ATEX DIRECTIVES: THE NEW APPROACH
Classification 0f Hazardous Areas for the Presence of Flammable Gas

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ABSTRACT

The ATEX Directives regulate use of electrical and mechanical equipment in explosive atmospheres and classification of explosive or hazardous zones. The ATEX "User" Directive 1999/92/EC gives minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

According to the Directive hazardous places shall be classified in terms of zones on the basis of the frequency and the duration of the occurrence of an explosive atmosphere. For this process the European Norm IEC EN 60079-10: "Electrical apparatus for explosive gas atmospheres. Part 10: Classification of hazardous areas" is used to determine classification of hazardous zones. This Norm does not give special features for the classification methodology; in Italy instead a Guide and a collection of specific examples of classification have been published: Guide CEI 31-35, "Electrical apparatus for explosive atmospheres. Guide for the application of the Norm CEI EN 60079-10 (CEI 31-30)" and Guide CEI 31-35/A, "Electrical apparatus for explosive atmospheres – Guide for the application of the Norm CEI EN 60079-10 (CEI 31-30) Classification of hazardous zones, Examples of application".

This paper presents the new approach introduced by the ATEX Directives and also the specific features of the Italian methodology for the classification of the hazardous areas highlighting the related potentiality and problems.

1.0 INTRODUCTION

In the so called "Old approach" the manufacturers of electrical equipment for use in potentially explosive atmospheres have traditionally followed a voluntary product certification procedure based on the 'old approach' EC directives 76/117/EEC, 79/196/EEC and 82/130/EEC. Each directive is addressed to the 'member states' of the European Union. It is the responsibility of each 'member state' to implement the necessary regulations nationally and to appoint bodies (Notified Bodies) to undertake the conformity assessment procedures specified in the directives.

The 'old approach' directives have been amended several times since 1976 to introduce new Harmonised European standards which reflect the state-of-the-art in the design and construction.

With the purpose to harmonize the various European national standards, that prevented the free commerce of electric equipments in the Community, in 1975 it was rated at Bruxelles a mandate for the harmonization of the legislations of the member states in relationship to the electric equipments to be used in explosive atmospheres; the responsibility for the preparation of this standard reverted on the CENELEC, *Comité Européen de Normalisation Electrotechnique* ("European Committee for Electrotechnical Standardization").of explosion protected electrical equipment. It is these standards which form the basis of certification.

On 7 May 1985 the European Community Ministers agreed on a 'New Approach' to the conformity assessment of products in order to fulfil the objective of achieving the free movement of goods within the European Union. New Approach directives set out the essential requirements, written in general terms which must be met before products may be sold anywhere in the European Union.

On March 1994, the Directive 94/9/EC of 23 March 1994 concerning equipment and protective systems for use in potentially explosive atmospheres, which entered into force on 1 March 1996, introduced the 'New Approach'. Compliance with the requirements of this directive were mandatory on 1 July 2003 when the 'old approach' directives were repealed. The notion of potentiality is important because it emphasizes that the law applies where there is a risk of an explosive atmosphere occurring, rather than just at the time when it is occurring.

The new approach directive (94/9/EC) named ATEX Directive, with the acronym meaning ATEX AT= Atmosphere EX= Explosive, has a much wider scope and differs from the 'old approach' directives in many ways. Some examples of this different approach are (a) the CE marking is introduced and must be applied together with the specific explosion protection markings, (b) mining (Group I) and surface (Group II) equipment are addressed together, in the same directive, (c) the directive applies to electrical and mechanical equipment, (d) equipment categories are introduced, Category 1 equipment is intended for use in high risk areas and Category 3 equipment in low risk areas and (e) dust laden atmospheres are also addressed.

On January 1996 the CENELEC published the EU Norm EN 60079-10, 1st edition, "Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas", where the hazardous areas were defined and guidelines for their determination were given.

Moreover in 2003, the Worker Protection Directive 92/99/EC ("Directive … on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres") has come into force; it has become the legal requirement for classification of hazardous areas across Europe. The dangers of siting electrical apparatus in areas where explosive mixtures of flammable materials and air could occur are covered by this legislation.

