IEC 60079-10-1

Edition 3.0 2020-12
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

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

IEC 60079-10-1:2020-12 CMV(en)

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

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EXPLOSIVE ATMOSPHERES –

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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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. Futhermore, 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:

		Type		
Changes	**Clause**	**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:~~2013~~2017, ~~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, C_2H_2; monovinyl acetylene, CAS no. 689-97-4, C_4H_4; 1-propyl nitrate (vapour), CAS no. 627-13-4, CH_3 $(CH_2)_2$ NO_3; isopropyl nitrate (vapour), CAS no. 1712-64-7, $(CH_3)_2$ CH ONO_2; ethylene oxide (vapour), CAS no. 75-21-8, $(CH_2)_2$ O; hydrazine (vapour), CAS no. 302-01-2, H_4 N_2.

[SOURCE: IEC 60079-0:~~2013~~2017, ~~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~~ can 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:~~2009~~2020, 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:~~2009~~2020, 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 synomonous 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 60079-20-1~~ (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 m^3 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 quanities 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 °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 evapouration 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**

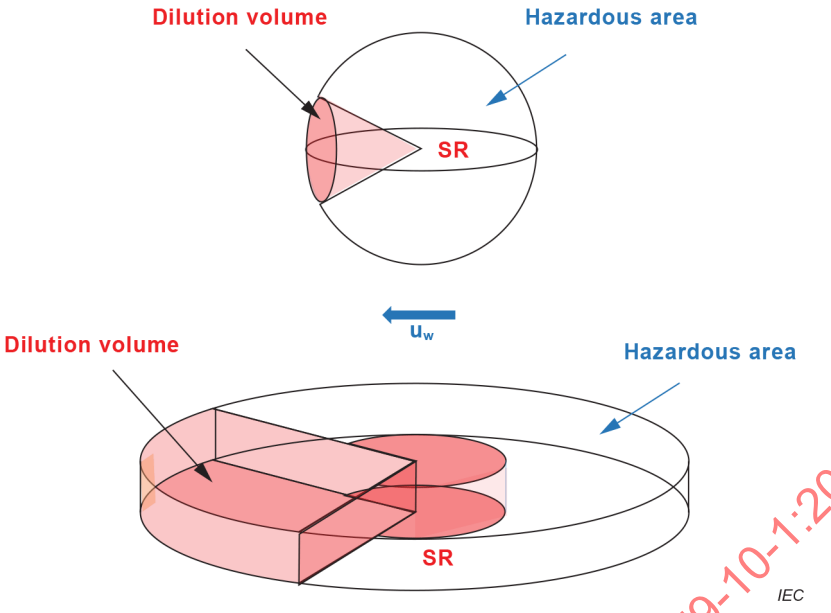


Figure 1 – Dilution Volume

The degree~~s~~ 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.

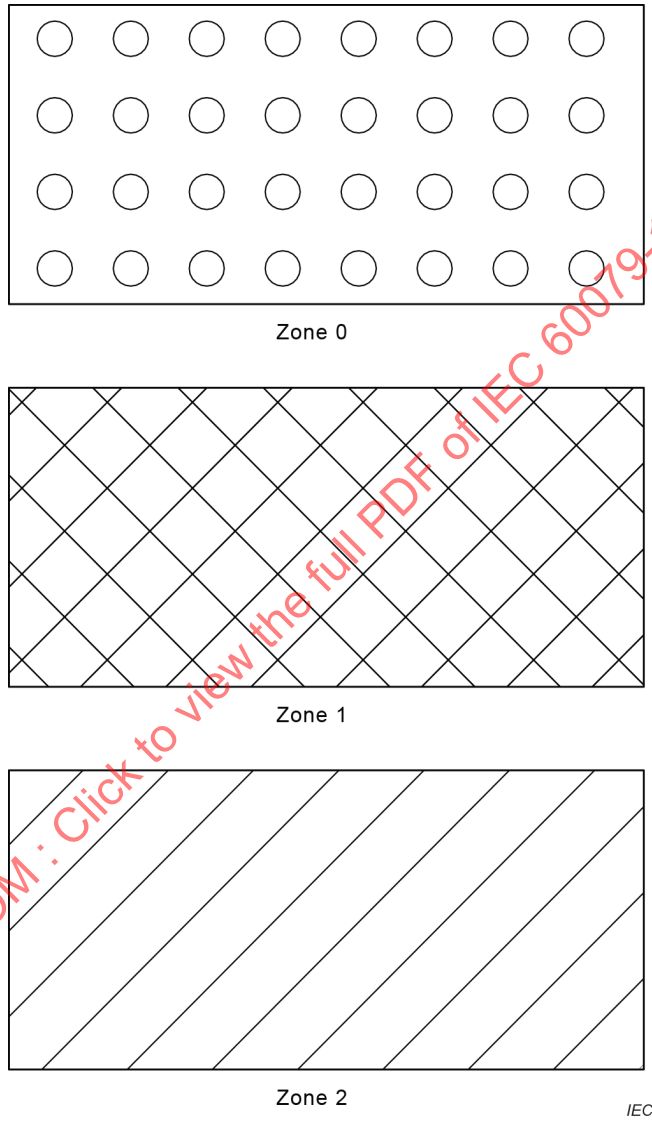


Figure A.1 – Preferred symbols for ~~hazardous area~~ zones

Table A.1 – Hazardous area classification data sheet – Part I: Flammable substance list and characteristics

Plant: **Area:**														**Reference drawing:**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Flammable substance							**Volatility**[a]		**LFL/UFL**		**Ex characteristics**		
	Name	Composition	Molar mass (kg/kmol)	Relative density gas/air	Polytropic index of adiabatic expansion γ	Flash point (°C)	Ignition temp. (°C)	Boiling point (°C)	Vapour pressure at 20 °C (kPa)	vol (%)	(kg/m^3)	Equip ment group	Temp. class	Any other relevant information ~~and remarks~~ or remark. E.g. Source of data
[a] Normally, the value of vapour pressure is given, but in the absence of that, boiling point can be used.														

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

Plant: **Area:**															**Reference 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**			
	Description	Location	Grade of release[a]	Rate of release (kg/s)	Release characteristic (m^3/s)	Reference[b]	Operating temperature and pressure		State[c]	Type[d]	Degree of dilution[e]	Availability	Zone type 0-1-2	Zone extent (m)	Reference[f]	Any other information or remark
							(°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.

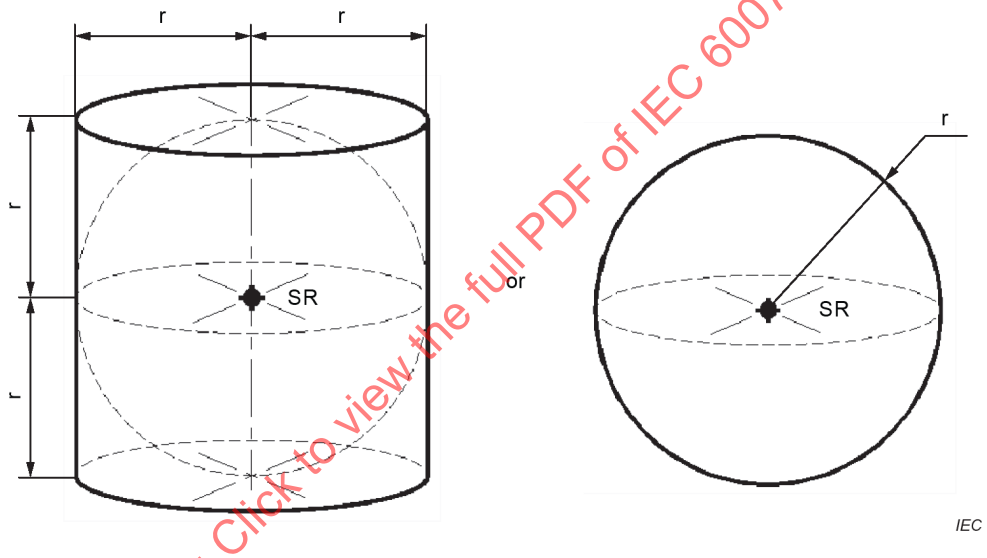


Figure A.2 – Gas~~/~~ or vapour at low pressure (or at high pressure in case of unpredictable release direction)

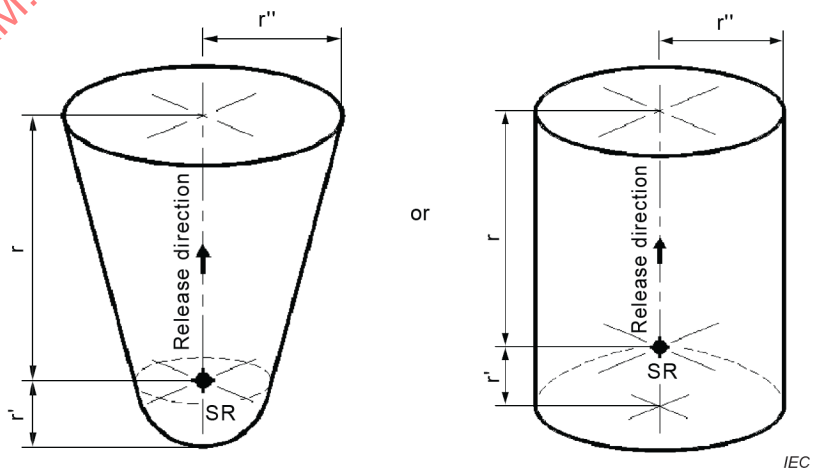
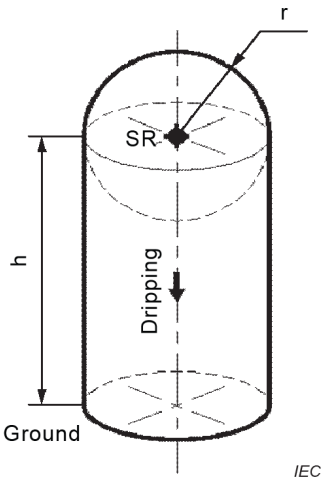
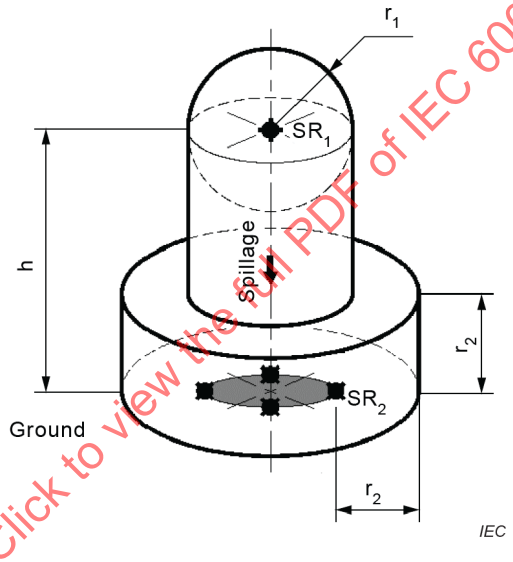


Figure A.3 – Gas~~/~~ or vapour at high pressure



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

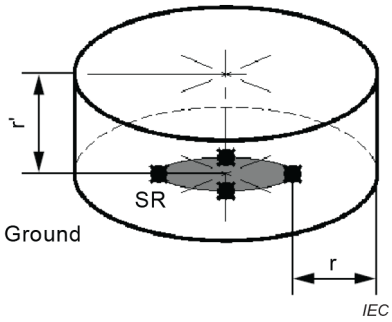
Figure A.4a) Gas or vapour (liquefied under pressure or by refrigeration)



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 (~~k~~Pa);

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 uncertaintity. 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 **52** 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.

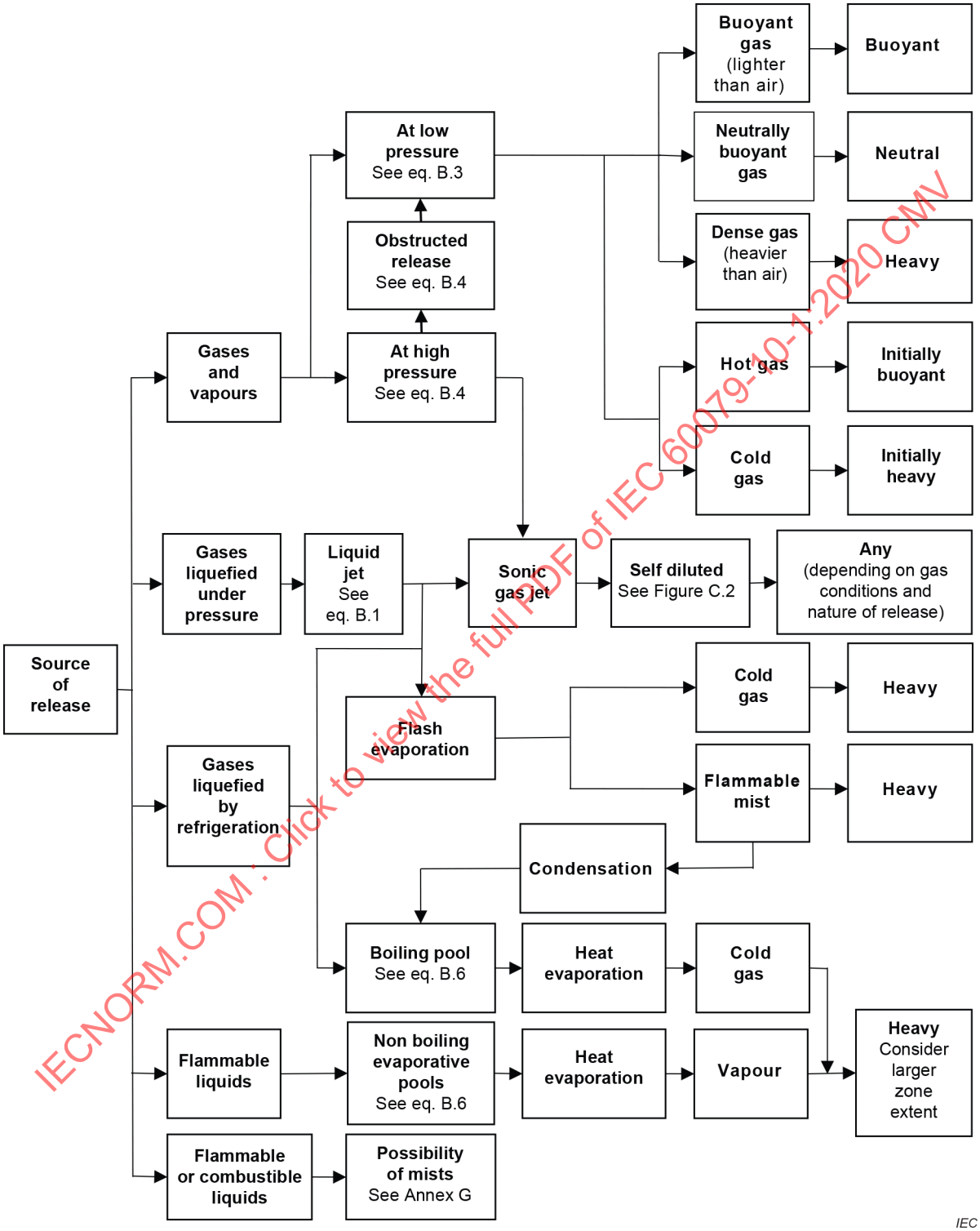


Figure B.1 – Forms of release

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:

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

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:

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

For ideal gas the equation $\gamma = \dfrac{M\, c_p}{M\, c_p - R}$ 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:

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

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

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

where

$\rho_g = \frac{p_a M}{R T_a}$ is the density of the gas (kg/m^3);

NOTE Where the temperature of the gas at the release opening may be below the ambient temperature, T_a is often used as equal to the gas temperature to provide an approximation for the purpose of easier calculation.

B.7.2.3.3 Release rate of gas with choked gas velocity (sonic releases)

Choked gas velocity (see B.7.2.3) is equal to the speed of sound for the gas. This is the maximum theoretical discharge velocity.

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

$$W_g = C_d S p \sqrt{\gamma \frac{M}{Z R T} \left(\frac{2}{\gamma + 1} \right)^{(\gamma+1)/(\gamma-1)}} \text{ (kg/s)} \quad \text{(B.5)}$$

B.7.3 Release rate of evaporative pools

Evaporative pools may be the result of liquid spillage or leakage ~~but also~~ in a bunded area or part of a process system where a flammable liquid is stored or handled in an open vessel. The assessment in this section does not apply to thin surface spills since no account is taken for specific factors that may be relevant to such spills e.g. thermodynamic input from the surface on which the liquid is spilt.

NOTE 1 A pool due to a catastrophic failure is not in the scope of this document (see Clause 1).

The following assumptions are made concerning the assessment below:

- ~~There is no phase change and the plume is at ambient temperature (phase and temperature changes would cause variations in dispersion and evaporation rates).~~
- ~~The flammable substance released is neutrally buoyant. Heavier than air vapour is treated the same way as neutrally buoyant gases in this analysis which will lead to a comparable assessment.~~
- ~~A continuous release for catastrophic spillage loss is not considered in this analysis.~~
- ~~Liquids are instantaneously spilled from containment onto a flat, level surface forming a 1 cm deep pool and are allowed to evaporate at ambient conditions.~~
- The flammable substance is evaporating, not boiling, and the plume is at ambient temperature (phase and temperature changes would cause variations in dispersion and evaporation rates).
- The evaporating flammable substance is assumed to have a relatively low vapour pressure, hence the concentration at the surface of the pool is also low, and the mixture of air and vapour is neutrally buoyant.
- Liquid pools develop quickly forming a nominal 1 cm deep pool
- Pools are allowed to evaporate at ambient conditions. **55**

Then the evaporation rate could be estimated by using following equation:

$$W_e = \frac{6{,}55\ u_w^{0{,}78}\ A_p\ p_v\ M^{0{,}667}}{R \times T} \text{(kg/s)}$$

$$W_e = \frac{18{,}3 \times 10^{-3}\ u_w^{0{,}78}\ A_p\ p_v\ M^{0{,}667}}{R \times T} \text{(kg/s)} \quad \text{(B.6)}$$

NOTE ~~1~~ 2 The source of this equation is U.S. Environmental Protection Agency, ~~Federal Emergency Management Agency, U.S. Department of Transportation, Technical Guidance for Hazard Analysis – Emergency Planning for Extremely Hazardous Substances, December 1987~~ Office for Solid Waste and Emergency Response, Risk management program for offsite consequence analysis, Appendix D, April 15 1999.

NOTE ~~2~~ 3 Vapour pressure can be estimated through various methods, e.g. derived from Antoine's equation.

NOTE ~~3~~ 4 It is assumed that the vapour pressure at the boiling temperature is ~~101,3 kPa~~ 101, 325 Pa.

Since the density of the vapour in (kg/m^3) is:

$$\rho_g = \frac{p_a\ M}{R\ T_a} \left(\text{kg/m}^3\right)$$

then, the volumetric evaporation rate in (m^3/s) is approximately:

$$Q_g \approx \frac{6{,}5\ u_w^{0{,}78}\ A_p\ p_v}{10^5\ M^{0{,}333}} \times \frac{T_a}{T} \left(\text{m}^3/\text{s}\right)$$

$$Q_g \approx \frac{18{,}15 \times 10^{-8}\ u_w^{0{,}78}\ A_p\ p_v}{M^{0{,}333}} \times \frac{T_a}{T} \left(\text{m}^3/\text{s}\right) \quad \text{(B.7)}$$

NOTE ~~4~~ 5 Since p_v increases with liquid temperature then the evaporation rate ultimately increases with the rise of T.

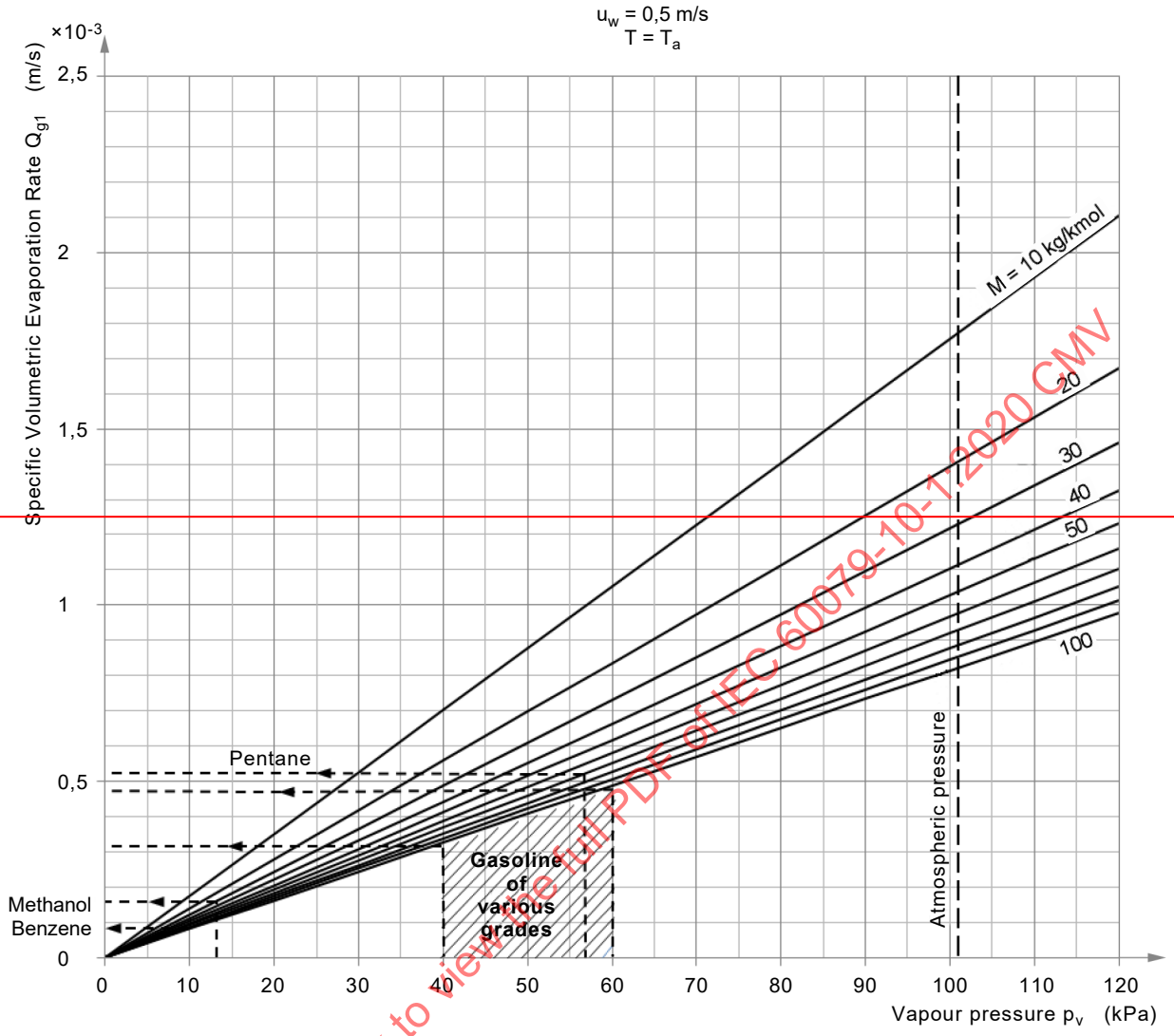
If we assume that the pool surface area is 1,0 m^2 that the wind speed ~~above ground level is 0,5 m/s~~ at the pool surface is 0,25 m/s **56** and that the liquid temperature is equal to the ambient temperature, then the volumetric evaporation rate in (m^3/s) would be:

$$Q_g \approx \frac{3{,}78 \times 10^{-5}\ p_v}{M^{0{,}333}} \left(\text{m}^3/\text{s}\right)$$

$$Q_g \approx \frac{6{,}15 \times 10^{-8}\ p_v}{M^{0{,}333}} \left(\text{m}^3/\text{s}\right) \quad \text{(B.8)}$$

The real pool area should be based on the quantity of the spilled liquid and the local conditions such as gradient and bunding at the spill location.

The wind speeds for evaluation of evaporation rate shall be consistent with the wind speeds in later calculations for estimating the degree of dilution (see C.3.4). It should be emphasized that increasing the wind, speed will increase evaporation but at the same time contributes to the dilution of flammable gas or vapour.



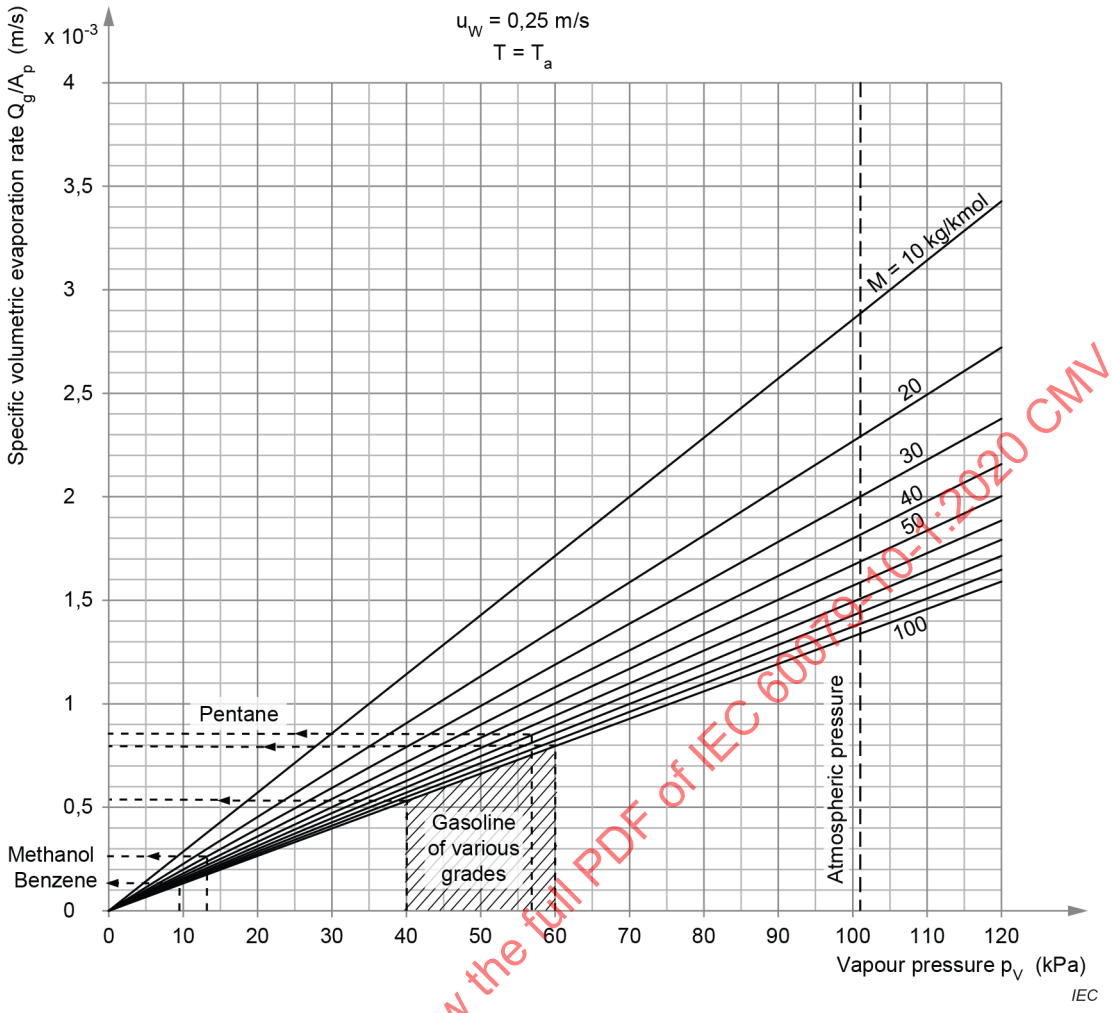


Figure B.2 – Specific volumetric evaporation rate of liquids

The chart in Figure B.2 is based upon equation B.8. The values on the vertical axis refer to the pool surface area of 1,0 m^2. Thus the evaporation rate is obtained by multiplying the value on the vertical axis with the real pool surface area.

The wind speed of ~~0,5~~ 0,25 m/s **56** is characteristic for meteorological calm just above ground level. Typically, it represents the worst case regarding dispersion of the vapour but not the worst case with respect to evaporation rate.

The value for vapour pressure on the horizontal axis should be taken for the relevant liquid temperature.

NOTE 6 The chart is only valid for atmospheric pressure. **57**

B.8 Release from openings in buildings

B.8.1 General

Subclauses B.8.2 and B.8.3 provide examples for openings in buildings or walls. They are not intended to be rigidly applied and may need to be varied to suit the particular situation.

B.8.2 Openings as possible sources of release

Openings between areas should be considered as possible sources of release. The grade of release will depend upon:

- the zone type of the adjoining area,
- the frequency and duration of opening periods,
- the effectiveness of seals or joints,
- the difference in pressure between the areas involved.

B.8.3 Openings classification

For the purpose of this assessment, openings are classified as A, B, C and D with the following characteristics:

Type A

Openings not conforming to the characteristics specified for types B, C or D, e.g.:

- open passages for access or utilities (examples of utilities include ducts or pipes through walls, ceilings and floors);
- openings which are frequently opened;
- fixed ventilation outlets in rooms, buildings and similar openings.

Type B

Openings which are normally closed (e.g. automatic closing), infrequently opened and close-fitting.

Type C

Openings which are normally closed (e.g. automatic closing), infrequently opened and fitted with sealing devices (e.g. a gasket) along the whole perimeter; or two type B openings in series, having independent automatic closing devices.

Type D

Openings which are effectively sealed, such as in utility passages; or openings normally closed conforming to type C which can only be opened by special means or in an emergency; or a combination of one opening type C adjacent to a hazardous area and one opening type B in series.

Table B.2 shows the effect of openings on grade of release when a ~~hazardous~~ zone has been established upstream of those openings.

Table B.2 – Effect of ~~hazardous~~ zones on openings as possible sources of release

Zone ~~upstream~~ outside of opening	Opening type	Grade of release of openings considered as sources of release
Zone 0	A	Continuous
	B	(Continuous)/primary
	C	Secondary
	D	Secondary / no release
Zone 1	A	Primary
	B	(Primary)/secondary
	C	(Secondary)/no release
	D	No release
Zone 2	A	Secondary
	B	(Secondary)/no release
	C	No release
	D	No release
For grades of release shown in brackets, the frequency of operation of the openings should be considered in the design.		

The grade of release of an opening may also be defined according to the basic principles.

The grade of release of the opening between an indoor naturally ventilated classified location and an outdoor non classified area may be defined considering the grade of release of the source generating the indoor ~~hazardous~~ zone.

Annex C
(informative)

Ventilation guidance

C.1 Symbols

A_1 effective area of the upwind or the lower opening where applicable (m^2);

A_2 effective area of the downwind or the upper opening where applicable (m^2).

A_e equivalent effective area for upwind and downwind openings at the same height or for the lower opening where applicable (m^2);

~~A_e equivalent effective area of the lower opening (m^2);~~

C air change frequency in the room (s^{-1});

ΔC_p pressure coefficient characteristic of the building (dimensionless);

C_d discharge coefficient (dimensionless), characteristic of large ventilation openings, inlet or outlet, and accounts for the turbulence and viscosity, typically 0,50 to 0,75;

f ~~mean background concentration X_b in the room divided by the concentration at the ventilation outlet~~ inefficiency of ventilation **58** (dimensionless);

g acceleration due to gravity (9,81 m/s^2);

H vertical distance between the midpoints of the lower and upper openings (m);

k ~~safety factor attributed to LFL;~~ **59**

LFL lower flammable limit (vol/vol);

M molar mass of gas or vapour (kg/kmol);

p_a atmospheric pressure (101 325 Pa);

Δp pressure difference, due to wind or temperature effects (Pa);

Q_a volumetric flow rate of air (m^3/s);

Q_1 volumetric flow rate of air entering the room through apertures (m^3/s);

Q_g volumetric flow rate of flammable gas from the source (m^3/s);

$Q_2 = Q_1 + Q_g$ volumetric flow rate of air/gas mixture leaving the room (m^3/s);

Q_C volumetric release characteristic of the source (m^3/s); **60**

R universal gas constant (8314,5 J/kmol K);

ρ_a air density (kg/m^3);

ρ_g ~~density of the~~ gas or vapour density at the ambient conditions (kg/m^3);

T_a ~~absolute~~ ambient temperature (K);

T_{in} indoor temperature (K);

T_{out} outdoor temperature (K);

ΔT difference between the indoor and the outdoor temperature (K);

u_w wind speed at a specified reference height or ventilation velocity at given release conditions where applicable (m/s);

V_0 volume under consideration (room or building) (m^3);

W_g mass release rate of flammable substance (kg/s), for mixtures, only the total mass of flammable substance should be considered;

X_b background concentration (vol/vol);

X_{crit} the desired/critical value of the flammable substance concentration (vol/vol). **60**

C.2 General

The purpose of this annex is to provide guidance on determining the type of zone(s) by assessing the type and likely extent of gas or vapour releases and comparing these factors with the dispersion and dilution of those gases or vapours by ventilation or air movement.

It should be emphasised that releases may take many forms and can be influenced by many conditions (see Clause B.6). These include:

- gases, vapours or liquids;
- indoor or outdoor situations;
- sonic or subsonic jets, fugitive or evaporative releases;
- obstructed or unobstructed conditions;
- gas or vapour density.

The information presented in this annex is intended to provide qualitative guidance on the assessment of the ventilation and dispersion conditions to determine the type of zone. The guidance applies to the conditions noted in each section and therefore may not be applicable to all installations.

The guidance herein may be used in the selection and assessment of artificial ventilation systems and natural ventilation arrangements, since these are of paramount importance in the control and dispersion of releases of flammable gasses and vapours in enclosed spaces.

NOTE Ventilation criteria for specific applications can also be found in national standards or industry codes.

It is important to distinguish throughout these discussions between the concepts of ‘ventilation’ (the mechanism by which air enters and leaves a room or other enclosed space) and dispersion (the mechanism by which clouds dilute). These are very different concepts, and both are important.

In indoor situations it should be noted that the hazard depends on the ventilation rate, the nature of the expected source of gas and the properties of the gas released, in particular the gas density/buoyancy. In some situations the hazard may depend sensitively on the ventilation; in others it may be almost independent of it.

In outdoor situations the concept of ventilation is not strictly applicable and the hazard will depend on the nature of the source, the properties of the gas and the ambient air flow. In open air situations, air movement will often be sufficient to ensure dispersal of any explosive gas atmosphere which arises in the area. Table C.1 provides guidance on wind speed for outdoor situations.

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

C.3 Assessment of ventilation and dilution and its influence on hazardous area

C.3.1 General

The size of a cloud of flammable gas or vapour and the time for which it persists after the release stops can often be controlled by means of ventilation. Approaches for evaluating the degree of dilution required to control the extent and persistence of an explosive gas atmosphere are described below. Other calculations from reputable sources or alternative forms of calculation, e.g. computational fluid dynamics (CFD), may also be applied.

Any assessment of the degree of dilution first requires an assessment of the expected release conditions including the size of the source of the release and the maximum release rate of gas or vapour at the source (see Annex B).

It is normally indicated that a continuous grade of release leads to a Zone 0, a primary grade to Zone 1 and a secondary grade to Zone 2. However, this is not always the case and may vary depending on the ability of a release to mix with sufficient air to dilute down to a safe level.

In some cases, the degree of dilution and level of availability of ventilation may be so high that in practice there is no hazardous area or a hazardous area of negligible extent. Alternatively, the degree of dilution may be so low that the resulting zone has a lower zone number than might otherwise be applicable for the grade of release (i.e. a Zone 1 hazardous area from a secondary grade source). This occurs, for example, when the level of ventilation is such that the explosive gas atmosphere persists and is dispersed only slowly after the gas or vapour release has stopped. Thus, the explosive gas atmosphere persists for longer than would be expected for the grade of release.

The dilution of a release is determined by the interaction of the momentum and buoyancy forces of the release and the atmosphere within which it is dispersing. For an unimpeded jetted release, for example from a vent, the jet momentum dominates and the initial dispersion is dominated by the shear between the release and the atmosphere. However, if a jetted release is at low velocity or is impeded to such an extent that the momentum is redirected or dissipated, the release buoyancy and atmospheric effects become more important.

For small releases of lighter than air gas the dispersion in the atmosphere will dominate, for example similar to dispersion of cigarette smoke. For larger releases of lighter than air gas the stage may eventually be reached, especially in low wind conditions, when the release buoyancy is significant and the release will lift off from the ground and disperse like a plume, for example similar to the plume from a large bonfire. For vapour releases from a liquid surface the vapour buoyancy and local air movement will dominate the dispersion behaviour.

In all cases, where there is adequate fresh air for dilution of a release to very small concentrations (i.e. well below the LFL), the diluted gas or vapour will tend to move along with the general mass of the air and exhibit neutral behaviour. The exact concentration where such neutral behaviour is reached will depend on the relative density of the gas or vapour to air. For greater relative density differences a lower concentration of the gas or vapour is required for neutral behaviour.

C.3.2 Effectiveness of ventilation

The most important factor is the effectiveness of ventilation, in other words the quantity of air relative to the type, release location and release rate of the flammable substance. The higher the amount of ventilation in respect of the possible release rates, the smaller will be the extent of the zones (hazardous areas) and shorter the persistence time of explosive gas atmosphere. With a sufficiently high effectiveness of ventilation for a given release rate, the extent of the hazardous ~~zone~~ area may be so reduced to be of negligible extent (NE) and be considered a non-hazardous area.

C.3.3 Criteria for dilution

The criteria for dilution are based upon the two values that are characteristic for any release:

- the relative release rate (ratio of release rate and LFL in mass units);
- the ventilation velocity (the value that symbolizes the atmospheric instability, i.e. air flow induced by ventilation or wind speed outdoors).

The relation between the two determines the degree of dilution as displayed in Figure C.1.

C.3.4 Assessment of ventilation velocity

If a gas leak exists, the gas must be transported away, or gas build up will occur. The gas can be transported away by flow induced by the momentum in the gas leak, by buoyancy induced by the gas, or by flow caused by natural or forced ventilation or by wind.

The flow caused by momentum in the release itself should generally not be taken into account unless it is very clear that this momentum will not be broken by impingement or other influence of geometry.

The flow to transport away the gas should be assessed primarily based on an assessment of the ventilation for indoor situations, or by flow caused by the wind for outdoor situations.

For indoor situations the flow or ventilation velocity may be based on an average flow velocity caused by the ventilation. This may be calculated as the volumetric flow of air/gas mixture divided by the cross section area perpendicular to the flow. This air velocity should be reduced by a factor due to inefficiency of the ventilation or due to flow being obstructed by different objects. Computational fluid dynamics (CFD) simulation is recommended if particular detail or accuracy is needed to get an estimate of the ventilation velocity in different parts of the room under consideration.

For naturally ventilated enclosures and for open areas, the ventilation velocity should be assessed as the velocity that is exceeded 95 % of the time. The availability of this ventilation can be considered to be ‘fair’.

Ventilation velocity for open areas may be based on wind speed statistics using a reduction factor considering the reference height applied for any weather statistics. Published values are usually available for elevations above the height of a process plant and may need to be reduced due to local geometry such as topography, buildings, vegetation and other obstacles. E.g. in a process area with a lot of structures, piping and process equipment, the effective ventilation velocity could typically be as low as 1/10 of the free flow velocity above the plant. Assessment could also be made by measurement of the velocity in some locations around the plant and comparing these to the published figures. Computational fluid dynamics (CFD) is also recommended for any complex plant where there are a number of equipment items that could affect localised air movement.

Lighter than air gases tend to move upwards where the ventilation normally will be better, and the buoyancy may also transport the gas away. This may be taken into account by increasing the effective ventilation velocity for such releases. For releases with a relative density of less than 0,8, it is normally considered safe to assume that the effective ventilation velocity is at least 0,5 m/s in outdoor situations. The availability of this minimum ventilation can be considered as good.

Heavier than air gases tend to move downwards where the ventilation generally will be lower, and accumulation at ground level is a possibility. This can be taken into account by lowering the effective ventilation velocity. A gas can be heavy due to the molecular weight or due to low temperature. Low temperature can be caused by leak from high pressure. For gases with a relative density above 1,0 the effective ventilation velocity should be reduced by a factor of approximately 2.

Where statistical data are not available, Table C.1 illustrates a practical approach to define ventilation velocity values outdoors.

Table C.1 – Indicative outdoor ventilation velocities (u_w) 61

Elevation from ground level / Type of ~~outdoor locations~~ Release	Unobstructed areas			Obstructed areas		
	≤ 2 m	> 2 m up to 5 m	> 5 m	≤ 2 m	> 2 m up to 5 m	> 5 m
~~**Indicative ventilation velocities for estimating the dilution of**~~ **Lighter than air gas/vapour releases**	0,5 m/s	1 m/s	2 m/s	0,5 m/s	0,5 m/s	1 m/s
~~**Indicative ventilation velocities for estimating the dilution of**~~ **Heavier than air and neutrally bouyant gas/vapour releases**	0,3 m/s	0,6 m/s	1 m/s	0,15 m/s	0,3 m/s	1 m/s
~~**Indicative ventilation velocities for estimating the**~~ **liquid pool evaporation rate at any elevation**	> 0,25 m/s			> 0,1 m/s		

~~Generally~~ Typically, values in the table ~~may be considered with~~ would result in an availability of ventilation as fair (see Clause D.2).

~~For indoor areas, the evaluations should normally be based on an assumed minimum air speed of 0,05 m/s, which will be present virtually everywhere. Different values may be assumed in particular situations (e.g. close to the air inlet/outlet openings). Where ventilation arrangement can be controlled, minimum ventilation velocity may be calculated.~~

Indicative ventilation velocities are not meant to suggest that actual air velocity will vary according to the gas/vapour density but take into account the influence of buoyancy for the gas/vapour when considering an apparent velocity which may be considered in the assessment of dilution.

C.3.5 Assessment of the degree of dilution

The following three degrees of dilution are normally 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 an explosive gas atmosphere after the release has stopped. 62

The degree of dilution may be assessed by using the chart in Figure C.1, where the velocity is reasonably consistent in the space under consideration. Where the ventilation is inefficient or is reduced due to flow being obstructed by different objects a lower apparent air velocity should be used.

The degree of dilution may also be influenced by the release velocity, e.g. a jet release in a large room (see C.3.6.1) and this is not accounted for in Figure C.1.

For indoor applications the background concentration should also be assessed in accordance with C.3.6.2 and if the background concentration exceeds 25 % of the LFL the degree of dilution should generally be considered as low.

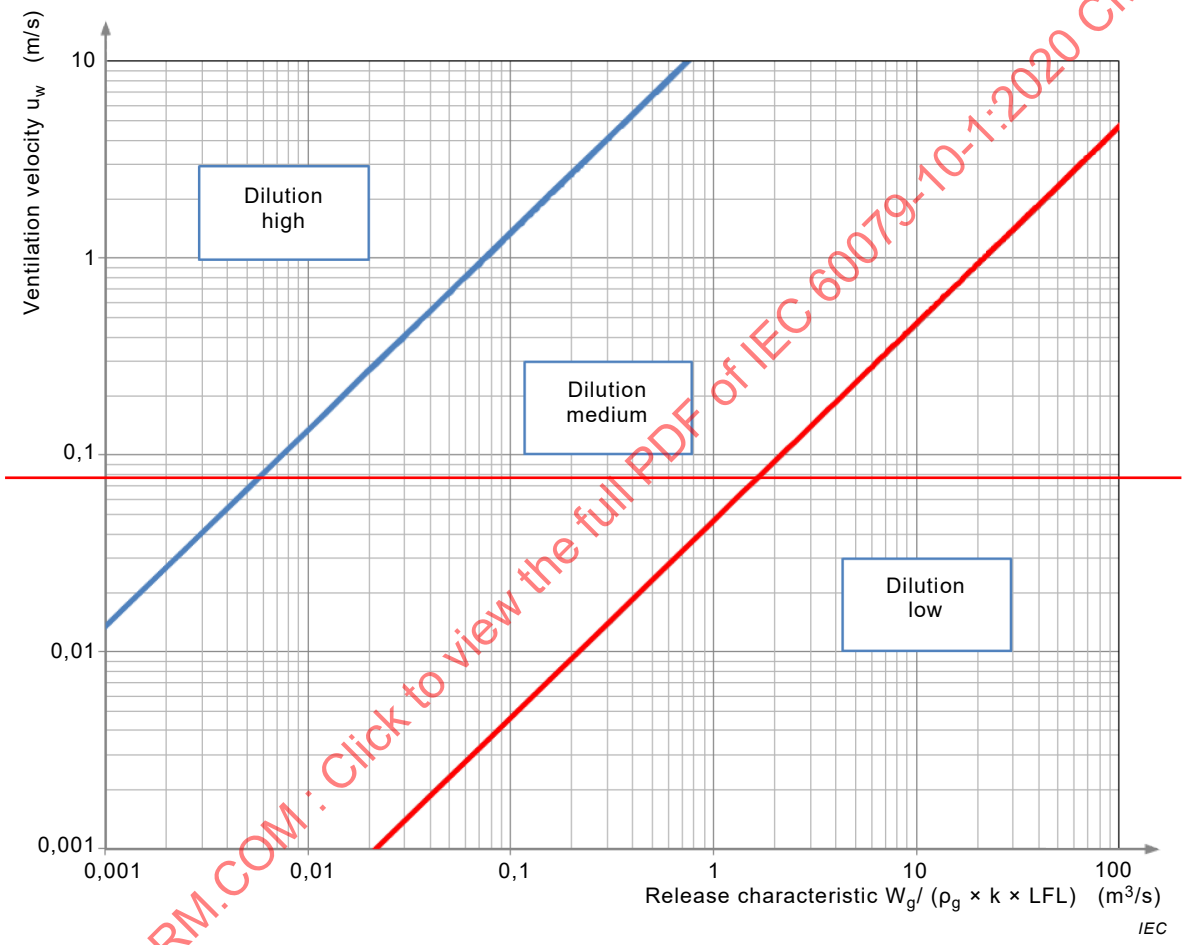
Figure C.1 is based on an initial background concentration that is negligible.

Figure C.1 is not intended for guidance when considering releases from large pools.

Extrapolation of the curves beyond the chart area shown in Figure C.1 should not be undertaken due to other factors that will affect the assessment beyond the limits indicated. **63**

The method of using the chart in Figure C.1 is demonstrated in the examples of Annex E.

~~The degree of dilution may be assessed by using the chart in Figure C.1:~~



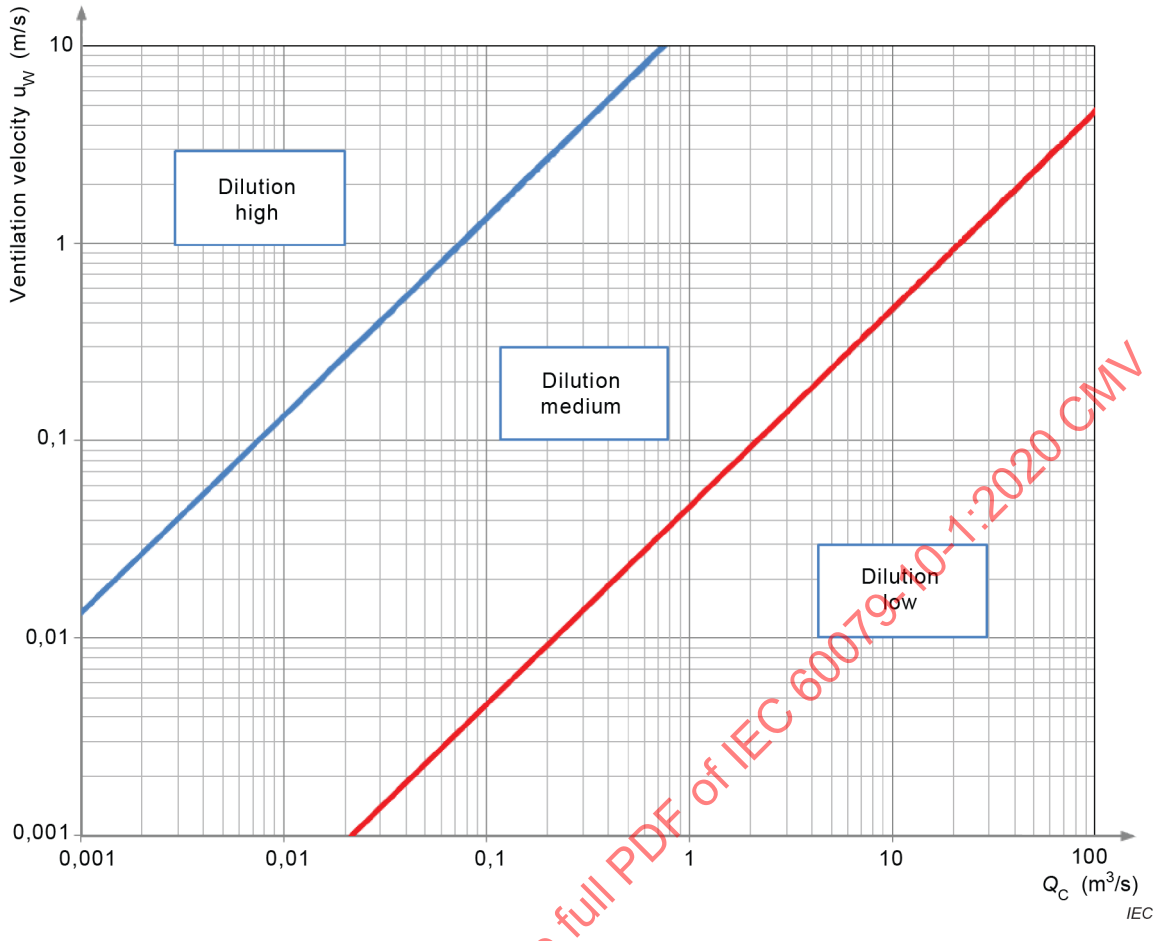


Figure C.1 – Chart for assessing the degree of dilution

Where

$\frac{W_g}{\rho_g k LFL}$ ~~is a characteristic of release in (m³/s);~~ **64**

$Q_C = \frac{W_g}{\rho_g \times LFL}$ is the volumetric release characteristic of the source (m³/s);

$\rho_g = \frac{p_a M}{R T_a}$ is the density of the gas/vapour (kg/m³);

~~k is the safety factor attributed to LFL, typically between 0,5 and 1,0.~~

~~Figure C.1 is based on an initial zero background concentration.~~

Figure C.1 does not include a specific safety factor. A suitable factor should be determined by the user based on the application and any safety factors applied to other parameters used in the assessment e.g. assumed release rate. **50**

The degree of dilution is obtained by finding the intersection of respective values displayed on horizontal and vertical axis. The line dividing the chart area between 'dilution high' and 'dilution medium' represents a flammable volume of 0,1 m³, so any intersection point left to this curve implies an even smaller flammable volume. The line dividing the chart area between 'dilution medium' and 'dilution low' represents a flammable volume of approximately 100m³, so any intersection point right to this curve implies an even larger flammable volume. **63**

In outdoor locations where there are no significant restrictions to air flow, the degree of dilution should be classified as medium if the condition for high dilution is not met. A low degree of dilution will not generally occur in open air situations. Situations where there are restrictions to air flow, for example, in pits, should be considered in the same way as an enclosed area.

~~For indoor applications users should also assess the background concentration in accordance with C.3.6.2 and if the background concentration exceeds 25 % of the LFL the degree of dilution should generally be considered as low.~~ **65**

C.3.6 Dilution in a room

C.3.6.1 General

Dilution may occur by either the exchange of fresh air that dominates the release of the gas or vapour or by having sufficient volume to allow the gas or vapour to disperse to a low concentration even with minimal fresh air. In this later case the volume available for dilution must be high with respect to the anticipated volume of the release.

For a jet release of gas, dilution may occur even without any local air movement due to entrainment of air in the expanding jet. However if a jet is impeded due to impact on nearby objects then the ability for self dilution is greatly reduced.

The degree of dilution can also be assessed by assessment of the average background concentration of the flammable substance (see C.3.6.2). The higher the ratio of release rate against the ventilation rate the higher will be the background concentration X_b and the lower will be the degree of dilution.

In assessing background concentration the release rate, ventilation rate and ~~efficiency~~ inefficiency **66** factor must be carefully selected to take into account all relevant factors considering an appropriate safety margin. The ventilation ~~efficiency~~ inefficiency factor should recognize if there is a possibility of recirculating or impeded air flow in a space which may reduce the efficiency compared to a good air flow pattern.

A zero background concentration should be considered only outdoors or in regions with local extraction ventilation which controls the movement of flammable substance near the source of release. A negligible background concentration, described as $X_b << X_{crit}$, may be considered in highly ventilated rooms or enclosures. X_{crit} is an arbitrary value below LFL, e.g. the value at which a gas detector is set to alarm.

A low background concentration does not mean that the whole room is a non hazardous area. The larger part of the room may be considered non hazardous but the area near the source of the release is still a hazardous area until the release is sufficiently dispersed (similar as for open air situations).

Consideration of background concentration and the extent of possible zones around sources of release also need to be moderated with practical factors considering variations in possible dispersion patterns in an enclosed space. Many enclosed areas contain multiple sources of release and it is not ~~good~~ safe practice to have multiple small hazardous areas within an enclosed area generally classified as non hazardous. Also, it is not ~~good~~ safe practice to have a limited hazardous area within a relatively small room and the whole room should be considered for a uniform classification.

C.3.6.2 Background concentration and releases in a ventilated room

For indoor releases it is necessary to specify the room background concentration, X_b, which embodies the effects of ventilation. Background concentration is the ~~mean~~ average concentration of flammable substance within the volume under consideration (room or

building) after a period of time during which a steady state has been established between the release and the flow of air induced by ventilation.

Consideration of the background concentration then provides a measure for assessing ventilation in a room which removes gas or vapour compared to dispersion of the gas or vapour. This ratio then influences the consideration of the degree of dilution.

The background concentration (vol/vol) may be assessed as:

$$X_b = \frac{f \times Q_g}{Q_g + Q_1} = \frac{f \times Q_g}{Q_2} (\text{vol/vol}) \quad \text{(C.1)}$$

and the air change frequency and ventilation flux are related by:

$$Q_2 = CV_0 \left(\text{m}^3 / \text{s} \right)$$

The average background concentration X_b which is ultimately achieved depends on the relative magnitude of source and ventilation fluxes, but the timescale over which this is achieved is inversely proportional to the air change frequency.

The safety factor f, ventilation inefficiency, is a measure of the degree to which the air in the enclosure outside of the release zone is well mixed and ~~can be considered as follows~~ is the mean background concentration X_b in the room divided by the concentration at the ventilation outlet (dimensionless). **67**

f =1: the background concentration is essentially uniform and the outlet is distant from the release itself, so that the concentration at the outlet reflects the mean background concentration.

f ~~>~~ =1: there's a gradient of background concentration in the room due to inefficient *mixing*, and the outlet is distant from the release itself, so that the concentration at the outlet is smaller than the mean background concentration. f may be between 1,5 for mildly inefficient mixing and 5 for very inefficient mixing.

Given the origin of the cases f =1 or f >1, this value may be denoted as a safety factor related to the inefficiency of mixing (as progressively larger values reflect progressively less efficient mixing of air within the room). This factor allows for imperfections of air flow patterns in a real space with obstructions and where ventilation openings may not be ideally positioned for maximum ventilation (see C.5). The degree of dilution should be taken as being low if the background concentration exceeds 25 % of the LFL or if indicated through an assessment based on Figure C.1. **63**

NOTE Ventilation alone which describes how air enters the room has little to say about the expected volume of a hazardous ~~volume~~ area. That depends on how the gas, or vapour and air are distributed within the room, i.e. on dispersion.

C.3.7 Criteria for availability of ventilation

C.3.7.1 General

The availability of ventilation has an influence on the presence or formation of an explosive gas atmosphere. Thus, the availability (as well as the ~~degree~~ effectiveness) of ventilation needs to be taken into consideration when determining the type of zone.

Three levels of availability of the ventilation should be considered (see Table D.1):

- **good:** ventilation is present virtually continuously;
- **fair:** ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods;
- **poor:** ventilation which does not meet the standard of fair or good, but discontinuities are not expected to occur for long periods.

Ventilation that does not even meet the requirement for poor availability ~~must~~ should not be considered to contribute to the ventilation of the area, i.e. low dilution would apply.

Different types of ventilation require different approaches for assessing their availability, e.g. availability of natural ventilation indoors shall never be considered as good because it depends heavily upon ambient conditions, i.e. outdoor temperature and wind (see Clause C.5). As a matter of fact, the availability of natural ventilation depends on how realistic the assessment of indoor or outdoor conditions has been, i.e. whether the worst case scenario has been applied. If yes, then it may be that the level of availability could be fair, but never good. It has to be assumed that the higher the difference between indoor and outdoor temperature applied for calculation, the lower the level of availability in terms of diluting an explosive gas atmosphere.

On the other hand, artificial ventilation that serves the areas exposed to explosion conditions usually has a good availability because it incorporates technical means to provide for high degree of reliability.

The level of availability should be assessed as realistically as possible taking into account all the relevant factors. For outdoor gas jet releases dilution will occur irrespective of the ambient wind, and so the dispersion must be considered as being equivalent to good availability of ventilation indoors.

C.3.7.2 Criteria for natural ventilation

In case of natural ventilation, the worst case scenario shall be considered to determine the ~~degree of~~ ventilation rate **68**. Such a scenario will then lead to a higher level of availability. Generally, for any natural ventilation, a lower ~~degree of~~ ventilation rate leads to a higher level of availability and vice versa. That will compensate for too optimistic assumptions made in the procedure of estimating the ~~degree of~~ ventilation rate.

There are some situations which require particular care. In the case of natural ventilation of enclosed spaces, consideration of unfavourable conditions needs to be accounted for, i.e. frequency and probability of occurrence of such situations. As an example, during hot and windy summer days, two potential scenarios exist. In one scenario the indoor temperature may be slightly above the outdoor temperature so that buoyancy induced ventilation may hardly work and the wind from a certain direction may prevent the flow of air. Therefore in this case there is a combination of poor ventilation and a poor availability which will likely result in a more onerous classification. In another scenario, if only buoyancy is considered, then modest, buoyancy induced ventilation could be present virtually all the time and hence the availability could be estimated as fair if not good.

In open air situations the degree of dilution is generally considered as medium while the availability of ventilation in terms of wind presence may be considered as good unless there is restricted ventilation such as within pits, dykes or areas surrounded by high structures.

C.3.7.3 Criteria for artificial ventilation

In assessing the availability of artificial ventilation, the reliability of the equipment and the availability of, for example, standby blowers should be considered. Good availability will normally require, on failure, automatic start-up of standby blower(s). However, if provision is made for preventing the release of flammable substance when the ventilation has failed (for example, by automatically closing down the process), the classification determined with the ventilation operating need not be modified, i.e. the availability may be assumed to be good.

C.4 Examples of ventilation arrangements and assessments

C.4.1 Introduction

The following examples are intended to illustrate the interaction between the release of flammable substance and ventilation based on the principles outlined in Clauses 6, 7 and 8. It is important to understand that dilution is a complex process which takes place either through air entrainment at the boundaries of a release jet, or through mixing with air caused by ventilation flow or atmospheric instabilities. Usually, both mechanisms are considered because a jet eventually becomes a passive plume susceptible to air movement. Mixing with air generally does not happen uniformly throughout the ventilated space and the background concentration as the result of the mixing with air is just a very rough measure of the average contamination of the volume under consideration.

In a real ventilated space the ventilation arrangement may not be adequate to dilute the flammable substance uniformly. In practice the true nature of dispersion and dilution may substantially deviate from the average results obtained by calculation. The ventilation arrangement, i.e. position of the inlet and outlet openings relative to each other and relative to source of the release, may sometimes have greater influence on the atmosphere than the capacity of the ventilation itself.

The examples below illustrate a few possible scenarios which may help in better understanding of the ventilation arrangements that may be suited for a particular situation.

C.4.2 Jet release in a large building

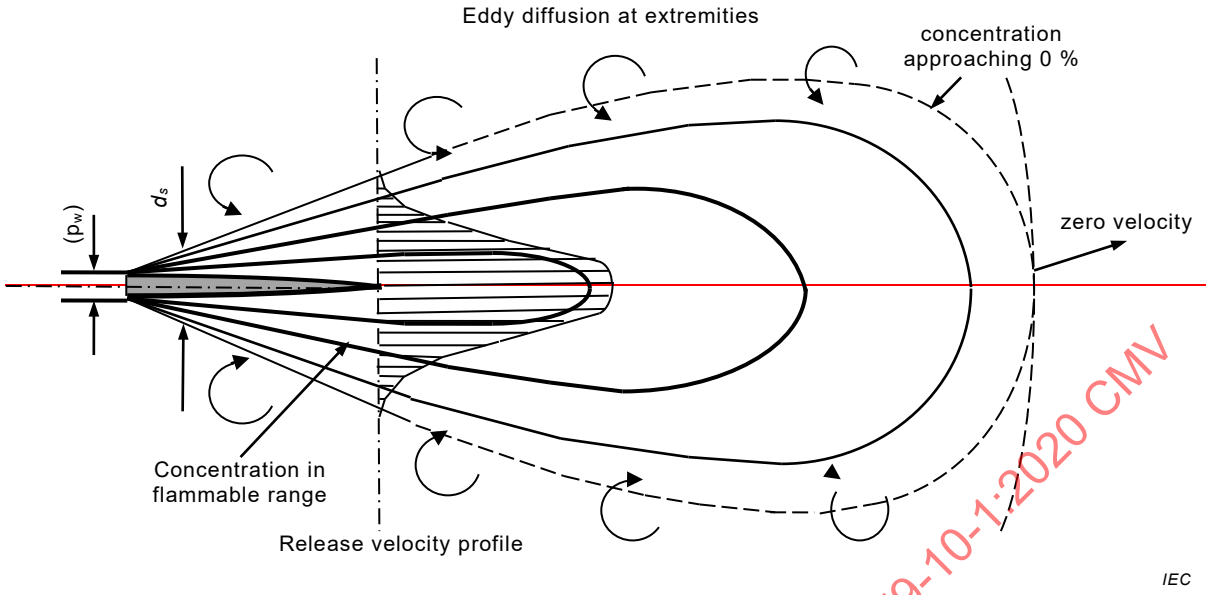
This example (see Figure C.2) illustrates the conditions where there are a limited number of sources of gas release in a large space e.g. gas release from pipe fittings.

A small leak in a pipe fitting would be expected to create a jet release with a high velocity if the pressure is high. The jet would self dilute and disperse even without much other apparent air movement in the building.

For a space with normal ventilation, (e.g. good sized door and wall openings and/or roof ventilation or other designated ventilation provisions), the volume of the space and natural air movement would suggest the degree of dilution is medium and the availability of ventilation is fair.

For a space with poor ventilation, (e.g. an unventilated basement), a jet release may initially self dilute and disperse into the space but the lack of air movement may also lead to a longer term build up of gas in the space. In this situation the diluted gas from the release will be re-entrained in the continuing jet release resulting in a build-up of the background gas concentration.

Unless the ventilation provisions are adequate to control the background concentration in the space the degree of dilution is considered low. However it may still be practical to provide for different zone classifications throughout the space.



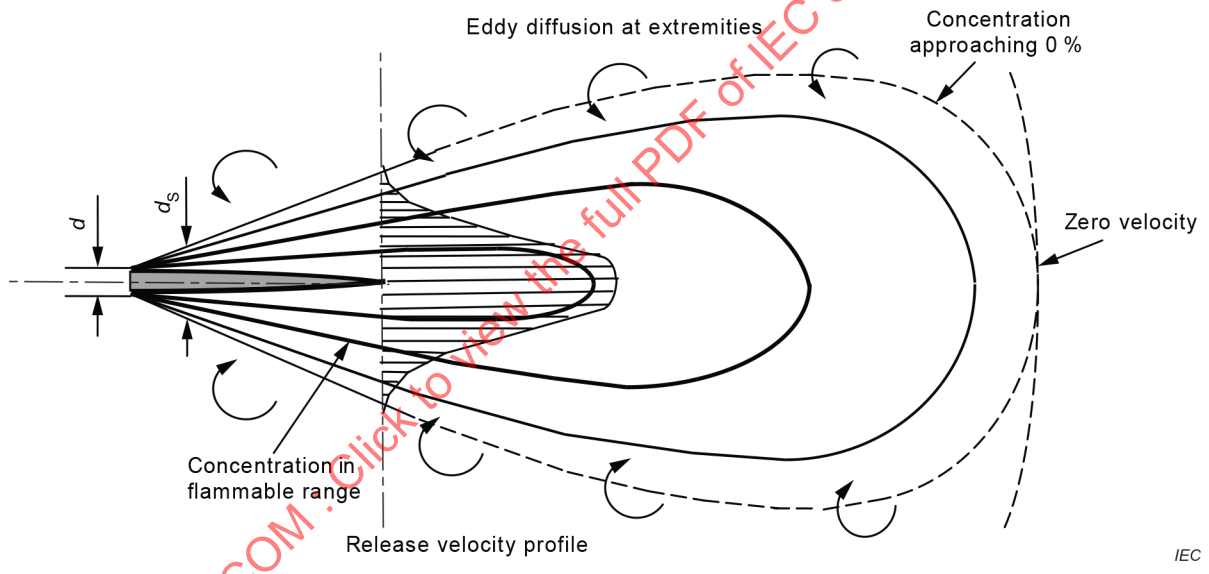


Figure C.2 – Self diffusion of an unimpeded high velocity jet release

NOTE d_s is pseudo source ~~radius~~ diameter **69**, i.e. the ~~radius~~ diameter of the jet at the downstream cross section at which it becomes isobaric (reduced to atmospheric pressure).

C.4.3 Jet release in a small naturally ventilated building

This example illustrates conditions where there may be sources of gas release in a small room or building.

Dispersion and dilution factors are the same as described in ~~6.5.4~~ C.3.5.

Where the building includes provision for ventilation to ensure adequate removal of any gas from a release then the interior of the building may be considered to have a medium degree of dilution.

Where there are a limited number of sources of release (or locations for the sources of release) it may be practical to classify hazardous areas that are limited to regions around the sources of release. Where there are large numbers of possible sources of release then it is common practice to classify the entire space with a single zone classification. This reflects the consideration of the self dilution volume from a jet from many possible positions and the possible variants in gas or vapour dispersion from various locations.

Where the degree of dilution is low then it is normal practice to provide a single zone classification for the enclosed space irrespective of the number of sources of release.

C.4.4 Jet release in a small artificially ventilated building

This example (see Figure C.3) might apply to a situation such as a gas compressor room.

Irrespective of the rate of ventilation or arrangement of a ventilation system a jet release is not likely to be diluted to below the LFL immediately at the source of release unless the pressure is very low. Therefore the degree of dilution at the source of release can rarely be described as high.

The degree of dilution for the remainder of the space is largely dependent on the arrangement and rate of artificial ventilation. The degree of dilution may also be highly sensitive to both these factors as illustrated by Figure C.3 and Figure C.4.

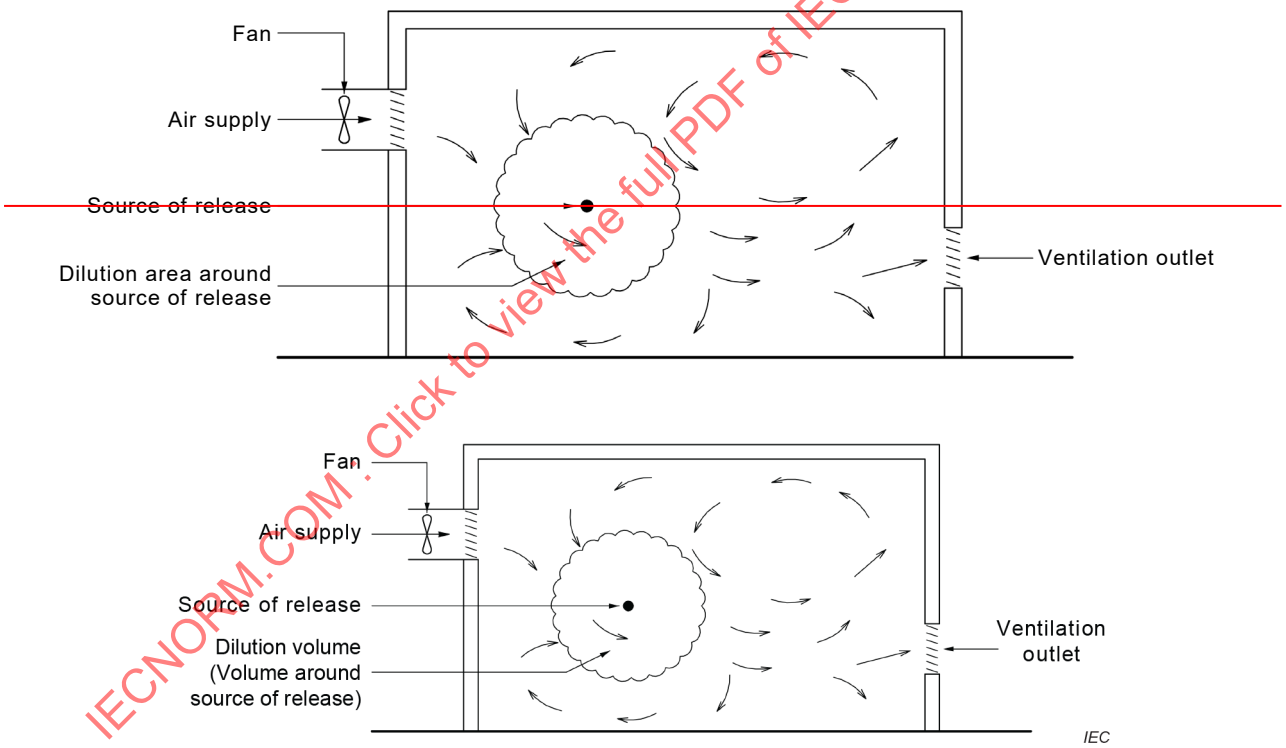


Figure C.3 – Supply only ventilation 70

In this case an enclosed space is supplied with fresh air with an equal volume discharging through a vent.

Despite an apparently high number of air changes per hour the ventilation arrangement can create a circulatory air movement within the enclosure resulting in an elevated background concentration. An alternative way of looking at this is that the re-entrained gas increases the dilution volume from the sources of release. Where this happens the degree of dilution should be treated as low.

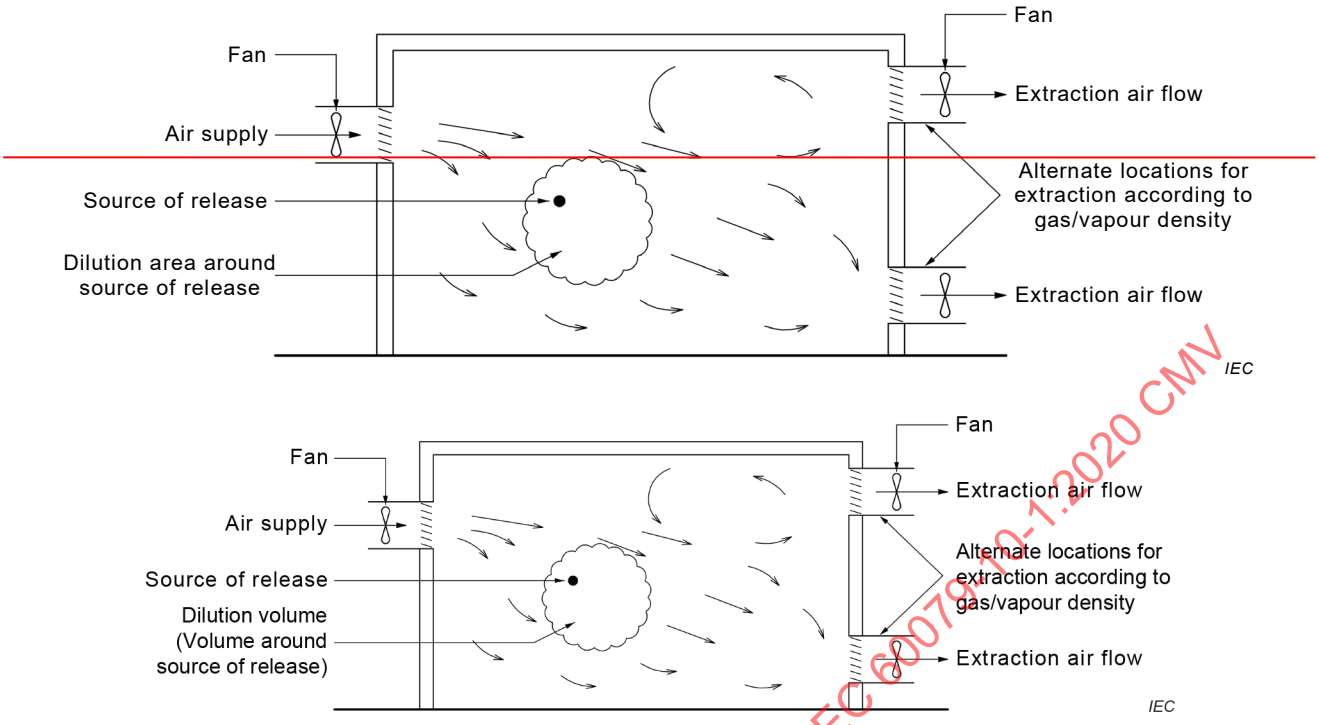


Figure C.4 – Supply and extraction ventilation 70

In this case the enclosed space is provided with both supply and extraction ventilation. As with the case for supply only there is a possibility that the ventilation arrangement will create recirculating air movement and result in re-entrainment of the diluted gas into a jet release thereby increasing the background gas concentration.

With careful consideration of the ventilation arrangements and positioning of the extraction points it is possible to minimize any re-circulatory air patterns. In this case a degree of dilution of medium or even high may be achieved.

