

INTERNATIONAL STANDARD



Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres



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IEC 60079-10-1

Edition 3.0 2020-12
COMMENTED VERSION

INTERNATIONAL STANDARD



**Explosive atmospheres –
Part 10-1: Classification of areas – Explosive gas atmospheres**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.260.20

ISBN 978-2-8322-9213-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPLOSIVE ATMOSPHERES –

Part 10-1: Classification of areas – Explosive gas atmospheres

FOREWORD

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This commented version (CMV) of the official standard IEC 60079-10-1:2020 edition 3.0 allows the user to identify the changes made to the previous IEC 60079-10-1:2015 edition 2.0. Furthermore, comments from IEC SC 31J experts are provided to explain the reasons of the most relevant changes.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

International Standard IEC 60079-10-1 has been prepared by subcommittee 31J: Classification of hazardous areas and installation requirements, of IEC technical committee 31: Equipment for explosive atmospheres.

This third edition of IEC 60079-10-1 cancels and replaces the second edition, published in 2015, and constitutes a technical revision. The significant technical changes with respect to the previous edition are as follows:

Changes	Clause	Type		
		Minor and editorial changes	Extension	Major technical changes
Deleting commercial and industrial applications for fuel gas from the Scope exemptions	1			C1
Updating editorial details and notes to the definitions	3		X	
Deletion of the previous edition clause 3.7.3 definition for catastrophic failure (dealt with in clause 4.5)			X	
Introduction of new Subclause 4.4.2 Zone of negligible extent	4.4.2		X	
Introduction of new clause 5.3.2 Fuel gas installations	5.3.2		X	
Renumbering of headings	7	X		
Introduction of Figure 1 – Dilution volume	7		X	
Upgrading Table A.1 with UFL and its column 15 heading with the 'source of data'	A.1	X		
Updating the flow-chart in Figure B.1	B.6		X	
Updating equations for evaporation rate to align with the recent source modifications	B.7.3		X	
Updating the chart in Figure B.2 according to the updated equations for evaporation rate and the ventilation velocity of 0,25 m/s	B.7.3		X	
Restructuring Table C.1	C.3.4		X	
Removal of safety factor k and deleting it from the horizontal axis of the chart in Figure C.1	C.3.5			C2
Revising equations (C.2) and (C.3)	C.5.2			C3
Revising equations (C.4) and (C.5)	C.5.3			C4
Revising the chart in Figure C.6 by changing the label on the horizontal axis	C.5.3			C5
Revising equation (C.6) and deleting equation (C.7)	C.5.4			C6
Removal of safety factor k and deleting it from the horizontal axis of the charts in Figure D.1	D.3			C7
Imposing limitations to the use of the chart in Figure D.1	D.3		X	
Updating and corrections in Annex E	Annex E		X	
Upgrading Annex G on Flammable mists	Annex G		X	
Introducing new items in Table K.1	Annex K		X	
Introducing new items in the Bibliography	Bibliography		X	
NOTE The technical changes referred to include the significance of technical changes in the revised IEC Standard, but they do not form an exhaustive list of all modifications from the previous version.				

Explanations:

A) Definitions

Minor and editorial changes	clarification decrease of technical requirements minor technical change editorial corrections
------------------------------------	--

These are changes which modify requirements in an editorial or a minor technical way. They include changes of the wording to clarify technical requirements without any technical change.

Extension	addition of technical options
------------------	-------------------------------

These are changes which add new or modify existing technical requirements, in a way that new options are given, but without increasing requirements.

Major technical changes	addition of technical requirements increase of technical requirements
--------------------------------	--

B) Information about the background of changes

- C1 The previous edition item e) was: “commercial and industrial applications where only low pressure fuel gas is used for appliances e.g. for cooking, water heating and similar uses, where the installation is compliant with relevant gas codes”. Industrial applications of any kind should not be exempted from the scope of this standard. See also new clause 5.3.2.
- C2 The factor k was initially intended to provide for additional safety for uncertainties in determining LFL for flammable substances, particularly gas mixtures. However, this was considered as unnecessary and confusing considering the derivation of the chart.
- C3 The equations are updated to align with BS 5925
- C4 The equations are updated to align with BS 5925
- C5 The chart is revised to match the new equation (C.4)
- C6 The equation is updated to align with BS 5925
- C7 See the explanation under C2

These are changes to technical requirements (addition, increase of the level or removal).

NOTE These changes represent current technological knowledge. However, these changes should not normally have an influence on equipment already placed on the market.

The text of this standard is based on the following documents:

FDIS	Report on voting
31J/307/FDIS	31J/310/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60079 series, under the general title *Explosive atmospheres*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

The contents of the corrigendum of March 2021 have been included in this copy.

INTRODUCTION

In areas where dangerous quantities and concentrations of flammable gas or vapour may arise, ~~protective~~ measures need to be applied in order to reduce the risk of explosions. This part of IEC 60079 sets out the essential criteria against which the ignition hazards can be assessed and gives guidance on the design and control parameters which can be used in order to reduce such hazards.

EXPLOSIVE ATMOSPHERES –

Part 10-1: Classification of areas – Explosive gas atmospheres

1 Scope

This part of IEC 60079 is concerned with the classification of areas where flammable gas or vapour hazards may arise and may then be used as a basis to support the proper ~~selection and installation~~ design, construction, operation and maintenance **1** of equipment for use in hazardous areas.

It is intended to be applied where there may be an ignition hazard due to the presence of flammable gas or vapour, mixed with air, but it does not apply to:

- a) mines susceptible to firedamp;
- b) the processing and manufacture of explosives;
- c) catastrophic failures or rare malfunctions which are beyond the concept of ~~abnormality~~ normality dealt with in this standard (see 3.7.3 and ~~3.7.4~~ 4.5);
- d) rooms used for medical purposes;
- ~~e) commercial and industrial applications where only low pressure fuel gas is used for appliances e.g. for cooking, water heating and similar uses, where the installation is compliant with relevant gas codes;~~ **2**
- e) domestic premises;
- f) where a hazard may arise due to the presence of combustible dusts or combustible flyings but the principles may be used in assessment of a hybrid mixture (refer also to IEC 60079-10-2).

NOTE Additional guidance on hybrid mixtures is provided in Annex I.

Flammable mists may form or be present at the same time as flammable vapour. In such case the strict application of the details in this document may not be appropriate. Flammable mists may also form when liquids not considered to be a hazard due to the high flash point are released under pressure. In these cases the classifications and details given in this document do not apply. Information on flammable mists is provided in Annex G.

For the purpose of this document, an area is a three-dimensional region or space.

Atmospheric conditions include variations above and below reference levels of 101,3 kPa (1 013 mbar) and 20 °C (293 K), provided that the variations have a negligible effect on the explosion properties of the flammable substances.

In any ~~process plant~~ site **3**, irrespective of size, there may be numerous sources of ignition apart from those associated with equipment. Appropriate precautions will be necessary to ensure safety in this context. This standard is applicable with judgement for other ignition sources but in some applications other safeguards may also need to be considered. E.g. larger distances may apply for naked flames when considering hot work permits. **4**

This document does not take into account the consequences of ignition of an explosive atmosphere except where a zone is so small that if ignition did occur it would have negligible consequences (see 3.3.8 and 4.4.2). **5**

2 Normative references

~~The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.~~

~~IEC 60079-0, Explosive atmospheres – Part 0: Equipment – General requirements~~

~~IEC 60079-14, Explosive atmospheres – Part 14: Electrical installations design, selection and erection~~

This document contains no normative references.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60079-0 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

NOTE Additional definitions applicable to explosive atmospheres can be found in IEC 60050-426.

3.1

explosive atmosphere

mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour, ~~or dust, fibres, or flyings,~~ which, after ignition, permits self-sustaining ~~flame~~ propagation

[SOURCE: IEC 60079-0:20132017, ~~3.30~~ 3.38]

3.2

explosive gas atmosphere

mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour, which, after ignition, permits self-sustaining flame propagation

Note 1 to entry: Although a mixture which has a concentration above the upper flammable limit (UFL) is not an explosive gas atmosphere, it can readily become so and, generally for **hazardous** area classification purposes, it is advisable to consider it as an explosive gas atmosphere.

Note 2 to entry: There are some gases and vapours which are explosive with the concentration of 100 % (e.g. acetylene, CAS no. 74-86-2, C₂H₂; monovinyl acetylene, CAS no. 689-97-4, C₄H₄; 1-propyl nitrate (vapour), CAS no. 627-13-4, CH₃ (CH₂)₂ NO₃; isopropyl nitrate (vapour), CAS no. 1712-64-7, (CH₃)₂ CH ONO₂; ethylene oxide (vapour), CAS no. 75-21-8, (CH₂)₂ O; hydrazine (vapour), CAS no. 302-01-2, H₄ N₂).

[SOURCE: IEC 60079-0:20132017, ~~3.32~~ 3.40, modified (addition of Notes to entry)]

3.3

hazardous areas and zones

3.3.1

hazardous area <on account of explosive gas atmospheres>

area in which an explosive gas atmosphere is **present or may** be expected to be present, in quantities such ~~as to require~~ that special precautions for the construction, installation and use of equipment **are required**

~~Note 1 to entry: The interior of many items of process equipment are commonly considered as a hazardous area even though a flammable atmosphere may not normally be present to account for the possibility of air entering the equipment. Where specific controls such as inerting are used the interior of process equipment may not need to be classified as a hazardous area.~~

3.3.2

non-hazardous area <on account of explosive gas atmospheres>

area in which an explosive gas atmosphere is not expected to be present in quantities such ~~as to require~~ that special precautions for the construction, installation and use of equipment ~~are required~~

3.3.3

zone

hazardous area classification based on the frequency of the occurrence and duration of the explosive atmosphere

3.3.4

Zone 0

area in which an explosive gas atmosphere is present continuously, or for long periods, or frequently

Note 1 to entry: Both “long” and “frequently” are the terms which are intended to describe a very high likelihood of a potentially explosive atmosphere in the area. In that respect, those terms do not necessarily need to be quantified.

3.3.5

Zone 1

area in which an explosive gas atmosphere is likely to occur ~~periodically or~~ occasionally in normal operation

3.3.6

Zone 2

area in which an explosive gas atmosphere is not likely to occur in normal operation, but, if it does occur, will exist for a short period only

Note 1 to entry: Indications of the frequency of the occurrence and duration of the explosive atmosphere ~~may~~ can be taken from codes or standards relating to specific industries or applications.

[SOURCE: IEC 60050-426:20092020, 426-03-05]

3.3.7

extent of zone

distance in any direction from the source of release to where a gas/air mixture will be diluted by air to a concentration below the lower flammable limit

3.3.8

Zone NE

zone of negligible extent such that if ignition did occur it would have negligible consequences **6**

Note 1 to entry: Zones of negligible extent could be Zone 0 NE, Zone 1 NE or Zone 2 NE.

3.4

releases

3.4.1

source of release

point or location from which a flammable gas, vapour, mist or liquid may be released into the atmosphere so that an explosive gas atmosphere could be formed

[SOURCE: IEC 60050-426:20092020, 426-03-06, ~~modified (addition of “mist”)~~]

3.4.2

continuous grade of release

release which is continuous or is expected to occur frequently or for long periods

Note 1 to entry: Both “frequently” and “long” are the terms which are intended to describe a very high likelihood of a potential release. In that respect, those terms do not necessarily need to be quantified.

3.4.3

primary grade of release

release which can be expected to occur periodically or occasionally during normal operation

3.4.4

secondary grade of release

release which is not expected to occur in normal operation and, if it does occur, is likely to do so only infrequently and for short periods

3.4.5

release rate

quantity of flammable gas, liquid, vapour or mist emitted per unit time from the source of release

3.5

ventilation and dilution

3.5.1

ventilation

movement of air and its replacement with fresh air due to the effects of wind, temperature gradients, or artificial means (for example, fans or extractors)

Note 1 to entry: Fresh air is intended to be synonymous with the term ‘clean air’ used in IEC 60079-13. Both terms mean air that is essentially free of flammable gas or vapour.

