Atmosphere Risk Analysis Gas Plus

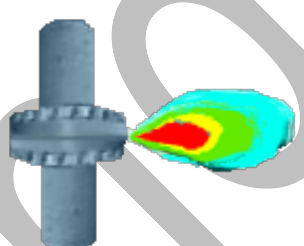
Classification and risk analysis of the areas at risk of explosion due to the presence of flammable gases and vapours in accordance with IEC 60079-10-1 (Edition 3.0 2020-12), [redacted] EN 1127-1 and UNI CEI 70029

General data:

Project name	Example 01
Environment name	Environment name
Environment type	Natural
Source of release name	SR 01: SR Name
Source of release position	SR Location
Flammable substance	Natural gas (NG)
Ambient pressure, p_a	101300 Pa
Ambient temperature, T_a	30 °C

Rate of release W_g [kg/s]

Calculation of emission rate W_g [kg/s] due to the jet in single phase gas/vapour.



Jet only Gas/vapour – rate of release W_g unknown

It is necessary to establish if the gas can go out the containment system, in which it is as gaseous phase, with a low velocity in a subsonic regime (no turbulent flow condition), or with a high velocity in a sonic regime (turbulent flow condition).

To evaluate the type of flow condition, it is applied the follow relation:

$$p_c = p_a \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma}{\gamma-1}}$$ = 186000 Pa - [B.2 – IEC60079-10-1]

Where p_c is the critical pressure

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

To define the polytropic index to adiabatic expansion in ideal gases can be used the following formula (for ideal gs):

$$= \frac{c_p}{c_v} = \frac{Mc_p}{Mc_p - R}$$ = 1,31 [f.GB.4.1-2]

Release rate of gas with choked gas velocity (sonic releases)

Choked gas velocity (see B.7.2.3 of IEC 60079-10-1) is equal to the speed of sound for the gas. This is the maximum theoretical discharge velocity.

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

$$W_g[kg/s] = C_d \cdot S \cdot p \sqrt{\gamma \cdot \frac{M}{Z \cdot R \cdot T} \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{2(\gamma-1)}}}$$ [B.5 - IEC 60079-10-1]

In equation it is considered that the emission takes place at the speed of sound:

$$v_s = \sqrt{\gamma \frac{R \cdot T}{M}}$$ = 326,1 [m/s] - [f.GB.4.1-4]

Release rate of gas with non-choked gas velocity (subsonic releases)

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

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

$$W_g\,[kg/s] = C_d \cdot S \cdot p \cdot \sqrt{\frac{M}{Z \cdot R \cdot T} \frac{2 \cdot \gamma}{\gamma - 1} \left[1 - \left(\frac{p_a}{p}\right)^{\frac{\gamma-1}{\gamma}}\right] \left(\frac{p_a}{p}\right)^{\frac{1}{\gamma}}}$$ [B.3 - IEC 60079-10-1]

The speed of the gas in the emission point can be calculated by the formula

$$W\ u_0 = \frac{}{C_d \quad {}_{exit} S}\ g$$

= 388 m/s - [f.GB.4.1-6]

The density of the gas, by sonic flow at the opening, can be calculated with the following formula (if the flow is subsonic $_{exit}$= $_0$):

$$\rho_{exit} = \rho_{\text{int}} \cdot \left(\frac{2}{\lambda+1}\right)^{\frac{1}{\gamma-1}} = \frac{p \cdot M}{Z \cdot R \cdot T} \cdot \left(\frac{2}{\lambda+1}\right)^{\frac{1}{\gamma-1}}$$

= 36,05 kg/m^3

The calculation of the equivalent density, $_0$, starting from the initial density can be calculated with the following formula:

$$\rho_0 = \rho_{\text{int}} \cdot \left(\frac{p_0}{p}\right)^{\frac{1}{\gamma}} = \frac{p \cdot M}{Z \cdot R \cdot T} \cdot \left(\frac{p_0}{p}\right)^{\frac{1}{\gamma}}$$