NOTE Ventilation is commonly applied as an extraction system only which may be either general or local (for local extraction ventilation see ~~6.5.3.3~~ 7.2.3.3).

C.4.5 Release with low velocity

Releases at low velocity are common in many industrial processes and include applications such as evaporation of flammable liquids from vents, baths, drains or printing and painting.

A jet release may also be considered a low velocity release if the jet impinges on a surface. Velocity of the jet can be reduced with the jet turning into a passive plume.

For releases at low velocity dispersion and dilution are influenced largely by air movement in the space and the buoyancy of the gas or vapour.

As for jet releases, the degree of dilution will be dependent on the size of the building or room, rate of release and ability to control any background concentration by general ventilation.

C.4.6 Fugitive emissions

Fugitive emissions are small releases of gases or vapours from pressurized equipment due to leaks (generally in an order of magnitude between 10^{-7} kg/s and 10^{-9} kg/s). Though small, these releases can still accumulate in enclosures that are not ventilated.

Such fugitive emissions may accumulate in the course of time thus giving rise to an explosion hazard. Therefore, care must be taken when designing particular facilities or equipment such as analyzer houses and sealed enclosures e.g. instrument panels or instrument weather protection enclosures, thermally insulated heated enclosures or enclosed spaces between pipe installations and the envelope of thermal insulation or similar items with higher pressure gas lines. Such items should be provided with some ventilation or provision for gas dispersion even if only for critical periods of time. ~~Where that is not possible or, practicable, effort should be made to keep major potential sources of release out of enclosures, e.g. pipe connections should normally be kept out of insulation enclosures as well as any other equipment that may be considered a potential source of release.~~ **71**

Where tightly closed enclosures are used the likely low effectiveness and availability of ventilation in such enclosures with natural ventilation may ~~need consideration as low and poor respectively~~ result in low dilution and hence may require classification as Zone 0 or Zone 1 according to Table D.1. **72**

C.4.7 Local ventilation-extraction

Local artificial ventilation is recommended wherever practical (see Figure C.5).

Local artificial ventilation can improve the degree of dilution near to the source of release. More importantly local artificial ventilation should control the movement of the gas or vapour to limit gas or vapour beyond the intended area of influence of the local ventilation system. Where this is achieved the degree of dilution around the source of release can be considered as medium.

Generally local artificial ventilation should be located close to the source of release to be effective. Local artificial ventilation can be very effective where the source of release is characterized by a very low release velocity. As local artificial ventilation needs to overcome the release velocity of the gas or vapour to control the movement of that release, the applicability of local artificial ventilation for jet releases is greatly reduced over other forms of release.

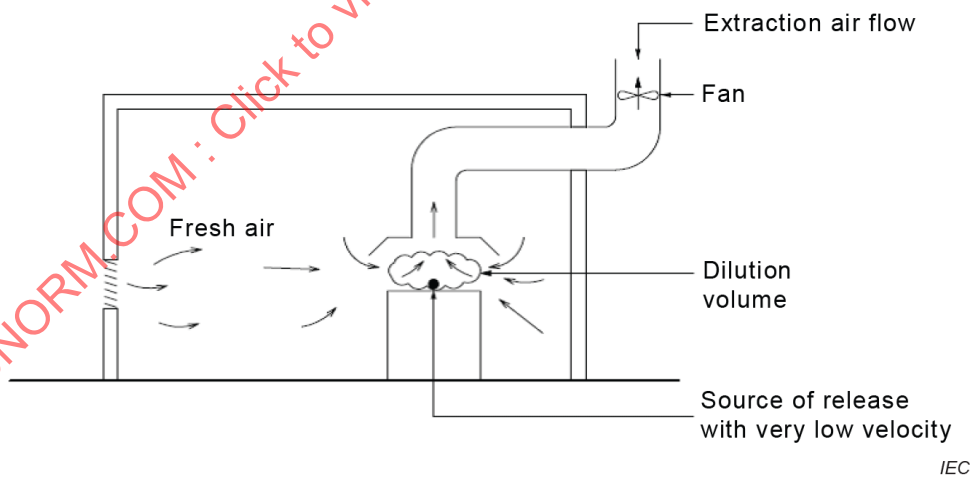


Figure C.5 – Local extraction ventilation

C.5 Natural Ventilation in buildings

C.5.1 General

Subclauses C.5.2 to C.5.4 provide a means for assessing the natural ventilation in buildings. Other means of assessment may also be suitable, e.g. by use of building standards such as BS 5925. **73**

Caution needs to be applied as without evidence and specific building features to promote natural ventilation, the size and shape of the building may not be conductive to promoting natural ventilation and in such cases the degree of the natural ventilation efficiency should be considered as low.

C.5.2 Wind induced ventilation

The degree of air movement in the interior of a building will depend on the size and position of the openings relative to wind direction, as well as on the shape of the building. Ventilation flows may be induced by infiltration through non-airtight doors and windows or cracks and gaps in parts of the structure even if there are no 'architectural' openings in the walls and/or roof, or if those are closed. The equations used here assume flow through openings designed for ventilation, rather than infiltration. This philosophy is also appropriate to adopt for the classification of hazardous areas.

Ventilation implies both ingress and egress of air and some openings will act primarily as inlet openings and others as outlet openings. Windward (upwind) openings will normally act as the inlet openings and leeward (downwind) and roof openings as the outlet openings. This implies that wind induced ventilation could be estimated only with a good knowledge of the wind rose diagram for a particular location.

The driving force of wind induced ventilation is the pressure differential between the windward and leeward sides of a building.

The air flow due to wind can be expressed as:

~~$$Q_a = C_d A_e u_w \sqrt{\frac{\Delta C_p}{2}} \left(m^3/s\right)$$~~

$$Q_a = C_d A_e u_w \sqrt{\Delta C_p} \left(m^3/s\right) \quad \text{(C.2)}$$ **74**

~~$$A_e = \sqrt{\frac{2A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(m^2\right)$$~~

$$A_e = \sqrt{\frac{A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(m^2\right) \quad \text{(C.3)}$$ **74**

Values for ΔC_p ~~C_d~~ should be derived from ventilation or building codes.

The values for A_1 and A_2 refer to effective areas of the upwind and the downwind openings respectively.

CFD modelling or wind tunnel testing may also be used to provide a more reliable assessment of the pressure coefficient for a building.

Wind strength and direction are variable and not generally predictable. Guidance on wind speed is provided in Table C.1. Wind should be considered in conjunction with other types of ventilation to verify whether it complements or opposes other ventilation. Wind may have a positive effect if the inlet and outlet openings for purely wind-induced ventilation are the same as they would have been for other sources of ventilation, but an impairing effect if they are opposed. e.g. wind of any direction will have a positive effect if there is a ventilation opening on the roof top, but will have an impairing effect if the outlet ventilation openings happen to be upwind.

C.5.3 Buoyancy induced ventilation

Buoyancy induced 'Stack Effect' ventilation is accomplished by the movement of air due to the difference between indoor and outdoor temperatures. The driving force is the difference in air density due to the different temperatures. The vertical pressure gradient depends on the density of air and will therefore not be the same indoors and outdoors, leading to a pressure difference.

If the average indoor temperature is higher than the outdoor temperature the indoor air will have a lower density. If an enclosed space has openings at different heights air will enter through the lower openings and leave through the upper level openings. The flow rate will increase as the magnitude of the temperature difference grows larger. Therefore buoyancy induced ventilation will be more effective at lower ambient outdoor temperatures. At higher ambient outdoor temperatures buoyancy induced ventilation will become less effective and if the ambient outdoor temperature rises above the indoor temperature the flow would reverse.

The indoor temperature may be higher due to natural causes, deliberate heating or process heat. Thermal currents may also be induced indoors varying the effect of average indoor temperature. Assuming that the inside of the building is fully mixed, constant temperatures can be used both inside and outside.

For a temperature gradient, assuming the inside temperature at the lower opening is the same as the outside temperature, T_{out}, and the inside temperature at the upper opening is T_{in}, the volume flow rate of air can be calculated from the following equation:

~~$$Q_a = C_d A_e \sqrt{\frac{\Delta T}{(T_{in} + T_{out})} g H} \left(m^3/s\right)$$~~

$$Q_a = C_d A_e \sqrt{\frac{4\Delta T}{(T_{in} + T_{out})} g H} \left(m^3/s\right) \quad \text{(C.4)} \quad \textbf{74}$$

~~$$A_e = \sqrt{\frac{2A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(m^2\right)$$~~

$$A_e = \sqrt{\frac{A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(m^2\right) \quad \text{(C.5)} \quad \textbf{74}$$

The values for A_1 and A_2 refer to effective areas of the lower and the upper openings respectively.

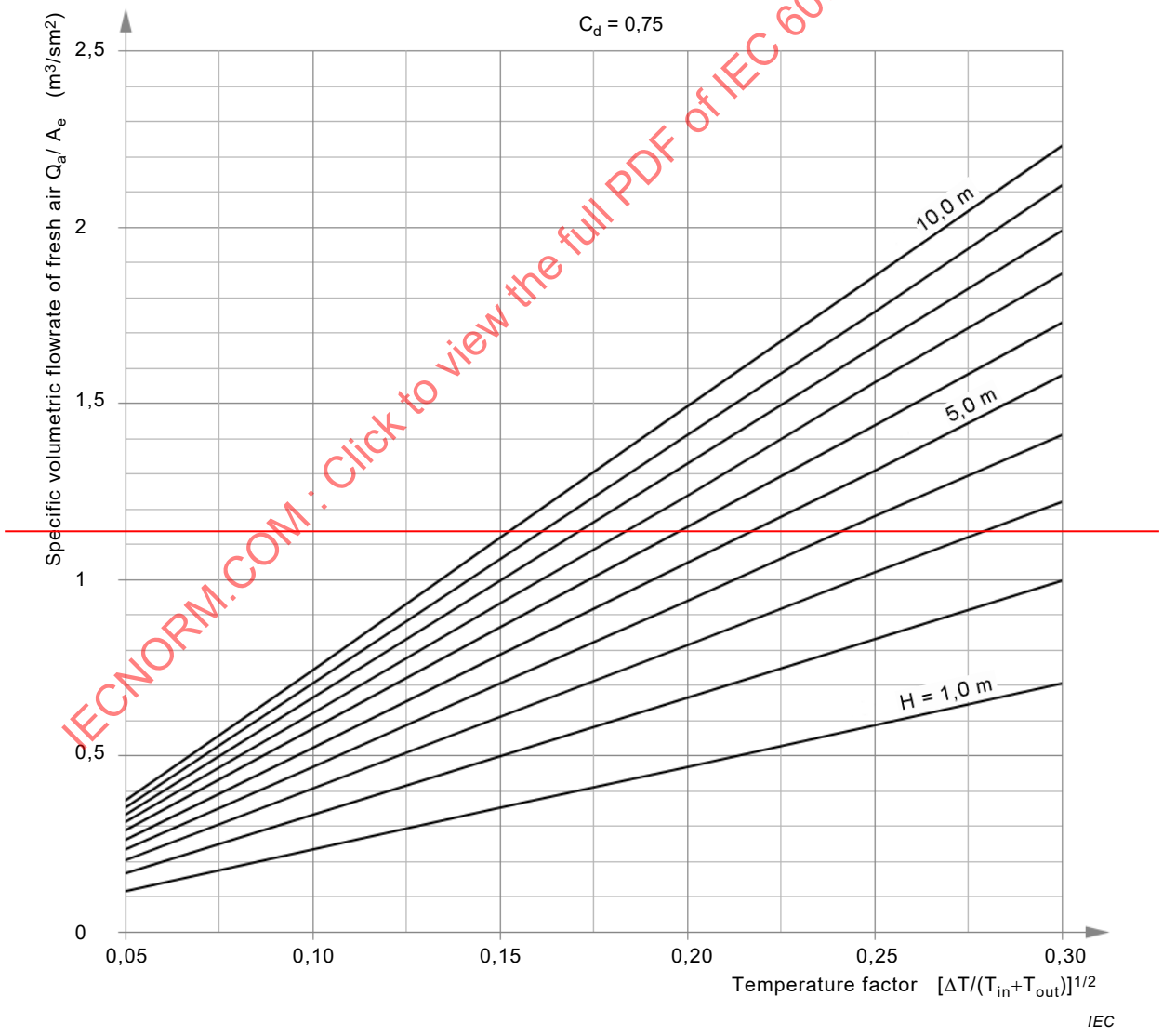
These equations give reasonable results only for rooms with inlet and outlet openings positioned on opposite walls relative to each other (see Figure C.7), and little or no obstructions which could impede the free flow of air. Also, if the vertical distance between the midpoints of the lower and upper openings H is small and the horizontal distance is large, then the buoyancy induced ventilation will be reduced and the calculation may be less accurate. E.g. where H is smaller than the width of the room, then a safety factor related to the inefficiency of ventilation must be applied (see C.3.6.~~1~~2).

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 types of openings or apertures. Any value above 0,75 should be based on established references for the application.

The indoor temperature must be higher than the outdoor temperature to achieve the necessary conditions for buoyancy induced ventilation. During periods of high outdoor ambient temperatures the indoor temperature may become lower than the outdoor unless there is some heat source indoors. Temperature gradients are also affected by the substance of the building and for some constructions the indoor temperature may be lower than the outside temperature under certain conditions. If the indoor temperature is lower than the outdoor temperature, then equation C.4 is not applicable.

The greater the vertical distance between the midpoints of the lower and upper openings, the more effective the natural ventilation will be. For buoyancy induced ventilation, the most desirable position for the inlet openings is at the bottom of the opposite walls and for outlet openings, at the roof top. However, where this is not feasible, the inlet and outlet openings should be positioned at the opposite walls to provide for air movement across the whole area.

In many cases the heating requirements at the lower ambient temperatures may be compromised by the natural ventilation thus imposing the need to reduce, or close the ventilation openings. Consideration must be given to reduction of the openings to the extent that might impair natural ventilation thus preventing the dilution of the explosive gas atmosphere. Generally, all the openings that could be normally closed such as doors, windows and adjustable louvres should not be considered as ventilation openings.



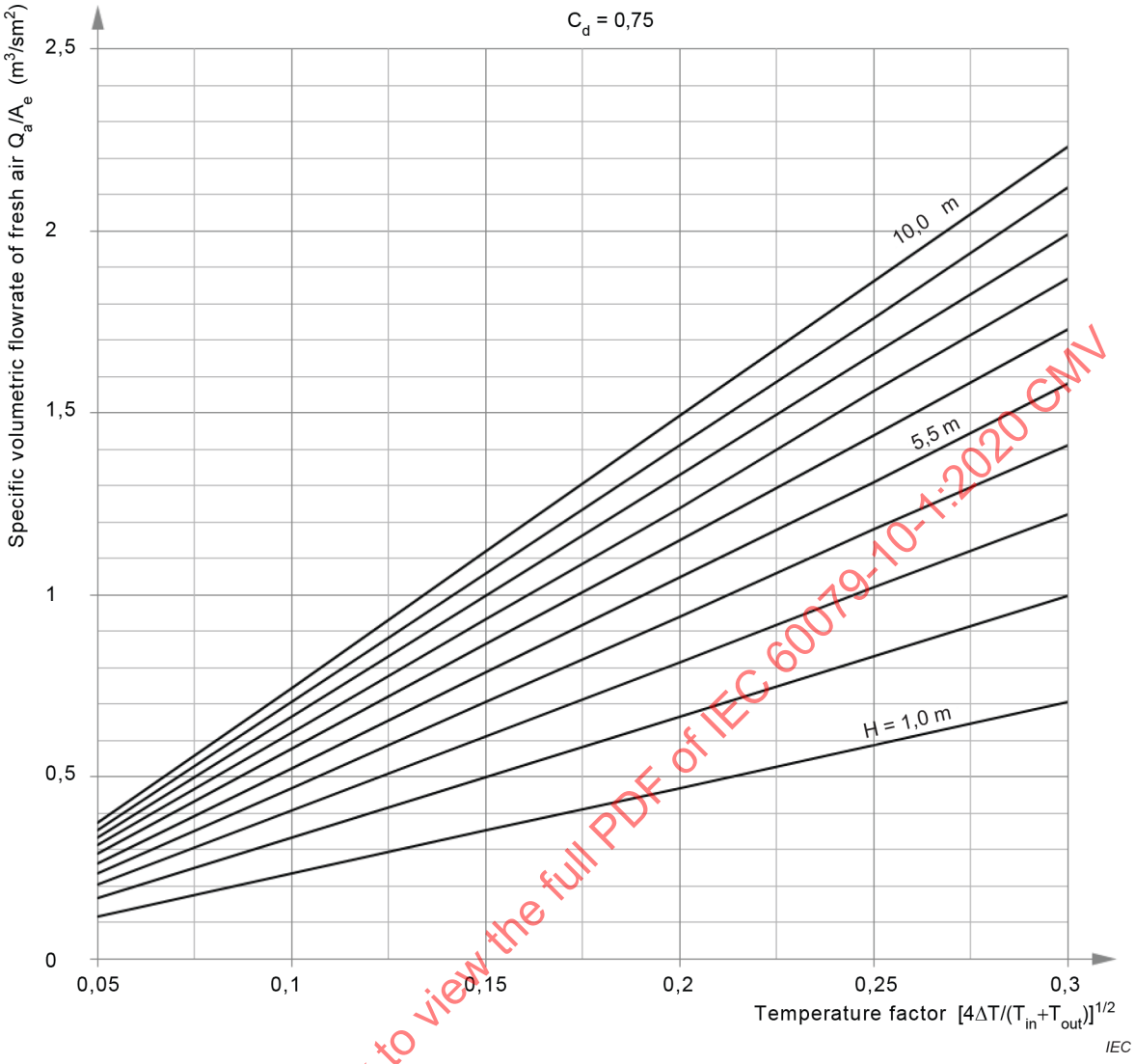


Figure C.6 – Specific volumetric flow rate of fresh air ~~per m²~~ of equivalent effective opening area 75

The chart in Figure C.6 is based upon equation (C.4). Therefore the limitations in the use of these calculations described in C.5.2 also apply.

C.5.4 Combination of the natural ventilation induced by wind and buoyancy

Both, wind and buoyancy induced ventilation can occur separately but are likely to occur at the same time. Pressure differences due to thermal buoyancy will typically be the dominating driving force on a calm cold day with practically no wind, whereas pressure differentials created by wind may be the dominating driving force on a windy hot day. Their forces can oppose or complement each other depending on the position of the inlet and outlet openings (of the buoyancy-induced ventilation) in relation to the wind direction (see Figure C.7).

A probability based assessment must be applied taking into account climate, the wind rose diagram for a particular location and the possible indoor temperatures.

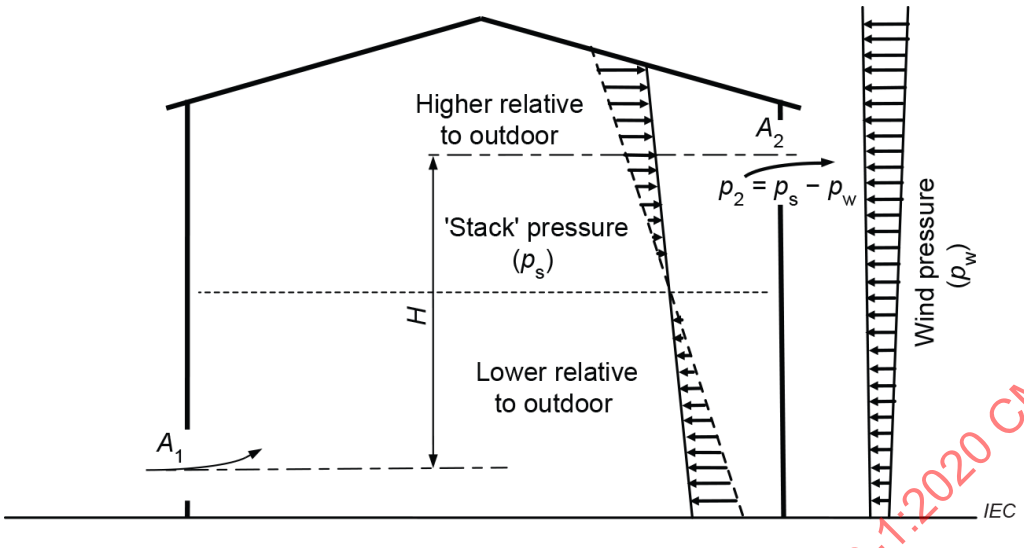


Figure C.7 – Example of opposing ventilation driving forces

~~The ventilation flows caused by pressure differences, due to wind, or temperature differences, can also be calculated. For larger openings, designed for ventilation, the flow can be obtained from the following equation using the pressure difference due to wind and the change in air density due to the average temperature:~~

$$Q_a = C_d A_e \sqrt{\frac{2\Delta p}{\rho_a}} \left(m^3/s\right) \qquad \text{~~(C.6)~~}$$

$$A_e = \sqrt{\frac{2A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(m^2\right) \qquad \text{~~(C.7)~~} \quad \textbf{76}$$

The ventilation flows caused by pressure differences due to a combination of wind and temperature differences can also be estimated through more complex calculations. For each ventilation opening, of area A, the flow can be obtained from the following equation based on the pressure difference due to wind and the change in air density: **77**

$$Q_a = C_d A \sqrt{\frac{2\Delta p}{\rho_a}} \left(m^3/s\right) \qquad \text{(C.6)} \quad \textbf{74}$$

Annex D
(informative)

Estimation of hazardous ~~zones~~ areas

D.1 General

The guidance in this annex provides for the estimation of the type of zone (D.2) and the extent of zone (D.3) to relate relevant factors including:

- the grade of release (Annex B),
- the effectiveness of ventilation and degree of dilution (Annex C), and
- the availability of ventilation (Annex C).

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

D.2 Estimating types of the zones

Table D.1 can be used for estimating the type of zone for indoor areas and open areas.

Table D.1 – Zones for grade of release and effectiveness of ventilation

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2[c]	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[d]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0 [d]

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

[b] The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

[c] Zone 1 is not needed here. I.e. small Zone 0 is in the area where the release is not controlled by the ventilation and larger Zone 2 for when ventilation fails.

[d] Will be Zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

Availability of ventilation in naturally ventilated enclosed spaces ~~shall never be~~ is commonly not **78** considered as good.

D.3 Estimating the extent of the hazardous ~~zone~~ area

The extent of the hazardous ~~zone~~ area or region where flammable gas may occur depends on the release rate and several other factors such as gas properties and release geometry and surrounding geometry.

Figure D.1 may be used as a guide to determine the extent of hazardous ~~zones~~ area for various forms of release. Other forms of calculation or assessment based on reputable sources~~, e.g. Computational fluid dynamics (CFD)~~ **79** may also be applied (see Annex K).

The curves are based on a zero background concentration and are not applicable for indoor medium and low dilution situations (see C.3.6.1).

NOTE The curves in the chart of Figure D.1 are based upon CFD simulations for different 'ventilation velocities'. The distances in the chart are given to be reasonably worst-case for the given release. This has been compard with CFD simulations and the distances given in reputable industry codes.

The chart represents a rough approximation for some large-scale situations but would not be reliable on a small scale level. Where a zone of negligible extent (NE) is suggested then the use of this chart is not applicable.

Extrapolation of the curves beyond the chart area shown in should not be undertaken due to other factors that will affect the assessment beyond the limits indicated even though hazardous distances can be less than 1 m as well as higher than those shown in Figure D.1. **80**

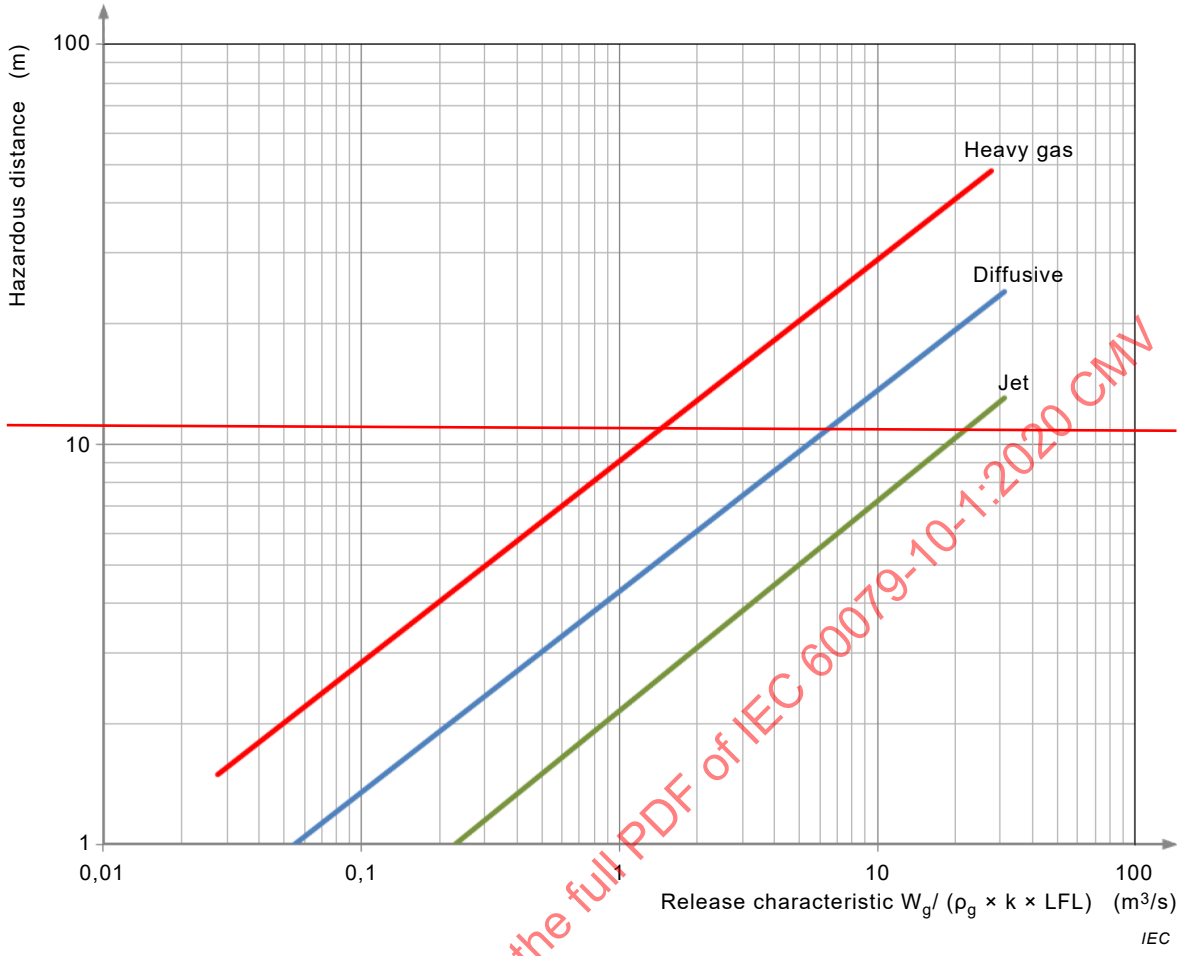
The appropriate line should be selected based on the type of release as either:

a) An unimpeded jet release with high velocity (typically a choked release);

b) A diffusive jet release with low velocity (typically a subsonic release) or a jet that loses its momentum due to the geometry of the release or impingement of the jet on nearby surfaces;

c) Heavy gases or vapours that spread along horizontal surfaces (e.g. the ground).

Use of the 'Jet' curve should applied with caution as many applications may be better represented by the 'Diffusive' curve. **81**



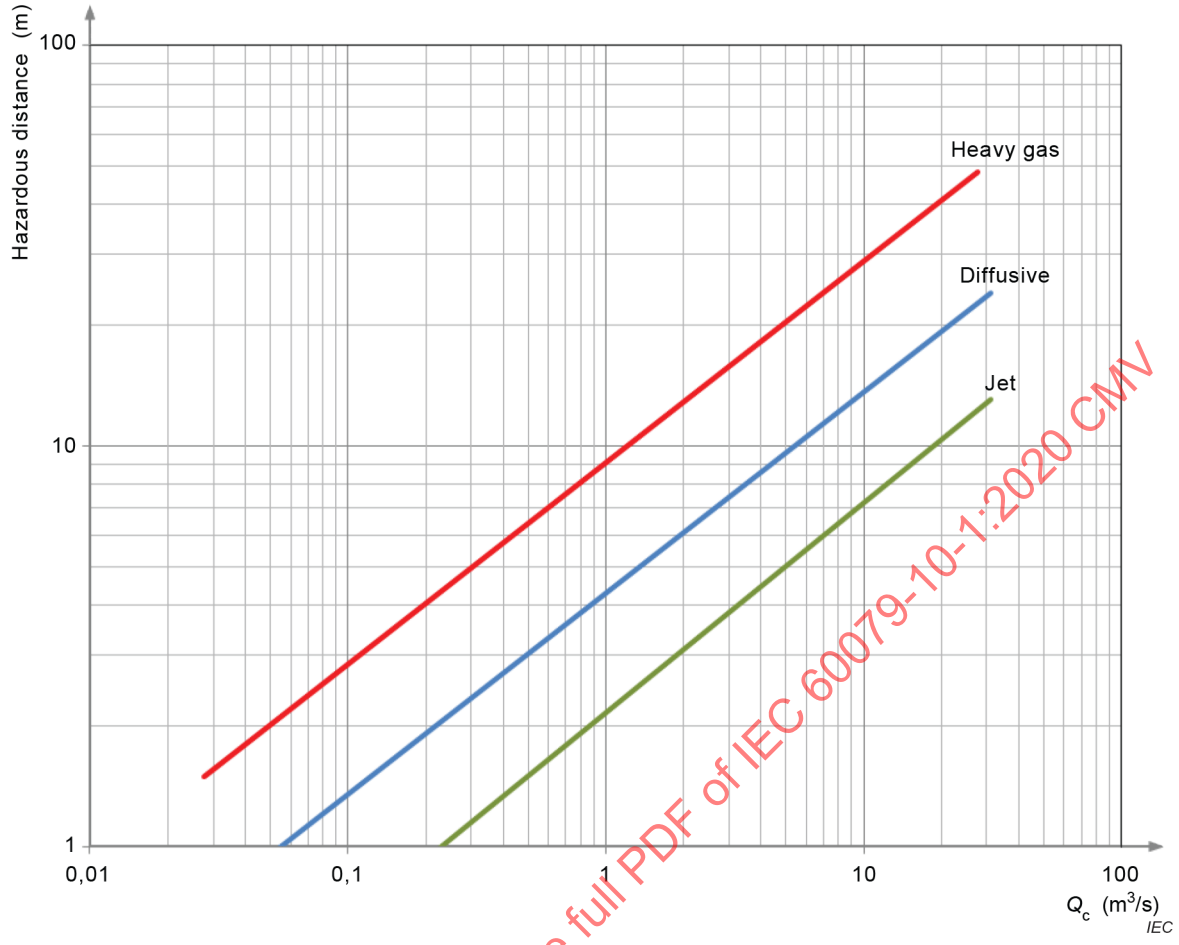


Figure D.1 – Chart for estimating hazardous area distances

Where

$\frac{W_g}{\rho_g k LFL}$ ~~is a characteristic of release in (m³/s);~~

$Q_C = \frac{W_g}{\rho_g \times LFL}$ is the volumetric release characteristic of the source (m³/s);

$\rho_g = \frac{p_a M}{R T_a}$ is the density of the gas/vapour (kg/m³);

~~k is the safety factor attributed to LFL, typically between 0,5 and 1,0.~~

~~Where a zone of negligible extent (NE) is suggested then the use of this chart is not applicable.~~

~~The curves are based on a zero background concentration and are not applicable for indoor low dilution situations.~~

~~NOTE This chart has been developed based on continuity equations and selected computational fluid dynamics (CFD) simulations assuming a dispersion distance proportional to the square root of the X axis and the results have been moderated for the purpose of this standard.~~ **82**

Where appropriate, other forms of calculation or assessment based on computational fluid dynamics (CFD) or testing may also be applied.

Figure D.1 does not identify different zones and zones should be assessed based on the ventilation around the source of release (see Annex C) and possible variations in release conditions.

The method of using the chart in Figure D.1 is demonstrated in the examples of Annex E ~~(see Figure E.2, Figure E.5, Figure E.7, Figure E.10 and Figure E.13)~~.

Annex E
(informative)

Examples of hazardous area classification

E.1 General

The practice of hazardous area classification involves knowledge of the behaviour of flammable gases and liquids when they are released from containment, and sound engineering judgement based on experience of the performance of items of plant equipment under specified conditions. For this reason, it is not practicable to give examples for every conceivable variation of plant and process characteristics.

The examples are not intended to be applied in practice and are provided only to illustrate an optional means of assessment as presented in this standard. The characteristics of release and other parameters used are also only provided to illustrate the means of assessment and may not represent real conditions. **83**

E.2 Examples

Example 1

A normal industrial pump with mechanical (diaphragm) seal, mounted at ground level, located outdoor, pumping flammable liquid.

Characteristics of release:

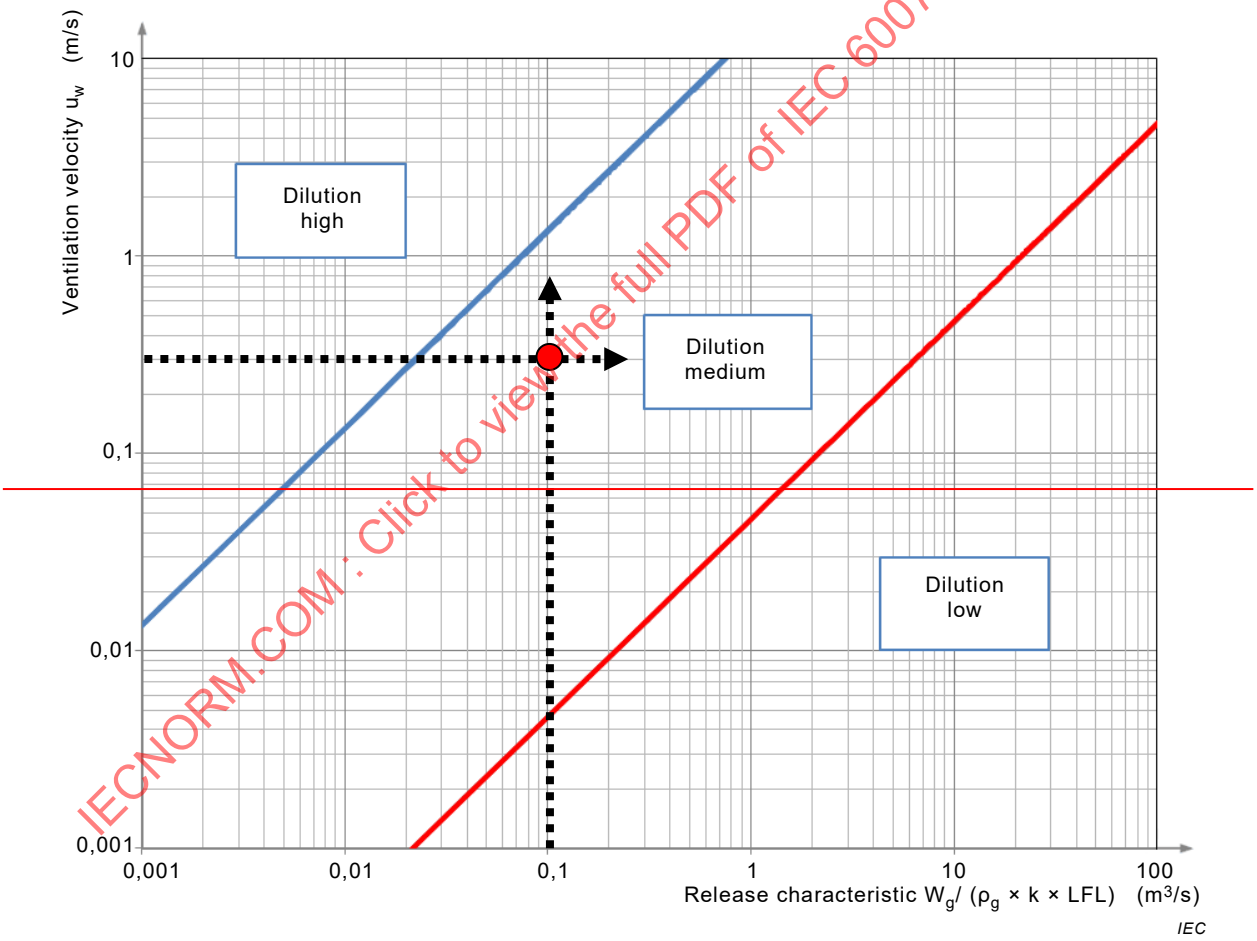
Flammable substance	Benzene (CAS no. 71-43-2)
Molar mass	78,11 kg/kmol
Lower flammable limit, LFL	1,2 % vol. (0,012 vol./vol.)
Auto-ignition temperature, AIT	498 °C
Gas density, ρ_g	~~3,25~~ 3,247 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, SR	Mechanical seal
Grade of release	Secondary (leakage due to a seal rupture)
Liquid release rate, W	~~0,19~~ 0,192 kg/s, determined considering a discharge coefficient C_d = 0,75, a hole size S = 5 mm^2, a liquid density ρ = 876,5 kg/m^3 and a pressure difference Δp = 15 bar
Gas release rate, W_g	3,85 × 10^{-3} kg/s, defined considering the fraction of liquid vaporised from the point of release (2 % of W); remaining liquid drained to sewer system
~~Release characteristic, $W_g/(\rho_g \times k \times LFL)$~~	~~0,1 m^3/s~~
~~Safety factor, k~~	~~1,0~~ **84**
Volumetric release characteristic, Q_C	0,099 m^3/s

Characteristics of location:

Outdoor situation	Unobstructed area
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T	20 °C (293 K)
Ventilation velocity, u_w	0,3 m/s
Ventilation availability	Good (wind speed at meteorological calm condition)

Effects of release:

Degree of dilution (see Figure E.1)	Medium
Type of zone(s)	Zone 2
Equipment group and temperature class	IIA T1



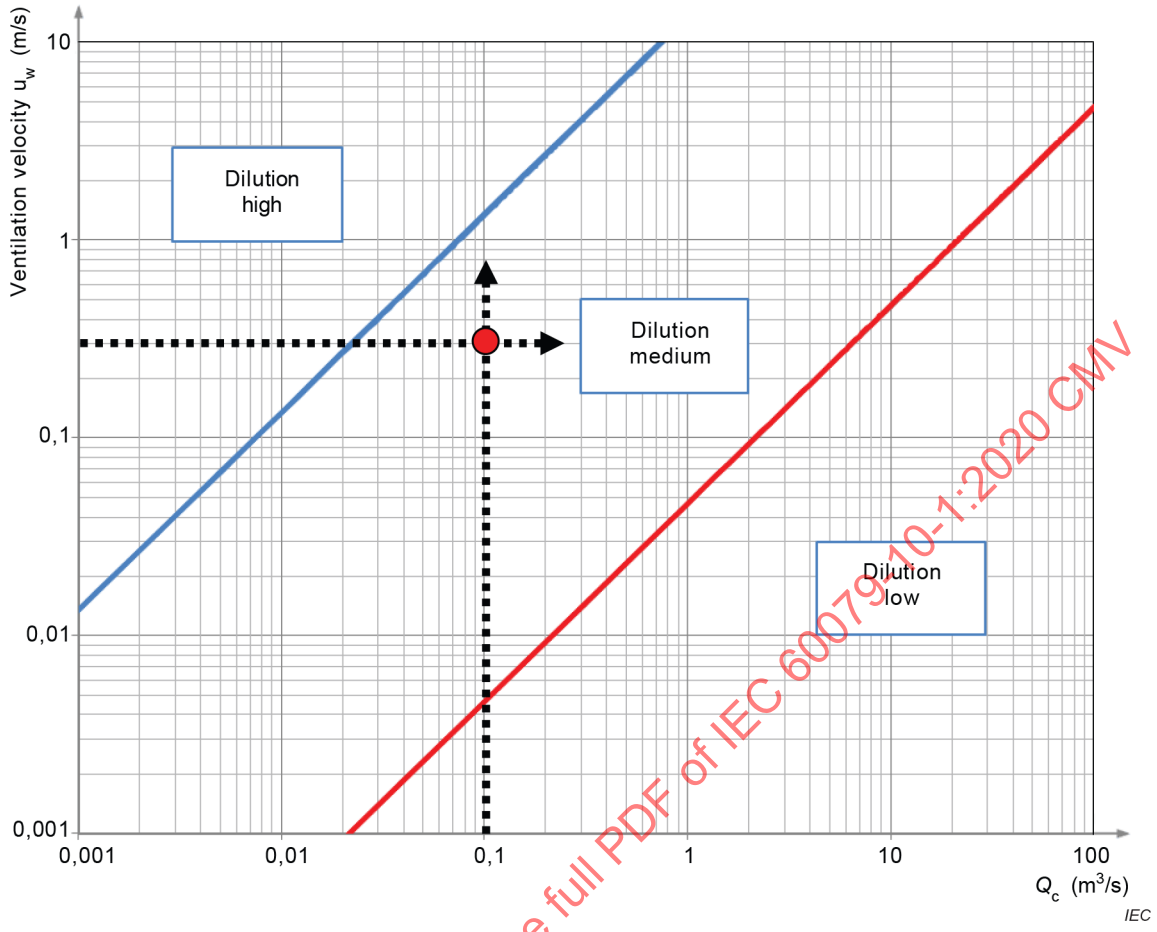
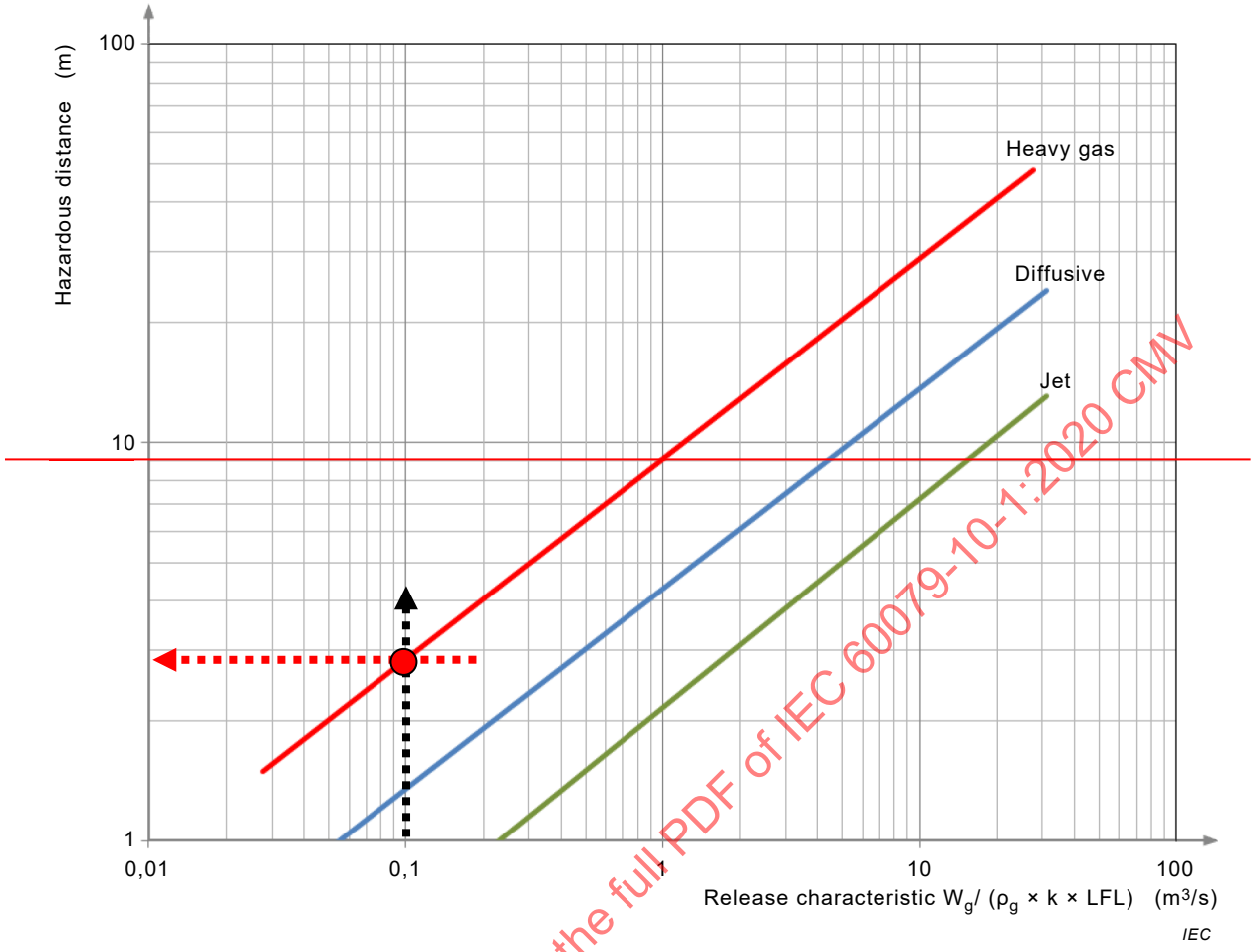


Figure E.1 – Degree of dilution (Example No. 1)



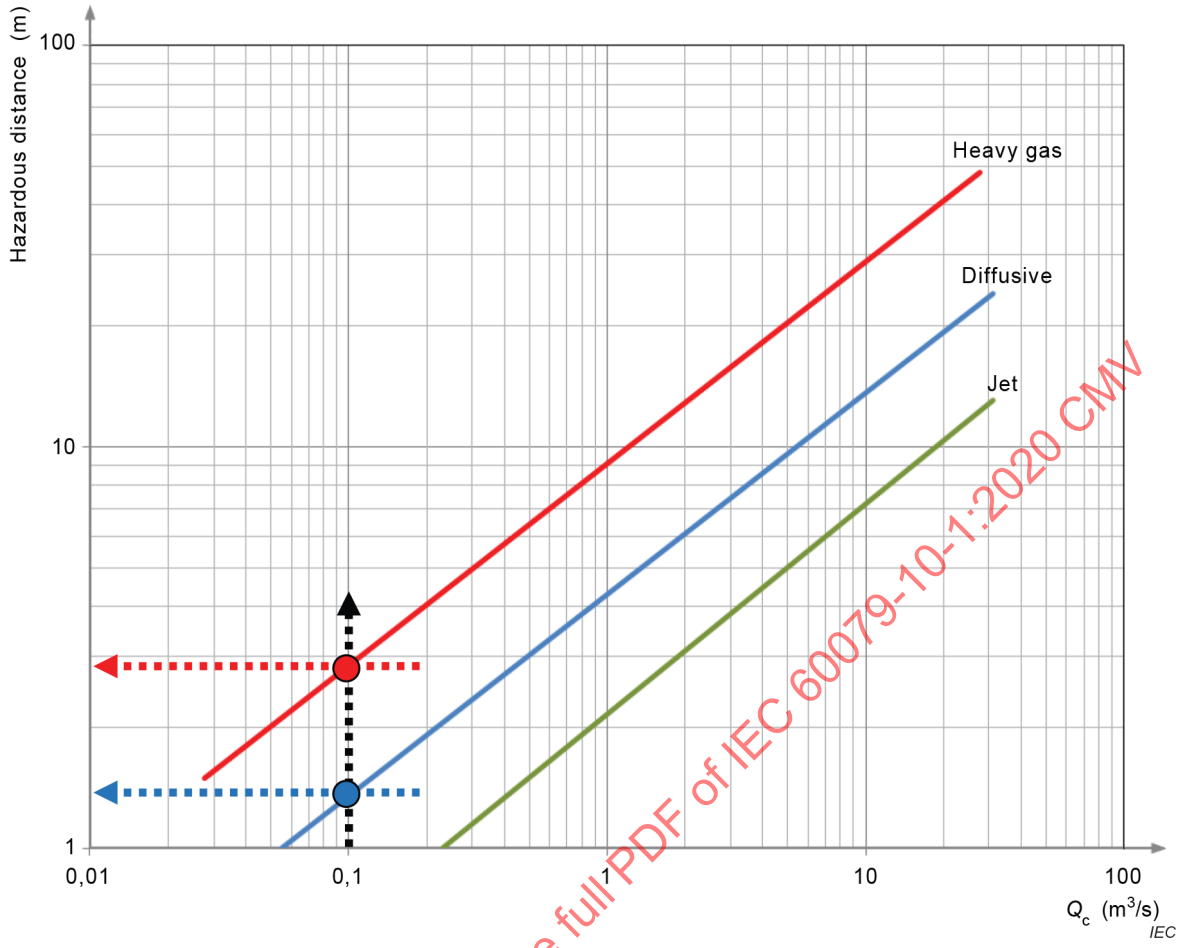
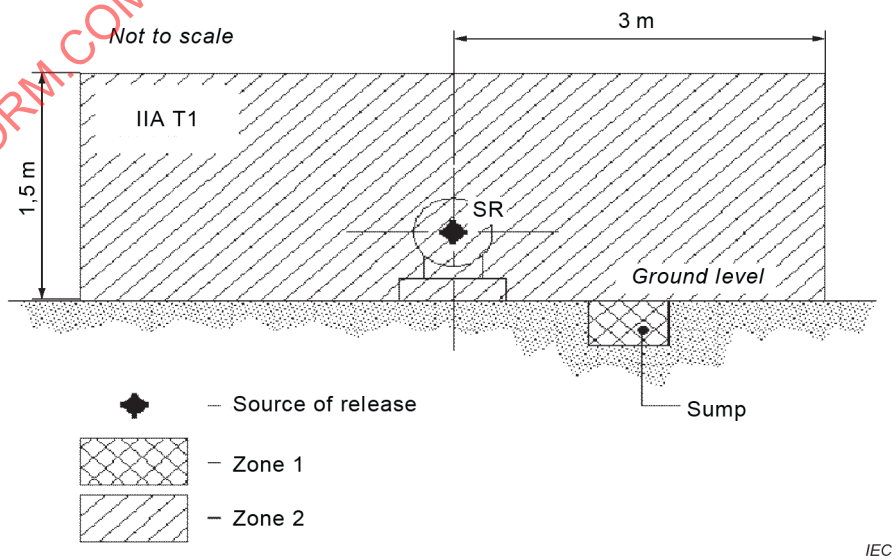


Figure E.2 – Hazardous distance (Example No. 1)

Hazardous area classification:

Hazardous area distances are based on the assessment from Figure E.2. Figure E.3 displays the front view of the facility. The figure is based on heavier than air vapour; the vertical distance is less than the horizontal as illustrated in Figure ~~A.5~~ E.3.



NOTE The more severe classification of the sump due to the low degree of dilution.

Figure E.3 – Zone classification (Example No. 1)

Example 2

A normal industrial pump with mechanical (diaphragm) seal, mounted at ground level, located indoor, pumping flammable liquid

Characteristics of release:

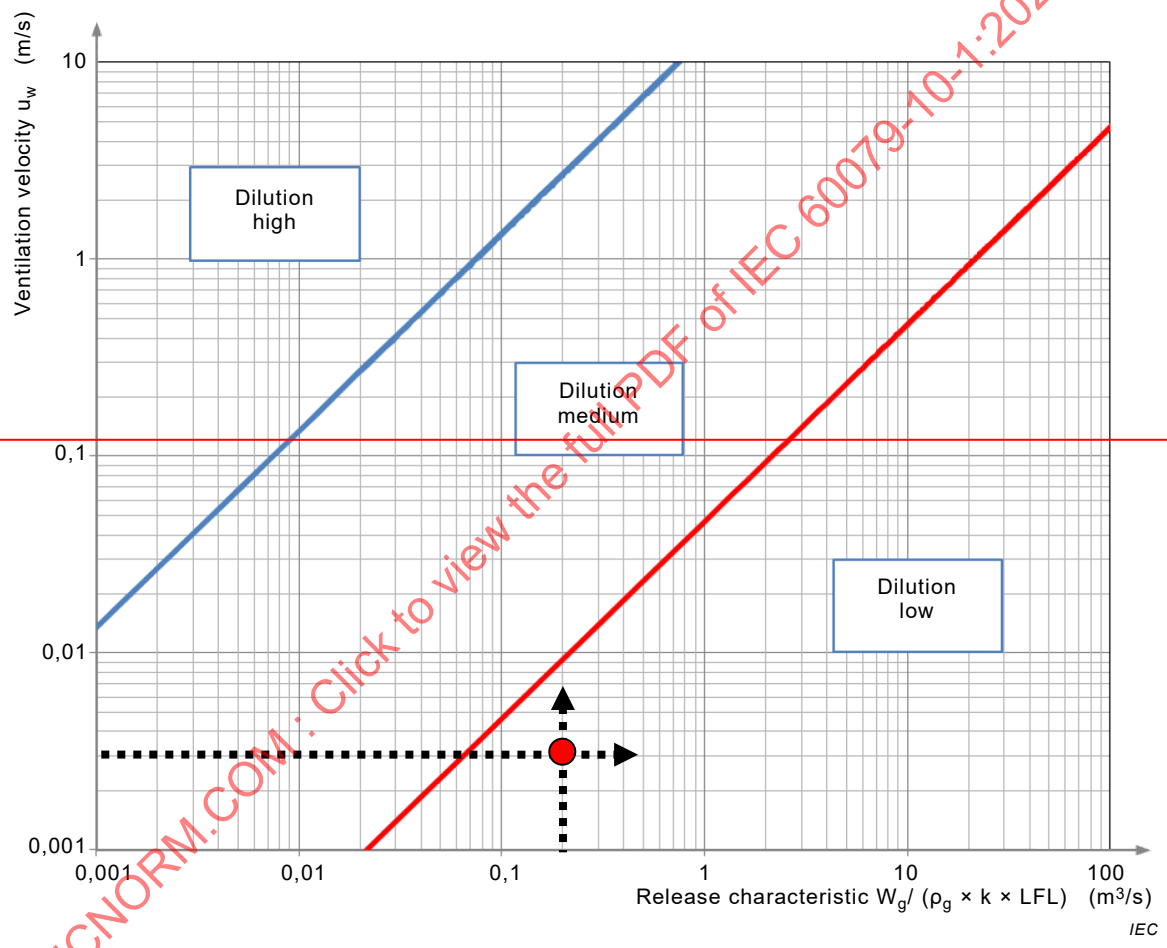
Flammable substance	Benzene based liquid product
Molar mass	78,11 kg/kmol
Lower flammable limit, LFL	1,2 % vol. (0,012 vol./vol.)
Auto-ignition temperature, AIT	498 °C
Gas density, ρ_g	~~3,25~~ 3,247 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, SR	Mechanical seal
Grade of release	Secondary (leakage due to a seal rupture)
Liquid release rate, W	~~0,19~~ 0,192 kg/s, determined considering a discharge coefficient C_d = 0,75, a hole size S = 5 mm^2, a liquid density ρ = 876,5 kg/m^3 and a pressure difference Δp = 15 bar
Evaporation rate, W_e	3,85 × 10^{-3} kg/s, defined considering the fraction of liquid vaporised from the point of release (2 % of W); remaining liquid drained to sewage system NOTE Information taken from industrial code.
Gas volumetric release rate, Q_g	1,19 × 10^{-3} m^3/s
~~Release characteristic, $W_g/(\rho_g \times k \times LFL)$~~	~~0,2 m^3/s~~
~~Safety factor, k~~	~~0,5 (due to high uncertainty related to LFL)~~ **84**
Volumetric release characteristic, Q_C	0,099 m^3/s

Characteristics of location:

Indoor situation	Building naturally ventilated (by wind)
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T_a	20 °C (293 K)
Enclosure size, $L \times B \times H = V_0$	6,0 m × 5,0 m × 5,0 m = 150,0 m^3
Air flow rate, Q_a	306 m^3/h (0,085 m^3/s)
Air flow rate availability	~~Good~~ Fair, defined considering the worst environmental conditions (wind speed at meteorological calm condition)
Ventilation velocity, u_w	0,003 m/s, estimated by $Q_a / (L \times H)$
Critical concentration, X_{crit}	0,003 vol./vol., equal to $(0,25 \times LFL)$

Effects of release:

Ventilation ~~(in)efficiency~~ inefficiency **85** factor, f	5
Background concentration, X_b	~~0,07~~ 0,068 vol./vol.
Concentrations comparison	$X_b > X_{crit}$
Time required to reach X_{crit}, t_d	7,67 h (safety margin equal to f)
Degree of dilution (see Figure E.4)	Low ~~also~~ due to $X_b > X_{crit}$
Type of zone(s)	Zone 1
Equipment group and temperature class	IIA T1



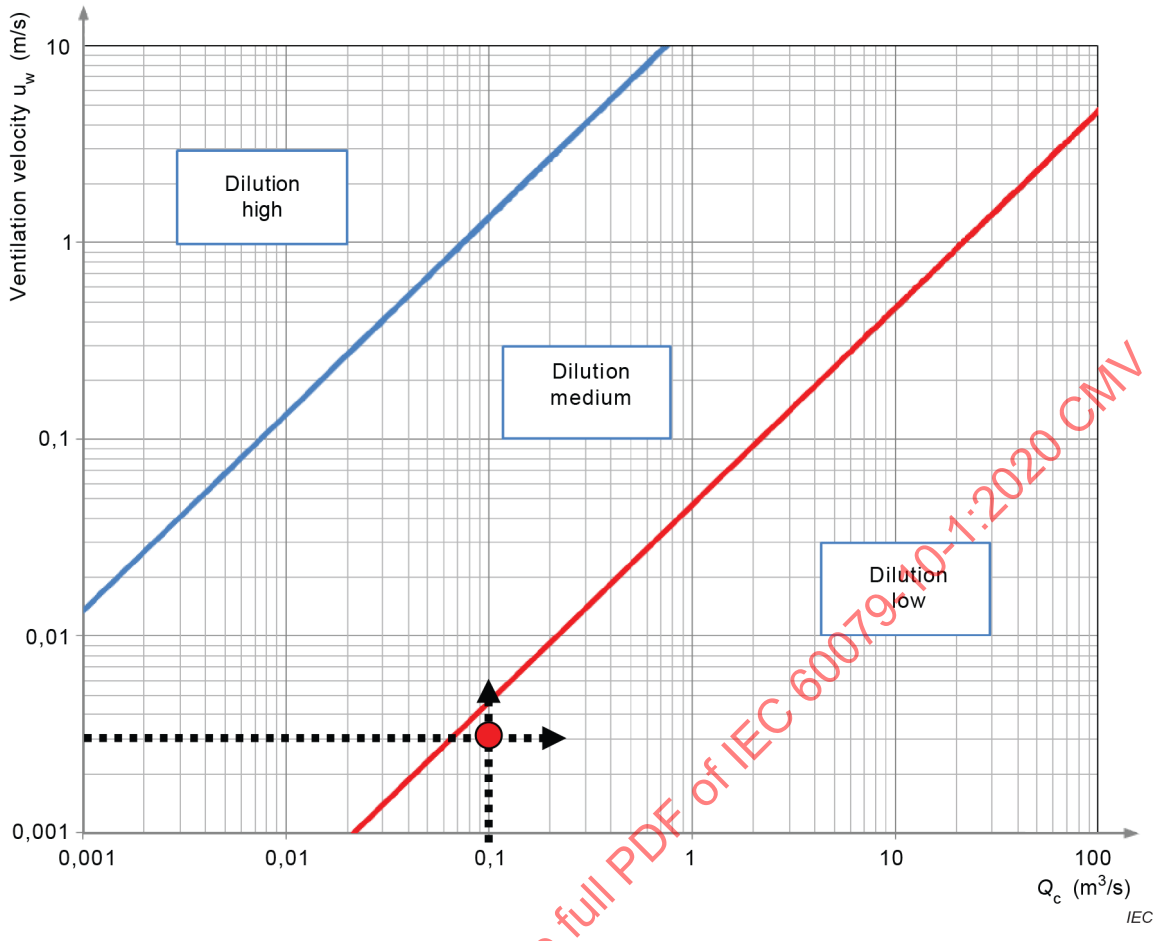
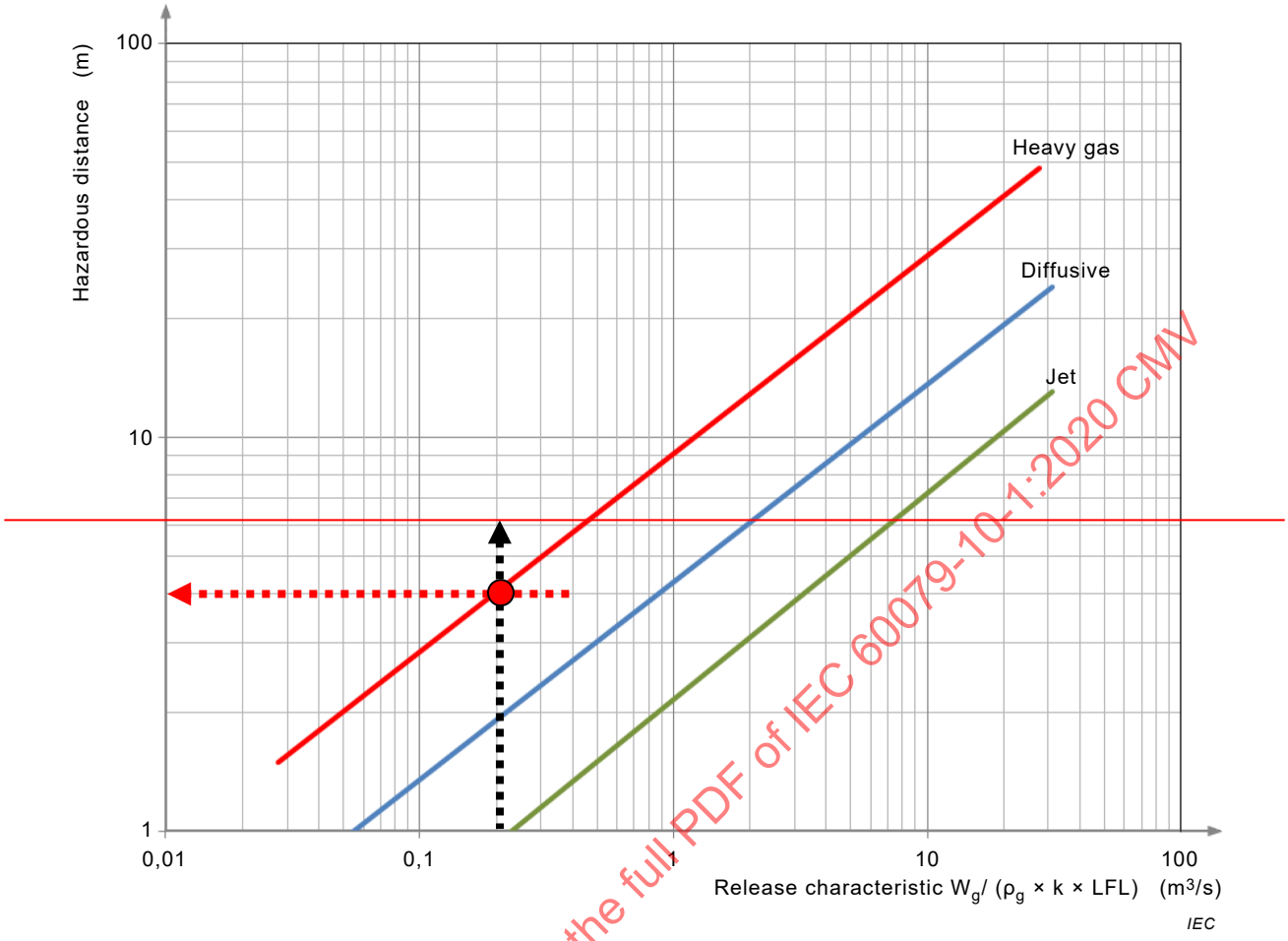


Figure E.4 – Degree of dilution (Example No. 2)

The procedure of estimating the degree of dilution by using the chart is not necessary in this case because the background concentration in the enclosed space is higher than the critical ($X_b > X_{crit}$). So the degree of dilution would be declared as low anyway. Figure E.4 simply confirms the assessment.



~~**Figure E.5 – Hazardous distance (Example No. 2)**~~

~~Extent of zone (see Figure E.5), x = 4,0 m (approximately)~~

Hazardous area classification:

The example deals with a relatively small indoor location where the background concentration is twice the critical one. Moreover, the time required to reach the critical background concentration is significant (almost 8 h). There are no reasons to establish a vertical zone or a Zone 2 beyond Zone 1. The resulting hazardous area will encompass the volume of the indoor location considering the comparisons of concentrations, and the time required to reach the critical ones after the stop of the release. Openings, if any, should be considered as potential sources of release.

If the air flow rate were to be improved, then the degree of dilution could be 'medium' and the ~~zone extent~~ hazardous area could be ~~smaller and maybe of~~ Zone 2 instead of Zone 1.

Example 3

Vapour from a breather valve in the open air, from a process vessel.

Characteristics of release:

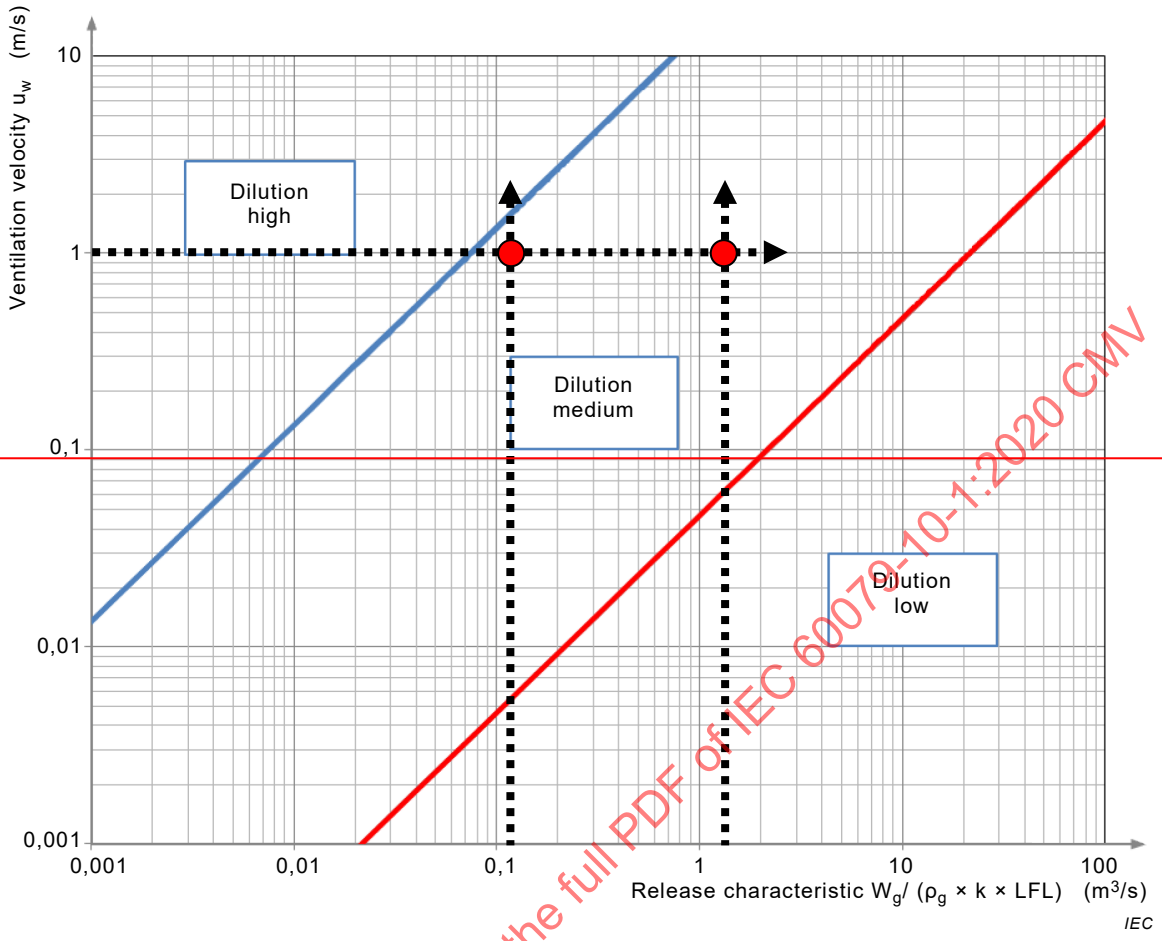
Flammable substance	Benzene (CAS no. 71-43-2)
Molar mass	78,11 kg/kmol
Lower flammable limit, LFL	1,2 % vol. (0,012 vol./vol.)
Auto-ignition temperature, AIT	498 °C
Gas density, ρ_g	~~3,25~~ 3,247 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, SR	Breather valve
Grade of release	Primary (process vessel filling)
Release rate, W_g	4,5 × 10^{-3} kg/s (manufacturer's data)
~~Release characteristic, $W_g/(\rho_g \times k \times LFL)$~~	~~0,12 m^3/s (k = 1,0)~~
Volumetric release characteristic, Q_C	0,115 m^3/s
Grade of release	Secondary (sealing device rupture)
Release rate, W_g	4,95 × 10^{-2} kg/s (manufacturer's data)
~~Release characteristic, $W_g/(\rho_g \times k \times LFL)$~~	~~1,27 m^3/s (k = 1,0)~~
Volumetric release characteristic, Q_C	1,27 m^3/s

Characteristics of location:

Outdoor situation	Un-obstructed area
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T	20 °C (293 K)
Ventilation velocity, u_w	1,0 m/s
Ventilation availability	Good (wind speed at calm conditions)

Effects of releases:

Degree of dilution (see Figure E.5)	Medium
Type of zone(s)	Zone 1 + Zone 2
Equipment group and temperature class	IIA T1



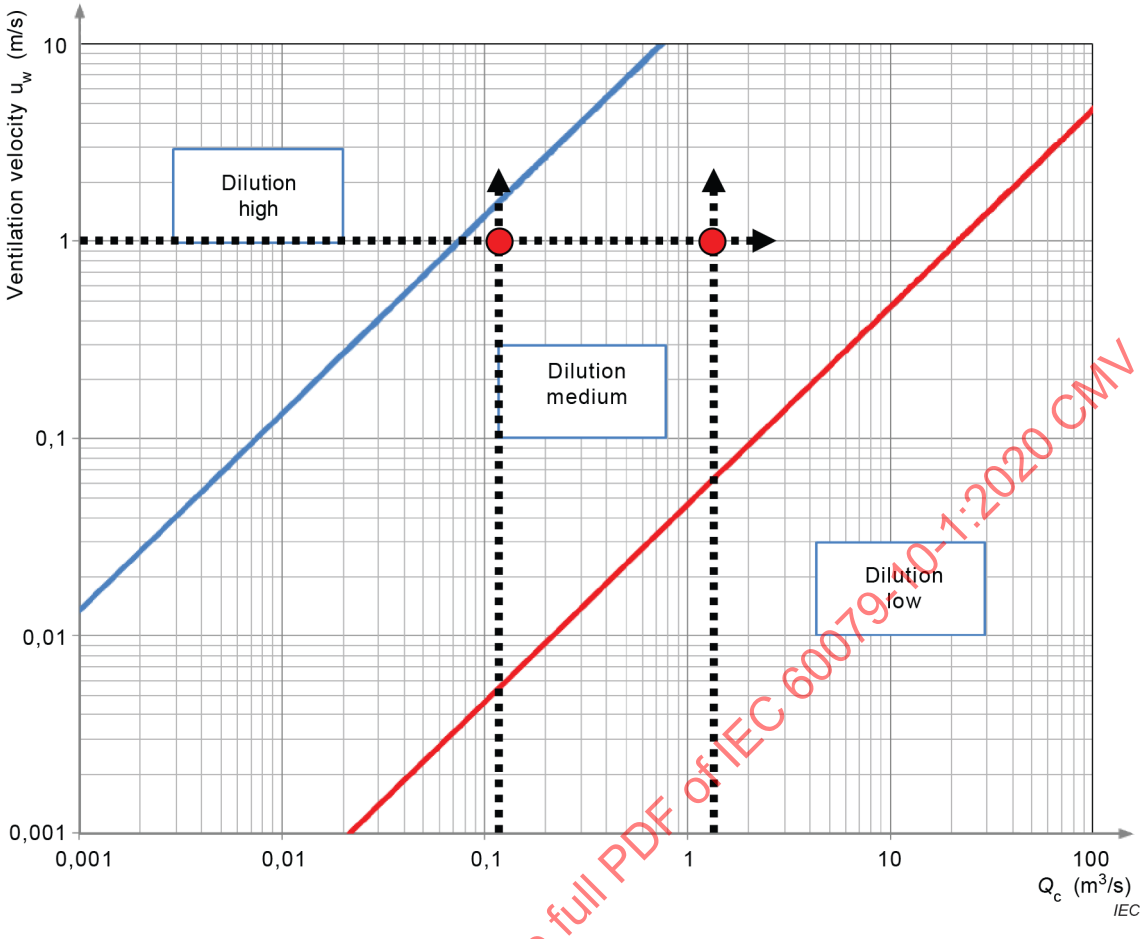
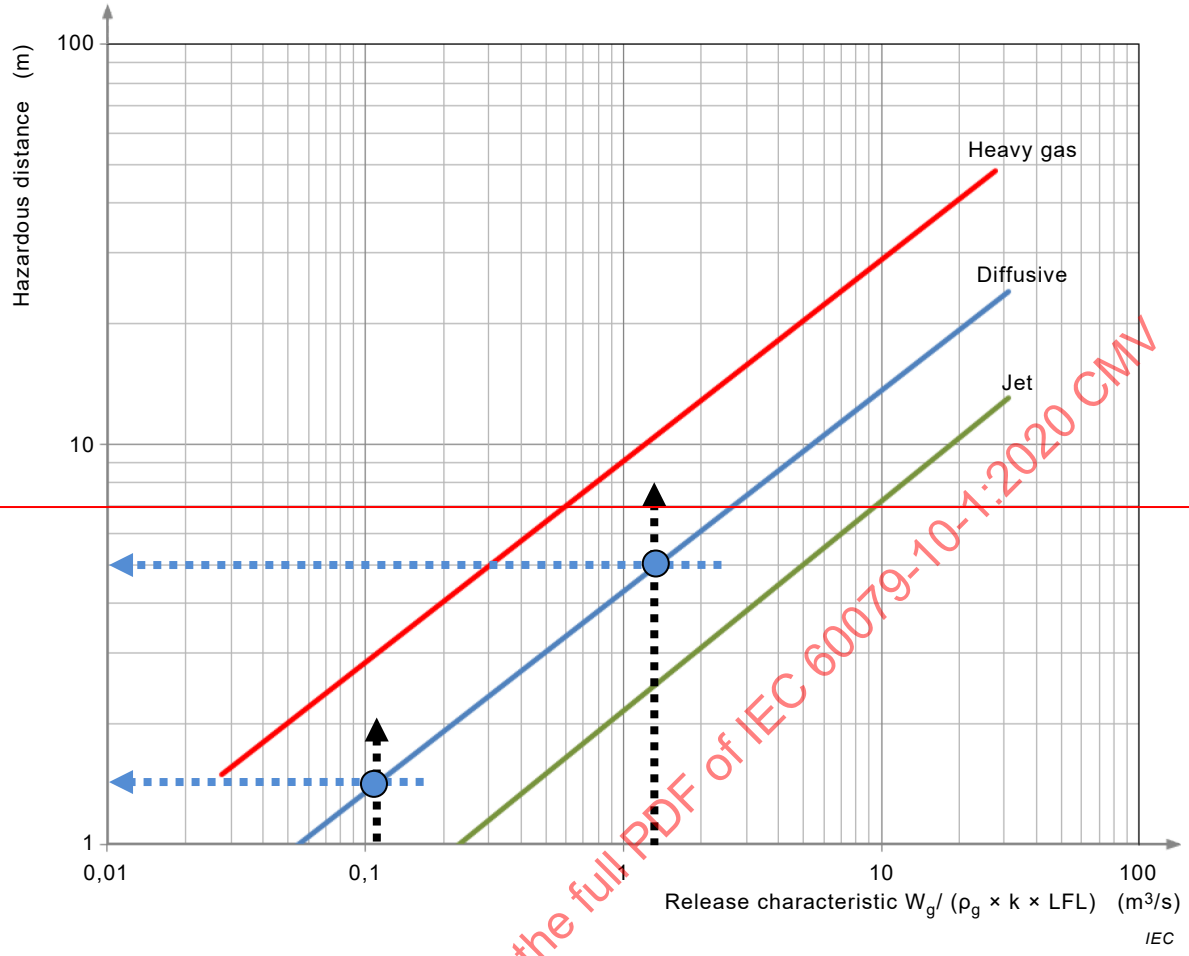


Figure E.5 – Degree of dilution (Example No. 3)



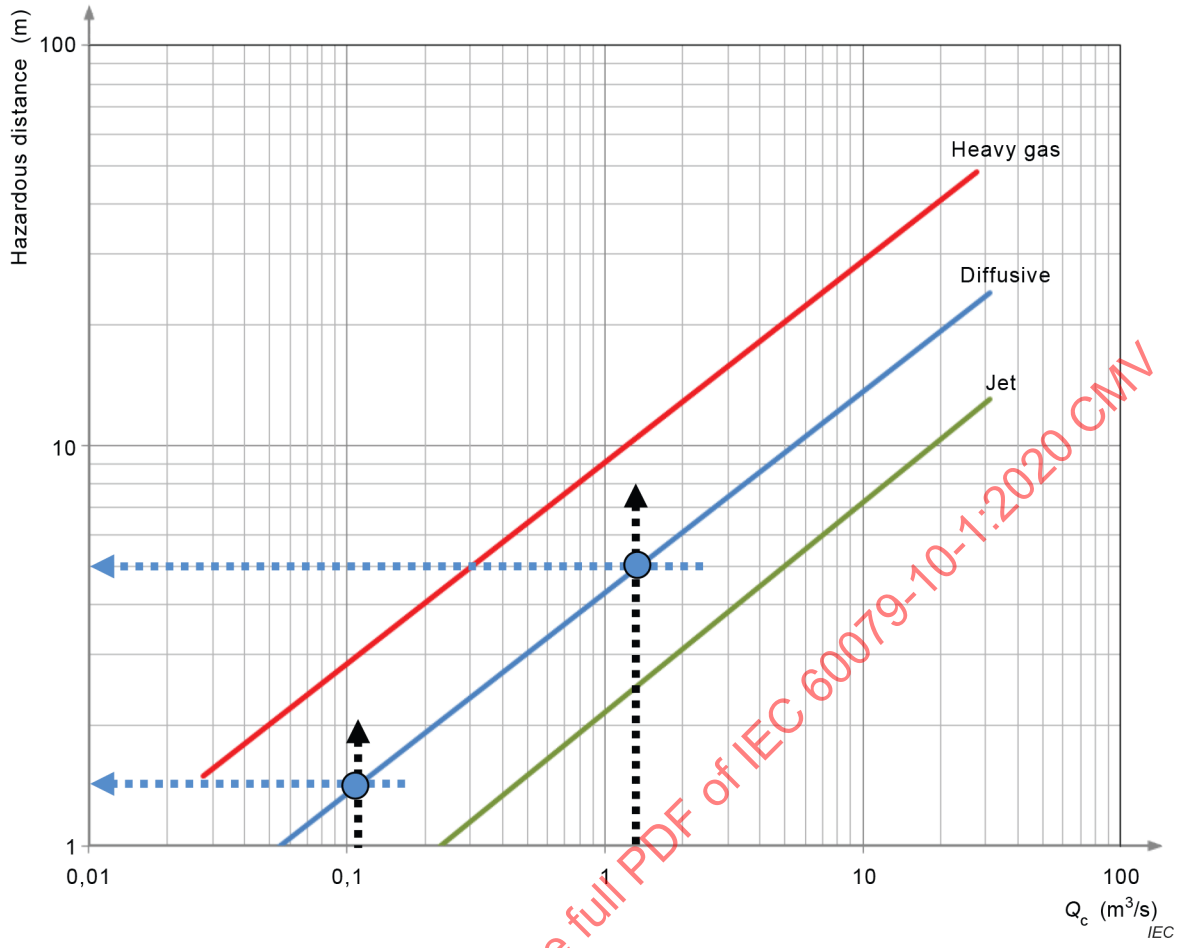


Figure E.6 – Hazardous distance (Example No. 3)

Extent(s) of zone(s), *r* for primary grade release = 1,5 m; for secondary grade release = 5,0 m

Hazardous area classification:

Hazardous area distances are based on the assessment from Figure E.6. Taking into account relevant parameters, the following hazardous areas are specific for the considered breather valve (see Figure E.7).

