IP

Model code of safe practice

Part 15

Area classification code for installations handling flammable fluids

3rd edition

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AREA CLASSIFICATION CODE FOR INSTALLATIONS HANDLING FLAMMABLE FLUIDS

PART 15
OF THE
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AREA CLASSIFICATION CODE FOR INSTALLATIONS
HANDLING FLAMMABLE FLUIDS

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CONTENTS

Contents Cont...

Contents Cont....

Page

ANNEXES

FOREWORD

Part 15 of the IP Model Code of Safe Practice in the Petroleum Industry ('IP 15') is a well-established, internationally accepted Code for the classification of hazardous areas in the petroleum industry. The second edition introduced an updated, demonstrable methodology for determining hazard radii, which broadened the applicability of the Code to all installations handling flammable fluids.

The third edition provides, primarily, both technical and editorial clarification on issues that have been raised by users of the second edition since its publication in 2002. In addition, further technical and editorial changes have been made. A summary of them is provided in Key Technical Changes. It is not anticipated that those changes will result in increased hazardous areas.

The 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 The former approach made a distinction between heavier and lighter-than-air materials but this is no longer valid. The current methodology takes account of both the composition of the material released and its release conditions including the release pressure.

The 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 Code includes the basis of the risk-based approach, the full methodology is provided in a separate publication: IP *A risk-based approach to hazardous area classification.*

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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 second and third editions of IP 15 (IP *Area classification code for installations handling flammable fluids*). To further assist users, additional information on the technical changes referenced to the page number and pertinent section, table or figure, is provided on the IP 15 page of the Energy Institute website (http://www.energyinst.org.uk/ip15). Note that the third edition of the Code also contains numerous editorial amendments.

The key technical changes are to:

— Clarify the three complimentary approaches for carrying out hazardous area classification.
— Clarify that the point source approach can also be used for facilities of common type.
— Clarify that an optional risk-based approach can be used in conjunction with the point source approach for facilities when the release rate is unknown. Provide new guidance on circumstances for applying the risk-based approach.
— Clarify the technical basis for the lower bound of 1 hr/yr.
— Clarify the limitations of Class of petroleum and introduce the concept of fluid category.
— Provide additional guidance on assigning nominal hazard radii for very low vapour release rates and clarify the significance of the outer boundary of the hazard radius.
— Clarify that hazardous area classification must be carried out before choosing appropriate equipment.
— Provide additional guidance on enclosure of a source of ignition when sufficient 'straight line' separation distances cannot be achieved.
— Provide additional guidance on the factors that may trigger an update to a hazardous area classification drawing.
— Provide new guidance and direct example hazardous area classification diagrams for loading of Class 0 materials into road tankers.
— Provide additional guidance and direct example hazardous area classification diagrams for unloading petroleum products (except Class 0) from road tankers at filling stations with various underground and above-ground storage tank arrangements. Includes requisite conditions for unloading, pertinent sources of release (e.g. vents, vapour connection points) and consequent hazard radii.
— Provide new guidance and direct example hazardous area classification diagrams for unloading road tankers carrying Class 0 materials to underground storage tanks.
— Provide additional guidance and revised direct example hazardous area classification diagrams for filling station dispensers for all petroleum products, where associated equipment is or is not present.
— Provide revised guidance on the impact on hazardous area classification and venting of operations in vehicle repair, servicing areas and inspection pits.
— Provide additional guidance and direct example hazardous area classification diagrams for enclosed operational areas above the weather deck in drilling and workover operations, and revised guidance regarding hazardous area classification of secondary grade releases.
— Provide additional guidance regarding treating mudgas separators as a main process vent.
— Clarify hazardous area classification for shale-shakers of less than 5 m length.

- Provide additional guidance on hazardous area classification of gas vents in mud degassing equipment.
- Clarify when risk-based approach should be used for hazardous area classification of point sources.
- Clarify why a different procedure is required for determining hazard radii for different grades of release in the point source approach.
- Clarify the procedure for determining hazard radii with secondary grade releases in the point source approach where the hole size is known or unknown.
- Clarify seal leakage rates from various pump types in the point source approach.
- Clarify guidance for determining hazard radii for pumps using data tables in the point source approach.
- Provide new guidance regarding the implications on hazardous area classification of the design lifting of pressure relief valves, which can be considered as vents.
- Provide revised guidance on the need not to apply the risk-based approach to flanges and valves when there are few release sources and operations are not under extreme conditions.
- Provide additional hazardous area classification guidance, including the implications of hot materials or category A or B fluids entering open surface drain channels.
- Provide modified flowchart for assessing type and degree of ventilation, which includes an additional outcome 'over pressurised area'.
- Provide additional guidance on positioning of fixed non-electrical sources of ignition and implications where located just outside of a hazardous area.
- Provide additional guidance on use of oil mist detectors in circumstances where there is a high risk of hydraulic oil release.
- Clarify limitations of Class of petroleum for more extreme conditions and provide guidance on the concept of fluid category, which enables the point source method or risk-based approach to be applied.
- Provide additional guidance for secondary grade releases regarding the relationship between release frequency LEVELs and individual risk, and calculation of the probabilities of occupancy and probability when using the risk-based approach.
- Provide new guidance on the relevance of the individual risk criterion on LEVELs with regard to determining hole sizes when using the risk-based approach.
- Provide new guidance that sets out the basis for the lower bound frequency of secondary grade releases in terms of the number of flanges, duration of releases, and probabilities of ignition and occupancy and referenced to the individual risk criterion.
- Provide additional terms and definitions for: 'equivalent diameter'; 'hazardous area classification'; and 'nominal hazard radius'.
- Update references.

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OVERVIEW

GENERAL: This Code presents three complementary approaches to be used in hazardous area classification. These are: the direct example approach, which is limited to common facilities, the point source approach, where release rates are dependent on process conditions, and the risk-based approach. The point source approach can be used for all situations; the risk-based approach is an optional methodology for secondary grade releases which may reduce the extent of the hazardous area determined by the point source approach.

CHAPTER 1: Establishes the scope of the Code and defines key terms. It indicates a means of defining flammable fluids for hazardous 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 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 hazardous area classification by use of either the direct example or point source approaches. It describes the hazardous area classification drawing.

CHAPTER 3: Provides examples, with diagrams, which can be used to classify common facilities; distances are valid for the conditions given. However, the chapter also refers to the point source approach in Chapter 5 for variable releases such as tank vents.

CHAPTER 4: Provides guidance for the classification of drilling rigs, both onshore and offshore with the aid of diagrams, although distances are derived with greater reference to the point source approach in Chapter 5.

CHAPTER 5: Describes the point source approach and provides the basis for the hazard radii specified throughout the Code. These are based on the results of dispersion modelling published in IP *Calculations in support of IP15,* 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 *a priori.*

CHAPTER 6: 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 6.1 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 hazardous area classification to each situation is described. Methods of artificial ventilation and the effect of loss of ventilation on the hazardous area classification are discussed.

CHAPTER 7: Gives guidance on selection of electrical equipment according to zone classification, type of protection, temperature class, apparatus group and enclosure ingress protection.

CHAPTER 8: Legislation requires users to carry out a hazardous area classification, to use this as a basis for selecting equipment, and to consider all sources of ignition. This chapter considers the ignition risks associated with non-electrical equipment.

1

INTRODUCTION

1.1 SCOPE

This 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 fixed sources of ignition in those areas. An 'area' in this context is always taken to be three-dimensional. Hazardous 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.

It is intended that the guidance given in this Code is applicable internationally to installations in processing, distribution, production and retail sectors. The application of this 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. Also, it does not address the releases of flammable refrigerated or cryogenic liquids, for which the dispersion characteristics are markedly different from those of fluids at higher temperatures. It can, however, be used for situations where vented boil-off vapour is released at around ambient temperatures. If it is desired to consider hazardous area classification for the liquids themselves, 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 3, published in IP *Calculations in support of IP15*.

General guidance as to the main principles, definitions and explanations of terms relating to hazardous area classification has also been set out internationally by the International Electrotechnical Commission (IEC) and in Europe by the European Committee for Electrotechnical Standardization (CENELEC), 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 Code where appropriate (summarised in Annex I). However, the reader is recommended to use the most up-to-date version of any referenced standard.

1.2 LIMITS OF APPLICABILITY

Hazardous 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 safety spacings between equipment and public boundaries and to other facilities, including sources of ignition, will be found in other IP Codes referenced in Annex I.

Note: If a resulting hazard radius is greater than 30 m then the size of the release is generally larger than that considered for hazardous area classification purposes and consideration should be given to modifying the facility to minimise the size of the release.

1.2.1 Small scale operations

Certain locations handling only small quantities of flammable fluids can, in the context of hazardous area classification, be classified as 'non-hazardous'. This may apply to laboratories for testing small petroleum fluid samples, for example. It is not possible to set a cut-off point as this must be judged according to the circumstances. For instance, the hazards of draining gasoline from a vehicle fuel tank in an enclosed garage space or a below-ground inspection pit necessitate strict avoidance of all sources of ignition and only Zone 1 electrical equipment should be permitted. In such cases due precautions must be taken to prevent ignition possibilities from any type of ignition source (see Chapter 8). In making such a judgement, the risk to an individual should be assessed.

In certain circumstances, ignition of quite small quantities of flammable gas/vapour mixed with air can cause danger to anyone in the immediate vicinity. Where this is the case, as in a relatively confined location from which rapid escape would be difficult, hazardous area classification may be needed down to quite small quantities of fluid.

Each vessel containing flammable fluids should be considered individually, with consideration of the surroundings and where people need to move about. As a rough guide, hazardous area classification may not be needed if the maximum amounts of material that could be released are below the quantities given in Table 1.1.

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

1.3 APPLICATION OF THIS CODE

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

1.3.1 Facility 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 Chapters 3 and 4. These facilities may also be classified using the point source approach, see 1.3.2.

1.3.2 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 is used, referred to as the 'point source approach'. This methodology is presented in Chapter 5. 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 reduce the extent of the hazard radius.

1.3.3 Mists and sprays

Flammable atmospheres may also be formed where flammable fluids handled below their flash points are released in the form of a mist or spray. Such materials, normally regarded as non-hazardous, should be treated as hazardous when they are pumped or under pressure and are capable of producing a mist or spray due to the possibility of a release from a small hole or flange leak. They should be regarded as a category C fluid (see Table 1.2) generating a hazardous area as appropriate.

1.4 FUNDAMENTAL SAFETY PRINCIPLES

1.4.1 Avoidance of fire and explosion

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

As prescribed by IEC (see IEC 60079-10), it is not the aim of hazardous area classification to guard against the ignition of major releases of flammable materials under catastrophic failure of plant, e.g. the rupture of a pressure vessel or pipeline, or the cold failure of a tank which, in properly run facilities, has a very low probability of occurrence. The incidence of such releases must be kept within acceptable limits by correct design, construction, maintenance and operation of facilities.

Table 1.1 Capacity thresholds above which hazardous 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
Outside	1 000 litres	100 litres	200 litres

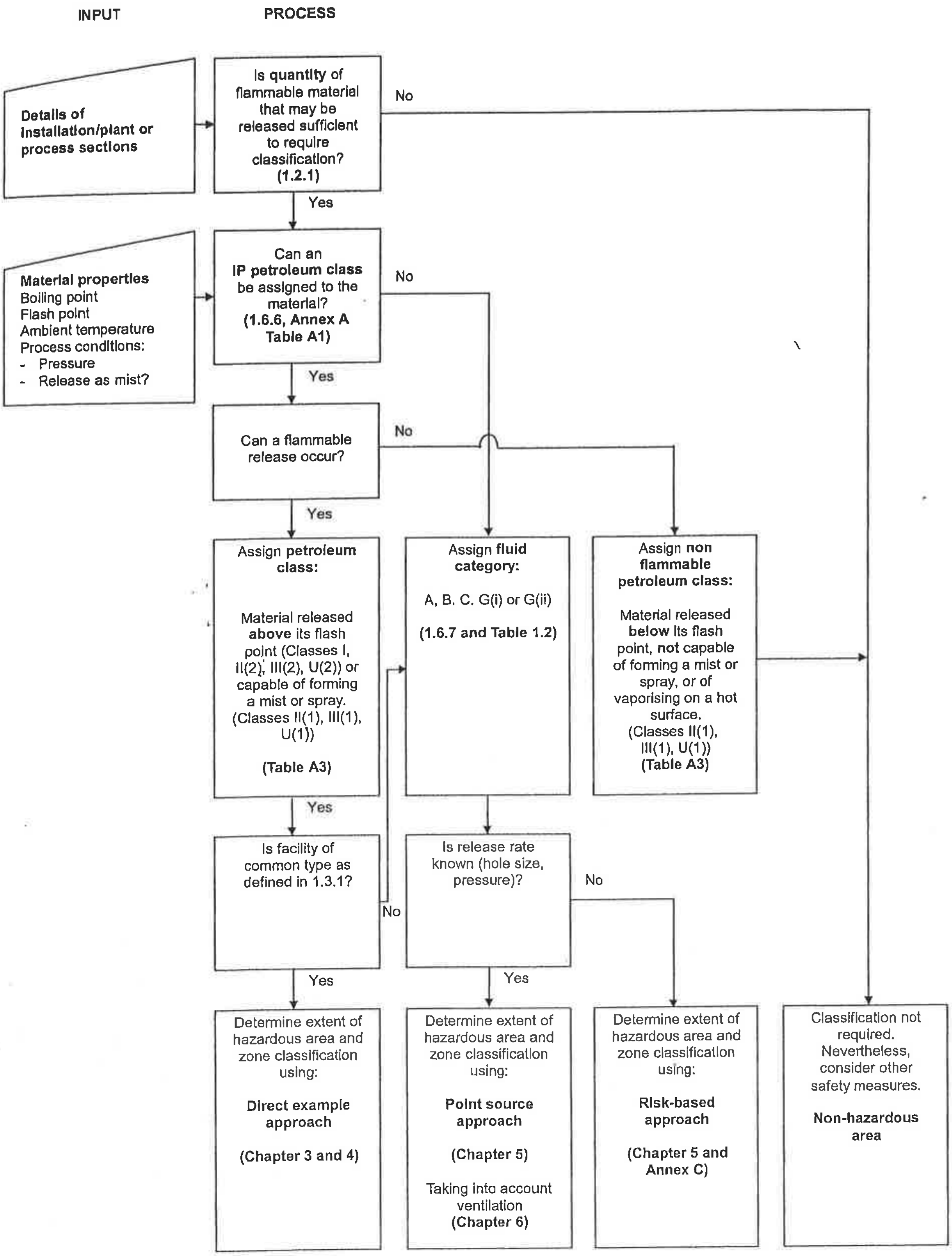


Figure 1.1 Application of Code

1.4.2 Good standard of design and operation

The hazardous area classification technique described here assumes that the facilities to which it is applied are designed, constructed, maintained and operated in accordance with good industry practice so as to reduce releases to a minimum. Equipment and piping should be designed to international standards or national equivalents. The recommendations of the IP publications (Annex I) or their equivalents, regarding good operational and maintenance practice should also be followed.

1.5 HAZARDOUS AREA CLASSIFICATION MANAGEMENT

Hazardous area classification should be incorporated into a company's Health, Safety and Environmental Management System. The person responsible for the co-ordination of the hazardous 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 safety, loss prevention and electrical engineering personnel, as appropriate. Agreements reached on the hazardous area classification should be formally recorded, continually 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 as covered in Chapter 7.

In principle, the classification of an area entails consideration of all the actual sources and potential sources of release of flammable fluid present. In practice, as will be shown in Chapter 2, the procedure can be simplified by adopting a standardised hazardous area classification diagram (Chapters 3 and 4). In other cases, the procedure of considering individual point sources will be necessary and this approach is detailed in Chapter 5.

In classifying a new facility or a modification, the hazardous 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 hazardous 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 hazardous 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 (1999/92/EC). Where a facility has been designed and built on a turnkey basis, the plant designers should have carried out such a study, and should have passed it over with other documentation to the owners at the end of commissioning.

1.6 KEY TERMS

These terms are consistent with the usage and principles in IEC 60079-10. They should be considered equivalent to definitions in ATEX 99/92/EC and in the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).

1.6.1 Flammable atmosphere

A flammable atmosphere is defined as a mixture of flammable gases or vapour with air in such proportion that, without any further admixture, it will burn when ignited.

An explosive atmosphere is a mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapour, mists or dusts, in which, after ignition has occurred, combustion rapidly spreads to the entire unburned mixture.

The term 'flammable' atmosphere is preferable and should be used because the term 'explosive' is a special case of 'flammable' where either congestion or confinement leads to the generation of over-pressure when the cloud is ignited.

1.6.2 Hazardous area classification

Hazardous 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.

1.6.3 Hazardous area and zone classification

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. Examples include petroleum distribution installations (see also section 8.4 and IP *Design, construction and operation* *of distribution installations*) and offshore production installations (see ISO 13702). Areas are subdivided into zones based on the likelihood of occurrence and duration of a flammable atmosphere, as follows:

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.

1.6.4 Source and grade of release

For the purpose of hazardous 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 i.e. a release which, in operating procedures, is not anticipated to occur. Such releases may be of known size e.g. fracture of a drain, or unknown size e.g. corrosion hole.

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 likely to be present for 1 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 1 to 10 hours per year but are anticipated in normal operation (e.g. routine sampling points) they should be regarded as primary grade releases, unless carried out under permit-to-work circumstances.

Details regarding the justification for the lower bound of 1 hour/year are provided in Annex C section C2.5. Even with an operator present at all times, the probability of ignition and the vulnerability likely to occur from an ignited release of flammable materials are such that the target risk within this Code of 1E-5/year is met without further precautions. Note that, as stated in section 1.2, hazard radii of greater than 30 m are outside the range for which normal hazardous area classification techniques can be applied. This should not exclude these events being considered for major hazards studies.

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 typical equipment may be found in Chapters 3 and 4. It should be noted that the respective grades of release, and thereby zonal identification, have already been taken into account.

1.6.5 Relationship between grade of release and zone classification

There is, in most cases, under unrestricted 'open air' conditions 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.

Table 1.2 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.

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. For example, poor ventilation may result in a more stringent zone while, with high ventilation provision, the converse will be true (see Chapter 6). Also 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 section 5.4.4). 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 part of 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.

1.6.6 Classification of petroleum fluids

Where the flammable fluid is a liquid, its volatility is a key property, since it will determine the extent of rapid vapour formation from any release.

In many of the commonly encountered types of facilities, such as those referred to in section 2.4, the classification of the flammable fluid by flash point class, in accordance with the IP classification of petroleum fluids (see Table A1, Annex A), will be adequate for this purpose, with its further subdivision of Classes II and III into sub-classes (1) and (2) according to whether the liquids are handled at temperatures above or below their flash point (see section A1.3). This system is used throughout the direct examples in Chapter 3.

1.6.7 Categorisation of flammable fluids

In other situations, in which greater variations of fluid volatility, temperature and pressure occur under typical processing conditions, the above classification based solely on closed-cup flash points is inadequate and the direct example approach in Chapter 3 cannot be applied. The point source approach in Chapter 5 is then required and, for this, five categories of fluids, supplemental to the classification of petroleum fluids by flash point, have been introduced. These fluid categories are defined in Table 1.2, and their application is described in section 5.3.2.

1.6.8 Special terminology - hazard radius

In addition to the standard terminology used throughout this Code, presentation of many cases of point source release covered in Chapter 5 uses a base parameter designated the 'hazard radius' which is defined as 'the horizontal extent, independent of ground effects, of the hazardous area that is generated by the source when situated in an open area'. This is the distance at which the concentration of flammable vapour in air has fallen to the lower flammable limit.

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.

1.6.9 Other terms

The Glossary at the end of this Code should be consulted for the definitions of other terms.

1.7 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.

The openness of a region is an important factor in determining the effectiveness of ventilation and the extent and severity of a hazardous area. Two boundary cases (open area, enclosed area) and an intermediate case (sheltered or obstructed area) are defined in 1.7.3-1.7.5. These relate to two main types of ventilation, natural in the case of an open area and artificial in the case of an enclosed area, also defined below.

The degree of ventilation (unrestricted, restricted, adequate or inadequate) is a key factor in determining the zone classification of an area.

In enclosed areas, different artificial ventilation options (general or local exhaust, dilution and over-pressure) may be used to provide adequate ventilation.

Chapter 6 provides guidance on how, in conjunction with Chapter 5, ventilation type and adequacy should be assessed. Figure 6.1 provides a summary of the inter-relationship of the type and degree of ventilation.

1.7.1 Natural ventilation

Ventilation caused by wind or convection effects, due to solar or hot equipment. It applies to open and sheltered/obstructed areas. Effective natural ventilation is typically achieved when the wind speed is greater than 0,5 m/s.

1.7.2 Artificial ventilation

Ventilation caused by air purge or by assisted mechanical means (such as fans or extractors) that may be applied generally (throughout the whole of an enclosure), or locally (to deal with a local release or a stagnant region). It applies to enclosed areas only.

1.7.3 Open area

An area that is outdoors without stagnant regions, where vapour is rapidly dispersed by wind and natural convection i.e. by natural ventilation. Typically, air velocities will rarely be less than 0,5 m/s and will frequently be above 2 m/s.

1.7.4 Sheltered or obstructed area

An area within or adjoining an open area (which may include a partially open building or structure) where, owing to obstructions, natural ventilation may be less than in a true open area. For example, below-grade areas such as pits and trenches, areas within tank bunds, and congested plant structures may be subject to restricted ventilation and therefore fall into this category. The extent or severity of the zone classification of the hazardous area may be increased as a result.

Where the obstructions are such that natural ventilation is severely restricted, it should be classified as an enclosed area (see 1.7.5).

1.7.5 Enclosed area

Any building, room or enclosed space e.g. cabinet, within which, in the absence of artificial ventilation, the air movement will be limited and any flammable atmosphere will not be dispersed naturally.

1.8 BUOYANCY OF RELEASE

Previous editions of this and other hazardous area classification codes have made a distinction between heavier-than-air and lighter-than-air gases and vapour in determining the shape profile of a hazardous region in open areas. However, recent work (IP *Calculations in support of IP15*) has shown that, for the majority of releases from pressurised sources, the shape of the hazardous region is not related to the relative density of the fluid. The shapes of these zones depend primarily on the angle of the release and how close the release point is to the ground. 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. Further, 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 areas are sheltered or enclosed, special reference should be made to the conditions in Chapter 6 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 Chapter 3, but these are all where heavier-than-air vapour exists (e.g. open road-tanker fill covers, sumps and pools etc.) If a lighter-than-air gas 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 HAZARDOUS AREA CLASSIFICATION

2.1 INTRODUCTION

The object of the hazardous area classification approach is to reduce, to an acceptable level, 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 electrical equipment is provided in Chapter 7 and in fuller detail by the various parts of IEC 60079 series and EN counterpart publications. **In these documents the term 'explosive' is used as a synonym for 'flammable'.**

As outlined in Chapter 8, this analytical approach is also of value when considering the location and control of non-electrical sources of ignition, such as diesel engines, gas turbine drives, hot surfaces, fired heaters and static discharge.

The hazardous 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 is 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) 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 section 1.6.7 and Annex A, to be determined. These will also be required to determine the apparatus sub-group and temperature class (see 2.5 and Chapter 7).

(c) Where relevant, a piping and instrumentation diagram (for example for processing plant).

(d) A layout drawing with typical plans and elevations showing the position of all equipment, including operational vents and drains to atmosphere. In addition this should show principal sources of ignition such as heaters, roadways with unrestricted access, flares, workshops, hot work areas etc.

(e) Knowledge of the equipment features and the mode of operation.

(f) Consideration of ventilation, whether open area, restricted (sheltered) or enclosed (see Chapter 6). For sheltered or enclosed situations 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.

(g) Identify material (e.g. diesel) and process conditions (temperature and pressure).

It is then necessary using the procedures that follow to determine the resulting Zone 0 and Zone 1 hazardous areas and the secondary grade releases which define the Zone 2 boundaries, together with the extent of these areas.

2.3 APPLICATION

In carrying out such an assessment, by either the direct example approach (2.4.1) or point source approach (2.4.2), the following basic principles should be considered:

(a) When classifying a new facility or modifying an existing one, the hazardous area classification should be carried out **before** the design and layout of equipment are finalised, as at this stage it may be possible to make considerable improvements at little cost and even some saving. The hazardous 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. 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.

(b) Where facilities such as storage, pumps or loading and discharge facilities, handle a number of materials, the classification should be based on the most volatile anticipated.

(c) Given the imprecision inherent in hazardous area classification it is not 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. Likewise, it is normally nct necessary to determine the hazardous area that would arise from each individual source of release when this would not influence the overall zone boundary.

(d) The basic guidance set out in Chapters 3, 4 and 5, 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 where such conditions may apply offshore.

(e) 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 6.

A good principle 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 hazardous 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.

(f) 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 section 6.2.3). 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 section 6.5).

(g) The relevance of the risk-based approach when the release rate is unknown (see 2.4.3).

2.4 HAZARDOUS AREA CLASSIFICATION APPROACHES

This Code presents three complementary methodologies to be used in hazardous area classification. These are: the direct example approach, which is limited to common facilities, the point source approach, where release rates are dependent on process conditions, and the risk-based approach. The point source approach can be used for all situations; the risk-based approach is an optional methodology for secondary grade releases which may reduce the extent of the hazardous area determined by the point source approach. Figure 1.1 illustrates how to select the appropriate approach to be used.

2.4.1 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, filling station forecourts. Typical classification should follow the approach in 2.2. Direct examples for these arrangements are presented in Chapters 3 and 4. 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 Chapters 3 and 4, but not shown in the diagrammatic examples, should be assessed according to the point source approach, see 2.4.2.

2.4.2 Point source approach

For installations or processes where the standard conditions assumed for the direct examples in Chapters 3 and 4 do not apply (due to variabilities of temperature, pressure, equipment and the degree and type of ventilation) the extent of vaporisation that would take place on release 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 5.

2.4.3 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 section 1.6.4, 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.

2.5 APPARATUS SUB-GROUP AND TEMPERATURE CLASS

To select electrical equipment appropriate to the zone classification, the apparatus sub-group and temperature class should be determined during the hazardous area classification, based on the flammable substances that can be released, and this information added to the drawing and/or records. Further guidance given in Chapter 7 should be followed.

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. See also Annex F, section F2 for situations where internal release within apparatus may occur.

The apparatus sub-group and temperature class appropriate to flammable fluids are listed in Table 7.2. When a release is a mixture of substances, the most restrictive apparatus sub-group and temperature class should be specified. If gases belonging to more than one electrical apparatus sub-group and temperature 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 IIC and Tl (see Table 7.2). See Annex B for a discussion of hydrogen-containing releases.

2.6 THE HAZARDOUS AREA CLASSIFICATION DRAWING

Hazardous area classification records can comprise detailed drawings with notes and/or can be in the form of tabulations. The hazardous 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, 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 hazardous 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.

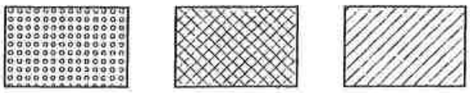


Figure 2.1 Hazardous area classification shading convention

The drawings and/or notes should indicate where the classification depends on the correct operation of a special ventilation arrangement. It should consider and indicate the effect of failure of such an arrangement (see sections 6.5 and 6.6).

The preparation of the hazardous 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, for 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.
- Reclassification as a result of measurements in and around hazardous areas.

3

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

3.1 SCOPE

The procedure in this chapter is for classification of those industry operations that are carried out in an open area in facilities so similar in layout and the material handled that they can be classified directly from typical examples. For facilities in sheltered or enclosed areas guidance is given in Chapter 6.

The diagrams in this section are based largely on experience but the distances given have been shown to be broadly consistent with those derived from more analytical studies covered in Chapter 5. 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 if justified by specific release and dispersion calculations. **Whilst every effort has been made to keep hazard radii in proportion it should be noted that the figures are NOT drawn to scale.**

Examples include:

(a) Floating roof and fixed cone or dome roof type tanks (including those which have an internal floating cover), buried or mounded tanks and filling station tankage.
(b) Road and rail loading and discharge facilities.
(c) Marine loading and discharge facilities.
(d) Drum filling.
(e) Retail dispensing on filling station forecourts.
(f) Tankage for high volatility/vapour pressure stocks, e.g. Class 0 (LPG), requiring pressure storage.

The following sections give guidance on the hazardous area classification applicable to such typical facilities. When using this approach, the site being assessed must not differ appreciably from the example in layout, equipment size or degree of ventilation. Where there are differences they should be accounted for by considering the individual sources of release and superimposing on the standard drawing as applicable.

3.1.1 Classification of an 'open area'

This is the fully open-air situation without stagnant areas where, through natural ventilation, vapour is readily dispersed by wind. This is recognised by the IEC as typical in the chemical and petroleum industries onshore where most crude oil and gas processing, refining, storage and distribution plants are open-type structures. Typical air velocities found onshore under these conditions are rarely less than 0,5 m/s and are frequently above 2 m/s.

For this reason, except where otherwise qualified as in the roofed area of loading facilities or in enclosed or partially enclosed noise-proofed or weather-proofed drilling rigs or mud tank systems, the direct examples given in Chapters 3 and 4 are based upon such open area conditions.

3.1.1.1 Abnormal topographical or meteorological limitations

In all the assessments outlined above the degree of openness of the surrounding topography of the site should also be considered, to ensure that there are no major unevenness or hollows where heavier-than-air vapour might collect, nor sloping ground down which such vapour might flow to lower levels of the installation.

Where severe limitations of topographical or meteorological features occur, in what would otherwise be an open area (or in sheltered areas, section 6.3), general artificial ventilation may be applied by the provision of suitably located fans to improve the general ventilation of the area.

3.1.2 Class of flammable fluid

With the exception of (f) in 3.1 above, the products associated with these direct examples will be those classified as Class I, II or III petroleum or fluid category C, and the guidance of Annex A should be applied. This includes the distinction between Classes II(1), II(2), III(1) and III(2).

3.1.3 Climate variations

For the purposes of this Code, a maximum ambient temperature of 30°C has been assumed. The hazard 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 chapter. 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 5 should be followed.

The division between the Class II and III subdivisions (l) and (2) will also depend upon ambient temperature and, in areas outside the United Kingdom, it will be necessary to determine the maximum ambient temperature levels and the influence they may have on handling temperatures. It should be noted that in Annex A there is also an upper limit to the temperature at which the Class II(2) or III(2) condition should be applied, namely the temperature at which the liquid would attain the boiling condition (above which the liquid should be regarded as a category B or A fluid). These temperature limits are unlikely to be encountered during any of the handling operations involved in storage, loading, discharge, etc., that are dealt with in this chapter.

3.1.4 Unclassified flammable fluids

Flammable fluids falling into the 'Unclassified' Class, i.e. flash point >100°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.

However, when unclassified products such as bitumens and heavy residual and bunker fuels are 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. Reference may also be made to the IP *Bitumen safety code*.

3.2 STORAGE TANKS

The following direct examples apply to tankage as defined in 3.l(a). 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 (see 3.1.2).

As indicated in Chapter 2, Table A3 and A1.3, liquids that are stored under Class II(1) or III(1) conditions will not normally require external hazardous area classification.

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

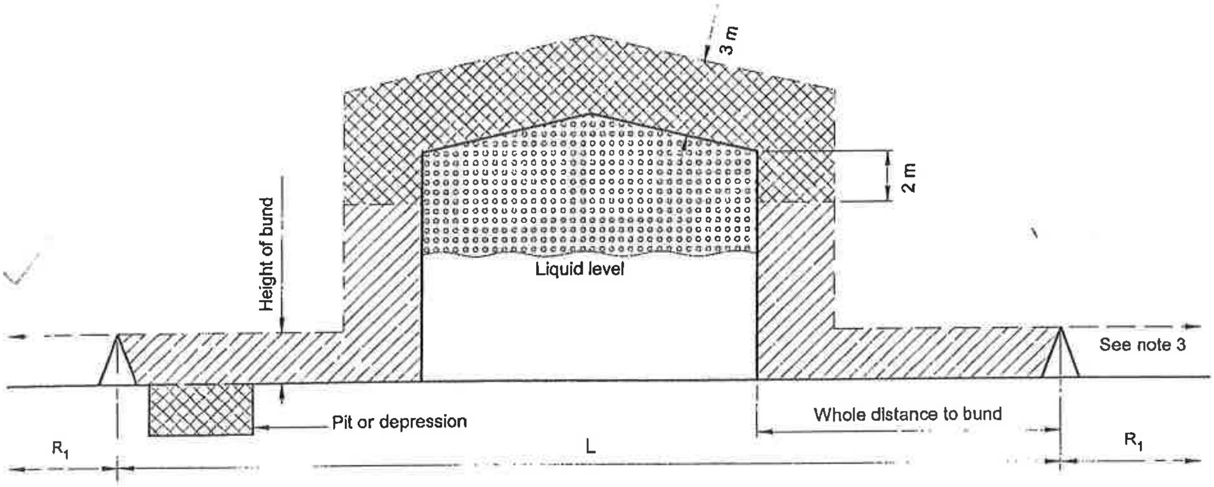
The zoning in 3.2.1 and 3.2.2 will normally be adequate for the fittings on the tank shell, but it should be confirmed that there is no equipment or release within the tank bund which would extend the hazardous area. If this cannot be confirmed, Chapter 5 should be applied.

3.2.1 Fixed roof tankage - Classes I, II(2) and III(2)

For fixed (cone or dome) roof tanks the ullage space should be classified as Zone 0 (see Figure 3.1 (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.

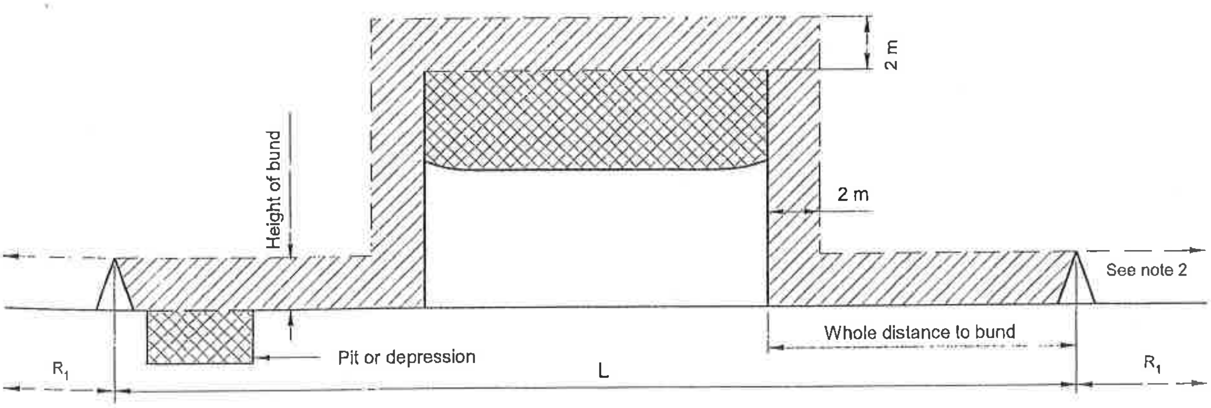
The area within the tank bund up to a height equal to the top of the bund or up to 1 m, whichever is the greater, should be classified as Zone 2, and any pits or depressions Zone 1, because of the greater tendency of heavier-than-air vapour to persist.



Notes:

1. Due to the possibility of mist, spray formation, the ullage space of Class II(1) and III(1) tanks should also be regarded 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 section 5.4.4.2 at the vent tip.
2. See 3.1.4 for heated residual fuel and bitumen tanks.
3. In the event of a large loss of containment which fills the bund, the hazardous area would extend beyond the bund wall. See Table 5.7. Any sources of ignition located close to the bund wall should be isolated in this event.

Figure 3.1(a) Bunded tanks - cone or dome



Notes:

1. This classification is based on the practice that the roof will not be grounded on its legs during the operational cycle, since the spare space so created below the roof would draw in air and create the possibility of ignition caused by friction. Roofs should only be landed for inspection, cleaning and maintenance under carefully supervised work permit control. Any vapour space below the roof or between the primary and secondary seals should be treated as Zone 0.
2. See note 3 of Figure 3.1(a).

Figure 3.1(b) Bunded tanks - floating roof

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 3.1(a). If the bund wall is less than 3 m from the tank shell, it may be desirable to adjust the zoned distance accordingly. These hazard distances apply to filling rates of up to 250 m^3/h.

Additional information and for filling rates greater than 250 m^3/h can be found in section 5.4.4.2.

3.2.2 Floating roof tankage - Classes I, II(2) and III(2)

The hazardous area classification around a floating roof tank should be drawn as in Figure 3.1(b). 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.

3.2.3 Tankage with outer containment

On any fixed or floating roof tanks with in-built outer containment, the annular space between should be classified as Zone 1, whatever Class of fluid is stored. The remaining area around the containment should be classified in accordance with 3.2.1 or 3.2.2. See Figure 3.2.

3.2.4 Underground tanks

Underground tanks are normally located at filling stations, or small industrial or domestic premises. Their classification is covered in 3.4 and in Figure 3.13 for the tank manhole 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 6, after considering the effect of any artificial ventilation system.

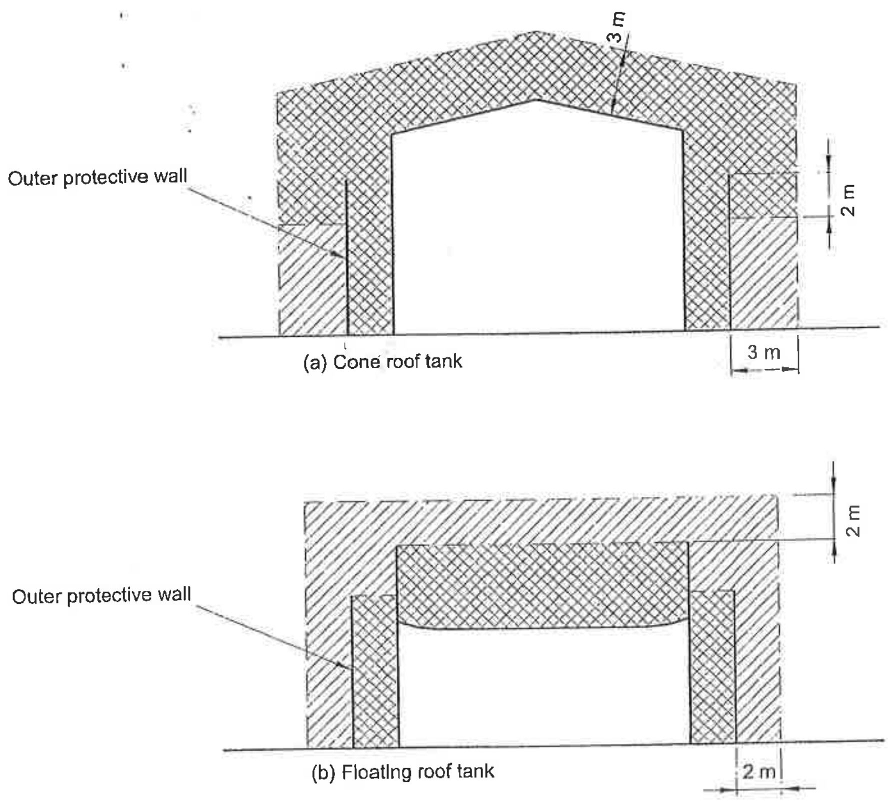


Figure 3.2 Tanks with outer protective wall

3.2.5 Bulk pressurised LPG installations (Class 0)

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 manhole covers, should have a nominal 3 m radius Zone 2 hazardous area. Note, where a soft seat relief valve is used, the Zone 2 hazard radius may be reduced to 0,5 m.

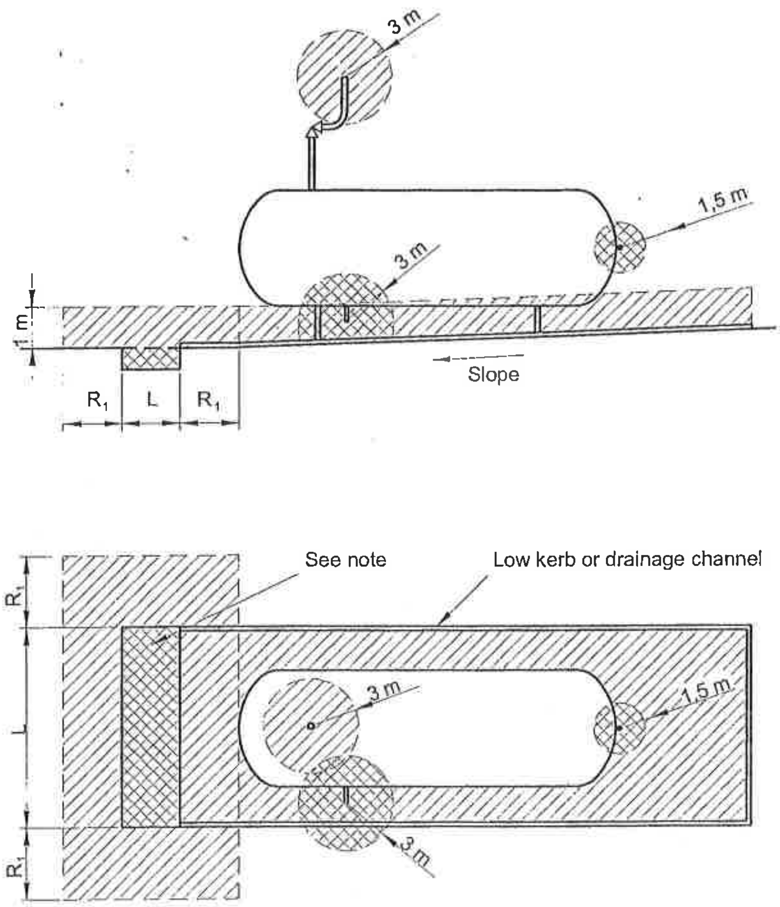
Any spill catchment area provided to retain liquid LPG spillages should be classified as shown in Figure 3.3 and in accordance with section 5.4.7. This transient spill area is classified as Zone 2.