So actually, in areas where dangerous quantities and concentration of flammable gas may arise, it is necessary to decide about the extension of the hazardous zones. These zones are "areas in which an explosive gas atmospheres is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of apparatus" [7]. The aim of the predisposition of a hazardous location is to prevent the ignition of an explosive atmosphere that might arise from leaks in normal operation and it does not apply to situations that could involve catastrophic failures.

In such areas, depending on the type of the Zone (Zone 0, 1 or 2), care must be taken for the installation of electrical equipment and other components and/or instrumentations capable of become a source of ignition. Zone 0 presents the strictest requirements on prevention of ignition, while less strict requirements are provided for Zone 1 and even less for Zone 2.

Table 1. Definition of Zone.

Directive 1999/92/EC ANNEX I	
Zone 0	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapor or mist is present continuously or for long periods or frequently
Zone 1	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapor or mist is likely to occur in normal operation occasionally
Zone 2	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapor or mist is not likely to occur in normal operation, if it does occur, will persist for a short period only

The end user must then ensure that all equipment (which has a potential source of ignition) within the hazardous area is suitable for use within its designated area zone classification. The end user is also obliged to ensure this equipment is regularly inspected and maintained to ensure its suitability for use within the designated zone area classification. This inspection and maintenance must be done by competent (trained) personnel.

2.0 GENERAL EUROPEAN METHODOLOGY

The objective of the classification of hazardous areas is the division of the area in different zones with a different level/probability of risk in order to be able to set up electrical equipments suitable for each zone.

The classification, as required by the European Norm EN 60079-10, should be based on an analytical study focused on the probability of the formation of certain volumes of explosive atmospheres.

The hazardous zones as already mentioned are classified into Zone 0, Zone 1 or Zone 2 (see Table 1); the classification process is based on the following parameters:

➢ *Grade of the emission sources*

- Continuous grade: "a release which is continuous or is expected to occur for long periods";

- Primary grade: "a release which can be expected to occur periodically or occasionally during normal operation";

- Secondary grade: "a release which is non expected to occur in normal operation and if it does occur, is likely to do so only infrequently and for short periods".

➢ *Degree of ventilation*:

- High (HV): the ventilation "can reduce the concentration at the source of release virtually instantaneously, resulting in a concentration below the lower explosive limit. A zone of negligible extent results. However, where the availability of ventilation is not good, another type of zone may surround the zone of negligible extent";

- Medium (MV): the ventilation "can control the concentration, resulting in a stable situation in which the concentration beyond the zone boundary is below the LEL whilst release is in progress and where the explosive atmosphere does not persist unduly after release has stopped. The extent and type of the zone are limited to the design parameters";

- Low (LV): the ventilation "cannot control the concentration whilst release is in progress and/or cannot prevent undue persistence of a flammable atmosphere after release has stopped".

➢ *Availability of ventilation*:

- Good: "ventilation is present virtually continuously";

- Fair: "ventilation is expected to be present during normal operation. Discontinuities are permitted provided they occur infrequently and for short periods";

- Poor: "ventilation which does not meet the standard of fair or good, but discontinuities re not expected to occur for long periods. Ventilation that does not even meet the requirements for poor availability must not be considered to contribute to the ventilation of the area".

A source of emission always generates around itself a first zone so correlated with the grade of emission:

> Continuous grade of emission: Zone 0

> Primary grade of emission: Zone 1

> Secondary grade of emission: Zone 2

Such Zones, when the ventilation degree is "High (VH)" and its availability is "Good", have negligible extensions and are often called Zone 0NE, Zone 1NE and Zone 2NE and are not influent in the hazardous classification process even if it is recommended to do not install electrical equipments within few dm3 around any emissions source.

If the ventilation degree is "High (VH)" and its availability is "Fair" or "Poor", around this first zone, it is generated also a Zone 1 or Zone 2 depending on the grade of the sources of emission.

The following table 2 summarised these general results.

Table 2. Type of zone and influence of the ventilation.

