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Safety distances: Definition and values

A. Marangon[a,*], M. Carcassi[a], A. Engebø[b], S. Nilsen[c]

[a]*Department of Mechanical, Nuclear and of Production Engineering, University of Pisa, Via Diotisalvi 2, Pisa 56126, Italy*
[b]*DNV Research, Det Norske Veritas AS, Veritasvn 1, Høvik N-1352, Norway*
[c]*Norsk Hydro Oil And Energy Research Centre Porsgrunn, N - 3908 Porsgrunn, Norway*

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Abstract

In order to facilitate the introduction of a new technology, as 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 achievement to be realized.

Useful tools of work could be the existing gaseous fuel codes (natural gas and propane) regulating 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 distance requirements.

In order to solve the above-mentioned problems, other questions come out: How have these safety distances been defined? Which hazardous 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 safety measures?

This paper presents an analysis of the definitions of "safety distances", as well as a synoptic analysis of the different values in force in several States for hydrogen and natural gas. The above-mentioned synoptic tables will highlight the lacks and so some fields that need to be investigated in order to produce a suitable hydrogen standard.

Keywords: Hydrogen; Safety distances; Refueling stations

1. Introduction

The term "safety distances" has, even if broadly used in both fields, different shades of meaning in the technical field and in the juridical field. 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 behaviour 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 ($R = 0.01 * \sqrt{\text{kW}}$).

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 case accident scenario over such distance there was nothing to fear". But still from the nuclear history we all well know that when such worst case 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

* Corresponding author. Tel.: +39 328 8519259; fax: +39 050 836679.
E-mail address: a.marangon@ing.unipi.it (A. Marangon).

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the worst condition (remembering that there is no limit to the worse) many technologies could not actually be in use.

So the modern key for the acceptance of a technology will necessarily have to be found in the risk–benefit analysis, where a technology may be accepted if the benefits are greater than 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 acceptance 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 acceptance 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 proceeds 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 distances 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 thex consequences of the accident that occurred in the past.

As this paper presents the state of the art of the safety distances 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 abovementioned 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 would even less help in a debate aimed at the adoption of some harmonized "safety distances" towards the introduction of the hydrogen technology.

2. Safety distances

2.1. *Definition of safety distances*

Safety distances are always defined to have some space between the hazardous installation and the 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 normal operation and conditions) 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 or that the risk is acceptably low, when a risk-based approach is used.

Without entering more into 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 their safety distances, sometimes very different from one regulation, standard and/or code to another and from country to country.

The targets to which the safety distances refer 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 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, etc.), street of high communication or railways, and so on.

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

Moreover, 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 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 (minimum 5 ton of hydrogen for example).

Moreover, even if the Seveso directive is a European directive, there is still the problem of harmonization due to the fact that every European country has transferred into 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