BS EN 60079-10-1:2015

Incorporating corrigendum December 2016

BSI Standards Publication

Explosive atmospheres

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

bsi.

National foreword

This British Standard is the UK implementation of EN 60079-10-1:2015. It is identical to IEC 60079-10-1:2015, incorporating corrigendum November 2015. It supersedes BS EN 60079-10-1:2009 which is withdrawn.

IEC corrigendum November 2015 corrects Equation B.6.

BSI, as a member of CENELEC, is obliged to publish EN 60079-10-1 as a British Standard. However, attention is drawn to the fact that during the document's development, the UK committee voted against its approval as a European Standard.

The UK Committee has some concerns that the methodologies in the Informative Annexes C and D for determining zone type and extents have not been appropriately validated as required in Section 5.2., and suggest Users consider the below issues when working with this standard:

- The ventilation rate (volume of air per unit time) relative to the release rate of the flammable substance is the most important factor that determines the ability of a release in an enclosure to become dilute. The 'ventilation velocity' has only a secondary effect: the UK Committee's view is that this is not adequately reflected in the standard.
- The extent of flammable gas or vapour from its point of release is dependent on the material being released, the release conditions (e.g. hole size and pressure) and the environment into which it is being released (e.g. ventilation rate or weather conditions). Various scientifically based approaches exist for determining these zone extents, including industry specific standards and dispersion models.
- EN 60079-10-1 places no limitations on a Zone 2 NE classification. However the UK committee believes a Zone 2 NE classification would only be applicable for a source pressure less than 10 barg which is the limit accepted in other industry based guidance.
- For assessment of pool evaporation from volatile hydrocarbons, other standards and sources of information need to be used to cross-check the results to ensure that risks are reduced to as low as reasonably practicable.

The UK Committee will revisit these issues during the next revision cycle of this standard, rather than publishing a national annex as previously stated.

The UK participation in its preparation was entrusted by Technical Committee EXL/31, Equipment for explosive atmospheres, to Subcommittee EXL/31/3, Codes of practice.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Amendments/corrigenda issued since publication

Date	Text affected
31 December 2016	National foreword updated

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 60079-10-1

December 2015

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Incorporating corrigendum November 2015

English Version

Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres (IEC 60079-10-1:2015 + COR1:2015)

Atmosphères explosives - Partie 10-1: Classement des emplacements - Atmosphères explosives gazeuses
(IEC 60079-10-1:2015 + COR1:2015)

Explosionsgefährdete Bereiche - Teil 10-1: Einteilung der Bereiche - Gasexplosionsgefährdete Bereiche
(IEC 60079-10-1:2015 + COR1:2015)

This European Standard was approved by CENELEC on 2015-10-13. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

The text of document 31J/253/FDIS, future edition 2 of IEC 60079-10-1, prepared by SC 31J "Classification of hazardous areas and installation requirements", of IEC/TC 31 "Equipment for explosive atmospheres" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60079-10-1:2015.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-07-13
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2018-10-13

This document supersedes EN 60079-10-1:2009.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60079-10-1:2015 + COR1:2015 [1] was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60079-10-2	NOTE	Harmonized as EN 60079-10-2.
IEC 61285:2004	NOTE	Harmonized as EN 61285:2004 (not modified).
IEC 60079-20-1	NOTE	Harmonized as EN 60079-20-1.

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[1] COR1:2015 applies to English version only.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60079-0	-	Explosive atmospheres - Part 0: Equipment - General requirements	EN 60079-0	-
IEC 60079-14	-	Explosive atmospheres - Part 14: Electrical installations design, selection and erection	EN 60079-14	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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 second edition of IEC 60079-10-1 cancels and replaces the first edition, published in 2008, 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**
Complete restructuring and dividing into sections to identify possible methodologies for classifying hazardous areas and to provide further explanation on specific assessment factors	Main body of the text	X	X	X
Introducing new terms and the definitions	3		X	
Introducing clauses for alternative methods of area classification	5		X	X
Updating examples for presentation of hazardous area classification	Annex A		X	X
Updating calculations for release rate	Annex B		X	X
Complete re-write with a new approach based upon the degree of dilution instead of the degree of ventilation	Annex C		X	X
Introduced as a new Annex for zone extents	Annex D		X	
Updated with new examples to explain the methodology set forth in Annexes A, B, C and D	Annex E			X
Update of the flow chart illustrating the area classification procedure by dividing it into four sections	Annex F		X	
Introduced as a new Annex on hydrogen	Annex H		X	
Introduced as a new Annex on hybrid mixtures	Annex I		X	
Introduced as a new Annex with supplementary equations	Annex J		X	
Introduced as a new Annex for reference to national and industry codes with specific examples of hazardous area classification	Annex K		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:

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

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/253/FDIS	31J/256/RVD

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

This publication 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 publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

A bilingual version of this publication may be issued at a later date.

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, 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 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 dealt with in this standard (see 3.7.3 and 3.7.4);
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;
f) domestic premises;
g) 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 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 standard 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 standard do not apply. Information on flammable mists is provided in Annex G.

For the purpose of this standard, 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, 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.

This standard does not take into account the consequences of ignition of an explosive atmosphere.

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*

3 Terms and definitions

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

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, dust, fibres, or flyings, which, after ignition, permits self-sustaining flame propagation

[SOURCE: IEC 60079-0:2013, 3.30]

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 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, 3.32, modified (addition of Notes to entry)]

3.3

hazardous areas and zones

3.3.1

hazardous area (on account of explosive gas atmospheres)
an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment

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

3.3.3

zones
hazardous area classification based upon the frequency of the occurrence and duration of an explosive atmosphere

3.3.4
zone 0
an 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
an area in which an explosive gas atmosphere is likely to occur periodically or occasionally in normal operation

3.3.6
zone 2
an area in which an explosive gas atmosphere is not likely to occur in normal operation but, if it does occur, it will exist for a short period only

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

[SOURCE: IEC 60050-426:2009, 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

3.4
releases

3.4.1
source of release
a 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, 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)

3.5.2
dilution

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

3.5.3
dilution volume

the 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

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

3.5.5
volume under consideration

the 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

3.6.6
hybrid mixture
mixture of a flammable gas or vapour with a dust.

Note 1 to entry: According 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
ignition temperature of an explosive gas atmosphere
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

[SOURCE: IEC 60079-0:2013, 3.37]

3.6.12
lower flammable limit (LFL)
the concentration of flammable gas, vapour or mist in air below which an explosive gas atmosphere will not be formed

[SOURCE: IEC 60050-426:2009, 426-02-09, modified (definition in 60050-426 referred to "Lower Explosive Limit")]

3.6.13
upper flammable limit (UFL)
the concentration of flammable gas, vapour or mist in air above which an explosive gas atmosphere will not be formed

[SOURCE: IEC 60050-426:2009, 426-02-10, modified (definition in 60050-426 referred to "Upper Explosive Limit")]

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

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.

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, 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.

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 area classification study.

In the case of activities other than those of normal operation, e.g. commissioning or non-routine maintenance, the 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 area classification should take into account any routine maintenance.

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

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

4.2 Area classification objectives

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. 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).

NOTE Selected characteristics may be designated for equipment e.g. ignition energy and temperature ratings, see IEC 60079-20-1.

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 area classification. The classification should be updated for any plant or operational changes. Reviews should be carried out during the life of the plant.

4.3 Explosion risk assessment

Subsequent to the completion of the 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.

In some cases a zone of negligible extent (NE) may arise and may be treated as non hazardous. 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.

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).

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.

4.4 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. 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 area classification process. The competency of the person shall be relevant to the nature of the plant and methodology used for carrying out the area classification. Appropriate continuing education or training should be undertaken by personnel on a regular basis where required.

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

5 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.

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, and which could therefore be a source of release.

Subclauses 5.3 to 5.6 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 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 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 be 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.

5.2 Classification by sources of release method

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

Refer Annex F. The source of release approach can be summarized as follows:

- 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), 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.

5.3 Use of industry codes and national standards

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.

5.4 Simplified methods

Where it is not practicable to make required assessments from individual sources of release, a simplified method may be used.

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 is 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 a LFL of 15 % by volume, will often dissipate rapidly in the open air, so an explosive gas atmosphere will, in most cases be of negligible extent.

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

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 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 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 standard.

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.

The 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.

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.

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.

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.

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 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

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 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 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.

6.3.4 Liquefied by refrigeration

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

An aerosol 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 cloud frequently makes the cloud visible to the naked eye. The dispersion of an aerosol may vary between the behaviour of a dense gas or a neutrally buoyant gas. Aerosol droplets can coalesce and rain out of the plume or cloud. Aerosols from flammable liquids may absorb heat from the surrounding environment, evaporate and add to the gas/vapour cloud (for more details see Annex G).

6.3.6 Vapours

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 releases

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 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.

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.

6.4 Ventilation (or air movement) and dilution

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 the gas disperses completely and 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 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 atmospheric conditions layering of the gas or vapour may occur and the distance for 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 is not taken into account in 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.

6.5 Main types of ventilation

6.5.1 General

The two types of ventilation are:

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

6.5.2 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 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.

Ventilation rates arising from natural ventilation are inherently very variable. Where dilution of releases is by natural ventilation, the worst case scenario shall preferably be considered to determine the degree of ventilation. 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.

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.

6.5.3 Artificial ventilation

6.5.3.1 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.

6.5.3.2 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.

6.5.3.3 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 C.4.

6.5.4 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 / 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 but the boundary of the hazardous area additionally takes into account other factors such as possible movement of the release due to the direction and velocity of the release and of the surrounding volume of air.

Degrees of dilution 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.

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.

7 Type of zone

7.1 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, 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.

7.2 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 (typical 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 7.3 and 7.4).

7.3 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).

7.4 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 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.

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.

8 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. 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;

   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.

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.

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 and 7).

For releases where only a small mass is available to be released a lesser distance may be accepted to an on-going release.

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.

9 Documentation

9.1 General

It is recommended that the steps taken to carry out area classification and the information and assumptions used are fully documented. The area classification document should be a living document and should include the method used for 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) recommendations from relevant codes and standards;

b) gas and vapour dispersion characteristics and calculations;

c) a study of ventilation characteristics in relation to flammable substance release parameters so that the effectiveness of the ventilation can be evaluated.

d) the properties of all process substances used on the plant (see IEC 60079-20-1), which may include:

- molar mass
- flash point
- boiling point
- minimum 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.

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

9.2 Drawings, data sheets and tables

Area classification documents may be in hard copy or electronic form and should include plans and elevations or three dimensional models, as appropriate, which show both the type and extent of zones, equipment group, 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 be helpful to itemize or number the sources of release so as to facilitate cross-referencing between the area classification data sheets and the drawings;

b) The position of openings in buildings (for example, doors, windows and inlets and outlets of air for ventilation).

The 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

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

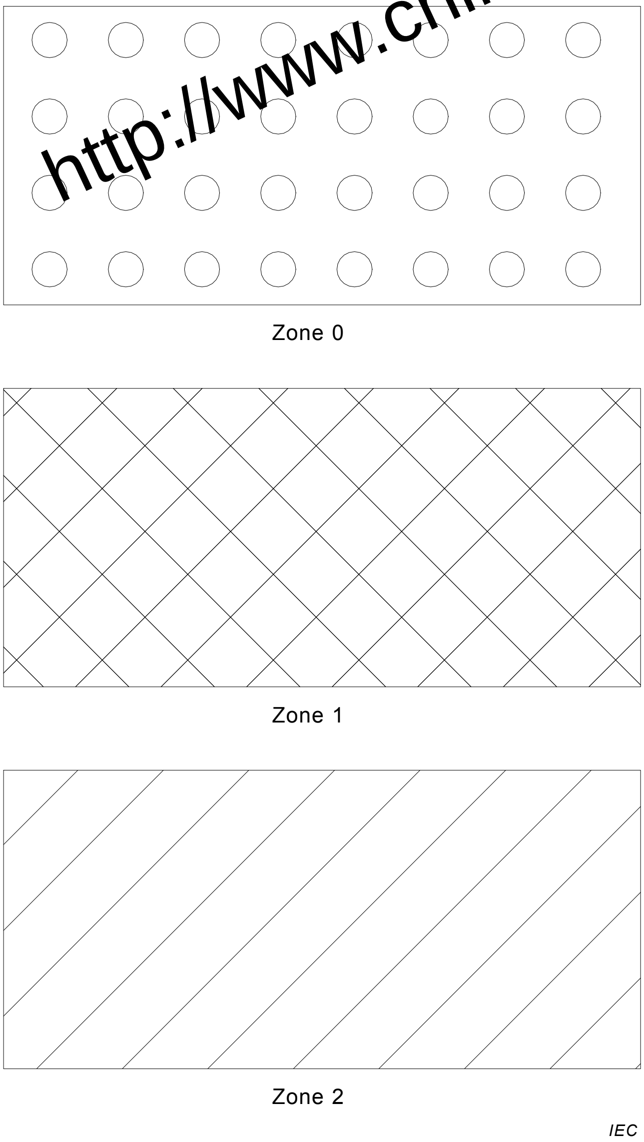


Figure A.1 – Preferred symbols for hazardous area zones

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**		**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

[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:**																	**Refer ence drawing:**
1	2	3	4	5	6	7	8		9	10	11	12	13	14		15	16
	Source of release					**Flammable substance**				**Ventilation**			**Hazardous area**				
	Descrip tion	Loca tion	Grade of release[a]	Rate of release (kg/s)	Rele ase charac teristic (m^3/s)	Refer ence[b]	Operating temperature and pressure		State[c]	Type[d]	Degree of dilution[e]	Availa bility	Zone type 0-1-2	Zone extent (m)		Refer ence[f]	Any other informa tion 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

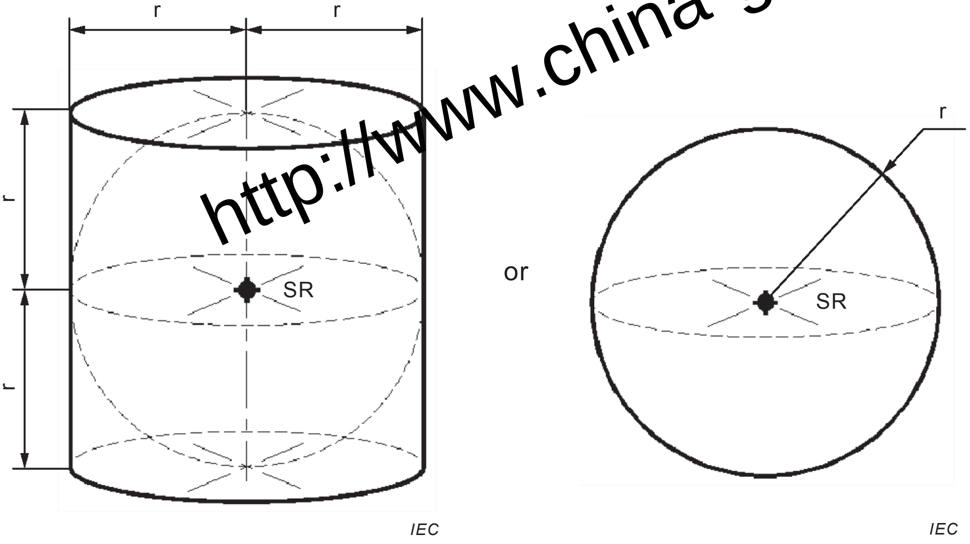
[d] N – Natural; AG – Artificial General; AL – Artificial Local

[e] See Annex C

[f] Indicate code reference if used, or calculation reference

A.2 Hazardous area suggested shapes

Figures A.2 to A.5 show some suggested hazardous area shapes based on the forms of release described in 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.