3.5.2

dilution

mixing of flammable vapour or gas with air which, over time, will reduce the flammable concentration

3.5.3

dilution volume

volume in the vicinity of a source of release where the concentration of flammable gas or vapour is not diluted to a safe level

Note 1 to entry: In certain instances, the volumes under 3.5.3 and 3.5.5 could be the same.

3.5.4

background concentration

mean concentration of flammable substance within the volume under consideration outside of the release plume or jet

3.5.5

volume under consideration

volume served by the ventilation in the vicinity of the release being considered

Note 1 to entry: For an enclosed space this could be an entire room or part of a larger space where the considered ventilation will dilute the gas or vapour from a given source of release. Outdoors, this is the volume around a source of release where an explosive mixture could form. In congested outdoor places this volume could be dictated by the partial enclosure provided by the surrounding objects.

3.6 properties of flammable substance

3.6.1

flammable substance

substance which is itself flammable, or is capable of producing a flammable gas, vapour or mist

3.6.2

flammable liquid

liquid capable of producing a flammable vapour under any foreseeable operating conditions

Note 1 to entry: An example of a foreseeable operating condition is one in which the flammable liquid is handled at temperatures close to or above its flash point.

Note 2 to entry: This definition is used for the classification of hazardous areas and may be different from the definition of flammable liquids used for other purposes e.g. codes for classification of flammable liquids for transport.

3.6.3

liquefied flammable gas

flammable substance which is stored or handled as a liquid and which at ambient temperature and atmospheric pressure is a flammable gas

3.6.4

flammable gas or vapour

gas or vapour which, when mixed with air in certain proportions, will form an explosive gas atmosphere

3.6.5

flammable mist

droplets of liquid, dispersed in air so as to form an explosive atmosphere

Note 1 to entry: Mists are also known as aerosols.

3.6.6

hybrid mixture

mixture of a flammable gas or vapour with a dust.

Note 1 to entry: According to IEC 60079-10-2 the term “dust” is defined as including both combustible dust and combustible flyings.

3.6.7

relative density of a gas or a vapour

density of a gas or a vapour relative to the density of air at the same pressure and temperature (air is equal to 1,0)

3.6.8

flashpoint

lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapours in a quantity such as to be capable of forming an ignitable vapour/air mixture

3.6.9

boiling point

temperature of a liquid boiling at an ambient pressure of 101,3 kPa (1 013 mbar)

Note 1 to entry: The initial boiling point ~~that should be~~ used for liquid mixtures ~~is~~ to indicate the lowest value of the boiling point for the range of liquids present, as determined in a standard laboratory distillation without fractionation.

3.6.10

vapour pressure

pressure exerted when a solid or liquid is in equilibrium with its own vapour

Note 1 to entry: This is also, the partial pressure of the substance in the atmosphere above the liquid. It is a function of the substance and of the temperature.

3.6.11

auto-ignition temperature of an explosive gas atmosphere (AIT)

~~lowest temperature of a heated surface which, under specified conditions (according to IEC 60079-20-1), will ignite a flammable substance in the form of a gas or vapour mixture with air~~

lowest temperature (of a surface) at which under specified test conditions an ignition of a flammable gas or vapour in mixture with air or air-inert gas occurs

[SOURCE: ~~IEC 60079-0:2013, 3.37~~ ISO/IEC 80079-20-1:2017, 3.3]

3.6.12

lower flammable limit (LFL)

concentration of flammable gas or vapour ~~or mist~~ in air below which an explosive gas atmosphere ~~will not be formed~~ does not form

Note 1 to entry: The term “lower explosive limit” is used especially in European standardization and regulations interchangeably to describe this limit.

[SOURCE: ~~IEC 60050-426:2009, 426-02-09, modified (definition in 60050-426 referred to “Lower Explosive Limit”)~~ ISO/IEC 80079-20-1:2017, 3.6.1]

3.6.13

upper flammable limit (UFL)

concentration of flammable gas or vapour ~~or mist~~ in air above which an explosive gas atmosphere ~~will not be formed~~ does not form

Note 1 to entry: The term “upper explosive limit” is used especially in European standardization and regulations interchangeably to describe this limit.

[SOURCE: ~~IEC 60050-426:2009, 426-02-10, modified (definition in 60050-426 referred to “Upper Explosive Limit”)~~ ISO/IEC 80079-20-1:2017, 3.6.2]

3.7

operation

3.7.1

normal operation

situation when the equipment is operating within its designed parameters

Note 1 to entry: Failures (such as the breakdown of pump seals, flange gaskets or spillages) caused by accidents which involve repair or shut-down are not considered to be part of normal operation.

Note 2 to entry: Normal operation includes start-up and shut-down conditions and routine maintenance, but excludes initial start up as part of commissioning.

3.7.2

routine maintenance

action to be performed occasionally or periodically in normal operation to maintain proper performance of equipment

Note 1 to entry: Routine maintenance does not include activities where the amount released or the rate of release is greater than that used for the area classification. E.g. Where equipment or systems require either partial dismantling or deliberate venting to atmosphere is required to enable the maintenance activity to be performed.

3.7.3

rare malfunction

type of malfunction which may happen only in rare instances

Note 1 to entry: Rare malfunctions in the context of this standard include failure of separate and independent process controls, that may be either automated or manual, that could trigger a chain of events that would lead to major release of flammable substance.

Note 2 to entry: Rare malfunctions could also include unanticipated conditions that are not covered by the plant design such as unexpected corrosion that results in a release. Where releases due to corrosion or similar conditions may or could reasonably be expected as part of the plant operations then this is not considered as a rare malfunction.

3.7.4

catastrophic failure

~~an occurrence which exceeds the design parameters of the process plant and control system resulting in a release of flammable substance~~

~~Note 1 to entry: Catastrophic failures in the context of this standard include, for example, major accidents such as the rupture of a process vessel, or large scale failures of equipment or piping such as total breakdown of a flange or seal.~~ **7**

4 General

4.1 Safety principles

Installations in which flammable substances are handled or stored should be designed, constructed, operated and maintained so that any releases of flammable substance, and consequently the extent of hazardous areas, are kept to a minimum, ~~whether in normal or abnormal operation,~~ **8** with regard to frequency, duration and quantity of a release.

It is important to examine those parts of process equipment and systems from which a release of flammable substance may arise and to consider modifying the design to minimize the likelihood and frequency of such releases and the quantity and rate of release of substance.

NOTE 1 Process equipment in the context of this document includes any item that may contain a flammable gas or liquid.

These fundamental considerations should be examined at an early stage of the design development of any process plant and should also receive prime attention in carrying out the hazardous **9** area classification study.

In the case of activities other than those of normal operation, e.g. commissioning or non-routine maintenance, the hazardous area classification may not be valid. It is expected that the activities other than those of normal operation would be dealt with by a safe system of work. The hazardous area classification should take into account any routine maintenance.

In a situation in which there may be an explosive gas atmosphere, ~~the following steps~~ action should be taken to eliminate:

- a) the likelihood of an explosive gas atmosphere occurring around the source of ignition, or
- b) the source of ignition.

Where this is not possible, protective measures, process equipment, systems and procedures should be selected and prepared so the likelihood of the coincidence of a) and b) is so small as to be accepted as low as reasonably practicable. Such measures may be used individually, if they are recognized as being highly reliable or in combination to achieve the required level of safety.

NOTE 2 As Low As Reasonably Practicable (ALARP) is a recognised term in many jurisdictions and includes implementing controls as possible according to the current state of the art and in accordance with relevant codes and standards.

This document provides guidance on aspects that should be considered and the classification of hazardous areas requires the application of good engineering practice. **10**

4.2 Hazardous area classification objectives

Hazardous area classification is a method of analysing and classifying the environment where explosive gas atmospheres may occur, so as to facilitate the proper selection, installation and operation of equipment to be used safely in that environment. The classification also takes into account the ignition characteristics of the gas or vapour such as ignition energy and ignition temperature. Hazardous area classification has two main objectives, the determination of the type of any ~~hazardous~~ zone, and the extent of the zone (see ~~7 and 8~~ Clause 8 and Clause 9).

NOTE Selected characteristics ~~may~~ might be designated for equipment e.g. ignition energy and temperature ratings, ~~see IEC 60079-20-4~~ (see ISO/IEC 80079-20-1).

In most practical situations where flammable substances are used, it is difficult to ensure that an explosive gas atmosphere will never occur. It may also be difficult to ensure that equipment will never give rise to a source of ignition. Therefore, in situations where an explosive gas atmosphere has a high likelihood of occurring, reliance is placed on using equipment which has a low likelihood of creating a source of ignition. Conversely, where the likelihood of an explosive gas atmosphere occurring is reduced, equipment constructed with less rigorous requirements may be used.

In particular, Zone 0 or Zone 1 areas should be minimized in number and extent by design or suitable operating procedures. In other words, plants and installations should be mainly Zone 2 or non-hazardous. Where release of a flammable substance is unavoidable, process equipment items should be limited to those which give secondary grade releases or, failing this (that is where primary or continuous grade releases are unavoidable), the releases should be of very limited quantity and rate. In carrying out plant design, these principles should receive prime consideration. Where necessary, the design, operation and location of process equipment should ensure that, even when it is operating abnormally, the amount of flammable substance released into the atmosphere is minimized, so as to reduce the extent of the hazardous area.

Once a plant has been classified and all necessary records prepared, it is important that no modification to equipment or operating procedures is made without reference to those responsible for the hazardous area classification. The hazardous area classification should be updated for any plant or operational changes. Reviews should be carried out during the lifetime of the plant.

4.3 Interior of equipment containing flammable materials

The interior of many items of equipment containing flammable substances such as tanks may be considered as a hazardous area even though an explosive gas atmosphere may not normally be present to account for the possibility of air entering the equipment.

NOTE 1 Items of equipment containing flammable substances are commonly given the generic term 'process equipment' in many industries.

Where specific controls such as inerting are used, the interior of equipment containing flammable substances may not need to be classified as a hazardous area or may be assigned a less onerous zone. In such cases the reliability of the control measures should be commensurate with the reduction in hazardous area that is determined for the interior of the equipment. E.g. control measures could be assessed using a suitable study such as SIL assessment to IEC 61511.

NOTE 2 Inerting is the replacement of atmospheric oxygen in a system by a non-reactive, non-flammable gas, to make the atmosphere within the system unable to propagate flame. The addition of flammable gases to ensure the space is always outside of the flammable range could prevent a hazardous area internal to equipment. **11**

4.4 Explosion risk assessment

4.4.1 General

Subsequent to the completion of the hazardous area classification, a risk assessment may be carried out to assess whether the consequences of ignition of an explosive atmosphere requires the use of equipment of a higher equipment protection level (EPL) or may justify the use of equipment with a lower equipment protection level than normally required.

The EPL requirements may be recorded, as appropriate, on the hazardous area classification documents and drawings to allow proper selection of equipment.

NOTE 1 IEC 60079-0 describes EPLs and IEC 60079-14 defines the application of EPLs to an installation. **12**

NOTE 2 This standard does not define the methodology for carrying out a risk assessment to vary the EPL ratings as specification for any risk assessment methodology is out of the scope of this standard. **13**

4.4.2 Zone of negligible extent

In some cases a zone of negligible extent (NE) may arise and may be treated as non hazardous. A zone of negligible extent would also imply either a negligible release rate or a negligible release quantity and considering the volume for dispersion.

Such a zone implies that an explosion, if it takes place, will have negligible consequences. The zone NE concept can be applied irrespective of any other adjustments for risk assessment to determine EPL.

