EVALUATION OF EXPLOSIVE ATMOSPHERES FORMATION IN INDUSTRIES WITH FLAMMABLE MATERIALS - A CRITICAL RISK ANALYSIS

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ABSTRACT

This paper discusses the elaboration of area classification documents, indispensable for safety and development of electrical installations design in the oil, gas and chemical industries, making a comparison of the results obtained with the use of generic figures introduced by API Recommended Practices with those obtained by the use of simulation software of flammable gases' dispersion.

1. INTRODUCTION

A "classified area" is defined as the region that has the possibility of an occurrence of an explosive atmosphere. An explosive atmosphere is defined as the mixture with air, under atmospheric conditions, of flammable vapors or gases, in which, after ignition, it allows to propagate the flames in a self-sustained manner. For the purposes of area classification, an explosive atmosphere of gas or vapor is considered to be one whose concentration of the flammable substance is above its Lower Explosive Limit (LEL).

Since flammable liquids and gases flow inside the pipelines and process equipment, an explosive atmosphere will only be formed in the environment when such flammable substance is released, which can occur in certain operational situations, such as in cases of abnormalities in the process.

It is up to the area classification study, based on the estimation of the release rate, the local ventilation and the chemical characteristics of the flammable product, to identify how far from each probable release point the concentration of the flammable mixture will remain above its LEL, and mark it in the design documents, which will then allow the correct specification of the electrical and electronic equipment to be installed in those regions, ensuring the safety of the plant against explosions.

As the area classification drawings are also consulted for the elaboration of safety procedures in the operation and maintenance of the unit, it is essential that they be elaborated based on the characteristic data of a given industrial plant.

2. DESCRIPTION

Two currents are internationally known for the area classification in relation to the presence of explosive atmospheres, whose correlation is given in Table 1.

Tab. 1 - Correlation between IEC and North American terminologies.

IEC	North American	Definitions
Zone 0	Division 1	A place in which an explosive atmosphere (air and flammable gas), is present continuously, or for long periods, or frequently
Zone 1	Division 1	A place in which an explosive atmosphere (air and flammable gas), is likely to occasionally occur in normal operation.
Zone 2	Division 2	A place in which an explosive atmosphere (air and flammable gas), is not likely to occur in normal operation and, if it does, will only exist for a short period of time.

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2.1 *T*he “standard x recommended practice” confusion

The processes of elaborating the area classification study according to the North American practice (whose characterization is given by “Divisions”), and according to the International Electrotechnical Commission (IEC) standards (which are graded by “Zones”), are discussed below.

The most consulted technical documents for the preparation of area classification drawings are:

2.1.1 *O*n the North American practice side: the API RP-500

Although commonly referred to as a “standard”, RP-500 [1] document is in fact a “Recommended Practice” issued by the American Petroleum Institute (API). It is worth to say that while a standard establishes the minimum requirements for performing a service or manufacturing a product, a “Recommended Practice” only shows some advice based on practices adopted by the companies whose employees participate in the respective Working Group.

Regarding the API RP-500 [1], its objective is “*to provide guidance for the classification of Class I Division 1 and Class I Division 2 regions in petroleum installations, which should be treated as a guide and applied through proper engineering analysis*”. It is a warning that the example figures presented there should not be just copied. Figure 1 shows a comparison between two API RP-500 editions: 1957 and 1997.

