SAFETY DISTANCES: DEFINITION AND VALUES

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ABSTRACT

In order to facilitate the introduction of a new technology, as it is the utilization of hydrogen as an energy carrier, development of safety codes and standards, besides the conduction of demonstrative projects, becomes a very important action to be realized.
Useful tools of work could be the existing gaseous fuel codes (natural gas and propane) regulating the stationary and automotive applications.
Some safety codes have been updated to include hydrogen, but they have been based on criteria and/or data applicable for large industrial facilities making the realization of public hydrogen infrastructures prohibitive in terms of space.
In order to solve the above mentioned problems, others questions come out: how these safety distances have been defined? Which hazard events have been taken as reference for calculation? Is it possible to reduce the safety distances through an appropriate design of systems and components, or through the predisposition of adequate mitigation measures?
This paper presents an analysis of the definitions of "safety distances" and "hazardous locations", as well as a synoptic analysis of the different values in force in several States for hydrogen and natural gas. The above mentioned synoptic table will highlight the lacks and so some fields that need to be investigated in order to produce a suitable hydrogen standard.

1.0 INTRODUCTION

The term "safety distances" has in technical field and in juridical field different shades of meaning, even if it is broadly used in both fields. Moreover, as for the term "Risk", a safety distance is perceived in different ways depending on the person (culture, position and responsibility) using it.

Such dichotomy does not belong only to the industrial field (hydrogen included), but more generally to all those fields where one, by applying physical distances, is trying to avoid disagreeable consequences that could be generated by the use of hazardous substances.

The first notions about safety distances in industrial field were tied up to the level of ignorance concerning the behavior of some technologies. As a consequence a certain level of protection was established.

As an example the safety distance problem in the nuclear energy pacific use, from which were derived the majority of the techniques and of the safety principles actually in force, was faced in the 1950 when the "Reactor Safety Committee" of the Atomic Energy Commission solved the problem of the safety distances (at that time the exact term was "exclusion distance", i.e. without resident population) by providing a formula in which the distance (in miles) was proportional to the square root of the thermal power (in kW) of the reactor ($R=0.01 * \sqrt{KW}$).

By that formula, derived by qualitative and quantitative argumentations and expressed in a simple way, therefore easily comprehensible from the population, the intent was to express an easy concept: "also in the case of the worst accident scenario over such distance there was nothing to fear". But still from the nuclear history we all well know that when such worst accident scenarios were analysed with greater details, such formula failed.

So other methodologies have been developed (i.e. risk assessment) to take into account the fact that the zero risk does not exist! If we theoretically proceed with the evaluation of the worst condition (remembering that there is no limit to the worse) many technologies couldn't be actually in use.

So the modern key for the acceptance of a technology has to be found necessarily in the risk-benefit analysis, with benefits greater with respect to the risks. This means, more or less unconsciously, that we have done the choice to cohabit with some residual risk different from zero. Besides, where could we find an application characterized by zero risk?

In synthesis, actually there are two different ways of characterization of the safety distances. The first characterization derives from the industrial world that pushes towards the predisposition of a safety distance on the basis of a risk assessment compared with the acceptability criteria. Such distances, even if they are estimated taking into account the maximum possible consequences of an accident, are then revaluated on the basis of the probability distribution of that event. So they really represent a safety measure balanced with the acceptability criteria.

The second characterization derives instead from the juridical field and from most of the authorities in the European Countries and it is tied up to the deterministic concept of the maximum consequences likely to occur (the probabilistic terms is never considered). This approach in some way is still the same as the one developed in the nuclear field in the first phase: try to have zero risk outside the safety distance.

To be honest, there is also an intermediate position. It is often used by the standardization bodies and it proceed with the determination of the characteristics of an accident scenario (i.e. maximum pressures, size of the leakage, etc.) on the basis of which the related safety distance are reproduced through numerical models. A variation of this last methodology is represented by the "expert's evaluation": the safety distances are settled on the basis of their judgment with expertise achieved through both specific experimental campaign and analysis of the consequences of the accident occurred in the past.