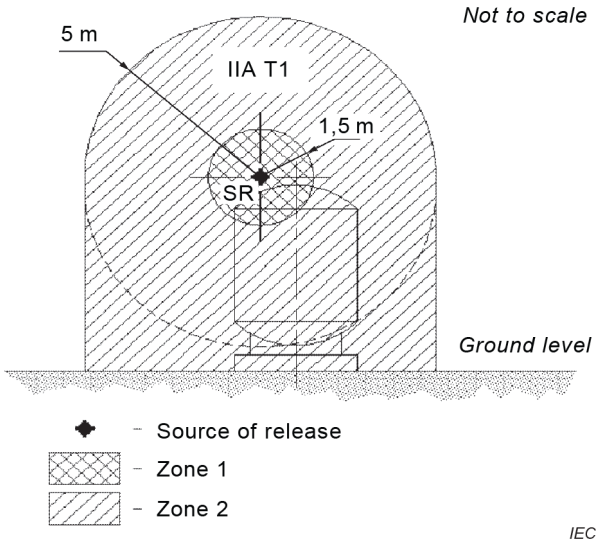


Figure E.7 – Zones classification (Example No. 3)

Example 4

Control valve in congested location, installed in a closed process pipe-work system conveying flammable gas.

Characteristics of release:

Flammable substance	Propane based gas mixture
Molar mass	44,1 kg/kmol
Lower flammable limit, LFL	1,7 % vol. (0,017 vol./vol.)
Auto-ignition temperature, AIT	450 °C
Gas density, ρ_g	~~1,83~~ 1,833 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, *SR*	Valve stem packing
Grade of release	Secondary (packing rupture)
Release rate, W_g	~~5,57~~ 5,06 × 10^{-3} kg/s, determined considering an operating pressure p = 10 bar, temperature T = 15 °C, hole size S = 2,5 mm^2, compressibility factor Z = 1, polytropic index γ = 1,1 and discharge coefficient C_d = 0,75
~~Safety factor, k~~	~~0,8 (due to uncertainty related to LFL)~~ **84**
~~Release characteristic, $W_g/(\rho_g$ x k x $LFL)$~~	~~0,22 m^3/s~~
Volumetric release characteristic, Q_C	0,162 m^3/s

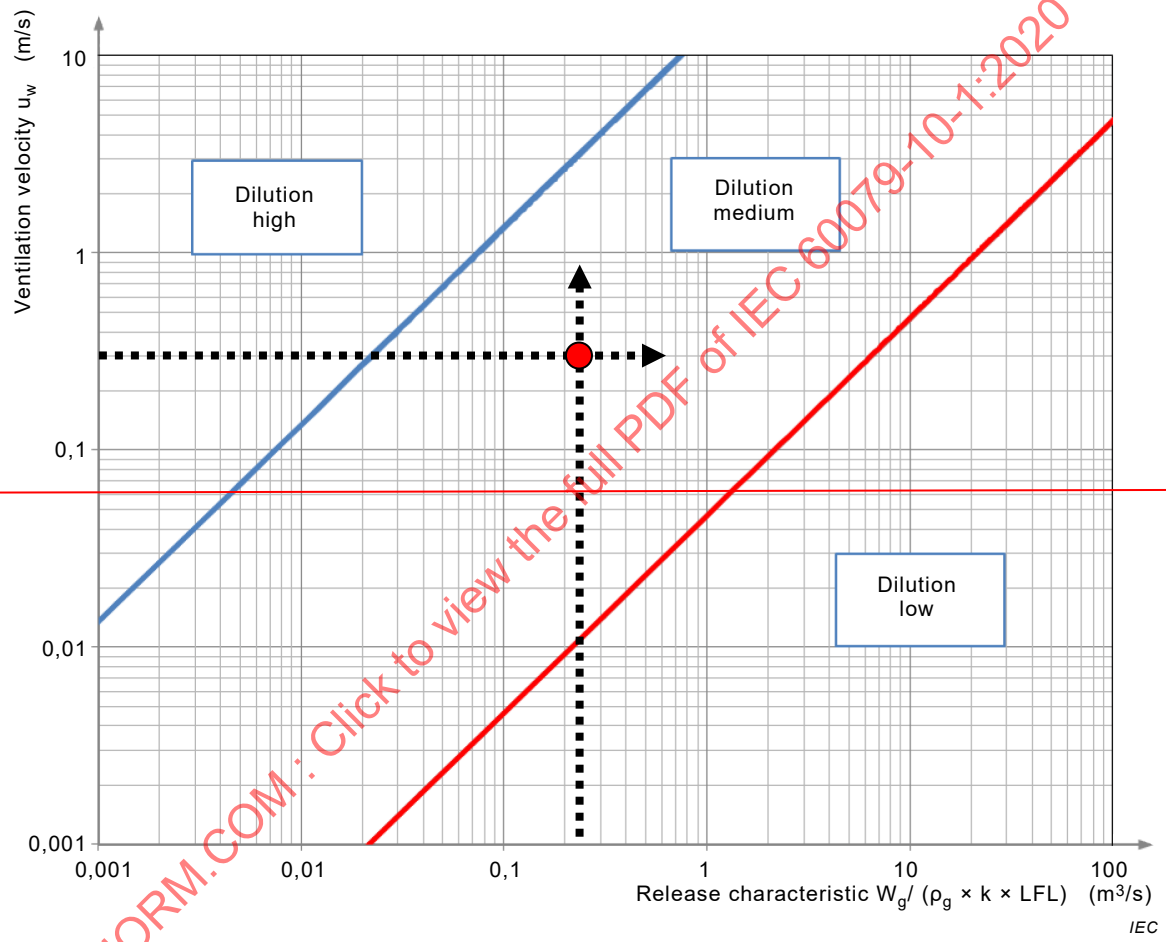
Characteristics of location:

Outdoor situation	Unobstructed area
Ambient pressure, p_a	101 325 Pa

Ambient temperature, T	20 °C (293 K)
Ventilation velocity, u_w	0,3 m/s
Ventilation availability	Good (wind speed at calm condition)

Effects of releases:

Degree of dilution (see Figure E.8)	Medium
Type of zone(s)	Zone 2
Equipment group and temperature class	IIA T1



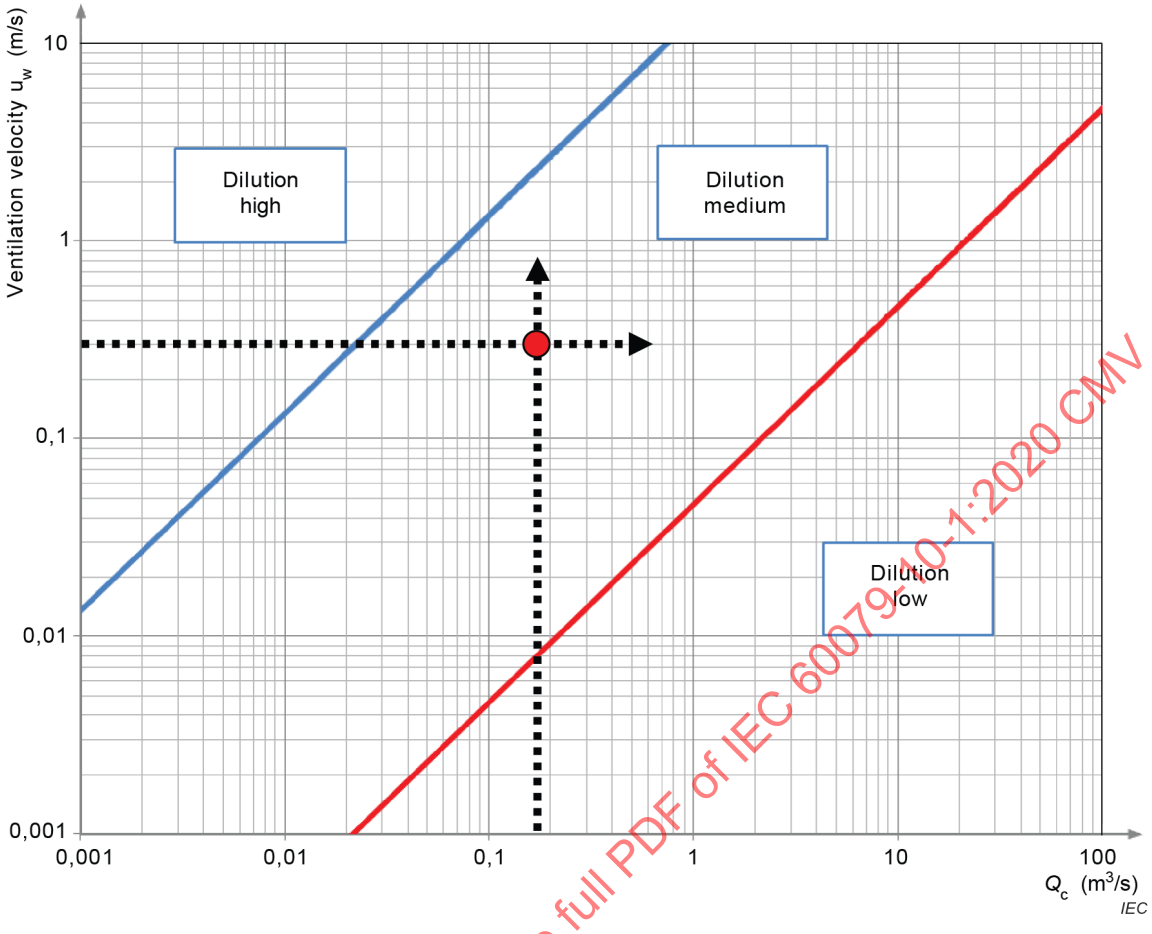
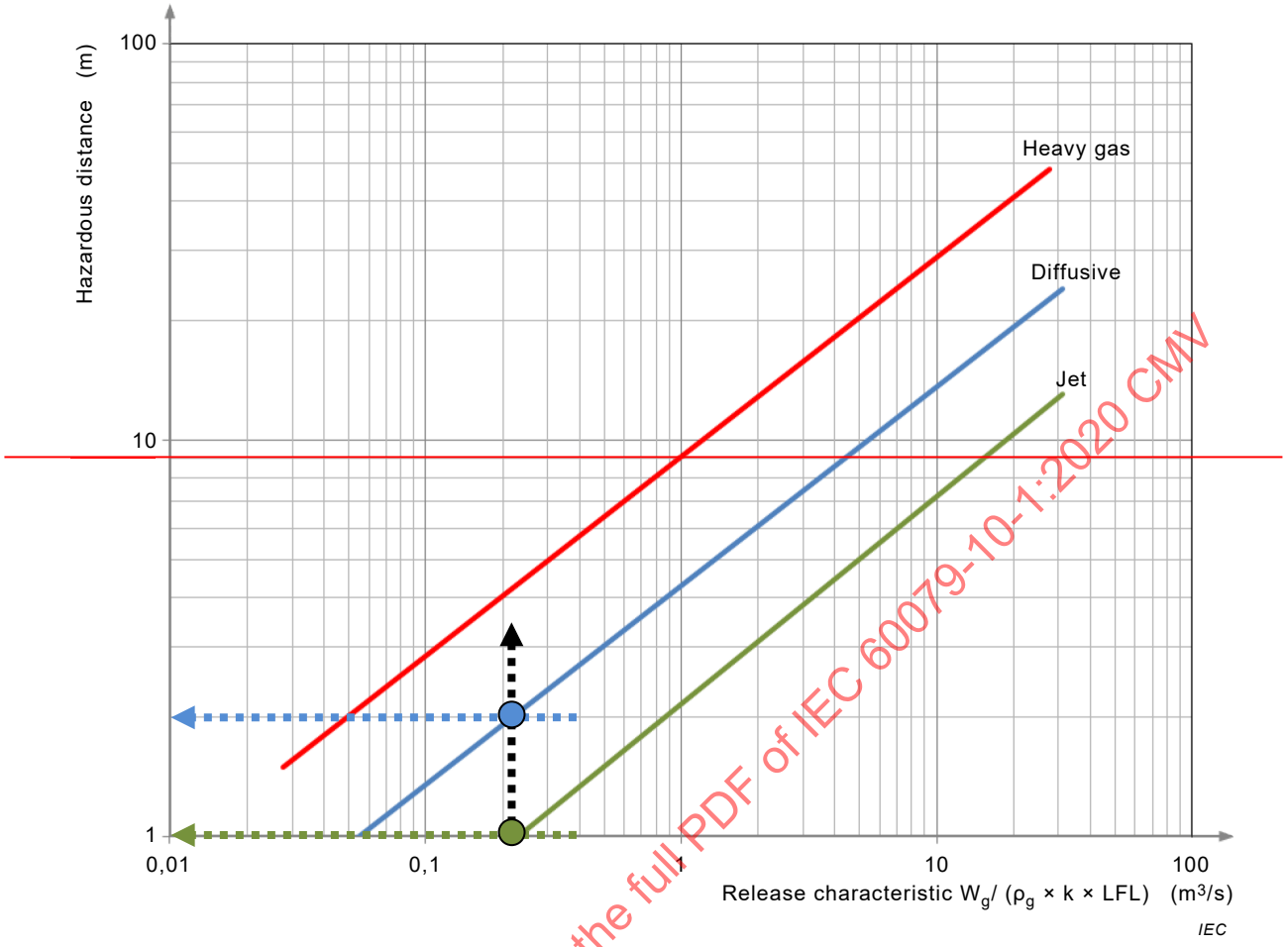


Figure E.8 – Degree of dilution (Example No. 4)



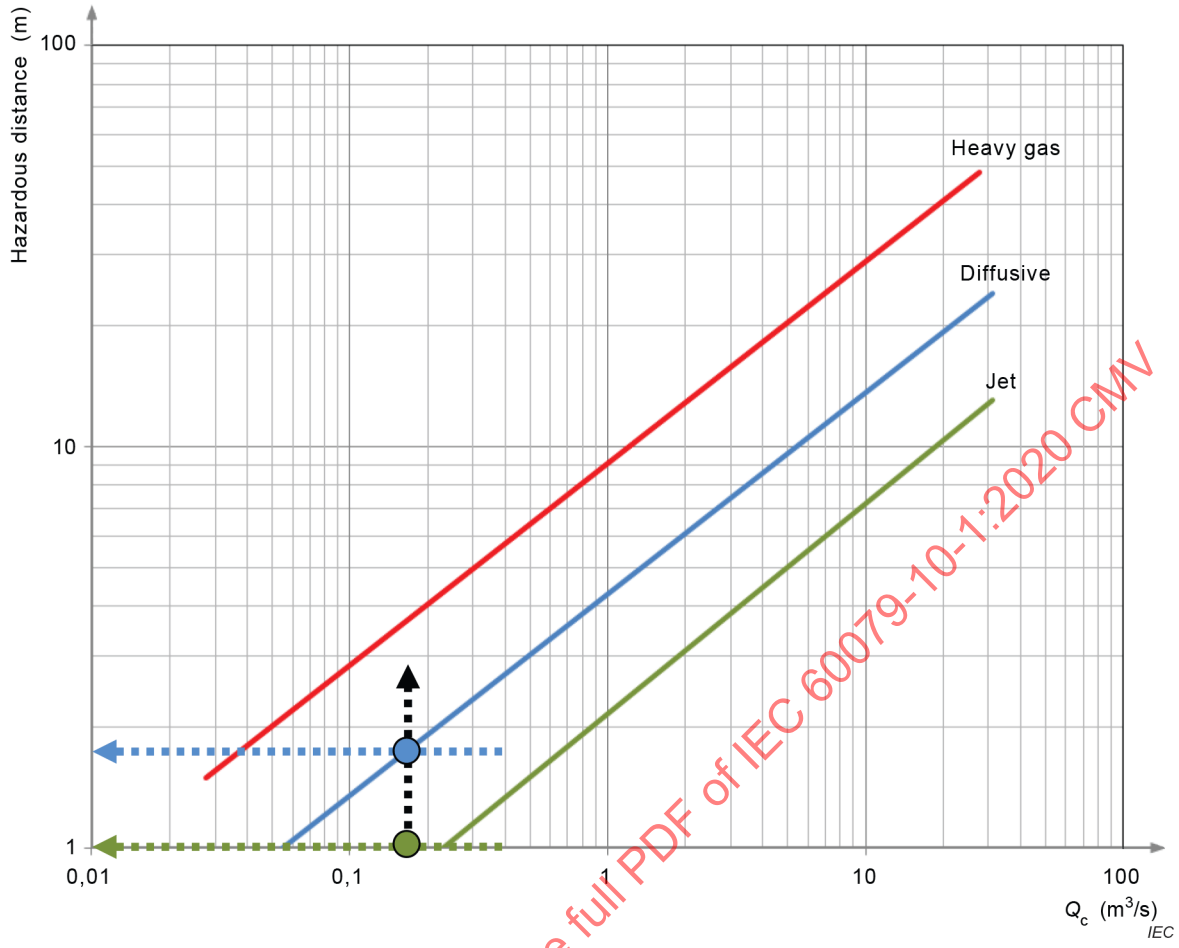


Figure E.9 – Hazardous distance (Example No. 4)

Extent(s) of zone(s) ~~(see Figure E.10), r extent of zone~~, r from 1,0 m to 2,0 m due to surrounding characteristics (i.e. impeded or unimpeded jet release).

Since the chart is not valid for less than 1 m the zone is assessed as 1 m. If further refinement of this zone extent is desired, then another assessment methodology should be used. **86**

Hazardous area classification:

Hazardous area distances are based on the assessment from Figure E.9. Taking into account relevant parameters, the following hazardous area is specific for the considered control valve (see Figure E.10).

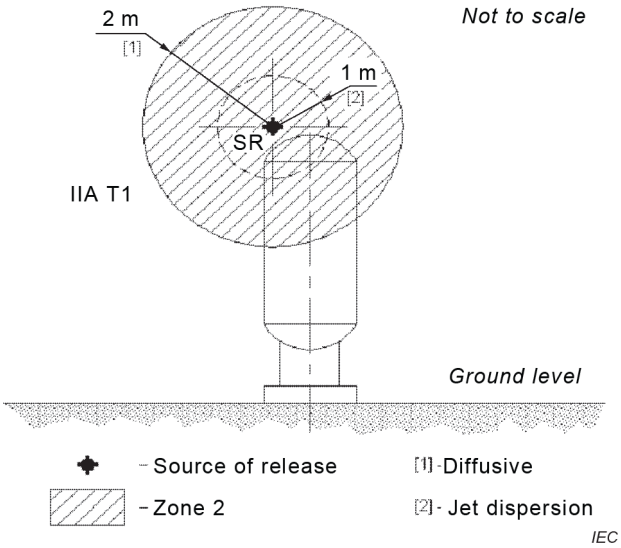


Figure E.10 – Zones classification (Example No. 4)

Example 5

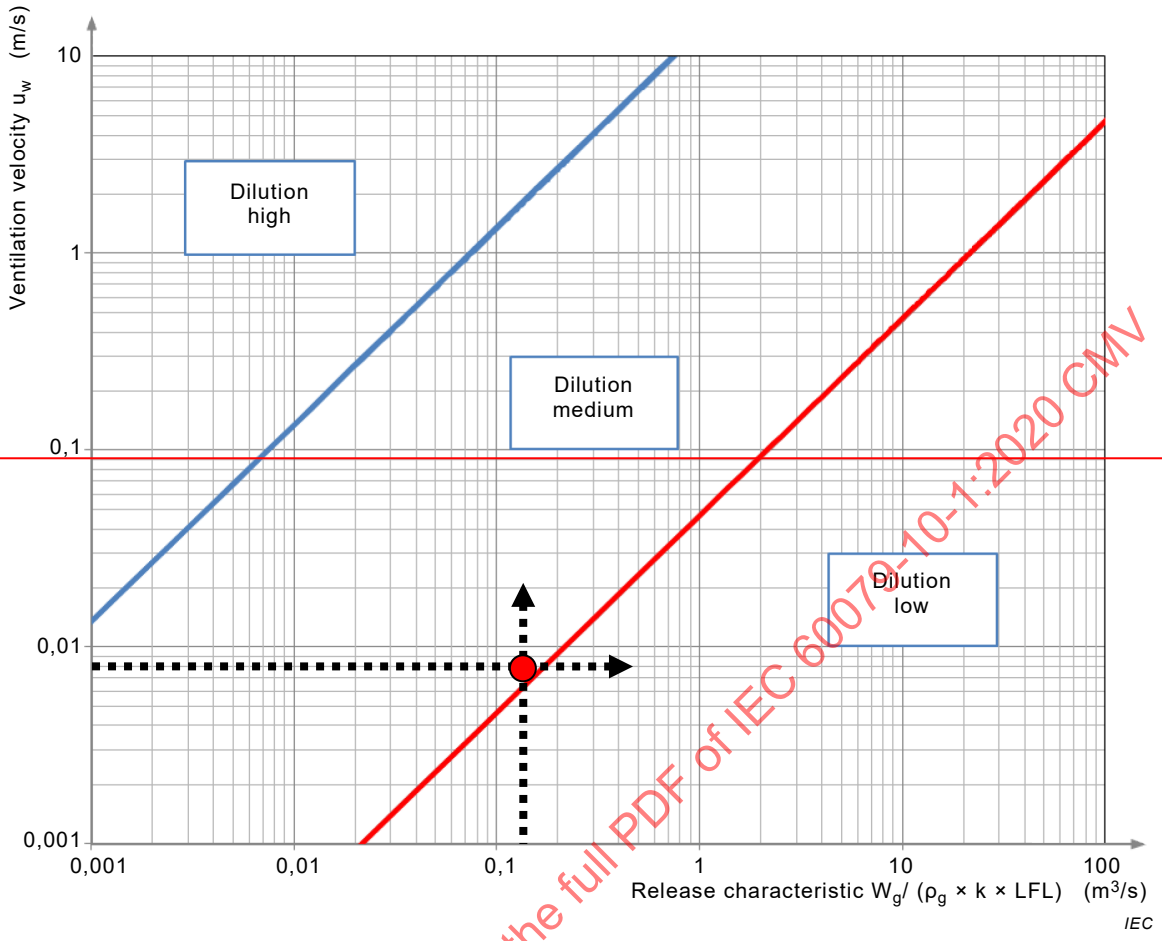
Closed process pipework system, located indoor, conveying flammable gas.

Characteristics of releases:

Flammable substance	Wet, oil well natural gas
Molar mass	20 kg/kmol
Lower flammable limit, LFL	4 % vol. (0,04 vol./vol.)
Auto-ignition temperature, AIT	500 °C
Gas density, ρ_g	~~0,83~~ 0,831 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1.
Multiple sources of release, MSR	
a) grade of release	Continuous (fugitive emissions)
– type	Pipe fittings (discontinuities along piping)
– release rate per unit, W_g	1,0 × 10^{-9} kg/s (laboratory data)
– volumetric release rate per unit, Q_g	1,2 × 10$^{-~~8~~ 9}$ m^3/s
– number of releases	10
b) grade of release	Primary
– type	Sealing elements on moving parts at low speed (control valves stem packing)
– release rate per unit, W_g	1,5 × 10^{-6} kg/s (manufacturer's data)
– volumetric release rate per unit, Q_g	1,8 × 10^{-6} m^3/s
– number of releases	3

c) grade of release	Secondary
– type	Sealing elements on fixed parts (flange with fibre gasket)
– release rate per unit, W_g	~~1,95~~ 1,7 × 10^{-3} kg/s, determined considering operating pressure p = 5 bar, a temperature T = 15 °C, a hole size S = 2,5 mm^2, a compressibility factor Z = 1, polytropic index γ = 1,1 and a discharge coefficient C_d = 0,75
– volumetric release rate per unit, Q_g	~~2,35~~ 2,05 × 10^{-3} m^3/s
– number of releases	1, the largest one
Characteristics of location:	
Indoor situation	Building naturally ventilated (by wind)
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T_a	20 °C (293 K)
Enclosure size, $L \times B \times H = V_0$	~~2,5 m × 2,5 m × 3,5 m = 21,9 m^3~~ 3,0 m × 3,0 m × 3,5 m = 31,5 m^3
Air flow rate, Q_a	~~266,4 m^3/h (0,074 m^3/s)~~ 189 m^3/h (0,053 m^3/s)
Air flow rate availability	~~Good~~ Fair, defined considering the worst environmental conditions (wind speed at meteorological calm condition)
Ventilation ~~(in)efficiency~~ inefficiency factor, f	3
Ventilation velocity, u_w	~~0,008~~ 0,005 m/s, estimated by Q_a / ~~($L \times H$~~ $B \times H$)
Critical concentration, X_{crit}	0,01 vol./vol., equal to $(0,25 \times LFL)$
Effects of multiple sources of release:	
Grade of release	Continuous (fugitive emissions)
summation of release rates, ΣW_g	1,0 × 10^{-8} kg/s
summation of volumetric release rates, ΣQ_g	1,2 × 10^{-8} m^3/s
background concentration, X_b	~~4,88~~ 6,79 × 10^{-7} vol./vol.
concentrations comparison	$X_b << X_{crit}$
~~release characteristic $W_g/(\rho_g \times k \times LFL)$~~	~~6,01 × 10^{-8} m^3/s~~
~~safety factor, k~~	~~0,5 (due to uncertainty of LFL)~~ **84**
volumetric release characteristic, Q_C	3,01 × 10^{-7} m^3/s
degree of dilution	High
type of zone(s)	Zone 0 NE
Grade of release	Primary plus continuous
summation of release rates, ΣW_g	~~4,5~~ 4,51 × 10^{-6} kg/s
summation of volumetric release rates, ΣQ_g	5,42 × 10^{-6} m^3/s

background concentration, X_b	~~2,2~~ 3,1 × 10^{-4} vol./vol.
concentrations comparison	$X_b << X_{crit}$
~~release characteristic $W_g/(\rho_g \times k \times LFL)$~~	~~9,02 × 10^{-5} m^3/s~~
~~safety factor, k~~	~~0,5 (due to uncertainty of LFL)~~ **84**
volumetric release characteristic, Q_C	1,36 × 10^{-4} m^3/s
degree of dilution	High
type of zone(s)	Zone 1 NE
Grade of release	Secondary plus primary plus continuous
~~summation of release rates, ΣW_g~~	~~2,18 × 10^{-3} kg/s~~
~~summation of volumetric release rates, ΣQ_g~~	~~2,63 × 10^{-3} m^3/s~~
release rate, W_g	1,7 × 10^{-3} kg/s
volumetric release rate, Q_g	2,05 × 10^{-3} m^3/s
background concentration, X_b	~~0,103~~ 0,12 vol./vol.
concentrations comparison	$X_b > X_{crit}$
time required to reach X_{crit}, t_d	~~0,57~~ 1,23 h (safety margin equal to f)
~~safety factor, k~~	~~0,5 (due to uncertainty of LFL)~~ **84**
~~release characteristic $W_g/(\rho_g \times k \times LFL)$~~	~~0,13 m^3/s~~
volumetric release characteristic, Q_C	0,051 m^3/s
degree of dilution ~~(see Figure E.12)~~	Low due to $X_b > X_{crit}$
type of zone(s)	Zone 1
Equipment group and temperature class	IIA T1



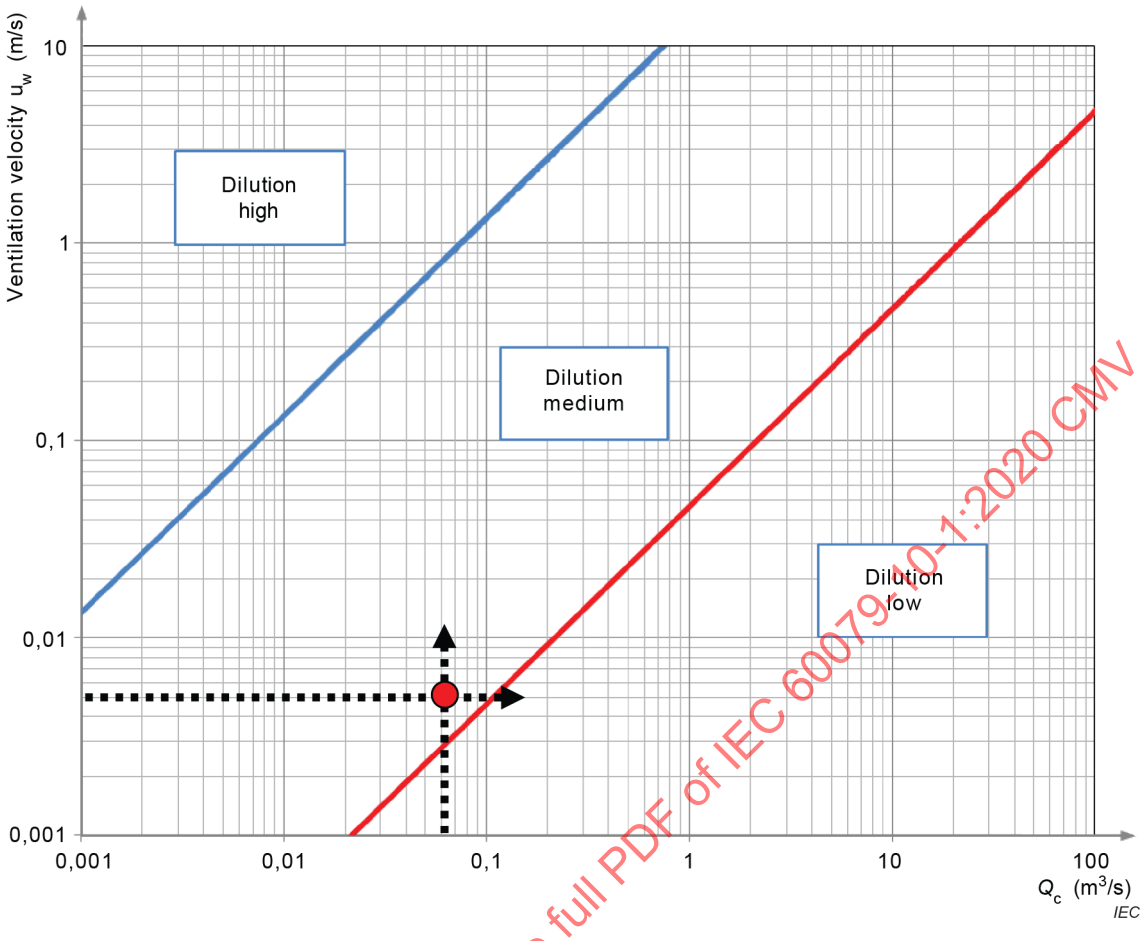
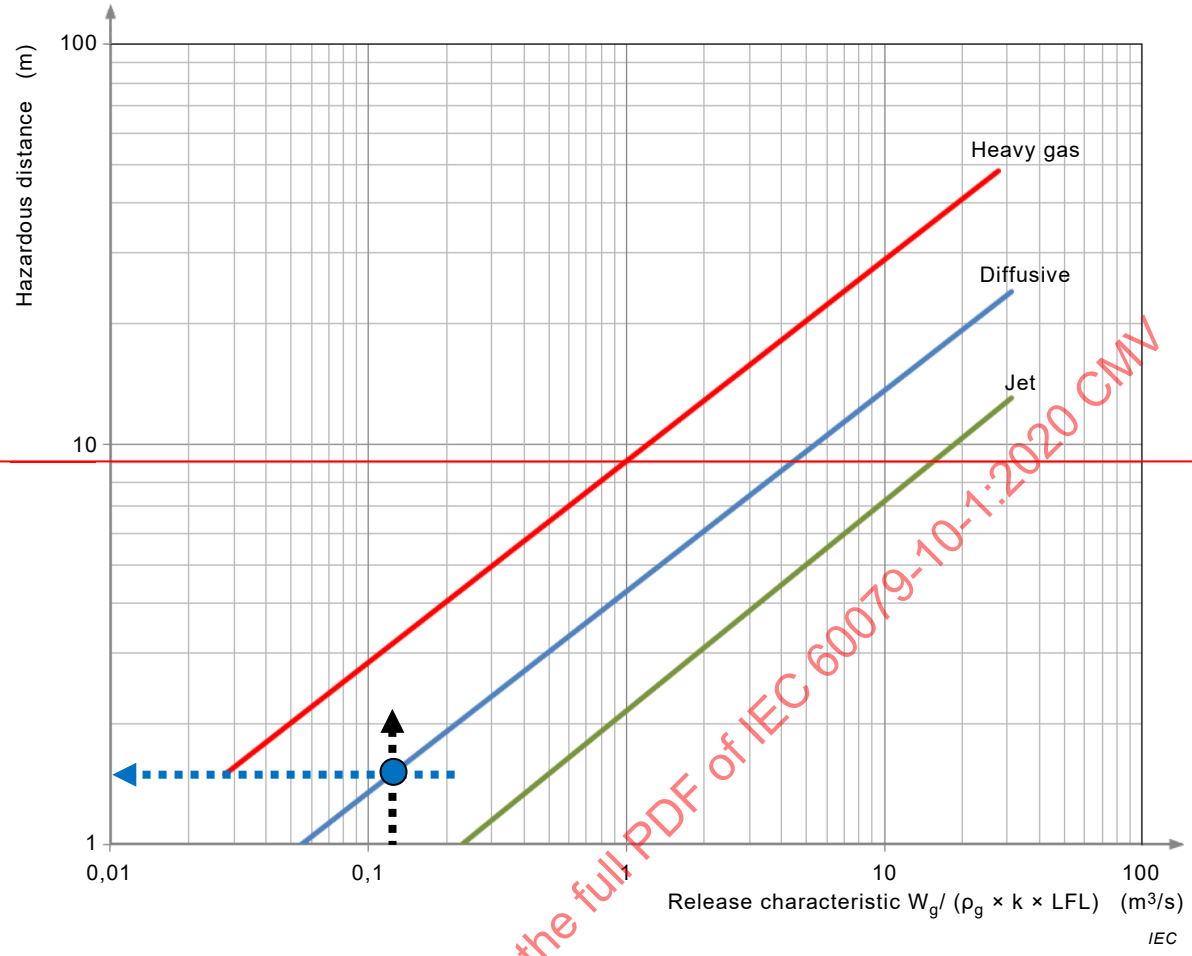


Figure E.11 – Degree of dilution (Example No. 5)

The procedure of estimating the degree of dilution by using the chart is not necessary in this case because the background concentration in the enclosed space is higher than the critical ($X_b > X_{crit}$). So the degree of dilution would be declared as low anyway. Figure E.411 shows that the intersection point is within the area of 'dilution medium' but ~~almost on~~ close to the dividing line. Allowing for uncertainties in the methodology this shows the preceding assessment is appropriate.



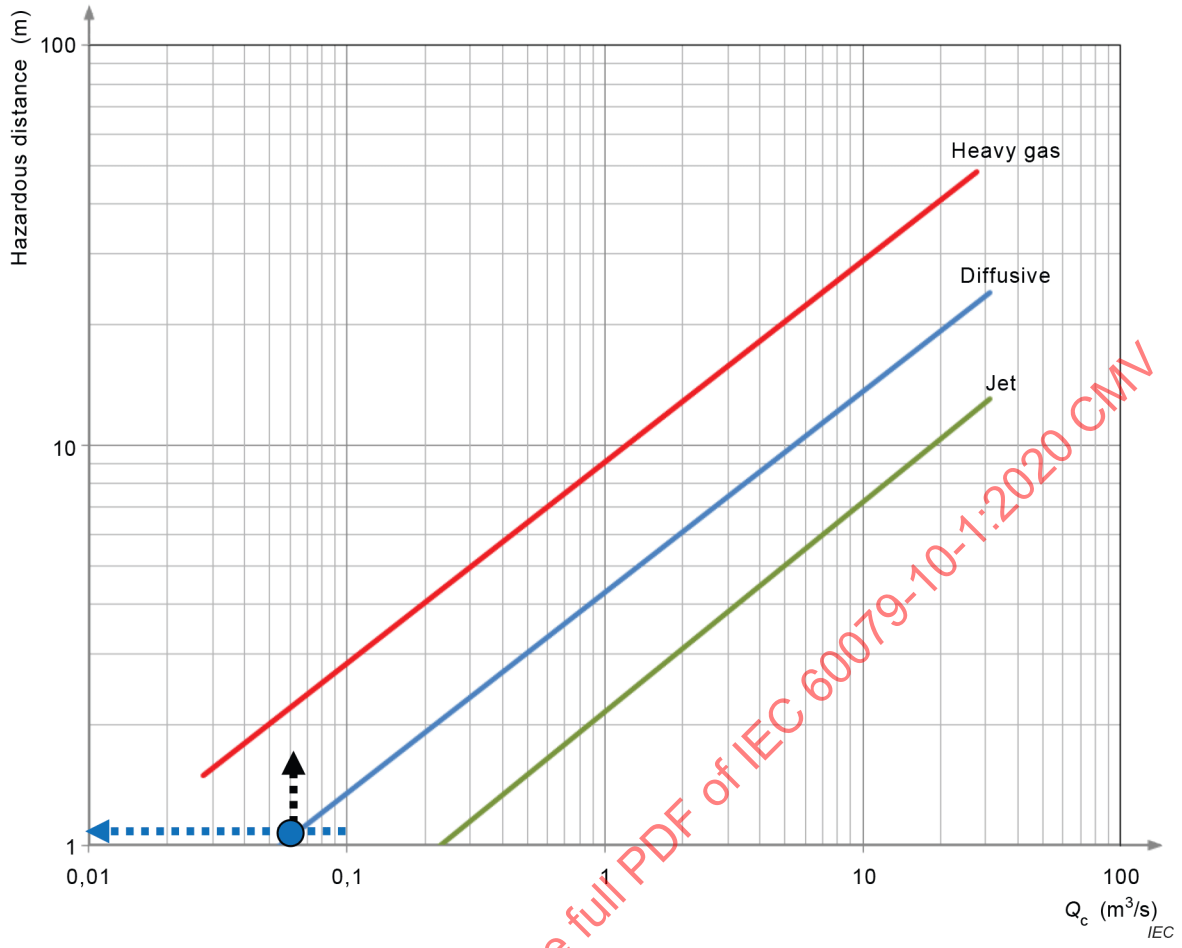


Figure E.12 – Hazardous distance (Example No. 5)

Extent of zone (see Figure E.12, *r* extent of zone is ~~1,5~~ approximately 1,0 m due to surrounding characteristics (i.e. impeded ~~or unimpeded~~ jet release)

Hazardous area classification:

The resulting hazardous area will encompass the whole volume of the indoor location because the background concentration exceeds the critical concentration and the time for the concentration to fall to the critical concentration after the release has stopped, is significant. Also, the extent of zone is significant related to the enclosure size (see C.3.6.1).

E.3 Example case study for hazardous area classification

The following example is intended to illustrate the methodology of hazardous area classification and the way in which zones should be displayed. Zone details may vary depending on the specific installation details or application of the relevant code of practice. This example has been taken because it contains a variety of forms of release which are frequently met in practice, separately or in various combinations or in different contexts. That's why the compressor facility in this example should be considered just as a framework for the methodology set forth in the standard.

The example is a compressor facility handling natural gas (see Figure E.13). The compressor units are skid mounted packages consisting of a gas engine, compressor, combined air cooler, process piping, on-skid scrubbers, pulsation bottles, and auxiliary equipment.

Gas engines and compressors in this example are considered to be installed within a naturally ventilated shelter with air entering through louvered openings at the bottom and an open front of the shelter and leaving through a rooftop opening (see Table E.1).

The external part of the facility is considered to consist of combined air coolers with cooling water and process gas heat exchangers, piping, valves (emergency shut down, block and regulating), off-skid scrubbers, etc.

The flammable substances that appear in this example are presented in Table E.2:

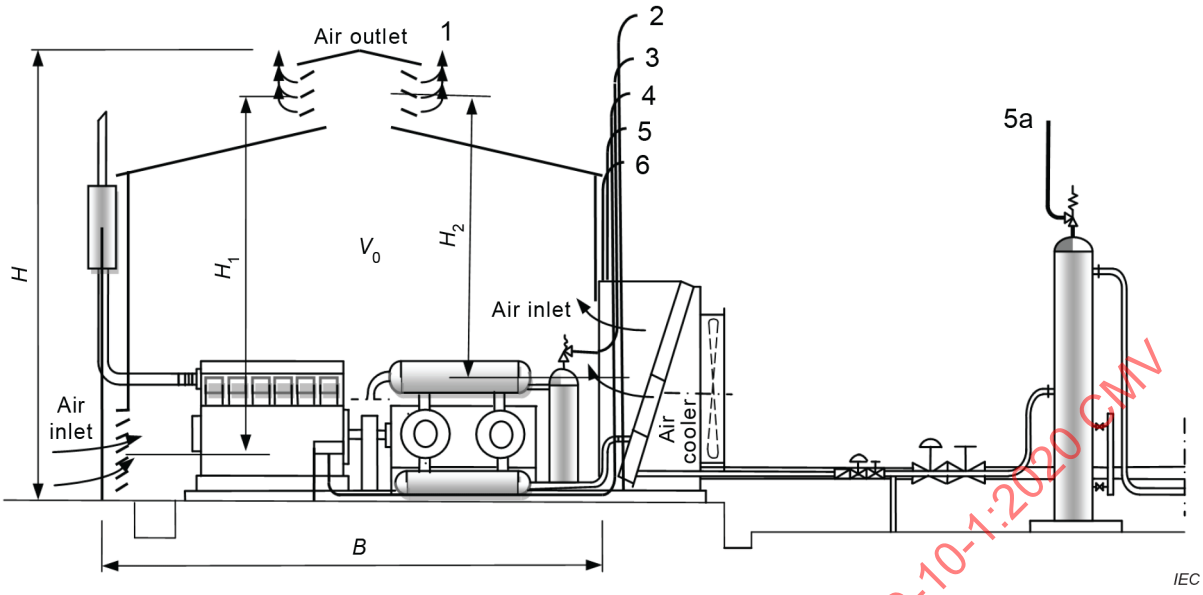
1) Process gas (natural gas with 80 % vol methane),
2) Process gas condensate collected in the scrubbers and automatically drained towards a collecting reservoir (mainly heavier hydrocarbons in quantities which are determined by the respective equilibrium state at each stage of compression),
3) Gas engine fuel and starting gas (dry pipeline quality natural gas, min 96 % vol methane),
4) Various chemicals applied in the process, e.g. corrosion inhibitors, antifreezing additives.

The sources of release that appear in this example are presented in Table E.~~2~~3:

1) Starting gas vent (a predictable source that gives primary grade of release; happens at each start of the engine),
2) Compressor blowdown vent (a predictable source that gives primary grade of release; happens at each depressurization of the blocked compressor),
3) Gas engine shut-off valve vent (a relatively predictable source that gives primary grade of release (happens at each shutdown of the engine when the incoming fuel gas gets blocked and the trapped gas is evacuated to atmosphere),
4) Pressure relief valve vent (a non predictable source that typically gives secondary grade of release; happens if the pressure upstream increases above the set point; usually a shutdown safety device is installed in the protective system of compressor units to trip before the safety relief valve opens and therefore it should not normally be considered as the source that gives primary grade of release; see B.2.2 and B.2.3),
5) Compressor piston rod packings vent (a source that typically gives primary grade of release, however, if in doubt regarding monitoring, control and quality of maintenance, this vent may be considered as a source that gives continuous grade of release, see B.2.2 and B.2.3),
6) Gas engine, compressor and air cooler (sources that give secondary grade of release),
7) Process gas scrubbers and drains (sources that give secondary grade of release of the liquid phase).
8) Valves inside and outside of the shelter (sources that give secondary grade of release).
9) Pipe connections (sources that give secondary grade of release).

The rates of release for the purpose of this illustration are assessed as follows:

1) For starting gas, the gas flow rate delivered as shown in the manufacturer's data sheet for pneumatic starters,
2) For blowdown vent, the pressurized gas trapped in the compressor cylinders, scrubbers, pulsation bottles and process piping,
3) For gas engine shut-off valve vent, the gas trapped in the fuel line and cylinders,
4) For safety relief valves vent, the gas flow rate delivered in the manufacturer's data sheet for the respective pressure set point, or the gas flow rates calculated according to ~~B.7.1.2.1, or B.7.1.2.2~~ B.7.2.3.2 or B.7.2.3.3, or estimated otherwise.
5) For all other sources of release, the gas flow rates calculated according to ~~B.7.1.2.1, or B.7.1.2.2~~ B.7.2.3.2, or B.7.2.3.3, or estimated otherwise.



Key

1 – Air outlet ventilation opening

2 – Starting gas vent

3 – Compressor blowdown vent

4 – Fuel gas shut-off valve vent

5 and 5a – Pressure relief valve vents

6 – Compressor piston rod packings vent

Figure E.13 – Enclosed compressor handling natural gas

Table E.1 – Compressor facility handling natural gas

Classification procedure considerations for the shelter		
01	What are the flammable substances involved?	Process gas, gas condensate collected in the interstage scrubbers of the compressor units and engine fuel and starting gas.
02	Is the composition of those substances known?	It is known for the process, fuel and starting gas but it is not known for the process gas condensate. ~~We can assume~~ For the purpose of this example It has been assumed that it is a mixture of various ~~higher~~ heavier hydrocarbons, mostly pentane and hexane with water.
03	~~Can we calculate or reasonably assume the lower flammable limits of the flammable substances?~~ For this example values calculated or assumed for the lower flammable limits of the flammable substances are provided.	• for the process gas: LFL = 0,04; • for the fuel and starting gas: LFL = 0,05; • for the condensate: LFL = 0,013 to 0,08 depending on the compression stage.
04	What are the sources of release within the shelter?	Pipe connections on the gas engines, compressors, scrubbers and the piping as well as local instruments connections
05	What are the grades of release?	The grades of release are all secondary. It is assumed that there should be no gas in the ~~room~~ shelter under normal operating conditions provided that the facility is well monitored and maintained.

Classification procedure considerations for the shelter		
06	What would be the most representative sources of release under given conditions?	Reciprocating compressors rarely leak at the cylinders. However, they are ~~vibrant~~ vibrating machinery with the process piping exposed to dynamic and thermal stresses. Therefore, any ~~hot~~ pipe connection may be a source of release. The other realistic source of release would be crankcase breather valve of the compressor. When a piston rod packing gets worn or broken, then the compressed gas may blow-by, enter the crankcase and then leak through the breather valve into the surrounding area. There are also other sources of release which have to be scrutinized. Some may not be obvious and may remain hidden for quite some time thus raising the doubts about the grade.
07	Since the sources that give secondary grades of release are not summated, which of those should be chosen for the purpose?	The one that will give higher release rate, e.g. at 2nd stage of compression which is the more stressed, taking the release orifice of 2,5 mm^2 (see Table B.1). • M = 21,6 kg/kmol; • γ = 1,2; • p = 51 bar~~A~~; • T = 422 K (max allowed working temperature).
08	~~If we decide~~ Assuming that the leak at the blown gasket appears as more abundant, what would be the release rate?	Since the operating pressure indicates sonic release, the result shall be: $W_g \approx 1{,}54 \times 10^{-2}$ kg/s; with C_d being 0,75 and S as 2,5 mm^2 (see equation B.4) $Q_g \approx 1{,}85 \times 10^{-2}$ m^3/s
09	Is natural ventilation of the shelter possible at all ambient conditions throughout a year?	Yes, the buoyancy induced natural ventilation will be possible even during hot summer days because the heat dissipated by the engines and compressors will constantly keep the interior temperature above the ambient. The configuration of the shelter will also enable wind to enhance the ventilation no matter at which direction it is blowing.
10	What are the geometrical characteristics of the building?	• Length of the shelter: L = 12 m • Breadth of the shelter: B = 12 m • Overall height of the shelter: H = 8,0 m • Total volume concerned: $V \approx 1\,000$ m^3 • Volume under consideration: $V_0 \approx 0{,}80 \times V$ = 800 m^3; A volume less than V_0 is applied as an allowance for the enclosed equipment which reduces the effective volume. • Total effective area of the air inlet openings: A_1 = 30 m^2 • Total effective area of the air outlet openings: A_2 = 24 m^2 • Vertical distance between the midpoints of rear inlet and outlet openings: H_1 = 7,0 m • Vertical distance between the midpoints of front inlet and outlet openings: H_2 = 5,4 m • Average vertical distance between the midpoint of the openings: H_a = 6,2 m
11	What is the equivalent effective area of the lower opening?	$A_e \approx$ 26,5 m^2 (see C.5.2)
12	What are the temperatures at the most unfavourable conditions?	• Average inside temperature: T_{in} = 316 K • Outside temperature: T_{out} = 313 K
13	What is the volumetric flow rate of fresh air?	$Q_a \approx 10{,}7\ m^3/s$; with C_d being 0,75 (see equation C.4)
14	What is the number of air changes per hour in the volume under consideration?	$C = \frac{Q_a}{V_0} \approx 48\ h^{-1}$ 48 air changes per hour is selected for the purpose of this example to illustrate very draughty conditions and may not be applicable for actual conditions in a real situation.

Classification procedure considerations for the shelter		
15	What is the ventilation velocity?	The ventilation velocity should be calculated according to the air flow pattern and that implies that the referent cross section of the shelter is horizontal: $u_w = \frac{Q_a}{L \times B} \approx 0{,}075\, m/s$
16	What is the background concentration in the volume under consideration?	$X_b = \frac{f \times Q_g}{C V_0} \approx 0{,}18\% \approx 4{,}5\%\ LFL$ (see equation C.1)
17	What is the volumetric release characteristic?	~~; with k being 1,0~~ $Q_C \approx 0{,}5\ m^3/s$ Since the air flow pattern indicates movement of the air upwards, there is no reason to apply a more strict factor of ~~(in)efficiency~~ inefficiency of ventilation than 1,0.
18	What is the degree of dilution?	See the chart in Figure C.1 and find the intersection of the values for axis X and Y. The dilution appears as medium.
19	Is the background concentration in this volume higher than 25 % LFL?	No, it is 4,5 % LFL. Taking into account the answer, the degree of dilution can be considered as medium.
20	What is the availability of the ventilation?	The availability in naturally ventilated enclosed spaces should never be considered as good due to the various natural uncertainties. So we have to consider the availability as fair.
21	What will be the type of the zone within the shelter?	Taking into account the grades of release, the degree of dilution and the availability of ventilation, the interior of the shelter is classified as zone 2 (see Table D.1).
22	Is there any opening which may be considered as the source of release?	Yes, it is the rooftop outlet opening. It is type A opening.
23	What is the mass release rate of the gas through this opening?	$W_g = u_2 A_2 \rho_g X_b = u_w L B \rho_g X_b$ $W_g \approx 1{,}54 \times 10^{-2}$ kg/s; The result is the same as with equation (B.4) which is in compliance with Mass Conservation Law.
24	What is the degree of dilution?	The degree of dilution is again obtained by using the chart in Figure C.1, except that the ventilation velocity u_w is now the wind speed. We assume that 1,0 m/s is a realistic approximation taking into account the height of the opening above the ground (see Table C.~~1~~2). The degree of dilution still appears as medium.
25	What is the hazardous area around the opening?	The hazardous area shall apparently be zone 2 (see Figure E.14).
26	What is the hazardous distance around the opening?	The hazardous distance can be estimated by applying the method set in Annex D (see Figure D.1). Taking into account the position of the source of release, there is no need for too much conservatism and the lower curve should be the logical choice. Hazardous distance in the chart appears somewhat above 1,0 m so the zone will have the extent of 1,5 m (see Figure E.14).
27	Conclusion	The whole area under the shelter is zone 2. There is no need to extend the zone beyond the walls except at the rooftop where the air and gas mixture may escape as result of the buoyancy induced natural ventilation (see Figure E.14 and Figure E.15).

Similar considerations could be applied for other sources of release quoted in this case study.

Table E.2 – Hazardous area classification data sheet – Part I: Flammable substance list and characteristics

Plant: Compressor facility handling natural gas (case analysis) **Area:**														**Figures ~~E.2~~ E.14, ~~E.2a~~ E.15**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Flammable substance							**Volatility[a]**		**LFL/UFL**		**Ex characteristics**		
	Name	Composition	Molar mass (kg/kmol)	Relative density gas/air	Polytropic index of adiabatic expansion γ	Flash point (°C)	Ignition temp. (°C)	Boiling point (°C)	Vapour pressure 20 °C (kPa)	vol (%)	(kg/m^3)	Equipment group	Temp. class	Any other relevant information or remark, E.g. source of data
1	Process gas	80 % vol CH_4+ higher hydrocarbons	21,6	0,8	1,2	–	>400	–	–	4,0/18	0,036/ 0,162	IIA	T2	Laboratory report
2	Process gas condensate	Iso- and normal pentane, hexane and heptane	46	>3,0	–	<30	<300	<50	unknown	1,3 to 8,0/ UFL unknown	0,025 to 0,153/ UFL unknown	IIA	T3	The values are estimated
3	Starting and fuel gas	96 % vol CH_4+ higher hydrocarbons	16,8	0,6	1,3	–	>500	–	–	5,0/15	0,035/ 0,105	IIA	T1	Laboratory report

[a] Normally, the value of vapour pressure is given, but in the absence of that, boiling point also indicates the volatility.

Table E.3 – Hazardous area classification data sheet – Part II: List of sources of release *(1 of 2)*

Sheet 2 of 3

Plant: Compressor facility handling natural gas (case analysis) **Area:**																**Figures** ~~E.2~~ E.14, ~~E.2a~~ E.15
1	2	3	4	5	6	7	8		9	10	11	12	13	14		15	16
	Source of release					**Flammable substance**				**Ventilation**			**Hazardous area**				
	Description	Location	Grade of release[a]	Rate of release (kg/s)	Release characteristic (m^3/s)	Reference[b]	Operating temperature and pressure		State[c]	Type[d]	Degree of dilution[e]	Availability	Zone type 0-1-2	Zone extent (m)		Reference[f]	Any other information or remark
							(°C)	(kPa)						Vertical	Horizontal		
1	Air outlet opening	Roof top	S	1,54 × 10^{-2}	0,5	1	-	101, 325	G	N	Medium	Good	2	1,5	1,5		
2	Starting gas vent	Above the roof	P	0,5	16	3	25	1 000	G	N	Medium	Good	1	9,0 from vent outlet	9,0 from vent outlet		Manufacturer's data
3	Compressor blowdown vent	Above the roof	P	1,75	52	1	35	5 000	G	N	Medium	Good	1	8,0 from vent outlet	8,0 from vent outlet		~~Limited~~ Trapped volume release
4	Fuel gas shut-off valve vent	Above the roof	P	0,25	7,7	3	25	50	G	N	Medium	Good	1	6,0 from vent outlet	6,0 from vent outlet		~~Limited~~ Trapped volume release
5	Safety valve vent	Above the roof	S	1,8 × 10^{-2}	0,54	1	149	2 800	G	N	Medium	Good	2	3,0 from vent outlet	3,0 from vent outlet		Leak (not full flow operation)
5a	Safety valve vent	Scrubber	S	1,8 × 10^{-2}	0,54	1	50	5 500	G	N	Medium	Good	2	3,0 from vent outlet	3,0 from vent outlet		Leak (not full flow operation)
6	Piston rod packings vent	Above the roof	P/C	1,0 × 10^{-2}	0,3	1	25	101, 325	G	N	Medium	Good	0 or 1	1,5 from vent outlet	1,5 from vent outlet		
7	Gas engine	Inside the shelter	S	1,54 × 10^{-2}	0,5	3	25	50	G	N	Medium	~~Good~~ Fair	2	Interior of the shelter	Interior of the shelter		
7a	Compressor	Inside the shelter	S	1,54 × 10^{-2}	0,5	1	149	200 to 5 000	G	N	Medium	~~Good~~ Fair	2	Interior of the shelter	Interior of the shelter		
7b	Air cooler	Infront of the shelter	S	1,8 × 10^{-2}	0,54	1	50	2 500 to 5 000	G	N	Medium	~~Medium~~ Good	2	3,0 from air cooler	3,0 from air cooler		

Table E.3 *(2 of 2)*

Sheet 3 of 3

Plant: Compressor facility handling natural gas (case analysis) **Area:**															**Figures** ~~E.2~~ E.14, ~~E.2a~~ E.15
1	2	3	4	5	6	7	8		9	10	11	12	13	14	15	16
	Source of release					**Flammable substance**				**Ventilation**			**Hazardous area**			
	Description	Location	Grade of release[a]	Rate of release (kg/s)	Release characteristic (m^3/s)	Reference[b]	Operating temperature and pressure		State[c]	Type[d]	Degree of dilution[e]	Availability	Zone type 0-1-2	Zone extent (m)		Reference[f]	Any other information or remark
							(°C)	(kPa)						Vertical	Horizontal		
8	Process gas scrubber	Inside the shelter	S	$0{,}93 \times 10^{-2}$	0,4	1	50	2 500	L	N	Medium	~~Medium~~ Fair	2	Interior of the shelter	Interior of the shelter		
8a	Process gas scrubber	Outside of the shelter	S	$0{,}93 \times 10^{-2}$	0,4	2	50	5 000	L	N	Medium	~~Medium~~ Good	2	3,0 from the scrubber	3,0 from the srcubber		
9	Valves	Inside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	~~Medium~~ Fair	2	Interior of the shelter	Interior of the shelter		
9a	Valves	Outside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	~~Medium~~ Good	2	3,0 from valves	3,0 from valves		
10	Pipe connections	Inside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	~~Medium~~ Fair	2	Interior of the shelter	Interior of the shelter		
10a	Pipe connections	Outside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	~~Medium~~ Good	2	3,0 from pipe connections.	3,0 from pipe connections		

[a] C – Continuous; S – Secondary; P – Primary

[b] Quote the number of list in Part I

[c] G – Gas; L – Liquid; LG – Liquid gas; S – Solid

[d] N – Natural; A – Artificial

[e] See Annex C

[f] Indicate code reference if used or calculation reference

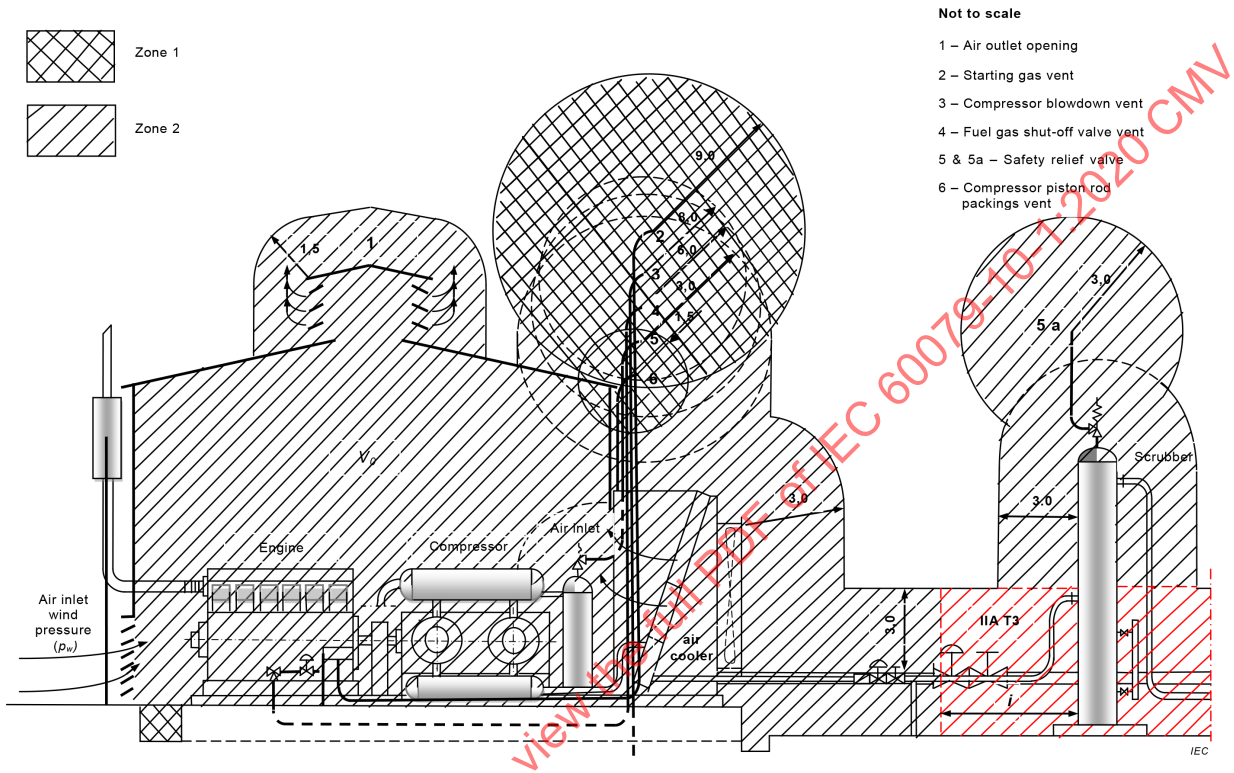


Figure E.14 – Example of hazardous area classification for a compressor facility handling natural gas (elevation)

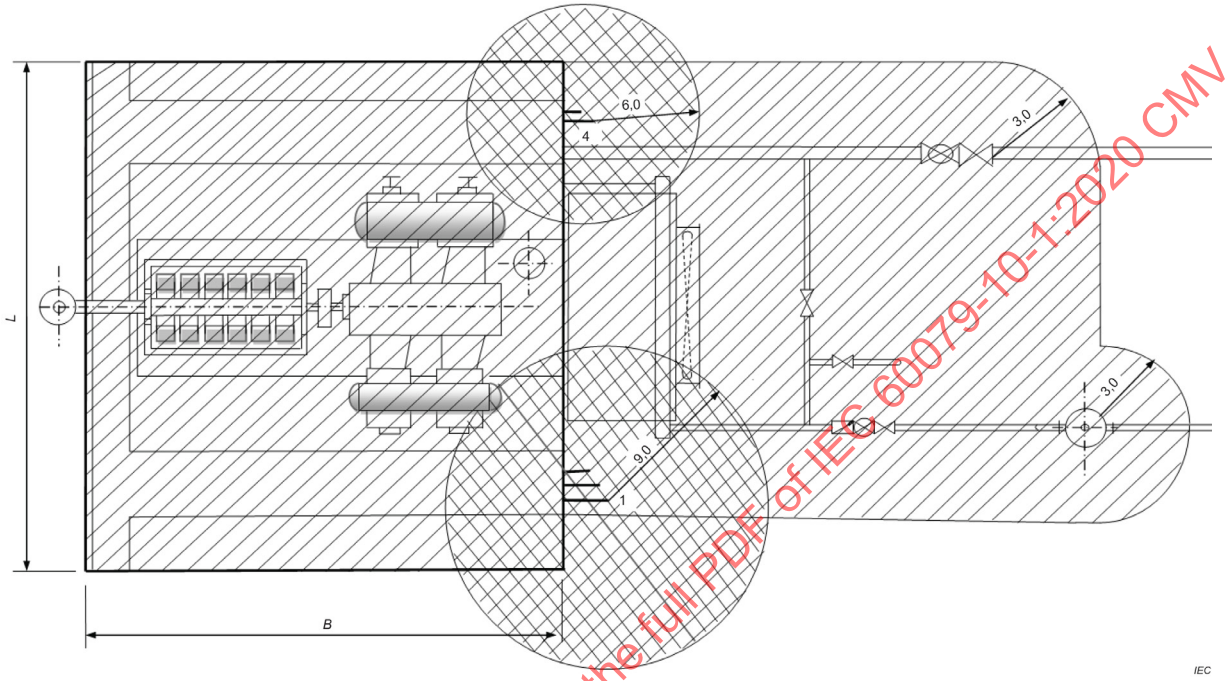


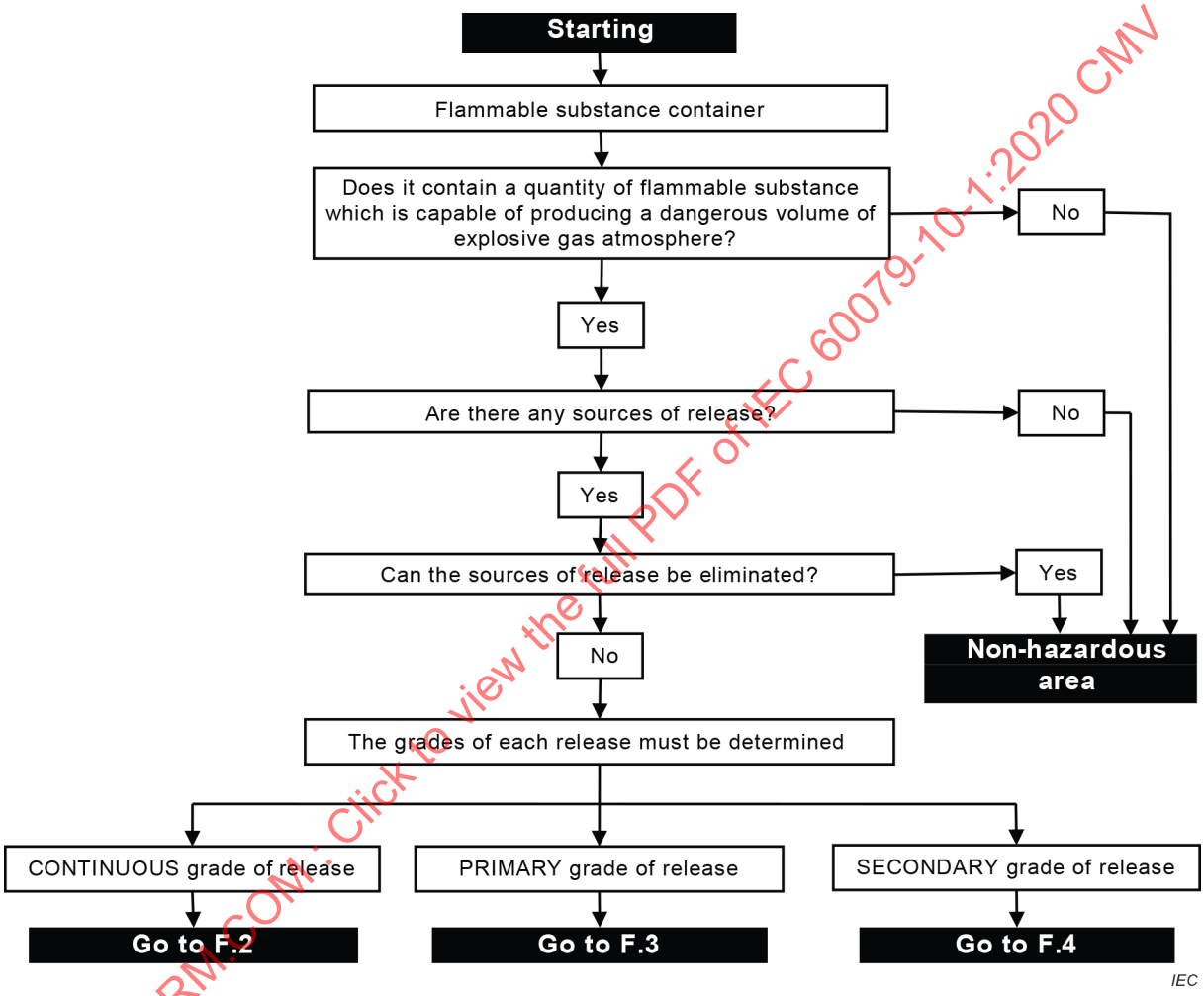
Figure E.15 – Example of hazardous area classification for a compressor facility handling natural gas (plan)

Annex F
(informative)

Schematic approach to classification of hazardous areas

F.1 Schematic approach to classification of hazardous areas

Figure F.1 shows a schematic approach to classification of hazardous areas.

