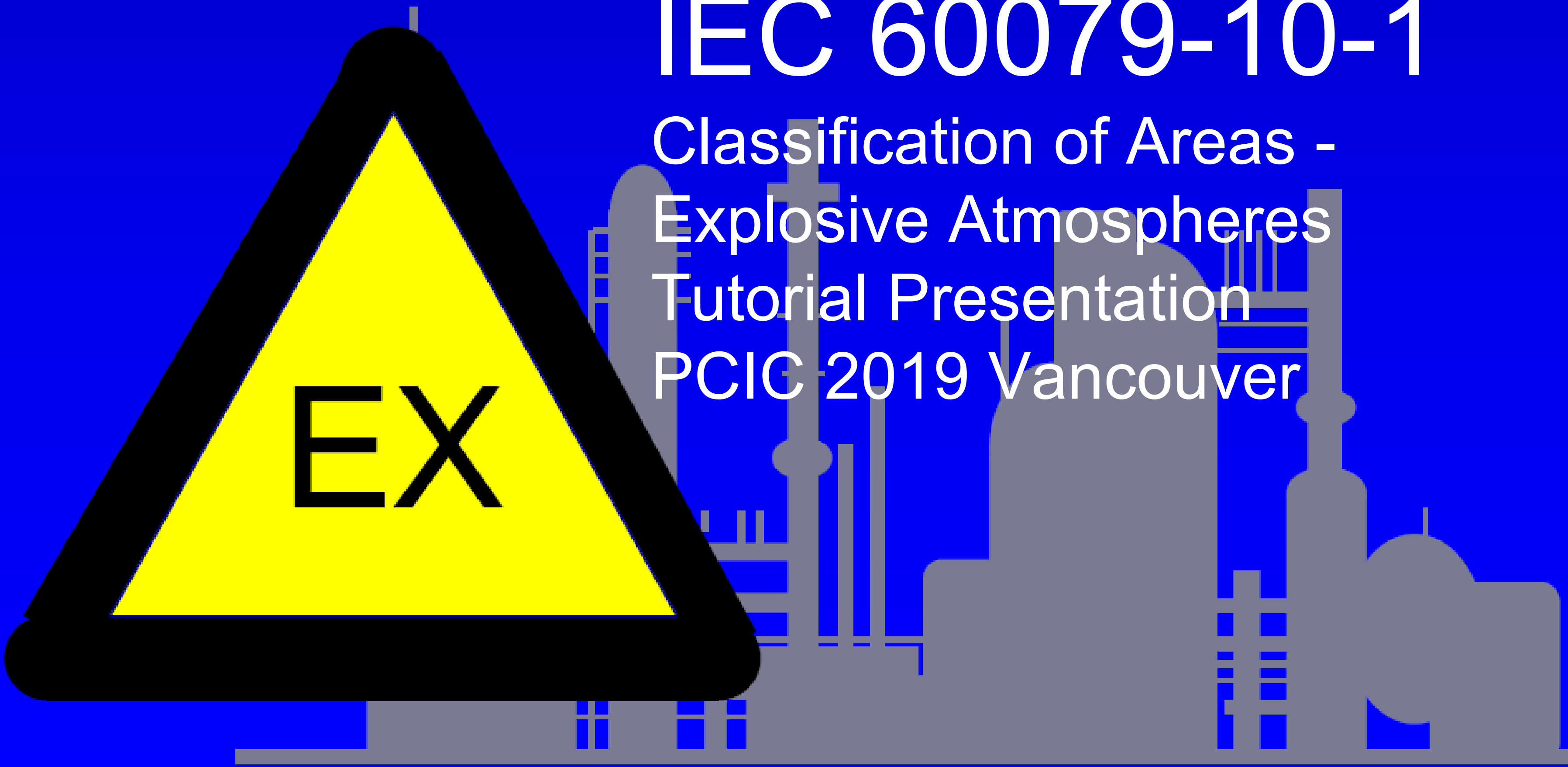
IEC 60079-10-1

Classification of Areas - Explosive Atmospheres Tutorial Presentation PCIC 2019 Vancouver



Allan Bozek, MBA, P.Eng. EngWorks, Calgary, CA
Rob Kohuch, P.Eng. QPS Evaluation Services, Edmonton, CA

Who is this guy?

Allan Bozek, P.Eng, MBA

Founder of EngWorks, a firm providing expertise in hazardous locations:

- Hazardous Area Classification design
- HazLoc Product Design
- Certification Support
- Training Services

Member of several hazardous location standards committees including:

- Canadian Electrical Code Section 18
- CSA Integrated Committee for Hazardous Locations (ICHL) providing technical support for product standards development

- IECEx COPC Certified Unit 001 Hazardous Locations
- IECEx COPC Certified Unit 002 Area Classification

- Professional Engineer
- Journeyman Electrician

Who is this other guy?

Robert Kohuch, P.Eng.

Senior Engineer, QPS Evaluation Services:

- Hazardous Area Product Certification
- ATEX, IECEx, North America
- IECEx CoPC Examiner
- ISO 80079-34 Auditor

Member of several hazardous location standards committees including:

- Canadian Electrical Code Section 18
- CSA Integrated Committee for Hazardous Locations (ICHL) providing technical support for product standards development
- NFPA - Technical Committee on Electrical Equipment in Chemical Atmospheres
- Professional Engineer

Tutorial Agenda

1. *Overview of the basic concepts of Hazardous Area Classification*
2. *Provide you with an overview of the various Codes and Recommended Practices and their application to facilities handling flammable fluids with an emphasis on IEC 60079-10-1*
3. *Provide guidelines on how to properly document your analysis and communicate it to third parties; who will rely on this information for subsequent design, installation and operating activities.*

How to get CEU credits for tutorials

- *Applicable only for the attendees who have paid to get CEU credit for tutorials.*
  This fee is in addition to the registration fee for attending the tutorials.
  - Fee for paying for PdH does not include CEU.
  - Ensure you sign the attendance sheet for each tutorial you have paid to attend
  - Obtain a CEU evaluation form from the tutorial coordinator on Thursday at the tutorials during the break
    You will need one evaluation form for each tutorial
  - MAKE SURE TO WRITE YOUR NAME
  - *Confirm that your email address and telephone number are correct*
  - *Answer all the questions on the Evaluation form*
  - Complete and return the completed evaluation form to the presenter at the end of each tutorial.
  - *These forms will not be accepted by mail, fax or email later*.
  - Proof of attendance and completed evaluation sheets are required to process the CEUs
- Contact : Daleep Mohla, D. Ray Crow or Neeraj Bhatia if you have any questions

Introduction

Section 1

Definition of a Hazardous Location

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

IEC 60079-10-1

Purpose of an Area Classification Historical

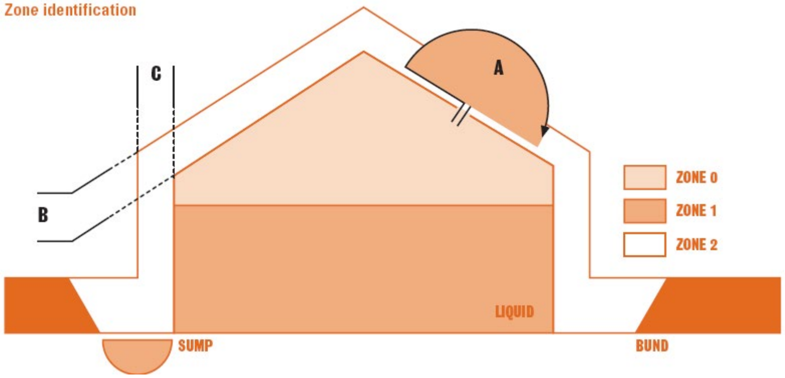
- “Identify the possibility of an explosive atmosphere being present and influencing the design of the plant or facility to minimize the risk of ignition”
- Based on *normal operating conditions* - does not deal with the potential of catastrophic failures
- Primarily used for establishing the type of electrical equipment and wiring methods that can be used within a hazardous area

Purpose of an Area Classification Present and Future

- ATEX Directive
  - Essential Health and Safety requirements with respect to:
    - Potential ignition sources from equipment in hazardous locations
    - Applies to non-electrical equipment
- Local Occupational Health & Safety Requirements
  - Hazardous area classification is now being used as a basis for implementation of the OH&S codes and standards
    - The hazardous area classification design is being used as a tool for performing the hazard risk assessment
    - Regulates the work activities performed within a classified location

Who is impacted by an Area Classification?

- Engineering
  - Selection of components
- Equipment manufacturers
  - Certification requirements
- Installers
  - Installation methods
- Inspectors
- Operations, Maintenance and Safety Personnel
  - Operational procedures
- Insurers
  - Risk premiums



What is Impacted by a Hazardous Area Classification?

Cost of Ownership

- Materials
  - The higher the classification, the more costly the equipment and materials
    - Up to 50% greater in some cases
    - Availability may also be an issue
- Installation
  - The higher the classification, the more time and labour is required for installation
- Maintenance
  - Ongoing maintenance costs can be significant

Operations

- Hot Work Permitting Requirements
  - Provides a basis for Restricted access

- Special procedures
  - Requirement for sniffing the area for gas before performing basic tasks
  - Shutdown of equipment components before inspection or repair

All this may have an impact on the on-line performance of a facility!

Common issues found in many HAC designs

- No group classification or Auto-ignition temperature and/or T-Code indicated on the drawings
  - Errors in the group classification of materials
  - Errors in determining the appropriate auto-ignition temperature and equipment temperature code
- Classification of locations where no flammable materials are present
- Over classification of areas relative to the risk
- Inconsistent application of classifications surrounding similar equipment items
- Unsupported classification of enclosed areas where adequate ventilation is required

Common issues found in many HAC designs

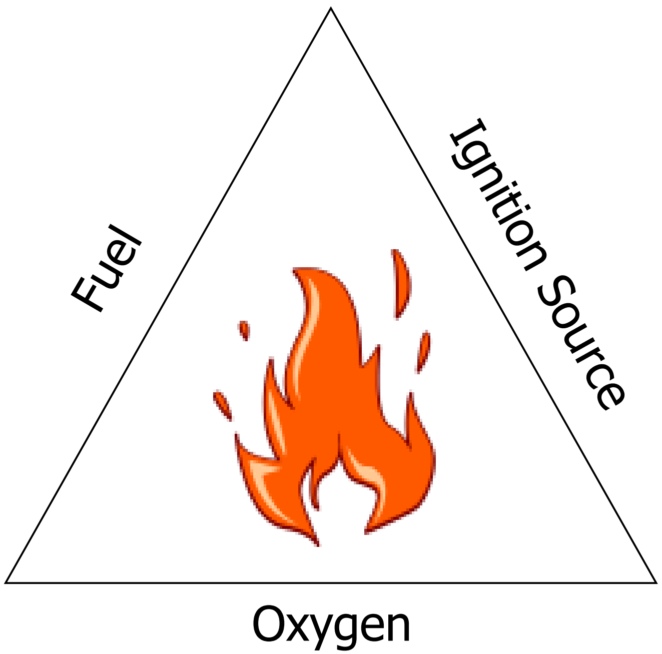
- Lack of identification of key design elements including vapour-tight walls and separations between classified and unclassified areas and gas detection
- Errors in the re-classification of locations from the Division to the Zone system of classification
  - Many try and present both Zone and Division classifications on the same drawing
- Inconsistent hatching of classified locations on drawings
- Erroneous notes on drawings
- *No supporting documentation defining the rationale applied for defining the hazardous area classification*

Defining the Hazard

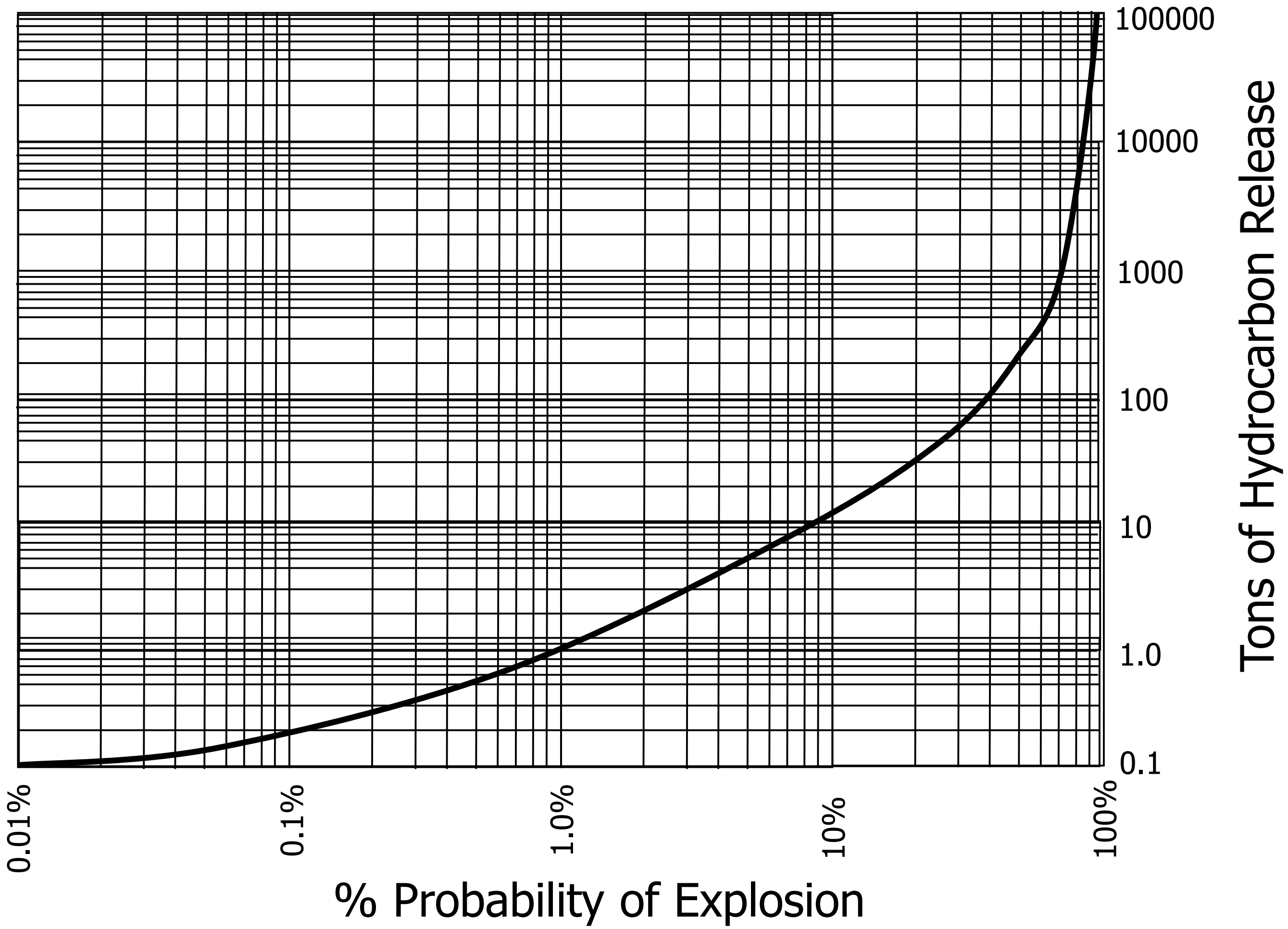
Section 2

The Fire Triangle

For an explosion or fire to occur, all three elements of the fire triangle must be present



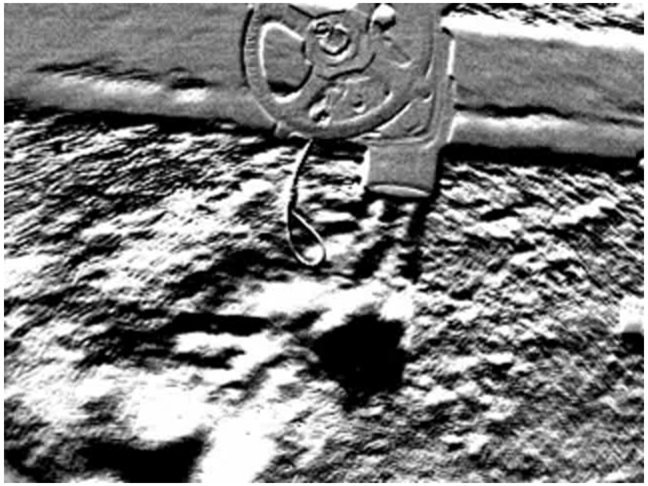
Risk of Explosion related to Size of Release



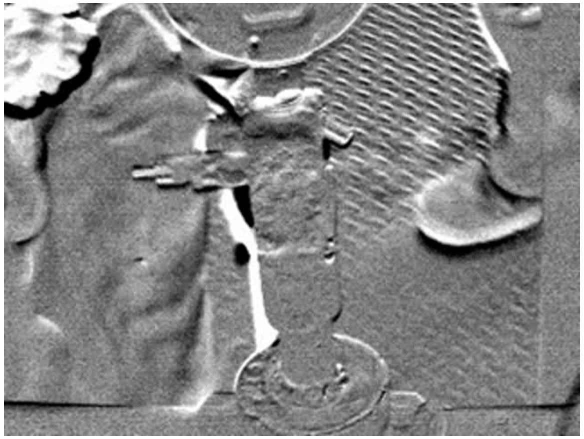
Source: Volatility and Mists – Electrical Area Classification Important Variables, J. Propst IEEE Paper PID 99-09

NDIR Leak Detection

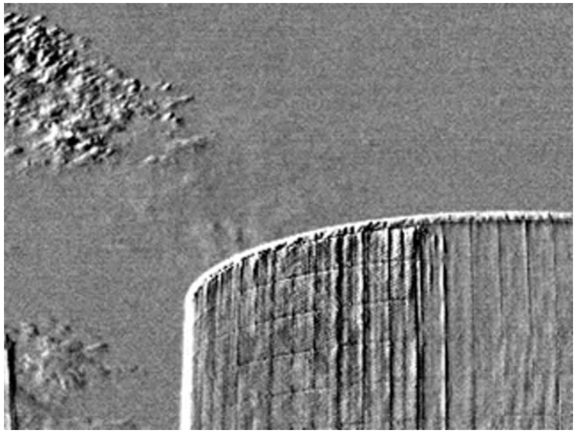
Valve Stem



Open Ended Valve



Needle Valve Leak



Storage Tank

Probability of a Component Leak (Source API 4615)

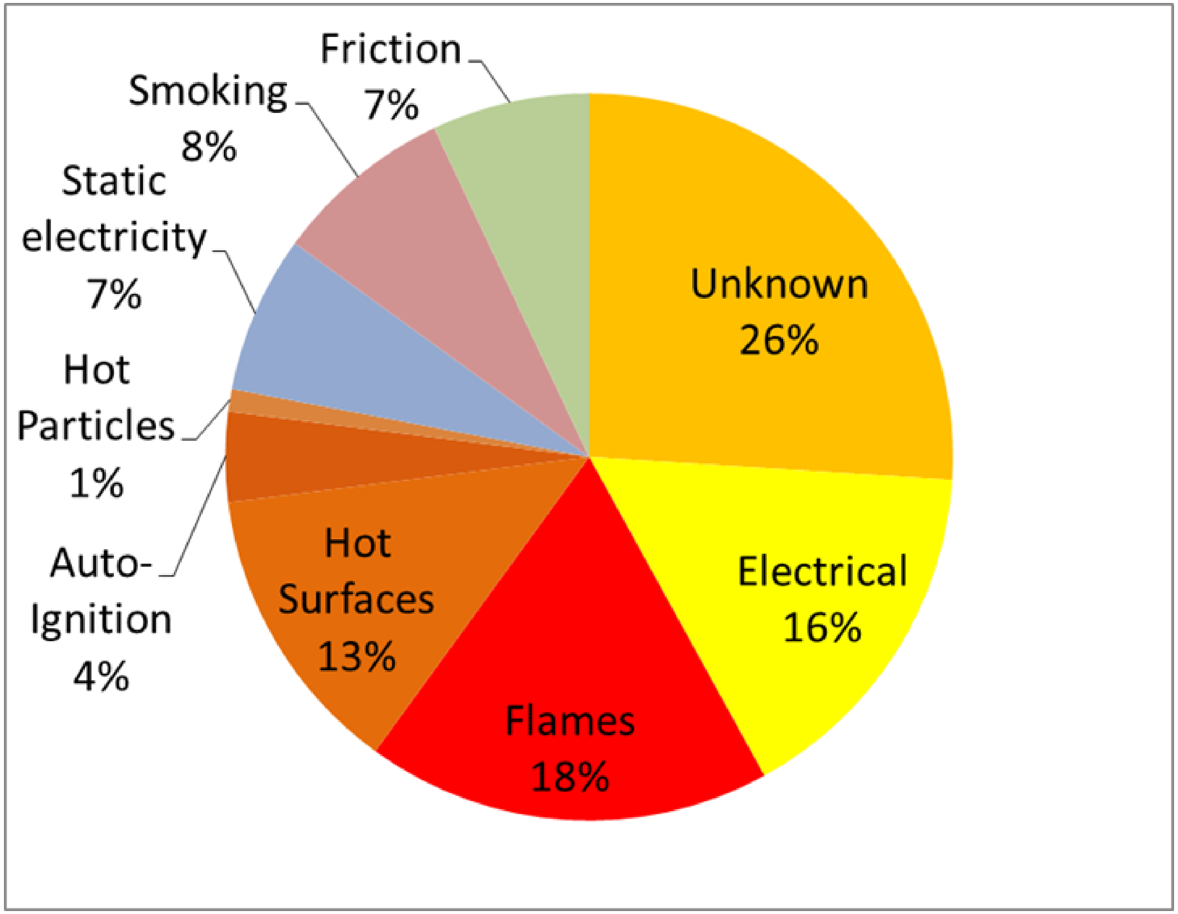
Facility Type	Components Screened	No Leaks	Minor Leaks 10 to 9999 ppmv	Major Leaks >10,000 ppmv
Light Crude	48652	97.90%	1.11%	0.90%
Heavy Crude	13756	99.54%	0.43%	0.00%
Gas Production	40178	96.23%	2.15%	1.61%
Gas Plant	57126	96.28%	1.73%	1.97%
Offshore Platform	45694	98.60%	0.81%	0.77%
Totals	**205397**	**97.41%**	**1.39%**	**1.18%**

Probability of a Component Leak (Source: Cox Lees and Ang)

Component	**Minor Leak** **0.01 x A**	**Major Leak** **0.1 x A**
Pipework 1” (leaks/m/yr)	1 in 10,000	1 in 100,000
Pipework 10” (leaks/m/yr)	1 in 100,000	3 in 1,000,000
Flanges (leaks/yr)	1 in 1,000	1 in 10,000
Valves (leaks/yr)	1 in 1,000	1 in 10,000
Pumps (leaks/yr)	3 in 1,000	3 in 10,000
Small Bore Connections 1/2” (leaks/yr)	-	5 in 1000

A = Cross Sectional Area of Pipe

Ignition Sources on Closed Process Plants



Source: UK HSE Data Bank April 1987 – March 1988

Rew and Spencer Model

Category (Strength of Source)	Examples of Ignition Sources	Ignition Potential
Certain	Pilot Lights, Fired Heaters, Flares	$p = 1$
Strong	Hot Work, Electrical Faults, Smoking	$p > 0.5$
Medium	Vehicles, Substations, Unclassified electrical equipment, Engines, Hot surfaces	$0.5 > p > 0.05$
Weak	Office Equipment, Electrical Appliances, Mechanical Sparks, Static electricity	$p < 0.05$
Negligible	Intrinsically safe equipment, Radio Frequency Sources	$p = 0$

Scope of a Hazardous Area Classification

- Fugitive emissions in plant operations are normal and expected
  - An area classification is valid under “Normal” and defined “abnormal” operating conditions
    - An abnormal condition is where a leak is detected but the process continues until such time as a repair can be made
- Catastrophic releases where large amounts of flammable material are released due to an equipment containment failure are not considered

Hazardous Area Classification Risk Assessment

- Based on the likelihood of a flammable mixture being present under "normal" and defined "abnormal" conditions
  - Source of ignition is not a criteria for classification
- Must be carried out *before* the choice of equipment and wiring methods are made
- Requires an understanding of process and mechanical engineering concepts
- Requires an understanding of the codes and practices and knowing which one is most suitable for a given situation

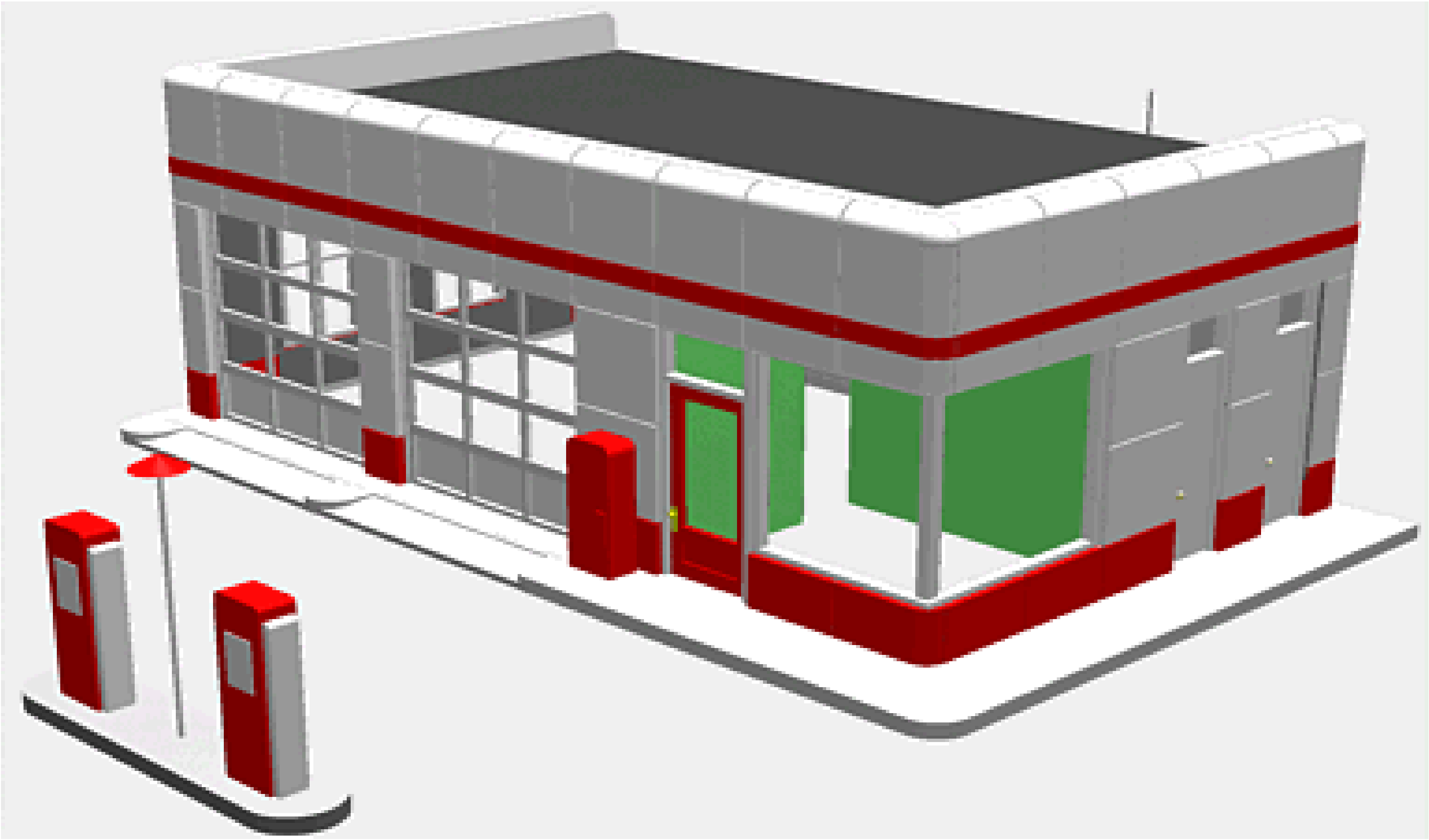
Hazardous Area Classification Risk Assessment

- Subjective in nature and will be influenced by:
  - Standards and practices within an operating company
  - Practices that vary between upstream, downstream and offshore facilities
  - Size and complexity of a facility
  - Remote, unmanned or inaccessible facilities
  - Cold weather facilities
  - Operations Experience