Ventilation		Grade of emission		
Degree	Availability	Continuous	Primary	Secondary
High (HV)	Good	Zone 0 NE	Zone 1 NE	Zone 2 NE
	Fair	Zone 0 NE + Zone 2	Zone 1 NE + Zone 2	Zone 2 NE
	Poor	Zone 0 NE + Zone 1	Zone 1 NE + Zone 2	Zone 2
Medium (MV)	Good	Zone 0	Zone 1	Zone 2
	Fair	Zone 0 + Zone 2	Zone 1 + Zone 2	Zone 2
	Poor	Zone 0+ Zone 1	Zone 1+ Zone 2	Zone 2
Low (LV)	Good, fair or poor	Zone 0	Zone 1 or Zone 0	Zone 1 or even Zone 0

When the ventilation has a "Low ventilation" (LV), some volumes of the environment, not affected by the air flow rate, could generate accumulation of the explosive atmosphere and in such cases could generate Zone 1 or Zone 0. It is the case for example of dome vault for light gases or burrows and basements for heavy gases.

Once that the general theory has been understood, it is clear that one of the difficulties in its application, is the practical evaluation of the degree of ventilation. In the EU Norm it is proposed the utilization of the hazardous volume ("Vz") as a parameter able to guide the choice of the ventilation degree. "Vz" depends on the release flow rate ("Qg"), air changes around the emission source ("C_0"), ventilation efficiency ("f"), ambient temperature ("Ta"), and lower flammable limit of the hazardous substance ("LELm", mass per volume, kg/m3). Moreover in the evaluation of the hazardous volume, it is applied to the LEL a safety factor ("k") that is equal to 0.25 for emission of continuous and primary grade and equal to 0.5 for emission of secondary grade.

$$Vz = \frac{f}{C_0} \cdot \frac{Qg}{k \cdot LELm} \cdot \frac{Ta}{293} \qquad [m^3] \qquad\qquad (1)$$

If the ventilation is able to reduce the hazardous volume "Vz" to a negligible value, then the degree of ventilation may be considered "high" with respect to the source of release and the area under consideration. If the ventilation is not able to reduce the hazardous volume "Vz" to a negligible value, but is able to limit its extension with respect to the emission source and the area under consideration than the degree of ventilation may be considered "medium". Finally, if the ventilation is not able to reduce the hazardous volume around the emission sources, the degree of ventilation should be considered "low". "Low ventilation" (LV) degree will not generally occur in open environment, except where there are significantly restrictions to the air flow, i.e. in pits.

Also the openings between different environments should be considered potential emission sources and in this case the grade of the release will depend upon the type of the Zone upstream the opening, the frequency and the duration of the opening periods, the effectiveness of seals or joints and finally on the difference in pressure between the areas involved.

According to the EU Norm 60079-10, the openings are classified in A, B, C or D (see table 3).

Table 3. Openings classification.

Opening type	Definition
Type A	Openings not conforming to the characteristics specified for Types B, C or D. Examples: ▪ Open passages for access or utilities (pipelines through walls, ceilings and floors,….); ▪ Fixed ventilation outlets in rooms, buildings, and similar openings of Types B, C and D which are opened frequently or for long periods.
Type B	Openings which are normally closed (i.e. automatic closing) and infrequently opened, and which are close-fitting.
Type C	Openings normally closed and infrequently opened, conforming to type B, which are also fitted with sealing devices (i.e. gaskets) along the whole perimeter; or 2 openings type B in series, having independent automatic closing devices.
Type D	Openings normally closed conforming to type C which can only be opened by special means or in an emergency; or a combination of one type C opening adjacent to a hazardous area and one opening type B in series.

In order to perform the classification of the area below the opening, it should be assumed a certain grade of release from the opening itself. This is a function of the type of the opening and of the type of the zone upstream (see table 4).

Table 4. Openings classification.

Zone upstream the opening	Opening type	Grade of release of the opening
Zone 0	A	Continuous
	B	(Continuous) [1] / Primary
	C	Secondary
	D	No release
Zone 1	A	Primary
	B	(Primary) [1] / Secondary
	C	(Secondary) [1] / No release
	D	No release
Zone 2	A	Secondary
	B	(Secondary) [1] / No release
	C	No release
	D	No release

[1] For grade of release shown in brackets, the frequency of operation of the openings should be considered.