As this paper presents the state of the art of the safety distances and hazardous zones settled for hydrogen components, to well face the reading of the data listed in the various standards, codes and regulations, it is opportune to keep in mind all the above mentioned approaches. It will help in the understanding of the different numerical values, as well of the different vulnerable targets, given by those documents. A mere comparison would give evidence only to the differences (difficult to understand) and even less will help in a debate aimed at the adoption of some harmonised "safety distances" towards the introduction of the hydrogen technology.

2.0 SAFETY DISTANCES

2.1 Definition of Safety Distances

Safety distances are always defined to have some space from the hazardous installation to different types of targets, so they are generally predisposed to keep a hydrogen facility or system far enough away from people and other facilities to minimize the effects of an accidental event (deviation from an exercise conforming to the destination of use) such as a fire and explosions. Moreover safety distances prevent the propagation of those events to other installations or components avoiding the happening of the so called "domino effect". At distances superior to the defined safety distance it is generally assumed that no consequences can be caused by an accidental event related to the hazardous installation.

Without entering no more in the understanding of the concept of safety distance, another point of discussion could be found in the vulnerable items taken as a reference and in the extensions of those distances that are sometimes very different from one regulation, standard and/or code to another and from country to country.

The targets to which refer the safety distances can be tied up to activity conducted inside the hazardous installation or to activity, and in general to the social life, conducted outside. Typical targets to which refer the safety distances are sources of ignition, other hazardous installations or components, storages of flammable or explosive substances as well as oxidizing ones, areas where people are likely to congregate (school, hospital, cinemas, parking areas, big shops…), street of high communication or railways, and so on.

The proposed safety distance can often be reduced through the interposition of opportune protective constructions, such as adequate fire walls located between the system and the vulnerable target.

Besides the safety distances sometimes could be opportune to predispose also an "exclusion area"; in the common understanding the exclusion area is an area, smaller compared to that identified by the safety distance, around the hydrogen installation / component (generally storage systems or applications in which the involved quantities are high) in which some particular shrewdness have to be applied as limiting access, approved equipment, predisposition of procedures, and so on.

In the European legislation there is no official definition of safety distance, but some guideline documents or codes present some definitions; in the table 1 are listed some definitions of safety distance as a function of the standard / code and as a function of the different country.

2.2 Numerical Determination of Safety Distances

Besides the definition of safety distance, another problem that comes out is the setting of its numerical value: how these values are estimated or calculated?

Sometimes, as it is the case of the European Directive Seveso Bis [1] they come out from the estimation of the consequences of severe accidental events taking into account the thermal loads and the pressure and missiles effects both on structures and persons. In this way the distances estimated are very high as they refer to severe accidents, with high inventories involved (5 ton of hydrogen for example).

Moreover even if the Seveso is a European directive, there is still a problem of harmonization due to the fact that every European country has transferred in their legislation different reference numerical values for the admissible damage caused by thermal loads, pressure and missiles effects on structures and persons. The consequence is that different European countries may predispose different safety distances for the same installation.

Just to show a particular case, in the table 2 presented at the end of the paper are listed the reference damage limits for the predisposition of a safety distance as they are in the IGC Doc 75/01/E/rev [2] (not mandatory) and in the Italian version of the Seveso directive taken into force by the Ministerial Decree of the 9th May 2001 (mandatory) [3].

Even if the IGC Doc 75/01/E/rev refers to events that are non catastrophic ("*the safety distance is not intended to provide protection against catastrophic events or major releases and these should be addressed by other means to reduce the frequency and/or consequences to an acceptable level*" [2]) and so the numerical values of the safety distances will not necessarily be very high, from the above mentioned table is well evident that sometimes the resulting safety distances of the IGC Doc are comparable with those of the Seveso directive as it is in force in Italy (for example the reference damage limits for explosions and flash fires).

In European countries where safety distances are not specified in the legislation, such as Norway and Sweden, the IGC document [2] is normally regarded as a guideline. In Norway for instance, the operator of an (onshore) installation will have to propose a local plan for the installation and the surrounding area, presenting safety distances and restrictions to the surroundings. This proposal should be based on a quantitative risk analysis, demonstrating the proposed safety distances will be sufficient to prevent unacceptable risk to third Party.

