FIRE PREVENTION TECHNICAL RULE FOR GASEOUS HYDROGEN REFUELLING STATIONS

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ABSTRACT

In the last years different Italian hydrogen projects provided for gaseous hydrogen motor vehicles refuelling stations. Motivated by the lack of suitable set of rules, in the year 2002 Italian National Firecorps (Institute under the Italian Ministry of the Interior) formed an Ad Hoc Working Group asked to regulate the above-said stations as regards fire prevention and protection safety. This Working Group consists of members coming from both Firecorps and academic world (Pisa University). Throughout his work, this Group produced a technical rule covering the fire prevention requirements for design, construction and operation of gaseous hydrogen refuelling stations. This document has been approved by the Ministry's Technical Scientific Central Committee for fire prevention (C.C.T.S.) and now it has to carry out the "Community procedure for the provision of information". This paper describes the main safety contents of the technical rule.

1.0 INTRODUCTION

In Italy, at the moment, there are no specific fire prevention rules regulating hydrogen bulk storage, delivery or use. For the above reason, when in the last years several hydrogen projects started (in Turin, in Milan and later in Mantua) providing for refuelling stations for gaseous hydrogen motor vehicles (buses, cars), the Italian National Firecorps (Institute under the Italian Ministry of the Interior) thought that their single Provincial Headquarters would have more than few difficulties in properly facing technical assessments indispensable to grant their positive judgement about the plans of the above-mentioned stations. Furthermore, the lack of suitable fire prevention set of rules could make plausible having on national territory refuelling stations complying with different safety strategies and objectives; in fact, when an activity under the National Firecorps control is not regulated by specific rules, requirements and general fire prevention and protection technical criteria are established by the competent Provincial Headquarter.

As a consequence, in the year 2002, Italian National Firecorps formed an Ad Hoc Working Group asked to regulate hydrogen motor vehicles refuelling stations as regards fire prevention and protection safety. This Working Group is constituted by both Technical Officials from the National Firecorps and leading members from the academic world (Pisa University): it succeeded in drawing up a text document that, in the year 2004, was approved by the Ministry of the Interior's Technical Scientific Central Committee for fire prevention (Comitato Centrale Tecnico Scientifico per la prevenzione incendi, C.C.T.S.). This document got the subsequent positive judgement by other competent Ministries (Ministry of Transport and Ministry of Industry) and now it is carrying out the Community procedure for the provision of information [1]. At the end of the procedure above, the same text will be issued as Ministry of the Interior's Decree (or Ministerial Decree, D.M.).

Even though such document has not been issued yet and so, formally, the preexistent lack of specific requirements persists in refuelling station matters, now Provincial Headquarters have at their disposal

helpful guidelines in order to give their judgements on whatever refuelling station plan will be submitted to them.

It has to be reminded that the Italian regulation in force [2,3] subdivides the Provincial Headquarters activity concerning the observance of fire prevention safety conditions into the following two coordinated phases:

- assessment of either new facilities plans and constructions, or changes made in those existing; this assessment is aimed at giving judgement on the compliance with the fire prevention rules

- control inspection aimed at verifying, also on the basis of suitable technical documentation, both the correspondence of the work carried out to the approved plan and the keeping of the fire prevention requirements in force; this control inspection is carried out in order to issue the so called Fire Prevention Certificate (Certificato di Prevenzione Incendi, C.P.I.).

2.0 GENERAL DESCRIPTION OF THE APPROVED DOCUMENT

The text of the approved document follows the standard model of fire prevention mandatory technical rule that regulates natural gas refuelling stations (D.M. 24/05/02 [4]); it was properly adapted to the specificities of hydrogen motor vehicles refuelling. The natural gas text model has been chosen in order to take advantage of its well-established and reliable structure, that makes its contents readily accessible by experts. Furthermore, the prescribing approach distinguishing this model has been thought especially suitable in order to standardize the safety features of the future first refuelling stations following its requirements and contents.