= 2,12 kg/m^3 - [f.GB.4.1-7]

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

$$Q_g = \frac{W}{\ }\ {}_g \quad {}_g$$

= 0,00367 m^3/s - [B.4 IEC 60079-10-1]

the density of the gas is

$$= {}_a\ \frac{p\ M\ {}_g}{R\ T_a}$$

= 0,714 kg/m^3

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

Release rate:

Number of releases	1
Discharge coefficient, C_d	0,75
Hole cross section, S	0,25 mm^2

Type of flow, φ	Sonic flow φ: 1
Absolute pressure immediately after the exit, p_0	101300 Pa
Absolute pressure inside the container in the emission point, p	7601300 Pa
The Universal Gas constant, R	8314 J/kmol K
Compressibility Factor, Z	1
Temperature of the substance, T	283,15 K
Main rate of release, W_g	0,00262 kg/s
Residual rate of release, W_{gr}	0,00262 kg/s

Characteristics of release:

Flammable substance	Natural gas (NG)
Physical state of the substance	Gaseous (gas or vapour)
Molar mass, M	17,77 kg/kmol
Lower flammable limit, LFL	4,43 %vol.
Auto-ignition temperature, *AIT*	482 °C
Relative density of a gas or a vapour to air	0,595
Fugitive emissions (Continuous)	0 kg/s
Source of release, *SR*	SR Description
Grade of release	Secondary
Safety factor, k	1
Main release characteristic, Q_c	0,0828 m³/s
Residual release characteristic, Q_c	0,0828 m³/s

Effects of release:

Type of release Diffusive

Critical concentration, $X_{crit.}$ 0,0111 vol./vol. equal to 25 % of LFL Background concentration,, $X_{b.}$ 0 vol./vol.

Time required to reach $X_{crit.}$, t_d	- s
Concentrations comparison, $X_b < X_{crit}$	Verified
Degree of dilution	Medium
Type of Zone	Zone 2

Type of equipment	3G Ex n, ic for Zone 2 - EPL Gc IIAT1	
Extent of zone, *a*=*d*$_z$ -Jet	- m	a = $k_z \cdot d_z$ = - m
Extent of zone, *a*=*d*$_z$ - Diffusive	1,23 m	a = $k_z \cdot d_z$ = 1,23 m
Extent of zone, *a*=*d*$_z$ - Heavy gas	- m	a = $k_z \cdot d_z$ = - m

$$Q_c = \frac{W_g}{{}_g LFL\ k}$$

Estimating the extent of the hazardous zone d$_z$ [m]

The extent of the hazardous zone or region where flammable gas may occur depends on the release rate and several other factors such as gas properties and release geometry and surrounding geometry. Figure D.1 may be used as a guide to determine the extent of hazardous zones for various forms of release. Other forms of calculation or assessment based on reputable sources, e.g. Computational fluid dynamics (CFD) may also be applied.