Besides the above mentioned methodology for the setting of a safety distance, in the majority of cases the numerical values come out from the know-out collected during years of industrial application's exercise. Often, when the numerical value of a safety distances is fixed on the basis of the experience acquired during the exercise of industrial plant, the derived value might be too high to be applied to hydrogen installation. That is the case of the existing codes and standards that refers to NFPA 50A [4] which is for hydrogen storage and not for hydrogen filling stations or other hydrogen applications; the results are prohibitive: the definition of indoor facilities and the setback distances are two examples of requirements that will make those installations unacceptable for commercial application.

In table 3 are listed the numerical values of the safety distances as a function of various vulnerable targets as they are in the American standard NFPA 50 A (the same values are listed in the 29 CFR 1910.103 [5]), in the European standard IGC 15/96/E [6] and in the Italian guideline document for the fire fighting in the design, construction and exercise of hydrogen filling station.

3.0 Hazardous zones

In Europe, up to 1996, documents of harmonization or norms, concerning the installation of components in explosive atmospheres, didn't exist; every Country made reference to a proper national standard: in Italy, for example, the matter was object of the norm CEI 64-2, *Impianti elettrici nei luoghi con pericolo di esplosione* ("Electrical apparatus in areas with explosion risk"), and 64 2/A, *Impianti elettrici nei luoghi con pericolo di esplosione-Appendici* ("Electrical apparatus in areas with explosion risk-Annex").

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").

In 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* [7], 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") [8] 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.

Besides the European status, in America (United States and Canada) the classification of the dangerous places for the presence of explosive atmospheres has had a history rich of changes; the matter "Hazardous or Classified Locations" has appeared for the 1st time in the NEC, National Electrical Code, of 1923 with the title of "Extra Hazardous Locations". In 1931 was added the division in Classes to identify the type of explosive atmosphere likely to be present in the dangerous area; in 1935 the Groups have been defined for identifying the main constituent substance of the explosive atmosphere and only in 1947 the Divisions have been introduced. Since then many other changes have happened, but certainly the most important are dated 1996 and, above all, 1999 with the introduction of the concept, already largely diffused in Europe, of the Zones.

So actually, in areas where dangerous quantities and concentration of flammable gas may arise, as in the case of hydrogen installations, besides the predisposition of safety distances, it is necessary to decide also 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; it does not apply to situations that could involve catastrophic failure or catastrophic discharge from process vessels, pipelines, tanks, or systems. So the resulting hazardous location extension is different from a “safety distance”.

The classification of hazardous areas is a multi-stage approach, that takes into account a large number of factors and that requires both expertise and interpretation of the various Codes of Practice, as well as a number of extremely in-depth calculations relating to each individual site.

The definition of the type of zones and the European and American reference documents for the classification of hazardous areas are listed in table 4 and 5.

In such areas, depending on the type (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.

4.0 Conclusions

It is not easy to draw some conclusions and especially ultimate conclusions on the meaning and, specially, on the numerical values of the safety distances. Motive is simple: it will be never possible to compare “apples with pears”, as much it is the difference provided to such term from the different subjects that participate in the determination of so call “safety distances”.

A possible solution is to define the use of this notion, which we intend to do in the practical applications as those related to the technologies using hydrogen as energy carrier.

If, as we believe, in this historical phase such distances give a value of reference to allow the industry to work, with the new technologies under development, then the point of mediation, among the various actors of the dispute, is to find a reasonable compromise, maybe as result of evaluations done together, industrial and regulative body, on typical cases that the industry is developing, aware of the fact that the result is a compromise (in such case the techniques of the Risk Assessment could help). On such compromise then the regulatory body could be thought of the further measures that, case by case, the single regulatory body could require in relation of the specificity of the particular application and the attitude of the single state.

The important fact is that such numbers and rules are established in short times. In fact the absence of rules, commonly approved, it is one of the most greater barriers for the industrial involvement and also to the possibility of research on new technologies.

