should be extended to cover the total length of the gantry to allow for different positions of the rail car either in the case of a multipoint system or in the case of a single rail car moving along the track whilst the fill cover is open.
2. The extent of the spillage area for Class I, II(2) and III(2) products will be determined by the means of spillage containment (see D3.3.1.3). To determine the extent of the Zone 2 area, see 3.8.1.
3. For rail cars with permanent loading and vapour recovery connections, the Zone 1 hazardous area above the fill covers may be downgraded to a Zone 2.
4. Without weather roofing, the 'fill-in' Zone 2 area up to the roof, above the Zone 2 generated by potential spillage and the Zone 1 area generated by the rail cars will not exist.

Figure D17: Top loading of rail cars

D3.4.3 Top loading of rail cars without vapour recovery

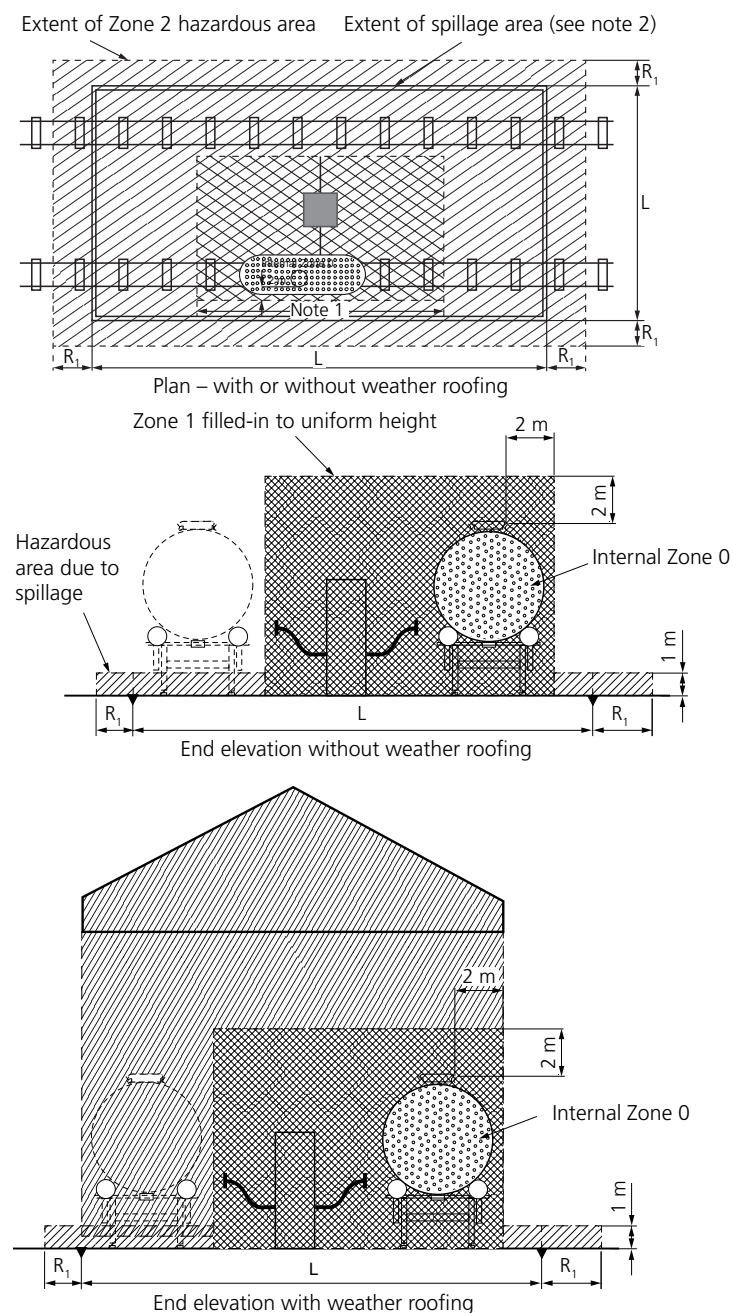
- (a) There will be a primary grade release whilst the rail car is being loaded due to vapour emission from the open or venting fill covers. Primary and secondary grade releases occur from loading arms when being removed from the rail car and returned to the parked position, from spillages due to overfilling, and from maintenance of filters and other associated equipment.
For loading rates up to and including 2,5 m³/min, it is recommended that a Zone 1 area extending in all directions to a distance of 1 m around each fill cover, with a vertical drop to ground level, be classified and that this be extended to cover the total length of the gantry to allow for different positions of the rail car or cars in the case of a multi-point system. For rates above 2,5 m³/min, the Zone 1 area should be extended to 2 m. The 2 m horizontal extent will cover the greater width of the rail car (see Figure D17).
- (b) The Zone 1 area for the gantry should extend from ground level to a height of 3 m above the working level of the gantry, as in D3.4.2.
- (c) Normally, impermeable catchment trays will be provided to contain spillages, in which case the Zone 2 area should be assessed as detailed in section D3.3.1.3. Otherwise, wetted areas from spillage will be restricted by the ballast on the track; in this case, for Class I, II(2) and III(2) products, a Zone 2 area should extend 3 m horizontally in all directions from the extremities of the gantry structure, with a height of 1 m (see also 3.8.1).
- (d) The interior of the rail car will, as in the case of a road tanker, be a Zone 0 area at all times that it is in service. However, when all fill covers and outlets are closed, as for the running condition and for entry and departure after loading, the exterior of the rail car can be classified as non-hazardous. (The control conditions for the safe entry and departure are dealt with in D3.4.6.)
- (e) The combination of the above factors is shown in Figure D17. It should be noted that the whole of the area below any weather roofing should be classified as Zone 2 down to the Zone 1 area.

D3.4.4 Bottom loading of rail cars

Where bottom loading of rail cars is carried out a similar analysis should be followed as detailed in section D3.4.3 for top loading, bearing in mind that bottom loading is carried out at ground level. Consideration should be given to the following:

- (a) Sealed couplings are normally used, from which a secondary grade release may occur due to leakage. Secondary grade releases can arise due to overfilling or accidental spillage when couplings are broken and from filters and associated equipment.
- (b) For bottom loading at rates up to and including 2,5 m³/min the area of the loading stand should be classified as Zone 1 area up to a height of 1 m above any vent level. For rates above 2,5 m³/min the height should be increased to 2 m.
- (c) The classification of the rail tanker will be as in D3.4.3(d). The envelope of the Zone 1 area associated with the fill covers and their vents extends, during filling operations, as described in D3.4.3(a) for top loading down to ground level.
- (d) The Zone 2 area designated for the various secondary grade releases arising due to spillages should be determined as detailed in D3.4.3(c).

The composite area classification drawing for bottom loading of rail cars is shown in Figure D18, both with and without overhead weather roofing. Note the in-fill in this composite of the vertical heights of the Zone 1 areas in (b) and (c).



Notes:

1. The Zone 1 area should be extended to cover the total length of the gantry to allow for different positions of the rail car either in the case of a multipoint system or in the case of a single rail car moving along the track whilst the fill cover is open.
2. The extent of the spillage area for Class I, II(2) and III(2) products will be determined by means of spillage containment (see D3.3.1.3). To determine the extent of the Zone 2 area, see 3.8.1.

Figure D18: Bottom loading of rail cars

D3.4.5 Rail car unloading via a hose connection – Classes I, II and III products

The area classification for the discharge of a train of rail cars will follow the general principles for the unloading of road tankers as detailed in D3.3.3, though the scale in most cases will be bigger and the concepts in D3.4.3 for rail car loading should be considered also (see Figure D19).

The unloading of a rail car using a tight hose connection is a closed system, usually employing self-sealing couplings. Secondary grade releases may occur due to leakage and, when coupling or uncoupling, hose and drainage line spillage may occur. A non-return valve, or set of valves in the case of discharge systems that have a common manifolding, should be installed and maintained in effective working condition, to ensure that back flow from receiving tankage cannot occur as a result of hose breakage, or during coupling or uncoupling.

Where the unloading area is paved or concreted over, the extent of the spillage area should be as shown in Figure D18. In such a case, the procedure in D3.3.1.3 should be applied with due consideration of boundaries such as spillage channels or drains. However, in the case of rail cars, because of the degree of manual participation and the multiple number of cars, spillage areas should be classified as Zone 1 areas. When ballasted track underlies the rail car discharge location, the spillage area will be curtailed by the drainage system. An area horizontally 3 m in all directions from the limits of hose and coupling positions and for a height of 2 m (to allow for raised connections) should be specified. This applies only to Class I, II(2) and III(2) products.

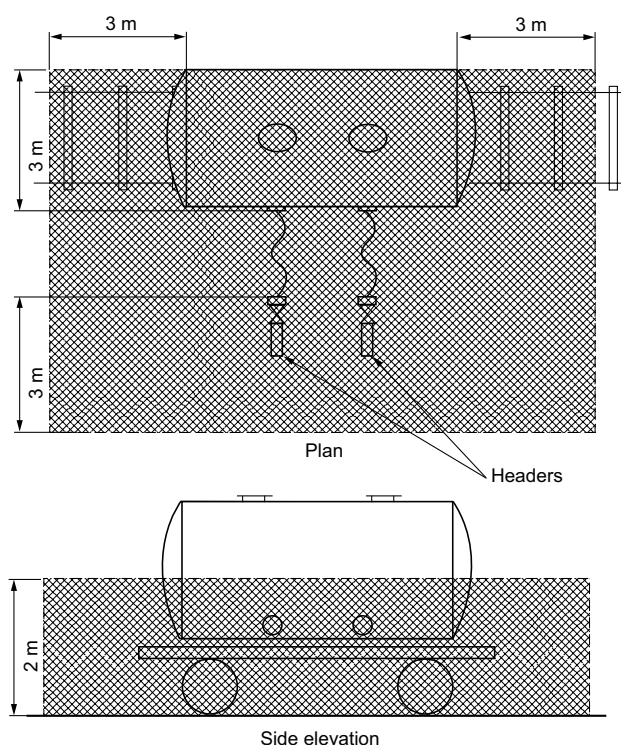


Figure D19: Rail car unloading via hose connection

D3.4.6 Conditions for entry and departure of rail tank car trains to and from loading and unloading facilities

The following points should be considered part of the general analysis of the installation:

- (a) The movement of vehicles to and from the loading position must take place with the loading gantry and vehicle in a flammable hazard-free state. Certain zones are transient and only exist whilst loading is being carried out. For further information on design and operation of rail loading facilities see *EI Model code of safe practice – Part 2: Design, construction and operation of petroleum distribution installations*.
- (b) Tracks serving loading or unloading facilities should wherever possible be reserved specifically for that purpose. They should be sited at least 15 m from the nearest running line or unrestricted roadway.
- (c) Loading and unloading facilities should be electrically continuous and earthed with means of bonding vehicles to the fixed facility. The installation of earth interlock systems is recommended to prevent product movements unless proper earthing and bonding connections have been made.
Rails should be bonded at all other joints in the loading and unloading area and bonded to the main earthing system of the unloading equipment. The track of the rail siding should also be independently earthed.
Rail sidings for loading and unloading of rail tank cars should be provided with insulating joints to isolate the track of the siding from the main line and to prevent contact with stray currents from electrified lines or railway signalling track circuits.
- (d) Unless designed in accordance with EN 1834 1: *Reciprocating internal combustion engines. Safety requirements for design and construction of engines for use in potentially explosive atmospheres. Group II engines for use in flammable gas and vapour atmospheres*, unprotected electric locomotives or diesel locomotives should not be allowed within 9 m of a point where Class I, II(2) or III(2) products are being loaded, unloaded or stored. Within such distance of these operations only lighting etc. certified as appropriate to the hazardous area zone classification should be in use.
- (e) Steam locomotives, except of the fireless type, and rail vehicles with an oil lamp should not be allowed within 15 m of a point where Class I, II(2) or III(2) products are being loaded or unloaded.

D3.5 MARINE FACILITIES AND JETTIES – CLASSES I, II AND III PRODUCT

D3.5.1 General

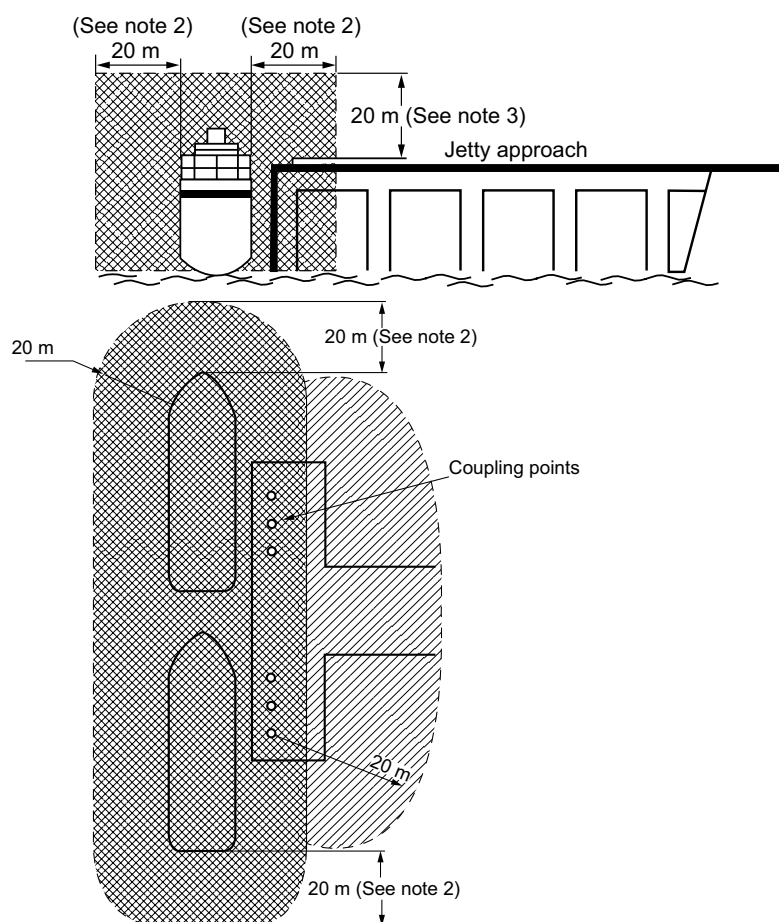
Guidance is provided on the hazardous areas on jetty and marine facilities arising from the loading or unloading of a tanker. It includes the hazardous area arising from the cargo hoses and from vents on the tanker. The hazardous area from other equipment on the jetty should be determined using the appropriate sections of Chapter 3. Area classification on jetties should always be based on the most onerous classification for the products handled, taking account of fluid classification and release conditions.