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

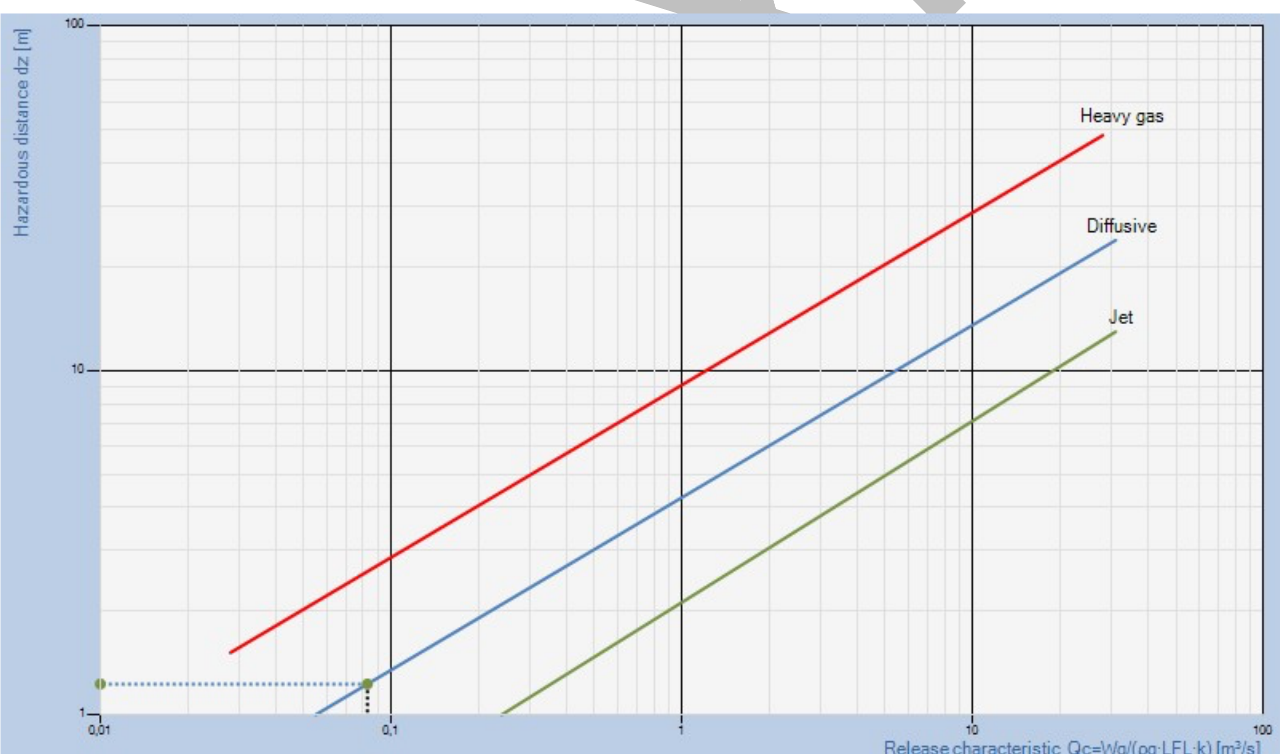


Figure D.1 – Chart for estimating hazardous area distances

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

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

Figure D.1 of IEC 60079-10-1 limits *below* and *above* the extension of the Danger Zone:
Below

1) Jet $d_z \geq 1$ m;
2) Diffusive $d_z \geq 1$ m;
3) Heavy gas $d_z \geq 1{,}5$ m.

Is the responsibility of the professional classifier assume a different value[1].

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)	Zone 2 (Zone 0 NE)	Zone 1 (Zone 0 NE)	Zone 0	Zone 0 + Zone 2	Zone 0 + Zone 1	Zone 0
Primary	Non hazardous (Zone 1 NE)	Zone 2 (Zona 1 NE)	Zone 2 (Zona 1 NE)	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 o Zone 0
Secondary	Non hazardous (Zone 2 NE)	Non hazardous (Zone 2 NE)	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 o Zone 0