According to the chosen model, the technical rule document is divided into two parts:

1) the first part will form the proper Italian Ministerial Decree; it is subdivided into the following Articles:

   - Art. 1. - Aim and field of application

   - Art. 2. - Objectives

   - Art. 3. - Technical instructions (this Article refers to the second part)

   - Art. 4. - Location

   - Art. 5. - Instructions for the trade on the CE market

   - Art. 6. - Additional and final requirements

2) the second part will form the annex covering the fire prevention technical rule, that’s to say the technical requirements for hydrogen refuelling station design, construction and operation; it is subdivided into the following Titles:

   - Title I - General requirements

   - Title II - Premises construction methods

   - Title III - Safety distances

   - Title IV - Operating instructions

   - Title V - Refuelling station for vehicles aimed at private use

   - Title VI - Multifuel refuelling stations

The approved technical rule (Art. 1) is aimed at issuing fire prevention requirements for the hydrogen refuelling stations design, construction and operation; four station typologies are taken into consideration:

a) stations fed by pipe (already taken into consideration for natural gas in D.M. 24/05/02 [4])

b) stations fed by tube trailer (already taken into consideration for natural gas in D.M. 24/05/02)

c) stations fed with hydrogen produced on site by steam reformer, electrolyser, etc.

d) small-sized stations fed with hydrogen produced on site by electrolysis or different systems, at a production rate of 50 Nm^3/hr.

The technical rule allows a maximum dispenser pressure equal to 350 bar.

The station typology in letter c) has been introduced because hydrogen refuelling station, as its main peculiarity, cannot be only hydrogen "storage facility" but also hydrogen "production facility". Possible production technologies are diversified; in letter c), steam reforming and electrolysis have been explicitly specified because they are the most widespread mature technologies at the moment and they are able to guarantee the minimum amount of hydrogen indispensable to current demonstrative stations.

The station typology in letter d) has been introduced, instead, in view of credible spreading, in a short time, of hydrogen experimental use in small-sized company fleets, due to the growing environmental issues, to the increasingly widespread sensitization by public opinion and to the demands concerning pollutants emissions in old town centres or in different circles. Title V in the annex covers this typology.

In order to achieve fire protection and main safety objectives relevant to people and goods safeguard (Art. 2), hydrogen refuelling station shall be constructed and operated so that the following objectives are assured:

a) causes of hydrogen accidental leakage, fire and explosion shall be reduced at minimum

b) in case of accident, people injuries shall be limited

c) in case of accident, damage to building and/or premises next to the station shall be limited

d) rescuers shall be allowed to act under safety conditions.

The technical rule contained in the annex has been provided in order to achieve the above-mentioned objectives (Art. 3). Finally, it should be noted that the permitted locations (Art. 4) are, with few exceptions, essentially identical to those given for both natural gas (D.M. 24/05/02 [4]) and LPG (D.P.R. 24/10/03, n. 340 [5]) refuelling stations; this requirement is aimed at allowing hydrogen fuel availability, accessibility and traceableness that don't disadvantage it in comparison with natural gas and other fuels; at the same time it will allow hydrogen to fully exploit its qualities as ecological fuel, especially for urban use.

In the annex, as regards every station typology, possible elements of a station are determined (Title I); among these, those considered as "dangerous elements of a station" are specified in order to provide safety distances (Title III). Among possible elements of a station are also specified those that could be provided with 1^{st} or 2^{nd} level of safety features according whether their premises characteristics guarantee, in the event of a possible burst, either materials containment both in side direction and in upward direction (1^{st} safety level) or only in side direction (2^{nd} safety level). Such safety levels are achieved by protections in accordance with the premises construction rules in Title II; they are identical to those provided in D.M. 24/05/02 [4] for possible elements of a natural gas refuelling station because they are common construction methods believed suitable when compressed gases are

used. Finally, Title VI provides requirements aimed at locating hydrogen refuelling stations near refuelling stations for different fuels, that's to say at accomplishing a so called multifuel station.

The identification of the possible elements in a specified station typology made indispensable an in-depth preliminary analysis about the different issues concerning hydrogen production, delivery and storage, in order to determine the model of station awaited in the middle-short run. A careful analysis highlighted that the station typology with hydrogen on site production is not characterized by constituting elements different from those of a station fed by pipe, if the production facility itself is excluded. Consequently, as regards possible station elements, these typologies have been traced back to a single typology as "stations fed by pipe or with hydrogen produced on site": in this latter case, the station is actually fed by pipe but linked up to the hydrogen on site production facility rather than to a delivering pipeline network. In order to distinguish between these two typologies, a "refuelling station pertaining area" has been purposely defined, within which all activities functional to the hydrogen refuelling station operation are traced back: according to such definition, if the production facility providing the station with hydrogen falls within the above-mentioned area, the station shall be intended as fed with hydrogen produced on site; instead, if it falls outside the above-mentioned area, the station shall be intended as fed by pipe. In short, as regards a gaseous hydrogen refuelling station, the following station typologies are thus envisaged:

- stations fed by pipe or with hydrogen produced on site
- stations fed by tube trailer

For these typologies, the following possible elements have been assumed (Table 1):

Table 1. Possible elements of a gaseous hydrogen refuelling station.

stations fed by pipe or with hydrogen produced on site	stations fed by tube trailer
a) hydrogen on site production facility b) pressure reduction and hydrocarbon measurement box c) hydrogen gas measurement device (only in case of external feeding by pipe) d) compressors premises e) storage vessels premises f) one or more dispensers g) tube trailer box h) electric energy distribution substation i) premises for accessory services (administrator's office, administrator's house, selling rooms, storehouse, sanitary service, washing facility, workroom without use of open flames, refreshment bar room, etc.)	a) storage vessels premises b) compressors premises c) one or more dispensers d) one or more tube trailer boxes e) electric energy distribution substation f) premises for accessory services (administrator's office, administrator's house, selling rooms, storehouse, sanitary service, washing facility, workroom without use of open flames, refreshment bar room, etc.)

Later on, main safety measures taken in the technical rule are described; they are aimed at meeting the objectives stated at Art. 2.

3.0 PREMISES CONSTRUCTION METHODS

Among the above-said possible elements (Table 1), those in letter a), b), d), e), and g) as regards stations fed by pipe or with hydrogen produced on site and those in letter a), b) and d) as regards stations fed by tube trailer can be provided with 1st or 2nd level of safety features (storage vessels premises are an exception because they shall be provided exclusively with 1st safety level). Safety levels are achieved by protections according to the following instructions (Table 2):

Table 2. Premises construction methods for 1st and 2nd level of safety features.

1st safety level	2nd safety level
- premises shall be constructed with reinforced concrete being 15 cm thick at least - as regards sides adjoining to other station premises, partition walls shall be 20 cm thick at least and shall be without openings - holes are permitted, if aimed at crossing components of technological connecting equipment - ceiling shall consist of either reinforced concrete or steel beam elements or either reinforced concrete or steel continuous slab; it has to be strong enough to assure containment of possible fragments projected in upward direction. When continuous slab is used, openings shall be made and located in a such position to allow natural ventilation in the room. Just next to the ventilation openings, an intrusion-proof protection shall be provided by railings or wire-net. The sum of the open surface areas, without space occupied by the intrusion-proof protections, shall be equal at least to 1/10 of premises surface area - (only required for storage vessels premises and tube trailer boxes) walls height, along all room sides, shall be at least 1 m longer than the highest point of vessels	- outside walls shall be constructed either with “two-heads” solid bricks or with reinforced concrete being 15 cm thick at least, or with different non-combustible material having equivalent strength - ceiling shall be light-type, constructed with non-combustible materials; openings shall be made and located in a such position to allow natural ventilation in the room. Just next to the ventilation openings intrusion-proof protection shall be provided by railings or wire-net. The sum of the open surface areas, without space occupied by the intrusion-proof protections, shall be equal at least to 1/10 of premises surface area

It should be noted that a maximum limit of hydrogen amount is allowed to be contained in boxes inside the storage premises: such limit is set at 2000 Nm^3. Therefore, if the storage premises are aimed at containing vessels having an overall storage capacity greater than 2000 Nm^3, they have to be subdivided into boxes and each box shall not store a gas amount greater than 2000 Nm^3. This is a general criterion borrowed from technical rules concerning the storage premises in a natural gas

storage facility (D.M. 24/11/84 [6]) and in a natural gas refuelling station (D.M. 24/05/02 [4]); in both the latter documents the above-said limit is fixed at 3000 Nm^3.

4.0 SAFETY DISTANCES

The Italian fire prevention regulation defines the following three typologies of safety distance [7]:

- protection distance: set by rule minimum value of the distances horizontally measured between the plan perimeter of each dangerous element of an activity and the enclosure (if required) or the boundary of area where the activity itself rises

- internal safety distance: set by rule minimum value of the distances horizontally measured between the respective plan perimeters of the dangerous element of an activity

- external safety distance: set by rule minimum value of the distances horizontally measured between plan perimeter of each dangerous element of an activity and the perimeter of the nearest building outside the activity itself or the perimeter of other public or private works; or horizontally measured in the direction of the boundaries of building areas with which such distances shall comply

These distances are assigned by a specific fire prevention technical rule to stated elements of an activity; for that reason these elements are known as “dangerous elements of a facility”. Each technical rule specifies both the possible constituting elements of a facility and those intended as dangerous in order to determine safety distances. The dangerous elements are chosen according to the fuel amount handled by a specific element (the so called “fire load”), to the major or minor probability of having fuel leakage and finally to the possible negative consequences coming from such leakage as regards both activities carried out inside the facility (internal safety distance) and activities or buildings in the neighbourhood (external safety distance).