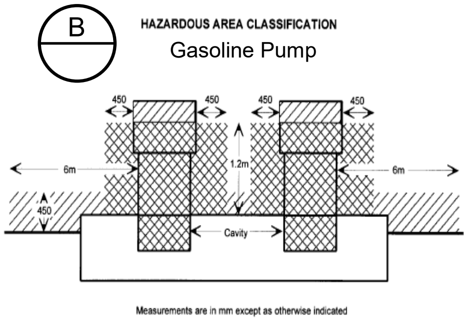
Terminology

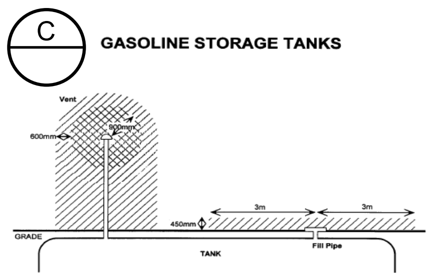
Section 3

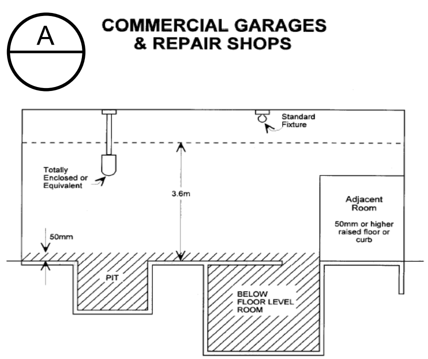
HAC of a Gas Station

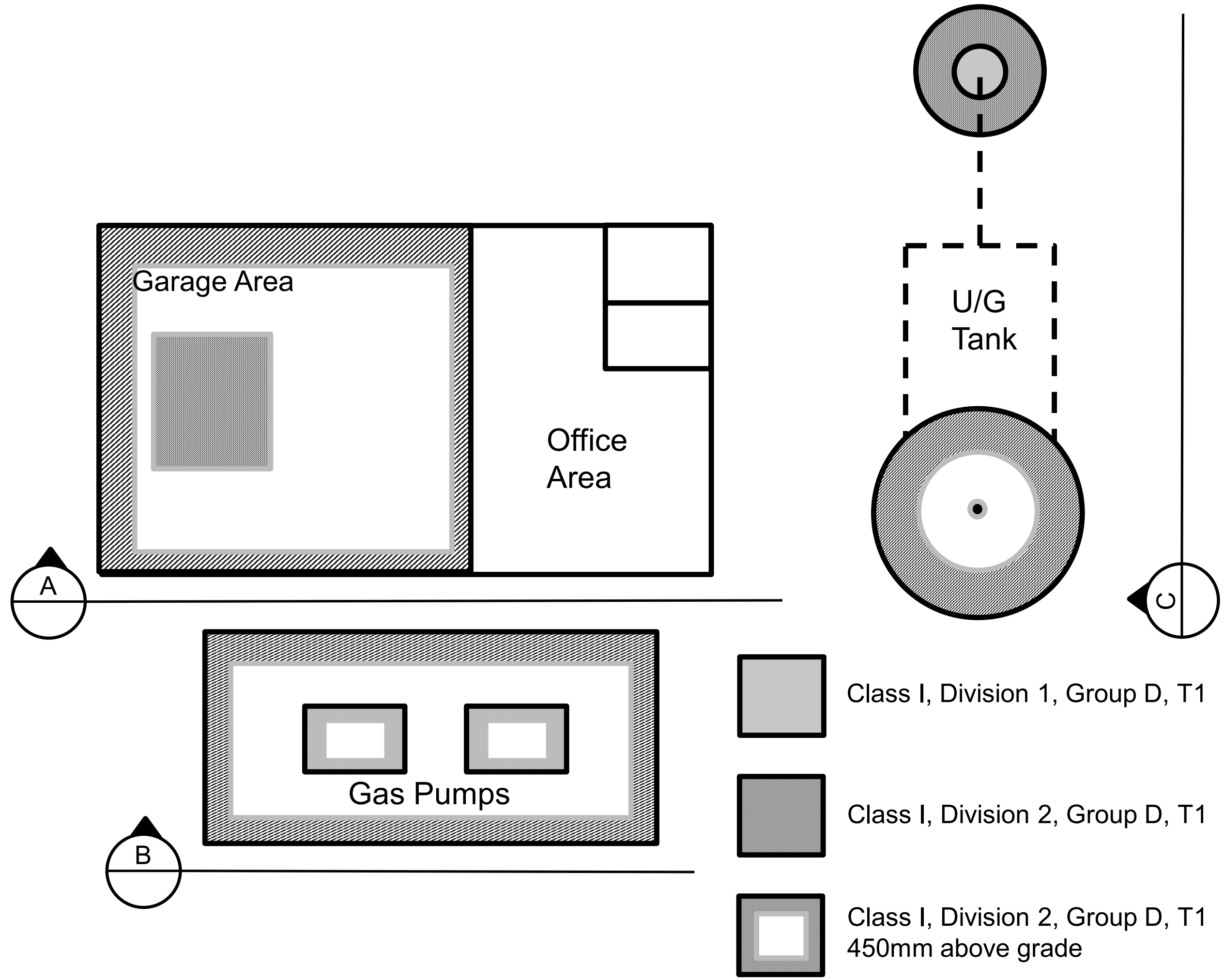


HAC Design Division Method

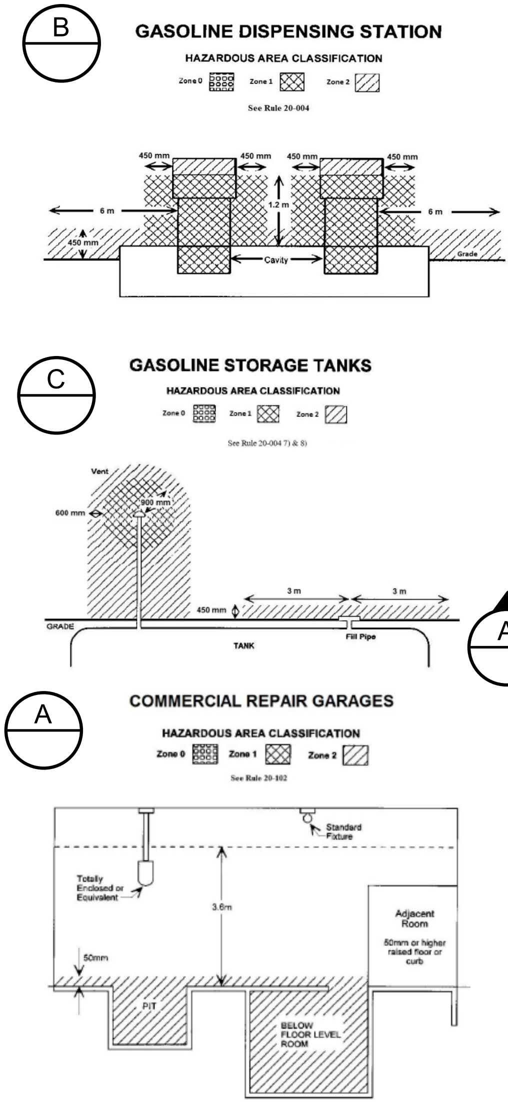


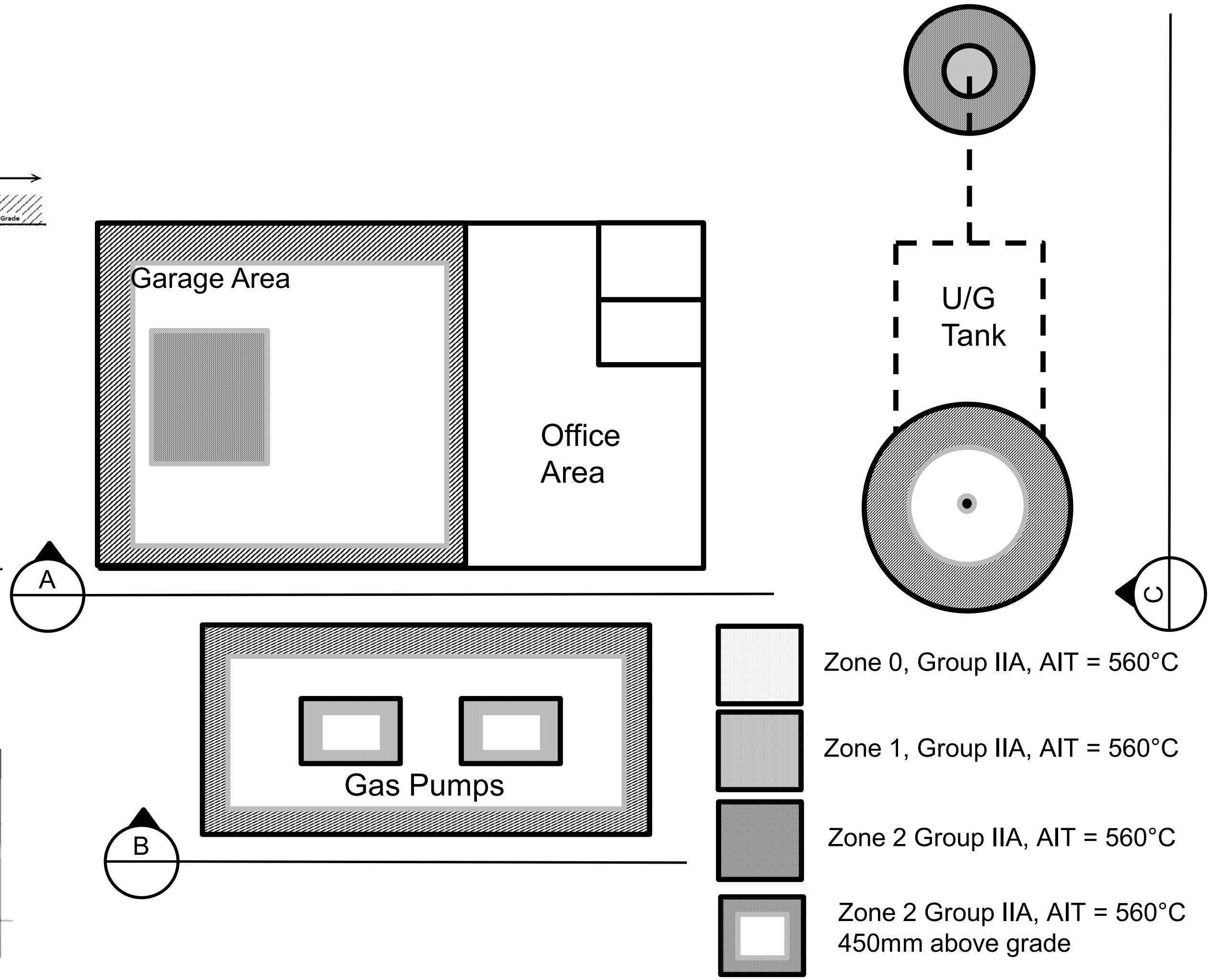






HAC Design Zone Method





HAC Drawing Legend

Division System

- Class I, Division 1, Group D, T1
- Class I, Division 2, Group D, T1
- Class I, Division 2, Group D, T1
  450mm above grade

Zone System

- Zone 0, Group IIA, AIT = 560°C
- Zone 1, Group IIA, AIT = 560°C
- Zone 2 Group IIA, AIT = 560°C
- Zone 2 Group IIA, AIT = 560°C
  450mm above grade

A drawing must indicate the nature of the hazard, the group classification and the Auto-ignition temperature of the materials handled before electrical equipment can be specified for the application

Interpreting the HAC Legend

Class	Definition of the Hazard
Zone or Division	Probability that a hazard may exist
Group	Characteristics of the Hazardous Materials
AIT	Auto-ignition temperature of the Hazardous Materials

Class* – Definition of the Hazard

As defined in the NEC and the CEC for Division classified facilities

- Class I – Flammable gases
- Class II – Combustible Dusts
- Class III – Ignitable Fibres or Flyings
- Unclassified – Areas where Class I, II or III substances are not expected to be present in quantities as to require special precautions

*The use of "Class" with respect to "Zone" classified facilities is no longer necessary

- Zone definition defines the nature of the hazard
  - Zone 0, 1, 2 implies flammable fluids
  - Zone 20, 21, 22 implies combustible dusts
  - "Non-hazardous" implies no explosion hazard present

Class I, Division 1 (NFPA 70 Article 500 Definition)

A Class I, Division 1 location is a location

(1) In which ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors can exist under normal operating conditions, or

(2) In which ignitible concentrations of such flammable gases, flammable liquid–produced vapors, or combustible liquids above their flash points may exist frequently because of repair or maintenance operations or because of leakage, or

(3) In which breakdown or faulty operation of equipment or processes might release ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors and might also cause simultaneous failure of electrical equipment in such a way as to directly cause the electrical equipment to become a source of ignition.

Class I, Division 2 (NFPA 70 Article 500 Definition)

Class I, Division 2. A Class I, Division 2 location is a location

(1) In which volatile flammable gases, flammable liquid– produced vapors, or combustible liquid–produced vapors are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems or in case of abnormal operation of equipment, or

(2) In which ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors are normally prevented by positive mechanical ventilation and which might become hazardous through failure or abnormal operation of the ventilating equipment, or

(3) That is adjacent to a Class I, Division 1 location, and to which ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid– produced vapors above their flash points might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

IEC 60079-10-1 Definitions

Zone 0

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

Greater than 1000 hrs/year (10% of the time) *API RP 505*

Zone 1

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

Greater than 10hrs/year and less than 1000hrs/year

(0.1% – 10% of the time) *API RP 505*

Zone 2

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

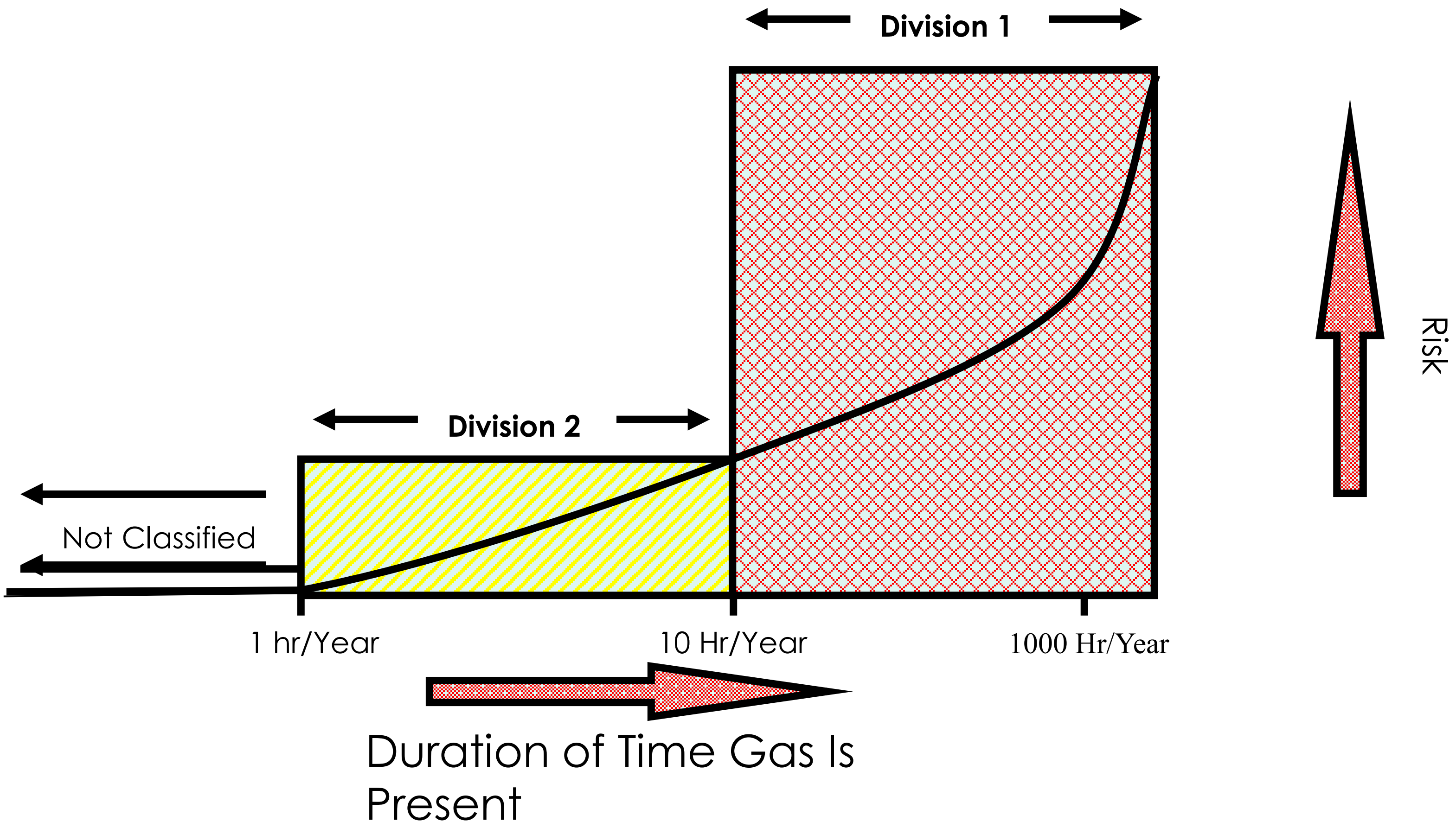
Less than 10hrs/year (<0.1% of the time) *API RP 505*

Important Facts to Remember

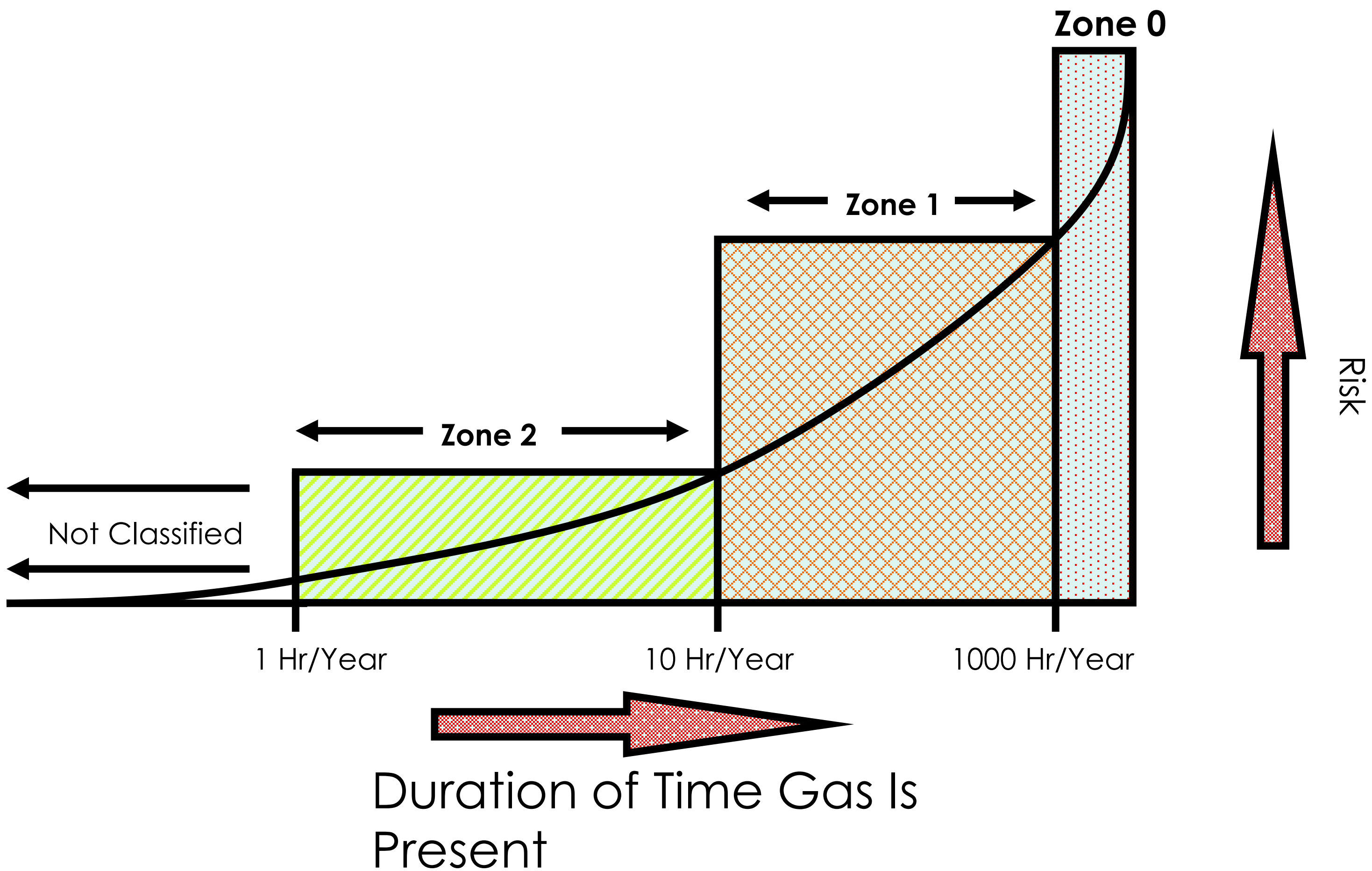
- Zone 1 and Division 1 locations are not the same
  - Division 1 is equivalent to the amalgamation of both Zone 0 and Zone 1
- Zone 2 and Division 2 locations are the same
  - Have an equivalent level of risk with respect to the time a hazard may exist

- *This differentiation has an impact on the type of electrical equipment that can be used in a given location*

Division Classification System



Zone Classification System



Interpreting the HAC Legend

Class	Definition of the Hazard
Zone or Division	Probability that a hazard may exist
Group	**Characteristics of the Hazardous Materials**
AIT	Auto-ignition temperature of the Hazardous Materials

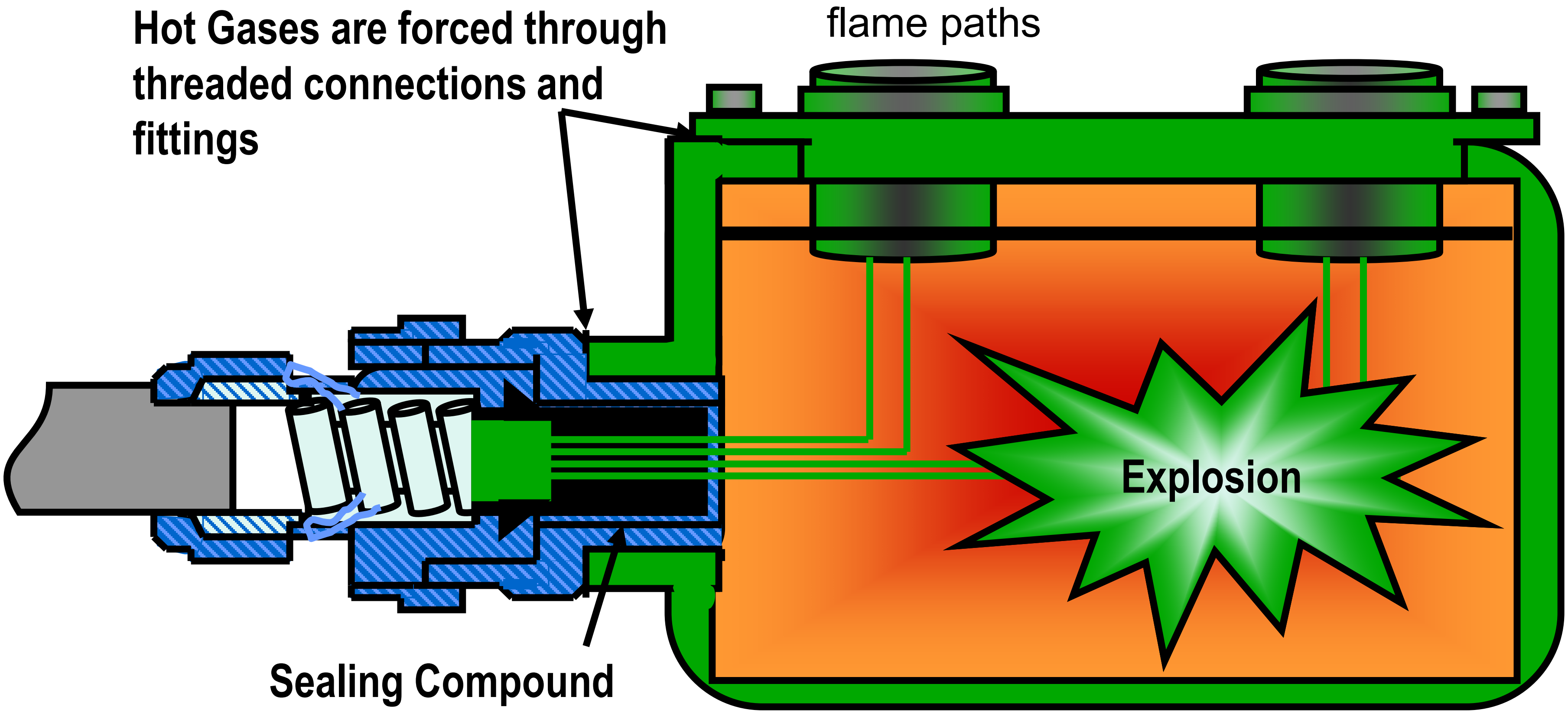
Group Classification (Gas)

- Related to the characteristics of the flammable materials
  - Important in the design of explosion proof electrical equipment and intrinsically safe components and systems

Group	Material
IIA	Methane
	Propane
	Butane
	Heptane
	Pentane
IIB	H2S
	Ethylene
IIC	Hydrogen
	Acetylene

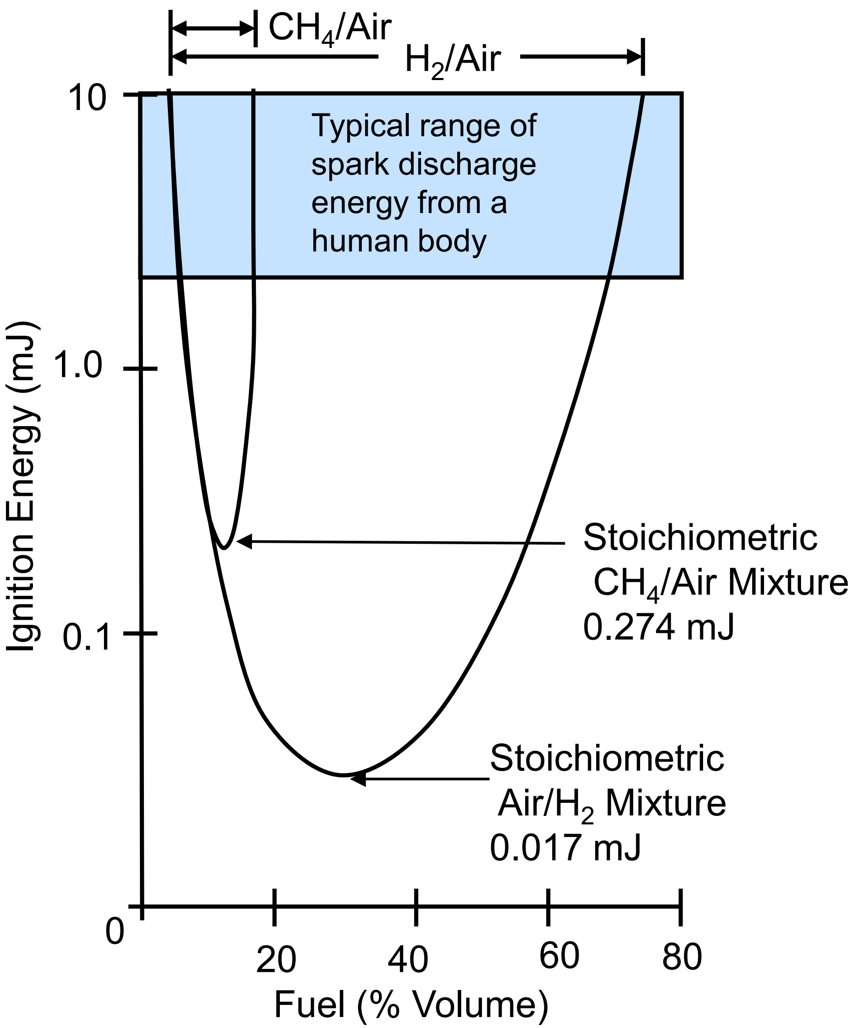
XP Equipment Protection Concept

Group classification impacts the product specifications applied to the various flame paths



Gases must be cooled sufficiently to prevent external atmosphere from being ignited

Intrinsically Safe Protection Concept



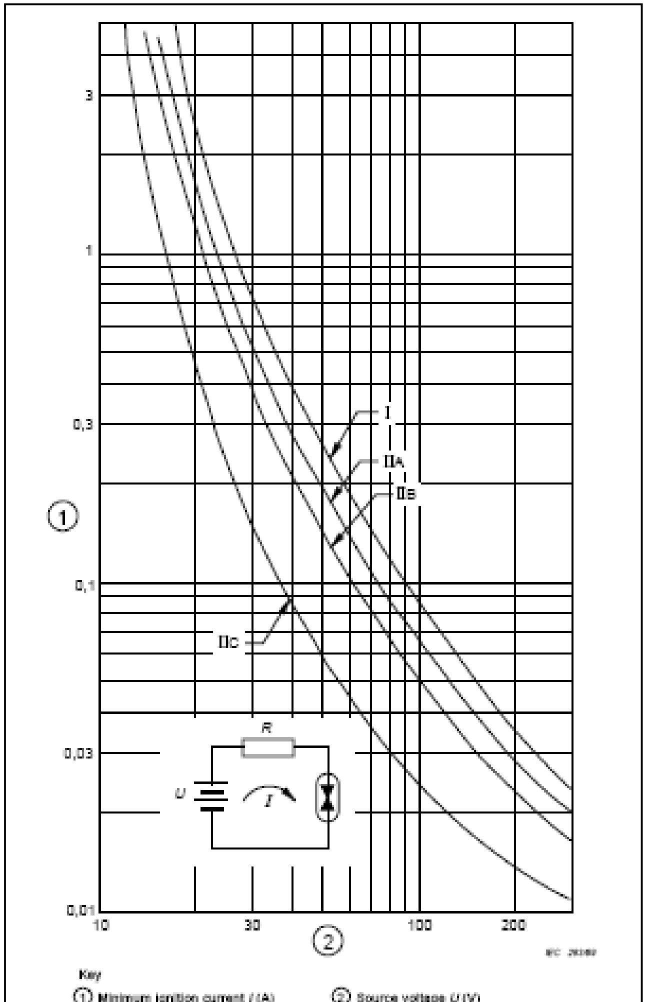


Figure A.1 – Resistive circuits

Division and Zone Group Classification Cross Reference

Group Classification Cross Reference Table	
Division	Zone
A	IIC
B	IIB + H_2
C	IIB
D	IIA

Lower Classification

Higher Classification

Equivalent Classification

Equipment marked IIC may be used in Group IIB+H_2, IIB and IIA classified locations
Likewise, equipment marked with Group B may be used in Group C and D locations

Interpreting the HAC Legend

Class	Definition of the Hazard
Zone or Division	Probability that a hazard may exist
Group	Characteristics of the Hazardous Materials
AIT	**Auto-ignition temperature of the Hazardous Materials**

Auto-Ignition Temperature

"the minimum temperature required to initiate or cause self-sustained combustion of a solid, liquid or gas independently of a heated or heating element."