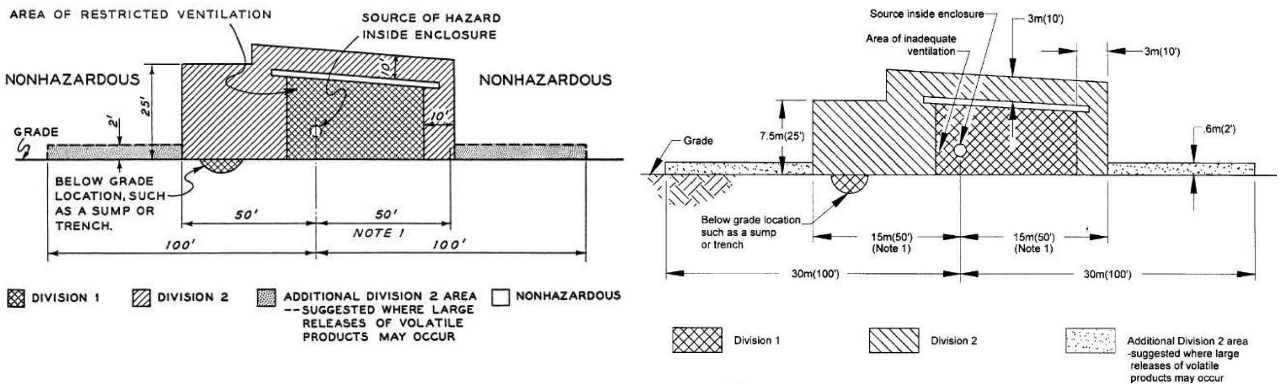

Fig.1 – Comparison between API RP-500 figures, 1957 (left) and 1997 (right) editions

It is important to say that API RP 500:1997 (under its figure 22, shown above on the right side), has the following note: “*Distances given are for typical refinery installations; they must be used with judgment, with consideration given to all factors discussed in the text. In some instances, greater or lesser distances may be justified*”.

But, no definition is given for a “*typical refinery*”. As shown in figure 1 above, the figures are identical, but, due to many improvements on refining processes since 1957, a modern oil refinery has different products and higher processes’ pressures. So, in case of an eventual gas leak, the plume will reach a much greater distance. That is why the API RP-500 figures are only suggestions, not representing real process conditions.

Additionally, it is important to note that the API RP-500 figures don’t identify the gases considered to elaborate them. Therefore, just copying and paste such figures into an area classification plan is unacceptable.

API published RP-505 [2] with its structure and text similar to the API RP-500, but adapted to the “Zones” terminology used in the IEC standard. [3]

2.1.2 *O*n the IEC side: the NBR IEC 60079-10-1

This ABNT standard [4] was issued from a full translation from the IEC 60079-10-1 standard. ABNT adopted the IEC standards in the eighties [5].

The current edition of this technical document has some equations for estimating the extensions of classified areas and some examples of area classification in its Annex E, with a caveat similar to that found in the API Recommended Practices that they should not be directly applied, as each situation or process equipment needs specific considerations. [6]

3. MATHEMATICAL MODELING

Since the API Recommended Practices warn that their "example figures" cannot simply be reproduced [7], and emphasize the need of case-by-case considerations (as environmental influences and process characteristics must be carefully analyzed), it is clear that the use of computational tools based on appropriate mathematical models give better results. [8].

In the real world, the shape of the flammable gas cloud can be quite different from the example figures of API recommended practices, as highlighted in blue in figure 2. [9]

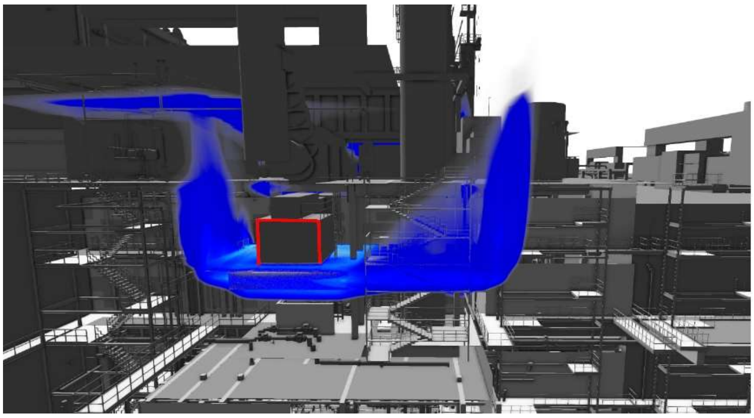

Fig. 2 – Simulation of fuel gas leakage in an offshore oil platform.