Such way of thinking certainly is not new. It characterizes, indeed, the technologies that use the traditional so-called combustible gases.

Moreover such way of behaviour is consistent to the rule of modern industrial development. There is not the claim to resolve once forever the entire problem associated to the safety distances for the use of the vector hydrogen. As the history of the industrial development demonstrates, it is the same development, even also with some mistake, that will furnish a continuous improvement to the safety of the use of hydrogen as energy carrier. Such development will be safe more and more if it will continually take comfort by appropriate studies and researches.

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6. IGC 15/96/E, Gaseous Hydrogen Stations, Industrial Gases Council, Bruxelles, 1997.
7. EN 60079-10, Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas, 2004, 2nd Edition.
8. Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC). Official Journal L 023 , 28/01/2000 P. 0057 - 0064.

Table 1. Definitions of safety distance as a function of different documents and countries.

Document	Country	Definition	Notes
ISO/TR 15916:2004(E): "Basic considerations for the safety of hydrogen systems" Not mandatory	International	"The separation distance requirements, also commonly referred to as the quantity-distance (Q-D) requirements, are determined as a function of the quantity of hydrogen involved. Generally, the larger the quantity of hydrogen involved, the greater are the recommended separation distances. Under some circumstances, small quantities of hydrogen may be stored and used in a room or building, but generally outdoor storage and use is recommended. The separation distance can be determined for the potential hydrogen events or for the potential events at other facilities, whichever requires the greater distance".	Q-D (quantity distance) relationship between quantity of flammable or explosive material and distance separation from the exposed object(s) that provide(s) a defined type of protection NOTE 1 These relationships are based on levels of risk considered acceptable for the stipulated exposures and are tabulated in appropriate Q-D tables. NOTE 2 Relationships include separation distances for safe operations between facilities, roadways, etc. and total quantities of energetic materials that can interact in a given location. NOTE 3 This approach to safety is commonly used for hydrogen in aerospace and military applications.
IGC Doc 75/01/E/rev "Determination of safety distances" Not mandatory	International	"The safety distance from a piece of equipment with inherent hazard is that minimum separation which will mitigate the effect of a likely foreseeable incident and prevent a minor incident escalating to a larger incident. The safety distance will also be determined to provide protection from foreseeable external impact (e.g. roadway, flare) or activities outside the control of the operation (e.g. plant or customer station boundary)".	This document establishes for the first time the basic principles to calculate appropriate safety distances for the industrial gas industry. In this document the safety distance is not intended to provide protection against catastrophic events or major releases; these should be addressed by other means to reduce the frequency and/or consequences to an acceptable level.