Key

SR	Source of release
r	Main extent of the hazardous area to be defined taking into consideration the estimated hazardous distance
r', r”	Secondary extents of the hazardous area to be defined taking into account release behaviour
h	Distances between the source of release and ground level or surface below the release

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

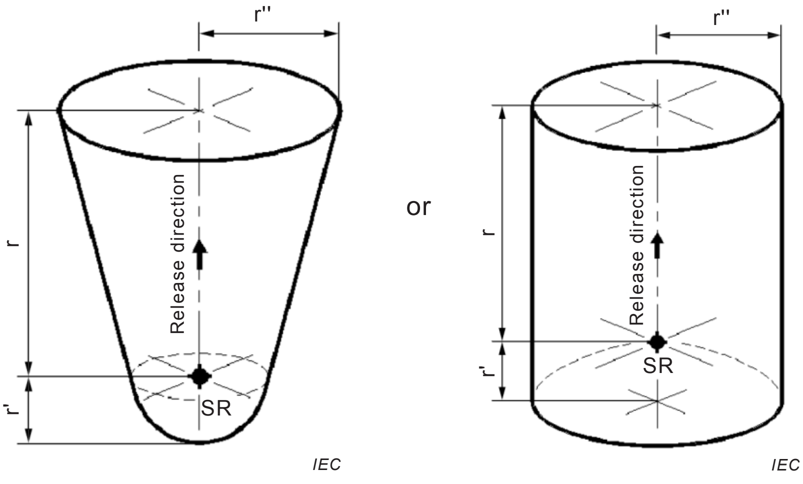
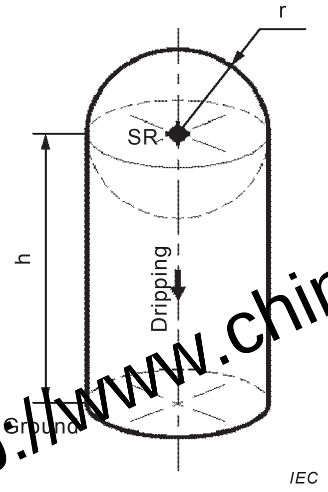
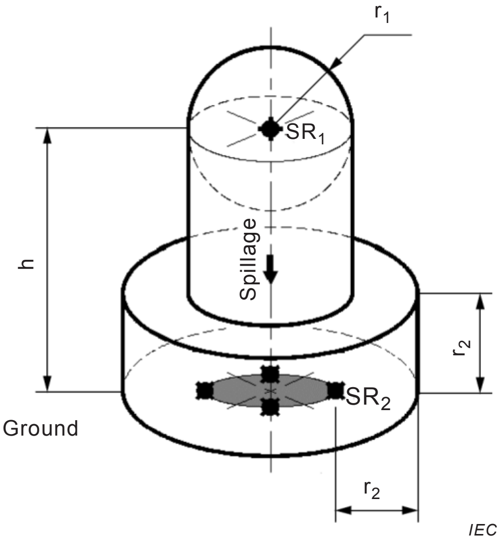


Figure A.3 – Gas/vapour at high pressure



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

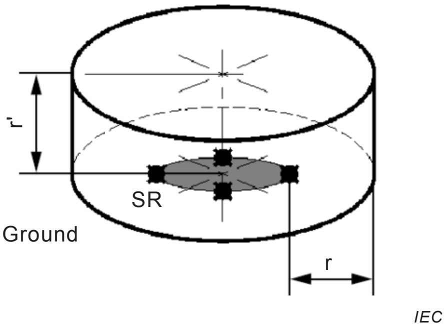
Figure A.4a – Gas or vapour (liquefied under pressure or by refrigeration)



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

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

Figure A.4 – Liquefied gas



NOTE Source of spillage of flammable substance is not indicated.

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

Annex B
(informative)

Estimation of sources of release

B.1 Symbols

A_p	pool surface area (m^2);
C_d	discharge coefficient (dimensionless) which is a characteristic of the release openings and accounts for the effects of turbulence and viscosity, typically 0,50 to 0,75 for sharp orifices and 0,95 to 0,99 for rounded orifices;
c_p	specific heat at constant pressure (J/kg K);
γ	polytropic index of adiabatic expansion or ratio of specific heats (dimensionless);
M	molar mass of gas or vapour (kg/kmol);
p	pressure inside the container (Pa);
Δp	pressure difference across the opening that leaks in (Pa);
p_a	atmospheric pressure (101 325 Pa);
p_c	critical pressure (Pa);
p_v	vapour pressure of the liquid at temperature T (kPa);
Q_g	volumetric flow rate of flammable gas from the source (m^3/s);
R	universal gas constant (8314 J/kmol K);
ρ	liquid density (kg/m^3);
ρ_g	gas or vapour density (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 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.

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 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. 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 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 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 all continuous grade releases should be included.

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 a number of different flammable substances being released the combined LFL 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 hole radius. 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 hole radius. A modest underestimate of the hole size will therefore lead to a gross underestimate of the calculated value for release rate, which should be avoided. Overestimate of the 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 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 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 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 S (mm²)	Typical values for the conditions at which the release opening may expand, e.g erosion S (mm²)	Typical values for the conditions at which the release opening may expand up to a severe failure, e.g blow out S (mm²)
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 mm² [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 mm² [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 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.

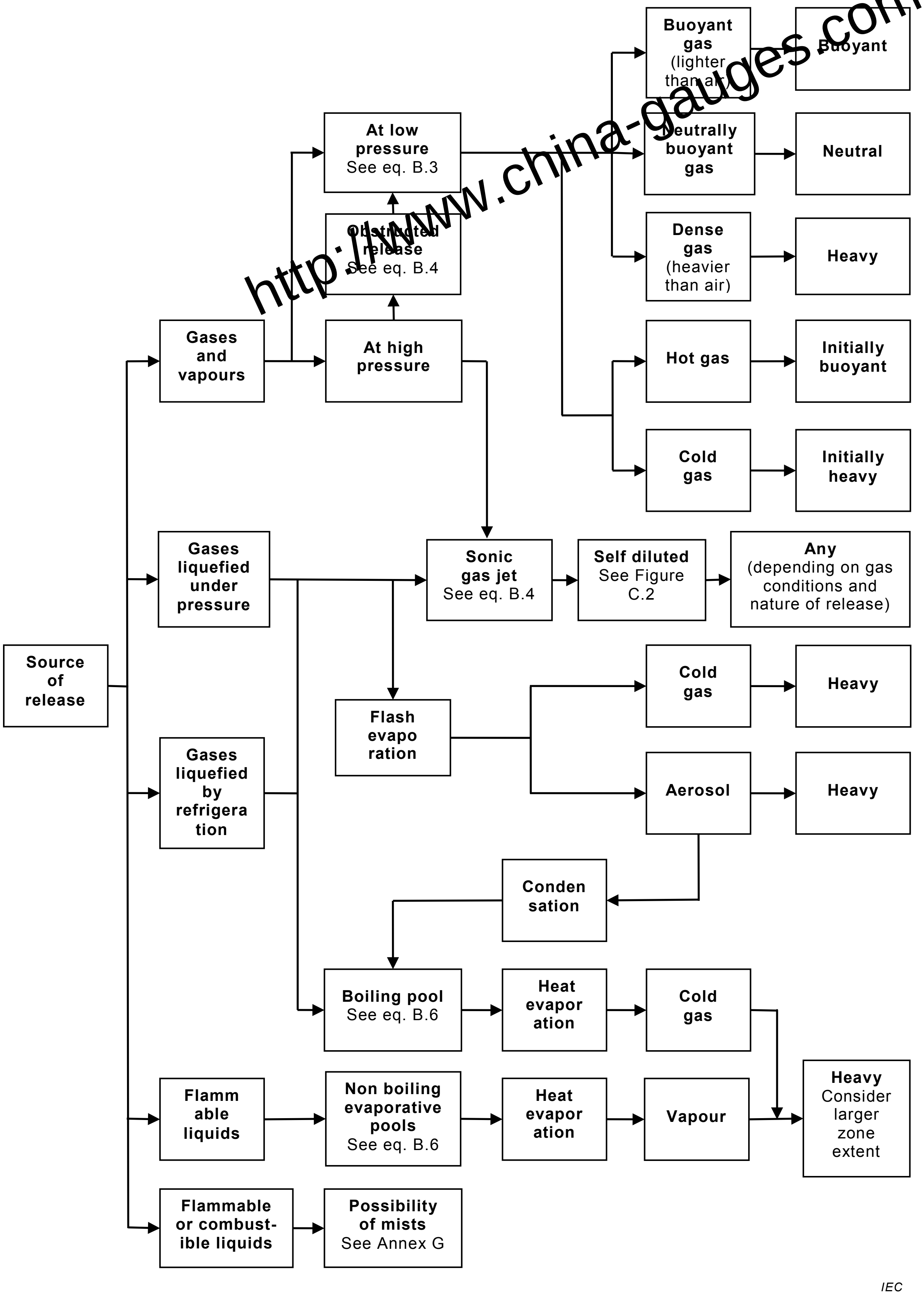


Figure B.1 – Forms of release

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 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 not 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 are 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 used. For a flammable liquid in the open, the open cup flash point may be used.

   NOTE 3 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 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 ($C_\mathrm{d} \leq 1$).

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:

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

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 a 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:

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

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).

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:

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

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:

$$W_g = C_d\, S\, p \sqrt{\gamma \frac{M}{Z\,R\,T} \left(\frac{2}{\gamma + 1} \right)^{(\gamma+1)/(\gamma-1)}} (\text{kg/s}) \qquad \text{(B.4)}$$

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

$$Q_g = \frac{W_g}{\rho_g}\left(\mathrm{m}^3/\mathrm{s}\right) \qquad \text{(B.5)}$$

where

$\rho_g = \dfrac{p_a\,M}{R\,T_a}$ 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.7.3 Release rate of evaporative pools

Evaporative pools may be the result of liquid spillage or leakage but also 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.

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.

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

$$W_e = \frac{6{,}55\; u_w^{\;0{,}78}\; A_p\; p_v\; M^{0{,}667}}{R \times T}\left(\mathrm{kg/s}\right) \qquad \text{(B.6)}$$

NOTE 1 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.

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

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

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

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

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

$$Q_g \approx \frac{6{,}5\; u_w^{\;0{,}78}\; A_p\; p_v}{10^5\; M^{0{,}333}} \times \frac{T_a}{T}\left(\mathrm{m}^3/\mathrm{s}\right) \qquad \text{(B.7)}$$

NOTE 4 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 and that the liquid temperature is equal to the ambient temperature, then the volumetric evaporation rate in (m^3/s) would be:

$$Q_g \approx \frac{3{,}78 \times 10^{-5}\, p_v}{M^{0{,}333}} \left(\mathrm{m^3/s}\right) \tag{B.8}$$

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.

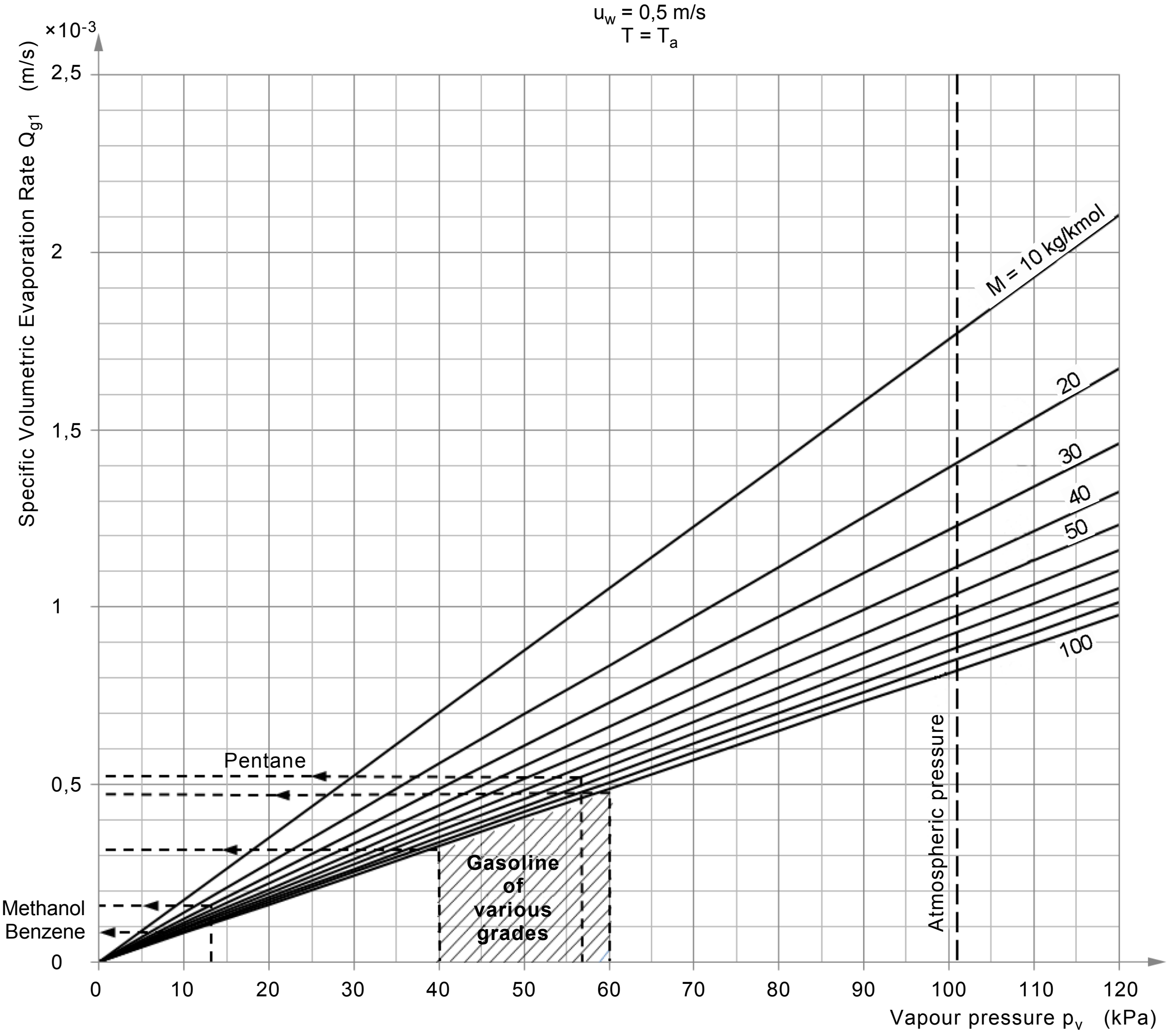


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Figure B.2 – Volumetric evaporation rate of liquids

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 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.

B.8 Release from openings in buildings

B.8.1 General

The following clause provides 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 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 (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 (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;
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);
R	universal gas constant (8314 J/kmol K);
ρ_a	air density (kg/m^3);
ρ_g	density of the gas or vapour (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).

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 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.

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 atmosphere. With a sufficiently high effectiveness of ventilation for a given release rate, the extent of the hazardous zone 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)

Type of outdoor locations	**Unobstructed areas**			**Obstructed areas**		
Elevation from ground level	≤ 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 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, values in the table may be considered with an availability of ventilation fair (see 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.

C.3.5 Assessment of the degree of dilution

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

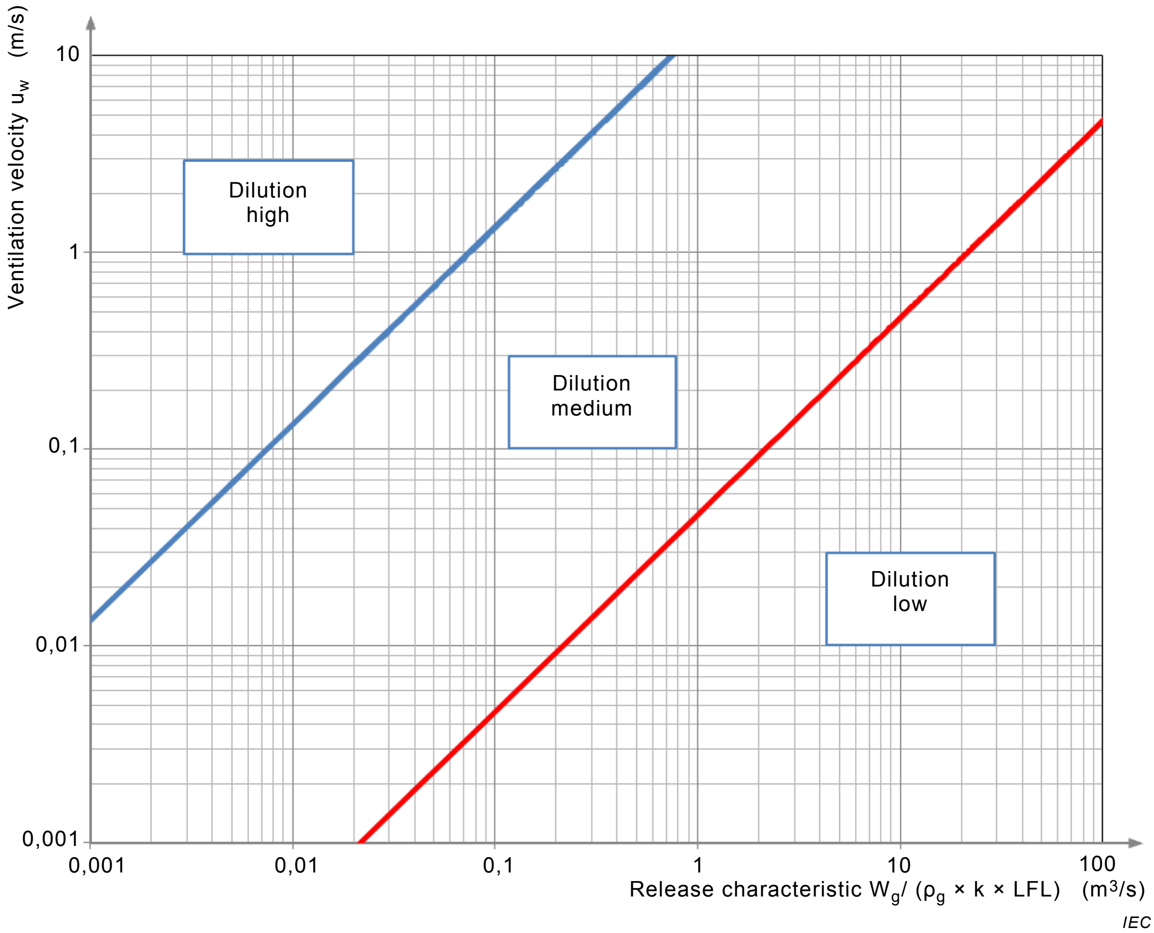


Figure C.1 – Chart for assessing the degree of dilution

Where

$\dfrac{W_g}{\rho_g\, k\, LFL}$ is a characteristic of release in (m^3/s);

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

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.