This section does not apply to the vessel itself, for which guidance should be sought in the appropriate maritime standard e.g. IEC 60092–502 *Electrical installations in ships. Tankers – Special features*. Further guidance on the precautions to be taken during handling on tankers and at terminals for crude oil and petroleum products is given in the *International Safety Guide for Oil Tankers and Terminals* (ISGOTT).

Where jetties are used for both loading (or ballasting of tanks containing vapour) and unloading, a composite hazardous area drawing for the facility should be obtained by combining the hazardous areas for the separate operations.

D3.5.2 Jetties – loading facilities

- (a) The hazardous areas should be established for each possible primary and secondary grade source of release associated with the jetty equipment.
- (b) Primary grade releases occur during tanker loading due to vapour vented from tanker compartments or during gas-freeing of tanker compartments, should the latter take place whilst the tanker is alongside or adjacent to the jetty.
For jetties with facilities for loading (including ballasting), the tanker vents will create a primary grade release. Due to the varying sizes of ships and tidal movements, it is recommended that an area extending 20 m in all directions horizontally around the hull of the tanker down to water level and vertically to a height of 20 m above the jetty approach level, should be classified as Zone 1 area. Possible hull locations should be based on the maximum breadth of tanker expected to use the jetty and the expected fore and aft positions at the extreme berthing locations (see Figure D20). For this purpose the hull of the tanker should be assumed to be in contact with the jetty, i.e. all shore side distances should be measured from the fixed water-side of the jetty.
- (c) Primary and secondary grade releases can occur from fixed and portable equipment such as filters, sample points, slop tanks, loading marine arms and hoses, drainage and drip trays, pump glands and seals, valves, meters and flanges.
The hazardous areas arising from the jetty equipment can be assessed by considering each possible source of release in accordance with the approach in Chapter 3. The hazardous area created by the tanker can then be superimposed on the hazardous area determined for the jetty alone. The loading/unloading equipment, when not in use and in the parked position may create a source of release whilst draining. However, the Zone 2 hazardous areas arising around the coupling points are enveloped by the existing Zone 1 classification for the loading operation shown in Figure D20.



Notes:

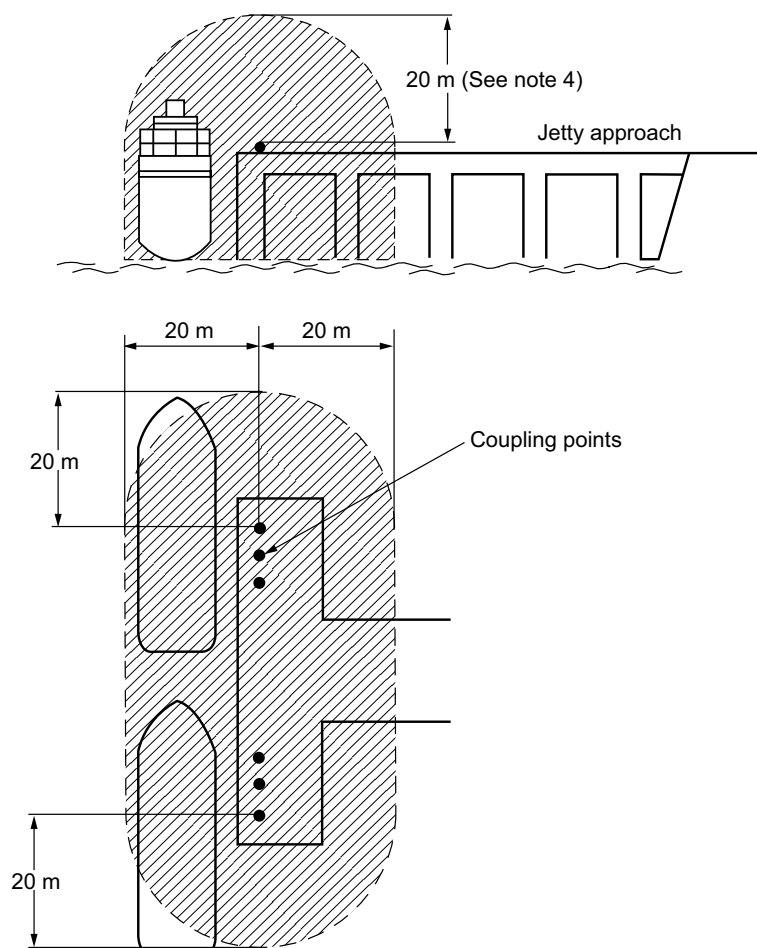
1. The Zone 1 area is additional to any hazardous area assessed in consequence of all other equipment on the jetty.
2. Distance may be reduced to 15 m for vessels with loading or unloading rates of 10 m³/min or less.
3. The hazardous area should extend 20 m above the coupling points. This may be reduced to 15 m for loading rates of 10 m³/min or less.
4. For category A fluids, reference should be made to the approach in Chapter 3.
5. These distances may be conservative. However, they cover a great variety and size of ships which may be berthed for loading. If the size of the vents and loading rates are well-defined, 3.4. may be used to determine more specific hazard radii.

Figure D20: Jetties – loading facilities only

D3.5.3 Jetties – unloading facilities

For jetties where unloading operations are carried out, the marine arms, hoses, etc, constitute a closed system, and only secondary grade releases are likely to occur. It is recommended that an area extending from the coupling points, a distance of 20 m horizontally, up to a height of 20 m above the coupling points and down to water level should be classified as Zone 2 (see Figure D21). Hazardous areas should be established for each individual source of release from the jetty equipment since some may necessitate localised Zone 1 areas within this overall

Zone 2 area. If ballasting is carried out during unloading into unsegregated ship's tanks which could contain vapour, or if gas-freeing of tanks is carried out whilst alongside the jetty, then the jetty should be classified using the guidance in section D3.5.2. For classification onboard the tanker vessel, see D3.5.1.



Notes:

1. The hazardous area for each piece of equipment on the jetty should be evaluated.
2. If non-segregated ballasting or gas-freeing is carried out, then the jetty must be classed as for loading.
3. For category A fluids, reference should be made to the methodology given in Chapter 3.
4. The height of the hazardous area should be 20 m above the coupling point. For a category C material, this is equivalent to a 5 mm diameter hole in the coupling. If larger hole sizes are possible reference should be made to Table C4 for the equivalent hazard radius.

Figure D21: Jetty – unloading

D4 TRANSPORTABLE CONTAINER FILLING AND STORAGE

This section applies to all types of atmospheric transportable containers including IBCs drums, totes, up to 5 000 l.

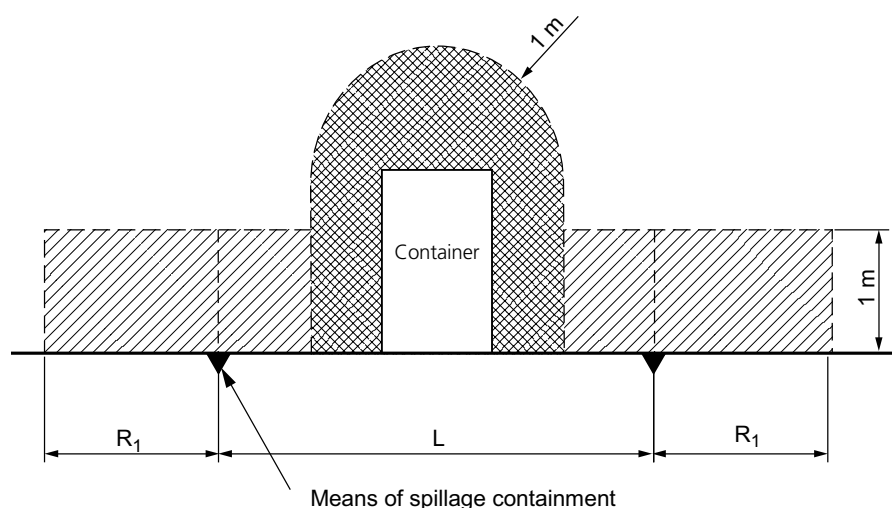
D4.1 CONTAINER FILLING

The container should be regarded as a primary grade source of release, giving rise to a Zone 1 area. It should extend 1 m in all directions from the edges of the filling or venting openings (see Figure D22). The spillage area should be determined using 3.8.1.

If filling takes place in an enclosed area, the hazardous area is based on ventilation requirements, see Chapter 4.

The filling line outlet should also be regarded as a primary grade source of release, giving rise to a Zone 1 area. The hazardous area should extend 1,5 m in all directions from the filling line outlet.

When filling containers with Class II(1) and III(1) products, the information on mists and sprays in A1.2 should be reviewed. The 1,5 m hazardous area in all directions from the end of the filling line outlet should also apply. Care should be taken to avoid sources of ignition that could give rise to a hazard in the event of a ground spill.



Notes:

1. For determination of extent of spillage Zone 2 area, see 3.8.1.
2. The dimensions of L are controlled by means of spillage containment such as ground contours, kerbs, and drains (as shown).

Figure D22: Container filling in an open area

D4.2 CONTAINER STORAGE AREAS – CLASSES I AND II(2) PRODUCTS

Where reasonably practicable, containers should be stored at ground level (singly or in stacks of no more than four high) and in an open area. This will enable leaks to be more readily detected, and any vapour arising to be dissipated. Such stacks for Class I or II(2) products should be placed in one or several compounds if the total volume of packed product exceeds 200 m³, with small walls or sills, e.g. of 150 mm height, to prevent uncontrolled leakage.

The storage and handling of sealed containers will not normally give rise to hazardous releases, but the area within the walls or sills should be classified as Zone 2 to a height of at least 1 m above the highest container.

Fork lift trucks or other materials handling equipment, if used within the hazardous areas denoted in Figure D22 and D4.3, should be suitable for use in Zone 2 areas. New equipment should be in accordance with EN 1755 *Safety of industrial trucks. Operation in potentially explosive atmospheres. Use in flammable gas, vapour, mist and dust*.

D4.3 CONTAINER STORAGE IN BUILDINGS – CLASSES I AND II(2) PRODUCTS

When it is not practicable to store containers in the open, they may be stored in suitable storage buildings. Such buildings should not be used for other purposes and, as in the case of storage in the open air, have means of containing spillage e.g. by sills or ramps 150 mm high across doorways. The flooring should be impermeable to liquid spills.

Storage buildings should be adequately ventilated, provided openings do not conflict with the need for a wall to be fire resisting, and should be classified as Zone 2 areas up to a height of 2 m above the highest container.

Where artificial ventilation is to be provided reference should be made to Chapter 4.

For further information on package filling and storage building construction see EI *Model code of safe practice – Part 2: Design, construction and operation of petroleum distribution installations*.

D5 RETAIL SERVICE STATIONS AND FUEL DISPENSING FACILITIES

D5.1 INTRODUCTION

Guidance is provided on the equipment and layout to be found on retail service stations under normal open area conditions. It should be applied also to non-retail gasoline dispensing sites and to dispensing to boats, light aircraft and into portable containers. The Zone 2 areas indicated cover the possibility of localised flammable atmospheres being present for short periods, with such areas being adequately ventilated under open area conditions.

The classified areas indicated relate to the installation of fixed electrical equipment, and should not be considered as extending beyond an unpierced wall, roof or other vapour barrier or solid partition (see D3.3.3.3).

The normal prohibition of smoking, non-electrical sources of ignition, and the running of engines, during both the fuelling of vehicles and the delivery of fuels from road tankers, should also be enforced. Further details are provided in EI *Guidance for design, construction, modification, maintenance, and decommissioning of filling stations*, 3rd edition.

D5.2 GASOLINE DISPENSERS AND OTHER CLASS I, II(2) AND III(2) PRODUCTS

Reference should be made to the dispenser manufacturer to determine the likely sources of release from a dispenser, based on the relevant standard to which it was designed and constructed. For new dispensers the manufacturer or supplier should provide a diagram with the unit showing the area classification in and around the unit. The zoning within and immediately above the housing of dispensers (both gasoline and LPG) will depend on their internal construction (e.g. employing vapour barriers). Details of the dispenser internal

zoning and its vapour barriers are necessary when more accurate determination of the external zones around the dispenser is required, as opposed to the generic examples given in this Model Code.

Figures D23 to D27 are intended to assist in the selection of electrical and other equipment suitable for operation in the vicinity of gasoline dispensers. Figures D23 to D26 summarise the hazardous areas arising around specific equipment; Figure D27 shows how these separate areas are aggregated together and indicates the extent of the transient hazardous areas that occur during dispensing which are not applicable when vehicles enter or leave the site. The figures can be used to assess the risks of other potential ignition sources in the area. They should not, however, be used to determine construction requirements of dispensers as these will have been designed and assessed against recognised national, European or International standards.

D5.2.1 Dispenser housing

Figure D23 shows the extent of hazardous areas around a dispenser housing, which applies to gasoline dispensers either with or without Stage 2 vapour recovery installed.

Figure D23(a) shows the extent of hazardous areas without a vapour barrier; Figure D23(b) shows the reduction in the hazardous area when there is a vapour barrier. The Zone 2 area may vary between 0 – 200 mm depending on the standard of construction of the dispenser housing. Where necessary, reference should be made to information from the dispenser manufacturer.

When the nozzles are not withdrawn for refuelling, the limited hazardous area around the dispenser enables vehicles to enter the filling station without passing through any hazardous areas.