The criteria for a zone NE classification should be based on the following factors:

- i) Ignition would not result in sufficient pressure to cause harm either due to the pressure wave or due to damage that could cause flying objects or particles e.g. broken glass from windows.
- ii) Ignition would not result in sufficient heat to cause harm or a fire from surrounding materials.
- iii) For gas distributed at pressures above 1 000 kPag (10 barg) consideration shall be given to a specific risk assessment
- iv) A zone NE shall not be applied to gas distributed at pressures above 2 000 kPag (20 barg) unless a specific detailed risk assessment can document otherwise. **14**

NOTE 1: An example of zone NE is a natural gas cloud with an average concentration that is 50 % by volume of the LFL and that is less than 0,1 m³ or 1,0 % of the enclosed space concerned (whichever is smaller). For other gases a zone NE may be considered based on the ratio of the heat of combustion, maximum explosion pressure and the maximum rate of pressure rise of the gas to methane multiplied by the parameters used for methane. **15**

~~The EPL requirements may be recorded, as appropriate, on the area classification documents and drawings to allow proper selection of equipment.~~

~~NOTE 2: IEC 60079-0 describes EPLs and IEC 60079-14 defines the application of EPLs to an installation.~~

NOTE 1 Natural gas in this context is gas used for conventional gas distribution networks and is predominately methane.

NOTE 2 Refrigeration and heat pump applications are not regarded as gas distribution systems. Risk assessments for this class of equipment have demonstrated that the value of 2 000 kPag (20 barg) might not be a suitable reference for these applications.

4.5 Catastrophic failures

As far as possible, such failures should be prevented.

Reasonably unexpected catastrophic failures need not be accounted for in the hazardous area classification. For example, major accidents such as the rupture of a process vessel, or large scale failures of equipment or piping such as total breakdown of a flange or seal.

The likelihood of such failures should be reduced by appropriate inspection, design, operation and maintenance of a plant. **16**

4.6 Competence of personnel

~~The area classification should be carried out by those who understand the relevance and significance of the properties of the flammable substances, principles of gas/vapour dispersion and those who are familiar with the process and the equipment.~~ The hazardous area classification should be carried out by persons who understand the nature of flammable substances, gas dispersion and ventilation and are familiar with the process aspects for the plant under consideration. **17** It may be beneficial for other engineering disciplines, e.g. electrical and mechanical engineers, and personnel with specific responsibility for safety to be part of and have an input to the hazardous area classification process. The competency of the person shall be relevant to the nature of the plant and methodology used for carrying out the hazardous area classification. Appropriate continuing education or training should be undertaken by personnel on a regular basis where required.

NOTE 1 Competency can be demonstrated in accordance with a training and assessment framework relevant to national regulations or standards or user requirements.

NOTE 2 Elements of competency are covered in several personnel certification schemes.

5 Hazardous area classification methodology

5.1 General

It is rarely possible by a simple examination of a plant or plant design to decide which parts of the plant can be equated to the three zonal definitions (Zones 0, 1 and 2). A more detailed approach is therefore necessary and this involves the analysis of the basic possibility of an explosive gas atmosphere occurring.

In determining where a release of flammable gas or vapour may occur, the likelihood and duration of the release should be assessed in accordance with the definitions of continuous, primary and secondary grades of release. Once the grade of release, the release rate, concentration, velocity, ventilation and other factors are assessed there is then a firm basis on which to assess the likely presence of an explosive gas atmosphere in the surrounding areas and determine the type and/or extent of the hazardous ~~zones~~ area.

This approach therefore requires detailed consideration to be given to each item of process equipment which contains a ~~substance~~ flammable ~~by itself or due to process conditions~~ substance, and which could therefore be a source of release.

Subclauses ~~5.3 to 5.6~~ 5.2 to 5.5 give guidance on options for classifying areas in which there may be an explosive gas atmosphere. An example of a schematic approach to the classification of hazardous areas is given in Annex F.

The hazardous area classification should be carried out when the initial process and instrumentation line diagrams and initial layout plans are available and should be confirmed before plant start-up.

Consideration should always be given to the type, number and location of various potential points of release so that relevant zone and boundary conditions are assigned in the overall assessment.

Control systems ~~designed and installed~~ according to a Functional Safety standard may reduce the potential for a source of release and/or the quantity of a release (e.g. batch sequence controls, inerting systems). Such controls may therefore be considered where relevant to the hazardous area classification.

When classifying areas consideration should be also given to a careful evaluation of ~~prior experience with~~ the same or similar installations. ~~It is not enough to identify only a potential source of flammable substance and proceed immediately to defining the extent of zone 1 or zone 2 classified areas.~~ Where ~~experience or~~ documented evidence indicates that a particular plant design and operations are sound this may be used to support the classification chosen. Furthermore, it is conceivable that an area could be reclassified based on ~~industry experience~~ or new evidence. **18**

For mass-produced equipment that can be deployed in a range of different situations such equipment may be subject to a generic hazardous area classification with relevant instructions about placement and ventilation, etc., to detail any limitations for the application and impact on the classification.

If the quantity of a flammable substance available for release is 'small', whilst a potential explosion condition may exist, it may not be appropriate to use this hazardous area classification procedure. Notwithstanding this general guidance, consideration should always be given to the potential for release and the ability to adequately dilute or disperse any release to avoid flammable conditions. I.e. small quantities in small spaces may still be a hazard.

For small quantities account shall also be taken of the particular factors involved. Such factors could include: levels of cleanliness, industry practice, competency and training of personnel handling the flammable substances, other spill or release control measures, ventilation, health risks and exposure controls, management of ignition sources by other than the use of 'Ex' rated equipment.

NOTE 1 Small quantities could apply to applications such as laboratories, small refrigerant systems or cylinders of gas.

NOTE 2 Industry codes commonly identify quantities below which the hazardous area classification process would not apply. **19**

5.2 Classification by sources of release method

Classification may be approached by calculation or test **20**, considering appropriate statistical and numerical assessments for the factors concerned, for each source of release.

The source of release approach can be summarized as follows (refer to Annex F):

- Identify sources of release;
- Determine the release rate and grade of release for each source based on likely frequency and duration of release;
- Assess ventilation or dilution conditions and effectiveness;
- Determine zone type based on grade of release and ventilation or dilution effectiveness;
- Determine extent of zone.

Formulae relevant to determining the release rates under specified conditions can be found in Annex B. These formulae are generally accepted as providing a good basis for calculating release rates for the conditions provided.

Guidance on the assessment of ventilation and dispersion is provided in Annex C. Other forms of assessment, e.g. computational fluid dynamics (CFD) or testing, may be used and may provide a good basis for assessment in some situations. Computer modelling is ~~also~~ an appropriate tool when assessing the interaction of multiple factors.

In all cases the assessment method and tools used should be validated as suitable or used with appropriate caution. Those carrying out the assessment should also understand the limitations or requirements of any tools and adjust the input conditions or results accordingly to ensure appropriate conclusions.

NOTE It is not expected that all methods or tools used for the classification of hazardous areas will give the same result and this need not indicate that one particular method or tool is unsuitable for the application. 21

5.3 Use of industry codes and national standards

5.3.1 General

Industry codes and national standards may be used where they provide guidance or examples appropriate to the application and comply with the general principles of this standard.

Annex K identifies some relevant industry codes and national standards that may provide further detail as well as examples.

5.3.2 Fuel gas installations

For commercial and industrial applications where only low pressure fuel gas is used for appliances e.g. for cooking, water heating and similar uses, then local gas codes would apply.

In most cases compliance to the relevant gas codes would result in a classification that is non hazardous or lead to a zone of negligible extent.

NOTE Low pressures are commonly considered to be pressures below 200 kPa (gauge). Refer Annex K for examples of relevant codes. 22

5.4 Simplified methods

Where it is not practicable to make required assessments from individual sources of release, a simplified method may be used. E.g. in basic projects, where the equipment or locations are not yet defined, or calculations for all sources of release may be too onerous. Simplified methods shall identify sources for each of the zone types, zone 0, 1 and 2 that are suitably conservative to allow for potential sources of release without individual detail. The judgement is best made by reference to a set of criteria based on industry experience and appropriate to the particular plant.

It is not necessary to carry out a detailed assessment of all items in a plant where an assessment for one item or condition would be adequate to provide a conservative classification for all other similar items or conditions on the plant.

Larger zone areas are characteristic of simplified methods, stemming from the approach and the necessity to apply more conservative zonal classification where doubt exists as to the hazards involved. This approach shall err on the side of safety.

To arrive at less conservative or more accurate figures of the boundaries of the classified area, reference to illustrative examples or more detailed assessment of point sources of release, as applicable should be used.

5.5 Combination of methods

The use of different methods may be appropriate for classification of a plant at various stages of its development or for various parts of the plant.

For example, at the initial conceptual stage of a plant the simplified method may be appropriate to set out the equipment separations, plant layout and plant boundaries. This might be the only method that could be applied due to lack of detailed data on sources of release. As the plant design proceeds and detailed data are available on the potential sources of release, the classification should be upgraded using a more detailed method of assessment.

In some cases the simplified method can be applied to a group of similar equipment in sections of plant (e.g. sections of piping with flanges, such as pipe racks) while applying a more detailed assessment to the more significant potential sources of release (e.g. relief valves, vents, ~~gas~~ compressors, pumps and the like).

In many cases the classification examples provided in relevant national or industry codes can, where appropriate, be used to classify some components of larger plants.

6 Release of flammable substance

6.1 General

The release rate of a flammable substance is the most important factor that affects the extent of a zone.

Generally, the higher the release rate the larger the extent of the zone.

NOTE Experience has shown that a release of ammonia (with an LFL of 15 % by volume), will often dissipate rapidly in the open air (~~outdoor~~), so an explosive gas atmosphere ~~will~~ can be, in most cases ~~considered~~ of negligible extent.

An introduction to the nature of releases that should be considered when approaching classification of potentially explosive areas is provided in Subclauses 6.2 to ~~6.5~~ 6.3.

6.2 Sources of release

The basic elements for establishing the ~~hazardous~~ zone types are the identification of the source of release and the determination of the grade or grades of the release.

Since an explosive gas atmosphere can exist only if a flammable gas or vapour is present with air, it is necessary to decide if any flammable substances can exist in the area concerned. Generally speaking, such gases and vapours (and flammable liquids or solids which may give rise to them) are contained within process equipment that may or may not be totally enclosed. It is necessary to identify where ~~a flammable~~ an explosive gas atmosphere can exist inside process equipment, or where a release of flammable substances can create a flammable atmosphere outside process equipment.

Each item of process equipment (for example, tank, pump, pipeline, vessel, etc.) should be considered as a potential source of release of a flammable substance. If the item cannot foreseeably contain a flammable substance, it will clearly not give rise to a hazardous area around it. The same will apply if the item contains a flammable substance but cannot release it into the atmosphere (for example, a fully welded pipeline is not considered to be a source of release).

If it is established that the item may release a flammable substance into the atmosphere, it is necessary, first of all, to determine the grade or grades of release in accordance with the definitions, by establishing the likely frequency and duration of the release. It should be recognized that the opening-up of parts of enclosed process systems (for example, during filter changing or batch filling) should also be considered as sources of release when developing the ~~hazardous~~ area classification. By means of this procedure, each release will be graded either 'continuous', 'primary' or 'secondary'.

NOTE 1 Releases may form part of process, e.g. taking samples, or may occur as part of a routine maintenance procedure. These forms of release are generally classified as continuous or primary grades of release. Accidental releases are generally classified as secondary grades of release.

NOTE 2 One item may give rise to more than one grade of release. For example, there may be a small primary grade release, but a larger release could occur under abnormal operation; thus giving rise to a secondary grade release. In this situation, both release conditions (both grades of release) need full consideration as described in this document.