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

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

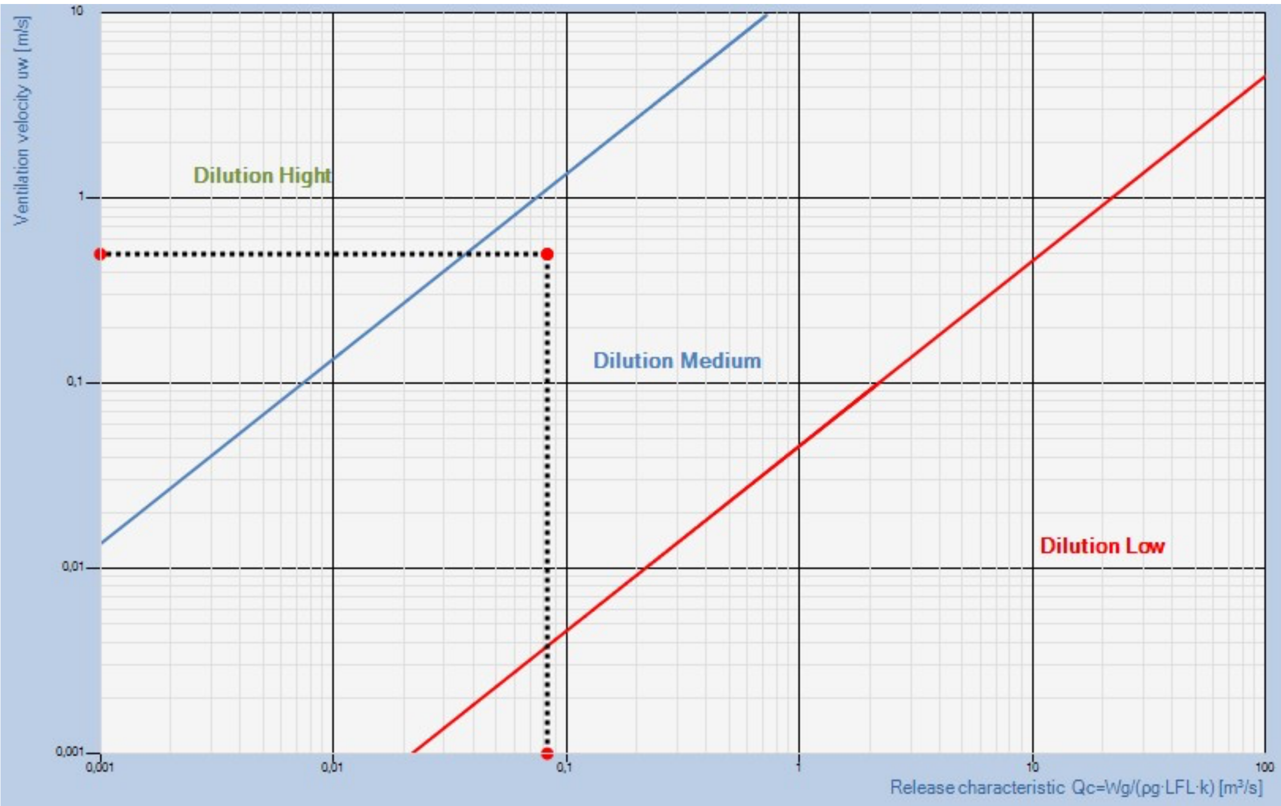


Figure C.1 – Chart for assessing the degree of dilution

Dilution with air of a flammable substance release - Q_{amin},

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

$$Q_{amin} = \frac{Q_g}{LFL_v} \cdot \frac{T_a}{293}$$

= 0,0821 m^3/s – [J.1 IEC 60079-10-1]

Where:

$$LFL_m = \frac{LFL_v}{100} \ldots_g$$

= 0,033 kg/m^3

Estimate of the time required to dilute a flammable substance release

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

$$t_d = \frac{f_a}{C} \ln \frac{X_b}{X_{crit}}$$

= - s - [J.2 IEC 60079-10-1 modified]

where

f_a = is the ventilation (in)efficiency of environment

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

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

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

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

Coefficient k_z

The k_z is the corrective coefficient to be applied at distance d_z to take into account the concentration of flammable gas or vapor in the environment (far field).

$$k_z = e^{\frac{k_1 X_b}{M\, LFL_v}}$$

= 1 [Guide CEI 31-35 3.26]

k_1= 13 for substances with molar mass M < 5; k_1 = 82 for other gases or vapors.

For open areas k_z=1.

Flammable substance background concentration X_b%

The background concentration X_b(t)% after the release time t [s] can be evaluated by means the follow equation

$$X_b(t)\% = f \frac{Q_g}{Q_1 + Q_g} (1 - e^{C\,t})\ 100$$

f = is the ventilation (in)efficiency of the emission source.

The graph in Figure A₁ shows the trend over time of the average hazardous substance concentration in the far field (X_b (t)%) for the emission level considered.