In case of the hydrogen refuelling station, the elements regarded as dangerous are all the above-said possible elements in Table 1 with the exception of:

- those in letter c), h) and i) as regards the stations fed by pipe or with hydrogen produced on site

- those in letter e) and f) as regards stations fed by tube trailer.

All the areas where the above-mentioned dangerous elements rise, with the exception of dispensers, shall be enclosed; the enclosure shall be realized at a distance equal to protection distance set for the specific element, it shall be 1.8 m high at least and can be either masonry realized or with prefabricated concrete panels, or with wire-net held up by piles on concrete stringcourse.

Following the technical rule for hydrogen refuelling station, safety distances are set by means of suitable tables depending on the safety level characterizing a dangerous element (Table 3 and Table 4), with the exception of dispensers which are always located outdoors (Table 5). Anyway the document also specifies the conditions (here not reported) for both the reduction of required safety distances and the doubling of required external safety distances (protection of building designed for general public such as schools and hospitals, and places usually crowded).

Table 3. Safety distances for elements with 1st level of safety features.

Element	Protection distance [m]	Internal safety distance [m]	External safety distance [m]
Pressure reduction and hydrocarbon measurement box	2	-	10
Compressors premises	5	-	10
Storage vessels premises	5	-	10
Tube trailer box	5	-	10

Table 4. Safety distances for elements with 2nd level of safety features.

Element	Protection distance [m]	Internal safety distance [m]	External safety distance [m]
Pressure reduction and hydrocarbon measurement box	2	10	10
Compressors premises	10	10	20
Tube trailer box	10	10	20

Table 5. Safety distances for dispensers.

Element	Protection distance [m]	Internal safety distance [m]	External safety distance [m]
Dispensers	10	8	20

The distances required are identical to those specified in D.M. 24/05/02 [4] because they are consistent with damage areas from validated safety reports relevant to hydrogen storage activities with major-accident hazards; moreover, as it will be said later, the technical rule requires all dangerous elements of a station to be continuously monitored by installation of hydrogen detection system and flame detection system connected to refuelling station emergency system.

Besides the above-mentioned distances, other distances are required to be guaranteed between dangerous elements and possible premises for accessory services in the station, for example administrator's office or house, storehouse, sanitary service, washing facility, selling or refreshment bar rooms, electric energy distribution substation, overhead power lines with given voltage values.

Safety distance is also the instrument used to allow installation of hydrogen refuelling stations in the neighbourhood of different fuels refuelling stations (multifuel station, Title VI): in this case the technical rule prescribes the separation distances between stated dangerous elements of adjacent stations (Table 6).

Table 6. Safety distances for multifuel station.

Type of exposition	Safety distances for multifuel stations [m]	
	Dangerous elements of hydrogen refuelling station	Hydrogen dispensers
Gasoline and diesel oil tanks	10	
LPG tanks	20	10
Dangerous elements of natural gas refuelling station	15	8
Dispensers		8

Among the dangerous elements of the hydrogen refuelling station, hydrogen on site production facility is an exception both in terms of premises construction rules and in terms of safety distances. In fact, as the methods adoptable for its realization are diversified and continuously developing, the consequent difficulties in putting them into a proper deterministic model made preferable for these systems a safety strategy founded on risk analysis methodology. Therefore, in this single case only, the prescribing approach which instead characterizes the whole technical rule has been left out: as a result, if an on site production facility is envisaged, it shall be the object of a specific risk analysis to be carried out consistently with the procedure followed when a particular activity under Firecorps control is not regulated by any specific technical rule [8].

5.0 MORE SAFETY MEASURES

5.1 Gas system

Gas system means the assembly of piping, valves as well as equipment making up gas feeding, compression, damping, bulk storage, dispensing network and emergency system; these components are required to be designed in accordance with requirements of Pressure Equipment Directive (PED) 97/23/EC [9].

Among the provided solutions, it has to be reminded:

- pressure relief valves, aimed at preventing overcoming of maximum working pressures
- stop valves (clearly identified by proper plates), aimed at isolating various components
- excess flow valves (located next to the anchorage between supply piping and dispensers) aimed at preventing gas leakage, also in the event of dispenser accidental removal

- a venting device aimed at allowing hydrogen to convey into a suitable pipe to the outdoors, in a safe area, at a minimum distance (2.5 m) from the level where walking is permitted (not necessary the ground level).