Having established the grade or grades of the release, it is necessary to determine the release rate and other factors that may influence the type and extent of the zone.

~~If the quantity of a flammable substance available for release is 'small', for example, laboratory use, whilst a potential explosion condition may exist, it may not be appropriate to use this area classification procedure. In such cases, account shall be taken of the particular factors involved.~~ **23**

In some cases, a mixture of different flammable substances with different characteristics for each flammable substance may need to be considered, e.g. relative density and temperature class. In such cases it is necessary to consider if the ratio of individual components in the mixture is sufficient to influence the relevant parameters, such as equipment group or temperature class, or may suggest a need to consider other factors such as hazardous area classification for both lighter than air and heavier than air release conditions. **24** The hazardous area classification of process equipment in which a flammable substance is burned, for example, fired heaters, furnaces, boilers, gas turbines ~~etc.~~, should take into account any purge cycle, start-up and shut-down conditions.

In some cases, the construction of closed systems where specific construction codes are met can be accepted as effectively preventing ~~and/or~~ limiting releases of flammable substances to a negligible leakage hazard. The hazardous area classification of such equipment or installations requires a complete assessment to verify the full compliance of the installation to the relevant constructional and operating standards. Verification of compliance should consider design, installation, operation, maintenance and monitoring activities.

Mists which form through leaks of pressurized liquid can be flammable even though the liquid temperature is below the flash point (see Annex G).

6.3 Forms of release

6.3.1 General

The characteristic of any release depends upon the physical state of the flammable substance, its temperature and pressure. The physical states include:

- a gas, which may be at an elevated temperature or pressure;
- a gas liquefied by the application of pressure, e.g. LPG;
- a gas which can only be liquefied by refrigeration, e.g. methane;
- a liquid with an associated release of flammable vapour.

Releases from such plant items as pipe connections, pumps and compressor seals and valve packings often start with a low flow rate. However, if the release is not stopped, erosion at the source of the release can greatly increase the rate of release and hence the extent of the hazard. Conversely if the source of release has a finite quantity, the release rate may decline over time reducing the extent of the hazard. For example, gas under pressure in a closed system. **25**

A release of flammable substance above its flashpoint will give rise to a flammable vapour or gas cloud which may initially be less or more dense than the surrounding air or may be neutrally buoyant. The forms of release and the pattern of behaviour at various conditions are

displayed as a flow chart in Figure B.1. This characteristic will affect the extent of the zone generated by a particular form of release.

~~Every form of release will eventually end as a gaseous or vapour release and the gas or vapour may appear as buoyant, neutrally buoyant or heavy (see Figure B.1). This characteristics will affect the extent of the zone generated by a particular form of release.~~ 26

The horizontal extent of the zone at ground level will generally increase with increasing relative density and the vertical extent above the source will generally increase with decreasing relative density.

6.3.2 Gaseous release

A gas release will produce a gas jet or plume at the release source depending on the pressure at the point of release, e.g. pump seal, pipe connection or evaporative pool area. The relative density of the gas, the degree of turbulent mixing and the prevailing air movement will all influence the subsequent movement of any gas cloud.

In calm conditions low velocity releases of a gas that is significantly less dense than air will tend to move upwards, e.g. hydrogen and methane. Conversely, a gas that is significantly denser than air will tend to accumulate at ground level or in any pits or depressions, e.g. butane and propane. Over time, atmospheric turbulence will cause the released gas to mix with air and become neutrally buoyant. A gas or vapour with density that is not significantly different to air is regarded as neutrally buoyant.

NOTE 1 Near-neutrally buoyant gases, such as ethane, could tend to follow the layering behaviour of dense gases, provided conditions are calm.

Higher pressure releases will initially produce jets of released gas which will mix turbulently with the surrounding air and entrain air in the jet.

At high pressures, a thermodynamic effect due to expansion can come into play. As the gas escapes, it expands and cools down and may initially behave as heavier than air. However, the cooling due to the Joule-Thomson effect is eventually offset by the heat supplied by the air. The resulting gas cloud will eventually become neutrally buoyant. The transition from heavier than air to neutrally buoyant behaviour may occur at any time, depending on the nature of the release, and may occur after the cloud has been diluted to below the LFL.

NOTE 2 Hydrogen demonstrates a reverse Joule-Thomson effect, heating up as it expands and so will never exhibit a heavier than air effect.

6.3.3 Liquefied under pressure release

Some gases can be liquefied by the application of pressure alone, e.g. propane and butane, and are usually stored and transported in this form.

When a pressurized liquefied gas leaks from its containment the most likely scenario is that the substance will escape as a gas from any vapour space or gas lines. The rapid evaporation produces significant cooling at the point of release and icing due to the condensation of water vapour from the atmosphere may occur.

A liquid leak will partially evaporate at the point of release. This is known as flash evaporation. The evaporating liquid pulls energy from itself and the surrounding atmosphere and in turn cools down the leaking fluid. The cooling of the fluid prevents total evaporation and therefore ~~an aerosol~~ a flammable mist 27 is produced. If the leak is large enough then cold pools of fluid can accumulate on the ground which will evaporate over time to add to the gas release.

The cold ~~aerosol~~ flammable mist cloud will act like a dense gas. A pressurized liquid release can often be seen as the cooling effect of evaporation will condense ambient humidity to produce a visible cloud.

For some applications where a gas is liquified under pressure, a release in the liquid part of the system may initially lead to a two phase release (liquid and vapour) with a 'spitting' behaviour. If there is a limited amount of flammable substance the release may transition to be only vapour as the rate and pressure decrease. 28

6.3.4 Liquefied by refrigeration release

Other gases, the so-called permanent gases, can only be liquefied by refrigeration e.g. methane and hydrogen. Small leaks of refrigerated gas will evaporate quickly without forming a pool of liquid by drawing heat from the environment. If the leak is large a cold pool of liquid may form.

As the cold liquid pulls energy from the ground and surrounding atmosphere the liquid will boil generating a cold dense gas cloud. As with liquids, dikes or bund walls can be used to direct or hold the flow of leakages.

NOTE 1 Care needs to be taken when classifying areas containing cryogenic flammable gases such as liquefied natural gas. Vapours emitted will generally be heavier than air at low temperatures but will become neutrally buoyant on approaching ambient temperature.

NOTE 2 Permanent gases have a critical temperature lower than $-50\text{ }^{\circ}\text{C}$.

6.3.5 Aerosols Flammable mists release 27

~~An aerosol~~ A flammable mist is not a gas but consists of small droplets of liquid suspended in air. The droplets are formed from vapours or gases under certain thermodynamic conditions or by flash evaporation of pressurized liquids. The scattering of light within ~~an aerosol~~ a flammable mist cloud frequently makes the cloud visible to the naked eye. The dispersion of ~~an aerosol~~ a flammable mist may vary between the behaviour of a dense gas or a neutrally buoyant gas. ~~Aerosol~~ Flammable mist droplets can coalesce and rain out of the plume or cloud. ~~Aerosols from~~ Flammable mists made of flammable liquids may absorb heat from the surrounding environment, evaporate and add to the gas/vapour cloud (for more details see Annex G).

NOTE In some cases a visible mist may form at concentrations below the flammable limit. For example anhydrous ammonia mist is visible at 4 % v/v due to absorption of atmospheric moisture in the liquid droplets but the LFL is 15 %. 29

6.3.6 Vapours release

Liquids at equilibrium with their environment will generate a layer of vapour above their surface. The pressure this vapour exerts in a closed system is known as the vapour pressure, which increases in a non-linear function with temperature.

The process of evaporation uses energy which may come from a variety of sources, for example from the liquid or the surrounding environment. The evaporation process may decrease the temperature of the liquid and limit temperature rise. However, changes in liquid temperature due to increased evaporation from normal environmental conditions are considered too marginal to affect the hazardous area classification. The concentration of the generated vapour is not easy to predict as it is a function of the evaporation rate, temperature of the liquid and the surrounding air flow.

6.3.7 Liquid release

The release of flammable liquids will normally form a pool on the ground, with a vapour cloud at the liquid's surface unless the surface is absorbent. The size of the vapour cloud will depend on the properties of the substance and its vapour pressure at the ambient temperature (see B.7.2).

NOTE 1 The vapour pressure is an indication of a liquid's evaporation rate. A substance with a high vapour pressure at normal temperatures is often referred to as volatile. As a general rule, vapour pressure of liquid at ambient temperatures increases with decreasing boiling point. As the temperature rises so does the vapour pressure.

NOTE 2 The evaporation rate could be reduced significantly over time if the liquid has a high latent heat. A high latent heat can cause the surface onto which the liquid is present to be cooled significantly which then limits the flow of heat into the liquid. For example, with a leak of anhydrous ammonia, which has a high latent heat, the rate of evaporation could slow considerably unless additional heat is brought to the liquid. 29

Release may also occur on water. Many flammable liquids are less dense than water and are often not miscible. Such liquids will spread on the surface of water, whether it is on the ground, in plant drains, pipe trenches or on open waters (sea, lake or river), forming a thin film and increasing the evaporation rate due to the increased surface area. In these circumstances the calculations in Annex B are not applicable.

7 Ventilation (or air movement) and dilution

7.1 General

Gas or vapour released into the atmosphere may dilute through turbulent mixing with air, and to a lesser extent by diffusion driven by concentration gradients, ~~until~~. Unless the release is into a space that is confined and well-sealed 30 the gas disperses completely ~~and until~~ the concentration is essentially zero. Air movement due to natural or artificial ventilation will promote dispersion. ~~Increased air movement may also increase the rate of release of vapour due to increased evaporation on an open liquid surface.~~

Suitable ventilation rates can reduce the persistence time of an explosive gas atmosphere thus influencing the type of zone.

A structure with sufficient openings to allow free passage of air through all parts of the building is considered in many cases to be well ventilated and should be treated as an open air area, e.g. a shelter with open sides and rooftop ventilation openings.

Dispersion or diffusion of a gas or vapour into the atmosphere is a key factor in reducing the concentration of the gas or vapour to below the lower flammable limit.

Ventilation and air movement have two basic functions:

- a) to increase the rate of dilution and promote dispersion to limit the extent of a zone;
- b) to ~~avoid~~ reduce 31 the persistence of an explosive atmosphere that may influence the type of a zone.

With increased ventilation or air movement the extent of a zone will normally be reduced. Obstacles which impede the ventilation or air movement may increase the extent of a zone. Some obstacles, for example, dykes, walls and ceilings, which limit the extent of vapour or gas movement, may also limit the extent of the zone.

NOTE 1 Increased air movement may also increase the release rate of vapour due to increased evaporation from open liquid surfaces. However, the benefits of increased air movement normally outweigh the increase in release rate.

For low velocity releases the rate of gas or vapour dispersion in the atmosphere increases with wind speed, but in ~~stable~~ calm atmospheric conditions layering of the heavier than air gas or vapour may occur and the distance for safe dispersal can be greatly increased. For low velocity releases where there are obstacles such as walls and ceiling, layering of lighter than air gas or vapour may occur at the ceiling and the distance for the safe dispersal can be greatly increased. 32

NOTE 2 In plant areas with obstructions to ventilation such as large vessels and structures, even at low wind speeds, eddies may be formed behind such obstructions thus forming pockets of gas or vapour without sufficient turbulence to promote dispersion.

In normal practice, the tendency of layering in outdoor situations is not taken into account in hazardous area classification because the conditions which give rise to this effect are rare and occur only for short periods. However, if prolonged periods of low wind speed are expected for the specific circumstance then the extent of the zone should take account of the additional distance required to achieve dispersion. The tendency for layering should be considered for indoor situations.