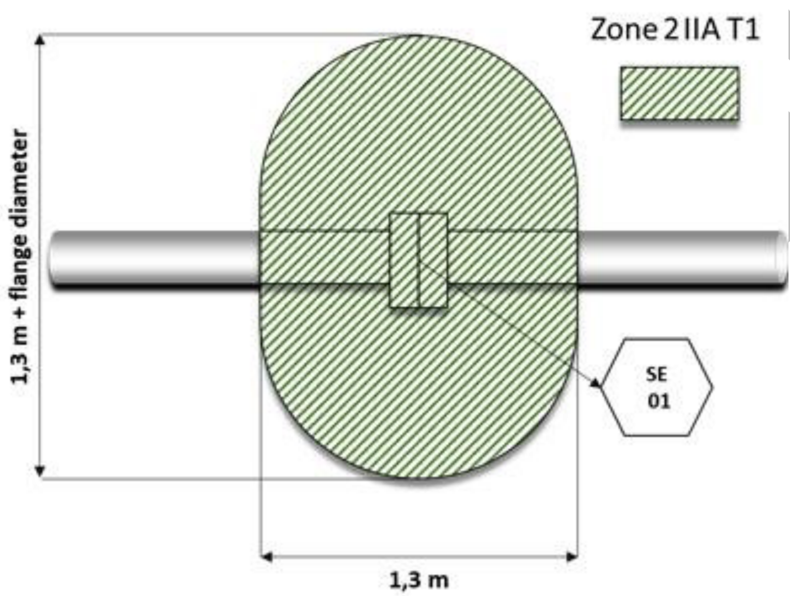
Not applicable

Figure A_1 - X_b(t)%

when the steady condition is established (after the transient period):

$$X_b\% = f \frac{Q_g}{Q_1 + Q_g} 100$$ [C.1 – IEC 60079-10-1]

$$Q_2 = Q_1 + Q_g = C\, V_a$$



The figure is representative of Zones classification

Reductive coefficient R of the hazardous distance d_z

For materials and/or mixtures characterised by a flash point (Ti) bigger than the maximum ambient temperature (Ta) and released at a temperature (Tu), which is above the flashpoint (Ti) but below the boiling point Te, it can be evaluated carefully the cooling that these materials and/or mixtures undergone when are released from the containment system to the ambient

For each case analysed, it is possible to estimate if it is appropriated to multiply the hazardous distance "d_z" per the reductive coefficient R. The value of R can be obtained by the follow plot (contained in the guide CEI 64-2 fig. 3.12 fourth edition 1990 and incorporated into the guide CEI 31-35).