5.2 Emergency system

This is a system operated by safety push-buttons, with manual reactivation, located near compressors premises, vehicles refuelling area and administrator's premises; this system shall be able to:

- completely isolate delivery lines to dispensers by means of stop valves remotely operated and located downstream each storage tank with overall capacity greater than 50 Nm^3

- completely isolate low pressure line from compressors intake or inlet

- integrally disconnect the electric circuit of the station and of the accessory facilities, with the exception of preferential lines supplying safety facilities.

5.3 Detection systems

All the dangerous elements of a refuelling station shall be continuously monitored by installation of hydrogen detection system and flame detection system connected to the above-mentioned emergency system.

5.4 Electrical system, grounding system, protection system against atmospheric discharges

The electrical system, the grounding system, the protection system against atmospheric discharges are required to be according to national law. Supply of the systems, with the exception of fire prevention water systems, shall be able to be disconnected not only by means of electric energy distribution substation but also by means of a different control in a protected location. Piping and metallic structures shall be connected with general grounding system. Furthermore, if premises containing main hydrogen systems aren't self-protected, a lightning rod facility shall be provided; (the cage model has to be preferred).

5.5 Fire fighting protection system

The following fire fighting systems to be envisaged on the station are specified: fire hydrants network, automatic quenching systems, portable and/or trucked extinguishers.

5.6 Operating instructions

Operating instructions prescribed by the technical rule are identical to those specified for a natural gas refuelling station [4] because they are general behavioural instructions suitable for refuelling a vehicle with a compressed gaseous fuel.

Station operation is allowed only under surveillance by one or more people who shall be expressly appointed to control operation itself; they also shall be aware of the station running and of the possible dangers and inconveniences coming from stored and used products. Furthermore, refuelling shall be performed by assigned staff and during fuel dispensing the above-said staff shall observe and have the following rules observed:

a) to locate, in the neighbourhood of dispenser and within reach, at least a ready to use extinguisher, which the station is issued with

b) to make sure that the engine of vehicles to be refuelled is shut off

c) to obey and have no smoking prohibition obeyed, also on board, and in any case to forbid lighting and moving of open flames within a radius of 6 m at least from the dispensers perimeter

d) not to refuel at all portable tanks (cylinders and tube trailers) with dispensers used for vehicles refuelling

As regards safety system of signs, the following instructions have to be observed:

- within the station circle and in a well visible location shall be displayed suitable posters reproducing a flow diagram of the gas system and a plan of the refuelling station

- in the dispensing area shall be located posters reminding that vehicle engine can be started up only after the dispensing gun has been disconnected by the personnel authorized to operate refuelling

- not far from dispensers, suitable posters shall show drivers prescriptions and prohibitions

- instructions for the personnel assigned at the station operation and vehicles refuelling shall be put up; the following specific instances have to be carried out:

  a) the proper behaviour in the event of an emergency

  b) the safety devices location

  c) the actions to be performed aimed at bringing the station in a safe condition operating, for example, emergency push-buttons and fire protection defences.

6.0 CONCLUSIONS

This paper has discussed the main characteristics of the fire prevention technical rule concerning gaseous hydrogen refuelling stations; this document was set by the Ad Hoc Working Group established by the Italian Ministry of the Interior and approved by its Technical Scientific Central Committee. Furthermore, this paper has briefly showed the principal requirements about both station fire prevention and protection: for example the construction rules for systems premises, the safety distances for their separation and the station operating instructions.

In conclusion, it has to be remarked once again that, unlike other occasions, the Italian National Firecorps wanted to face readily new issues about gaseous hydrogen refuelling station and it supplied a proper guideline; by means of this the Provincial Headquarters will be able to achieve on one side a certain uniformity of judgement and assessment on plans submitted to their evaluation; and on the other side they will be able to allow the construction, on national territory, of hydrogen refuelling stations following identical safety strategies.

NOMENCLATURE

C.C.T.S.: Comitato Centrale Tecnico Scientifico (Technical Scientific Central Committee)

C.P.I.: Certificato di Prevenzione Incendi (Fire Prevention Certificate)

D.M.: Decreto Ministeriale (Ministerial Decree)

D.P.R.: Decreto del Presidente della Repubblica (President of Italian Republic’s Decree)

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