NOTE 3 Layering may be a relevant factor in some particular applications such as rooms with very little air exchange to outside the room. 33

In some applications with a limited quantity of release, circulation airflow within a closed space can be used to provide sufficient mixing to dilute a release. 34

7.2 Main types of ventilation

7.2.1 General

The two types of ventilation are:

- a) natural ventilation; and,
- b) artificial (or forced) ventilation, either general to the area or local to the source of release.

7.2.2 Natural ventilation

Natural ventilation in buildings arises from pressure differences induced by the wind and/or by temperature gradients (buoyancy induced ventilation). Natural ventilation may be effective in certain indoor situations (for example, where a building has openings in its walls and/or roof) to dilute releases safely.

Examples of natural ventilation:

- an open building which, having regard to the relative density of the gases and/or vapours involved, has 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;
- a building which is not an open building but which has natural ventilation (generally less than that of an open building) provided by permanent openings made for ventilation purposes.

Consideration of natural ventilation in buildings should recognise that gas or vapour buoyancy may be a significant factor and so, ventilation should be arranged to promote dispersion and dilution. Where a gas or vapour has been released which exhibits a high or low density relative to air, the pressure head of the mixture close to openings in the space envelope may also be relied upon to generate its own ventilation. 35

Ventilation rates arising from natural ventilation are inherently very variable. Generally, with any natural ventilation, a lower ventilation rate leads to a higher level of availability and vice versa. Where dilution of releases is by natural ventilation, the worst case scenario shall preferably be considered to determine the degree of ventilation rate. Such a scenario will then lead to a higher level of availability ~~even though the degree of the ventilation is reduced. Generally, with any natural ventilation, a lower degree of ventilation leads to a higher level of availability and vice versa~~ which will compensate for overly optimistic assumptions made in estimating the degree of ventilation rate. 36

There are some situations which require special care. This is particularly the case where the ventilation openings are limited to mainly one side of the enclosure. Under certain unfavourable ambient conditions, such as windy days when the wind is blowing onto the ventilated face of the enclosure, the external air movement may prevent the operation of the thermal buoyancy mechanism. Under these circumstances the level of ventilation and the availability will both be poor resulting in a more rigorous classification.

7.2.3 Artificial ventilation

7.2.3.1 General

Air movement required for ventilation may also be provided by artificial means, for example, fans or extractors. Although artificial ventilation is mainly applied inside a room or enclosed space, it can also be applied to situations in the open air to compensate for restricted or impeded air movement due to obstacles.

The artificial ventilation may be either general (e.g. a whole room) or local (e.g. extraction near a point of release) and for both of these, differing degrees of air movement and replacement can be appropriate.

With the use of artificial ventilation it is sometimes possible to achieve:

- reduction in the type and/or extent of zones;
- shortening of the time of persistence of an explosive gas atmosphere;
- prevention of the generation of an explosive gas atmosphere.

7.2.3.2 Artificial ventilation considerations

Artificial ventilation can provide an effective and reliable ventilation system in an indoor situation. The following considerations should be included for artificial ventilation systems:

- a) classification of the inside of the extraction system and immediately outside the extraction system discharge point and other openings of the extraction system;
- b) for ventilation of a hazardous area the ventilation air should normally be drawn from a non-hazardous area taking into account the suction effects on the surrounding area;
- c) before determining the dimensions and design of the ventilation system, the location, grade of release, release velocity and release rate should be defined.

In addition, the following factors will influence the quality of an artificial ventilation system:

- a) flammable gases and vapours usually have densities other than that of air, thus they may accumulate near to either the floor or ceiling of an enclosed area, where air movement is likely to be reduced;
- b) proximity of the artificial ventilation to the source of release; artificial ventilation close to the source of release will normally be more effective and may be needed to adequately control gas or vapour movement;
- c) changes in gas density with temperature;
- d) impediments and obstacles may cause reduced, or even no, air movement, i.e. no ventilation in certain parts of the area;
- e) turbulence and circulating air patterns.

For more details, see Annex C.

Consideration should be given to the possibility or need for recirculation of air in the ventilation arrangement. This may impact the background concentration and effectiveness of the ventilation system in reducing the hazardous area. In such cases the classification of the hazardous area may need to be modified accordingly. Recirculation of air may also be necessary in some applications e.g. for some processes or to provide for the needs of personnel or equipment in high or low ambient temperatures where supplemental cooling or heating of the air is required. Where recirculation of air is needed then additional controls for safety may also be required, e.g. a gas analyzer with dampers controlling fresh air intake.

7.2.3.3 Examples of artificial ventilation

General artificial ventilation may include a building which is provided with fans in the walls and/or in the roof to improve the general ventilation in the building.

The role of fans may be twofold. They can increase the air flow through a building, helping to remove gas from the building. Fans within a building can also increase turbulence and aid the dilution of a cloud which is much smaller than the room which contains it, even if no gas is transported out of the room. Fans may also enhance dilution by increasing turbulence in some outdoor situations.

Local artificial ventilation may be:

- a) an air/vapour extraction system applied to an item of process equipment which continuously or periodically releases flammable vapour.
- b) a forced or extraction ventilation system applied to a local area where it is expected that an explosive gas atmosphere may otherwise occur.

For more details, see Clause C.4.

7.2.4 Degree of dilution

The effectiveness of the ventilation in controlling dispersion and persistence of the explosive atmosphere will depend upon the degree of dilution, the availability of ventilation and the design of the system. For example, ventilation may not be sufficient to prevent the formation of an explosive atmosphere but may be sufficient to avoid its persistence.

The degree of dilution is a measure of the ability of ventilation or atmospheric conditions to dilute a release to a safe level. Therefore a larger release corresponds with a lower degree of dilution for a given set of ventilation/or atmospheric conditions, and a lower ventilation rate corresponds with a lower degree of dilution for a given size of release.

If other forms of ventilation, e.g. cooling fans are taken into account, then care should be exercised as to ventilation availability. Ventilation for other purposes may also affect dilution in either a positive or negative manner.

The degree of dilution will also affect the dilution volume. The dilution volume is ~~mathematically~~ equal to the ~~hazardous~~ volume that may be above the LFL, including any safety factor, i.e. the volume that could be flammable ~~37~~ but. However the boundary of the hazardous area additionally takes into account other factors such as any possible movement of the release i.e. due to the direction and velocity of the release and of the surrounding volume of air. The hazardous area is then normally much larger than the dilution volume. The concept of dilution volume and relationship to the hazardous area classification is shown in Figure 1. ~~38~~

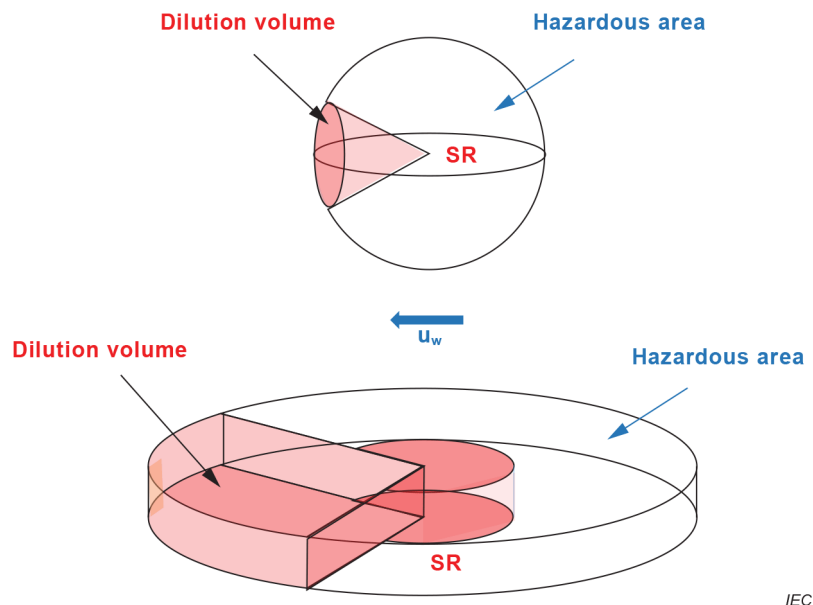


Figure 1 – Dilution Volume

The degrees of dilution will depend not only on the ventilation, but also on the nature and the type of the expected release of gas. Some releases, e.g. release with low velocity, will be amenable to mitigation by enhanced ventilation with others much less so, e.g. release with high velocity.

Commonly applied degrees of dilution are described in C.3.5.

~~The following three degrees of dilution are recognized:~~

~~a) High dilution~~

~~The concentration near the source of release reduces quickly and there will be virtually no persistence after the release has stopped.~~

~~b) Medium dilution~~

~~The concentration is controlled resulting in a stable zone boundary, whilst the release is in progress and the explosive gas atmosphere does not persist unduly after the release has stopped.~~

~~c) Low dilution~~

~~There is significant concentration whilst release is in progress and/or significant persistence of a flammable atmosphere after the release has stopped.~~ **39**

8 Type of zone

8.1 General

The likelihood of the presence of an explosive gas atmosphere depends mainly on the grade of release and the ventilation. This is identified as a zone. Zones are recognized as: Zone 0, Zone 1, Zone 2 and the non-hazardous area.

Where zones created by adjacent sources of release overlap and are of different ~~zonal classification~~ zone types, including temperature class and equipment group **40**, the more severe classification criteria will apply in the area of overlap. Where overlapping zones are of the same classification, this common classification will normally apply.

8.2 Influence of grade of the source of release

There are three basic grades of release, as listed below in order of decreasing frequency of occurrence and/or duration of release of flammable substance:

- a) continuous grade;
- b) primary grade;
- c) secondary grade.

A source of release may give rise to any one of these grades of release, or to a combination of more than one.

The grade of release generally determines type of the zone. In an adequately ventilated area (for example in an open air plant) a continuous grade of release generally leads to a Zone 0 classification, a primary grade to Zone 1 and a secondary grade to Zone 2. This general rule may be modified by considering the degree of dilution and availability of ventilation which may result in a more or less severe classification (see 8.3, 8.4 and Annex D).

8.3 Influence of dilution

The effectiveness of ventilation or degree of dilution shall be considered when estimating the type of zone classification.

A medium degree of dilution will generally result in the predetermined types of the zones based upon the types of the sources of release. A high degree of dilution will allow a less severe classification, e.g. Zone 1 instead of Zone 0, Zone 2 instead of Zone 1 and even Zone of negligible extent in some cases. On the other hand a low degree of dilution will require a more severe classification (see Annex D).

8.4 Influence of availability of ventilation

The availability of ventilation has an influence on the presence or formation of an explosive gas atmosphere and thus also on the type of zone. As availability, or reliability, of the ventilation decreases, the likelihood of not dispersing flammable gas explosive atmospheres increases. The zone classification will tend to be more severe, i.e. a Zone 2 may change to a Zone 1 or even Zone 0. Guidance on availability is given in Annex D.

Commonly applied descriptions for the availability of ventilation are provided in C.3.7.1. 41

NOTE Combining the concepts of the efficiency of ventilation and the availability of ventilation results in a qualitative method for the evaluation of the zone type. This is further explained in Annex D.

9 Extent of zone

The extent of the zone depends on the estimated or calculated distance over which an explosive atmosphere exists before it disperses to a concentration in air below its lower flammable limit. ~~Determination of the extent of the zone should consider the level of uncertainty in the assessment by the application of a safety factor.~~ 42 When assessing the area for spread of gas or vapour before dilution to below its lower flammable limit, expert advice should be sought.

Consideration should always be given to the possibility that a gas which is heavier than air may flow into areas below ground level (for example, pits or depressions) and that a gas which is lighter than air may be retained at high level (for example, in a roof space).