3.0 SPECIFIC FEATURES OF THE ITALIAN METHODOLOGY

In Italy two guides for the classification of hazardous areas for the presence of flammable gases have been published to help in the application of the requirements of the AEX Directives:

- Guide CEI 31-35, "Electrical apparatus for explosive atmospheres. Guide for the application of the Norm CEI EN 60079-10 (CEI 31-30)";

- Guide CEI 31-35/A, "Electrical apparatus for explosive atmospheres – Guide for the application of the Norm CEI EN 60079-10 (CEI 31-30) Classification of hazardous zones, Examples of application".

These two guides give special features for the determination of the type of the zone and for the evaluation of its extension.

As already highlighted, the type of the hazardous area depends upon the probability of the formation of certain volumes of explosive atmospheres. But while in the European Norm EN 60079-10, there aren't any indications on which values of frequency should be taken as reference in the decisional process of classification, in the Italian Guide CEI 31-35, there are some indications on how to proceed.

In fact, as seen in the previous chapter, the type of the zone is settled on the basis of the relations highlighted in table 2, between the grade of the release and the influence of the present ventilation (Degree and Availability).

When applying the Italian method, once settled the type of the Zone, it should be verified that the likelihood of presence of the explosive atmosphere in one year and the total duration of the presence of the explosive atmosphere in one year (release duration plus time of persistence after the release has been stopped) are under some critical value. This verification introduces a risk probabilistic based approach.

Table 5. Relation between the Zone type and the likelihood and duration of the explosive atmosphere.

Zone	Likelihood of presence of the explosive atmosphere in 365 days (1 year)	Total duration of presence of a explosive atmosphere in 365 days (1 year): release duration + time of persistence after release
Zone 0	$P > 10^{-1}$	More than 1000 hours
Zone 1	$10^{-1} \geq P > 10^{-3}$	More than 10 hours up to 1000 hours
Zone 2 (2)	$10^{-3} \geq P > 10^{-5}$	More than 0.1 hours up to 10 hours (1)
(1) In the case of total duration of the release (explosive atmosphere) in 365 days (1 year) less than 0.1 hours, the area is generally non hazardous, in particular when the emission are more than one in 365 days. However, to be sure than the area is really non hazardous, it is better to perform a risk assessment analysis case by case.		
(2) In the case that reliable fault rates are not available, it can be assumed that at least one event is likely to occur in one year.		

The Italian approach, introduced by the publication of the two Guides, is a sequential process for the classification of the hazardous areas that at the end gives both the type of the Zone and its extension. The guidelines present indications on the:

✓ most suitable size of leakage to apply as a function of the type of component (pump/compressor; piping connections; valve; etc.);

✓ flow rates for structural (so continuous) emission as a function of the component's type (pump/compressor; piping connections; valve; etc.) on the basis of statistical data;

✓ flow rates for primary and secondary grade of emissions evaluated/calculated on the basis of specific reference formulas;

✓ evaluation of the extension of the hazardous areas as a function of the release flow rate, ventilation and flammable substance under examination.

To better explain the Italian method here there is presented the specific case of classification of hazardous areas generated by a natural gas compression unit located inside a box.

First of all it is needed to the define the substance and the environment (see table 6 and 7).

Table 6. Definition of the hazardous substance.

Substance	natural gas
Density, ρ_{gas} (T=20 °C and p=101325 Pa)	0.719 kg/m^3
Molar mass, M	16.34 kg/kmol
Ratio between specific heat at constant pressure and specific heat at constant volume, $\gamma = Cp/Cv$	1.31
LEL	3,93 vol.%; 0.0267 kg/m^3
Minimum ignition temperature	482 °C

Table 7. Definition of the environment.

Location	Inside a box (confined environment) with natural ventilation
Box volume	Total volume : 32.4 m^3
	Free volume: 27 m^3 (total volume minus the space occupied by the compressor, the buffer tanks, the pipings, etc. Reduction of about 15%)
Ventilation	Natural ventilation through openings
Openings	1 on the roof: 1.3 m^2
	1 in the upper part of the box front side: 1 m^2
	1 in the bottom part of the box front side: 1 m^2
Vent line	1 on the roof at H=3 m from the ground level
Compressor nominal flow rate:	700 m^3/h maximum (design parameter)