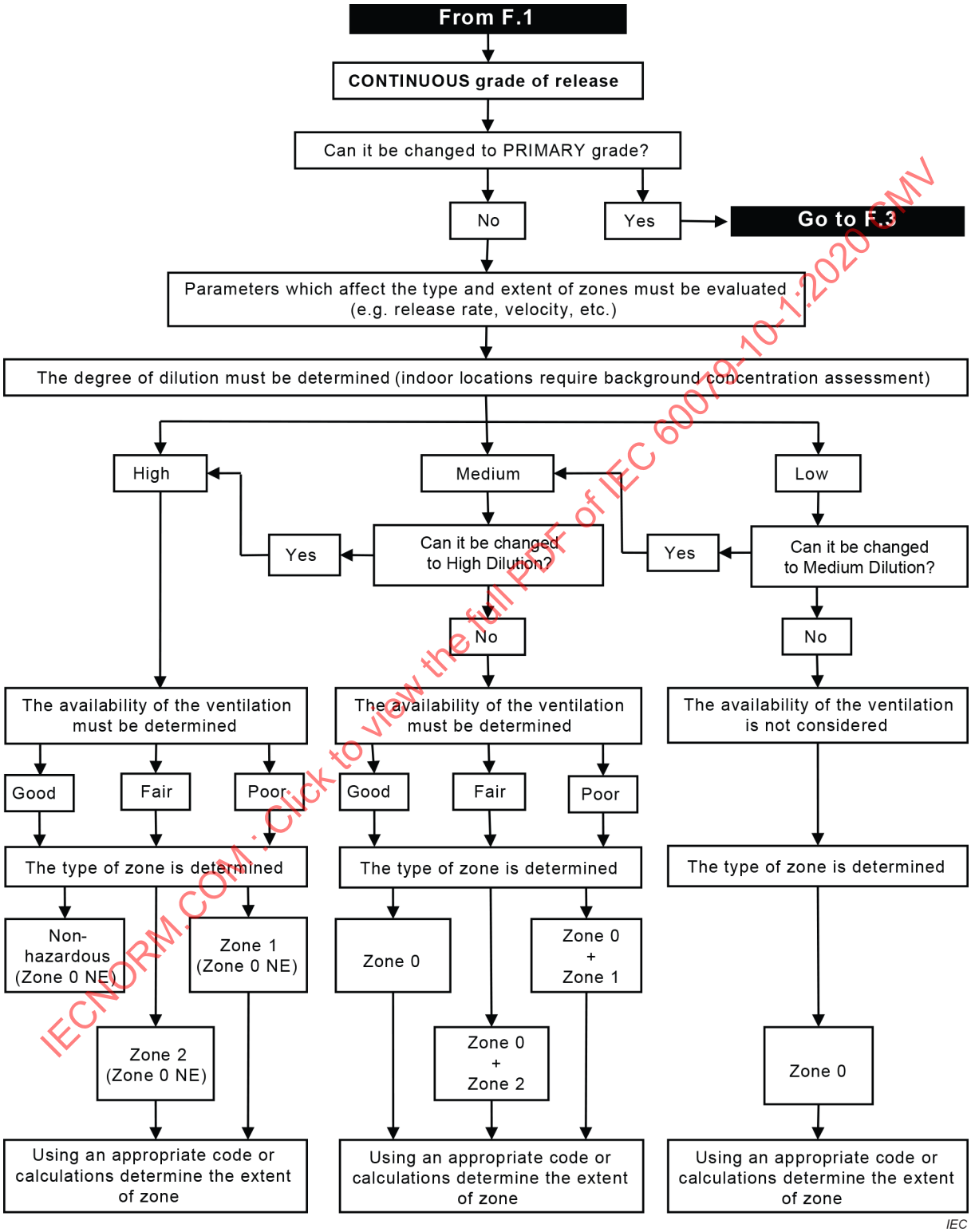


NOTE A source of release may give rise to more than one grade of release or a combination.

Figure F.1 – Schematic approach to classification

F.2 Schematic approach to classification of hazardous areas

Figure F.2 shows a schematic approach to classification of hazardous areas.

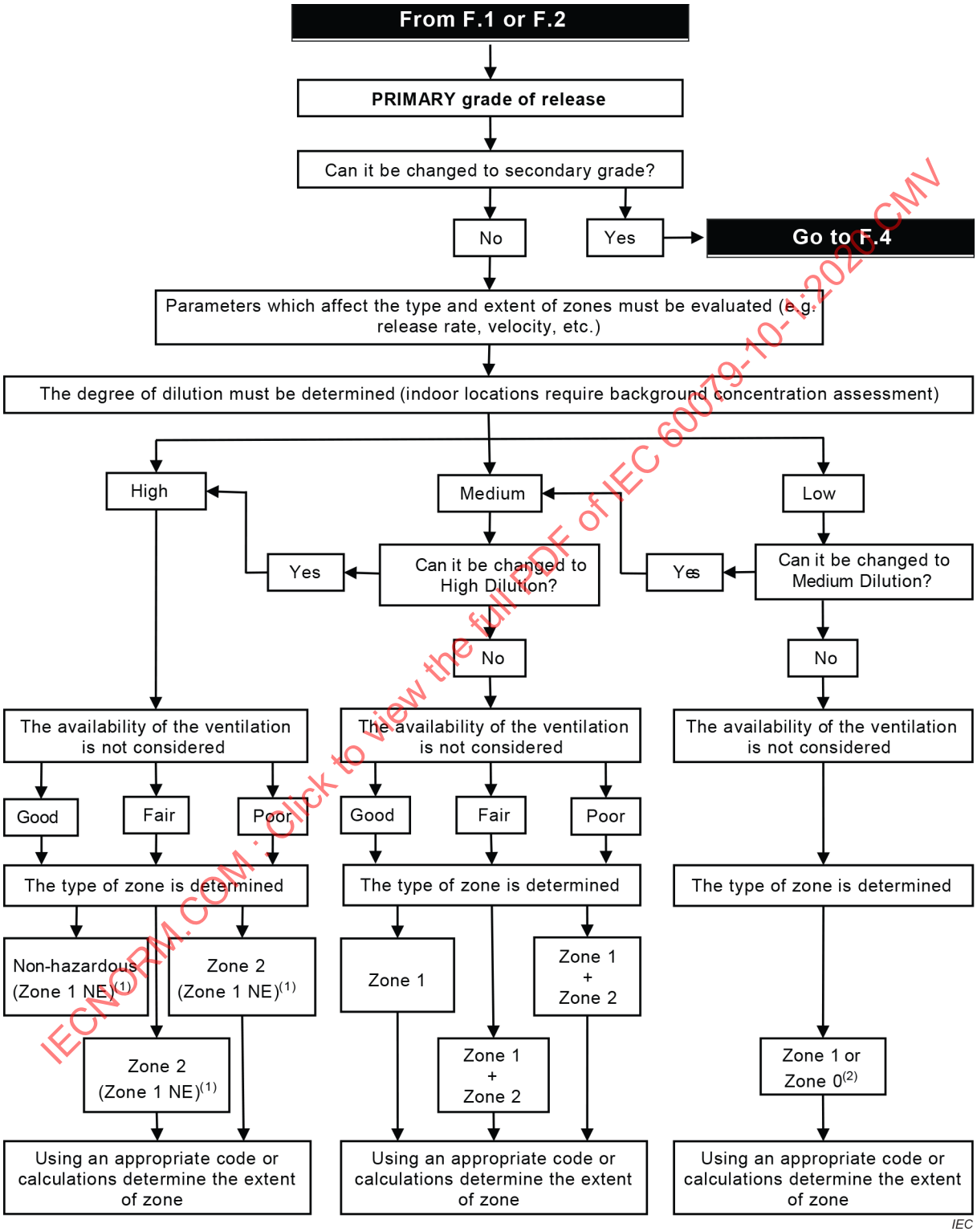


NOTE Zones NE indicate ~~theoretical~~ zones which would be of negligible extent under normal conditions.

Figure F.2 – Schematic approach to classification for continuous grade releases

F.3 Schematic approach to classification of hazardous areas

Figure F.3 shows a schematic approach to classification of hazardous areas.



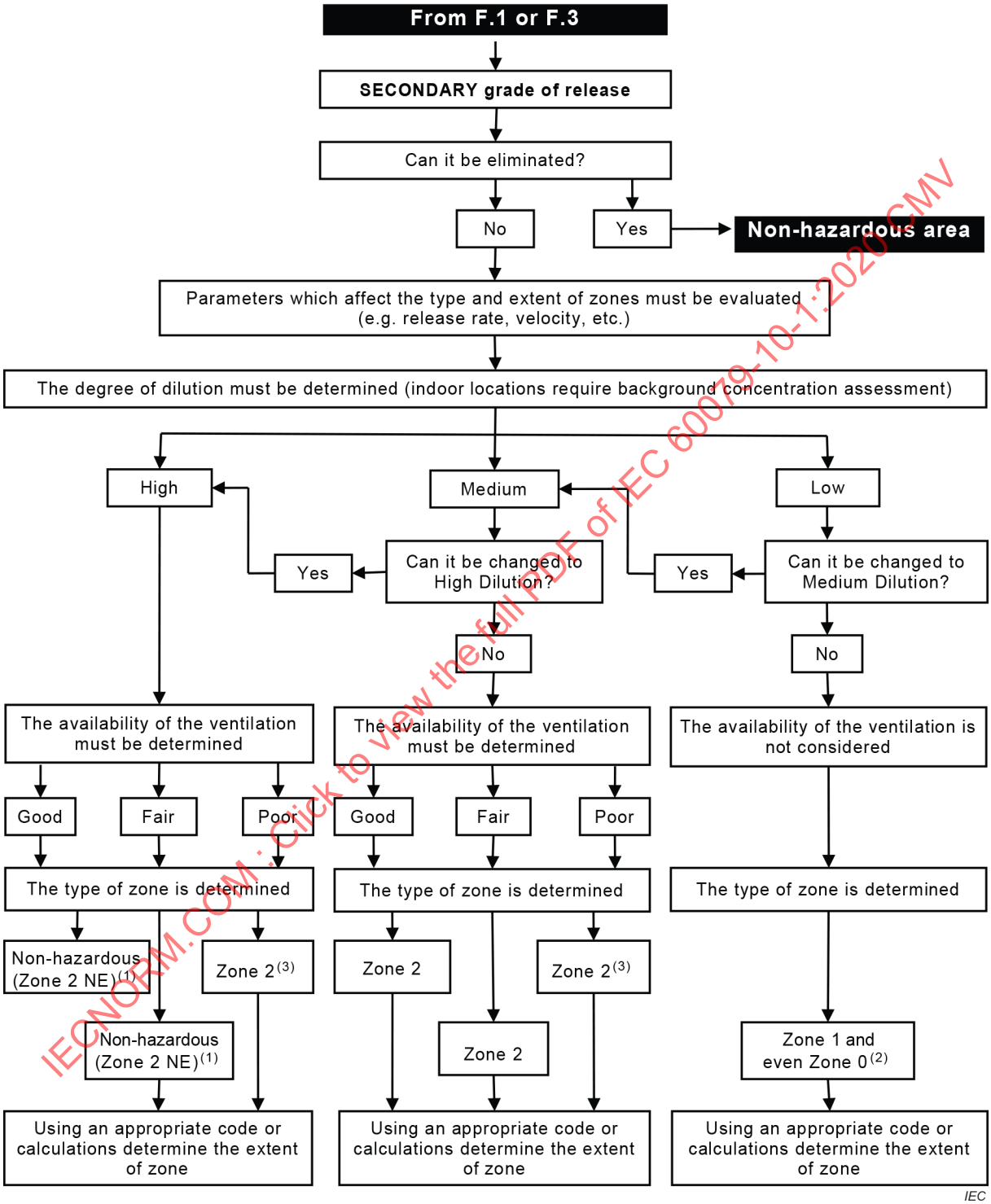
NOTE 1 Zones NE indicate ~~theoretical~~ zones which would be of negligible extent under normal conditions.

NOTE 2 Will be Zone 0 if the low dilution is so weak and the release is such that in practice an explosive gas atmosphere exist virtually continuously i.e. approaching a “no ventilation” condition.

Figure F.3 – Schematic approach to classification for primary grade releases

F.4 Schematic approach to classification of hazardous areas

Figure F.4 shows a schematic approach to classification of hazardous areas.



NOTE 1 Zones NE indicate ~~theoretical~~ zones which would be of negligible extent under normal conditions.

NOTE 2 Will be Zone 0 if the low dilution is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously i.e. approaching a “no ventilation” condition.

NOTE 3 The Zone 2 area created by secondary grade of release can exceed that attributable to a primary or continuous grade of release.

Figure F.4 – Schematic approach to classification for secondary grade releases

Annex G
(informative)

Flammable mists

G.1 When a liquid is handled at or above its flash point, any release will be treated through the normal hazardous area classification process described in this standard. If it is released below the flash point, under certain conditions, it may form a flammable mist cloud. Even the liquids that can be considered as non hazardous at process temperatures, in some situations may form a flammable mist which may then give rise to an explosion hazard. Examples of liquids that are commonly considered in this regard include high flash point liquid fuels, heat exchange oils and lubricating oils.

G.2 In practice, a liquid release will normally comprise of broad range of droplet sizes with larger droplets tending to fallout immediately, leaving only a small fraction of the release airborne in the form of ~~an aerosol~~ a flammable mist **87**. The flammability of the mist depends upon the concentration in air of the droplets plus any vapour, a function of the volatility of the liquid and the droplet sizes within the cloud. The size of droplets depends upon the pressure at which the liquid is being released, the properties of the liquid (primarily density, surface tension and viscosity) and the size and shape of the release opening. Normally, higher pressures and smaller openings will contribute to the degree of atomization of the release jet thus giving the rise to an explosion hazard. On the other hand, smaller release openings imply smaller release rates thus reducing the hazard.

G.3 It has been proved that ~~aerosol~~ flammable mist sized droplets are the most easily ignitable portion of the mist cloud, though generally these are only a small fraction of the total release. This fraction may increase if the release jet impacts on a nearby surface.

NOTE 1 ~~Aerosols~~ Flammable mists are small (sub-micron to 50 microns) particles in suspension in the atmosphere.

NOTE 2 Droplets in the ~~aerosol~~ flammable mist range might be as low as 1 % of the total mass released, subject to release conditions.

NOTE 3 Fuel droplet clouds have generally been found difficult to ignite, unless there is sufficient mass of vapour or very small droplets present.

G.4 The likelihood that the release of liquid will generate a flammable mist during normal operation and/or expected malfunctions should be carefully assessed along with the likelihood of events that could lead to such a release. The assessment may indicate that the release of substance is of a very low probability or that the mist cloud could be generated only during rare malfunctions or catastrophic failures. Assessments should be backed up by references or operational experience with similar plants. However, due to thermodynamic complexity of mists and a large number of factors that influence formation and flammability of mists, the reference may not be available for every given situation. In such cases, a judgement based upon relevant data should be applied.

G.5 It is important to point out that not every leak will cause a mist formation, e.g. the leaks through broken flange gaskets or stuffing boxes/packing glands that are the most common secondary grades of release in case of gases or vapours, will usually be negligible in case of viscous liquids and in most cases will cause dripping rather than mist. That means that the likelihood of mists being generated through leaks at pipe joints, valves, etc. should not be overstated. Such considerations should take into account the physical properties of the liquid, the conditions at which it is being handled, mechanical details of the equipment through which it is being processed, quality of equipment and obstructions near a source of release.

NOTE 1 For liquids released well below their flash point, examples of mist explosions are rare in process industries. This is probably due to difficulty in generating sufficiently small droplet sizes from an accidental release and the associated difficulty of ignition.

NOTE 2 Flammable mists may be ignited by sparks of similar energy as for vapour ignition but generally require very high surface temperatures for ignition. Ignition of mists by contact with hot surfaces generally requires temperatures higher than for vapour ignition.

G.6 If formation of a flammable mist is considered possible, then the source of release should preferably be contained or managed to reduce the hazard, e.g. by porous guards in order to promote the coalescing of the mist, mist detectors or suppression systems. Where containment or similar controls cannot be assured, then the potential for a ~~hazardous area~~ mist hazard should be considered. However, because the dispersion mechanisms and the criteria of flammability for mists are different than those for gases and vapours, the methodology of classification presented in Annex B cannot be applied.

NOTE 1 The conditions that are needed to form a flammable mist are so complex that only a qualitative approach may be appropriate. It might be useful to identify the factors related to the handled liquid which contribute to formation, and to the flammability of mist. These factors along with the probability of events that would lead to release of the liquid may be sufficient to evaluate the degree of the hazard and help to decide whether a hazardous area is required.

NOTE 2 In general, the only element relevant to determining the type of zone is the grade of release. In most cases, it will be a secondary grade of release. Continuous or primary grades of release would typically be associated with equipment which is intended for spraying, e.g. spray painting.

~~If a hazardous area for mist has been established, it shall be distinguished on the area drawing from other areas associated with gases and vapours, e.g. by appropriate marking.~~ **88**

G.7 Taking into account that there are many uncertainties involved in formation of a flammable mist cloud, the assessment of a mist hazard should be based on specific industry experience and specific codes. E.g. Mist hazards are recognized for some heat transfer applications where the liquid is heated to near or above the flashpoint and used at very high temperatures. Mist hazards for typical fuel distribution networks designed to suitable piping codes are not considered a credible risk based on the many years of operations for such installations worldwide.

NOTE Industry codes for the classification of hazardous areas for flammable liquids generally do not account for misting as if misting was considered then larger hazardous areas would be recommended for common applications. This also suggests the potential for mists due combustible liquids should not be overstated when the combustible liquid is handled at a similar pressures and with comparable integrity of piping codes. **89**

G.8 If a mist hazard has been established, it should not be classified as Zone 0, 1 or 2 hazardous areas as the types of protection applied for these zones are not required for mist hazards. See IEC 60079-14. The potential for a mist hazard should be distinguished on the area drawing from other hazardous areas associated with gases and vapours, e.g. by appropriate marking. **90**

G.9 Even the mists that are not ignitable according to the criteria of droplets size could eventually land on a hot surface, relative to the auto-ignition temperature of the vapour, thus causing a fire hazard. Other high energy ignition sources such as flames should also be considered. Care should be taken to contain potential releases and prevent contact with hot surfaces and other high energy ignition sources.

G.10 Mists require minimum concentrations to be flammable (in a similar manner to flammable vapours or combustible dusts). For ~~non-flammable~~ liquids well below their flash point, this would typically be associated with a cloud that reduces visibility.

Mists are typically visible and hence releases can be usually mitigated. Consideration should be given to the time frame before a leak is detected.

NOTE Lower flammability limits for fuel ~~aerosols~~ flammable mists have been shown to be similar to or less than those associated with the fuel vapour.

G.11 Flammable mists may occur within equipment due to oil lubrication systems, splashing or agitation as a part of the process operations. The hazards associated with internal parts of process plant should then be considered ~~as hazardous areas~~ and may require specific mitigation measures to be applied. E.g. mist explosion or fire suppression system. Under certain conditions, such mists may also be vented to atmosphere, e.g. lubricating oil mists through crankcase breathers, tank or gearbox vents, thus giving the rise to fire hazard. Venting of such mists should preferably be eliminated by mist extractors.

G.12 Additional considerations should be applied for situations where the liquids are being sprayed intentionally, e.g. spray painting. Hazardous area classification in such cases is usually the subject of specific industrial codes.

G.13 IEC 60079-14 for selection of equipment and installations does not include requirements for mist hazards due to liquids with a high flash point where flammable vapours are not present.

Annex H
(informative)

Hydrogen

H.1 The flammable range of hydrogen in air is between 4 % and 77 % by volume. Hydrogen is also commonly found in mixtures of flammable gases such as refinery process streams. With gas mixtures, the ~~gas~~ equipment group should be considered as IIC or IIB+H_2 where a gas mixture includes 30 % or more of hydrogen by volume unless other specific data is available. The temperature class should be taken as the lowest auto-ignition temperature for any gas exceeding 3 % in the mixture.

NOTE ~~IEC 60079-20-1~~ ISO/IEC 80079-20-1 includes guidance for specific gas mixtures including hydrogen such as coke oven gas and industrial methane for relevant ~~gas~~ equipment groups.

H.2 The auto-ignition temperature of hydrogen is 560 °C. Although very high temperatures are required to ignite a hydrogen-in-air mixture, precautions should be taken to ensure hydrogen leaks are not exposed to any hot surfaces.

H.3 The diffusion rate of a gas due to buoyancy is proportional to its density relative to that of air. Hydrogen is a lighter than air gas which diffuses rapidly with a tendency to rise upwards. However, as the gas diffuses the bulk density of a given volume will tend to approach that of air. As the concentration of hydrogen reduces, such that the bulk density approaches that of air, the low concentration of hydrogen will tend to move with the air.

H.4 High volume releases of hydrogen are likely to accumulate in overhead spaces. A hydrogen gas release can form gas pockets in alcoves, roof peaks, and dormers which tend to be poorly ventilated. Conversely, relatively small openings in such spaces will allow hydrogen to escape and may be sufficient to prevent hydrogen concentrating due to low volume releases.

H.5 Hydrogen gas releases will generally result in a jet plume in the orientation of the point of release. Once the jet momentum is dissipated the plume will take a more vertical ascent and generally harmlessly disperse in a well ventilated area.

H.6 A liquid hydrogen spill, which commonly has a vessel saturation pressure of 4 bar, can suddenly expose the cryogenic content of the vessel to ambient pressure. Such a condition will instantly boil or flash a significant portion of the liquid to cryogenic vapour potentially resulting in the remaining contents to spill. Liquid hydrogen boils at 20 K at 1 atmosphere and the contents when exposed to ambient temperatures will have sufficient heat to rapidly vaporize the liquid hydrogen. The exposed cross-sectional area of the liquid hydrogen spill affects the rate at which the contents flash to vapour and warms. At hydrogen's boiling point, the cold hydrogen vapour is heavier than air until it warms. As the cold vapours mix with air, the air can be chilled below the dew point, causing condensation and forming a visible cloud. After dwelling near the ground and warming sufficiently, the visible vapour cloud may form a plume as it rises.

H.7 The flame fronts observed with hydrogen-in-air mixtures burn less readily when constrained to burning in a horizontal direction, and even less so in a downward direction.

The release of a large quantity of hydrogen can form a plume that possesses an increasing concentration of hydrogen towards the centreline of the plume. Regions of lower-concentration hydrogen-air mixtures require greater initiation energy to ignite than those of higher concentration towards the centre of a plume. Movement and water vapour in a plume will also result in greater initiation energy when compared to the same composition mixture, that is dry and without movement.

Therefore, as a plume of hydrogen rises, the exterior regions of the plume (the regions likely to encounter an ignition source) are less likely to ignite when compared to near-stoichiometric mixtures. Should ignition occur in an exterior region of the plume, only the gas in the immediate vicinity of the ignition source will tend to burn and the potential for flame propagation or deflagration throughout the cloud is reduced. Therefore, unless some process rapidly mixes the hydrogen plume to form a near-stoichiometric mixture with air throughout the cloud, the normal factors that typically influence mixing (diffusion, buoyancy, wind, and turbulence) in a release will not result in complete combustion of the plume.

H.8 Mitigation strategies for hydrogen release should consider providing for rapid ascension of the gas to open air away from structures to assist with prevention of potential ignition during a release. Indoors, supplemental ventilation and/or adequate space for dilution and dispersion of a release may be provided. Where gas detection is used as a control measure, sensors should be placed above release points and/or near the ceiling, exit fan or exit duct. The sensors require a routine calibration schedule, and the sensor should only be calibrated using hydrogen as the calibration gas.

H.9 Hydrogen gas has several personnel safety and health hazard implications that should be considered during facility installation.

Hydrogen gas has the potential to cause oxygen deficiency. An increased hydrogen-in-air mixture condition may be safe for breathing for short periods of time, but the atmosphere would be above the lower flammable limit (LFL) causing a potentially explosive gas atmosphere.

Hydrogen flames, unless seeded with impurities, are very hard to see in daylight. This property, combined with its low emissivity producing very little infrared radiation, makes hydrogen combustion hard to sense until physical contact is made with the flame. Hydrogen combustion in air also produces ultraviolet (UV) radiation capable of producing effects similar to overexposure to the sun. Direct exposure to hydrogen flames produces immediate burns.

Hydrogen is very easily ignited where it is released and ignition and/or fire is normally expected to occur. Small leaks may occur and ignite, but go unnoticed until maintenance personnel enter the area. A plume of hydrogen that is ignited will rapidly flash back to the source of hydrogen. From the perspective of controlling hazards, a hydrogen fire localized to a source or leak is often preferable to a growing hydrogen plume.

Where hydrogen leaks are known to be problematic, e.g. very high pressure or high temperature systems, then additional safeguards for the leak sources should be considered. These safeguards could include:

- Deflection guards to limit jet momentum and promote dispersion,
- Steam jets around the source of release to cool high temperature releases, wet the gas and modify jet dispersion behaviour.

Combustion of a hydrogen cloud will occur completely within several seconds. There is not enough deposition of thermal energy to ignite typical substances of construction used in buildings. Personnel caught in close proximity may be severely burned and directly exposed flammable liquids may also be ignited.

Hydrogen stored at high pressure will normally produce a jet on release. If ignited, this would create a loud jet of nearly invisible flame that would be extremely dangerous to anything in its path. In high pressure systems with joints that are known to be susceptible to leakage supplemental controls should be considered.

H.10 ISO/TR 15916 provides additional guidance on safety for hydrogen but does not consider the classification of hazardous areas or suitably reference the IEC 60079 series. In this case the safety guidance may be useful but the requirements from IEC 60079 series and ISO/IEC 80079 series should also be followed. **91**

Annex I
(informative)

Hybrid mixtures

I.1 General

A hybrid mixture is a combined mixture of a flammable gas or vapour with a combustible dust or combustible flyings. This hybrid mixture may behave differently than the gas/vapour or dust individually. The number of situations that may be encountered in industry will be highly variable and as such it is not practical to provide specific guidance. However this Annex provides guidance on issues that should be considered when hybrid mixtures are found.

I.2 Use of ventilation

The use of ventilation as a control measure needs to be carefully considered as it may reduce the gas/vapour hazard but increase the dust hazard or have other varying effects on the different components of the mixture.

I.3 Concentration limits

A hybrid mixture may form an explosive atmosphere outside the individual explosive limits of the gas/vapour or explosive concentrations for the dust. It is recommended, unless further data is available, that a hybrid mixture is considered explosive if the concentration of the gas/vapour exceeds 25 % of the LFL or the concentration of the dust exceeds 25 % of the *MEC*.

I.4 Chemical reactions

Considerations should also be taken to chemical reactions that may occur within the materials or entrapped gas in the dust that may result in evolution of gas in the process.

I.5 Energy/temperature limits

Where a hybrid mixture exists, the minimum ignition parameters such as MIE and auto-ignition temperature for gas/vapour or minimum ignition temperature of a dust cloud could be lower than any component parameter in the mixture. In the absence of other information, the parameter used should be the lowest of any component in the mixture.

I.6 Zoning requirements

Consideration should be given to the assignment of both gas and dust zones with the same rating to match the worst case requirement for any component, e.g. zone 21 with zone 2 should be considered as zone 21 with zone 1. It should be identified that the result of ignition of any component will lead to a worst case consequence when considering any EPL assessment.

Annex J
(informative)

Useful equations in support to hazardous area classification

J.1 General

The approach to hazardous area classification requires sound understanding of flammable substance properties to identify their behaviour when released or being released. The following sections contain useful equations that could be used to calculate some parameters influencing the dispersion and dilution of flammable gas or vapour in air at ambient conditions. Laboratory or field tests are preferred where appropriate.

J.2 Dilution with air of a flammable substance release

The theoretical minimum ventilation flow rate of fresh air to dilute a given release of flammable substance to a concentration below the lower flammable limit $Q_{a\ min}$ can be calculated by means of the equation:

$$Q_{a\,min} = \frac{W_g}{k\,LFL_m} \times \frac{T_a}{293}$$

where

$Q_{a\ min}$ is theoretical minimum ventilation flow rate of fresh air required for dilution (m^3/s);

W_g is the release rate of flammable substance (kg/s);

k is the safety factor attributed to LFL_m ($\leq 1{,}0$);

LFL_m is the mass based lower flammable limit (kg/m^3);

T_a is the ambient temperature (K).

EXAMPLE

Find the theoretical minimum ventilation flow rate of fresh air required to dilute a release rate W_g = 0,003 kg/s of benzene due to the evaporation of a confined liquid pool, at an ambient temperature of 40 °C:

$$Q_{a\,min} = \frac{W_g}{k\,LFL_m} \times \frac{T_a}{293} = \frac{0{,}003}{0{,}5 \times 0{,}039} \times \frac{313}{293} = 0{,}164\ m^3/s$$

NOTE The lower flammable limit was taken from IEC 60079-20-1.

$$Q_{a\,min} = \frac{Q_g}{LFL} \times \frac{T_a}{293} \qquad (J.1)$$

where

$Q_{a\ min}$ is theoretical minimum ventilation flow rate of fresh air required for dilution (m^3/s);

Q_g is the volumetric release rate of flammable substance (m^3/s);

LFL is the lower flammable limit (vol/vol);

T_a is the ambient temperature (K).

Safety margins should always be considered to account for other factors such as turbulence or uneven distribution of the fresh air.

EXAMPLE

Find the theoretical minimum ventilation flow rate of fresh air required to dilute a release rate Q_g = 8,64 × 10^{-4} m^3/s of benzene due to the evaporation of a confined liquid pool, at an ambient temperature of 40 °C:

$$Q_{a\,min} = \frac{Q_g}{LFL} \times \frac{T_a}{293} = \frac{8{,}64 \times 10^{-4}}{0{,}012} \times \frac{313}{293} = 0{,}077\ m^3/s$$

A safety margin could be considered upon a sound judgement and hence a higher value would be obtained.

NOTE The lower flammable limit was taken from ISO/IEC 80079-20-1.

J.3 Estimate of the time required to dilute a flammable substance release

The theoretical time t_d required to dilute the concentration of flammable substance from a certain steady state background concentration X_b to a required critical concentration X_{crit}, in a specific volume, can be estimated from:

~~$$t_d = \frac{1}{C} \ln\left(\frac{X_b}{X_{crit}}\right)$$~~

$$t_d = \frac{f}{C} \ln\left(\frac{X_b}{X_{crit}}\right) \qquad \text{(J.2)}$$

where

t_d is the theoretical time required to dilute a defined value of flammable substance concentration to another one lesser than first (s);

f is the ventilation inefficiency factor;

C is the number of air changes per unit time in the specific volume (s^{-1});

X_b is the flammable substance background concentration at steady-state conditions (vol/vol);

X_{crit} is the desired/critical value of the flammable substance concentration (vol/vol).

EXAMPLE

~~Find the theoretical time to reduce a flammable substance concentration into an enclosure artificially ventilated to obtain a number of air changes per unit time C = 6 h^{-1} (0,002 s^{-1}) from the initial value X_b = 0,012 to the desired value X_{crit} = 0,0024.~~

~~$$t_d = \frac{1}{C} \ln\left(\frac{X_b}{X_{crit}}\right) = \frac{1}{0{,}002} \times \ln\left(\frac{0{,}012}{0{,}0024}\right) = 2\,347\ s = 0{,}65\ h$$~~

Find the theoretical time to reduce the average flammable substance concentration in an artificially ventilated enclosure with a number of air changes per unit time C = 0,002 s^{-1} (≈ 6 h^{-1}) from the initial value X_b = 0,012 to the desired value X_{crit} = 0,0024 if the ventilation inefficiency factor is 3:

$$t_d = \frac{f}{C} \ln\left(\frac{X_b}{X_{crit}}\right) = \frac{3}{0{,}002} \times \ln\left(\frac{0{,}012}{0{,}0024}\right) = 2415\ s = 40{,}3\ \text{min}$$

The theoretical time t_d calculated as above is based on an ideal dilution of the flammable substance released into the enclosure. Safety margins should always be considered to account other factors such as turbulence or uneven distribution of the flammable substance.

Annex K
(informative)

Industry codes and national standards

K.1 General

In general, examples of classification may be accepted in accordance with national or industry codes where their application to the particular situation can be clearly demonstrated. Any criteria or limitations identified in the ~~national or~~ industry code or national standard should be followed.

If it is intended that the examples given in the reference ~~national or~~ industry codes or national standards be used for hazardous area classification, account ~~must~~ should be taken of the specific details of each individual case, e.g. process and location characteristics.

In general, the examples provided in industry codes and national standards are based on the assumption that plant and equipment are adequately maintained.

The codes and standards may not apply to specific situations, for example where:

a) the quantity of release is either very large or very small;

b) the design of a particular plant does not comply with all the requirements of the appropriate national standard or industry code; or

c) ventilation, use of inert gases, vapour barriers or other methods are used to reduce the extent of the hazard or the likelihood of the occurrence of a particular hazardous area.

Where the use of examples from specific codes or standards is followed, standards and codes addressing the same example should not be interchanged, e.g. where a standard is selected as a preferred base for a site or application, examples from another standard should not be selected to achieve a less rigorous classification without due justification. Notwithstanding this principle, in some cases the classification examples provided in relevant industry codes or national standards can, where appropriate, be used to classify some components of larger plants associated with other relevant national or industry codes.

Where examples from industry codes or national standards are used, then they ~~shall~~ should be quoted as the basis for classification ~~and not~~ rather than IEC 60079-10-1. Examples of national standards or industry codes include, but are not limited to those shown in Table K.1. The countries of origin are listed in alphabetical order.

Table K.1 – Examples of codes and standards

Country or Region of Origin	Code or Standard Designation	Title	Developing Body	Application Notes
Australia and New Zealand	AS/NZS (IEC) 60079.10.1	Explosive Atmospheres Part 10-1: Classification of areas – Explosive Gas Atmospheres	Standards Australia/ Standards New Zealand	~~Introduced in AS/NZS 60079.10.1 as the national Annex~~ Additional detail is included in AS/NZS 60079.10.1 as a national Annex or Supplement
Germany	~~DGUV-Regel 113-001 "Explosions schutz-Regeln (Rx-RL)"~~	~~ExRL "Explosionsschutz-Regeln – Regeln für das Vermeiden der Gefahren durch explosionsfähige Atmosphäre mit Beispielsammlung"~~ ~~ExRL "Explosion Protection- Rules – Rules for avoiding the dangers of explosive atmospheres with examples collection"~~		
	~~TRBS 2152.~~	~~Technischen Regeln für Betriebssicherheitsverordnung~~ ~~Technical Rules for Plant Safety Provisions~~		
	DGUV-Regel 113-001 "Explosionsschutzregeln (EX-RL)"	Explosionsschutz-Regeln (EX-RL) – Sammlung technischer Regeln für das Vermeiden der Gefahren durch explosionsfähige Atmosphäre mit Beispielsammlung zur Einteilung explosionsgefährdeter Bereiche in Zonen Explosion Protection Rules (EX-RL) – Collection of technical rules for avoiding the dangers of explosive atmospheres with examples collection for classification of hazardous areas into zones	DGUV-Deutsche Gesätzliche Unfallversicherung	
	TRBS 2152/ TRGS 720	Gefährliche explosionsfähige Atmosphäre – Allgemeines Hazardous explosive atmospheres – General information	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	

Country or Region of Origin	Code or Standard Designation	Title	Developing Body	Application Notes
	TRBS 3151/TRGS 751	Vermeidung von Brand-, Explosions und Druckgefährdungen an Tankstellen und Gasfüllanlagen zur Befüllung von Landfahrzeugen Avoidance of fire, explosion and pressure hazards at filling stations and gas filling systems for filling land vehicles	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	
	TRGS 509	Lagern von flüssigen und festen Gefahrstoffen in ortsfesten Behältern sowie Füll und Entleerstellen für ortsbewegliche Behälter Storage of liquid and solid hazardous substances in fixed containers as well as filling and emptying points for mobile containers	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	
	TRGS 510	Lagerung von Gefahrstoffen in ortsbeweglichen Behältern Storage of hazardous substances in transportable containers	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	
~~Italy~~	~~GUIDA CEI 31-35 & GUIDE CEI 31-35/A~~	~~Explosive atmospheres – Guide for classification of hazardous areas for the presence of gas in application of CEI EN 60079-10-1 (CEI 31-87)~~	~~CEI – Comitato elettrotecnico Italiano CEI – Italian Electrotechnical Commission~~	~~Scope of this Guide is the analysis in details of the classification of hazardous areas due to the presence of flammable gases, vapours or mists, according to IEC standard 60079-10-1.~~
Sweden	Klassning av explosionsfarliga områden	Classification of Hazardous Areas	SEK Svensk Elstandard	Available only in Swedish
Switzerland	SUVA Merkblatt Nr. 2153	Explosionsschutz-Grundsätze- Mindestvorschriften-Zonen Explosion protection-Basics-Minimal requirements-Zones	Schweizerische Unfall-versicherungsanstalt	
The Netherlands	NPR 7910-1	Netherlands practical guideline NPR 7910-1, Classification of hazardous areas with respect to explosion hazard – part 1: gas explosion hazard, based on NEN-EN-IEC 60079-10-1	Netherlands Standardization Institute, NEN	

Country or Region of Origin	Code or Standard Designation	Title	Developing Body	Application Notes
UK	~~IP15~~ EI15	Model code of safe practice for the petroleum industry, Part 15: Area Classification Code for Petroleum Installations Handling Flammable Liquids.	Energy Institute	~~IP15~~ EI15 is used as an industry standard in the petro(chem) industry in many countries
	IGEM/SR/25	Hazardous area classification of natural gas installations.	Institution of Gas Engineers and Managers	
USA	API RP 505	Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities classified as Class I, Zone 0, Zone 1 and Zone 2.	American Petroleum Institute (API)	
	NFPA 59A	Standard for the Production, Storage, and Handling of Liquefied Natural Gas.	National Fire Protection Association	
	NFPA 496	Standard for Purged and Pressurized Enclosures for Electrical Equipment	National Fire Protection Association	Where relevant to pressurized control room
	NFPA 497	Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapours and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.	National Fire Protection Association	

Bibliography

[1] A.W. Cox; F.P. Lee & M.L. Ang; *Classification of Hazardous Locations, Ichem*, 1993

[2] IGEM/SR/25; *Hazardous Area Classification of Natural Gas Installations*; UK Institution of Gas Engineers and Managers, 2010

[3] P.F. Linden, *The Fluid Mechanics of Natural Ventilation,* Annual Review, Fluid Mechanics, 1999.

[4] A. Walker, *Natural Ventilation*, National Renewable Energy Laboratory, 06.03.2008

[5] ASHRAE, Handbook of Fundamentals, 2001

[6] M.J. Ivings, S. Clarke, S.E. Gant, B. Fletcher, A. Heather, D.J. Pocock, D.K. Pritchard, R. Santon and C.J. Saunders, 2008, *Area Classification for secondary releases from low pressure natural gas systems,* Health and Safety Executive Research Report RR630

[7] Ballal and Lefebvre (1982), *Flammability of Fuel Mists.* Int. Symposium of Combustion

[8] Bowen and Shirvill (1994), *Combustion Hazards posed by Pressurised Release of High Flashpoint Liquid Fuels* (Journal of Loss Prevention)

[9] Bowen, Bull and Rowson (1997), *Explosions in Fuel Aerosol Systems*. Combustion, Science and Technology

[10] Bowen and Cameron (2001), *Explosions in Flammable Mists: A Review*. Journal of Institute of Chemical Engineers

[11] R P Cleaver, R E Britter, *A workbook approach to estimating the flammable volume produced by a gas release*, FABIG Newsletter, Issue 30, R416 (2001)

[12] Maragkos and Bowen (2003), *Combustion Hazards from Impinging Jets of High* Flashpoint Liquid Fuels. Int. Symposium on Combustion

~~[13] The Institute of Petroleum, *Model Code of Safe Practice – Part 15 – Area Classification Code for Installations Handling Flammable Fluids; 2005-07*~~

~~[14] The Institute of Petroleum, *Model Code of Safe Practice – Part 15 – Area Classification Code for Installations Handling Flammable Fluids; 2005-07*~~

[13] The Energy Institute, *Model Code of Safe Practice – Part 15 – Area Classification Code for Installations Handling Flammable Fluids; 4th Edition, June 2015*

[14] The Institute of Petroleum, *A Risk Based Approach to Hazardous Area Classification – 1998-11*

[15] American Petroleum Institute, *Risk Based Inspection – Base Resource Document – API Publication 581; 2000-05*

[16] American Petroleum Institute, *Risk-Based Inspection Technology – API Recommended Practice 581: 2008-09*

[17] BS 5925:1991, *Code of practice for ventilation principles and designing for natural ventilation*

[18] IEC 60050, *International Electrotechnical Vocabulary*

[19] IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

[20] IEC 60079-10-2, *Explosive atmospheres - Part 10-2: Classification of areas - Explosive dust atmospheres*

[21] IEC 60079-13, *Explosive atmospheres - Part 13: Equipment protection by pressurized room "p" and artificially ventilated room "v"*

[22] IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

[23] IEC 61285, *Industrial-process control - Safety of analyser houses*

[24] IEC 61511-1:2016, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and application programming requirements*

[25] European Standard EN 1127-1, *Explosive Atmospheres – Explosion Prevention and Protection – Part 1: Basic Concept and Methodology; ~~2010-05~~ 2019-08*

[26] Comitato Elettrotecnico Italiano, *Guide CEI 31-35 – Electrical Apparatus for Explosive Gas Atmospheres – Guide for Classification of Hazardous Areas; 2011-03*

[27] American National Standards, *Pipe Flanges and Flange Fittings: 1981*

[28] Committee for the Prevention of Disasters (TNO Yellow Book), CPR-14E, *Methods for the Calculation of the Physical Effects Due to Releases of Hazardous Substances, The Hague, The Netherlands; 1997*

[29] D M Webber, M J Ivings, R C Santon (2011), *Ventilation theory and dispersion modelling applied to hazardous area classification;* Journal of Loss prevention in the Process Industries

[30] U.S. Environmental Protection Agency, ~~Federal Emergency Management Agency, U.S. Department of Transportation, *Technical Guidance for Hazard Analysis – Emergency Planning for Extremely Hazardous Substances, December 1987*~~ Office for Solid Waste and Emergency Response, *Risk management program for offsite consequence analysis, Appendix D, April 15 1999*

[31] P Persic, *Hypothetical Volume of Potentially Explosive Atmosphere in the Context of IEC Standard 60079-10-1*, Ex-Bulletin, Croatia 2012. Vol 40, 1-2

[32] ~~IEC 60079-20-1~~ ISO/IEC 80079-20-1, *Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data*

List of comments

1 Updated to align with the scope of the complete IEC 60079 and ISO/IEC 80079 series of standards.

2 Industrial applications of any kind are not exempted from the scope of this standard. However, the assessment in accordance with this standard might result in a non-hazardous area classification. See also new Subclause 5.3.2.

3 "Site" is used to clarify that the intent of IEC 60079-10-1 is to cover an area of land or buildings rather than imply application to process equipment.

4 Other ignition sources have different risks to equipment and this statement reinforces that the scope of IEC 60079-10-1 is to cover hazards due to equipment.

5 The criteria for a zone of negligible extent includes consideration of the consequences of ignition.

6 See further detail in 4.4.2.

7 The definition is deleted as consideration of catastrophic failures is described more fully in 4.5.

8 Safety principles are applied irrespective of the zone classification.

9 The terminology from "area classification" to "hazardous area classification" is updated to be consistent throughout the document.

10 The statement clarifies that the range of situations that might need to be classified for a hazardous area is too broad for a detailed standard that would cover all situations to be prepared.

11 The principles here were included in previous editions of IEC 60079-10-1 and are restated here with some further explanations.

12 The text here is relocated from the previous edition and hence is shown as a change for that reason.

13 The note clarifies why a recommended methodology for risk assessment is not included in this standard.

14 The Zone NE concept was introduced into the first edition of IEC 60079-10-1 based on research by the UK HSL for natural gas ignitions and is expanded in this edition for general principles.

15 The text here is intended to clarify the assessment of Zone NE for other gases which was not provided in previous editions of IEC 60079-10-1.

16 Catastrophic failures are excluded from consideration when classifying hazardous areas and the text here is only relocation and an alternative expression to principles in previous editions.

17 The text here slightly modifies previous text to highlight understanding the nature of the factors and not just the principles involved.

18 The reduction of text here is for simpler expression and does not change the intent from previous editions.

19 Previous editions of IEC 60079-10-1 have recognized that for small quantities it may not be practical to apply a hazardous area classification. The text here restates that principle but with updates to further explain aspects that may need to be considered.

20 Testing is added as this could be used and may also be associated with validation of other forms of assessment. For example, testing to calibrate or validate CFD modelling.

21 While this is a note, the significance of the note should be highlighted.

22 The text here reflects the change in the scope from the previous edition.

23 This text is relocated to Subclause 5.1.

24 The influence of individual components in a gas mixture varies considerably depending on the mixture. As a result of these variances more specific guidance is not provided.

25 This text highlights the need to consider not only the release rate but the total quantity available for a release in the classification assessment.

26 The text is deleted here as the concepts are covered elsewhere.

27 Terminology is reconciled to be "flammable mist" for consistency of expression throughout the standard.

28 This is particularly relevant to some systems, e.g. refrigeration systems, and is introduced to help with understanding such systems since classification of hazardous areas is becoming more relevant in such industries.

29 Further information on ammonia is introduced as a special case to assist with understanding the hazardous area classification of ammonia systems.

30 The text is revised to clarify that dispersion is relevant to the volume available and the volume of the release.

31 Since "persistence time" is a variable, reducing the persistence of a condition is a better expression than avoiding the persistence.

32 The text is added to clarify that layering may be possible with both heavier than air gas or vapour and lighter than air gas or vapour depending on the conditions.

33 The text and associated note further clarify factors for indoor situations even with limited quantity releases.

34 This text is added to highlight that sometimes ventilation can help with dilution even if there is little air exchange in a room.

35 The text clarifies that natural air exchange is not the only driver for air movement in a room.

36 The added text and struck out text say much the same thing and the expression is modified for improvement.

37 The text is updated to remove the ambiguity in the previous edition between the flammable volume and hazardous area.

38 This text is added to help clarify the relationship of dilution or flammable volume and hazardous area.

39 The deleted text is relocated to C.3.5 to keep descriptions in the annexes consistent.

40 The text is updated as the previous term of "zonal classification" is not defined.

41 A pointer to the descriptions for ventilation is added to be consistent with the previous pointer for degree of dilution.

42 The text is deleted here as safety factors are described elsewhere in the standard.

43 The note is relocated and updated below.

44 The text is updated to describe options for purging more fully.

45 Guidance in Annexes C and D is based on continuous releases.

46 Updated for a change in designation. ISO/IEC 80079-20-1 is effectively a later revision of IEC 60079-20-1.

47 The text is updated and relocated to Subclause 10.2.

48 This text is relocated from the previous edition without significant technical change.

49 The expression is the converse of the previous edition to be more practical.

50 The application of safety factors on top of other safety factors could lead to overly conservative results and this text tries to highlight that issue.

51 "Detection" implied some form of monitoring and this is not the intent. Hence the change to "identified".

52 The need to consider summation of releases is explained in the text below for different grades of release.

53 The expression here is updated to correctly reference the lowest LFL.

54 Holes are rarely round and so the equivalent hole size is used in all expressions of hole size.

55 The conditions are re-expressed to be technically correct and follow the intent of conditions described in the source document for the calculation.

56 Updated to align with Table C.1.

57 Additional information as the basis for the chart.

58 The description of the term is updated to align with the new text.

59 Specific safety factors have been deleted as general safety factors in determining each parameter should be sufficient.

60 Missing from edition 2.0.

61 The table is updated for clarity.

62 This text has been relocated from Subclause 7.2.4.

63 Further information is provided as background to the derivation of Figure C.1 so the figure may be used correctly within the limitations of the derivation.

64 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.

65 The text is relocated to be with other factors related to the derivation of Figure C.1.

66 The factor applied is described as inefficiency as the value increases with reduced ability to disperse a release.

67 The text is introduced to clarify how the safety factor is derived.

68 Terminology is corrected as the degree of ventilation is a factor which is assessed for the release conditions whereas the rate of ventilation is independent of the release conditions.

69 Correction of terms from the previous edition.

70 The figure is updated for correction of terms to align the text.

71 The text is deleted as it does not add value considering the rest of the paragraph.

72 The expression is updated to align more closely with other guidance in the standard.

73 The possibility to use other calculations or forms of assessment is highlighted as this is just an example in an informative annex.

74 The equation is updated to align with BS 5925.

75 The chart is revised to match the new Equation (C.4).

76 The equation is deleted to align with BS 5925.

77 The paragraph is updated for clarity.

78 The text is updated for an informative annex rather than a requirement.

79 The mention of CFD is deleted as this is not the only form of assessment that might be acceptable.

80 The additions are to assist in correct application of the curves and charts based on the derivation and modelling used to develop the curves and charts.

81 This guidance is provided since many installations will have obstructions that would result in the "diffusive" curve being the more appropriate curve to use.

82 This deleted text is relocated and re-expressed in other text.

83 The text is added to highlight the examples are used to demonstrate the assessment method rather than be taken as conditions that should be used.

84 Specific safety factors have been deleted as individual parameters should be selected to provide an overall level of safety. Additional safety factors could then lead to overly conservative results.

85 Updated terminology, see C.3.6.2.

86 The comment is provided to reinforce the limitations when using the charts provided.

87 The terms are updated for use of consistent terminology.

88 Replaced by new guidance in G.8.

89 The clause is added so the likelihood of misting in normal piping installations is not overstated.

90 The clause is added since IEC 60079-14 does not deal with mist hazards.

91 This text is added until ISO/TR 15916 can be updated to improve referencing to the IEC 60079 and ISO/IEC 80079 series of standards.

IEC 60079-10-1

Edition 3.0 2020-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Atmosphères explosives –
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IEC 60079-10-1:2020-12(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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EXPLOSIVE ATMOSPHERES –

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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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:

		Type		
Changes	**Clause**	**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.

INTRODUCTION

In areas where dangerous quantities and concentrations of flammable gas or vapour may arise, 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 design, construction, operation and maintenance 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 normality dealt with in this standard (see 3.7.3 and 4.5);

d) rooms used for medical purposes;

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 site, 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.

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).

2 Normative references

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 which, after ignition, permits self-sustaining propagation

[SOURCE: IEC 60079-0:2017, 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, C_2H_2; monovinyl acetylene, CAS no. 689-97-4, C_4H_4; 1-propyl nitrate (vapour), CAS no. 627-13-4, CH_3 $(CH_2)_2$ NO_3; isopropyl nitrate (vapour), CAS no. 1712-64-7, $(CH_3)_2$ CH ONO_2; ethylene oxide (vapour), CAS no. 75-21-8, $(CH_2)_2$ O; hydrazine (vapour), CAS no. 302-01-2, H_4 N_2.

[SOURCE: IEC 60079-0:2017, 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 can be expected to be present, in quantities such that special precautions for the construction, installation and use of equipment are required

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 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 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 can be taken from codes or standards relating to specific industries or applications.

[SOURCE: IEC 60050-426:2020, 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

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 60050-426:2020, 426-03-06]

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 synomonous 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 used for liquid mixtures 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 (AIT)
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: ISO/IEC 80079-20-1:2017, 3.3]

3.6.12
lower flammable limit (LFL)
concentration of flammable gas or vapour in air below which an explosive gas atmosphere 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: ISO/IEC 80079-20-1:2017, 3.6.1]

3.6.13
upper flammable limit (UFL)
concentration of flammable gas or vapour in air above which an explosive gas atmosphere 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: 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.

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, 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 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 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.

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 zone, and the extent of the zone (see Clause 8 and Clause 9).

NOTE Selected characteristics might be designated for equipment e.g. ignition energy and temperature ratings (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.

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.

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.

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.

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 m^3 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.

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.

4.6 Competence of personnel

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. 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 area.

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

Subclauses 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 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 the same or similar installations. Where 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 new evidence.

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 quanities 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.

5.2 Classification by sources of release method

Classification may be approached by calculation or test, 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 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.

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.

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, 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 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 6.3.

6.2 Sources of release

The basic elements for establishing the 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 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.

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. The hazardous area classification of process equipment in which a flammable substance is burned, for example, fired heaters, furnaces, boilers, gas turbines, 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 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.

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.

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 a flammable mist 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 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.

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 °C.

6.3.5 Flammable mists release

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 a flammable mist cloud frequently makes the cloud visible to the naked eye. The dispersion of a flammable mist may vary between the behaviour of a dense gas or a neutrally buoyant gas. Flammable mist droplets can coalesce and rain out of the plume or cloud. 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 %.

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 evapouration could slow considerably unless additional heat is brought to the liquid.

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. Unless the release is into a space that is confined and well-sealed the gas disperses completely until the concentration is essentially zero. Air movement due to natural or artificial ventilation will promote dispersion.

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 reduce 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 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.

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.

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.

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.

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 ventilation rate. Such a scenario will then lead to a higher level of availability which will compensate for overly optimistic assumptions made in estimating the ventilation rate.

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 equal to the volume that may be above the LFL, including any safety factor, i.e. the volume that could be flammable. 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.

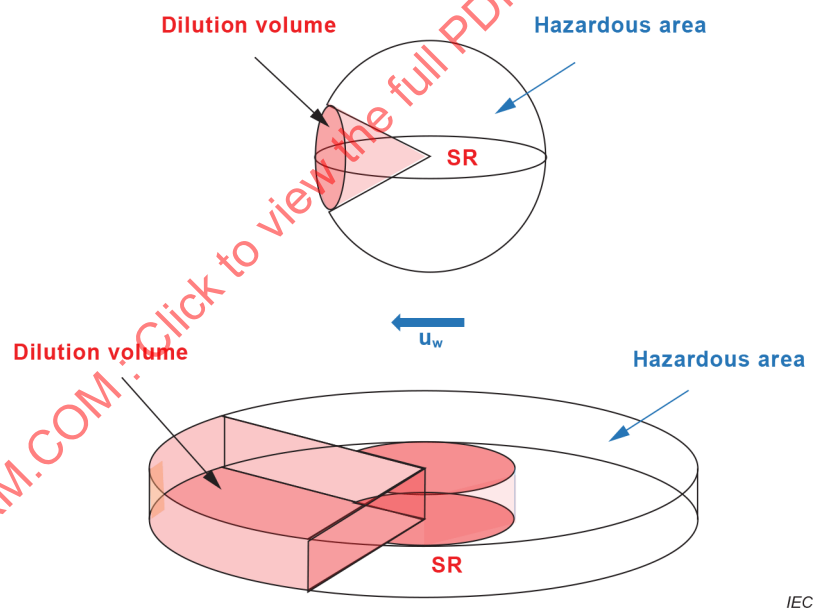


Figure 1 – Dilution Volume

The degree 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.

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 zone types, including temperature class and equipment group, 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 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.

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. 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,

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 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.

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 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.

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 ISO/IEC 80079-20-1), which may include:

- molar mass
- flash point
- boiling point
- auto-ignition temperature
- vapour pressure
- vapour density
- flammability limits
- equipment group and temperature class

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.

Drawings should include plans and elevations or three dimensional presentation, as appropriate, which show both the type and extent of zones, equipment group, auto-ignition temperature 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 practical to itemize or number all the sources of release in which case simplified methods may be used as outlined in 5.4;

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 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 – Preferred symbols for zones

Figure A.1 shows preferred symbols for zones.

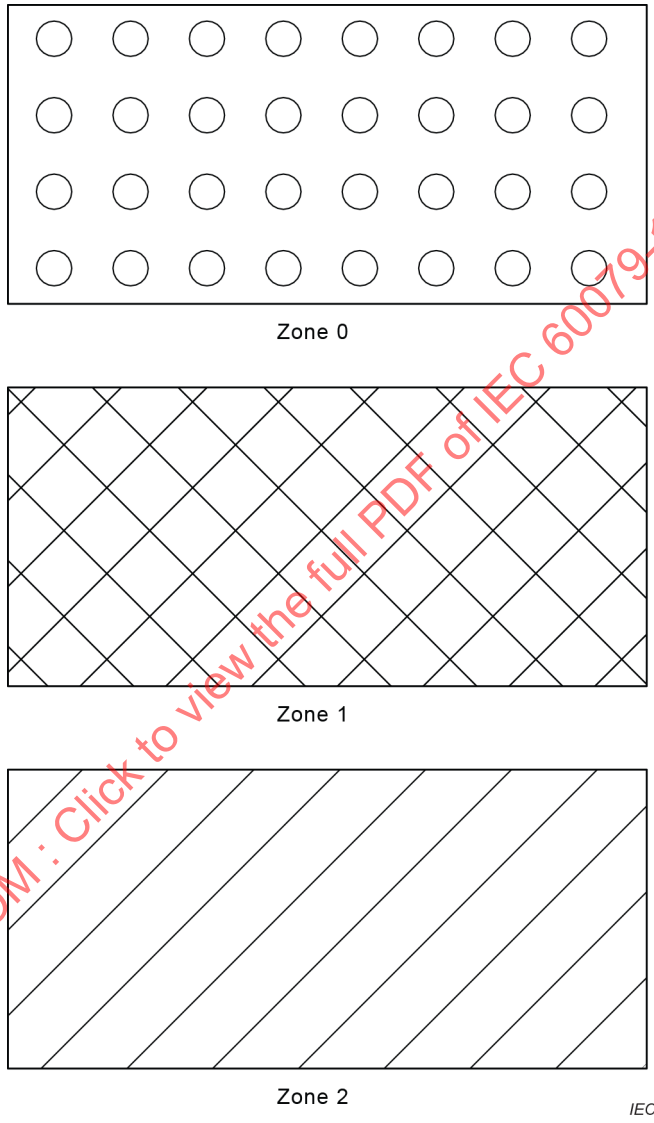


Figure A.1 – Preferred symbols for zones

Table A.1 – Hazardous area classification data sheet – Part I: Flammable substance list and characteristics

Plant: **Area:**														**Reference drawing:**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Flammable substance							**Volatility**[a]		**LFL/UFL**		**Ex characteristics**		
	Name	Composition	Molar mass (kg/kmol)	Relative density gas/air	Polytropic index of adiabatic expansion γ	Flash point (°C)	Ignition temp. (°C)	Boiling point (°C)	Vapour pressure at 20 °C (kPa)	vol (%)	(kg/m^3)	Equip ment group	Temp. class	Any other relevant information or remark. E.g. Source of data
[a] Normally, the value of vapour pressure is given, but in the absence of that, boiling point can be used.														

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

Plant: **Area:**															**Reference 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**			
	Description	Location	Grade of release[a]	Rate of release (kg/s)	Release characteristic (m^3/s)	Reference[b]	Operating temperature and pressure		State[c]	Type[d]	Degree of dilution[e]	Availability	Zone type 0-1-2	Zone extent (m)	Reference[f]	Any other information or remark
							(°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.

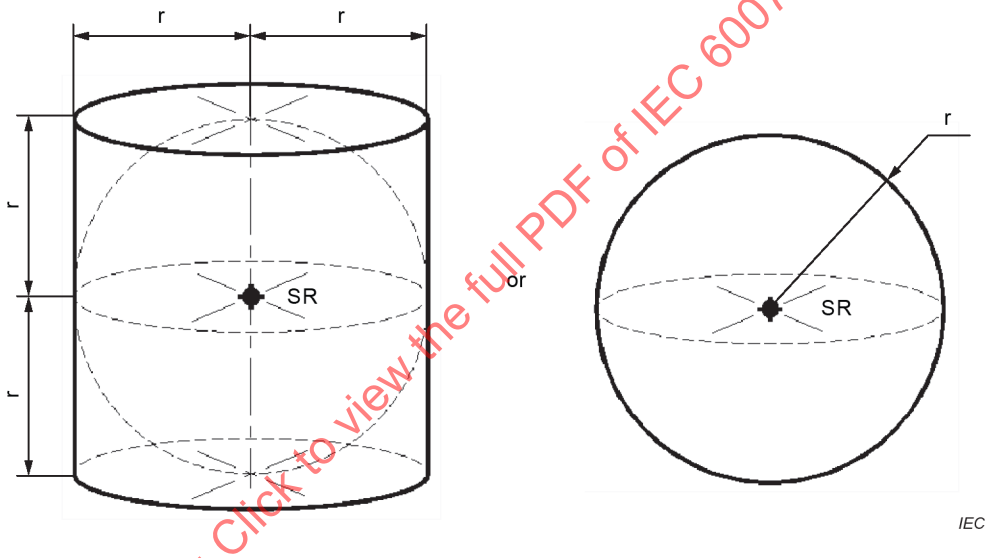


Figure A.2 – Gas or vapour at low pressure (or at high pressure in case of unpredictable release direction)

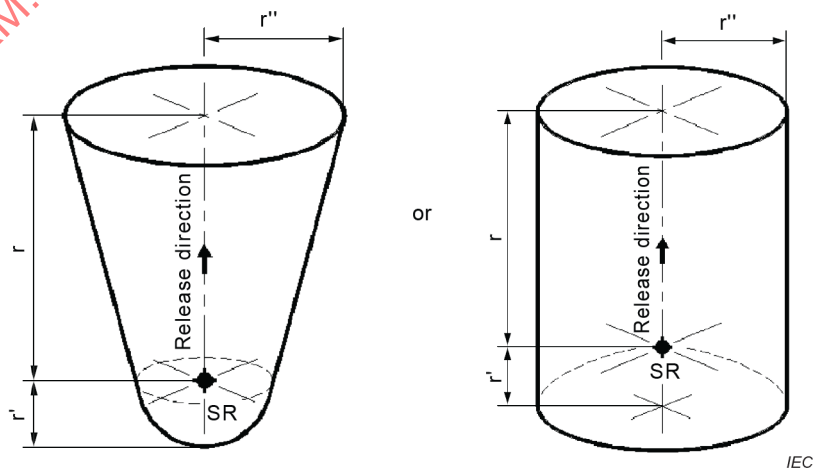
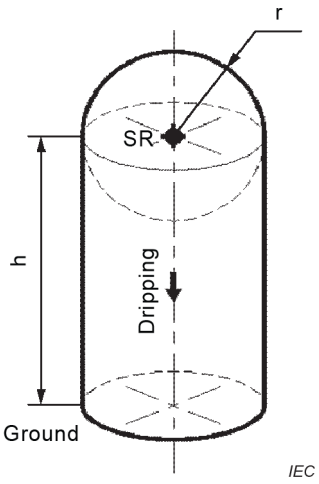
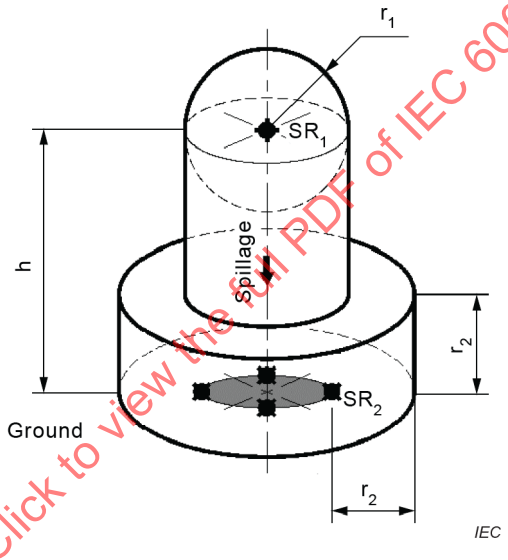


Figure A.3 – Gas or vapour at high pressure



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

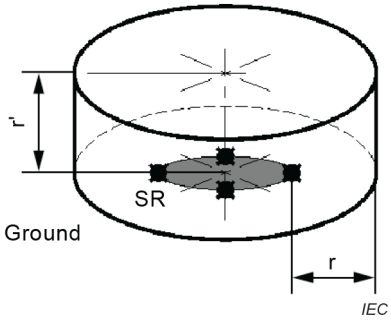
Figure A.4a) Gas or vapour (liquefied under pressure or by refrigeration)



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 (Pa);

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 temperature of the fluid, gas or liquid (K);

T_a ambient temperature (K);

u_w wind speed 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 uncertaintity. Based on this approach, specific safety factors are not shown.

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 identified 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.

Continuous grade releases can be expected to be releasing most if not all of the time and so all continuous grade releases should be 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. Since there could be a number of different flammable substances being released the lowest LFL of the potential sources of release 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 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 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 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.

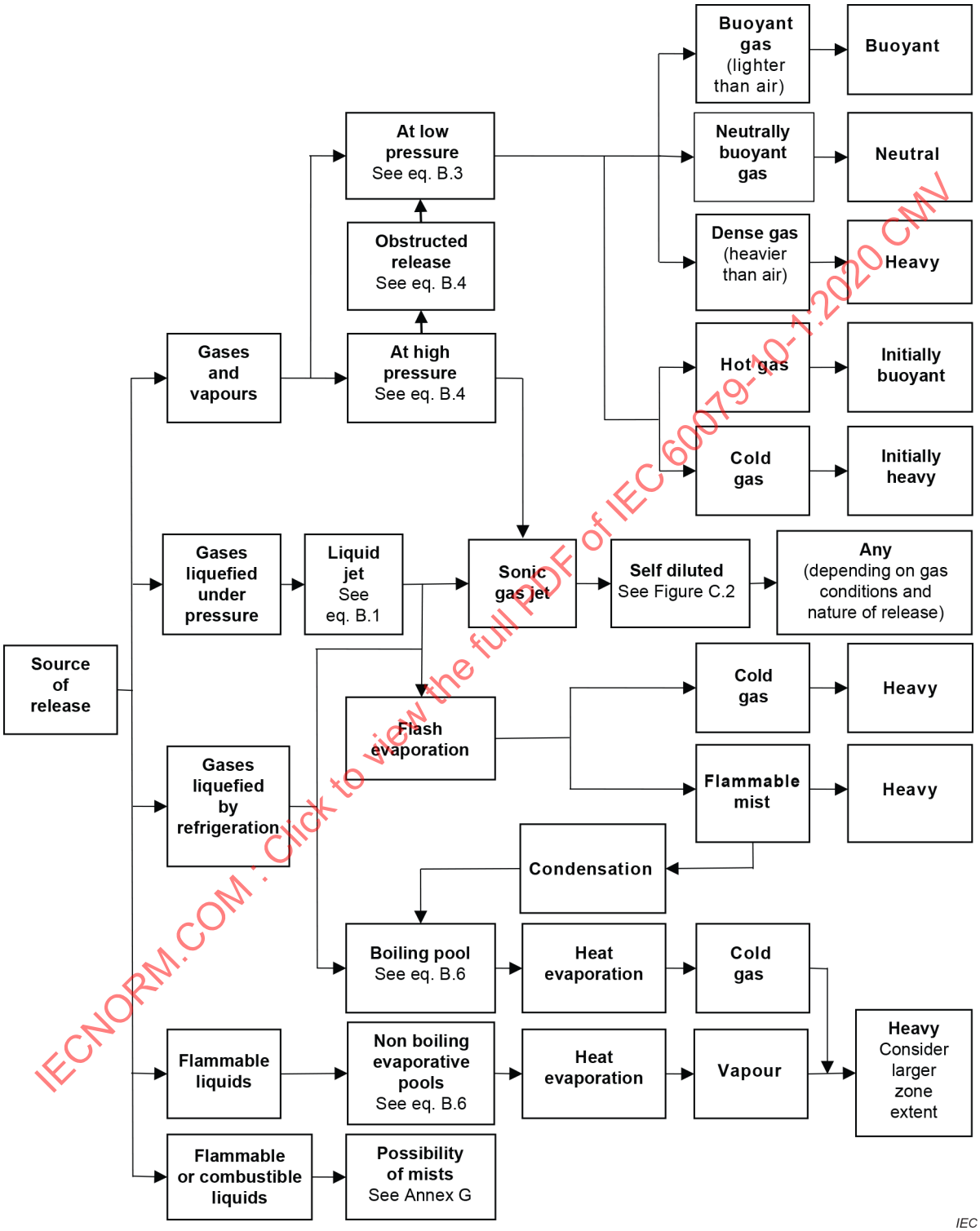


Figure B.1 – Forms of release

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 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.

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 is used. For a flammable liquid in the open, the open cup flash point can be used.

NOTE 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 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.

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:

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

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:

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

For ideal gas the equation $\gamma = \dfrac{M\, c_p}{M\, c_p - R}$ 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 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. 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:

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

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

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

where

$\rho_g = \frac{p_a M}{R T_a}$ is the density of the gas (kg/m^3);

NOTE Where the temperature of the gas at the release opening may be below the ambient temperature, T_a is often used as equal to the gas temperature to provide an approximation for the purpose of easier calculation.

B.7.2.3.3 Release rate of gas with choked gas velocity (sonic releases)

Choked gas velocity (see B.7.2.3) is equal to the speed of sound for the gas. This is the maximum theoretical discharge velocity.

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

$$W_g = C_d S p \sqrt{\gamma \frac{M}{Z R T} \left(\frac{2}{\gamma + 1} \right)^{(\gamma+1)/(\gamma-1)}} \left(\text{kg/s}\right) \quad \text{(B.5)}$$

B.7.3 Release rate of evaporative pools

Evaporative pools may be the result of liquid spillage or leakage in a bunded area or part of a process system where a flammable liquid is stored or handled in an open vessel. The assessment in this section does not apply to thin surface spills since no account is taken for specific factors that may be relevant to such spills e.g. thermodynamic input from the surface on which the liquid is spilt.

NOTE 1 A pool due to a catastrophic failure is not in the scope of this document (see Clause 1).

The following assumptions are made concerning the assessment below:

- The flammable substance is evaporating, not boiling, and the plume is at ambient temperature (phase and temperature changes would cause variations in dispersion and evaporation rates).
- The evaporating flammable substance is assumed to have a relatively low vapour pressure, hence the concentration at the surface of the pool is also low, and the mixture of air and vapour is neutrally buoyant.
- Liquid pools develop quickly forming a nominal 1 cm deep pool
- Pools are allowed to evaporate at ambient conditions.

Then the evaporation rate could be estimated by using following equation:

$$W_e = \frac{18{,}3 \times 10^{-3} \; u_w^{0{,}78} \; A_p \; p_v \; M^{0{,}667}}{R \times T} \left(\text{kg/s}\right) \quad \text{(B.6)}$$

NOTE 2 The source of this equation is U.S. Environmental Protection Agency, Office for Solid Waste and Emergency Response, Risk management program for offsite consequence analysis, Appendix D, April 15 1999.

NOTE 3 Vapour pressure can be estimated through various methods, e.g. derived from Antoine's equation.

NOTE 4 It is assumed that the vapour pressure at the boiling temperature is 101 325 Pa.

Since the density of the vapour in (kg/m^3) is:

$$\rho_g = \frac{p_a M}{R T_a} \left(\text{kg/m}^3\right)$$

then, the volumetric evaporation rate in (m^3/s) is approximately:

$$Q_g \approx \frac{18{,}15 \times 10^{-8}\ u_w^{\,0{,}78}\ A_p\ p_v}{M^{0{,}333}} \times \frac{T_a}{T} \left(m^3/s\right) \tag{B.7}$$

NOTE 5 Since p_v increases with liquid temperature then the evaporation rate ultimately increases with the rise of T.

If we assume that the pool surface area is 1,0 m^2 that the wind speed at the pool surface is 0,25 m/s and that the liquid temperature is equal to the ambient temperature, then the volumetric evaporation rate in (m^3/s) would be:

$$Q_g \approx \frac{6{,}15 \times 10^{-8}\ p_v}{M^{0{,}333}} \left(m^3/s\right) \tag{B.8}$$

The real pool area should be based on the quantity of the spilled liquid and the local conditions such as gradient and bunding at the spill location.

The wind speeds for evaluation of evaporation rate shall be consistent with the wind speeds in later calculations for estimating the degree of dilution (see C.3.4). It should be emphasized that increasing the wind, speed will increase evaporation but at the same time contributes to the dilution of flammable gas or vapour.