Document	Country	Definition	Notes
NSS 1740.16 "SAFETY STANDARD FOR HYDROGEN AND HYDROGEN SYSTEMS Guidelines for Hydrogen System Design, Materials Selection, Operations, Storage, and Transportation". Not mandatory.	USA	"Location and quantity distance (QD) requirements are based on the concept that the effects of fire, explosion, and detonation can be reduced to tolerable levels if the source of the hazard is kept far enough away from people and other facilities".	The Q-D are referred principally to hydrogen storage systems. NOTE 1: the installation and location of GH_2 storage facilities shall conform to 29 CFR 1910.103 and NFPA 50A. NOTE 2: LH_2 storage for non propellant use shall be in accordance with 29 CFR 1910.103 and NFPA 50B.
Seveso II Directive [96/82/EC], "Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances". Mandatory.	Europe	"In order to provide greater protection for residential areas, areas of substantial public use and areas of particular natural interest or sensitivity, it is necessary for land-use and/or other relevant policies applied in the Member States to take account of the need, in the long term, to keep a suitable distance between such areas and establishments presenting such hazards and, where existing establishments are concerned, to take account of additional technical measures so that the risk to persons is not increased".	This Directive refers to hydrogen inventory higher than 5 ton.
D.M. 24 Maggio 2002, "Norme di sicurezza antincendio per il trasporto, la distribuzione, l'accumulo e l'utilizzazione del gas naturale con densità non superiore a 0,8" (Ministerial Decree of 24th Maggio 2002, Safety fire fighting norms for the transport, the distribution, the accumulation and the use of the natural gas with density less than 0,8). Mandatory.	Italy	<u>Distanza di protezione</u>: "fascia libera di terreno che intercorre tra il componente in questione e la recinzione dell'area in cui esso è localizzato" (Protection distance: "free area between the component and the fencing of the area in which it is located"). <u>Distanza di sicurezza interna</u>: "distanza che intercorre fra il componente in questione e gli altri elementi pericolosi dell'impianto" (Internal safety distance: "distance between the component and other hazardous components or installations of the same plant"). <u>Distanza di sicurezza esterna</u>: "distanza che intercorre fra il componente in questione ed il perimetro del più vicino fabbricato esterno allo stabilimento o confine di aree edificabili" (External safety distance: "distance between the component and the perimeter of the nearest external construction or border of building areas"). The external safety distance has to be doubled in the case of areas where people are likely to congregate.	This Italian regulation, even if it refers to natural gas, has been taken as a reference document to the predisposition of the Italian hydrogen guideline "Norme di prevenzione incendi per la progettazione, costruzione ed esercizio degli impianti di distribuzione di idrogeno per autotrazione" ("Safety fire fighting norms for the design, construction and exercise of hydrogen filling station"). This guideline document include multifuel installations.

Table 2. Damage limits for the predisposition of a safety distance.

Criteria for harm potential Reference damage limit values	Seveso directive as it is in force in Italy through the Ministerial Decree of 9th May 2001 Mandatory	IGC Doc 75/01/E/rev Not mandatory
Fires (stationary thermal load)	Minor harm to people: 3 kW/m^2 High harm to people: 5 kW/m^2 Start value for lethal effect: 7 kW/m^2 High lethality: 12.5 kW/m^2 Damage to equipment / domino effect: 12.5 kW/m^2	No harm: 1.6 kW/m^2 Harm to people: 9.5 kW/m^2 (pain threshold reached after 8s; second decree burns after 20s) Damage to equipment: 37.5 kW/m^2
Bleve / fireball (variable thermal load)	Minor harm to people: 125 kJ/m^2 High harm to people: 200 kJ/m^2 Start value for lethal effect: 359 kJ/m^2 High lethality: fireball radius Damage to equipment / domino effect: 200-800 m (*)	
Flash-fire (instantaneous thermal load)	Start value for lethal effect: ½ LFL High lethality: LFL	No harm: ½ LFL Harm to people: LFL
Explosions (peak overpressure)	Minor harm to people: 0.03 bar High harm to people: 0.07 bar Start value for lethal effect: 0.14 bar High lethality: 0.3 bar (0.6 bar in open spaces) Damage to equipment / domino effect: 0.3 bar	No harm: 0.02 bar Harm to people: 0.07 bar Damage to equipment: 0.2 bar

(*) Depending on the size and type of the storage system

Table 3. Numerical values of some proposed safety distances for hydrogen systems located outdoor.

Vulnerable target	NFPA 50A(1)	IGC 15/96/E	Italian Guideline for hydrogen filling stations
Open flames and other source of ignition	7.5 m	5 m	10 m
Wall openings	3 or 7 m (2)	5 m	10 m
Air compressor intakes or inlets to ventilating or air-conditioning equipment	15 m		20 m (6)
Concentration of people	7.5 or 15 m (3)	8 m	20 m
Flammable liquids above ground	3 - 15 m (4)	8 m	10 m
Flammable liquids below ground	3 - 7 m (4)	3-5 m (5)	10 m
Flammable gas storage, either high pressure or low pressure, other than hydrogen	3 - 15 m (4)	5 m	8-10 m
Gaseous oxygen storage (cylinders)		5 m	10 m
Fast burning solids such as ordinary lumber, excelsior or paper	15 m		10 m

Vulnerable target	NFPA 50A(1)	IGC 15/96/E	Italian Guideline
Slow burning solids such as heavy timber or coal	7.5 m	8 m	10 m

(1) all the values have been converted in SI units
(2) 3.1 m if they are above the system; 7.6 m in the other case
(3) depending on hydrogen inventory
(4) depending on flammable liquid, hydrogen inventories and on the specific vulnerable target (tank or vent and connections)
(5) depending if the vulnerable target is the tank or vent and connections
(6) the value can be 50 % reduced if there is a protective wall between the hydrogen component and the vulnerable target

Table 4. 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, vapour 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, vapour 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, vapour or mist is not likely to occur in normal operation, if it does occur, will persist for a short period only.