The natural ventilation is due to the wind that enters the local through the openings; the natural ventilation flow rate, Qa, is evaluated as:

$$Qa = 0.65 \cdot A_w \cdot w \cdot \left(\Delta c_p\right)^{0.5} = 0.25 \, \mathrm{m}^3/\mathrm{s} \tag{2}$$

$$\frac{1}{A_w^2} = \frac{1}{\left(A_{high}\right)^2} + \frac{1}{\left(A_{low}\right)^2} \qquad [\mathrm{m}^{-2}] \tag{3}$$

where:

$A_w =$ opening's area coefficient = 0.92 m^2 (A_{high}: total area of the openings located in the high part of the box = 2.3 m^2; A_{low}: total area of the openings located in the bottom part of the box = 1 m^2)

$w =$ wind's speed outside the confined environment = 0.5 m/s

$\Delta c_p =$ 0.9 ÷ 0.1; it is the coefficient that takes into account the wind speed prevalent direction with respect to the openings (Δc_p = 0.9 when the wind prevalent direction is perpendicular to the openings; Δc_p = 0.4 when the wind prevalent direction is at 45° with respect to openings; Δc_p = 0.2 when the wind prevalent direction is <45° with respect to openings; Δc_p = 0.1 when the openings are shielded by other structures or obstacles). In the present case it is assumed Δc_p = 0.7, since the wind prevalent direction in a year is perpendicular to the openings located in the front side of the box (Δc_p = 0.9); however it is cautelative to apply some reduction factor due to protection structures on the openings (grates).

The number of air changes inside the free volume of the box is evaluated as:

$$Ca = \frac{Qa}{Va} = 0.01 \ \text{s}^{-1} \tag{4}$$

where Va is the internal free volume of the box = 27 m^3.

All the emission sources with the related emission grade, that are present inside the box of the compression unit, should be evaluated as they are all potentially able to generate hazardous areas. The emissions of continuous grade from all the connections, valves and the compressor itself do not generate hazardous areas, so here it is presented the approach for the secondary grade emissions. The primary grade emissions from the pressure safety relief devices does not generate hazardous areas inside the box of the compression unit, as they are collected and conveyed to the vent line to the atmosphere.

The secondary emissions are not expected to occur in normal operation and, if it does occur, is likely to do so only infrequently and for short period. All the secondary emissions within the internal volume of the box have been assimilated to a fault of a valve with an emission hole "A" equal to 0.25 mm^2 (statistical datum taken from the Guide CEI 31-25, 2001).

The emission flow rate from a hole can be sonic or sub-sonic. The type of the flux is evaluated through the verification of the following relation:

if $\quad \dfrac{Pa}{P} \leq \left(\dfrac{2}{\gamma+1} \right)^{\frac{\gamma}{\gamma-1}} \qquad$ then the flux is sonic $\tag{5}$

as $\quad 0.01 \leq 0.54 \qquad$ then the flux is sonic

Where:

Pa: 101325 Pa, atmospheric pressure

P: 190 10^5 Pa (190 bar): absolute pressure within the piping

γ: 1.31, ratio between specific heat at constant pressure and specific heat at constant volume.

The emission flow rate is expressed as:

$$Qg = \varphi \cdot c \cdot A \cdot \left[\gamma \cdot \left(\frac{2}{\gamma+1} \right)^{\beta} \right]^{0.5} \cdot \frac{P}{\left(R_0 \cdot \dfrac{T}{M} \right)^{0.5}} = 6.3 \cdot 10^{-3} \ \text{kg/s} \tag{6}$$

Where:

φ: 1   in the case of sonic flux

c: 0.8   emission coefficient

A: 0.25 10^{-6} m^2 emission area

β: $(\gamma+1)/(\gamma-1) = 7.45$

P: 190 10^5 Pa (190 bar): absolute pressure within the piping

R_0:   8314 J/kmol K: universal constant of gas

T: 313 K: gas temperature

M: 16.34 kg/kmol: gas molar mass

When evaluating the medium concentration of the explosive atmosphere in the confined environment, due to the secondary grade emission, also the continuous grade emissions should be taken into account, as they might occur contemporarily. The gas concentration in air, due to the secondary grade emissions, rises in an exponential way depending on the free volume of the environment. The medium volume concentration, $Xt_e\%$, after the emission time "t_e" is estimated as:

$$Xt_e\% = \frac{Qg}{Qa \cdot \rho gas} \cdot \left(1 - e^{-Ca \cdot t_e}\right) \cdot 100$$
(7)