NFPA 497

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

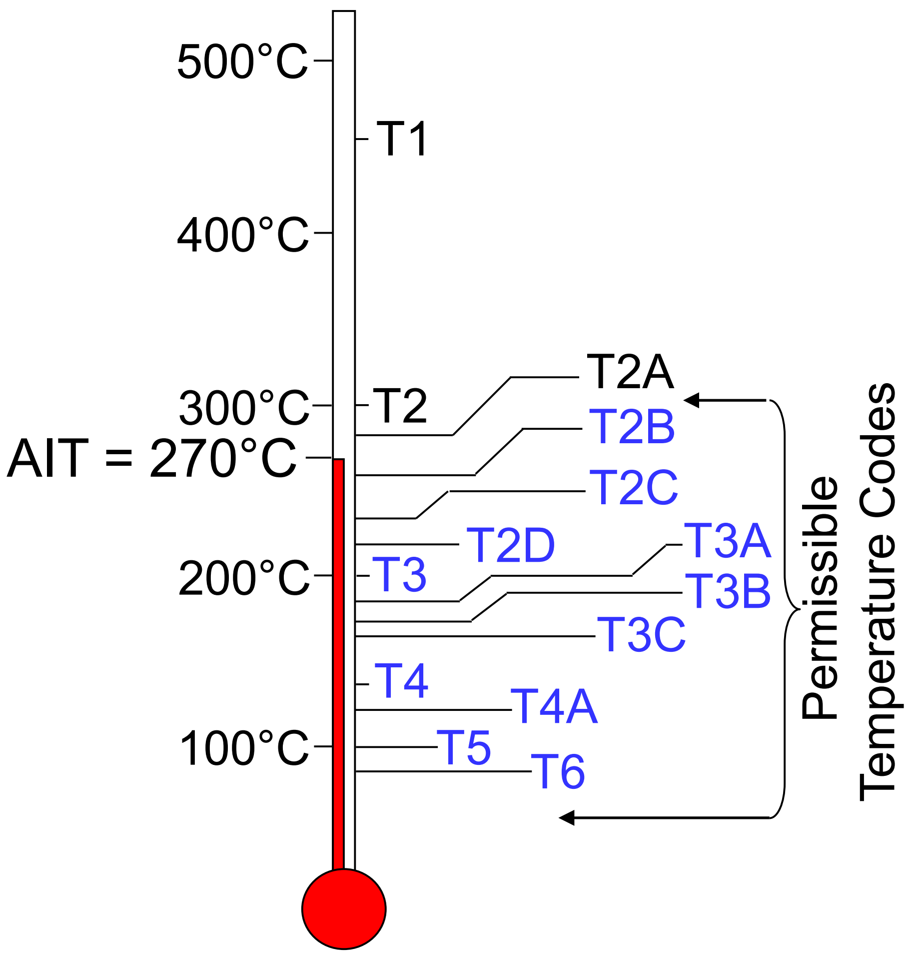
IEC 60079-10-1

Temperature Codes

- Used as a means to indicate the maximum surface operating temperature of an electrical device
  - The temperature codes indicated in yellow are the standard IEC codes
  - The intermediate codes are only applicable to the NEC Division and CEC Zone and Division certified products
  - CEC allows equipment to be marked with a maximum surface temperature in lieu of a temperature code
  - Often indicated on Hazardous Area Classification drawings instead of an AIT

T1 - 450ºC	T3A - 180ºC
T2 -300ºC	T3B - 165ºC
T2A - 280ºC	T3C - 160ºC
T2B - 260ºC	T4 - 135ºC
T2C - 230ºC	T4A - 120ºC
T2D - 215ºC	T5 - 100ºC
T3 - 200ºC	T6 - 85ºC

Temperature Code Application

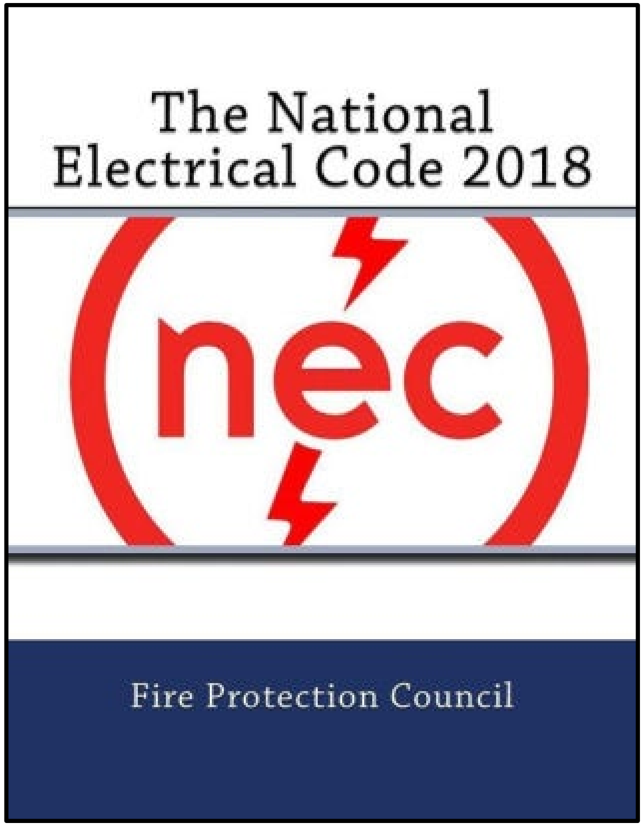


- Maximum surface operating temperature of the device cannot exceed the AIT defined for the area
  - A number of temperature codes are permitted so long as the surface temperature as defined by temperature code is lower than the AIT

Codes, Standards and Recommended Practices

Section 4

NFPA 70 (NEC)



- Sets the minimum standards for electrical installations in hazardous locations in the US
  - Article 500 applies to Division classified facilities
  - Article 505 applies to Zone Classified facilities
    - Must be done under the supervision of a Registered Professional Engineer
      - Reference Article 505.7A
- All areas designated as hazardous (classified) locations shall be properly documented
  - Reference Article 500.4A and 505.4A

NFPA 70 (NEC)

- NEC provides descriptions c/w diagrams to assist the use in classifying a hazardous location for the following:

  - Article 511 - Commercial Garages
  - Article 513 - Aircraft hangers
  - Article 514 - Motor fuel bulk storage plants
  - Article 515 - Bulk storage plants
  - Article 516 - Paint application facilities

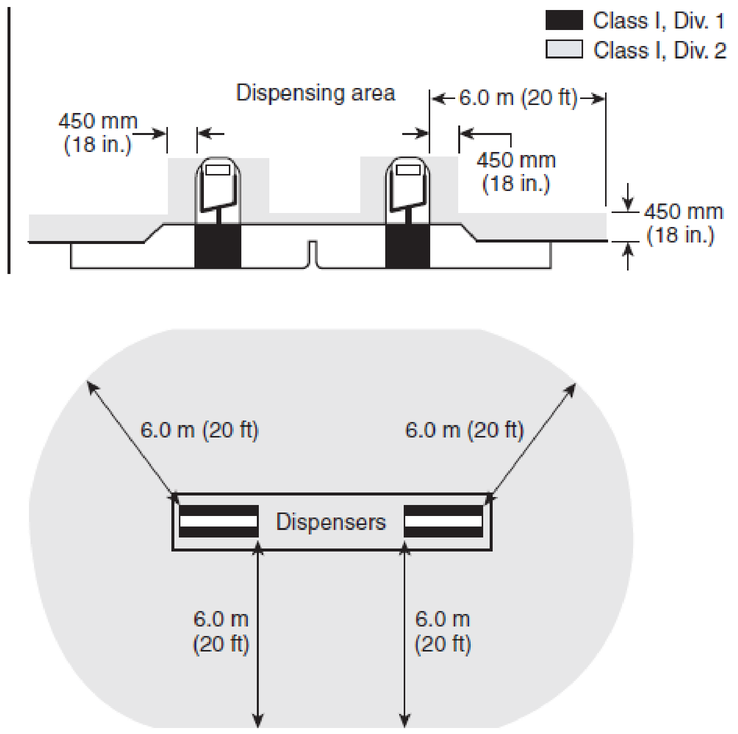
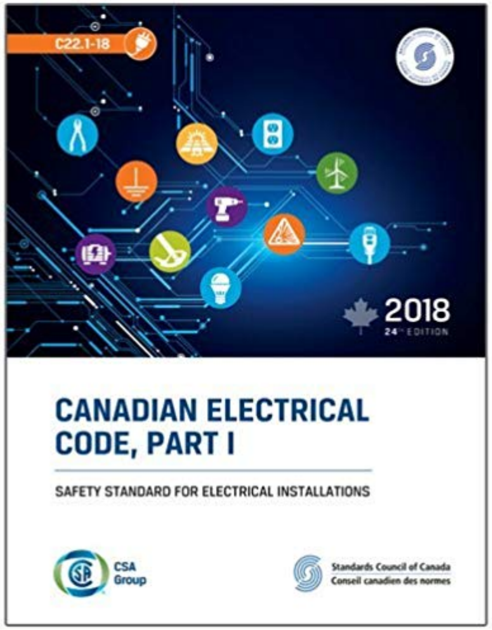


Figure 514.3 Classified Areas Adjacent to Dispensers as Detailed in Table 514.3(B)(1). [NFPA 30A:Figure 8.3.1]

Canadian Electrical Code



- Sets the minimum standards for electrical installations in hazardous areas in Canada
- Section 18 deals with Hazardous Locations classified using the Zone Method
  - Zone Method of Classification is the required method for new installations
- Appendix J refers to locations where the Division method of classification is used
  - Division method may be employed for existing installations at the discretion of the Owner/User

Canadian Electrical Code

- CEC Section 20 provides guidance on area classification for:
  - Commercial Garages
  - Aircraft Hangers
  - Motor Fuel Dispensing Facilities
  - Bulk Storage Plants
  - Paint Application Facilities
  - Table 63 provides guidance for propane dispensing, container filling and storage
  - Diagrams 4 – 9 in Diagrams section of CEC provide additional guidance for a variety of common applications

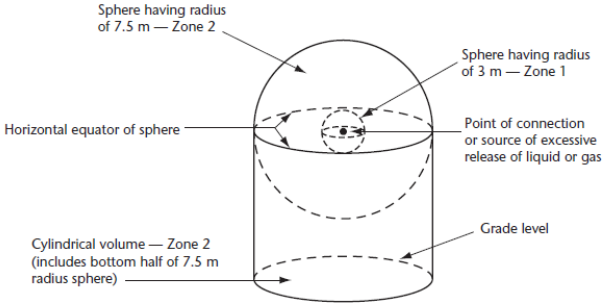


Diagram 7
Extent of hazardous location for tank vehicle and tank car loading and unloading
(See Part B of Table 63.)

API RP 500 & RP 505

Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2

API RECOMMENDED PRACTICE 500
THIRD EDITION, DECEMBER 2012

AMERICAN PETROLEUM INSTITUTE

Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2

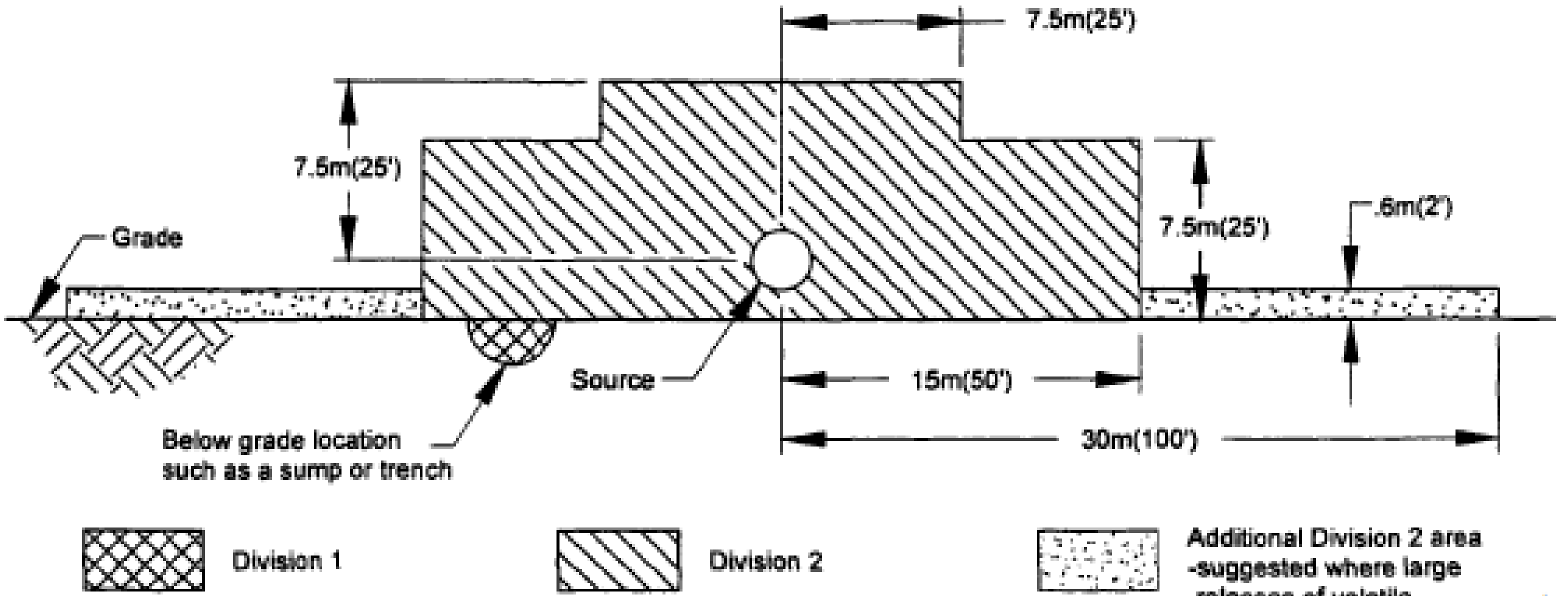
API RECOMMENDED PRACTICE 505
SECOND EDITION, AUGUST 2018

AMERICAN PETROLEUM INSTITUTE

API RP 500 & RP 505

- Prescriptive in nature
  - If this is the situation – this is how you should classify the area.
- Does not attempt to describe the properties of flammable materials
  - References NFPA 497 for flammable material properties
- The extent of classified areas indicated are based on experience

RP 500 Figure 20

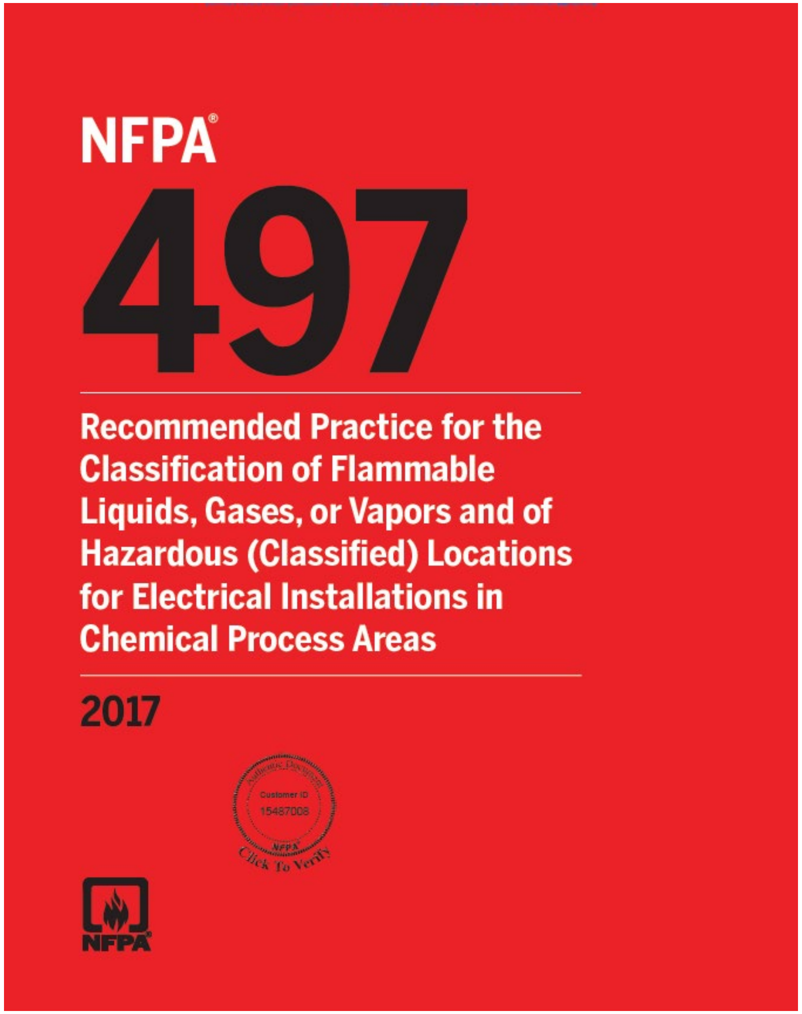


Note:

Distances given are for typical refinery installations: they must be used with judgement, with consideration given to all factors discussed in the text. In some instances, greater or lesser distances may be justified.

Figure 20—Adequately Ventilated Process Location With Heavier-Than-Air Gas Or Vapor Source Located Near Grade
(See Section 9.2.1.1)

NFPA 497

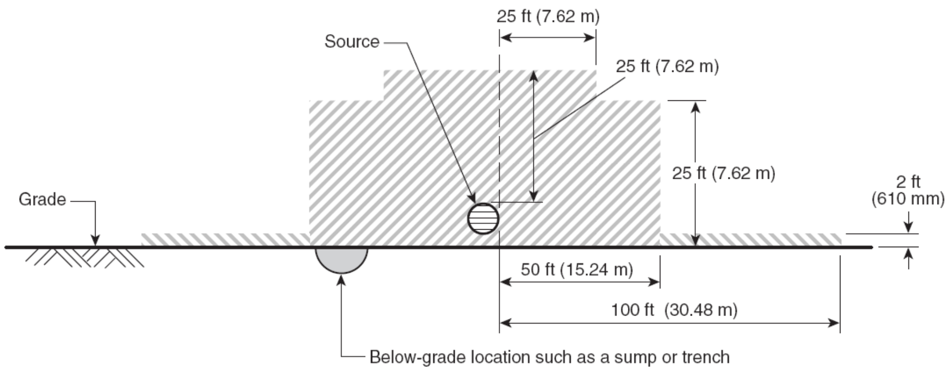


- Developed for the classification of chemical process plants
  - Based on the premise that the classification of chemical plants should be less strict than for petrochemical facilities
  - Appropriate for small to mid size chemical plants

NFPA 497

- Incorporates both the Zone and Division method of Classification into one document
- Incorporates an extensive list of Flammable and Combustible materials c/w their physical properties
- Incorporates a list of point source diagrams to assist the user in defining the extent of a classified area
  - Size of a classified area is dependent on the volume, pressure and flow rate within the process

NFPA 497 Figures



Material: Flammable liquid

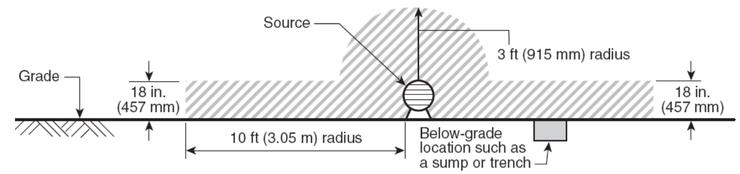
	Small/low	Moderate	Large/high
Process equipment size			X
Pressure		X	X
Flow rate			X

Zone 1

Zone 2

Additional Zone 2 location. Use extra precaution where large release of volatile products may occur.

FIGURE 5.10.1(g) Leakage Located Outdoors, at Grade. The material being handled is a flammable liquid.



Material: Flammable liquid

	Small/low	Moderate	Large/high
Process equipment size	X	X	
Pressure	X	X	
Flow rate	X	X	

Zone 1

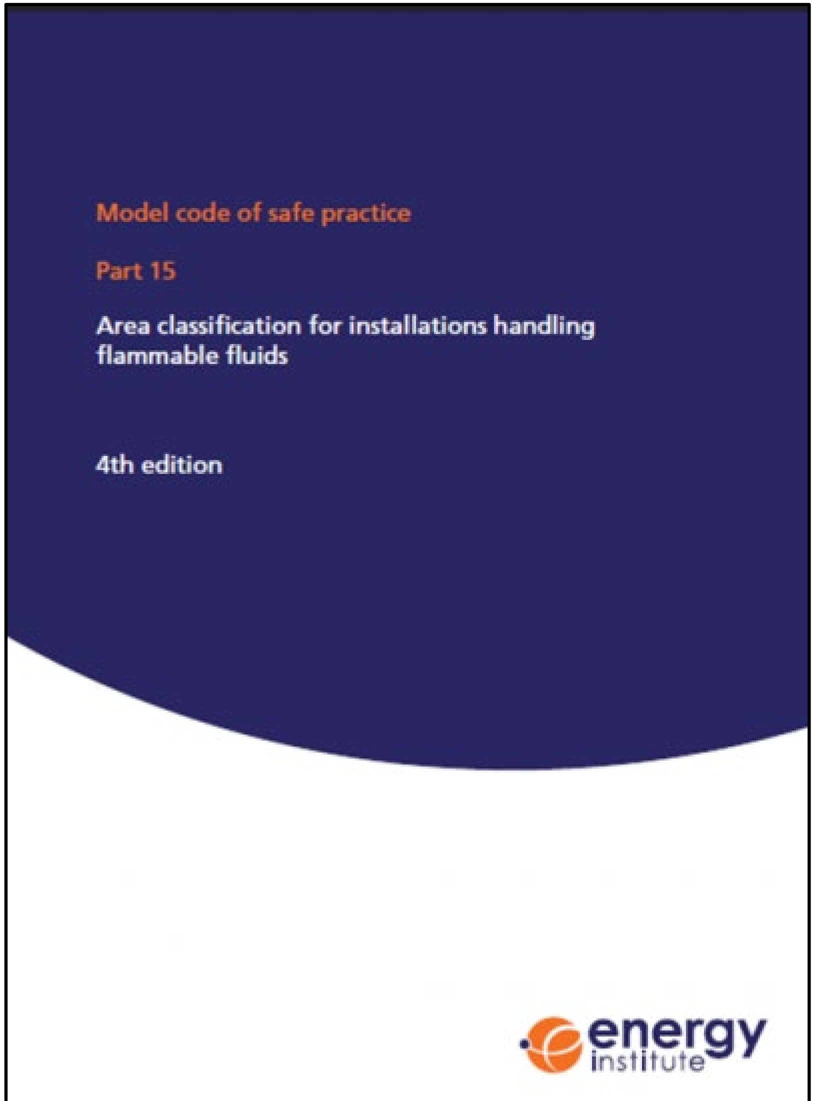
Zone 2

IGURE 5.10.1(a) Leakage Located Outdoors, at Grade. The material being handled is a flam- ıable liquid.

Table 5.7.4 Relative Magnitudes of Process Equipment and Piping that Handles Combustible Materials

Process Equipment	Units	Small (Low)	Moderate	Large (High)
Size	gal	<5000	5000–25,000	>25,000
Pressure	psi	<100	100–500	>500
Flow rate	gpm	<100	100–500	>500

EI 15
Model Code of Safe Practice



- Incorporates three different approaches to area classification
  - Introduces the concept of a risk-based approach to area classification
  - First code to use dispersion modeling as a basis for defining the extent of classified areas

IEC 60079-10-1


IEC 60079-10-1

Edition 2.0 2015-09

INTERNATIONAL STANDARD

colour inside

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.260.20

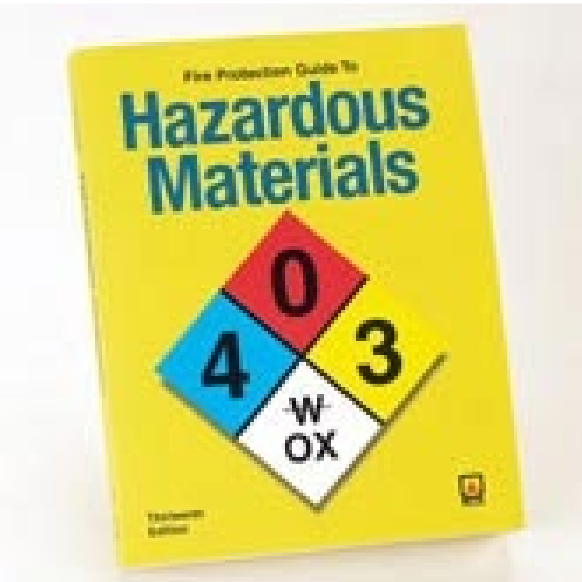
ISBN 978-2-8322-2867-8

- International standard used for the classification of facilities handling flammable fluids
- Edition 2 issued in 2015
- Edition 3 expected to be released in 2020

Codes vs. Recommended Practices

- NEC and CEC are mandatory requirements
  - Set the minimum safety standards
- OH&S rules are mandatory requirements
  - Vary between States and Provinces
- Recommended practices are not mandatory – They are guidelines only
  - API RP-500
  - API RP-505
- International Jurisdictions
  - Mandated codes will be referenced in national directives
    - Example – ATEX directive for Europe

NFPA Hazardous Materials Guide



- New reference standard published by NFPA for hazardous materials
- Incorporates:
  - NFPA 497 – Area Classification of Chemical Facilities
  - NFPA 499 – Area Classification of Combustible Dusts
  - NFPA 49 – Hazardous Chemicals Data
  - NFPA 325 – Flammable Materials Data

- New API RP 500 and RP 505 will now reference NFPA 497 as the bases for flammable material properties

ISO/IEC 80079-20-1

ISO IEC ISO/IEC 80079-20-1

Edition 1.0 2017-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Explosive atmospheres –
Part 20-1: Material characteristics for gas and vapour classification – Test methods and data

Atmosphères explosives –
Partie 20-1: Caractéristiques des produits pour le classement des gaz et des vapeurs – Méthodes et données d'essai

- Designed specifically for area classification purposes
  - Complete set of material properties
- Minor discrepancies in data between IEC 80079-20-1 and NFPA 497
  - Test methods are similar

Material Safety Data Sheets

- Can often provide useful information on the flammable properties of materials
  - Many have incomplete data with respect to flashpoint and auto-ignition temperatures
  - Do not incorporate key information related to the group classification of a flammable material

Classification of Facilities using IEC 60079-10-1

Section 5

Design Objectives

IEC 60079-10-1

- “*Zone 0 or zone 1 areas should be minimised in number and extent by design or suitable operating procedures. In other words, plants and installations should be mainly zone 2 or non-hazardous*”
  - Implies that flammable releases should not be intentional
  - Where a process is operating abnormally, the amount of flammable material released should be minimized

Area Classification Methodologies

- Simplified Methods
  - Use of diagrams to convey zones and extents
- Source of Release Methods
  - Based on calculations to determine zone classification and extent
- Operating experience
  - Facilities are classified based on operating experience with same or similar installations
- Combination of Methods

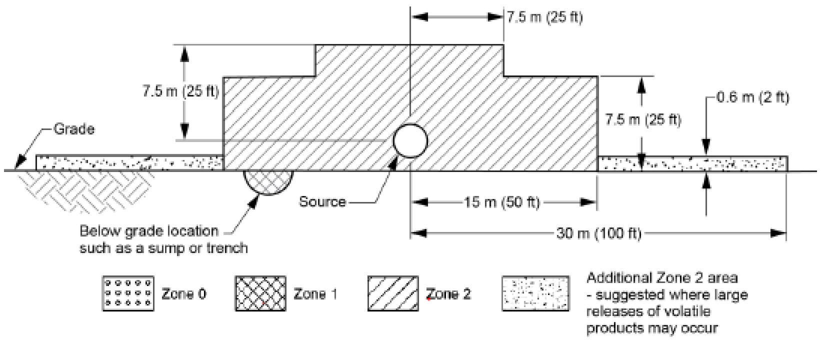
Simplified Methods

- Used where it is not practicable to make a proper assessments from individual sources of release
  - Process information is of poor quality
  - Plant documentation is incomplete
  - FEED stage of a project
- Involves applying standard diagrams depicting the classification surrounding typical sources of release Diagrams may be based on:
  - Industry publications
  - Operating experience.