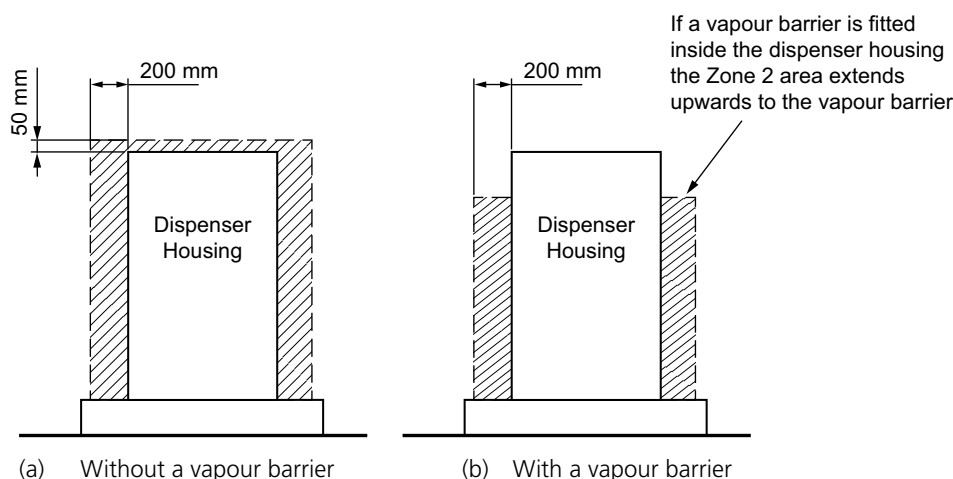


Figure D23: Typical hazardous area classification around a gasoline dispenser housing

D5.2.2 Hazardous area around external dispenser air separator vent

Figure D24 illustrates the extent of the hazardous area around an air separator vent on the outside of a gasoline dispenser (either with or without Stage 2 vapour recovery installed). The Zone 1 area should extend 250 mm horizontally, down to ground level, and 100 mm vertically above the vent.

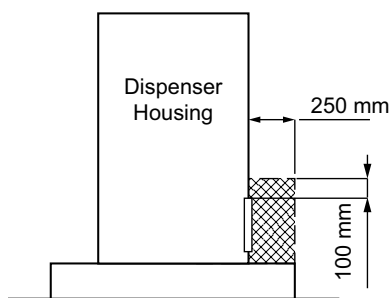


Figure D24: Typical hazardous area zone classification around an external dispenser air separator vent

D5.2.3 Hazardous area around a vehicle fill pipe during refuelling

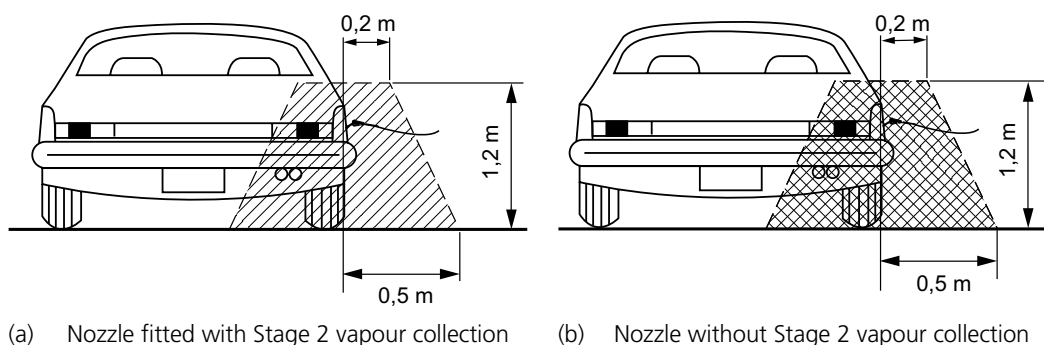
When a nozzle is inserted into the vehicle fill pipe and the nozzle trigger is operated, flow of gasoline begins and vapour is displaced from the vehicle's tank.

Where the dispenser/filling station is fitted with Stage 2 vapour recovery, displaced vapour is recovered by the nozzle and very little is displaced to atmosphere. This situation will give rise to a Zone 2 area as shown in Figure D25(a).

Where Stage 2 vapour recovery is not installed then, as gasoline enters the vehicle tank, vapour is displaced to atmosphere and, because it is heavier than air, it rolls down the side of the vehicle and slumps towards the ground. The hazardous area in this case will be Zone 1 area as shown in Figure D25(b).

The height of the hazardous area created by the refuelling operation is dependent on the height of the vehicle tank fill point. A minimum of 1,2 m is considered sufficient to allow for varying heights of vehicle tank fill points.

The typical hazardous area zone classification in Figure D25 does not take account of leakage due to hose or nozzle failure, providing the dispenser is taken out of service immediately, since the duration of the leak under these circumstances may be considered to be too infrequent to be considered for area classification.



(a) Nozzle fitted with Stage 2 vapour collection (b) Nozzle without Stage 2 vapour collection

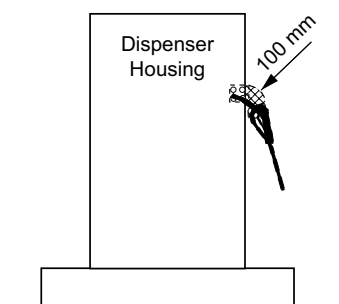
Note: 1,2 m allows for those cases where the hose is lifted over the vehicle on its return to the nozzle housing and for vehicles with a high fuel tank opening.

Figure D25: Typical hazardous area zone classification around a nozzle during vehicle refuelling

D5.2.4 Return of nozzle to dispenser housing

On completion of vehicle refuelling, liquid and/or vapour will be present in the nozzle when it is withdrawn. This gives rise to a small Zone 1 area around the nozzle until it is returned to the nozzle housing on the dispenser. Up until 100 mm from the nozzle housing this may be considered a Zone 2 due to the likelihood of it existing at any number of points within the locus of the hose length (see Figure D26). As the nozzle will always be returned to the same position, a Zone 1 hazardous area will arise within a 100 mm radius around the dispenser nozzle housing. The area within the nozzle housing should be classified as Zone 0.

These are only normally relevant for the design of the dispenser, but should be considered if electronic displays are mounted on the nozzle.



Note: Any unclassified electrical equipment should be located at a safe distance above the nozzle housing.

Figure D26: Typical hazardous area zone classification around nozzle spout housing

D5.2.5 Composite hazardous areas around dispensers during refuelling

Figure D27 shows the typical composite hazardous areas around a dispenser with two side mounted hoses. It is based on:

- A dispenser **without** a vapour barrier, **with** an external air separator vent.
- A standard dispenser hose length.

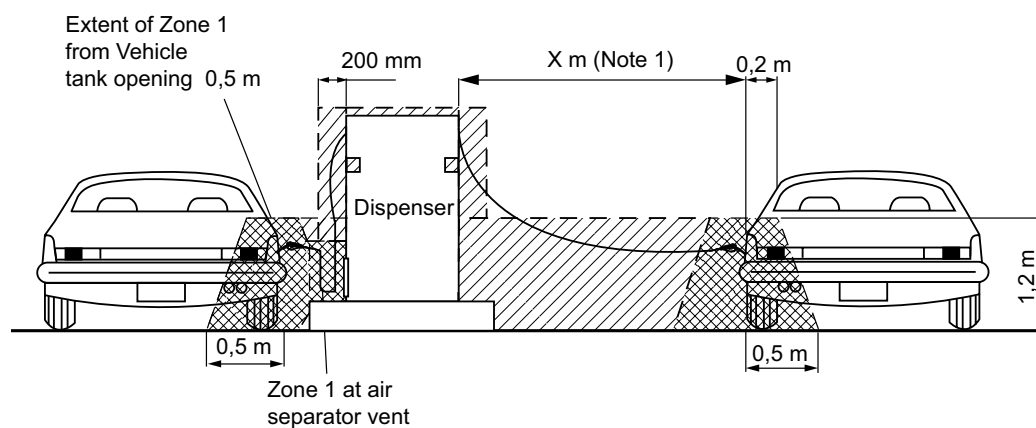
The vehicle refuelling location is not the same for every refuelling operation, but is restricted by the distance to which the nozzle may be extended. Since a vehicle may park in various positions the hazardous area created by the refuelling operation shown in Figure D25 will occur wherever the vehicle is parked. This results in a composite hazardous area which extends from the maximum length of the hose all the way back to the dispenser.

- A small hazardous area around the nozzle after refuelling, as described in D5.2.4.

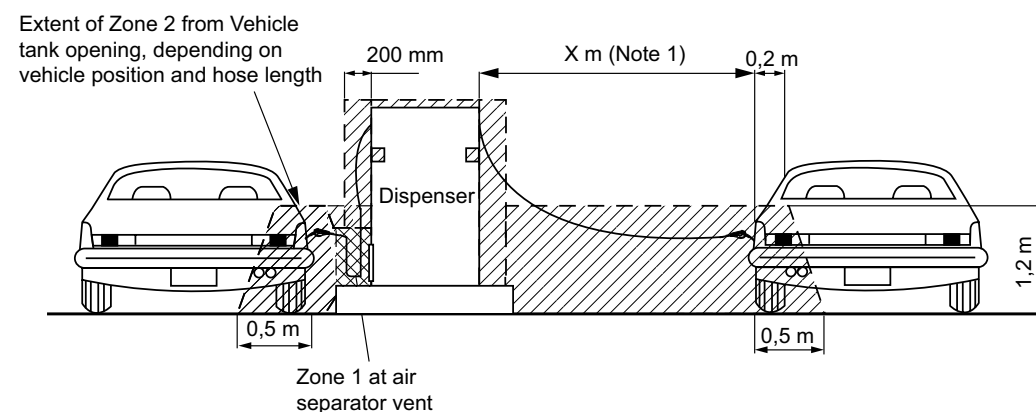
Again, since the vehicle may park in various positions, the hazardous area created by the nozzle will occur wherever the vehicle is parked all the way back to the dispenser as it is being returned to the housing. In addition, since the release volume is relatively small, this, together with the variety of parking positions, significantly reduces the frequency of the release occurring in the same position every time and allows the Zone 1 which would otherwise occur all the way back to the dispenser, to be downgraded to a Zone 2, **except**

where the nozzle nears the dispenser housing, as the nozzle will always be returned to the same position. Note, the Zone 2 hazardous area created by the nozzle is enveloped by the hazardous area created by the refuelling operation as shown in D27.

Note: Where a dispenser is fitted with a vapour barrier, consideration should be given to the hazardous area associated with the nozzle after vehicle refuelling as it is returned from the vehicle tank fill point to the dispenser nozzle housing.



(a) Without Stage 2 vapour collection installed



(b) With Stage 2 vapour collection installed

Note 1: Size of hazardous area equal to length of dispenser hose.

Figure D27: Typical composite hazardous area zone classification around a dispenser⁸ during refuelling

D5.3 LPG DISPENSERS AND OTHER CLASS 0 PRODUCTS⁹

The design of LPG dispensers incorporates such safety measures as back check valves, hose breakaway couplings (safebreaks) and other isolating valves to limit releases during normal operation to those associated with the filling hose. Dispenser hoses with self-sealing valves in

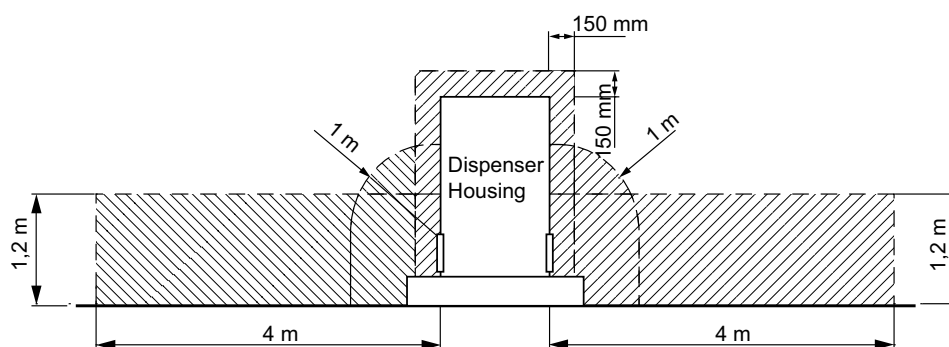
⁸ As described in D5.2.5.

⁹ Area classification is typical only. Site-specific conditions may lead to changes in the size and extent of hazardous areas.

the filling nozzle limit the loss of LPG on disconnection to 10 ml. However, this can occur at any position between the dispenser and the full extent of the hose and is therefore classified as a Zone 2 hazardous area equivalent to the length of the hose, to a height of 1,2 m above ground (i.e. typical height to which the hose will be handled during the refuelling operation), see Figure D28.

Dispensers fitted with relief valves with set pressures above the normal shut-off head of the filling pump should only give rise to infrequent releases of LPG into the dispenser casing due to the valve passing. Whilst this results in the inside of the dispenser casing being classified as Zone 1, the resultant hazardous area around any casing vents will be limited to a Zone 2 of 1 m¹⁰ radius around the apertures.

With adequate low-level venting of the dispenser casing, LPG should not be vented from the upper part of the dispenser. However to ensure uncertified electrical equipment is not mounted on the hydraulic part of the dispenser casing, a nominal Zone 2 of 150 mm should be applied surrounding the casing.



Notes:

1. Area within dispenser casing defined by manufacturer.
2. Suitable for dispensers using hose lengths of up to 4 m.

Figure D28: Typical hazardous area zone classification around an LPG dispenser¹¹ during refuelling

D5.4 OIL/WATER SEPARATOR

Surface run-off from areas where spillage of oily materials is possible may be routed via an oil/water separator.

Access chambers should be classified as Zone 1 areas when these are sealed (i.e. gas-tight). If the chamber is covered but not gas-tight, this will give rise to an additional Zone 2 area above the cover of radius 2 m from the edge to a height of 1 m, in accordance with 3.8.2.

Where oily materials are not removed directly following spillage, the ullage space in the separator will be classified as a Zone 0 area, giving rise to a Zone 1 hazardous area of 1 m radius around the top of the separator vent (See Figure D29).

¹⁰ This is equivalent to a leakage of 0,01 kg/s of LPG. A 1,5 m radius is suitable for losses within the casing of LPG at 10 bar(a) of up to 0,015 kg/s.

¹¹ As described in D5.2.5.

Where oily materials are emptied directly following spillage, the ullage space in the separator may be classified as a Zone 1 area, giving rise to a Zone 2 hazardous area of radius 1 m around the top of the separator vent.