Any ancillary equipment associated with the storage area, e.g. pump sets, should carry 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 Chapter 5 of this Code.

Diagrammatic representation of the above is shown in Figure 3.3. Classification of buried/mounded LPG storage is covered in 3.4.3.2.

3.2.6 Vent stacks

High level vents e.g. from underground or mounded tankage 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), in accordance with section 5.4.4.



Note: see section 5.4.7

Figure 3.3 LPG storage facilities (Class 0)

3.3 ROAD TANKER LOADING

3.3.1 Introduction

This section covers both bottom and top loading of petroleum Classes I, II, III and similar flammable fluids in the normal case where such facilities are located in an open area, under conditions defined in 3.1.1. Class 0 (i.e. LPG-type materials) loading should be classified by referring to 3.3.6.

It should be noted that under normal ambient conditions, materials below their flash points such as kerosine and gas oil, i.e. Classes II(1) and III(1), may give rise to hazardous areas around equipment in which they are handled under pressure, due to the possibility of mist or spray formation on release. Also, if these materials are loaded into a vehicle compartment which has previously contained a high vapour pressure product such as gasoline, i.e. switch-loaded, they may displace any flammable atmosphere that remains in the vapour space. In such cases the loading facility should be classified as in 3.3.3 for a Class I, II(2) or III(2) product. However, switch-loading of cargoes should be avoided wherever possible.

3.3.2 Open air facilities with weather roofing

As depicted in the direct examples that follow, loading facilities should normally be located in the open air (see IP *Design, construction and operation of 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 3.4. 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.

3.3.3 Loading of Classes I, II and III

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

(1) The loading island and bay area with no vehicle present.
(2) The loading island and bay area with vehicle present, including during filling.
(3) Any spillage of flammable materials.

The direct examples in this chapter are only valid providing the design of road tankers is in accordance with relevant national and international statutory requirements (guidance is given in IP *Petroleum road tanker design and construction*), and suitable safety and operating procedures are followed (see IP *Design, construction and operation of distribution installations)*. Unless these conditions 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 unsafe. 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 unsafe. It should be noted that certain hazardous areas are transient and only exist whilst loading is being carried out.

3.3.4 Bottom loading of Classes I, II and III

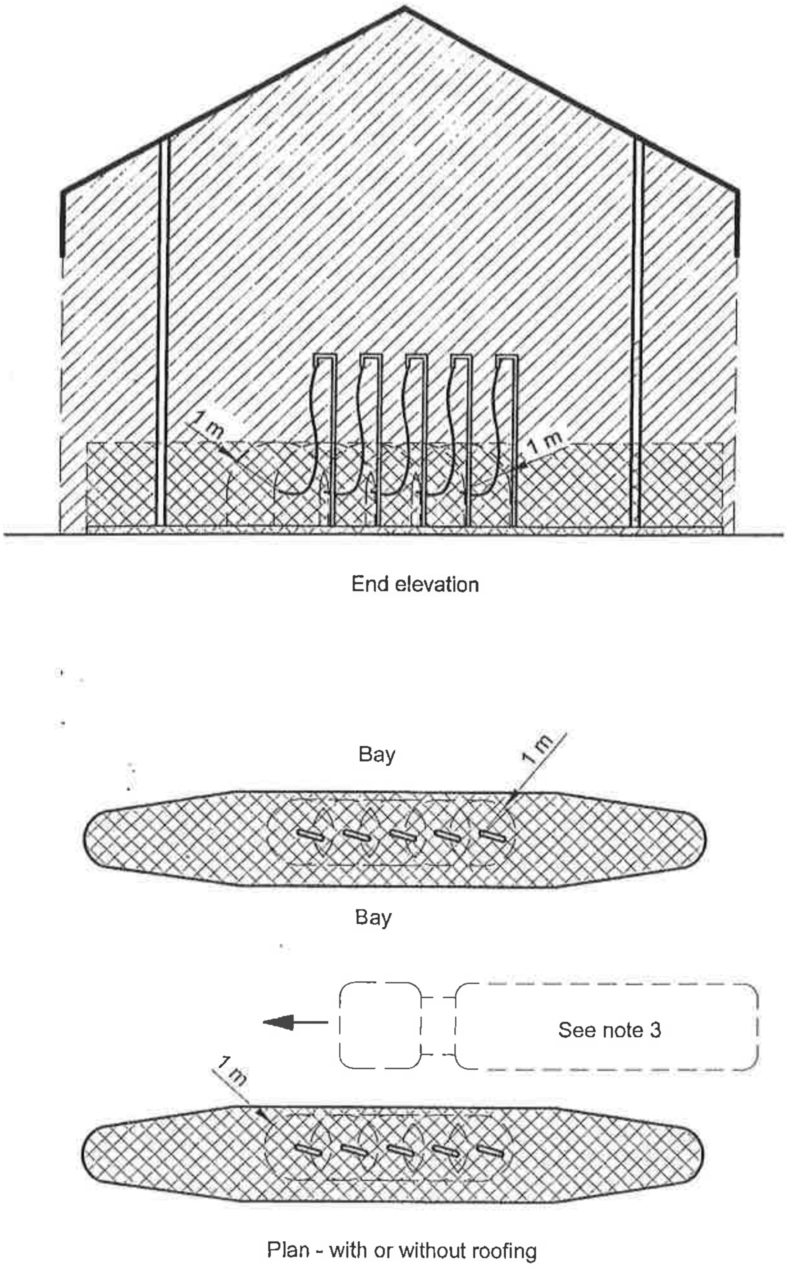
The hazardous areas around all possible sources of release which could arise from the installed loading equipment and slop facilities, in the absence of a tank vehicle, should be assessed and a practical envelope devised. This should include hazardous areas arising from routine operations such as filter 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 fill covers are closed and the loading arms have been returned to the parked position. Spillages arising during tank vehicle filling should, however, be considered.

Following the steps in 3.3.3 the analysis should be carried out in stages as follows:

3.3.4.1 Classification of loading island and bay area - no vehicle present

For the purposes of this guidance, 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 3.4.



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.

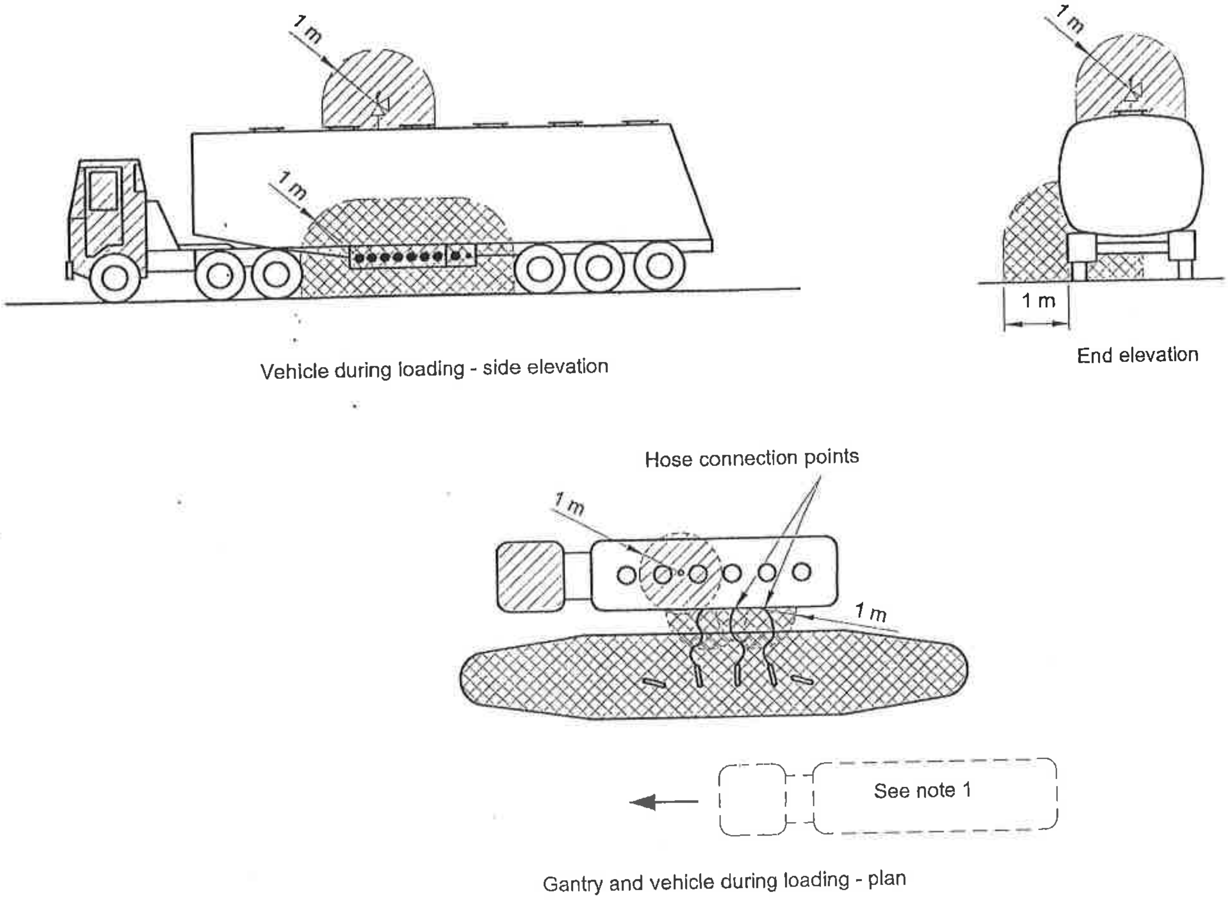
Figure 3.4 Bottom loading island, no vehicle present

3.3.4.2 Classification of loading island and bay area during loading - vehicle present

The vehicle cab should always be treated as a Zone 2 within the Zone 2 classified area in accordance with IP *Petroleum road tanker design and construction.*

Vapour is piped from the collection manifold on the vehicle top to a low-level connection on the loading island, through a self-sealing coupling. From this connection, the vapour is routed to a vapour collection unit or, when this is not provided, to a vent direct to atmosphere (see 3.3.4.6). There is, therefore, no free venting in the loading area from compartment fill covers. 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 3.5). This distance assumes that the self-sealing couplings normally used for bottom loading limit the normal release on disconnection to less than 10 ml.

Since there is no free venting, 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 IP *Petroleum road tanker design and construction* requires the design of the overfill prevention system to 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 3.5.



Notes:
1. Empty bay with no spillage present is in safe condition for vehicle entry/departure, with vents and all connections closed.
2. When bottom loading tankers are being filled with open fill covers, the hazardous area due to vapour emission from vents during loading at a filling rate of 2,5 m^3/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.
3. The ullage space in the tank should be classified as Zone 0.

Figure 3.5 Road tanker equipped for bottom loading with vapour collection, during loading

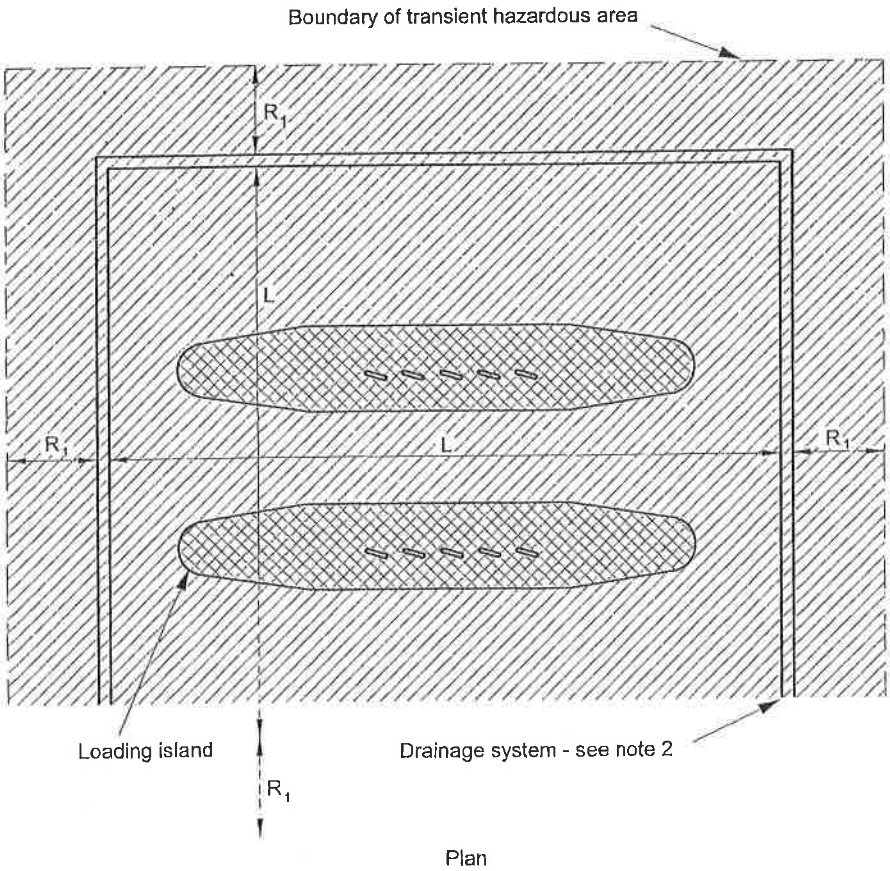
3.3.4.3 *Provision for spillage*

In addition to the aggregated Zone 1 areas of Figures 3.4 and 3.5 during the loading operation, transient Zone 2 hazardous areas apply where spillages of Class I, II(2) or III(2) materials could occur.

Spillages in the loading area should be considered 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 vehicle 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 vehicle 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.

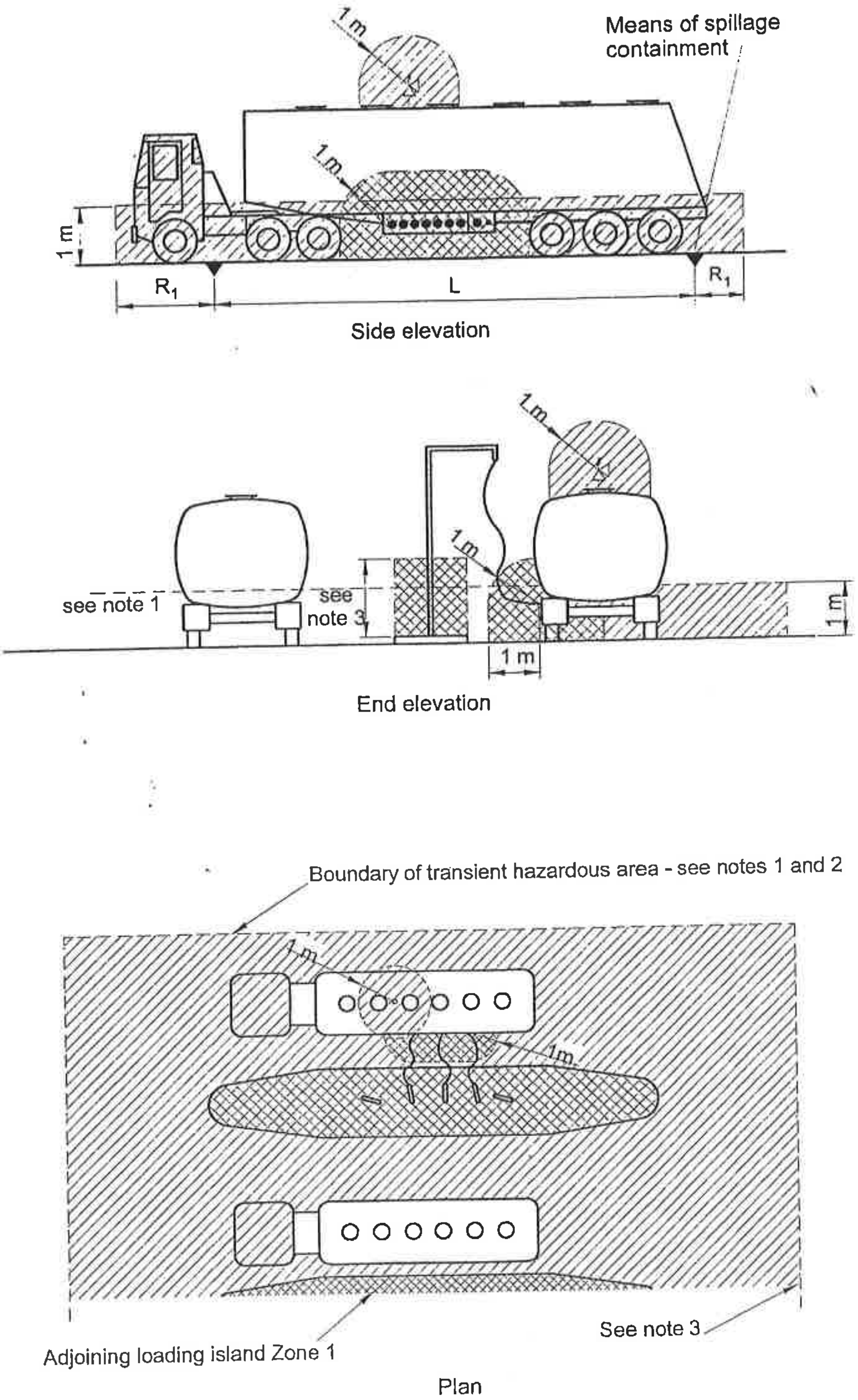
The spillage is assumed to be of a category C fluid and the size of the hazardous area (Zone 2) from these secondary grade release sources is based on the means of spillage containment as recommended in section 5.4.7. The height of the Zone 2 area should therefore be 1 m. Where there is a drainage channel, 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 3.6 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 section 5.4.7.
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 above 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 3.6 Area classification in event of spillage



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 3.3.4.5).
3. For height of Zone 1 area see 3.3.4.1.

Figure 3.7 Composite area classification drawing for bottom loading road tanker during loading in the event of a spillage

3.3.4.4 The composite classification drawing
From the detailed analysis carried out above it is possible to assemble a composite of Figures 3.4 to 3.6, resulting in a final drawing illustrated in Figure 3.7.

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. This is ensured by adherence to the operational controls prescribed in IP *Design, construction and operation of distribution installations*.

3.3.4.5 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 3.4).

3.3.4.6 Safe disposal of vented vapour
Where the vapour emitted from vehicle loading is routed to a vapour collection system, the latter will be distant from the loading areas. With the collection system in operation, any emissions should be lean in hydrocarbon levels. However, to allow for process malfunction the vent should be regarded as a secondary grade source of release, and its hazardous area should be assessed in accordance with section 5.4.4.

Where a vapour collection system is not provided, facilities should be available to enable the road tanker's vapour collection 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 (IP *Petroleum road tanker design and construction)*. The hazardous area from such a vent should be assessed in accordance with section 5.4.4. Given the frequency of most loading operations, the classification should be Zone 1.

3.3.5 Top loading of road tankers - Classes I, II and III

A detailed analysis, analogous to that of 3.3.4 for bottom loading, should be carried out to produce a composite classification diagram.

As in 3.3.4, 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 filled 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 3.3.3 the analysis should be carried out in stages as follows:

3.3.5.1 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 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. If detachment is via a 'dry-break' coupling, a typical release of up to 10 ml may result and the nominal hazard radius may be reduced to 1 m for a closed system. 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 3.8.

3.3.5.2 Classification of loading island and bay area during loading - vehicle present
When all the tank compartments of a vehicle are closed, the unoccupied space of an empty bay between the Zone 1 areas of adjacent loading islands permits the safe 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, or filling connections are made or disconnected.

Whilst the hazardous area due to vapour emission from vents during loading at a filling rate of 2,5 m^3/min extends in all directions to less than 1 m for Class I petroleum, it has been shown as 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 to be assumed is shown in Figure 3.9.

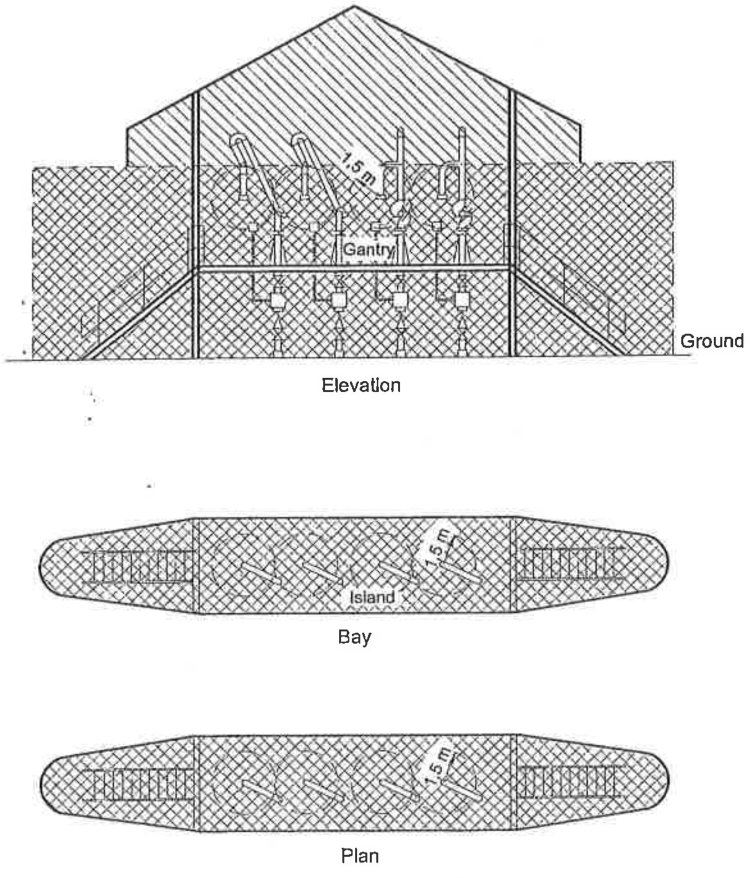
3.3.5.3 Provision for spillage

This will apply only for Class I, II(2) and III(2) materials. See 3.3.4.3 and Figure 3.10.

3.3.5.4 The composite classification drawing

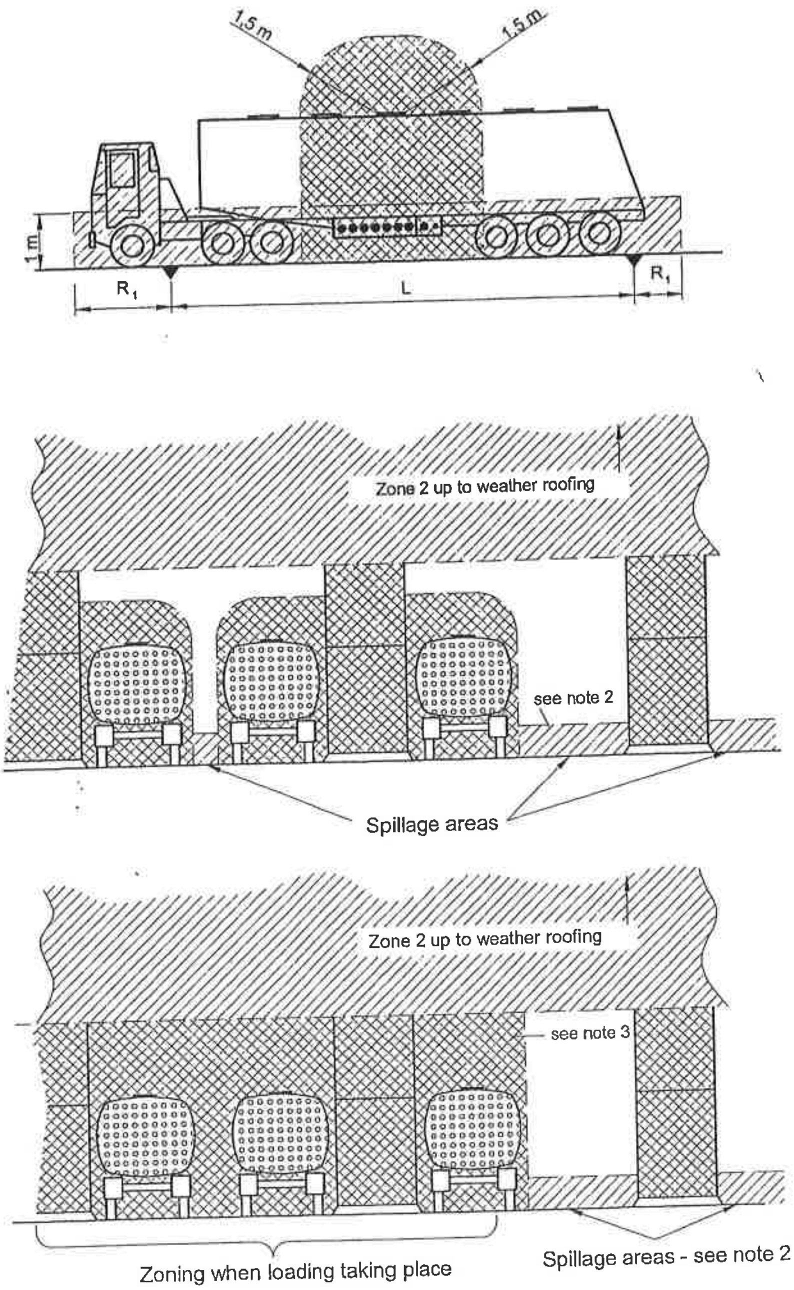
From the detailed analysis carried out above it is then possible to assemble a composite of Figures 3.8 to 3.10, resulting in the final drawing illustrated in Figure 3.11.

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. This is ensured by adherence to the operational controls prescribed in IP *Design, construction and operation of distribution installations.*



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.

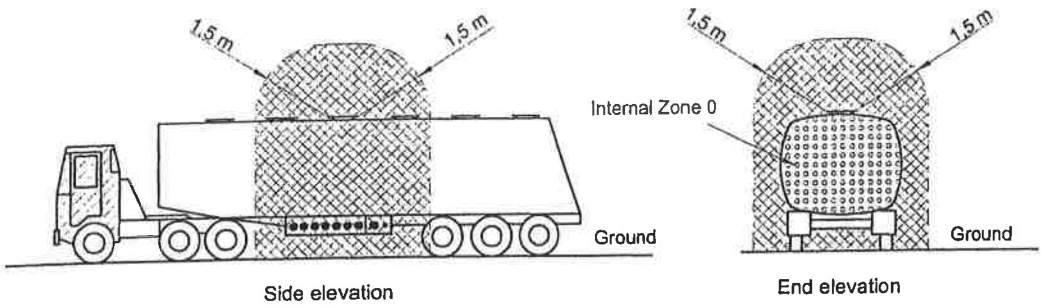
Figure 3.8 Top loading island and bay area - no vehicle present



Simple aggregation of Figures 3.8, 3.9 and 3.10. For treatment of unoccupied bay on right hand side in condition to receive a road tanker, see note 2.

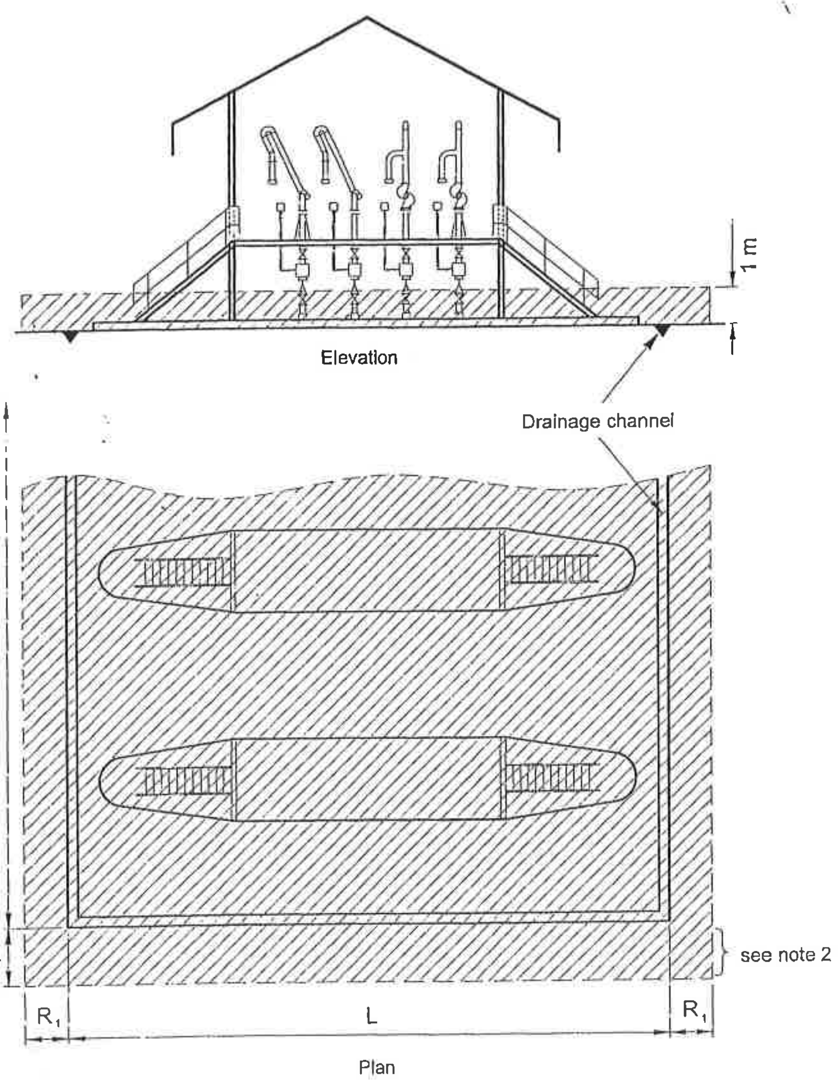
Notes:
1. If weather roofing is provided, all space above the Zone 1 area will be Zone 2 up to the roof.
2. Transient hazardous areas normally free from flammable hazard when no spillage present, or for Class II(1) and III(1) materials.
3. Areas filled-in, as shown.

Figure 3.11 Composite area classification drawing for top loading road tankers during loading, in the event of a spillage - Classes I, II and III



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

Figure 3.9 Top loading of road tanker through open or vent fill covers



Notes:

1. For determination of the Zone 2 hazardous area resulting from spillage, for Class I, II(2) and III(2) materials, see 3.3.4.3 and section 5.4.7.
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 above is not necessarily the same dimension in both directions.

Figure 3.10 Typical Zone 2 provision for spillage area with drainage

frequency that this is likely to occur, this may be considered to have a Zone 2 hazardous area of 1 m radius.

In the event of manual measurement of the road 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 can be reduced to 1 m.

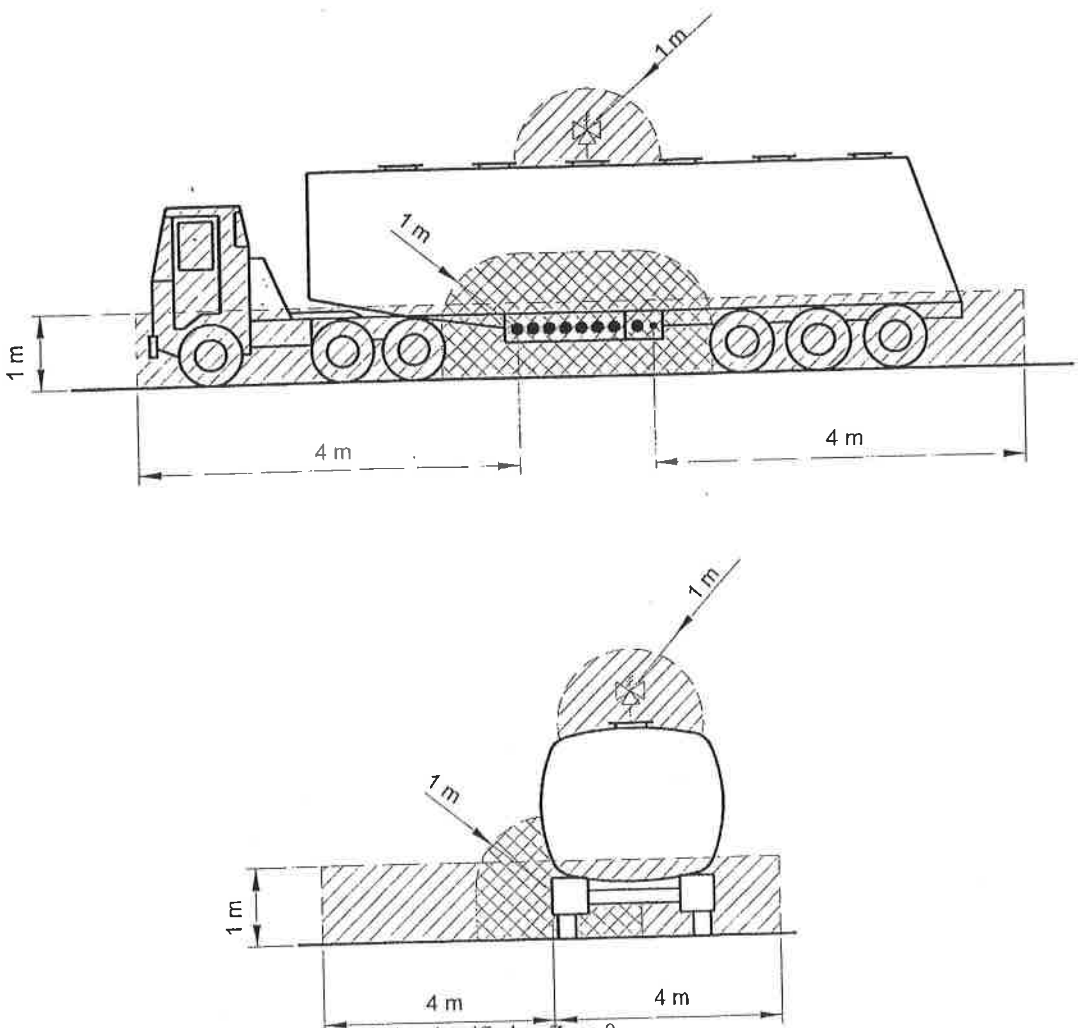
Note that for substances handled below their flash points such as diesel, the generation of hazardous areas by the formation of mists or sprays from leaks is unlikely, so with these substances, the above areas may be treated as non-hazardous.

3.4.2.3 Underground storage tanks and fill points

Removal of the sealing cap from the tank fill pipe 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 vehicle 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.



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

Figure 3.12 Typical hazardous area classification of a road tanker during unloading

3.3.6 Loading of Class 0 i.e. LPG and similar materials

Hazardous area classification around an LPG tanker during loading should be carried out in accordance with 3.4.3.1, Figure 3.15 with the exception that loading from bulk storage will be carried out using an external pump connected to the road tanker via flexible hoses 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 (Table C9a). 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 shown in Figure 3.15.

3.4 ROAD TANKER UNLOADING

3.4.1 General

This section covers the unloading of all flammable fluids. Under ambient conditions, materials handled below their flash points, such as diesel, may give rise to hazardous areas around equipment in which they are handled under pressure, due to the possibility of mist or spray formation. At filling stations, members of the public should be kept outside the classified area during tanker unloading; warning signs and/or barriers may be needed for this purpose.

3.4.2 Unloading of gasoline - Classes I, II, III and similar flammable fluids

3.4.2.1 Entry and departure of road tankers

The area may be considered safe for entry and exit of tankers as long as fill point sealing caps are in position, the manhole 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 in accordance with section 5.4.7.

3.4.2.2 Connection, unloading and disconnection of delivery hoses for flammable materials

The hazardous areas shown in Figure 3.12 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.

The releases outlined below 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 vehicle bottom loading adaptor, 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, as shown in Figure 3.12:

- 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.

Where vapour collection between the unloading tanker and storage tank is used, external breathing of the road tanker should not occur. However, under certain conditions e.g. leaving the vehicle standing boxed-in under strong sunlight, this could cause the tanker to emit vapour through its P/V breather vent. At the

The above sources of release will give rise to the following hazardous areas, shown in Figure 3.13:

— Zone 0 within the tank itself and within any manhole 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 manhole, the radius should be extended from the edge of the sump as shown in Figures 3.13(a) and (b). Note, 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 m [1] 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 3.13(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.

Note that for diesel fuels, under these low pressure conditions the generation of hazardous regions by the formation of mists or sprays from leaks is unlikely, so the hazardous areas shown around the fill points and in the pits or manholes would not apply. The delivery point area may also be treated as non-hazardous. The Zone 0 regions shown inside the tanks should, however, be retained. 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, diesel fill points should be classified as if they contain gasoline.

3.4.2.4 Vapour connection point

Pressure build-up in the vapour collection system can by-pass the poppet valve and cause small releases of vapour when the dust 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.

3.4.2.5 Unloading to above ground storage tanks

A different situation to that in 3.4.2.3 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 hazardous area classification is determined by the location of the unloading point and whether the pump is provided on the vehicle or at the installation.

(i) 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 hazardous area classification should be prepared for the coupling points and hose draining as above. There will be an additional Zone 2 around the pump, the radius of which will depend on the type of pump installed: for a pump of a high integrity type this will be 4 m. Further guidance on the hazardous area classification of pumps may be found in section 5.4.1. Entry and departure of the vehicle should be controlled by specific site procedures.

(ii) 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) hazardous area classification will be necessary, for both gasoline and diesel (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. However, again, if the pump is of a high integrity type it will be 4 m [2]. For the hazardous area around any coupling point, see Figure 3.12.

3.4.2.6 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 collection is not practised for any reason. Failure to observe this precaution will lead to the discharge of flammable vapour at low level, bypassing the normal tank vent outlets.

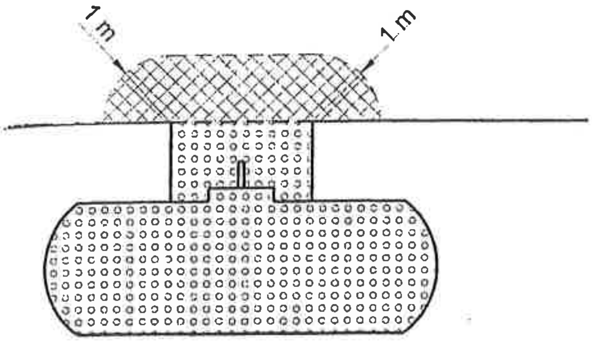
Hazardous area classification around vents from underground storage tanks will depend on whether there is a vapour collection system in place or whether tanks are vented directly to atmosphere.

Systems with vapour collection fitted will give rise

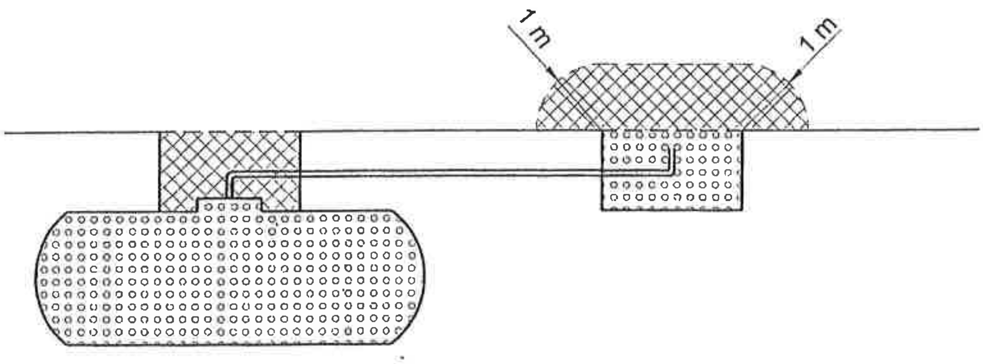
[1] Radius of 4 m is suitable for spills of up to 2,5 litres on unrestricted level surfaces.

[2] Valid for a high integrity pump with an outlet pressure of up to 5 bar(a).