Use of Industry Codes and National Standards (IEC 60079-10-1)

- *"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 of IEC-60097-10-1 provides a list of "acceptable standards"
  - API RP 505, NFPA 497, EI 15
  - The diagrams provided in the publications must be applied with "Good Engineering Judgement" taking in account the basis for the diagram in the publication and the actual situation to be classified

API RP 505 Diagrams



[1] Distances given are for typical refinery installations: they shall be used with judgment, with consideration given to all factors discussed in the text. In some instances, greater or lesser distances may be justified.

Figure 20—Adequately Ventilated Process Location with Heavier-than-air Gas or Vapor Source Located Near Grade (See 9.2.1.1)

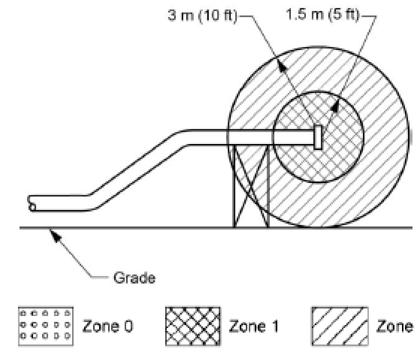
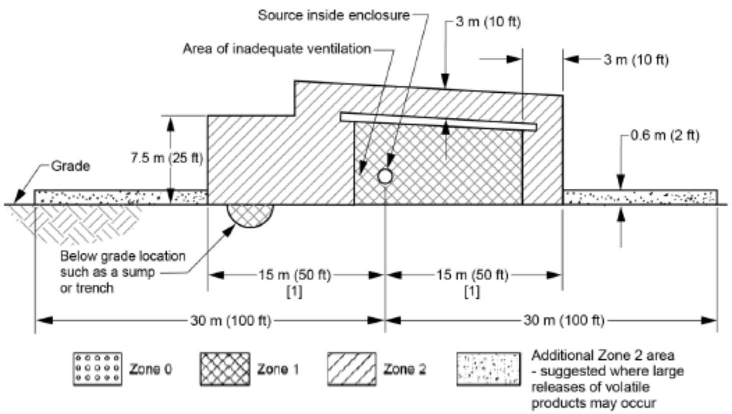


Figure 49—Ball or Pig Launching or Receiving Installation in a Non-enclosed, Adequately Ventilated Area (See 10.6.6.1.1, 10.6.6.1.2, 10.6.6.2.1, and 10.6.6.2.2)



[1] Apply horizontal distances of 15 m (50 ft) from the source of gas or vapor or 3 m (10 ft) beyond the perimeter of the building, whichever is greater, except that beyond unpierced vaportight walls the area is unclassified.

[2] Distances given are for typical refinery installations: they shall be used with judgment, with consideration given to all factors discussed in the text. In some instances, greater or lesser distances may be justified.

Figure 22—Inadequately Ventilated Process Location with Heavier-than-air Gas or Vapor Source (See 9.2.1.2)

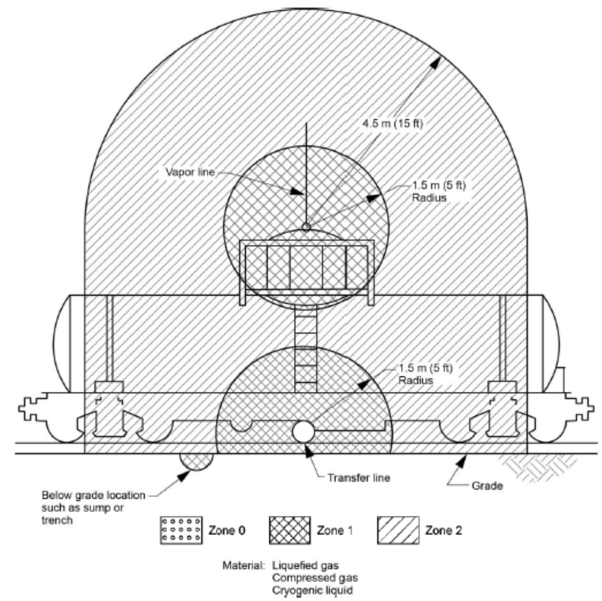
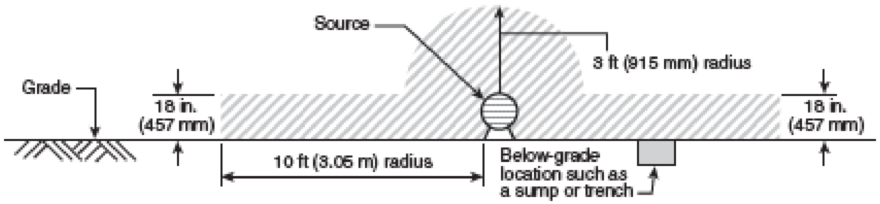


Figure 13—Tank Car or Tank Truck Loading and Unloading Via Closed System. Product Transfer Through Bottom Only (See 8.2.2.5)

NFPA 497 Diagrams



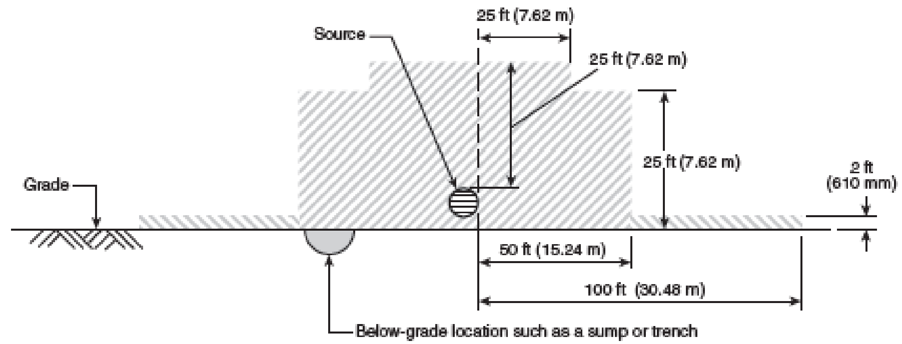
Material: Flammable liquid

	Small/low	Moderate	Large/high
Process equipment size	X	X	
Pressure	X	X	
Flow rate	X	X	

Zone 1

Zone 2

FIGURE 5.11.1(a) Leakage Located Outdoors, at Grade. The material being handled is a flammable liquid.



Material: Flammable liquid

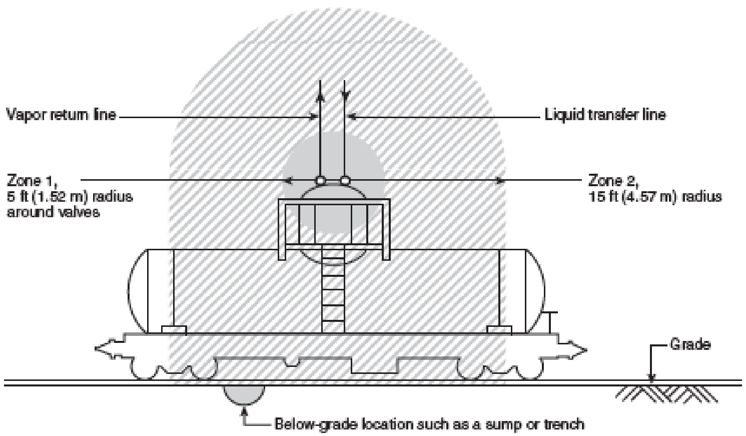
	Small/low	Moderate	Large/high
Process equipment size			X
Pressure		X	X
Flow rate			X

Zone 1

Zone 2

Additional Zone 2 location. Use extra precaution where large release of volatile products may occur.

FIGURE 5.11.1(g) Leakage Located Outdoors, at Grade. The material being handled is a flammable liquid.



Material: Flammable liquid, flammable compressed gas, flammable cryogenic liquid

Zone 1

Zone 2

FIGURE 5.11.5 Tank Car (or Tank Truck) Loading and Unloading via a Closed Transfer System. Material is transferred only through the dome. The material being transferred could be a liquefied or compressed flammable gas or a flammable cryogenic liquid.

Source of Release Method

1. Identify potential sources of release
2. Determine the release rate and grade of release for each source based on likely frequency and duration of release
3. Assess ventilation effectiveness;
4. Determine the appropriate zone based on grade of release and ventilation effectiveness;
5. Determine the appropriate extent of the zone

Customized Diagrams derived from Point Source Calculations

- Involves applying the "Point Source Method" to typical diagrams using worst case process parameters.
  - Effectively creating HAC details like the ones in API and NFPA and EI
  - Extents are based on point source calculations
  - Diagrams are applied to all release sources of a similar nature

Operating Experience

"When classifying areas consideration should be also given to a careful evaluation of the same or similar installations…

… Where documented evidence indicates that a particular plant design and operations are sound this may be used to support the classification chosen…

….furthermore, it is conceivable that an area could be reclassified based on new evidence"

IEC 60079-10-1
NFPA 497

Combination of Methods

- Different methods may be appropriate for classification of a facility at various stages of its design development
  - Preliminary (FEED) design: Simplified Methods
  - Detailed design: Point Source Methods
- Simplified methods can be applied to a group of similar equipment items (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 (Process buildings, gas compressors, pumps)

Typical Diagrams

- HAC Diagrams required for a typical process facility may include:
  - Process building
  - Process vessel
  - Piping manifold
  - Process pump and compressor
  - Process vents
  - Process cooler
- May be a combination of Industry publication diagrams and Point Source derived diagrams

Sources of Release

Section 6

Sources of Release

- The basic elements for establishing a zone classification is based on identification of the source of release and the determination of the "grade" of the release
- Each item of process equipment handling flammable materials should be considered as a potential source of release
  - Tanks
  - Pumps
  - Vessels
- Equipment items such as welded pipelines are not considered to be a source of release
  - May contain a flammable substance but cannot release it to atmosphere

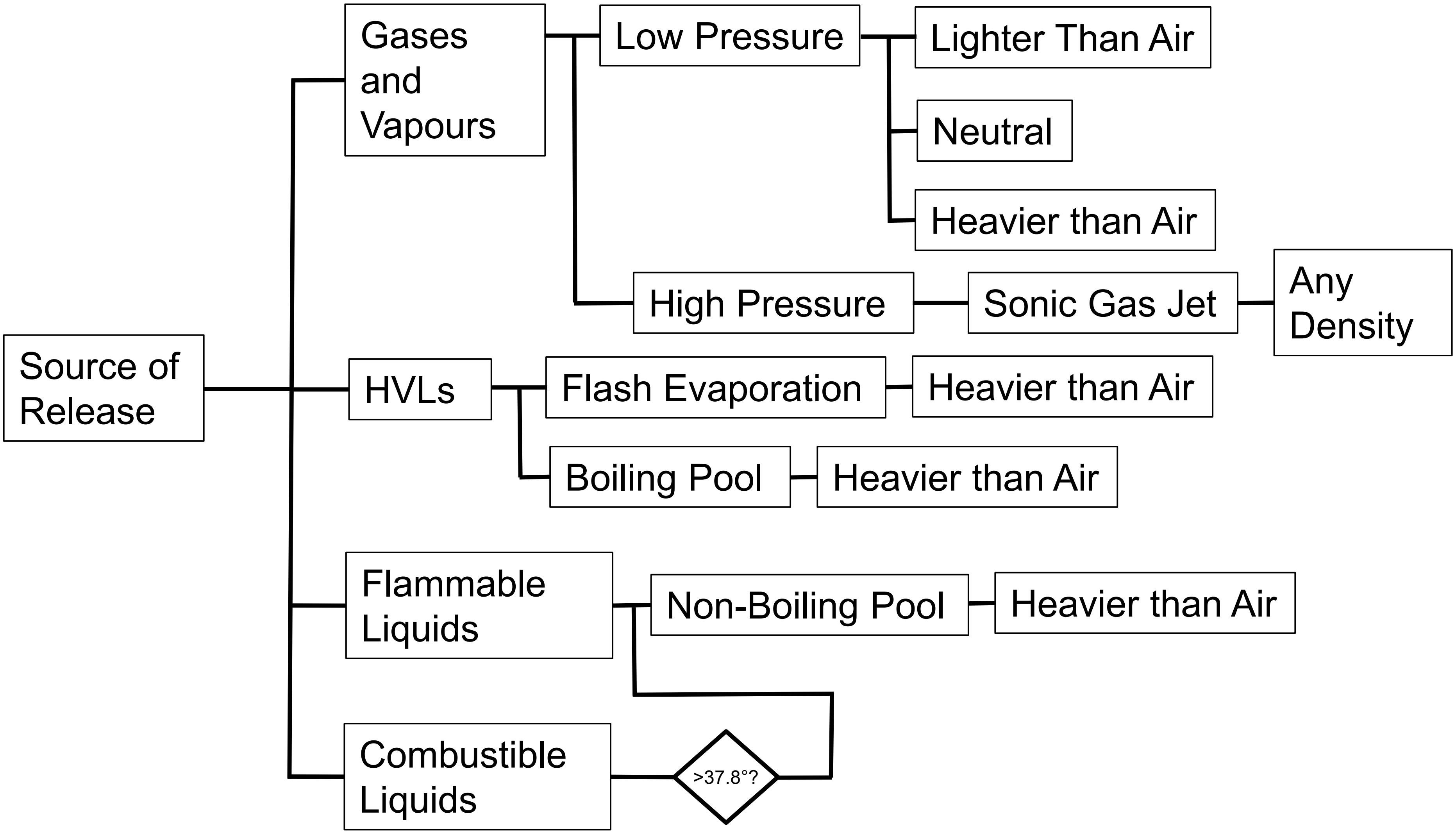
Grade of Release

- Sources of release that may release flammables to the atmosphere are graded according to the following criteria:
  - **Continuous:** release which is continuous or is expected to occur frequently or for long periods
  - **Primary:** release which can be expected to occur periodically or occasionally during normal operation
  - **Secondary:** 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

Grade the release

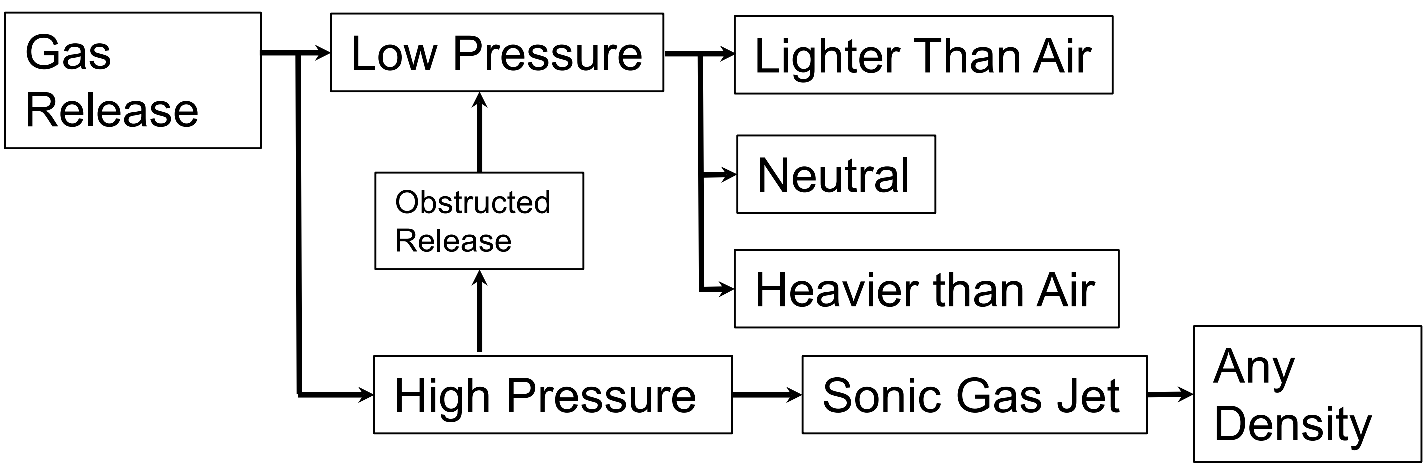
Source	Frequency	Duration	Grade
Process vent from analyzer	Continuous	Continuous	Continuous
Instrumentation manifold vent	Infrequent	Brief	Secondary
API Pump Seal	Occasionally	Short	Secondary
Filter Vessel	Periodically open for maintenance	Short	Primary
Piping Manifold	Infrequent	Short	Secondary

Forms of Release



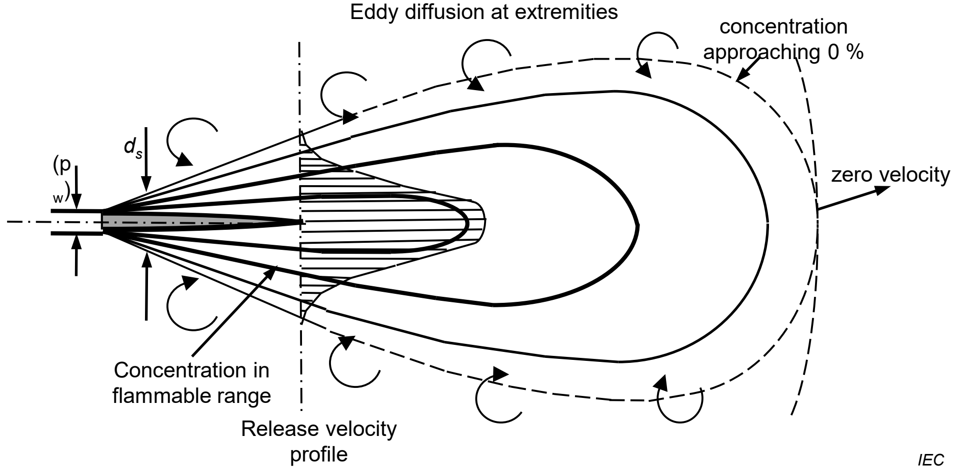
Gaseous Release

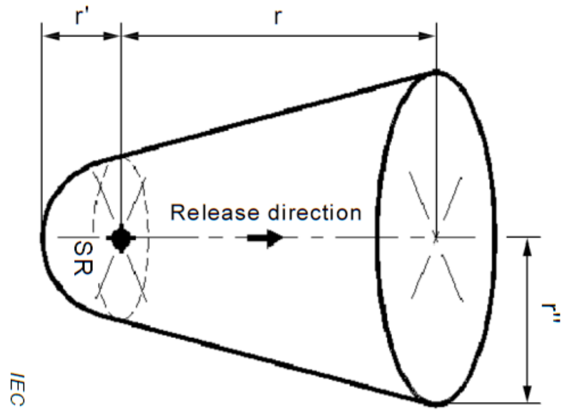
- Typically produces a gas jet or plume
- Influenced by:
  - Pressure at the point of release
  - Density of the gas relative to air
  - Degree of turbulent mixing
  - Air movement surrounding the release



Gaseous High-Pressure Release

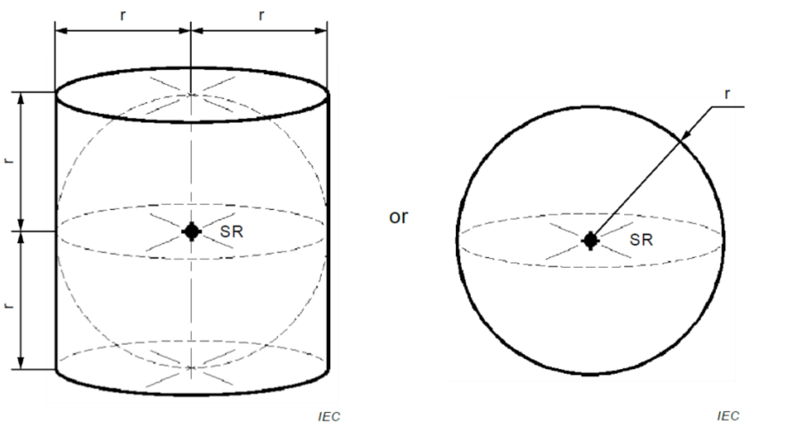
- High pressure release will produce jets of released gas which mix turbulently with the surrounding air
  - In non-enclosed areas, the jet release may be self-diluting

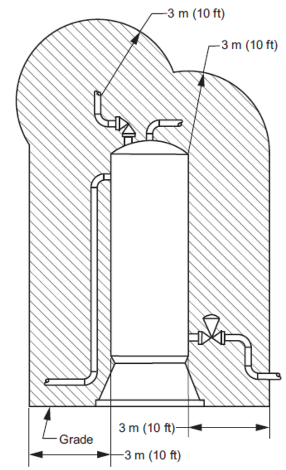




Gaseous Low-Pressure Release

- Low velocity releases will be highly influenced by the gas density
  - Gases that are less dense than air will move upwards
  - Gases denser than air will accumulate at ground level
- Over time, atmospheric turbulence will cause the released gas to mix with air and become neutrally buoyant
- Most area classification diagrams are based on a low-pressure release scenario





Calculating Release Rates

- Annex B of the IEC 60079-10-1 provides a structured approach for determining an appropriate release rate to based the area classification design upon
  - Calculation method to determine if a release is considered “low pressure” (subsonic or non-choked) release or “high pressure” (sonic or choked) release
  - Table to provide an appropriate “hole size” to base the calculation on
    - Hole size has a large influence on the release rate

Subsonic vs. Sonic releases

- Related to the velocity of the gas upon release
  - > Critical pressure → Sonic release
  - ≤ Critical pressure → Subsonic release
  - Most gas releases will be sonic releases
    - Quick check is to use the approximation $p_c = 1.89\ p_a$
      - *Approximation works for the majority of gases*
      - *Example: Natural gas application at 400 kPa*
        - » *Critical pressure using approximation = 1.89 x 101325 Pa = 191 kPa*
        - » *Critical pressure using formula = 187 kPA*
        - » *400 kPa > 191 kPa → application is sonic*
  - Subsonic releases are characteristic of low-pressure fuel gas and atmospheric storage tank blanket gas applications

Subsonic Release Rate of a Gas

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

- Where
  - W_g = mass release rate of gas (kg/s)
  - C_d = discharge coefficient of the release opening
  - S = cross section of the hole opening
  - M = molar mass of gas or vapour (kg/kmole)
  - Z = compressibility factor (dimensionless)
  - R = Universal gas constant (8314 J/kmole K)
  - T = Absolute temperature of the gas (°K)
  - γ = polytropic index of adiabatic expansion (dimensionless)
  - p_a = atmospheric pressure (101 325 Pa)
  - p = pressure inside the container (Pa)

Sonic Release Rate of a Gas

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

- Where
  - W_g = mass release rate of gas (kg/s)
  - C_d = discharge coefficient of the release opening
  - S = cross section of the hole opening
  - M = molar mass of gas or vapour (kg/kmole)
  - Z = compressibility factor (dimensionless)
  - R = Universal gas constant (8314 J/kmole K)
  - T = Absolute temperature of the gas (°K)
  - γ = polytropic index of adiabatic expansion (Ratio of Specific Heats) (dimensionless)
  - p_a = atmospheric pressure (101 325 Pa)
  - p = pressure inside the container (Pa)

Release hole size

- Cross section of a hole opening for secondary releases can be estimated using Table B.1 from IEC 60079-10-1

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 compre- ssors** [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.

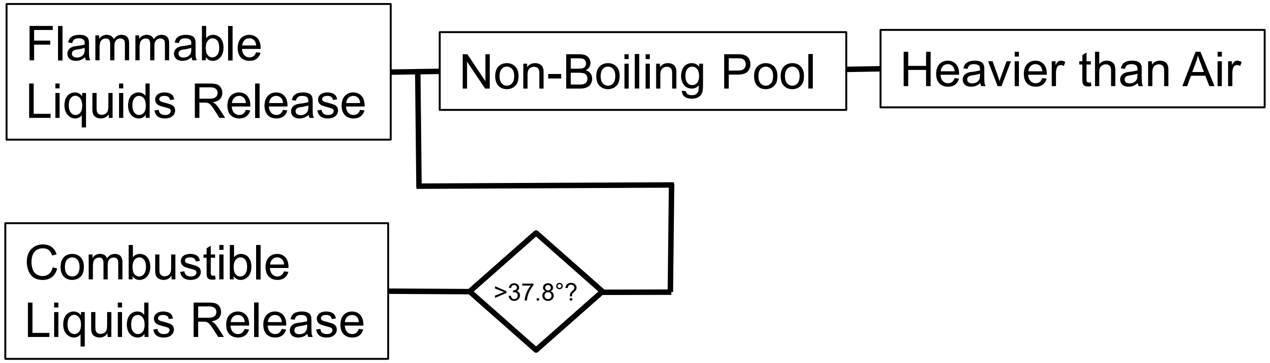
d Equipment Manufacturer's Data – Cooperation with equipment's manufacturer is required to assess the effects in case of an expected failure (e.g. the availability of a drawing with details relevant to sealing devices).

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.

Liquid Releases

- Liquids will typically form a pool on the ground close to the release source
- Vapour cloud may form surrounding the pool release
  - Rate of vapour cloud generation will be dependent on the vapour pressure of the fluid and the ambient temperature
  - Vapour cloud will typically be heavier than air



Release Rate of Liquids

- Release rate of liquid may be approximated by:

$$W = C_d \, S \sqrt{2 \rho \Delta p} \; (\text{kg/s})$$

- Where
  - W = release rate of a liquid in kg/s
  - C_d = discharge coefficient of the release opening
  - S = Cross section of the hole opening
  - ρ = liquid density (kg/m^3)
  - Δp = pressure difference across the leaks (pa)
- Once the liquid release rate has been determined, the rate of vapourization of the liquid release needs to be determined

Release Rate of Evaporative Pools

- Release rate may be approximated by:

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

- Where
  - W_e = Evaporation rate of a liquid (kg/s)
  - u_w = Wind speed over the liquid pool surface (m/s)
  - A_p = Pool surface area (m^2)
  - p_v = vapour pressure of the liquid at temperature T (kPa)
  - M = molar mass of gas or vapour (kg/kMole)
  - R = Universal gas constant (8314 J/kmole K)
  - T = absolute temperature of the fluid or liquid

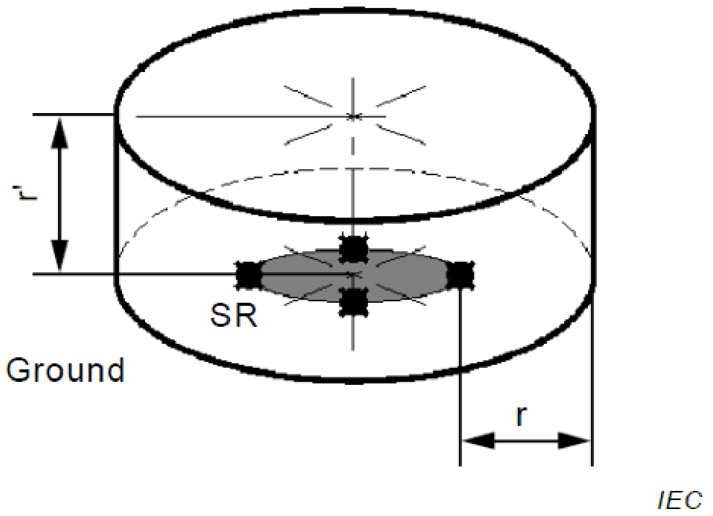
u_w = Wind Speed

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		
Typically, values in the table would result in an availability of ventilation as fair (see D.2).						