Table 5. Reference guidelines/standards for area classification.

Title, reference	Type of document and Short Description	Risk based (Y/N)	Widely used (Y/N/?)
IEC/EN60079-10 Electrical apparatus for explosive gas atmospheres. Part 10: Classification of hazardous areas	EU norm (not harmonised norm) used for decision of haz zones. The zones are estimated by assessing the likelyhood of an explosive atmosphere to occur (likely frequency and duration), and to assess the area/volume of the explosive atmosphere. Ventilation can be used to reduce the extension of the zone or to avoid persistence of an explosive atmosphere. Important norm, reference in many guidelines and methods for zone classification. Some examples given, for a H2 compressor inside a building	Y (partly)	Y
NEK 420:2003 Elektriske anlegg i eksplosjonsfarlige områder med gass og støv (untatt gruver)	Norwegian translation of the norms: NEK EN 60079-10, NEK EN 60079-14, NEK EN 60079-17 NEK EN 60079-19 NEK EN 50281-3, NEK EN 50281-1-1, NEK EN 50281-1-2 NEK IEC 62086-1, NEK IEC 62086-2		Y (in Norway)
SEK Handbook 426 Klassning av explosionsfarliga områden, 2000	Includes a Swedish translation of IEC EN 60079-10, but with several more examples, also for hydrogen	Y	Y in Sweeden, will also be used in Norway
CEI 31-35, "Costruzioni elettriche per atmosfere potenzialmente esplosive per la presenza di gas. Guida all'applicazione della Norma CEI EN 60079-10 (CEI 31-30). Translation: CEI 31-35, Electrical apparatus for explosive atmospheres, Guide for classification of hazardous areas.	Guideline giving specific figures for the application of the EU norm IEC/EN 60079-10 . The contents of the document are as follows: Principles of area classification, Procedure of area classification, Source of emission, Location with explosion's controls, Location with temperature's monitoring. Appendixes give list of flammable or combustible substances and list of their physic and chemical properties, principles for the definition of hazardous zone extent, statistical data of the Italian territory concerning the wind frequency in order to assess a reliable natural ventilation, examples of hazardous area classification (several examples for natural gas, including transport and refueling stations and one example for hydrogen used as generator's coolant in confined spaces). In paragraph 2.2.4 (Determination of the zone type) it is said that for the predisposition of Zone 2 the total duration of a gas mixture in air should be less than 10 h/yr and more than 0,1 h/yr or in probabilistic terms 10-3≥P>10-5 source-event yr-1.	N	Y, in Italy