Where the source of release is situated outside an area or in an adjoining area, the penetration of a significant quantity of flammable gas or vapour into the area can be prevented by suitable means such as:

- a) physical barriers; or,

~~NOTE An example of a physical barrier is a wall or other obstruction that will limit the passage of gas or vapour at atmospheric pressure, thus preventing the accumulation of a flammable atmosphere.~~ **43**

- b) maintaining a sufficient overpressure in the area relative to the adjacent hazardous areas, so preventing the ingress of the explosive gas atmosphere.
- c) purging the area with ~~sufficient flow of fresh air, so ensuring that the air escapes from all openings where the flammable gas or vapour may enter~~ fresh air or a protective non-flammable gas such as nitrogen or carbon dioxide at a sufficient flow and positive pressure to reduce the concentration of any flammable gas or vapor initially present to non-hazardous concentration. **44**

NOTE An example of a physical barrier is a sealed wall with no openings or other obstruction that will limit the passage of gas or vapour at atmospheric pressure, thus preventing the penetration of a significant quantity of flammable gas or vapour into the area.

The extent of the zone requires assessment of a number of physical and chemical parameters, some of which are intrinsic properties of the flammable substance; others are specific to the situation (refer also to Clauses 6, 7 and 8).

For releases where only a small ~~mass~~ quantity is available to be released a lesser distance may be accepted to an on-going release. In cases of a small quantity, much of the guidance in Annex C and Annex D is not applicable. **45**

Under some conditions heavier than air gases and vapours can behave like a spilled liquid spreading down terrain slopes, through plant drains or pipe trenches and can be ignited at a point remote from the original leakage, therefore putting at risk large areas of a plant (see B.6). The layout of the plant, where possible, should be designed to aid the rapid dispersal of explosive gas atmospheres.

An area with restricted ventilation (for example, in pits or trenches) that would otherwise be Zone 2 may require Zone 1 classification; on the other hand, wide shallow depressions used for pumping complexes or pipe reservations may not require such rigorous treatment.

10 Documentation

10.1 General

It is recommended that the steps taken to carry out a hazardous area classification and the information and assumptions used are fully documented. The hazardous area classification document should be a living document and should include the method used for hazardous area classification and should be revised during any plant changes. All relevant information used should be referenced. Examples of such information, or of a method used, would be:

- a) process and operating conditions;
- b) recommendations from relevant codes and standards;
- c) gas and vapour dispersion characteristics and calculations;
- d) a study of ventilation characteristics in relation to flammable substance release parameters so that the effectiveness of the ventilation can be evaluated;
- e) any limitations or basis of the assessment which may affect the classification e.g for manufactured assemblies when installed on site;
- f) the properties of all process substances used on the plant (see ~~IEC 60079-20-1~~ ISO/IEC 80079-20-1 **46**), which may include:
 - molar mass
 - flash point
 - boiling point

- ~~minimum~~ auto-ignition temperature
- vapour pressure
- vapour density
- flammability limits
- equipment group and temperature class

~~A suggested format for the substances listing is given in Table A.1 and a format for recording the results of the area classification study and any subsequent alterations is given in Table A.2.~~ 47

The source of information (code, national standard, calculation) needs to be recorded so that, at subsequent reviews, the philosophy adopted is clear to the ~~hazardous~~ area classification team.

10.2 Drawings, data sheets and tables

Hazardous area classification documents may be in hard copy or electronic form and should be kept in a form that is suitable for the site.

Possible hard copy formats for the substances listing is given in Table A.1 and for recording the results of the hazardous area classification study and any subsequent alterations is given in Table A.2. 48

~~Area classification documents may be in hard copy or electronic form and~~ Drawings should include plans and elevations or three dimensional ~~models~~ presentation, as appropriate, which show both the type and extent of zones, equipment group, auto-ignition temperature ~~and/or~~ temperature class.

Where the topography of an area influences the extent of the zones, this should be documented.

The documents should also include other relevant information such as:

- a) the location and identification of sources of release. For large and complex plants or process areas it may ~~not be helpful~~ practical to itemize or number all the sources of release ~~so as to facilitate cross-referencing between the area classification data sheets and the drawings~~ in which case simplified methods may be used as outlined in 5.4; 49
- b) the position of openings in buildings (for example, doors, windows and inlets and outlets of air for ventilation).

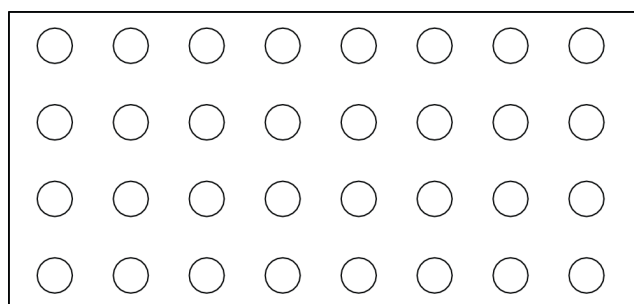
The ~~hazardous~~ area classification symbols which are shown in Figure A.1 are the preferred ones. A symbol key shall always be provided on each drawing. Different symbols may be necessary where multiple equipment groups ~~and/or~~ temperature classes are required within the same type of zone (for example, Zone 2 IIC T1 and Zone 2 IIA T3).

Annex A (informative)

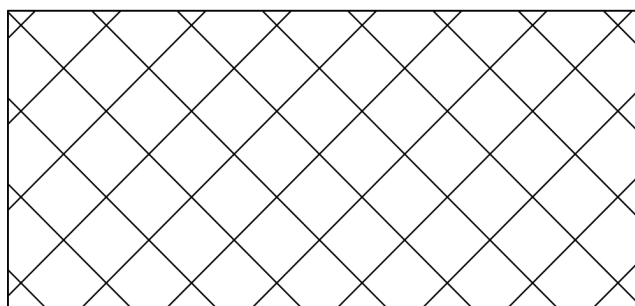
Suggested presentation of hazardous areas

A.1 Hazardous area ~~zones~~ – Preferred symbols for zones

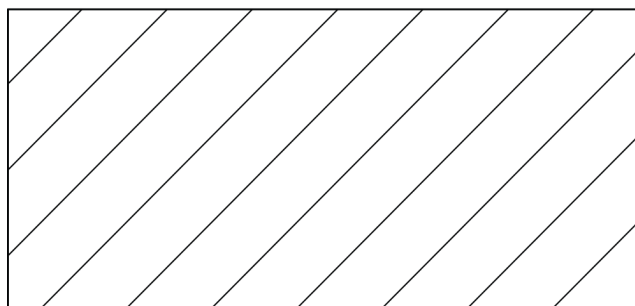
Figure A.1 shows preferred symbols for ~~hazardous area~~ zones.



Zone 0



Zone 1



Zone 2

IEC

Figure A.1 – Preferred symbols for ~~hazardous area~~ zones

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Table A.2 – Hazardous area classification data sheet – Part II: List of sources of release

Plant: Area:																Refer ence drawing:	
1	2	3	4	5	6	7	8		9	10	11	12	13	14		15	16
	Source of release					Flammable substance			Ventilation			Hazardous area				Any other informa tion or remark	
	Descrip tion	Location	Grade of release ^a	Rate of release (kg/s)	Release charac teristic (m ³ /s)	Refer ence ^b	Operating temperature and pressure		State ^c	Type ^d	Degree of dilution ^e	Availa bility	Zone type 0-1-2	Zone extent (m)			Refer ence ^f
							(°C)	(kPa)						Vertical	Horizontal		

^a C – Continuous; S – Secondary; P – Primary

^b Quote the number of list in Part I

^c G – Gas; L – Liquid; LG – Liquefied gas; S – Solid

^d N – Natural; AG – Artificial General; AL – Artificial Local

^e See Annex C

^f Indicate code reference if used, or calculation reference

A.2 Hazardous area suggested shapes

Figure A.2 to Figure A.5 show some suggested hazardous area shapes based on the forms of release described in Clause B.6, which may be useful in the preparation of hazardous area classification drawings. The effects of impingement of the release on obstacles and the influence of topography are not considered. The hazardous area generated by a release may also result in the combination of different shapes.

For Figure A.2 to Figure A.5:

- SR is the source of release
- r is the main extent of the hazardous area to be defined taking into consideration the estimated hazardous distance;
- r' , r'' are the secondary extents of the hazardous area to be defined taking into account release behaviour;
- h are the distances between the source of release and ground level or surface below the release.

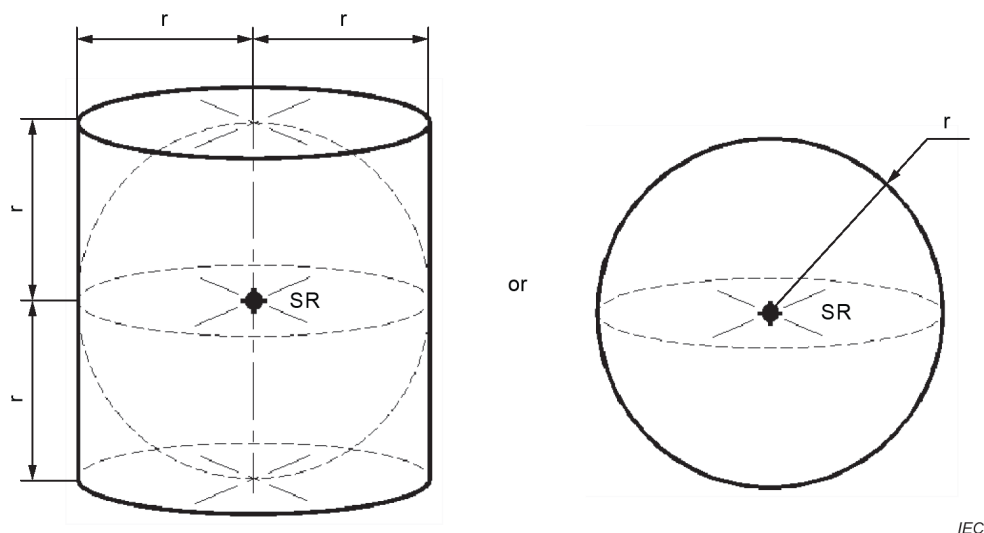


**Figure A.2 – Gas or vapour at low pressure
(or at high pressure in case of unpredictable release direction)**

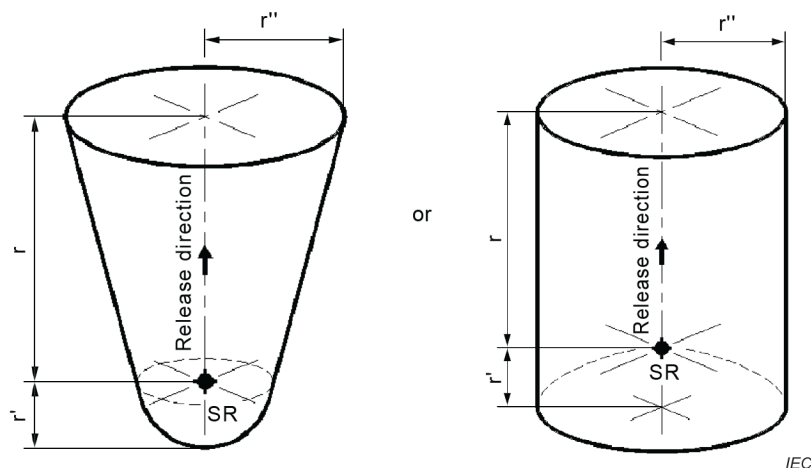
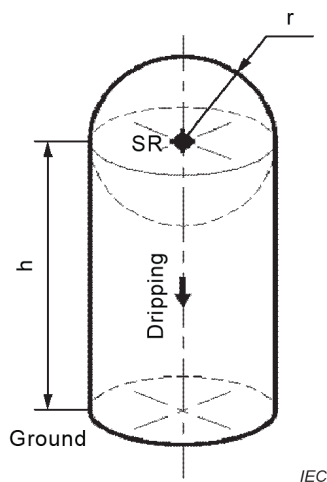
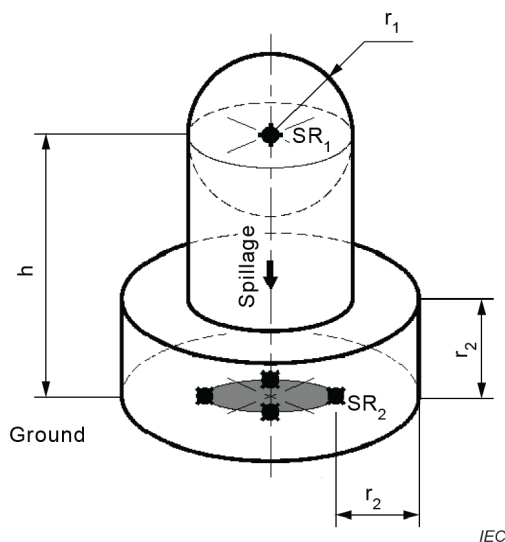


Figure A.3 – Gas or vapour at high pressure



NOTE Liquid pool would not normally be formed in case of dripping.