Volumetric Evaporation Rate

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



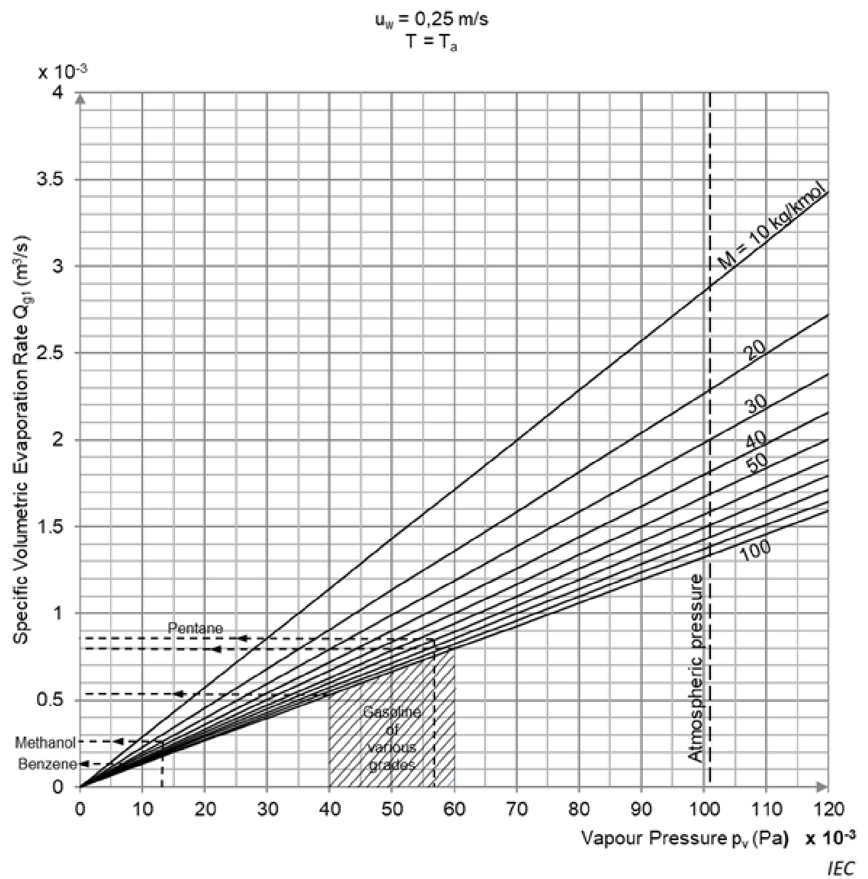
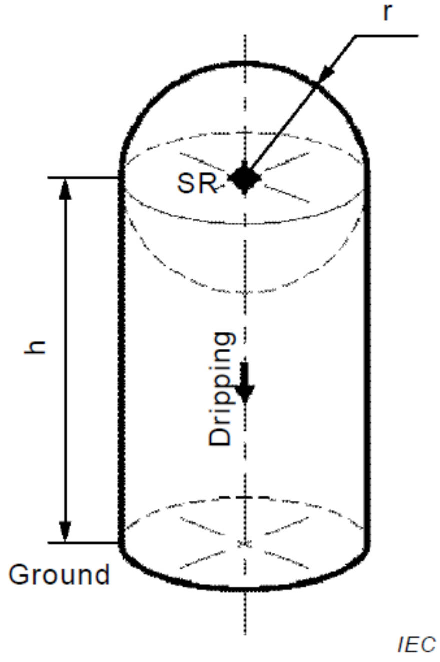
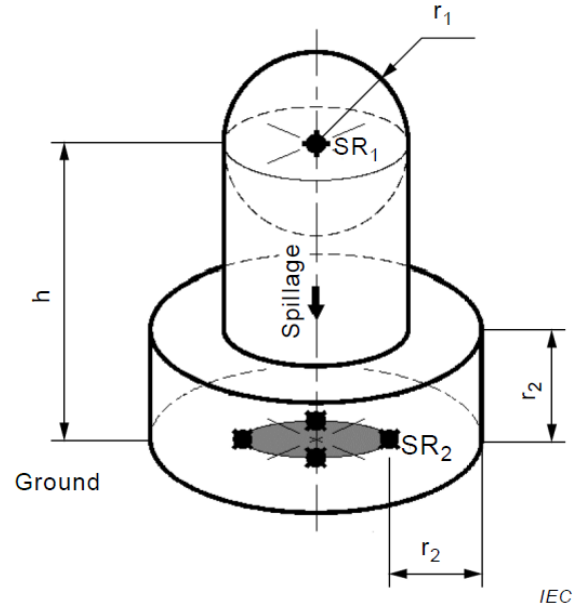


Figure B.2 – Volumetric evaporation rate of liquids
For a pool surface area of 1m² with liquid temperature = ambient temperature

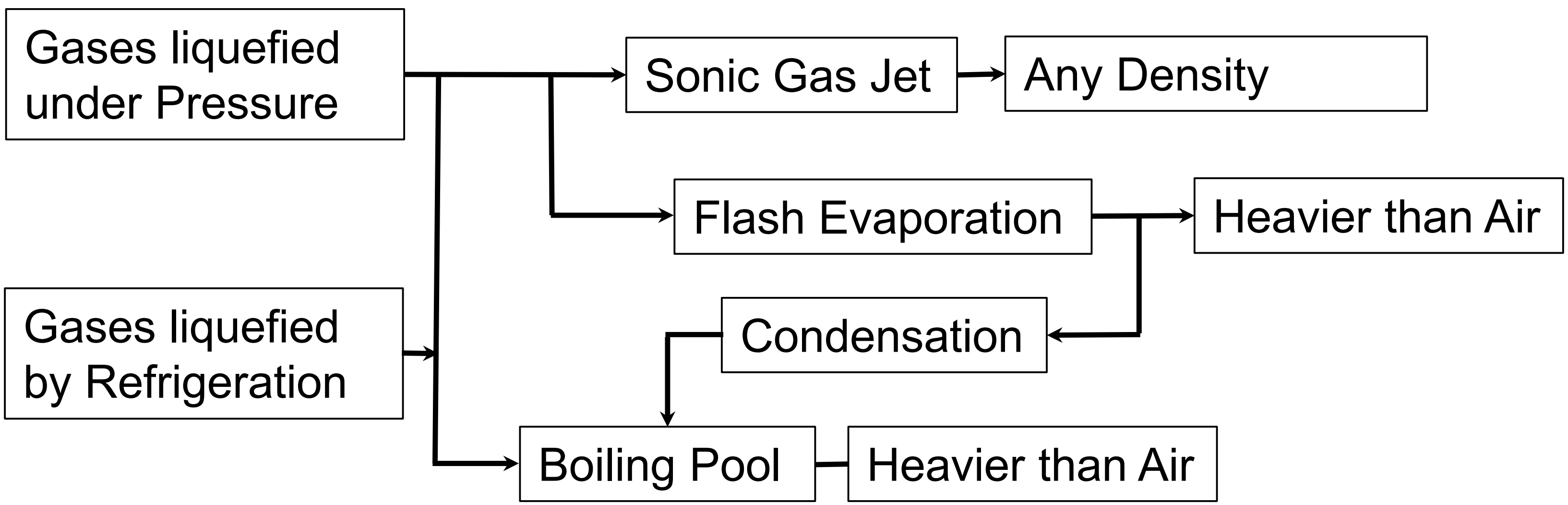
- Application Considerations
  - Two phase release
    - Two phase releases may result in both gas a liquid phases
      - Pool formation a distinct possibility





Gas Liquefied by Pressure/Temperature

- Gas is kept in a liquefied state by pressure/temperature
  - Examples:
    - Propane in a pressurized cylinder
    - LNG facilities



Gas Liquefied by Pressure

- A gas liquefied by pressure release results in the rapid evaporation of the fluid with significant cooling at the point of release
  - Known as “flash evaporation”
    - Evaporating liquid pulls energy from itself and the surrounding atmosphere and cools the leaking fluid
    - Often results in cold pools of fluid near the source of release
    - Pools of fluid will evaporate as the fluid warms
    - May create a visible dense cloud

Gas Liquefied by Refrigeration

- Often referred to as “Permanent Gases”
- Small leaks result in a gas release
- Large leaks may result in a cold pool of liquid
  - Cold pool will draw heat from the surrounding environment causing the pool to “boil” creating a cold dense cloud
  - Release will become neutrally buoyant as the gas temperature approach ambient temperatures

Aerosols/Flammable Mists

- Consists of small droplets of liquid suspended in air
  - May form a flammable mist cloud under certain conditions
    - Aerosol droplets may coalesce and condense out of the aerosol cloud forming a pool release on the ground
    - Behaves like a dense gas or neutrally buoyant gas
  - Flammability is dependent on:
    - Size of the droplets
    - Volatility of the flammable material
    - Air/Aerosol mixture
  - Aerosols may be a concern if the process incorporates high pressures and the release sources have very small openings

Zone Classification

Section 7

Zone Classification

- The likelihood of a flammable atmosphere being present is dependent on the grade of release and the ventilation available for an area
- For a given application, ventilation is evaluated in terms of its “effectiveness” and its “availability”
  - Ventilation effectiveness is described by its ability to dilute a release
  - Ventilation availability is defined by its ability to provide a reliable source of ventilation
- Table D.1 of Annex D provides guidance in defining the appropriate zone classification

Zone Classification based on Grade of Release and Ventilation

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 is commonly not considered as good.

Grade of Release

- **Continuous:** release which is continuous or is expected to occur frequently or for long periods
  - Examples:
    - Process vent from a flammable liquid tank
    - Surface of a flammable liquid in a sump
- **Primary:** release which can be expected to occur periodically or occasionally during normal operation
  - Examples:
    - Water drainage points on a vessel containing flammable liquids
    - Closure hatch on a pig launcher
- **Secondary:** 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
  - Examples:
    - Flanges connections and pipe fittings
    - Relief valves and vents

Effectiveness of Ventilation

- Ventilation effectiveness is described by its ability to dilute a release
  - Determined by the relative release rate and the ventilation velocity
    - Velocity is defined as a value that symbolizes atmospheric instability
    - Velocity may be influenced by the release itself (jet gas release) and/or by ambient air speed
  - Influenced by:
    - Ventilation rate
    - Distribution of the ventilation
    - Obstacles and their geometry
    - Location of the release source

Ventilation and Dilution

- Ventilation: movement of air and its replacement with fresh air due to the effects of wind, temperature gradients, or artificial means (fans, HVAC units)
- Dilution: the mixing of flammable vapour or gas with air which, over time, will reduce the flammable concentration
- Ventilation and air movement serve two functions:
  - Dilute a flammable release and promote dispersion to limit the extent of the zone
  - Avoid the persistence of an explosive atmosphere

Types of Ventilation

- Open Air – situations where free air movement is provided through all parts of the process
- Natural ventilation – ventilation within buildings resulting from pressure differences induced by wind or temperature gradients
- Artificial Ventilation – ventilation within buildings provided by fans or extractors
  - General artificial ventilation – Ventilation provided to a whole area
  - Local artificial ventilation – Ventilation provided near the point of release

Degree of Dilution – Assessment

- Assessment is performed using Figure C.1 using the "Release characteristic" and the "Ventilation velocity " assumed for a given situation

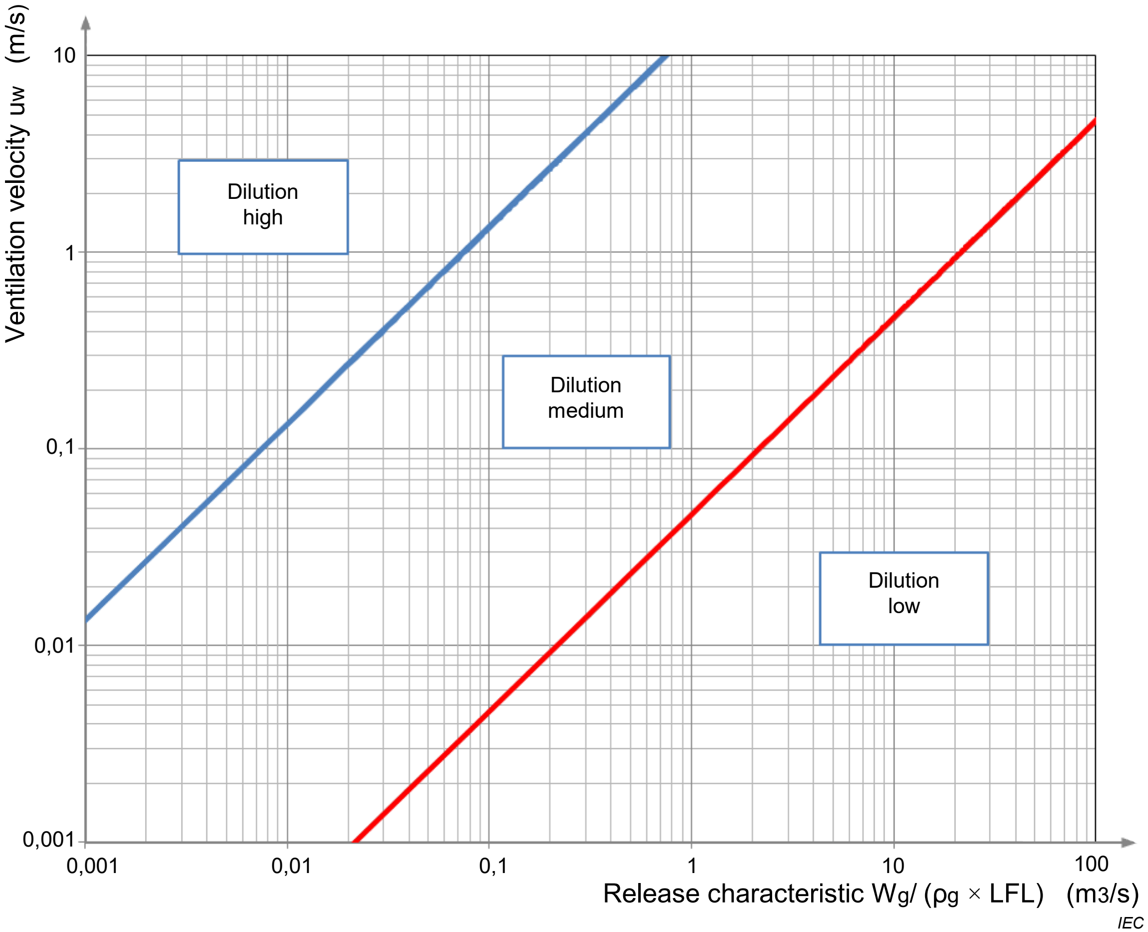


Figure C.1 – Chart for assessing the degree of dilution

Volume Release Characteristic (formerly Characteristic of Release)

- The Volume Release Characteristic describes the flammable source of release in the context of the size and rate of release.

$$Qc = \frac{W_g}{\rho_g \times LFL}$$ is the volume release characteristic in (m^3/s);

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

LFL	lower flammable limit (vol/vol)	To convert %LFL to LFL (vol/vol) divide %LFL by 100
M	molar mass of gas or vapour (kg/kmol)	
P_a	atmospheric pressure (101325 Pa)	
T_a	absolute ambient temperature (K);	To convert Celsius to Kelvin K = °C + 273.15
R	universal gas constant (8314 J/kmol K);	
W_g	mass release rate of flammable substance (kg/s), for mixtures, only the total mass of flammable substance should be considered;	

Ventilation velocity

- A measure of turbulence which is necessary to dilute a gas or vapour release
  - Air movement is required to promote a turbulent boundary layer between the release source and the surrounding atmosphere
    - Permits air to mix with the flammable release reducing the LFL

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		
Typically, values in the table would result in an availability of ventilation as fair (see D.2).						

Availability of Ventilation

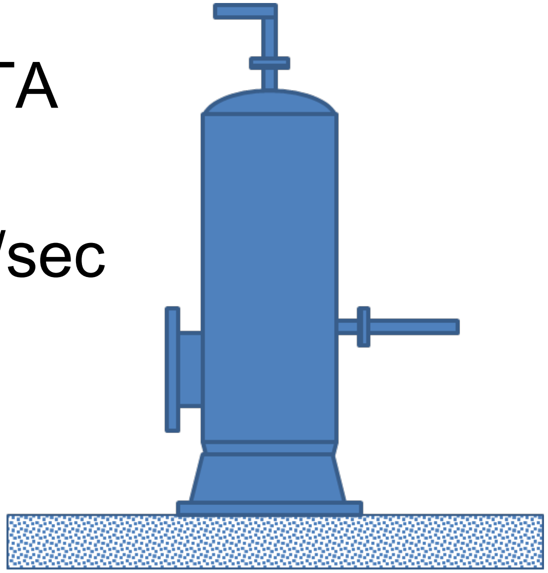
- Good: ventilation is present continuously
- Fair: ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods
- Poor: ventilation that does not meet the standard of fair or good, but discontinuities are not expected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

Availability of Ventilation – Open Air

- Lighter than air release (relative density < 0.8)
  - LTA releases tend to move upwards where the effective ventilation velocity is better
  - Availability can be considered "Good"
- Heavier than air release (relative density ≥ 1.0)
  - HTA release tend to move downwards where the effective ventilation velocity is lower
  - Availability of ventilation can be considered "Fair"

Open Air Assessment - Example

- Methane release from a flange in open air
  - Operating pressure = 5000 kPA
  - Operating temperature = 10°C
  - Grade of release → "Secondary"
  - Relative density of methane = 0.6 → LTA
    - Availability → "Good"
  - Mass release rate: W_g = 1.67 X 10^{-3} kg/sec
    - Based on 0.25mm^2 hole size
  - Density of gas: ρ = 0.643 kg/m^3
  - LFL = 4% = 0.04 vol/vol
  - Obstructed area



Parameter Calculation

- Volume Release Characteristic

$$Qc = \frac{W_g}{\rho_g \, LFL} = \frac{1.67 \times 10^{-3} \text{ kg/sec}}{0.643 \text{kg/m}^3 \times 0.04} = 0.065 \text{ m}^3\text{/sec}$$

- Ventilation velocity

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		
Typically, values in the table would result in an availability of ventilation as fair (see D.2).						

Degree of Dilution

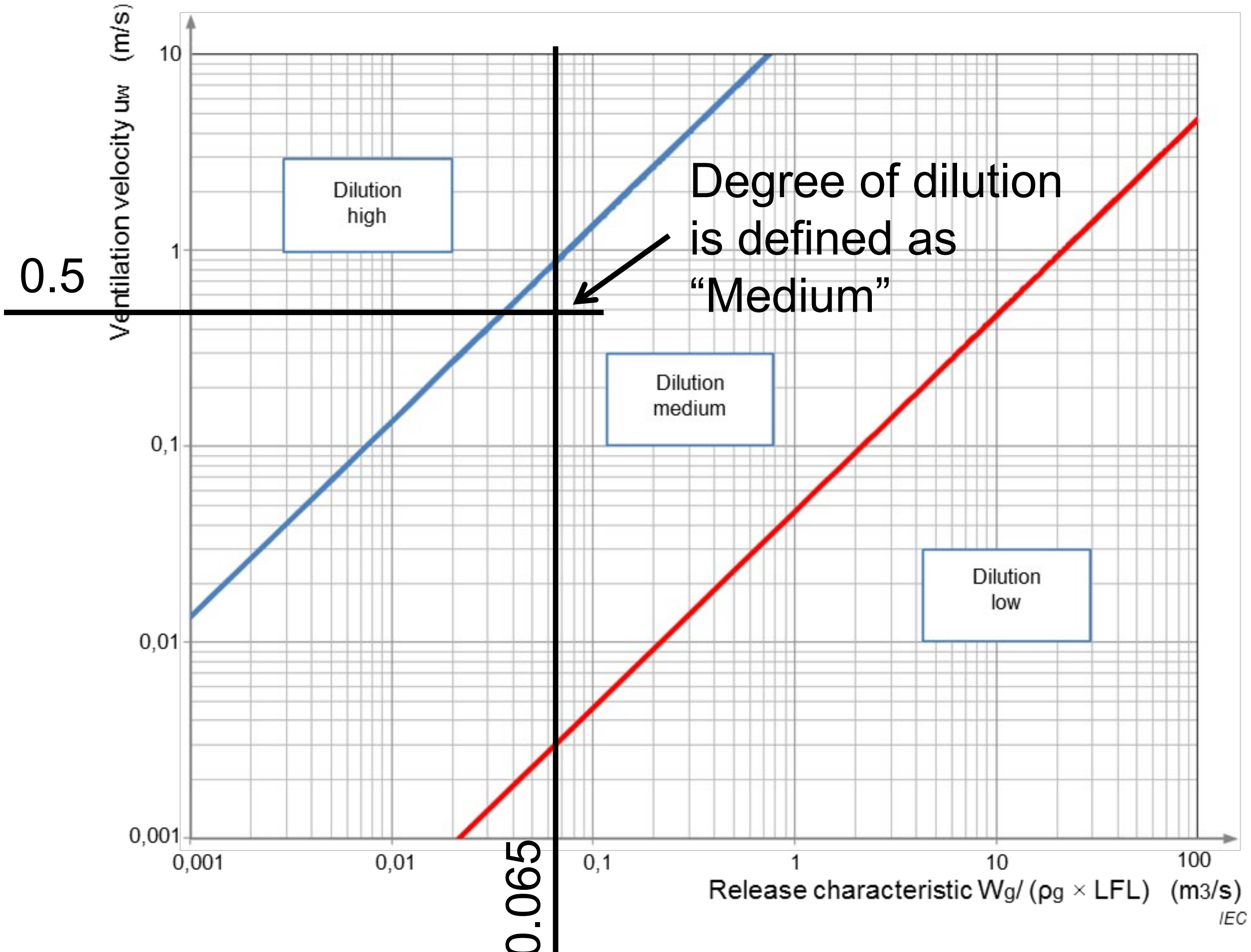


Figure C.1 – Chart for assessing the degree of dilution

Zone Classification Assessment

- Grade of release → “Secondary”
- Degree of dilution → “Medium”
- Availability → “Good”
  - (Methane is LTA)

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.

Zone 2 Classification is appropriate for this situation

Degree of Dilution – Open Air

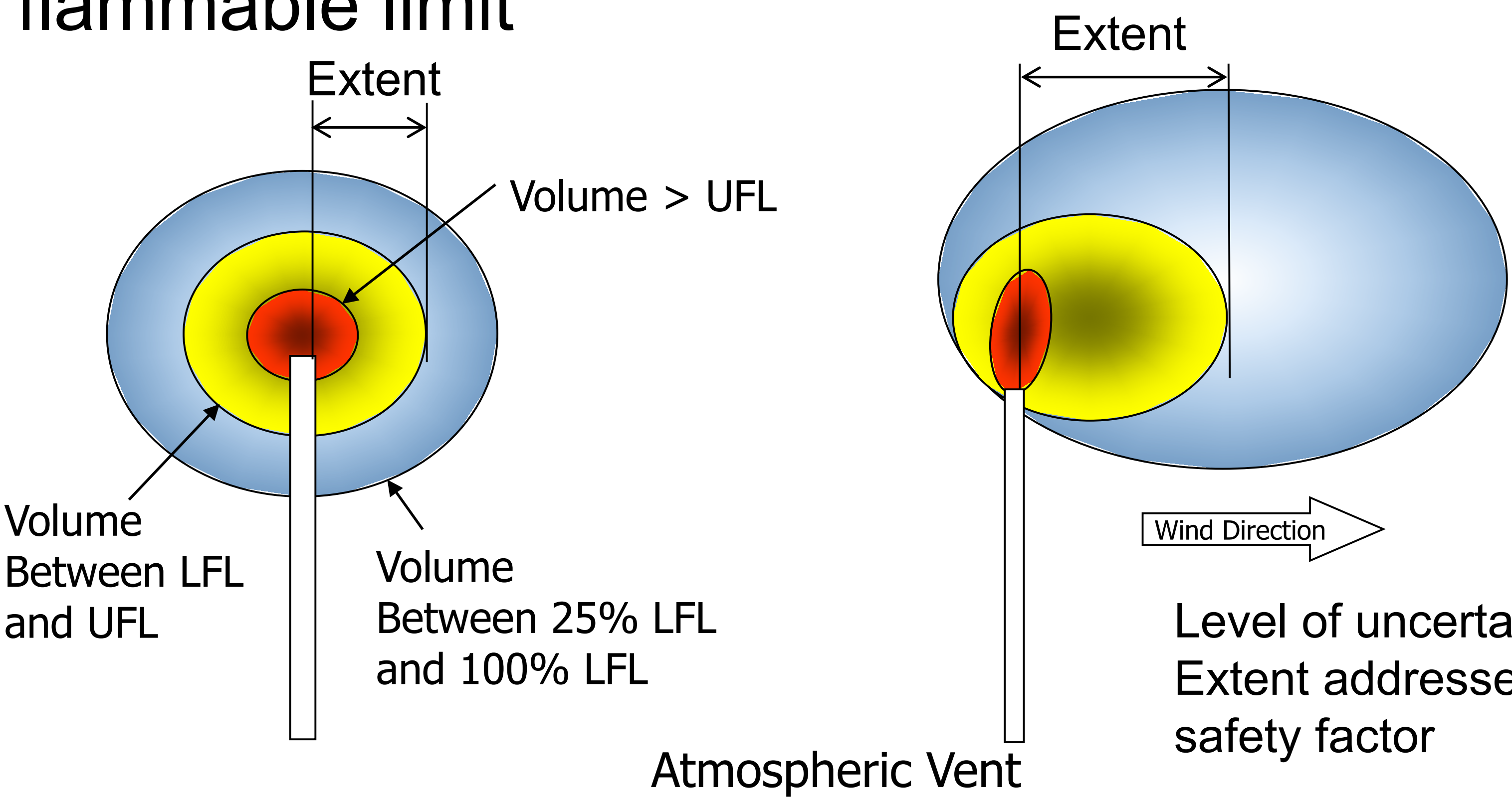
- In most outdoor locations with no restrictions
  - Degree of Dilution = Medium
  - Below grade locations = Low
- In open air conditions, the likelihood of a flammable atmosphere being present is mostly dependent on the "grade of release"
  - A "continuous" grade of release usually leads to a Zone 0 classification
  - A "primary" grade of release typically leads to a Zone 1 classification
  - A "secondary" release typically leads to a Zone 2 classification

Extent of a Zone

Section 8

Definition: Extent of a Zone

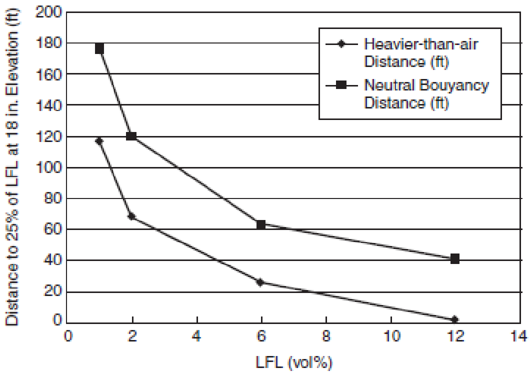
- The distance in any direction from the source of release to where a gas/air mixture will be diluted by air to a concentration below the lower flammable limit



Level of uncertainty wrt Extent addressed by a safety factor

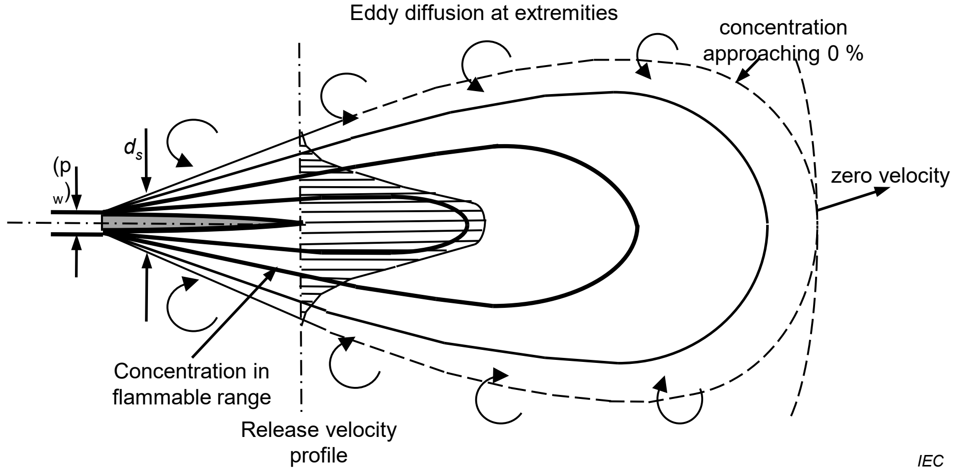
Extent may be influence by:

- Chemical properties of the flammable gas/vapour
  - Physical state upon release
    - Gas vs. Liquid
    - Volatility
      - Function of a materials vapour pressure vs. release temperature
      - The lower the flashpoint, the greater the extent
  - Density relative to air
    - Lighter than air releases will accumulate in the upper regions of enclosed spaces
    - Heavier than air release may flow into areas below ground level
  - Lower Flammable Limit
    - The lower the LFL, the greater the extent



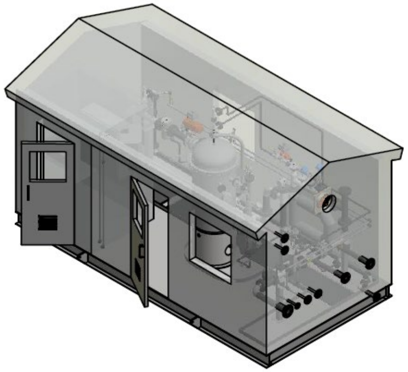
Extent may be influence by:

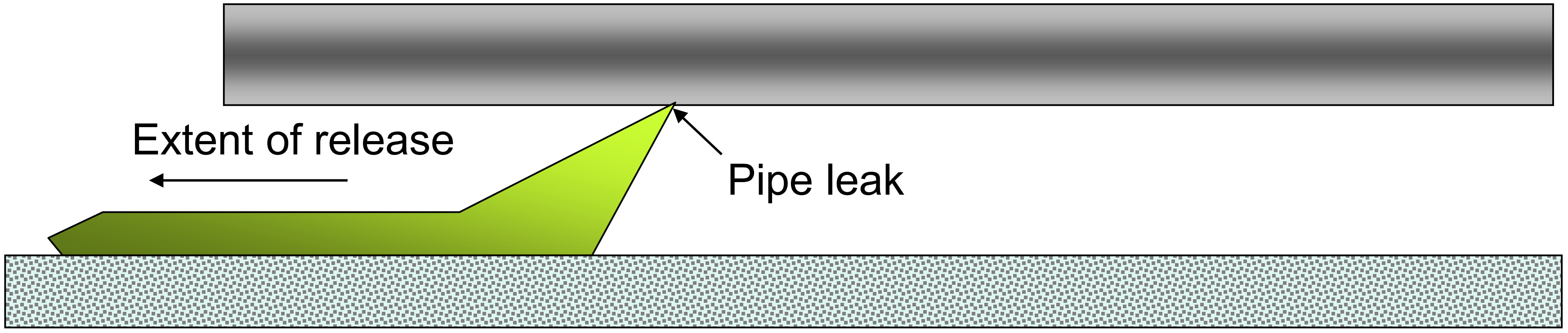
- Rate of release
  - Nature and type of release
    - ➢ Related to the physical characteristics of the release source
      - – Examples: Pool surface, flange, pump seal
  - Release velocity
    - ➢ Driven by release pressure
      - – High velocity releases may be self diluting
      - – Low velocity releases require air movement for dilution



Extent may be influence by:

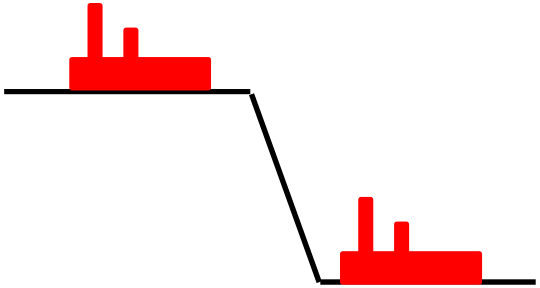
- Physical barriers
  - Enclosed spaces
    - Building walls or equipment enclosures
    - The use of vapour barriers to segregate classified locations from non-hazardous location
    - Use of pressurization in enclosed areas to limit extents

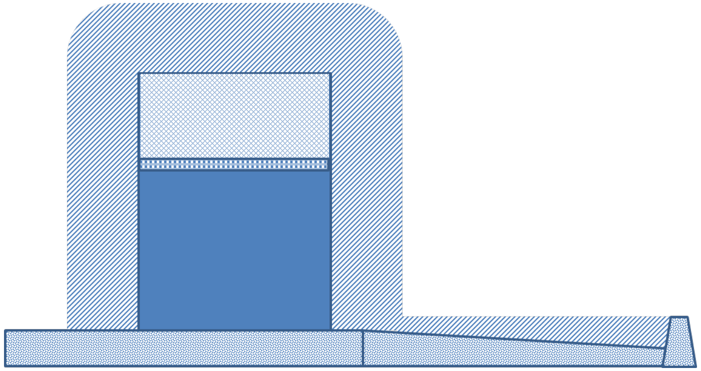




Extent may be influence by:

- Topography
  - Characteristics of the physical terrain
    - Spill containment dikes
    - Raised roads and drainage ditches surrounding sources of release
    - Plant terrain and elevations
    - Snow removal operations





Extent may be influence by:

- Ventilation
  - Likely the most important factor in determining the degree and the extent of a hazardous location
  - Function of air movement and the ability of the ventilation design to “dilute” a flammable release to a level below the LFL
    - Increased air movement will typically reduce the extent of a classification
    - Obstacles that impede air movement will increase the extent of a classification

Estimating the Extent

1. Predict the Type of Release
   - Jet release
     - A high-pressure gaseous release above its critical pressure (choked release)
   - Diffusive release
     - Low velocity gaseous release below its critical pressure (subsonic release) or a jet release that impinges on nearby surfaces
   - Heavy gas release
     - Heavy gas vapours typically resulting from an evaporative or boiling pool release
2. Calculate the volumetric release characteristic

$$Qc = \frac{W_g}{\rho_g \, LFL}$$

Estimating the Extent

3. Apply Figure D.1

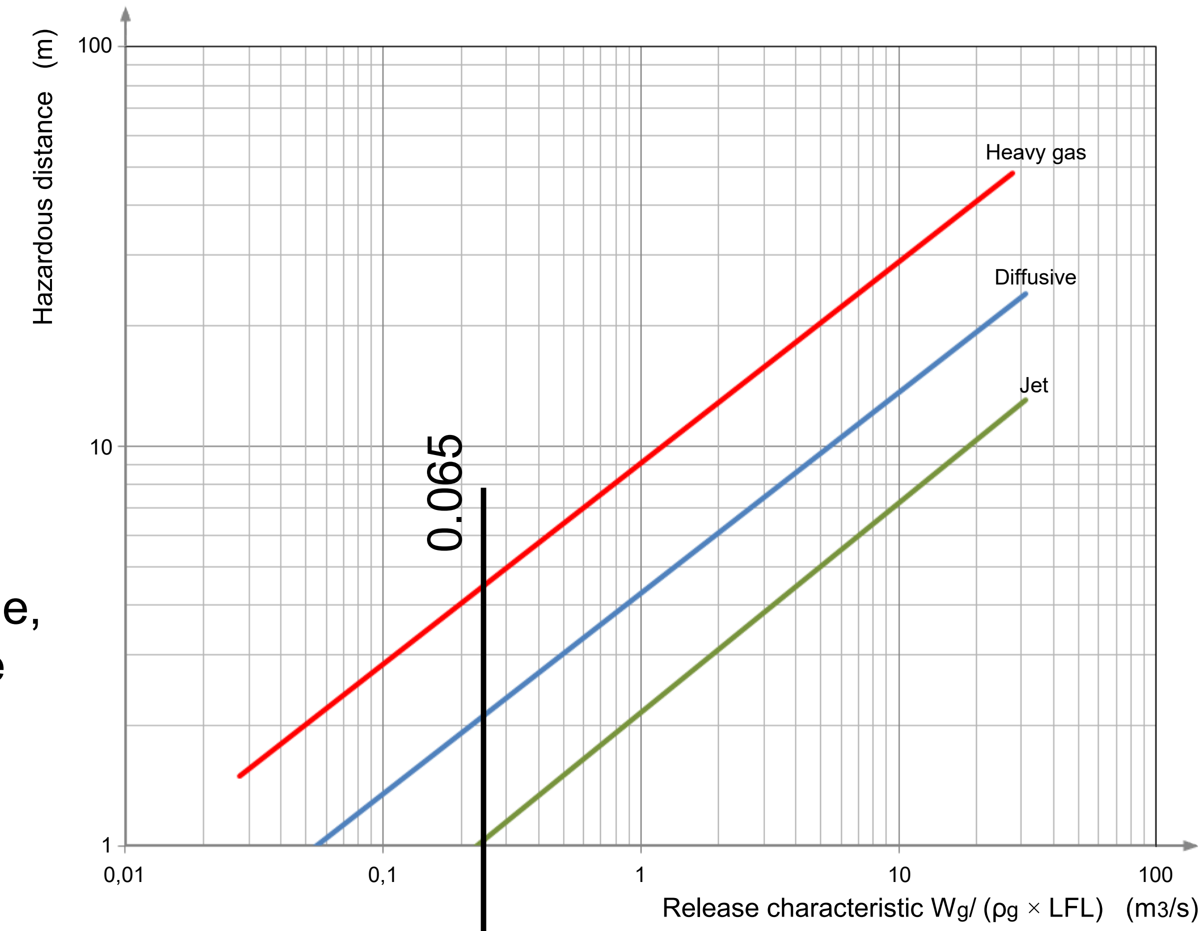


Figure D.1 – Chart for estimating hazardous area distances

Question:
From our last example, what curve should be used?

Extent Tutorial

- Estimate the appropriate extent for the following situations:
  - Pentane pool release with a volumetric release characteristic of 0.1
  - Methane gas compressor release with a volumetric release characteristic of 0.4
  - Extent surrounding a methane compressor building with a volumetric release characteristic of 0.4
  - Propane release with a volumetric release characteristic of 1.2

Figure D.1

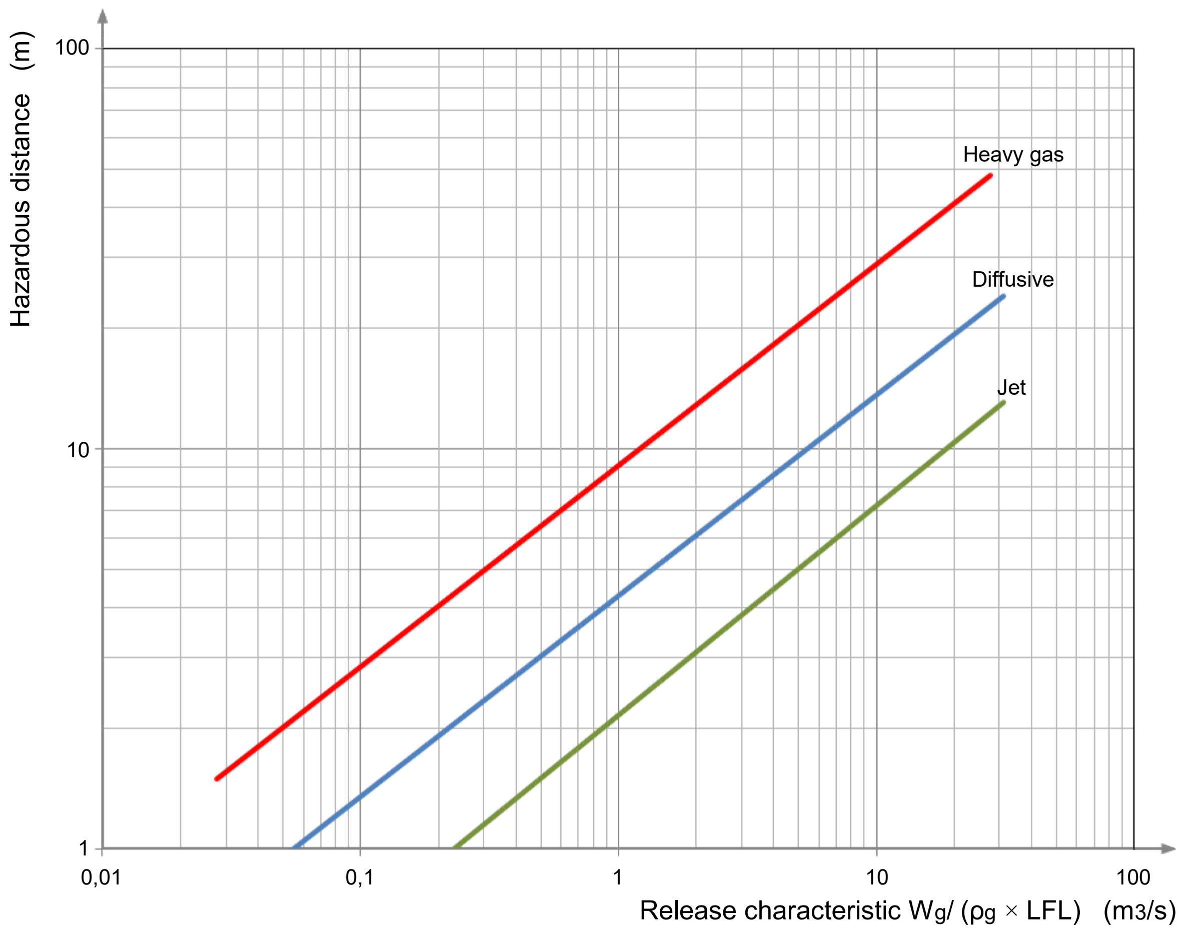


Figure D.1 – Chart for estimating hazardous area distances

Tutorial Answer

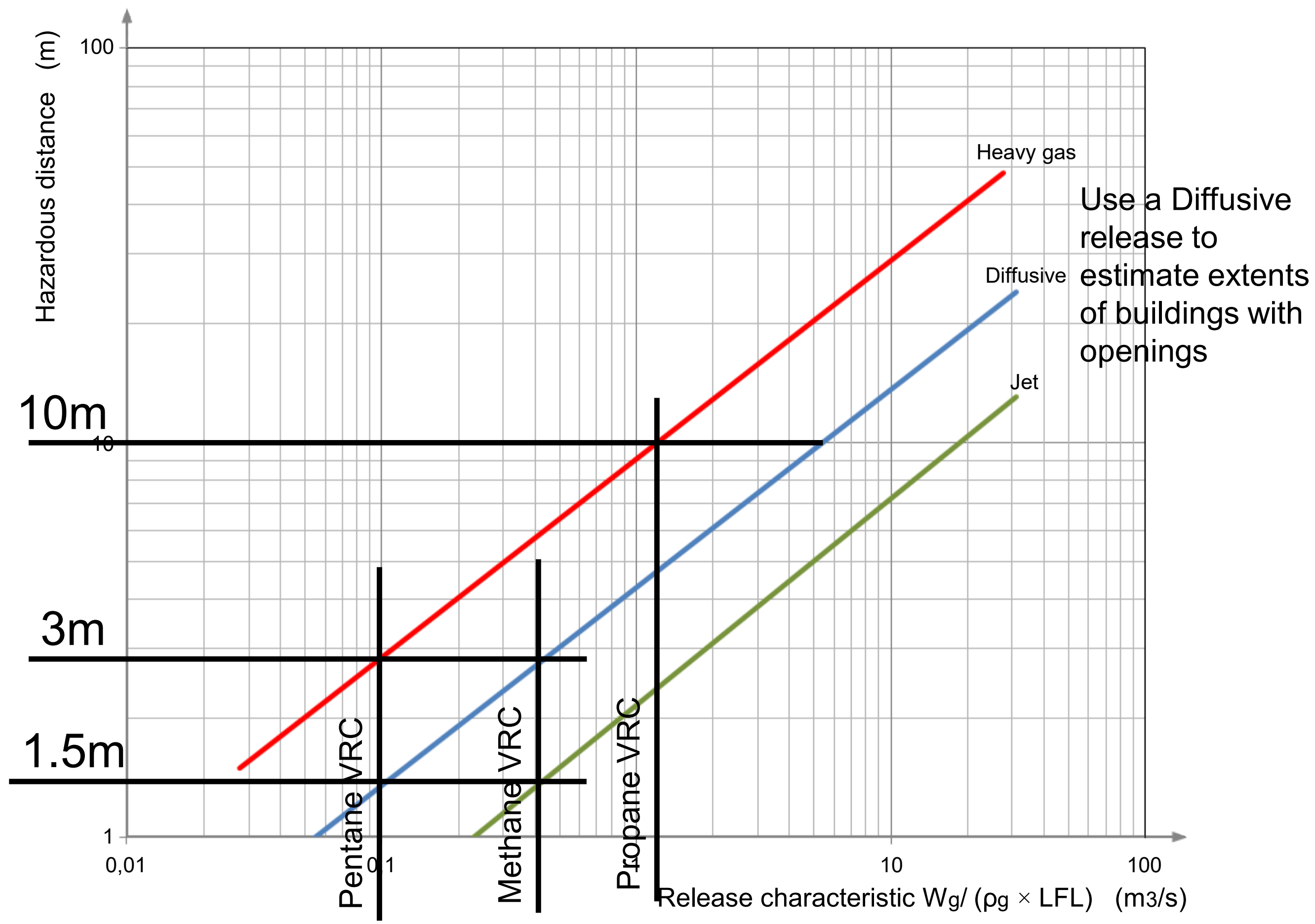
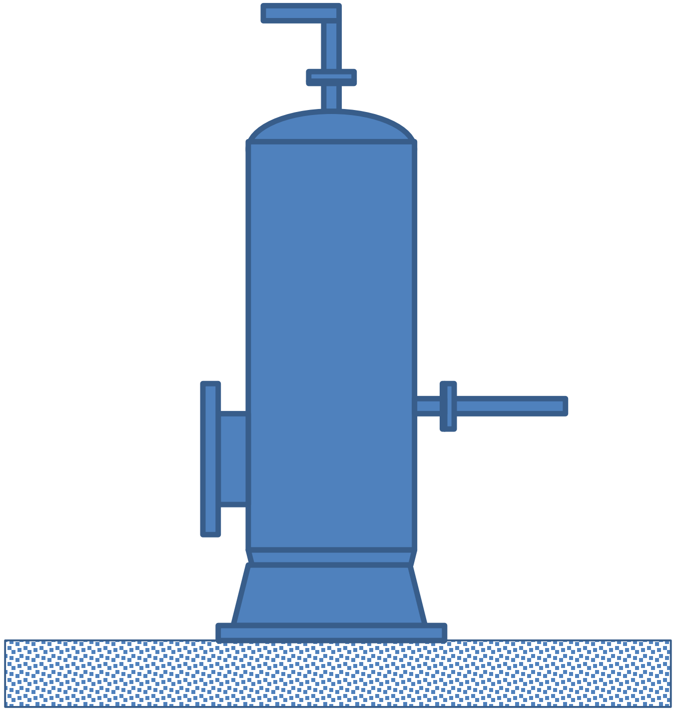


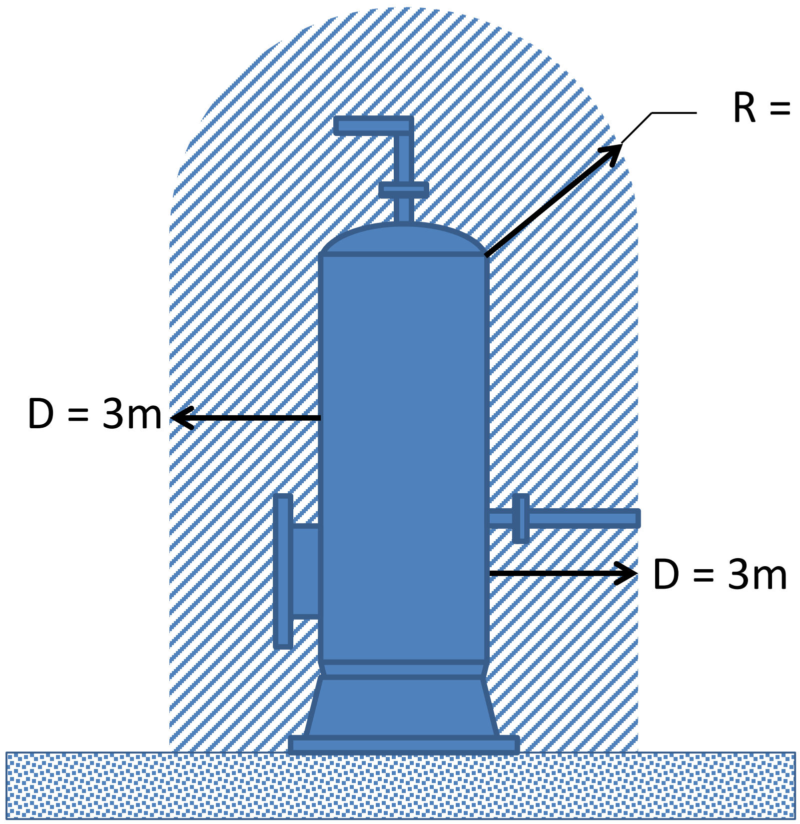
Figure D.1 – Chart for estimating hazardous area distances

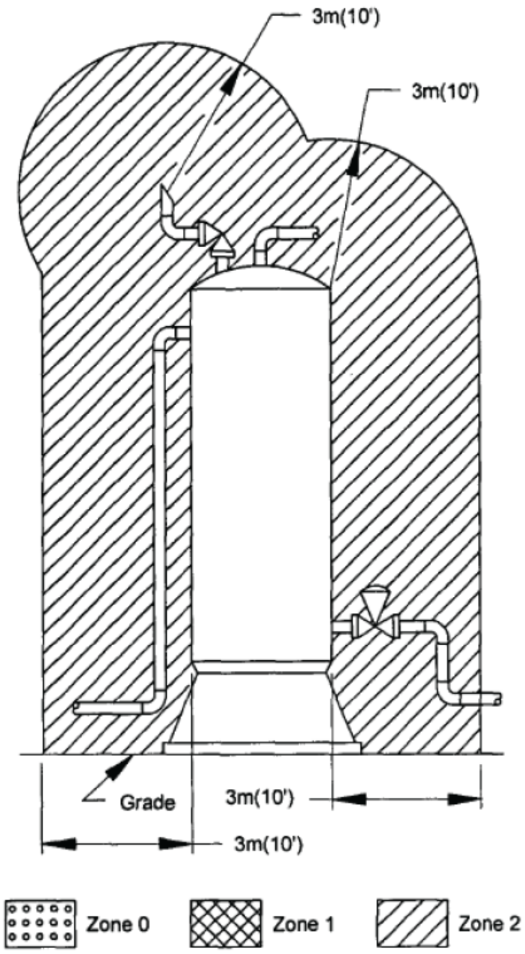
Gas Vessel Application Example

- Outdoor Vessel handling natural gas
  - Secondary flange release
  - Good ventilation
- Process parameters:
  - Operating pressure: p = 5000kPA
  - Operating temperature: T = 25C
  - Mole Weight: M = 19 kg/kmole
  - Polytropic Index of expansion: γ = 1.32
  - LFL = 4%
  - Density of gas vapour: $\rho_g = 0.764\ kg/m^3$



Simplified Method using API





API RP 505 Fig. 48

Point Source Application Example

- Sonic or Subsonic release?
  - Rule of thumb → Release is sonic if:
    - $p_c = 1.89\ p_a = 190\text{kPa}$
    - 5000 kPa > 190 kPa → Sonic release

Hole Size: $S = 0.25\text{mm}^2$

$$W_g = C_d S p \sqrt{\gamma \frac{M}{ZRT} \left(\frac{2}{\gamma + 1}\right)^{(\gamma+1)/(\gamma-1)}} \quad (kg/s)$$

C_d= Coefficient of Discharge
C_d= 1.0 for Vents
C_d= 0.75 for irregular holes

W_g determined to be a sonic jet release at 1.74×10^3 kg/sec

Hole Size Considerations

- Selection of the hole size will have a large effect on the release rate
  - May require additional information on the equipment

Typical values for Secondary Release sources of short duration

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 compre-ssors [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.

Volumetric Release Characteristic and Ventilation Velocity

$$Qc = \frac{W_g}{\rho_g \, LFL}$$

W_g – mass release rate of the flammable substance (kg/s)
ρ_g – Density of the gas or vapour = 0.764 kg/m3
LFL – Lower Flammable Limit (vol/vol) = 4%

$$Qc = 0.057$$

Ventilation velocity from Table C.1 = 0.5 m/s

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

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

Zone Classification

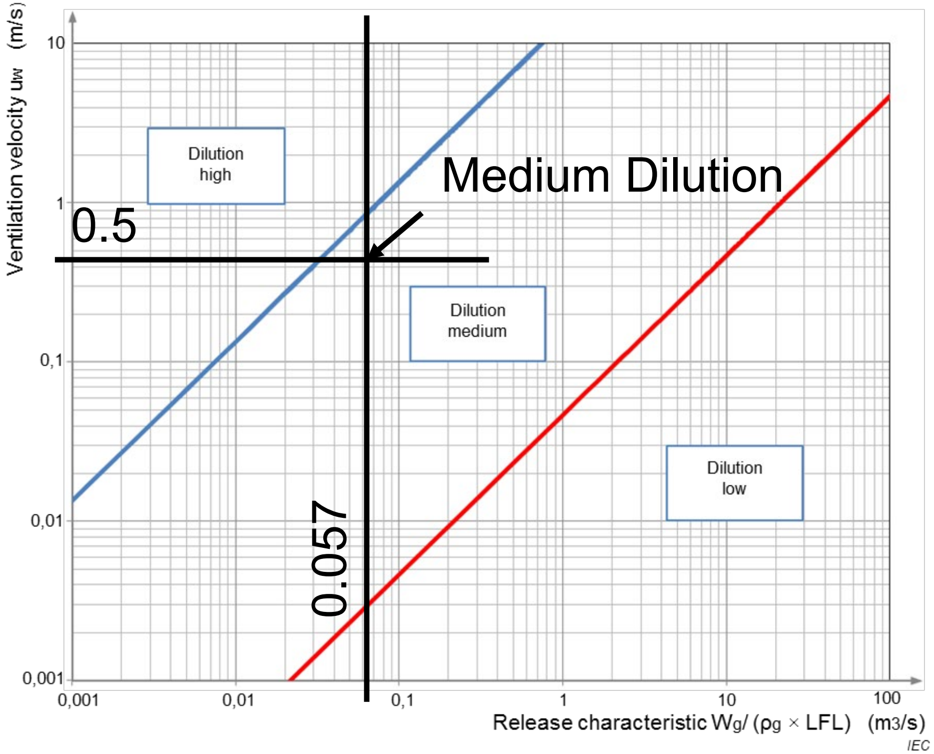


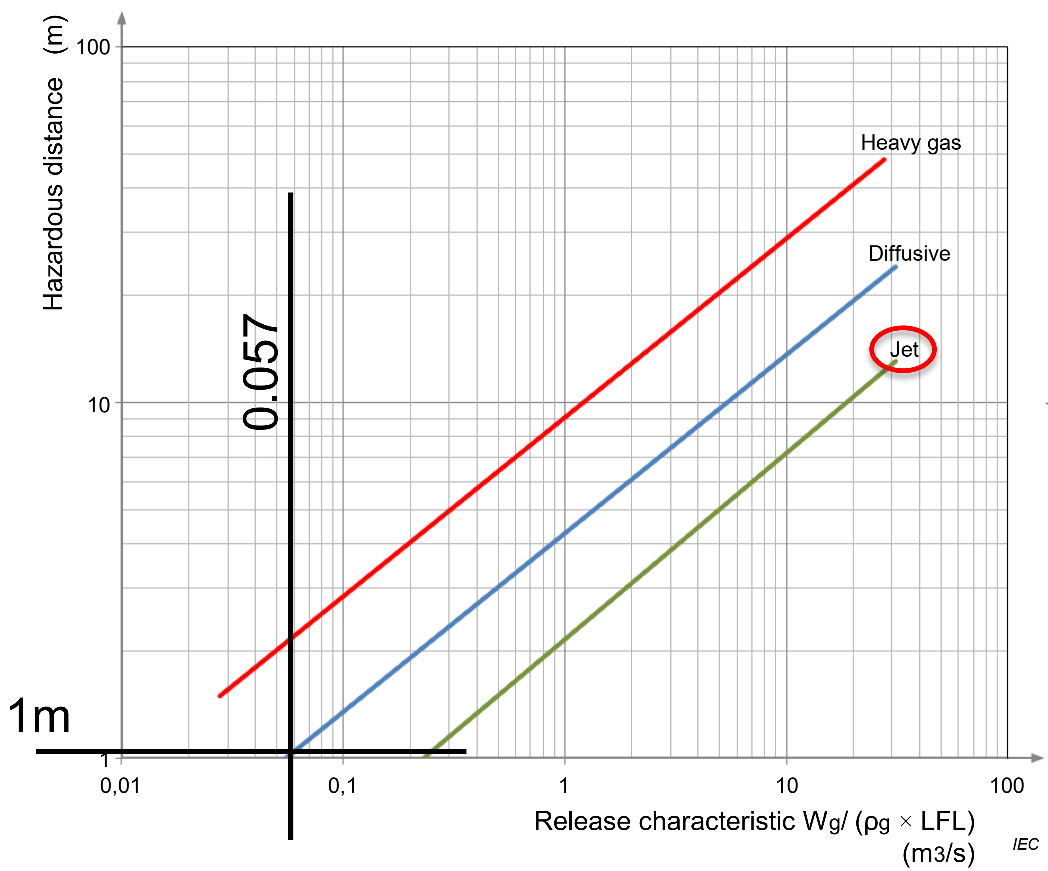
Figure C.1 – Chart for assessing the degree of dilution

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]

Secondary release
Medium dilution
Good availability of ventilation

Conclusion: Zone 2 Classification is appropriate

Zone Extent



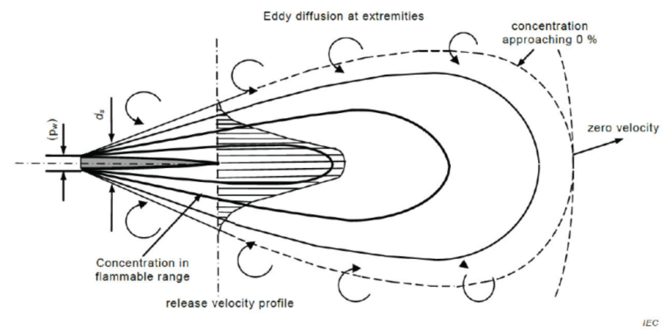
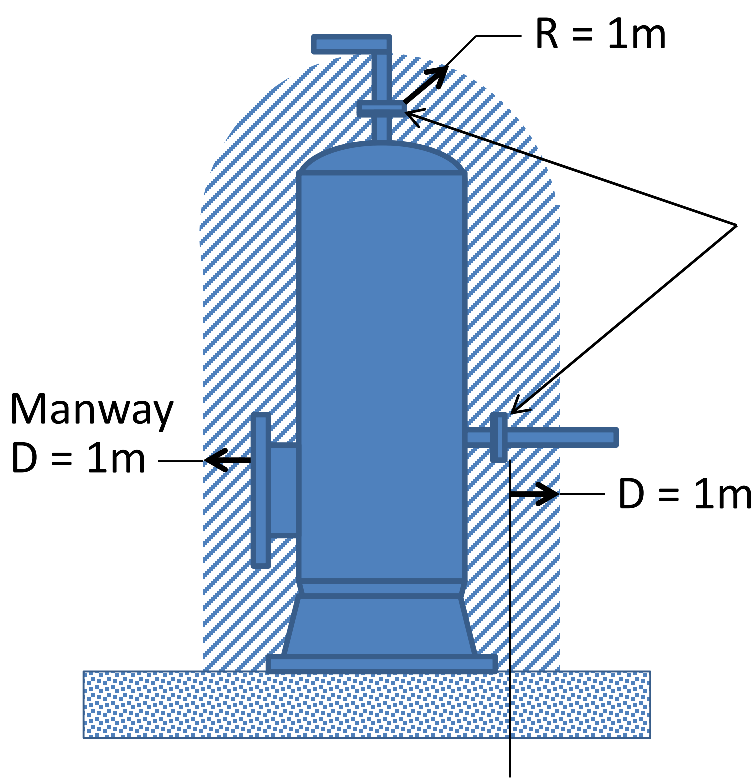


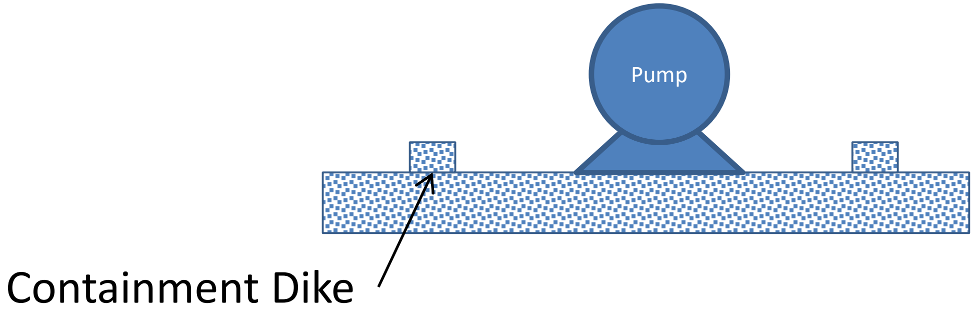
Figure D.1 implies that a 1m hazardous extent would be appropriate

Point Source Classification



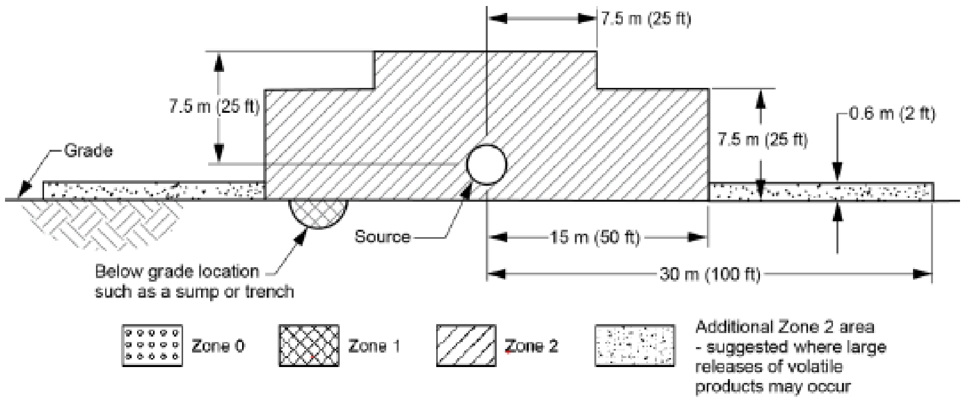
Pentane Pump Assessment

- Pentane pump within a 2m^2 containment dyke in open air within a refinery application



API RP 505 Figure 20

What Diagram would you apply?