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 the curve implies an even smaller 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.

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.

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 factor must be carefully selected to take into account all relevant factors considering an appropriate safety margin. The ventilation efficiency 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 practice to have multiple small hazardous areas within an enclosed area generally classified as non hazardous. Also, it is not good 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 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 (vol/vol) concentration may be assessed as:

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

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 factor f 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:

$f = 1$; 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).

NOTE Ventilation alone which describes how air enters the room has little to say about the expected hazardous volume. 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) 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 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 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 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. Such a scenario will then lead to a higher level of availability. Generally, for any natural ventilation, a lower degree of ventilation 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.

There are some situations which require particular care. In the case of natural ventilation of enclosed spaces, consideration of unfavorable 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 and 7. 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

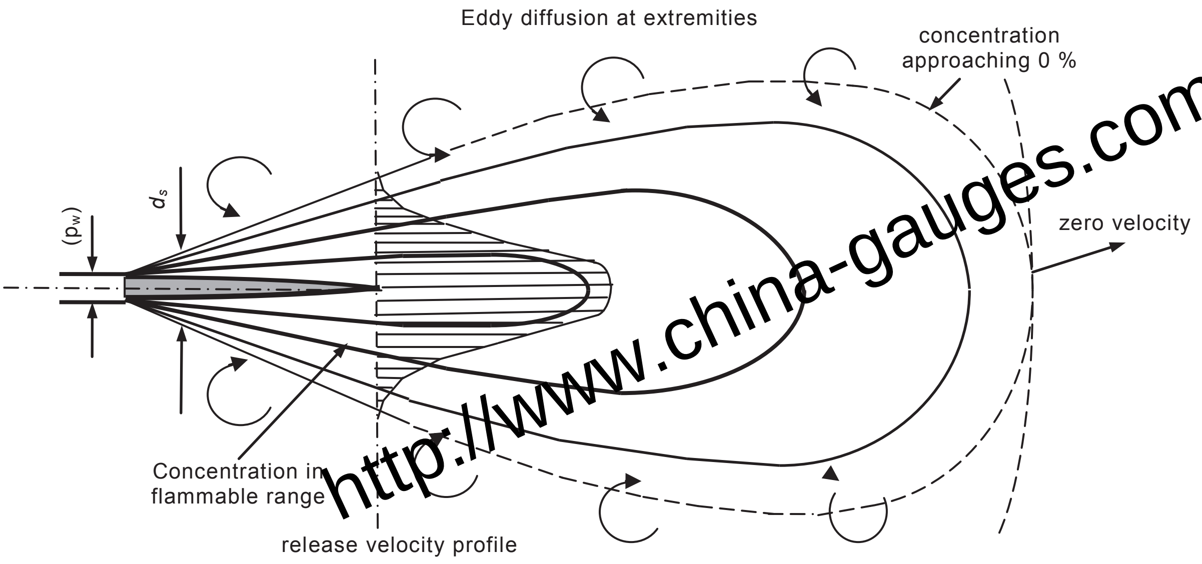
This example (see Figure C.2) illustrates the conditions where there are a limited number of sources of gas release in a large space e.g. gas release from pipe fittings.

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.



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

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

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.

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.

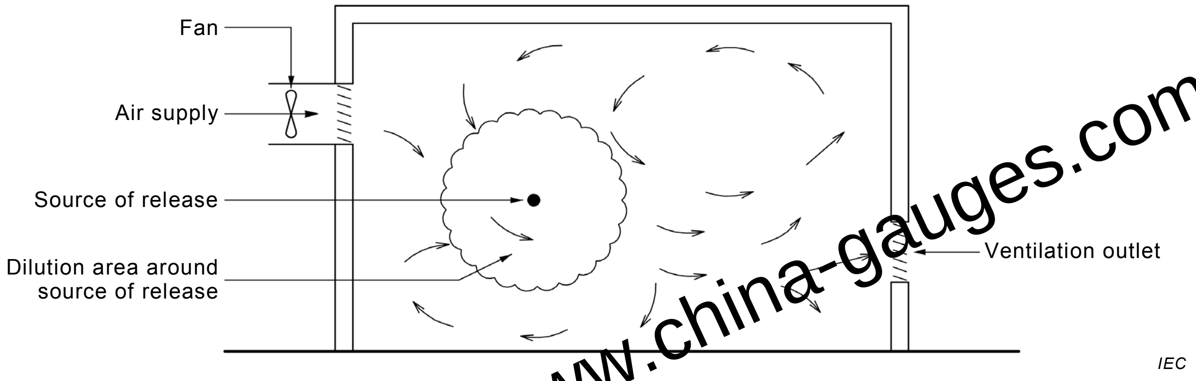


Figure C.3 – Supply only ventilation

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.

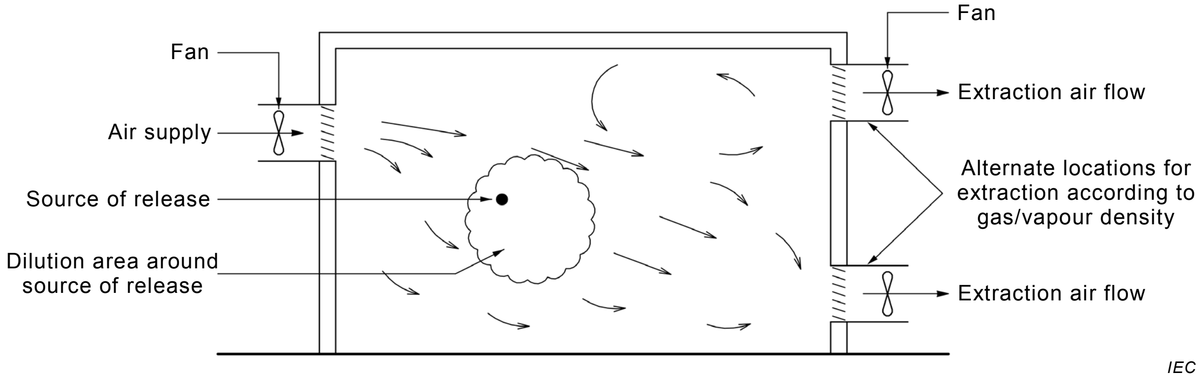


Figure C.4 – Supply and extraction ventilation

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 6.5.3.3).

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.

Where tightly closed enclosures are used the effectiveness and availability of ventilation in such enclosures with natural ventilation may need consideration as low and poor respectively.

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.

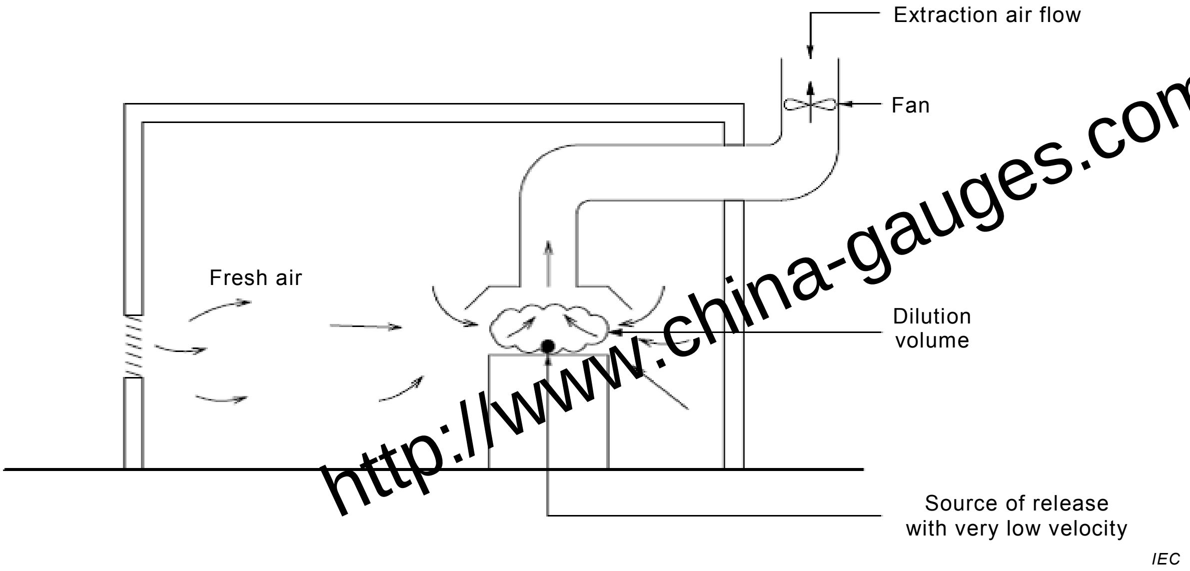


Figure C.5 – Local extraction ventilation

C.5 Natural Ventilation in buildings

C.5.1 General

The clauses below provide a means for assessing the natural ventilation in buildings.

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:

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

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

Values for 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:

$$Q_\mathrm{a} = C_\mathrm{d}\, A_\mathrm{e} \sqrt{\frac{\Delta T}{\left(T_\mathrm{in} + T_\mathrm{out}\right)}\, g\, H} \left(\mathrm{m}^3/\mathrm{s}\right) \tag{C.4}$$

$$A_\mathrm{e} = \sqrt{\frac{2A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(\mathrm{m}^2\right) \tag{C.5}$$

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.3.6.1).

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 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 atmosphere. Generally, all the openings that could be normally closed such as doors, windows and adjustable louvres should not be considered as ventilation openings.

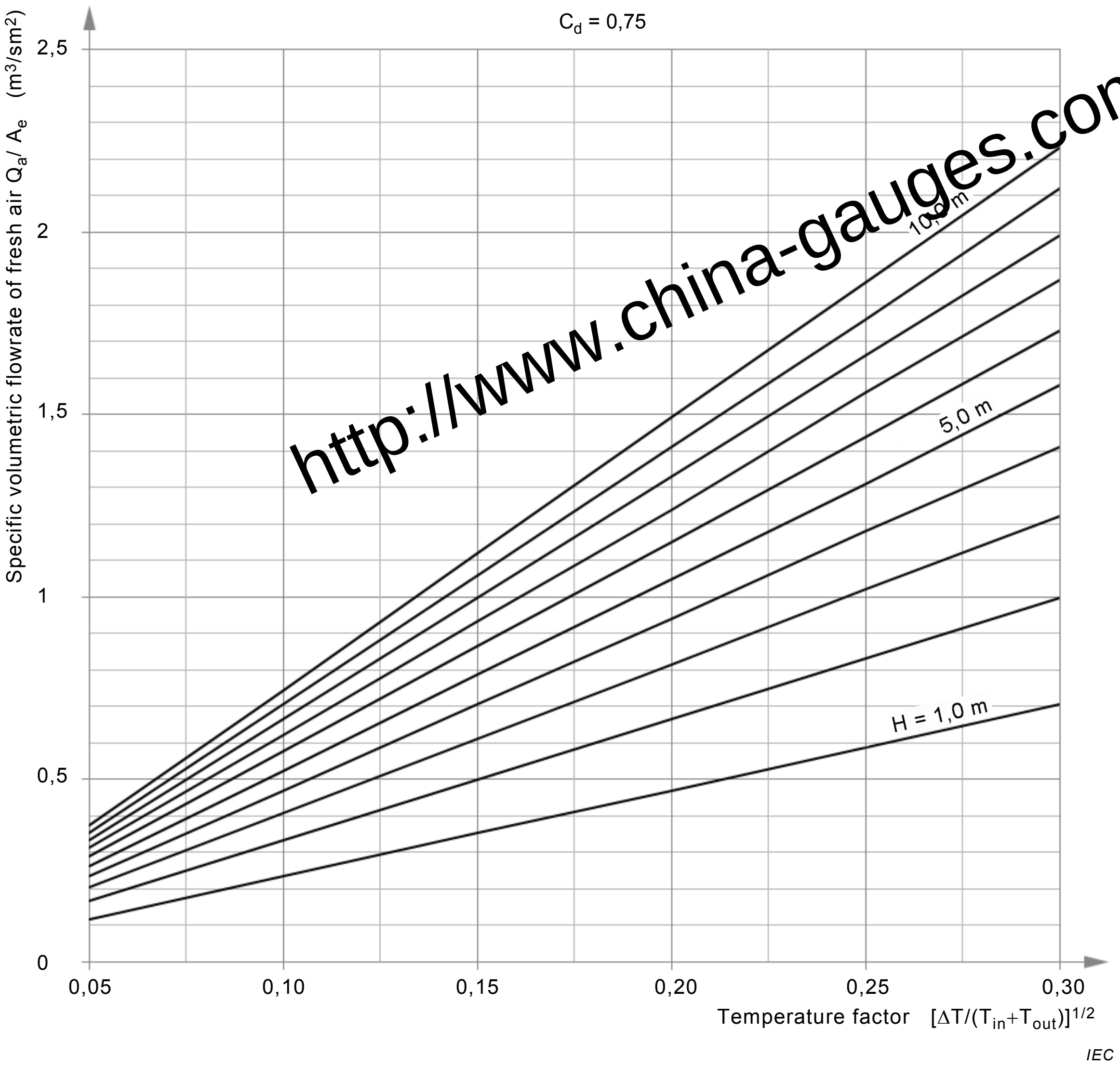


Figure C.6 – Volumetric flow rate of fresh air per m^2 of equivalent effective opening area

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.

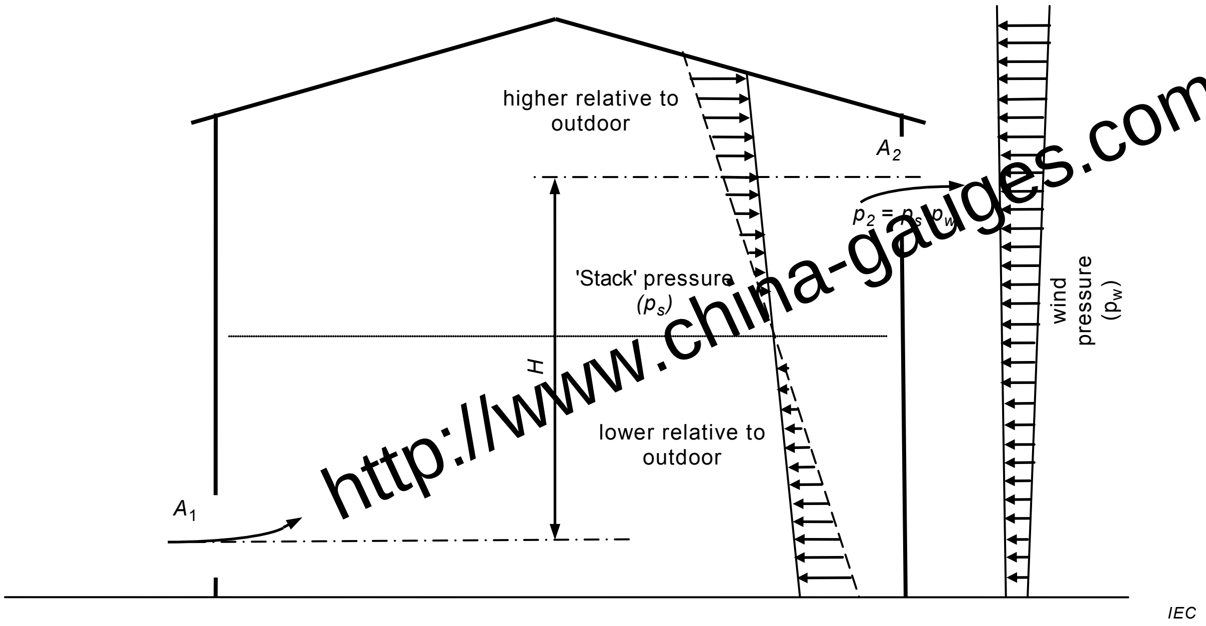


Figure C.7 – Example of opposing ventilation driving forces

The ventilation flows caused by pressure differences, due to 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:

$$Q_\mathrm{a} = C_\mathrm{d}\, A_\mathrm{e} \sqrt{\frac{2\Delta p}{\rho_\mathrm{a}}} \left(\mathrm{m}^3/\mathrm{s}\right) \tag{C.6}$$

$$A_\mathrm{e} = \sqrt{\frac{2 A_1^2 A_2^2}{A_1^2 + A_2^2}} \left(\mathrm{m}^2\right) \tag{C.7}$$

Annex D
(informative)

Estimation of hazardous zones

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).