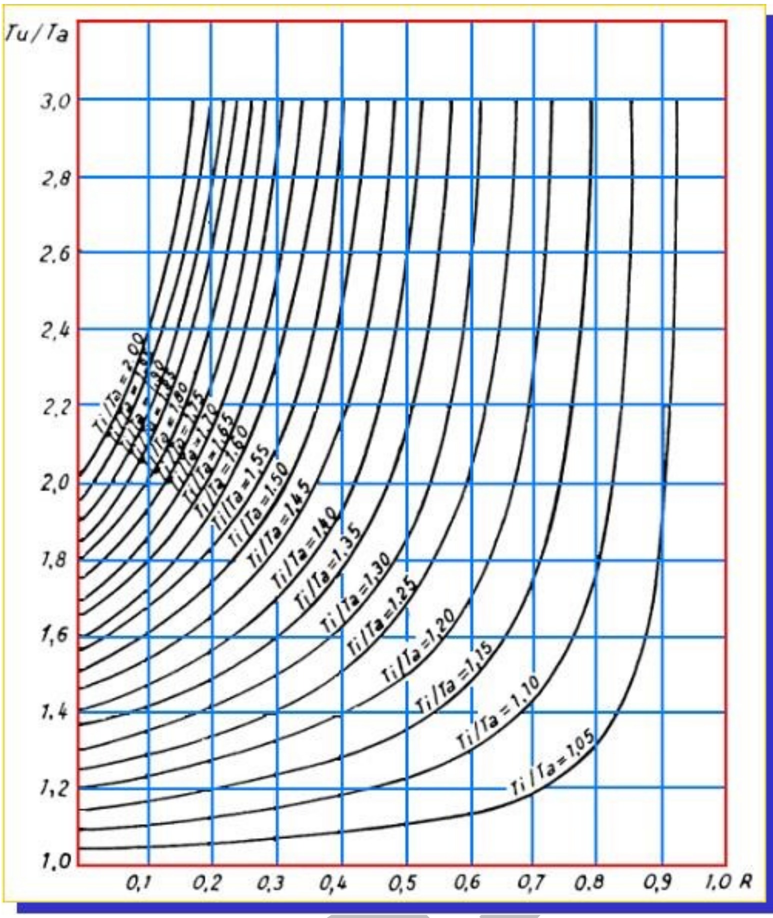


Figure 1- reductive coefficient of the hazardous zone extension GB.5.2-A of the guide CEI 31-35

Froude number Fr (not applicabile)

$$F_r = \frac{\rho_0}{|\rho_a - \rho_0|} \cdot \frac{u_0^2}{g \cdot d}$$ =

F_r is Froude number;

$_0$ is the density of the gas leaving the emission source [kg/m^3]; $_a$ is the density of the air [kg/m^3];

u_0 is outlet gas velocity [m/s]; d is the diameter of the source of release[m]; g is gravity acceleration 9,81 [m/s^2].

The jet area will have an amplitude not less than the following:

$$J = 0{,}5 \cdot d \cdot \sqrt{F_r} \cdot \left(\frac{\rho_0}{\rho_a}\right)^{\frac{1}{4}} = [\mathrm{m}]$$

J [m] is the limit of momentum region.

The limit of momentum region ***J*** is of the ***d*****zJet** necessary to consider the extent of the danger zone due to diffusion by diffusion ***d*****zDiffusive**.

EXPLOSION RISK ASSESSMENT

Area	**Environment name**		
Presence of workers		Distance of the load R [m]	**-**
Substance	**Natural gas (NG)**	Explosion index K_G [bar·m/s]	**0**
Source of release	**SR 01: Test**		
Obstruction/confinement:			

FIRST TYPE OF ZONE

Zone	**Zone 2**
d_{za} [m]	**1,23**
a [m] = $k_z \cdot d_{za}$	**1,23**
b [m]	**-**
c [m]	**-**
Equipment	**3G Ex n, ic for Zone 2 - EPL Gc IIAT1**

SECOND TYPE OF ZONE

Zone	
d_{za} [m]	
a [m] = $k_z \cdot d_{za}$	
b [m]	

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c [m]	
Equipment	

FACTORS OF THE RISK OF EXPLOSION FOR: FIRST TYPE OF ZONE	0	1	2	3	4	5	6
Probability of presence an explosive atmosphere (hazard factor P)		**X**					
Presence of efficacy ignition source (hazard factor C)	**X**						
Evaluation of explosion effects (consequences factor D)	**X**						

Risk index= P·C·D	**20**
Partial risk R' index	**20**
Total Risk index=R + R'	**20**

FACTORS OF THE RISK OF EXPLOSION FOR: SECOND TYPE OF ZONE	0	1	2	3	4	5	6
Probability of presence an explosive atmosphere (hazard factor P)							
Presence of efficacy ignition source (hazard factor C)							
Evaluation of explosion effects (consequences factor D)							

Risk index= P·C·D	
Partial risk R' index	
Total Risk index=R + R'	

RISK INDEX = P X C X D + PARTIAL RISK INDEX - FIRST TYPE OF ZONE				
Risk index	Negligible	Low	Medium	High
Negligible risk	**X**			

Risk Index = P x C x D + Partial Risk Index - Second type of Zone				
Risk index	Negligible	Low	Medium	High

Priority intervention improvement actions for the First type of Zone
No action, The probability of the presence of explosive atmospheres is almost impossible and there are no sources of ignition effective. The exposure level is almost zero, so there is no damage to persons or property. The probability of propagation of the explosion is to be considered almost nothing

Priority intervention improvement actions for the Second type of Zone

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