Title, reference	Type of document and Short Description	Risk based (Y/N)	Widely used (Y/N/?)
IP(Institute of Petroleum): "A risk-based approach to hazardous area classification", November 1998, ISBN 0 85293 238 3, 1998.	Presents a methodology for calculation of hazardous areas. Risk acceptability criteria are proposed, and description of a generalized risk calculation procedure. Frequency data are given. Appliance of the methodology to continuous, primary and secondary releases are given. Focused on offshore installations, but can be used generally. Flow rates and corresponding hazard radii are proposed dependent on type of gas (incl. refinery hydrogen), pressure, release hole diameter.	Y	?
IP: Calculations in Support of IP15: The area Classification Code for Petroleum Installations, 2001	Provide a record for the calculations, methodology and assumptions used to calculate dispersion distances as a support to the document above.	N, focus only on consequence calculations	?
API 505, 1997: Classification of locations for electrical installations in petroleum refineries – API recommended practice 505 – (ANSI/API RP 505-1998	Recommended practice. Provide guidelines for classifying locations Class I, Zone 0, Zone 1, and Zone 2 locations at petroleum facilities for the selection and installation of electrical equipment . Guidelines for classifying and determining the extent of hazardous zones for common applications in many petroleum facilities. Examples of diagrams propose extents of zones established by the use of industrial feedback, use of experimental data, diffusion models and by careful weighing of pertinent factors such as number of potential sources, release rate and volume of possible release. No information given about the choice of hole sizes and leak flows. Draws attention on careful use of proposed diagrams	N	Y, for petroleum instal-lations
NFPA 497, 2004 Classification of flammable liquids, gases, or vapors and of hazardous (classified) locations for electrical installations in chemical process areas	Describes division classification and zones classification. Gives factors, which have to be taken into account to determine the extent of classified locations. Proposes also a series of diagrams that illustrate how typical sources of combustible material should be classified and recommended extent of the classified location. Includes practices, which exist to classify hazardous locations. A procedure for classifying locations into 4 steps is proposed. Two diagrams dedicated to liquid hydrogen storage and gaseous hydrogen storage	N	Y in USA
Netherlands Government Labour Inspection, 1993:Area classification with respect to gas explosion hazard - Health and Safety Executive (HSE), P182 E	Rules for classification of industrial installations where gases or flammable vapours may form explosive atmospheres are given. Procedure can be applied to complicated situations guaranteeing a good safety level since it includes safety margins. Ventilation is taken into account. The extent of zones depends on: degree of ventilation, ventilation conditions, combustible material relative density, obstacles near the leakage source. Typical examples of classification are given and also some more specific examples illustrated for a few equipment or situations.	N	?

Title, reference	Type of document and Short Description	Risk based (Y/N)	Widely used (Y/N/?)
ATS France 1992: Recommendations for electrical equipment used in explosive atmospheres	Guideline prepared for steel industry. Includes general aspects for explosive atmospheres and protected equipment, a method for classification of zones and selection of equipment, details the calculations of release flow dependent of pressure, compares empirical calculations with FAUSKE and CEA SUTTON, give distances from leak source to zone limit for different release rates and wind speed og 5 m/s (Fauske's law.)	N	?
TNO 1987. Principles of classification of hazardous zones	General overview of zone classification, definition analogous to EN 60079-10. Determines the extension of the zone where there is a probability to have an explosive atmosphere. Reference situation is an unconfined area. When lack of ventilation (confined?) evaluation is more stringent.	Y?	?
Inter-institutional group on the classification of hazardous locations 1990. Classification on haz locations (Cox and Lees, Ang)	Zones definition analogous to EN 60079-10. Empirical approach for zone classification. Quantitative methods for zone classification based on risk based approach, divided into several steps:1) List of leakage sources and release scenarios, list of industries where there is a explosion risk, evaluation of sources sizes (many sources sizes defined for a lot of industries), Estimation of release frequencies according to source size and situation where release occurs, use of release and dispersion models, selection of representative fluids (H2, CH4, etc), Numerical investigation of release and dispersion models for a few leakage sources (joins, pumps, compressors, sampling points, etc) and evaluation of the distance to LFL	Y	?
Guide de l'union des industries Chimiques 1996 Electrical equiopment in potential explosive atmospheres	Guideline. Method based on analysis of locations where explosive atmosphere may occur. Basic principles are fundamental safety concepts and factors which play an important role for classification and extension of zones. Ventilation important. Maps and typical diagrams illustrate use of the method. Some numerical methods are suggested – equations based on FAUSKE and CEA SUTTON	N?	?
SIRA, 1989. Classification of hazardous areas containing potentially explosive atmospheres	Document summarising a conference related to hazardous zone classification. Reference to EN60079-10. Qualitative analysis describes specific situations by using examples and typical diagrams. Presentation of structure useful for zone classification (process conditions, equipment,comb. Materials, leak sources, release an ventilation). Specific examples of classification such as for electrolyser and sea petroleum installation	N?	?