(a) Fill point/vapour connection in manhole



(b) Offset fill point/vapour connection in manhole



(c) Above ground offset fill point and vapour connection

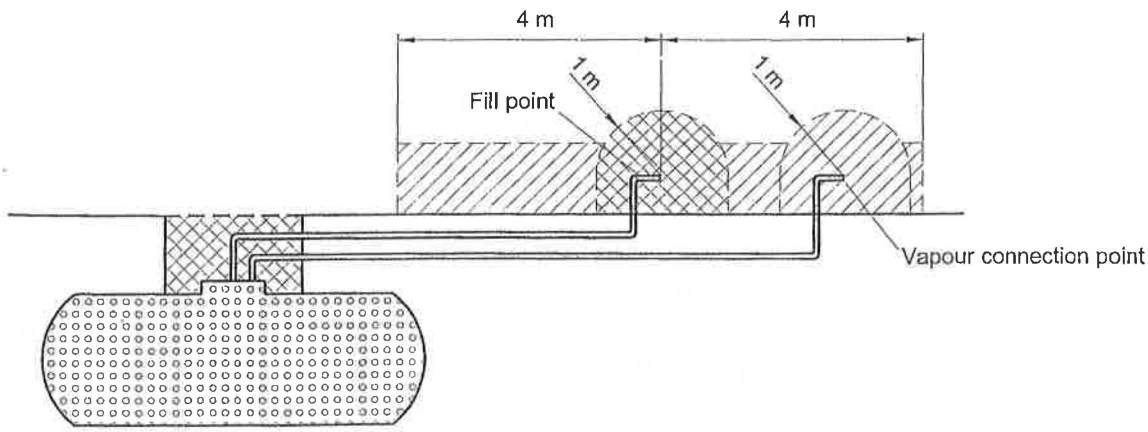
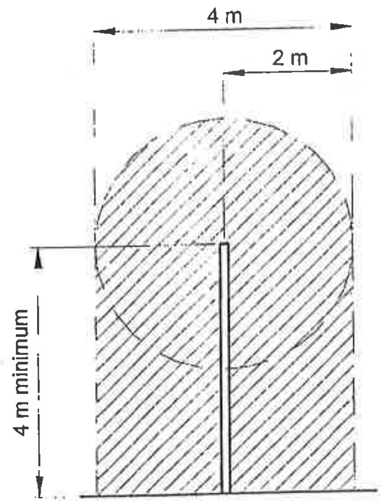
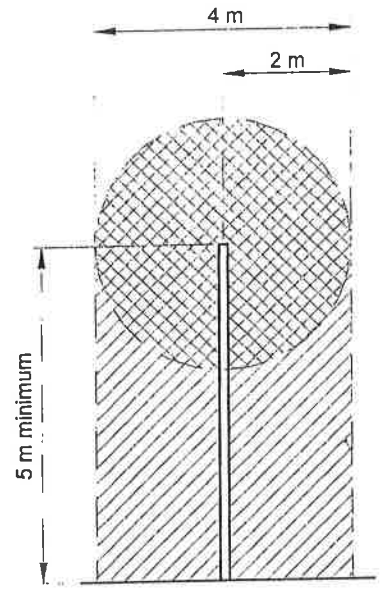


Figure 3.13 Typical hazardous area classification for underground gasoline storage tanks and fill points during road tanker connection, unloading and disconnection



(a) With vapour collection



(b) Without vapour collection

Figure 3.14 Typical hazardous area classification around a storage tank vent pipe

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 3.14.

Note, the above hazard radii are applicable for all vent pipes up to 80 mm in diameter and tanker unloading rates up to 250 000 litres/hr. For larger vent pipes and faster filling rates, see section 5.4.4.

3.4.3 Unloading of Class 0 i.e. LPG and similar flammable fluids [3]

3.4.3.1 Road tanker classification

Road tankers delivering LPG should be assessed for hazardous area classification in accordance with Figure 3.15 together with the provisions of safe entry of vehicles covered in 3.4.2.1 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 tank but without the need for vapour collection 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 of radius 4 m around the pump. In cases where an external pump is used for delivery, a 1,5 m 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 section 5.4.1.

Road tankers fitted with relief valves having a soft seat will give rise to a Zone 2 hazardous area of radius 0,5 m. For other types of relief valve, this radius should be increased to 2,5 m.

An ullage level indicator is shown with a Zone 1 hazardous area of radius 1,5 m. However, it is anticipated that this will not be used during the unloading operation.

3.4.3.2 Unloading to underground storage tanks

LPG storage is typically in buried storage tanks as shown in Figure 3.16(a) and (b). Buried storage tanks will have tank 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

[3] Hazard radii due to small losses have been derived using *Aeroplume* dispersion model, in conjunction with LP Gas Association.

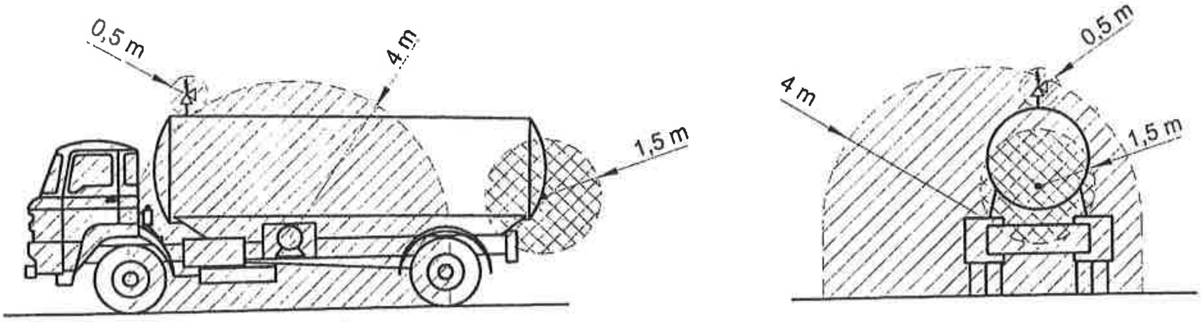


Figure 3.15 Typical composite hazardous area classification around an LPG road tanker during unloading

hazardous area of 1,5 m above ground around 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 m [4] radius, see Figure 3.16(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, 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.

The ullage space within the tank should be classified as Zone 0 unless the storage facilities are purged with nitrogen prior to filling and emptying to ensure the tank ullage never contains a flammable atmosphere due to air. In this case, the ullage space may be considered as non-hazardous.

Unless there are 10 or more flanges all within a 2 m radius, a hazardous area need not be assigned to a single flange. However, where it is necessary to classify flanges they should each have a Zone 2 hazardous area of 2 m radius.

3.4.3.3 Unloading to above ground storage tanks
Where the tanker is unloaded to above ground storage tanks, these should be classified in accordance with 3.2.5.

3.5 RAIL CAR LOADING AND UNLOADING - CLASSES I, II AND III

3.5.1 General

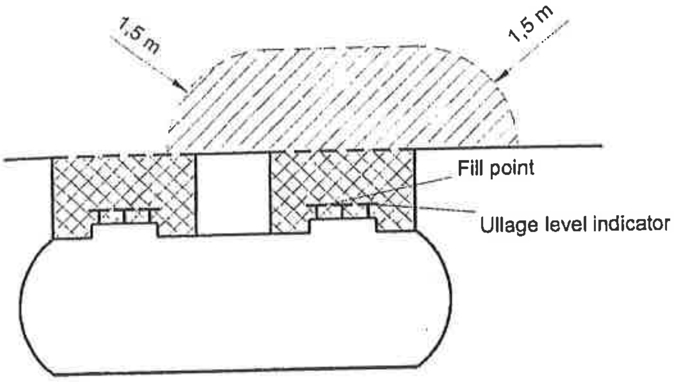
Rail car loading facilities vary in design. They may consist of a loading siding provided with a number of loading points spaced at intervals to suit rail car dimensions. An alternative to this multi-point system is a single-point installation in which the loading arms are grouped in one position and the train of rail cars is moved so that each car is brought into the loading position successively. In either case the installations are fundamentally similar to the road tanker loading facilities considered in 3.3 and should be analysed in the same way.

Rail car loading rates and therefore the rate of vapour displacement can be higher than that considered for road vehicles. The size of the hazardous area should be increased at these higher loading rates with allowance for greater width of rail cars and larger loading arms.

The hazardous area classification guidance given in 3.5.3 to 3.5.5 for the loading and discharge of rail tank cars is in accordance with the more general guidance for such installations, as given in IP *Design, construction and operation of distribution installations*.

[4] Valid for losses of up to 100 ml.

(a) Buried



(b) Buried with offset fill point and ullage level indicator

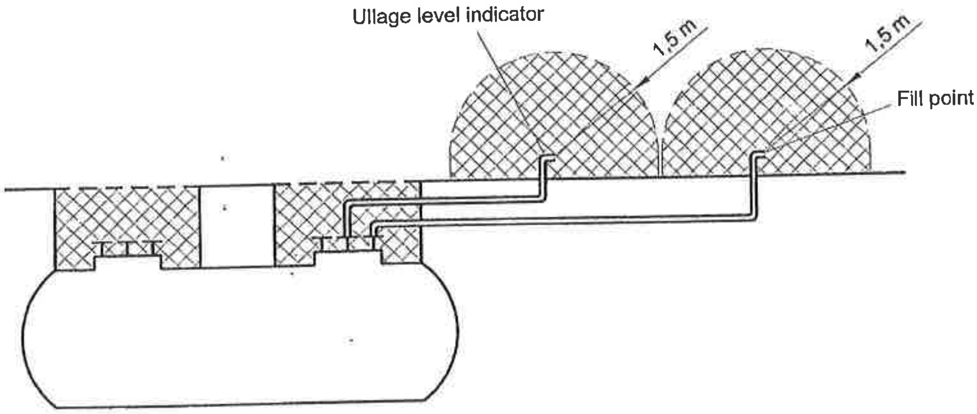


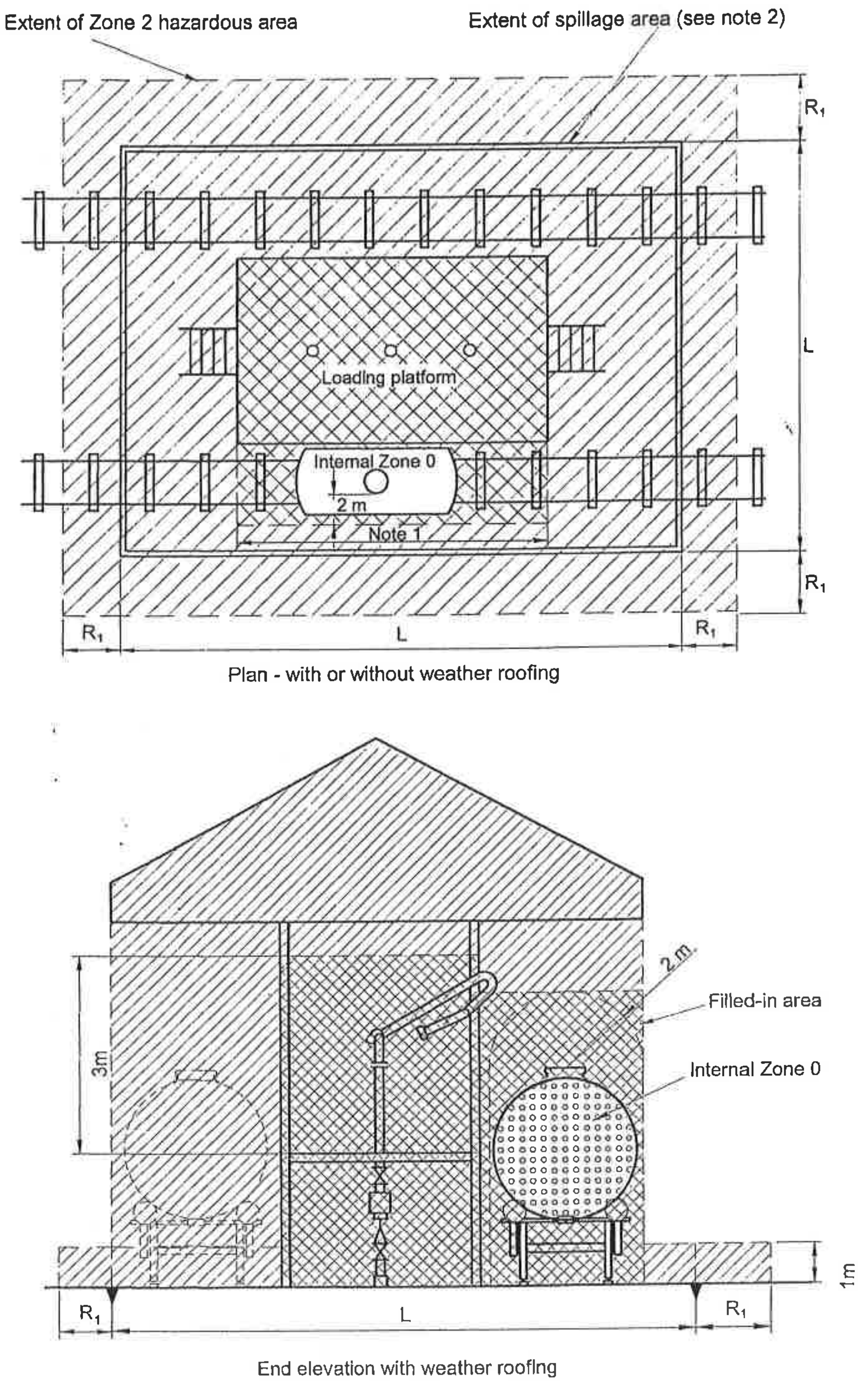
Figure 3.16 Typical hazardous area classification for underground LPG storage tanks

3.5.2 Top loading of rail cars with vapour collection

Loading of rail cars with vapour collection should eliminate routine emissions of flammable materials from the fill covers. 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 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 is designated a primary grade release creating a 2 m radius Zone 1 area around the fill cover extending to ground level (see Figure 3.17). Where rail cars are fitted with permanent filling and vapour collection connections, there should be no release of vapour except where failure leads to emergency venting of the compartment. Accordingly, this is designated a secondary grade release allowing the Zone 1 above the fill covers in Figure 3.17 to be downgraded to a Zone 2 classification.

The possible losses of vapour from the loading arm itself will generate 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 Zone 0 at all times. Figure 3.17 shows the individual aspects which should be combined to produce the overall hazardous area 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) materials will be determined by the means of spillage containment (see 3.3.4.3). To determine the extent of the Zone 2 area, see section 5.4.7.
3. For rail cars with permanent loading and vapour collection 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 3.17 Top loading of rail cars, single or multipoint, with vapour collection

3.5.3 Top loading of rail cars without vapour collection

(a) A primary grade release occurs 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 m^3/min, it is recommended that an area extending in all directions to a distance of 1 m around each fill cover, with a vertical drop to ground level, be classified as Zone 1 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 m^3/min, the area should be extended to 2 m. The 2 m horizontal extent will cover the greater width of the rail car (see Figure 3.17).

(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 3.5.2.

(c) The interior of the rail car will, as in the case of a road tanker, be Zone 0 at all times that the vehicle 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 3.5.6).

(d) Normally, impermeable catchment trays will be provided to contain spillages, in which case the Zone 2 should be assessed as detailed in 3.3.4.3. Otherwise, wetted areas from spillage will be restricted by the ballast on the track; in this case, it is recommended that, for Class I, II(2) and III(2) materials, 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 in accordance with Table 5.7.

(e) The combination of the above factors is shown in Figure 3.17.

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.

3.5.4 Bottom loading of rail cars

Bottom loading of rail cars is a less common practice. However, where it is carried out a similar analysis should be followed as in 3.5.3 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.

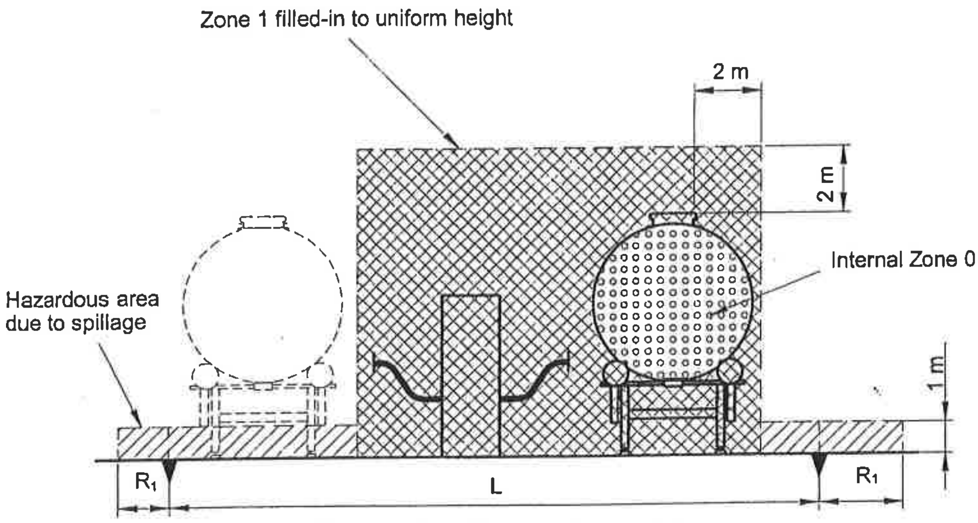
(b) For bottom loading at rates up to and including 2,5 m^3/min the area of the loading stand should be classified as Zone 1 up to a height of 1 m above any vent level. For rates above 2,5 m^3/min the height should be increased to 2 m.

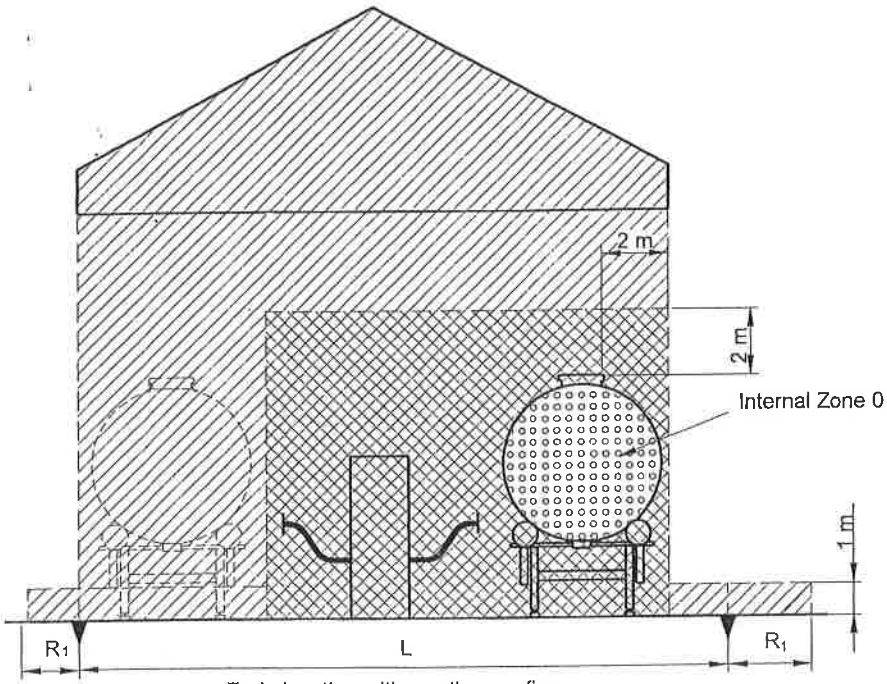
(c) The classification of the rail tanker will be as in 3.5.3(c). The envelope of the Zone 1 area associated with the fill covers and their vents extends, during filling operations, as described in 3.5.3(a) for top loading down to ground level.

(d) The Zone 2 hazardous area that is required to allow for the various secondary grade releases arising due to spillages should be derived as detailed in 3.5.3(d).

The composite area classification drawing is shown in Figure 3.18, 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) above.





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) materials will be determined by means of spillage containment (see 3.3.4.3). To determine the extent of the Zone 2 area, see section 5.4.7.

Figure 3.18 Bottom loading of rail cars, single or multipoint, with vapour collection

3.5.5 Rail car unloading via a hose connection - Classes I, II and III

The hazardous area classification for the discharge of a train of rail cars will follow the general principles for the discharge of road tanker vehicles in 3.4, though the scale will be in most cases be bigger and the concepts in 3.5.3 for rail car loading should be borne in mind (see Figure 3.19).

The discharge 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 defined as shown in Figure 3.18. In such a case, the procedure in 3.3.4.3 should be applied with due consideration of boundaries such as spillage channels or drains. However, in the case of rail cars, it is recommended that, because of the degree of manual participation and the multiple number of cars, spillage areas should be classified as Zone 1. When ballasted track underlies the rail car discharge location, the spillage area will be curtailed. 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) materials.

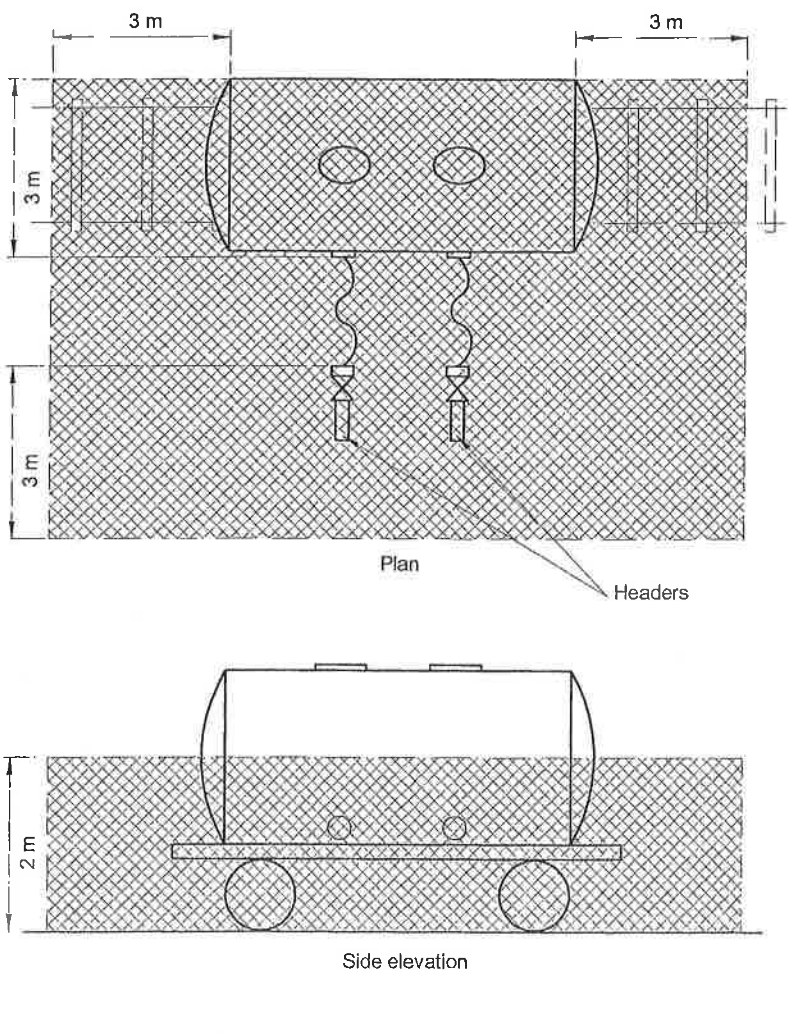


Figure 3.19 Rail car unloading via hose connection

3.5.6 Conditions for safe entry and departure of rail tank car trains to and from loading and unloading facilities - Classes I, II and III

The following points provide an important 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; safety is assured by adhering to prescribed safety and operating procedures (for details see IP *Design, construction and operation of distribution installations*).

(b) Tracks serving loading or discharge 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) Unprotected electric locomotives or diesel locomotives, unless conforming with the EEMUA 107 *Recommendations for the protection of diesel engines operating in hazardous areas* (see Chapter 8), should not be allowed within 9 m of a point where Class I, II(2) or III(2) material is being loaded, discharged or stored. Within such distance of these operations only lighting etc. certified as appropriate to the hazardous area classification should be permitted.

(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) material is being loaded or discharged.

3.6 MARINE FACILITIES AND JETTIES - CLASSES I, II AND III

3.6.1 General

This section considers the hazardous area 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 estimated using the appropriate sections of Chapter 5. Hazardous area classification on jetties should always be based on the most volatile product handled.

This section does not apply to the vessel itself for which guidance should be sought in the appropriate maritime code of regulation, i.e. IEC 60092-502, *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 discharge, a composite hazardous area for the facility should be obtained by combining the hazardous areas for the separate operations.

3.6.2 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. 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 3.20). 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 Chapter 5. 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 3.20.

(d) For jetties berthing only barges, coasters or other tankers with loading rates of 10 m^3/min or less, the horizontal distance in (b) may be reduced to 15 m and the vertical to 15 m.

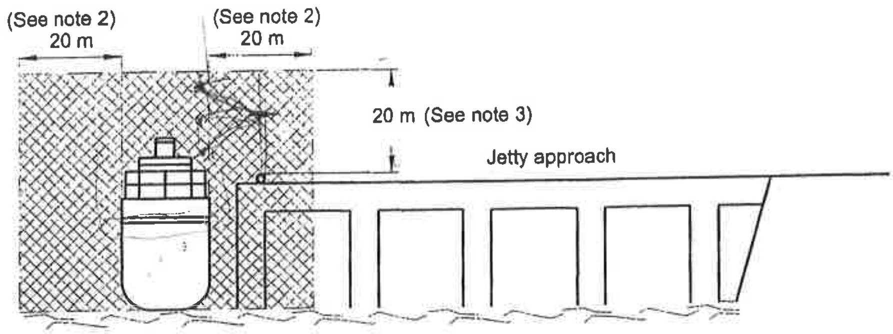
3.6.3 Jetties - unloading facilities

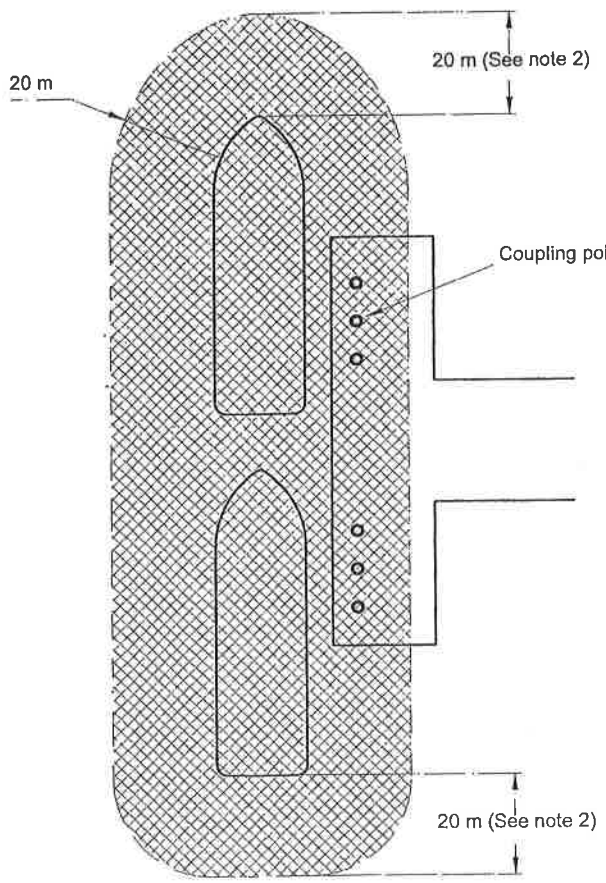
For jetties where unloading operations are carried out, the marine arms, hoses, etc., constitute a closed system, and only secondary grade releases are likely to occur. It is recommended that an area extending from the coupling points, a distance of 20 m horizontally, up to a height of 20 m above the coupling points and down to water level should be classified as Zone 2 (see Figure 3.21).

Hazardous areas should be established for each individual source of release from the jetty equipment since some may necessitate localized Zone 1 areas within the above 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 in accordance with 3.6.2.

For classification onboard the tanker vessel, see 3.6.1.

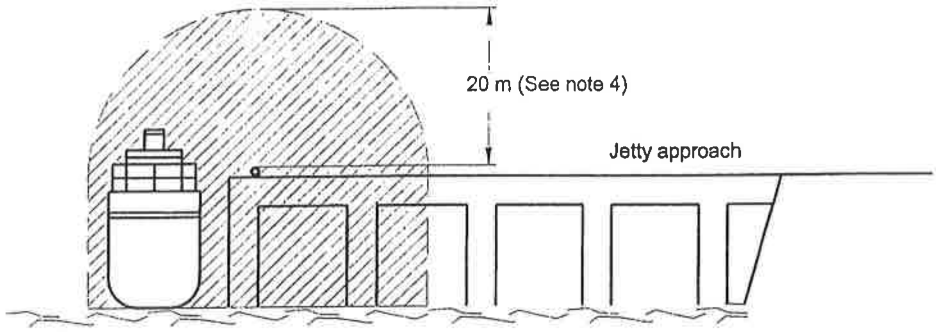


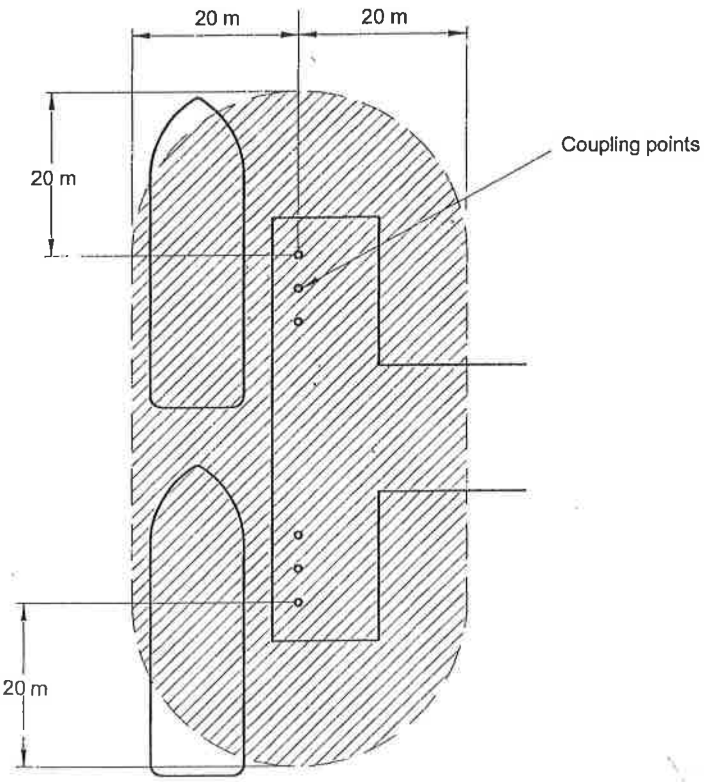


Notes:

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 $10 m^3$/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 $10\ m^3$/min or less.
4. For category A fluids, reference should be made to the methodology given in Chapter 5.
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, section 5.4 may be used to determine more specific hazard radii.

Figure 3.20 Jetties - loading facilities only





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 5.
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 C9(a) for the equivalent hazard radius.

Figure 3.21 Jetty - unloading

3.7 DRUM FILLING AND STORAGE - CLASSES I, II AND III

This section applies to the filling of storage drums of a nominal capacity of 205 litres or less.

3.7.1 General

Drum filling should normally be carried out in an open or sheltered area. If not, this section does not apply and the drum filling area should be regarded as an enclosed area with a primary grade release source, and local exhaust ventilation should be provided (see section 6.4.3.1).

The drum should be regarded as a primary grade source of release. The hazardous area should be classified as Zone 1. It should extend 1 m in all directions from the edges of the filling or venting openings (see Figure 3.22). The spillage area should be determined according to section 5.4.7.

The filling line outlet is also a primary grade source of release. 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) materials, section A1.3 (formation of mists and sprays) will apply. Therefore 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.

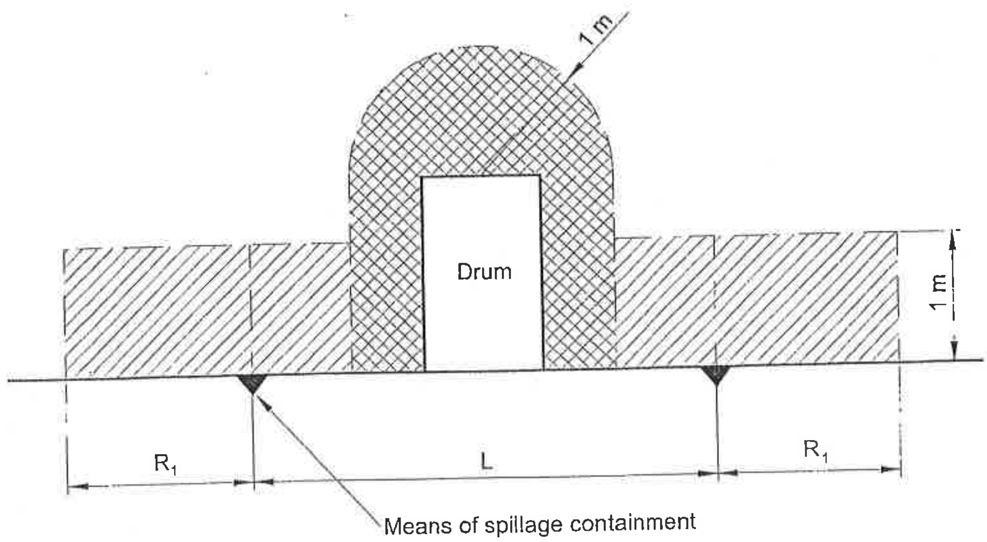
3.7.2 Drummed storage areas - Classes I and II(2)

Where reasonably practicable, such containers should be stored at ground level (singly or in stacks of no more than four high) and in the open air. This will enable leaks to be more readily detected, and any vapour arising to be dissipated. Such stacks for Class I or II(2) materials should be placed in one, or several compounds if the total volume of packed product exceeds 200 m^3, 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 3.22 and 3.7.3, should be protected to Zone 2 standards. New equipment should be built to BS EN 1755.

Where the recommended zone distances cannot be achieved, consideration may be given to the provision of a fixed water spray system or an appropriate firewall, as in section 6.2.3. Such a firewall should be at least as high as the top of the container stack, and be sited 1-3 m from the stack. The firewall may form part of a bund, unpierced building wall, or boundary wall, and to ensure adequate ventilation normally be on one side only of the stack.



Notes:
1. For determination of extent of spillage Zone 2 area, see section 5.4.7.
2. The dimensions of L are controlled by means of spillage containment such as ground contours, kerbs, and drains (as shown).

Figure 3.22 Drum filling in the open air

3.7.3 Drum storage in buildings - Classes I and II(2)

When it is not practicable to store containers in the open, they may be stored in suitable storage buildings, which should not be used for other purposes. Such buildings should, 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 well ventilated, provided openings do not conflict with the need for a wall to be fire resisting, and be classified as Zone 2 up to a height of 2 m above the highest container. If heating is provided it should not be a source of ignition.

For details of package filling and storage building construction, see IP *Design, construction and operation of distribution installations*.

Where artificial ventilation is to be provided the guidance given in Chapter 6 should be followed, with fan motors protected to Zone 2 standard.

3.7.4 Package manufacture and reconditioning

When packages are to be manufactured at an installation and this entails hot work or the use of any source of ignition, this should be located at least 15 m from any filling area, tankage or storage area where Class I or II(2) petroleum is stored or handled.

Where used drums are to be reconditioned or repaired, cleaning and gas-freeing should be carried out in the open air or in a well-ventilated building, and appropriate precautions taken against any source of ignition.

No hot work should be carried out on any package until it is cleaned and made gas-free (usually by steaming). Such hot work/repair should be carried out within an area that is otherwise designated non-hazardous (see section 8.4). Containers that have carried a heavy oil can appear gas free when tested, but when heat is applied traces of product remaining can vaporise to form a flammable atmosphere; thorough cleaning out is therefore essential in all cases.

3.8 INTERMEDIATE BULK CONTAINERS (IBCS), OTHER TRANSPORTABLE CONTAINERS AND PACKAGED UNITS

Where these contain flammable fluids on a site, consideration should be given to the hazardous area created by potential losses from the system and the spill area created (see section 5.4.7).

3.9 FILLING STATIONS AND FUEL DISPENSING FACILITIES

3.9.1 Introduction

This section covers the equipment and layout to be found on the forecourt under the normal open area condition. It should be applied also to non-retail gasoline dispensing sites and to dispensing to boats, light aircraft and into portable containers. As applied below, the Zone 2 areas indicated cover the possibility of localised flammable atmospheres being present for short periods, with such areas being well 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 section 6.2.3).

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 vigorously enforced (see Chapter 8).

3.9.2 Gasoline dispensers and other Class I, II(2) and III(2) fluids

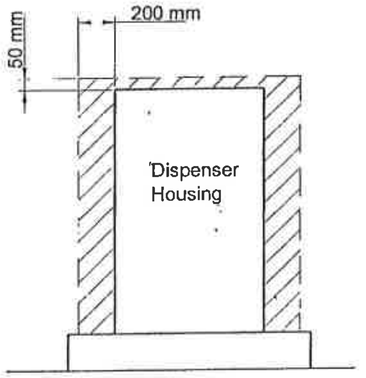
Reference should be made to the dispenser manufacturer to determine the likely sources of release from a dispenser, based on the relevant standard to which it was designed and constructed. For new dispensers the manufacturer or supplier should provide a diagram with the unit showing the zones in and 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 section (or other user codes).

Figures 3.23 to 3.27 are intended to assist in the selection of electrical and other equipment suitable for operation in the vicinity of gasoline dispensers. Figures 3.23 to 3.26 summarise the hazardous areas arising around specific equipment; Figure 3.27 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 relevant national, European or International Standards.

3.9.2.1 Dispenser housing

Figure 3.23 shows the extent of hazardous areas around a dispenser housing, which applies to gasoline dispensers either with or without Stage 2 vapour collection installed. Figure 3.23(a) shows the extent of hazardous areas without a vapour barrier; Figure 3.23(b) shows the reduction in the area when there is a vapour barrier. The Zone 2 hazardous 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.

(a) Without a vapour barrier



(b) With a vapour barrier

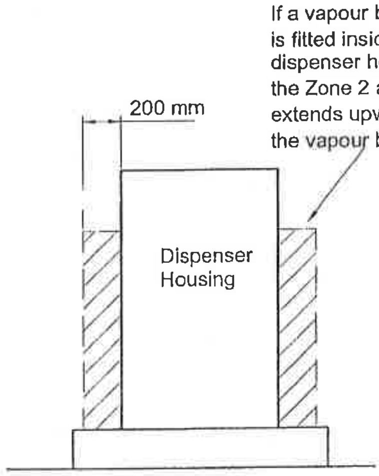


Figure 3.23 Typical hazardous area classification around a gasoline dispenser housing

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.

3.9.2.2 Hazardous area around external dispenser air separator vent

Figure 3.24 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 collection installed). The Zone 1 hazardous area extends 250 mm horizontally, down to ground level, and 100 mm vertically above the vent.

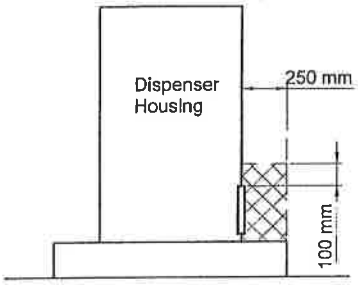


Figure 3.24 Typical hazardous area classification around an external dispenser air separator vent

3.9.2.3 Hazardous area around a vehicle fill pipe during refuelling

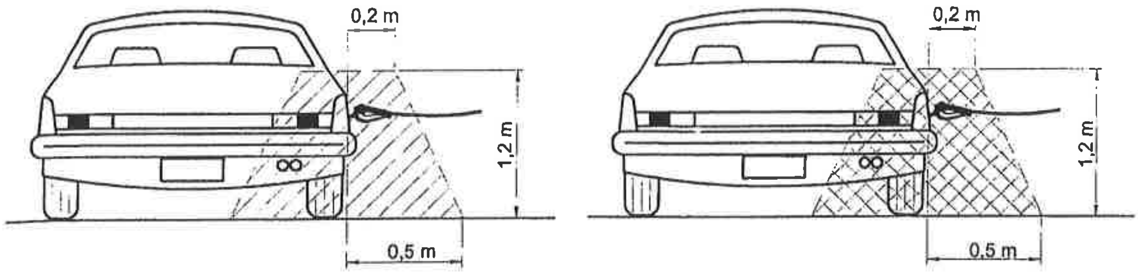
When a nozzle is inserted into the vehicle fill pipe and the nozzle trigger is operated, flow of gasoline begins and vapour is displaced from the vehicle's tank.

Where the dispenser/filling station is fitted with Stage 2 vapour collection, displaced vapour is recovered by the nozzle and very little is displaced to atmosphere. The hazardous area in this case will be Zone 2 as shown in Figure 3.25(a).

Where Stage 2 vapour collection 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 as shown in Figure 3.25(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 classification in Figure 3.25 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 hazardous area classification.



(a) Nozzle fitted with Stage 2 vapour collection

(b) Nozzle without Stage 2 vapour collection

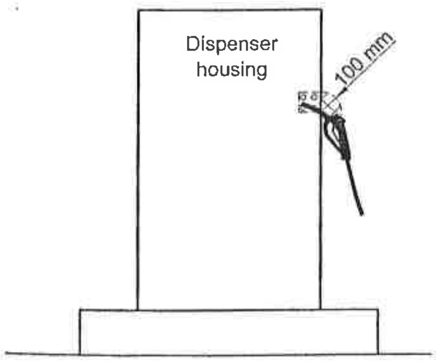
Note: 1,2 m allows for those cases where the hose is lifted over the vehicle on its return to the nozzle housing and for vehicles with a high fuel tank opening.