Where:

ρ_{gas}:   0.64 kg/m^3, density of the gas at 40°C

t_e: 300 s, time of emission evaluated considering the time needed for the operator to intervene

Instead, for the continuous grade emissions the initial transitory phase could be ignored and the medium gas concentration in air is estimated as:

$$Xr\% = \frac{Qg}{Qa \cdot \varphi_{gas}} \cdot 100 \quad \%$$
(8)

So the medium gas concentration in the confined environment is the sum of the one due to the secondary grade emissions and the one due to the continuous grade emissions:

$$Xm\% = \sum Xr \,(\text{cont grade emissions}) + Xt_e \,(\text{secon. grade emissions}) \quad \% = 3.75\,\%$$
(9)

In order to consider the flammable volume, due to the secondary emissions within the box, non extended to the whole internal volume, the medium concentration of the explosive atmosphere within the confined environment has to be compared with the lower flammability limit corrected with a safety factor (k*LEL) and with the real ventilation efficacy.

$$Xm\% \leq \frac{k \cdot LEL\%vol.}{f} = 0.98\,\%$$
(10)

Since this relation is not verified, the flammable atmosphere should be considered extended to the whole internal volume of the compression unit box, and the grade of ventilation should be considered "Low" (LV). The availability of natural ventilation is "Good" ("the ventilation is present virtually in continuously" CEI EN 60079-10). Now Entering the table 2, it results that the emissions from the medium pressure compression unit box, give origin to a Zone 1 extended to the all the internal volume of the box. It would have been Zone 0 if the ventilation would have been is so weak and the release would have been such that in practice an explosive atmosphere would exist virtually continuously (i.e. approaching a "no ventilation" condition).

As already highlighted, also all the openings of the compression unit box generate hazardous areas. Since all the openings in the present case are of Type A (see table 3), it results that the openings have to be considered sources of emission of primary grade (see table 4).

For safety reasons, the gas flow rate of the opening is assumed equal to the gas flow rate from the valve that generate the hazardous Zone 1 (i.e. $Qg = 6.3 \ 10^{-3}$ kg/s).

The extension of the hazardous Zone from the opening is evaluated through:

$$dz = 16.5 \cdot \left(P \cdot 10^{-5}\right)^{0.5} \cdot M^{-0.4} \cdot \left(\frac{LEL\%vol.}{100}\right)^{-1} \cdot A^{0.5} \cdot 1.5 \quad = \quad 1.42 \ m \tag{11}$$

The hazardous volume, Vz, is evaluated taking into account the minimum fresh air flow rate, Qa_{min}, needed around the sources of emission to keep the concentration below the k*LELm:

$$Qa_{min} = \frac{Qg}{k \cdot LELm} \cdot \frac{Ta}{293} = \quad 1.02 \ \frac{m^3}{s} \tag{12}$$

The air changes, C_0, in the proximity of the opening:

$$C_0 = \frac{w}{L_0} = 0.18 \ s^{-1} \tag{13}$$

Where:

L_0:   is the diameter (2*dz) of the hazardous zone considering the emission sources as punctual.

w: wind velocity in the open environment = 0.5 m/s

The flammable volume, Vz, is evaluated as:

$$V_z = \frac{f \cdot Qa_{min}}{C_0} \quad = 5.79 \ m^3 \tag{14}$$

The hazardous volume generated by the primary grade emission from the opening is not negligible. So it can be assumed a "Medium" (VM) degree of ventilation. The availability of natural ventilation is "Good" ("the ventilation is present virtually in continuously" CEI EN 60079-10, 2004, 2nd edition). So entering the table 2, it results that the area just outside all the openings of the compression unit box is Zone 1 with an extension of 1.5 m.

Finally, also the vent line generates a hazardous area. The vent line is located on the roof of the compression unit box at 3 m from the ground level. The vent line foresees two different types of emission, Continuous grade emission, because of the leaks from the compressor's shaft that are collected and conveyed to the vent, and Secondary grade emission because of the opening of the safety valves of the compressor.