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	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[c]
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[c]

[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] 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 considered as good.

D.3 Estimating the extent of the hazardous zone

The extent of the hazardous zone 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 for various forms of release. Other forms of calculation or assessment based on reputable sources, e.g. Computational fluid dynamics (CFD) may also be applied.

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

a) An unimpeded jet release with high velocity;

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

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

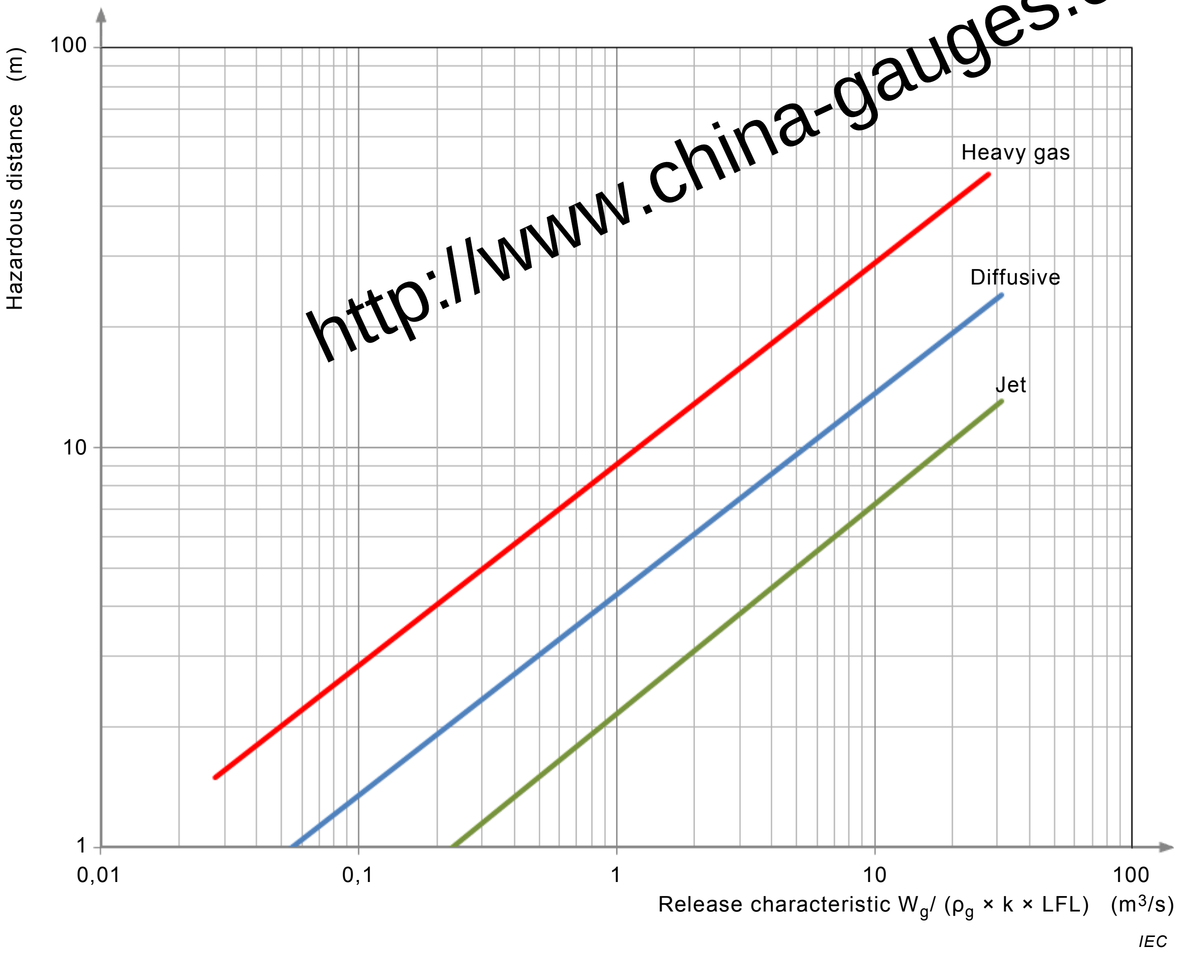


Figure D.1 – Chart for estimating hazardous area distances

Where

$\frac{W_g}{\rho_g \, k \, LFL}$ is a characteristic of release in (m^3/s);

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

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.

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 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.

E.2 Examples

Example No. 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 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 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

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	0,3 m/s
Ventilation availability	Good (wind speed at meteorological calm conditions)

Effects of release:

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

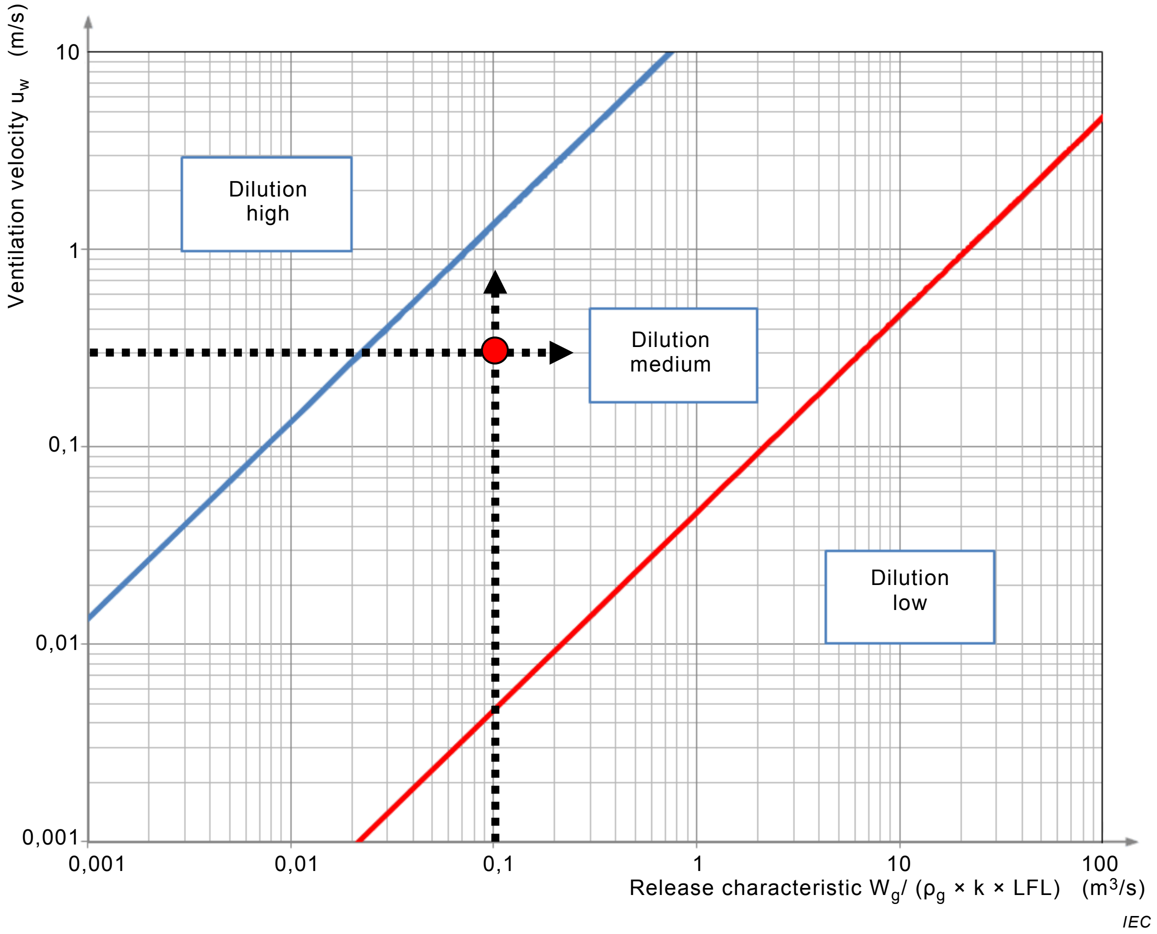


Figure E.1 – Degree of dilution (Example No. 1)

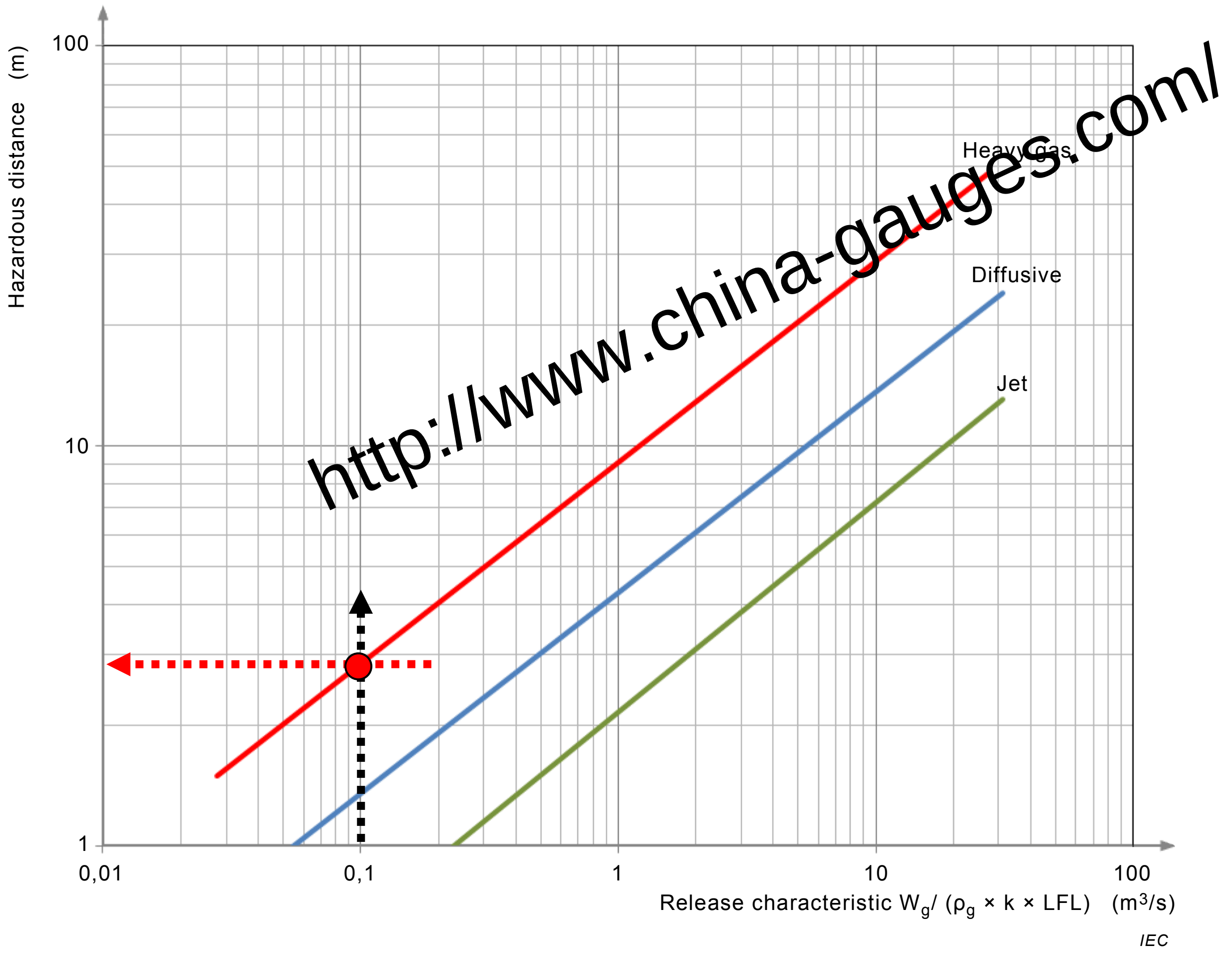
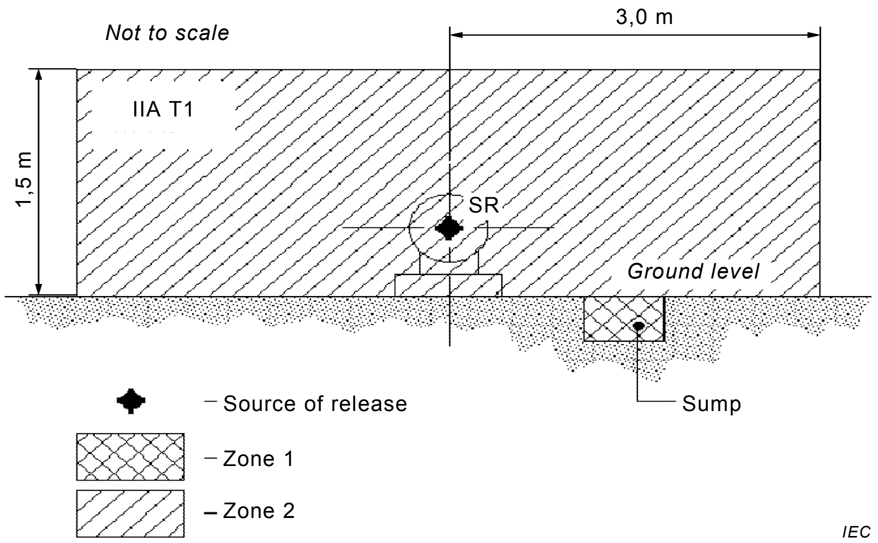


Figure E.2 – Hazardous distance (Example No. 1)

Hazardous area classification :

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.