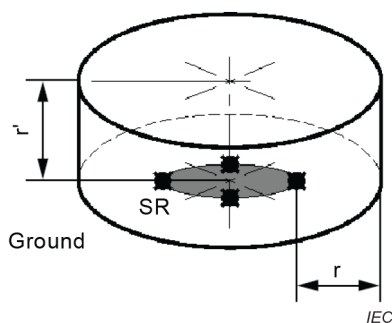
Figure A.4a) Gas or vapour (liquefied under pressure or by refrigeration)



NOTE Liquid pool could be formed in case of spillage. In this case, an additional source of release could be considered.

Figure A.4b) Gas or vapour (liquefied under pressure or by refrigeration) with spillage

Figure A.4 – Liquefied gas



NOTE Source of spillage of flammable substance is not indicated.

Figure A.5 – Flammable liquid (non boiling evaporative pool)

Annex B (informative)

Estimation of sources of release

B.1 Symbols

A_p	pool surface area (m ²);
C_d	discharge coefficient (dimensionless) which is a characteristic of the release openings and accounts for the effects of turbulence and viscosity, typically 0,50 to 0,75 for sharp orifices and 0,95 to 0,99 for rounded orifices;
c_p	specific heat at constant pressure (J/kg K);
γ	polytropic index of adiabatic expansion or ratio of specific heats (dimensionless);
M	molar mass of gas or vapour (kg/kmol);
p	pressure inside the container (Pa);
Δp	pressure difference across the opening that leaks in (Pa);
p_a	atmospheric pressure (101 325 Pa);
p_c	critical pressure (Pa);
p_v	vapour pressure of the liquid at temperature T (kPa);
Q_g	volumetric flow rate of flammable gas from the source (m ³ /s);
R	universal gas constant (8314,5 J/kmol K);
ρ	liquid density (kg/m ³);
ρ_g	gas or vapour density at the ambient conditions (kg/m ³);
S	cross section of the opening (hole), through which the fluid is released (m ²);
T	absolute temperature of the fluid, gas or liquid (K);
T_a	absolute ambient temperature (K);
u_w	wind speed over at the liquid pool surface (m/s);
W	release rate of liquid (mass per time, kg/s);
W_e	evaporation rate of liquid (kg/s);
W_g	mass release rate of gas (kg/s);
Z	compressibility factor (dimensionless).

B.2 Examples of grade of release

B.2.1 General

The examples given in B.2.2 to B.2.4 are not intended to be rigidly applied and may need to be varied to suit particular process equipment and the situation. It needs to be recognised that some equipment may exhibit more than one grade of release.

The values for the parameters in the formulae provided should be selected to give an appropriate level of conservatism considering any uncertainty. Based on this approach, specific safety factors are not shown. 50

B.2.2 Sources giving a continuous grade of release

Hereunder are some typical examples:

- a) the surface of a flammable liquid in a fixed roof tank, with a permanent vent to the atmosphere.
- b) the surface of a flammable liquid which is open to the atmosphere continuously or for long periods.

B.2.3 Sources giving a primary grade of release

Hereunder are some typical examples:

- a) Seals of pumps, compressors or valves if release of flammable substance during normal operation is expected.
- b) Water drainage points on vessels which contain flammable gases or liquids, which may release flammable substance into the atmosphere while draining off water during normal operation.
- c) Sample points which are expected to release flammable substance into the atmosphere during normal operation.
- d) Relief valves, vents and other openings which are expected to release flammable substance into the atmosphere during normal operation.

B.2.4 Sources giving a secondary grade of release

Hereunder are some typical examples:

- a) Seals of pumps, compressors and valves where release of flammable substance during normal operation of the equipment is not expected.
- b) Flanges, connections and pipe fittings, where release of flammable substance is not expected during normal operation.
- c) Sample points which are not expected to release flammable substance during normal operation.
- d) Relief valves, vents and other openings which are not expected to release flammable substance into the atmosphere during normal operation.

B.3 Assessment of grades of release

A wrong assessment of grades of release may compromise the outcome of the whole procedure. Although the grades of release are defined (see 3.4.2, 3.4.3 and 3.4.4), in practice it is not always easy to distinguish one grade of release from the other.

For example, it is usually considered that every release that does not occur in normal operation is a secondary release and the anticipated duration of the release is usually neglected. However, the concept of a secondary grade of release is also based upon the assumption that the release will only last for short periods. This implies that a potentially ongoing release will be ~~detected~~ identified **51** soon after the beginning of the release and that remedial action will be taken as soon as possible. Such assumption leads to the issue of regular monitoring and maintenance of the equipment and installation.

Obviously, if there is no regular monitoring and the maintenance is poor, the releases may last for hours if not days before being detected. Such delay in detection does not mean that the sources of the release should therefore be declared as primary or continuous. There are many unattended remote installations where a release may occur without being noticed for long time, but even such installations should be monitored and inspected on a reasonably regular basis. So, any assessment of the release grade must be based upon careful considerations and the assumption that monitoring and inspection of the equipment and installations will be performed in a reasonable way according to any manufacturer's instructions, relevant regulations and protocols and sound engineering practice. Hazardous area classification should not be a cover for a poor maintenance practice but the user must be aware that poor practices may compromise the established basis for the hazardous area classification.

There are many cases of release which may apparently fit comfortably with the definition of a primary grade of release. However when scrutinizing the nature of the release it may be revealed that the release could happen so frequently and so unpredictably that one cannot be reasonably assured that an explosive atmosphere will not exist near the source of release. In such cases the definition of continuous grade of release may be more suitable. Therefore the definition of a continuous grade of release implies not only continuous releases but releases with a high frequency as well (see 3.4.2).

B.4 Summation of releases

In indoor areas with more than one source of release, in order to determine the type and extent of zones, the releases might need to be summated before the degree of dilution and background concentration is determined.

Since Continuous grade releases, ~~by definition,~~ can be expected to be releasing most if not all of the time, ~~then~~ and so all continuous grade releases should be ~~included~~ summated.

Primary grade releases occur in normal operation but it is unlikely that all of these sources will be releasing at the same time. Knowledge and experience of the installation should be used to determine the maximum number of primary grade releases that may release simultaneously under worst conditions.

Secondary grade releases are not expected to release in normal operation so, given that it is unlikely that more than one secondary source would release at any one time, only the largest secondary release should be considered.

The summation of sources of release with regular (i.e. predictable) activity should be based on detailed analysis of operating conditions. In the determination of the summated releases (both mass and volumetric):

- the overall continuous release is the sum of all the individual continuous releases,
- the overall primary release is the sum of some of the individual primary releases combined with the overall continuous release,
- the overall secondary release is the largest individual secondary release combined with the overall primary release.

Where the same flammable substance is released from all of the release sources then the release rates (both mass and volumetric) can be summated directly.

However, when the releases are of different flammable substances, the situation is more complex. In the determination of the degree of dilution (see Figure C.1), the release characteristics need to be determined for each flammable substance before any summation takes place. The secondary release with the highest value should be used.

In the determination of the background concentration (see equation C.1) the volumetric release rates can be summated directly. The critical concentration with which the background concentration is compared is a proportion of the LFL ~~(typically 25 %)~~. Since there ~~are~~ could be a number of different flammable substances being released the ~~combined~~ lowest LFL of the potential sources of release **53** should be used as the comparator.

In general, continuous and primary sources of release should preferably not be located in areas with a low degree of dilution. Either the sources of release should be relocated, ventilation should be improved or the grade of release should be reduced.

B.5 Hole size and source radius

The most significant factor to be estimated in a system is the equivalent **54** hole radius for the respective source of release. It determines the release rate of the flammable substance and thus eventually the type of zone and the extent of the zone.

Release rate is proportional to the square of the equivalent hole radius. A modest underestimate of ~~the~~ this equivalent hole size will therefore lead to a gross underestimate of the calculated value for release rate, which should be avoided. Overestimate of the equivalent hole size will lead to a conservative calculation which is acceptable for safety reasons, however, the degree of conservatism should also be limited because it eventually ~~results with~~ leads to overlarge zone extents. A carefully balanced approach is therefore needed when estimating the hole size.

NOTE While the term 'hole radius' is used, most unintended holes are not round. In such cases the coefficient of discharge is used as a compensating term to reduce the release rate given a hole of equivalent area.

For continuous and primary grades of release the equivalent holes sizes are defined by the size and the shape of the release orifice, e.g. various vents and breather valves where the gas is released under relatively predictable conditions. A guide to equivalent hole sizes that may be considered for secondary grade releases is included in Table B.1.

Table B.1 – Suggested hole cross sections for secondary grade of releases

Type of item	Item	Leak Considerations		
		Typical values for the conditions at which the release opening will not expand	Typical values for the conditions at which the release opening may expand, e.g. erosion	Typical values for the conditions at which the release opening may expand up to a severe failure, e.g. blow out
		S (mm ²)	S (mm ²)	S (mm ²)
Sealing elements on fixed parts	Flanges with compressed fibre gasket or similar	≥ 0,025 up to 0,25	> 0,25 up to 2,5	(sector between two bolts) × (gasket thickness) usually ≥ 1 mm
	Flanges with spiral wound gasket or similar	0,025	0,25	(sector between two bolts) × (gasket thickness) usually ≥ 0,5 mm
	Ring type joint connections	0,1	0,25	0,5
	Small bore connections up to 50 mm ^a	≥ 0,025 up to 0,1	> 0,1 up to 0,25	1,0
Sealing elements on moving parts at low speed	Valve stem packings	0,25	2,5	To be defined according to Equipment Manufacturer's Data but not less than 2,5 mm ^{2 d}
	Pressure relief valves ^b	0,1 × (orifice section)	NA	NA
Sealing elements on moving parts at high speed	Pumps and compressors ^c	NA	≥ 1 up to 5	To be defined according to Equipment Manufacturer's Data and/or Process Unit Configuration but not less than 5 mm ^{2 d and e}

^a Hole cross sections suggested for ring joints, threaded connections, compression joints (e.g. metallic compression fittings) and rapid joints on small bore piping.

^b This item does not refer to full opening of the valve but to various leaks due to malfunction of the valve components. Specific applications could require a hole cross section bigger than suggested.

^c Reciprocating Compressors – The frame of compressor and the cylinders are usually not items that leak but the piston rod packings and various pipe connections in the process system.

^d Equipment Manufacturer's Data – Cooperation with equipment's manufacturer is required to assess the effects in case of an expected failure (e.g. the availability of a drawing with details relevant to sealing devices).