The leaks from the compressor's shaft in normal operation are about the 0.3% of the nominal gas flow rate (design parameter). So in the present case $Qg = 4.19 \ 10^{-4}$ kg/s. The radius of the hazardous zones around the sources of emission, in this case of sub-sonic flux (continuous emission) is evaluated through:

$$dz = \left(\frac{42300 \cdot Qg \cdot f}{M \cdot LEL\%vol. \cdot w}\right)^{0.55} \cdot 1.2 \quad = 0.87 \ m \tag{15}$$

Once determined the extension of the hazardous zone around the vent line due to the continuous emission of the leaks of the compressor's shaft, it should be evaluated the air changes, C_0, in the proximity of the vent discharge, the minimum fresh air flow rate, Qa_{min}, needed around the continuous sources of emission to keep the concentration below the k*LELm, and the flammable volume, Vz. Through the application of the formulas 12, 13, and 14, it is found that: $C_0 = 0.29$ s^{-1}, $Qa_{,min} = 0.0671$ m^3/s, and Vz = 0.23 m^3.

The hazardous volume generated by the continuous emission from the vent discharge line in air is not negligible, but limited by the natural ventilation. So it can be assumed a "Medium" (MV) degee of ventilation, while the availability of natural ventilation is "Good". So entering the table 2, it results that the continuous emission from the vent discharge line in air generates a Zone 0 of 0.9 m.

Now, also the secondary grade emission sources should be considered. The gas flow rate from the safety valves are collected and conveyed to the vent line that discharges the gas at 3 m high from the ground level on the roof of the box. This type of discharge is of secondary grade as it can occur only in case of fault or malfunctions.

To evaluate the flow rate from the vent line due to the opening of a safety valve, it is assumed, as reference value, the maximum flow rate of the compression unit, i.e. Qg = 700 m^3/h (design parameter). The equivalent hole of emission is evaluated through:

$$A = \frac{Q_g}{\varphi \cdot c \cdot P} \cdot \frac{\left(\dfrac{R_0 \cdot T}{M}\right)^{0.5}}{\left[\gamma \cdot \left(\dfrac{2}{\gamma+1}\right)^{\beta}\right]^{0.5}} = 5.5 \ 10^{-6} \ m^2$$

(16)

The radius of the hazardous zones around the source of emission is evaluated, through the formula 11 (sonic flux), and then dz = 6.66 m. Through the application of the formulas 12, 13, and 14, it is found that: $C_0 = 0.04$ s^{-1}, $Qa_{,min} = 11.20$ m^3/s, and Vz = 298.23 m^3.

Another useful parameter is the time of persistence of the explosive atmosphere once stopped the gas flow (by the operator or by the automatic shut down system). This time is evaluated as:

$$t = \frac{-f}{C_0} \cdot \ln \frac{LEL\%vol. \cdot k}{X_0} \approx 87 \ s$$

(17)

The hazardous volume generated by the secondary grade emissions from the vent discharge in air is not negligible, but limited by the natural ventilation (the hazardous volume is in open environment). So it can be assumed a "Medium" (MV) degree of ventilation. The availability of natural ventilation is "Good", so once again entering the table 2, it results that the secondary grade emission from the vent discharge point in air generate a Zone 2 of 6.7 m.

As the gas release occurs under free jet conditions and as the natural gas is lighter than air, it is assumed a cone-shaped geometry of the hazardous zone, with height equal to dz (6.7 m) and angle at the vertex equal to 30°.