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

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

Example No. 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 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 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	$3,85 \times 10^{-3}$ 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	$1,19 \times 10^{-3}$ 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)

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, 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 factor, f	5
Background concentration, X_b	0,07 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

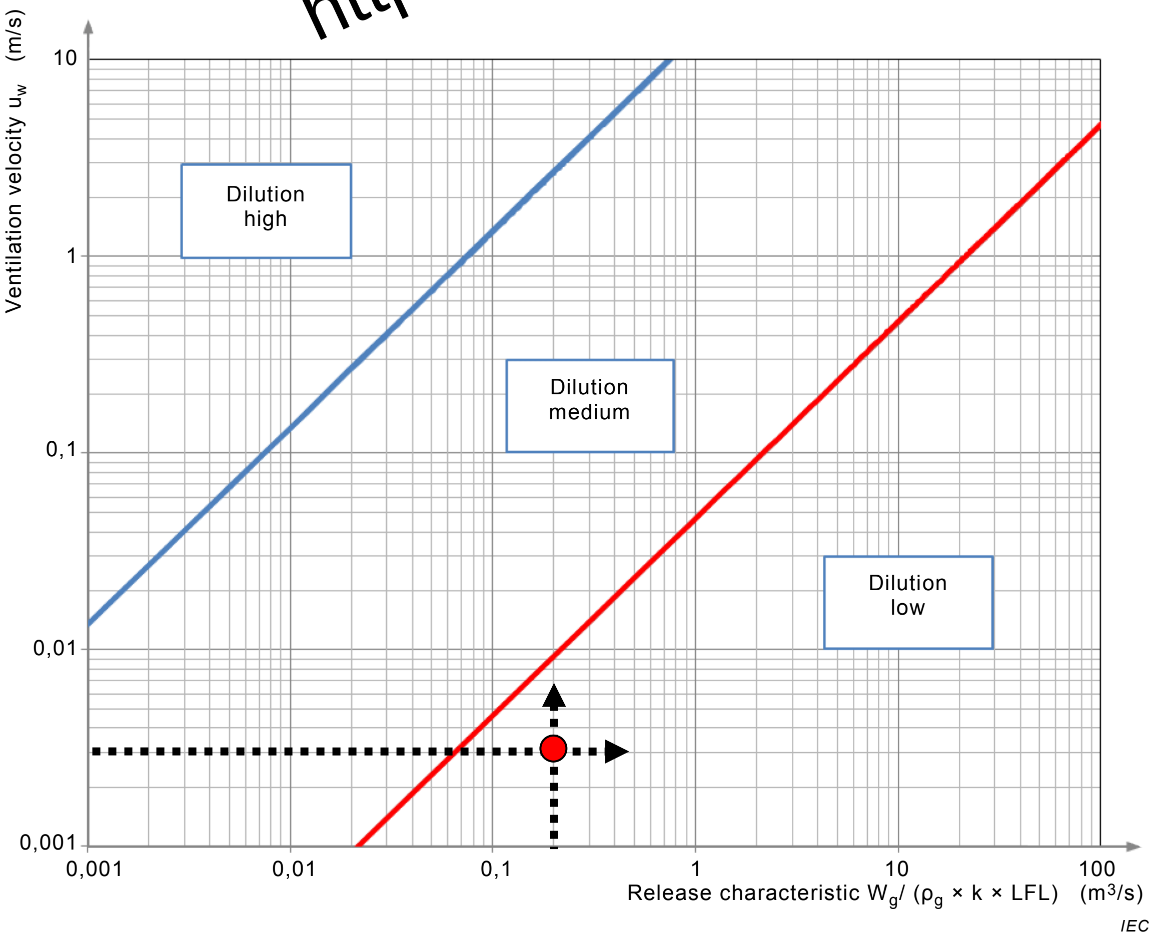


Figure E.4 – Degree of dilution (Example No. 2)

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 just confirms the assessment.

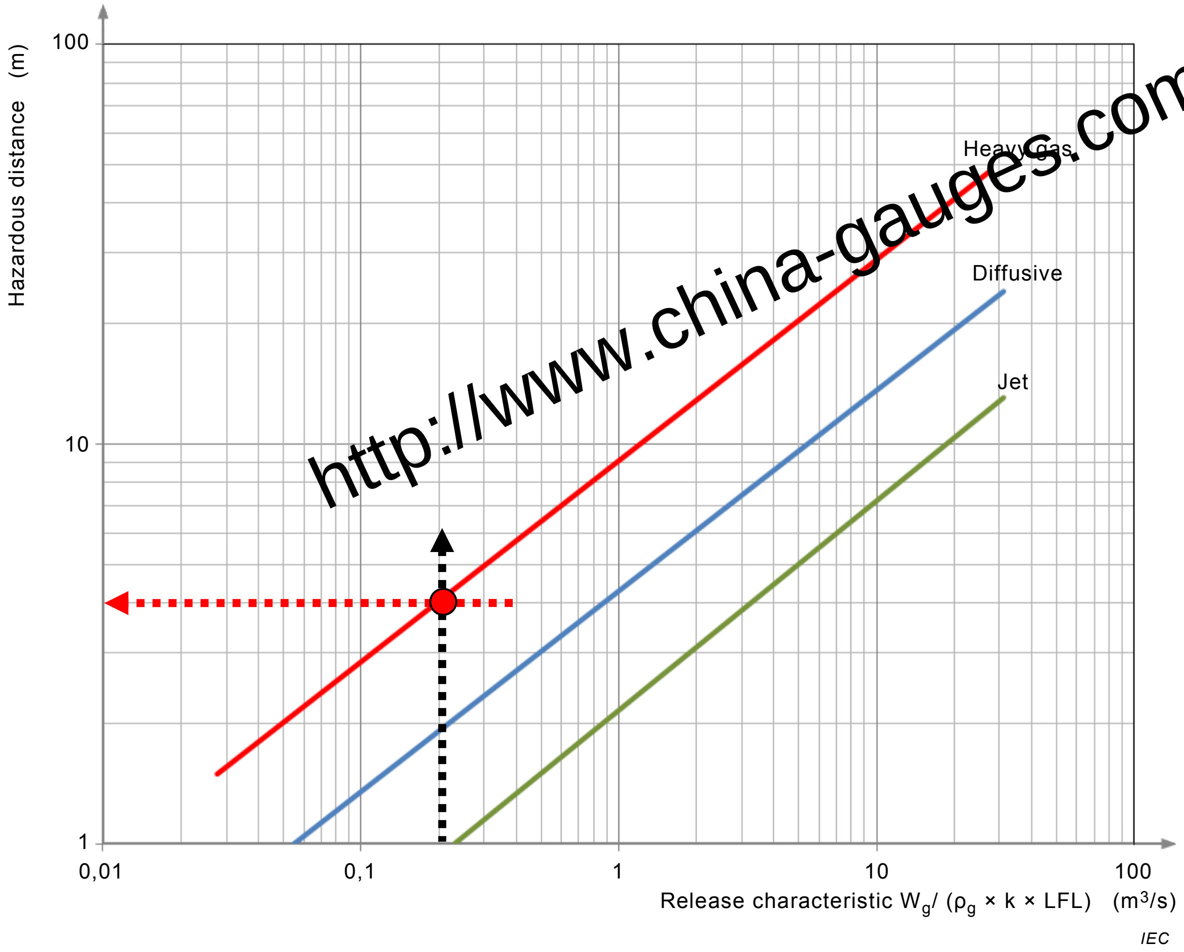


Figure E.5 – Hazardous distance (Example No. 2)

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

<u>Hazardous area classification:</u>

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 could be smaller and maybe of zone 2 instead of zone 1.

Example No. 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 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	4,50 × 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)
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)

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.6)	Medium
Type of zone(s)	Zone 1 + Zone 2
Equipment group and temperature class	IIA T1

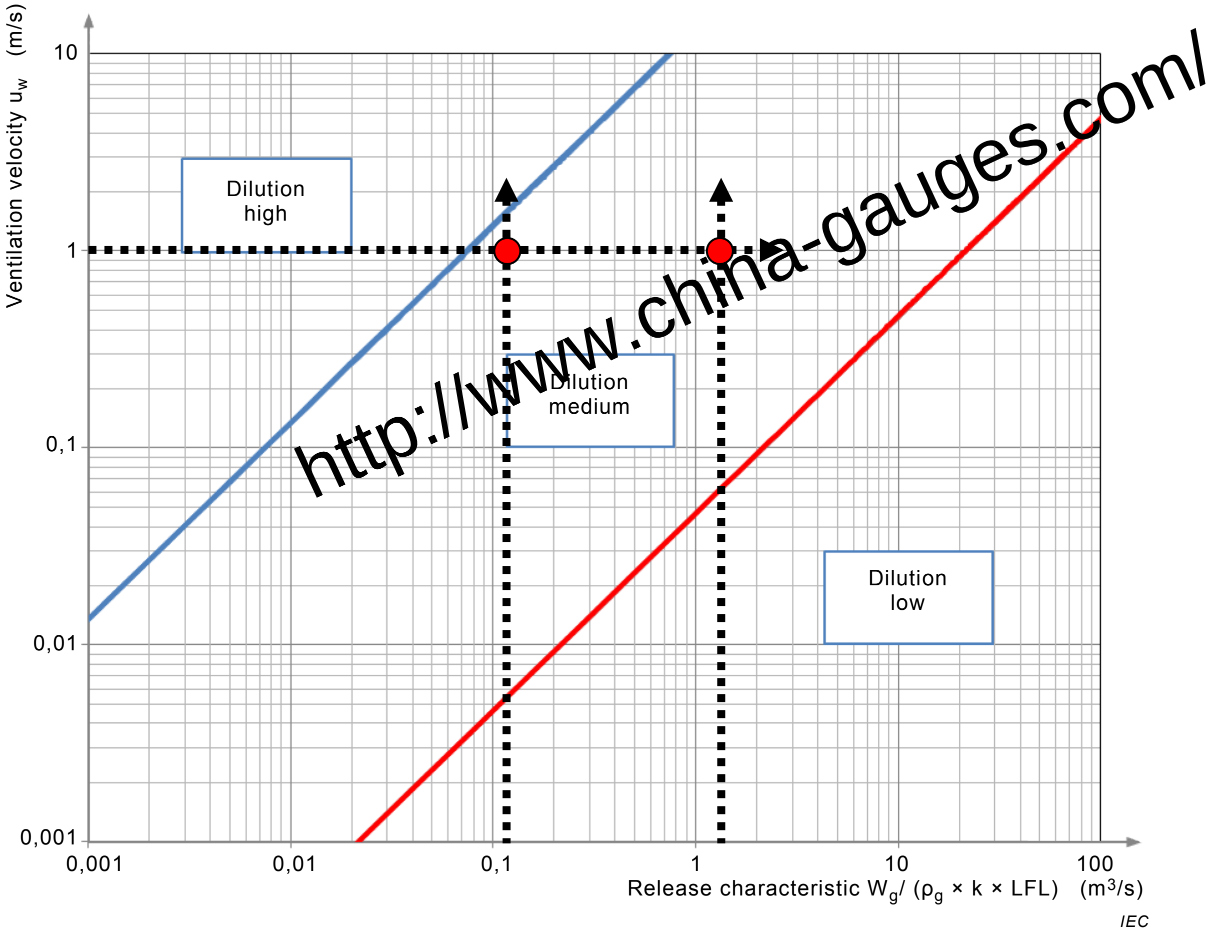


Figure E.6 – Degree of dilution (Example No. 3)

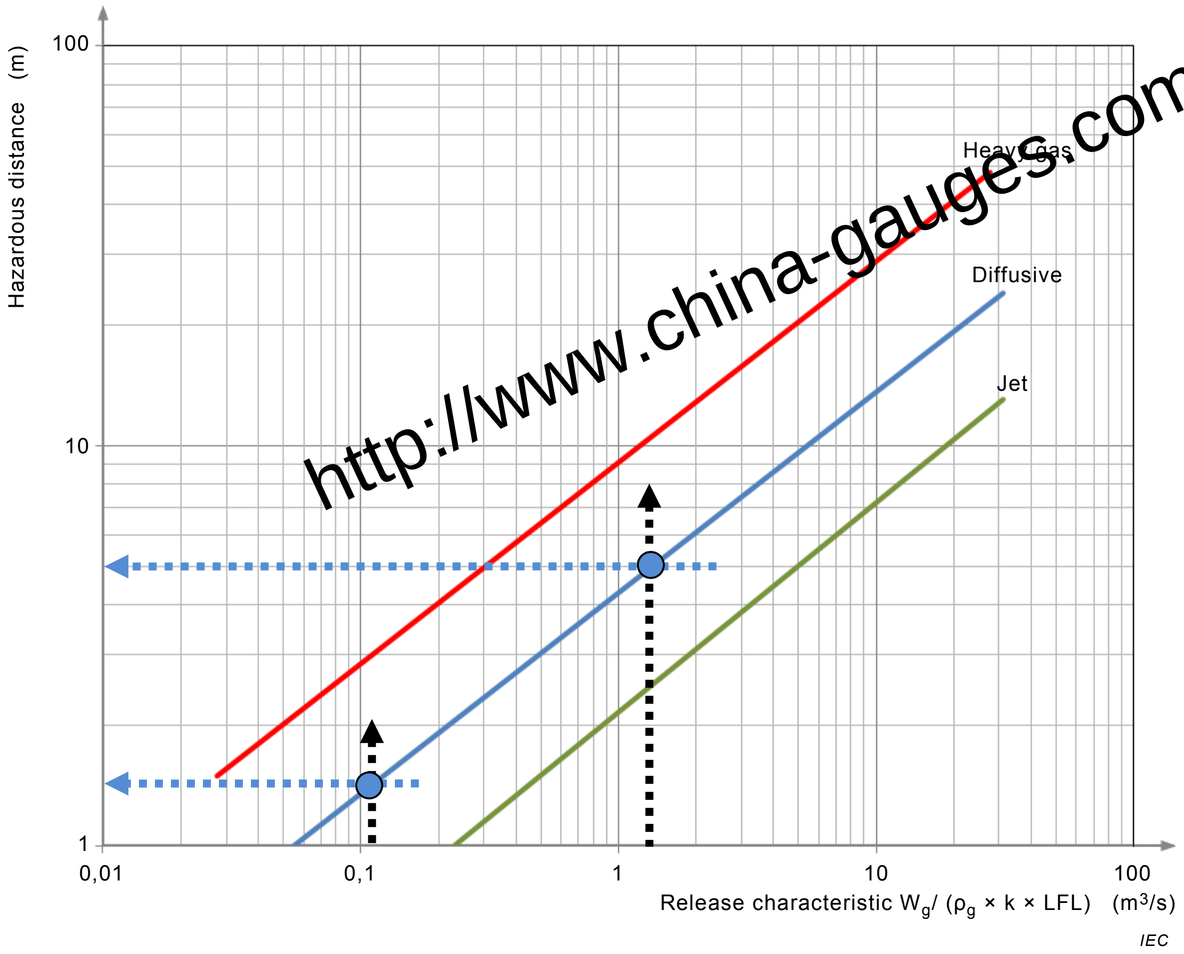


Figure E.7 – Hazardous distance (Example No. 3)

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

Hazardous area classification :

Taking into account relevant parameters, the following hazardous areas are specific for the considered breather valve (see Figure E.7).

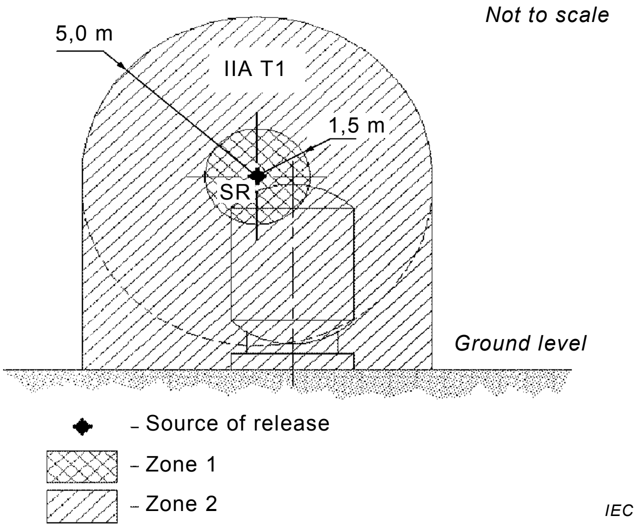


Figure E.8 – Zones classification (Example No. 3)

Example No. 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 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	$5,57 \times 10^{-3}$ 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)
Release characteristic, $W_g/(\rho_g \times k \times LFL)$	0,22 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.9)	Medium
Type of zone(s)	Zone 2
Equipment group and temperature class	IIA T1