Figure 3.25 Typical hazardous area classification around a nozzle during vehicle refuelling

3.9.2.4 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 hazardous 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. 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 3.26 Typical hazardous area classification around nozzle spout housing

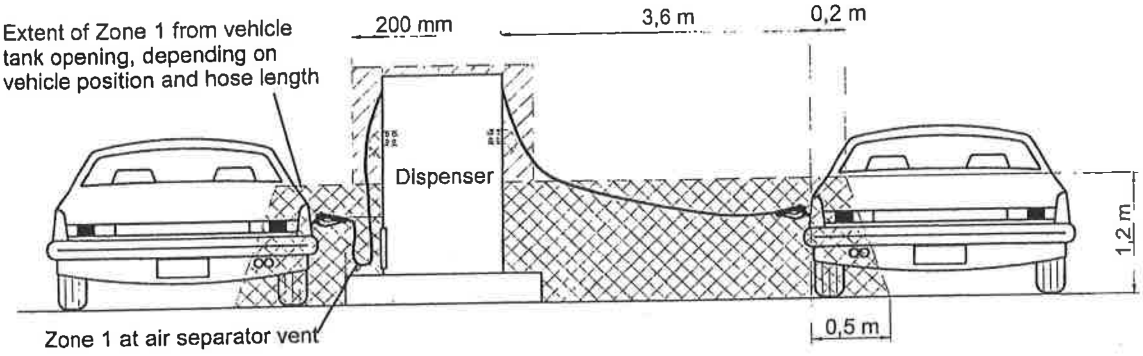
3.9.2.5 Composite hazardous areas around dispensers during refuelling

Figure 3.27 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 of 3,6 m.
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 3.25 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 3.9.2.4.
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 hazardous 2 area created by the nozzle is enveloped by the hazardous area created by the refuelling operation.

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

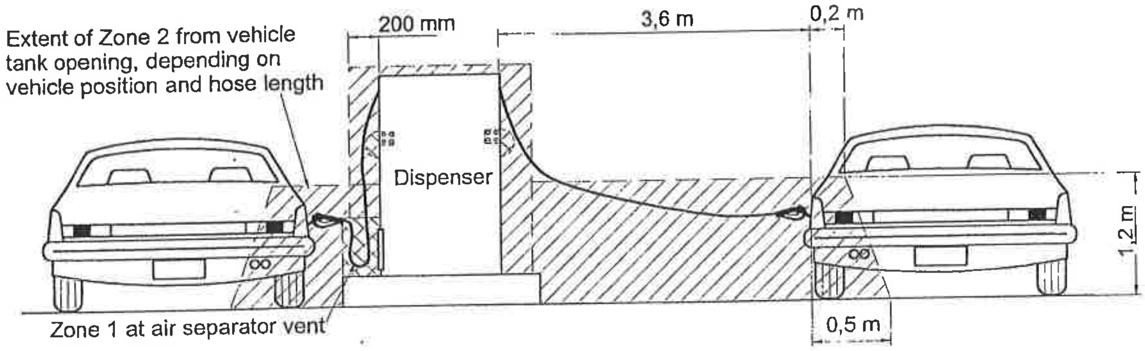
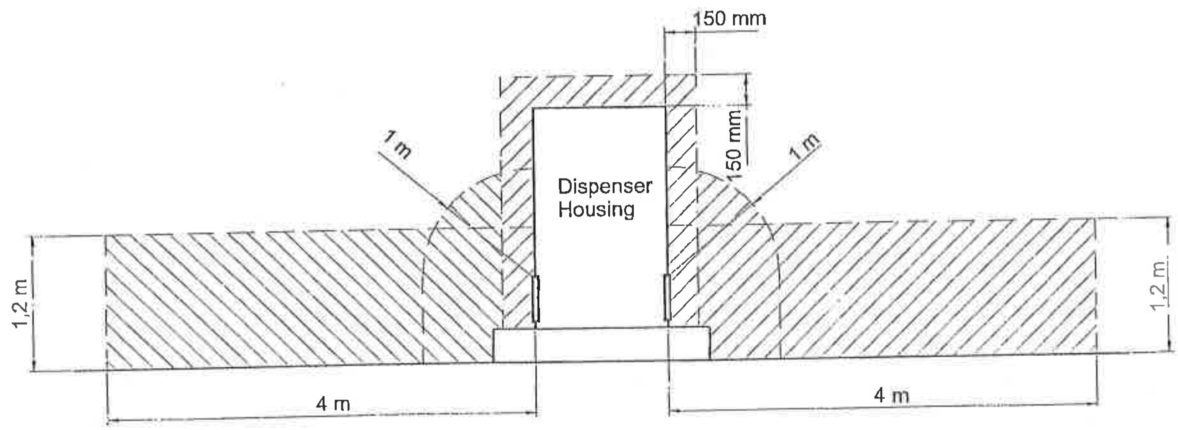


Figure 3.27 Typical composite hazardous area classification around a dispenser[5] during refuelling



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

Figure 3.28 Typical hazardous area classification around an LPG dispenser during refuelling

[5] As described in 3.9.2.5.

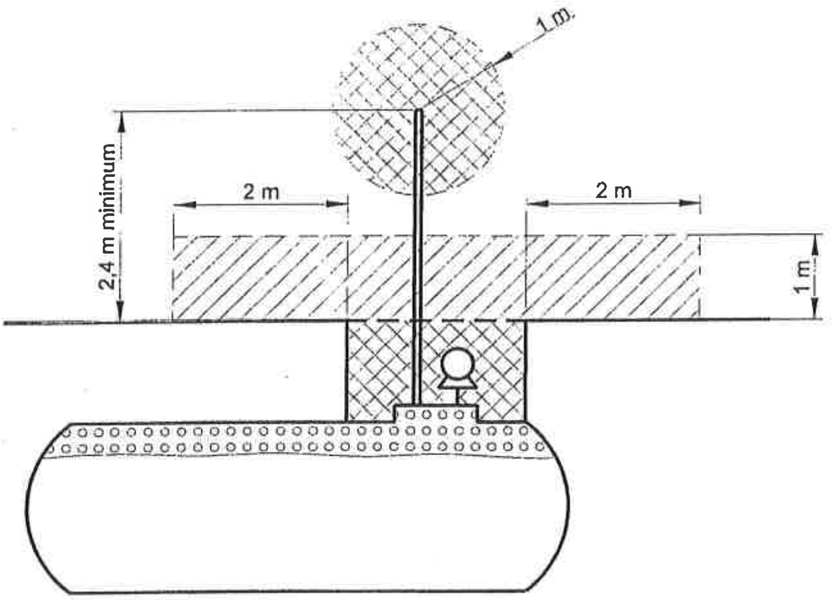


Figure 3.29 Typical hazardous area classification for an oil/water separator

3.9.3 LPG dispensers and other Class 0 fluids

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 the filling nozzle limit the loss of autogas 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).

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 m [6] 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.

3.9.4 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 foregoing 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.

3.9.5 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 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 hazardous area above the cover of

[6] 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.

radius 2 m from the edge to a height of 1 m, in accordance with Table 5.7.

Where oily materials are not removed directly following spillage, the ullage space in the separator will be classified as Zone 0 giving rise to a Zone 1 hazardous area of 1 m radius around the top of the separator vent. See Figure 3.29.

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

3.10 VEHICLE REPAIR, SERVICING AREAS AND INSPECTION PITS

The danger of 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 a Zone 2 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 material to parts of the facility which have been deemed to be non-hazardous areas.

It is recognised that 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 shops should be obtained from the local regulatory inspector.

4

THE HAZARDOUS AREA CLASSIFICATION OF DRILLING RIGS, EQUIPMENT AND WELL OPERATIONS

4.1 INTRODUCTION

This chapter 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;
- 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 Chapter 5. The storage and loading of crude oil after stabilisation to fluid category C condition, as defined in Table 1.2, should follow the guidance for Class I petroleum given in Chapter 3. The guidance in this chapter, which adopts a risk-based approach allied to practical experience, follows the principles of IEC (61892 series) 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. However, well blow-outs giving rise to large releases are outside the scope of hazardous area classification and should be a matter for standing operational practices.

Whilst the Code is principally concerned with the selection and installation of electrical equipment as outlined in Chapter 7, it also gives guidance on the safe operation of non-electrical sources of ignition, such as fixed combustion engines and gas turbine equipment and on hot surface protection (see Chapter 8).

4.1.1 Use of the chapter

Despite a number of differences, 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 this chapter to be set out in the form of 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 5. 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 section 1.7 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 6.

Although many Mobile Offshore Drilling Units (MODUs) operating internationally will be certified in accordance with the IMO *Code for the construction and equipment of mobile offshore drilling units* (either 1979 or 1989 edition), the guidance of this Code has been widened to include semi-submersibles, jack-ups and drill-ships.

4.1.2 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 classification 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 5.

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 hazardous 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 hazardous 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.

4.1.3 Groupings for area classification

The recommended procedure for hazardous 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 de-gasser and HVAC vents.

These subsections differentiate as appropriate between open area and enclosed or sheltered conditions. Other enclosures not covered by these examples should be dealt with by reference to Chapters 5 and 6.

4.2 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 sections 1.7.3 and 6.2, hazardous areas should be assigned in accordance with 4.2.1 to 4.2.5 below.

4.2.1 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 in accordance with section 5.4.8. 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 in accordance with section 5.4.5. 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 as per section 5.4.8.

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 according to section 5.4.5. 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 hazardous area, and if enclosed, as Zone 1.

4.2.2 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 5.4.7 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 defined in accordance with section 5.4.4.3 as described in 4.3.3.

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.

4.2.3 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 as a sump in accordance with section 5.4.8 as shown in Figure 4.2. 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, as defined in section 6.3, the hazardous area should extend 3 m outside any opening in the shelter or a distance equal to R_1 calculated as in section 5.4.8 from the bell-nipple, whichever is the greater.

Spillages in open wellhead areas on fixed offshore installations should be treated in accordance with section 5.4.7. Where one or more wellheads are enclosed in 'cells', they should not be regarded as 'open'.

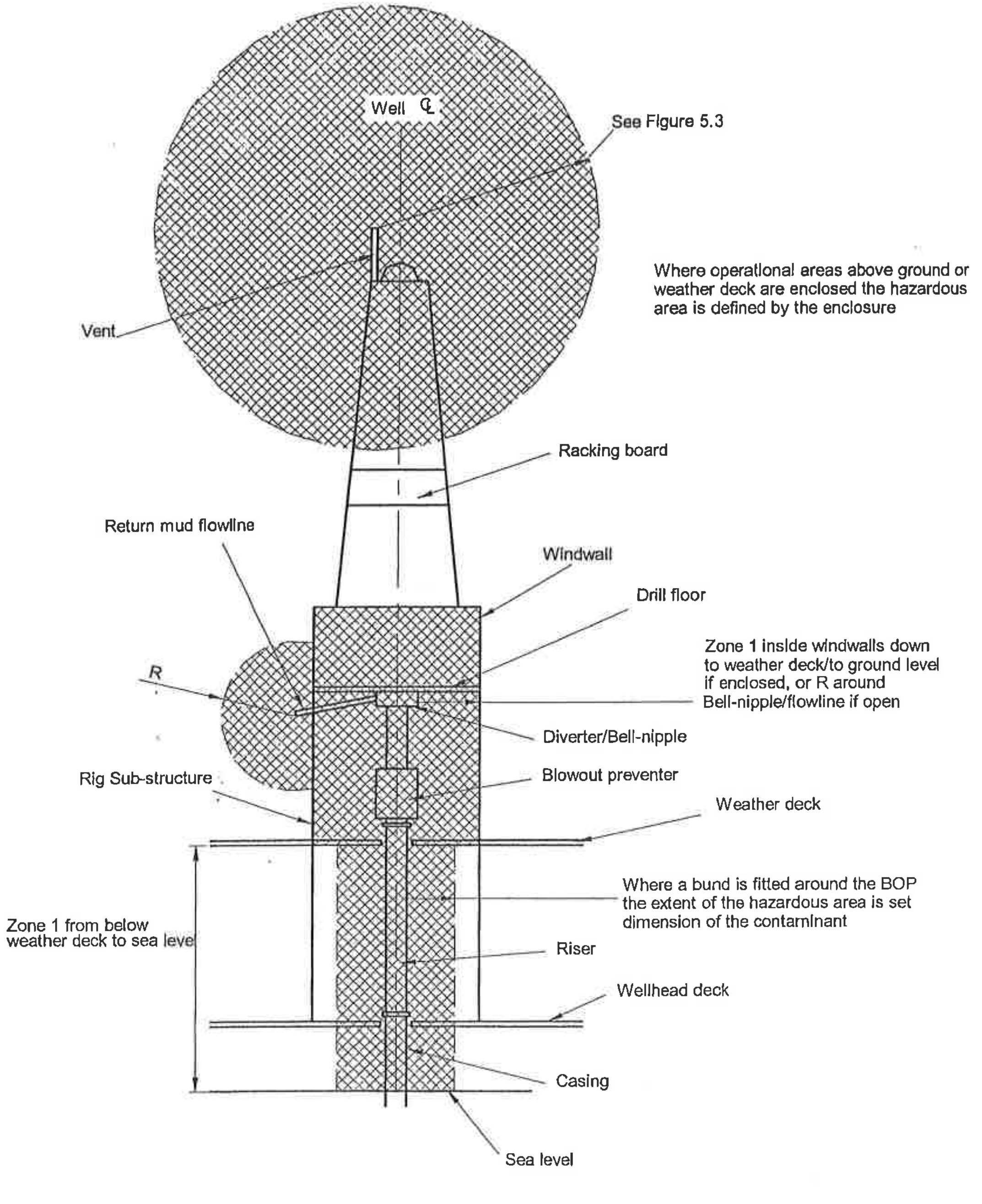
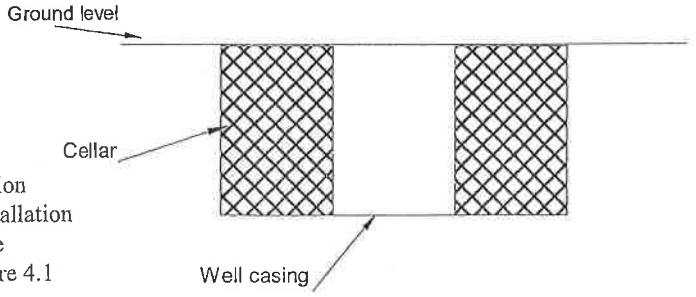


Figure 4.1 Drilling and workover



Note: only part of installation shown; for parts of the installation above the ground level, see corresponding part of Figure 4.1 above weather deck.

Figure 4.2 Typical well cellar (land rig)

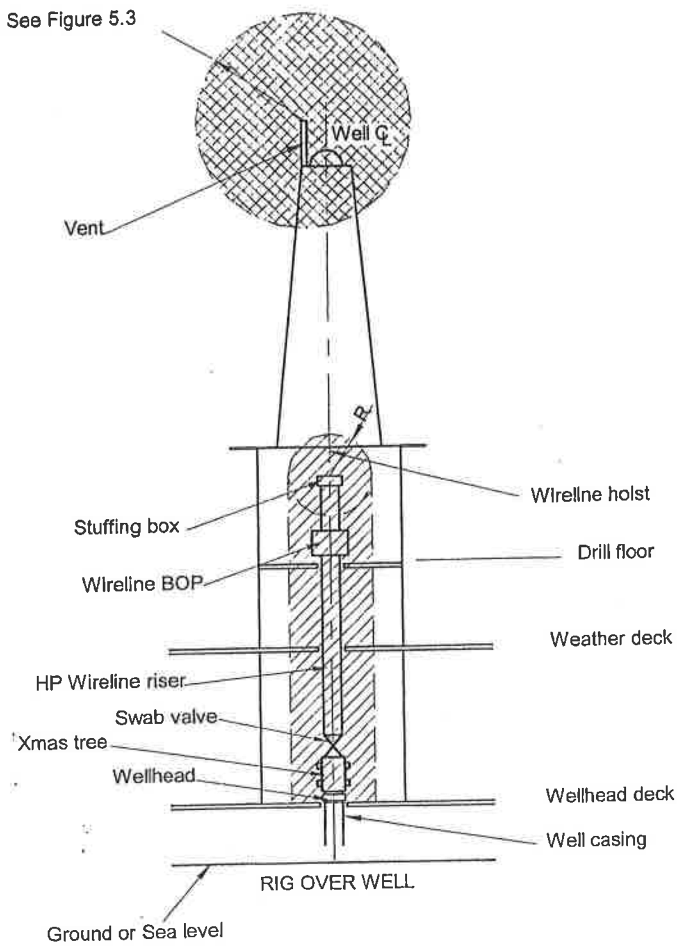


Figure 4.3 Freestanding wireline operation (open areas)

4.2.4 Workover, snubbing, coiled tubing and wirelining operations

The classification derived in 4.2.1 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 as in 4.2.5. Potential leakage rates should be obtained from equipment suppliers and the hazard radius determined by reference to Annex C Part 3 or by a similar calculation methodology. In the absence of supplier leakage rate information, hole sizes should be estimated by reference to Table C6 and the hazard radius should be determined using Table C9(a).

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 are considered equivalent and are represented by the wireline operation in Figure 4.3.

4.2.5 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 section 6.4.1), 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 section 6.4. Where a vent line is fitted on the derrick, the radius (R_1) of the hazardous area should be calculated in accordance with Table 5.5.

If the sub-structure is totally enclosed, the bell-nipple should be treated as a sump in accordance with section 5.4.8 and the internal space should be classified as Zone 1 with a Zone 2 area extending 3 m outside any aperture in the enclosure (see also section 6.4). Enclosed onshore well cellars and other non-open areas are covered in 4.2.2.

4.2.6 Notes on Figures 4.1, 4.2, and 4.3 – open areas

Figure 4.1 shows the extent of hazardous areas in the drill floor, substructure and upper-works of 'open area' (offshore and land) drilling rigs. Figure 4.2 shows hazardous areas for a well cellar. Figure 4.3 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 4.3. However, if the mud itself is regarded as hazardous, as in 4.3, or the return flow-line is open, then the effect of any sources relevant to Figures 4.1 and 4.3 should be considered, as in 4.2.1.

4.3 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;
- cuttings treatment and re-injection 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 advice may be required to estimate the maximum operating temperature of the mud. The effect of hazardous drilling mud is considered in 4.3.6.

4.3.1 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.

4.3.2 Shale-shakers and solids removal equipment

A shale-shaker located in an open area should be treated as a sump (see section 5.4.8), with a horizontal Zone 1 area of 3 m, extending 3 m above the top of the shale-shaker, as shown in Figure 4.4. 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.

4.3.3 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 de-gasser. 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 in accordance with section 5.4.4.3. 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 section 5.4.4. 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.

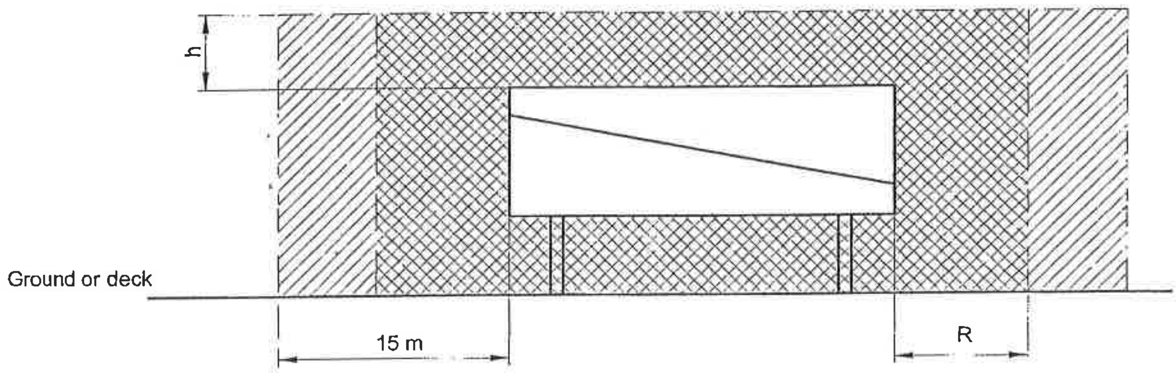
With a vent at the derrick top, any area within the derrick less than 15 m from the vent tip should be considered hazardous.

The gas vent should normally be considered a secondary grade release.

4.3.4 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 4.5. The space within the tank walls should be classified as Zone 1, with a Zone 2 area outside in accordance with section 5.4.8.

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. For artificial ventilation see 4.3.5 and Chapter 6.



Note: R = 3 m, h = 3 m based on a sump of less than 5 m in length (see 4.3.2).

Figure 4.4 Hazardous area around a shale-shaker in an open area

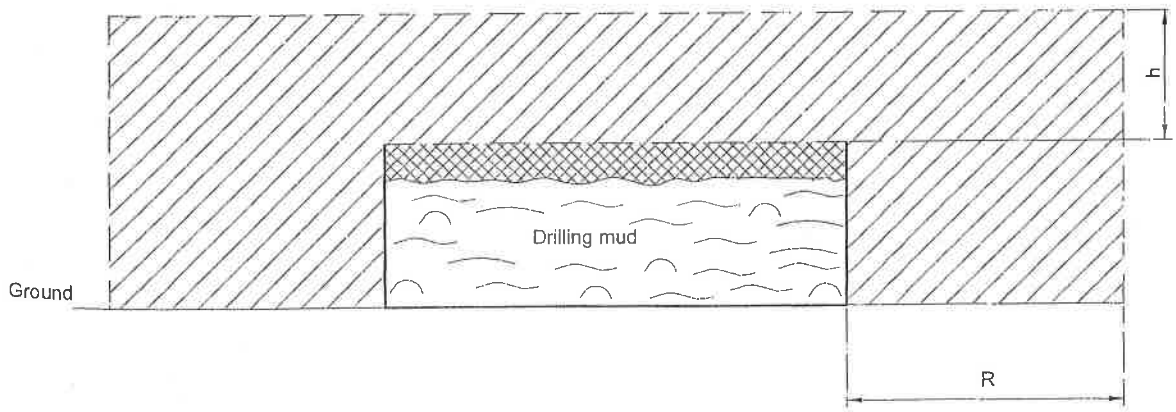


Figure 4.5 Hazardous area around mud tanks

4.3.5 Mud mixing, storage and transfer - ventilation of enclosed systems

In respect of 4.3.2 and 4.3.4, 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 sections 6.3 and 6.4).

Generally, mud-room air changes of 12 per hour may be sufficient, but higher rates may often be required for specific equipment, e.g. shale-shakers or to ensure removal of vapour from partially closed mud tanks.

4.3.6 Hazardous drilling muds

When drilling mud itself is considered to be hazardous in consequence of factors explained in 4.3, 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 section 5.4.8). The larger of the estimated distances based upon Chapter 5 or calculated as in 4.3.2 to 4.3.4 should be used to define the hazard 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 5.

4.3.7 Cuttings treatment, storage and re-injection 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 re-injection. 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 hazardous area outside calculated in accordance with section 5.4.8. Washed cuttings and injection slurry may be regarded as non-hazardous.

4.3.8 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 defined in accordance with the relevant parts of sections 5.4.7 and 5.4.8.

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 in accordance with section 5.4.8. Where adequate ventilation is provided (see 4.3.5), the Zone 2 area may be reduced as in 4.3.2.

Other solids removal equipment should be considered as a source of primary grade release and a Zone 1 hazardous area established, as described in 4.3.2. Other process equipment in the separation train should be treated in accordance with relevant sections of Chapter 5.

4.4 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 4.2.1 to 4.2.5 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 above and their ventilation should be assessed in accordance with 4.7 below. In all other cases, the extent of the hazardous area should be determined using Chapter 5.

4.5 OTHER SPACES

The ventilation in any other spaces on a drilling facility not specifically covered in this chapter should be assessed as outlined in Chapter 6 and the zone classification and area boundaries for non-open areas assessed in accordance with Chapters 5 and 6. 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 6. 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. See section 7.17.

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 section 6.2.3).

4.6 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 from Chapter 5. 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.

4.7 EMERGENCY SYSTEMS

Alarm and shutdown systems embodying gas detection and other sensors, with redundancy to avoid false operation, are covered in the examples in Chapters 6 and 8. In considering zone classification in 4.2 and 4.5, it is recommended that electrical apparatus required to operate under conditions of breakdown should be of a type suitable for Zone 1 operation (see Chapter 7).

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.

4.8 NON-ELECTRICAL SOURCES OF IGNITION

Although area classification is intended primarily for the selection and location of electrical equipment, as described in Chapter 7, area classification should also take into account non-electrical sources of ignition. These are described in Chapter 8.

5

THE POINT SOURCE APPROACH FOR CLASSIFICATION OF INDIVIDUAL SOURCES OF RELEASE

5.1 SCOPE

This chapter covers all facilities that fall outside the direct examples of Chapters 3 and 4. Typical hazard radii are provided, using the results of dispersion modelling published in IP *Calculations in support of IP15*.

The hazardous 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 5.6 to form a three-dimensional envelope of the hazardous area. The hazard radii in Chapter 5 are for the condition of open area natural ventilation and are valid within the process conditions given.

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 methodology provides a means of adjusting release frequency and hence hazard radii, to fit specific process scenarios.

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.

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 hazardous area classification purposes, and consideration should be given to modifying the facility to minimise the size of release.

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

Release sources evaluated under this category are referred to as 'point sources'. Some are true point sources as with vents, drains and sample points; 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 identifiable potential release.

5.3 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 hazard radii (R_1) given in 5.4 are typical; where conditions fall outside of the range of the tabulated values e.g. operating pressure, equipment size etc., specific hazard radii (R_1 and, where appropriate, R_2) may be determined using Tables C9(a) and C9(b) respectively in Annex C Part 3.

The methodology involves the following steps:

- identify point sources;
- determine grade of release and fluid category;
- establish zone classification;
- determine hazard radii;
- determine hazardous area.

5.3.1 Identify point sources

The first stage in the hazardous area classification of a plant or facility is the identification of the point sources, usually small, that are possible from the associated equipment which typically includes 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 will usually result in secondary grade releases with a limited number of primary and continuous grade releases. Subject to any restrictions caused by reduced ventilation within enclosed areas (see Chapter 6), the hazardous area will mainly therefore be Zone 2 with several smaller Zone 1 areas. Zone 0 areas will normally be restricted to the interior of cone roof tanks, or other equipment containing both flammable fluids and air, e.g. vapour collection lines, open sumps and any substantially continuous vents.

5.3.2 Determine grade of release and fluid category

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. However, for secondary grade sources of release, it is often only necessary to consider those sources located towards the periphery of a plant that may affect the outer boundary of a Zone 2 area since many plant areas constitute a general Zone 2 area based on boundary features, as outlined below. This consideration should include any areas where spillage could collect. 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.

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.

5.3.2.1 Determination of the grade of release
The grade of a release is an expression of frequency and duration, in accordance with the international definitions of continuous, primary or secondary as stated in section 1.6. It is 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, secondary or continuous. Such a decision can usually be made at the planning stage (see section 1.6.4).

(b) For releases that are uncontrolled (e.g. leakage from pump seals, glands and pipe flanges) a secondary grade of release is applicable. Generalised assessments of hole sizes from experience of the equipment type in question, (e.g. pump and compressor seals and glands, flanged joints etc.) have been compiled (see the risk-based approach Annex C Part 2) and incorporated in specific subsections of 5.4 and may be used accordingly - or until either specific manufacturers' release rates or measured release rates are available, or individual failure rates become apparent through observation, e.g. where service conditions are untypical, such as where fluids handled are corrosive or abrasive. Correct choice of materials for gaskets, glands, seals etc. is important.

5.3.2.2 Determination of the fluid category
The fluid category for each point source may be determined using Tables 1.2 (Chapter 1) and A3 (Annex A). Note, the fluid condition of a release under shutdown conditions may vary and be of a different vapour-producing potential than under normal operating conditions. An example would be the fluids in a fractionating column or receiver which at shutdown might be less well separated from lighter fractions. Guidance for this type of activity falls into the cleaning and gas-freeing sections of codes such as IP *Design, construction and operation of distribution installations,* IP *Tank cleaning code* and the HSE *Cleaning and gas-freeing of tanks containing flammable residues*.

5.3.3 Establish zone classification

The zone classification (i.e. Zone 0, 1 or 2), which is a function of the grade of release, the duration of a flammable atmosphere and the degree of ventilation should be determined according to sections 1.6.3 to 1.6.5 and Chapter 6.

5.3.4 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 may therefore be of unknown rate (hole size and pressure).

Having determined the grade of release, Figures 5.1 and 5.2 should be used to determine the procedure for establishing the hazard radii.

5.3.4.1 Primary and continuous grade releases
See Figure 5.1.

5.3.4.2 Secondary grade releases
There is a two-step procedure to determine hazard radii for secondary grade releases:

Step 1: Either use actual hole size as specified or, where hole size is unknown, assign LEVEL of release frequency appropriate to the installation using the procedure in Figures C1 and C2, (Annex C Part 1).

Step 2: Use Figure 5.2 to determine which procedure to use to obtain hazard radii.

5.3.5 Determine hazardous area

Having determined the hazard radii in 5.3.4, they are then used to obtain the three-dimensional form and extent of the hazardous area envelope (see 5.5 and Figure 5.6), taking into account the various ventilation situations described in Chapter 6.

5.4 POINT SOURCES

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

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

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 Tables C9(a) and C9(b) respectively of Annex C Part 3. Shape factors for the hazardous areas are determined using 5.5.

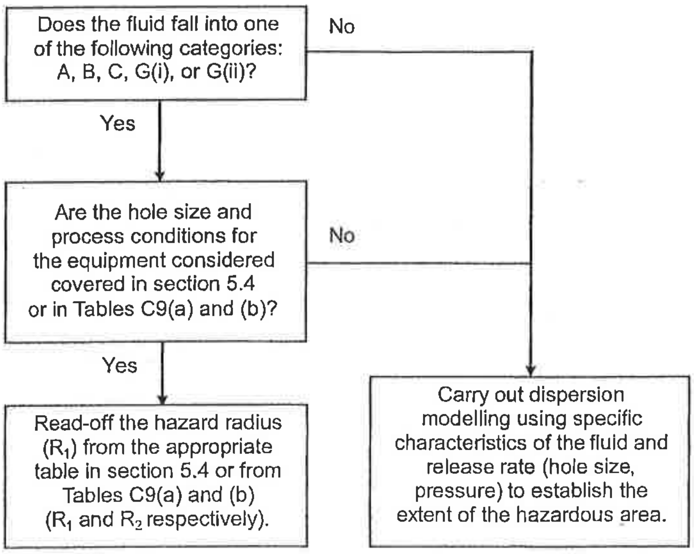
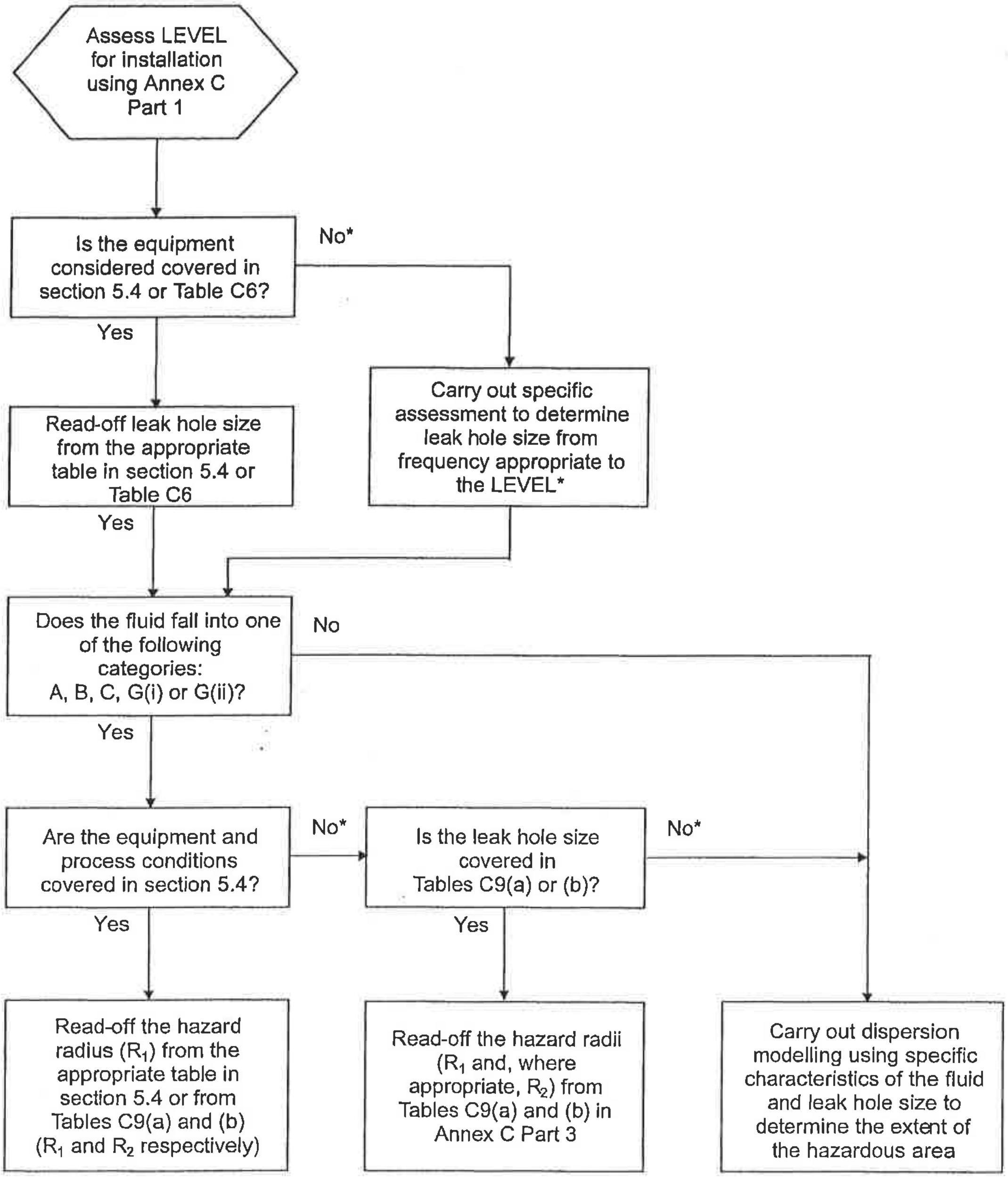


Figure 5.1 Procedure for determining the hazard radii for primary and continuous grade releases



* Optional, irrespective of whether covered in section 5.4; modelling may always be used to determine frequency of leak hole size and hazard radius.

Figure 5.2 Procedure for determining the hazard radii for secondary grade releases

5.4.1 Pumps

It is recommended that 'standard pumps' (i.e. those fitted with single mechanical seals) should have an external throttle bush. The throttle bush is designed to limit the release rate in the event of seal failure.

Equivalent hole sizes are given in Table C6 (Annex C Part 2) for leaks from standard pumps with and without throttle bushes.

On standard pumps handling category A or B liquids there is likely to be some small continuous vapour leak around the seal. Pumps with packed glands are not recommended for these liquids but may be used on category C liquids although there is likely to be a continuous weep of liquid. The packed glands for category C liquids and single mechanical seals for category A and B liquids should both be regarded as primary grade release sources giving rise to a nominal Zone 1 hazard radius of 0,3 m. This is not intended to govern the type of protection of the motor (which should conform to the general Zone 2 area) but can limit the proximity of instrumentation. Where a larger release occurs due to seal failure, this is covered by the hazard radii based on the secondary grade releases as determined from Table C6 (Annex C Part 2).

Where adequate ventilation is necessary to gain the Zone 2 classification it is recommended that pumps should have high integrity seals.

5.4.1.1 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 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.

5.4.1.2 Estimation of leak hole size and determination of hazard radii

Due to the variety of different seal and shaft arrangements, it is recommended that the hazard radii associated with seal failure are calculated using seal failure release flow rates (at normal operational conditions) supplied by the pump vendor. In the absence of manufacturers' data, hazard radii may be calculated using the equivalent leak hole diameters given in Table C6 (Annex C). These values are based on published data (Cox, Lees and Ang *Classification of hazardous areas*) on seal leaks and are likely to over predict the size of seal failure holes. The data suggest that an equivalent release hole diameter of 0,1SD may be used for standard pumps with throttle bushes and 0,23SD for standard pumps without throttle bushes, where SD is the pump shaft diameter in mm. Seal manufacturers may have more precise leak sizes for their seals which, if used, will give considerably reduced hazard radii.

Seal leakage rates from standard pumps are generally greater than from those pumps fitted with throttle bushes or from high integrity type pumps. A nominal hole size of 2 mm diameter (IP *A risk-based approach*) can be taken to represent the leak from a high integrity pump.

At LEVELS II and III, the leakage rate is independent of the seal type and is controlled by other features such as discharge pipe connections or casing failures. Since the hazard radii are dominated by leak sources other than seal failure the hole size is expressed in terms of the diameter of the pipe discharge line.

5.4.1.3 Example hazard radii (R_1) for pumps

The following examples (Tables 5.1(a) to (c)) are for a pump located at a height greater than 1 m above ground with a discharge pressure 10 bar(a), a shaft diameter of 25 mm and a discharge pipe diameter of 100 mm, assuming that manufacturers' data for a seal failure rate release rate are not available. Where a pump is at a height less than or equal to 1 m above ground, the ground effect hazard radius R_2 may be determined using Table C9(b). Hole sizes are determined from Table C6 (Annex C Part 2). Hazard radii are based on the dispersion distances given in Annex C Part 3.

5.4.2 Equipment drains and liquid sample points

The hazard caused by equipment drains and sample points depends upon design, which can include, for example:

— open valve draining to the ground;
— open valve draining to tundish and drain system;
— valve draining to closed cabinet and drain system.

Gaseous sample points or drain points from gas systems should be considered as vents. Good practice is to allow for abnormal release if a sample valve were to be jammed open, for example by double valving. 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.

Table 5.1(a) Hazard radii (R_1) for standard pumps without throttle bushes

Fluid category	LEVEL I		LEVEL II		LEVEL III	
	Hole size (mm) i.e. 0,23SD	R_1 (m)	Hole size (mm) i.e. 0,1DP	R_1 (m)	Hole size (mm) i.e. 0,3DP	R_1 (m)
A	5,75	10	10	16	30	†
B	5,75	10	10	16	30	†
C	5,75	10	10	17	30	†

SD = shaft diameter (mm)
DP = diameter of discharge pipe (mm)
† For this release, the hazard radius exceeds 30 m. The release is greater than that normally considered for hazardous area classification and should be avoided.

Table 5.1(b) Hazard radii (R_1) for standard pumps with throttle bushes

Fluid category	LEVEL I		LEVEL II		LEVEL III	
	Hole size (mm) i.e. 0,1SD	R_1 (m)	Hole size (mm) i.e. 0,1DP	R_1 (m)	Hole size (mm) i.e. 0,3DP	R_1 (m)
A	2,5	5	10	16	30	†
B	2,5	5	10	16	30	†
C	2,5	5,5	10	17	30	†

SD = shaft diameter (mm)
DP = diameter of discharge pipe (mm)
† For this release, the hazard radius exceeds 30 m. The release is greater than that normally considered for hazardous area classification and should be avoided.

Table 5.1(c) Hazard radii (R_1) for high integrity pumps

Fluid category	LEVEL I		LEVEL II		LEVEL III	
	Hole size (mm)	R_1 (m)	Hole size (mm) i.e. 0,1DP	R_1 (m)	Hole size (mm) i.e. 0,3DP	R_1 (m)
A	2	4	10	16	30	†
B	2	4	10	16	30	†
C	2	4,5	10	17	30	†

Note: High integrity pumps are taken as pumps fitted with double seals and throttle bush, or better.
DP = diameter of discharge pipe (mm)
† For this release, the hazard radius exceeds 30 m. The release is greater than that normally considered for hazardous area classification and should be avoided.

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 precautions are taken to ensure that draining of flammable liquid is improbable. Suitable precautions which would reduce the process drain to a secondary grade source of release include:

- draining into an intermediate drain pot;
- the use of multiple valves on the drain including at least one valve which springs closed unless held open by the operator.

5.4.2.1 Point sources

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

5.4.2.2 Grade of release

Drains and sample points should be graded according to the expected frequency of use. They should be regarded as at least primary grade release sources if used more than once a day.

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.

5.4.2.3 Determination of hazard radii

The hazard radii may be determined using the tables in Annex C Part 3. However, more accurate hazard radii may be determined using dispersion models which take into account the actual characteristics of process fluid, and the physical characteristics of the drain/sample point.

Table 5.2 shows the maximum hazard radius (R_1) for fluid categories A, B and C for the 'worst case' discharge pressure given in Annex C Part 3. (For fluid categories A and B the maximum dispersion distance is proportional to the pressure.)

5.4.3 Compressors

Piping on compressor systems may be subject to vibration. The distances recommended in this section assume that failure of joints and nozzles due to vibration are considered separately.

5.4.3.1 Point sources and grade of release

Point sources on compressors include seals, glands and joints. However, for the purposes of hazardous area classification the compressor should be regarded as a secondary grade point source.

5.4.3.2 Estimation of leak hole size and determination of hazard radii

It is recommended that the manufacturers' data for seal failure leak rates are used to establish the hazard radii equivalent to a LEVEL I release. In the absence of vendor data, Cox, Lees and Ang *Classification of hazardous areas* suggests an equivalent release hole diameter of 0,12SD for a purged labyrinth seal and 0,053SD for a floating ring seal, where SD is the shaft diameter in mm (see Table C6, Annex C). LEVEL II and III hole sizes are provided based on E&P Forum data. These hole sizes are independent of seal type, and are considered to be larger failure cases than normally considered for hazardous area classification purposes.