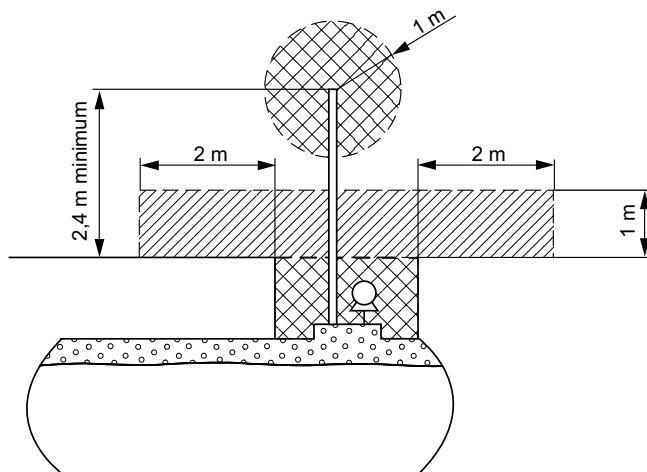


Figure D29: Typical hazardous area zone classification for an oil/water separator

D5.5 PREVENTION OF SPILLAGE DUE TO MECHANICAL DAMAGE AND PROTECTION OF BUILDINGS WITH ACCESS TO THE FORECOURT

- (a) Pumps and dispensing units should be protected to prevent damage by collision that could result in releases of a scale that would invalidate the area classification.
- (b) Nevertheless, access to buildings within a classified area should be provided with a sill or step not less than 150 mm in height.

Adequately ventilated kiosks and any other small buildings with openings in a hazardous area should apply the appropriate zone throughout the building, including to its full height, as vapour in a confined space is unlikely to remain at low level.

D6 VEHICLE REPAIR, SERVICING AREAS AND INSPECTION PITS

The dangers associated with releases of petroleum fuels, whether accidental or intentional, such as by drainage of equipment and fuel tanks in such areas, should be emphasised to all staff. The necessity of either excluding or strictly controlling both electrical and non-electrical sources of ignition should always be observed. Consideration should be given to segregating hot work from areas where flammable spillage could occur.

Where releases of flammable materials could occur in above ground repair and servicing areas, these should be treated as Zone 2 areas up to a height of 1 m above floor level. However, in large service areas the Zone 2 need not be extended to the entire workshop provided adequate ventilation is provided to prevent the spread of any flammable vapours to parts of the facility which have been deemed to be non-hazardous areas.

Blanket hazardous area classification would prevent some maintenance activities which create sources of ignition being carried out. Inspection pits, for the purpose of fixed sources of ignition, should be classified as Zone 1 areas and where maintenance activities may result in a source of ignition, management systems should be in place to halt and prevent such activities once a spill of flammable materials has occurred. Further activities should not be restarted until the pit has been deemed gas-free and safe.

Note, inspection-type pits for motor vehicles cannot be considered as freely ventilated spaces, irrespective of location. Forced ventilation to purge vapour from pits cannot be taken into account when classifying such areas, since it cannot be guaranteed to sweep the area under all conditions, bearing in mind obstructions that can occur and ventilation failure.

This guidance is applicable to repair and servicing areas in refining and petrochemical facilities; guidance for local garages and repair workshops can be found in *EI Design, construction and operation of workshops for petroleum road tanker maintenance*.

D7 DRILLING RIGS, EQUIPMENT AND WELL OPERATIONS

IMPORTANT NOTE: Whilst every effort has been made to make this guidance consistent with the guidance in the point source approach, during development of this edition of EI15 it has not been possible to secure specialist drilling expertise to review this section. Therefore, aside from a number of editorial changes, it is included unchanged from the previous edition of EI15 and should be used with caution.

Production oil rigs should be classified using the point source methodology detailed in Chapter 3.

D7.1 INTRODUCTION

This section gives guidance on the application of area classification to drilling rigs, workover rigs, coiled tubing units, snubbing units and well servicing equipment, which are operated:

- on land;
- on fixed offshore installations, and
- on mobile offshore installations.

It is not applicable to production wellheads and manifolds, nor to production operations downstream of the wellhead, e.g. oil/gas separation, de-watering, or pumping or compressor units, which should be classified in accordance with the approach in Chapter 3. The guidance in this section, which adopts a risk-based approach allied to practical experience, follows the principles of the IEC 61892 *Mobile and fixed offshore units – Electrical installations* series of standards and applies only to the small releases of gas and oil that can occur in the above operations. Guidance is provided on the installation of equipment for the control of gas kicks using normal operating procedures.

Well blow-outs giving rise to large releases are outside the scope of area classification and should be considered based on design, operational and maintenance practices.

D7.1.1 Use of this section

There are sufficient common factors in drilling and well-servicing practices, whether on land or offshore, on fixed platforms or mobile units of all types, to allow area classification to be undertaken using direct examples.

In applying the examples, users should check that there are not significant differences between the examples presented here and the layout proposed which would necessitate the individual consideration of special features, including the application of the point source approach in Chapter 3. Hazardous areas should be defined considering all well operations for which the rig might be used.

The guidance applies both to drilling rigs located in unrestricted open area conditions as defined in 4.2.1 and to facilities located in sheltered, enclosed or partially enclosed situations. In the latter cases, the ventilation condition should be considered in accordance with Chapter 4.

D7.1.2 Sources of flammable release

During normal drilling and well-servicing operations, hydrocarbon release to the surface can occur in the following ways:

- (a) Dissolved gas which comes out of solution under reduced pressures at the surface, often while drilling at near balance or under-balanced hydrostatically, or as trip gas during a round trip to pull the drillstring from the hole.
- (b) As a 'kick' which occurs when downhole formation pressure unexpectedly exceeds the hydrostatic head of the circulating mud column.
- (c) From residual mud on the surface of drillpipe being racked in the derrick during a round-trip, or on production or coiled tubing being withdrawn from the hole, or from core samples laid out for inspection.
- (d) Gas escape from the stuffing box on a wireline lubricator, the injector of a coiled tubing unit or the stripper bowl of a snubbing unit.
- (e) Small hydrocarbon releases from rotating equipment, pumps and pipework, occurring in normal operations and maintenance.
- (f) Shallow gas blow-out.
- (g) Vapours present in oily drainage systems, vents or ducting.

For hazardous area purposes throughout the drilling installation, (a) is the major consideration, with potential sources of primary grade release at the bell-nipple and around the mud return flowline outlet, shale shakers and active mud-pits. These points should be considered as similar to sumps or vents as described in Chapter 3.

Gas release in the event of a kick, (b), is dealt with by operating practices which establish controlled conditions for responses using equipment provided on the rig. Significant releases can occur from the vent lines of the mud/gas separator downstream of the choke and from the diverter line and should be considered in area classification.

Liquid hydrocarbons entering the circulation systems downhole under normal circumstances are likely to be very much diluted by the mud system. However, under conditions of underbalanced drilling, the proportion of hydrocarbons in mud returns may be significant, with a potential for continuous release, and should be considered in area classification.

Releases from (c) are likely to be insignificant in an open derrick or mast, but may be considered as secondary grade releases in an enclosed derrick.

Releases from (d) may be significant in certain types of operation.

Releases from (e) are not normally significant, except in the case of inadvertent releases from high-pressure pipework.

Secondary grade releases from (g) may occur at sumps or drainage tanks and be conveyed by vents or drains to areas where potential sources of ignition are present. Outlets or entries to vent and drain systems should be considered accordingly.

D7.1.3 Groupings for area classification

The recommended procedure for area classification is to consider the elements of any drilling or well-servicing facility under the following groupings:

- (a) The rig substructure – the space between the rig floor and main platform deck (offshore) or ground level on a land rig, and in which the bell-nipple, diverter and blow-out preventers are located.
- (b) The wellhead area down to the cellar deck offshore, or wellhead cellar on land-based rigs.
- (c) The upper works of the rig, above the rig floor.
- (d) The circulating surface mud system, including shale shaker, mud pits or tanks etc.
- (e) Other spaces adjoining these areas subject to miscellaneous small releases from tanks, flanges, vents or drains.
- (f) Gas vents from any of the above, including mud degasser and HVAC vents.

These subsections differentiate as appropriate between open area and enclosed or sheltered areas.

D7.2 AREA CLASSIFICATION FOR DRILLING, WORKOVER AND WIRELINE OPERATIONS IN OPEN AREAS

Many drilling rigs onshore and some drilling and wellhead areas offshore may be considered open areas, although they may include some small, localised sheltered areas. When the rig substructure and any combined wellhead area can be considered open, as defined in 4.2, hazardous areas should be derived using D7.2.1 to D7.2.5.

D7.2.1 Substructure, drilling riser and BOP area

For drilling and workover installations where a bell-nipple is used at the top of the riser, it should be regarded as a source of primary grade release and treated as a sump. In an open area, the Zone 1 hazardous area should extend vertically and horizontally from the bell-nipple and down to ground or sea level to limits calculated using 3.8.2. Where a diverter is installed, hazardous areas will exist at the bell-nipple and at the diverter line outlets. Where the return mud is routed through a gas-tight flow line, the Blowout Preventer (BOP) and riser assembly should be considered as a potential source of secondary grade release from flanges or drain points and the Zone 2 hazardous area should extend horizontally and above the drill floor and below the well casing flange to limits calculated using 3.7.3. Any

trough-type flow-line, open-top tanks or equipment connected to the return system that is not gas-tight should be treated as sumps and thus as potential sources of primary grade release necessitating a Zone 1 hazardous area.

It is good practice for the hazardous area originating at the bell-nipple or wellhead to include the hazardous area from any other adjacent sources, e.g. vents and drains on the BOP riser system and diverter, including the BOP valves and accessories. Where operational areas above the weather deck are enclosed, the extent of the hazardous area is defined by the enclosure. Any releases originate from the bell-nipple and therefore the hazardous area should be extended vertically to the height of the bell-nipple. In certain circumstances, i.e. when 'reverse circulating', an area around the path of the Topdrive or Kelly Swivel should also be regarded as hazardous. Where a rig is fitted with containment around the BOP, the extent of the hazardous area is defined by the dimensions of the containment.

Where there is no containment of spillages on the weather deck, the extent of the hazardous area below the weather deck will be calculated using 3.8.2.

For fixed and mobile offshore installations, similar principles should be applied; the full extent of the BOP and riser assembly down to the wellhead flange of the well casing should, due to potential leakage, be considered as potential sources of secondary release and the hazardous area defined using 3.7.3. However these secondary releases are generally incorporated in the Zone 1 areas for normal rig operation. If the area around a potential source of release is open, it should be treated as a Zone 2 area, and if enclosed, as a Zone 1 area.

D7.2.2 Rig upperworks

For an open design derrick (i.e. non-enclosed) a Zone 2 hazardous area due to spillage on the rig floor should extend a distance equal to R_1 calculated as in section 3.8.1 above the rig floor. Where rig floor wind-walls are fitted, the Zone 2 hazardous area should extend to at least the top of the wind-wall.

Some drillstring components when racked in the derrick can be coated with residual mud or solids and produce a small hazardous release, but in the open this will rapidly disperse due to natural ventilation. Coring samples laid out on the drill floor or elsewhere may also be a source of hydrocarbon release and give rise to spillage potential areas and should be classified accordingly.

The hazardous area created by a mudgas separator vent should be derived using 3.6.2.3 (see also D7.2.4).

Hoists on coiled tubing and snubbing units should be treated in the same way as drilling derricks. However, consideration should also be given to the hazards of residual mud or fluid inside and on the exterior of coiled tubing or production tubing.

D7.2.3 Cellar decks and well cellars

Unless artificially ventilated, the space around the wellhead in an onshore cellar should be regarded as inadequately ventilated and classified using 3.8.2, as shown in Figure D31. The ventilation in any spaces adjoining well cellars or wellhead areas and moonpools on offshore installations should be assessed and the zone classification and boundaries established.

For spillages in a sheltered area (see 4.3), the hazardous area should extend 3 m outside any opening in the shelter or a distance equal to R_1 calculated as in 3.8.2 from the bell-nipple, whichever is the greater.

Spillages in open wellhead areas on fixed offshore installations should be classified using 3.8.1. Where one or more wellheads are enclosed in 'cells', they should not be regarded as 'open'.