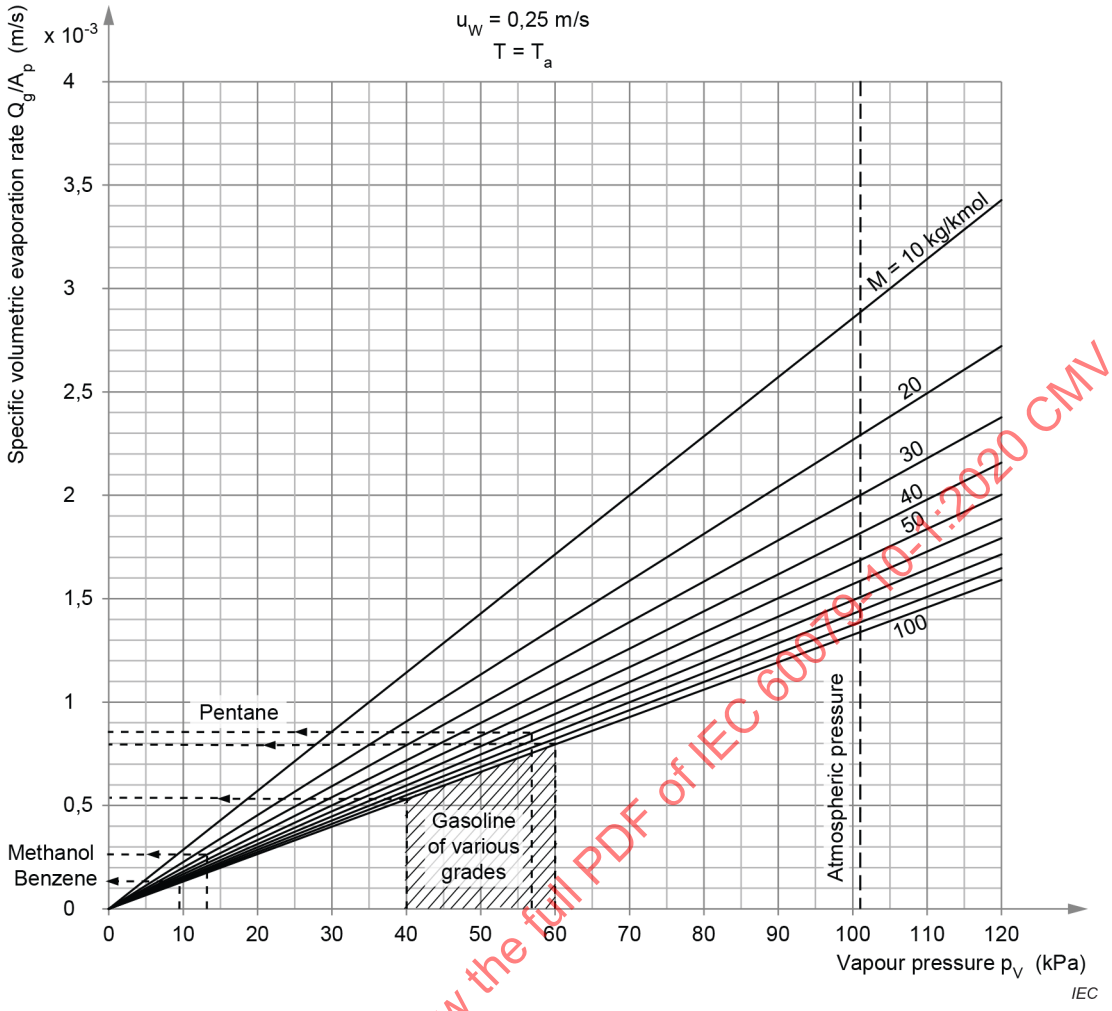


Figure B.2 – Specific volumetric evaporation rate of liquids

The chart in Figure B.2 is based upon equation B.8. The values on the vertical axis refer to the pool surface area of 1,0 m^2. Thus the evaporation rate is obtained by multiplying the value on the vertical axis with the real pool surface area.

The wind speed of 0,25 m/s is characteristic for meteorological calm just above ground level. Typically, it represents the worst case regarding dispersion of the vapour but not the worst case with respect to evaporation rate.

The value for vapour pressure on the horizontal axis should be taken for the relevant liquid temperature.

NOTE 6 The chart is only valid for atmospheric pressure.

B.8 Release from openings in buildings

B.8.1 General

Subclauses B.8.2 and B.8.3 provide examples for openings in buildings or walls. They are not intended to be rigidly applied and may need to be varied to suit the particular situation.

B.8.2 Openings as possible sources of release

Openings between areas should be considered as possible sources of release. The grade of release will depend upon:

- the zone type of the adjoining area,
- the frequency and duration of opening periods,
- the effectiveness of seals or joints,
- the difference in pressure between the areas involved.

B.8.3 Openings classification

For the purpose of this assessment, openings are classified as A, B, C and D with the following characteristics:

Type A

Openings not conforming to the characteristics specified for types B, C or D, e.g.:

- open passages for access or utilities (examples of utilities include ducts or pipes through walls, ceilings and floors);
- openings which are frequently opened;
- fixed ventilation outlets in rooms, buildings and similar openings.

Type B

Openings which are normally closed (e.g. automatic closing), infrequently opened and close-fitting.

Type C

Openings which are normally closed (e.g. automatic closing), infrequently opened and fitted with sealing devices (e.g. a gasket) along the whole perimeter; or two type B openings in series, having independent automatic closing devices.

Type D

Openings which are effectively sealed, such as in utility passages; or openings normally closed conforming to type C which can only be opened by special means or in an emergency; or a combination of one opening type C adjacent to a hazardous area and one opening type B in series.

Table B.2 shows the effect of openings on grade of release when a zone has been established upstream of those openings.

Table B.2 – Effect of zones on openings as possible sources of release

Zone outside of opening	Opening type	Grade of release of openings considered as sources of release
Zone 0	A	Continuous
	B	(Continuous)/primary
	C	Secondary
	D	Secondary / no release
Zone 1	A	Primary
	B	(Primary)/secondary
	C	(Secondary)/no release
	D	No release
Zone 2	A	Secondary
	B	(Secondary)/no release
	C	No release
	D	No release
For grades of release shown in brackets, the frequency of operation of the openings should be considered in the design.		

The grade of release of an opening may also be defined according to the basic principles.

The grade of release of the opening between an indoor naturally ventilated classified location and an outdoor non classified area may be defined considering the grade of release of the source generating the indoor zone.

Annex C
(informative)

Ventilation guidance

C.1 Symbols

A_1 effective area of the upwind or the lower opening where applicable (m^2);

A_2 effective area of the downwind or the upper opening where applicable (m^2).

A_e equivalent effective area for upwind and downwind openings at the same height or for the lower opening where applicable (m^2);

C air change frequency in the room (s^{-1});

ΔC_p pressure coefficient characteristic of the building (dimensionless);

C_d discharge coefficient (dimensionless), characteristic of large ventilation openings, inlet or outlet, and accounts for the turbulence and viscosity, typically 0,50 to 0,75;

f inefficiency of ventilation (dimensionless);

g acceleration due to gravity (9,81 m/s^2);

H vertical distance between the midpoints of the lower and upper openings (m);

LFL lower flammable limit (vol/vol);

M molar mass of gas or vapour (kg/kmol);

p_a atmospheric pressure (101 325 Pa);

Δp pressure difference, due to wind or temperature effects (Pa);

Q_a volumetric flow rate of air (m^3/s);

Q_1 volumetric flow rate of air entering the room through apertures (m^3/s);

Q_g volumetric flow rate of flammable gas from the source (m^3/s);

$Q_2 = Q_1 + Q_g$ volumetric flow rate of air/gas mixture leaving the room (m^3/s);

Q_C volumetric release characteristic of the source (m^3/s);

R universal gas constant (8314,5 J/kmol K);

ρ_a air density (kg/m^3);

ρ_g gas or vapour density at the ambient conditions (kg/m^3);

T_a ambient temperature (K);

T_{in} indoor temperature (K);

T_{out} outdoor temperature (K);

ΔT difference between the indoor and the outdoor temperature (K);

u_w wind speed at a specified reference height or ventilation velocity at given release conditions where applicable (m/s);

V_0 volume under consideration (room or building) (m^3);

W_g mass release rate of flammable substance (kg/s), for mixtures, only the total mass of flammable substance should be considered;

X_b background concentration (vol/vol);

X_{crit} the desired/critical value of the flammable substance concentration (vol/vol).

C.2 General

The purpose of this annex is to provide guidance on determining the type of zone(s) by assessing the type and likely extent of gas or vapour releases and comparing these factors with the dispersion and dilution of those gases or vapours by ventilation or air movement.

It should be emphasised that releases may take many forms and can be influenced by many conditions (see Clause B.6). These include:

- gases, vapours or liquids;
- indoor or outdoor situations;
- sonic or subsonic jets, fugitive or evaporative releases;
- obstructed or unobstructed conditions;
- gas or vapour density.

The information presented in this annex is intended to provide qualitative guidance on the assessment of the ventilation and dispersion conditions to determine the type of zone. The guidance applies to the conditions noted in each section and therefore may not be applicable to all installations.

The guidance herein may be used in the selection and assessment of artificial ventilation systems and natural ventilation arrangements, since these are of paramount importance in the control and dispersion of releases of flammable gasses and vapours in enclosed spaces.

NOTE Ventilation criteria for specific applications can also be found in national standards or industry codes.

It is important to distinguish throughout these discussions between the concepts of ‘ventilation’ (the mechanism by which air enters and leaves a room or other enclosed space) and dispersion (the mechanism by which clouds dilute). These are very different concepts, and both are important.

In indoor situations it should be noted that the hazard depends on the ventilation rate, the nature of the expected source of gas and the properties of the gas released, in particular the gas density/buoyancy. In some situations the hazard may depend sensitively on the ventilation; in others it may be almost independent of it.

In outdoor situations the concept of ventilation is not strictly applicable and the hazard will depend on the nature of the source, the properties of the gas and the ambient air flow. In open air situations, air movement will often be sufficient to ensure dispersal of any explosive gas atmosphere which arises in the area. Table C.1 provides guidance on wind speed for outdoor situations.

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

C.3 Assessment of ventilation and dilution and its influence on hazardous area

C.3.1 General

The size of a cloud of flammable gas or vapour and the time for which it persists after the release stops can often be controlled by means of ventilation. Approaches for evaluating the degree of dilution required to control the extent and persistence of an explosive gas atmosphere are described below. Other calculations from reputable sources or alternative forms of calculation, e.g. computational fluid dynamics (CFD), may also be applied.

Any assessment of the degree of dilution first requires an assessment of the expected release conditions including the size of the source of the release and the maximum release rate of gas or vapour at the source (see Annex B).

It is normally indicated that a continuous grade of release leads to a Zone 0, a primary grade to Zone 1 and a secondary grade to Zone 2. However, this is not always the case and may vary depending on the ability of a release to mix with sufficient air to dilute down to a safe level.

In some cases, the degree of dilution and level of availability of ventilation may be so high that in practice there is no hazardous area or a hazardous area of negligible extent. Alternatively, the degree of dilution may be so low that the resulting zone has a lower zone number than might otherwise be applicable for the grade of release (i.e. a Zone 1 hazardous area from a secondary grade source). This occurs, for example, when the level of ventilation is such that the explosive gas atmosphere persists and is dispersed only slowly after the gas or vapour release has stopped. Thus, the explosive gas atmosphere persists for longer than would be expected for the grade of release.

The dilution of a release is determined by the interaction of the momentum and buoyancy forces of the release and the atmosphere within which it is dispersing. For an unimpeded jetted release, for example from a vent, the jet momentum dominates and the initial dispersion is dominated by the shear between the release and the atmosphere. However, if a jetted release is at low velocity or is impeded to such an extent that the momentum is redirected or dissipated, the release buoyancy and atmospheric effects become more important.

For small releases of lighter than air gas the dispersion in the atmosphere will dominate, for example similar to dispersion of cigarette smoke. For larger releases of lighter than air gas the stage may eventually be reached, especially in low wind conditions, when the release buoyancy is significant and the release will lift off from the ground and disperse like a plume, for example similar to the plume from a large bonfire. For vapour releases from a liquid surface the vapour buoyancy and local air movement will dominate the dispersion behaviour.

In all cases, where there is adequate fresh air for dilution of a release to very small concentrations (i.e. well below the LFL), the diluted gas or vapour will tend to move along with the general mass of the air and exhibit neutral behaviour. The exact concentration where such neutral behaviour is reached will depend on the relative density of the gas or vapour to air. For greater relative density differences a lower concentration of the gas or vapour is required for neutral behaviour.

C.3.2 Effectiveness of ventilation

The most important factor is the effectiveness of ventilation, in other words the quantity of air relative to the type, release location and release rate of the flammable substance. The higher the amount of ventilation in respect of the possible release rates, the smaller will be the extent of the zones (hazardous areas) and shorter the persistence time of explosive gas atmosphere. With a sufficiently high effectiveness of ventilation for a given release rate, the extent of the hazardous area may be so reduced to be of negligible extent (NE) and be considered a non-hazardous area.

C.3.3 Criteria for dilution

The criteria for dilution are based upon the two values that are characteristic for any release:

- the relative release rate (ratio of release rate and LFL in mass units);
- the ventilation velocity (the value that symbolizes the atmospheric instability, i.e. air flow induced by ventilation or wind speed outdoors).

The relation between the two determines the degree of dilution as displayed in Figure C.1.

C.3.4 Assessment of ventilation velocity

If a gas leak exists, the gas must be transported away, or gas build up will occur. The gas can be transported away by flow induced by the momentum in the gas leak, by buoyancy induced by the gas, or by flow caused by natural or forced ventilation or by wind.

The flow caused by momentum in the release itself should generally not be taken into account unless it is very clear that this momentum will not be broken by impingement or other influence of geometry.

The flow to transport away the gas should be assessed primarily based on an assessment of the ventilation for indoor situations, or by flow caused by the wind for outdoor situations.

For indoor situations the flow or ventilation velocity may be based on an average flow velocity caused by the ventilation. This may be calculated as the volumetric flow of air/gas mixture divided by the cross section area perpendicular to the flow. This air velocity should be reduced by a factor due to inefficiency of the ventilation or due to flow being obstructed by different objects. Computational fluid dynamics (CFD) simulation is recommended if particular detail or accuracy is needed to get an estimate of the ventilation velocity in different parts of the room under consideration.

For naturally ventilated enclosures and for open areas, the ventilation velocity should be assessed as the velocity that is exceeded 95 % of the time. The availability of this ventilation can be considered to be ‘fair’.

Ventilation velocity for open areas may be based on wind speed statistics using a reduction factor considering the reference height applied for any weather statistics. Published values are usually available for elevations above the height of a process plant and may need to be reduced due to local geometry such as topography, buildings, vegetation and other obstacles. E.g. in a process area with a lot of structures, piping and process equipment, the effective ventilation velocity could typically be as low as 1/10 of the free flow velocity above the plant. Assessment could also be made by measurement of the velocity in some locations around the plant and comparing these to the published figures. Computational fluid dynamics (CFD) is also recommended for any complex plant where there are a number of equipment items that could affect localised air movement.

Lighter than air gases tend to move upwards where the ventilation normally will be better, and the buoyancy may also transport the gas away. This may be taken into account by increasing the effective ventilation velocity for such releases. For releases with a relative density of less than 0,8, it is normally considered safe to assume that the effective ventilation velocity is at least 0,5 m/s in outdoor situations. The availability of this minimum ventilation can be considered as good.

Heavier than air gases tend to move downwards where the ventilation generally will be lower, and accumulation at ground level is a possibility. This can be taken into account by lowering the effective ventilation velocity. A gas can be heavy due to the molecular weight or due to low temperature. Low temperature can be caused by leak from high pressure. For gases with a relative density above 1,0 the effective ventilation velocity should be reduced by a factor of approximately 2.

Where statistical data are not available, Table C.1 illustrates a practical approach to define ventilation velocity values outdoors.

Table C.1 – Indicative outdoor ventilation velocities (u_w)

Elevation from ground level / Type of Release	Unobstructed areas			Obstructed areas		
	≤ 2 m	> 2 m up to 5 m	> 5 m	≤ 2 m	> 2 m up to 5 m	> 5 m
Lighter than air gas/vapour releases	0,5 m/s	1 m/s	2 m/s	0,5 m/s	0,5 m/s	1 m/s
Heavier than air and neutrally bouyant gas/vapour releases	0,3 m/s	0,6 m/s	1 m/s	0,15 m/s	0,3 m/s	1 m/s
liquid pool evaporation rate at any elevation	> 0,25 m/s			> 0,1 m/s		
Typically, values in the table would result in an availability of ventilation as fair (see Clause D.2). Indicative ventilation velocities are not meant to suggest that actual air velocity will vary according to the gas/vapour density but take into account the influence of buoyancy for the gas/vapour when considering an apparent velocity which may be considered in the assessment of dilution.						

C.3.5 Assessment of the degree of dilution

The following three degrees of dilution are normally 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 an explosive gas atmosphere after the release has stopped.

The degree of dilution may be assessed by using the chart in Figure C.1, where the velocity is reasonably consistent in the space under consideration. Where the ventilation is inefficient or is reduced due to flow being obstructed by different objects a lower apparent air velocity should be used.

The degree of dilution may also be influenced by the release velocity, e.g. a jet release in a large room (see C.3.6.1) and this is not accounted for in Figure C.1.

For indoor applications the background concentration should also be assessed in accordance with C.3.6.2 and if the background concentration exceeds 25 % of the LFL the degree of dilution should generally be considered as low.

Figure C.1 is based on an initial background concentration that is negligible.

Figure C.1 is not intended for guidance when considering releases from large pools.

Extrapolation of the curves beyond the chart area shown in Figure C.1 should not be undertaken due to other factors that will affect the assessment beyond the limits indicated.

The method of using the chart in Figure C.1 is demonstrated in the examples of Annex E.

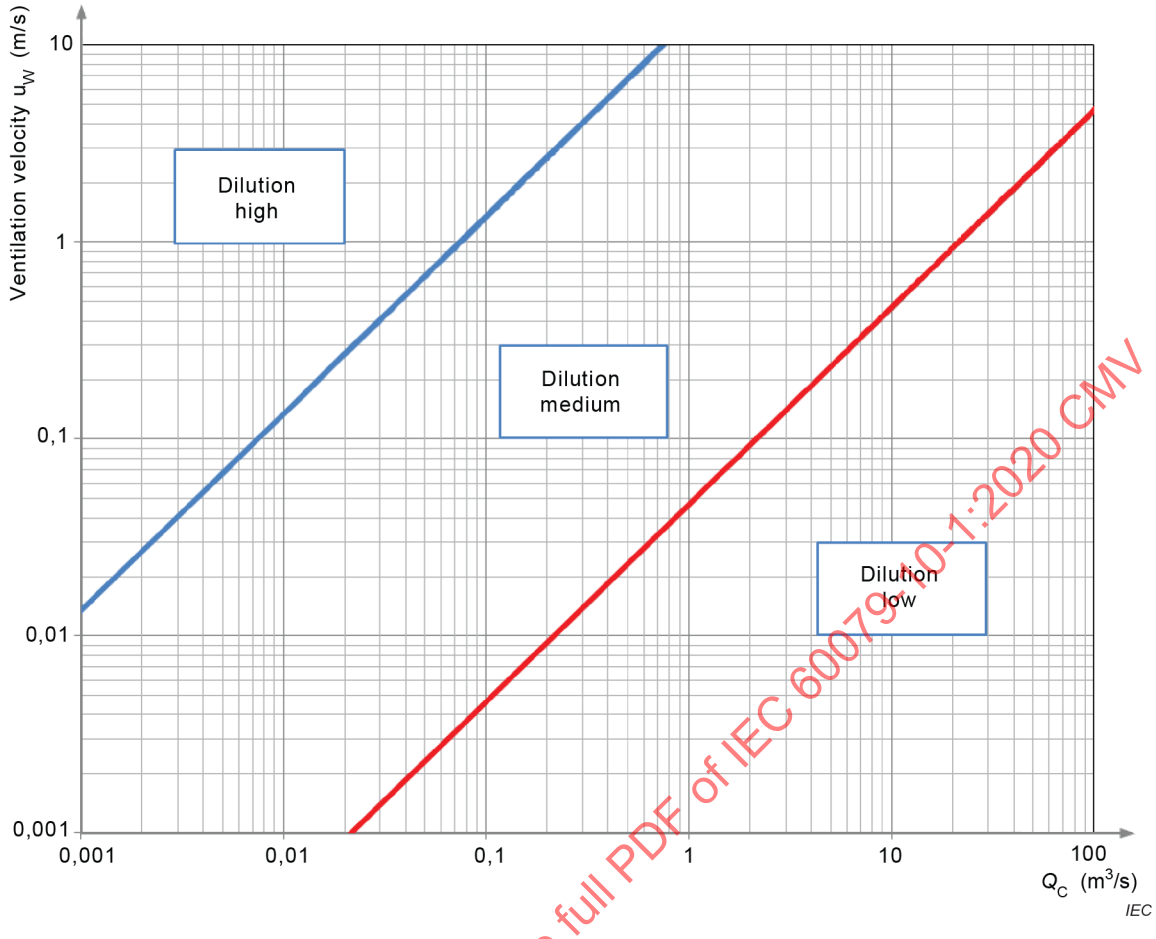


Figure C.1 – Chart for assessing the degree of dilution

Where

$Q_C = \frac{W_g}{\rho_g \times LFL}$ is the volumetric release characteristic of the source (m^3/s);

$\rho_g = \frac{p_a M}{R T_a}$ is the density of the gas/vapour (kg/m^3);

Figure C.1 does not include a specific safety factor. A suitable factor should be determined by the user based on the application and any safety factors applied to other parameters used in the assessment e.g. assumed release rate.

The degree of dilution is obtained by finding the intersection of respective values displayed on horizontal and vertical axis. The line dividing the chart area between 'dilution high' and 'dilution medium' represents a flammable volume of 0,1 m^3, so any intersection point left to this curve implies an even smaller flammable volume. The line dividing the chart area between 'dilution medium' and 'dilution low' represents a flammable volume of approximately 100m^3, so any intersection point right to this curve implies an even larger flammable volume.

In outdoor locations where there are no significant restrictions to air flow, the degree of dilution should be classified as medium if the condition for high dilution is not met. A low degree of dilution will not generally occur in open air situations. Situations where there are restrictions to air flow, for example, in pits, should be considered in the same way as an enclosed area.

C.3.6 Dilution in a room

C.3.6.1 General

Dilution may occur by either the exchange of fresh air that dominates the release of the gas or vapour or by having sufficient volume to allow the gas or vapour to disperse to a low concentration even with minimal fresh air. In this later case the volume available for dilution must be high with respect to the anticipated volume of the release.

For a jet release of gas, dilution may occur even without any local air movement due to entrainment of air in the expanding jet. However if a jet is impeded due to impact on nearby objects then the ability for self dilution is greatly reduced.

The degree of dilution can also be assessed by assessment of the average background concentration of the flammable substance (see C.3.6.2). The higher the ratio of release rate against the ventilation rate the higher will be the background concentration X_b and the lower will be the degree of dilution.

In assessing background concentration the release rate, ventilation rate and inefficiency factor must be carefully selected to take into account all relevant factors considering an appropriate safety margin. The ventilation inefficiency factor should recognize if there is a possibility of recirculating or impeded air flow in a space which may reduce the efficiency compared to a good air flow pattern.

A zero background concentration should be considered only outdoors or in regions with local extraction ventilation which controls the movement of flammable substance near the source of release. A negligible background concentration, described as $X_b << X_{crit}$, may be considered in highly ventilated rooms or enclosures. X_{crit} is an arbitrary value below LFL, e.g. the value at which a gas detector is set to alarm.

A low background concentration does not mean that the whole room is a non hazardous area. The larger part of the room may be considered non hazardous but the area near the source of the release is still a hazardous area until the release is sufficiently dispersed (similar as for open air situations).

Consideration of background concentration and the extent of possible zones around sources of release also need to be moderated with practical factors considering variations in possible dispersion patterns in an enclosed space. Many enclosed areas contain multiple sources of release and it is not safe practice to have multiple small hazardous areas within an enclosed area generally classified as non hazardous. Also, it is not safe practice to have a limited hazardous area within a relatively small room and the whole room should be considered for a uniform classification.

C.3.6.2 Background concentration and releases in a ventilated room

For indoor releases it is necessary to specify the room background concentration, X_b, which embodies the effects of ventilation. Background concentration is the average concentration of flammable substance within the volume under consideration (room or building) after a period of time during which a steady state has been established between the release and the flow of air induced by ventilation.

Consideration of the background concentration then provides a measure for assessing ventilation in a room which removes gas or vapour compared to dispersion of the gas or vapour. This ratio then influences the consideration of the degree of dilution.

The background concentration (vol/vol) may be assessed as:

$$X_b = \frac{f \times Q_g}{Q_g + Q_1} = \frac{f \times Q_g}{Q_2}(\text{vol/vol}) \quad \text{(C.1)}$$

and the air change frequency and ventilation flux are related by:

$$Q_2 = CV_0\left(\text{m}^3/\text{s}\right)$$

The average background concentration X_b which is ultimately achieved depends on the relative magnitude of source and ventilation fluxes, but the timescale over which this is achieved is inversely proportional to the air change frequency.

The safety factor f, ventilation inefficiency, is a measure of the degree to which the air in the enclosure outside of the release zone is well mixed and is the mean background concentration X_b in the room divided by the concentration at the ventilation outlet (dimensionless).

f=1: the background concentration is essentially uniform and the outlet is distant from the release itself, so that the concentration at the outlet reflects the mean background concentration.

f=1: there's a gradient of background concentration in the room due to inefficient *mixing*, and the outlet is distant from the release itself, so that the concentration at the outlet is smaller than the mean background concentration. f may be between 1,5 for mildly inefficient mixing and 5 for very inefficient mixing.

Given the origin of the cases f=1 or f>1, this value may be denoted as a safety factor related to the inefficiency of mixing (as progressively larger values reflect progressively less efficient mixing of air within the room). This factor allows for imperfections of air flow patterns in a real space with obstructions and where ventilation openings may not be ideally positioned for maximum ventilation (see C.5). The degree of dilution should be taken as being low if the background concentration exceeds 25 % of the LFL or if indicated through an assessment based on Figure C.1.

NOTE Ventilation alone which describes how air enters the room has little to say about the expected volume of a hazardous area. That depends on how the gas, or vapour and air are distributed within the room, i.e. on dispersion.

C.3.7 Criteria for availability of ventilation

C.3.7.1 General

The availability of ventilation has an influence on the presence or formation of an explosive gas atmosphere. Thus, the availability (as well as the effectiveness) of ventilation needs to be taken into consideration when determining the type of zone.

Three levels of availability of the ventilation should be considered (see Table D.1):

- **good:** ventilation is present virtually continuously;
- **fair:** ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods;
- **poor:** ventilation which does not meet the standard of fair or good, but discontinuities are not expected to occur for long periods.

Ventilation that does not even meet the requirement for poor availability should not be considered to contribute to the ventilation of the area, i.e. low dilution would apply.

Different types of ventilation require different approaches for assessing their availability, e.g. availability of natural ventilation indoors shall never be considered as good because it

depends heavily upon ambient conditions, i.e. outdoor temperature and wind (see Clause C.5). As a matter of fact, the availability of natural ventilation depends on how realistic the assessment of indoor or outdoor conditions has been, i.e. whether the worst case scenario has been applied. If yes, then it may be that the level of availability could be fair, but never good. It has to be assumed that the higher the difference between indoor and outdoor temperature applied for calculation, the lower the level of availability in terms of diluting an explosive gas atmosphere.

On the other hand, artificial ventilation that serves the areas exposed to explosion conditions usually has a good availability because it incorporates technical means to provide for high degree of reliability.

The level of availability should be assessed as realistically as possible taking into account all the relevant factors. For outdoor gas jet releases dilution will occur irrespective of the ambient wind, and so the dispersion must be considered as being equivalent to good availability of ventilation indoors.

C.3.7.2 Criteria for natural ventilation

In case of natural ventilation, the worst case scenario shall be considered to determine the ventilation rate. Such a scenario will then lead to a higher level of availability. Generally, for any natural ventilation, a lower ventilation rate leads to a higher level of availability and vice versa. That will compensate for too optimistic assumptions made in the procedure of estimating the ventilation rate.

There are some situations which require particular care. In the case of natural ventilation of enclosed spaces, consideration of unfavourable conditions needs to be accounted for, i.e. frequency and probability of occurrence of such situations. As an example, during hot and windy summer days, two potential scenarios exist. In one scenario the indoor temperature may be slightly above the outdoor temperature so that buoyancy induced ventilation may hardly work and the wind from a certain direction may prevent the flow of air. Therefore in this case there is a combination of poor ventilation and a poor availability which will likely result in a more onerous classification. In another scenario, if only buoyancy is considered, then modest, buoyancy induced ventilation could be present virtually all the time and hence the availability could be estimated as fair if not good.

In open air situations the degree of dilution is generally considered as medium while the availability of ventilation in terms of wind presence may be considered as good unless there is restricted ventilation such as within pits, dykes or areas surrounded by high structures.

C.3.7.3 Criteria for artificial ventilation

In assessing the availability of artificial ventilation, the reliability of the equipment and the availability of, for example, standby blowers should be considered. Good availability will normally require, on failure, automatic start-up of standby blower(s). However, if provision is made for preventing the release of flammable substance when the ventilation has failed (for example, by automatically closing down the process), the classification determined with the ventilation operating need not be modified, i.e. the availability may be assumed to be good.

C.4 Examples of ventilation arrangements and assessments

C.4.1 Introduction

The following examples are intended to illustrate the interaction between the release of flammable substance and ventilation based on the principles outlined in Clauses 6, 7 and 8. It is important to understand that dilution is a complex process which takes place either through air entrainment at the boundaries of a release jet, or through mixing with air caused by ventilation flow or atmospheric instabilities. Usually, both mechanisms are considered because a jet eventually becomes a passive plume susceptible to air movement. Mixing with

air generally does not happen uniformly throughout the ventilated space and the background concentration as the result of the mixing with air is just a very rough measure of the average contamination of the volume under consideration.

In a real ventilated space the ventilation arrangement may not be adequate to dilute the flammable substance uniformly. In practice the true nature of dispersion and dilution may substantially deviate from the average results obtained by calculation. The ventilation arrangement, i.e. position of the inlet and outlet openings relative to each other and relative to source of the release, may sometimes have greater influence on the atmosphere than the capacity of the ventilation itself.

The examples below illustrate a few possible scenarios which may help in better understanding of the ventilation arrangements that may be suited for a particular situation.

C.4.2 Jet release in a large building

This example (see Figure C.2) illustrates the conditions where there are a limited number of sources of gas release in a large space e.g. gas release from pipe fittings.

A small leak in a pipe fitting would be expected to create a jet release with a high velocity if the pressure is high. The jet would self dilute and disperse even without much other apparent air movement in the building.

For a space with normal ventilation, (e.g. good sized door and wall openings and/or roof ventilation or other designated ventilation provisions), the volume of the space and natural air movement would suggest the degree of dilution is medium and the availability of ventilation is fair.

For a space with poor ventilation, (e.g. an unventilated basement), a jet release may initially self dilute and disperse into the space but the lack of air movement may also lead to a longer term build up of gas in the space. In this situation the diluted gas from the release will be re-entrained in the continuing jet release resulting in a build-up of the background gas concentration.

Unless the ventilation provisions are adequate to control the background concentration in the space the degree of dilution is considered low. However it may still be practical to provide for different zone classifications throughout the space.

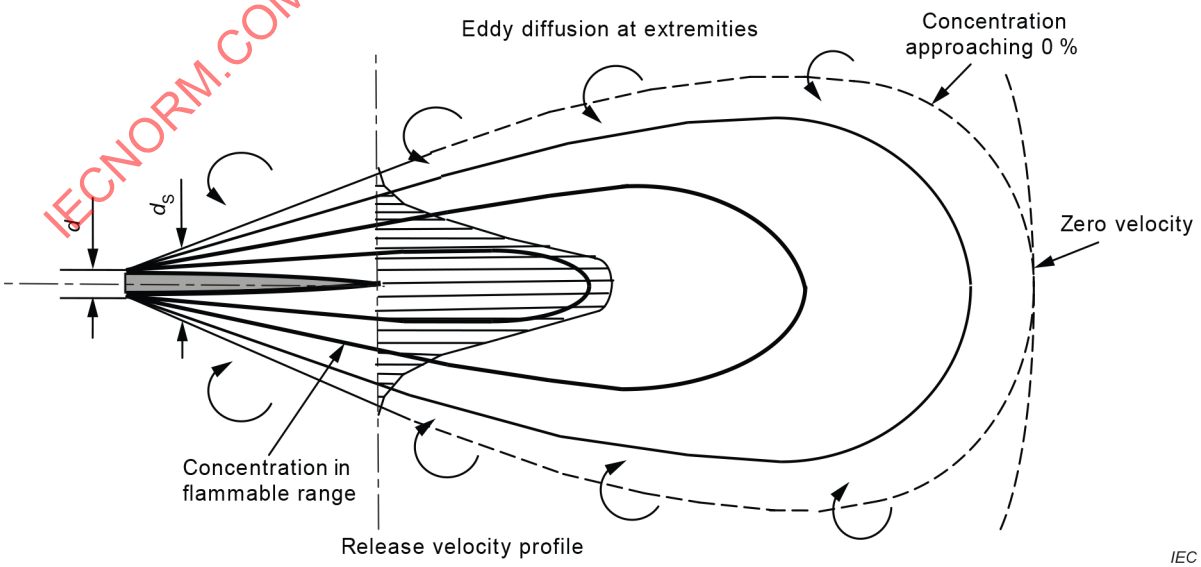


Figure C.2 – Self diffusion of an unimpeded high velocity jet release

NOTE d_s is pseudo source diameter, i.e. the diameter of the jet at the downstream cross section at which it becomes isobaric (reduced to atmospheric pressure).

C.4.3 Jet release in a small naturally ventilated building

This example illustrates conditions where there may be sources of gas release in a small room or building.

Dispersion and dilution factors are the same as described in C.3.5.

Where the building includes provision for ventilation to ensure adequate removal of any gas from a release then the interior of the building may be considered to have a medium degree of dilution.

Where there are a limited number of sources of release (or locations for the sources of release) it may be practical to classify hazardous areas that are limited to regions around the sources of release. Where there are large numbers of possible sources of release then it is common practice to classify the entire space with a single zone classification. This reflects the consideration of the self dilution volume from a jet from many possible positions and the possible variants in gas or vapour dispersion from various locations.

Where the degree of dilution is low then it is normal practice to provide a single zone classification for the enclosed space irrespective of the number of sources of release.

C.4.4 Jet release in a small artificially ventilated building

This example (see Figure C.3) might apply to a situation such as a gas compressor room.

Irrespective of the rate of ventilation or arrangement of a ventilation system a jet release is not likely to be diluted to below the LFL immediately at the source of release unless the pressure is very low. Therefore the degree of dilution at the source of release can rarely be described as high.

The degree of dilution for the remainder of the space is largely dependent on the arrangement and rate of artificial ventilation. The degree of dilution may also be highly sensitive to both these factors as illustrated by Figure C.3 and Figure C.4.

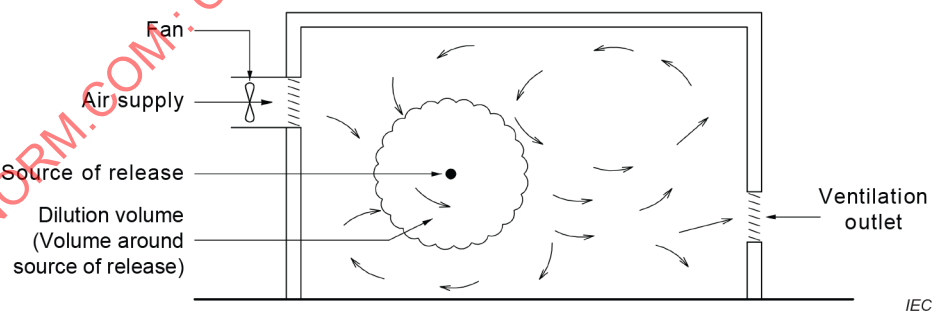


Figure C.3 – Supply only ventilation

In this case an enclosed space is supplied with fresh air with an equal volume discharging through a vent.

Despite an apparently high number of air changes per hour the ventilation arrangement can create a circulatory air movement within the enclosure resulting in an elevated background concentration. An alternative way of looking at this is that the re-entrained gas increases the dilution volume from the sources of release. Where this happens the degree of dilution should be treated as low.

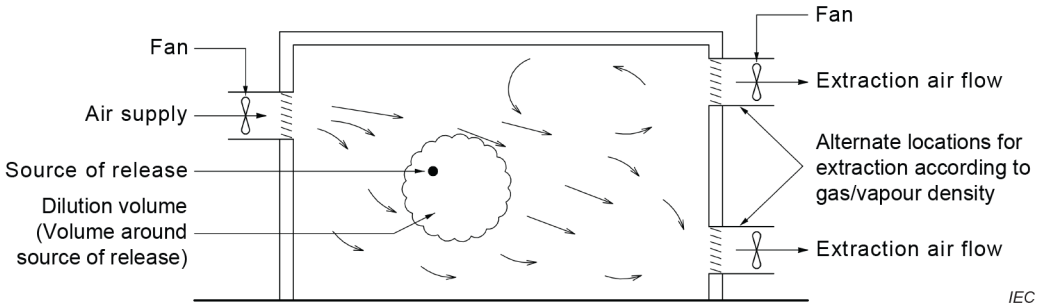


Figure C.4 – Supply and extraction ventilation

In this case the enclosed space is provided with both supply and extraction ventilation. As with the case for supply only there is a possibility that the ventilation arrangement will create recirculating air movement and result in re-entrainment of the diluted gas into a jet release thereby increasing the background gas concentration.

With careful consideration of the ventilation arrangements and positioning of the extraction points it is possible to minimize any re-circulatory air patterns. In this case a degree of dilution of medium or even high may be achieved.

NOTE Ventilation is commonly applied as an extraction system only which may be either general or local (for local extraction ventilation see 7.2.3.3).

C.4.5 Release with low velocity

Releases at low velocity are common in many industrial processes and include applications such as evaporation of flammable liquids from vents, baths, drains or printing and painting.

A jet release may also be considered a low velocity release if the jet impinges on a surface. Velocity of the jet can be reduced with the jet turning into a passive plume.

For releases at low velocity dispersion and dilution are influenced largely by air movement in the space and the buoyancy of the gas or vapour.

As for jet releases, the degree of dilution will be dependent on the size of the building or room, rate of release and ability to control any background concentration by general ventilation.

C.4.6 Fugitive emissions

Fugitive emissions are small releases of gases or vapours from pressurized equipment due to leaks (generally in an order of magnitude between 10^{-7} kg/s and 10^{-9} kg/s). Though small, these releases can still accumulate in enclosures that are not ventilated.

Such fugitive emissions may accumulate in the course of time thus giving rise to an explosion hazard. Therefore, care must be taken when designing particular facilities or equipment such as analyzer houses and sealed enclosures e.g. instrument panels or instrument weather protection enclosures, thermally insulated heated enclosures or enclosed spaces between pipe installations and the envelope of thermal insulation or similar items with higher pressure gas lines. Such items should be provided with some ventilation or provision for gas dispersion even if only for critical periods of time.

Where tightly closed enclosures are used the likely low effectiveness and availability of ventilation in such enclosures with natural ventilation may result in low dilution and hence may require classification as Zone 0 or Zone 1 according to Table D.1.

C.4.7 Local ventilation-extraction

Local artificial ventilation is recommended wherever practical (see Figure C.5).

Local artificial ventilation can improve the degree of dilution near to the source of release. More importantly local artificial ventilation should control the movement of the gas or vapour to limit gas or vapour beyond the intended area of influence of the local ventilation system. Where this is achieved the degree of dilution around the source of release can be considered as medium.

Generally local artificial ventilation should be located close to the source of release to be effective. Local artificial ventilation can be very effective where the source of release is characterized by a very low release velocity. As local artificial ventilation needs to overcome the release velocity of the gas or vapour to control the movement of that release, the applicability of local artificial ventilation for jet releases is greatly reduced over other forms of release.

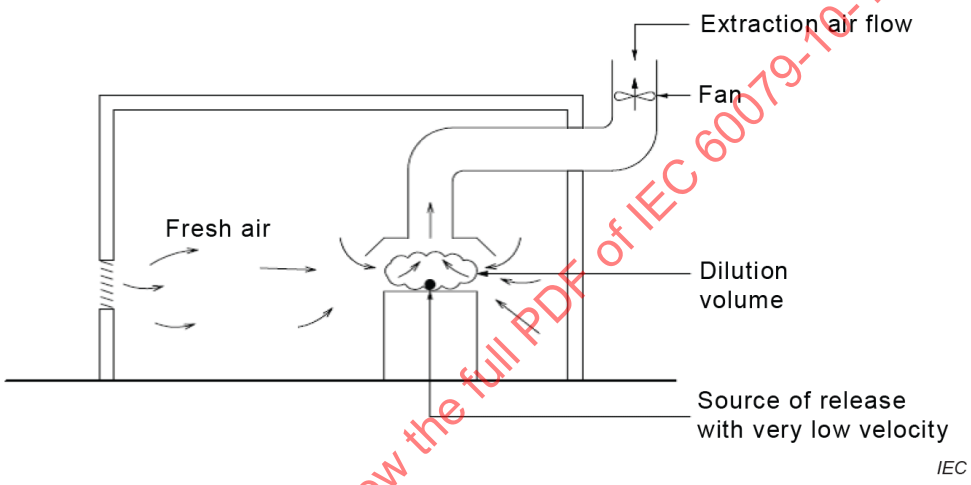


Figure C.5 – Local extraction ventilation

C.5 Natural Ventilation in buildings

C.5.1 General

Subclauses C.5.2 to C.5.4 provide a means for assessing the natural ventilation in buildings. Other means of assessment may also be suitable, e.g. by use of building standards such as BS 5925.

Caution needs to be applied as without evidence and specific building features to promote natural ventilation, the size and shape of the building may not be conductive to promoting natural ventilation and in such cases the degree of the natural ventilation efficiency should be considered as low.

C.5.2 Wind induced ventilation

The degree of air movement in the interior of a building will depend on the size and position of the openings relative to wind direction, as well as on the shape of the building. Ventilation flows may be induced by infiltration through non-airtight doors and windows or cracks and gaps in parts of the structure even if there are no ‘architectural’ openings in the walls and/or roof, or if those are closed. The equations used here assume flow through openings designed for ventilation, rather than infiltration. This philosophy is also appropriate to adopt for the classification of hazardous areas.

Ventilation implies both ingress and egress of air and some openings will act primarily as inlet openings and others as outlet openings. Windward (upwind) openings will normally act as the inlet openings and leeward (downwind) and roof openings as the outlet openings. This implies that wind induced ventilation could be estimated only with a good knowledge of the wind rose diagram for a particular location.

The driving force of wind induced ventilation is the pressure differential between the windward and leeward sides of a building.

The air flow due to wind can be expressed as:

$$Q_{\mathrm{a}} = C_{\mathrm{d}} A_{\mathrm{e}}\, u_{\mathrm{w}} \sqrt{\Delta C_p}\ \left(\mathrm{m}^3/\mathrm{s}\right) \tag{C.2}$$

$$A_{\mathrm{e}} = \sqrt{\frac{A_1^2 A_2^2}{A_1^2 + A_2^2}}\ \left(\mathrm{m}^2\right) \tag{C.3}$$

Values for ΔC_{p} should be derived from ventilation or building codes.

The values for A_1 and A_2 refer to effective areas of the upwind and the downwind openings respectively.

CFD modelling or wind tunnel testing may also be used to provide a more reliable assessment of the pressure coefficient for a building.

Wind strength and direction are variable and not generally predictable. Guidance on wind speed is provided in Table C.1. Wind should be considered in conjunction with other types of ventilation to verify whether it complements or opposes other ventilation. Wind may have a positive effect if the inlet and outlet openings for purely wind-induced ventilation are the same as they would have been for other sources of ventilation, but an impairing effect if they are opposed. e.g. wind of any direction will have a positive effect if there is a ventilation opening on the roof top, but will have an impairing effect if the outlet ventilation openings happen to be upwind.

C.5.3 Buoyancy induced ventilation

Buoyancy induced 'Stack Effect' ventilation is accomplished by the movement of air due to the difference between indoor and outdoor temperatures. The driving force is the difference in air density due to the different temperatures. The vertical pressure gradient depends on the density of air and will therefore not be the same indoors and outdoors, leading to a pressure difference.

If the average indoor temperature is higher than the outdoor temperature the indoor air will have a lower density. If an enclosed space has openings at different heights air will enter through the lower openings and leave through the upper level openings. The flow rate will increase as the magnitude of the temperature difference grows larger. Therefore buoyancy induced ventilation will be more effective at lower ambient outdoor temperatures. At higher ambient outdoor temperatures buoyancy induced ventilation will become less effective and if the ambient outdoor temperature rises above the indoor temperature the flow would reverse.

The indoor temperature may be higher due to natural causes, deliberate heating or process heat. Thermal currents may also be induced indoors varying the effect of average indoor temperature. Assuming that the inside of the building is fully mixed, constant temperatures can be used both inside and outside.

For a temperature gradient, assuming the inside temperature at the lower opening is the same as the outside temperature, T_{out}, and the inside temperature at the upper opening is T_{in}, the volume flow rate of air can be calculated from the following equation:

$$Q_a = C_d A_e \sqrt{\frac{4\Delta T}{(T_{in} + T_{out})} g H} \left(m^3 / s\right) \quad (C.4)$$

$$A_e = \sqrt{\frac{A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(m^2\right) \quad (C.5)$$

The values for A_1 and A_2 refer to effective areas of the lower and the upper openings respectively.

These equations give reasonable results only for rooms with inlet and outlet openings positioned on opposite walls relative to each other (see Figure C.7), and little or no obstructions which could impede the free flow of air. Also, if the vertical distance between the midpoints of the lower and upper openings H is small and the horizontal distance is large, then the buoyancy induced ventilation will be reduced and the calculation may be less accurate. E.g. where H is smaller than the width of the room, then a safety factor related to the inefficiency of ventilation must be applied (see C.3.6.2).

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 types of openings or apertures. Any value above 0,75 should be based on established references for the application.

The indoor temperature must be higher than the outdoor temperature to achieve the necessary conditions for buoyancy induced ventilation. During periods of high outdoor ambient temperatures the indoor temperature may become lower than the outdoor unless there is some heat source indoors. Temperature gradients are also affected by the substance of the building and for some constructions the indoor temperature may be lower than the outside temperature under certain conditions. If the indoor temperature is lower than the outdoor temperature, then equation C.4 is not applicable.

The greater the vertical distance between the midpoints of the lower and upper openings, the more effective the natural ventilation will be. For buoyancy induced ventilation, the most desirable position for the inlet openings is at the bottom of the opposite walls and for outlet openings, at the roof top. However, where this is not feasible, the inlet and outlet openings should be positioned at the opposite walls to provide for air movement across the whole area.

In many cases the heating requirements at the lower ambient temperatures may be compromised by the natural ventilation thus imposing the need to reduce, or close the ventilation openings. Consideration must be given to reduction of the openings to the extent that might impair natural ventilation thus preventing the dilution of the explosive gas atmosphere. Generally, all the openings that could be normally closed such as doors, windows and adjustable louvres should not be considered as ventilation openings.

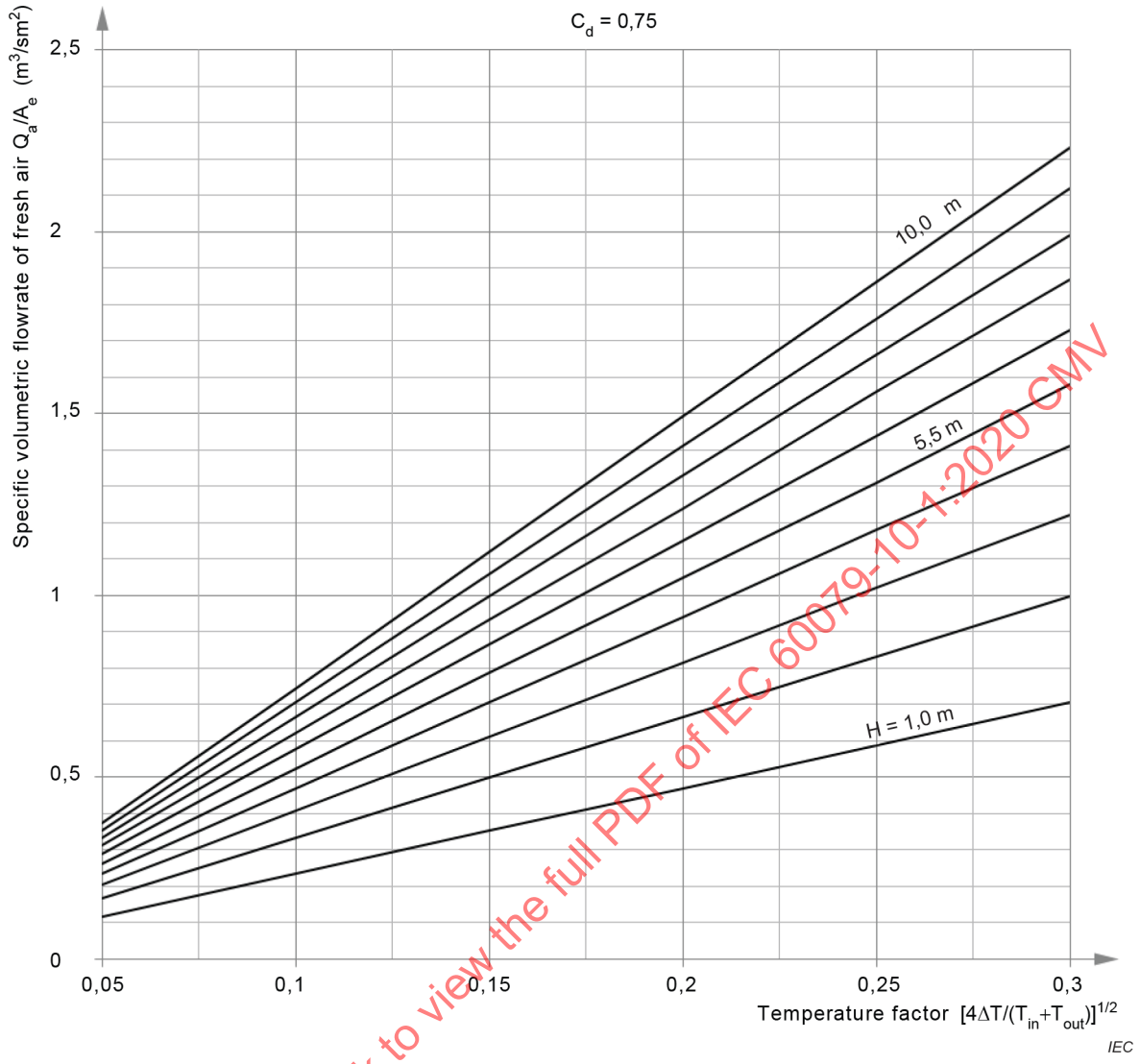


Figure C.6 – Specific volumetric flow rate of fresh air of equivalent effective opening area

The chart in Figure C.6 is based upon equation (C.4). Therefore the limitations in the use of these calculations described in C.5.2 also apply.

C.5.4 Combination of the natural ventilation induced by wind and buoyancy

Both, wind and buoyancy induced ventilation can occur separately but are likely to occur at the same time. Pressure differences due to thermal buoyancy will typically be the dominating driving force on a calm cold day with practically no wind, whereas pressure differentials created by wind may be the dominating driving force on a windy hot day. Their forces can oppose or complement each other depending on the position of the inlet and outlet openings (of the buoyancy-induced ventilation) in relation to the wind direction (see Figure C.7).

A probability based assessment must be applied taking into account climate, the wind rose diagram for a particular location and the possible indoor temperatures.

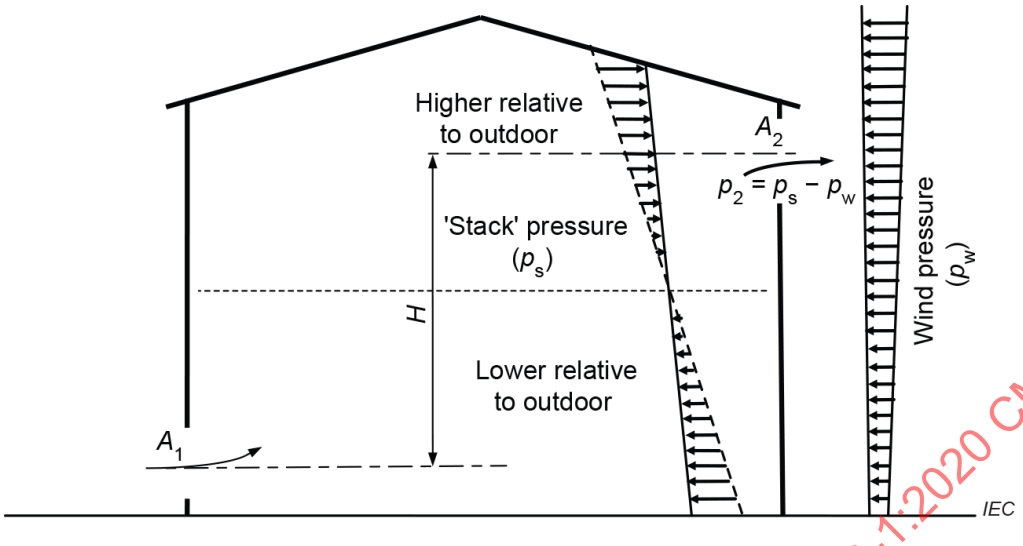


Figure C.7 – Example of opposing ventilation driving forces

The ventilation flows caused by pressure differences due to a combination of wind and temperature differences can also be estimated through more complex calculations. For each ventilation opening, of area A, the flow can be obtained from the following equation based on the pressure difference due to wind and the change in air density:

$$Q_a = C_d A \sqrt{\frac{2\Delta p}{\rho_a}} \left(m^3/s\right) \quad (C.6)$$

Annex D
(informative)

Estimation of hazardous areas

D.1 General

The guidance in this annex provides for the estimation of the type of zone (D.2) and the extent of zone (D.3) to relate relevant factors including:

- the grade of release (Annex B),
- the effectiveness of ventilation and degree of dilution (Annex C), and
- the availability of ventilation (Annex C).

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

D.2 Estimating types of the zones

Table D.1 can be used for estimating the type of zone for indoor areas and open areas.

Table D.1 – Zones for grade of release and effectiveness of ventilation

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2[c]	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[d]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0[d]

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

[b] The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

[c] Zone 1 is not needed here. I.e. small Zone 0 is in the area where the release is not controlled by the ventilation and larger Zone 2 for when ventilation fails.

[d] Will be Zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

Availability of ventilation in naturally ventilated enclosed spaces is commonly not considered as good.

D.3 Estimating the extent of the hazardous area

The extent of the hazardous area or region where flammable gas may occur depends on the release rate and several other factors such as gas properties and release geometry and surrounding geometry.

Figure D.1 may be used as a guide to determine the extent of hazardous area for various forms of release. Other forms of calculation or assessment based on reputable sources may also be applied (see Annex K).

The curves are based on a zero background concentration and are not applicable for indoor medium and low dilution situations (see C.3.6.1).

NOTE The curves in the chart of Figure D.1 are based upon CFD simulations for different 'ventilation velocities'. The distances in the chart are given to be reasonably worst-case for the given release. This has been compard with CFD simulations and the distances given in reputable industry codes.

The chart represents a rough approximation for some large-scale situations but would not be reliable on a small scale level. Where a zone of negligible extent (NE) is suggested then the use of this chart is not applicable.

Extrapolation of the curves beyond the chart area shown in should not be undertaken due to other factors that will affect the assessment beyond the limits indicated even though hazardous distances can be less than 1 m as well as higher than those shown in Figure D.1.

The appropriate line should be selected based on the type of release as either:

a) An unimpeded jet release with high velocity (typically a choked release);

b) A diffusive jet release with low velocity (typically a subsonic release) or a jet that loses its momentum due to the geometry of the release or impingement of the jet on nearby surfaces;

c) Heavy gases or vapours that spread along horizontal surfaces (e.g. the ground).

Use of the 'Jet' curve should applied with caution as many applications may be better represented by the 'Diffusive' curve.

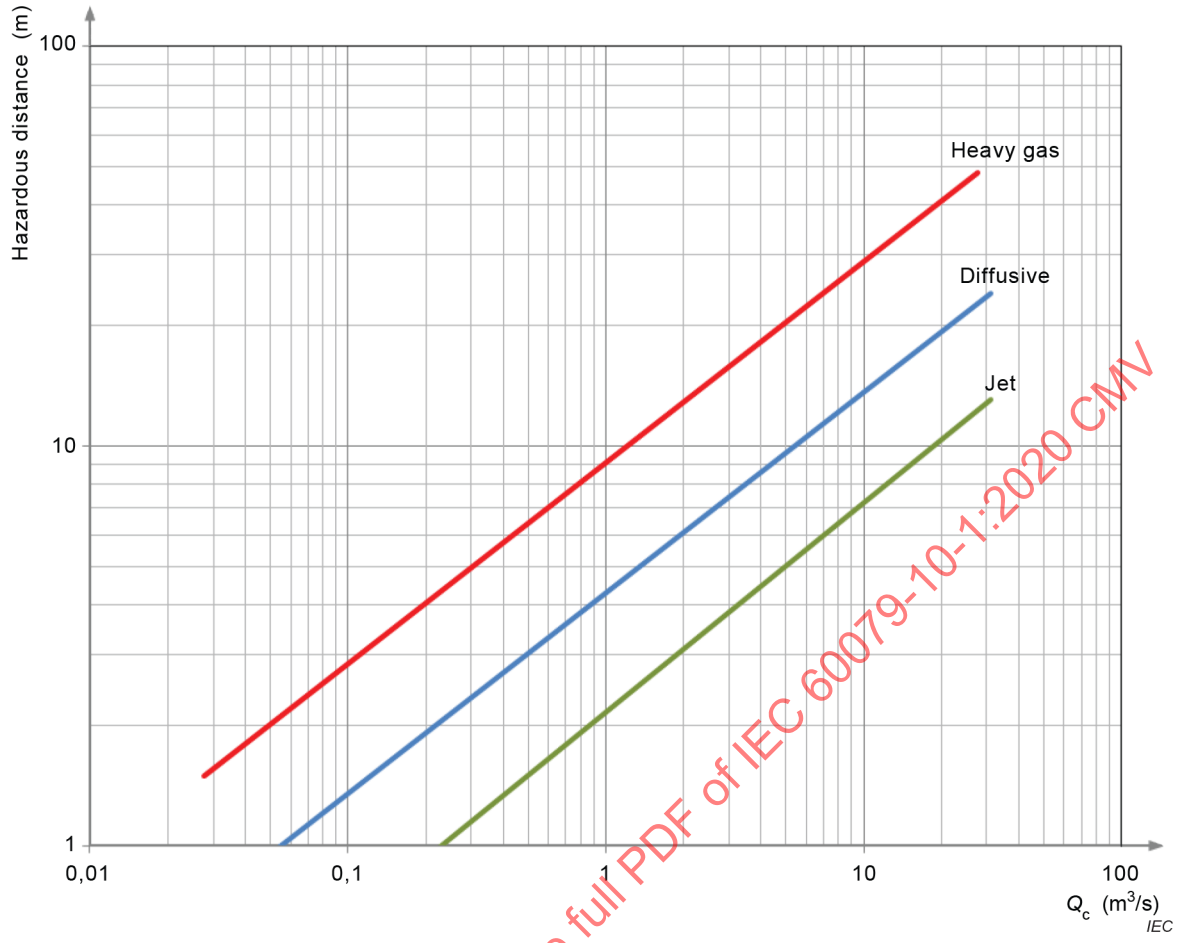


Figure D.1 – Chart for estimating hazardous area distances

Where

$Q_C = \frac{W_g}{\rho_g \times LFL}$ is the volumetric release characteristic of the source (m^3/s);

$\rho_g = \frac{p_a M}{R T_a}$ is the density of the gas/vapour (kg/m^3);

Where appropriate, other forms of calculation or assessment based on computational fluid dynamics (CFD) or testing may also be applied.

Figure D.1 does not identify different zones and zones should be assessed based on the ventilation around the source of release (see Annex C) and possible variations in release conditions.

The method of using the chart in Figure D.1 is demonstrated in the examples of Annex E.

Annex E
(informative)

Examples of hazardous area classification

E.1 General

The practice of hazardous area classification involves knowledge of the behaviour of flammable gases and liquids when they are released from containment, and sound engineering judgement based on experience of the performance of items of plant equipment under specified conditions. For this reason, it is not practicable to give examples for every conceivable variation of plant and process characteristics.

The examples are not intended to be applied in practice and are provided only to illustrate an optional means of assessment as presented in this standard. The characteristics of release and other parameters used are also only provided to illustrate the means of assessment and may not represent real conditions.

E.2 Examples

Example 1

A normal industrial pump with mechanical (diaphragm) seal, mounted at ground level, located outdoor, pumping flammable liquid.

Characteristics of release:

Flammable substance	Benzene (CAS no. 71-43-2)
Molar mass	78,11 kg/kmol
Lower flammable limit, LFL	1,2 % vol. (0,012 vol./vol.)
Auto-ignition temperature, AIT	498 °C
Gas density, ρ_g	3,247 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, SR	Mechanical seal
Grade of release	Secondary (leakage due to a seal rupture)
Liquid release rate, W	0,192 kg/s, determined considering a discharge coefficient C_d = 0,75, a hole size S = 5 mm^2, a liquid density ρ = 876,5 kg/m^3 and a pressure difference Δp = 15 bar
Gas release rate, W_g	3,85 × 10^{-3} kg/s, defined considering the fraction of liquid vaporised from the point of release (2 % of W); remaining liquid drained to sewer system
Volumetric release characteristic, Q_C	0,099 m^3/s

Characteristics of location:

Outdoor situation	Unobstructed area
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T	20 °C (293 K)
Ventilation velocity, u_w	0,3 m/s
Ventilation availability	Good (wind speed at meteorological calm condition)

Effects of release:

Degree of dilution (see Figure E.1)	Medium
Type of zone(s)	Zone 2
Equipment group and temperature class	IIA T1

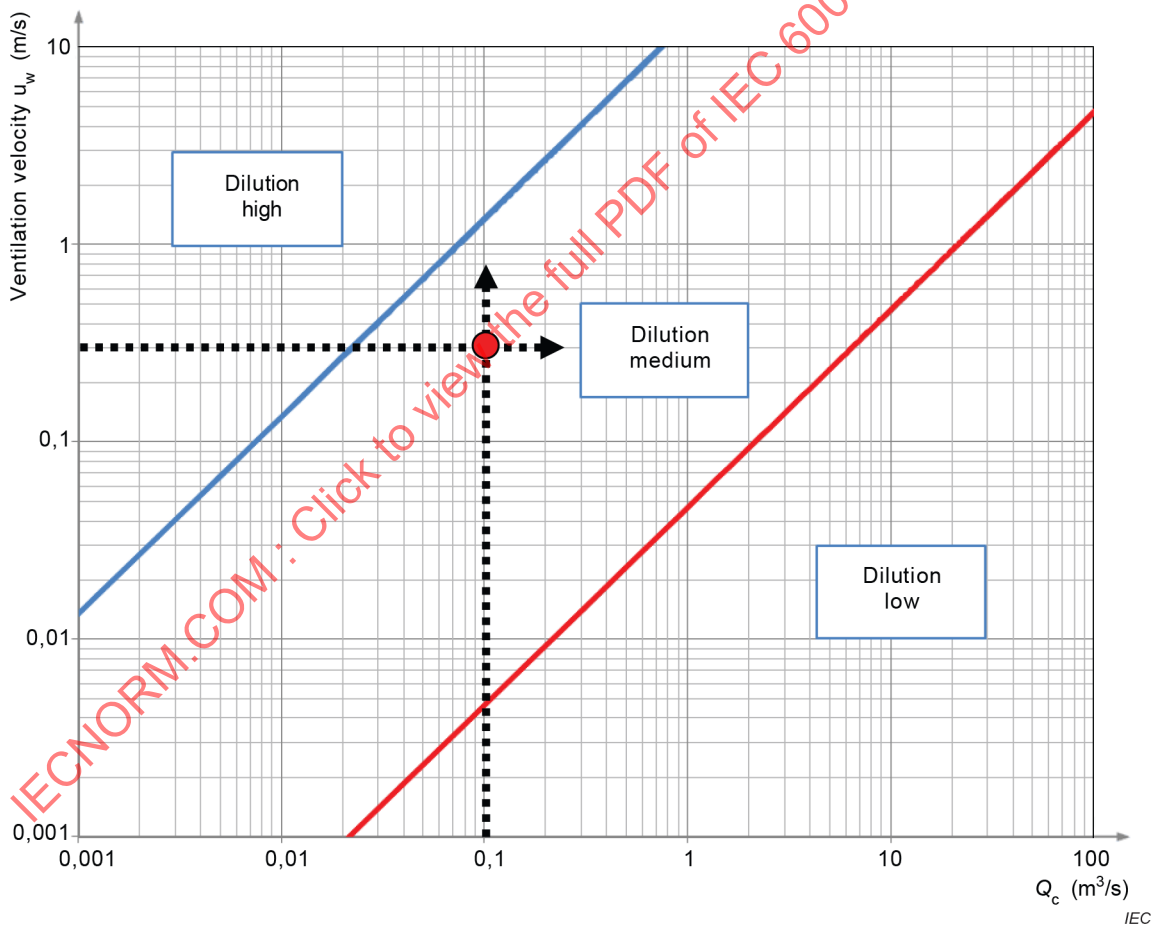


Figure E.1 – Degree of dilution (Example No. 1)

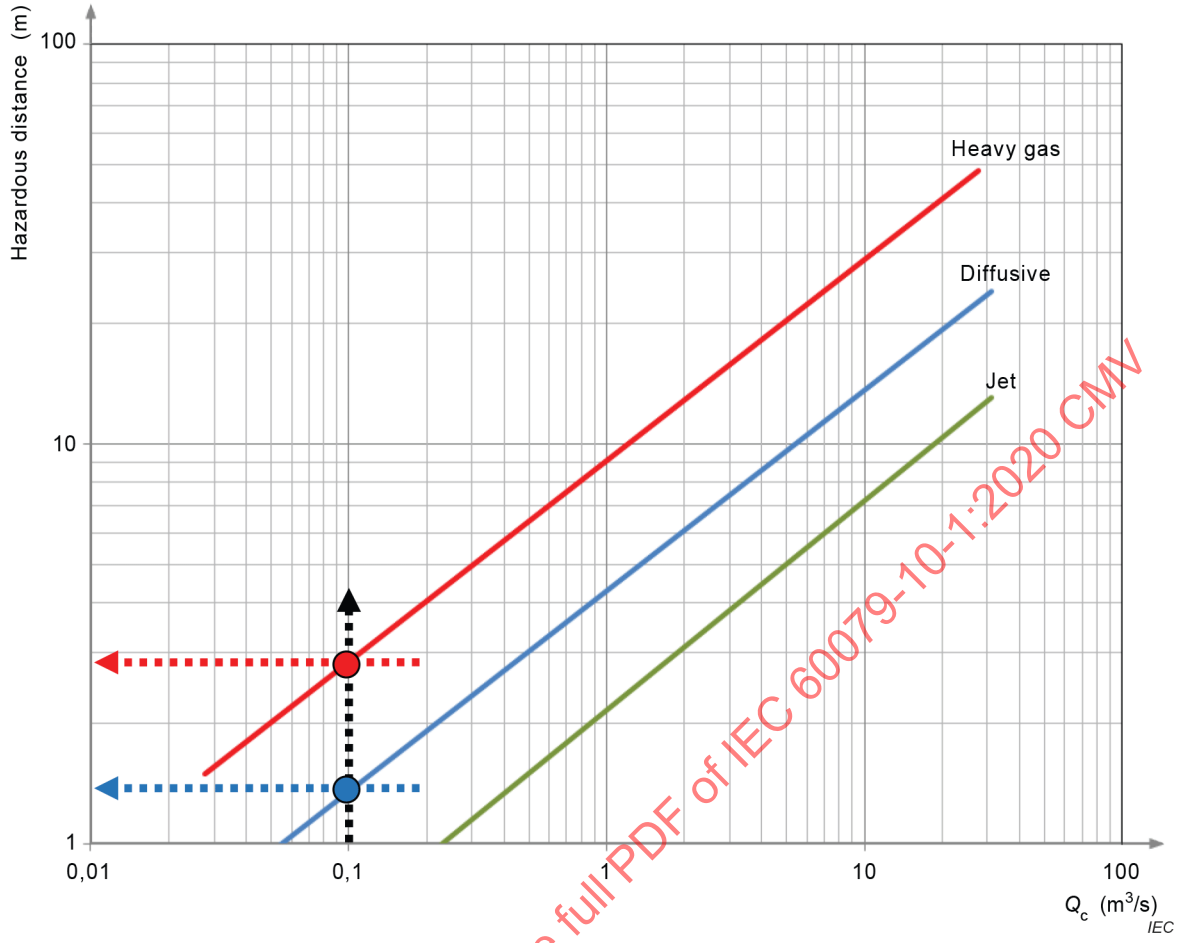
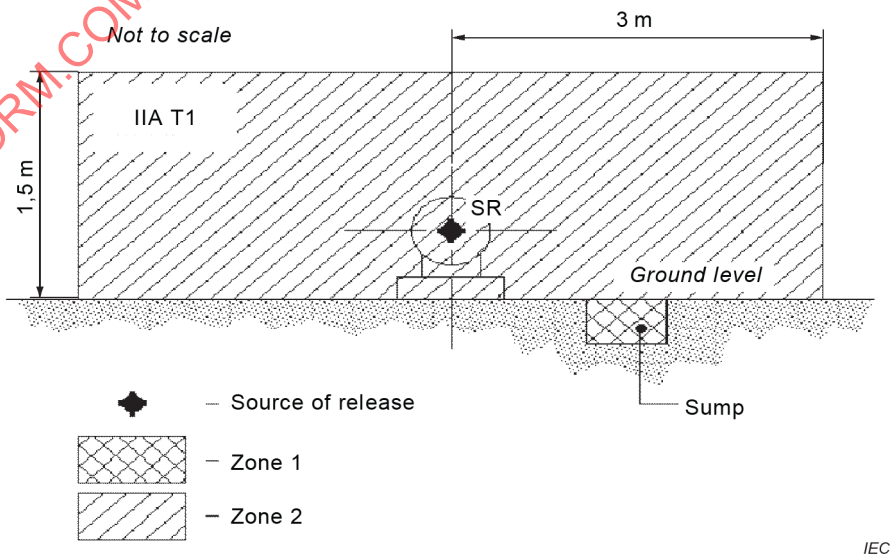


Figure E.2 – Hazardous distance (Example No. 1)

Hazardous area classification:

Hazardous area distances are based on the assessment from Figure E.2. Figure E.3 displays the front view of the facility. The figure is based on heavier than air vapour; the vertical distance is less than the horizontal as illustrated in Figure E.3.



NOTE The more severe classification of the sump due to the low degree of dilution.

Figure E.3 – Zone classification (Example No. 1)

Example 2

A normal industrial pump with mechanical (diaphragm) seal, mounted at ground level, located indoor, pumping flammable liquid

Characteristics of release:

Flammable substance	Benzene based liquid product
Molar mass	78,11 kg/kmol
Lower flammable limit, LFL	1,2 % vol. (0,012 vol./vol.)
Auto-ignition temperature, AIT	498 °C
Gas density, ρ_g	3,247 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, SR	Mechanical seal
Grade of release	Secondary (leakage due to a seal rupture)
Liquid release rate, W	0,192 kg/s, determined considering a discharge coefficient C_d = 0,75, a hole size S = 5 mm^2, a liquid density ρ = 876,5 kg/m^3 and a pressure difference Δp = 15 bar
Evaporation rate, W_e	3,85 × 10^{-3} kg/s, defined considering the fraction of liquid vaporised from the point of release (2 % of W); remaining liquid drained to sewage system NOTE Information taken from industrial code.
Gas volumetric release rate, Q_g	1,19 × 10^{-3} m^3/s
Volumetric release characteristic, Q_C	0,099 m^3/s

Characteristics of location:

Indoor situation	Building naturally ventilated (by wind)
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T_a	20 °C (293 K)
Enclosure size, $L \times B \times H = V_0$	6,0 m × 5,0 m × 5,0 m = 150,0 m^3
Air flow rate, Q_a	306 m^3/h (0,085 m^3/s)
Air flow rate availability	Fair, defined considering the worst environmental conditions (wind speed at meteorological calm condition)
Ventilation velocity, u_w	0,003 m/s, estimated by $Q_a / (L \times H)$
Critical concentration, X_{crit}	0,003 vol./vol., equal to $(0{,}25 \times LFL)$

Effects of release:

Ventilation inefficiency factor, f	5
Background concentration, X_b	0,068 vol./vol.

Concentrations comparison	$X_b > X_{crit}$
Time required to reach X_{crit}, t_d	7,67 h (safety margin equal to f)
Degree of dilution (see Figure E.4)	Low due to $X_b > X_{crit}$
Type of zone(s)	Zone 1
Equipment group and temperature class	IIA T1

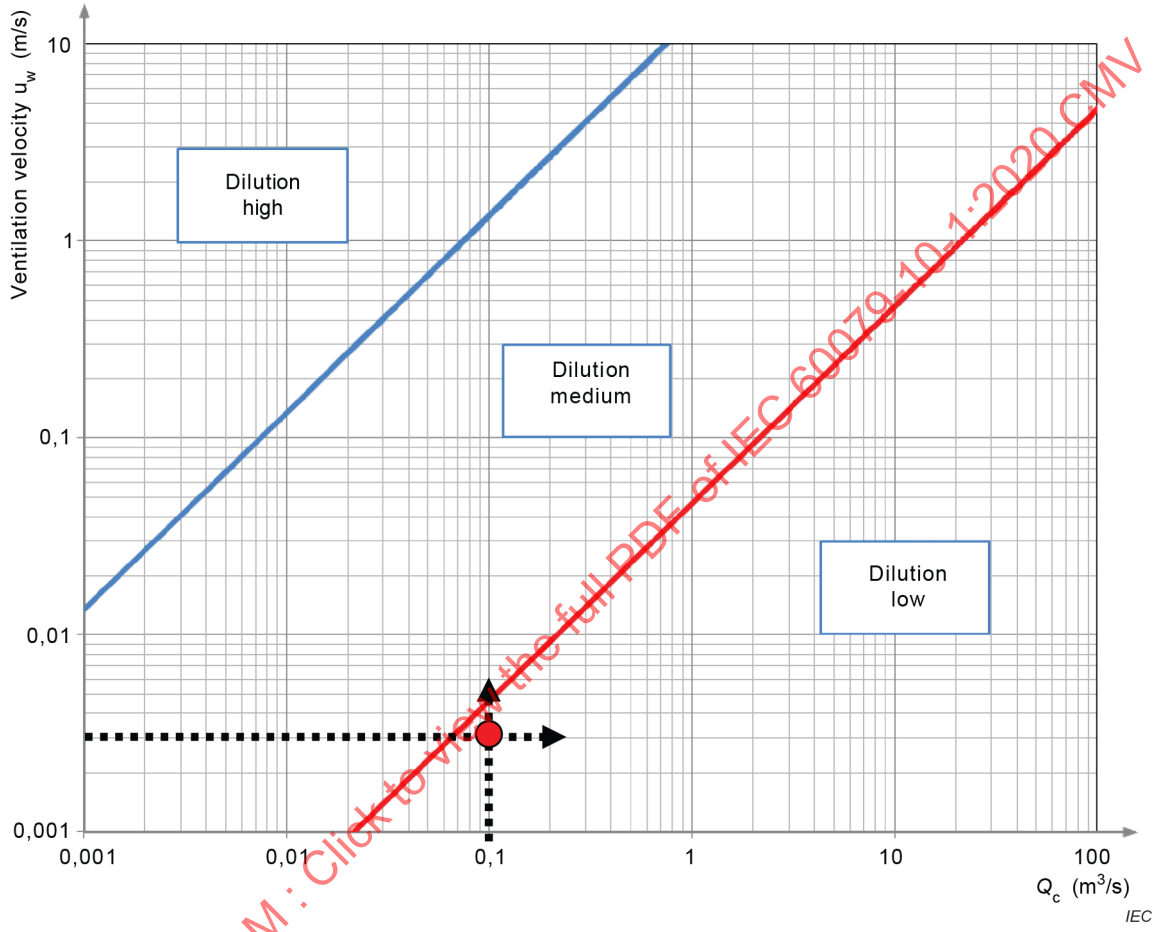


Figure E.4 – Degree of dilution (Example No. 2)

The procedure of estimating the degree of dilution by using the chart is not necessary in this case because the background concentration in the enclosed space is higher than the critical ($X_b > X_{crit}$). So the degree of dilution would be declared as low anyway. Figure E.4 simply confirms the assessment.