Having determined the hole size, the hazard radius R_1 may be determined using Table C9(a) in Annex C Part 3, and C9(b) where R_2 is required. Table 5.3 gives the hazard radii determined by this process for an example case of a compressor with a seal pressure of 100 bar(a) with a shaft diameter of 100 mm for typical gases described by categories G(i) and G(ii).

Table 5.2 Hazard radii (R_1) for drains and liquid sample points

Fluid category	Pressure (Bar(a))	Hazard radius R_1(m)			
		Diameter 2 mm	Diameter 5 mm	Diameter 10 mm	Diameter 20 mm
A	100	5	11	22	†
B	100	4	10	20	†
C	100	5	12	22	†

† For this diameter the radius exceeds 30 m. The size of the potential release is greater than normally considered for hazardous area classification and should be avoided.

Table 5.3 Example calculation for compressors – leak hole size and hazard radius (R_1)

Release frequency	Seal type	Release hole diameter (mm)	Hazard radius R_1 (m)	
			G(i)	G(ii)
LEVEL I	Floating ring	5	4	6
	Purged labyrinth	12	10	13
LEVEL II	N/A	22	†	†
LEVEL III	N/A	70	†	†

N/A Not applicable since hole size is independent of seal type.
† These hole sizes are considered greater than should be used for hazardous area classification purposes. This Code does not therefore give hazard radii for these hole sizes. The user may determine the hazard radii by calculation.

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 a non-hazardous location. The hazardous area around the vent should be based on 5.4.4. 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 5.4.2 and 5.4.4.

5.4.4 Vents to atmosphere

5.4.4.1 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 IP *Calculations in support of IP15* (see also Annex C Part 3). Where any impedance to venting exists (e.g. weather plates) the hazard radius is likely to be greater. If the calculated hazard radius is greater than 30 m, then the size of release is greater than that normally considered for hazardous area classification purposes.

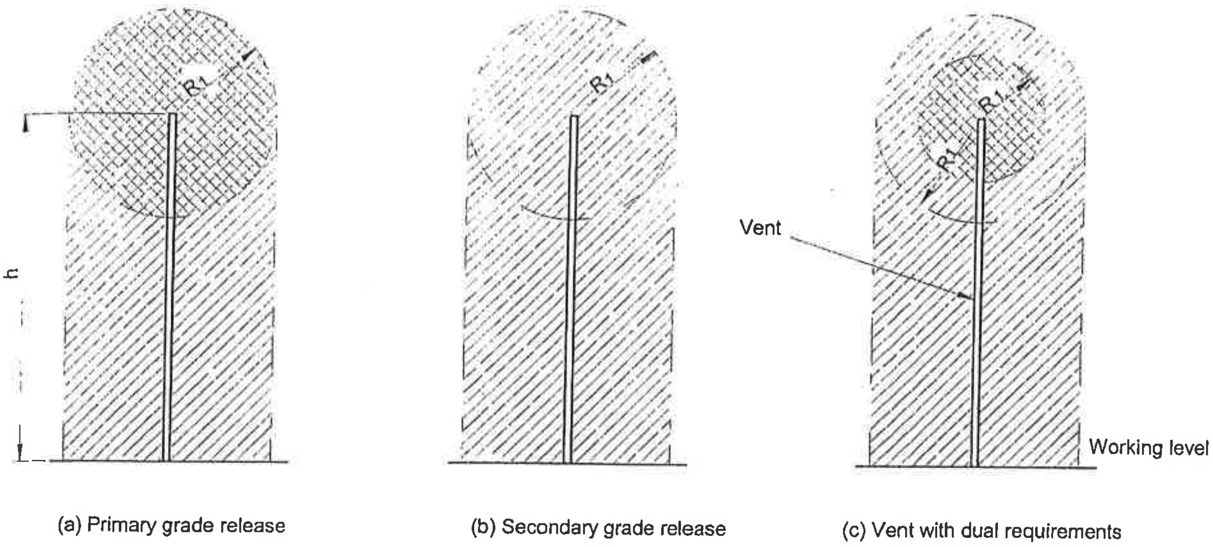
It is assumed that the vents provided are remote from any structure and, if attached, are elevated sufficiently for the dispersion of gases and vapour to the lower flammability limit to be unaffected by structure-induced flow.

5.4.4.2 Tank vents

Freely vented tanks will allow vapour/air mixtures to be released in normal operation. The pressure within the tank rises very little above atmospheric. High level vents from tankage 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. Figure 5.3 together with Table 5.4 give the hazardous area around the vent from the storage of a typical category C fluid.

5.4.4.3 Process vents

Process vents may release mixtures of hydrocarbons undiluted with air, or gas/vapour mixtures with air of any composition. The pressure driving the release will often be much greater than atmospheric. 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 5.5 to be used in conjunction with section 5.5 and the shape factors in Figure 5.6. 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 + 2m from ground or the nearest working level. For specific vent conditions not given in Table 5.5, 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.



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 above the working level should be greater than the possible liquid level in the road tanker to prevent overspill, and in no case less than 5 m above working level.
3. To avoid placing a working platform in a Zone 1 area, h should be measured from any working level within R_1 metres of the vent stack.
4. In (c), R_1 for Zone 1 should be for the primary grade release and R_1 for Zone 2 should be for the secondary grade release.

Figure 5.3 Typical hazardous areas around tank vents

Table 5.4 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) of IP *Calculations in support of IP15*)

5.4.4.4 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 m^3/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 C9(a), Annex C Part 3.

5.4.4.5 Pressure relief valves
Pressure relief valves lifting at their design condition are not covered under hazardous area classification. However, the design of relief valve vents should ensure they are discharged to a safe location. To cover any small leakages that may occur, a Zone 2 of nominal 1 m radius should be placed around the end of the discharge point.

5.4.5 Piping systems

Piping systems designed and constructed to ANSI/ASME B31.3 (ISO 15649) or equivalent and without valves, instruments or significant flanges should not be considered as sources of release.

Table 5.5 Hazard radius (R_1) for process vents

Vapour emission rate (Nm^3/h)	(Average molecular weight 7 g/mol)			(Average molecular weight 48 g/mol)		
	Vent diameter (mm)			Vent diameter (mm)		
	50	100	250	50	100	250
10	2	3	5	3	5	6
100	2	3	5	2	5	6
250	2	3	5	3	6	6
500	2	3	5	4	5	7
1 000	3	4	5	5	5	9
2 500	5	5	6	7	7	13

(Based on Tables 13 and 15 of IP *Calculations in support of IP15*)
Note: The example fluids used here correspond to typical category G(ii) and A products given in Table C7.

Table 5.6 Upper bound hazard radii (R_1) for flanges and valves

Fluid category	Pressure (bar(a))	LEVEL I		LEVEL II		LEVEL III	
		Hole size (mm)	Hazard radius R_1(m)	Hole size (mm)	Hazard radius R_1(m)	Hole size (mm)	Hazard radius R_1(m)
A	100	1	2,5	2	5	6	13
B	100	1	2	2	4	6	12
C	100	1	2,5	2	5	6	14
G(i)	100	1	1	2	1,5	6	5
G(ii)	100	1	1	2	2	6	7

The importance of choosing the correct constructional materials is paramount. In addition, materials for gaskets, jointing compounds, gland packings etc. should be selected, installed and maintained in accordance with the piping material specification.

Small bore piping systems are particularly prone to accidental damage and possible release to atmosphere. Support and bracing of small bore connections used for purging, draining, venting, sampling, pressure gauge connections, injection points, etc., should be considered in accordance with IP/UKOOA *Guidelines for the management, design, installation and maintenance of small bore tubing systems*.

Pipes smaller than 15 mm diameter should be avoided. Where this is not possible, e.g. on instrument systems, tubing with an upstream isolating valve close to the vessel or main line should be provided.

Flanges should be designed and constructed in accordance with UKOOA/IP *Guidelines for the management of the integrity of bolted pipe joints*.

5.4.5.1 Point sources and grades of release

The majority of flange joints are rarely broken, e.g. only during major maintenance work, typically at intervals of about two years or more. Therefore flanges should be considered as sources of secondary grade releases. However, flanges should be regarded as primary grade releases when they are broken during normal operation (e.g. for spade changing) where a release is likely to occur or where factors such as pressure spikes, thermal shock, mechanical stresses and corrosion increase the risk of leak. As a guide, a flange should be considered as a primary grade release when it is broken with a frequency greater than once per week. Where flanges are broken under normal operation, there should be valves adjacent to the flange to minimise any release. Also, if there are a large number of potential leak sources (as a guide, 50 to 100) in close proximity (i.e. where the Zone 2 areas overlap) the combined hazardous area may be regarded as a Zone 1.

Leakage is unlikely on well-maintained, infrequently used valves and these should therefore be regarded as sources of secondary grade release. 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.

For both flanges and valves, the likelihood of release from an individual item is very small and so it may not warrant classification as generating a hazard if a risk-based approach is followed, particularly if it is not operated at high pressures or temperatures. Only when there are a number of possible leak sources close together, e.g. at a plant battery limit, should this area be classified. As a guide, where there are more than 10 leak sources within close proximity (i.e. where their notional Zone 2 areas would overlap) the area should be classified as Zone 2. If isolated potential release sources give a problem in a particular case, consideration should be given to removing the hazard e.g. by welding-up flanges.

5.4.5.2 Determination of hazard radius

Specific hole sizes for flanges and valves are given in Table C6 in Annex C Part 2 for the appropriate LEVEL of release frequency. Table 5.6 gives typical hazard radii (R_1) based on the upper bound hole sizes at a pressure of 100 bar(a), based on the hazard radii in Table C9(a), Annex C Part 3. Actual hazard radii may be determined using the hole sizes in Table C6 for specific system pressures.

5.4.6 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. Thus 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 a properly maintained pressure gauge. 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 a safe location and the hazard radii from any vents, equipment drains or open sumps should be estimated using the appropriate section of this chapter.

5.4.6.1 Grade of release

Pig receivers and launchers are likely to be opened frequently and should normally be regarded as sources of primary grade release. The hazardous area should be classified as Zone 1.

5.4.6.2 Determination of hazard radii

With an interlock system as recommended above, 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, the probability of a release is increased and a prominent warning notice against such a practice should be displayed. Nevertheless it cannot be ruled out, hence there should be an additional Zone 2 area from the equipment door. The hazard radii should be determined; Tables C9(a) (and (b) where appropriate) 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 hazardous area classification. Other precautions such as re-designing the system or strictly controlled work permit procedures are necessary.

5.4.7 Liquid pools due to spillage

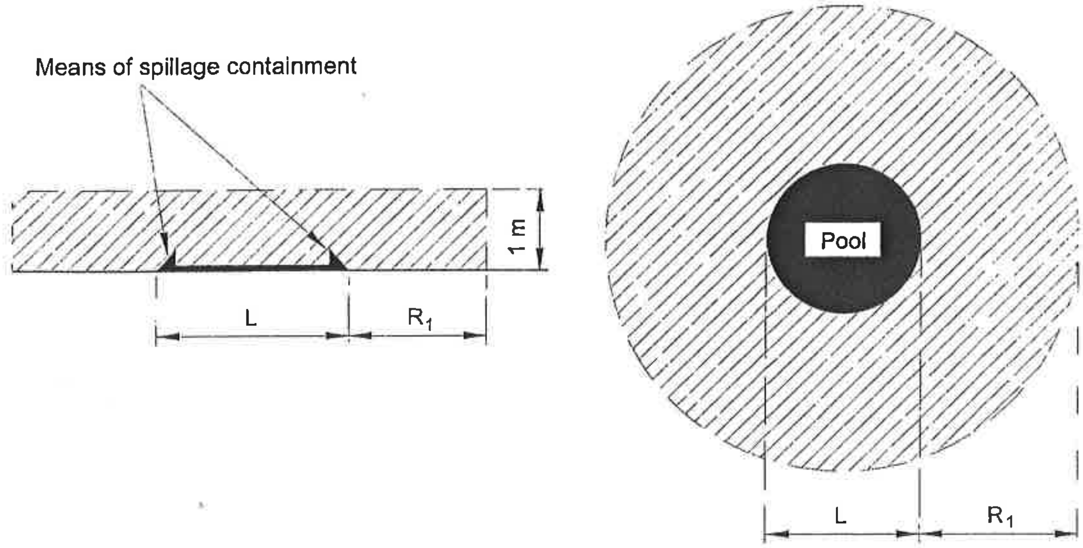
Plant design should minimise liquid spills by providing tundishes or other suitable collecting points for sample points, drains and liquid overflows. However, inadvertent spills can occur, and this may influence the size and area of an overall Zone 2 boundary.

On each facility the positions at which spillage is credible should be identified. If they cannot be eliminated by economically practicable changes to plant design, then the size and position of the likely pool should be estimated. This requires information on the grading of the site, the location of collecting points for drains and the position of bunds or collecting walls.

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 Table 5.7 and Figure 5.4. These distances are supported by calculations in IP *Calculations in support of IP15* and are applicable to category C liquids for temperatures up to 50°C. For gases or 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. The exact extent should be determined by calculation.

Any resultant liquid pool should be considered as a category C liquid. This is because any vapour will already have been released and therefore the liquid pool cannot be boiling.



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. However, it is recommended that this height is verified by calculation.

Figure 5.4 Liquid pool due to spillage

Table 5.7 Hazardous area from liquid pool

Equivalent diameter of pool, L (m)	**Hazard radius R_1 (m)**
Less than 5	3
5 to less than 10	7,5
10 or greater	15

(Table 17 of IP *Calculations in support of IP15)*

5.4.8 Sumps, interceptors and separators

For the purposes of this Code a sump means a vessel, 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.

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 5.4.4, 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.

In contrast, interceptors and separators are vessels 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.

5.4.8.1 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.

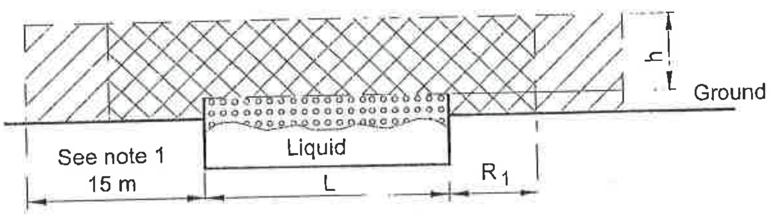
Where there is a possibility that, in normal operation, appreciable quantities of flammable gas or materials in fluid categories A or B can enter, a degasser installed upstream of the sump or a sealed but vented sump is recommended. Otherwise the system should be designed so that normally only oil in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

5.4.8.2 Determination of hazardous area

The typical layout of sumps, interceptors and separators is shown in Figure 5.5. 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 5.7 for the sump equivalent diameter where it can be assumed that entry of category C fluids only (below 50°C) 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 that category A or B material 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. The 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 5.7.
3. 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. However, it is recommended that this height is verified by calculations.
4. For a secondary grade release, the areas shown as Zones 0 and 1 would be Zones 1 and 2 respectively.

Figure 5.5 Open sump – zoning for primary grade release

5.4.9 Pits or depressions

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

5.4.10 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 5.5 assuming a vent rate of not more than 10 m^3/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 using dimensions given in Table 5.5 consistent with the higher vapour emission rate.

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

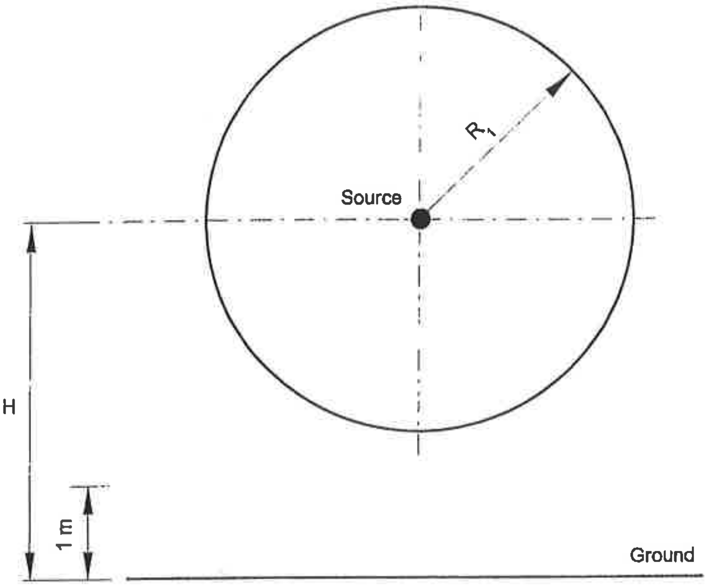
Note: Drainage systems should be designed with consideration given to the principles detailed in IP *Environmental guidelines for petroleum distribution installations*. In the case of filling stations, the design should be in accordance with APEA/IP *Design, construction, modification, maintenance and decommissioning of filling stations*.

5.5 SHAPE FACTORS AND HAZARD RADII FOR PRESSURISED RELEASES

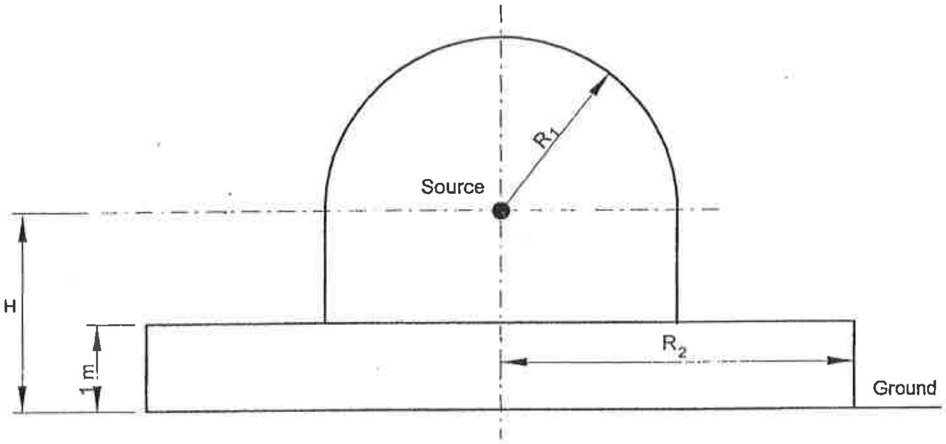
The relationship between the hazard radius R_1 (as determined in the preceding section) and the full three-dimensional envelope of the hazardous area is determined using Figure 5.6. The shape factor depends upon the height and orientation of the release and the hazard radius. The key features are:

- 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.

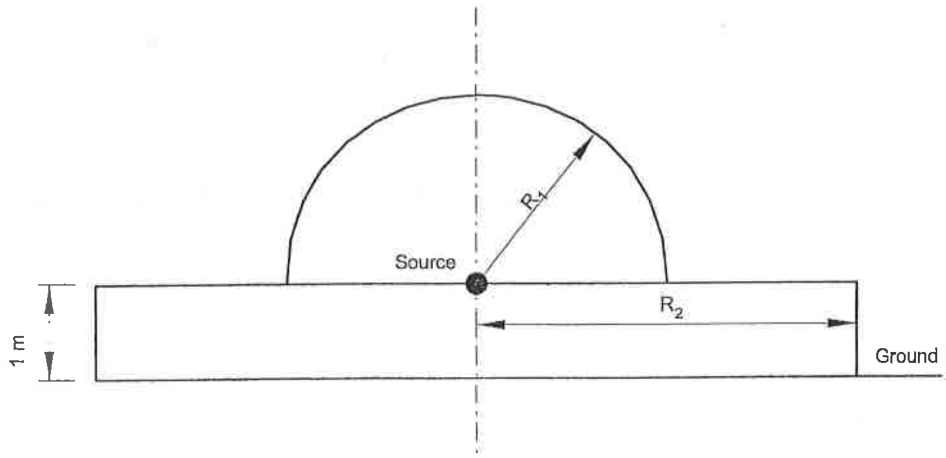
The ground effect radius R_2 can be determined using Table C9(b) (Annex C). The ratio R_2/R_1 decreases as release pressure increases due to improved mixing.



(a) Releases where H > R_1 + 1 m



(b) Releases where 1 m < H > R_1+1 m



(c) Releases where H ≤ 1 m

Figure 5.6 Shape factors for pressurised releases

6

EFFECT OF VENTILATION ON HAZARDOUS AREA CLASSIFICATION

6.1 INTRODUCTION

Ventilation comprises the movement of air within and through a volume to achieve the introduction of fresh[7] 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 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.

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'.

Whatever the situation, the ventilation of a confined space is typically quantified by a single parameter - the number of air volume changes per hour. 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 (restricted, adequate or inadequate) 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 different types and degrees of ventilation are described below under the sections Open Areas, Enclosed Areas and Sheltered or Obstructed Areas which cover the subdivisions of 'outdoor' and 'indoor' ventilation used in other Codes. Figure 6.1 may be used to determine how to assess the degree of ventilation for any given situation.

[7] 'Fresh' implies free from flammable contaminants.

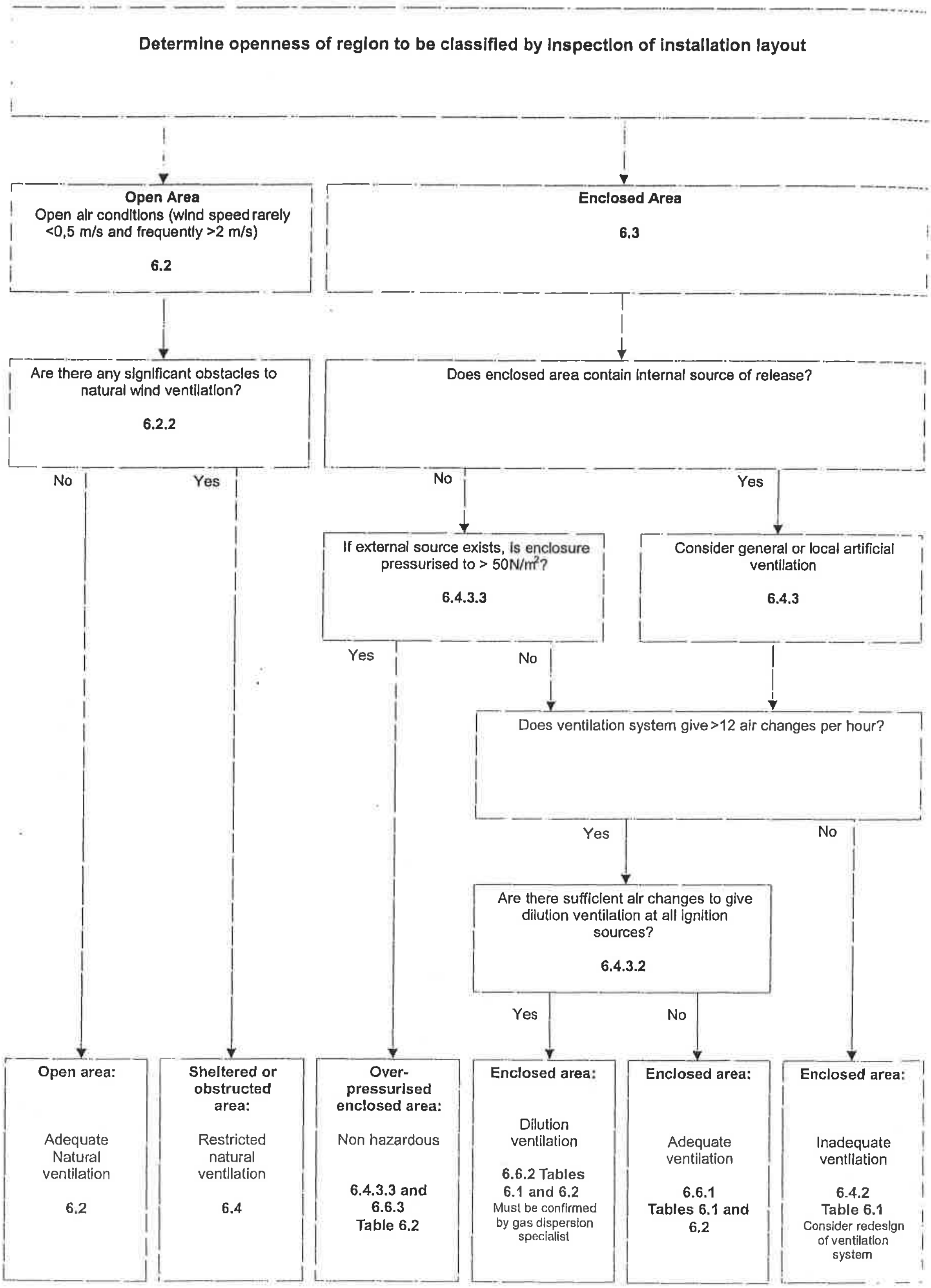


Figure 6.1 Procedure for assessing type and degree of ventilation

6.2 OPEN AREAS

An open area is defined as an area that is outdoors without stagnant regions, where vapour is rapidly dispersed by wind and natural convection. Typically, air velocities will rarely be less than 0,5 m/s and will frequently be above 2 m/s. Obstructions such as dense trees, cliffs or other buildings preclude an area being considered 'open' unless it can be shown that wind velocities meet the criteria within that particular area.

The hazardous area classification exercise is simplified if all continuous and primary grade sources of release can be located within open areas. However, obstructed or partially obstructed situations cannot always be avoided in the layout of facilities, particularly where there is a space limitation. The advantages of onsidering hazardous area classification at an early stage of plant design are covered in section 1.5.

6.2.1 Natural ventilation

Natural ventilation is caused by wind or convection effects. In respect of 'natural ventilation', IEC 60079-10 cites:

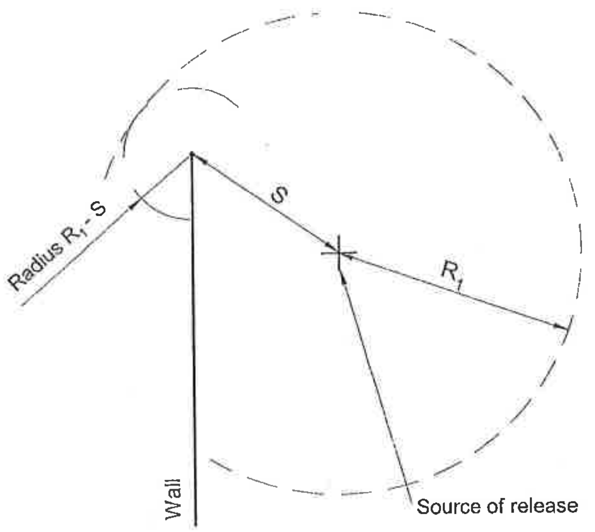
(a) Open air situations typical of those in the chemical and petroleum industries which comprise open structures, pipe racks, pump bays etc.

(b) Open buildings which, having regard to the relative density of the gases and/or vapour involved, have openings in the walls and/or roof so dimensioned and located that the ventilation inside the building for the purpose of hazardous area classification can be regarded as equivalent to that in an open air situation.

Where a facility is classified as an 'open area' i.e. with natural ventilation, the hazardous area classification according to Chapters 3, 4 and 5 applies without further ventilation considerations.

6.2.2 Obstacles to free air movement

IEC 60079-10 recognises that obstacles may impede natural ventilation, 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 6.2.3.



Notes:
1. R_1 is the hazard radius obtained from Chapter 5.
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 6.2 Extent of hazardous area around wall producing sheltered area

6.2.3 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 imperforate firewall. 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 6.2. It has no formal technical basis, and its adoption reflects an engineering judgement or assessment.

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 (as in Figures 3.1 and 3.2), 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 (Chapter 8) and numerous cases in the compact circumstances of an offshore platform.

6.2.4 Buildings adjacent to open hazardous areas

A building may contain no internal sources of release, but have openings directly into an adjacent open classified area. The building should be assigned a zone classification of a higher severity than the adjacent area if it is possible for any leakage to persist in the building (see Table 6.2). If the openings are not too large, over-pressurisation ventilation may be a feasible option, allowing the building to remain unclassified (see 6.4.3.3).

6.3 SHELTERED OR OBSTRUCTED AREAS

A sheltered or obstructed area is defined as an area within or adjoining an open area (which may include a partially open building or structure) where, owing to obstruction, natural ventilation is restricted and less than in a true open area. **Where the obstruction is such that natural ventilation is severely restricted, it should be classified as an enclosed area (see 6.4).**

The hazardous area classification exercise is simplified if all continuous and primary grade sources of release can be located within open areas. There is, however, a variety of naturally ventilated situations where the assumption of minimum wind speeds given in IEC 60079-10 for an open area (i.e. wind speed rarely less than 0,5 m/s and frequently above 2 m/s) may not apply, but air change rates will be much greater than those found inside enclosed areas or even well-ventilated buildings. It should be noted that air movement may be funnelled selectively in particular directions due to the layout of a facility. Typical examples include: closely-spaced pipe racks within open air plant; structures having a roof but only partial walls (compressor houses, road tanker loading areas); open air plant where air movement is obstructed by large tanks or walls; tank bunds and below-grade areas such as pits and pipe trenches. In such locations, neither the classification by direct example (Chapters 3 and 4), nor the classification by point source method (Chapter 5) may be appropriate (although some of the direct examples do include sheltered areas). With partial buildings, wind-flows past the building will create areas of high turbulence and rapid dispersion of releases, particularly around the edges of the building and above roof level. A judgement will have to be made, based on the particular situation, but generally such an area with restricted natural ventilation should be assigned a zone classification of a severity of one step higher than if it were a fully open area e.g. a below-grade pit in a Zone 2 area would become Zone 1. 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. With no dilution, 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 5. A reduction in the hazard radius may be estimated based on the anticipated level of dilution of the release within the building.

The extent of the hazardous areas around sources of gas at high pressure in the open air is not so affected by wind speed because releases at high pressure induce their own mixing. The extent of the hazardous area around a release in a sheltered area will be of a similar size to that in the free atmosphere provided that there is a sufficient supply of air to remove the diluted mixture from the neighbourhood of the release and there are no directly enclosing surfaces to encourage recirculating motions or retain the diluted mixture. Provided the surrounding atmosphere does not contain concentrations above 20% of the lower flammable limit, the hazardous area around high pressure gaseous releases will not be greater than twice the hazardous area in free air. If any mixture accumulation does occur, however, then the hazardous area may be increased through the reentrainment of gas mixture along with the air. Releases from low pressure or evaporation sources are dependent upon the ventilation flow to induce mixing as well as transport. Under these conditions, precautions need to be taken if the vapour or gases are denser than air (categories A, B, C) or lighter than air (categories G(i), G(ii)) to ensure that there is no scope for vapour trapping at floor/roof level respectively because the density stratification can seriously impede local mixing rates.

The use of a wall to restrict the extent of a hazardous area in a particular direction and so increase the effective distance between a source of release and a source of ignition is covered in 6.2.3.

6.4 ENCLOSED AREAS

An enclosed area is any building, room or enclosed space within which, in the absence of artificial ventilation, the air movement will be limited and any flammable atmosphere will not be dispersed naturally.

This section applies to buildings, rooms or enclosed spaces where there are potential sources of release of flammable vapour or gases, and natural ventilation does not provide a minimum of 12 air changes/hr throughout the space. Normally, artificial ventilation (i.e. mechanical ventilation) should be provided in order to dilute and remove flammable gases or vapour released within the building. In most cases there will also be openings in the walls, through which flammable gases 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 ıfely 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 are detected. Special precautions are also necessary if the ventilation system fails e.g. all unsuitably certified electrical equipment may be automatically isolated (see 6.6).

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

For further discussion of the effects of ventilation in enclosed areas containing sources of release, see Annex D.

6.4.1 Adequate ventilation

Adequate ventilation is a reference condition used extensively, defined in a number of Codes worldwide and particularly offshore as 'the achievement of a uniform ventilation rate of at least 12 air changes/hr, with no stagnant area'. As such it will usually have air velocities lower than in an open area. A ventilation rate of 12 air changes/hr is likely to be sufficient, if there are no stagnant regions, to ensure that flammable atmospheres arising from an improbable short term release of gas or vapour will not persist for longer than about ten minutes. The extent of the flammable atmosphere that will exist during the release from a low momentum source can be estimated using the equations given in IEC 60079-10 or by specialist calculations, as appropriate.

The objective of adequate ventilation is to ensure that a building containing secondary grade release sources can be properly classified as Zone 2. In large buildings it may be possible to classify some parts as non-hazardous, while other parts are Zone 2. Continuous or primary grade releases should not be discharged internally, 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.

Although adequate ventilation is defined by the 12 air changes/hr criterion it must be remembered that the hazardous area that will be formed is also dependent on the size of the release and the building volume directly affected by the release. In small buildings, 12 air changes/hr can often be achieved simply by providing sufficient ventilation openings, at high and low levels, and in more than one wall of the building. With larger buildings or structures artificial ventilation is often needed to achieve 12 air changes/hr, and where this is provided, careful design and balancing of air inlet or extraction points is needed to ensure no stagnant areas exist. Measurements made after the ventilation system is installed may be needed to check for stagnant areas, and the tests may need to be carried out both on an empty building, and after large items of plant, or stocks of products have been introduced. With very large buildings it may become impracticable to provide artificial ventilation to achieve 12 air changes/hr; it is certainly inefficient to blow very large amounts of air around constantly, simply to deal with a small secondary grade release that may occur quite infrequently. An alternative approach is needed, and the best solution will depend on the number and location of the secondary grade releases occurring.

Localised exhaust ventilation (LEV see 6.4.3.1), 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.

If hazardous concentrations are created within a building then there is the potential to produce a hazardous area outside the building. An extreme worst case scenario is for the whole building contents 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 20% of LFL be avoided within the bulk atmosphere in the building.

In a building with a well-mixed atmosphere into which a constant flow of flammable gas 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. The minimum ventilation flow rate required to ensure that concentrations of above 20% of the LFL are not produced can also be estimated by similar methods from the size of the release and the LFL of the gas. The recommended design target is to ensure that the average concentration of flammable atmosphere within the building does not exceed 20% of the LFL in the event of a prolonged release from a secondary grade source. The zoning external to the building 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 C9(a) and may extend to R_2 in the event of interaction with the ground. In cases where the release impinges internally within the building, specialist advice should be sought because the outcome may be building, 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 building, unless the opening is within the local zone immediately surrounding the release location. However, it is recommended that specialist advice is sought to confirm this is the case.

Ventilation rates greatly above the target 12 air changes/hr are likely to cause discomfort to operators dressed for indoor conditions. A building sized 1 000 m^3 and having a ventilation design that encouraged mixing of the release, rather than displacement, would experience a problem in that significant regions of flammable mixture may arise for releases of about 0,03 kg/s and larger for category A, B and G(i) fluids and about 0,01 kg/s and larger for category G(ii) fluids. If foreseeable secondary grade sources of release exceed these values, the design of the whole installation should be reviewed. For a G(i) fluid this release rate corresponds approximately to a 5 mm diameter hole in a line at 10 bar(a); the corresponding figure for a G(ii) fluid is a 5 mm diameter hole in a line at 50 bar(a). Leaks of this size should be detected promptly. Category C fluids will generate localised Zone 1 areas around open liquid surfaces, and a larger Zone 2 is often assigned as well, but it may not be necessary to classify the whole building as Zone 2, especially if there are no sources of release present in the upper parts of the enclosure.

6.4.2 Inadequate ventilation

Where an enclosed area is not provided with artificial ventilation, air movement is likely to vary substantially, and no general assumptions can be made about the mixing of a release. 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 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. These require, in addition to the controls on entry, the provision of arrangements for dealing with emergencies including rescue from a confined space and equipment to enable resuscitation. If ventilation cannot be improved, the use of flammable gas detectors should be considered (see section 8.3). 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.

6.4.3 Artificial ventilation types

The assumption of good mixing is likely to be reasonable for releases from pressurised sources, which entrain air into a jet. For releases with low momentum, very careful design of the air extract points may be needed to ensure good mixing is achieved. Measurement of localised air movement within the building after all equipment is installed may be needed.

Artificial ventilation may be applied to part of an area i.e. local artificial ventilation, or to the whole area i.e. general artificial ventilation. Over-pressurisation for example may be applied either locally or generally.

If extractive ventilation is used, the outlet should normally be at high level, 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. Where ventilation is achieved by blowing fresh air into the building, diluted vapour will escape through all the openings. The flows are likely to be influenced by wind and convective forces. In any case, provided the atmosphere inside the building does not reach the LFL and the hazardous areas around the source of the release do not reach any of the openings, this should not lead to the formation of a hazardous area around the outside as a result of release sources inside.

Where category B or C fluids can be released, these could flow in liquid form towards any openings out of the enclosed area. Suitable drains and sills are needed to prevent the flow into non-hazardous areas. Normal doors, including fire doors are not likely to prevent such flow.

6.4.3.1 Local exhaust ventilation

LEV is a recommended means of controlling the release of flammable gases, where there are a small number of readily identifiable primary or secondary grade release sources. This is a common situation, including for example: a routine drum filling operation; a sampling point that is regularly used; around equipment that needs regular opening for cleaning.

LEV systems can only effectively capture released gases and vapour over quite short distances, determined by the inlet velocity and correct design of the inlet. Factors that need to be considered when the system is designed include: the rate of release; the momentum of the gas flow; any air movement due to general ventilation nearby; and the position of the operator. Capture velocities in the range 0,5-1,0 m/s are typically used for releases at low velocity into moderately still air. The concept of air change rates does not apply to the design of LEV.

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 unclassified, even though primary grade releases are present. More commonly it will be 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 secondary grade 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. Some means to ensure the LEV is always operating when it is needed is required.

6.4.3.2 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 LEV. A forced draught fan may be used in conjunction with an extractor fan. This arrangement has been used inside the acoustic hoods 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 ignition cannot occur. 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. See section 8.2.5 for further information on gas turbine drives.

6.4.3.3 Over-pressurisation

This term is used to describe a system of ventilation for a room or other enclosed area, and also a protective method for a single item of electrical equipment.

Where it is applied to a room, 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. Where it is applied to a single item of equipment, or a group of equipment items inside a single well-sealed cabinet, it is designed to prevent ingress of flammable gas, and hence prevent the formation of a flammable atmosphere inside. This technique may allow electrical equipment that is unobtainable in an ignition-protected form to be installed in a hazardous area.

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 N/m^2 (5 mm WG) is maintained between the enclosed area and any hazardous area. Warning, preferably audible and visual, should be provided for loss of pressure differential. 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 hazardous area.

Section 6.6.3 gives advice on other actions that should follow any failure of the ventilation system. As air locks may allow pressure differentials to be briefly lost, some delay on the activation of any shut down of electrical equipment may be considered. Such a delay following an audible alarm should not normally exceed 30 seconds.

Detailed requirements for the application of pressurisation to electrical apparatus are described in BS EN 50016. This distinguishes between static pressurisation, where the inside of the apparatus is held above the pressure of the surroundings, pressurisation with leakage compensation, and pressurisation with continuous flow of the protective gas. It requires the use of an inert gas for static pressurisation. The standard sets requirements for equipment to be used in Zone 1. A variation of this, which will specify less rigorous requirements for equipment that will only be used in Zone 2, is under active development by the international standards bodies.

6.4.3.4 Air intakes and exhausts

The location of air intakes (including intakes to: heating and ventilating systems; combustion plant; air compressors for instrument, process or breathing air; gas turbines) should be chosen to avoid transfer of a flammable atmosphere to a source of ignition. Air intakes should be located as far as is reasonably practicable from the boundary of any hazardous area. The location should be selected after considering the effects of:

— Air contamination with flammable material.
— Any additional safety systems, e.g. equipment trips on detection of flammable material in the air intakes.

The exhaust outlets of heating or ventilation systems serving installations classified as hazardous should themselves be classified appropriately.

6.5 EFFECT OF VENTILATION ON ZONE CLASSIFICATION OF ENCLOSED AREAS

Section 6.4.3 considered the objective of providing artificial ventilation to enclosed areas i.e. those confined volumes in which natural ventilation provides less than 12 air changes per hour throughout the whole volume. The consequences of releases in these enclosures were briefly discussed. The purpose of this section is to define the zone classification that should be applied within such enclosed areas. The classification depends on the degree of ventilation and the grade and location of the release. Table 6.1 considers the zone classification within enclosures containing sources of release within the volume, whilst Table 6.2 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. Figure 6.1 provides a flow chart that defines when the different types of ventilation apply.

Attention is drawn to the notes to Table 6.1, in particular to note 1. Continuous grade releases in enclosures are not acceptable practice unless small with local artificial or dilution ventilation, and primary grade releases should be avoided as far as is practicable or made as small as possible. This zoning would be applied to the whole of the enclosure, with the exception of the situation in note 5, in which the zone created by a release is small in relation to the size of the building, and sufficient ventilation is present to prevent accumulation above 20% of the LFL of the bulk atmosphere. Under these conditions, local hazardous area classification may be allowed. The situation when there are no internal sources is specified in Table 6.2. The notes to Table 6.2 explain the reasoning for the different zone classifications.