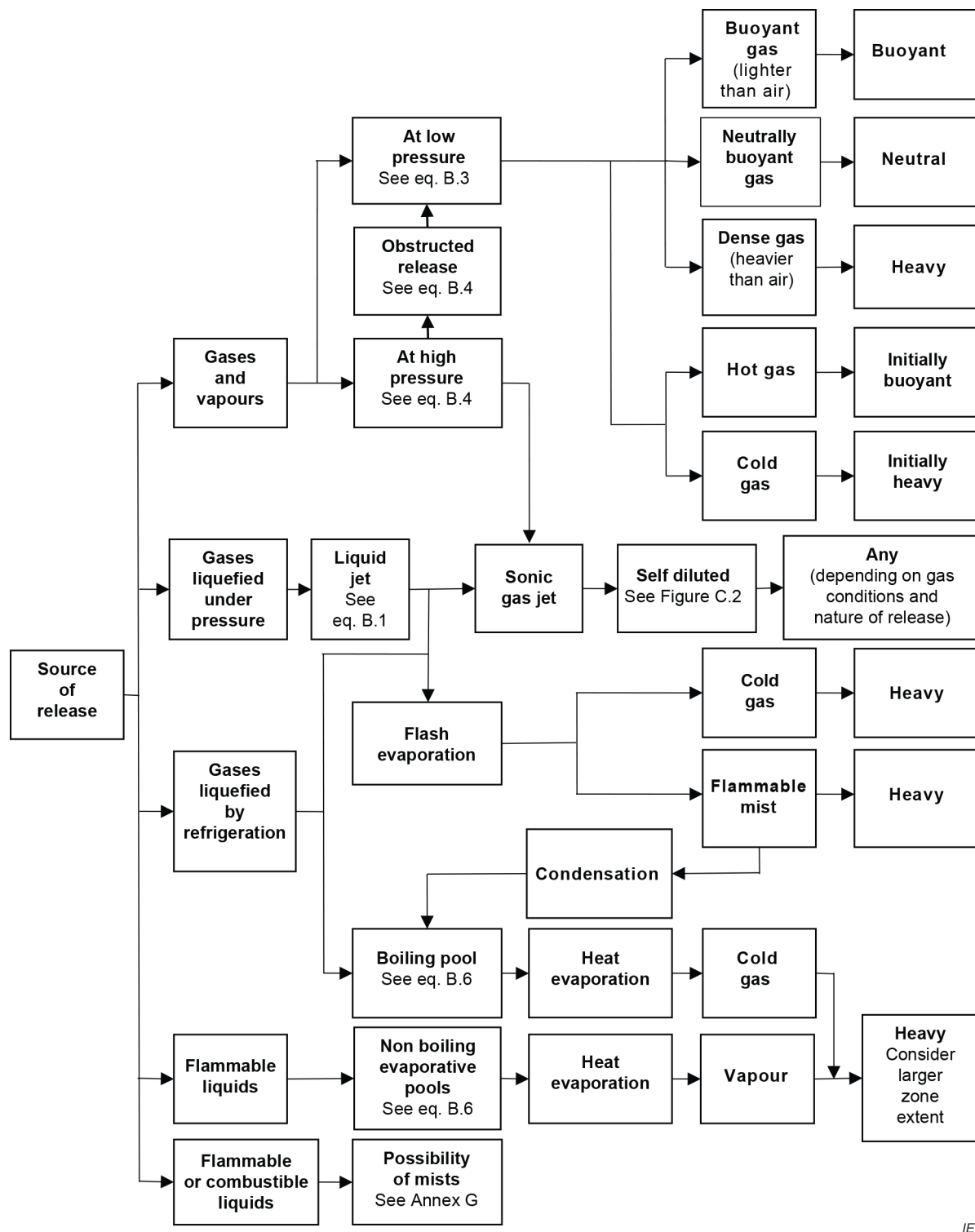
^e Process Unit Configuration – In certain circumstances (e.g. a preliminary study), an operational analysis to define the maximum accepted release rate of flammable substance may compensate lack of equipment manufacturer's data.

NOTE Other typical values or guidance on erosion and failure conditions may also be found in national or industry codes relevant to specific applications.

Lower values in a range should be selected for ideal conditions where the likelihood of failure is low, e.g. operating at well below design ratings. Higher values in a range should be selected where operating conditions are close to design ratings and where adverse conditions such as vibration, temperature variations, poor environmental conditions or contamination of gases may increase the likelihood of failure. Generally, unattended installations require special considerations to avoid severe failure scenarios. The basis for selection of a hole size should be properly documented.

B.6 Forms of release

Figure B.1 illustrates the general nature of different forms of release.



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Figure B.1 – Forms of release

B.7 Release rate

B.7.1 General

The release rate depends on parameters such as:

a) Nature and type of release

This is related to the physical characteristics of the source of release, for example, an open surface, leaking flange, etc.

b) Release velocity

For a given source of release, the release rate increases with the release pressure. For a subsonic release of gas, the release velocity is related to the process pressure. The size of a cloud of flammable gas or vapour is determined by the rate of flammable gas or vapour release and the rate of dilution. Gas and vapour flowing from a leak at high velocity will entrain air and may be self-diluting. The extent of the explosive gas atmosphere may be almost independent of air flow. If the substance is released at low velocity or if its velocity is reduced by impingement on a solid object, it will be carried by the air flow and its dilution and extent will depend on air flow.

c) Concentration

The mass of flammable substance released increases with the concentration of flammable vapour or gas in the released mixture.

d) Volatility of a flammable liquid

This is related principally to the vapour pressure, and the enthalpy (heat) of vaporization. If the vapour pressure is not known, the boiling point and flashpoint can be used as a guide.

An explosive atmosphere cannot exist if the flashpoint is above the relevant maximum temperature of the flammable liquid (see NOTE 1). The lower the flashpoint, the greater may be the extent of the zone. However, if a flammable substance is released in a way that forms a mist (for example, by spraying) an explosive atmosphere may be formed below the flashpoint of the substance.

NOTE 1 Published tables and experimentation giving data on flashpoint ~~may~~ do not always record accurate values and test data will vary. Unless values for flashpoint are known to be accurate, some margin of error is allowed against quoted values. A margin of ± 5 deg C for pure liquids, with greater margins for mixtures, is not uncommon.

~~NOTE 2~~ There are two measures of flash point; closed cup and open cup. For closed equipment, and to be more conservative, the closed cup flash point ~~should be~~ is used. For a flammable liquid in the open, the open cup flash point ~~may~~ can be used.

~~NOTE 3~~ 2 Some liquids (for example, some halogenated hydrocarbons) do not possess a flashpoint although they are capable of producing an explosive gas atmosphere. In these cases, the equilibrium liquid temperature which corresponds to the saturated concentration at the lower flammable limit ~~should~~ is to be compared with the relevant maximum liquid temperature.

e) Liquid temperature

Increasing liquid temperature increases the vapour pressure, thus increasing the release rate due to evaporation.

~~NOTE 4~~ The temperature of the liquid may be increased after it has been released, for example, by a hot surface or by a high ambient temperature. However, vapourisation will also tend to cool the liquid until an equilibrium condition is reached based on the energy input and the enthalpy of the liquid.

B.7.2 Estimation of release rate

B.7.2.1 General

The equations and assessment methodologies presented in this clause are not intended to be applicable to all installations and only apply to the limited conditions noted in each section. The equations also provide indicative results due to the restrictions of trying to describe complex matters with simplified mathematical models. Other calculation methods may also be adopted.

The following equations give the approximate release rates of flammable liquids and gases. Further refinement of release rate estimation would be achieved with consideration of properties of any openings and the viscosity of the liquid or gas. Viscosity may significantly reduce the release rate if the opening, through which the flammable substance is released, is long compared to the width of the opening. These factors are normally considered in the coefficient of discharge ($C_d \leq 1$).

The coefficient of discharge C_d is an empirical value which is obtained through a series of experiments for specific cases of release and for specific orifice details. As a result C_d may take a different value for each particular case of release. A C_d of not less than 0,99 for items with regularly shaped holes, e.g. for vents, and 0,75 for irregular holes can be a reasonably safe approximation if there is no other relevant information upon which to make the assessment.

If C_d is applied to the calculations the value applied should be used by reference to a suitable guide for the application.

B.7.2.2 Release rate of liquids

The release rate of liquid can be estimated by means of the following approximation:

$$W = C_d S \sqrt{2 \rho \Delta p} \text{ (kg/s)} \quad (\text{B.1})$$

The rate of vapourisation of a liquid release is then required to be determined. Liquid releases may take many forms. The nature of the release and how any vapour or gas is generated is also dependant on many variables. Examples of releases include:

a) Two phase release (i.e. combined liquid and gas release)

Liquids such as liquefied petroleum gas (LPG), may include both gas and liquid phases either immediately before the release orifice or after the release orifice through a variety of thermodynamic or mechanical interactions. This may further lead to droplet and/or pool formation which results in further boiling of the liquid contributing to the vapour cloud.

b) Single phase release of a non-flashing liquid

For liquids with higher boiling points (above atmospheric ranges) the release will generally include a significant liquid component which may evaporate near the source of release. The release may also break up into small droplets as a result of a jet action. Vapour released will then depend on any jet formation and vapourisation from the point of release, from any droplets or any subsequent pool formation.

Due to the large number of conditions and variables methodology for assessing the vapour conditions of a liquid release is not provided in this standard. Users should carefully select a suitable model observing any limitations of the model and/or applying an appropriately conservative approach with any results.

B.7.2.3 Release rate of gas or vapour

B.7.2.3.1 General

The equations below are considered to provide reasonable estimations of release rate for gases. If the gas density approaches that of liquefied gas then two phase releases may need to be considered as noted in B.7.2.2.

The release rate of gas from a container can be estimated based on adiabatic expansion of an ideal gas if the pressurized gas density is much lower than liquefied gas density.

The velocity of released gas is choked (sonic) if the pressure inside the gas container is higher than the critical pressure p_c .

Critical pressure is determined by the following equation:

$$p_c = p_a \left(\frac{\gamma + 1}{2} \right)^{\gamma / (\gamma - 1)} \text{ (Pa)} \quad (\text{B.2})$$

For ideal gas the equation $\gamma = \frac{M c_p}{M c_p - R}$ may be used.

NOTE For the majority of gases the approximation $p_c \approx 1,89 p_a$ will generally serve the purpose for a quick estimate. Critical pressures are generally low compared with the majority of operating pressures found in common industrial processes. Pressures below the critical pressure are normally found in terminal gas supply lines to fired equipment like e.g. heaters, furnaces, reactors, incinerators, vaporizers, steam generators, boilers and other process equipment. Such pressures can also be found in atmospheric storage tanks with moderate overpressures (usually up to ~~0,5 barG~~ 50 kPag).

In the following equations the compressibility factor for ideal gases is 1,0. For the real gases, the compressibility factor takes values below or above 1,0 depending on type of the gas concerned, the pressure and the temperature. For low to medium pressures, $Z = 1,0$ can be used as a reasonable approximation ~~and may be conservative~~. For higher pressures, e.g. above 50 bar, and where improved accuracy is required the real compressibility factor should be applied. The values for compressibility factor can be found in data books for gas properties.

B.7.2.3.2 Release rate of gas with non choked gas velocity (subsonic releases)

Non choked gas velocity is a discharge velocity below the speed of sound for the particular gas.

The release rate of gas from a container, if the gas velocity is non-choked, can be estimated by means of the following approximation:

$$W_g = C_d S p \sqrt{\frac{M}{Z R T} \frac{2\gamma}{\gamma - 1} \left[1 - \left(\frac{p_a}{p} \right)^{(\gamma - 1)/\gamma} \right] \left(\frac{p_a}{p} \right)^{1/\gamma}} \text{ (kg/s)} \quad (\text{B.3})$$

The volumetric flow rate of gas in (m^3/s) is equal to:

$$Q_g = \frac{W_g}{\rho_g} \text{ (m}^3/\text{s)} \quad (\text{B.4})$$