[1] Distances given are for typical refinery installations: they shall be used with judgment, with consideration given to all factors discussed in the text. In some instances, greater or lesser distances may be justified.

Figure 20—Adequately Ventilated Process Location with Heavier-than-air Gas or Vapor Source Locat Near Grade (See 9.2.1.1)

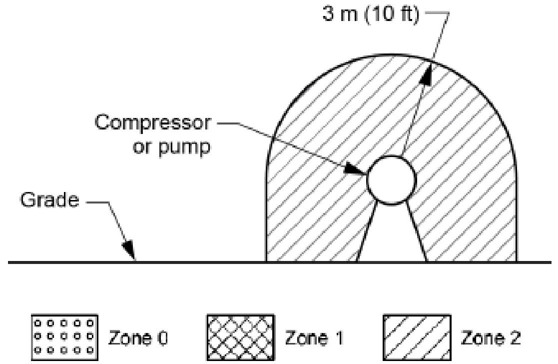


Figure 51—Compressor or Pump in an Adequately Ventilated Non-enclosed Area (See 10.9.1)

Pentane Pump Assessment

- Process Conditions
  - Discharge pressure of pump: 400 kPa
  - Temperature of fluid release = 75°C = 348.15K
  - Standard seal technology
- What would the most like leak scenario be?

Pool Release Assessment

- Determine the outdoor ventilation velocity in the area of the pump

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

Type of Release \ Elevation from ground level	Unobstructed areas			Obstructed areas		
	≤ 2 m	> 2 m up to 5 m	> 5 m	≤ 2 m	> 2 m up to 5 m	> 5 m
Lighter than air gas/vapour releases	0,5 m/s	1 m/s	2 m/s	0,5 m/s	0,5 m/s	1 m/s
Heavier than air and neutrally bouyant gas/vapour releases	0,3 m/s	0,6 m/s	1 m/s	0,15 m/s	0,3 m/s	1 m/s
liquid pool evaporation rate at any elevation	> 0,25 m/s			> 0,1 m/s		

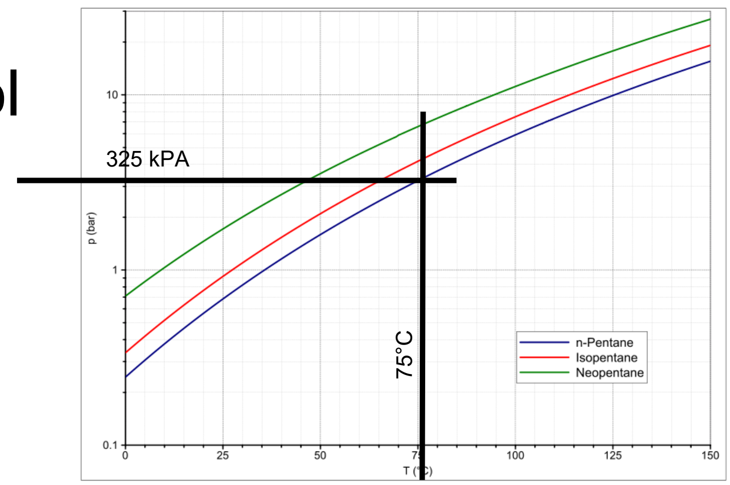
Typically, values in the table would result in an availability of ventilation as fair (see D.2).

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

Characteristics of Pentane

CAS-No.	Name formula	Relative density (air = 1)	Melting point [°C]	Boiling point [°C]	Flash point [°C]	Lower flam. limit [Vol. %]	Upper flam. limit [Vol. %]	Lower flam. limit [g/m³]	Upper flam. limit [g/m³]	Auto ign. temp. [°C]	Most inc. mixture [Vol. %]	MESG [mm]	$g_{100} - g_0$ [mm]	MIC ratio	Temp. class	Equip. group	Method of class.
109-66-0	n-Pentane $CH_3(CH_2)_3CH_3$	2,48	-130	36	−40	1,1	8,7	33	260	243	2,55	0,93	0,02	0,97	T3	IIA	c

- Information from IEC 60079-20-1
  - Relative density of pentane vapours = 2.48 → HTA
  - LFL = 1.1% = 0.011 vol/vol



- Information from chemistry references
  - Molar mass of pentane M = 72.15
  - Vapour pressure of pentane at 75°C p_v = 325 kPa

Pool Release Assessment

- Pool release rate may be approximated by:

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

  - Where
    - W_e = Evaporation rate of a liquid (kg/s)
    - u_w = Wind speed over the liquid pool surface (m/s)
    - A_p = Pool surface area (m^2)
    - p_v = vapour pressure of the liquid at temperature T (Pa)
    - M = molar mass of gas or vapour (kg/kMole)
    - R = Universal gas constant (8314 J/kmole K)
    - T = absolute temperature of the fluid or liquid

$$W_e = 2.42 \times 10^{-2} \text{ kg/s}$$

Parameter Calculation

- Volumetric Release Characteristic

$$Qc = \frac{W_g}{\rho_g \, LFL} = \frac{2.42 \times 10^{-2} \text{ kg/sec}}{2.9 \text{ kg/m}^3 \times 0.011} = 0.76 \text{ m}^3\text{/sec}$$

W_g – mass release rate of the flammable substance (kg/s)

ρ_g – Density of the gas or vapour

$$\rho_g = \frac{p_a M}{R T_a} = 2.9 \text{ kg/m}^3$$

LFL – Lower Flammable Limit 1.1% = 0.011vol/vol

Degree of Dilution

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.

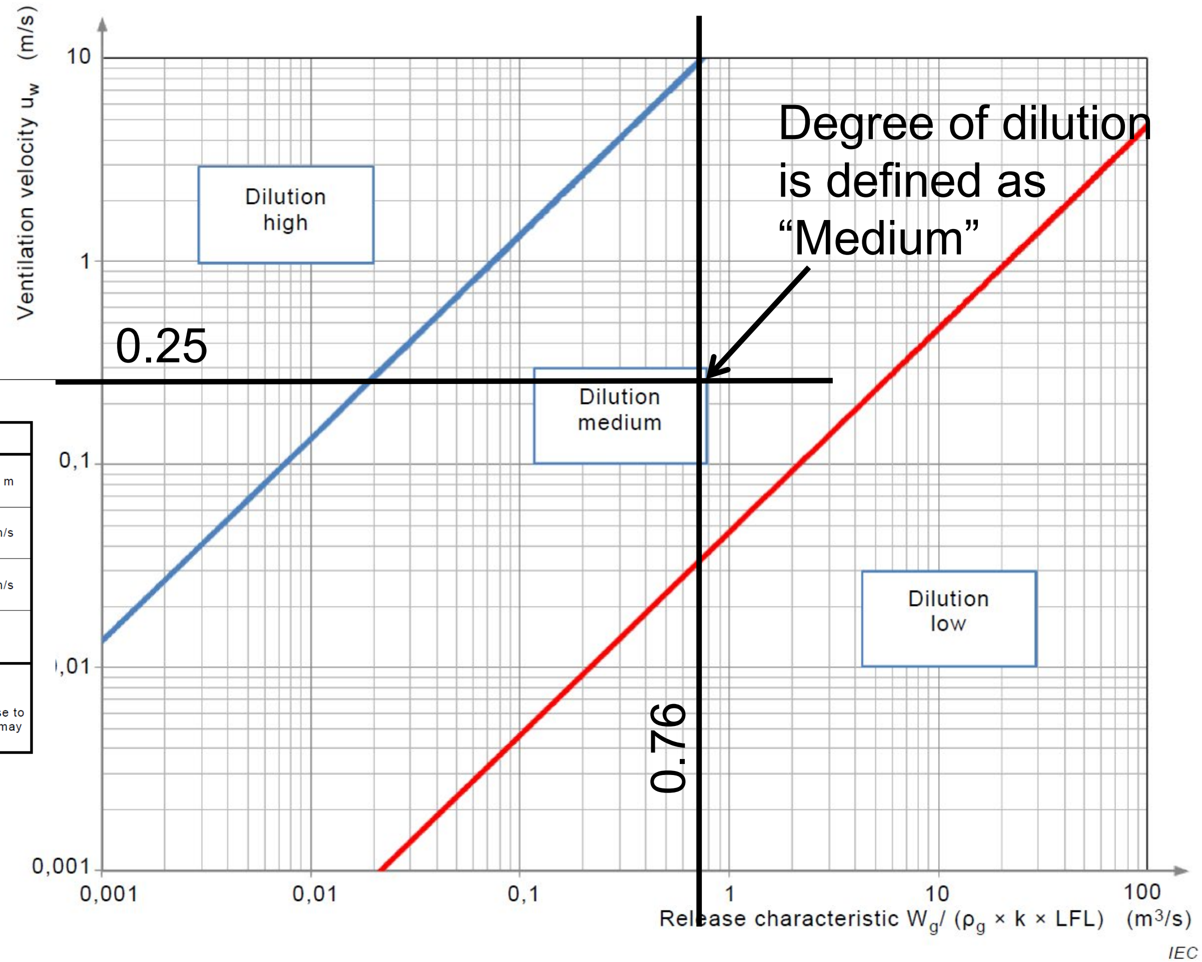


Figure C.1 – Chart for assessing the degree of dilution

Zone Classification Assessment

- Grade of release → “Secondary”
- Degree of dilution → “Medium”
- Availability → “Fair”
  - Relative density of pentane = 2.48 → HTA

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.

Zone 2 Classification

Extent of the Zone

- Extent of a zone may be estimated using Figure D.1

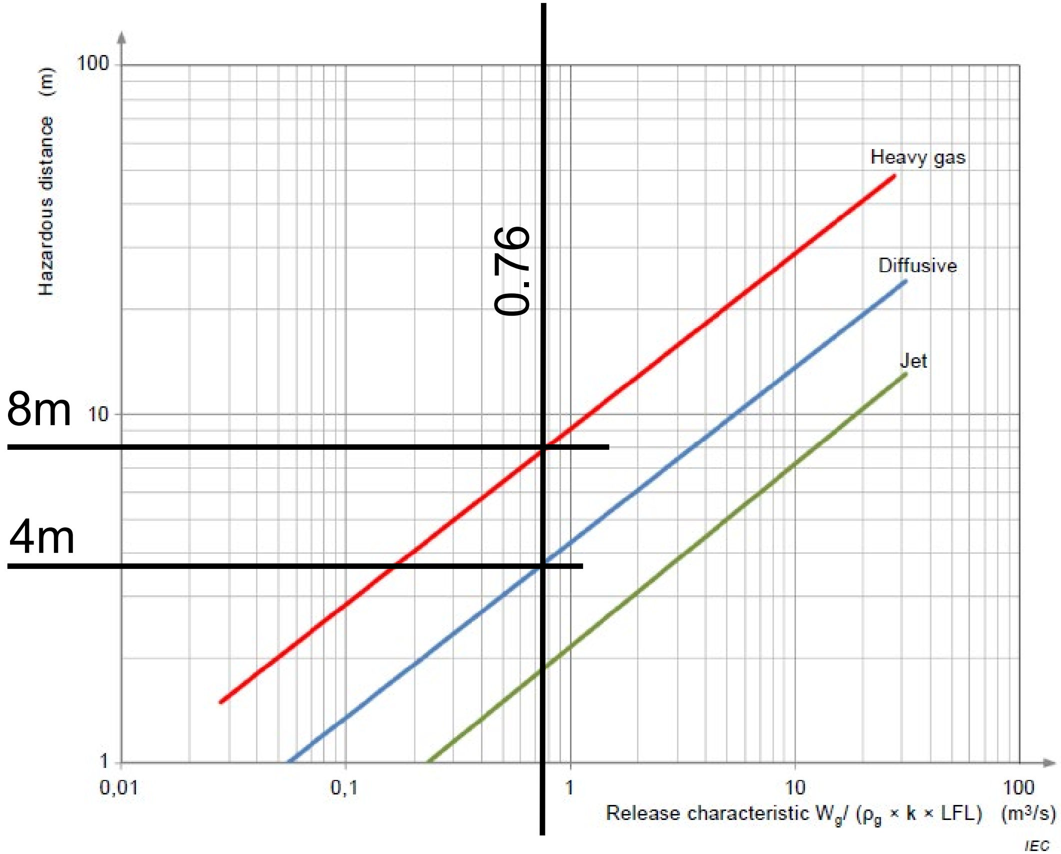
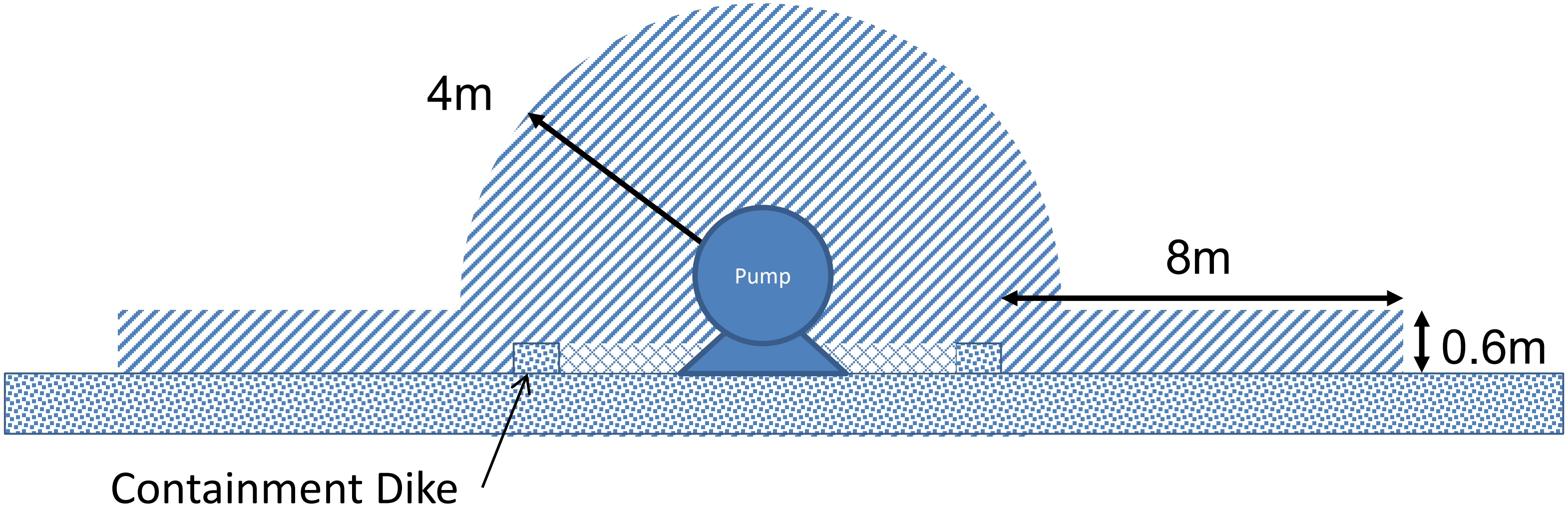


Figure D.1 – Chart for estimating hazardous area distances

Point Source Hazard Extent

A diffusive gas release models the area immediately surrounding the pump
A heavy gas release models the transient vapour extent



Ventilation of Enclosed Locations

Section 9

Enclosure Air Exchange Rate

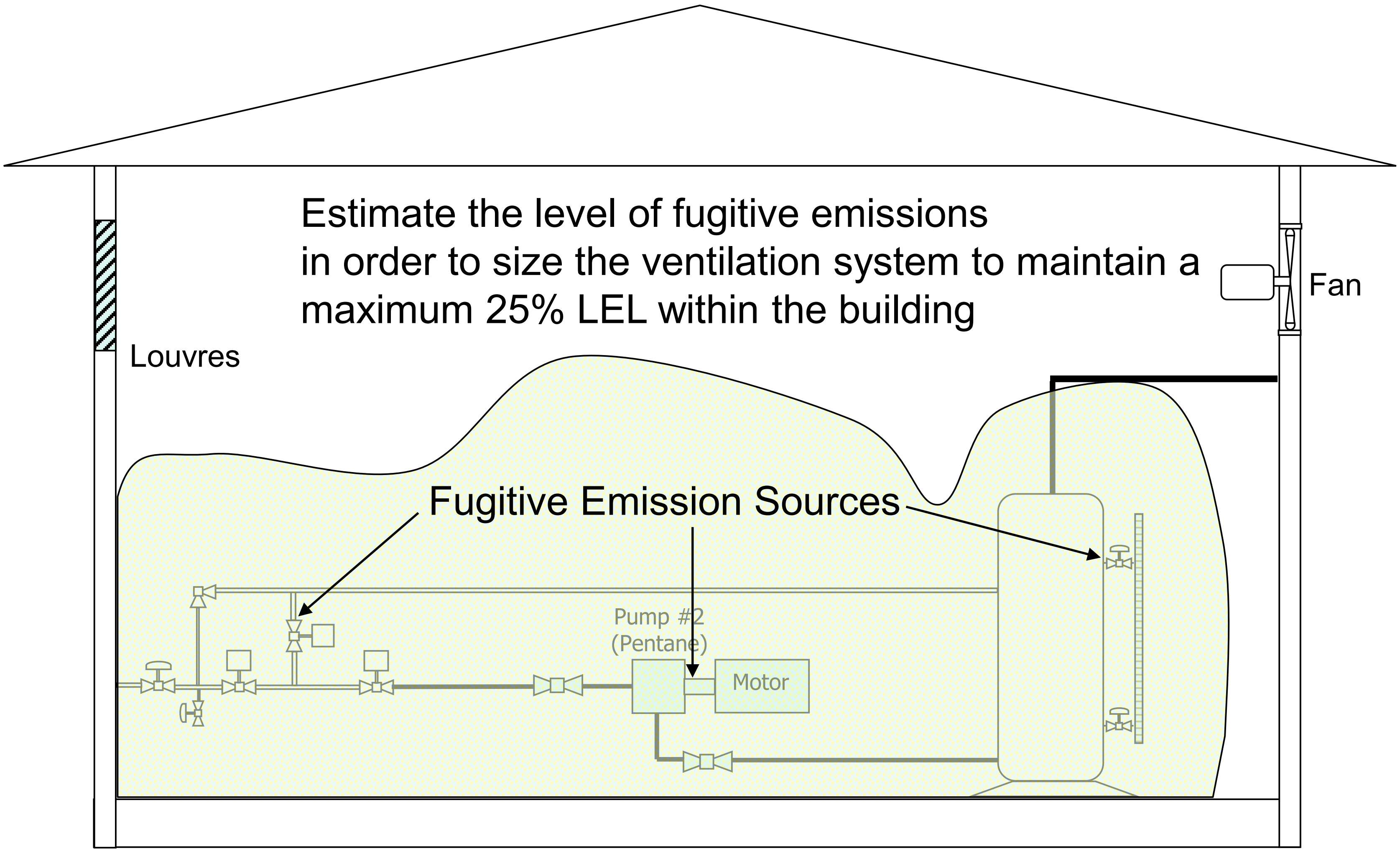
- Air Changes per Hour (ACPH) is often used as a measure of ventilation effectiveness
  - API, EI 15 and NFPA reference ACPH as the defining criteria for a ventilation systems design
- Relates the ventilation rate to the size of enclosure rather than the process that it encloses
- Does not take in to account the distribution of ventilation throughout an enclosure
- Can lead to very high ventilation rates in terms of volume flow for large enclosures

"Adequate" Ventilation
API RP-500/505 NFPA 497

"Ventilation (natural or artificial) that is sufficient to prevent the accumulation of significant quantities of vapor-air or gas-air mixtures in concentrations above 25% of their lower flammable (explosive) limit"

- Enclosed areas are considered adequately ventilated if 6 ACPH is provided on a continuous basis
- Non-enclosed outdoor areas are considered adequately ventilated

API RP500/505
Fugitive Emissions Calculation



API Fugitive Emissions Calculation

- Procedure is outlined in API RP 500/505 APPENDIX B – *Calculation of Minimum Air Introduction to Achieve Adequate Ventilation using Fugitive Emissions*
- Calculation determines what air exchange rate is required to ensure that the fugitive emissions do not exceed 25% of the LFL of the hazardous material present.
- Safety factor of 4 is applied
- Emission rates based on EPA studies from late 1980's

API 4615 Background

Emission Factors for Oil and Gas Operations

Health and Environmental Sciences Departments

API PUBLICATION NUMBER 4615

PREPARED UNDER CONTRACT BY:
STAR ENVIRONMENTAL
P.O. BOX 13425
TORRANCE, CA 90503

DECEMBER 1994

American Petroleum Institute

- Summarizes the results of several studies conducted by API and published in 1993
- 185,000 components in 20 different facilities
- A total of 4796 components were found to be leaking
- Intent was to support the EPA clean air act of 1990
- Not originally intended for area classification purposes

API Fugitive Emissions Calculation

- Does not reflect reality
  - Data implies that all sources of release leak “a little”
  - In reality, most potential sources of release do not leak and only 1-2% of components do leak
- Does not take into account the pressure and temperature of a release
- Does not recognize the importance of air movement in mitigating a release in an enclosed area
  - Relies primarily on ACPH of an enclosed area

Probability of a Component Leak (Source API 4615)

Facility Type	Components Screened	No Leaks	Minor Leaks 10 to 9999 ppmv	Major Leaks >10,000 ppmv
Light Crude	48652	97.90%	1.11%	0.90%
Heavy Crude	13756	99.54%	0.43%	0.00%
Gas Production	40178	96.23%	2.15%	1.61%
Gas Plant	57126	96.28%	1.73%	1.97%
Offshore Platform	45694	98.60%	0.81%	0.77%
Totals	**205397**	**97.41%**	**1.39%**	**1.18%**

API 4638 Fugitive Emission Factors Abnormal Operation (Gas Service)

lbs/component/day

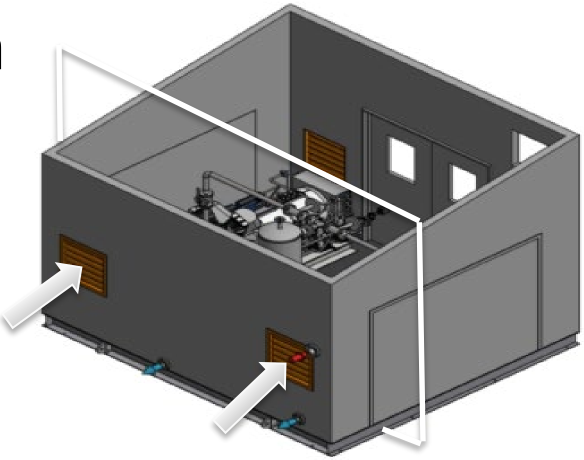
Component	Normal	Abnormal	Emissions Increase
Connections	1.1E-02	1.4	127 X
Flanges	2.1E-02	4.3	204 X
Pumps and pump seals	1.3E-01	3.9	30 X
Valves	2.4E-01	5.2	21 X
Open ended devices	1.1E-01	2.9	26 X
Other	4.7E-01	4.7	10 X

API Natural Ventilation Calculation

- API describes a method for sizing louvers for a naturally ventilated building
  - Sample calculation provided in Annex A
- Suitable for buildings 30m^3 (1000 ft^3) or less
  - 12'H x 10'W x 8'H would be a typical size
- Calculation sizes louvers sized for 12 ACPH under the most extreme ambient conditions
  - Typically results in higher air exchange rates under normal ambient conditions
    - This is not so good in cold weather!