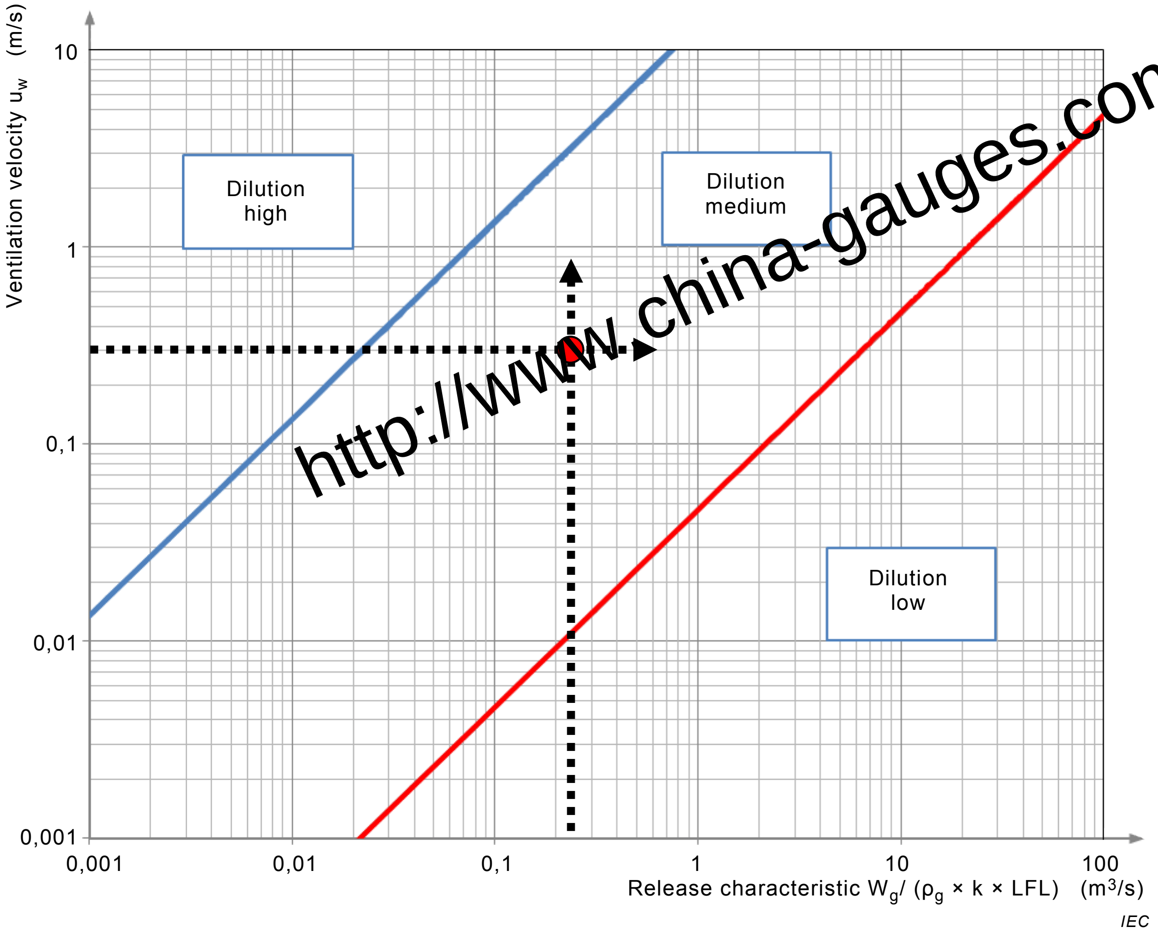


Figure E.9 – Degree of dilution (Example No. 4)

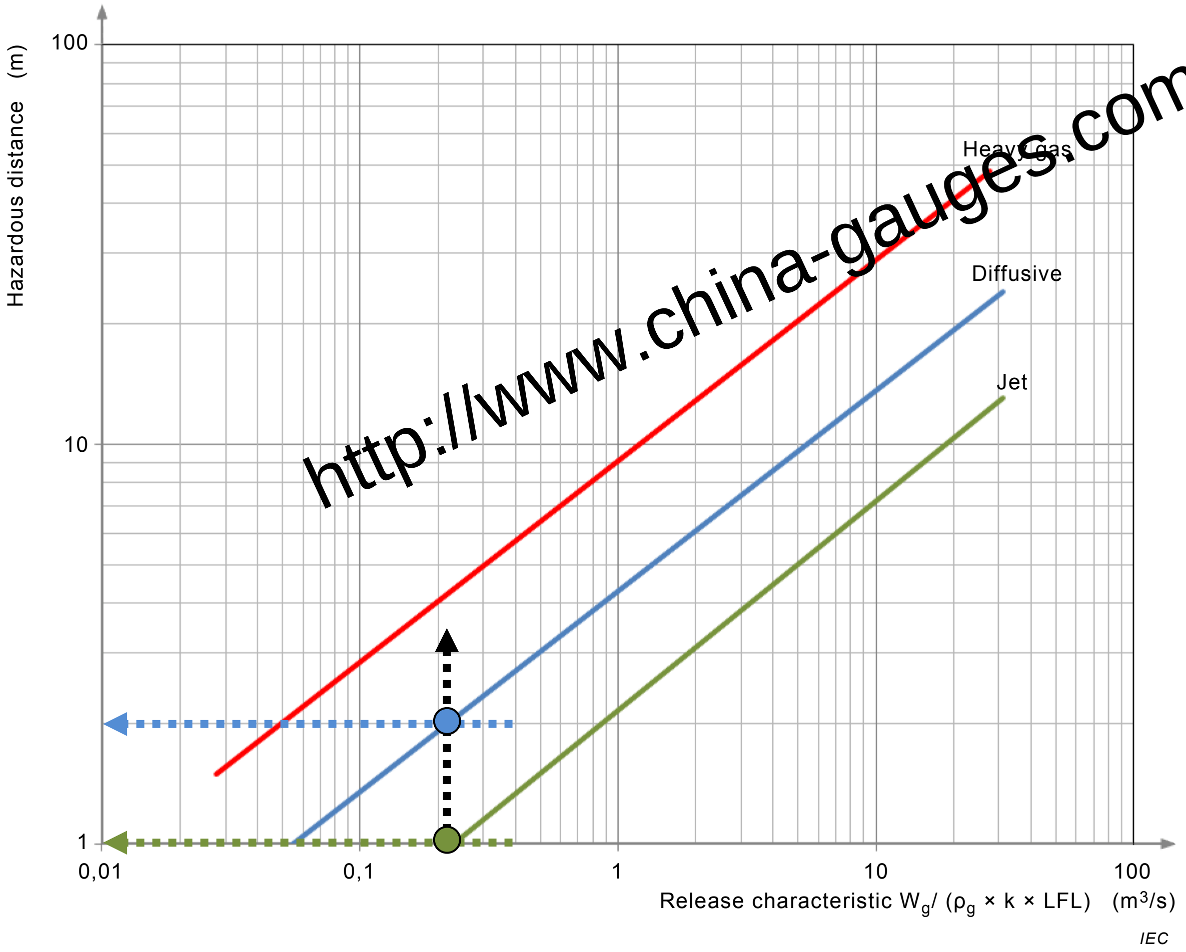


Figure E.10 – Hazardous distance (Example No. 4)

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

Hazardous area classification:

Taking into account relevant parameters, the following hazardous area is specific for the considered control valve.

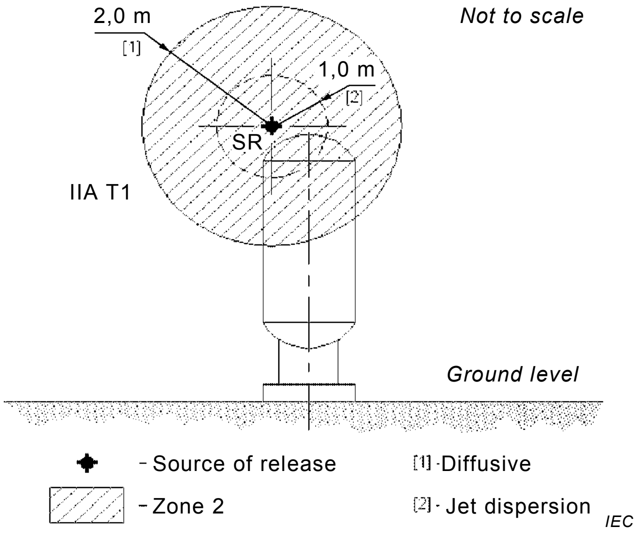


Figure E.11 – Zones classification (Example No. 4)

Example No. 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 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	1×10^{-9} kg/s (laboratory data)
– volumetric release rate per unit, Q_g	$1{,}2 \times 10^{-8}$ 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	$1{,}5 \times 10^{-6}$ kg/s (manufacturer's data)
– volumetric release rate per unit, Q_g	$1{,}8 \times 10^{-6}$ 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	$1{,}95 \times 10^{-3}$ 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	$2{,}35 \times 10^{-3}$ m^3/s
– number of releases	1, the largest ones

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
Air flow rate, Q_a	266,4 m^3/h (0,074 m^3/s)
Air flow rate availability	Good, defined considering the worst environmental conditions (wind speed at meteorological calm condition)

Ventilation (in)efficiency factor, f	3
Ventilation velocity, u_w	0,008 m/s, estimated by $Q_a / (L \times H)$
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	$1,0 \times 10^{-8}$ kg/s
summation of volumetric release rates, ΣQ_g	$1,2 \times 10^{-8}$ m^3/s
background concentration, X_b	$4,88 \times 10^{-7}$ vol./vol.
concentrations comparison	$X_b << X_{crit}$
release characteristic $W_g/(\rho_g \times k \times LFL)$	$6,01 \times 10^{-8}$ m^3/s
safety factor, k	0,5 (due to uncertainty of LFL)
degree of dilution	High
type of zone(s)	Zone 0 NE
Grade of release	Primary plus continuous
summation of release rates, ΣW_g	$4,5 \times 10^{-6}$ kg/s
summation of volumetric release rates, ΣQ_g	$5,42 \times 10^{-6}$ m^3/s
background concentration, X_b	$2,2 \times 10^{-4}$ vol./vol.
concentrations comparison	$X_b << X_{crit}$
release characteristic $W_g/(\rho_g \times k \times LFL)$	$9,02 \times 10^{-5}$ m^3/s
safety factor, k	0,5 (due to uncertainty of LFL)
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	$2,18 \times 10^{-3}$ kg/s
summation of volumetric release rates, ΣQ_g	$2,63 \times 10^{-3}$ m^3/s
background concentration, X_b	0,103 vol./vol.
concentrations comparison	$X_b > X_{crit}$
time required to reach X_{crit}, t_d	0,57 h (safety margin equal to f)
safety factor, k	0,5 (due to uncertainty of LFL)
release characteristic $W_g/(\rho_g \times k \times LFL)$	0,13 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

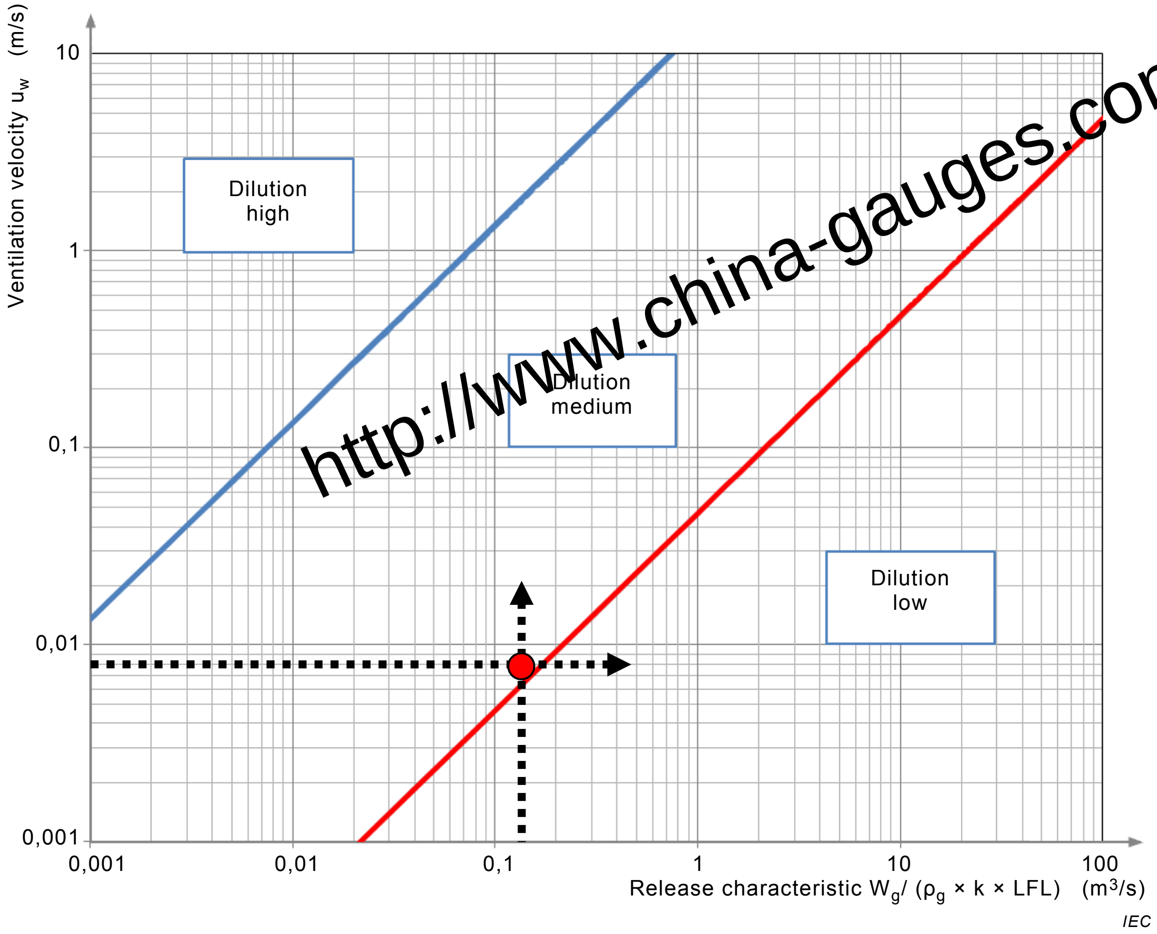


Figure E.12 – Degree of dilution (Example No. 5)

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.4 shows that the intersection point is within the area of “dilution medium” but almost on the dividing line. Allowing for uncertainties in the methodology this shows the preceding assessment is appropriate.

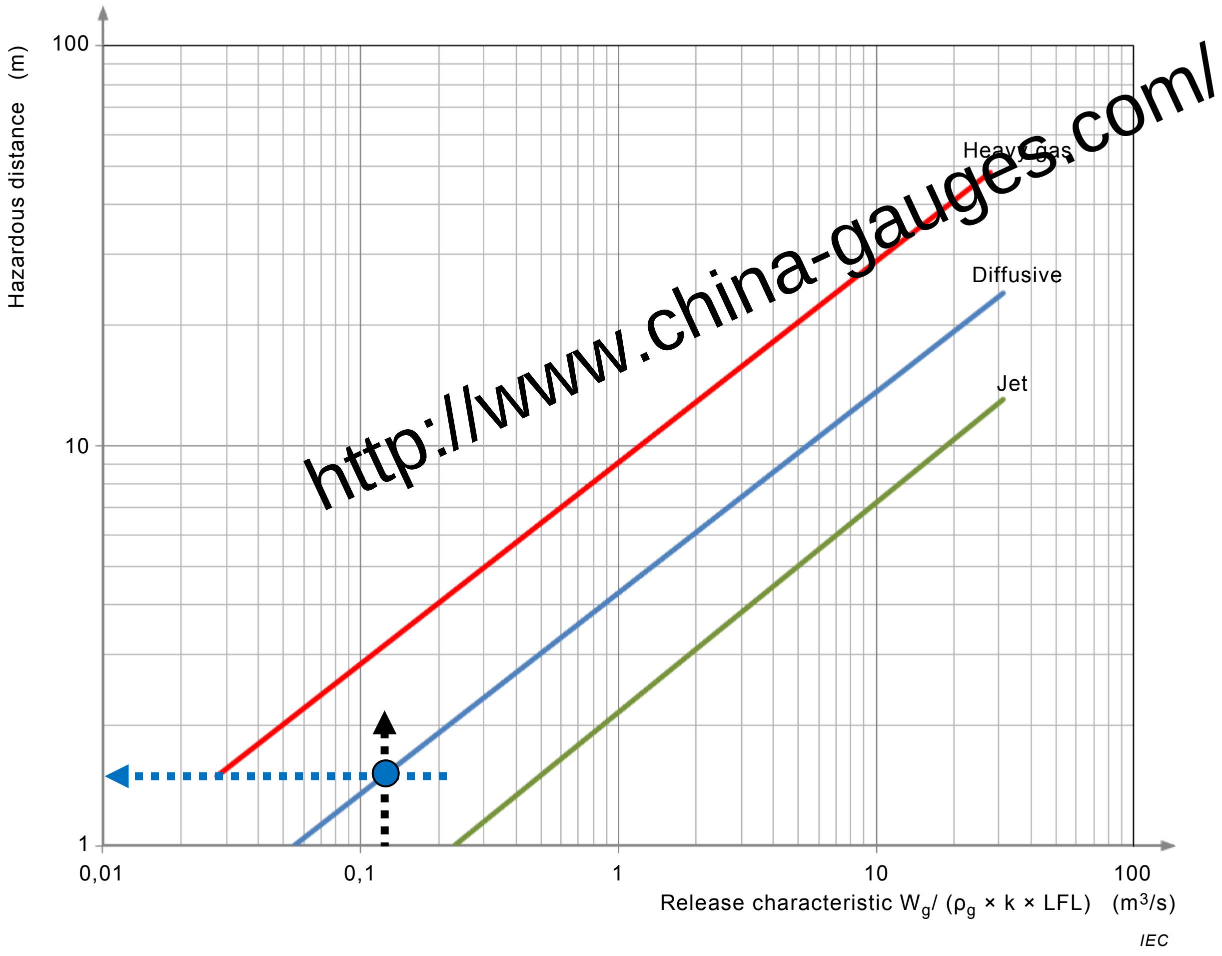


Figure E.13 – Hazardous distance (Example No. 5)

Extent of zone (see Figure E.13), *r* extent of zone is 1,5 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.