Hazardous area classification:

The example deals with a relatively small indoor location where the background concentration is twice the critical one. Moreover, the time required to reach the critical background concentration is significant (almost 8 h). There are no reasons to establish a vertical zone or a Zone 2 beyond Zone 1. The resulting hazardous area will encompass the volume of the indoor location considering the comparisons of concentrations, and the time required to reach the critical ones after the stop of the release. Openings, if any, should be considered as potential sources of release.

If the air flow rate were to be improved, then the degree of dilution could be ‘medium’ and the hazardous area could be Zone 2 instead of Zone 1.

Example 3

Vapour from a breather valve in the open air, from a process vessel.

Characteristics of release:

Flammable substance	Benzene (CAS no. 71-43-2)
Molar mass	78,11 kg/kmol
Lower flammable limit, LFL	1,2 % vol. (0,012 vol./vol.)
Auto-ignition temperature, AIT	498 °C
Gas density, ρ_g	3,247 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, SR	Breather valve
Grade of release	Primary (process vessel filling)
Release rate, W_g	4,5 × 10^{-3} kg/s (manufacturer's data)
Volumetric release characteristic, Q_C	0,115 m^3/s
Grade of release	Secondary (sealing device rupture)
Release rate, W_g	4,95 × 10^{-2} kg/s (manufacturer's data)
Volumetric release characteristic, Q_C	1,27 m^3/s

Characteristics of location:

Outdoor situation	Un-obstructed area
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T	20 °C (293 K)
Ventilation velocity, u_w	1,0 m/s
Ventilation availability	Good (wind speed at calm conditions)

Effects of releases:

Degree of dilution (see Figure E.5)	Medium
Type of zone(s)	Zone 1 + Zone 2
Equipment group and temperature class	IIA T1

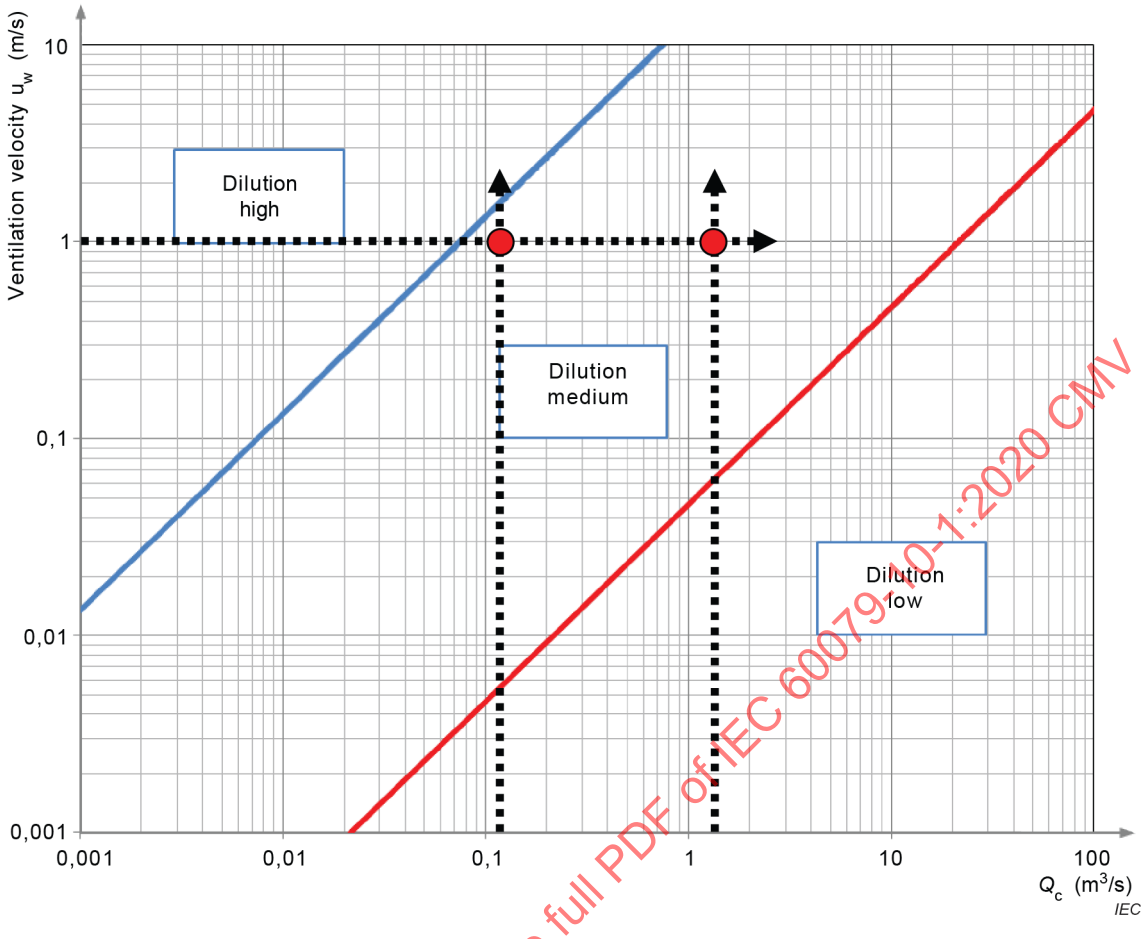


Figure E.5 – Degree of dilution (Example No. 3)

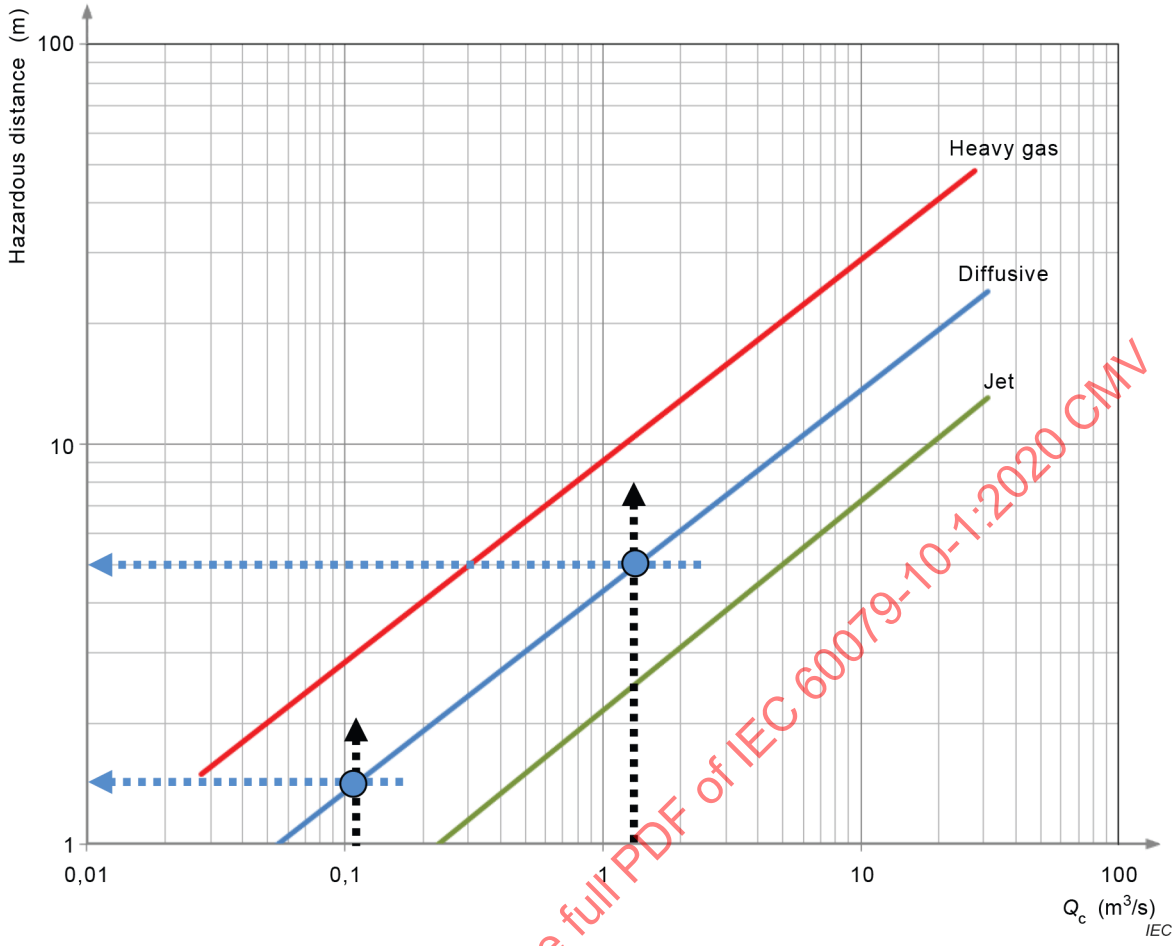


Figure E.6 – Hazardous distance (Example No. 3)

Extent(s) of zone(s), r for primary grade release = 1,5 m; for secondary grade release = 5,0 m

Hazardous area classification:

Hazardous area distances are based on the assessment from Figure E.6. Taking into account relevant parameters, the following hazardous areas are specific for the considered breather valve (see Figure E.7).

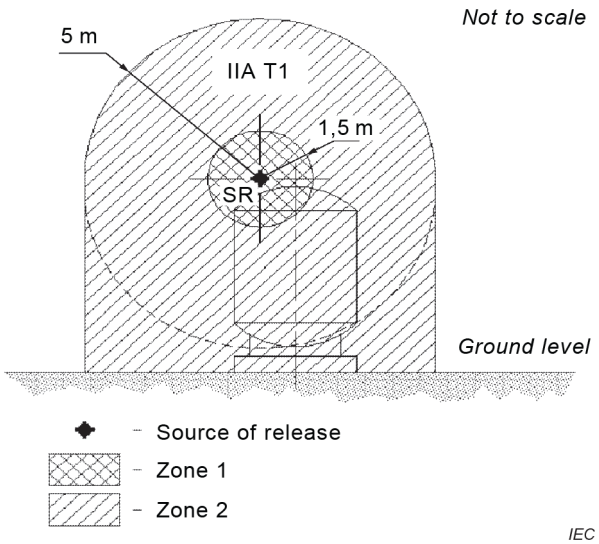


Figure E.7 – Zones classification (Example No. 3)

Example 4

Control valve in congested location, installed in a closed process pipe-work system conveying flammable gas.

Characteristics of release:

Flammable substance	Propane based gas mixture
Molar mass	44,1 kg/kmol
Lower flammable limit, LFL	1,7 % vol. (0,017 vol./vol.)
Auto-ignition temperature, AIT	450 °C
Gas density, ρ_g	1,833 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1
Source of release, SR	Valve stem packing
Grade of release	Secondary (packing rupture)
Release rate, W_g	5,06 × 10^{-3} kg/s, determined considering an operating pressure p = 10 bar, temperature T = 15 °C, hole size S = 2,5 mm^2, compressibility factor Z = 1, polytropic index γ = 1,1 and discharge coefficient C_d = 0,75
Volumetric release characteristic, Q_C	0,162 m^3/s

Characteristics of location:

Outdoor situation	Unobstructed area
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T	20 °C (293 K)
Ventilation velocity, u_w	0,3 m/s
Ventilation availability	Good (wind speed at calm condition)

Effects of releases:

Degree of dilution (see Figure E.8)	Medium
Type of zone(s)	Zone 2
Equipment group and temperature class	IIA T1

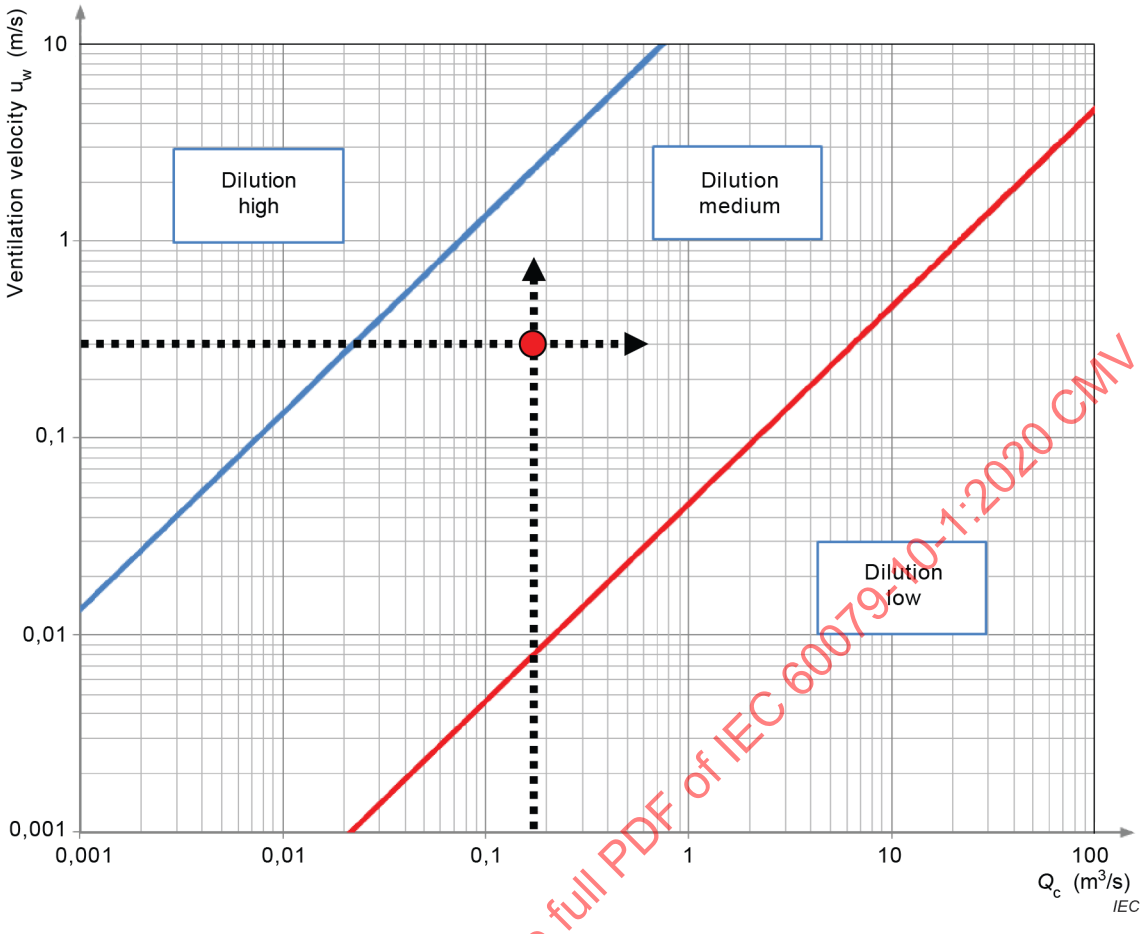


Figure E.8 – Degree of dilution (Example No. 4)

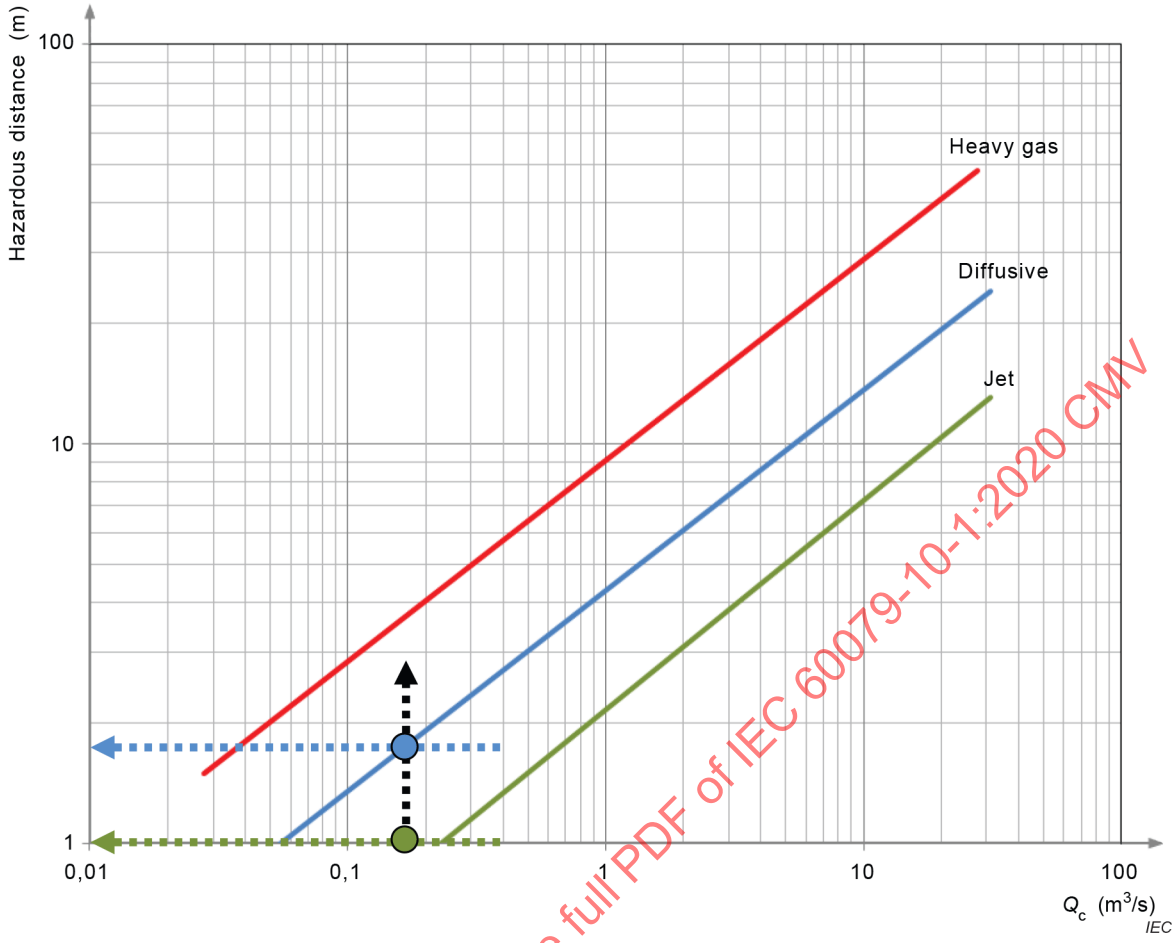


Figure E.9 – Hazardous distance (Example No. 4)

Extent(s) of zone(s), r from 1,0 m to 2,0 m due to surrounding characteristics (i.e. impeded or unimpeded jet release).

Since the chart is not valid for less than 1 m the zone is assessed as 1 m. If further refinement of this zone extent is desired, then another assessment methodology should be used.

Hazardous area classification:

Hazardous area distances are based on the assessment from Figure E.9. Taking into account relevant parameters, the following hazardous area is specific for the considered control valve (see Figure E.10).

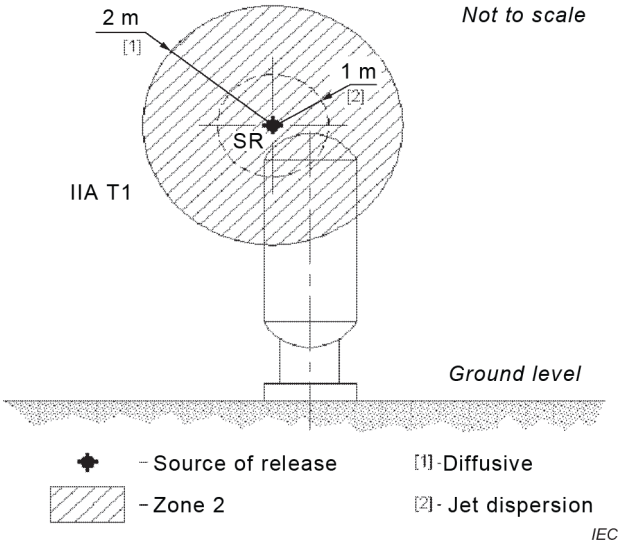


Figure E.10 – Zones classification (Example No. 4)

Example 5

Closed process pipework system, located indoor, conveying flammable gas.

Characteristics of releases:

Flammable substance	Wet, oil well natural gas
Molar mass	20 kg/kmol
Lower flammable limit, LFL	4 % vol. (0,04 vol./vol.)
Auto-ignition temperature, AIT	500 °C
Gas density, ρ_g	0,831 kg/m^3 (calculated at ambient conditions) Gas density indicates the curve that should be applied from the chart in Figure D.1.
Multiple sources of release, MSR	
a) grade of release	Continuous (fugitive emissions)
– type	Pipe fittings (discontinuities along piping)
– release rate per unit, W_g	1,0 × 10^{-9} kg/s (laboratory data)
– volumetric release rate per unit, Q_g	1,2 × 10^{-9} m^3/s
– number of releases	10
b) grade of release	Primary
– type	Sealing elements on moving parts at low speed (control valves stem packing)
– release rate per unit, W_g	1,5 × 10^{-6} kg/s (manufacturer's data)
– volumetric release rate per unit, Q_g	1,8 × 10^{-6} m^3/s
– number of releases	3

c) grade of release	Secondary
– type	Sealing elements on fixed parts (flange with fibre gasket)
– release rate per unit, W_g	1,7 × 10^{-3} kg/s, determined considering operating pressure p = 5 bar, a temperature T = 15 °C, a hole size S = 2,5 mm^2, a compressibility factor Z = 1, polytropic index γ = 1,1 and a discharge coefficient C_d = 0,75
– volumetric release rate per unit, Q_g	2,05 × 10^{-3} m^3/s
– number of releases	1, the largest one

Characteristics of location:

Indoor situation	Building naturally ventilated (by wind)
Ambient pressure, p_a	101 325 Pa
Ambient temperature, T_a	20 °C (293 K)
Enclosure size, $L \times B \times H = V_0$	3,0 m × 3,0 m × 3,5 m = 31,5 m^3
Air flow rate, Q_a	189 m^3/h (0,053 m^3/s)
Air flow rate availability	Fair, defined considering the worst environmental conditions (wind speed at meteorological calm condition)
Ventilation inefficiency factor, f	3
Ventilation velocity, u_w	0,005 m/s, estimated by $Q_a / (B \times H)$
Critical concentration, X_{crit}	0,01 vol./vol., equal to $(0,25 \times LFL)$

Effects of multiple sources of release:

Grade of release	Continuous (fugitive emissions)
summation of release rates, ΣW_g	1,0 × 10^{-8} kg/s
summation of volumetric release rates, ΣQ_g	1,2 × 10^{-8} m^3/s
background concentration, X_b	6,79 × 10^{-7} vol./vol.
concentrations comparison	$X_b << X_{crit}$
volumetric release characteristic, Q_C	3,01 × 10^{-7} m^3/s
degree of dilution	High
type of zone(s)	Zone 0 NE
Grade of release	Primary plus continuous
summation of release rates, ΣW_g	4,51 × 10^{-6} kg/s
summation of volumetric release rates, ΣQ_g	5,42 × 10^{-6} m^3/s
background concentration, X_b	3,1 × 10^{-4} vol./vol.
concentrations comparison	$X_b << X_{crit}$
volumetric release characteristic, Q_C	1,36 × 10^{-4} m^3/s

degree of dilution	High
type of zone(s)	Zone 1 NE
Grade of release	Secondary plus primary plus continuous
release rate, W_g	1,7 × 10^{-3} kg/s
volumetric release rate, Q_g	2,05 × 10^{-3} m^3/s
background concentration, X_b	0,12 vol./vol.
concentrations comparison	$X_b > X_{crit}$
time required to reach X_{crit}, t_d	1,23 h (safety margin equal to f)
volumetric release characteristic, Q_C	0,051 m^3/s
degree of dilution	Low due to $X_b > X_{crit}$
type of zone(s)	Zone 1
Equipment group and temperature class	IIA T1

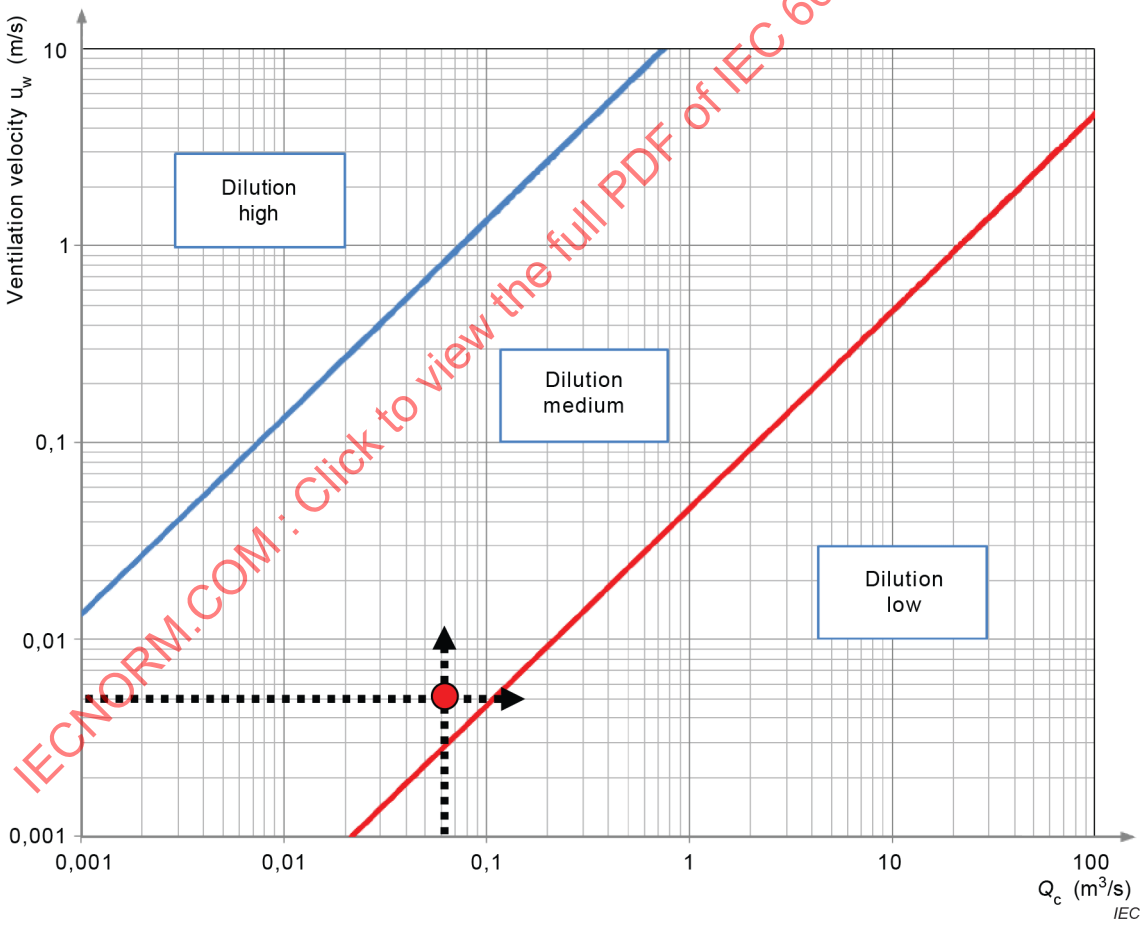


Figure E.11 – Degree of dilution (Example No. 5)

The procedure of estimating the degree of dilution by using the chart is not necessary in this case because the background concentration in the enclosed space is higher than the critical ($X_b > X_{crit}$). So the degree of dilution would be declared as low anyway. Figure E.11 shows that the intersection point is within the area of 'dilution medium' but close to the dividing line. Allowing for uncertainties in the methodology this shows the preceding assessment is appropriate.

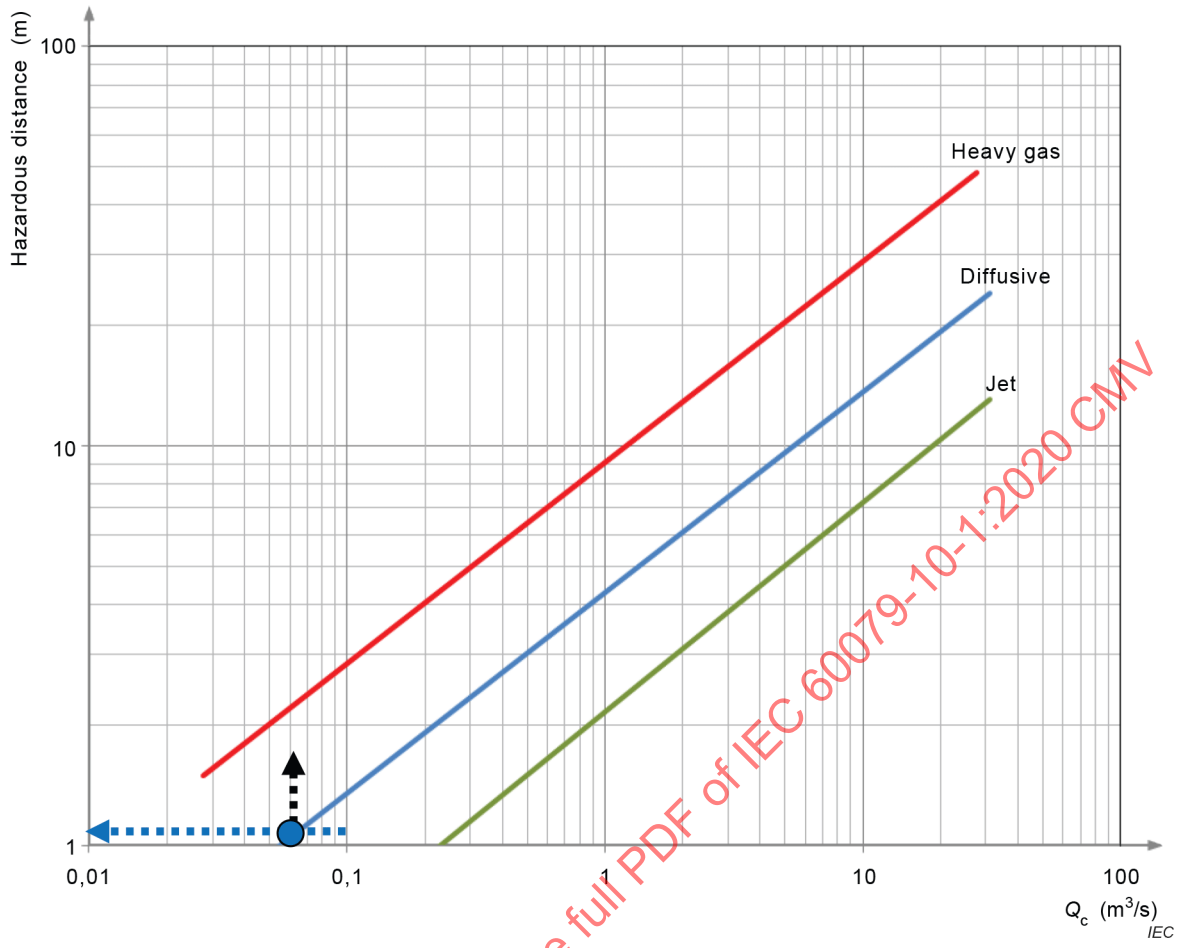


Figure E.12 – Hazardous distance (Example No. 5)

Extent of zone (see Figure E.12, r extent of zone is approximately 1,0 m due to surrounding characteristics (i.e. impeded jet release)

Hazardous area classification:

The resulting hazardous area will encompass the whole volume of the indoor location because the background concentration exceeds the critical concentration and the time for the concentration to fall to the critical concentration after the release has stopped, is significant. Also, the extent of zone is significant related to the enclosure size (see C.3.6.1).

E.3 Example case study for hazardous area classification

The following example is intended to illustrate the methodology of hazardous area classification and the way in which zones should be displayed. Zone details may vary depending on the specific installation details or application of the relevant code of practice. This example has been taken because it contains a variety of forms of release which are frequently met in practice, separately or in various combinations or in different contexts. That's why the compressor facility in this example should be considered just as a framework for the methodology set forth in the standard.

The example is a compressor facility handling natural gas (see Figure E.13). The compressor units are skid mounted packages consisting of a gas engine, compressor, combined air cooler, process piping, on-skid scrubbers, pulsation bottles, and auxiliary equipment.

Gas engines and compressors in this example are considered to be installed within a naturally ventilated shelter with air entering through louvered openings at the bottom and an open front of the shelter and leaving through a rooftop opening (see Table E.1).

The external part of the facility is considered to consist of combined air coolers with cooling water and process gas heat exchangers, piping, valves (emergency shut down, block and regulating), off-skid scrubbers, etc.

The flammable substances that appear in this example are presented in Table E.2:

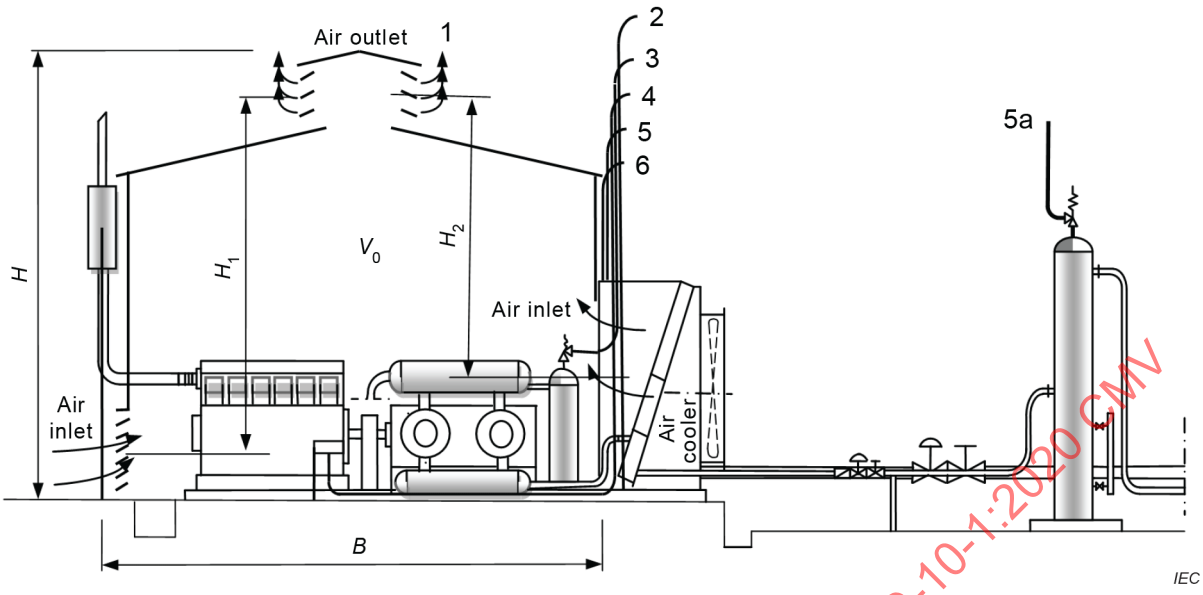
1) Process gas (natural gas with 80 % vol methane),
2) Process gas condensate collected in the scrubbers and automatically drained towards a collecting reservoir (mainly heavier hydrocarbons in quantities which are determined by the respective equilibrium state at each stage of compression),
3) Gas engine fuel and starting gas (dry pipeline quality natural gas, min 96 % vol methane),
4) Various chemicals applied in the process, e.g. corrosion inhibitors, antifreezing additives.

The sources of release that appear in this example are presented in Table E.3:

1) Starting gas vent (a predictable source that gives primary grade of release; happens at each start of the engine),
2) Compressor blowdown vent (a predictable source that gives primary grade of release; happens at each depressurization of the blocked compressor),
3) Gas engine shut-off valve vent (a relatively predictable source that gives primary grade of release (happens at each shutdown of the engine when the incoming fuel gas gets blocked and the trapped gas is evacuated to atmosphere),
4) Pressure relief valve vent (a non predictable source that typically gives secondary grade of release; happens if the pressure upstream increases above the set point; usually a shutdown safety device is installed in the protective system of compressor units to trip before the safety relief valve opens and therefore it should not normally be considered as the source that gives primary grade of release; see B.2.2 and B.2.3),
5) Compressor piston rod packings vent (a source that typically gives primary grade of release, however, if in doubt regarding monitoring, control and quality of maintenance, this vent may be considered as a source that gives continuous grade of release, see B.2.2 and B.2.3),
6) Gas engine, compressor and air cooler (sources that give secondary grade of release),
7) Process gas scrubbers and drains (sources that give secondary grade of release of the liquid phase).
8) Valves inside and outside of the shelter (sources that give secondary grade of release).
9) Pipe connections (sources that give secondary grade of release).

The rates of release for the purpose of this illustration are assessed as follows:

1) For starting gas, the gas flow rate delivered as shown in the manufacturer's data sheet for pneumatic starters,
2) For blowdown vent, the pressurized gas trapped in the compressor cylinders, scrubbers, pulsation bottles and process piping,
3) For gas engine shut-off valve vent, the gas trapped in the fuel line and cylinders,
4) For safety relief valves vent, the gas flow rate delivered in the manufacturer's data sheet for the respective pressure set point, or the gas flow rates calculated according to B.7.2.3.2 or B.7.2.3.3, or estimated otherwise.
5) For all other sources of release, the gas flow rates calculated according to B.7.2.3.2, or B.7.2.3.3, or estimated otherwise.



Key

1 – Air outlet ventilation opening

2 – Starting gas vent

3 – Compressor blowdown vent

4 – Fuel gas shut-off valve vent

5 and 5a – Pressure relief valve vents

6 – Compressor piston rod packings vent

Figure E.13 – Enclosed compressor handling natural gas

Table E.1 – Compressor facility handling natural gas

Classification procedure considerations for the shelter		
01	What are the flammable substances involved?	Process gas, gas condensate collected in the interstage scrubbers of the compressor units and engine fuel and starting gas.
02	Is the composition of those substances known?	It is known for the process, fuel and starting gas but it is not known for the process gas condensate. For the purpose of this example It has been assumed that it is a mixture of various heavier hydrocarbons, mostly pentane and hexane with water.
03	For this example values calculated or assumed for the lower flammable limits of the flammable substances are provided.	• for the process gas: LFL = 0,04; • for the fuel and starting gas: LFL = 0,05; • for the condensate: LFL = 0,013 to 0,08 depending on the compression stage.
04	What are the sources of release within the shelter?	Pipe connections on the gas engines, compressors, scrubbers and the piping as well as local instruments connections
05	What are the grades of release?	The grades of release are all secondary. It is assumed that there should be no gas in the shelter under normal operating conditions provided that the facility is well monitored and maintained.
06	What would be the most representative sources of release under given conditions?	Reciprocating compressors rarely leak at the cylinders. However, they are vibrating machinery with the process piping exposed to dynamic and thermal stresses. Therefore, any pipe connection may be a source of release. The other realistic source of release would be crankcase breather valve of the compressor. When a piston rod packing gets worn or broken, then the compressed gas may blow-by, enter the crankcase and then leak through the breather valve into the surrounding area. There are also other sources of release which have to be scrutinized. Some may not be obvious and may remain hidden for quite some time thus raising the doubts about the grade.

Classification procedure considerations for the shelter		
07	Since the sources that give secondary grades of release are not summated, which of those should be chosen for the purpose?	The one that will give higher release rate, e.g. at 2nd stage of compression which is the more stressed, taking the release orifice of 2,5 mm^2 (see Table B.1). • M = 21,6 kg/kmol; • γ = 1,2; • p = 51 bar; • T = 422 K (max allowed working temperature).
08	Assuming that the leak at the blown gasket appears as more abundant, what would be the release rate?	Since the operating pressure indicates sonic release, the result shall be: $W_g \approx 1{,}54 \times 10^{-2}$ kg/s; with C_d being 0,75 and S as 2,5 mm^2 (see equation B.4) $Q_g \approx 1{,}85 \times 10^{-2}$ m^3/s
09	Is natural ventilation of the shelter possible at all ambient conditions throughout a year?	Yes, the buoyancy induced natural ventilation will be possible even during hot summer days because the heat dissipated by the engines and compressors will constantly keep the interior temperature above the ambient. The configuration of the shelter will also enable wind to enhance the ventilation no matter at which direction it is blowing.
10	What are the geometrical characteristics of the building?	• Length of the shelter: L = 12 m • Breadth of the shelter: B = 12 m • Overall height of the shelter: H = 8,0 m • Total volume concerned: $V \approx 1\,000$ m^3 • Volume under consideration: $V_0 \approx 0{,}80 \times V$ = 800 m^3; A volume less than V_0 is applied as an allowance for the enclosed equipment which reduces the effective volume. • Total effective area of the air inlet openings: A_1 = 30 m^2 • Total effective area of the air outlet openings: A_2 = 24 m^2 • Vertical distance between the midpoints of rear inlet and outlet openings: H_1 = 7,0 m • Vertical distance between the midpoints of front inlet and outlet openings: H_2 = 5,4 m • Average vertical distance between the midpoint of the openings: H_a = 6,2 m
11	What is the equivalent effective area of the lower opening?	$A_e \approx$ 26,5 m^2 (see C.5.2)
12	What are the temperatures at the most unfavourable conditions?	• Average inside temperature: T_{in} = 316 K • Outside temperature: T_{out} = 313 K
13	What is the volumetric flow rate of fresh air?	$Q_a \approx 10{,}7\ m^3/s$; with C_d being 0,75 (see equation C.4)
14	What is the number of air changes per hour in the volume under consideration?	$C = \frac{Q_a}{V_0} \approx 48\ h^{-1}$ 48 air changes per hour is selected for the purpose of this example to illustrate very draughty conditions and may not be applicable for actual conditions in a real situation.
15	What is the ventilation velocity?	The ventilation velocity should be calculated according to the air flow pattern and that implies that the referent cross section of the shelter is horizontal: $u_w = \frac{Q_a}{L \times B} \approx 0{,}075\ m/s$
16	What is the background concentration in the volume under consideration?	$X_b = \frac{f \times Q_g}{C V_0} \approx 0{,}18\% \approx 4{,}5\%\ LFL$ (see equation C.1)

Classification procedure considerations for the shelter		
17	What is the volumetric release characteristic?	$Q_C \approx 0{,}5\ m^3/s$ Since the air flow pattern indicates movement of the air upwards, there is no reason to apply a more strict factor of inefficiency of ventilation than 1,0.
18	What is the degree of dilution?	See the chart in Figure C.1 and find the intersection of the values for axis X and Y. The dilution appears as medium.
19	Is the background concentration in this volume higher than 25 % LFL?	No, it is 4,5 % LFL. Taking into account the answer, the degree of dilution can be considered as medium.
20	What is the availability of the ventilation?	The availability in naturally ventilated enclosed spaces should never be considered as good due to the various natural uncertainties. So we have to consider the availability as fair.
21	What will be the type of the zone within the shelter?	Taking into account the grades of release, the degree of dilution and the availability of ventilation, the interior of the shelter is classified as zone 2 (see Table D.1).
22	Is there any opening which may be considered as the source of release?	Yes, it is the rooftop outlet opening. It is type A opening.
23	What is the mass release rate of the gas through this opening?	$W_g = u_2\ A_2\ \rho_g\ X_b = u_w\ L\ B\ \rho_g\ X_b$ $W_g \approx 1{,}54 \times 10^{-2}$ kg/s; The result is the same as with equation (B.4) which is in compliance with Mass Conservation Law.
24	What is the degree of dilution?	The degree of dilution is again obtained by using the chart in Figure C.1, except that the ventilation velocity u_w is now the wind speed. We assume that 1,0 m/s is a realistic approximation taking into account the height of the opening above the ground (see Table C.2). The degree of dilution still appears as medium.
25	What is the hazardous area around the opening?	The hazardous area shall apparently be zone 2 (see Figure E.14).
26	What is the hazardous distance around the opening?	The hazardous distance can be estimated by applying the method set in Annex D (see Figure D.1). Taking into account the position of the source of release, there is no need for too much conservatism and the lower curve should be the logical choice. Hazardous distance in the chart appears somewhat above 1,0 m so the zone will have the extent of 1,5 m (see Figure E.14).
27	Conclusion	The whole area under the shelter is zone 2. There is no need to extend the zone beyond the walls except at the rooftop where the air and gas mixture may escape as result of the buoyancy induced natural ventilation (see Figure E.14 and Figure E.15).

Similar considerations could be applied for other sources of release quoted in this case study.

Table E.2 – Hazardous area classification data sheet – Part I: Flammable substance list and characteristics

Plant: Compressor facility handling natural gas (case analysis) **Area:**														**Figures E.14, E.15**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Flammable substance							**Volatility**[a]		**LFL/UFL**		**Ex characteristics**		
	Name	Composition	Molar mass (kg/kmol)	Relative density gas/air	Polytropic index of adiabatic expansion γ	Flash point (°C)	Ignition temp. (°C)	Boiling point (°C)	Vapour pressure 20 °C (kPa)	vol (%)	(kg/m^3)	Equipment group	Temp. class	Any other relevant information or remark, E.g. source of data
1	Process gas	80 % vol CH_4+ higher hydrocarbons	21,6	0,8	1,2	–	>400	–	–	4,0/18	0,036/ 0,162	IIA	T2	Laboratory report
2	Process gas condensate	Iso- and normal pentane, hexane and heptane	46	>3,0	–	<30	<300	<50	unknown	1,3 to 8,0/ UFL unknown	0,025 to 0,153/ UFL unknown	IIA	T3	The values are estimated
3	Starting and fuel gas	96 % vol CH_4+ higher hydrocarbons	16,8	0,6	1,3	–	>500	–	–	5,0/15	0,035/ 0,105	IIA	T1	Laboratory report

[a] Normally, the value of vapour pressure is given, but in the absence of that, boiling point also indicates the volatility.

Table E.3 – Hazardous area classification data sheet – Part II: List of sources of release *(1 of 2)*

Sheet 2 of 3

Plant: Compressor facility handling natural gas (case analysis) **Area:**																**Figures E.14, E.15**
1	2	3	4	5	6	7	8		9	10	11	12	13	14		15	16
	Source of release					**Flammable substance**				**Ventilation**			**Hazardous area**				
	Description	Location	Grade of release[a]	Rate of release (kg/s)	Release characteristic (m^3/s)	Reference[b]	Operating temperature and pressure		State[c]	Type[d]	Degree of dilution[e]	Availability	Zone type 0-1-2	Zone extent (m)		Reference[f]	Any other information or remark
							(°C)	(kPa)						Vertical	Horizontal		
1	Air outlet opening	Roof top	S	$1{,}54 \times 10^{-2}$	0,5	1	-	101, 325	G	N	Medium	Good	2	1,5	1,5		
2	Starting gas vent	Above the roof	P	0,5	16	3	25	1 000	G	N	Medium	Good	1	9,0 from vent outlet	9,0 from vent outlet		Manufacturer's data
3	Compressor blowdown vent	Above the roof	P	1,75	52	1	35	5 000	G	N	Medium	Good	1	8,0 from vent outlet	8,0 from vent outlet		Trapped volume release
4	Fuel gas shut-off valve vent	Above the roof	P	0,25	7,7	3	25	50	G	N	Medium	Good	1	6,0 from vent outlet	6,0 from vent outlet		Trapped volume release
5	Safety valve vent	Above the roof	S	$1{,}8 \times 10^{-2}$	0,54	1	149	2 800	G	N	Medium	Good	2	3,0 from vent outlet	3,0 from vent outlet		Leak (not full flow operation)
5a	Safety valve vent	Scrubber	S	$1{,}8 \times 10^{-2}$	0,54	1	50	5 500	G	N	Medium	Good	2	3,0 from vent outlet	3,0 from vent outlet		Leak (not full flow operation)
6	Piston rod packings vent	Above the roof	P/C	$1{,}0 \times 10^{-2}$	0,3	1	25	101, 325	G	N	Medium	Good	0 or 1	1,5 from vent outlet	1,5 from vent outlet		
7	Gas engine	Inside the shelter	S	$1{,}54 \times 10^{-2}$	0,5	3	25	50	G	N	Medium	Fair	2	Interior of the shelter	Interior of the shelter		
7a	Compressor	Inside the shelter	S	$1{,}54 \times 10^{-2}$	0,5	1	149	200 to 5 000	G	N	Medium	Fair	2	Interior of the shelter	Interior of the shelter		
7b	Air cooler	Infront of the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1	50	2 500 to 5 000	G	N	Medium	Good	2	3,0 from air cooler	3,0 from air cooler		

Table E.3 *(2 of 2)*

Sheet 3 of 3

Plant: Compressor facility handling natural gas (case analysis) **Area:**																**Figures E14, E.15**
1	2	3	4	5	6	7	8		9	10	11	12	13	14		15	16
	Source of release					**Flammable substance**				**Ventilation**			**Hazardous area**				
	Description	Location	Grade of release[a]	Rate of release (kg/s)	Release characteristic (m^3/s)	Reference[b]	Operating temperature and pressure		State[c]	Type[d]	Degree of dilution[e]	Availability	Zone type 0-1-2	Zone extent (m)		Reference[f]	Any other information or remark
							(°C)	(kPa)						Vertical	Horizontal		
8	Process gas scrubber	Inside the shelter	S	$0{,}93 \times 10^{-2}$	0,4	1	50	2 500	L	N	Medium	Fair	2	Interior of the shelter	Interior of the shelter		
8a	Process gas scrubber	Outside of the shelter	S	$0{,}93 \times 10^{-2}$	0,4	2	50	5 000	L	N	Medium	Good	2	3,0 from the scrubber	3,0 from the srcubber		
9	Valves	Inside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	Fair	2	Interior of the shelter	Interior of the shelter		
9a	Valves	Outside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	Good	2	3,0 from valves	3,0 from valves		
10	Pipe connections	Inside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	Fair	2	Interior of the shelter	Interior of the shelter		
10a	Pipe connections	Outside the shelter	S	$1{,}8 \times 10^{-2}$	0,54	1/2/3	50	2 500 to 5 000	G/L	N	Medium	Good	2	3,0 from pipe connections.	3,0 from pipe connections		

[a] C – Continuous; S – Secondary; P – Primary

[b] Quote the number of list in Part I

[c] G – Gas; L – Liquid; LG – Liquid gas; S – Solid

[d] N – Natural; A – Artificial

[e] See Annex C

[f] Indicate code reference if used or calculation reference

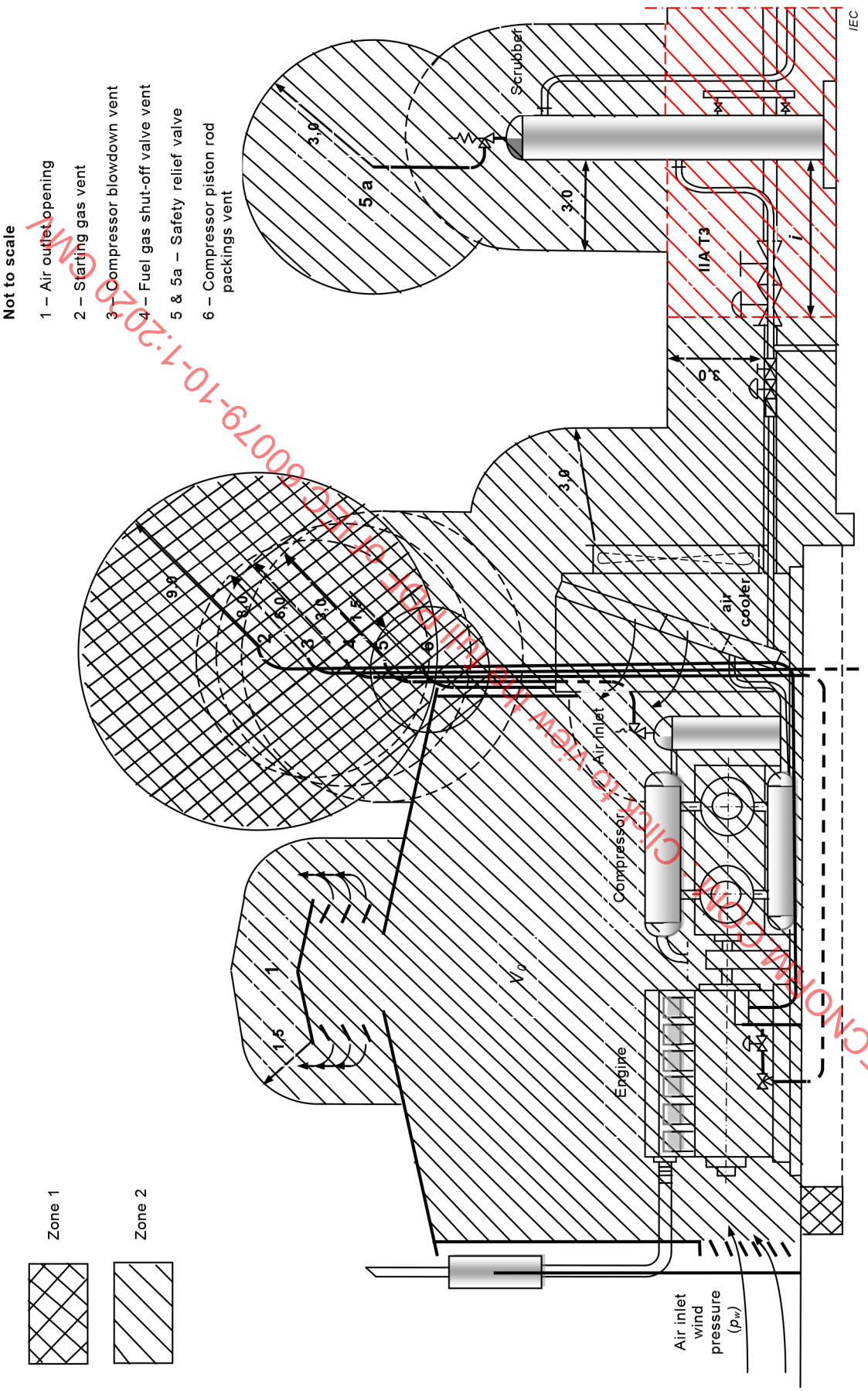


Figure E.14 – Example of hazardous area classification for a compressor facility handling natural gas (elevation)

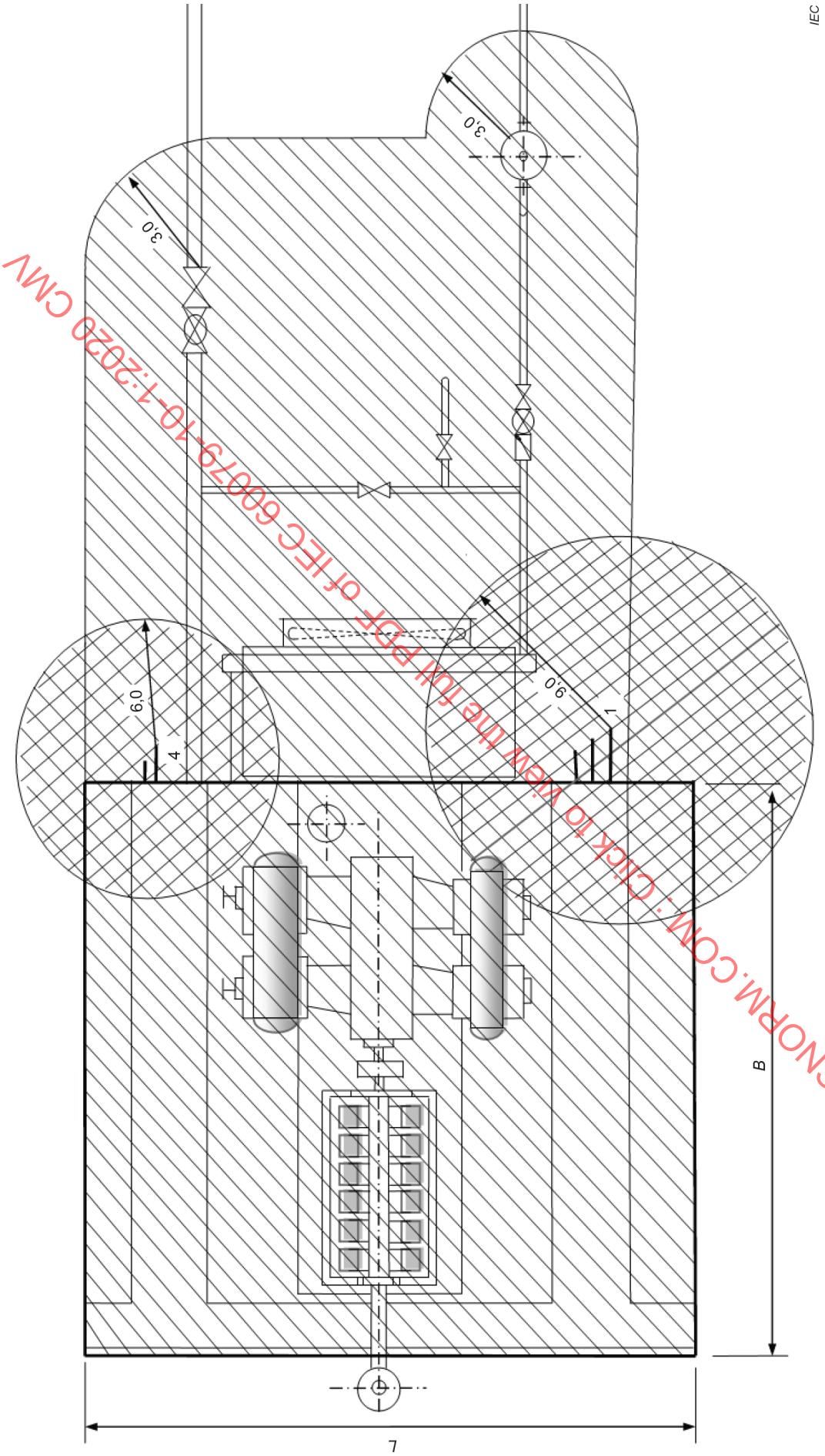


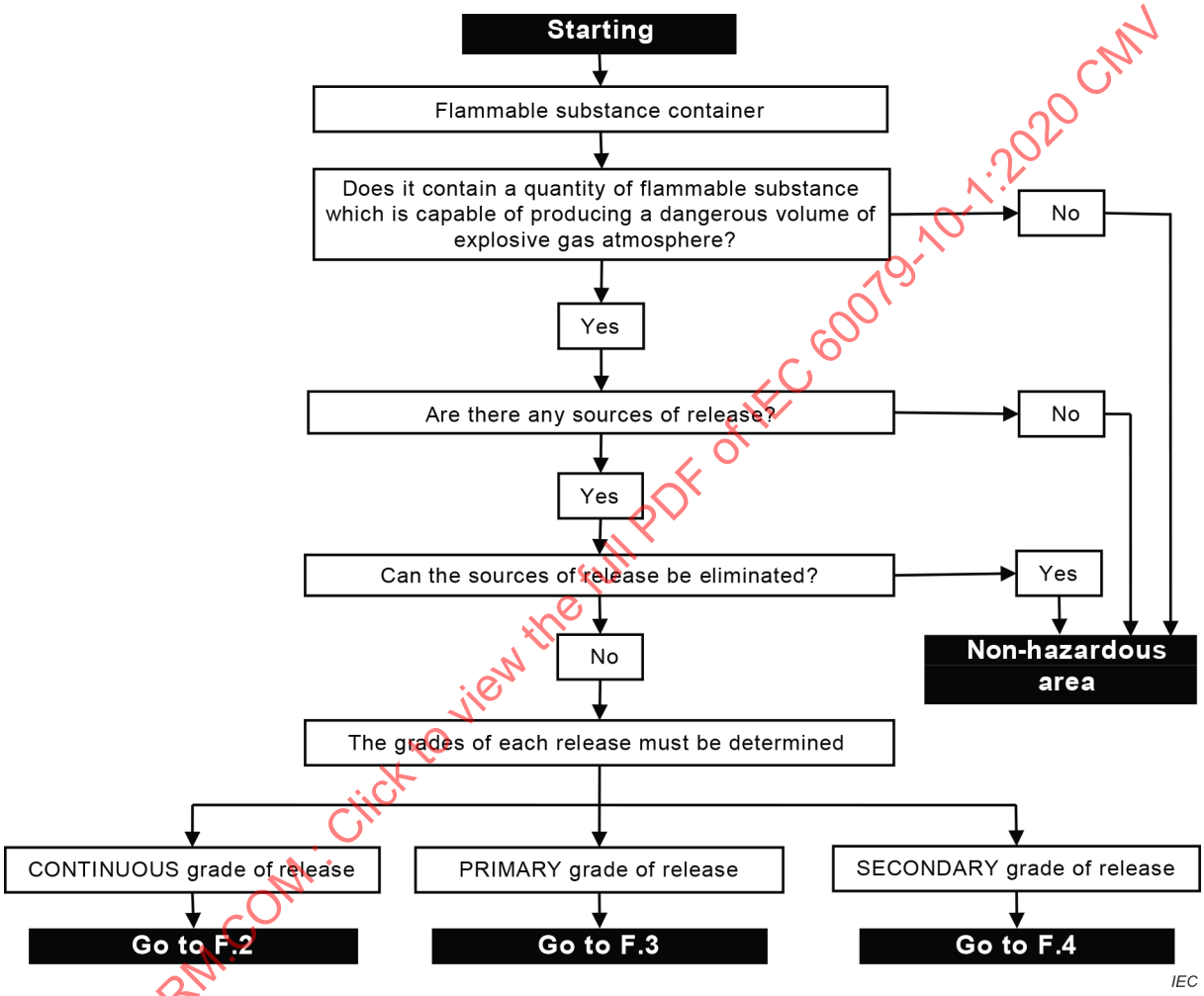
Figure E.15 – Example of hazardous area classification for a compressor facility handling natural gas (plan)

Annex F
(informative)

Schematic approach to classification of hazardous areas

F.1 Schematic approach to classification of hazardous areas

Figure F.1 shows a schematic approach to classification of hazardous areas.

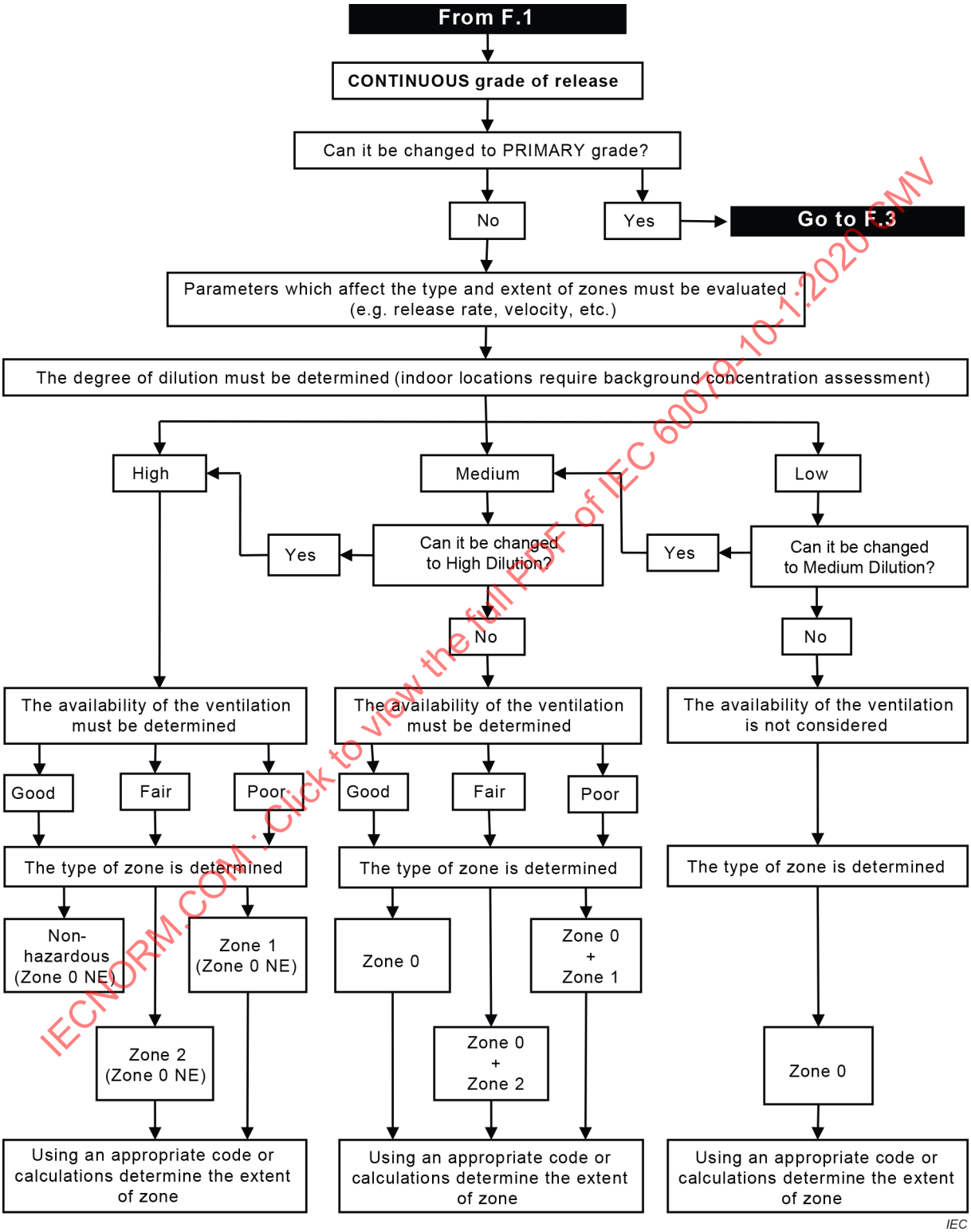


NOTE A source of release may give rise to more than one grade of release or a combination.

Figure F.1 – Schematic approach to classification

F.2 Schematic approach to classification of hazardous areas

Figure F.2 shows a schematic approach to classification of hazardous areas.

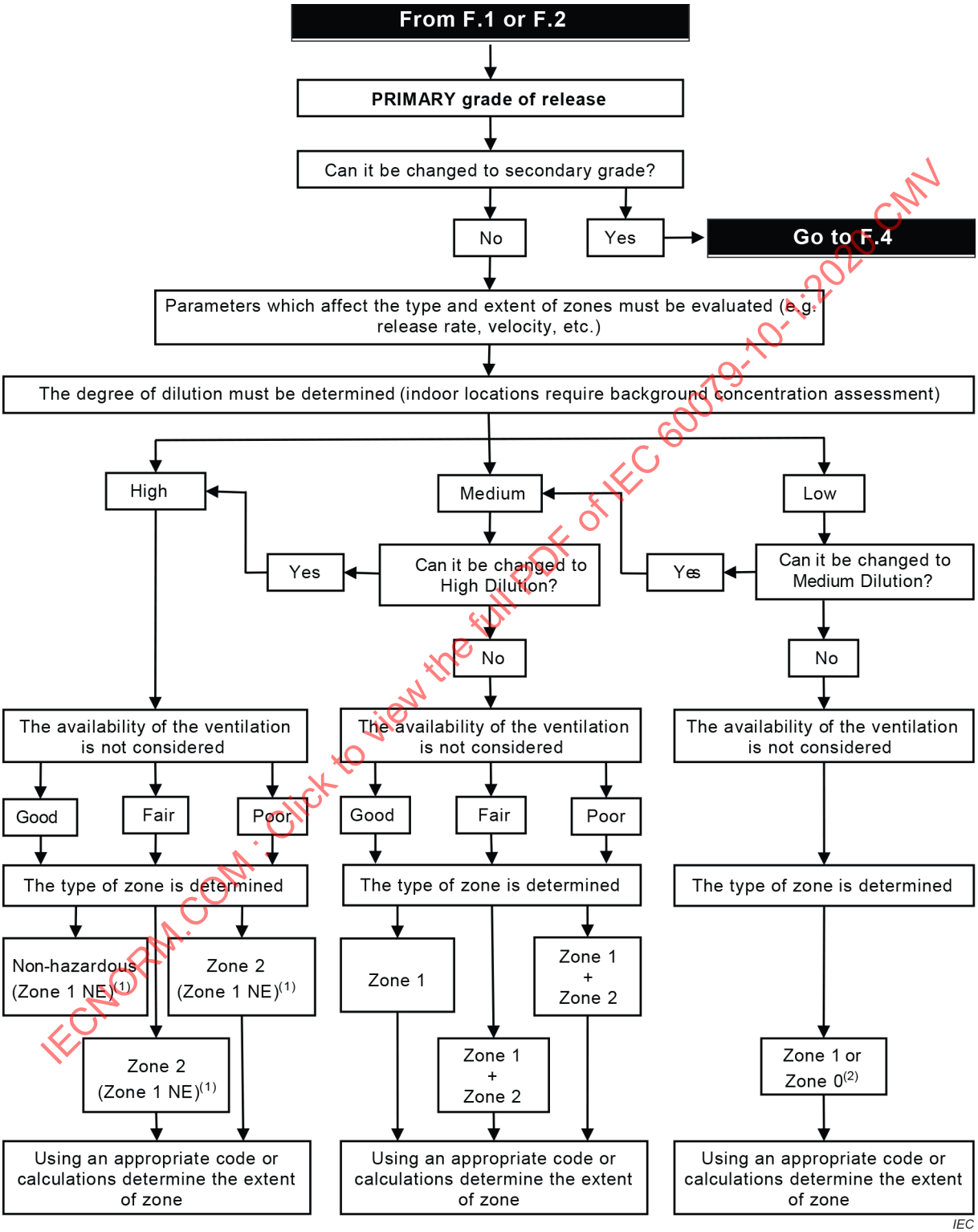


NOTE Zones NE indicate zones which would be of negligible extent under normal conditions.

Figure F.2 – Schematic approach to classification for continuous grade releases

F.3 Schematic approach to classification of hazardous areas

Figure F.3 shows a schematic approach to classification of hazardous areas.



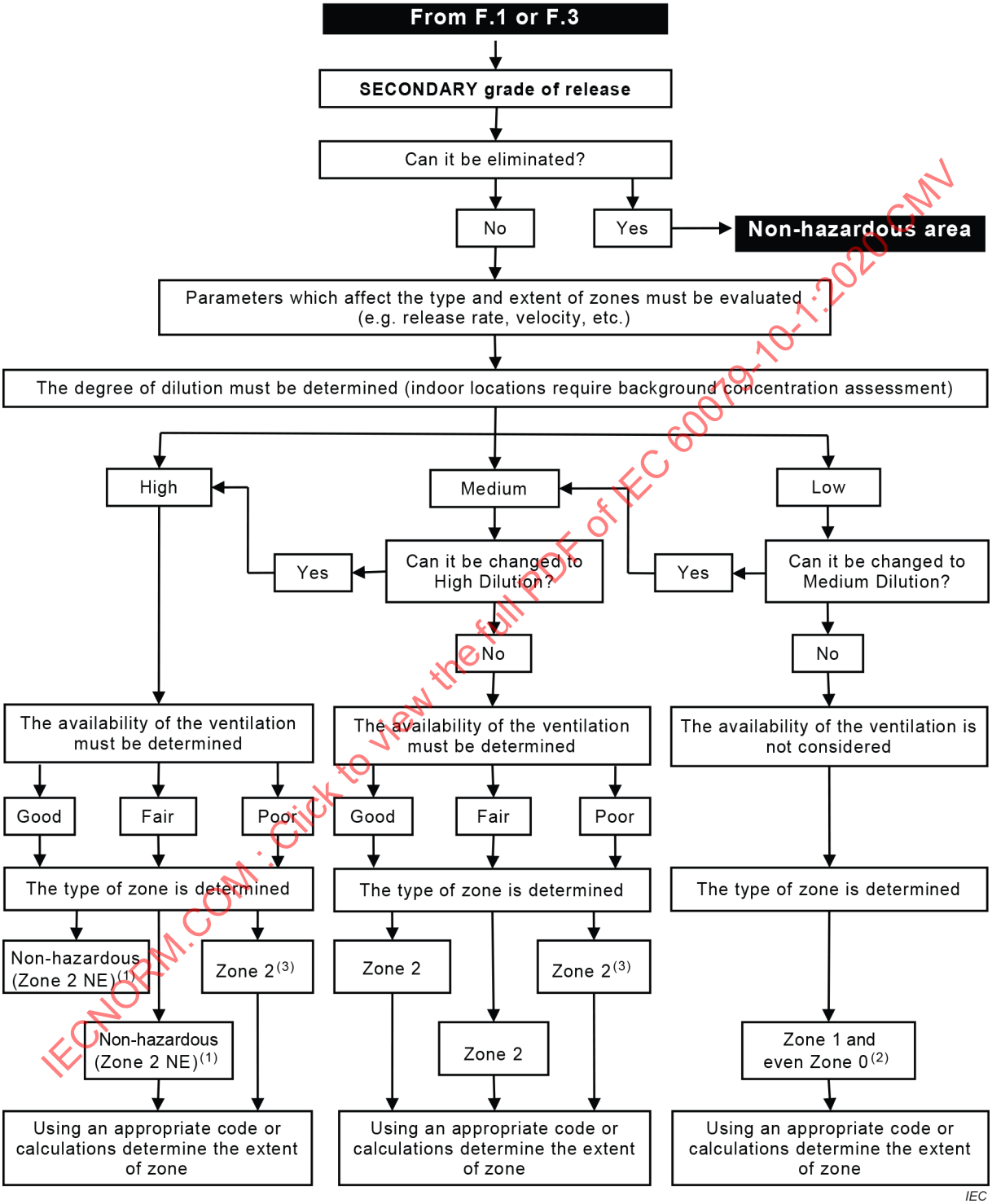
NOTE 1 Zones NE indicate zones which would be of negligible extent under normal conditions.