In the following figure is presented the hazardous zone classification within the enclosure of the medium pressure compression unit.
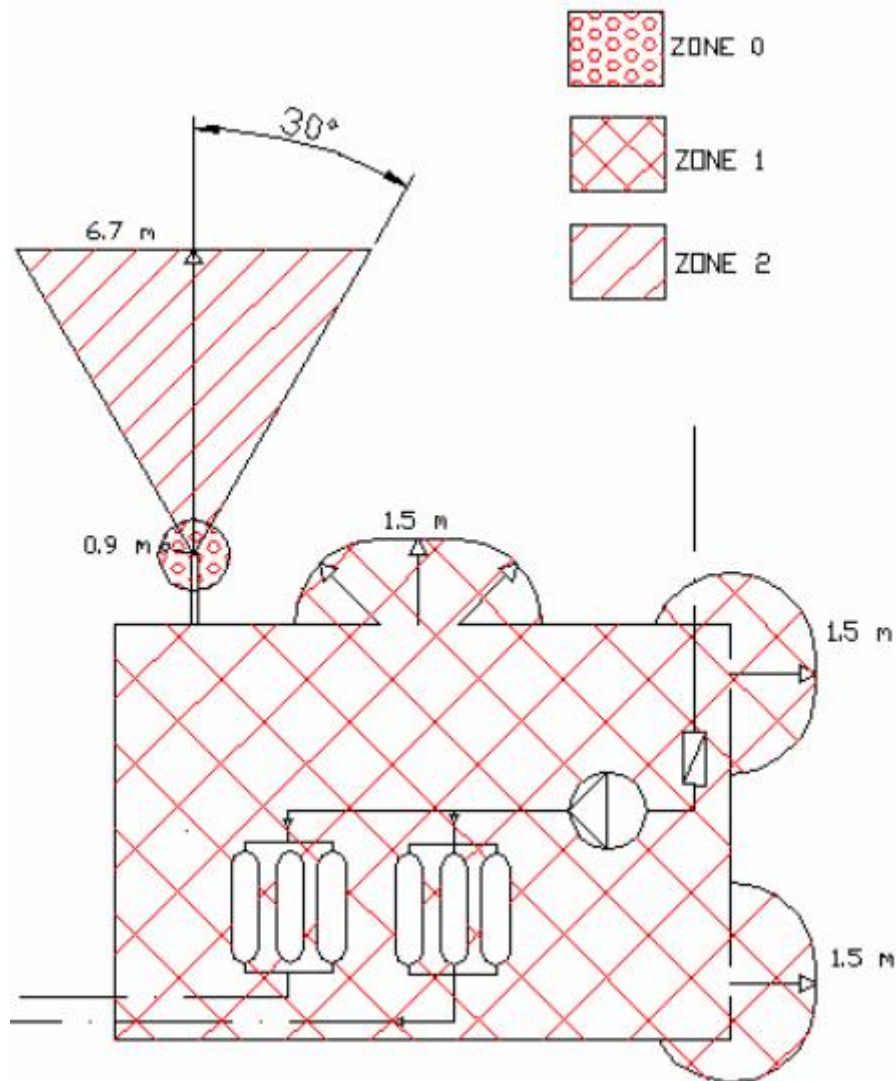
Figure 1. Hazardous area classification for the natural gas compression unit.

4.0 CONCLUSIONS

The ATEX Directives regulate use of electrical and mechanical equipment in explosive atmospheres and classification of explosive or hazardous zones. The ATEX "User" Directive 1999/92/EC gives minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

Potentially explosive areas are classified into 'Zones' and these must be clearly marked. The European Norm EN 60079-10 gives some indications on how to proceed for the predisposition of the Zones in areas where flammable gases are used. The zoning is based on the likelihood and persistence of a potential explosive atmosphere, and the ventilation is the main parameter for the risk reduction in these areas, as well as the elimination of all the ignition sources, both electrical and non electrical ones.

The major challenge of this new approach introduced for the classification of hazardous areas will be the uniform application of the requirements and the assessment of products. In fact in Europe up to know does not exist any European standard that gives specific features for the clear predisposition of the Zones (type and extension).

On the other side, in Italy there are two specific Guides, CEI 31-35 and CEI 31-35/A, to the application of the EU Norm EN 60079-10; these standards introduce a sequential method for the determination of the Zones in the presence of potentially explosive atmospheres due to the presence of flammable gases.

The Italian approach is based on a rational, systematic and well structured methodology founded on a simple, but fundamental physic. The main limit of such methodology is the high conservative approach that leads to an over estimation of the Zone's extension.

For all these reasons, and because it is up to know the only structured method, the Italian approach is under evaluation in the framework of the European Network of Eccellence, HySafe ("Hydrogen Safety"). The final output will be the predisposition of some European harmonized guidelines for the predisposition of hazardous areas.

These guidelines could then be proposed, within an international agreement (i.e. CENELEC or ISO), as a base for the official publication of a harmonized European standard for the predisposition of hazardous area for the presence of flammable gases.

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