E.3 Example case study for area classification

The following example is intended to illustrate the methodology of 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.14). 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:

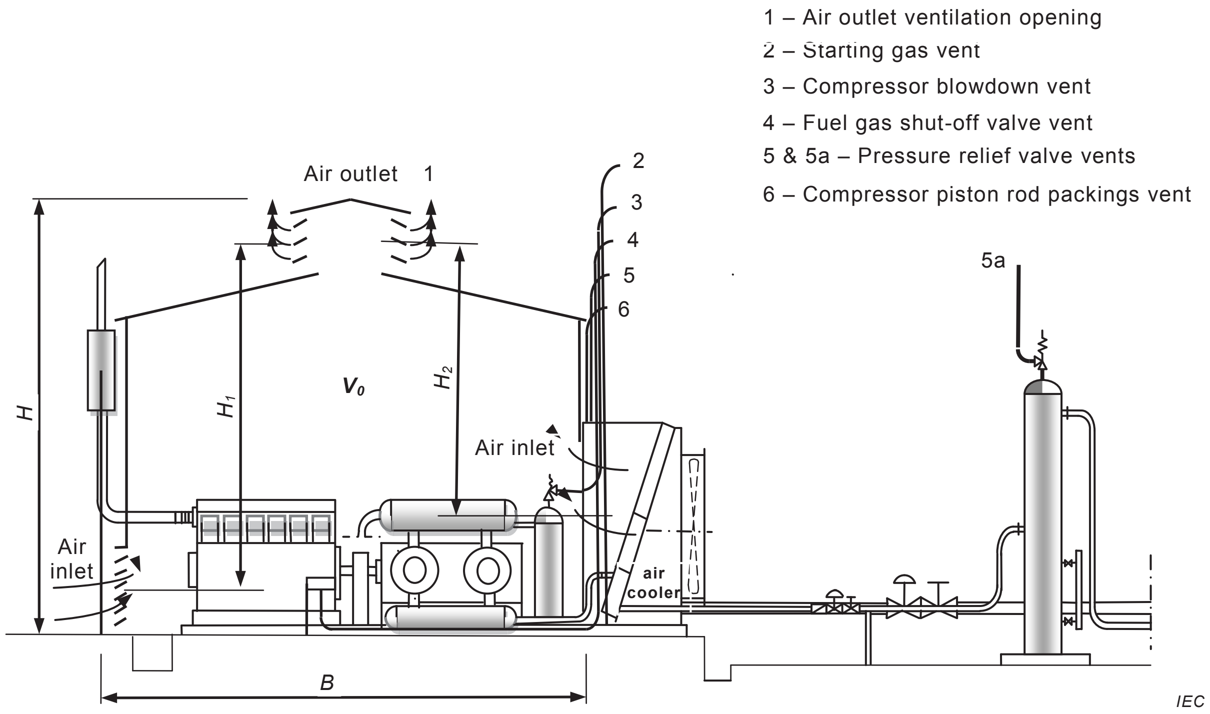
1) Process gas (natural gas with 80 % vol methane),
2) Process gas condensate collected in the scrubbers and automatically drained towards a collecting reservoir (mainly heavier hydrocarbons in quantities which are determined by the respective equilibrium state at each stage of compression),
3) Gas engine 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:

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, 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, or estimated otherwise.



1 – Air outlet ventilation opening
2 – Starting gas vent
3 – Compressor blowdown vent
4 – Fuel gas shut-off valve vent
5 & 5a – Pressure relief valve vents
6 – Compressor piston rod packings vent

Figure E.14 – 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 that it is a mixture of various higher hydrocarbons, mostly pentane and hexane with water.
03	Can we calculate or reasonably assume the lower flammable limits of the flammable substances?	• 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 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 vibrant 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 barA; • T = 422 K (max allowed working temperature).
08	If we decide 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: $V_0 \approx 0{,}80$ = 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)

Classification procedure considerations for the shelter		
14	What is the number of air changes per hour in the volume under consideration?	$C = \frac{Q_\mathrm{a}}{V_0} \approx 48\,h^{-1}$ 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: $u_\mathrm{w} = \frac{Q_\mathrm{a}}{L \times B} \approx 0{,}075\,m/s$
16	What is the background concentration in the volume under consideration?	$X_\mathrm{b} = \frac{f \times Q_\mathrm{g}}{C\,V_0} \approx 0{,}18\% \approx 4{,}5\%\ LFL$ (see equation C.1)
17	What is the release characteristic?	$\frac{W_\mathrm{g}}{\rho_\mathrm{g}\,k\,LFL} \approx 0{,}5\,m^3/s$; with k being 1,0 Since the air flow pattern indicates movement of the air upwards, there is no reason to apply a more strict factor of (in)efficiency 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?	$W_\mathrm{g} = u_2\,A_2\,\rho_\mathrm{g}\,X_\mathrm{b} = u_\mathrm{w}\,L\,B\,\rho_\mathrm{g}\,X_\mathrm{b}$ $W_\mathrm{g} \approx 1{,}54 \times 10^{-2}\ kg/s$; 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). 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.15).
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.15).
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.15 and Figure E.16).

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

Sheet 1 of 3

Plant: Compressor facility handling natural gas (case analysis) **Area:**														**Figures E.2, E.2a**
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Flammable substance							**Volatility**[a]		**LFL**		**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/m³)	Equipment group	Temp. class	Any other relevant information or remark
1	Process gas	80 % vol CH_4+ higher hydrocarbons	21,6	0,8	1,2	–	>400	–	–	4,0	0,036	IIA	T2	
2	Process gas condensate	Iso- and normal pentane, hexane and heptane	46	>3,0	–	<30	<300	<50	unknown	1,3 to 8,0	0,025 to 0,153	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	0,035	IIA	T1	

[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.2a**
1	2	3	4	5	6	7	8		9	10	11	12	13	14		15	16
	Source of release					**Flammable substance**				**Ventilation**			**Hazardous area**				
	Descrip tion	Location	Grade of rele ase^a	Rate of release (kg/s)	Release characte ristic (m^3/s)	Refere nce^b	Operating temperature and pressure		State^c	Type^d	Degree of dilution^e	Availa bility	Zone type 0-1-2	Zone extent (m)		Refe rence^f	Any other informa tion 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		Manufac turer's data
3	Compre ssor 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 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 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		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		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	2	Interior of the shelter	Interior of the shelter		
7a	Compre ssor	Inside the shelter	S	1,54 × 10^{-2}	0,5	1	149	200 to 5 000	G	N	Medium	Good	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	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 E2, E.2a**
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	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	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	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	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	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	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

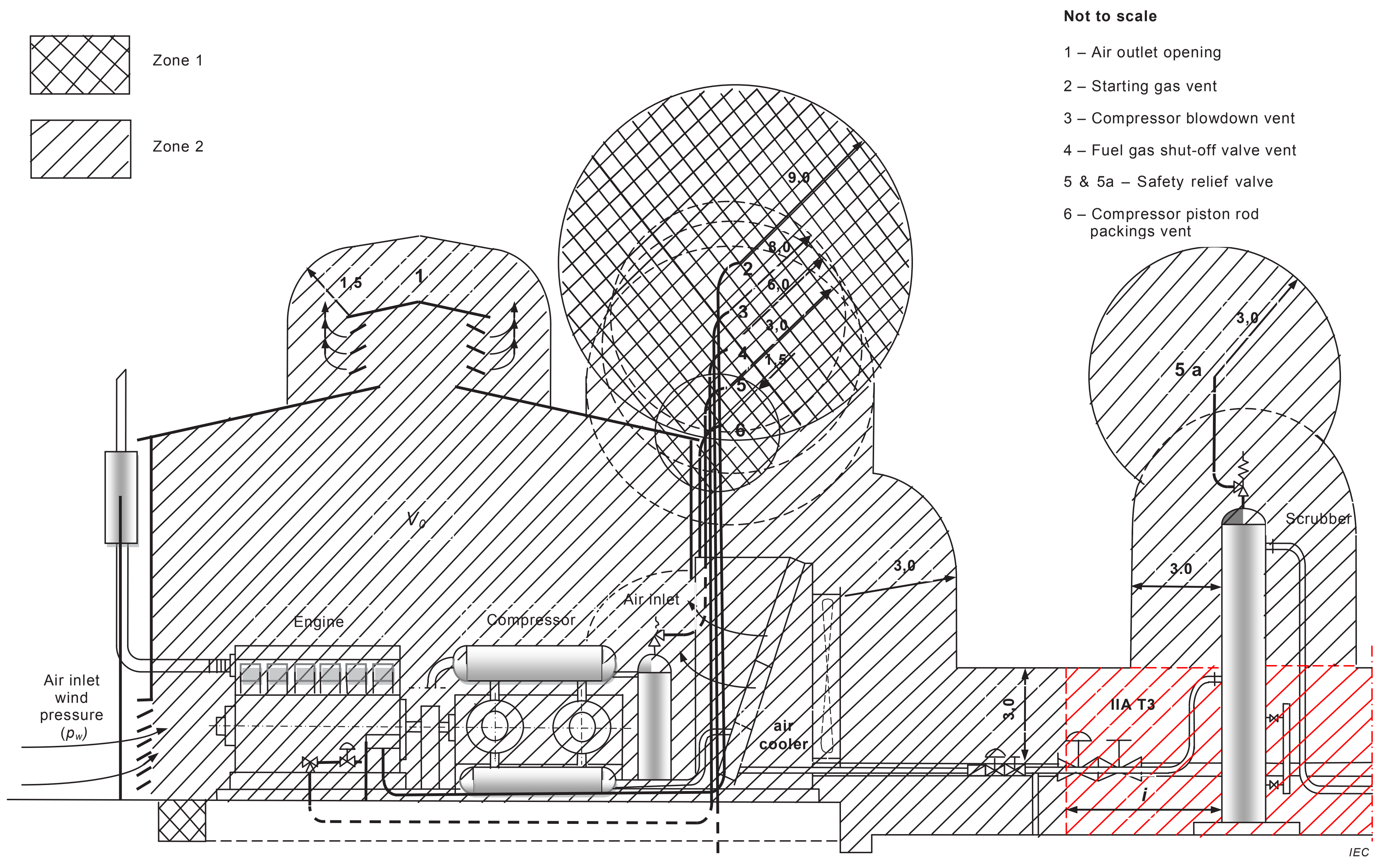


Figure E.15 – Example of area classification for a compressor facility handling natural gas (elevation)

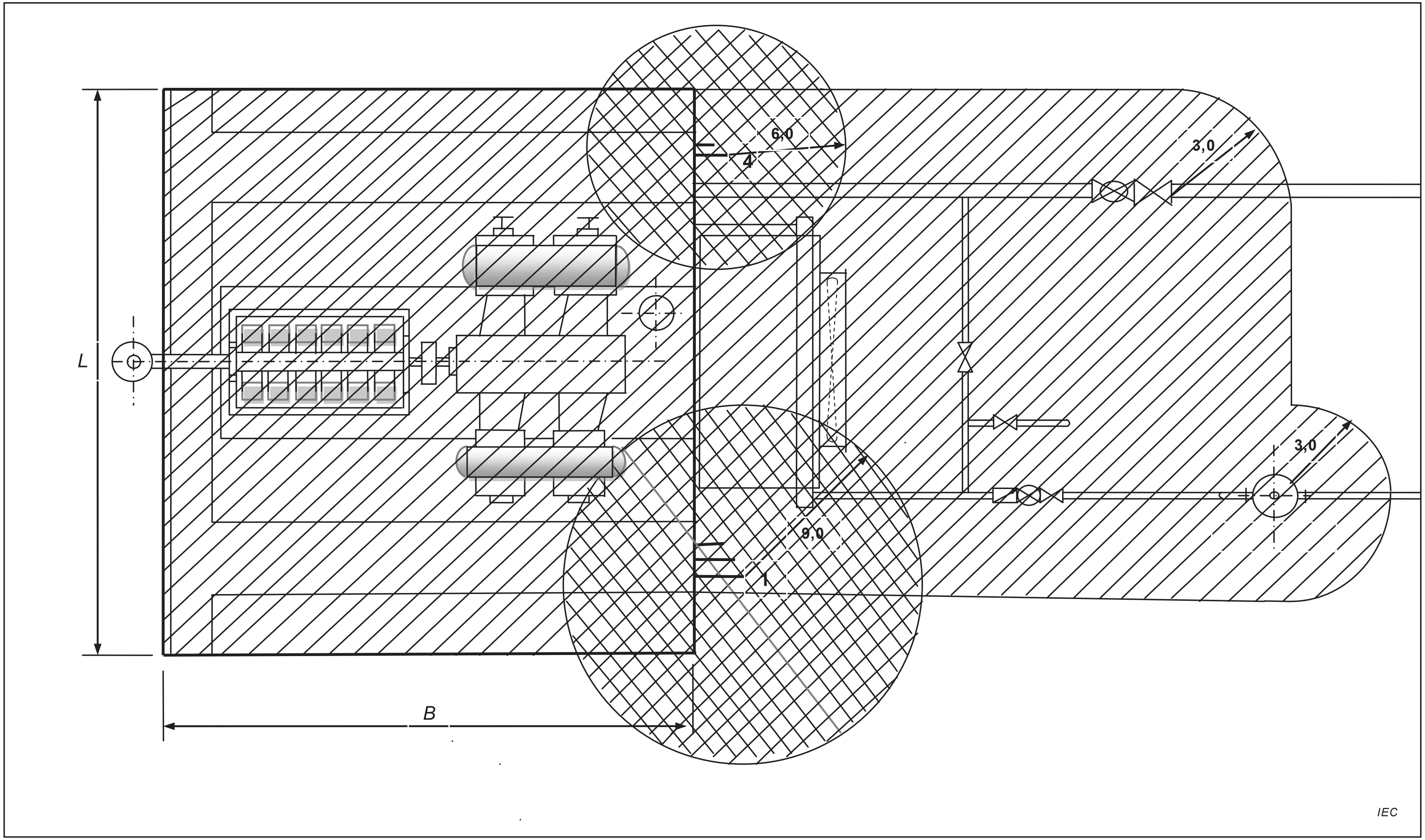


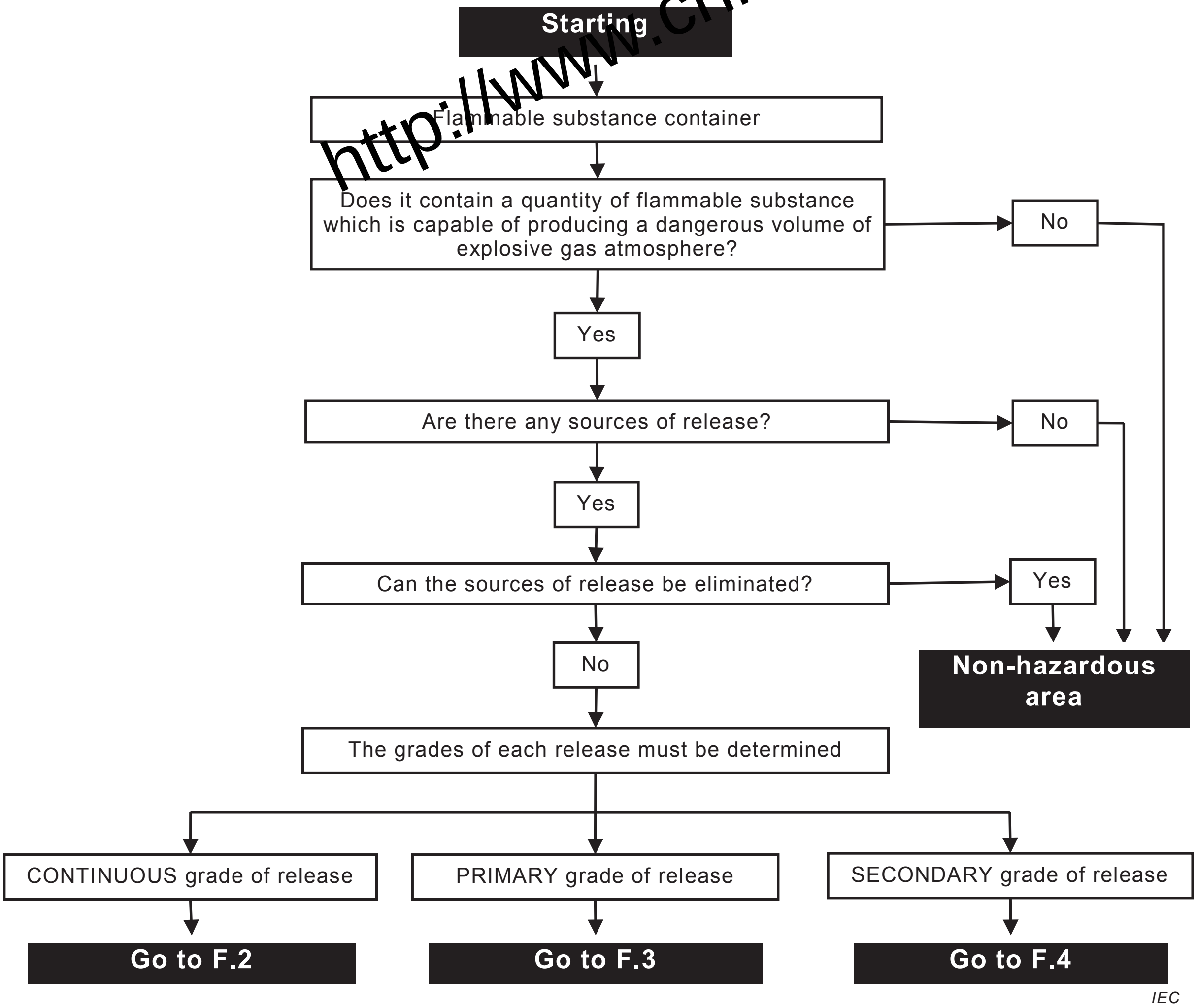
Figure E.16 – Example of area classification for a compressor facility handling natural gas (plan)

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.