NOTE 2 Will be Zone 0 if the low dilution is so weak and the release is such that in practice an explosive gas atmosphere exist virtually continuously i.e. approaching a “no ventilation” condition.

Figure F.3 – Schematic approach to classification for primary grade releases

F.4 Schematic approach to classification of hazardous areas

Figure F.4 shows a schematic approach to classification of hazardous areas.



NOTE 1 Zones NE indicate zones which would be of negligible extent under normal conditions.

NOTE 2 Will be Zone 0 if the low dilution is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously i.e. approaching a “no ventilation” condition.

NOTE 3 The Zone 2 area created by secondary grade of release can exceed that attributable to a primary or continuous grade of release.

Figure F.4 – Schematic approach to classification for secondary grade releases

Annex G
(informative)

Flammable mists

G.1 When a liquid is handled at or above its flash point, any release will be treated through the normal hazardous area classification process described in this standard. If it is released below the flash point, under certain conditions, it may form a flammable mist cloud. Even the liquids that can be considered as non hazardous at process temperatures, in some situations may form a flammable mist which may then give rise to an explosion hazard. Examples of liquids that are commonly considered in this regard include high flash point liquid fuels, heat exchange oils and lubricating oils.

G.2 In practice, a liquid release will normally comprise of broad range of droplet sizes with larger droplets tending to fallout immediately, leaving only a small fraction of the release airborne in the form of a flammable mist. The flammability of the mist depends upon the concentration in air of the droplets plus any vapour, a function of the volatility of the liquid and the droplet sizes within the cloud. The size of droplets depends upon the pressure at which the liquid is being released, the properties of the liquid (primarily density, surface tension and viscosity) and the size and shape of the release opening. Normally, higher pressures and smaller openings will contribute to the degree of atomization of the release jet thus giving the rise to an explosion hazard. On the other hand, smaller release openings imply smaller release rates thus reducing the hazard.

G.3 It has been proved that flammable mist sized droplets are the most easily ignitable portion of the mist cloud, though generally these are only a small fraction of the total release. This fraction may increase if the release jet impacts on a nearby surface.

NOTE 1 Flammable mists are small (sub-micron to 50 microns) particles in suspension in the atmosphere.

NOTE 2 Droplets in the flammable mist range might be as low as 1 % of the total mass released, subject to release conditions.

NOTE 3 Fuel droplet clouds have generally been found difficult to ignite, unless there is sufficient mass of vapour or very small droplets present.

G.4 The likelihood that the release of liquid will generate a flammable mist during normal operation and/or expected malfunctions should be carefully assessed along with the likelihood of events that could lead to such a release. The assessment may indicate that the release of substance is of a very low probability or that the mist cloud could be generated only during rare malfunctions or catastrophic failures. Assessments should be backed up by references or operational experience with similar plants. However, due to thermodynamic complexity of mists and a large number of factors that influence formation and flammability of mists, the reference may not be available for every given situation. In such cases, a judgement based upon relevant data should be applied.

G.5 It is important to point out that not every leak will cause a mist formation, e.g. the leaks through broken flange gaskets or stuffing boxes/packing glands that are the most common secondary grades of release in case of gases or vapours, will usually be negligible in case of viscous liquids and in most cases will cause dripping rather than mist. That means that the likelihood of mists being generated through leaks at pipe joints, valves, etc. should not be overstated. Such considerations should take into account the physical properties of the liquid, the conditions at which it is being handled, mechanical details of the equipment through which it is being processed, quality of equipment and obstructions near a source of release.

NOTE 1 For liquids released well below their flash point, examples of mist explosions are rare in process industries. This is probably due to difficulty in generating sufficiently small droplet sizes from an accidental release and the associated difficulty of ignition.

NOTE 2 Flammable mists may be ignited by sparks of similar energy as for vapour ignition but generally require very high surface temperatures for ignition. Ignition of mists by contact with hot surfaces generally requires temperatures higher than for vapour ignition.

G.6 If formation of a flammable mist is considered possible, then the source of release should preferably be contained or managed to reduce the hazard, e.g. by porous guards in order to promote the coalescing of the mist, mist detectors or suppression systems. Where containment or similar controls cannot be assured, then the potential for a mist hazard should be considered. However, because the dispersion mechanisms and the criteria of flammability for mists are different than those for gases and vapours, the methodology of classification presented in Annex B cannot be applied.

NOTE 1 The conditions that are needed to form a flammable mist are so complex that only a qualitative approach may be appropriate. It might be useful to identify the factors related to the handled liquid which contribute to formation, and to the flammability of mist. These factors along with the probability of events that would lead to release of the liquid may be sufficient to evaluate the degree of the hazard and help to decide whether a hazardous area is required.

NOTE 2 In general, the only element relevant to determining the type of zone is the grade of release. In most cases, it will be a secondary grade of release. Continuous or primary grades of release would typically be associated with equipment which is intended for spraying, e.g. spray painting.

G.7 Taking into account that there are many uncertainties involved in formation of a flammable mist cloud, the assessment of a mist hazard should be based on specific industry experience and specific codes. E.g. Mist hazards are recognized for some heat transfer applications where the liquid is heated to near or above the flashpoint and used at very high temperatures. Mist hazards for typical fuel distribution networks designed to suitable piping codes are not considered a credible risk based on the many years of operations for such installations worldwide.

NOTE Industry codes for the classification of hazardous areas for flammable liquids generally do not account for misting as if misting was considered then larger hazardous areas would be recommended for common applications. This also suggests the potential for mists due combustible liquids should not be overstated when the combustible liquid is handled at a similar pressures and with comparable integrity of piping codes.

G.8 If a mist hazard has been established, it should not be classified as Zone 0, 1 or 2 hazardous areas as the types of protection applied for these zones are not required for mist hazards. See IEC 60079-14. The potential for a mist hazard should be distinguished on the area drawing from other hazardous areas associated with gases and vapours, e.g. by appropriate marking.

G.9 Even the mists that are not ignitable according to the criteria of droplets size could eventually land on a hot surface, relative to the auto-ignition temperature of the vapour, thus causing a fire hazard. Other high energy ignition sources such as flames should also be considered. Care should be taken to contain potential releases and prevent contact with hot surfaces and other high energy ignition sources.

G.10 Mists require minimum concentrations to be flammable (in a similar manner to flammable vapours or combustible dusts). For liquids well below their flash point, this would typically be associated with a cloud that reduces visibility.

Mists are typically visible and hence releases can be usually mitigated. Consideration should be given to the time frame before a leak is detected.

NOTE Lower flammability limits for fuel flammable mists have been shown to be similar to or less than those associated with the fuel vapour.

G.11 Flammable mists may occur within equipment due to oil lubrication systems, splashing or agitation as a part of the process operations. The hazards associated with internal parts of process plant should then be considered and may require specific mitigation measures to be applied. E.g. mist explosion or fire suppression system. Under certain conditions, such mists may also be vented to atmosphere, e.g. lubricating oil mists through crankcase breathers, tank or gearbox vents, thus giving the rise to fire hazard. Venting of such mists should preferably be eliminated by mist extractors.

G.12 Additional considerations should be applied for situations where the liquids are being sprayed intentionally, e.g. spray painting. Hazardous area classification in such cases is usually the subject of specific industrial codes.

G.13 IEC 60079-14 for selection of equipment and installations does not include requirements for mist hazards due to liquids with a high flash point where flammable vapours are not present.

Annex H
(informative)

Hydrogen

H.1 The flammable range of hydrogen in air is between 4 % and 77 % by volume. Hydrogen is also commonly found in mixtures of flammable gases such as refinery process streams. With gas mixtures, the equipment group should be considered as IIC or IIB+H_2 where a gas mixture includes 30 % or more of hydrogen by volume unless other specific data is available. The temperature class should be taken as the lowest auto-ignition temperature for any gas exceeding 3 % in the mixture.

NOTE ISO/IEC 80079-20-1 includes guidance for specific gas mixtures including hydrogen such as coke oven gas and industrial methane for relevant equipment groups.

H.2 The auto-ignition temperature of hydrogen is 560 °C. Although very high temperatures are required to ignite a hydrogen-in-air mixture, precautions should be taken to ensure hydrogen leaks are not exposed to any hot surfaces.

H.3 The diffusion rate of a gas due to buoyancy is proportional to its density relative to that of air. Hydrogen is a lighter than air gas which diffuses rapidly with a tendency to rise upwards. However, as the gas diffuses the bulk density of a given volume will tend to approach that of air. As the concentration of hydrogen reduces, such that the bulk density approaches that of air, the low concentration of hydrogen will tend to move with the air.

H.4 High volume releases of hydrogen are likely to accumulate in overhead spaces. A hydrogen gas release can form gas pockets in alcoves, roof peaks, and dormers which tend to be poorly ventilated. Conversely, relatively small openings in such spaces will allow hydrogen to escape and may be sufficient to prevent hydrogen concentrating due to low volume releases.

H.5 Hydrogen gas releases will generally result in a jet plume in the orientation of the point of release. Once the jet momentum is dissipated the plume will take a more vertical ascent and generally harmlessly disperse in a well ventilated area.

H.6 A liquid hydrogen spill, which commonly has a vessel saturation pressure of 4 bar, can suddenly expose the cryogenic content of the vessel to ambient pressure. Such a condition will instantly boil or flash a significant portion of the liquid to cryogenic vapour potentially resulting in the remaining contents to spill. Liquid hydrogen boils at 20 K at 1 atmosphere and the contents when exposed to ambient temperatures will have sufficient heat to rapidly vaporize the liquid hydrogen. The exposed cross-sectional area of the liquid hydrogen spill affects the rate at which the contents flash to vapour and warms. At hydrogen's boiling point, the cold hydrogen vapour is heavier than air until it warms. As the cold vapours mix with air, the air can be chilled below the dew point, causing condensation and forming a visible cloud. After dwelling near the ground and warming sufficiently, the visible vapour cloud may form a plume as it rises.

H.7 The flame fronts observed with hydrogen-in-air mixtures burn less readily when constrained to burning in a horizontal direction, and even less so in a downward direction.

The release of a large quantity of hydrogen can form a plume that possesses an increasing concentration of hydrogen towards the centreline of the plume. Regions of lower-concentration hydrogen-air mixtures require greater initiation energy to ignite than those of higher concentration towards the centre of a plume. Movement and water vapour in a plume will also result in greater initiation energy when compared to the same composition mixture, that is dry and without movement.

Therefore, as a plume of hydrogen rises, the exterior regions of the plume (the regions likely to encounter an ignition source) are less likely to ignite when compared to near-stoichiometric mixtures. Should ignition occur in an exterior region of the plume, only the gas in the immediate vicinity of the ignition source will tend to burn and the potential for flame propagation or deflagration throughout the cloud is reduced. Therefore, unless some process rapidly mixes the hydrogen plume to form a near-stoichiometric mixture with air throughout the cloud, the normal factors that typically influence mixing (diffusion, buoyancy, wind, and turbulence) in a release will not result in complete combustion of the plume.

H.8 Mitigation strategies for hydrogen release should consider providing for rapid ascension of the gas to open air away from structures to assist with prevention of potential ignition during a release. Indoors, supplemental ventilation and/or adequate space for dilution and dispersion of a release may be provided. Where gas detection is used as a control measure, sensors should be placed above release points and/or near the ceiling, exit fan or exit duct. The sensors require a routine calibration schedule, and the sensor should only be calibrated using hydrogen as the calibration gas.

H.9 Hydrogen gas has several personnel safety and health hazard implications that should be considered during facility installation.

Hydrogen gas has the potential to cause oxygen deficiency. An increased hydrogen-in-air mixture condition may be safe for breathing for short periods of time, but the atmosphere would be above the lower flammable limit (LFL) causing a potentially explosive gas atmosphere.

Hydrogen flames, unless seeded with impurities, are very hard to see in daylight. This property, combined with its low emissivity producing very little infrared radiation, makes hydrogen combustion hard to sense until physical contact is made with the flame. Hydrogen combustion in air also produces ultraviolet (UV) radiation capable of producing effects similar to overexposure to the sun. Direct exposure to hydrogen flames produces immediate burns.

Hydrogen is very easily ignited where it is released and ignition and/or fire is normally expected to occur. Small leaks may occur and ignite, but go unnoticed until maintenance personnel enter the area. A plume of hydrogen that is ignited will rapidly flash back to the source of hydrogen. From the perspective of controlling hazards, a hydrogen fire localized to a source or leak is often preferable to a growing hydrogen plume.

Where hydrogen leaks are known to be problematic, e.g. very high pressure or high temperature systems, then additional safeguards for the leak sources should be considered. These safeguards could include:

- Deflection guards to limit jet momentum and promote dispersion,
- Steam jets around the source of release to cool high temperature releases, wet the gas and modify jet dispersion behaviour.

Combustion of a hydrogen cloud will occur completely within several seconds. There is not enough deposition of thermal energy to ignite typical substances of construction used in buildings. Personnel caught in close proximity may be severely burned and directly exposed flammable liquids may also be ignited.

Hydrogen stored at high pressure will normally produce a jet on release. If ignited, this would create a loud jet of nearly invisible flame that would be extremely dangerous to anything in its path. In high pressure systems with joints that are known to be susceptible to leakage supplemental controls should be considered.

H.10 ISO/TR 15916 provides additional guidance on safety for hydrogen but does not consider the classification of hazardous areas or suitably reference the IEC 60079 series. In this case the safety guidance may be useful but the requirements from IEC 60079 series and ISO/IEC 80079 series should also be followed.

Annex I
(informative)

Hybrid mixtures

I.1 General

A hybrid mixture is a combined mixture of a flammable gas or vapour with a combustible dust or combustible flyings. This hybrid mixture may behave differently than the gas/vapour or dust individually. The number of situations that may be encountered in industry will be highly variable and as such it is not practical to provide specific guidance. However this Annex provides guidance on issues that should be considered when hybrid mixtures are found.

I.2 Use of ventilation

The use of ventilation as a control measure needs to be carefully considered as it may reduce the gas/vapour hazard but increase the dust hazard or have other varying effects on the different components of the mixture.

I.3 Concentration limits

A hybrid mixture may form an explosive atmosphere outside the individual explosive limits of the gas/vapour or explosive concentrations for the dust. It is recommended, unless further data is available, that a hybrid mixture is considered explosive if the concentration of the gas/vapour exceeds 25 % of the LFL or the concentration of the dust exceeds 25 % of the *MEC*.

I.4 Chemical reactions

Considerations should also be taken to chemical reactions that may occur within the materials or entrapped gas in the dust that may result in evolution of gas in the process.

I.5 Energy/temperature limits

Where a hybrid mixture exists, the minimum ignition parameters such as MIE and auto-ignition temperature for gas/vapour or minimum ignition temperature of a dust cloud could be lower than any component parameter in the mixture. In the absence of other information, the parameter used should be the lowest of any component in the mixture.

I.6 Zoning requirements

Consideration should be given to the assignment of both gas and dust zones with the same rating to match the worst case requirement for any component, e.g. zone 21 with zone 2 should be considered as zone 21 with zone 1. It should be identified that the result of ignition of any component will lead to a worst case consequence when considering any EPL assessment.

Annex J
(informative)

Useful equations in support to hazardous area classification

J.1 General

The approach to hazardous area classification requires sound understanding of flammable substance properties to identify their behaviour when released or being released. The following sections contain useful equations that could be used to calculate some parameters influencing the dispersion and dilution of flammable gas or vapour in air at ambient conditions. Laboratory or field tests are preferred where appropriate.

J.2 Dilution with air of a flammable substance release

The theoretical minimum ventilation flow rate of fresh air to dilute a given release of flammable substance to a concentration below the lower flammable limit $Q_{a\ min}$ can be calculated by means of the equation:

$$Q_{a\,min} = \frac{Q_g}{LFL} \times \frac{T_a}{293} \tag{J.1}$$

where

$Q_{a\ min}$ is theoretical minimum ventilation flow rate of fresh air required for dilution (m^3/s);

Q_g is the volumetric release rate of flammable substance (m^3/s);

LFL is the lower flammable limit (vol/vol);

T_a is the ambient temperature (K).

Safety margins should always be considered to account for other factors such as turbulence or uneven distribution of the fresh air.

EXAMPLE

Find the theoretical minimum ventilation flow rate of fresh air required to dilute a release rate Q_g = 8,64 × 10^{-4} m^3/s of benzene due to the evaporation of a confined liquid pool, at an ambient temperature of 40 °C:

$$Q_{a\,min} = \frac{Q_g}{LFL} \times \frac{T_a}{293} = \frac{8{,}64 \times 10^{-4}}{0{,}012} \times \frac{313}{293} = 0{,}077\ m^3/s$$

A safety margin could be considered upon a sound judgement and hence a higher value would be obtained.

NOTE The lower flammable limit was taken from ISO/IEC 80079-20-1.

J.3 Estimate of the time required to dilute a flammable substance release

The theoretical time t_d required to dilute the concentration of flammable substance from a certain steady state background concentration X_b to a required critical concentration X_{crit}, in a specific volume, can be estimated from:

$$t_d = \frac{f}{C} \ln\left(\frac{X_b}{X_{crit}}\right) \quad (J.2)$$

where

t_d is the theoretical time required to dilute a defined value of flammable substance concentration to another one lesser than first (s);

f is the ventilation inefficiency factor;

C is the number of air changes per unit time in the specific volume (s^{-1});

X_b is the flammable substance background concentration at steady-state conditions (vol/vol);

X_{crit} is the desired/critical value of the flammable substance concentration (vol/vol).

EXAMPLE

Find the theoretical time to reduce the average flammable substance concentration in an artificially ventilated enclosure with a number of air changes per unit time C = 0,002 s^{-1} (≈ 6 h^{-1}) from the initial value X_b = 0,012 to the desired value X_{crit} = 0,0024 if the ventilation inefficiency factor is 3:

$$t_d = \frac{f}{C} \ln\left(\frac{X_b}{X_{crit}}\right) = \frac{3}{0{,}002} \times \ln\left(\frac{0{,}012}{0{,}0024}\right) = 2415\ s = 40{,}3\ \text{min}$$

The theoretical time t_d calculated as above is based on an ideal dilution of the flammable substance released into the enclosure. Safety margins should always be considered to account other factors such as turbulence or uneven distribution of the flammable substance.

Annex K
(informative)

Industry codes and national standards

K.1 General

In general, examples of classification may be accepted in accordance with national or industry codes where their application to the particular situation can be clearly demonstrated. Any criteria or limitations identified in the industry code or national standard should be followed.

If it is intended that the examples given in the reference industry codes or national standards be used for hazardous area classification, account should be taken of the specific details of each individual case, e.g. process and location characteristics.

In general, the examples provided in industry codes and national standards are based on the assumption that plant and equipment are adequately maintained.

The codes and standards may not apply to specific situations, for example where:

a) the quantity of release is either very large or very small;

b) the design of a particular plant does not comply with all the requirements of the appropriate national standard or industry code; or

c) ventilation, use of inert gases, vapour barriers or other methods are used to reduce the extent of the hazard or the likelihood of the occurrence of a particular hazardous area.

Where the use of examples from specific codes or standards is followed, standards and codes addressing the same example should not be interchanged, e.g. where a standard is selected as a preferred base for a site or application, examples from another standard should not be selected to achieve a less rigorous classification without due justification. Notwithstanding this principle, in some cases the classification examples provided in relevant industry codes or national standards can, where appropriate, be used to classify some components of larger plants associated with other relevant national or industry codes.

Where examples from industry codes or national standards are used, then they should be quoted as the basis for classification rather than IEC 60079-10-1. Examples of national standards or industry codes include, but are not limited to those shown in Table K.1. The countries of origin are listed in alphabetical order.

Table K.1 – Examples of codes and standards

Country or Region of Origin	Code or Standard Designation	Title	Developing Body	Application Notes
Australia and New Zealand	AS/NZS (IEC) 60079.10.1	Explosive Atmospheres Part 10-1: Classification of areas – Explosive Gas Atmospheres	Standards Australia/ Standards New Zealand	Additional detail is included in AS/NZS 60079.10.1 as a national Annex or Supplement
Germany	DGUV-Regel 113-001 "Explosionsschutzregeln (EX-RL)"	Explosionsschutz-Regeln (EX-RL) – Sammlung technischer Regeln für das Vermeiden der Gefahren durch explosionsfähige Atmosphäre mit Beispielsammlung zur Einteilung explosionsgefährdeter Bereiche in Zonen Explosion Protection Rules (EX-RL) – Collection of technical rules for avoiding the dangers of explosive atmospheres with examples collection for classification of hazardous areas into zones	DGUV-Deutsche Gesätzliche Unfallversicherung	
	TRBS 2152/ TRGS 720	Gefährliche explosionsfähige Atmosphäre – Allgemeines Hazardous explosive atmospheres – General information	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	
	TRBS 3151/TRGS 751	Vermeidung von Brand-, Explosions und Druckgefährdungen an Tankstellen und Gasfüllanlagen zur Befüllung von Landfahrzeugen Avoidance of fire, explosion and pressure hazards at filling stations and gas filling systems for filling land vehicles	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	
	TRGS 509	Lagern von flüssigen und festen Gefahrstoffen in ortsfesten Behältern sowie Füll und Entleerstellen für ortsbewegliche Behälter Storage of liquid and solid hazardous substances in fixed containers as well as filling and emptying points for mobile containers	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	

Country or Region of Origin	Code or Standard Designation	Title	Developing Body	Application Notes
	TRGS 510	Lagerung von Gefahrstoffen in ortsbeweglichen Behältern Storage of hazardous substances in transportable containers	BauA-Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	
Sweden	Klassning av explosionsfarliga områden	Classification of Hazardous Areas	SEK Svensk Elstandard	Available only in Swedish
Switzerland	SUVA Merkblatt Nr. 2153	Explosionsschutz-Grundsätze- Mindestvorschriften-Zonen Explosion protection-Basics-Minimal requirements-Zones	Schweizerische Unfall-versicherungsanstalt	
The Netherlands	NPR 7910-1	Netherlands practical guideline NPR 7910-1, Classification of hazardous areas with respect to explosion hazard – part 1: gas explosion hazard, based on NEN-EN-IEC 60079-10-1	Netherlands Standardization Institute, NEN	
UK	EI15	Model code of safe practice for the petroleum industry, Part 15: Area Classification Code for Petroleum Installations Handling Flammable Liquids.	Energy Institute	EI15 is used as an industry standard in the petro(chem) industry in many countries
	IGEM/SR/25	Hazardous area classification of natural gas installations.	Institution of Gas Engineers and Managers	
USA	API RP 505	Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities classified as Class I, Zone 0, Zone 1 and Zone 2.	American Petroleum Institute (API)	
	NFPA 59A	Standard for the Production, Storage, and Handling of Liquefied Natural Gas.	National Fire Protection Association	
	NFPA 496	Standard for Purged and Pressurized Enclosures for Electrical Equipment	National Fire Protection Association	Where relevant to pressurized control room

Country or Region of Origin	Code or Standard Designation	Title	Developing Body	Application Notes
	NFPA 497	Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapours and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.	National Fire Protection Association	

Bibliography

[1] A.W. Cox; F.P. Lee & M.L. Ang; *Classification of Hazardous Locations, Ichem*, 1993

[2] IGEM/SR/25; *Hazardous Area Classification of Natural Gas Installations*; UK Institution of Gas Engineers and Managers, 2010

[3] P.F. Linden, *The Fluid Mechanics of Natural Ventilation,* Annual Review, Fluid Mechanics, 1999.

[4] A. Walker, *Natural Ventilation*, National Renewable Energy Laboratory, 06.03.2008

[5] ASHRAE, Handbook of Fundamentals, 2001

[6] M.J. Ivings, S. Clarke, S.E. Gant, B. Fletcher, A. Heather, D.J. Pocock, D.K. Pritchard, R. Santon and C.J. Saunders, 2008, *Area Classification for secondary releases from low pressure natural gas systems,* Health and Safety Executive Research Report RR630

[7] Ballal and Lefebvre (1982), *Flammability of Fuel Mists.* Int. Symposium of Combustion

[8] Bowen and Shirvill (1994), *Combustion Hazards posed by Pressurised Release of High Flashpoint Liquid Fuels* (Journal of Loss Prevention)

[9] Bowen, Bull and Rowson (1997), *Explosions in Fuel Aerosol Systems*. Combustion, Science and Technology

[10] Bowen and Cameron (2001), *Explosions in Flammable Mists: A Review*. Journal of Institute of Chemical Engineers

[11] R P Cleaver, R E Britter, *A workbook approach to estimating the flammable volume produced by a gas release*, FABIG Newsletter, Issue 30, R416 (2001)

[12] Maragkos and Bowen (2003), *Combustion Hazards from Impinging Jets of High* Flashpoint Liquid Fuels. Int. Symposium on Combustion

[13] The Energy Institute, *Model Code of Safe Practice – Part 15 – Area Classification Code for Installations Handling Flammable Fluids; 4th Edition, June 2015*

[14] The Institute of Petroleum, *A Risk Based Approach to Hazardous Area Classification – 1998-11*

[15] American Petroleum Institute, *Risk Based Inspection – Base Resource Document – API Publication 581; 2000-05*

[16] American Petroleum Institute, *Risk-Based Inspection Technology – API Recommended Practice 581: 2008-09*

[17] BS 5925:1991, *Code of practice for ventilation principles and designing for natural ventilation*

[18] IEC 60050, *International Electrotechnical Vocabulary*

[19] IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

[20] IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

[21] IEC 60079-13, *Explosive atmospheres - Part 13: Equipment protection by pressurized room "p" and artificially ventilated room "v"*

[22] IEC 60079-10-2, *Explosive atmospheres – Part 10-2: Classification of areas – Explosive dust atmospheres*

[23] IEC 61285, *Industrial-process control – Safety of analyser houses*

[24] IEC 61511-1:2016, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and application programming requirements*

[25] European Standard EN 1127-1, *Explosive Atmospheres – Explosion Prevention and Protection – Part 1: Basic Concept and Methodology; 2019-08*

[26] Comitato Elettrotecnico Italiano, *Guide CEI 31-35 – Electrical Apparatus for Explosive Gas Atmospheres – Guide for Classification of Hazardous Areas; 2011-03*

[27] American National Standards, *Pipe Flanges and Flange Fittings: 1981*

[28] Committee for the Prevention of Disasters (TNO Yellow Book), CPR-14E, *Methods for the Calculation of the Physical Effects Due to Releases of Hazardous Substances, The Hague, The Netherlands; 1997*

[29] D M Webber, M J Ivings, R C Santon (2011), *Ventilation theory and dispersion modelling applied to hazardous area classification;* Journal of Loss prevention in the Process Industries

[30] U.S. Environmental Protection Agency, Office for Solid Waste and Emergency Response, *Risk management program for offsite consequence analysis, Appendix D, April 15 1999*

[31] P Persic, *Hypothetical Volume of Potentially Explosive Atmosphere in the Context of IEC Standard 60079-10-1*, Ex-Bulletin, Croatia 2012. Vol 40, 1-2

[32] ISO/IEC 80079-20-1, *Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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ATMOSPHÈRES EXPLOSIVES –

Partie 10-1: Classification des emplacements – Atmosphères explosives gazeuses

AVANT-PROPOS

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La Norme internationale IEC 60079-10-1 a été établie par le sous-comité 31J: Classification des emplacements dangereux et règles d'installation, du comité d'études 31 de l'IEC: Équipements pour atmosphères explosives.

Cette troisième édition de l'IEC 60079-10-1 annule et remplace la deuxième édition parue en 2015. Cette édition constitue une révision technique. Les modifications techniques majeures par rapport à l'édition précédente sont les suivantes:

		Type		
Modifications	**Article**	**Modifications mineures et rédactionnelles**	**Extension**	**Modifications techniques majeures**
Suppression des applications commerciales et industrielles du gaz combustible des exemptions du Domaine d'application	1			C1
Mise à jour de détails éditoriaux et de notes dans les définitions	3		X	
Suppression de la définition 3.7.3 de l'édition antérieure portant sur les défaillances catastrophiques (traitées au 4.5)			X	
Introduction d'un nouveau **4.4.2 Zone d'étendue négligeable**	4.4.2		X	
Introduction d'un nouveau **5.3.2 Installations au gaz combustible**	5.3.2		X	
Nouvelle numérotation des titres	7	X		
Introduction de la **Figure 1 – Volume de dilution**	7		X	
Mise à niveau du **Tableau A.1** avec la limite supérieure d'inflammabilité (LSI) et l'en-tête de sa colonne 15 avec la "source de données"	A.1	X		
Mise à jour du schéma de la **Figure B.1**	B.6		X	
Mise à jour des équations de la vitesse d'évaporation de façon à sd'alignerr les récentes modifications des sources	B.7.3		X	
Mise à jour du graphique de la **Figure B.2** selon les équations mises à jour de la vitesse d'évaporation et de la vitesse de ventilation de 0,25 m/s	B.7.3		X	
Restructuration du **Tableau C.1**	C.3.4		X	
Suppression du facteur de sécurité ***k*** et en le supprimant de l'axe horizontal du graphique de la **Figure C.1**	C.3.5			C2
Révision des équations (C.2) et (C.3)	C.5.2			C3
Révision des équations (C.4) et (C.5)	C.5.3			C4
Révision du graphique de la **Figure C.6**: modification de l'étiquette de l'axe horizontal	C.5.3			C5
Révision de l'équation (C.6) et suppression de l'équation (C.7)	C.5.4			C6
Suppression du facteur de sécurité ***k*** et et en le supprimant de l'axe horizontal des graphiques de la **Figure D.1**	D.3			C7
Imposition de limitations à l'utilisation du graphique de la **Figure D.1**	D.3		X	
Mise à jour et corrections dans l'**Annexe E**	Annexe E		X	
Mise à niveau de l'**Annexe G** relative aux brouillards inflammables	Annexe G		X	
Introduction de nouveaux points dans le **Tableau K.1**	Annexe K		X	
Introduction de nouveaux points dans la Bibliographie	Bibliographie		X	
NOTE Les modifications techniques dont il est fait mention comprennent les modifications techniques majeures contenues dans la version révisée de la norme IEC, mais elles ne constituent pas une liste exhaustive de toutes les modifications par rapport à la version précédente.				

Explications:

A) Définitions

Modifications mineures et rédactionnelles	clarification réduction des exigences techniques modifications techniques mineures corrections d'ordre rédactionnel

Ces modifications portent sur les exigences et sont de nature rédactionnelle ou technique mineure. Elles comprennent des modifications de formulations destinées à clarifier les exigences techniques sans apporter de modification technique.

Extension	ajout d'options techniques

Ces modifications ajoutent de nouvelles exigences techniques ou modifient les exigences techniques existantes, de manière à fournir de nouvelles options sans toutefois augmenter les niveaux d'exigences.

Modifications techniques majeures	ajout d'exigences techniques augmentation du niveau d'exigences techniques

B) Information sur le contexte des modifications

C1 Le point e) de l'édition antérieure énoncait: "applications commerciales et industrielles dans lesquelles seul du gaz combustible basse pression est utilisé, par exemple, pour cuisiner, chauffer l'eau, etc., l'installation satisfaisant aux codes de gaz correspondants. Il convient que les applications industrielles ne soient, en aucune façon, exclues du champ d'application de la présente norme. Se reporter également au nouveau 5.3.2.

C2 Le facteur ***k*** était initialement destiné à prévoir une sécurité supplémentaire concernant les incertitudes liées à la détermination de la LII pour les substances inflammables, en particulier les mélanges gazeux. Toutefois, celui-ci a été jugé inutile et prêtant à confusion compte tenu de l'origine du graphique.

C3 Les équations ont été mises à jour de façon à s'aligner sur la BS 5925

C4 Les équations ont été mises à jour de façon à s'aligner sur la BS 5925

C5 Le graphique est révisé pour prendre en compte la nouvelle équation (C.4)

C6 L'équation a été mise à jour de façon à s'aligner sur la BS 5925

C7 Se reporter aux explications figurant sous C2

Ces modifications sont apportées aux exigences techniques (ajout, augmentation de leur niveau ou suppression).

NOTE Ces modifications reflètent le niveau de maîtrise technologique actuel. Cependant, en règle générale, il convient que ces modifications n'aient pas une incidence sur les matériels déjà mis sur le marché.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
31J/307/FDIS	31J/310/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60079, publiées sous le titre général *Atmosphères explosives*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

IMPORTANT – Le logo "colour inside" qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer ce document en utilisant une imprimante couleur.

INTRODUCTION

Dans les emplacements où des quantités et concentrations dangereuses de gaz ou vapeurs inflammables peuvent apparaître, il est nécessaire d'appliquer des mesures pour réduire le risque d'explosions. La présente partie de l'IEC 60079 expose les critères essentiels en fonction desquels les dangers d'inflammation peuvent être évalués et donne des recommandations relatives aux paramètres de conception et d'exploitation qui peuvent être appliquées pour réduire ces dangers.

ATMOSPHÈRES EXPLOSIVES –

Partie 10-1: Classification des emplacements – Atmosphères explosives gazeuses

1 Domaine d'application

La présente partie de l'IEC 60079 concerne la classification des emplacements dans lesquels des phénomènes dangereux dus à des gaz ou vapeurs inflammables peuvent apparaître, et peut ainsi constituer une base pour la conception, l'exploitation et la maintenance correctes du matériel utilisé dans de tels emplacements.

Elle est destinée à être appliquée là où il peut exister un danger d'inflammation du fait de la présence de gaz ou vapeurs inflammables, en mélange avec l'air, mais elle ne s'applique pas:

a) aux mines grisouteuses;

b) au traitement et à la fabrication des explosifs;

c) aux défaillances catastrophiques ou rares dysfonctionnements, qui dépassent le concept de normalité traité dans la présente norme (voir 3.7.3 et 4.5);

d) aux locaux utilisés à des fins médicales;

e) aux locaux à usage domestique;

f) lorsqu'un danger peut apparaître compte tenu de la présence de poussières combustibles ou de particules combustibles en suspension dans l'air, mais les principes définis peuvent toutefois être appliqués dans l'évaluation d'un mélange hybride (se reporter également à l'IEC 60079-10-2).

NOTE Des recommandations supplémentaires relatives aux mélanges hybrides sont fournies dans l'Annexe I.

Des brouillards inflammables peuvent se former ou être présents en même temps que les vapeurs inflammables. Dans ce type de cas, l'application stricte des détails du présent document peut ne pas être appropriée. Les brouillards inflammables peuvent également se former lorsque les liquides qui ne sont pas considérés comme dangereux en raison du point d'éclair élevé sortent sous pression. Dans ces cas, les classifications et détails donnés dans le présent document ne s'appliquent pas. Des informations relatives aux brouillards inflammables sont données à l'Annexe G.

Pour les besoins du présent document, un emplacement est une région ou un espace tridimensionnel.

Les conditions atmosphériques englobent les écarts au-dessus et au-dessous des niveaux de référence de 101,3 kPa (1 013 mbar) et 20 °C (293 K) à condition que cela ait un effet négligeable sur les propriétés explosives des substances inflammables.

Dans tout site quelle que soit son importance, il peut y avoir de nombreuses sources d'inflammation en dehors de celles qui sont associées au matériel. Il est nécessaire dès lors de prendre les précautions appropriées pour garantir la sécurité. La présente norme est applicable avec prudence pour ces autres sources d'inflammation mais d'autres applications peuvent nécessiter de prendre en considération d'autres mesures de protection. Par exemple, de plus grandes distances peuvent s'appliquer aux flammes nues lorsqu'il s'agit de permis de travaux à chaud.

Le présent document ne tient pas compte des conséquences de l'inflammation d'une atmosphère explosive, sauf dans une zone si petite que si une inflammation se produit, ses conséquences sont négligeables (voir 3.3.8 et 4.4.2).

2 Références normatives

Ce document ne contient aucune référence normative.

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'IEC 60079-0 et les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

NOTE Des définitions supplémentaires applicables aux atmosphères explosives peuvent être consultées dans l'IEC 60050-426.

3.1
atmosphère explosive
mélange avec l'air, sous conditions atmosphériques, de substances inflammables sous forme de gaz, de vapeur ou de poussières qui, après inflammation, permet une propagation autoentretenue

[SOURCE: IEC 60079-0:2017, 3.38]

3.2
atmosphère explosive gazeuse
mélange avec l'air, sous conditions atmosphériques, de substances inflammables sous forme de gaz ou de vapeur qui, après inflammation, permet une propagation autoentretenue

Note 1 à l'article: Bien qu'un mélange dont la concentration est supérieure à la limite supérieure d'inflammabilité (LSI) ne soit pas une atmosphère explosive gazeuse, il peut aisément le devenir et il est recommandé de le considérer comme tel généralement à des fins de classification des emplacements dangereux.

Note 2 à l'article: Certains gaz et certaines vapeurs sont explosifs à une concentration de 100 % (par exemple, acétylène, CAS n° 74-86-2, C_2H_2; monochlorure de vinyle acétylène, CAS n° 689-97-4, C_4H_4; nitrate de 1-propyle [vapeur], CAS n° 627-13-4, CH_3 $[CH_2]_2$ NO_3; nitrate d'isopropyle [vapeur], CAS n° 1712-64-7, $[CH_3]_2$ CH ONO_2; oxyde d'éthylène [vapeur], CAS n° 75-21-8, $[CH_2]_2$ O; hydrazine [vapeur], CAS n° 302-01-2, H_4 N_2).

[SOURCE: IEC 60079-0:2017, 3.40, modifiée (ajout des Notes à l'article)]

3.3
emplacements et zones dangereux

3.3.1
emplacement dangereux <en raison d'atmosphères explosives gazeuses>
emplacement dans lequel une atmosphère explosive gazeuse est présente ou dont il peut être prévu qu'elle est présente, en quantités suffisantes pour exiger des précautions particulières pour la construction, l'installation et l'utilisation d'équipements

3.3.2
emplacement non dangereux <en raison d'atmosphères explosives gazeuses>
emplacement dans lequel il n'est pas prévu qu'une atmosphère explosive gazeuse soit présente en quantités suffisantes pour exiger des précautions particulières pour la construction, l'installation et l'utilisation d'équipements

3.3.3
zone
classification des emplacements dangereux d'après la fréquence d'apparition et la durée de la présence de l'atmosphère explosive

3.3.4
Zone 0
emplacement dans lequel une atmosphère explosive gazeuse est présente en permanence, ou pour de longues périodes ou fréquemment

Note 1 à l'article: Les termes "longues" et "fréquemment" sont destinés à décrire une très forte probabilité de présence d'une atmosphère potentiellement explosive dans l'emplacement. À cet égard, il n'est pas nécessaire de quantifier ces termes.

3.3.5
Zone 1
emplacement dans lequel une atmosphère explosive gazeuse est susceptible de se présenter occasionnellement en fonctionnement normal

3.3.6
Zone 2
emplacement dans lequel une atmosphère explosive gazeuse n'est pas susceptible de se présenter en fonctionnement normal mais qui si c'est le cas, peut persister uniquement sur une durée courte

Note 1 à l'article: Des indications sur la fréquence d'apparition et la durée peuvent être obtenues à partir des codes des industries spécifiques ou des applications.

[SOURCE: IEC 60050-426:2020, 426-03-05]

3.3.7
étendue de zone
distance, dans toutes les directions, à partir de la source de dégagement et jusqu'au point où un mélange gaz/air est dilué par l'air à une concentration au-dessous de la limite inférieure d'inflammabilité

3.3.8
Zone EN
zone d'étendue négligeable telle que si l'inflammation se produit, ses conséquences sont négligeables

Note 1 à l'article: Les zones d'étendue négligeable peuvent être une Zone 0 EN, une Zone 1 EN ou une Zone 2 EN.

3.4
dégagements

3.4.1
source de dégagement
point ou localisation à partir duquel un gaz, une vapeur, un brouillard ou un liquide inflammable peut être dégagé dans l'atmosphère, de telle sorte qu'une atmosphère explosive gazeuse peut être formée

[SOURCE: IEC 60050-426:2020, 426-03-06]

3.4.2
degré "dégagement continu"
dégagement qui est continu ou qui est supposé apparaître fréquemment ou sur de longues périodes

Note 1 à l'article: Les termes "fréquemment" et "longues" sont destinés à décrire une très forte probabilité de dégagement potentiel. À cet égard, il n'est pas nécessaire de quantifier ces termes.

3.4.3
degré "dégagement primaire"
dégagement qui peut être périodique ou occasionnel, en fonctionnement normal

3.4.4
degré "dégagement secondaire"
dégagement non prévisible en fonctionnement et qui, s'il se produit néanmoins, le fait avec une probabilité faible et sur de courtes durées

3.4.5
taux de dégagement
quantité de gaz, de liquide, de vapeur ou de brouillard inflammable émise par unité de temps par la source de dégagement

3.5
ventilation et dilution

3.5.1
ventilation
mouvement de l'air et son remplacement par de l'air frais dus aux effets du vent et/ou à des gradients de température, ou à des moyens artificiels (par exemple, ventilateurs ou extracteurs)

Note 1 à l'article: Le terme "air frais" est destiné à être synonyme du terme "air propre" utilisé dans l'IEC 60079-13. Les deux termes définissent de l'air sans gaz ou vapeur inflammable.

3.5.2
dilution
mélange de vapeur ou de gaz inflammable avec l'air qui, dans le temps, réduit la concentration inflammable

3.5.3
volume de dilution
volume à proximité d'une source de dégagement où la concentration d'un gaz ou d'une vapeur inflammable n'est pas diluée à un niveau sûr

Note 1 à l'article: Dans certains cas, les volumes de 3.5.3 et 3.5.5 peuvent être identiques.

3.5.4
concentration de fond
concentration moyenne de substance inflammable dans le volume à l'étude hors du panache ou du jet de dégagement

3.5.5
volume à l'étude
volume concerné par la ventilation à proximité du dégagement à l'étude

Note 1 à l'article: S'agissant d'un espace clos, il peut s'agir d'une pièce entière ou d'une partie d'un espace plus important dans laquelle la ventilation à l'étude dilue le gaz ou la vapeur à partir d'une source de dégagement donnée. En extérieur, il s'agit du volume qui entoure une source de dégagement dans laquelle un mélange explosif peut se former. Dans les espaces extérieurs exigus, ce volume peut être dicté par l'enveloppe partielle fournie par les objets environnants.

3.6
propriétés d'une substance inflammable

3.6.1
substance inflammable
substance inflammable par elle-même ou capable de produire un gaz, une vapeur ou un brouillard inflammable

3.6.2
liquide inflammable
liquide capable de produire une vapeur inflammable dans toute condition d'exploitation prévisible

Note 1 à l'article: Un exemple de condition d'exploitation prévisible est la manipulation du liquide inflammable à des températures proches ou au-dessus de son point d'éclair.

Note 2 à l'article: Cette définition est utilisée pour la classification des emplacements dangereux et peut être différente de la définition des liquides inflammables utilisés pour d'autres besoins (codes de classification des liquides inflammables pour le transport, par exemple).

3.6.3
gaz liquéfié inflammable
substance inflammable qui est stockée ou manipulée comme un liquide et qui, à température ambiante et à pression atmosphérique, est un gaz inflammable

3.6.4
gaz ou vapeur inflammable
gaz ou vapeur qui, mélangé(e) à l'air dans certaines proportions, forme une atmosphère explosive gazeuse

3.6.5
brouillard inflammable
gouttelettes de liquide, dispersées dans l'air et qui forment une atmosphère explosive

Note 1 à l'article: Les brouillards sont également appelés aérosols.

3.6.6
mélange hybride
mélange de gaz ou de vapeur inflammable avec une poussière

Note 1 à l'article: Conformément à l'IEC 60079-10-2, le terme "poussière" est défini comme incluant à la fois les poussières combustibles et les particules combustibles en suspension dans l'air.

3.6.7
densité relative d'un gaz ou d'une vapeur
rapport de la densité d'un gaz ou d'une vapeur à la densité de l'air à la même pression et à la même température (elle est égale à 1,0 pour l'air)

3.6.8
point d'éclair
température la plus basse d'un liquide à laquelle, dans certaines conditions normalisées, ce liquide libère des vapeurs en quantité telle qu'un mélange vapeur/air inflammable puisse se former

3.6.9
point d'ébullition
température à laquelle un liquide bout à la pression ambiante de 101,3 kPa (1 013 mbar)

Note 1 à l'article: Le point d'ébullition initial utilisé dans les mélanges de liquides pour indiquer la valeur la plus basse du point d'ébullition de la plage des liquides présents dans le mélange, telle que cette valeur est déterminée par distillation en laboratoire normale sans fractionnement.

3.6.10
pression de vapeur
pression exercée quand un solide ou un liquide est en équilibre avec sa propre vapeur

Note 1 à l'article: Il s'agit également de la pression partielle de la substance dans l'atmosphère au-dessus du liquide. Elle dépend de la substance et de la température.

3.6.11
température d'auto-inflammation (TAI)
température la plus basse (d'une surface) à laquelle se produit l'inflammation d'un gaz ou d'une vapeur inflammable mélangé(e) à l'air ou d'un mélange air/gaz inerte, dans des conditions d'essais spécifiées

[SOURCE: ISO/IEC 80079-20-1:2017, 3.3]

3.6.12
limite inférieure d'inflammabilité (LII)
concentration de gaz ou de vapeur inflammable dans l'air, au-dessous de laquelle une atmosphère explosive gazeuse ne se forme pas

Note 1 à l'article: Le terme "limite inférieure d'explosivité" est utilisé en particulier en normalisation européenne et dans les règlements pour décrire cette limite.

[SOURCE: ISO/IEC 80079-20-1:2017, 3.6.1]

3.6.13
limite supérieure d'inflammabilité (LSI)
concentration de gaz ou de vapeur inflammable dans l'air, au-dessus de laquelle une atmosphère explosive gazeuse ne se forme pas

Note 1 à l'article: Le terme "limite supérieure d'explosivité" est utilisé en particulier en normalisation européenne et dans les règlements pour décrire cette limite.

[SOURCE: ISO/IEC 80079-20-1:2017, 3.6.2]

3.7
manœuvre

3.7.1
fonctionnement normal
situation dans laquelle le matériel fonctionne selon ses paramètres nominaux

Note 1 à l'article: Des défaillances (la rupture de garnitures d'étanchéité de pompe ou de joints d'étanchéité de brides ou des déversements accidentels, par exemple) qui entraînent une réparation ou un arrêt ne sont pas considérées comme faisant partie du fonctionnement normal.

Note 2 à l'article: Le fonctionnement normal inclut les conditions de démarrage et d'arrêt, ainsi que la maintenance courante, mais exclut le démarrage initial de la mise en service.

3.7.2
maintenance courante
action à réaliser occasionnellement ou périodiquement en fonctionnement normal afin de maintenir les performances correctes du matériel

Note 1 à l'article: La maintenance courante ne comprend pas les activités au cours desquelles la quantité dégagée ou le taux de dégagement est supérieur à la quantité ou au taux utilisé pour la classification d'emplacement. Par exemple, lorsque le matériel ou les systèmes exigent un démontage partiel, ou lorsqu'une purge délibérée dans l'atmosphère est exigée pour permettre la réalisation de l'activité de maintenance.

3.7.3
dysfonctionnement rare
type de dysfonctionnement qui peut se produire mais uniquement dans de rares cas

Note 1 à l'article: Dans le contexte de la présente norme, les dysfonctionnements rares incluent la défaillance des commandes de processus séparées et indépendantes, qui peuvent être automatisées ou manuelles, et qui entraînent une série d'événements qui donnent lieu à un dégagement important de substance inflammable.

Note 2 à l'article: Les dysfonctionnements rares peuvent également inclure les conditions imprévues non couvertes par la conception des installations (la corrosion imprévue qui donne lieu à un dégagement, par exemple). Lorsque des dégagements dus à la corrosion ou à des conditions analogues peuvent ou sont susceptibles d'être raisonnablement prévus dans le cadre de l'exploitation de l'installation, il ne s'agit pas d'un dysfonctionnement rare.

4 Généralités

4.1 Principes de sécurité

Il convient que les installations dans lesquelles des substances inflammables sont manipulées ou stockées soient conçues, construites, exploitées et entretenues de sorte que tous les dégagements de substances inflammables, et par conséquent, que l'étendue des emplacements dangereux soit maintenue la plus réduite possible, en ce qui concerne la fréquence, la durée et l'importance d'un dégagement.

Il est important d'examiner les parties du matériel de production et les systèmes d'où peut survenir un dégagement de substance inflammable et d'envisager la modification de la conception pour réduire le plus possible tant la probabilité que la fréquence de tels dégagements, ainsi que la quantité et le taux de dégagement de substance.

NOTE 1 Dans le contexte du présent document, le matériel de production comprend tout élément qui peut contenir un gaz ou un liquide inflammable.

Il convient d'examiner ces considérations fondamentales à un stade précoce du développement de la conception d'un local industriel, et il convient également de leur accorder une attention extrême lors de la réalisation de l'étude de classification des emplacements dangereux.

Dans le cas d'activités autres que le fonctionnement normal (la mise en service ou la maintenance non courante, par exemple), la classification des emplacements dangereux peut ne pas être valable. L'hypothèse est faite que les activités autres que celles de fonctionnement normal sont traitées par un système de travail sécurisé. Il convient que la classification des emplacements dangereux tienne compte de la maintenance courante.

Dans les situations où il peut y avoir une atmosphère explosive gazeuse, il convient de prendre les mesures suivantes pour éliminer:

a) la probabilité d'apparition d'une atmosphère explosive gazeuse à proximité de la source d'inflammation, ou

b) la source d'inflammation.

Lorsque cela n'est pas possible, il convient de choisir et de préparer des mesures préventives, des matériels de production, des systèmes et des procédures tels que la probabilité de la simultanéité de a) et b) soit ramenée à un niveau admis comme étant aussi faible que raisonnablement possible. De telles mesures peuvent être appliquées individuellement, s'il est reconnu qu'elles présentent une grande fiabilité, ou combinées de façon à obtenir le niveau de sécurité exigé.

NOTE 2 "Aussi faible que raisonnablement possible (ALARP)" est un terme reconnu dans de nombreuses juridictions et comprend le fait de mettre en place des contrôles conformes à l'état de l'art actuel et aux codes et normes pertinents.

Le présent document donne des recommandations relatives aux aspects qu'il convient de prendre en considération et la classification des emplacements dangereux exige d'appliquer de bonnes pratiques techniques.

4.2 Objectifs de la classification des emplacements dangereux

La classification des emplacements dangereux est une méthode d'analyse et de classification de l'environnement dans lequel peuvent apparaître des atmosphères explosives gazeuses, de façon à faciliter le choix, l'installation et l'exploitation corrects du matériel utilisable sans danger dans cet environnement. La classification prend également en compte les caractéristiques d'inflammabilité du gaz ou des vapeurs telles que l'énergie d'inflammation et la température d'inflammation. La classification des emplacements dangereux a deux objectifs principaux: la détermination du type d'une zone dangereuse, et l'étendue de zone (voir l'Article 8 et l'Article 9).

NOTE Les caractéristiques choisies peuvent être désignées pour les matériels (l'énergie d'inflammation et les caractéristiques assignées de température, par exemple). Voir l'ISO/IEC 80079-20-1.

En pratique, dans la plupart des cas où des substances inflammables sont utilisées, il est difficile de faire en sorte qu'une atmosphère explosive gazeuse n'apparaisse jamais. Il peut aussi être difficile de faire en sorte que le matériel ne produise jamais de source d'inflammation. C'est pourquoi, lorsque la présence d'une atmosphère explosive gazeuse est hautement probable, un matériel qui a une faible probabilité de créer une source d'inflammation est utilisé. Inversement, si la probabilité de présence d'une atmosphère explosive gazeuse est faible, un matériel qui répond à des exigences moins sévères peut être utilisé.

En particulier, il convient de réduire le plus possible tant en nombre qu'en étendue, les emplacements de Zone 0 ou de Zone 1 par conception ou par des procédures de fonctionnement adaptées. En d'autres termes, il convient que les usines et les installations soient principalement en Zone 2 ou en zone non dangereuse. Quand un dégagement de substance inflammable est inévitable, il convient de limiter les matériels de production à ceux qui produisent des degrés "dégagement secondaire", ou sinon (à savoir quand des degrés "dégagement primaire" ou "dégagement continu" sont inévitables), il convient de limiter les dégagements à de petites quantités et à des taux faibles. Lors de la conception des installations, il convient de prendre en considération ces principes en premier lieu. Si cela est nécessaire, il convient que la conception, le fonctionnement et l'emplacement du matériel de production assurent que, même en condition anormale d'exploitation, la quantité de substance inflammable dégagée dans l'atmosphère est réduite le plus possible, de sorte que l'étendue de l'emplacement dangereux soit réduite.

Dès lors que la classification d'une installation a été réalisée et que tous les enregistrements nécessaires ont été préparés, il est important qu'aucune modification de matériels ou de procédures ne soit effectuée sans qu'il n'en soit fait référence auprès des responsables de la classification des emplacements dangereux. Il convient de mettre à jour la classification des emplacements dangereux en cas de modification de l'installation ou de modifications opérationnelles. Il convient d'effectuer des examens tout au long de la durée de vie de l'installation.

4.3 Intérieur du matériel qui contient des matériaux inflammables

L'intérieur de nombreux matériels qui contiennent des substances inflammables (des réservoirs, par exemple) peut être considéré comme étant un emplacement dangereux, même si une atmosphère explosive gazeuse peut ne pas être normalement présente pour prendre en compte la possibilité d'entrée d'air dans les matériels.

NOTE 1 Dans un grand nombre de secteurs industriels, le terme générique "équipements de processus" est souvent donné aux matériels qui contiennent des substances inflammables.

Lorsque des commandes particulières (l'inertage, par exemple) sont utilisées, il peut ne pas être nécessaire de classer l'intérieur du matériel qui contient des substances inflammables comme étant un emplacement dangereux; une zone moins sévère peut lui être attribuée. Dans ces cas, il convient d'adapter la fiabilité des mesures de contrôle à la réduction d'emplacement dangereux déterminée pour l'intérieur du matériel. Par exemple, les mesures de contrôle peuvent être évaluées dans le cadre d'une étude adaptée (évaluation du SIL selon l'IEC 61511, par exemple).

NOTE 2 L'inertage désigne le remplacement de l'oxygène atmosphérique dans un système par un gaz non réactif et non inflammable, afin de rendre l'atmosphère à l'intérieur du système incapable de propager la flamme. Il est possible d'éviter la formation d'un emplacement dangereux à l'intérieur du matériel en ajoutant des gaz inflammables afin d'assurer que l'espace se situe toujours hors de la plage d'inflammabilité.

4.4 Appréciation du risque d'explosion

4.4.1 Généralités

Après la classification des emplacements dangereux, une appréciation du risque peut être réalisée pour évaluer si les conséquences d'inflammation d'une atmosphère explosive exigent l'utilisation d'un matériel de niveau de protection du matériel supérieur (EPL – *equipment protection level*) ou peuvent justifier l'utilisation d'un matériel de niveau de protection du matériel inférieur à celui normalement exigé.

Les exigences d'EPL peuvent être, le cas échéant, consignées dans les documents et les plans de classification des emplacements dangereux, afin de permettre le bon choix des matériels.

NOTE 1 L'IEC 60079-0 décrit les EPL et l'IEC 60079-14 définit l'application des EPL à une installation.

NOTE 2 La présente norme ne définit pas la méthodologie pour la réalisation d'une appréciation du risque visant à varier les caractéristiques assignées EPL, dans la mesure où la spécification d'une méthodologie d'appréciation du risque ne relève pas du domaine d'application de la présente norme.

4.4.2 Zone d'étendue négligeable

Dans certains cas, une zone d'étendue négligeable (EN) peut apparaître et peut être traitée comme étant non dangereuse. Une zone d'étendue négligeable implique également un taux de dégagement ou une quantité de dégagement négligeable et de prendre en considération le volume de dispersion.

Ce type de zone implique qu'une explosion, si elle se produit, a des conséquences négligeables. Le concept de zone EN peut être appliqué quels que soient les autres réglages pour l'appréciation du risque permettant de déterminer l'EPL.

Il convient que les critères de classification de zone EN reposent sur les facteurs suivants:

i) L'inflammation ne génère pas de pression dangereuse soit en raison de l'onde de pression soit en raison des dommages liés à des projections d'objets ou de particules (bris de vitres de fenêtre, par exemple).

ii) L'inflammation ne génère pas de chaleur dangereuse ou un incendie à partir des matériaux environnants.

iii) Pour les gaz distribués à des pressions supérieures à 1 000 kPag (10 barg), une appréciation du risque particulière doit être prise en considération.

iv) Une zone EN ne doit pas être appliquée à des gaz distribués à des pressions supérieures à 2 000 kPag (20 barg), sauf si une appréciation du risque détaillée spécifique peut le justifier.

Un nuage de gaz naturel est un exemple de zone EN avec une concentration moyenne de 50 % par volume de LII et inférieure à 0,1 m^3 ou 1,0 % de l'espace clos concerné (selon la plus faible des deux valeurs). Pour les autres gaz, une zone EN peut être prise en considération en fonction du rapport de la chaleur de combustion, de la pression d'explosion maximale et de la vitesse maximale de montée en pression du gaz sur le méthane multiplié par les paramètres utilisés pour le méthane.

NOTE 1 Dans ce contexte, le gaz naturel est celui qui est utilisé dans les réseaux conventionnels de distribution; il s'agit dans la plupart des cas de méthane.

NOTE 2 Les pompes de réfrigération et les pompes à chaleur ne sont pas considérées comme des systèmes de distribution du gaz. Les appréciations du risque pour cette classe de matériels ont permis de démontrer que la valeur de 2 000 kPag (20 barg) peut ne pas être une référence pertinente pour ces applications.

4.5 Défaillances catastrophiques

Dans toute la mesure du possible, il convient de prévenir ce type de défaillances.

Il n'est pas nécessaire de tenir compte des défaillances catastrophiques raisonnablement imprévues dans la classification des emplacements dangereux. Il s'agit, par exemple, d'accidents majeurs (la rupture d'une cuve, par exemple) ou de défaillances à grande échelle du matériel ou de la tuyauterie (rupture d'une bride ou d'un joint, par exemple).

Il convient de réduire la probabilité de ce type de défaillances par un examen, une conception, une exploitation et une maintenance appropriées de l'installation.

4.6 Compétences du personnel

Il convient que la classification des emplacements dangereux soit réalisée par des personnes qui comprennent la nature des substances inflammables, la dispersion et la ventilation des gaz et qui ont une bonne connaissance des aspects liés au processus de l'installation à l'étude. Il peut s'avérer avantageux pour d'autres disciplines techniques (les ingénieurs électriciens et mécaniciens, par exemple) et d'autres personnes qui assument des responsabilités particulières en matière de sécurité, de s'inscrire dans un processus de classification des emplacements dangereux et d'avoir une influence sur cette dernière. La compétence de la personne doit correspondre à la nature de l'installation et à la méthodologie utilisée pour procéder à la classification des emplacements dangereux. Le cas échéant, il convient de prévoir une formation régulière et continue appropriée du personnel.

NOTE 1 La compétence peut être démontrée dans le cadre d'une formation et d'un programme d'évaluation qui répondent aux réglementations nationales, aux normes ou aux exigences de l'utilisateur.

NOTE 2 Les éléments de compétence sont traités dans plusieurs programmes de certification des personnes.

5 Méthodologie de classification des emplacements dangereux

5.1 Généralités

Exceptionnellement, il est possible de décider, par un simple examen d'une installation ou par la conception d'une installation, quelles parties de l'installation peuvent être réparties dans les trois définitions de zone (Zone 0, Zone 1 et Zone 2). Une approche plus détaillée est donc nécessaire et elle implique l'analyse de la possibilité fondamentale d'apparition d'une atmosphère explosive gazeuse.

En déterminant à quel endroit un dégagement de gaz ou de vapeur inflammable peut se produire, il convient d'évaluer la probabilité et la durée du dégagement conformément aux définitions du degré "dégagement continu" et des degrés "dégagement primaire" et "dégagement secondaire". L'évaluation du degré de dégagement, du taux de dégagement, de la concentration, de la vitesse, de la ventilation et des autres facteurs permet d'établir un socle solide d'évaluation de la présence éventuelle d'une atmosphère explosive gazeuse dans les emplacements environnants et de déterminer le type et/ou l'étendue de l'emplacement dangereux.

Cette approche exige par conséquent de porter une attention particulière à chaque matériel de production qui contient une substance inflammable, et qui peut donc être une source de dégagement.

Les paragraphes 5.2 à 5.5 donnent des recommandations relatives aux options de classification des emplacements dans lesquels peut régner une atmosphère explosive gazeuse. L'Annexe F fournit un exemple d'approche schématique de la classification des emplacements dangereux.

Il convient de procéder à la classification des emplacements dangereux lorsque les schémas initiaux de lignes de production et d'instrumentation et les plans initiaux d'implantation sont disponibles et de le confirmer avant le démarrage de l'installation.

Il convient de toujours prendre en considération le type, le nombre et l'emplacement des différents points de dégagement potentiels, de manière à attribuer la zone et les conditions aux limites pertinentes dans l'ensemble de l'évaluation.

Les systèmes de commande conformes à une norme de sécurité fonctionnelle peuvent réduire les risques de source de dégagement et/ou la quantité d'un dégagement (contrôles de séquences par lots, systèmes d'inertage, par exemple). Ces commandes peuvent donc être considérées comme étant adaptées à la classification des emplacements dangereux.

Lors de la classification des emplacements, il convient également de prendre en considération une évaluation précise des installations identiques ou similaires. Lorsque des éléments de preuve circonstanciés indiquent qu'une conception et des exploitations d'installation particulières sont solides, ces éléments peuvent venir à l'appui de la classification choisie. De plus, il est envisageable qu'un emplacement puisse être reclassé en fonction de nouveaux éléments de preuve.

Les matériels produits en masse qui peuvent être déployés dans de nombreuses situations peuvent faire l'objet d'une classification générique des emplacements dangereux avec des instructions relatives aux emplacements et à la ventilation, etc., pour détailler toutes les limitations relatives à l'application et l'impact sur la classification.

Si la quantité de substance inflammable disponible pour le dégagement est "faible", alors qu'un risque d'explosion potentiel peut exister, il peut ne pas être approprié d'appliquer cette procédure de classification des emplacements dangereux. Malgré cette recommandation générale, il convient de toujours prendre en considération le risque de dégagement et l'aptitude à diluer ou disperser de manière adéquate le dégagement afin d'éviter les conditions inflammables. En d'autres termes, de petites quantités dans de petits espaces peuvent toujours représenter un danger.

Pour de petites quantités, les facteurs particuliers impliqués doivent également être pris en compte. Ces facteurs peuvent inclure: les niveaux de propreté, les pratiques industrielles, la compétence et la formation du personnel qui manipule les substances inflammables, d'autres mesures de contrôle du déversement ou du dégagement, la ventilation, les risques pour la santé et les contrôles d'exposition, la gestion des sources d'inflammation par d'autres moyens que l'utilisation d'un matériel assigné "Ex".

NOTE 1 De petites quantités peuvent concerner, par exemple, les laboratoires, les petits systèmes réfrigérants ou les bouteilles de gaz.

NOTE 2 Les référentiels applicables à l'industrie identifient souvent des quantités inférieures que le processus de classification des emplacements dangereux n'applique pas.

5.2 Méthode de classification des sources de dégagement

La classification peut être approchée par calcul ou essai, en s'appuyant sur des évaluations statistiques et numériques appropriées pour les facteurs concernés et pour chaque source de dégagement.

La méthode de classification des sources de dégagement peut être résumée comme suit (se reporter à l'Annexe F):

- Identifier les sources de dégagement;
- Déterminer le taux de dégagement et le degré de dégagement pour chaque source sur la base de la fréquence et de la durée de dégagement probables;
- Évaluer les conditions de ventilation ou de dilution ainsi que l'efficacité;
- Déterminer le type de zone sur la base du degré de dégagement et de l'efficacité de ventilation ou de dilution;
- Déterminer l'étendue de zone.

Les formules pertinentes pour déterminer les taux de dégagement dans des conditions spécifiques sont données dans l'Annexe B. Il est généralement accepté que ces formules fournissent une base correcte pour calculer les taux de dégagement pour les conditions fournies.

Des recommandations relatives à l'évaluation de la ventilation et de la dispersion sont données à l'Annexe C. D'autres formes d'évaluation, par exemple la dynamique des fluides numérique (CFD – *computational fluid dynamics*) ou des essais, peuvent être utilisées et peuvent représenter une bonne base d'évaluation dans certaines situations. La modélisation informatique est un outil approprié lors de l'évaluation de l'interaction de plusieurs facteurs.

Dans tous les cas, il convient de valider la méthode d'évaluation et les outils utilisés ou de les utiliser avec la prudence qui s'impose. Il convient que les personnes qui procèdent à l'évaluation mesurent également les limites ou les exigences relatives à des outils, et ajustent les conditions d'entrée ou les résultats en conséquence afin d'en tirer les conclusions appropriées.

NOTE Il n'est pas attendu que toutes les méthodes ou tous les outils utilisés pour la classification des emplacements dangereux donnent le même résultat. Il n'est pas nécessaire d'indiquer qu'une méthode particulière ou un outil particulier n'est pas adapté à l'application.

5.3 Utilisation des référentiels applicables à l'industrie et des normes nationales

5.3.1 Généralités

Les normes nationales et les référentiels applicables à l'industrie peuvent être utilisés s'ils donnent des recommandations ou des exemples adaptés à l'application et s'ils satisfont aux principes généraux de la présente norme.

L'Annexe K identifie certains référentiels applicables à l'industrie et normes nationales pertinents qui peuvent donner plus de détails et d'exemples.

5.3.2 Installations au gaz combustible

Pour les applications commerciales et industrielles dans lesquelles seul du gaz combustible basse pression est utilisé, par exemple, pour cuisiner, chauffer l'eau, etc., les codes de gaz locaux s'appliquent.

Dans la plupart des cas, la conformité aux codes de gaz donne lieu à une classification qui n'est pas dangereuse ou à une zone d'étendue négligeable.

NOTE Les basses pressions sont souvent considérées comme étant les pressions inférieures à 200 kPa (manomètre). Voir l'Annexe K pour des exemples de codes pertinents.

5.4 Méthodes simplifiées

Lorsqu'il s'avère impossible de procéder aux évaluations exigées à partir de sources de dégagement individuelles, une méthode simplifiée peut être utilisée. Par exemple, dans les projets de base, si les matériels ou les emplacements ne sont pas encore définis ou que les calculs pour toutes les sources de dégagement peuvent se révéler trop onéreux. Les méthodes simplifiées doivent identifier les sources pour chacun des types de zones classiques (zone 0, zone 1 et zone 2) afin de tenir compte des sources potentielles de dégagement sans détail individuel. L'appréciation est portée en s'appuyant sur un ensemble de critères reposant sur l'expérience acquise dans le secteur industriel et en fonction de l'installation particulière.

Il n'est pas nécessaire de procéder à une évaluation détaillée de tous les éléments d'une installation lorsqu'une évaluation d'un élément ou d'une condition s'avère suffisante pour donner une classification correcte pour tous les autres éléments ou toutes les autres conditions analogues de l'installation.

Des emplacements de zone plus importants sont caractéristiques des méthodes simplifiées, issus de l'approche et de la nécessité d'appliquer une classification en zones plus classique où le doute existe quant aux dangers impliqués. Cette approche doit privilégier la sécurité.

Pour parvenir à des chiffres moins prudents ou plus exacts des limites de l'emplacement classé, il convient d'utiliser une référence à des exemples représentatifs ou à une évaluation plus détaillée des sources de dégagement, selon le cas.

5.5 Combinaison de méthodes

L'utilisation de différentes méthodes peut être appropriée pour la classification d'une installation à différents stades de son développement ou pour différentes parties de l'installation.

Par exemple, au stade conceptuel initial d'une installation, la méthode simplifiée peut être appropriée pour définir les séparations de matériel, l'implantation de l'installation et les limites de l'installation. Cette méthode peut être la seule à appliquer en raison du manque de données détaillées sur les sources de dégagement. Au fur et à mesure de l'avancée de la conception de l'installation et de la disponibilité de données détaillées sur les sources potentielles de dégagement, il convient de mettre à niveau la classification à l'aide d'une méthode d'évaluation plus détaillée.

Dans certains cas, la méthode simplifiée peut être appliquée à un groupe de matériels analogues dans des sections de l'installation (sections de tuyauteries avec brides, comme les râteliers à tuyaux, par exemple) tout en appliquant une évaluation plus détaillée aux sources potentielles de dégagement les plus importantes (soupapes de décharge, évents, compresseurs, pompes et analogues, par exemple).

Dans un grand nombre de cas, les exemples de classifications fournis dans les normes nationales ou les codes applicables à l'industrie correspondants peuvent, le cas échéant, être utilisés pour classer certains composants d'installations plus importantes.

6 Dégagement de substance inflammable

6.1 Généralités

Le taux de dégagement d'une substance inflammable est le facteur le plus important qui affecte l'étendue d'une zone.

Généralement, plus le taux de dégagement est élevé, plus la zone est étendue.

NOTE L'expérience a démontré qu'un dégagement d'ammoniac dont la LII est de 15 % par volume se dissipe souvent rapidement à l'air libre (extérieur), si bien que l'étendue d'une atmosphère explosive gazeuse peut être considérée comme étant négligeable dans la plupart des cas.

Une présentation de la nature des dégagements qu'il convient de prendre en considération lors de la classification des emplacements potentiellement explosifs est fournie dans les paragraphes 6.2 à 6.3.

6.2 Sources de dégagement

Les éléments de base pour identifier les types de zones sont l'identification de la source de dégagement et la détermination du ou des degrés de dégagement.

Étant donné qu'il ne peut y avoir d'atmosphère explosive gazeuse qu'en présence de gaz ou de vapeur inflammable dans l'air, il est nécessaire de poser la question de la possibilité de l'existence de l'une de ces substances inflammables dans l'emplacement concerné. En règle générale, de tels gaz et vapeurs (et les liquides ou solides inflammables qui peuvent les engendrer) sont contenus à l'intérieur du matériel de production, lequel peut être ou peut ne pas être entièrement clos. Il est nécessaire d'identifier les endroits où une atmosphère explosive gazeuse peut exister à l'intérieur d'un matériel de production ou les endroits où un dégagement de substances inflammables peut engendrer une atmosphère inflammable à l'extérieur du matériel de production.

Il convient de considérer chaque matériel de production (réservoir, pompe, canalisation, cuve, par exemple) comme une source potentielle de dégagement de substance inflammable. Si le matériel ne peut, de toute évidence, pas contenir de substance inflammable, il est évident qu'il n'engendrera pas autour de lui un emplacement dangereux. Cela vaut aussi si le matériel contient une substance inflammable mais ne peut toutefois pas la libérer dans l'atmosphère (une canalisation entièrement soudée n'est pas considérée comme une source de dégagement, par exemple).

S'il est constaté que le matériel peut libérer une substance inflammable dans l'atmosphère, il est nécessaire de déterminer en premier lieu le ou les degrés de dégagement conformément aux définitions, en déterminant la fréquence et la durée probables du dégagement. Par ailleurs, au moment de la réalisation de la classification des emplacements dangereux, il convient également de considérer les ouvertures des parties de systèmes de traitement fermés (par exemple pendant un changement de filtre ou un chargement de matière) comme des sources de dégagement. Cette procédure permet ainsi de noter chaque dégagement comme suit: degré "dégagement continu", degré "dégagement primaire" ou degré "dégagement secondaire".

NOTE 1 Les dégagements peuvent faire partie du processus (prélèvement d'échantillons, par exemple) ou peuvent se produire dans le cadre d'une procédure de maintenance courante. Ces formes de dégagement sont en général classées comme étant de degré continu ou de degré "dégagement primaire". Les dégagements accidentels sont en général classés comme étant de degré "dégagement secondaire".

NOTE 2 Un matériel peut faire l'objet de plusieurs degrés de dégagement. Par exemple, un faible degré "dégagement primaire" peut avoir lieu, mais un dégagement plus important peut se produire en fonctionnement anormal, donnant lieu à un degré "dégagement secondaire". Dans cette situation, il est nécessaire de prendre pleinement en considération les deux conditions de dégagement (les deux degrés de dégagement) comme cela est décrit dans le présent document.

Après avoir constaté le ou les degrés de dégagement, il est nécessaire de déterminer le taux de dégagement et les autres facteurs qui peuvent avoir une influence sur le type et l'étendue de zone.