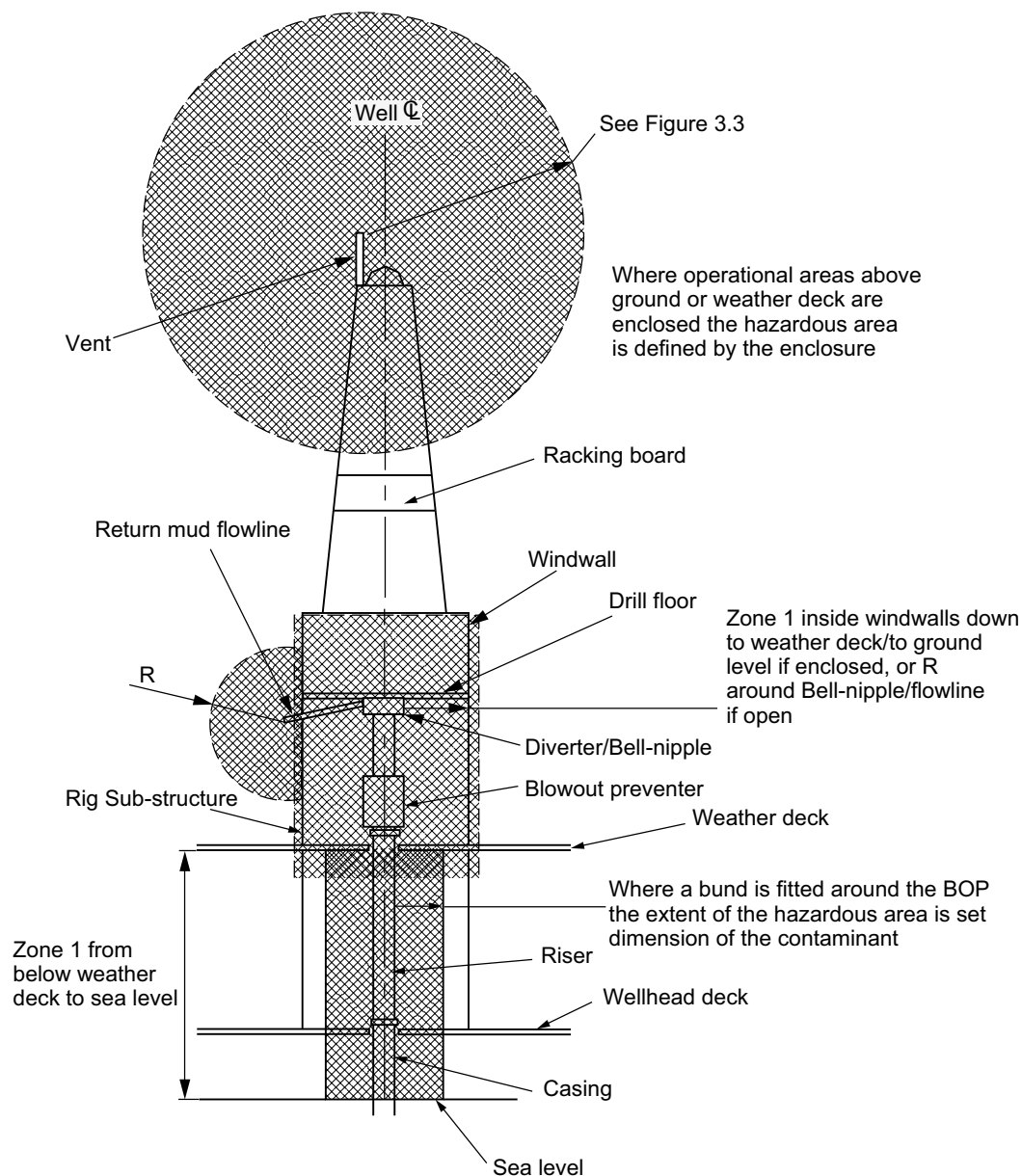
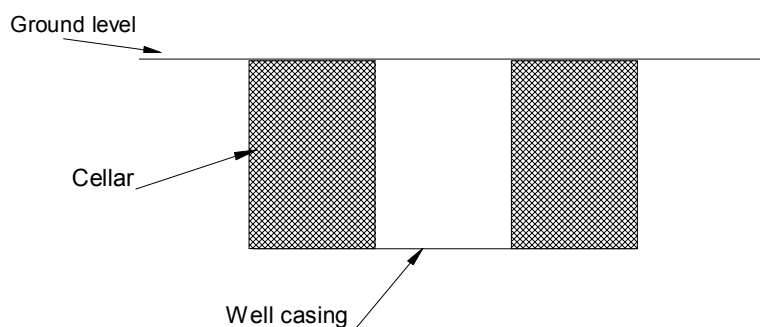


Figure D30: Drilling and workover



Note: only part of installation shown; for parts of the installation above the ground level, see corresponding part of Figure D30. above weather deck.

Figure D31: Typical well cellar (land rig)

D7.2.4 Workover, snubbing, coiled tubing and wirelining operations

The classification derived in D7.2.1 should be applied to work-over, snubbing, coiled tubing and wireline operations. For these operations, the most probable point of hydrocarbon release is the stripping unit, injector head or stuffing box. The extent of the hazardous area should be assessed from the configuration of the equipment to be installed. Where the area surrounding the drilling riser and BOP assembly is enclosed, the hazardous area should be defined using D7.2.5. Potential leakage rates should be obtained from equipment suppliers and the hazard radius determined by reference to Annex C or by a similar calculation methodology. In the absence of supplier leakage rate information, hole sizes should be estimated by reference to Table C13 and the hazard radius should be determined using Table C4.

Where these operations are carried out using the main drilling rig, these areas are generally incorporated in the Zone 1 areas defined for normal rig operations. Where they are carried out without the drilling rig, the hazardous areas should be considered equivalent and are represented by the wireline operation in Figure D32.

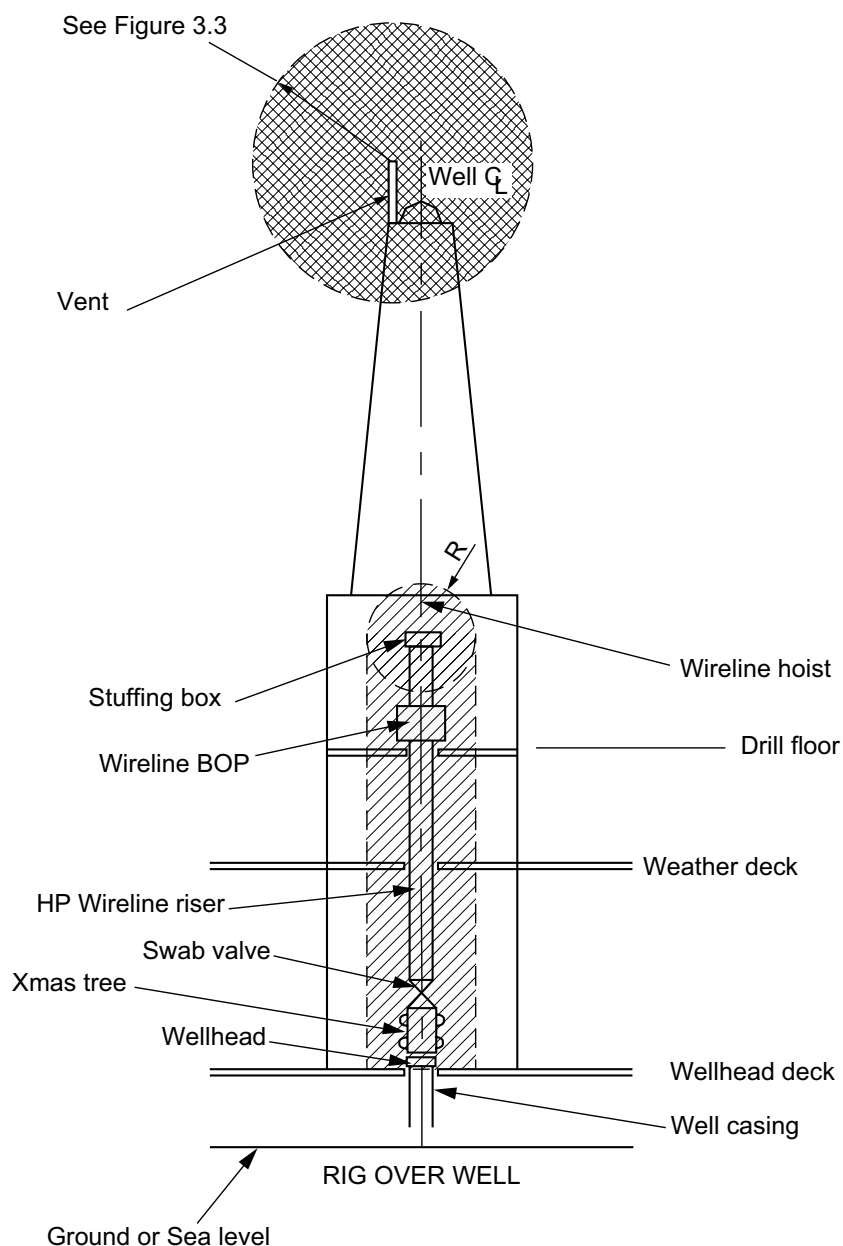


Figure D32: Freestanding wireline operation (open areas)

D7.2.5 Operations where rig or wellhead areas are not 'open'

Where any part of a rig drill-floor, sub-structure or upper-works is enclosed (see 4.3.1), all apertures from the enclosed area containing a source or sources of release should be regarded as secondary grade release sources and a hazardous area extending 3 m from each aperture should be specified.

If the derrick is partially or totally enclosed for weather or other protection, the internal space should be classified as Zone 1 with a Zone 2 area extending outside apertures in the

enclosure to limits determined in accordance with guidance in 4.3. Where a vent line is fitted on the derrick, the radius (R_1) of the hazardous area should be calculated using 3.6.2.3.

If the sub-structure is totally enclosed, the bell-nipple should be treated as a sump in accordance with 3.8.2 and the internal space should be classified as Zone 1 with a Zone 2 area extending 3 m outside any aperture in the enclosure. Enclosed onshore well cellars and other non-open areas are covered in D7.2.3.

D7.2.6 Notes on Figures D30, D31, and D32 – open areas

Figure D30 shows the extent of hazardous areas in the drill floor, substructure and upper-works of 'open area' (offshore and land) drilling rigs. Figure D31 shows hazardous areas for a well cellar. Figure D32 shows hazardous areas associated with wireline operations offshore.

In these drawings the hazardous area arising from the surface mud circulation system is excluded since this is dealt with in Figure D32. However, if the mud itself is regarded as hazardous, as in Figure D32, or the return flow-line is open, then the effect of any sources relevant to Figures D30 and D32 should be considered, as in D7.2.1.

D7.3 SURFACE MUD SYSTEMS

The surface mud system includes:

- high pressure mud pumps and manifolds;
- shale-shakers and other solids removal equipment;
- mud degassing equipment;
- mud pits (settling tanks) and active tanks;
- liquid mud mixing, storage and transfer system, and
- cuttings treatment and reinjection system.

Drilling fluids may be water-based or oil-based. Oil-based drilling fluids may be mineral, vegetable or synthetic. Either type may contain a wide variety of chemicals. The possibility of the mud being hazardous should be considered. Drilling mud should be considered hazardous when its temperature can be raised to its flash-point or auto-ignition temperature during use, storage or on release. High temperatures may occur as a result of high downhole temperatures, high subsurface temperature and/or dilution by pick-up of formation hydrocarbons. On release, fluids may be affected by the heat of the sun, contact with hot objects or spray atomisation, causing a mist to form. Geological guidance may be required to estimate the maximum operating temperature of the mud. The effect of hazardous drilling mud is considered in D7.3.6.

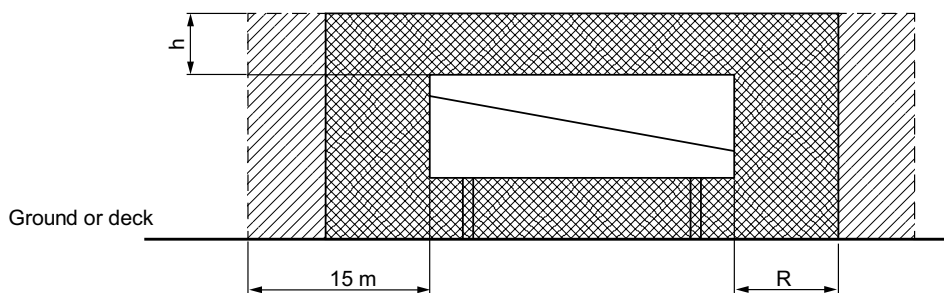
D7.3.1 High pressure mud pumps and manifolds

High pressure mud pumps and manifolds in the surface mud system may normally be excluded as sources of release because any leakage would be small, with a low hydrocarbon content. Thus the area surrounding a mud pump may be unclassified unless it is located in an area that is classified because of some other facility or mud properties.

D7.3.2 Shale-shakers and solids removal equipment

A shale-shaker located in an open area should be treated as a sump (see 3.8.2), with a horizontal Zone 1 area of 3 m, extending 3 m above the top of the shale-shaker, as shown in Figure D33. These dimensions are suitable for shale-shakers of less than 5 m length.

When a shale-shaker is located in an enclosure with adequate artificial ventilation, the enclosure should also be classified as Zone 1, with an additional Zone 1 area extending from any opening to no more than 3 m.



Note: $R = 3\text{ m}$, $h = 3\text{ m}$ based on a sump of less than 5 m in length (see D7.3.2).

Figure D33: Hazardous area around a shale-shaker in an open area

D7.3.3 Mud degassing equipment

All parts of the surface mud system excluding the reserve pits and transfer pumps should generally be considered to be active, with the potential to contain oil or flammable gas, both lighter and heavier than air. The sections of tank below the shale-shakers and mud treatment equipment are the most likely to contain hydrocarbons in the form of dissolved gas and traces of crude oil. Gas should be removed by circulation through a mud degasser. Any traces of crude oil will usually be heavily diluted by drilling mud, but can be removed by skimming.

When mud from the active system is transferred to the reserve pits, it may still contain traces of hydrocarbons. However, the quantity of hydrocarbon circulating will normally be small and thus the extent of the hazardous area from any secondary grade releases will be correspondingly small.

The extent of the hazardous area arising from sources on mud degasser systems (active system and choke) should be assessed as a main process vent using 3.6.2.3. The main mud system gas vent may be located at the top of the derrick or it can be remote from the drilling area.

When geological or other knowledge allows the maximum likely vent rate to be estimated, the extent of the hazardous area should be based on 3.6.2. When this information is not available, the hazardous area should extend at least 15 m in all directions from the vent or down to ground level if the vent is less than 15 m from the ground.

With a vent at the derrick top, any area within the derrick less than 15 m from the vent tip should be considered hazardous.

The gas vent should normally be considered a secondary grade release.

D7.3.4 Mud pits and active tanks

The active mud tanks should be regarded as secondary grade sources of release, except when there is a probability that gas-cut mud could enter the tank to produce a significant release, in which case the tank concerned should be regarded as a primary grade source of release. In an open area with adequate ventilation, the hazardous area should be as defined by Figure D34. The space within the tank walls should be classified as Zone 1, with a Zone 2 area outside in accordance with 3.8.2.

It is the preferred practice for mud tanks to be sited in an open area. Where this is not practicable and there is not adequate artificial ventilation, the area around a mud tank located in an enclosure should be classified as Zone 1 to the extent of the enclosure, with an additional Zone 2 area extending 3 m from any openings in the enclosure.