6.6 EFFECT OF LOSS OF VENTILATION ON HAZARDOUS AREA CLASSIFICATION OF AN ENCLOSED AREA

In enclosed areas with artificial ventilation, the classification guidance given in Tables 6.1 and 6.2 is based on the specified ventilation operating effectively. If this ventilation were to fail the classification situation would revert to that of 'inadequate' ventilation in these tables, hence it is necessary to consider what measures should be taken to prevent this occurring, or what additional back-up systems are needed. The ventilation system should be designed to be reliable, with, for example, automatic start-up of a standby fan in the event of primary fan failure. Power for the main and standby fans should not be from a common supply. However, whilst total ventilation failure is unlikely, it is foreseeable and the actions required are considered below.

6.6.1 Provisions for loss of adequate ventilation

An enclosed area classified as Zone 2 by virtue of 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 only suitable for Zone 2. Nevertheless, there should be an audio-visual 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. Fixed gas detectors should normally be provided. Equipment not suitable for Zone 1 should be electrically isolated immediately if gas is detected, or the source of the

Table 6.1 Enclosed area with an internal source of release - effect of ventilation on zone classification within enclosed area

Grade of internal release source	Ventilation			
	Inadequate[2]	**Adequate[3]**	**Dilution**	**Over-pressure**
Continuous	Zone 0[1]	Zone 0[1]	Non-hazardous	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	Zone 0[1]	Zone 1[1]	Non-hazardous	
Secondary	Zone 1	Zone 2	Non-hazardous	

Notes:
1. Location of continuous or primary grade sources within an enclosed area is not acceptable practice and should be avoided.
2. With inadequate ventilation, for a source within an enclosed area the **external** zone classification will be: for continuous grade release: Zone 0; for a primary grade release: Zone 1; for a secondary grade release: Zone 2.
3. With adequate ventilation, for a source within an enclosed area the **external** zone classification will be the same as that of the enclosed area itself.
4. An area within a larger enclosure subject to local artificial ventilation, i.e. by extractor fan, should be classified according to the local ventilation rate in that local area, i.e. either dilution or adequate depending on which is met.
5. 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 whole enclosure. There would still be a local Zone 1 or 2 around the source and the extent of this zone should be greater than in the open air, typically about twice the dimensions.

Table 6.2 Enclosed area with no internal source of release but adjacent to an external hazardous area - effect of ventilation on zone classification within enclosed area

Grade of external release source	Ventilation			
	Inadequate	**Adequate**	**Dilution**	**Over-pressure[1]**
Continuous, i.e. Zone 0	Zone 0[1]	Zone 0[1]	Not applicable	Non-hazardous with source outside enclosed area, but see failure mode (6.6.3)
Primary, i.e. Zone 1	Zone 0[1]	Zone 1[1]	Not applicable	
Secondary, i.e. Zone 2	Zone 1[2]	Zone 2	Not applicable	

Notes:
1. Location of an enclosed area without over-pressure protection in a Zone 0 or 1 is not acceptable practice and should be avoided.
2. An inadequately ventilated enclosed area within an external Zone 2 and not containing a source of release may sometimes be classified as Zone 2 when the only aperture is a self-closing vapour-tight door. The frequency of door opening and the ventilation level must be considered to assess the risk.

release stopped if more practicable. A master switch is normally provided to facilitate the electrical isolation when necessary.

6.6.2 Provisions for loss of dilution ventilation

An enclosed area classified as non-hazardous by virtue of dilution ventilation normally contains primary grade sources of release and may contain small continuous grade release sources. 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 audio-visual alarm should be provided.

6.6.3 Provision for loss of over-pressure ventilation

An enclosed area with over-pressure ventilation is separated by vapour-tight barriers from adjacent hazardous areas and contains no continuous or primary grade sources of release. On loss of over-pressure ventilation, therefore, the development of flammable atmospheres within the area is likely to be slow and it is not normally necessary immediately to isolate electrical equipment. Nevertheless, there should be an audio-visual alarm to indicate ventilation loss and a written procedure to cover the electrical isolation that would be required if the ventilation loss persisted. A master switch is normally provided to facilitate the electrical isolation when necessary. 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 immediately if gas is detected.

6.6.4 Reliability, location and choice of fixed gas detectors

The need for fixed gas detection to monitor, alarm and, as appropriate, initiate shutdown has been stated in the preceding measures for protection against loss of artificial ventilation by dilution ventilation or pressurisation. The comments in section 8.3 are pertinent. In view of the difficulties with regard to the accuracy of some gas detector types, specialist guidance should be sought in respect of their selection and location, and also the choice of alarm settings (in some cases these may be as low as 10% LFL for audible alarm, with a second trigger, say, at 50% for shutdown). It may well be necessary, to avoid false indications and possible inadvertent shutdown, to apply coincidence voting arrangements where monitoring is carried out, employing three detectors in which operation of any detector at low level will sound an alarm and where coincidence operation of two out of the three at high level will activate the shutdown. It should be noted that gas detectors are not intrinsically safe and must be certified for the groups of gases in which they will operate. Both gas group and temperature class must be specified (see Chapter 7).

7

SELECTION, INSTALLATION, MAINTENANCE AND USE OF EQUIPMENT IN HAZARDOUS AREAS

7.1 INTRODUCTION

Once the hazardous area classification of a plant is determined, it should be used as the basis for selecting suitable equipment. To reach the intended level of safety, equipment must then be installed correctly, operated within its design envelope and maintained adequately. Further information on these aspects is contained in this chapter. Electrical equipment specially constructed to prevent it igniting a flammable atmosphere is referred to as protected equipment throughout the rest of this chapter.

Traditionally, hazardous area classification has been used as a tool to specify what types of fixed electrical equipment may be used at different locations within a hazardous installation. As a simple extension to this, hazardous area classification has sometimes been used as a guide to specifying locations where special control is needed over transient activities which create an ignition hazard, such as the maintenance or movement of vehicles (see Chapter 8).

As a general policy, electrical equipment should not be located in a hazardous area if it is possible to place it in a non-hazardous area, nor should it be placed in Zone 1 if it can be placed in Zone 2.

7.2 STANDARDS

Over many years standards for electrical equipment for use in hazardous areas have been developed and refined. Increasingly these standards have been agreed at European or international level. In various countries, such protected electrical equipment has been tested and certified by independent test houses, although different countries had slightly different tests. A driving force behind the standardisation work has been a desire by manufacturers to have equipment testified and certified only once to a common basis. Most hazardous installations will contain older electrical equipment designed and constructed to earlier standards which can remain in operation providing it is properly operated and maintained and test certificates remain valid.

7.2.1 International standards on selection and maintenance

In addition to standards on the design of protected equipment, there are also standards on the selection of equipment (BS EN 60079-14), inspection and maintenance (BS EN 60079-17) and the repair and overhaul of protected equipment (BS IEC 60079-19). This chapter does not attempt to repeat the content of all these standards, but to outline the principles, and to draw attention to aspects which relate particularly to hazardous installations. See Table 7.1 and Annex F.

Table 7.1 Standards relevant to electrical equipment categories for use in hazardous areas

Type of protection and marking letter	Current British standard and date BS EN	Current IEC standard and date	Intended for use in zones:	Earlier standards approximately equivalent BS
General requirements	60079/0 2004	60079/0 2000	Used in combination with other standards	50014 & 5501/1
Oil filled 'o'	50015 1998	60079/6 1995	1	5501/2
Pressurised 'p'	60079/2 2004	60079/2 2001	1	50016 & 5501/3
Powder filled 'q'	50017 1998	60079/5 1997	1	5501/4
Flameproof 'd'	60079/1 2004	60079/1 2003	1	50018 & 5501/5 4683/2
Increased safety 'e'	60079/7 2003	60079/7 1990	1	50019 & 5501/6 4683/4
Intrinsically safe 'ia' and 'ib'	60079/25 2004	60079/11 1999	'ia' 0 'ib' 1	50020 & 5501/7
Non incendive 'n'	60079/15 2003	60079/14 1996 60079/15 2005	2	50021
Encapsulated 'm'	60079/18 2004	60079/18 1992	1	50028 & 5501/8
Data on properties of flammable gases	50014, PD IEC 60079/20 contains data on flammable gases and vapours	TR60079/20 1996	-	BS 5345 Part 1

Notes:
1. Equipment type of protection 'special protection'/marking letter 's' is no longer applicable; however, ATEX equipment catergory II 1 G is appropriate, i.e. meeting the requirements of IEC 60079-26 or EN 50284.
2. Further guidance on the types of protection is provided in Annex F.
3. Dates refer to the last full edition. In many cases amendments have been issued subsequently. For more details see Annex F.

7.2.2 The type and grouping of equipment

European requirements (ATEX Directives) for electrical apparatus for hazardous areas distinguish between:

Group I — Electrical equipment for mines susceptible to firedamp (methane).

Group II — Electrical equipment for places other than mines. Group II is subdivided into IIG for use where gases or vapour may be present and IID for use where dusts may be present.

Some types of non-electrical equipment may also create an ignition hazard and EU legislation (the ATEX Directives) establishes very similar requirements on electrical and non-electrical equipment sold specifically as suitable for use in hazardous areas. Group I and Group IID apparatus are not considered in this Code.

7.3 SELECTION OF GROUP II APPARATUS EQUIPMENT

Correct selection of equipment requires three factors to be taken into account. These are:

- Zone in which the equipment will be used.
- Sensitivity to ignition of the gases or vapour likely to be present, expressed as a gas group.
- Sensitivity of the gases or vapour present to ignition by hot surfaces, expressed as a temperature classification.

There is no simple link between ignition sensitivity and ignition temperature. As an example, hydrogen is extremely sensitive to ignition by sparks, but has a high ignition temperature.

Some types of non-electrical equipment may also create an ignition hazard, and the ATEX Directives establish very similar requirements on electrical and non-electrical equipment sold specifically as suitable for use in hazardous areas.

The ATEX Directives establish a framework of essential safety requirements, and the existing electrical standards are being adjusted to comply with these. In addition there will be mutual recognition of test certificates and compulsory standard markings, so that a certificate issued by one test house under the ATEX procedures will be valid anywhere within the European Union. Users should be able to establish from the marking where any item of equipment may be safely installed.

7.4 TYPE OF PROTECTION

Various concepts are used to build protected electrical equipment and these are set out in different standards. As a simple example, oil-filled apparatus prevents sparks igniting a flammable atmosphere by submerging contactors in oil, while intrinsically safe apparatus is designed to limit the energy within the system so that even under fault conditions a spark cannot occur (see Table 7.1).

7.5 SELECTION ACCORDING TO ZONE CLASSIFICATION

Equipment built to different protection concept standards may not offer the same degree of safety. This is recognised in the older standards by specifying that some protected equipment is suitable only for use in Zone 2, while other types may be used in Zones 1 and 2, and equipment offering the highest degree of protection may be used in Zones 0, 1 or 2. Under the ATEX Directives, these differences are recognised by describing three categories of equipment:

Category 1: equipment providing the most secure level of protection and suitable for use in Zones 0, 1 or 2
Category 2: equipment suitable for use in Zones 1 or 2
Category 3: equipment suitable for use in Zone 2

A parallel series of standards for non-electrical equipment are being prepared by the European standards organisation CEN, as EN 13463. These will address the risks associated with possibilities such as overheating, e.g. frictional heating, and impact sparks arising from rotating equipment, and describe different protection concepts.

7.6 APPARATUS SUB-GROUPS

Not all flammable fluids are equally easy to ignite, and the different properties are usually measured as minimum ignition temperature, and minimum ignition energy. Electrical equipment standards recognise these differences by subdividing the equipment categories into subgroups, and temperature classes. The three subgroups reflect different minimum ignition energies. Only hydrogen and acetylene appear in subgroup IIC as the gases most sensitive to ignition. Table 7.2 lists the subgroup applicable to common petroleum products. These subgroups apply only to equipment made to protection concepts 'i', 'd', 's' and 'p'.

This sub-grouping is determined by certifying test bodies in accordance with the grouping of gases and vapour as prescribed in IEC 60079-12.

Reference may also be made to IEC 60079-0, IEC 60079-10 and BS EN 50014.

(a) For other types of protection than 'i', 'd', 's' and 'p' above, the protective techniques apply equally to all gases and vapour, subject only to the further aspect of temperature classification as in 7.7. Apparatus sub-grouping for these other types of protection is not therefore applicable. There should, however, be awareness that these are 'multiple' types of protection in which, increasingly, electrical apparatus may incorporate more than one type of protection.

(b) The apparatus sub-groups for a large number of gases and vapours have been listed in IEC 60079-20. A shorter list for those most commonly handled in the petroleum, petrochemical and gas sectors, including methane in surface handling and hydrogen, is given in Table 7.2. The recommendations in section 2.5 where mixtures of gases are involved should be consulted.

Note: Apparatus certified in the UK to the earlier flameproof BS 229 and BS 4683-2 standards and to BS 1259 (intrinsic safety) are also grouped according to the experimental data for limiting safe gaps or igniting surfaces (see IEC 60079-14) and they remain operationally acceptable.

(c) The effects of an internal release, if differing in composition from the external flammable atmosphere, should be taken into account when selecting the apparatus grouping (see also 7.10 and Annex F).

Table 7.2 Recommended apparatus sub-group and temperature class for some flammable fluids

Flammable fluid	Apparatus sub-group	Temperature (T) class+ of suitable equipment
Hydrogen	IIC	T1
Methane	IIA	T1
Ethane	IIA	T1
Propane	IIA	T1
LPG*	IIA†	T2
Ethylene	IIB	T2
Acetylene	IIC	T2
Benzene	IIA	T1
Toluene	IIA	T1
Xylene	IIA	T1
Gasoline*	IIA	T3
Naphtha*	IIA	T3
White spirit*	IIA	T3
Kerosine*	IIA	T3
Gas oil*	IIA	T2
Residual products*	IIA	T2
Crude oil*	IIA	T3

* Where the flammable fluid is a mixture, the apparatus sub-group and temperature class relate to the most onerous constituent of the mixture. The apparatus sub-group and temperature class are therefore only typical in these cases and should be verified for individual mixtures using laboratory checks.

\+ Based on ignition temperature of the substance in accordance with IEC 60079-14 and determined by IEC 60079-4.

† If LPG contains significant quantities of 2-butene then the appropriate apparatus group is IIB.

A fuller list of materials and equipment sub-groups may be found in IEC 60079-0.

(d) As the sub-grouping becomes more severe in going from IIA to IIB to IIC, sub-group B apparatus may be used in place of sub-group A apparatus and sub-group C can be used in place of apparatus for both sub-groups A and B, but the converse is not true. This will be seen to be particularly relevant in respect of mobile and portable type apparatus that will be used in a variety of locations (see 7.15).

7.7 TEMPERATURE CLASS AND GAS IGNITION TEMPERATURE

Since flammable gas or vapour can be ignited by contact with a hot surface, for all type of protection apparatus it is necessary to specify an appropriate Temperature (T) class, such that the maximum accessible surface temperature internally or externally will not exceed the ignition temperature of the gases and vapour to which it may become exposed.

This is achieved by consideration of the following two factors:

7.7.1 The maximum surface temperature rating of the apparatus

This is defined under test by an appropriate certifying body as: 'The highest temperature which is attained in service under the most adverse conditions (but within the tolerances) by any part or surface of an electrical apparatus, which would be able to produce an ignition of the surrounding atmosphere'.

Note: The most adverse conditions include recognised overloads and any fault conditions recognised in the specific standard for the type of protection.

The test results are corrected to allow for a maximum ambient temperature of 40°C. Equipment that may be exposed to surrounding temperatures above this needs special consideration. The tests measure the maximum surface temperature of any unprotected internal or external surface (i.e. casing) due to self-heating from electrical energy within the apparatus.

From such testing, the testing authority will assign the apparatus to one of the six recognized international Temperature class ratings T1 to T6 in accordance with IEC 60079-14 and BS EN 50014. These six T classes are shown in Table 7.3.

7.7.2 The ignition temperature of the gas or vapour

Ignition temperatures are measured in a standard apparatus, and results are tabulated for many materials. Apparatus is then simply selected by matching the ignition temperature to the temperature class of the equipment. Very small hot surfaces do not ignite gases and IEC 60079-0 and BS EN 50014 allow a relaxation of the temperature limits for equipment with a surface area of less than 10 sq cm. Note that the relaxation is 25 °C for temperatures T4 to T6 and 50 °C for T1 to T3 classes. The margins for small components used in i circuits are given in IEC 60079-11.

Note: Ignition temperature, formerly known as the 'auto- or spontaneous ignition temperature' is not the same as the flash point of the material (see section 8.2.6.1). It is the temperature at which, when mixed with air at normal pressure and as a consequence of chemical reactions initiated on account solely of temperature, the substance will ignite and burn in the absence of any initiating source of spark or flame.

A table giving the determined ignition temperatures of a large number of gases and vapours may be found in IEC 60079-20.

Table 7.3 Relationship between temperature class and maximum surface temperature of the apparatus*

Temperature class	Maximum surface temperature (°C)
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

* In accordance with IEC 60079-0. The assumed maximum ambient temperature related to the above values is 40°C. If required to be designed for other ambient temperatures, this fact should be specified and indicated on the apparatus marking (see 7.11)

7.7.3 Selection of T class

Table 7.3 lists the appropriate T class of equipment for common petroleum products.

Notes:

(a) Apparatus having a lower maximum surface temperature, i.e. higher temperature class may be used in place of that having a higher maximum surface temperature (lower T class), but not conversely.

(b) As with apparatus sub-group the effects of both internal and external release should be considered in the selection of temperature class. The temperature classes indicated in Table 7.2 relate to the external hazards. Apparatus with an internal and possibly different release may require a different T class, in which case the more severe of the two should be selected. See also Annex F.

(c) An ambient temperature other than 40 °C may also be adopted as in the case of cold climate conditions as encountered in the Arctic or northern North Sea, for which likewise this procedure will apply.

(d) Ignition temperatures are not inherent properties of a substance, but depend also on the method of test. The selection of apparatus based on Tables 7.2 and 7.3 is conservative and no additional safety factor is needed.

(e) When mixtures of substances can be released the most restrictive temperature class should be specified (see section 2.5).

(f) For ignition temperatures of mists, see Annex A.

7.8 ENCLOSURE INGRESS PROTECTION

Other non-electrical factors specified in the selection of the electrical apparatus are measures required to be applied to the enclosure to provide a chosen degree of protection to:

(a) Persons against contact with internal live or rotating parts inside the enclosure, and to the apparatus against ingress of solid objects, dusts, etc.

(b) The apparatus against the ingress of water, spray, jets, heavy seas and even total immersion.

Fuller details on the degrees of protection and their classification are provided in IP *Electrical safety code*.

7.9 OTHER REQUIREMENTS

All electrical apparatus should be installed, used and maintained for use within their electrical ratings for power, voltage, current, frequency, etc., and such other general, e.g. earthing, factors that might affect the safety of the installation. Electrical protection standards against such factors as overload or overcurrent are outside the scope of this Code, or of hazardous area classification. Other publications of a requisite general nature and all statutory requirements should be followed, such as IEC 60364, BS 7671 in the UK (commonly known as the IEE wiring regulations), the *Electricity at Work Regulations* 1989 and the associated memorandum of guidance, where they apply.

7.10 DOCUMENTATION

To help future maintenance, and to help demonstrate that the ignition hazards have been properly addressed, an inventory of equipment installed in a hazardous area should be maintained. This will include the type of protection, temperature class, and where relevant the subgroup of the apparatus as well as its location.

The hazardous area classification documentation should also include details of the properties of flammable fluids expected to be present in different parts of the installation. Relevant details include: the boiling point, or vapour pressure at ambient temperatures; ignition temperature; flash point; flammable limits and relative density of the gas or vapour.

All the above selection advice applies to typical atmospheric conditions including normal variations in temperature and pressure. Where these cannot be assumed, or where a raised oxygen content is possible, specialist advice should be sought.

Some types of protected apparatus, particularly analytical equipment, contain flammable fluids within the enclosure, and may have the potential for an internal unintended source of release. This should have been considered when the equipment was certified. Once equipment selection has been finalised, the hazardous area classification should be rechecked, in case the internal source of release can locally affect the zoning around the equipment.

7.11 MARKING OF APPARATUS

The various standards for equipment specify marking requirements in considerable detail. Equipment should be installed so its marking plate can be seen. The ATEX Directive 94/9/EC extends the marking requirements, making it a legal requirement for new explosion-protected equipment to be marked with the CE mark; the symbol of explosion protection, ⟨Ex⟩; the year of construction, the manufacturer's name and other details.

Individual testing laboratories also specify marks to show where equipment has been certified.

7.12 INSTALLATION

To achieve the intended level of safety, explosion-protected equipment needs to be installed correctly. Installation practices are given in IEC 60079-14. Those involved in this work need to be trained in the specific requirements for equipment made to the different protection concepts. The requirements for intrinsically safe circuits are particularly detailed and important.

7.13 PROTECTION OF ELECTRICAL APPARATUS AND CABLES FROM PHYSICAL DAMAGE

Protected electrical equipment is designed to be robust enough to withstand normal industrial conditions, without failing in a way that would create a spark. IEC 60079-0 specifies impact and mechanical strength tests for equipment. There are also tests for resistance to some chemicals, but these cannot cover all the possible types of corrosive chemicals that may be present in an industrial installation.

Despite these requirements, installers should take care to locate equipment and cabling where it is not vulnerable to obvious damage, e.g. careless movement of a vehicle or the operation of a crane.

In particular cables should be provided with adequate protection, and be adequately supported throughout their length, e.g. on supports or cable trays or through protective troughs or tubes, and be protected against corrosive fluids or organic chemicals that could weaken plastic sheathing. The vulnerability of cable runs to fire should also be considered.

7.14 MAINTENANCE AND INSPECTION

These lie outside the scope of hazardous area classification and of this Code, and detailed advice is contained in the IP *Electrical safety code* and IEC 60079-17. Requirements vary according to the particular type of protection selected. The following, however, should be stressed:

(a) All electrical circuits should be provided with an effective means of isolation. Where equipment may be located in hazardous areas it is important that the neutral is also isolated. It is equally important that these are provided with adequate labelling to ensure foolproof and rapid identification. A master isolator or isolators may be provided that will permit large areas of plant to be disconnected in the event of severe emergency.

(b) The inspection, testing, maintenance, replacement and repair of certified equipment should be entrusted only to persons qualified in the special techniques involved.

(c) For apparatus other than type of protection 'i' and for low-power non-incendive apparatus type N, no apparatus should be opened in a hazardous area until it has been isolated from its source of supply and effective measures, such as the locking of the isolating switch in the open position or fuse removal, have been taken to prevent its being made live before reassembly. See *Electricity at Work Regulations*, regulations 14 and 16.

(d) No flameproof apparatus should be serviced in a Zone 1 area until it has been isolated from its source of power and stringent measures have been taken to prevent it being reconnected before it is reassembled.

(e) When, for the purpose of electrical testing, it is essential to reconnect to the source of power before the apparatus is reassembled, the substance giving rise to the risk should be removed and appropriate tests made by a gas detector at sufficient intervals while the apparatus is live in a partially dismantled condition. See *Electricity at Work Regulations*, regulations 14 and 16.

Particular attention should be paid in the case of apparatus that may be live even after it has been disconnected from a source of supply. Where heavy rotating machinery is involved, the back e.m.f. of such plant should be considered and precautions will usually need to be taken to ensure that the apparatus, or any apparatus associated with it, is not opened until the rotating plant is stationary. Most power capacitors are fitted with discharge resistors and it should be noted that these take a finite time to bring the terminal voltage to a harmless value.

7.15 MOBILE, PORTABLE AND TRANSPORTABLE ELECTRICAL APPARATUS AND ITS CONNECTIONS

(a) Some types of portable equipment are designed and constructed to explosion-protected standards. Generally it will not be suitable for all zones and every possible type of explosive atmosphere. It is generally advised that equipment should be suitable for use in Zone 1, as the boundary between Zone 1 and 2 is usually not evident on an actual plant. The boundary of Zone 0 is usually easier to define, and instructions should then make clear whether a particular item of equipment is suitable for use in Zone 0. For example instructions with a protected torch may state 'do not use inside storage tanks and process vessels (Zone 0)'.

If flammable materials requiring equipment to sub groups IIB or IIC are present, to avoid confusion, where possible portable apparatus should be built to the most onerous requirement. Alternatively, instructions should ensure that equipment certified to IIA standards is not used inappropriately. For example, instructions with a IIA torch might say 'do not use on the hydrogen plant'.

(b) Account should be taken of the electric shock risk with mains supplied portable or transportable apparatus, which may require double insulation, earth leakage protection, etc.

(c) Plugs and sockets to be used in a hazardous area during normal operation should be certified as being suitable for use in the particular zone and should have mechanical and/or electrical interlocking to prevent danger during insertion or removal of the plug.

Portable equipment is often exposed to:

(a) increased risk of mechanical damage;
(b) the effects of the weather, natural hazards, temperature or pressure;
(c) the effects of wet, dirty, dusty or corrosive conditions, as well as potentially explosive

atmospheres. Regular maintenance is particularly important.

Mobile apparatus includes both electrically propelled or electrically powered apparatus and also mobile equipment which itself generates electricity. In the latter case due regard must be paid to the mode of use and type of protection adopted for the primary power source as well as for the electrical generator.

(d) If standard industrial portable or transportable apparatus is to be used in a hazardous area, it should only be used under the clearly prescribed and closely controlled conditions, including a gas-free check, outlined in Chapter 8.

7.16 PERSONAL APPARATUS

Hand torches and mobile telephones are examples of personal apparatus that should not be taken into a hazardous area unless they are built to an appropriate standard or a gas-free certificate has been issued for the period of use. Some uncertified apparatus such as battery operated watches and hearing aids may be approved by the facility management due to the very low power requirement since the main risk is the shorting of battery terminals.

7.17 BATTERY ROOMS

A battery room contains electrical cells or batteries which may be on charge or discharge. Most types of batteries will create sparks or overheat to a dangerous degree if the terminals are shorted out. It is not possible to build powerful batteries to prevent this risk.

Lead acid batteries emit hydrogen during charging, and can create a hazardous area above banks of cells. Battery rooms should be adequately ventilated in order to assist in the dispersion of the hydrogen. This may entail the use of artificial ventilation.

Electrical apparatus thus may need to be suitable for use in Zone 1 hazardous areas with apparatus of sub-group IIC T1 class suitability for hydrogen as in Table 7.2 unless there is dilution by LEV, as provided for in Chapter 6.

Further guidance is given in BS 6132, BS 6133, IEC 60896 and IEC 60623. Similar precautions should be applied to non-open buildings etc. where electrical vehicles are recharged.

7.18 CATHODIC PROTECTION, EARTHING AND BONDING

Guidance is given in the IP *Electrical safety code*.

8

NON-ELECTRICAL SOURCES OF IGNITION

8.1 INTRODUCTION

The concept of hazardous area classification was originally developed for the selection and location of fixed electrical equipment for use near flammable fluids. However, it is not only incorrectly-selected electrical equipment that can be a source of ignition but also items such as naked flames in directly-fired furnaces, vehicles, hot surfaces on compressors or any equipment which may cause friction sparks. All sources of ignition need to be controlled where flammable atmospheres may form, and hazardous area classification is a good basis for deciding what equipment may be used at any particular location.

While the principal objective of this Code remains the classification of areas for the selection of the appropriate type of protection for electrical apparatus, this chapter provides additional guidance for the use of the hazardous area classification approach to aid the location and control of non-electrical sources of ignition. This is in accordance with the ATEX Directives, which apply equally to electrical and non-electrical equipment capable of causing an ignition of a flammable atmosphere. The term 'control' should, in this context, be regarded as extending to the training of personnel for safe working in such areas, including work permit control.

European standards are currently being written for non-electrical equipment for use in flammable atmospheres drawing on the principles adopted for electrical equipment. New equipment that creates a potential ignition hazard should now be marked with the CE mark and Ex mark, an equipment category and temperature class and other details to show where it can be used safely.

An alternative method of control is the use of gas detectors. These may be portable, and used when maintenance work creating a risk of ignition has to be carried out in an area normally classified as hazardous. Fixed gas detection systems are sometimes used where it is more practical to shut a system down in the event of a gas leak, than to fit ignition-protected equipment of an appropriate standard. These alternatives are considered below.

8.2 SOURCES OF IGNITION

Non-electrical equipment may create an ignition risk if parts become hot in normal operation or as a result of mechanical failure, such as a failed bearing. The hot surface may be inside equipment or outside. Faulty mechanical equipment may cause showers of hot metal sparks to be thrown from rubbing surfaces, or a few sparks from single impacts. Both types of fault create an ignition risk.

Most equipment designed for controlled combustion is inevitably hot, and hazardous area classification cannot be sensibly applied close to it. Examples are fired heaters, flares, gas turbines and internal combustion engines. The approach should then be to minimise the risk of leaks, and to ensure that any that do occur are quickly diluted below the flammable range. The particular precautions that apply to starting up fired heaters are covered in Annex G.

Other potential ignition sources such as lightning, static electricity and pyrophoric scale are not primarily controlled by equipment selection and hazardous area classification, and are considered briefly in 8.2.8.

The location of fixed sources of ignition should be determined during plant layout work. Note, a situation where a fixed source of ignition is located just outside a hazardous area leads to a much higher probability of ignition than suitably classified equipment located just inside. It is good practice therefore to locate fixed sources of ignition as far as practical outside the hazardous area.

8.2.1 Fired heaters and furnaces

Fired heaters and furnaces are a source of ignition because of the naked flame, and in some cases can also have surfaces hot enough to cause ignition. Open ports on combustion chambers, in principle, create a risk that the flames inside the furnace could directly ignite a flammable atmosphere on the outside. This is particularly likely if fluctuations in the fuel and air pressures cause flames to emerge from the port. It is preferable to design furnaces to avoid the need for ports to be opened while they are operating.

Fired heaters, furnaces and other combustion equipment should be located as far as is practicable outside any hazardous area, preferably at the edge of process blocks. There remains the risk that fuel lines or process lines to and from the equipment may leak and ignite on hot surfaces or electrical equipment. Hot surfaces associated with fired equipment cannot be completely avoided and industry experience suggests that they are one of the most common causes of ignition offshore, though they can of course be minimised by proper lagging and insulation which is anyway necessary for reducing energy losses. The risk of ignition by the electrical equipment can be reduced by hazardous area classification around the potential leakage points in the fuel and process lines. If the latter run at temperatures above the auto ignition temperature of the process material, however, then hazardous area classification may be judged to be unnecessary for them. The maintenance of flanges, valves and other potential sources of release in the immediate vicinity of the heater should receive particular attention. Following any work on fuel lines, so far as is practicable, they should be pressure tested before the fired equipment is re-commissioned.

Flammable gas detectors are sometimes provided in buildings containing gas fired heaters. If forced ventilation is also provided to the building, particular care is needed when selecting the location for gas detectors, if they are to detect all gas escapes promptly. Depending on the location of the leak, and the distribution of the airflow, it is possible for a dangerous accumulation of gas in one part of the room to coexist with a very low gas concentration in the airflow leaving the room. A high air speed may also reduce the sensitivity of the detector.

8.2.2 Flares

Flares should be sited as far away as possible from a hazardous area. In selecting the location the possibility that burning liquid or hot carbon particles could be ejected from the flare should be considered. For detailed guidance on the design of flares, see API RP 521.

8.2.3 Vehicles - road and rail traffic

Normal vehicles contain many sources of ignition, including electrical circuits, hot parts on the engine, overheating brakes, and static discharges. The impact of vehicles with process plant is also liable to create a release of gas or liquid, and many accidents have occurred where a vehicle has both caused a leak and ignited it. Therefore the control of vehicle movement around hazardous areas requires consideration.

Road traffic and rail locomotives should be regarded as a source of ignition unless specially protected in accordance with 8.2.4. For mobile equipment driven by diesel or electric engines, various methods of protection have been devised for operation in Zone 1 or Zone 2. It is not practical to build a spark ignition engine suitable for use in a hazardous area. For the design and operation of explosion-protected lift trucks, see BS EN 1834-1 and 2, and BS EN 1755. There are also trucks fitted with gas detection systems that can automatically shut down the vehicle, and when properly designed, these can achieve the same standard of safety. Where such equipment has no such protection, its introduction should be based on work permit control, as for hot work.

The use of roads within hazardous areas should therefore be restricted. This should normally be achieved by physical barriers, which are controlled by a person responsible for protection of the hazardous area but may be achieved by other means, e.g. warning beacons. Special control must be exercised over road tanker vehicles at Class I petroleum loading and discharge areas, and it should be ensured that unprotected rail locomotives, including conventional electric powered units, do not enter beyond the permitted safe distance. Recommended basic standards and practice for the operation of road and rail vehicles is provided in IP *Design, construction and operation of distribution installations*.

Fire fighting and other emergency service vehicles of standard type and design can also present a source of ignition. Their entry to plant, storage and distribution areas etc., under normal or emergency conditions (including liaison exercises) other than fire, should also be strictly controlled. Where, as in a refinery, there is internal provision of such vehicles as a component of that facility's emergency plan, they should be housed in a central but non-hazardous area which has good immediate access but is remote from possible sources of major hydrocarbon release. Consideration should again be given to inlet and exhaust protection of their diesel engines.

8.2.4 Fixed combustion engines

A flammable atmosphere may be formed by a release from the fuel line to the engine, or other sources of lammable material. Both possibilities should be considered. Hot surfaces on engines and engine exhausts are a particular problem, as special checks may be needed to establish just how hot these get during operation. See also 8.2.6.2 for a discussion of the significance of measured ignition temperatures for particular products.

8.2.4.1 Internal combustion engines for permanent installation

The safety requirements for internal combustion engines are set out in BS EN 1834-1. Wherever possible they should be installed in locations that are non-hazardous, although the fuel itself may result in a hazardous area. However, it should normally be possible to avoid installation of engines in a Zone 1 situation. For older installations typical precautions for engines are as follows:

ı) No spark ignition engine should be installed or operated in a hazardous area.

(b) Engines should be mounted above grade to prevent accumulation of flammable vapour.

(c) Internal combustion engines should not be permanently installed within tank compounds.

(d) If weather protection is required the shelter should preferably be open-sided.

(e) Emergency stop facilities should be installed both local to and remote from the engine.

(f) Consideration should be given to the provision of a separating vapour-tight wall between the engines and the driven equipment, containing sealed sleeves through which piston rods or shafts pass.

(g) Flammable gas or smoke detection equipment may be used, either for alarm only or for alarm and shutdown.

(h) Where possible, the air intake should be drawn from outside any hazardous area, and the exhaust should terminate outside the hazardous area. If this is not possible, the precautions used on the inlet and exhaust from vehicles should be used. See 8.2.3.

(i) Electric starters will usually be inappropriate, and alternatives that create no ignition risk should be used e.g. hand cranking, or a compressed air drive.

(j) Water-cooling may be used on the exhaust manifold, or other particularly hot parts.

(k) In the case of exhaust gas temperature control it should be noted that air-cooled or turbo-charged diesels can have exhaust temperatures higher than water-cooled machines, and heat exchange or finned coolers may be desirable on the exhaust manifold system.

(l) Overheating due to failure of cooling water supply or loss of lube oil pressure, and the provision of an alarm or, in the case of a permanently installed machine, an automatic shutdown device may be requisite.

(m) An effective spark arrestor on the exhaust system.

(n) A quick closing valve in the air intake manifold which can be used to stop the engine promptly in case of emergency.

Note: On some plants such engines and especially diesels are installed to drive emergency power generators or fire pumps. They are then required to work in a general emergency condition and should be located as far as is reasonably practicable outside a hazardous area. (For fire fighting and other emergency service vehicles see 8.2.3.)

In the case of permanent, mobile or temporary equipment, it should be stressed that the effectiveness of protective systems is dependent upon a high standard of maintenance and inspection of the equipment by properly qualified persons (see EEMUA 107).

Road tanker vehicles are excluded from the above recommendations, since the conditions under which they may enter and load or unload at distribution installations are controlled by the operational procedures of IP *Design, construction and operation of distribution installations* and equivalent codes (see also 8.2.3).

8.2.4.2 Internal combustion engines for drilling rigs
When internal combustion engines are required to provide power for drilling/well servicing rigs, only diesel engines should be used in a hazardous area. The following protection and quick shutdown systems should be fitted to engines that are installed within areas of a rig which may become hazardous areas in the event of the accidental escape of hydrocarbons from the well bore:

(a) Flameproof electrical equipment and flameproof electrical or non-electrical starter system.

(b) An effective spark arrestor on the exhaust system.

(c) A quick closing valve in the air intake manifold which can be used to stop the engine promptly in case of emergency.

When used on rig draw works and hoists, diesel engines must be further equipped with the following systems to provide extra protection:

(d) An effective flame arrestor in the air intake manifold.

(e) A system for quick shut-off of fuel.

(f) Protection systems controls located so they are easily operated from the driller's position on the rig.

(g) Exhaust ducts to discharge to a safe area.

(h). Antistatic and fire-resistant driving belts with non-metallic fan blades on the cooling systems.

(i) Automatic shutdown system in the event of engine overspeed.

8.2.5 Gas turbine drives

Gas turbines are employed in many major installations, including offshore platforms, as drives for pumps and compressors. Sometimes the gas turbine can be separated from the process equipment by a gas-tight wall with a drive shaft seal, in which case it can be installed outside any hazardous area created by process plant it is driving if it has fully open area ventilation and the seal is well-maintained. Any weather protection provided should comprise only a roof and partial walling.

Many gas turbines are provided for electric power generation. These are normally installed in an enclosed area (the 'turbine room or enclosure'), often with an additional acoustic enclosure that has a separate ventilation system. In either case the fuel supply systems often have many flexible connections and joints, run at high pressures, and should be considered as potential sources of release. The engine surface temperatures are often well above the auto-ignition temperature of the fuel, particularly for aero-engine derived units. Hazardous area classification is inappropriate in these circumstances and safety can only be achieved by a combination of factors including adequate maintenance, suitable ventilation, gas detection systems, and/or explosion venting. Further information is provided in the HSE *Control of safety risks at gas turbines used for power generation.*

8.2.5.1 Fuel types
Gas turbines may be driven by liquid or gaseous fuels. Gaseous fuels are often supplied at very high pressures, and any release from the fuel lines will emerge as a supersonic jet, which will entrain air into itself irrespective of any forced ventilation in the enclosure. Liquid fuels are usually supplied at lower pressures, but may still be released as a stream which atomises itself, or which can spread a considerable distance before impacting on the surroundings and breaking up.

8.2.5.2 Forced ventilation
Forced ventilation is normally provided to control the temperature of the unit. A high flow rate does not necessarily ensure effective mixing of the atmosphere throughout an enclosure, and studies in some installations have shown that gas leaks can build up until a dangerous volume of explosive mixture is formed. Simply increasing the flow rate may not prevent this problem, and redesigning the ventilation inlets and outlets from the enclosure is more effective. Computational Fluid Dynamics (CFD) modelling of the airflows has been found helpful when designing new systems. With existing plant, on-site measurements within the enclosure are needed to assess the design. If problems are evident CFD modelling may help in the selection of methods to improve the air mixing.

8.2.5.3 Gas detection
Gas detection is important otherwise leaking systems may go undetected for an extended period. Careful siting of the detector heads is essential. One head should be sited in the ventilation outlet, but this alone may not be adequate. A high overall airflow may dilute a modest leak below the detection limit, while allowing a gas build-up in parts of the enclosure where the air change rates are less.

8.2.5.4 Classification within the turbine enclosure
Where gas detection and well designed ventilation are provided, protected electrical equipment selected on the

basis of hazardous area classification is no longer the primary means of ensuring safety. Nevertheless, it is recommended as a secondary protective measure that the inside of the turbine enclosure is Zone 2 and electrical equipment is chosen accordingly. If there is equipment energised before the ventilation is established, this should be certified for Zone 1 operation.

8.2.6 Hot surfaces

Mechanical equipment may become hot under normal operation, or under fault conditions e.g. excessive friction between moving parts. If it is to be installed in a hazardous area, this risk should be considered. The hottest part of the equipment may be on the inside or outside. Appropriate selection of equipment depends oth on the zone, and ignition temperature of the fluids present. The latter is a particular concern as fluids heated to above a specific temperature can ignite on mixing with air in the absence of any source of ignition.

8.2.6.1 Ignition temperatures and flash points

Flash point and ignition temperature are two entirely different properties of a substance. The flash point of a liquid is the minimum temperature at which it is deemed the liquid can form a flammable atmosphere in air under the conditions of the test procedure, in which a small test flame is repeatedly lowered to the liquid surface as its temperature is raised until a flammable condition is first observed. Ignition does not occur at this flash point unless there is a source of ignition (see also Annex A). If the sample is heated further, at some point it will ignite without the application of an external flame at the ignition temperature. This may be considerably higher than the flash point. The ignition mechanism involves composition of the compound by heat to give active radicals, which result in propagation and branching as these radicals react with more molecules or with oxygen.

The ignition temperature (also referred to synonymously as the auto-ignition temperature or spontaneous ignition temperature) is the lowest temperature at which a flammable gas or vapour ignites under test conditions. These vary widely even for hydrocarbons, from 537 °C for methane, down to 201 °C for decane. Values for typical flammable fluids are given in IEC 60079-20.