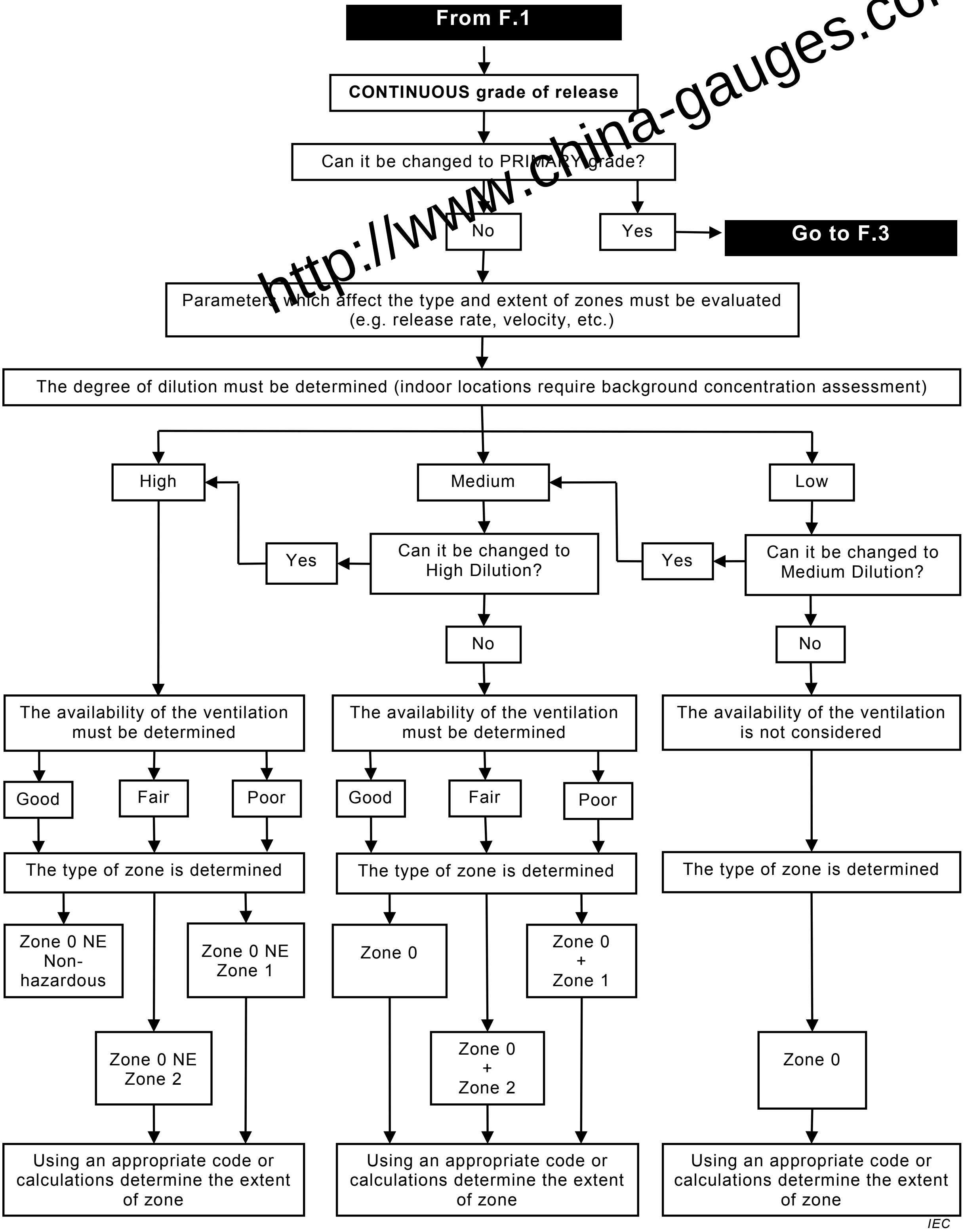


NOTE A source of release may give rise to more than one grade of release or a combination.

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.

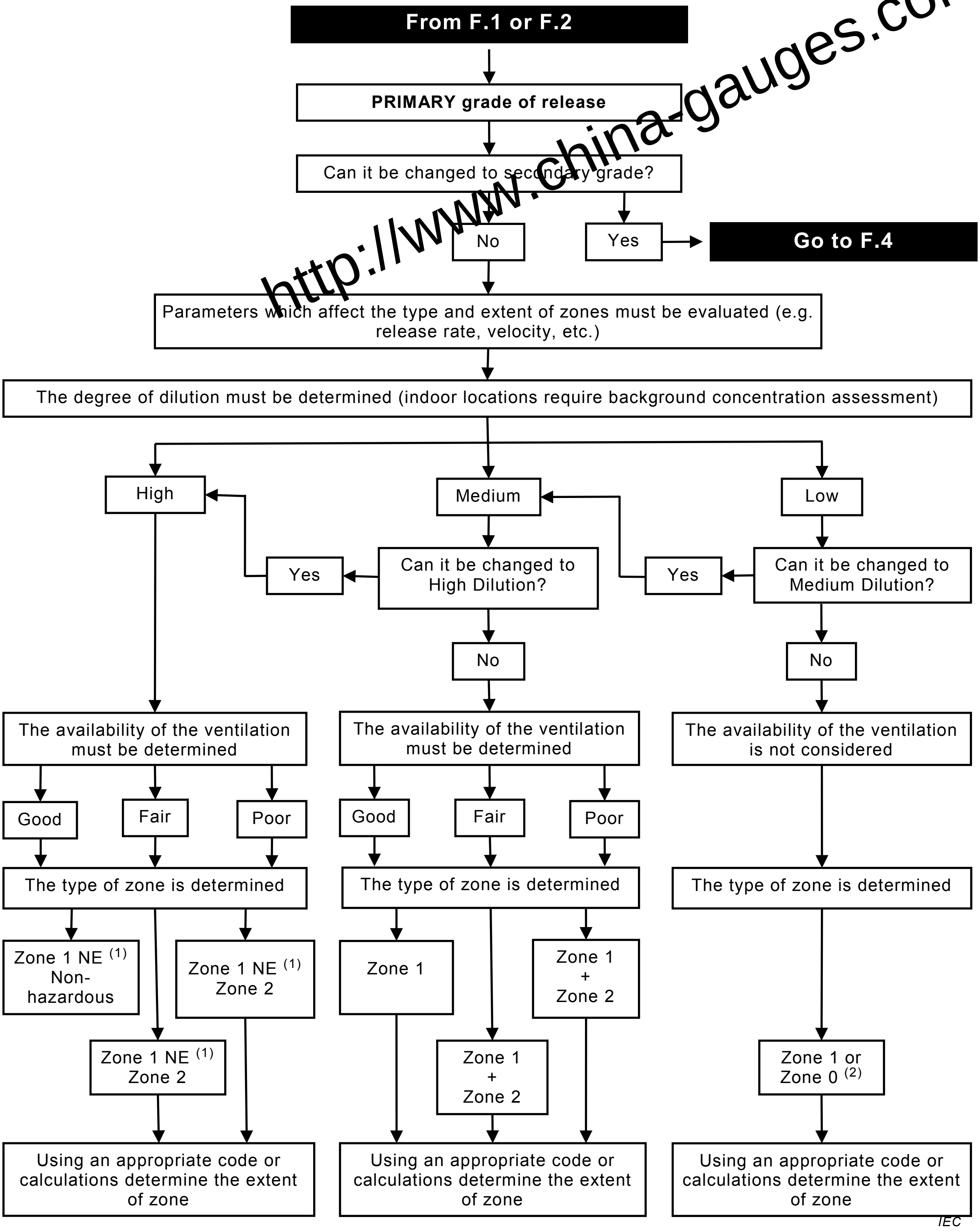


NOTE Zones NE indicate theoretical zones which would be of negligible extent under normal conditions.

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.



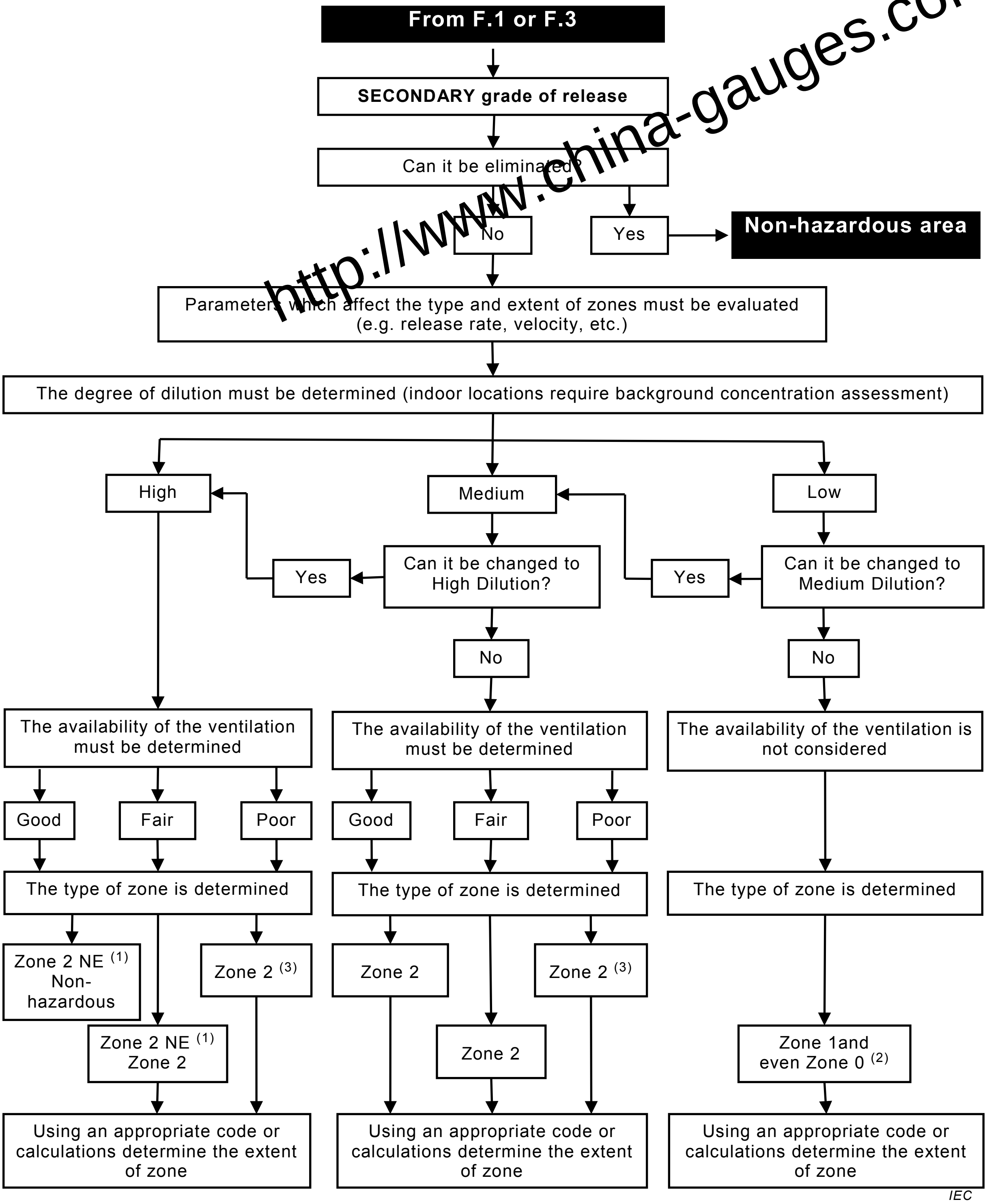
NOTE 1 Zones NE indicate theoretical zones which would be of negligible extent under normal conditions.

NOTE 2 Will be Zone 0 if the low dilution is so weak and the release is such that in practice an explosive 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 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 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 fall out immediately, leaving only a small fraction of the release airborne in the form of an aerosol. 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 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 are small (sub-micron to 50 microns) particles in suspension in the atmosphere.

NOTE 2 Droplets in the aerosol 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 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 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.

G.7 Even the mists that are not ignitable according to the criteria of droplets size could eventually land on a hot surface, relative to the ignition temperature of the vapour, thus causing a fire hazard. Care should be taken to contain potential releases and prevent contact with hot surfaces.

G.8 Mists require minimum concentrations to be flammable (in a similar manner to flammable vapours or combustible dusts). For non-flammable liquids, 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 have been shown to be similar to or less than those associated with the fuel vapour.

G.9 Flammable mists may occur within equipment due to oil lubrication systems, splashing or agitation as a part of the process operations. Internal parts of process plant should then be considered as hazardous areas. 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.10 Additional considerations should be applied for situations where the liquids are being sprayed intentionally, e.g. spray painting. Area classification in such cases is usually the subject of specific industrial codes.

G.11 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 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 ignition temperature for any gas exceeding 3 % in the mixture.

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

H.2 The 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 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.

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 LEL 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 $Q_{\text{a min}}$ can be calculated by means of the equation:

$$Q_{\text{a min}} = \frac{W_{\text{g}}}{k\,LFL_{\text{m}}} \times \frac{T_{\text{a}}}{293} \tag{J.1}$$

where

$Q_{\text{a min}}$ 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 $W_{\text{g}} = 0{,}003$ kg/s of benzene due to the evaporation of a confined liquid pool, at an ambient temperature of 40 °C:

$$Q_{\text{a min}} = \frac{W_{\text{g}}}{k\,LFL_{\text{m}}} \times \frac{T_{\text{a}}}{293} = \frac{0{,}003}{0{,}5 \times 0{,}039} \times \frac{313}{293} = 0{,}164\ m^3/s$$

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

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:

$$t_{\text{d}} = \frac{1}{C} \ln\left(\frac{X_{\text{b}}}{X_{\text{crit}}}\right) \tag{J.2}$$

where

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

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 $X_{crit} = 0{,}0024$.

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

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.

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 should be followed.

If it is intended that the examples given in the reference national or industry codes be used for area classification, account must 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.

Where examples from industry codes or national standards are used, then they shall be quoted as the basis for classification and not 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 set 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
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		
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	Svensk Elstandard	Available only in Swedish
Switzerland	SUVA Merkblatt Nr. 2153	Explosionsschutz Grundsätze Mindestvorschriften Zonen Explosion protection Basics Minimal requirements Zones	Schweizerische Unfall- versicher-ungsanstalt	
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	IP15	Model code of safe practice for the petroleum industry, Part 15: Area Classification Code for Petroleum Installations Handling Flammable Liquids.	Energy Institute	IP15 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 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	

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