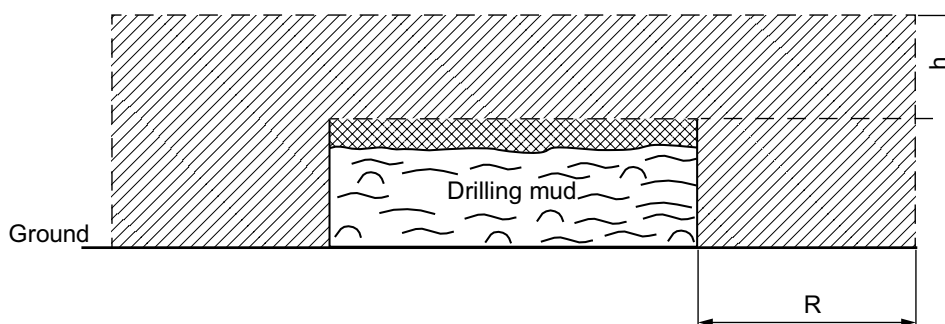


Figure D34: Hazardous area around mud tanks

D7.3.5 Mud mixing, storage and transfer – ventilation of enclosed systems

In respect of D7.3.2 and D7.3.4, it should be noted that ventilation in areas of significant hydrocarbon release can be set by the requirement for air change to meet environmental and health exposure criteria, rather than consideration of flammability. In sheltered or enclosed areas, local air velocities can be made sufficiently high with the aid of local artificial ventilation to avoid classifying all of the sheltered or enclosed area as Zone 1 (see 4.2 and 4.3).

For further guidance on ventilation see Chapter 4.

D7.3.6 Hazardous drilling muds

When drilling mud itself is considered to be hazardous in consequence of factors in D7.3, the extent of the hazardous areas should be estimated for the equipment in the mud system, with any open tanks being considered as sumps (see 3.8.2). The larger of the estimated distances based upon Chapter 3 or calculated as in D7.3.2 to D7.3.4 should be used to define the hazardous areas.

Mud pumps and associated pipework, valves and fittings should be considered as sources of release when the mud is itself hazardous, and the extents of the hazardous areas should be based upon the relevant sections of Chapter 3.

D7.3.7 Cuttings treatment, storage and reinjection systems

Untreated cuttings may be contaminated with liquid hydrocarbons or potentially hazardous drilling mud. Other hazardous fluids may also be added to waste streams for reinjection. Any release is likely to be secondary grade and small. Open feed systems and first-stage processing equipment should be regarded as sumps with a Zone 1 area within unventilated tanks and ducts and a Zone 2 area outside calculated using 3.8.2. Washed cuttings and injection slurry may be regarded as non-hazardous.

D7.3.8 Under-balanced drilling separation systems

In under-balanced drilling operations, the returning fluid stream will contain drilling fluids, hydrocarbons (oil and/or gas) and solids. In the majority of cases, depending on their composition, it is beneficial to treat the well returns in a closed-loop system prior to conditioning the drilling fluid. Separation of water, oil and gas can be achieved by use of tank or cyclone separators rather than by conventional shale-shakers. Thus, the first stage of the process should be the separation of hydrocarbons from the fluid stream. The process design should be arranged so as to avoid the use of electrical or moving mechanical equipment in places where there may be a continuous or significant release of hydrocarbons. Suitable arrangements should be made for sampling and the removal of accumulated solids.

The separation system should be treated as a potential source of primary grade release and be designed accordingly. If there is a significant risk of hydrocarbon release downstream of the separation process, the complete system should be designed as a 'closed loop'. A hazardous area should be derived using the relevant parts of 3.8.1 and 3.8.2.

Thereafter, the treatment of the drilling fluid to remove any residual solids should be designed to minimise the potential for further hydrocarbon release.

When the shale-shaker is located in an enclosure without artificial ventilation, the enclosure should be classified as Zone 1, with an additional Zone 2 area extending from any opening calculated using 3.8.2. Where adequate ventilation is provided (see D7.3.5), the Zone 2 area may be reduced as in D7.3.2.

Other solids removal equipment should be considered as a source of primary grade release and a Zone 1 hazardous area established, as described in D7.3.2. Other process equipment in the separation train should be treated in accordance with relevant sections of Chapter 3.

D7.4 MISCELLANEOUS SOURCES OF RELEASE

The extent of the hazardous area from other miscellaneous sources, e.g. flanges, vents and drains, will normally lie within the hazardous areas described in sections D7.2.1 to D7.2.5 or within the hazardous areas of the lubricator or wellhead when conducting wireline or drilling/workover operations. Hydrocarbon vents and drains should normally connect to a closed system. The classification of spaces other than those covered in previous sections and their ventilation should be assessed in accordance with D7. In all other cases, the extent of the hazardous area should be determined using Chapter 3.

D7.5 OTHER SPACES

The ventilation in any other spaces on a drilling facility not specifically covered should be assessed as outlined in Chapter 4 and the zone classification and area boundaries for non-open areas assessed in accordance with Chapter 3. This should include:

- (a) Any enclosures which do not themselves contain a source of release, but which fall within and have openings to, an external hazardous area. The internal space should be classified as having the same zone number as the external area, unless protected by artificial ventilation as prescribed in Chapter 4. There need be no hazardous area drawn from apertures in the enclosures beyond that covered by the area within which the enclosures lie.
- (b) Areas on an offshore installation where space does not permit utility process areas, electrical equipment rooms, control rooms and accommodation or office areas to be located in a non-hazardous area which it is proposed to protect by pressurisation/over-pressure.
Battery rooms sited in a non-hazardous area which, because of their release of electrolytic gas containing hydrogen and oxygen, require specific area classification.

Note: In some cases the provision of an appropriately rated fire wall between the ignition and release sources can reduce the extent of the hazardous area so as to provide adequate separation (see 4.2.4.1).

D7.6 WELL TEST SYSTEMS

Equipment to test wells is often installed on a temporary basis. The extents of hazardous areas associated with a temporary installation should be determined using the point source approach in Chapter 3. When permanent facilities are provided to locate temporary well test equipment in specific locations, hazardous areas should be defined as though the temporary equipment was permanently installed.

D7.7 EMERGENCY SYSTEMS

Alarm and shutdown systems embodying gas detection and other sensors, with redundancy to avoid false operation, are covered in the examples in D7. In considering zone classification in D7.2 and D7.5, it is recommended that electrical apparatus required to operate under conditions of breakdown should be of a type suitable for Zone 1 operation (for further information see *EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas*).

Where such systems are installed, there should also be independent means of providing essential services such as emergency lighting, escape route lighting, voice and radio communications, with appropriate protection, that will remain in operation in the zone in question under the most adverse conditions. Normally the protection required will be of a type suitable for a flammable atmosphere. In addition, such apparatus should not be de-energised or shut off as part of any shutdown procedure and should be provided with an independent, protected power supply such as a battery backup.

D7.8 NON-ELECTRICAL SOURCES OF IGNITION

Although area classification is intended primarily for the selection and location of electrical equipment, area classification should also take into account non-electrical sources of ignition. For further information see *EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas*.

ANNEX E

SMALL SCALE OPERATIONS (LABORATORIES AND PILOT PLANTS)

E1 GENERAL

Research and development installations have special features which need to be considered in assessing the fire and explosion risks, and the approach to area classification for laboratories and pilot plants. The starting point is as usual, the identification of sources of release, both from normal operations, and as a result of failure of equipment or poor handling. At laboratory scale, primary grade sources of release of flammable vapour and gases should be small. Some may be controlled simply by good ventilation of the room. This is likely to be needed in any case to control the health risks from substances released.

Many operations involve manipulation of flammable liquids. The release of vapour as a primary grade source is likely to be very small. Where normal operations are likely to release more vapour, for example where solvents are to be evaporated or liquids are sprayed, they should be carried out in fume cupboards, to control personal exposure, but these also have the effect of minimising the risk of an explosive atmosphere. Consideration should be given to the possibility that the external fume cupboard vents could generate hazardous areas in the event of a release within the cupboards.

Possible secondary grade sources of release in many circumstances are numerous and include breakage of glassware, loss of cooling to a condenser, mains gas taps on an open bench, temporary pipework between a gas bottle and other apparatus, boilover of reaction mixtures, spillage from poor handling techniques, storage containers left open, unsuitable disposal of contaminated rags. The size and possible duration of any of these possibilities should be considered.

It should be recognised that many items of laboratory equipment are not available in a form that is protected against the risk of igniting flammable atmospheres; hot plates, heating mantles and ovens are all likely to have surfaces hot enough to be capable of igniting some materials that may be used. Small motors and instrumentation are often potential sources of ignition. Consequently laboratories are not usually zoned, and the risk of fire or explosion has to be controlled in other ways.

These may include:

- Training in techniques to reduce the frequency and size of sources of release e.g. handling techniques that minimise the risk of liquid spills.
- Appropriate use of fume cupboards, to control primary or larger secondary grade sources.
- A high standard of awareness of the fire risk, and training in the actions to be taken in the event of spillage, or leaks.
- Means to isolate from a safe place any electrical equipment that is live, in the event of a spillage or leak.
- Suitable equipment and training for dealing with small fires.
- Close supervision of laboratory work where prompt action may be needed to deal with releases of any sort.
- Good ventilation.

If precautions of this type are provided, and the risk assessment shows that foreseeable fires are likely to be controlled safely by laboratory staff, e.g. using a single fire extinguisher or fire blanket, relaxation from the need for area classification may be justified. Precautions to limit the risk of escalation of any incident are also needed, for example limiting the quantities of all combustible materials stored within the laboratory and protection from fire of any highly toxic products. Further guidance may be found in the HSE report *Hazardous area classification and laboratory operations*, available at the UK Health and Safety Laboratory website.

E2 HAZARDS ASSOCIATED WITH PARTICULAR CLASSES OF MATERIAL

This section is not intended to be comprehensive guidance on safe laboratory practice, but is restricted to advice on storage.

Limits should be set on the amount of flammable liquids that are stored within a laboratory. In most cases a maximum of 50 litres, stored in a purpose-designed cupboard should be allowed. Larger quantities should be stored in a room designed for the purpose, or in the open air. After use, storage vessels should be returned to the cupboard promptly, and not left in fume cupboards or on open benches.

Compressed or liquefied flammable gases should be either stored outside the building, or in a specially ventilated area. Small numbers of cylinders in regular use may be kept within the laboratory, but the main cylinder valve should be closed at all times when the cylinder is not in use. Proper control of pressures and piping of sufficient strength are needed to minimise the risk of leaks, or fracturing glassware. Permanent pipework for gases in regular use should be made out of metal, and operate at as low a pressure as practicable. Liquefied flammable gases are a particular hazard, especially if they are provided for laboratory purposes in an unstonched form. Quantities kept in the laboratory should be kept to a minimum, and effective ventilation is needed.

E3 PILOT PLANTS AND LARGE SCALE LABORATORIES

There is no sharp dividing line between larger scale laboratories and pilot plants, and each situation should be considered individually. Local ventilation may be purpose-designed for a specific rig, or it may be installed in a large fume cupboard. In either case, adequate ventilation may limit the extent of any flammable atmosphere that could be formed. Area classification is then not needed. Often apparatus will be floor mounted, in which case individual facilities should be surrounded by a shallow sill to prevent escalation by any liquid spill flowing from one unit to another. Where general ventilation only is provided, or where there is the possibility of escalation to involve rapidly more than one rig, a full area classification is more likely to be needed. In any case where flammable liquids or heavy flammable vapour may be released at low momentum and collect at floor level, the lowest levels of the room should be designated Zone 2. Where area classification is needed, the facility should not be located in the same room as an unclassified small scale laboratory because of the difficulty of defining and maintaining a boundary between the classified and unclassified areas. Even if area classification is not considered essential, it should be possible to isolate heat and power sources from a safe place, and to raise the alarm without causing an ignition risk.

ANNEX F

BACKGROUND AND EXAMPLES ON VENTILATION OF ENCLOSED AREAS, RELEASES WITHIN ENCLOSED AREAS AND ASSOCIATED EXTERNAL HAZARDOUS AREAS

F1 INTRODUCTION

A release of flammable material into an enclosed area, such as a building, is potentially an extremely hazardous event. Ignition may lead to the development of over-pressure causing structural damage to the enclosed area and neighbouring buildings. Consequently, there is a need to distinguish between releases that can be controlled by suitable ventilation, area classification and correct control of equipment, and events that could release so much material that a more fundamental design review is needed. Events leading to a sustained release of significant quantities of flammable material should not be considered as normal operation but be subject to a detailed risk analysis.

In previous editions of EI 15, guidance was supplied on the zoning to be applied within enclosed areas and their associated external areas. It is believed that this guidance was a practical assessment, based largely on engineering judgement, of what is in reality a complex situation. The behaviour in any situation will depend on the release location, direction, momentum and buoyancy and the particular size and nature of the internal obstructions within the enclosure and the location and size of its openings, both in relation to the prevailing wind or other forced ventilation flows and the release itself.

Further research assessing ventilation requirements for hazardous areas has been carried out by the Health & Safety Laboratory (HSL), and is contained in the HSE Research Report RR993 *Technical input on ventilation effectiveness for area classification guidance EI15*. The conclusion of this research is that, for a specified release of flammable material if the ventilation rate is sufficient to dilute the release down to below an average of 25 % LFL throughout the enclosure, then adequate ventilation has been achieved.

The guidance contained in Chapter 4 reflects this position and provides criteria that can be applied, based on operating experience and engineering judgement, to the determination of the type of ventilation (Figure 4.1) and the effect of the degree of ventilation on the zone classification (Tables 4.2). The purpose of this Annex is to provide further explanation and background information relating to release behaviour in enclosures. The content is based on calculations EI Research report: *Dispersion modelling and calculations in support of EI Model code of safe practice – Part 15: Area classification code for installations handling flammable fluids* and HSE Research Report RR993 *Technical input on ventilation effectiveness for area classification guidance EI15*.

F2 NATURAL VENTILATION OF ENCLOSED AREAS

Natural ventilation of enclosed areas is driven primarily by two forces: the atmospheric wind outside the enclosure, which gives rise to a pressure distribution around the external faces of the enclosure, and buoyancy forces, which result from temperature differences between the inside and outside of the enclosure.

The flow rate of air into and out of enclosed areas due to natural ventilation can be predicted using a range of approaches, from simple analytical approaches to complex CFD simulations to tracer gas measurement.

For simple cases, an analytical approach can be used to determine the ventilation flow rate due to wind or thermal buoyancy, based on methods described in BS 5925 *Code of practice for ventilation principles and designing for natural ventilation*. However, this approach is limited in terms of the possible location of openings, and it cannot account for combined wind and thermal-buoyancy effects.

An alternative iterative method can be used which allows greater flexibility and can account for these more complex effects. Spreadsheets or simple programmes using these iterative methods have been written and are widely available, for example from HSL¹² and CIBSE¹³.