8.2.6.2 Conditions for auto-ignition

Ignition from a hot surface can occur either when a gas-air mixture comes in contact with the surface or when a liquid leak falls onto that surface. Such leaks should be avoided. Sources that could release a fluid above the ignition temperature (e.g. a pump on hot oil duty) and any equipment that could raise the temperature of liquid likely to be spilt on it to above the ignition temperature should not be located in a Zone 0 or Zone 1 area.

The ignition temperature or auto-ignition temperature (AIT) of a substance is not an absolute property of that substance, but will depend upon factors such as:

— How near a vapour/air concentration is to the stoichiometric concentration.
— The temperature of surfaces in contact with the mixture.
— The contact time between the mixture and the surface.
— Whether the surface is 'active' or inert (see 8.2.6.3).
— The area of the hot surface.

Under open-air ventilation conditions it is generally more difficult to raise the temperature of a gas or vapour release to above the ignition temperature, with the result that AITs measured in small confined volume tests are very conservative in relationship to the maximum safe temperature of a hot surface in the open air.

Nevertheless, it is good practice to avoid very hot surfaces, e.g. with an internal fluid temperature above 650 °C, in process plant in hazardous areas even with open-air ventilation. In areas with less ventilation it is easier for a hot surface to heat a gas or vapour release to above the AIT, and equipment surfaces should not exceed the AIT of any likely release. For conditions where a general exposure to a range of flammable vapour and gases may be encountered, a limit of 200 °C is recommended.

8.2.6.3 Catalytically active surfaces – Auto-ignition of oil impregnated materials

Surfaces that are catalytically active can ignite vapour or liquid at temperatures lower than the normal ignition temperatures referred to above. Auto-ignition of bitumen or heavy oils can occur at temperatures which, depending upon grade, can be as low as 240 °C; self-heating leading to auto-ignition of porous or fibrous materials impregnated with oils or bitumens can occur at temperatures as low as 100 °C. Oil and bitumen contamination of thermal insulating materials and the accumulation of oily rags or similar material near hot surfaces should therefore be avoided, especially in areas classified as hazardous.

8.2.6.4 High-pressure flammable hydraulic oil leakage

Hydraulic oil systems can be used for transmitting power or motion, and *inter alia* are so used on offshore platforms and drilling rigs. The fluids in these systems are normally mineral oils having closed cup flash points in the range 150-250 °C and AITs in the range

315-425 °C. They are often used under very high pressures (several hundred bar) and all hydraulic systems are prone to leak. Although the temperature of the oil in a correctly operating system is usually less than 65°C at the pump inlet, i.e. considerably lower than its flash point, there is always a risk of fire if a leak occurs, due to atomisation of the oil, the reasons for some ignitions being imperfectly understood (see HSE *The fire and explosion hazards of hydraulic accumulators*).

Where it is impossible to remove all ignition sources, the use of more 'fire-resistant' hydraulic fluids should be considered. Flexible hoses should be used only where absolutely necessary and should be covered in braiding. Rigid pipes with swivel joints should be used instead of flexible pipes, wherever possible, adequately supported to protect against vibration and mechanical damage.

An automatic excess flow valve is desirable and a quick operating valve provided so that the flow of oil can be stopped in the event of serious leakage or a fire. Oil mist detectors may be useful in circumstances where there is a high risk.

8.2.7 Gas detectors - inherent risks

Some types of gas detector contain a hot element, on which controlled combustion of a flammable mixture takes place. These are prevented from igniting a surrounding flammable atmosphere by flame traps on the inlet and outlet. BS EN 61779-4 and BS EN 61779-5 describe requirements for instruments for different purposes. Not all instruments will be suitable where hydrogen or acetylene may be present, and users should check that any instrument provided is safe for use wherever it is used on the plant.

8.2.8 Electrostatic and pyrophoric ignition hazards

In process plant and tank vapour spaces likely to contain pyrophoric deposits, special care is necessary to avoid the simultaneous occurrence of flammable atmospheres and the conditions necessary for self-heating of the deposits. The grades of bitumen with which there is a probability of these two circumstances becoming coincident, with the consequence of fire or explosion, should be considered. IP *Bitumen safety code* provides further guidance on precautions against the formation of pyrophoric scale in heated bitumen tanks resulting from high temperature. Tanks may be self-inerting because of gradual oxidation of the bitumen, and accumulation of carbon dioxide, as well as flammable vapour formed from the bitumen. Operating procedures need to ensure that the introduction of fresh air does not simultaneously create a flammable atmosphere, and the formation of glowing coke deposits.

Guidance on static and the control of ignition hazards may be found in IP *Guidelines for the control of hazards arising from static electricity*, BS 5958-1 and -2, and BS PD CLC/TR 50404.

8.2.9 Light metals

The impact of a light metal (aluminium, titanium, zirconium) object with a rusty surface may cause a reaction known as the thermite reaction. This produces hot metal sparks that are particularly incendive. Standards for electrical and non-electrical equipment for use in hazardous areas place restrictions on the use of light metals on the outside of equipment to prevent this risk. For the same reason, the use of aluminium ladders or scaffolding may create an ignition risk, and this should be considered before they are used in a Zone 1 area.

8.2.10 Radio frequency electromagnetic radiation

Radio-frequency electromagnetic radiation can be a potential ignition source even at an appreciable distance from the transmitting equipment. This radiation can induce electric currents in any metal structure on which it impinges. Advice on whether specific equipment can cause a hazard is given in BS 6656. See also IP *Recommendation for radio telephone equipment and its installation in petroleum road tankers*.

8.3 USE OF GAS DETECTORS IN HAZARDOUS AREAS

8.3.1 Use of gas detectors during maintenance

The use of gas detectors as a pre-condition to hot work and as a check during the course of this activity is essential. Flammable gas detectors may be calibrated for a particular gas, or mixture of gases and vapour, and may not accurately respond to other gases. They should be recalibrated if required to monitor for different gases from those for which the calibration has been carried out.

The most commonly used portable gas detector is of the catalytic filament type and the manufacturer should be consulted for information on their operation, calibration and maintenance. Catalytic detectors can give false results on an atmosphere that is oxygen deficient, either because inert gas is present, or because the flammable gas concentration is above the UFL. For this reason instruments may be made to different standards.

BS EN 61779-4 describes instruments designed to measure up to 100 % LFL, while BS EN 61779-5 describes instruments designed for reading up to 100% flammable gas. Where an inert gas may be present inside a vessel, an instrument designed to read up to 100% gas should be used, or the oxygen content of the vessel should be separately checked.

Catalyst type instruments suffer 'poisoning' of the sensor filament, which gives a falsely low reading if used on atmospheres that contain organic lead compounds, halogenated hydrocarbons, potassium, sodium or organic phosphorus compounds, which form a deposit on the filament. Special instruments should be used, e.g. when leaded atmospheres have to be tested, incorporating carbon filters or high-temperature filaments. The only safeguard against such poisoning is to test the instrument with a reference sample gas immediately before and after use. Frequent recalibration will be necessary.

Atmospheres containing water or steam can present similar problems and inaccurate readings, with the possibility of condensation within the instrument; drying tubes are a possible solution.

All certification is carried out for gas mixtures with air only, and is not valid for oxygen-rich atmospheres; specialist advice from the suppliers is necessary for such a case.

The operator must be trained in their use and the above limitations, and always follow the manufacturer's instructions. Regular maintenance of the instrument is necessary, and written records should be kept. The instrument itself may develop internal faults and regular checks on its calibration are necessary.

If any doubt arises from the response of the instrument, the atmosphere under test should be regarded as hazardous.

8.3.2 Use of gas detectors for work other than maintenance

Gas detectors may be an appropriate method of control where the normal hazardous area classification is not adequate or as a means to activate additional safeguards. Examples are:

— The safeguarding of non-hazardous areas such as public places when unusual activities take place, such as the gas-freeing of tankage with the evolution of large quantities of vapour, the transfer/off-loading of large volumes of very volatile materials, and the carrying out of complex hot work repairs, in locations in proximity to processes that cannot readily be shut down temporarily.

— To safeguard automatic ventilation against failure and the development of unsafe flammable concentrations in control rooms and similar protected enclosures such as analyser houses, turbine hoods, etc.

— To provide automatic alarm and initiate shutdown of process or other equipment.

— To assist safe evacuation from such situations.

— Alerting of and triggering of fire protection systems.

8.3.2.1 Selection of location and number of such sensors

One, or a combination, of the following two alternative approaches may be used according to the circumstances:

(a) Source detection, in which the sensors are located adjacent to the likely sources of hazardous release.

(b) Perimeter detection, in which the detectors are located to surround the whole area or plant from which the hazard may arise, i.e. adjacent to the possible sources of ignition.

Method (a) is applicable for small enclosed situations, such as gas turbine enclosures and hoods (see 8.2.5) and pressurised control rooms (sections 6.5 and 6.6). Thus such non-hazardous areas within Zone 1 or 2 areas should be safeguarded by gas detectors at the inlets to the ventilation system. Enclosures with an internal gas source such as gas turbine assemblies should have gas detection within the enclosure, preferably on the ventilation outlet. Detection of gas within or at the inlet to an enclosed space should have an alarm and initiate appropriate action such as shutdown of unprotected equipment.

For detection of large gas accumulations in open areas, source detection may provide an early warning of a gas cloud in still air, but provides no warning if the wind is in an adverse direction. On the other hand, perimeter protection alone would have to be extensive if a delayed warning were not to result in a still air situation. Thus a combination of (a) and (b) is most effective for large outdoor sites.

The objective is to detect only large abnormal gas releases; the spacing can be proportionately large. The basic principles therefore are that gas detectors should be located as near as possible to gas leak sources rather than to sources of ignition, and close enough to each other to detect significant gas accumulation while being far enough away from known gas/vapour sources of release such as pump glands, valve stems etc., to avoid false alarm/shutdown initiation action.

The positioning of sensors should also take into account whether the releases are likely to be lighter or heavier than air, i.e. above or below the level of the release respectively. They should also be protected against physical damage and undue vibration.

8.3.3 Infra-red and other types of gas detectors

Though more expensive, infra-red detectors are reliable and stable and can have a fast response, an important requisite for gas detection systems required to initiate an alarm or shutdown of equipment. In general they are unaffected by poisons and the presence of inert gases and can measure gas concentrations up to 100%. The principle employed is dependent upon the comparison of the absorption of an infra-red beam by the gas being sampled with that of a similar beam, or the same beam, in a prescribed reference gas. Such sensors should be used only for detection of gas mixtures for which they have been calibrated, since other gases may be undetected if their absorption band lies outside that of the calibration band-width (see also below).

Other types of gas detection include thermal conductivity sensors and semiconductor sensors, which depend upon changes in the electrical conductivity of a semiconductor due to chemisorption at its surface on contact with the gas. The former are suitable mostly at relatively high concentrations, usually above the LFL, and should not be used for measurement below the LFL except in the case of gases such as hydrogen for which they are exceptionally sensitive. The semiconductor sensor type can be used for the detection of gases in any concentration, but is sensitive to inhibition by certain substances, on which manufacturer's guidance should be given.

Note: All three above types cannot be relied upon to discriminate between combustible and non-combustible gases - or between gases and water vapour or products of combustion - except where these are predetermined. Water removal conditioning is desirable.

8.3.4 Reliability of fixed gas detection equipment

The reliability of a detection system is only as good as its installation, subsequent maintenance and regular inspection and test check routine. It should be recognised that, whereas portable gas detection apparatus is in frequent use and lends itself to frequent checks by maintenance and calibration, in the case of a fixed detection sensor it may go for long periods without encountering a positive atmosphere by which it will be activated.

This poses the problem of ensuring the reliability of such equipment over the long-term cycle of operation during which the dependability of it to perform its expected function will be crucial.

The need for ensuring adequate resistance to the anticipated environmental stresses under which it will be required to function and the inherent limitations of all types of sensor as outlined above (together with the interfering effects of certain gases, water vapour etc.) must be taken into account in the scrupulous observance of regular inspection and recheck with the reference test gas recommended by the supplier.

Where this involves removal of the equipment and the related section of plant cannot be shut down, care must be taken to provide a suitable replacement such as a transportable unit.

Where onstream equipment cannot be accessed, the principle of multiple gas detection systems with coincidence voting may be necessary. An example is given in section 6.6.4.

8.4 HAZARDOUS AREA CLASSIFICATION DURING MAINTENANCE WORK

Hazardous area classification is primarily a means of determining what equipment may be used in a particular location during normal operation. It is not intended to apply during repair or maintenance. Many installations have site rules which restrict maintenance operations in a wider general area than the hazardous areas determined using this Code. This is necessary because maintenance activities can release flammable fluids in quantities not considered as part of the hazardous area classification study, and because hot work can vaporise heavy products, to form flammable atmospheres where none would normally exist (see HSE *Hot work*). Note in particular that gas-freeing of process plant by forced ventilation can create vapour clouds that spread far beyond the normal hazard zone. Within the wider restricted area, techniques such as work permits, and gas-free testing will often be needed, and local site rules should be followed. In particular, it is essential that before heat is applied to the outside of process plant, regardless of the zone, full precautions including effective isolation, removal of residual product and gas-free checks are carried out. When hot work is to be undertaken in a hazardous area, the normal zonal classification should be suspended.

The conditions and supervision that are required should, *inter alia*, include the following under work permit:

(a) Reduce temporarily for the duration of the activity the extent of the hazardous areas and zones in the vicinity by arrangements, which eliminate primary grade releases and detect rapidly and reliably any secondary grade releases.

(b) Avoid any unnecessary sources of ignition and any transmission of fire or sparks from the work into the adjoining hazardous areas.

(c) Stop the work if particular releases are detected that may affect the area of the work.

It is not the place of this Code to deal with the details of work permit control, for which further details may be found elsewhere (e.g. HSE *Guidance on permit-to-work systems*, HSE *Safe isolation of plant and equipment*, IP *Design, construction and operation of distribution installations*, APEA/IP *Design, construction, modification, maintenance and decommissioning of filling stations* and IP *Road tank vehicle workshop code*). Preparation for work under permit will however need to consider *inter alia* blanking or spading off connections to ensure positive isolation, electrical disconnection, gas-freeing, and arrangements for continuous checks to ensure that heat generated as a result of the work itself does not produce localised vaporisation of residues on walls etc. with a risk of explosion.

In respect of hot work to be carried out on or around tanks and their vents and other openings, attention should be drawn to section 3.1.4. This states that where heated products that contain residual fractions, such as fuel oils and bitumens, are stored in confined situations, such as tankage with an ullage space with open vents, the flash point as sampled of the bulk liquid is no indicator of the presence or absence of a flammable/explosive atmosphere in the head space. This can only be ascertained by gas testing checks prior to the initiation and in the course of hot work.

ANNEX A

CLASSIFICATION AND CATEGORISATION OF PETROLEUM AND FLAMMABLE FLUIDS

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

The IP classes of petroleum conform to the most frequently used flash point divisions in European Directives and UK Regulations, and with the subdivision of Classes II and III have been standardised by the Energy Institute in its various IP publications to govern the handling of petroleum materials throughout the sectors of 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 Chapter 3, above which they should not be extended; this upper limit is the temperature at which the liquid would boil.

Table A1 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, propylenes	Not applicable	Propane -42 Butane -1 Isobutane -12
I <21°C	Gasoline (petrol) Stabilised crude oil Avtage 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 H) 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 difference between flash point and ignition temperature is explained in section 8.2.6.1.

The IP 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 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.

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 the paper *Pressurised atomisation of high flash point liquids - Implications for hazardous area classification*, by P.J. Bowen and L.C. Shirvill.

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. Further research is needed. It does suggest that porous spray guards can be used around flanges and known potential leakage points, causing the material to coalesce back to a liquid below its flash point, rendering it non-hazardous. But this is only practicable in a few specialised applications, and requires rigorous control over maintenance activities to ensure that the guards are replaced afterwards.

In some cases, a 'rule of thumb' is used that material which cannot be heated to within 5°C of its flash point can be regarded as non-hazardous.

To clarify the position pending further research, 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 given in Chapter 5 of this Code, because of the possibility of mist or spray formation from a small hole or a flange leak.

In applying the IP flash point classification in Chapter 3, and in those cases where it is used with the procedure of Chapter 5, the two principles outlined above will take effect.

A1.2 Class I fluids

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

A1.3 Class II and III petroleum 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 give rise to insufficient vapour for ignition.

When a Class II or III product cannot be raised to the flash point (i.e. Class II(1) or III(1)), nor its release be in the form of a flammable mist or spray, then for the purposes of hazardous 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. 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 flashpoint. 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.

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 (see Chapter 8).

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 of the kerosine type (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 section 3.1.3).

When petroleum materials 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 Chapter 3. For the alternative cases the procedure of the point source method of Chapter 5 is to be applied to facilities in the Class II(2) or III(2) condition.

A1.4 Unclassified

Petroleum materials having a flash point above 100 °C can be given the subdivision accorded to Class III petroleum 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 3.1).

It should also be recognised in respect of heated petroleum of high flash point that although flash point and 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 classification procedure of Chapter 5 should be applied and the appropriate fluid category A, B, C or G (gas) selected (see below).

A2 RELATIONSHIP BETWEEN PETROLEUM CLASS AND FLUID CATEGORY

Where flammable fluids are handled under more extreme conditions of temperature, pressure, composition and volatility, the simple classification by means of the above IP system for petroleum fluids is inadequate and the concept of 'fluid category' has been introduced (see section 1.6.7). This enables the determination of hazardous areas by use of the point source (Chapter 5) or risk-based (Chapter 5 and Annex C) approaches.

A2.1 Simple relationship between petroleum class and fluid category

For simple situations Table A3 may be used to convert 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 IP 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**
0	Liquefied petroleum gases (LPG)	Yes	A	A	A [2]
I	Flash point less than 21 °C	Yes	B	C	C
II(1)	Flash point 21-55 °C	No	N/A [1]	C	N/A [1]
II(2)	Flash point 21-55 °C	Yes	B	C	C
III(1)	Flash point 55-100 °C	No	N/A [1]	C	N/A [1]
III(2)	Flash point 55-100 °C	Yes	B	C	C
Unclassified(1)	Flash point greater than 100 °C	No	N/A [1]	C	N/A [1]
Unclassified(2)	Flash point greater than 100 °C	Yes	B	C	C

Note 1 Not applicable (N/A) because liquids not handled above their flash point cannot be above their boiling point.
Note 2 Cryogenic fluids need special consideration.

ANNEX B

HAZARDOUS 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 hazardous 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 mixtures containing hydrogen is given in IP *Predictions of minimum spark ignition energy and quenching distances for CH_4/H_2 and C_3H_8/H_2 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.

Annex C Part 3 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

C1.0 INTRODUCTION

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 leak rates are unknown, this Annex provides a procedure for determining an appropriate leak rate. This Annex is split into three parts:

Part 1: Describes the procedure for determining appropriate release frequency 'LEVEL' to be used in conjunction with section 5.4 and is based on IP *A risk-based approach to hazardous area classification.*

Part 2: Describes the background to the risk-based approach and how risk tolerability criteria are related to release frequency LEVELS and corresponding release hole sizes.

Part 3: Presents the background to the calculation of hazard radii for **given** release rates used in Chapter 5 and is based on IP *Calculations in support of IP15.*

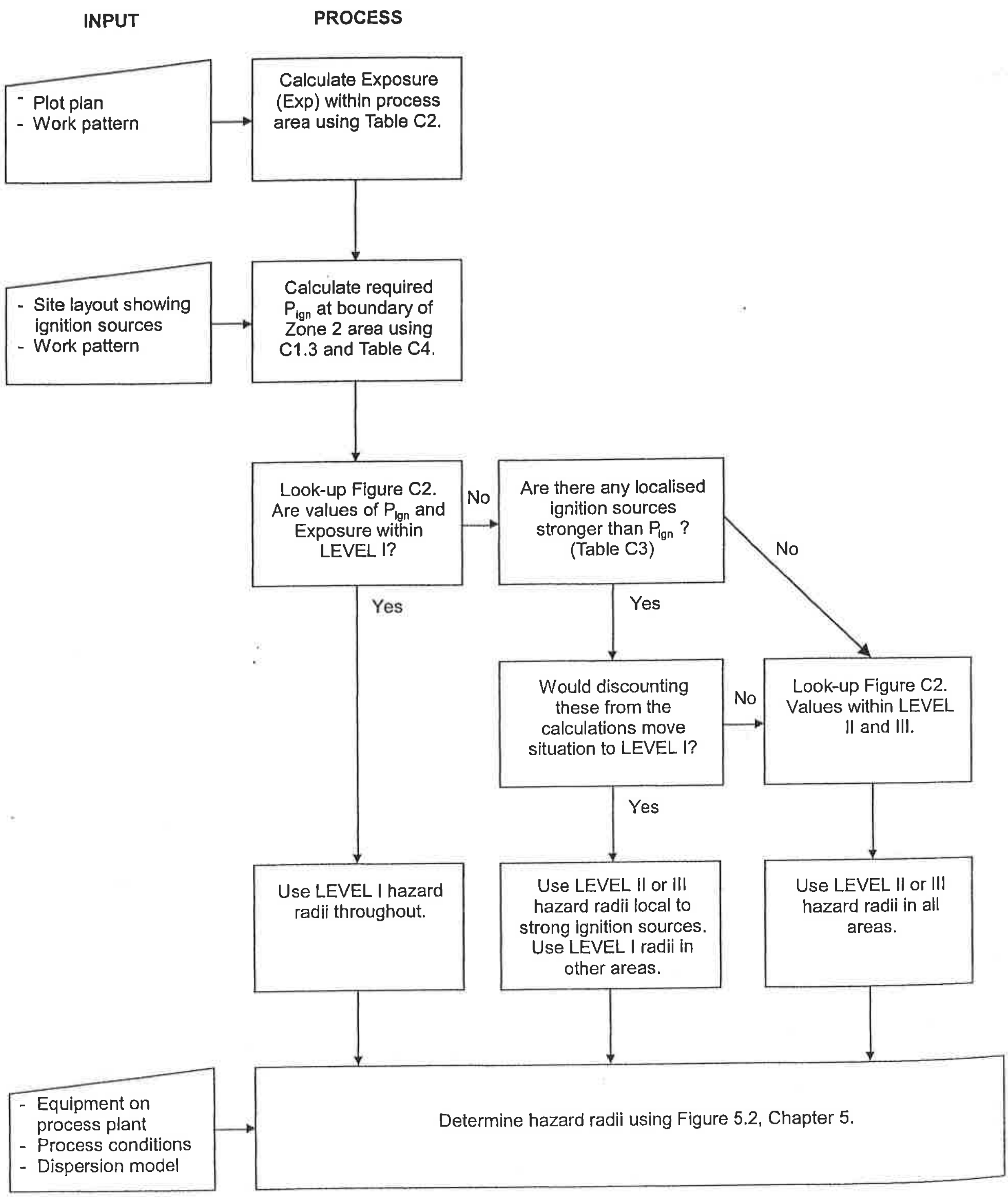


Figure C1 Risk-based procedure for calculation of hazard radii for secondary grade releases

ANNEX C - PART 1

PROCEDURE FOR ESTABLISHMENT OF APPROPRIATE RELEASE FREQUENCY LEVEL

C1.1 SECONDARY GRADE RELEASE FREQUENCIES

A secondary grade release, as defined in section 1.6.4, is one which would not be anticipated to occur during normal operation. Examples include failure of pump/ compressor seals, leaks from corrosion holes and flanges, or operational error.

Since for these situations the release rate may be of an unknown, unspecified and variable quantity, a methodology is proposed to determine the hole size to be used for such a secondary grade release. This methodology is described in IP *A Risk-based approach to hazardous area classification* and is based on a concept of 'release frequency LEVEL'. The objective of the methodology is to ensure the 'individual risk' (IR) to the most exposed worker on the plant does not exceed 1,0E-5/yr.

Historical failure data e.g. Cox, Lees and Ang *Classification of hazardous areas* indicate that, for a given item of equipment, small release holes occur more frequently than larger release holes.

These data have been assessed to determine the hole size that corresponds to a particular release frequency LEVEL for each type of equipment considered (see Table C6).

The release frequency LEVEL to be used on a specific plant is based on the exposure of the most exposed individual to flammable releases and the probability of ignition of those releases. The release frequency LEVEL is then used to determine hole sizes for secondary grade releases.

This Code suggests three LEVELS of release frequency (LEVELS I, II and III) 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 release frequency LEVEL will increase, which will result in larger failure scenarios.

Note that frequency LEVEL is inverse to release frequency: LEVEL 1 is highest frequency (1,0E-2) and LEVEL 3 is lowest frequency (1,0E-4).

Figure C1 describes the procedure for determining the appropriate release frequency LEVEL (I, II or III) to be used when determining hazard radii in section 5.4. For the purpose of this Code, the release frequency LEVEL is based on personnel risk only. The methodology does not preclude any company including other risk criteria or including other aspects e.g. business or economic risk. For further details see C2.2. It should be noted that even when the occupancy of an area is zero, the user will still be directed to release frequency LEVEL I as a minimum requirement.

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

C1.2 DETERMINATION OF 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:

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

where

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

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

These parameters are described as follows:

C1.2.1 Probability of occupancy (P_{occ})

P_{occ} is calculated by estimating the proportion of time the individual spends on site exposed to at least one potential release source (i.e. within a hazardous area). This is simply 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 1920 hr/yr (i.e. 40 hours * 48 weeks) is taken. This corresponds to a maximum P_{occ} of 0,22 i.e. 1920/8760.

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

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

These values are presented in Table C2.

C1.2.2 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 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 plants 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 C1 presents suggested values for average number of release sources within range.

C1.2.3 Calculation of Exposure (Exp)

Table C2 gives various input values of P_{occ} and N_{range} for determining exposure in the expression:

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

Table C1 Average number of release sources in 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 C2 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** **1 source**	**Congested plant** **5 sources**	**Many release sources** **30 sources**	Average number of sources in range during time on site	$P_{occ} * N_{range}$
1920	1	1920	**0,220**	0%	0%	100%	**30**	**6,6**
1920	1	1920	**0,220**	20%	30%	50%	**16,7**	**3,7**
1920	1	1920	**0,220**	20%	50%	30%	**11,7**	**2,6**
1920	1	1920	**0,220**	50%	30%	20%	**8**	**1,8**
1920	1	1920	**0,220**	100%	0%	0%	**1**	**0,2**
1920	0,6	1152	**0,130**	0%	0%	100%	**30**	**3,9**
1920	0,6	1152	**0,130**	20%	30%	50%	**16,7**	**2,2**
1920	0,6	1152	**0,130**	20%	50%	30%	**11,7**	**1,5**
1920	0,6	1152	**0,130**	50%	30%	20%	**8**	**1,0**
1920	0,6	1152	**0,130**	100%	0%	0%	**1**	**0,13**
1920	0,25	480	**0,055**	0%	0%	100%	**30**	**1,65**
1920	0,25	480	**0,055**	20%	30%	50%	**16,7**	**0,92**
1920	0,25	480	**0,055**	20%	50%	30%	**11,7**	**0,64**
1920	0,25	480	**0,055**	50%	30%	20%	**8**	**0,44**
1920	0,25	480	**0,055**	100%	0%	0%	**1**	**0,06**
1920	0,125	240	**0,028**	0%	0%	100%	**30**	**0,8**
1920	0,125	240	**0,028**	20%	30%	50%	**16,7**	**0,5**
1920	0,125	240	**0,028**	20%	50%	30%	**11,7**	**0,3**
1920	0,125	240	**0,028**	50%	30%	20%	**8**	**0,2**
1920	0,125	240	**0,028**	100%	0%	0%	**1**	**0,03**

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

Table C3 Probability of ignition (P_{ign}) for varying sources of ignition strengths

Source of ignition	Description	Probability of ignition given release
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

C1.3 PROBABILITY OF IGNITION (P_{ign}) AT THE ZONE 2 OUTER BOUNDARY

Sources of ignition are controlled within Zone 2 hazardous areas. However on the Zone 2/unclassified boundary it is acceptable to locate any sources of ignition.

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 IP *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 given release 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*. These values are summarised in Table C3.

Table C4 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
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

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.

Typical cases are given in Table C4.

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.

C1.4 DETERMINATION OF 'LEVEL'

As described in Annex C Part 2, release frequencies are banded into three levels as follows (shown graphically on Figure C2):

LEVEL	Frequency of release per leak 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

These release levels are plotted on Figure C2 against various values of Exp and P_{ign}.

Figure C2 may therefore be used to select the appropriate release frequency (LEVEL I, II or III) to use for a given P_{ign} at the Zone 2 boundary and a given exposure (Exp) of an individual to secondary grade release sources.

The following observations may be made about Figure C2:

— In general the release which occurs at a frequency of LEVEL I (1,0E-2/release source-yr) may be used to establish the Zone 2 boundary; however, if the exposure as defined in C1.2 is high, a frequency of LEVEL II (1,0E-3 /release source-yr) should be used.

— A frequency of LEVEL II (1,0E-3 /release source-yr) should also be used in situations where there is average occupancy and a concentration of strong ignition sources, giving a value of P_{ign} in excess of 0,1.

— 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.

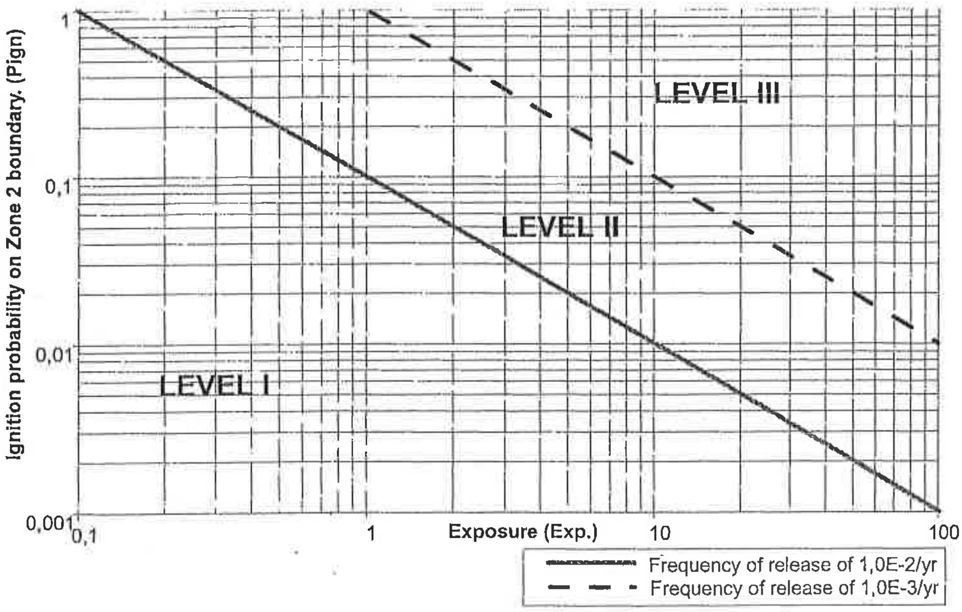


Figure C2 Release frequency LEVEL to achieve IR criterion of 1,0E-5 (or lower) given P_{Ign} and Exp

ANNEX C - PART 2

BACKGROUND TO RISK-BASED APPROACH

C2.0 INTRODUCTION

Part 2 provides extracts from IP *A risk-based approach to hazardous area classification* as background to the determination of release frequency LEVELS and hole sizes for secondary grade releases quoted in Chapter 5.

C2.1 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 C5 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 1000 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 C5 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. (BMA *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.) and, especially for offshore workers, 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.

This Code's 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 x 1,0E-4 = 1,0E-5/yr).

The value of 1,0E-5/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/yr.

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

C2.2 EFFECT OF INDIVIDUAL RISK CRITERION ON DETERMINING HOLE SIZES

This Code bases the hazard radii derived using the risk-based approach on an individual risk of 1,0E-5/yr as justified in C2.1. 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 release sizes 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 release frequencies 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 the LEVEL 1 event frequency, reducing still further the hazard radii.

C2.3 RELATIONSHIP OF INDIVIDUAL RISK TO RELEASE FREQUENCY

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

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

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} described below.

Individual Risk (/yr) from a number of ignited secondary grade release sources is defined as:

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

where:

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.
IP *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.

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

$IR_{ignited\ release}$ Maximum acceptable IR due to ignited releases. As described in C2.1, this is taken to be 1,0E-5/yr.

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). Exp = P_{occ} * N_{range}

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

Figures C3 and C4 show the relationship of $IR_{ignited\ release}$ (/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 frequency of flammable releases are banded into three LEVELS which are shown graphically on Figure C2.

C2.4 SELECTION OF HOLE SIZE FOR RELEASE FREQUENCY LEVEL

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

IP *A risk-based approach to hazardous area classification* contains a detailed description of how the leak frequency level vs. hole size relationship was determined for items of equipment considered to be release point sources. This is summarised in Annex C Part 1. It also provides a methodology which allows hazard radii to be calculated given a hole size and process conditions.

Table C6 summarises the hole size distribution for secondary grade releases at various frequencies from the items of equipment covered in section 5.4.

C2.5 JUSTIFICATION OF LOWER BOUND FREQUENCY FOR SECONDARY GRADE RELEASES

The previous edition of this Code stated that secondary grade releases were those present for less than 10 hours per year with a lower bound duration of 0 hours (i.e. no lower bound). However, in section 5.4 on flanges, the concept of a minimum number of flanges (i.e. 10 or more) was introduced. Ten or more flanges were required within close proximity to create sufficient likelihood of release to justify classification as a secondary grade release. In section 1.6 of this edition a secondary grade release is defined as one which is present for between 1 and 10 hr/yr i.e. introducing a lower bound of 1 hour duration.

1 hour per year is equivalent to an approximate frequency of 1E-4/yr and therefore, to meet the IR criterion of 10E-5/yr only requires the combined mitigating probabilities for ignition and occupancy to be less than or equal to 0,1 which, for a maximum probability of occupancy of 0,22, will be met in all circumstances except where there are strong continuous sources of ignition.

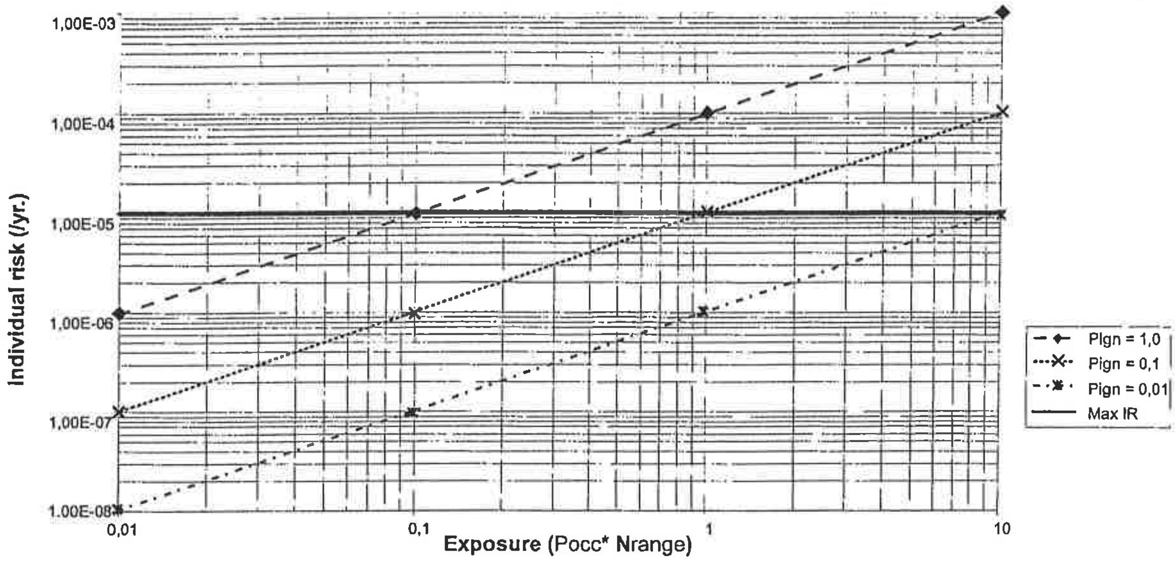


Figure C3 Individual risk (/yr) vs. exposure (release frequency = 1,0E-2 /release source-yr)

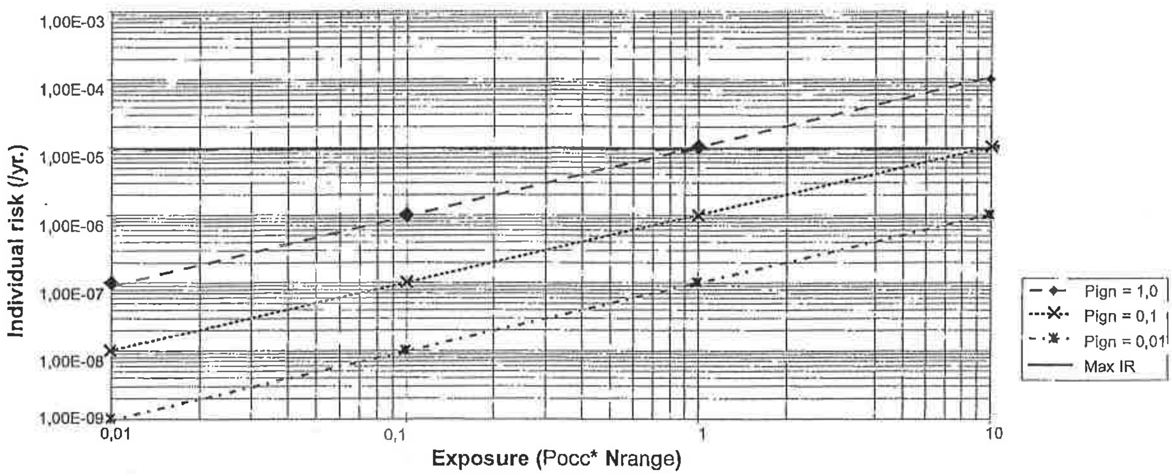


Figure C4 Individual risk (/yr) vs. exposure (release frequency = 1,0E-3 /release source-yr)

Table C6 Equivalent hole sizes for a range of release frequencies

Equipment type	Release frequency level		
	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**
Pumps			
Single seal throttle bush	0,1SD	0,01A or 0,1SD or D*	0,1A
Single seal no throttle bush	0,23SD	0,01A or 0,23SD or D*	
Double seal throttle bush	N/A	0,01A or 0,1SD or D*	
Compressors			
Purged labyrinth	0,12SD	22 mm	70 mm
Floating ring	0,053SD		
Flange (upper bound)	0,6 mm	2,0 mm	6,0 mm
Compressed asbestos fibre	N/A	0,5 mm	2,3 mm
Spiral wound joint	N/A	0,2 mm	0,5 mm
Ring type joint	N/A	0,1 mm	1,0 mm
Valves	0,1 mm	2 mm	0,1DP
Other	Hole size distribution versus frequency to be determined using historical leak data if available, or suitable synthesis technique e.g. fault trees.		

* = Select largest hole size
N/A = Data not available; use a nominal hole size of 2 mm diameter
D = Equivalent diameter (mm) of seal leak from pump/compressor vendor
SD = Shaft diameter (mm) for pumps and compressors
A = Area of pipeline connected to equipment (mm^2) where 0,01A and 0,1A are equivalent to 0,1DP and 0,3DP respectively and DP is the diameter of the pipeline connected to the equipment
DP = Pipeline diameter (mm) for valves

Note that for pumps and compressors it is recommended that the actual size of the hole which would result from seal failure is established using manufacturers' data. In the absence of such data the values given above may be used.

ANNEX C - PART 3

BACKGROUND TO THE CALCULATION OF HAZARD RADII IN CHAPTER 5

C3.0 INTRODUCTION

This Annex provides extracts from IP *Calculations in support of IP15* as background to the calculation of hazard radii based on dispersion modelling. Dispersion modelling was used to determine the hazard radius, R_1, for each release source quoted in section 5.4. 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.

C3.1 BASIS FOR DISPERSION MODELLING

Dispersion modelling[8] was carried out for representative fluids for categories A, B, C, G(i) and G(ii). The compositions used are shown in Table C7. In addition, the physical parameters used during modelling are shown in Table C8. If actual compositions of flammable fluids or dispersion parameters vary widely from those used here, specific dispersion modelling should be carried out to verify safe hazard radii.

Table C7 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	100	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
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_2O 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 2 of IP *Calculations in support of IP15*)

[8] Dispersion modelling was carried out using Shell Global Solutions' HGSYSTEM package, which is freely available on the internet at http://www.hgsystem.com to users for determining hazard radii for other conditions if required.

C3.2 HAZARD RADIUS 'LOOK-UP' TABLES BASED ON DISPERSION MODELLING

Hazard radii appropriate to the release hole sizes quoted for items of equipment in section 5.4 may be directly read off Tables C9(a) and (b). Where the equipment is not covered by section 5.4, hole sizes may be determined by historical data or synthesis techniques.

The numerical values given in Tables C9(a) and (b) are specific to the example fluids. The release rate for these fluids is only weakly dependent upon small variations in the storage temperature of about 20°C, which is chosen to reflect a daily average UK summer temperature. Other fluids may be more sensitive to temperature changes.

The ground effect radius, R_2, should be used in conjunction with section 5.5 and Figure 5.6 to determine the shape of a hazardous area.

Typical hazard radii from Tables C9(a) and (b) are presented in tabular form in the relevant sections of Chapter 5.