For simulating the gas leaks events in complex installations, mathematical models can be included in dedicated software. [10]

To estimate the gas mass flow, the Gaussian model for the plume can be used in its simplest case: a subsonic jet emitted by a circular orifice. [10]

Equation 1 describes this simplified model. [11]

$$\frac{C_x}{C_o} = 5\frac{d_o}{x}\sqrt{\left(\frac{\rho_A}{\rho_o}\right)}, \qquad (1)$$

Where:

Cx	- volumetric concentration at x meters (m^3/m^3)
Co	- volumetric concentration in the orifice (m^3/m^3)
d_0	- hole diameter (m)
x	- axial distance (m)
ρ_A	- the local air density ($kg.\ m^{-3}$)
ρ_0	- the density of the gas in the orifice ($kg.\ m^{-3}$)

Greater precision in this model is obtained by introducing some factors to reflect the influences of pressure and density of the flammable gas on the extent of the classified area, as shown in equation 2. [12]

$$x = \frac{5C_o d_o}{0.2 \times \mathrm{LEL}} \left(\frac{\rho_x}{\rho_o} \right)^{0.5} k_{\rho_o} k_{\mathrm{pr}_o} \quad (2)$$

Where:

LEL - lower explosive limit [%]
C_o - concentration at the output [% vol]
d_o - outer diameter [m]
x - distance from release point until to 20% LEL [m]
p_x - density of the environment [kg/m^3]
p_o - gas density at the outlet [kg/m^3]
k_{po} - density adjustment factor
k_{pro} - pressure adjustment factor

3.1 *S*imulation software features

Software for area classification must have an intuitive interface, be able to simulate various situations, and be accompanied by a detailed operating manual. The manual must also contain an example of validation of the simulation models, and highlight the limits for using the software.

An example of an area classification software's splash screen is shown in figure 3.

Fig. 3 – Splash screen of an area classification software.

After selecting the type of emission to be simulated, it will be necessary to fill in the fields with the characteristics of the flammable product (such as temperature, process pressure, density, etc.) in addition to the characteristics of local ventilation and relative humidity.

The simulation will be based on an emission area in the process piping, defined by the user. The user must also define up to which LEL percentage value the software should consider as of interest.

The figure 4 shows the result of a software simulation.

The use of simulation software allows evaluating the emission behavior of the flammable gases, considering the safety factors defined by the user. This method provides results that are very different from those found in the figures of API Recommended Practices.

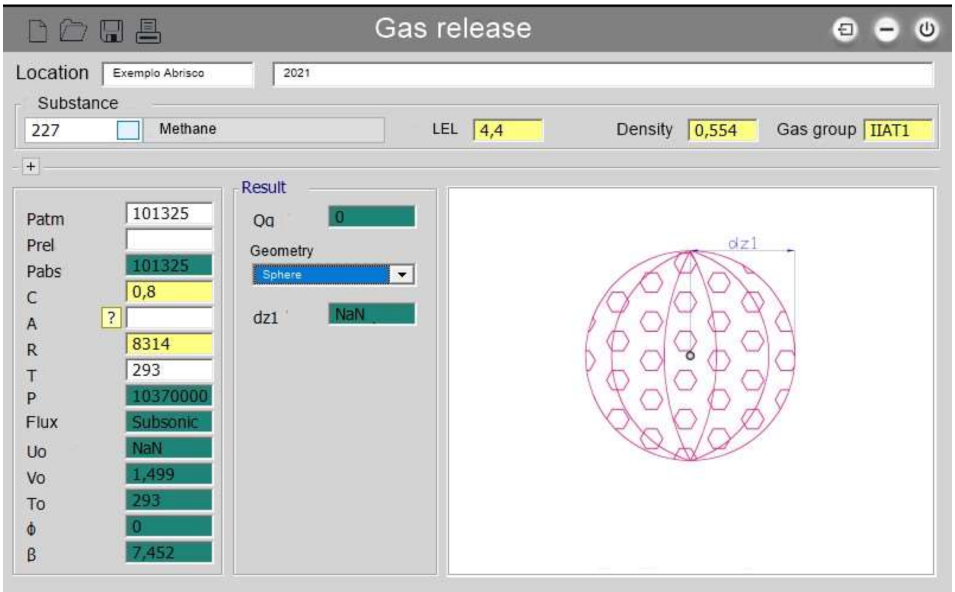

Fig. 4 – Simulation for a methane emission simulation.