For more general cases, involving ventilation in multi-compartment enclosed areas, models such as COMIS and CONTAM can be used. A summary of other modelling techniques for estimating natural ventilation rates is given in Table F1.

Table F1: Classification of approaches available for estimating ventilation rates in naturally ventilated enclosed areas

Approach	Application	Notes
Single space (analytical)	Flow through the enclosed area envelope	Uncoupled external and internal flow. Only describes a limited range of geometries. Equations for the effect of wind or buoyancy. Combination of effects of wind and buoyancy is approximate.
Single space (iterative)	Flow through the enclosed area envelope	As above, but: Can be used for openings on multiple sides of structures and heights of openings. Effects of wind, buoyancy (and mechanical) can be combined.
Multiple space	Flow through the envelope and between internal spaces	As above, but also can include pressure drops between internal spaces, implemented in freely available software, e.g. COMIS, CONTAM.
CFD	External flow and pressure coefficients over structures. Coupled external/internal flows	Few limits on geometry. Coupled flows where internal geometry affects envelope flow. Requires more information and greater effort than simpler modelling approaches.
Physical modelling	External flow and pressure coefficients over structures	Few limits on geometry. Production of physical models and performance of measurements require information, equipment and effort.
On-site measurements, for example, tracer gas techniques	Enclosed area ventilation rates	Specific to the structure of interest but will depend on the conditions on the day measurements are performed.

¹² Quadvent is an area classification programme available from HSL. See <http://www.hsl.gov.uk/products/quadvent.aspx>

¹³ <http://www.cibse.org/knowledge/Design-Tool-for-IAQ-Analysis>

F3 ADEQUATE VENTILATION OF ENCLOSED AREAS

It has been shown that limiting the average concentration to 25 % LFL in an enclosed area generally achieves the objective of adequate ventilation. The ventilation rates provided in Chapter 4 provide the minimum level of ventilation required to ensure that the average concentration stays below 25 % LFL.

Dispersion modelling in QUADVENT¹² has been used to calculate gas cloud volumes for a jet release imposed on a background gas concentration greater than zero, for fluid categories G(i) and G(ii). The results of these calculations are compared in Table F2.

Table F2: Comparison of cloud volumes above LFL for zero background concentration and ventilation dilution to 25 % LFL

Fluid category	Release pressure (bar(a))	Gas cloud volume above LFL, zero background concentration (m ³)				Gas cloud volume above LFL, background concentration 25 % LFL (m ³)			
		Release hole diameter				Release hole diameter			
		1 mm	2 mm	5 mm	10 mm	1 mm	2 mm	5 mm	10 mm
G(i)	5	0,0001	0,0008	0,01	0,1	0,0002	0,002	0,03	0,24
	10	0,0003	0,002	0,04	0,3	0,0007	0,005	0,08	0,67
	50	0,003	0,03	0,4	3,2	0,007	0,06	0,91	7,30
	100	0,009	0,07	1,13	9,0	0,02	0,16	2,57	20,6
G(ii)	5	0,0007	0,006	0,09	0,7	0,002	0,01	0,20	1,58
	10	0,002	0,02	0,24	1,92	0,004	0,04	0,55	4,37
	50	0,02	0,17	2,64	21,1	0,05	0,39	6,01	48,1
	100	0,06	0,48	7,46	59,7	0,16	1,08	17,0	135,8

When interpreting these data, the gas cloud volume resulting from a gas release in an enclosed area with a background concentration of 25 % LFL is approximately 2,3 times larger than for the equivalent outdoor unobstructed release. The same scaling factor may be applied to the dispersion modelling resulting in Annex C Part 1 across all of the fluid categories to obtain the gas cloud volumes inside enclosed areas with a background concentration of 25 % LFL. While this is a significant assumption, as the dispersion mechanisms leading to gas cloud build up are rather different for the different fluid categories, the results provide a reasonable first estimate of the magnitude of the hazard posed by a release in an enclosure. Table F3 indicates the gas cloud volumes that might be expected from a release in an enclosed area where the average gas concentration is limited to 25 % LFL.

Table F3: Mass flow rates and ventilation flow rates for dilution to 25 % LFL, releases calculated using DNV PHAST and gas cloud volumes calculated from QUADVENT (for G(i) and G(ii)), scaled from DNV PHAST free jet calculations (for other fluids)

Fluid category	Release pressure (bar(a))	Release flow rate (kg/s)					Ventilation flow rate to dilute to 25 % LFL (m ³ /s)					Gas cloud volume above LFL, (m ³)				
		Release hole diameter					Release hole diameter					Release hole diameter				
		1 mm	2 mm	5 mm	10 mm		1 mm	2 mm	5 mm	10 mm		1 mm	2 mm	5 mm	10 mm	
A	6,8	0,01	0,05	0,29	(1,17) ¹		1,14	4,56	28,5	(114)		0,020	0,145	2,40	(21,9)	
	10	0,02	0,06	0,381	(1,50)		1,46	5,84	36,5	(146)		0,027	0,203	3,37	(32,2)	
	50	0,04	0,14	0,88	(3,50)		3,40	13,6	85,1	(340)		0,050	0,513	8,94	(92,6)	
	100	0,05	0,20	1,24	(4,97)		4,83	19,3	121	(483)		0,078	0,648	11,70	(122)	
B	5	0,01	0,05	0,30	(1,18)		0,99	3,94	24,6	(98,4)		0,074	0,559	12,49	(103)	
	10	0,02	0,07	0,44	(1,76)		1,47	5,86	36,6	(147)		0,111	0,933	19,96	(163)	
	50	0,04	0,16	1,02	(4,09)		3,41	13,6	85,3	(341)		0,121	0,978	18,66	(191)	
	100	0,06	0,23	1,45	(5,81)		4,84	19,4	121	(484)		0,116	1,014	18,52	(194)	
C	5	0,01	0,05	0,31	(1,23)		0,94	3,74	23,4	(93,6)		0,110	0,684	8,48	(62,0)	
	10	0,02	0,07	0,46	(1,84)		1,40	5,62	35,1	(140)		0,113	0,984	19,66	(161)	
	50	0,04	0,17	1,07	(4,29)		3,27	13,1	81,8	(327)		0,121	1,051	19,29	(190)	
	100	0,06	0,24	1,52	(6,10)		4,65	18,6	116	(465)		0,124	1,061	18,95	(196)	
G(i)	5	0,001	0,002	0,015	0,06		0,07	0,27	1,70	6,79		0,00006	0,0006	0,007	0,059	
	10	0,001	0,005	0,032	0,13		0,14	0,56	3,48	13,9		0,0002	0,0018	0,028	0,223	
	50	0,007	0,027	0,170	0,68		0,75	2,99	18,7	74,7		0,0031	0,025	0,364	3,059	
	100	0,015	0,059	0,370	1,48		1,63	6,51	40,7	163		0,0096	0,076	1,33	11,389	
G(ii)	5	0,0004	0,0015	0,01	0,04		0,13	0,52	3,23	12,9		0,0005	0,004	0,040	0,445	
	10	0,001	0,003	0,02	0,07		0,26	1,05	6,57	26,3		0,0010	0,009	0,152	1,297	
	50	0,004	0,02	0,1	0,4		1,33	5,31	33,2	133		0,0157	0,115	1,896	16,02	
	100	0,008	0,03	0,2	0,7		2,64	10,6	66,1	264		0,0351	0,305	5,461	50,07	
Note that the cases in brackets are those for which area classification is not appropriate for outdoor releases (E15) and therefore are by default also inappropriate for area classification indoors. The data are therefore provided for information only.																

These data show that in most cases the gas cloud volume is relatively small, and that therefore the ventilation is sufficient to control the release. For example for hole sizes up to 2 mm diameter the flammable gas cloud volume is always less than about 1 m³. However, there are some circumstances where larger gas cloud volumes are produced. Although this demonstrates that the overall level of ventilation is sufficient, it does not demonstrate that the *local ventilation* is adequate. It is the local ventilation effectiveness that will determine how the release disperses. It is therefore important that the 25 % LFL criterion should be a *minimum* requirement as other factors need to be taken into account. If such a criterion is only just met then this is a good indication that further effort may be required to ensure that the ventilation local to the release point can be considered adequate.

In Chapter 4 guidance is provided on accounting for the effects of congestion/ confinement on the ventilation rate (to achieve the 25 % LFL criterion). If the degree of confinement/ congestion is particularly high or the ventilation is poorly distributed within the enclosure then the ventilation rate scaled by the efficiency of mixing (ϵ) is unlikely to indicate whether or not the local ventilation is adequate.

Judging whether or not the room ventilation rate scaled by ϵ is an appropriate way of assessing the adequacy of the ventilation for diluting a specific release can only be made by visual inspection. If it is not then in these cases an assessment of the local ventilation effectiveness needs to be carried out or the extent of the zone needs to be determined appropriately (i.e. increased). Carrying out smoke tests would be one such approach that could be used for assessing the local ventilation effectiveness. The degree to which the 25 % LFL criterion is met, taking into account a suitable value for ϵ provides a useful indication of the amount of effort needed in these additional assessments.

To determine whether or not an area should be classed as congested, an assessment should be made of the number and size of obstructions within the distance in which it takes for an equivalent unobstructed release to dilute to below the flammability limit.

F4 EXAMPLES OF ASSESSMENT OF ADEQUATE VENTILATION

In all of the examples it has been assumed that the ventilation flow rate (m³/sec) is known, either through calculating the natural ventilation rate or through knowledge of the mechanical ventilation rate. Table 4.1 has been reproduced below as Table F4 for ease of reference in going through the examples. Table 4.1 presents the ventilation flow rates required to achieve 'adequate ventilation', (i.e. to maintain an average concentration in the enclosure of less than 25 % LFL) for a range of release cases.

Table F4: Ventilation flow rate to dilute to 25 % LFL (adequate ventilation)

Fluid category	Release pressure (bar(a))	Ventilation flow rate to dilute to 25 % LFL (m³/s)			
		Release hole diameter			
		1 mm	2 mm	5 mm	10 mm
A	6,8	1,2	4,6	29	(120)
	10	1,5	5,9	37	(150)
	50	3,4	14	86	(340)
	100	4,9	20	130	(490)
B	5	1,0	4,0	25	(99)
	10	1,5	5,9	37	(150)
	50	3,5	14	86	(350)
	100	4,9	20	130	(490)
C	5	1,0	3,8	24	(94)
	10	1,4	5,7	36	(140)
	50	3,3	14	82	(330)
	100	4,7	19	120	(470)
G(i)	5	0,1	0,3	1,7	6.8
	10	0,2	0,6	3,5	14
	50	0,8	3,0	19	(75)
	100	1,7	6,6	41	(170)
G(ii)	5	0,2	0,6	3,3	13
	10	0,3	1,1	6,6	27
	50	1,4	5.4	34	(140)
	100	2,7	11	67	(270)
Notes 1. The cases in brackets are those for which area classification may not be appropriate for outdoor releases. The hazard radii of these releases may exceed 30 m and therefore are by default also inappropriate for area classification indoors. This should be avoided. The data are provided for information only. 2. At the fluid storage temperature of 20 °C the nominal discharge pressure of 5 bar(a) is below the saturated vapour pressure of Fluid category A. The saturated vapour pressure (6,8 bar(a)) was used to calculate the discharge rate and dispersion. 3. The required ventilation flow rate should take account of any primary release within the enclosure.					

The efficiency of mixing ϵ within the enclosure is assigned as described in 4.3.1.2 and presented in Table F5.

Table F5: Efficiency of mixing ϵ within the enclosure

Description	Efficiency of mixing factor (ϵ)
Unconfined/non congested enclosures	1,0
Moderate level of confinement/congestion	0,5
Higher levels of confinement/congestion a value of	0,33

Example 1

Consider a case where fluid category A is stored at saturation pressure (6,8 bar) and area classification is to be carried out for a secondary grade release through a 1 mm diameter hole. The enclosure is assessed to be unconfined and therefore an efficiency of mixing factor (ϵ) of 1,0 is used. Table F4 indicates that a ventilation flow rate of 1,2 m³/s or greater is required for it to be classified as adequate ventilation. Note that this ventilation flow rate is independent of the enclosure volume and therefore does not equate to a single value for the air change rate.

If this secondary release occurred in an enclosure with dimensions 10 m × 5 m × 3 m giving an enclosure volume of 150 m³, then the air change rate requirement would be $1,2 / 150 = 0,008 \text{ s}^{-1} = 29$ air changes per hour or greater.

Example 2

In this second example consider a case where fluid category B is stored in an enclosure at 10 bar and area classification is required with a hole diameter of 1 mm. The enclosure is assessed to be unconfined and therefore an efficiency of mixing factor (ϵ) of 1,0 is used. In this case Table F4 indicates that a ventilation flow rate of 1,5 m³/s or greater is required for it to be classified as adequate ventilation.

In an enclosure 10 m × 15 m × 6 m, which gives an enclosure volume of 900 m³, this ventilation flow rate equates to an air change rate of six air changes per hour or greater.

Example 3

Consider an example where area classification is required for a Category C fluid stored at 5 bar using a 5 mm diameter hole. The enclosure is assessed to be unconfined and therefore an efficiency of mixing factor (ϵ) of 1,0 is used. In this case Table F4 indicates that a ventilation flow rate requirement of 24 m³/s or greater is required for it to be classified as adequate ventilation. For an enclosure 25 m × 12 m × 7 m, giving an enclosure volume of 2 100 m³, the ventilation flow rate equates to an air change rate of 41 air changes per hour or greater, which is unlikely to be practicable for such a large enclosure volume.

However, if the same piece of equipment was in a much larger enclosure, say 50 m × 50 m × 7 m giving an enclosure volume of 17 500 m³, then the ventilation flow rate requirement, still 24 m³, gives an air change requirement of 4.9 air changes per hour or greater for it to be classified as adequate ventilation. Note however, that for these larger enclosure volumes it is important to assess whether the leak location is efficiently affected by the ventilation flow and therefore is not in a stagnant area.

Example 4

In this final example, consider a Category G(i) release at 50 bar through a hole with a diameter of 1 mm. This gives rises to a ventilation flow rate requirement of 0,8 m³/s or greater.