Table C8 Physical parameters used in dispersion modelling

Standard conditions	Value
Ambient temperature	20°C
Relative humidity	70%
Wind speed	2 m/s
Reference height	10,0 m
Stability class	D
Surface roughness	0,03 m
Sample time	18,75 s
Release height	1,0 m
Reservoir temperature	20°C
Release orientation (in relation to wind direction)	0 degrees

Table C9(a) Hazard radius (R_1)

Fluid category	Release pressure (bar(a))	Release flow rate (kg/s)				Hazard radius R_1 (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*	0,01	0,04	0,3	1	2	4	8	14
	10	0,01	0,06	0,4	1,5	2,5	4	9	16
	50	0,03	0,14	0,9	3,5	2,5	5	11	20
	100	0,05	0,2	1,2	5	2,5	5	11	22
B	5	0,01	0,04	0,3	1	2	4	8	14
	10	0,02	0,07	0,4	1,7	2	4	9	16
	50	0,04	0,15	1	4	2	4	10	19
	100	0,06	0,2	1,4	5,5	2	4	10	20
C	5	0,01	0,06	0,3	1,1	2	4	8	14
	10	0,02	0,1	0,4	1,7	2,5	4,5	9	17
	50	0,04	0,2	1	4	2,5	5	11	21
	100	0,06	0,25	1,4	6	2,5	5	12	22
G(i)	5	0,001	0,002	0,02	0,06	< 1	< 1	<1	1,5
	10	0,001	0,005	0,03	0,1	< 1	< 1	1	2
	50	0,007	0,03	0,2	0,7	< 1	1	2,5	5
	100	0,015	0,06	0,4	1,5	< 1	1,5	4	7
G(ii)	5	0,0004	0,001	0,01	0,04	< 1	<1	1,5	3
	10	0,001	0,003	0,02	0,07	< 1	1	2	4
	50	0,004	0,02	0,1	0,4	< 1	2	4	8
	100	0,007	0,03	0,2	0,7	1	2	6	11

Table C9(b) Hazard radius at ground level (R_2)

Fluid category	Release pressure (bar(a))	Release flow rate (kg/s)				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*	0,01	0,04	0,3	1	2	4	16	40
	10	0,01	0,06	0,4	1,5	2,5	4,5	20	50
	50	0,03	0,14	0,9	3,5	3	5,5	20	50
	100	0,05	0,2	1,2	5	3	6	20	50
B	5	0,01	0,04	0,3	1	2	4	14	40
	10	0,02	0,07	0,4	1,7	2,5	4	16	40
	50	0,04	0,15	1	4	2,5	5	17	40
	100	0,06	0,2	1,4	5,5	3	5	17	40
C	5	0,01	0,06	0,3	1,1	2,5	4	20	50
	10	0,02	0,1	0,4	1,7	2,5	4,5	21	50
	50	0,04	0,2	1	4	3	5,5	21	50
	100	0,06	0,25	1,4	6	3	6	21	50
G(i)	5	0,001	0,002	0,02	0,06	< 1	< 1	1	2
	10	0,001	0,005	0,03	0,1	< 1	< 1	1,5	3
	50	0,007	0,03	0,2	0,7	< 1	1,5	3,5	7
	100	0,015	0,06	0,4	1,5	1	2	5	11
G(ii)	5	0,0004	0,001	0,01	0,04	< 1	< 1	2	4
	10	0,001	0,003	0,02	0,07	< 1	1	2,5	5
	50	0,004	0,02	0,1	0,4	1	2	6	11
	100	0,007	0,03	0,2	0,7	2	3	8	14

* 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.

ANNEX D

RELEASES WITHIN BUILDINGS AND ASSOCIATED EXTERNAL HAZARDOUS AREAS

D1 INTRODUCTION

In the first edition of IP15 *Area classification code for petroleum installations*, guidance was supplied on the zoning to be applied within buildings 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 enings, both in relation to the prevailing wind or other forced ventilation flows and the release itself. Experience in the use of the guidance suggests that it provided a pragmatic approach in the absence of any more detailed analysis. Nevertheless, the scientific basis for this guidance is not clear and, unlike the situation in Chapter 5, where specific consequence models can be used within their limits of applicability in order to produce tables of recommended dispersion distances for individual point sources for releases in open areas, no such generally applicable analysis can be produced for releases inside enclosures. The guidance contained in Chapter 6 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 6.1) and the effect of the degree of ventilation on the zone classification (Tables 6.1 and 6.2). The purpose of this Annex is to provide further explanation and background information relating to release behaviour in enclosures. The material is based on IP *Calculations in support of IP15* (item 6).

D2 TYPES OF VENTILATION

A release of flammable material into a confined space, such as a building, is potentially an extremely hazardous event. Ignition may lead to the development of overpressure causing structural damage to the enclosure and neighbouring buildings. Consequently, there is a need to distinguish between releases that can be controlled by suitable ventilation, hazardous 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.

A further concern related to releases inside enclosures is how to assess the conditions under which a release might escape the enclosure at a flammable concentration and require external ignition prevention precautions. This will depend on the degree to which the release is diluted within the enclosure by any ventilating flows. General guidance for the safe ventilation of building enclosures is given in Chapter 6 by dividing activities that may lead to releases into categories requiring different grades of ventilation. Grades of ventilation are then parameterised by the air change rate, α, expressed as the number of times per hour that the air in the building is changed. Four categories are identified:

Adequate ventilation:
To quickly reduce possibly flammable concentrations to safe concentrations in the event of a leak or spillage. Based on engineering experience, 12 air changes/hr is recommended where action is taken to stop the fluid source as quickly as possible.

Dilution ventilation:
Forced ventilation at sufficient rate to limit the formation of a gas volume at a concentration of 20 % of the LFL is recommended. Typically dilution ventilation will be vigorous (30 - 90 air changes/hr) and the output diverted to vents.

Local exhaust ventilation:
The use of either small scale dilution ventilation (use of extractors etc.) or an enhancement of flow in obstructed areas to attain adequate ventilation is recommended.

Overpressure ventilation:
Prevention of the ingress of flammable material to a confined area by maintaining an over-pressure within it is recommended for cases where buildings are close to potential sources but do not contain sources themselves.

Of the above categories, only adequate ventilation need be quantified since it applies generally to small spills. The dilution ventilation rate needs to be specially designed for each application. It usually requires fresh air to be forced into an enclosure; forced extraction may be needed as well. Local exhaust ventilation is essentially the same as adequate ventilation for small enclosures within a larger confined workplace. Its effectiveness depends on effective capture of the release by ensuring an adequate flow velocity as well as adequate volume flow of air. In the normal case the effluent is ducted to a vent. Overpressure ventilation requires a minimum pressure differential to be maintained during all normal operations.

D3 ADEQUATE VENTILATION

Assuming for the purposes of illustration that the gaseous flammable material that is released mixes uniformly with the ventilating flow within a building or enclosure, it is possible to calculate the time-dependent accumulation of gas concentration within the enclosure. Further details are provided in IP *Calculations in support of IP15*, item 6. The results of these calculations indicate the following for different density gases:

D3.1 For a heavier-than-air gas

In round figures, if the gas is well mixed, a release of ≅ 0,1 kg/s could give rise to potentially flammable conditions through an adequately ventilated building (12 air changes per hour), of volume 1 000 m^3, on a time scale of ~700 s. This would be an extremely hazardous condition. Larger releases might lead to potential flammable regions outside of the building because the material leaving would be above the lower flammability limit for the gas within the building. Certainly a release as large as about 1 kg/s, capable of filling the building to the UFL should not be tolerated.

For pressurised releases a release rate of ≅ 0,1 kg/s for a category A or B fluid could arise for a hole size as small as 2 mm for pressures below 50 bar. The hazard radius for an unconfined release of this magnitude is ≅ 5 m which is half the characteristic length scale of the example building and the order of magnitude of the free path of a centrally placed release. The hazard radius is also the distance over which the unconfined jet entrains enough air to dilute the mass flow to the LFL. This entrainment is comparable to the circulation in the building and it is thus reasonable to propose that the volume of air passing through the building can be well mixed by a pressurised release, in the absence of impaction on surrounding surfaces or obstructions. If significant impaction occurs, it may be that buoyancy effects will be more significant, leading to preferential mixture accumulation.

D3.2 For a lighter-than-air gas

The analysis above can be reworked for category G(i) and G(ii) gases and it can be deduced that quite small pressurised releases of the type used to underpin the hazard radius recommendations for unconfined releases and of size of about 0,1 kg/s could result in the establishment of a flammable mixture within a 1 000 m^3 building having a ventilation rate of 12 air changes per hour for category A and G(i) fluids, and a somewhat lower value of ≅ 0,04 kg/s for category G(ii) fluid.

D4 FLOW AND MIXING AROUND BUILDINGS

Flow and dispersion are strongly influenced by the building shape and orientation to the wind. Buildings are classified as bluff rather than streamlined bodies and this greatly complicates the description of the flow. Consequently there is a large body of work reporting the study of flow and dispersion in building wakes, referenced in IP *Calculations in support of IP15*.

The main feature of a bluff rather than a streamlined body is that the wind flow cannot pass smoothly around the body but instead separates from the upwind edges of the body. This forms a region along the sides and behind the body in which pressure is reduced. The pressure difference across this region causes the separated flow from each edge and side of the body to curve towards each other and eventually intercept to form a recirculation region behind the body in which the mean flow is actually reversing as fluid is returned towards the low pressure regions. Depending on the shape of the body this region can extend back up the building sides to the building front. The flow within the recirculation region is highly time varying and unsteady. It was originally thought that the recirculation region was a closed 'bubble' bounded by a separation streamline and ıat material was transported in and out of the region by turbulent mixing across this boundary. This remains a useful simplification of the flow but it is now known that transfer of material in and out of the recirculation region is not limited to turbulent transport across the boundary. Material is also advected into the region along entering mean streamlines and advected out via vertical spiral vortices or through entrainment by horseshoe vortices. The entire recirculation region may even collapse intermittently causing all the contents to be flushed downstream.

There is no simple and accurate way of assessing the fate of material released into the wake of a building. Dispersion models in regulatory use (ADMS, ISC, AERMOD) recognise that significant mixing takes place in a building wake and this can reduce concentrations downwind of the building by up to an order of magnitude compared with an unconfined release. The models do not attempt to describe events in the near ˀke and treat this as a well-stirred region of constant ‚oncentration i.e. any material leaving the building is predicted to undergo a step change in concentration.

Such models should not be used closer to the building than 3-5 times the extent of the recirculation zone. Typically the extent of the recirculation zone for squat shaped buildings scales as the building height and for tall thin buildings it scales as the building width. For a building of characteristic dimension 10 m this imposes a region of modelling uncertainty of 30-50 m. This is of greater extent than the present code for the external hazard radii.

An alternative to regulatory models is to use experimentation or CFD to explore some release scenarios. The disadvantage, in addition to that of cost, is that generalisation of the results is difficult. This particular problem is also difficult to solve with computational methods because of the physical complexity of the problem and the requirement for validation.

D5 EXTERNAL HAZARDS

The implication of section D3 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:

(i) 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. For a building of size ~ 1 000 m^3 this implies pressurised releases have to exceed ~ 0,1 kg/s and assumes that the releases take place within the body of the building.

(ii) The efflux from the building will comprise a flow of approximately 3,33 m^3/s for a building of size ~ 1 000 m^3 with adequate ventilation and will take place through the normal ventilation openings in the building fabric.

(iii) 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.

(iv) Hence, the hazardous areas will be restricted to the immediate vicinity of vent openings and the building fabric.

If releases are larger than 0,1 kg/s then a greater hazard will exist.

For slightly higher flow rates, 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 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 hazardous 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 pipe work between a gas bottle and other apparatus, boil over 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 hazardous 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.

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 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 unstenched form. Quantities kept in the laboratory should be kept to a minimum, and effective low level 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 so it is of negligible extent. Hazardous 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 hazardous 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 hazardous 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 hazardous 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

TYPES OF PROTECTION AND ELECTRICAL APPARATUS THAT MAY HAVE AN INTERNAL SOURCE OF RELEASE

F1 DESCRIPTION OF THE RECOGNISED TYPES OF PROTECTION LISTED IN TABLE 7.1

A brief description of the internationally standardised types of protection listed in Table 7.1 follows for ease of reference.

Oil immersed protection (Ex o)

A type of protection in which the electrical apparatus or parts thereof are immersed in non-volatile oil such that an explosive atmosphere which may occur above the oil level or outside of the enclosure cannot be ignited e.g. switch gear. See IEC 60079-6, BS EN 50015. Acceptable for Zone 2.

Pressurisation or continuous dilution (Ex p)

A method of protection using the pressurisation of an enclosure of a protective gas to prevent the ingress of an external flammable atmosphere. Where there is no internal release, the protective gas may be air; where there is an internal release then pressurisation with an inert gas is applied, or continuous dilution with air at a rate that will dilute and prevent the release from reaching the LFL.

For details see IEC 60079-2 or BS EN 50016. In protection of large enclosures such as control rooms, see also sections 6.4.3.2 and 6.4.3.3. Suitable for Zone 1.

Powder-filled protection (Ex q)

Achieved by filling the enclosure with finely granulated material (usually quartz) so that in the intended service any arc occurring within the enclosure will not ignite any external atmosphere. Suitable for Zone 2 only. See IEC 60079-5, BS EN 50017.

Flame-proof enclosure (Ex d)

An enclosure that will withstand an internal explosion of an explosive mixture without suffering damage or propagating the internal flammation, through any joints or structural openings in the enclosure, to an external explosive mixture for which it is designed. A flame-proof enclosure may be used for apparatus containing an internal source of release. However, see F2 note (1) regarding the need for release of any internal pressure that could rise above atmospheric. For details see references in Table 7.1 and the note to section 7.6(b).

Note that a flame-proof enclosure is usually certified with the protected electrical apparatus in place. This type of protection is permitted in all zones **except** Zone 0.

Increased safety (Ex e)

A type of protection giving an increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks. See BS EN 50019. IEC 60079-7 gives requirements for construction and tests.

This type of protection is permitted in all zones **except** Zone 0. (In some countries authorities may restrict its use to Zone 2.)

Intrinsic safety (Ex ia and Ex ib)

Intrinsic safety applies to electrical apparatus, or part of such apparatus, intended for use in a hazardous area, in which the electrical circuits themselves are incapable of causing ignition. Furthermore, it applies to associated apparatus and to any parts located outside the hazardous area, from where the intrinsic safety of the electrical circuits may be influenced by the design, construction and use of such apparatus or parts.

An intrinsically-safe circuit is one in which any spark or thermal effect, produced either when it conforms electrically and mechanically with its design specification or in specified fault conditions, is incapable of causing ignition of a given explosive mixture. A fault is defined as a defect or electrical breakdown of any fallible component or connection between components, upon which the intrinsic safety of the circuit depends. Typical test conditions are prescribed in IEC 60079-11. An intrinsically-safe apparatus is one in which all electrical circuits are intrinsically safe. It is placed in one of two categories:

Category Ex ia:
Apparatus in this category is incapable of causing ignition in normal operation, or with a single fault, or with any combination of two faults applied, with a specified safety factor for current and/or voltage.

When the apparatus has unprotected sparking contacts in any part of the apparatus likely to be exposed continuously or for long periods to an explosive mixture, such contacts require the application of supplementary protective measures.

Apparatus in this category offers the highest degree of protection and is permitted **in all zones**.

Category Ex ib:
Apparatus in this category is incapable of causing ignition in normal operation, or with any single fault applied with a specified safety factor for current and/or voltage. This type of protection is permitted in all zones **except** Zone 0.

Non-incendive (Ex n)

A type of protection such that in normal operation within its rated duty it will not ignite a surrounding flammable atmosphere, and a fault capable of ignition is unlikely to occur. See BS EN 50021. It includes equipment which is hermetically sealed.

Included in this category is a range of types of protection, such as:

(a) Energy limited.
(b) Non-sparking.
(c) Restricted breathing.

This type of protection is permitted in Zone 2. Further details on sub-designations of Ex n are provided in IEC 60079-15.

Encapsulation type of protection (Ex m)

Electrical equipment is described as encapsulated when it is embedded into a mass of fire-resistant solid insulating material. Detailed requirements for electrical and mechanical properties are set out in BS EN 50028. Equipment of this type is suitable for use in Zones 1 and 2.

Special protection (Ex s)

This category is no longer applicable; however, ATEX equipment category II 1 G is appropriate, i.e. meeting the requirements of IEC 60079-26 or EN 50284.

F2 ELECTRICAL APPARATUS WITH AN INTERNAL SOURCE OF RELEASE

It is important to note in selecting explosion-protected apparatus that, as indicated in sections 7.6(c) and 7.7.3 note (b), consideration should be given to whether there may be a possible internal release of flammable material **within** the equipment itself, which could require a different allocation of what zone may be applicable for this selection, and, if so, whether a difference in composition as compared to the external atmosphere could affect the selection of apparatus sub-group and T class.

While not exhaustive, and the advice of the manufacturer or supplier should always be ascertained, the following notes may be of assistance:

(a) An internal source of release in any category of explosion-protected electrical apparatus is defined as a device(s) in the apparatus from which flammable gas or vapour is released in the course of normal operation or may be released in abnormal circumstances, e.g. due to failure of the containment system.

Thus sometimes a flammable substance is of necessity introduced into the enclosure of an electrical apparatus, in particular in the case of a process analyser and in certain instruments used for measurement and control where there is connection with the process fluid.

For some types of instrument, protection by pressurisation or continuous dilution by either air or inert gas such as nitrogen may be provided, as in type of protection 'p' in accordance with IEC 60079-2.

(b) It should be noted that an 'enclosure' may be of any size and may range from a small instrument case to a structure such as an analyser house or control room containing multiple apparatus. The enclosure may serve solely as a mechanical protection or may constitute an integral part of the type of explosion protection, and for the variant cases section 6.4 should be consulted. The following notes apply to the release that may occur within a single apparatus enclosure, but it should be borne in mind that there may be 'nested enclosures' when one or more enclosures are placed one within another. In such a case it is necessary to assess the probability of a flammable substance of potentially explosive force being present between each successive enclosure boundary before proceeding to determine the type of protection for apparatus inside each. In placing one or more enclosures within one another the atmosphere of the inner enclosures may prove more significant in determining the types of protection for apparatus inside than the hazardous area classification in the zone of application.

(c) The nature of an internal hazard within the enclosure (casing) of a single apparatus will depend, as in general classification, upon a number of circumstances such as the integrity of construction and in-service maintenance, whether an internal release occurs in normal or abnormal conditions as defined below, and whether when, for example, the protection of the apparatus is pressurisation or dilution with air, the release is 'restricted' or 'unrestricted'.

The following comments are made on the assumption that such equipment is correctly installed, tested and maintained:

(1) A 'restricted release' is one in which any release of flammable material within the apparatus is limited to an extent within the containment or diluent capacity of a protective gas system.

An 'unrestricted release' is one in which the above can be exceeded. As outlined later, it is not just the performance of equipment when new; the effect of long-term ageing and deterioration must also be considered.

(Where release internally could be significant, there will be need for adequate and safe means of relieving this to the exterior by special breather or similar provision, which will not affect the type of protection. With a flammable release, such devices should include flame arrestor provision, as in the case of the flame-proof enclosure of Ex d equipment.)

(2) Assessment of an internal release. The assessment should recognise that the consequences of an internal release of flammable gas or vapour within an apparatus may be more severe than a release externally, since in the former, in the absence of a dilution protective system, it can remain and accumulate. Thus a release that could be undetectable in the open due to diffusion can slowly raise the level within such an enclosure to a point that comes within the flammable range.

While individual judgement must always apply, the broad types of release potential that can arise with various forms of equipment can be considered as follows.

Evaluation of internal release hazard relative to the external hazard zoning. It will be seen from the foregoing generalised review that the internal hazard assessment will in some cases override the external classification and be the factor that determines the type of protection. In other cases, when the same equipment is to be installed in a more severe external hazard zoning, it will be these external hazards that will determine the actual hazard type of protection to be applied.

(3) 'No normal release'. This term recognises that for certain equipment there is minimal risk of a release within its enclosure throughout its in-service duration between inspection and maintenance intervals.

While it is not possible to be absolutely specific, it is normally assigned to equipment in which there is enclosure in metallic piping, tubing and elements such as Bourdon gauges, bellows or spirals operated within their established ratings, and with joints with threads, welding, metallic compression fittings, etc., which could similarly be considered as having no normal release.

Such a criterion entails materials and construction that withstand time and service, and do not age or degrade, which normally would militate against window assemblies in casings, moving seals, elastomeric seal materials and non-metallic flexible tubing, unless experience demonstrates the contrary.

Since seals, rotating or sliding, flanged joints and flexible non-metallic tubing can be assumed often to leak minutely after a period in service, the lower categorisation of 'limited normal release' may be considered, against the possibility that degradation with age could give rise to release above that expected for new equipment.

(4) 'No abnormal release'. Electrical apparatus may be considered in this category if under any foreseeable abnormal conditions there is no possibility that an internal release could occur.

An example that can be quoted would be a Bourdon tube with a mechanical strength such that any foreseeable overpressure would not cause failure of the tube.

Conversely, when under foreseeable abnormal conditions an internal release could occur, e.g. a thin-walled metal diaphragm or bellows, which could mechanically fail due to repeated flexing or application outside the intended range of operation, the apparatus should be considered as having an abnormal release potential.

F3 SELECTION OF ZONE CLASSIFICATION

The following generalised examples may be illustrative of the approach that may be taken, using more detailed guidance than is possible here. The effect of the internal release composition on apparatus sub-group and temperature class should always be considered.

(a) When there is normal internal release, the internal hazards are comparable to the hazards of an external Zone 0, and comparable type of protection limitations should be assumed, with consideration of type of protection 'p' to protect against the release by continuous dilution with air to circa 25 % of the LFL.

(b) Pressurisation with inert gas such as nitrogen can also be applied, since the internal releases cannot create a flammable atmosphere in the absence of oxygen.

With type of protection 'p', the requirements of protection against loss of protective gas input by alarm or shutdown should be observed.

(c) Where dilution with air is applied in the case of a 'restricted normal release', the internal hazards are reduced to a level comparable to those in an external non-hazardous zone. This applies also in the event of abnormal release which would be in the 'restricted' category. Were the abnormal release to be in the 'unrestricted' category as defined in note (1), this would not be applicable and the internal hazard would become comparable to that of an external Zone 1.

(d) When protective gases are used, as in the above examples, pre-purging by the passage of such gas through the enclosure and its associated ductings should be carried out prior to the energisation of the system, so that flammable gas is first cleared from the enclosure.

(e) In all other types of protection, provided there is no normal release and that an abnormal release would be only very infrequent and of relatively short duration, the internal hazards are comparable to those of an external Zone 2 release.

Thus if such apparatus is installed in an external non-hazardous or Zone 2 area, the internal hazards are the determining factor calling for Zone 2 type protection.

(f) However, where the same apparatus as in (e) is installed in an external Zone 1 or Zone 0, it is the latter external classification that will determine the type of protection level, not the internal conditions.

Again, with an apparatus in which the internal release hazards are assessed as comparable to that of an external Zone 1, installation of that apparatus in a Zone 0 external zone will result in the latter determining that the type of protection should also be that for Zone 0.

ANNEX G

SAFEGUARDS ON FIRED PROCESS HEATERS

G1.0 INTRODUCTION

It is not appropriate to classify the inside of a plant designed for controlled combustion as a hazardous area, although if fuel is supplied to a combustion chamber when there is no flame or other form of ignition, a flammable atmosphere can quickly form. With fired heaters, dangerous conditions can occur:

- While the plant is shut down, if fuel can leak past a control valve or valves.
- During start up if too much fuel is supplied before source of ignition is provided.
- During normal running if the flame fails for any reason, e.g. brief interruption to the fuel supply, or sudden surge of combustion air or at shut down if the combustion air supply is shut before the fuel supply.

Detailed technical specifications for burner control systems have been developed for many applications, and the requirements depend mainly on the designed heat input, and whether the plant runs for long continuous periods, or intermittently. Fired process heaters should normally follow the requirements for similar heaters in other applications and the general guidance given in HSC *Safe operation of ceramic kilns* can be applied.

Precautions can be grouped under the headings of flame failure safeguards, safety shut off valves for fuel lines, ignition sequences, operating procedures, shut down sequences, additional safety monitors and explosion relief.

G1.1 Flame failure safeguards

These are required on all burners operating below 750°C, and higher temperature burners that operate intermittently. Ionising detectors (particularly flame rectification) or radiation detectors are preferred.

Burners operating for long periods above 750°C may not be fitted with flame failure protection, and may have manual operated valves in the fuel supply to individual burners or a group of burners. Where this is the case, control systems are required to prevent fuel supply to a burner when no pilot flame or other source of ignition is present.

G1.2 Safety shut off valves

Recommendations on types and monitoring systems are given in BS EN 161, BS EN 676, BS EN 1643 and BS 5885.

G1.3 Ignition sequences

These should preferably be fully automatic with timed sequences, incorporating the following:

- Prepare checks on safety system.
- Pre-ignition purge, typically 5 times combustion chamber volume of air.
- Ignition, with fuel supply before ignition controlled so that the maximum energy release is limited to 53 KJ/m^3 of combustion chamber volume.
- Flame proving, with post purge if ignition is not established.

G1.4 Operating procedures

These should be available in clear, unambiguous form, with concise instructions for emergency shut down.

G1.5 Shut down sequences

Air supplies should be maintained until all pilot/main fuel valves have been closed, and continue for a period to purge residual combustion products. The safety shut down system should be in the closed position when the plant is shut down.

G1.6 Additional safety monitors

These may be appropriate, e.g. flow and pressure sensors on fuel and air supplies or exhaust and recirculation fans.

G1.7 Explosion relief

The design should consider the possible risk of explosions, and if necessary incorporate explosion relief. See BS EN 746-2.

ANNEX H

GLOSSARY

Adequate ventilation: This is ventilation, natural, artificial or a combination of both, sufficient to avoid persistence of flammable atmospheres within sheltered or enclosed areas but insufficient to avoid their initial formation and spread throughout the area. This will normally be achieved by a uniform ventilation rate of a minimum of 12 air changes/hr with no stagnant areas (see section 6.4.1 and Annex D).

Apparatus group (or sub-group): Certain electrical apparatus for use in a hazardous area is allocated to a group or sub-group depending on its suitability for use with specific gases (see section 7.6).

Area classification: see hazardous area classification.

ATEX: This acronym is short for Atmosphere Explosiv, and is used in relation to directives 94/9/EC 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. Further details are given in Chapter 7. 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. It is implemented into UK law as part of the *Dangerous Substances and Explosive Atmospheres Regulations* that also transcribe the requirements of other European legislation.

Auto-ignition temperature (AIT): see ignition temperature; also synonymous with spontaneous ignition temperature (SIT).

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 IP *Electrical safety code.*

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 section 1.8).

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). The ATEX 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 IP 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 Hot work). It includes the use of tools for erection, dismantling and cleaning, which are not liable to produce incendive 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 Gas detector.

Continuous grade release: A release that is continuous or nearly so (see section 1.6.4).

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 (see section 6.4.3.2 and Annex D).

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 IP *Electrical safety code*.

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 (see section 6.4.1).

Equivalent diameter: The diameter of the circle of equivalent area to the rectangle.

Equivalent leak hole diameter: Dispersion distances quoted in Annex C (Part 3) 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 arrestor: 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 'inflammable'): 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 Flash point and Annex A.

Flammable atmosphere: A mixture of flammable gases or vapours with air in such a proportion that, without any further admixture, it will burn when ignited (see section 1.6.1).

Flammable limits (or range): The limits of combustibility of flammable gases or vapour when mixed with air (see Upper flammable limit and Lower flammable limit). 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 hazardous area classification of flammable petroleum fluids by the point source method of Chapter 5 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 1.2, Chapter 1).

Gas detector: An instrument, fixed or portable, designed to detect and measure the presence and concentration of flammable gas in an area (see section 8.3).

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 classification: The notional division of a facility into hazardous areas and non-hazardous areas, and the subdivision of hazardous areas into zones (see section 1.6.2).

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 recognized (see section 1.6.3).

Hazardous atmosphere: An atmosphere containing flammable gas or vapour in a concentration capable of ignition. (The term is synonymous with flammable atmosphere 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 section 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 Cold work.)

Ignition temperature (synonymous with 'auto-' and 'spontaneous-ignition temperatures'): The temperature at which a substance will begin to burn without application of any source of ignition (see sections 8.2.6.1, 8.2.6.2 and 7.7.2).

Inadequate ventilation: Ventilation, natural or artificial, which is insufficient to avoid persistence of a flammable atmosphere within sheltered or enclosed areas (see sections 6.4.2 and 6.6).

Incendive spark: A spark of sufficient temperature and energy to ignite a flammable gas.

Inflammable: see flammable.

Internal release (internal source of release): see Annex F.

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 (see section 7.4 and the description in the list of F1 in Annex F).

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 (see Chapter 6 and Annex D).

Lower explosive limit (LEL): Synonymous with lower flammable limit.

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 (see sections 3.1.1 and 6.2).

Overpressure ventilation: Artificial ventilation of an enclosed area to maintain the area at a controlled pressure above the ambient pressure (see section 6.4.3.3).

Primary grade release: A release that is likely to occur in normal operation (see section 1.6.4).

Pyrophoric scale or deposits: Usually finely divided ferrous sulphide formed inside a tank, pipeline or equipment, in the presence of mercaptans or hydrogen sulphide. 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 (see section 1.6.4).

Sheltered area: An area within an open area where ventilation may be less than in a true open area but is adequate ventilation as defined in section 6.3.

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 (see section 1.6.4).

Source of ignition: Naked lights, fires, certain electrical equipment, hot surfaces above ignition temperature, or a spark or flame produced by any other means (see Chapters 7 and 8).

Spontaneous ignition temperature (SIT): see Ignition temperature.

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 (see section 7.7).

Types of protection: Measures applied in the construction of electrical apparatus to prevent the ignition of a surrounding flammable release. See section 7.4 and the descriptive list in F2 in Annex F. (See also Internal release.)

Upper explosive limit (UEL): Synonymous with upper flammable limit.

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 (see section 1.7).

Work permit: A document issued by an authorised person to permit work to be carried out safely in a defined area under specified conditions (see section 8.4).

Zone 0: That part of a hazardous area in which a flammable atmosphere is continuously present or present for long periods (see section 1.6.3).

Zone 1: That part of a hazardous area in which a flammable atmosphere is likely to occur in normal operation (see section 1.6.3).

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 (see section 1.6.3).

ANNEX I

REFERENCES

The following publications are referred to in this Code:

American Petroleum Institute (API)
API Recommended Practice 521 Guide for Pressure-Relieving and Depressuring Systems: 1997

American Society of Mechanical Engineers (ASME)
ANSI/ASME B31.3 Process piping 2002

British Standards Institution (BSI)
BS 229:1957 Specification. Flameproof enclosure of electrical apparatus
BS 1259:1958 Intrinsically safe electrical apparatus and circuits for use in explosive atmospheres
BS 4683-2:1971 Specification for electrical apparatus for explosive atmospheres. The construction and testing of flameproof enclosures of electrical apparatus
BS 4683-4:1973 Specification for electrical apparatus for explosive atmospheres. Type of protection 'e'
BS 5501 series Electrical apparatus for potentially explosive atmospheres
BS 5885:1988 Automatic gas burners
BS 5958:1991 Code of practice for control of undesirable static electricity
BS 6132:1983 Code of practice for safe operation of alkaline secondary cells and batteries
BS 6133:1995 Code of practice for safe operation of lead-acid stationary batteries
BS 6656:2002 Guide to prevention of inadvertent ignition of flammable atmospheres by radio-frequency radiation
BS 7671:2001 Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition
BS EN 161:2002 Automatic shut-off valves for gas burners and gas appliances
BS EN 676:2003 Automatic forced draught burners for gaseous fuels
BS EN 746-2:1997 Industrial thermoprocessing equipment. Safety requirements for combustion and fuel handling systems
BS EN 1643:2000 Valve proving systems for automatic shut-off valves for gas burners and gas appliances. See G1.2
BS EN 1755:2000 Safety of industrial trucks. Operation in potentially explosive atmospheres. Use in flammable gas, vapour, mist and dust
BS EN 1834-1:2000 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
BS EN 1834-2:2000 Reciprocating internal combustion engines. Safety requirements for design and construction of engines for use in potentially explosive atmospheres. Group I engines for use in underground workings susceptible to fire damp and/or combustible dust
BS EN 13463 series Non-electrical equipment for potentially explosive atmospheres
BS EN 50014:1998 Electrical apparatus for potentially explosive atmospheres. General requirements
BS EN 50015:1998 Electrical apparatus for potentially explosive atmospheres. Oil immersion 'o'
BS EN 50016:1996 Electrical apparatus for potentially explosive atmospheres. Pressurized apparatus 'p'
BS EN 50017:1998 Electrical apparatus for potentially explosive atmospheres. Powder filling 'q'
BS EN 50019:2000 Electrical apparatus for potentially explosive atmospheres. Increased safety 'e'

BS EN 50021:1999 Electrical apparatus for potentially explosive atmospheres. Type of protection "n"
BS EN 50028:1987 Electrical apparatus for potentially explosive atmospheres. Encapsulation 'm'
BS EN 61779-4:2000 Electrical apparatus for the detection and measurement of combustible gases. Performance requirements for Group II apparatus indicating up to 100% lower explosive limit
BS EN 61779-5:2000 Electrical apparatus for the detection and measurement of combustible gases. Performance requirements for Group II apparatus indicating up to 100% (V/V) gas
BS EN 60079-14:2003 Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)
BS EN 60079-17:2003 Electrical apparatus for explosive gas atmospheres - Part 17: Inspection and maintenance of electrical installations in hazardous areas (other than mines)
BS IEC 60079-19:1993 Electrical apparatus for explosive gas atmospheres. Repair and overhaul for apparatus used in explosive atmospheres (other than mines)
BS PD CLC/TR 50404:2003 Electrostatics. Code of practice for the avoidance of hazards due to static electricity
EN 50284 Special requirements for construction, test and marking of electrical apparatus of equipment group II, category 1 G

Engineering Equipment and Materials Users' Association (EEMUA)
Publication 107 Recommendations for the protection of diesel engines operating in hazardous areas

European Directives
1994/9/EC Approximation of the laws of member states concerning equipment and protective systems intended for use in potentially explosive atmospheres
1999/92/EC Minimum requirements for improving the health and safety of workers at risk from explosive atmospheres

Health and Safety Executive (HSE) and Health and Safety Commission, published by HSE Books
HSC Safe isolation of plant and equipment, 1997
HSC Safe operation of ceramic kilns, 1993
HSE CS15: Cleaning and gas-freeing of tanks containing flammable residues, 1997
HSE HS(G)250 Guidance on permit-to-work systems: A guide for the petroleum, chemical and allied industries, 2005
HSE Technology Division Specialist Inspector Report No.9, The fire and explosion hazards of hydraulic accumulators, May 1988
HSE The tolerability of risk from nuclear power stations, 1992

HS(G)5 Hot Work: Welding and cutting on plant containing flammable materials
PM84 Control of safety risks at gas turbines used for power generation, 2003

Institution of Chemical Engineers
Cox, Lees and Ang Classification of hazardous areas

Institution of Electrical Engineers (IEE)
Recommendations for the Electrical and Electronic Installations of Mobile and Fixed Offshore Installations 1992

International Association of Oil and Gas Producers (OGP) (formerly E&P Forum)
Hydrocarbon leak and ignition database, Publication 180, 1992

International Chamber of Shipping/Oil Companies' International Marine Forum/International Association of Ports and Harbours
International Safety Guide for Oil Tankers and Terminals (ISGOTT)

International Electrotechnical Commission (IEC)
IEC 60079-0 Electrical apparatus for explosive gas atmospheres - Part 0: General requirements
IEC 60079-1 Electrical apparatus for explosive gas atmospheres - Part 1: Flameproof enclosures 'd'
IEC 60079-2 Electrical apparatus for explosive gas atmospheres - Part 2: Pressurized enclosures 'p'
IEC 60079-4 Electrical apparatus for explosive gas atmospheres - Part 4: Method of test for ignition temperature
IEC 60079-5 Electrical apparatus for explosive gas atmospheres - Part 5: Powder filling 'q'
IEC 60079-6 Electrical apparatus for explosive gas atmospheres - Part 6: Oil-immersion 'o'
IEC 60079-7 Electrical apparatus for explosive gas atmospheres - Part 7: Increased safety 'e'
IEC 60079-10 Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas
IEC 60079-11 Electrical apparatus for explosive gas atmospheres - Part 11: Intrinsic safety 'i'
IEC 60079-12 Electrical apparatus for explosive gas atmospheres - Part 12: Classification of mixtures of gases of vapours with air according to their maximum experimental safe gaps and minimum igniting currents
IEC 60079-14 Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in

hazardous areas (other than mines)
IEC 60079-15 Electrical apparatus for explosive gas atmospheres - Part 15: Type of protection 'n'
IEC 60079-17 Electrical apparatus for explosive gas atmospheres - Part 17: Inspection and maintenance of electrical installations in hazardous areas (other than mines)
IEC 60079-18 Electrical apparatus for explosive gas atmospheres - Part 18: Construction, test and marking of type of protection encapsulation 'm' electrical apparatus
IEC 60079-19 Electrical apparatus for explosive gas atmospheres - Part 19: Repair and overhaul for apparatus used in explosive atmospheres (other than mines or explosives)
IEC 60079-20 Electrical apparatus for explosive gas atmospheres - Part 20: Data for flammable gases and vapours, relating to the use of electrical apparatus
IEC 60079-26 Electrical apparatus for explosive gas atmospheres - Part 26: Construction, test and marking of Group II Zone 0 electrical apparatus
IEC 60092-502 Electrical installations in ships - Part 502: Tankers - Special features
IEC 60364 Electrical installations of buildings
IEC 60896 Stationary lead-acid batteries
IEC 60623 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic re-chargeable single cells
IEC 61892-1: 2001 Mobile and fixed offshore units - Electrical installations - Part 1: General requirements and conditions
IEC 61892-3: 1999 Mobile and fixed offshore units - Electrical installations - Part 3: Equipment
IEC 61892-5: 2000 Mobile and fixed offshore units - Electrical Installations - Part 5: Mobile units
IEC 61892-6: 1999 Mobile and fixed offshore units - Electrical installations - Part 6: Installation
IEC 61892-7: 1997 Mobile and fixed offshore units - Electrical installations - Part 7: Hazardous area

International Maritime Organization (IMO)
Code for the construction and equipment of mobile offshore drilling units

International Standardisation Organisation (ISO)
ISO 13702:1999 Petroleum and Natural Gas Industries - Control and mitigation of fires and explosions on offshore production installations - Requirement and guidelines
ISO 15649: 2001 Petroleum and Natural Gas Industries - Piping

IP, published by Energy Institute
Model Codes of Safe Practice in the Petroleum Industry:
Part 1: Electrical safety code
Part 2: Design, construction and operation of distribution installations
Part 11: Bitumen safety code
Part 16: Tank cleaning code
Part 21: Guidelines for the control of hazards arising from static electricity

Other publications:
- Road tank vehicle workshop code
- A risk-based approach to hazardous area classification
- Predictions of minimum spark ignition energy and quenching distances for CH_4/H_2 and C_3H_8/H_2 mixtures with air
- Calculations in support of IP15: The area classification code for petroleum installations
- Environmental guidelines for petroleum distribution installations
- Recommendation for radio telephone equipment and its installation in petroleum road tankers
- Standard Test Methods for analysis and testing of petroleum and related products, and British Standard 2000 Parts, 2005 (includes IP 34 Determination of flash point - Pensky-Martens closed cup method and IP 170 Determination of flash point - Abel closed cup method)
- Petroleum road tanker design and construction

APEA/IP, published by Energy Institute and The Association for Petroleum and Explosives Administration
- Design, construction, modification, maintenance and decommissioning of filling stations

IP/UKOOA, published by Energy Institute and United Kingdom Offshore Operators Association
- Guidelines for the management, design, installation and maintenance of small bore tubing systems

Technical Papers
Bowen, P. J. and Shirvill, L. C. 'Pressurised atomisation of high flash point liquids - Implications for hazardous area classification', Symposium on European Advances in Process Safety, UMIST, Manchester 19-21 April 1994.
Gale, W. E. 'Module ventilation rates quantified', Oil and Gas Journal, 23 December 1985, pp.39-42
Marshall, M. R. 'The effect of ventilation on the accumulation and dispersal of flammable gases', I.Chem.E. 4th International Symposium, Harrogate, 1983

The British Medical Association, 'Living with risk'

UK Regulations

1989 UK Electricity at Work Regulations

1995 SI 0743 Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations

1996 SI 192 Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations (As amended SI 2001/3766)

1997 SI 1713 Confined Spaces Regulations

1998 SI 2306 Provision and Use of Work Equipment Regulations

2002 SI 2776 Dangerous Substances and Explosive Atmospheres Regulations

2004 SI 568 The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations

United Kingdom Offshore Operators Association (UKOOA)

UKOOA/IP, published by UKOOA

Guidelines for the management of the integrity of bolted pipe joints