4 RESULTS

The figures 5 and 6 show simulations of isopentane releases at 30 ºC and 120 ºC, highlighting the different shapes of the formed clouds. [13]

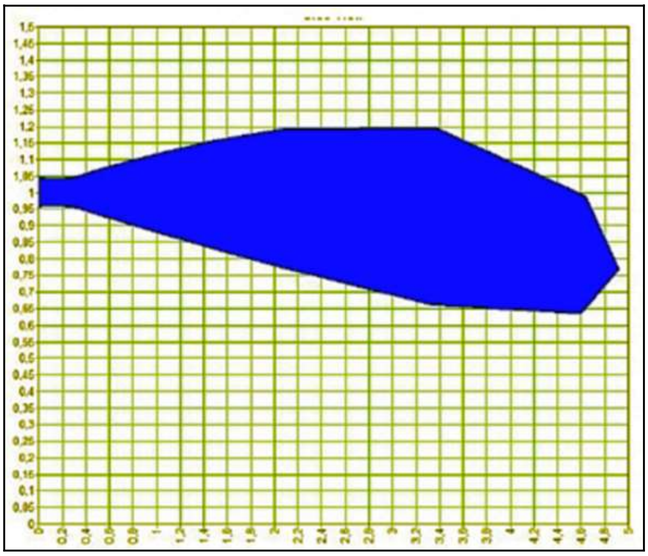

Fig. 5 - Simulation of isopentane release at 30º C. Horizontal and vertical axes in meters.

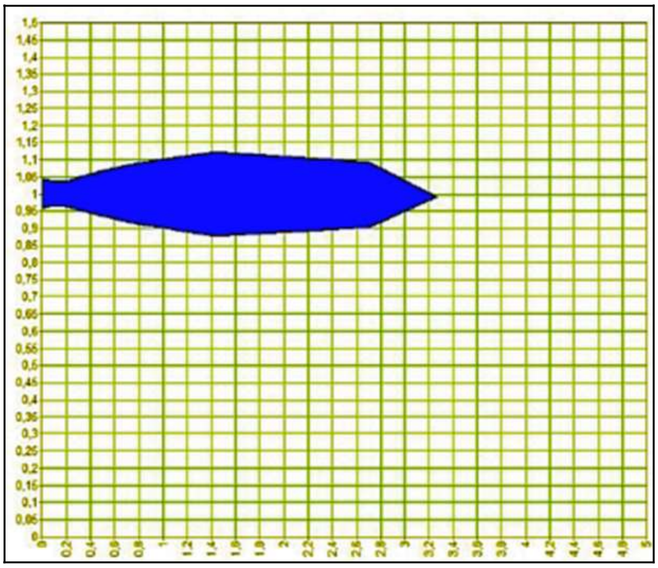

Fig. 6 - Simulation of isopentane liberation at 120º C. Horizontal and vertical axes in meters.

5. DISCUSSION

It is proven that the distances shown in the example figures of API RP-500/505 cannot be simply copied in area classification studies, as they define fixed distances that do not reflect the real behavior of a flammable gas release in the oil & gas processes. [14]

As such “generic examples” do not show on which substances, pressures, or processes temperatures they were based, there is no guarantee that reproducing them will give the required safety against explosions.

Knowing the extent of the classified areas makes it possible to correctly specify the special electrical and electronic equipment for use in these environments, which are built according to specific standards to allow them to function without the risk of being sources of ignition.

The oil, gas and chemical industries, as they process flammable liquids and gases at large volumes, pressures and flows, are considered to have the biggest amount of “classified areas”. [15]

6. CONCLUSIONS

As the area classification study decisively contributes to the unit's safety, its documents must have an adequate basis, since they can be consulted both for issuing operational procedures and for carrying out maintenance and inspection services.

It is noteworthy that the usage of a computational tool does not aim to put a set of equations to be manipulated by people without the necessary knowledge, but to provide a resource that allows the multidisciplinary team responsible for the study to define the extents of the classified areas in a correct way, expressing the real conditions of the industrial plant.

The figures given by the API Recommended Practices were identified as not adherent to real situations, specially when the release of the flammable product into the environment is with low flow or low pressure.

A reliable area classification study is essential for managing the greatest risk involved in the oil and gas industry units: explosion, that can be capable of causing great material and personal losses.

Considering the involved explosion risks, the oil and gas companies should check their area classification studies, and if identified that they were done by simply copying-and-pasting generic figures from the API Recommended Practices, they should urgently arrange for a review, under the supervision of an expert.

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