IEC Ventilation Evaluation

- Determined by volumetric flow of the ventilation system divided by the cross-sectional area perpendicular to the flow
- Annex C provides guidance in determining the ventilation velocity of an enclosed location
  - Forced ventilated
  - Naturally ventilated
- Background concentration calculation performed to ensure an adequate air exchange rate to prevent persistence of a flammable atmosphere



Ventilation and Dilution

- Ventilation: movement of air and its replacement with fresh air due to the effects of wind, temperature gradients, or artificial means (fans, HVAC units)
- Dilution: the mixing of flammable vapour or gas with air which, over time, will reduce the flammable concentration
- Ventilation and dilution serve two functions:
  - Dilute a flammable release and promote dispersion to limit the extent of the zone
  - Avoid the persistence of an explosive atmosphere

Effectiveness of Ventilation

- Ventilation effectiveness is described by its ability to dilute a release
  - Determined by the relative release rate and the ventilation velocity
    - Velocity is defined as a value that symbolizes atmospheric instability
    - Velocity may be influenced by the release itself (jet gas release) and/or by ambient air speed
  - Influenced by:
    - Ventilation rate
    - Distribution of the ventilation
    - Obstacles and their geometry
    - Location of the release source

Background Concentration

- Required evaluation for enclosed locations
- Flow rate from flammable release source is compared to the fresh air introduction rate accounting for mixing inefficiencies

$$X_b = \frac{f \; x \; Q_g}{Q_g + Q_1}$$

where X_b – Background concentration (vol/vol)
Q_g – Volumetric flow of flammable gas/vapour (m^3/sec)
Q_1 – Volumetric flow rate of air entering the room (m^3/sec)
f – Degree to which the air inside the enclosure is well mixed
$f = 1$ – uniform
$f > 1$ – inefficient mixing

Background Concentration

- Criteria for assessment
  - $X_b \ll X_{crit}$ where X_{crit} is the maximum acceptable gas concentration determined by the User
    - X_{crit} is usually the LFL alarm setpoint for gas detectors
- Observation:
  - It is possible for large enclosed areas to have minimal interior/exterior air exchange rates while maintaining adequate ventilation effectiveness to disperse a release

Degree of Dilution – Assessment

- Assessment is performed using Figure C.1 using the “volumetric release characteristic” and the “Ventilation velocity “ assumed for a given situation

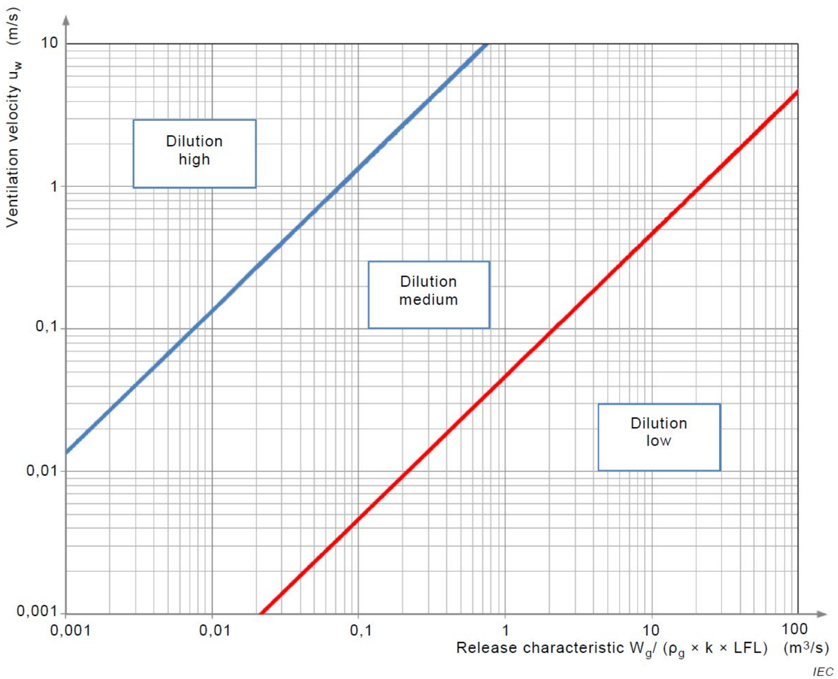


Figure C.1 – Chart for assessing the degree of dilution

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.

$$Qc = \frac{W_g}{\rho_g \, LFL}$$

Ventilation Options

- Open Air – situations where free air movement is provided through all parts of the process
- Natural ventilation – ventilation within buildings resulting from pressure differences induced by wind or temperature gradients
- Artificial Ventilation – ventilation within buildings provided by fans or extractors
  - General artificial ventilation – Ventilation provided to a whole area
  - Local artificial ventilation – Ventilation provided near the point of release

Natural Ventilation

- Requires assessment of:
  - Wind induced ventilation
  - Buoyancy (stack effect) induced ventilation
  - Combination of wind induced, and buoyancy induced ventilation

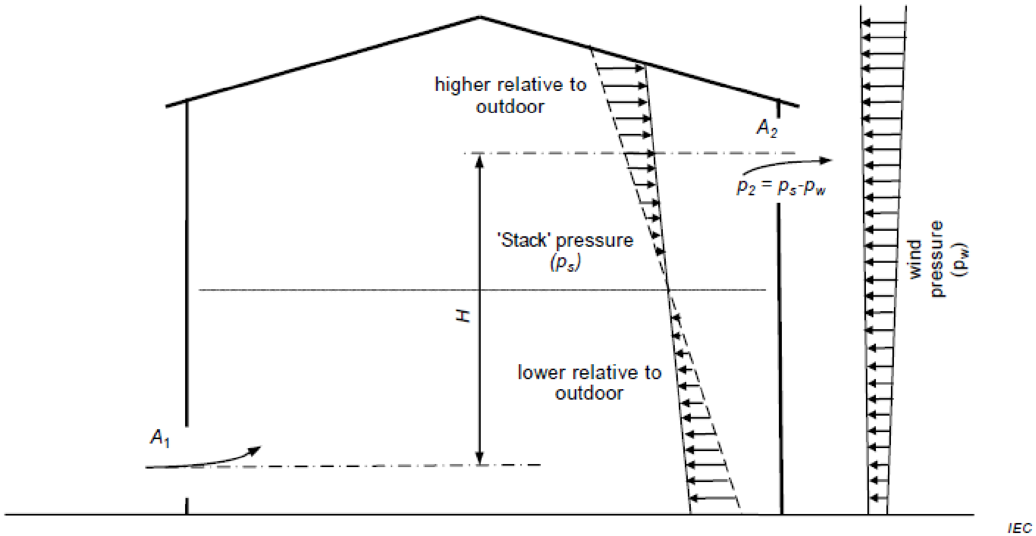
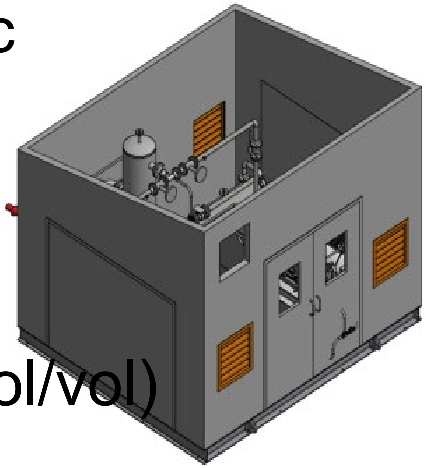


Figure C.7 – Example of opposing ventilation driving forces

Enclosed Area Application Example

- Methane release from a flange in enclosed location
  - Operating pressure = 5000 kPA
  - Operating temperature = 10°C
  - Grade of release → "Secondary"
  - Relative density of methane = 0.6 → LTA
    - Availability → "Good"
  - Mass release rate: W_g = 1.79 X 10^{-4} kg/sec
    - Based on 0.025mm^2 hole size
  - Density of gas: ρ = 0.643 kg/m^3
  - LFL = 4% = 0.04 vol/vol
  - LFL Gas alarm setpoint 20% LFL (0.008 vol/vol)
  - Forced ventilated

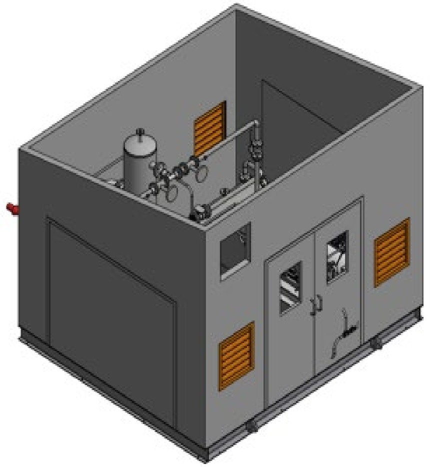


Enclosed Area Application Example

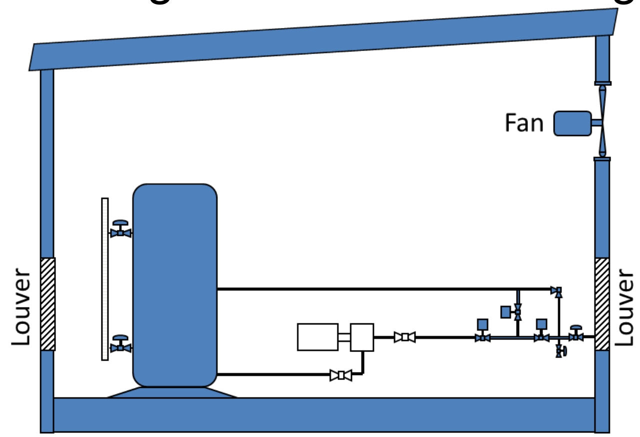
- Volumetric release characteristic

$$Qc = \frac{W_g}{\rho_g \, LFL}$$

  - $Q_c = 0.006$
- Building is mechanically ventilated at 200 CFM (0.09 m^3/sec)
  - Roughly equal to 4 ACPH exchange rate with outside air
  - Availability of ventilation assessed as being "Fair"



6m long x 4m wide x 3.5m high



Ventilation Flow Velocity

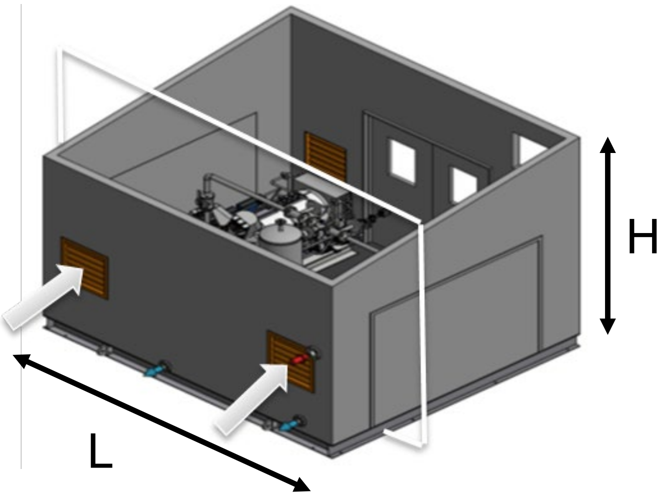
- May be calculated based on the volumetric flow of the gas/air mixture divided by the cross-sectional area perpendicular to the flow using the following formula:

$$U_w = \frac{Q_a}{L \times H} \text{ (m/sec)} = \frac{0.9\text{m}^3\text{/sec}}{6\text{m} \times 3.5\text{m}}$$

where

U_w	Ventilation velocity (m/sec)
Q_a	Air flow rate (m^3/sec)
L	Length of the enclosed area (m)
H	Height of the enclosed area (m)

$$U_w = 0.004 \text{ m/sec}$$



Degree of Dilution

- Degree of dilution determined to be “Medium”
- Background concentration must also be determined
  - Want to ensure that air exchange rate is sufficient to limit the LFL to a level below the LFL alarm setpoint under release conditions
- Assessment Criteria
  - $X_b << X_{crit}$
  - Where X_{crit} is 20% LFL
    - 20% LFL of methane = 0.0080 vol/vol

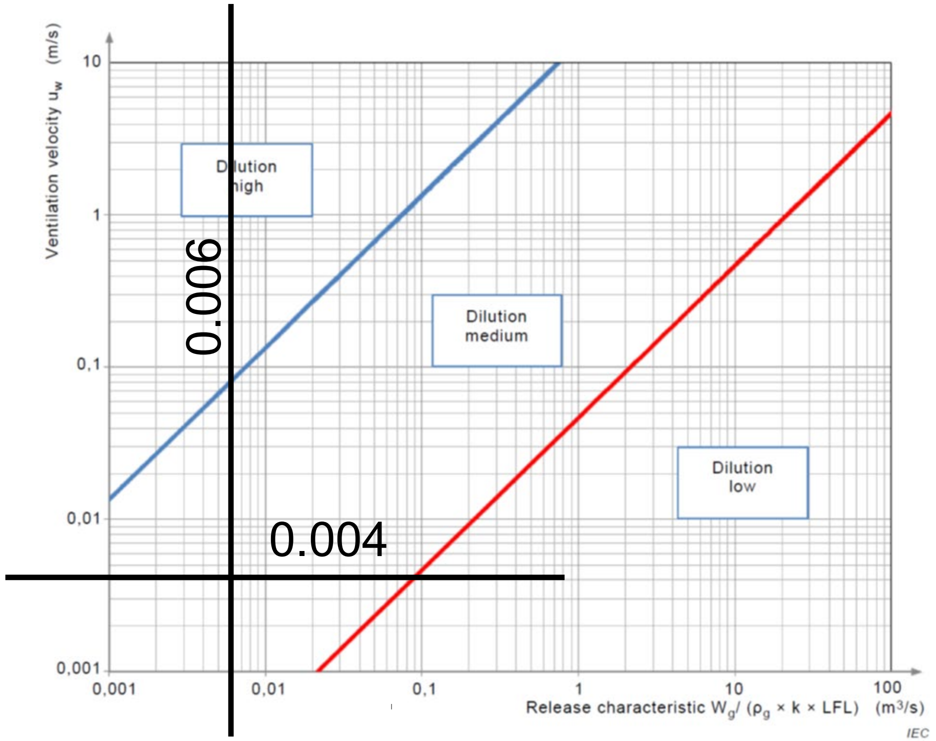


Figure C.1 – Chart for assessing the degree of dilution

Background Concentration

f = 2 implying that the building has a relatively open layout

$$X_b = \frac{f \times Q_g}{Q_g + Q_1} \text{ (vol/vol)} = \frac{2 \times 0.00023 \text{ m}^3\text{/sec}}{0.00023 + 0.09 \text{ m}^3\text{/sec}}$$

$X_b = 0.005$ vol/vol

X_{crit} = 20% of LFL of Methane = 0.008 vol/vol

0.005 << 0.008

$X_b << X_{crit}$ criteria is satisfied

$$Q_g = \frac{W_g}{\rho_g} (m^3/s)$$

$$Q_g = \frac{1.79 \times 10^{-4} \text{ kg/sec}}{0.764 \text{ kg/m}^3}$$

$Q_g = 0.00023$ m³/sec

where

X_b	Background concentration (vol/vol)
Q_g	Volumetric flow of flammable gas from the source of release (m^3/sec)
Q_1	Volumetric flow rate of air entering the room through aperatures (m^3/sec)
f	Degree to which the air inside the enclosure is well mixed f = 1 where the background concentration is uniform thoughout the enclosure f > 1 where inefficient mixing inside the enclosure results in gradients of background concentration

Zone Classification for Enclosed Building

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.

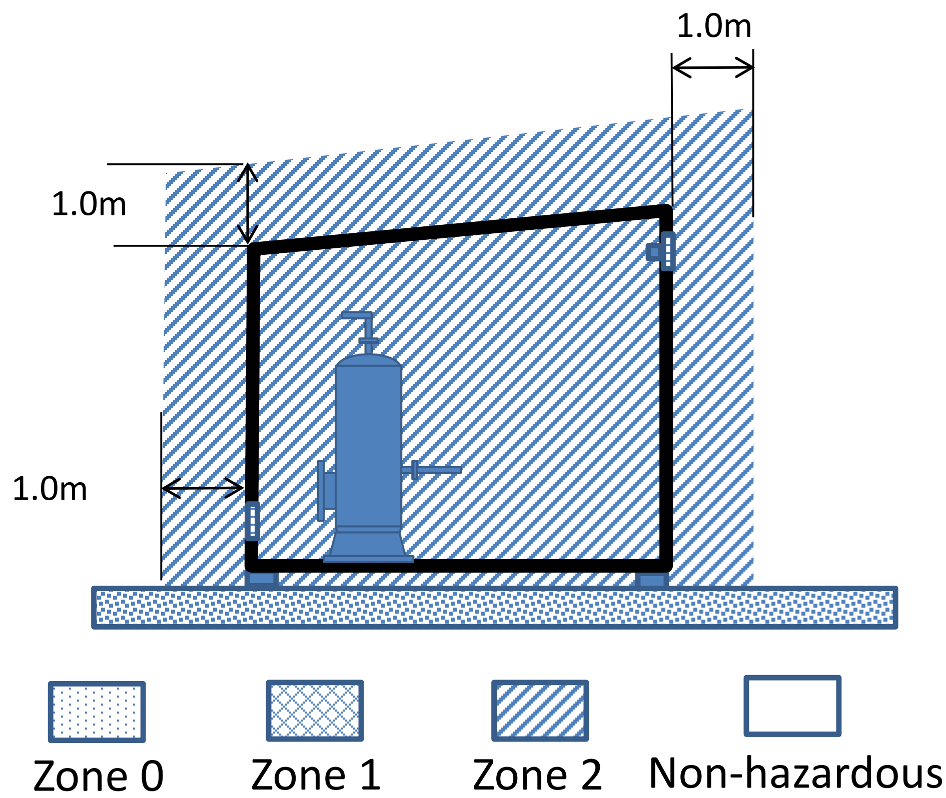
Conclusion: Zone 2 Classification is appropriate

Zone Extent Surrounding Building

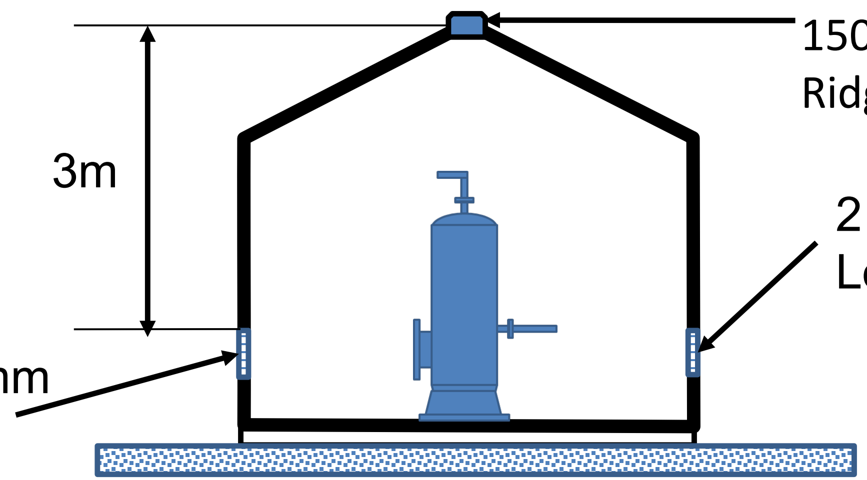
Typically based on a diffusive release on the premise that any release within the building will be at a fairly low velocity when it exits through a ventilation or door/window opening

Figure D.1 implies that a 1m hazardous extent would be appropriate

Hazardous Area Classification Surrounding Building



Naturally Ventilation Design



6m long x 4m wide x 3.5m high

Natural Ventilation Assessment

- Assessment procedure is outlined in Annex C of IEC 6079-10-1
  - Wind Induced ventilation
    - $Q_a = C_d A_e u_w \sqrt{\frac{\Delta C_p}{2}} (m^3/s)$
  - Buoyancy Induced ventilation
    - $Q_a = C_d A_e \sqrt{\frac{\Delta T}{(T_{\text{in}} + T_{\text{out}})} gH} (m^3/s)$
  - Combination of wind and buoyancy
    - $Q_a = C_d A_e \sqrt{\frac{2\Delta p}{\rho_a}} (m^3/s)$

Natural Ventilation Assessment

- Assessment procedure will provide an estimate of the airflow ventilation rate in m^3/sec that can be used to assess the building airflow velocity ventilation and then determine the Zone classification and extent
  - Requires that the worst case ventilation scenario be used to estimate airflow velocity
  - May require multiple calculation to determine the effects of modulating louvers under different temperature conditions

Natural Ventilation Assessment

- Wind induced ventilation = 0.03 m^3/sec
- Buoyancy induced ventilation = 0.065 m^3/sec
- Combination effects = -0.008 m3/sec
- Total natural airflow ventilation Q_a = 0.09 m^3/sec

$$U_w = \frac{Q_a}{L \times H} \text{ (m/sec)} = \frac{0.09 m^3/sec}{6m \times 3.5m}$$

U_w = 0.004 m/sec

Degree of Dilution

- Degree of dilution determined to be "Medium"
- Background concentration must also be determined
  - Want to ensure that air exchange rate is sufficient to limit the LFL to a level well below the LFL alarm setpoint under release conditions

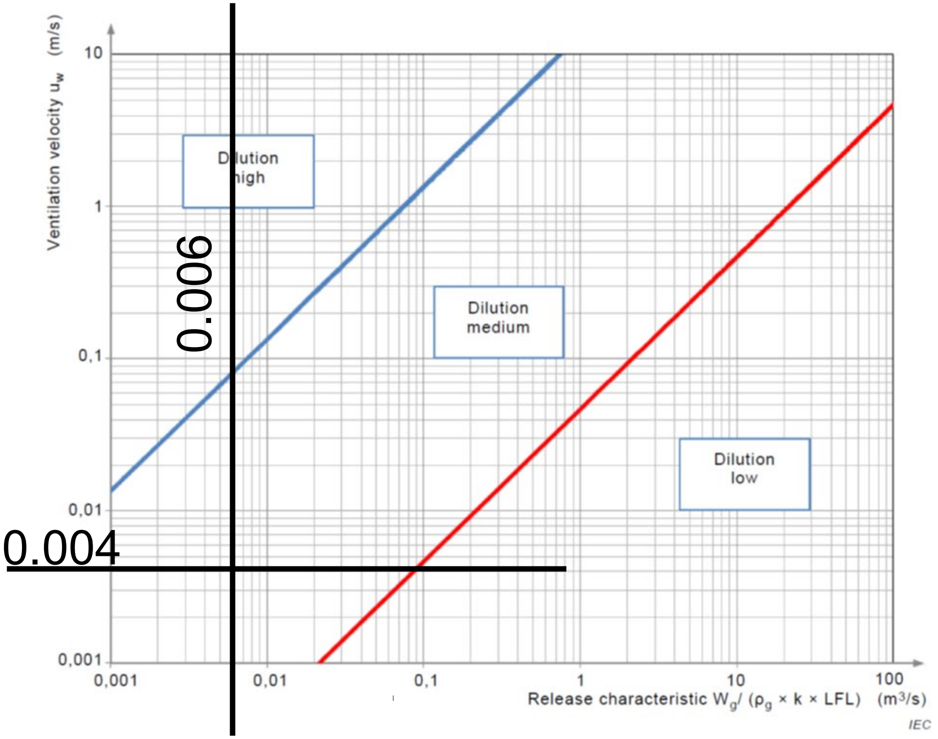


Figure C.1 – Chart for assessing the degree of dilution

Background Concentration

$$Qa = Q1 = 0.09\ m^3/sec$$

f = 2 implying that the building has a relatively open layout

$$X_b = \frac{f \times Q_g}{Q_g + Q_1}\ (vol/vol) = \frac{2 \times 0.00023\ m^3/sec}{0.00023 + 0.09\ m^3/sec}$$

$$X_b = 0.005\ vol/vol$$

$$X_{crit} = 20\%\ \text{of LFL of Methane} = 0.008\ vol/vol$$

0.005 << 0.008

$X_b << X_{crit}$ criteria is satisfied

$$Q_g = \frac{W_g}{\rho_g}(m^3/s)$$

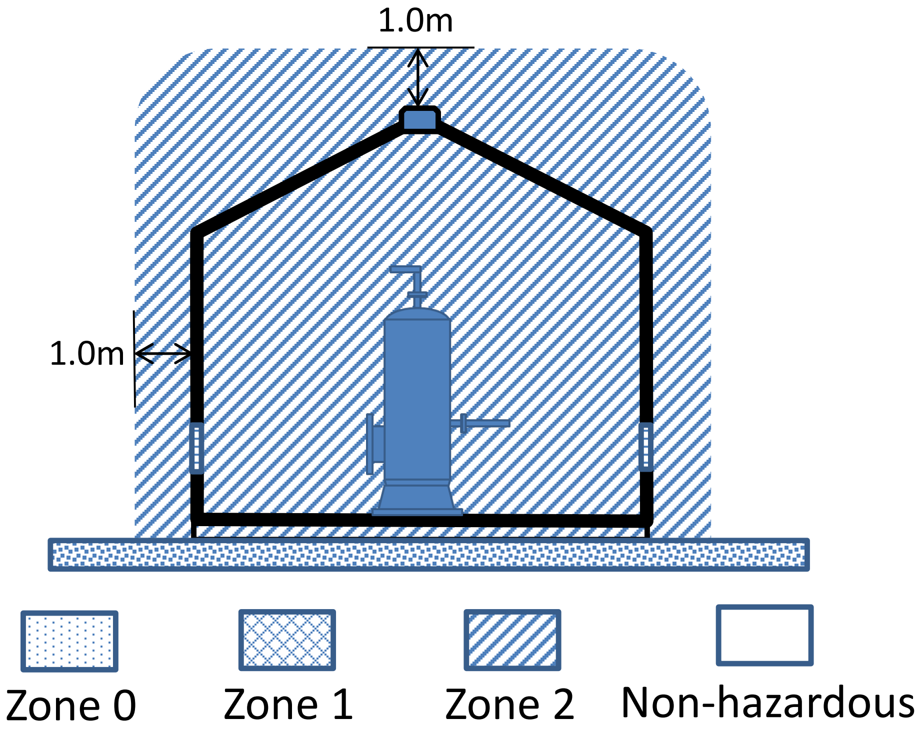
$$Q_g = \frac{1.79 \times 10^{-4}\ kg/sec}{0.764\ kg/m^3}$$

$$Q_g = 0.00023\ m^3/sec$$

where

X_b	Background concentration (vol/vol)
Q_g	Volumetric flow of flammable gas from the source of release (m^3/sec)
Q_1	Volumetric flow rate of air entering the room through aperatures (m^3/sec)
f	Degree to which the air inside the enclosure is well mixed *f* = 1 where the background concentration is uniform thoughout the enclosure f > 1 where inefficient mixing inside the enclosure results in gradients of background concentration

Naturally Ventilation Design



Documentation

Section 10

Documentation Requirements

- Important for capturing the design rationale and maintaining the integrity of the design over the life of the facility
  - Codes and Standard used
  - Properties of the flammable materials
  - Sources of release
  - Design calculations
- Templates are provided to assist in documenting a design

HAC Design Basis Document

- Typical contents of the Design Basis Document include:
  - Description of the Process
  - Codes and Recommended Practices Used
  - List of assumptions
    - Normal verses Abnormal Operation
  - Hazardous Materials Worksheet
  - Source of Release Worksheet

Flammable Material Datasheet

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/m^3)	Equipment group	Temp. class	Any other relevant information or remark, E.g. source of data
1	Process gas	80 % vol CH_4+ higher hydrocarbons	21,6	0,8	1,2	–	>400	–	–	4,0	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.

Source of Release Datasheet

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	Locatio n	Grade of rele ase[a]	Rate of release (kg/s)	Releas e charact eristic (m3/s)	Refer ence[b]	Operating temperature and pressure (°C)	Operating temperature and pressure (kPa)	State[c]	Type[d]	Degree of dilution[e]	Availa bility	Zone type 0-1-2	Zone extent (m) Vertical	Zone extent (m) Horizontal	Refe rence[f]	Any other informa tion or remark
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 blowdow n 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 operatio n
5a	Safety valve vent	Scrubb er	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 operatio n
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	Fair	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	Fair	2	Interior of the shelter	Interior of the shelter		
7b	Air cooler	Infront of the shelter	S	1,8 ′ 10-2	0,54	1	50	2 500 to 5 000	G	N	Medium	Good	2	3,0 from air cooler	3,0 from air cooler		

HAC Design Basis Document

- Ventilation Calculations
  - Minimum ventilation requirements and location and settings of vents and louvres
- List of recommendations
  - Installation and operations
- Area Classification Drawings
  - Plan view and cross sections
- Professional Engineering Stamp
  - (In Canada)

Drawing requirements

- Area Classifications Information
  - Class (if Division Classified)
  - Zone
    - Provide a legend consistent with IEC recommendations
  - Group Classification
    - May be more than one Group for a facility
  - AIT
    - Indicate the maximum auto-ignition temperature and what material it is based on rather than specifying a Temperature Code on the drawings
- Cross section drawing details where appropriate

IEC Area Classification Shading Conventions for Drawings

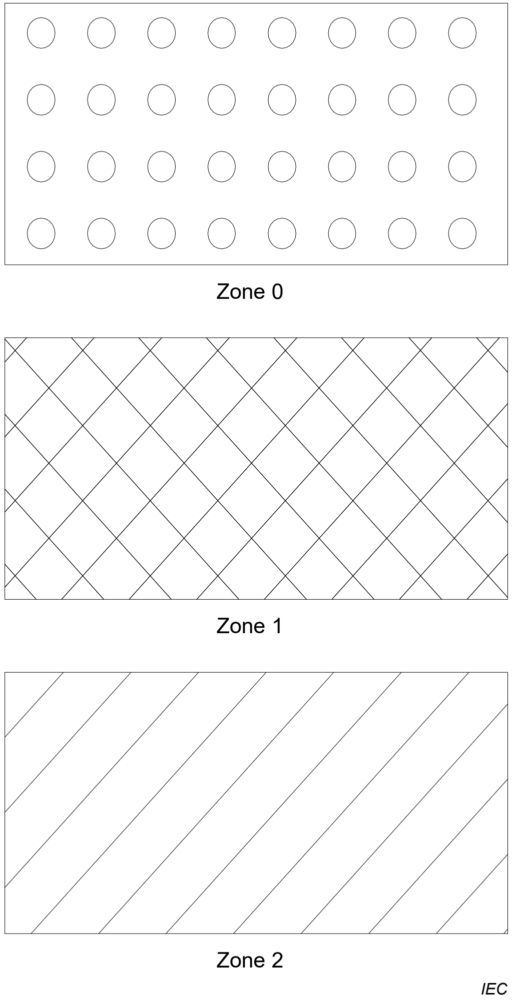


Figure A.1 – Preferred symbols for hazardous area zones

Notes to the Drawings

- Reference the Hazardous Area Classification Design Basis Document
- Indicate ventilation operation requirements for each building
- Indicate gas detection and equipment operating requirements
- Indicate walls that are required to be vapour-tight
- Indicate locations required to be pressurized

Change Management

IEC 60079-10-1

- Once a plant has been classified and all necessary records made, it is important that no modification to equipment or operating procedures is made without discussion with those responsible for the area classification.
- Unauthorised action may invalidate the area classification.

Change Management

- Area classification may change over the life of the facility based on operating and maintenance experience
  - Reviews should be carried out throughout the life of the facility
  - New or modified equipment
  - Changes in installation protection
  - Operations experience
  - Changes in operational procedures
  - Actual measurements
- Must be incorporated into a facility's change management procedure

Competence of Personnel

IEC 60079-10-1

"The area classification should be carried out by those who understand the relevance and significance of properties of flammable materials and those who are familiar with the process and the equipment along with safety, electrical, mechanical and other qualified engineering personnel"

"should also include operations and maintenance personnel"

IECEx Competency scheme

- COPC Unit Ex 002 – Perform area classification of Hazardous Areas

IECEx scheme for certification of personnel competence

1. Provide third party assessment of competencies for persons working in and around Explosive Atmospheres (Hazloc/Classified)
2. Assessment to international IEC standards
3. Industry driven
4. Installers, Designers, Inspectors
5. 3 part assessment:
   I. Education/Training
   II. Work Experience
   III. Knowledge/Practical Exam
6. IECEx –HQ in Sydney, AUS
7. IEC – HQ in Geneva,SUI

- Basic knowledge and awareness to enter a site that includes a classified hazardous area (Unit Ex 000)
- Applying the basic principles of protection in explosive atmospheres (Unit Ex 001)
- Performing classification of hazardous areas (Unit Ex 002)
- Installing explosion-protected equipment and wiring systems (Unit Ex 003)
- Maintaining equipment in explosive atmospheres (Unit Ex 004)
- Overhauling and repairing explosion-protected equipment (Unit Ex 005)
- Testing electrical installations in or associated with explosive atmospheres (Unit Ex 006)
- Performing visual and close inspection of electrical installations in or
- associated with explosive atmospheres (Unit Ex 007)
- Performing detailed inspection of electrical installations in or associated with explosive atmospheres (Unit Ex 008)
- Designing electrical installations in or associated with explosive atmospheres (Unit Ex 009)
- Performing audit inspection of electrical installations in or associated with explosive atmospheres (Unit Ex 010)

Est-ce que je peux poser une question ?

Can I ask a Question?