If the release is in a confined/congested location then the effect of the ventilation will be less than optimal and the average concentration in the enclosure may be higher than the average concentration at the ventilation outlet. A useful first assessment of this effect is to scale the ventilation rate using the efficiency of mixing factor, ϵ , as described in 4.3.1.2 and tabulated in Table F5. If for example $\epsilon = 0.5$ (a moderate degree of congestion) then in this example the ventilation flow rate requirement increases to $0.8 / 0.5 = 1.6 \text{ m}^3/\text{s}$ or greater for it to be classified as adequate ventilation.

For an enclosure volume of $1\,000 \text{ m}^3$, this ventilation requirement corresponds to an air change rate of 5.8 air changes per hour or greater. Again it is important to stress that while the global ventilation flow rate may be sufficient to provide adequate ventilation based on this assessment (even taking into account the efficiency of mixing factor), evidence should be sought to demonstrate that the release is not located in a stagnant region and that any gas/vapour releases from that location will be mixed by the enclosure ventilation.

F5 EXTERNAL HAZARDS

The implication of F4 is that there may be situations in which flammable material is emitted from a building as a result of an internal release. The fate of this material needs to be assessed. The following general comments can be made regarding an external hazardous area:

- (a) Unless a release is directed towards a particular opening within an enclosure or building, an external hazardous area will only exist if the release is sufficiently large to raise concentrations within the building above the LFL.
- (b) The efflux from the building will take place through the normal ventilation openings in the building fabric.
- (c) The efflux is a relatively small flow and will be mixed into the recirculation zone behind the building in the presence of wind. This mixing process is a result of highly unsteady flow and is wind speed and wind direction dependent but is highly effective.
- (d) Hence, the hazardous areas will be restricted to the immediate vicinity of vent openings and the building fabric.

If the efflux buoyancy (positive or negative) is not negligibly small it will influence the dynamics of the ventilation flow. Specifically, it will preferentially direct hazards to roof or floor and enhance ventilation, and if the buoyancy driven outflow exceeds the ventilation flow a counter flow (additional ventilation) will be induced.

For much larger flow rates specific cases need to be considered. Containment and building effects will keep external concentrations low but events that create an opening in the fabric of the building, such as opening a door, that make greater ventilation possible, would lead to the outflow of flammable material presenting a localised hazard.

ANNEX G

GLOSSARY

adequate ventilation	This is ventilation, natural, artificial or a combination of both, sufficient to avoid persistence of flammable atmospheres within enclosed areas but insufficient to avoid their initial formation and spread throughout the area. (See 4.3.1 and Annex F.)
area classification	The notional division of a facility into hazardous areas and non-hazardous areas, and the subdivision of hazardous areas into zones.
ATmosphere EXplosive (ATEX)	Used in relation to directives 94/9/2014/34/EU and 1999/92/EC (known as ATEX 95 and ATEX 137 respectively). Directive 94/9 concerns the establishment of a single market for equipment to be used in potentially explosive atmospheres. Directive 1999/92 concerns common health and safety standards at places where explosive atmospheres may form. It establishes minimum requirements for the protection of workers, specifically requires areas to be classified where explosive atmospheres may form, and provides a legal definition of the zones.
auto-ignition temperature (AIT)	See <i>ignition temperature</i> ; also synonymous with <i>spontaneous ignition temperature (SIT)</i> .
black heat type heating	Black heat type heating equipment is that in which the external radiant or convection heating surface operates at a temperature not exceeding 200 °C and which has no internal source of ignition.
bonding	Provision of a low-resistance electrical conductor between sections of plant, equipment or structures. See <i>EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas</i> .
buoyancy of release	A gas or vapour should be considered as buoyant and lighter than air if its density on release to atmosphere from a non-pressurised source would be less than 0,75 relative to the ambient air (see 1.7).
certification	Procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements. (Third party – person or body that is recognised as independent of the parties involved, as concerns the issue in question.)

certification continued...	Directive 94/9/EC requires electrical equipment of categories 1 and 2 to be subject to a process of certification, before the CE mark can be affixed, and the product sold within the EU. The certification may be carried out by any of the Notified Bodies (government appointed test houses) within the EU. Category 3 equipment does not have to be certified, instead the manufacturer may issue a self-declaration of conformity.
class of petroleum	System of EI classification of petroleum liquids including crude oil and its products into Classes 0, I, II(1), II(2), III(1), III(2) and Unclassified based upon their flash points, see Annex A.
cold work	The carrying out of any task, or the use of any tool or equipment that will not produce a source of ignition (see also <i>hot work</i>). It includes the use of tools for erection, dismantling and cleaning, which are not liable to produce incensive sparks, and operations such as drilling, tapping and cutting carried out in such a way as to limit the heat produced and keep the temperature of the tools and work below 100 °C.
combustible gas indicator	See <i>gas detector</i> .
confined	A confined space is an area around a potential release location that, due to the presence of large obstructions (e.g. walls and obstacles), gives rise to local dispersion behaviour approaching that for a semi-enclosed area.
congested	A congested leak location is one where there is a significant amount of small scale obstacles that compromises the ventilation flow rate through that area.
continuous grade release	A release that is continuous or nearly so.
dilution ventilation	Artificial ventilation sufficient to maintain generally as non-hazardous an enclosed area containing a source of release or an aperture into a hazardous area.
dry break coupling	A hose coupling designed to minimise the leakage of liquid when the hose is disconnected. Each half of the coupling contains a valve which closes when the latches holding the halves together are released.

earthing	The provision of a safe path of electrical current to ground, in order to protect structures, plant and equipment from the effects of stray electrical currents and electrostatic discharge. See <i>EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas</i> .
enclosed area	Any building, room or enclosed space within which, in the absence or failure of artificial ventilation, the ventilation does not meet the requirements for adequate ventilation.
equivalent diameter	The diameter of the circle of equivalent area to the rectangle.
equivalent leak hole diameter	Dispersion distances quoted in Annex C Part 1 are based on releases from circular release holes. Leak holes which are not typically circular in cross-section (e.g. leaks through the annular space of a pump/compressor seal or leaks through cracks in gasket joints) are expressed as a circular leak hole diameter with an equivalent dispersion range to the non-circular leak hole.
fire resistant	A term used to denote a defined standard of resistance to fire exposure.
flame arrester	A device to prevent the back propagation of flame. It can take the form of perforated plates, fine slots in metal blocks, wire mesh gauzes, crimped metal or bunches of narrow metal tubes.
flammable (synonymous with <i>inflammable</i>)	Refers to any substance, solid, liquid, gas or vapour that is easily ignited. The addition of the prefix 'non' indicates that the substances are not readily ignited but does not necessarily indicate that they are non-combustible. A petroleum liquid is classified as flammable if it has a flash point up to and including 55 °C. See <i>flash point</i> and Annex A.
flammable atmosphere	A mixture of flammable gases or vapours with air in such a proportion that it will burn when ignited.
flammable limits (or range)	The limits of combustibility of flammable gases or vapour when mixed with air (see <i>upper flammable limit</i> and <i>lower flammable limit</i>). Note these terms are synonymous with explosive limits (or range).

flash point

The lowest temperature, corrected to a barometric pressure of 101,3 kPa, at which the application of a source of ignition causes the vapour of the test portion to ignite and the flame propagate across the surface of the liquid under the specified conditions of test.

Flash point values are dependent on the test method used, the apparatus design, the condition of the apparatus used, the vaporisation characteristics of mixed and contaminated samples, and the operator procedure carried out.

Flash point can therefore only be defined in terms of a standard test method and no generally applicable valid correlation can be guaranteed between values obtained by different test methods or where different test apparatus is specified.

For the purposes of this Code, when reference is made to flash point it will be to a closed cup non-equilibrium test method. For liquids having flash points below 40 °C the test method to be used to determine the flash point should be IP 170 *Determination of flash point – Abel closed cup method*. For liquids having flash points above 40°C the method used to determine the flash point should be IP 34 *Determination of flash point – Pensky-Martens closed cup method*.

fluid

A gas, liquid or vapour.

fluid categories

A categorisation for the purposes of area classification of flammable petroleum fluids by the point source method of Chapter 3 according to their potential for rapid production of flammable vapour on release to the environment. Four fluid categories are defined: A, B, C and G (see Table 1.3, Chapter 1).

gas detector

An instrument, fixed or portable, designed to detect and measure the presence and concentration of flammable gas in an area.

gas-free

A tank is considered to be gas-free when the concentration of flammable gases or vapour is within safe prescribed limits. The term gas-free does not imply absence of toxic gases or sufficiency of oxygen for vessel entry.

hazardous area and zone	A three-dimensional space in which a flammable atmosphere is or may be expected to be present in such frequencies as to require special precautions for the construction and use of electrical apparatus. All other areas are referred to as non-hazardous in this context. In a hazardous area three types of zone are recognised.
hazardous atmosphere	An atmosphere containing flammable gas or vapour in a concentration capable of ignition. (The term is synonymous with <i>flammable atmosphere</i> and refers exclusively to hazards arising from ignition. Where there is hazard from other causes such as toxicity, asphyxiation or radioactivity, this is specifically mentioned.)
hazard radius	The largest horizontal extent of the hazardous area, independent of ground effects, that is generated by the source when situated in an open area under unrestricted natural ventilation (see 1.6.8). This is the distance at which the concentration of flammable vapour in air has fallen to the lower flammable limit.
hot work	This includes welding or the use of any flame or electric arc or the use of any equipment likely to cause heat, flame or spark. It also includes caulking, chipping, drilling, riveting and any other heat-producing operation, unless it is carried out in such a way as to keep the temperature below the level at which ignition of a flammable atmosphere could occur. (See also <i>cold work</i> .)
ignition temperature (synonymous with <i>auto- and spontaneous-ignition temperatures</i>)	The temperature at which a substance will begin to burn without application of any source of ignition.
inadequate ventilation	Ventilation, natural or artificial, which is insufficient to avoid persistence of a flammable atmosphere within sheltered or enclosed areas.
incendive spark	A spark of sufficient temperature and energy to ignite a flammable gas.
inflammable	See <i>flammable</i> .

intrinsically safe	An intrinsically safe electrical circuit is one in which any sparking that may occur, under the conditions specified by the certifying authority and with the prescribed components, is incapable of causing ignition of the prescribed flammable gas or vapour. For further information see <i>EI Model code of safe practice – Part 1: The selection, installation, inspection, and maintenance of electrical and non electrical apparatus in hazardous areas</i> .
local artificial ventilation	Air movement and replacement with fresh air by artificial means applied to a particular source of release or local area within a more general area.
lower explosive limit (LEL)	Synonymous with <i>lower flammable limit</i> .
local exhaust ventilation (LEV)	The use of either small scale dilution ventilation (use of extractors etc.) or an enhancement of flow in obstructed areas to attain adequate ventilation.
lower flammable limit (LFL)	The lowest concentration of a flammable gas or vapour in air at atmospheric pressure capable of being ignited. The figure is expressed as percentage by volume.
mobile equipment	Equipment mounted on its own wheels or tracks or having some other facility for mobility.
nominal hazard radius	For very low vapour release rates, e.g. the breathing from open road tanker hatches due only to ambient temperature variations or evaporation of liquids from small drain channels, the rate of vapour flow is too small for dispersion modelling to predict the hazard radius accurately. In such cases, a nominal value, based on experience and engineering judgement is suggested.
non-hazardous area	An area in which flammable atmospheres are not expected to be present so that special precautions for the construction and use of electrical apparatus or for the control of non-electrical sources of ignition are not required. Note: Such an area may still be part of a greater restricted area.
offset fill pipe	A filling pipe, e.g. on a filling station tank, on which connection for the hose of the delivery vehicle is at some distance from the tank.
open area	An area in an open air situation where vapour is readily dispersed by wind. Typically air velocities will rarely be less than 0,5 m/s and will frequently be above 2 m/s.

overpressure ventilation	Artificial ventilation of an enclosed area to maintain the area at a controlled pressure above the ambient pressure.
primary grade release	A release that is likely to occur in normal operation.
pyrophoric scale or deposits	Usually finely divided ferrous sulfide formed inside a tank, pipeline or equipment, in the presence of mercaptans or hydrogen sulfide. It is capable of such rapid oxidation on exposure to air that heating to incandescence can occur.
secondary grade release	A release that is unlikely to occur in normal operation and, in any event, will be of short duration.
source and grade of release	For the purpose of hazardous area classification, a point from which a flammable gas, vapour or liquid may be released into the atmosphere. Three grades of release are defined in terms of their likely frequency and duration: continuous; primary and secondary.
source of ignition	Naked lights, fires, certain electrical equipment, hot surfaces above ignition temperature, or a spark or flame produced by any other means.
spontaneous ignition temperature (SIT)	See <i>ignition temperature</i> .
stagnant area	A region where the degree of congestion is such that air velocities will always be below 0,5 m/s. See 4.2.3.
static electricity	The build-up of an electrical difference of potential or charge through friction of dissimilar materials or substances.
temperature class (T class)	One of six values of temperature allocated to electrical apparatus derived from a system of classification according to the maximum surface temperature of the apparatus.
types of protection	Measures applied in the construction of electrical apparatus to prevent the ignition of a surrounding flammable release.
upper explosive limit (UEL)	Synonymous with <i>upper flammable limit</i> .
upper flammable limit (UFL)	The concentration of flammable gas or vapour in air at atmospheric pressure above which combustion will not occur. The figure is expressed as a percentage by volume.

ventilation	A general term to indicate air movement and replacement by fresh air. Natural ventilation refers to ventilation caused by wind or convection effects. Artificial ventilation refers to ventilation caused by air purges or mechanical means such as fans.
work permit	A document issued by an authorised person to permit work to be carried out safely in a defined area under specified conditions.
zone 0	That part of a hazardous area in which a flammable atmosphere is continuously present or present for long periods.
zone 1	That part of a hazardous area in which a flammable atmosphere is likely to occur in normal operation.
zone 2	That part of a hazardous area in which a flammable atmosphere is not likely to occur in normal operation and, if it occurs, will exist only for a short period.

ANNEX H

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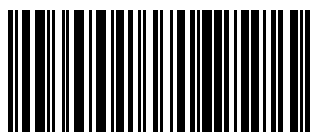
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