Dans certains cas, il peut être nécessaire de prendre en considération un mélange de différentes substances inflammables aux caractéristiques différentes (classe de densité relative et de température, par exemple). Dans ces cas, il est nécessaire de savoir si le rapport des composantes individuelles du mélange est suffisant pour influencer les paramètres concernés (le groupe de matériels et la classe de température, par exemple) ou s'il peut indiquer la nécessité de prendre d'autres facteurs en considération (l'emplacement dangereux pour les conditions de dégagement de gaz plus légers que l'air ou plus lourds que l'air, par exemple). Il convient que la classification des emplacements dangereux pour le matériel de production où brûle une substance inflammable (par exemple, postes de chauffage, fours, chaudières, turbines à gaz) prenne en compte le cycle de purge et les conditions de démarrage et d'arrêt.

Dans certains cas, la construction de systèmes clos, dans lesquels des codes de construction particuliers sont respectés, peut être acceptée si elle empêche ou limite efficacement les dégagements de substances à un niveau de danger de fuite négligeable. La classification des emplacements dangereux de ce type de matériel ou de ces installations exige une évaluation exhaustive visant à vérifier la totale conformité de l'installation aux normes de construction et de fonctionnement correspondantes. Il convient que la vérification de la conformité prenne en considération les activités de conception, d'installation, de fonctionnement, de maintenance et de surveillance.

Les brouillards qui résultent de fuites de liquide sous pression peuvent être inflammables, même si la température du liquide est inférieure au point d'éclair (voir l'Annexe G).

6.3 Formes de dégagement

6.3.1 Généralités

La caractéristique d'un dégagement dépend de l'état physique de la substance inflammable, de sa température et de sa pression. Les états physiques incluent:

- un gaz, qui peut être à une température ou une pression élevée;
- un gaz liquéfié par l'application d'une pression (GPL, par exemple);
- un gaz qui peut uniquement être liquéfié par réfrigération (le méthane, par exemple);
- un liquide avec un dégagement de vapeur inflammable associé.

Les dégagements qui proviennent de ces éléments d'installation (raccords de tuyauterie, pompes, joints de compresseur et garnitures d'étanchéité d'une vanne, par exemple) commencent souvent par un faible débit. Toutefois, si le dégagement n'est pas interrompu, l'érosion à la source de dégagement peut considérablement augmenter le taux de dégagement, et donc l'étendue du danger. À l'inverse, si la quantité de sources de dégagement est finie, le taux de dégagement peut décroître dans le temps, ce qui réduit l'étendue du danger. Par exemple: un gaz sous pression dans un système fermé.

Un dégagement de substance inflammable au-dessus de son point d'éclair se traduit par un nuage de vapeur ou de gaz inflammable qui peut à l'origine être plus ou moins dense que l'air environnant ou peut présenter une flottabilité neutre. Les formes de dégagement et le comportement général à différentes conditions sont présentés dans l'organigramme de la Figure B.1. Cette caractéristique affecte l'étendue de zone générée par une forme particulière de dégagement.

L'étendue horizontale de la zone au niveau du sol s'accroît généralement lorsque la densité relative s'accroît, et l'étendue verticale au-dessus de la source s'accroît généralement lorsque la densité relative décroît.

6.3.2 Dégagement gazeux

Un dégagement gazeux produit un jet ou un panache de gaz au niveau de la source de dégagement selon la pression au point de dégagement (joint de pompe, raccord de tuyauterie ou zone d'évaporation, par exemple). La densité relative du gaz, le degré de mélange turbulent et le mouvement d'air dominant ont tous une influence sur le mouvement ultérieur d'un nuage de gaz.

Dans des conditions calmes, les dégagements lents d'un gaz beaucoup moins dense que l'air ont tendance à s'élever (l'hydrogène et le méthane, par exemple). À l'inverse, un gaz beaucoup plus dense que l'air a tendance à s'accumuler au niveau du sol ou dans des creux ou des dépressions (le butane et le propane, par exemple). Avec le temps, les turbulences atmosphériques provoquent le mélange du gaz dégagé et de l'air, dont la flottabilité est alors neutre. Un gaz ou une vapeur dont la densité n'est pas sensiblement différente de celle de l'air est considéré(e) comme présentant une flottabilité neutre.

NOTE 1 Les gaz dont la flottabilité est presque neutre, comme l'éthane, peuvent avoir tendance à suivre le comportement de formation de couches des gaz denses, à condition que les conditions soient calmes.

Les dégagements à pression plus élevée produisent à l'origine des jets de gaz dégagé qui se mélangent avec turbulence à l'air ambiant et font monter l'air dans le jet.

À des pressions élevées, un effet thermodynamique dû à la dilatation peut intervenir. Au fur et à mesure de l'échappement, le gaz se dilate et se refroidit, et peut à l'origine devenir plus lourd que l'air. Toutefois, le refroidissement dû à l'effet de Joule-Thomson est finalement décalé par la chaleur de l'air. La flottabilité du nuage de gaz qui en résulte est finalement neutre. Un gaz plus lourd que l'air peut à tout moment devenir un gaz à flottabilité neutre, selon la nature du dégagement, et cette transition peut avoir lieu après dilution du nuage au-dessous de la LII.

NOTE 2 L'hydrogène présente un effet de Joule-Thomson inverse, son échauffement accompagnant sa dilatation. Ainsi, il ne présente jamais un effet plus lourd que l'air.

6.3.3 Dégagement liquéfié sous pression

Certains gaz peuvent être liquéfiés par la seule application de pression (le propane et le butane, par exemple) et sont en général stockés et transportés sous cette forme.

Lorsqu'un gaz liquéfié sous pression s'échappe de son confinement, le scénario le plus probable est que la substance s'échappe sous la forme d'un gaz depuis l'espace de vapeur ou les canalisations de gaz. L'évaporation rapide engendre un refroidissement important au point de dégagement, et du givre peut apparaître en raison de la condensation de la vapeur d'eau de l'atmosphère.

Une fuite s'évapore partiellement au point de dégagement. Il s'agit d'une évaporation éclair. Le liquide sujet à évaporation puise l'énergie en lui-même et dans l'atmosphère environnante et, en retour, refroidit le fluide qui fuit. Le refroidissement du fluide empêche l'évaporation totale, ce qui produit par conséquent un brouillard inflammable. Si la fuite est suffisamment importante, des flaques de fluide froid peuvent s'accumuler sur le sol, et s'évaporer avec le temps pour s'ajouter au dégagement de gaz.

Le nuage de brouillard inflammable agit comme un gaz dense. Un dégagement de liquide sous pression peut souvent s'apparenter à un effet refroidissant de l'évaporation qui condense l'humidité ambiante pour générer un nuage visible.

Dans certaines applications dont le gaz est liquéfié sous pression, un dégagement d'une partie du fluide du système peut à l'origine entraîner un dégagement en deux phases (liquide et vapeur) avec un comportement de "projection". En présence d'une quantité limitée de substance inflammable, le dégagement peut uniquement se transformer en vapeur, car le taux et la pression diminuent.

6.3.4 Dégagement liquéfié par réfrigération

Les autres gaz (appelés gaz permanents) peuvent uniquement être liquéfiés par réfrigération (le méthane et l'hydrogène, par exemple). Les petites fuites de gaz réfrigéré s'évaporent rapidement sans former de flaque de liquide en récupérant la chaleur de l'environnement. Si la fuite est importante, une flaque de liquide froid peut se former.

Dans la mesure où le liquide froid puise l'énergie du sol et de l'atmosphère environnante, il bout et génère un nuage de gaz dense et froid. Comme pour les liquides, des digues ou des murs de protection peuvent être utilisés pour acheminer ou maintenir les fuites.

NOTE 1 Il est nécessaire d'accorder une attention particulière à la classification des emplacements qui contiennent des gaz cryogéniques inflammables comme le gaz naturel liquéfié. Les vapeurs émises sont généralement plus lourdes que l'air à basses températures, mais leur flottabilité devient neutre à l'approche de la température ambiante.

NOTE 2 Les gaz permanents ont une température critique inférieure à –50 °C.

6.3.5 Dégagement de brouillards inflammables

Un brouillard inflammable n'est pas un gaz. Il est composé de gouttelettes de liquide en suspension dans l'air. Les gouttelettes sont formées à partir de vapeurs ou de gaz dans certaines conditions thermodynamiques ou par évaporation éclair des liquides sous pression. La diffusion de lumière à l'intérieur d'un nuage de brouillard inflammable permet souvent de le voir à l'œil nu. La dispersion d'un brouillard inflammable peut varier selon qu'il s'agit d'un gaz dense ou d'un gaz à flottabilité neutre. Les gouttelettes de brouillard inflammable peuvent fusionner et tomber du panache ou du nuage. Les brouillards inflammables qui proviennent de liquides inflammables peuvent absorber la chaleur du milieu ambiant, s'évaporer et s'ajouter au nuage de gaz/vapeur (pour plus de détails, voir l'Annexe G).

NOTE Dans certains cas, un brouillard visible peut se former à des concentrations inférieures à la limite inflammable. Par exemple, un brouillard d'ammoniac anhydre est visible à 4 % v/v en raison de l'absorption de l'humidité atmosphérique dans les gouttelettes de liquide, mais la LII est de 15 %.

6.3.6 Dégagement de vapeurs

Les liquides à l'équilibre avec leur environnement génèrent une couche de vapeur au-dessus de leur surface. La pression exercée par cette vapeur dans un système clos est appelée pression de vapeur, qui augmente de manière non linéaire en fonction de la température.

Le processus d'évaporation utilise l'énergie qui peut provenir d'un large éventail de sources (du liquide ou du milieu ambiant, par exemple). Le processus d'évaporation peut diminuer la température du liquide et limiter l'échauffement. Toutefois, les variations de température du liquide en raison de l'augmentation de l'évaporation dans les conditions normales d'environnement sont considérées comme étant trop marginales pour avoir un impact sur la classification des emplacements dangereux. La concentration de la vapeur générée n'est pas facile à prévoir, étant donné qu'elle dépend de la vitesse d'évaporation, de la température du liquide et du débit d'air environnant.

6.3.7 Dégagement de liquide

Le dégagement de liquides inflammables forme en général une flaque sur le sol, avec un nuage de vapeur à la surface du liquide, sauf si la surface est absorbante. La taille du nuage de vapeur dépend des propriétés de la substance et de sa pression de vapeur à la température ambiante (voir B.7.2).

NOTE 1 La pression de vapeur est une indication de la vitesse d'évaporation du liquide. Une substance qui présente une pression de vapeur élevée aux températures normales est souvent dite volatile. En règle générale, la pression de vapeur du liquide aux températures ambiantes augmente au fur et à mesure de la diminution du point d'ébullition. Lorsque la température augmente, la pression de vapeur augmente également.

NOTE 2 Le taux d'évaporation peut être réduit de manière significative dans le temps si la chaleur latente du liquide est élevée. Une chaleur latente élevée peut provoquer le refroidissement important de la surface sur laquelle le liquide est présent, ce qui limite le flux de chaleur dans le liquide. Par exemple, dans le cas d'une fuite d'ammoniac anhydre, dont la chaleur latente est élevée, le taux d'évaporation peut ralentir considérablement, sauf si de la chaleur supplémentaire est amenée sur le liquide.

Le dégagement peut également se produire sur de l'eau. De nombreux liquides inflammables sont moins denses que l'eau et ne sont souvent pas miscibles. Ces liquides se diffusent à la surface de l'eau, que ce soit sur le sol, dans les tuyaux de drainage, les nappes en tranchées ou en eaux libres (mer, lac ou rivière), formant un film mince et augmentant la vitesse d'évaporation en raison de la surface plus importante. Dans ces circonstances, les calculs de l'Annexe B ne sont pas applicables.

7 Ventilation (ou mouvement d'air) et dilution

7.1 Généralités

Le gaz ou la vapeur qui se dégage dans l'atmosphère peut se diluer par mélange turbulent avec l'air et, dans une moindre mesure, par diffusion en fonction des gradients de concentration. À moins que le dégagement ne se produise dans un espace confiné et bien étanche, le gaz se disperse complètement tant que la concentration n'est pas nulle. Le mouvement d'air dû à la ventilation naturelle ou artificielle favorise cette dispersion.

Des taux de ventilation appropriés peuvent réduire la durée de persistance d'une atmosphère explosive gazeuse et ainsi affecter le type de zone.

Une structure qui comporte un nombre suffisant d'ouvertures pour assurer le libre passage de l'air dans toutes les parties du bâtiment est considérée, dans un grand nombre de cas, comme étant bien ventilée, et il convient de la traiter comme un emplacement à l'air libre (un abri avec les côtés ouverts et des prises d'air de ventilation sur le toit, par exemple).

La dispersion ou la diffusion de gaz ou de vapeur dans l'atmosphère est un facteur essentiel de réduction de la concentration de gaz ou de vapeur sous la limite inférieure d'inflammabilité.

La ventilation et le mouvement d'air ont deux fonctions de base:

a) augmenter le taux de dilution et favoriser la dispersion afin de limiter l'étendue d'une zone;

b) réduire la persistance d'une atmosphère explosive qui peut influencer le type d'une zone.

L'étendue d'une zone est normalement réduite lorsque la ventilation ou le mouvement d'air augmente. Les obstacles qui gênent la ventilation ou le mouvement d'air peuvent augmenter l'étendue d'une zone. Certains obstacles (les digues, les parois et plafonds, par exemple) qui limitent l'étendue de circulation du gaz ou de la vapeur peuvent également limiter l'étendue de zone.

NOTE 1 L'augmentation du mouvement d'air peut également augmenter le taux de dégagement de la vapeur dû à une augmentation de l'évaporation sur des surfaces liquides ouvertes. Toutefois, l'augmentation du mouvement d'air présente normalement plus d'avantages que l'augmentation du taux de dégagement.

Pour les dégagements à basse vitesse, le taux de dispersion du gaz ou de la vapeur dans l'atmosphère augmente avec la vitesse du vent. Toutefois, dans des conditions atmosphériques calmes, la formation de couches de gaz ou de vapeur plus lourdes que l'air peut se produire, et la distance de dispersion sûre peut être considérablement augmentée. Pour des dégagements à basse vitesse, et en présence d'obstacles comme des murs et un plafond, la formation de couches de gaz ou de vapeur plus légères que l'air peut se produire au plafond, et la distance de dispersion sûre peut être considérablement augmentée.

NOTE 2 Dans les emplacements d'installation qui comportent des obstacles à la ventilation tels que des grandes cuves et structures, même à faibles vitesses du vent, des turbulences peuvent apparaître derrière ces obstacles, formant ainsi des poches de gaz ou de vapeur, sans turbulences suffisantes pour favoriser la dispersion.

En pratique normale, la tendance de formation de couches en situations extérieures n'est pas prise en compte dans la classification des emplacements dangereux, dans la mesure où les conditions qui donnent lieu à cet effet sont rares et se produisent uniquement pendant de courtes périodes. Cependant, si des périodes prolongées de vitesse faible du vent sont prévues dans la circonstance particulière, alors il convient que l'étendue de zone prenne en compte la distance supplémentaire exigée pour réaliser la dispersion. Il convient de prendre en considération la tendance à la formation de couches pour les situations intérieures.

NOTE 3 La formation de couches peut être un facteur pertinent dans certaines applications particulières, comme les pièces avec très peu d'échange d'air avec l'extérieur.

Dans certaines applications dont la quantité de dégagement est limitée, l'écoulement d'air de circulation à l'intérieur d'un espace fermé peut être utilisé pour fournir un mélange suffisant pour diluer un dégagement.

7.2 Principaux types de ventilations

7.2.1 Généralités

Les deux types de ventilations sont:

a) la ventilation naturelle; et

b) la ventilation artificielle (ou forcée), générale par rapport à l'emplacement ou locale par rapport à la source de dégagement.

7.2.2 Ventilation naturelle

La ventilation naturelle des bâtiments est le résultat des différences de pression induites par le vent et/ou les gradients de température (ventilation induite par la flottabilité). La ventilation naturelle peut être efficace dans certaines situations à l'intérieur de bâtiments (quand les murs et/ou le toit d'un bâtiment comportent des ouvertures, par exemple) pour diluer les dégagements en toute sécurité.

Exemples de ventilations naturelles:

- un bâtiment ouvert qui, compte tenu de la densité relative des gaz et/ou vapeurs en cause, a des ouvertures dans les murs et/ou le toit, qui sont dimensionnées et localisées de façon telle que la ventilation à l'intérieur du bâtiment puisse, pour l'objectif de classification des emplacements dangereux, être considérée comme équivalente à celle en plein air;
- un bâtiment qui n'est pas un bâtiment ouvert mais qui possède une ventilation naturelle (généralement plus faible que celle qu'il y a dans un bâtiment ouvert) assurée par des ouvertures permanentes réalisées à des fins de ventilation.

Il convient que la ventilation naturelle dans les bâtiments prenne en considération le fait que la flottabilité du gaz ou de la vapeur peut être un facteur significatif. De ce fait, il convient de placer la ventilation de manière à favoriser la dispersion et la dilution. Si la densité d'un gaz ou de la vapeur dégagé(e) est élevée ou basse par rapport à l'air, la hauteur de pression du mélange proche des ouvertures de l'enveloppe de locaux peut également être utilisée pour générer sa propre ventilation.

Les taux de ventilation qui résultent de la ventilation naturelle sont par définition très variables. En règle générale, avec une ventilation naturelle, un taux de ventilation inférieur donne un niveau de disponibilité supérieur, et inversement. Lorsque la dilution des dégagements est assurée par ventilation naturelle, le scénario le plus défavorable doit de préférence être pris en considération pour déterminer le taux de ventilation. Ce type de scénario donne donc lieu à un niveau plus élevé de disponibilité, ce qui compense les hypothèses trop optimistes formulées lors de l'estimation du taux de ventilation.

Certaines situations exigent une attention particulière. Cela est particulièrement le cas lorsque les prises d'air de ventilation sont limitées principalement à un seul côté de l'enveloppe. Dans certaines conditions ambiantes défavorables (les jours de vent, lorsque le vent souffle sur le côté ventilé de l'enveloppe, par exemple), le mouvement d'air extérieur peut empêcher le fonctionnement du mécanisme de flottabilité thermique. Dans ces circonstances, le niveau de ventilation et la disponibilité sont tous deux faibles, ce qui donne lieu à une classification plus rigoureuse.

7.2.3 Ventilation artificielle

7.2.3.1 Généralités

Le mouvement d'air exigé pour la ventilation peut également être assuré par des moyens artificiels (des ventilateurs ou des extracteurs, par exemple). Bien que la ventilation artificielle soit principalement utilisée dans une pièce ou un espace clos, elle peut également l'être en plein air de façon à compenser la réduction ou la gêne apportée au mouvement d'air par des obstacles.

La ventilation artificielle peut être générale (une pièce entière, par exemple) ou locale (extraction proche du point de dégagement, par exemple) et, dans ces deux cas, différents degrés de mouvement et de remplacement d'air peuvent être appropriés.

Avec l'utilisation de la ventilation artificielle, il est parfois possible de:

- réduire le type et/ou l'étendue des zones;
- raccourcir la durée de persistance d'une atmosphère explosive gazeuse;
- prévenir la formation d'une atmosphère explosive gazeuse.

7.2.3.2 Considérations relatives à la ventilation artificielle

La ventilation artificielle peut fournir un système de ventilation efficace et fiable à l'intérieur d'un bâtiment. Il convient de prendre en considération ce qui suit pour les systèmes de ventilation artificielle:

a) la classification de l'emplacement à l'intérieur du système d'extraction et immédiatement à l'extérieur du point de rejet et des autres ouvertures du système d'extraction;

b) il convient que l'air qui assure la ventilation d'un emplacement dangereux soit en principe issu d'un emplacement non dangereux en tenant compte des effets d'aspiration sur l'emplacement environnant;

c) il convient de définir l'emplacement des dégagements, ainsi que le degré, la vitesse et le taux de dégagement avant de déterminer les dimensions et la conception du système de ventilation.

En outre, les facteurs suivants ont une influence sur la qualité d'un système de ventilation artificielle:

a) les gaz et vapeurs inflammables ont généralement des densités différentes de celle de l'air, et peuvent ainsi s'accumuler à proximité soit du sol, soit du plafond de l'emplacement clos, où les mouvements d'air sont susceptibles d'être réduits;

b) la proximité de la ventilation artificielle de la source de dégagement; la ventilation artificielle proche de la source de dégagement est en principe plus efficace et peut être nécessaire pour contrôler de manière appropriée la circulation de gaz ou de vapeur;

c) les variations de la densité des gaz avec la température;

d) des obstacles peuvent provoquer des réductions des mouvements d'air, voire leur absence, c'est-à-dire que certaines parties de l'emplacement ne sont plus ventilées;

e) les turbulences et circulations d'air.

Pour plus de détails, voir l'Annexe C.

Il convient de prendre en considération la possibilité ou la nécessité de la recirculation de l'air dans la disposition de la ventilation. Cela peut avoir un impact sur la concentration de fond et l'efficacité du système de ventilation dans la réduction de l'emplacement dangereux. Dans ces cas, il peut s'avérer nécessaire de modifier la classification de l'emplacement dangereux en conséquence. La recirculation de l'air peut également être nécessaire dans certaines applications (pour certains processus ou pour répondre aux besoins de personnel ou de matériel, par exemple) à basse ou haute température ambiante en cas de besoin supplémentaire de refroidissement ou réchauffement de l'air. En cas de besoin de recirculation de l'air, des commandes supplémentaires pour la sécurité peuvent également être exigées (un analyseur de gaz avec des registres qui permettent de contrôler l'entrée d'air frais, par exemple).

7.2.3.3 Exemples de ventilations artificielles

Une ventilation artificielle générale peut inclure un bâtiment équipé de ventilateurs dans les murs et/ou dans le toit afin d'améliorer la ventilation générale du bâtiment.

Le rôle des ventilateurs peut être double. Ils peuvent augmenter le débit d'air dans un bâtiment, ce qui facilite l'évacuation du gaz du bâtiment. Les ventilateurs installés dans un bâtiment peuvent également augmenter les turbulences et faciliter la dilution d'un nuage beaucoup plus petit que la pièce qui le contient, même si aucun gaz n'est chassé de la pièce. Les ventilateurs peuvent également améliorer la dilution en augmentant les turbulences dans certaines situations extérieures.

La ventilation artificielle locale peut être:

a) un système d'extraction d'air/vapeur appliqué à un matériel de production qui dégage de façon permanente ou périodique une vapeur inflammable.

b) un système de ventilation forcée ou d'extraction appliqué à un emplacement local où, par ailleurs, l'apparition d'une atmosphère explosive gazeuse peut se produire.

Pour plus de détails, voir l'Article C.4.

7.2.4 Degré de dilution

L'efficacité de la ventilation à maîtriser la dispersion et la persistance de l'atmosphère explosive dépend du degré de dilution, de la disponibilité de la ventilation et de la conception du système. Par exemple, la ventilation peut ne pas être suffisante pour prévenir la formation d'une atmosphère explosive, mais peut être suffisante pour empêcher sa persistance.

Le degré de dilution est une mesure de l'aptitude des conditions de ventilation ou des conditions atmosphériques à assurer la dilution d'un dégagement à un niveau sûr. Par conséquent, un dégagement plus important correspond à un degré de dilution plus faible pour un ensemble donné de conditions de ventilation ou de conditions atmosphériques, un taux de ventilation plus faible correspondant à un degré de dilution moins élevé pour une quantité de dégagement donnée.

Si d'autres formes de ventilation (des ventilateurs de refroidissement, par exemple) sont prises en compte, il convient alors de prendre des précautions quant à la disponibilité de la ventilation. La ventilation utilisée à d'autres fins peut également avoir un impact positif ou négatif sur la dilution.

Le degré de dilution a également un impact sur le volume de dilution. Le volume de dilution est égal au volume qui peut être supérieur à la LII, y compris les facteurs de sécurité. En d'autres termes, il s'agit du volume qui peut être inflammable. Toutefois, la limite de l'emplacement dangereux prend également en compte d'autres facteurs, tels que le mouvement possible du dégagement, c'est-à-dire celui dû à la direction et à la vitesse du dégagement et du volume d'air environnant. En principe, l'emplacement dangereux est donc beaucoup plus grand que le volume de dilution. Le concept de volume de dilution et sa relation avec la classification des emplacements dangereux sont représentés à la Figure 1.

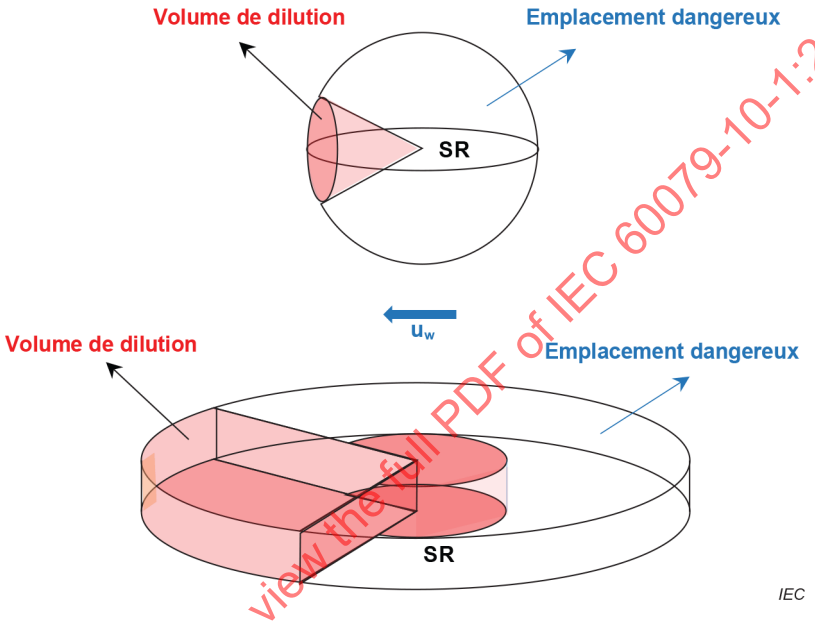


Figure 1 – Volume de dilution

Le degré de dilution dépend non seulement de la ventilation, mais également de la nature et du type de dégagement de gaz prévu. Certains dégagements (à basse vitesse, par exemple) sont limitables par une ventilation améliorée avec d'autres qui le sont beaucoup moins (dégagement à grande vitesse, par exemple).

Les degrés de dilution couramment appliqués sont décrits en C.3.5.

8 Type de zone

8.1 Généralités

La probabilité de présence d'une atmosphère explosive gazeuse dépend principalement du degré de dégagement et de la ventilation. Cela est identifié comme une zone. Les zones sont reconnues de la manière suivante: Zone 0, Zone 1, Zone 2 et zone non dangereuse.

Lorsque des zones créées par des sources adjacentes de dégagement se chevauchent et relèvent de différents types de zones, y compris la classe de température et le groupe de matériels, les critères de classification plus sévères s'appliquent dans l'emplacement de chevauchement. Lorsque les zones de chevauchement relèvent de la même classification, cette classification commune s'applique normalement.

8.2 Influence du degré de la source de dégagement

Il existe trois degrés de dégagement de base, énumérés ci-dessous dans l'ordre décroissant de fréquence d'occurrence et/ou de durée de dégagement de substance inflammable:

a) degré "dégagement continu";

b) degré "dégagement primaire";

c) degré "dégagement secondaire".

Une source de dégagement peut donner lieu à n'importe lequel de ces degrés de dégagement ou à une combinaison de deux degrés ou plus.

Le degré de dégagement détermine en général le type de la zone. Dans un emplacement correctement ventilé (une installation à l'air libre, par exemple), un degré "dégagement continu" se traduit en principe par une classification en Zone 0, un degré "dégagement primaire" par une classification en Zone 1 et un degré "dégagement secondaire" par une classification en Zone 2. Cette règle générale peut être modifiée en prenant en considération le degré de dilution et la disponibilité de la ventilation qui peuvent donner lieu à une classification plus ou moins sévère (voir 8.3, 8.4 et l'Annexe D).

8.3 Influence de la dilution

L'efficacité de la ventilation ou du degré de dilution doit être prise en considération lors de l'estimation du type de classification en zones.

En règle générale, un degré moyen de dilution donne lieu à des types de zones prédéterminés en fonction des types de sources de dégagement. Un degré élevé de dilution permet une classification moins sévère (Zone 1 au lieu de la Zone 0, Zone 2 au lieu de la Zone 1 et même, dans certains cas, une Zone d'étendue négligeable, par exemple). Par ailleurs, un degré faible de dilution exige une classification plus sévère (voir l'Annexe D).

8.4 Influence de la disponibilité de la ventilation

La disponibilité de la ventilation a une influence sur la présence ou la formation d'une atmosphère explosive gazeuse et, par conséquent, également sur le type de zone. La probabilité de ne pas disperser les atmosphères explosives gazeuses augmente au fur et à mesure de la diminution de la disponibilité (ou fiabilité) de la ventilation. La classification en zones a tendance à être plus sévère, c'est-à-dire qu'une Zone 2 peut devenir une Zone 1, voire une Zone 0. Des recommandations relatives à la disponibilité sont données à l'Annexe D.

Des descriptions couramment appliquées de la disponibilité de la ventilation sont fournies en C.3.7.1.

NOTE La combinaison des concepts d'efficacité et de disponibilité de la ventilation génère une méthode qualitative d'évaluation du type de zone. Cela est expliqué plus en détail à l'Annexe D.

9 Étendue de zone

L'étendue de zone dépend de la distance estimée ou calculée sur laquelle existe une atmosphère explosive avant sa dispersion pour atteindre une concentration dans l'air au-dessous de sa limite inférieure d'inflammabilité. Lors de l'évaluation de l'emplacement de diffusion de gaz ou de vapeur avant sa dilution au-dessous de sa limite inférieure d'inflammabilité, il convient de demander conseil à un expert.

Il convient de toujours prendre en considération la possibilité selon laquelle un gaz qui est plus lourd que l'air peut se diffuser dans des emplacements souterrains (dans des puits ou des dépressions par exemple) et que le gaz qui est plus léger que l'air peut être retenu à un niveau élevé (par exemple, sur le toit).

Lorsque la source de dégagement est située à l'extérieur d'un emplacement ou dans un emplacement avoisinant, la pénétration d'une quantité significative de gaz ou de vapeurs inflammables dans l'emplacement peut être évitée par des moyens appropriés, tels que:

a) des barrières physiques; ou

b) le maintien d'une surpression statique dans l'emplacement contigu aux emplacements dangereux, empêchant ainsi la pénétration de l'atmosphère explosive gazeuse.

c) la purge de l'emplacement avec de l'air frais ou un gaz de protection non inflammable (azote ou dioxyde de carbone, par exemple) à un débit suffisant et une pression positive, de manière à réduire la concentration de gaz ou de vapeurs inflammables à l'origine présents à une concentration inoffensive.

NOTE Un exemple de barrière physique est un mur étanche sans ouverture ou autre obstacle qui limite le passage de gaz ou de vapeurs à la pression atmosphérique, empêchant ainsi la pénétration d'une quantité significative de gaz ou de vapeur inflammable dans l'emplacement.

L'étendue de zone exige d'évaluer un certain nombre de paramètres physiques et chimiques, dont certains sont des propriétés intrinsèques de la substance inflammable, les autres étant spécifiques à la situation (se reporter également aux Articles 6, 7 et 8).

Pour les dégagements où seule une quantité réduite est effectivement libérée, une distance plus petite peut être acceptée avec un dégagement en cours. Dans le cas d'une petite quantité, la plupart des recommandations de l'Annexe C et de l'Annexe D ne sont pas applicables.

Dans certaines conditions, les gaz et vapeurs plus lourds que l'air peuvent se comporter comme un liquide déversé et s'écoulant sur un terrain en pente, à travers des tuyaux de drainage ou des nappes en tranchées, et peuvent s'enflammer à distance de la fuite d'origine, ce qui entraîne par conséquent un risque au niveau des surfaces importantes d'une installation (voir B.6). Il convient de concevoir l'implantation de l'installation, lorsque cela est possible, pour faciliter la dispersion rapide des atmosphères explosives gazeuses.

Un emplacement à ventilation restreinte (par exemple dans des puits ou des tranchées) qui correspond normalement à la Zone 2 peut exiger la classification en Zone 1. D'autre part, de larges dépressions de faible profondeur utilisées pour des complexes de pompage ou des réservations pour canalisation peuvent ne pas exiger un traitement aussi rigoureux.

10 Documentation

10.1 Généralités

Il est recommandé de documenter de manière exhaustive la procédure de classification des emplacements dangereux et les informations et hypothèses utilisées. Il convient que le document de classification des emplacements dangereux soit évolutif, contienne la méthode de classification des emplacements dangereux utilisée et soit révisé pendant les modifications de l'installation. Il convient de référencer toutes les informations pertinentes utilisées. Exemples de telles informations ou d'une méthode utilisée:

a) processus de montage et de fonctionnement;

b) recommandations tirées de codes et de normes appropriés;

c) caractéristiques de dispersion des gaz et vapeurs et calculs;

d) étude des caractéristiques de ventilation par rapport aux paramètres de dégagement de substance inflammable, de sorte que l'efficacité de la ventilation puisse être évaluée;

e) toutes les limitations ou bases de l'évaluation qui peuvent avoir un impact sur la classification (pour les ensembles fabriqués lors de l'installation sur site, par exemple);

f) les propriétés de toutes les substances de processus utilisées dans l'installation (voir l'ISO/IEC 80079-20-1), qui peuvent inclure:

- la masse molaire
- le point d'éclair
- le point d'ébullition
- la température d'auto-inflammation
- la pression de vapeur
- la densité de vapeur
- les limites d'inflammabilité
- le groupe de matériels et la classe de température

Il est nécessaire d'enregistrer la source des informations (code, norme nationale, calcul) de sorte que, lors des examens suivants, la philosophie adoptée soit claire pour l'équipe chargée de la classification des emplacements dangereux.

10.2 Plans, fiches techniques et tableaux

Les documents pour la classification des emplacements peuvent être sous forme de copie papier ou sous format électronique. Il convient de les conserver dans un format adapté au site.

Les formats de copie papier possibles pour la liste de substances sont proposés dans le Tableau A.1. Un format d'enregistrement des résultats de l'étude de classification des emplacements dangereux et de toutes les modifications apportées est donné dans le Tableau A.2.

Il convient que les dessins comportent des vues en plan et en élévation ou des présentations tridimensionnelles, selon le cas, qui fassent apparaître à la fois le type et l'étendue des zones, le groupe de matériels, la température d'auto-inflammation ou la classe de température.

Lorsque la topographie d'un emplacement a une influence sur l'étendue des zones, il convient de le documenter.

Il convient également que les documents comprennent d'autres informations appropriées, telles que:

a) l'emplacement et l'identification des sources de dégagement. Pour les installations ou aires de traitement complexes de grandes dimensions, il peut ne pas être pratique de détailler ou de numéroter toutes les sources de dégagement, auquel cas des méthodes simplifiées peuvent être utilisées (voir 5.4);

b) la position des ouvertures dans les bâtiments (les portes, fenêtres, orifices d'entrée et de sortie d'air pour la ventilation, par exemple).

La Figure A.1 représente les symboles préférentiels relatifs à la classification des emplacements dangereux. Une légende des symboles doit toujours être fournie sur chaque plan. Différents symboles peuvent être nécessaires lorsque plusieurs groupes de matériels ou classes de températures sont exigés au sein du même type de zone (la Zone 2 IIC T1 et la Zone 2 IIA T3 par exemple).

Annexe A
(informative)

Suggestion de présentation des emplacements dangereux

A.1 Emplacements dangereux – Symboles préférentiels pour les zones

La Figure A.1 représente les symboles préférentiels pour les zones.

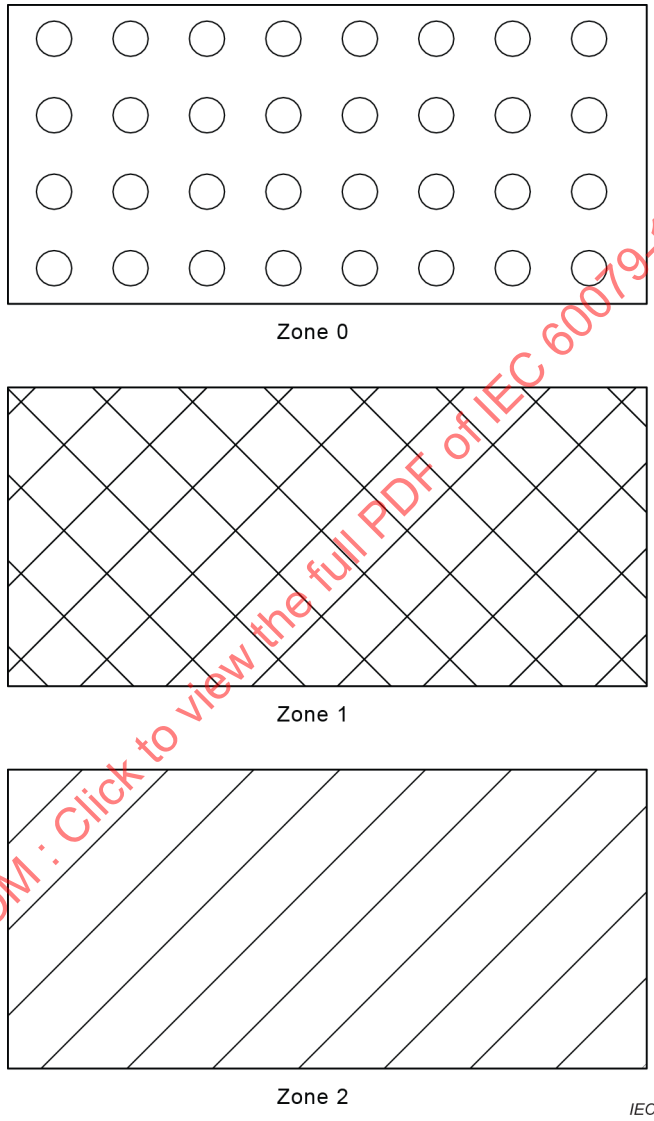


Figure A.1 – Symboles préférentiels pour les zones

Tableau A.1 – Fiche de données de classification des emplacements dangereux – Partie I: Liste et caractéristiques des substances inflammables

Installation: **Emplacement:**														**Dessin de référence:**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Substance inflammable							**Volatilité**[a]		**LII/LSI**		**Caractéristiques Ex**		
	Nom	Composition	Masse molaire (kg/kmol)	Densité relative gaz/air	Indice polytropique de détente adiabatique γ	Point d'éclair (°C)	Temp. d'inflam-mation (°C)	Point d'ébullition (°C)	Pression de vapeur à 20 °C (kPa)	Vol. (%)	(kg/m^3)	Groupe de matériel	Classe de temp.	Toute autre information ou remarque pertinente Par exemple, source des données
[a] En général, la valeur de la pression de vapeur est donnée, mais en son absence, le point d'ébullition peut être utilisé.														

Tableau A.2 – Fiche de données de classification des emplacements dangereux – Partie II: Liste des sources de dégagement

Installation: **Emplacement:**																**Dessin de référence**
1	2	3	4	5	6	7	8		9	10	11	12	13	14		15	16
	Sources de dégagement					**Substance inflammable**				**Ventilation**			**Zone dangereuse**				
	Description	Emplacement	Degré de degagement[a]	Taux de dégagement (kg/s)	Caractéristique du dégagement (m^3/s)	Référence[b]	Température et pression de fonctionnement		État[c]	Type[d]	Degré de dilution[e]	Disponibilité	Type de zone 0-1-2	Étendue de zone (m)		Référence[f]	Toute autre information ou remarque
							(°C)	(kPa)						Verticale	Horizontale		

[a] C – Continue; S – Secondaire; P – Primaire

[b] Citer le numéro de liste de la Partie I

[c] G – Gaz; L – Liquide; LG – Gaz liquéfié; S – Solide

[d] N – Naturel; AG – Artificiel Général; AL – Artificiel Local

[e] Voir l'Annexe C

[f] Indiquer la référence du code s'il est utilisé, ou la référence des calculs

A.2 Formes suggérées des emplacements dangereux

La Figure A.2 à la Figure A.5 représentent certaines formes suggérées d'emplacement dangereux en fonction des formes de dégagement décrites dans l'Article B.6, qui peuvent être utiles dans la préparation des plans de classification des emplacements dangereux. Les effets de l'incidence du dégagement sur les obstacles et l'influence de la topographie ne sont pas pris en considération. L'emplacement dangereux généré par un dégagement peut également donner lieu à la combinaison de différentes formes.

De la Figure A.2 à la Figure A.5:

SR est la source de dégagement

r est l'étendue principale de l'emplacement dangereux à définir en prenant en considération la distance dangereuse estimée;

r', r" sont les étendues secondaires de l'emplacement dangereux à définir en tenant compte du comportement du dégagement;

h sont les distances entre la source de dégagement et le sol ou la surface sous le dégagement.

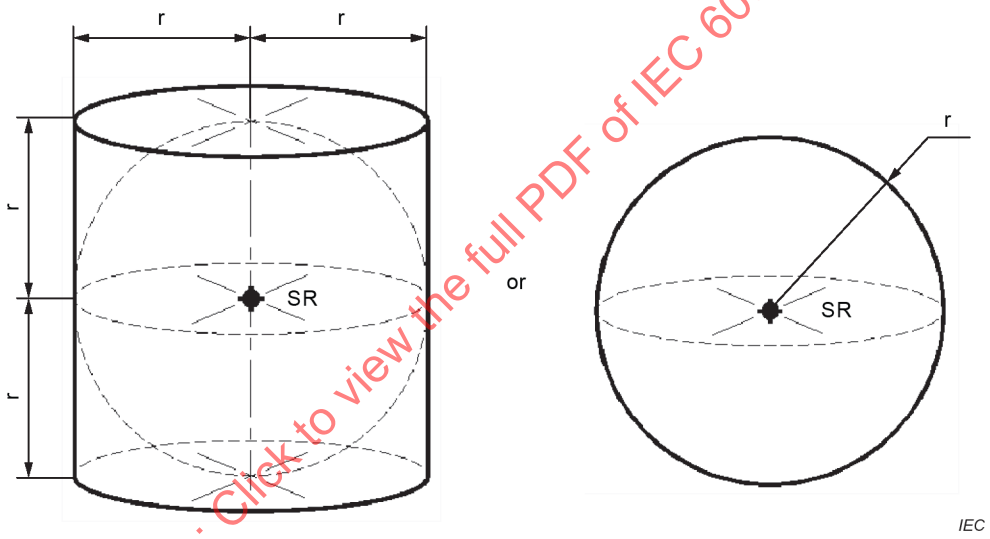


Figure A.2 – Gaz ou vapeur à basse pression
(ou à haute pression dans le cas où le sens de dégagement n'est pas prévisible)

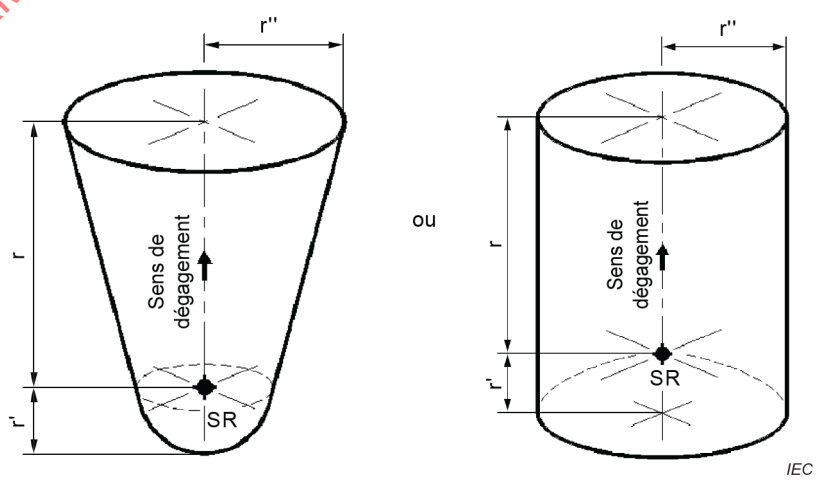
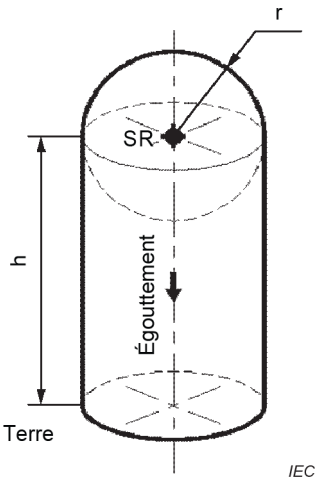
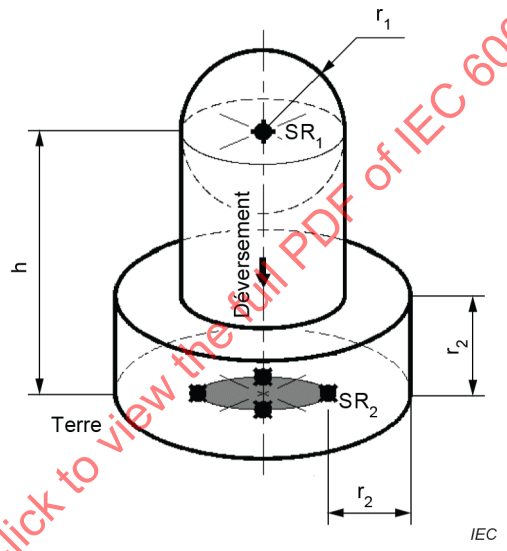


Figure A.3 – Gaz ou vapeur à haute pression



NOTE En cas d'égouttement, il ne se forme généralement pas de flaque de liquide.

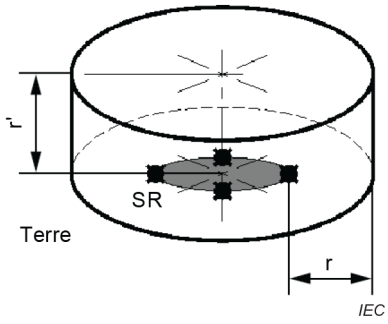
Figure A.4a) Gaz ou vapeur (liquéfié(e) sous pression ou par réfrigération)



NOTE En cas de déversement accidentel, une flaque de liquide peut se former. Dans ce cas, une source de dégagement supplémentaire peut être prise en considération.

Figure A.4b) Gaz ou vapeur (liquéfié(e) sous pression ou par réfrigération) avec déversement accidentel

Figure A.4 – Gaz liquéfié



NOTE La source de déversement accidentel de substance inflammable n'est pas indiquée.

Figure A.5 – Liquide inflammable
(flaque d'évaporation qui n'est pas en ébullition)

Annexe B
(informative)

Estimation des sources de dégagement

B.1 Symboles

A_p surface de la flaque (m^2);

C_d coefficient de débit (sans dimension) caractéristique des ouvertures de dégagement et qui prend en compte les effets de turbulence et de viscosité, généralement de 0,50 à 0,75 pour les orifices à arête vive et de 0,95 à 0,99 pour les orifices arrondis;

c_p chaleur massique à pression constante (J/kg K);

γ indice polytropique de la détente adiabatique ou rapport des chaleurs massiques (sans dimensions);

M masse molaire du gaz ou de la vapeur (kg/kmol);

p pression dans le conteneur (Pa);

Δp différence de pression dans l'ouverture qui fuit (Pa);

p_a pression atmosphérique (101 325 Pa);

p_c pression critique (Pa);

p_v pression de vapeur du liquide à la température T (Pa);

Q_g débit volumétrique du gaz inflammable par rapport à la source (m^3/s);

R constante universelle des gaz (8314,5 J/kmol K);

ρ densité du liquide (kg/m^3);

ρ_g densité du gaz ou de la vapeur dans les conditions ambiantes (kg/m^3);

S section transversale de l'orifice (trou) par lequel le fluide est dégagé (m^2);

T température du fluide, du gaz ou du liquide (K);

T_a température ambiante (K);

u_w vitesse du vent à la surface de la flaque de liquide (m/s);

W taux de dégagement du liquide (masse par unité de temps, kg/s);

W_e vitesse d'évaporation du liquide (kg/s);

W_g taux de dégagement massique du gaz (kg/s);

Z facteur de compressibilité (sans dimension).

B.2 Exemples de degrés de dégagement

B.2.1 Généralités

Les exemples donnés de B.2.2 à B.2.4 ne sont pas destinés à être appliqués de façon stricte. Ils peuvent nécessiter des adaptations en fonction du matériel de production particulier et de la situation. Il est nécessaire de savoir que certains matériels peuvent avoir plusieurs degrés de dégagement.

Il convient de choisir les valeurs des paramètres dans les formules fournies de manière à donner un niveau approprié de prudence en prenant en considération l'incertitude. Dans cette approche, les facteurs de sécurité spécifiques ne sont pas indiqués.

B.2.2 Sources qui donnent le degré "dégagement continu"

Ci-dessous quelques exemples caractéristiques:

a) surface d'un liquide inflammable dans un réservoir à toit fixe équipé d'un évent, avec une ventilation continue vers l'atmosphère.

b) surface d'un liquide inflammable ouvert à l'atmosphère de façon permanente ou pendant de longues périodes.

B.2.3 Sources qui donnent le degré "dégagement primaire"

Ci-dessous quelques exemples caractéristiques:

a) Garnitures de pompes, compresseurs ou vannes, si un dégagement de substance inflammable est prévu pendant le fonctionnement normal.

b) Points de vidange d'eau placés sur des cuves qui contiennent des gaz ou des liquides inflammables qui peuvent donner lieu à des dégagements de substance inflammable dans l'atmosphère tandis que s'effectue la vidange de l'eau pendant le fonctionnement normal.

c) Points d'échantillonnage dans lesquels des dégagements de substance inflammable sont prévus dans l'atmosphère pendant le fonctionnement normal.

d) Soupapes de décharge, évents et autres ouvertures où sont prévus des dégagements de substance inflammable dans l'atmosphère pendant le fonctionnement normal.

B.2.4 Sources qui donnent le degré "dégagement secondaire"

Ci-dessous quelques exemples caractéristiques:

a) Garnitures de pompes, compresseurs et vannes, où ne sont pas prévus de dégagements de substance inflammable pendant le fonctionnement normal du matériel.

b) Brides, raccords et accessoires de tuyauteries où ne sont pas prévus de dégagements de substance inflammable pendant le fonctionnement normal.

c) Points d'échantillonnage où ne sont pas prévus de dégagements de substance inflammable pendant le fonctionnement normal.

d) Soupapes de décharge, évents et autres ouvertures où ne sont pas prévus de dégagements de substance inflammable dans l'atmosphère pendant le fonctionnement normal.

B.3 Évaluation des degrés de dégagement

Une mauvaise évaluation des degrés de dégagement peut compromettre le résultat de l'ensemble de la procédure. Bien que les degrés de dégagement soient définis (voir 3.4.2, 3.4.3 et 3.4.4), il n'est pas toujours facile, dans la pratique, de distinguer un degré de dégagement d'un autre.

Par exemple, il est en général considéré que chaque dégagement qui ne se produit pas en fonctionnement normal est un degré "dégagement secondaire". La durée prévue du dégagement est en général négligée. Toutefois, le concept de degré de "dégagement secondaire" repose également sur l'hypothèse selon laquelle le dégagement ne dure que très peu de temps. Cela implique qu'un éventuel dégagement est identifié dès le début et que la mesure corrective est prise dès que possible. Ce type d'hypothèse permet de procéder à une surveillance et une maintenance régulières du matériel et de l'installation.

De toute évidence, si la surveillance n'est pas régulière et que la maintenance est insuffisante, il peut s'écouler plusieurs heures, voire plusieurs jours, avant de détecter les dégagements. Ce retard de détection ne signifie pas qu'il convient donc de déclarer les sources de dégagement comme primaire ou comme continu. Un dégagement peut se produire dans de nombreuses installations éloignées laissées sans surveillance sans qu'il soit signalé pendant une longue période, mais il convient également de surveiller et d'examiner ces installations d'une manière régulière raisonnable. Par conséquent, une évaluation du degré de dégagement doit reposer sur des considérations attentives et sur l'hypothèse selon laquelle le matériel et les installations sont surveillés et examinés de manière raisonnable, selon les instructions du fabricant, les règlements et protocoles pertinents et des pratiques techniques sûres. Il convient que la classification des emplacements dangereux ne serve pas de prétexte à une maintenance insuffisante; l'utilisateur doit au contraire être conscient du fait que de mauvaises pratiques peuvent compromettre les bases établies pour la classification des emplacements dangereux.

Dans un grand nombre de cas, le dégagement peut correspondre assez bien à la définition d'un degré "dégagement primaire". Toutefois, dans le cadre de l'examen minutieux de la nature du dégagement, il peut s'avérer que le dégagement se produit de manière si fréquente et imprévisible que personne ne peut raisonnablement affirmer qu'une atmosphère explosive n'apparaît pas à proximité de la source de dégagement. Dans ces cas, la définition du degré "dégagement continu" peut être plus adaptée. Par conséquent, la définition d'un degré "dégagement continu" implique non seulement que les dégagements sont continus, mais également très fréquents (voir 3.4.2).

B.4 Cumul des dégagements

Dans les emplacements intérieurs qui contiennent plusieurs sources de dégagement, et afin de déterminer le type et l'étendue des zones, il pourrait être nécessaire de cumuler les dégagements avant de déterminer le degré de dilution et la concentration de fond.

Il peut être prévu que les degrés "dégagement continu" ont souvent, sinon toujours, lieu, et il convient donc de cumuler tous les degrés "dégagement continu".

Le degré "dégagement primaire" se produit en fonctionnement normal, mais il est peu probable que toutes ces sources fassent simultanément l'objet d'un dégagement. Il convient de s'appuyer sur les connaissances et l'expérience de l'installation pour déterminer le nombre d'occurrences du degré "dégagement primaire" qui peuvent se produire simultanément dans les conditions les plus défavorables.

Les occurrences du degré "dégagement secondaire" ne sont pas réputées se produire en fonctionnement normal. Par conséquent, étant donné qu'il s'avère peu probable que plusieurs sources secondaires fassent simultanément l'objet d'un dégagement, il convient de prendre en considération uniquement le dégagement secondaire le plus important.

Il convient d'établir le cumul des sources de dégagement avec une activité régulière (c'est-à-dire prévisible) sur la base d'une analyse détaillée des conditions d'exploitation. Dans la détermination des dégagements cumulés (massiques et volumétriques):

- l'ensemble du dégagement continu est égal à la somme de tous les dégagements continus individuels,
- l'ensemble des dégagements primaires est égal à la somme des dégagements primaires individuels combinés à l'ensemble des dégagements continus,
- l'ensemble des dégagements secondaires se compose du dégagement secondaire individuel le plus important combiné à l'ensemble des dégagements primaires.

Lorsque la même substance inflammable s'échappe de toutes les sources de dégagement, les taux de dégagement (massiques et volumétriques) peuvent alors être cumulés directement.

Toutefois, en cas de dégagements de substances inflammables différentes, la situation est plus complexe. Dans la détermination du degré de dilution (voir la Figure C.1), il est nécessaire de déterminer les caractéristiques de dégagement pour chaque substance inflammable avant de procéder au cumul. Il convient d'utiliser le dégagement secondaire qui présente la valeur la plus élevée.

Dans la détermination de la concentration de fond (voir l'équation C.1), les taux de dégagement volumétrique peuvent être cumulés directement. La concentration critique à laquelle est comparée la concentration de fond est proportionnelle à la LII. Étant donné qu'un certain nombre de substances inflammables différentes peuvent s'échapper, il convient d'utiliser la LII la plus faible des sources potentielles de dégagement en comparaison.

En général, il convient que les sources de dégagement primaires et continues ne soient, de préférence, pas situées dans des emplacements avec un faible degré de dilution. Il convient de relocaliser les sources de dégagement, d'améliorer la ventilation ou de diminuer le degré de dégagement.

B.5 Alésage et rayon de la source

Le facteur le plus significatif à estimer dans un système est le rayon de la surface de fuite de la source de dégagement respective. Il détermine le taux de dégagement de la substance inflammable et donc, finalement, le type et l'étendue de zone.

Le taux de dégagement est proportionnel au carré du rayon de la surface de fuite équivalent. Une légère sous-estimation de cet alésage équivalent se traduit par conséquent par une large sous-estimation de la valeur calculée du taux de dégagement, ce qu'il convient d'éviter. Une surestimation de l'alésage équivalent donne un calcul prudent, ce qui est acceptable pour des raisons de sécurité. Toutefois, il convient également de limiter le degré de prudence, car il donne finalement des étendues de zone démesurées. Une approche soigneusement équilibrée est donc nécessaire lors de l'estimation de l'alésage.

NOTE Même si le terme "rayon de la surface de fuite" est utilisé, la plupart des fuites imprévues ne sont pas rondes. Dans ces cas, le coefficient de débit est utilisé en compensation pour réduire le taux de dégagement à une surface de fuite équivalente.

Pour le degré "dégagement continu" et le degré "dégagement primaire", les alésages équivalents sont définis par la taille et la forme de l'orifice de dégagement (divers évents et dispositifs de respiration, par exemple) par lequel le gaz s'échappe dans des conditions relativement prévisibles. Un guide relatif aux alésages équivalents qui peuvent être pris en considération pour les degrés "dégagement secondaire" est inclus dans le Tableau B.1.

Tableau B.1 – Sections d'alésage suggérées pour les degrés "dégagement secondaire"

Type d'élément	Élément	Considérations relatives aux fuites		
		Valeurs classiques pour les conditions dans lesquelles l'ouverture de dégagement n'est pas étendue	Valeurs classiques pour les conditions dans lesquelles l'ouverture de dégagement peut être étendue (érosion, par exemple)	Valeurs classiques pour les conditions dans lesquelles l'ouverture de dégagement peut être étendue jusqu'à une défaillance sévère (éclatement, par exemple)
		S (mm^2)	S (mm^2)	S (mm^2)
Organes d'étanchéité sur les parties fixes	**Brides avec joints en fibres comprimées ou matériau analogue**	≥ 0,025 jusqu'à 0,25	> 0,25 jusqu'à 2,5	(zone entre deux boulons) × (épaisseur du joint) en général ≥ 1 mm
	Brides avec garnitures d'étanchéité en spirale ou analogues	0 025	0,25	(zone entre deux boulons) × (épaisseur du joint) en général ≥ 0,5 mm
	Raccords à joints annulaires	0,1	0,25	0,5
	Raccords à faible alésage jusqu'à 50 mm[a]	≥ 0,025 jusqu'à 0,1	> 0,1 jusqu'à 0,25	1,0
Organes d'étanchéité sur les parties mobiles à basse vitesse	**Garnitures de tiges de manœuvre**	0,25	2,5	À définir en fonction des données du fabricant du matériel, mais pas moins de 2,5 mm^2 [d]
	Soupapes de décharge [b]	0,1 × (section de l'orifice)	s.o.	s.o.
Organes d'étanchéité sur les parties mobiles à grande vitesse	**Pompes et compresseurs**[c]	s.o.	≥ 1 jusqu'à 5	À définir en fonction des données du fabricant du matériel et/ou de la configuration de l'unité de traitement, mais pas moins de 5 mm^2 [d et e]

[a] Les sections d'alésage suggérées pour les joints annulaires, les raccords filetés, les joints à compression (les raccords à compression métalliques, par exemple) et les joints rapides sur les canalisations à faible alésage.

[b] Ce point ne fait pas référence à l'ouverture complète de la soupape, mais à diverses fuites dues au dysfonctionnement des composants de la soupape. Des applications particulières peuvent exiger une section d'alésage plus importante que celle suggérée.

[c] Compresseur à pistons – Le châssis du compresseur et les cylindres ne sont en général pas ceux qui fuient, sauf les garnitures de tiges de piston et les différents raccords de tuyauterie dans le système de traitement.

[d] Données du fabricant du matériel – La coopération avec le fabricant du matériel est exigée pour évaluer les effets d'une défaillance imprévue (la disponibilité d'un plan qui contient les détails des dispositifs d'étanchéité, par exemple).

[e] Configuration de l'unité de traitement – Dans certaines circonstances (une étude préliminaire, par exemple), une analyse opérationnelle visant à définir le taux de dégagement maximal accepté de substance inflammable peut compenser le manque de données du constructeur du matériel.

NOTE D'autres valeurs typiques ou des recommandations relatives à l'érosion et aux conditions de défaillance peuvent également être consultées dans les codes nationaux ou applicables à l'industrie concernant des applications spécifiques.

Il convient de choisir des valeurs inférieures dans une plage de valeurs pour les conditions théoriques, lorsque la probabilité de défaillance est faible (fonctionnement à des caractéristiques assignées de conception bien inférieures, par exemple). Il convient de choisir

des valeurs plus élevées dans une plage de valeurs lorsque les conditions d'exploitation sont proches des caractéristiques assignées de conception et que des conditions défavorables (vibrations, variations de température, conditions environnementales défavorables ou contamination des gaz, par exemple) peuvent augmenter la probabilité de défaillance. En règle générale, les installations laissées sans surveillance exigent des considérations particulières afin d'éviter de graves défaillances. Il convient de correctement documenter les raisons qui expliquent le choix d'un alésage.

B.6 Formes de dégagement

La Figure B.1 représente la nature générale des différentes formes de dégagement.

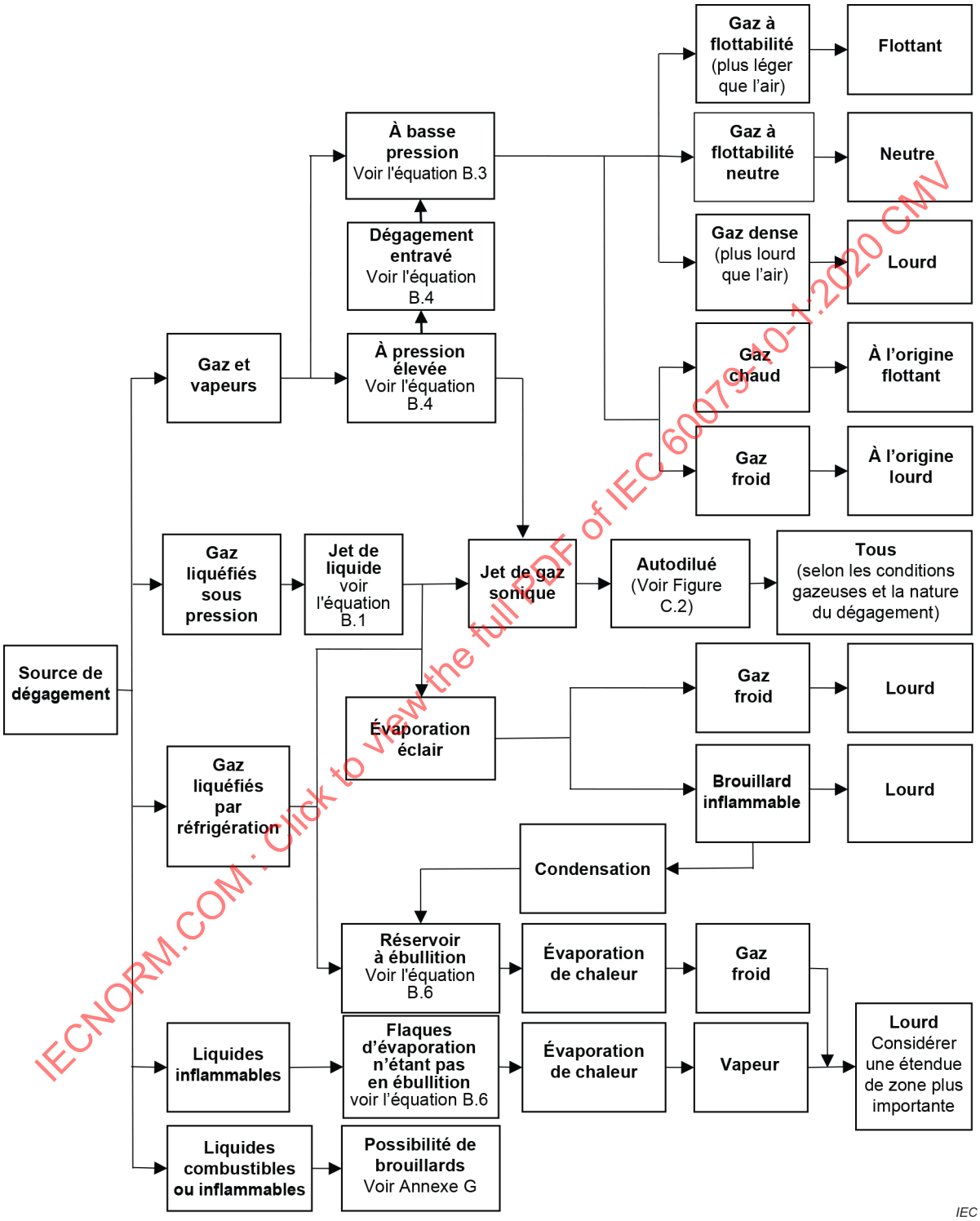


Figure B.1 – Formes de dégagement

B.7 Taux de dégagement

B.7.1 Généralités

Le taux de dégagement dépend de paramètres tels que:

a) La nature et le type de dégagement

Cela est lié aux caractéristiques physiques de la source de dégagement (par exemple, surface libre, bride sur laquelle il y a une fuite, etc.).

b) La vitesse de dégagement

Pour une source de dégagement donnée, le taux de dégagement augmente avec la pression de dégagement. Pour un dégagement subsonique de gaz, la vitesse de dégagement est liée à la pression de travail. La dimension d'un nuage de gaz ou de vapeur inflammable est déterminée par le taux de dégagement de gaz ou de vapeur inflammable et le taux de dilution. Le gaz et la vapeur qui s'échappent à grande vitesse par une fuite entraînent l'air et peuvent s'autodiluer. L'étendue de l'atmosphère explosive gazeuse peut alors être presque indépendante du débit d'air. Si la substance est dégagée à basse vitesse ou si un objet solide réduit sa vitesse, elle est transportée par le débit d'air et sa dilution et son étendue dépendent du débit d'air.

c) La concentration

La masse de la substance inflammable dégagée augmente avec la concentration du gaz ou de la vapeur inflammable dans le mélange dégagé.

d) La volatilité d'un liquide inflammable

Cela est lié principalement à la pression de vapeur et à l'enthalpie ("chaleur") de vaporisation. Si la pression de vapeur n'est pas connue, le point d'ébullition et le point d'éclair peuvent servir de guide.

Une atmosphère explosive ne peut pas exister si le point d'éclair est au-dessus de la température maximale appropriée du liquide inflammable (voir la NOTE 1). Plus le point d'éclair est bas, plus l'étendue de zone peut être importante. Cependant, si une substance inflammable est dégagée de façon à former un brouillard (par pulvérisation, par exemple), une atmosphère explosive peut être produite à une température inférieure au point d'éclair de cette substance.

NOTE 1 Les tableaux publiés et l'expérimentation à l'origine des données relatives au point d'éclair n'enregistrent pas toujours de valeurs exactes, et les données d'essai varient. À moins que les valeurs de point d'éclair ne soient réputées être exactes, une certaine marge d'erreur est admise par rapport aux valeurs indiquées. Une marge de ± 5 °C pour les liquides purs, avec des marges plus importantes pour les mélanges, n'est pas inhabituelle.

Deux méthodes permettent de mesurer le point d'éclair: en vase clos et en vase ouvert. Pour le matériel fermé, et par mesure de prudence, le point d'éclair en vase clos est utilisé. Pour un liquide inflammable dans l'ouverture, le point d'éclair en vase ouvert peut être utilisé.

NOTE 2 Certains liquides (certains hydrocarbures halogénés, par exemple) n'ont pas de point d'éclair bien qu'ils soient capables de produire une atmosphère explosive gazeuse. Dans ces cas, la température d'équilibre du liquide, qui correspond à la concentration de saturation à la limite inférieure d'inflammabilité, doit être comparée avec la température maximale pertinente du liquide.

e) La température du liquide

L'augmentation de la température du liquide augmente la pression de vapeur, augmentant ainsi le taux de dégagement dû à l'évaporation.

La température du liquide peut augmenter après dégagement (par une surface chaude ou une température ambiante élevée, par exemple). Toutefois, la vaporisation tend également à refroidir le liquide tant qu'une condition d'équilibre n'a pas été obtenue, en fonction de l'apport énergétique et de l'enthalpie du liquide.

B.7.2 Estimation du taux de dégagement

B.7.2.1 Généralités

Les équations et méthodes d'évaluation présentées dans le présent article ne sont pas destinées à être appliquées à toutes les installations. Elles s'appliquent uniquement aux conditions limitées indiquées dans chaque section. Les équations donnent également des résultats indicatifs en raison des restrictions liées à la volonté de décrire des concepts complexes avec des modèles mathématiques simplifiés. D'autres méthodes de calcul peuvent également être adoptées.

Les équations suivantes donnent les taux de dégagements approximatifs pour des liquides et gaz inflammables. Une estimation de taux de dégagement plus fine est obtenue en considérant les propriétés des ouvertures et la viscosité du liquide ou du gaz. La viscosité peut réduire sensiblement le taux de dégagement si l'ouverture par laquelle la substance inflammable est dégagée est longue comparée à sa largeur. Ces facteurs sont en général pris en considération dans le coefficient de débit ($C_d \leq 1$).

Le coefficient de débit C_d est une valeur empirique obtenue par une série d'expériences qui correspondent à des cas spécifiques de dégagement et des détails d'orifice spécifiques. Il en résulte que la valeur de C_d peut être différente pour chaque cas particulier de dégagement. Une valeur de C_d d'au moins 0,99 pour les éléments qui comportent des trous aux formes régulières (les évents, par exemple) et de 0,75 pour les trous irréguliers peut être une approximation raisonnablement sûre en l'absence d'autres informations pertinentes qui permettent de procéder à l'évaluation.

Si C_d est utilisé dans les calculs, il convient d'utiliser la valeur appliquée en référence à un guide approprié pour l'application.

B.7.2.2 Taux de dégagement des liquides

Le taux de dégagement d'un liquide peut être estimé à partir de l'approximation suivante:

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

Le taux de vaporisation d'un dégagement de liquide doit alors être déterminé. Les dégagements de liquide peuvent prendre de nombreuses formes. La nature du dégagement et la manière dont la vapeur ou le gaz est généré dépendent également de nombreuses variables. Exemples de dégagements:

a) Dégagement biphasique (c'est-à-dire dégagement de liquide et de gaz combinés)

   Les liquides, tels que le gaz de pétrole liquéfié (GPL), peuvent inclure les phases gazeuses et liquides soit immédiatement avant l'orifice de dégagement, soit après l'orifice de dégagement avec un ensemble d'interactions thermodynamiques ou mécaniques. Cela peut donner lieu à la formation de gouttelettes et/ou de flaque, puis à l'ébullition du liquide, ce qui participe au nuage de vapeur.

b) Dégagement monophasique d'un liquide sans tension de vapeur

   Pour les liquides qui présentent des points d'ébullition plus élevés (au-dessus des plages atmosphériques), le dégagement comprend en général un composant liquide significatif qui peut s'évaporer à proximité de la source de dégagement. Le dégagement peut également se décomposer en gouttelettes par l'action d'un jet. La vapeur dégagée dépend alors de la formation d'un jet et de la vaporisation à partir du point de dégagement, de gouttelettes ou de la formation ultérieure d'une flaque.

   En raison du grand nombre de conditions et de variables, une méthode d'évaluation des états de vapeur d'un dégagement de liquide n'est pas fournie dans la présente norme. Il convient que les utilisateurs choisissent avec soin un modèle adapté en observant toutes les limites du modèle et/ou en appliquant une approche judicieusement prudente des résultats.

B.7.2.3 Taux de dégagement de gaz ou vapeur

B.7.2.3.1 Généralités

Les équations ci-dessous sont réputées fournir des estimations raisonnables du taux de dégagement des gaz. Si la densité du gaz avoisine celle du gaz liquéfié, il peut alors être nécessaire de prendre en considération les dégagements biphasiques comme indiqué en B.7.2.2.

Le taux de dégagement d'un gaz d'un conteneur peut être estimé par la détente adiabatique d'un gaz parfait, si la densité du gaz sous pression est nettement inférieure à celle du gaz liquéfié.

La vitesse du gaz dégagé est constante (vitesse du son) si la pression dans le conteneur du gaz est supérieure à la pression critique p_c.

La pression critique est déterminée par l'équation suivante:

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

Pour le gaz parfait, l'équation $\gamma = \frac{M\, c_p}{M\, c_p - R}$ peut être utilisée.

NOTE Pour la majorité des gaz, l'approximation $p_c \approx 1{,}89\, p_a$ sert généralement à une estimation rapide. Les pressions critiques sont généralement faibles comparées à la majorité des pressions de service présentes dans les processus industriels habituels. Les pressions inférieures à la pression critique sont en général présentes dans les tuyaux d'alimentation en gaz de terminal vers les appareils d'utilisation (réchauffeurs, fours, réacteurs, incinérateurs, vaporisateurs, générateurs de vapeur, chaudières et autres matériels de production, par exemple). Ces pressions peuvent également apparaître dans les cuves de stockage atmosphériques à surpressions modérées (en général jusqu'à 50 kPag).

Dans les équations suivantes, le facteur de compressibilité pour les gaz parfaits est de 1,0. Pour les gaz réels, les valeurs du facteur de compressibilité sont inférieures ou supérieures à 1,0 selon le type de gaz concerné, la pression et la température. Pour les pressions basses à moyennes, la valeur Z = 1,0 peut servir d'approximation raisonnable. Pour des pressions plus élevées (au-dessus de 50 bars, par exemple) et lorsqu'une plus grande exactitude est exigée, il convient d'appliquer le facteur de compressibilité réel. Les valeurs du facteur de compressibilité peuvent être obtenues dans les recueils de données relatifs aux propriétés des gaz.

B.7.2.3.2 Taux de dégagement d'un gaz avec une vitesse du gaz non constante (dégagements subsoniques)

La vitesse du gaz non constante est une vitesse de décharge au-dessous de la vitesse du son pour un gaz particulier.

Le taux de dégagement d'un gaz d'un conteneur, si la vitesse du gaz n'est pas constante, peut être estimé par l'approximation suivante:

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