HyTecHeat

HYbrid TEChnologies for sustainable steel reheating – HyTecHeat

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Deliverable 2.1: Safety and hazards study report for tests and industrial application

WP2: Burner and combustion system design for hybrid heating.

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0	Paolo Marrelli Eleonora Bonassi	Filippo Cirilli (project coordinator)	Filippo Cirilli (project coordinator)	20/12/2023

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EXECUTIVE SUMMARY

The deliverable 2.1 was prepared as part of the European Commission Horizon 2022 funded project Hytecheat, "HYbrid TEChnologies for sustainable steel" (Grant Agreement-101092087-HyTecHeat). The aim of this deliverable, accordingly to project Technical Annex and as agreed during the technical meeting on 21st November 2023, focuses on the identification of the main regulatory framework for H2 production and use in industry, by gathering the relevant normative and standards that can be applicable in the European Union about safety design and operation of H_2 system. This document is a Confidential Deliverable for the partners of the Hytecheat project and the European Commission (EC).

The core content in this deliverable is presented in Chapters 4 and 5. Chapter 4 is dedicated to the relevant standards that can impact the Hytecheat equipment designing with specific focus on heating systems using burners fed with mixtures of H_2 and CH_4. Whereas Chapter 5 analyses the specific regulations applicable in Italy, where the first democase takes place, and reports a comparison with the reference regulations from other project partners countries.

The information reported in the document provide a general overview of the reference standards to be considered for the accomplishment of next project deliverables.

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1. LIST OF ABBREVIATIONS AND ACRONYMS

AEM - Anion exchange membrane
ASME - American Society of Mechanical Engineers
ASTM - American Society for Testing and Materials
API - American Petroleum Institute
CEI - Italian Electrotechnical Committee
CEN - European Committee for Standardization
CGA - Compressed Gas Association
D – Deliverable
DM – Ministerial decree
EC – European Commission
EIGA - European Industrial Gases Association
EMC - Electromagnetic Compatibility
EN – European standard
ESS - Emergency System
GA – Grant agreement
GARCS – gas/air ratio control systems
GHS - Globally Harmonized System
IEC - International Electrotechnical Commission
ISO - International Organization for Standardization
H2020 – Horizon 2020 The EU Framework Programme for Research and Innovation
HIC – Hydrogen Induced Cracking
LPG – Liquefied Petroleum Gas
LVD - Low voltage Directive
MAWP - Maximum allowable working pressure
MD - Machinery Directive
NEN - Nederlands Normalisatie-Instituut (Netherlands Standards Institute)
NFPA – National Fire Prevention Association
PC – Project Coordinator
PED – Pressure equipment directive
PEM - proton exchange membrane
RES - Renewable energy source
STD - Standard
WP – Work package
UNI - Ente Nazionale Italiano di Unificazione
TR – Technical report

2. INTRODUCTION

In the HyTecHeat project, hydrogen is evaluated for different downstream combustion processes within steel production. Hybrid combustion systems employing up to 100 % H_2 will be evaluated in a number of pilot and demonstration experimental combustion trials using pure hydrogen and mixtures with natural gas and LPG.

To accomplish projects deliverables, it is important to identify all the standards and normative related to the H_2 production and usage. Only a comprehensive and structured collection of those will guarantee a correct and safety design and operation of a system exploiting H_2 as a fuel.

The main goal of the document is to analyse the HyTecHeat system as a whole, and the different elements that constitute it in detail, in order to identify all the current normative and standards and the ones under development/update.

3. METHODOLOGY

The HytecHeat project is focused on application of hybrid heating (Hydrogen/natural gas) technologies in downstream steelmaking processes. In order to allow the hydrogen utilization in steelmaking process, taking into consideration the regulation and legislative framework, the whole value chain has been considered in this deliverable. This system, represented schematically in Fig. 1, has been divided into four main sections:

1. H_2 production
2. Hydrogen storage
3. Gas grid connections and H_2 pipeline
4. Burner

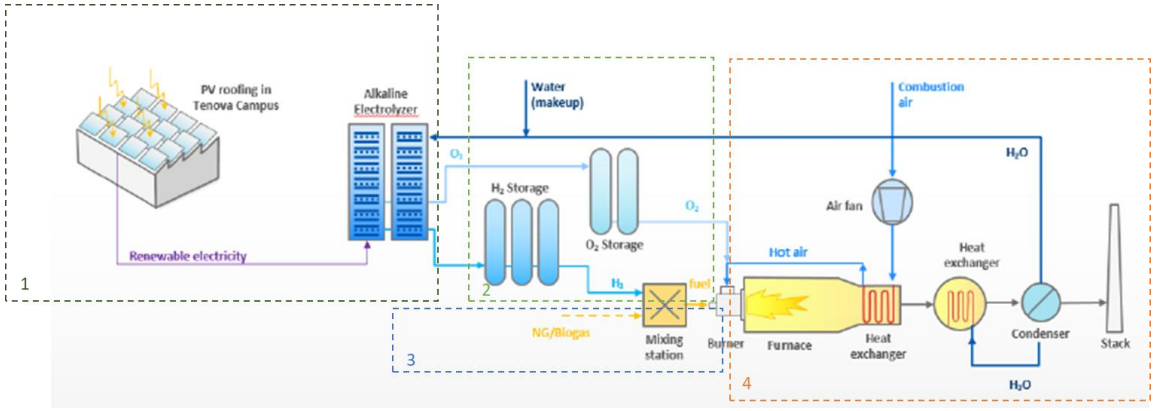

Figure 1: HyTecHeat system (Hydrogen value chain in steelmaking downstream processes)

Each element refers to a certain number of standards, that should be considered to implement the technology and apply it in the different democases. In the following paragraphs, the main standards for each component will be identified and described, focusing on its system integration. Being not in the scope of the deliverable, some elements of the system will be not analysed in detail: RES electricity production plant.

It is important to state that all the information and normative reported in this document does not replace the specific reading of each document, as well as the investigation of other normative during the design and implementation phase of the project.

4. STANDARDS AND REGULATION

This chapter analyses the standards and regulations [1] [2] [3] that can be applied to the different elements of the HytecHeat system, divided in four sections: (1) Hydrogen production system, (2) H_2 storage,(3) Gas grid connections/H_2 pipeline and (4) Burner.

4.1 HYDROGEN PRODUCTION SYSTEM

Different standards should be considered for the Hydrogen production system since the electrolyzer is an electrochemical device that manages pressurized hydrogen and medium temperature.

Standards

ISO 22734: Hydrogen generators using water electrolysis – Industrial, commercial, and residential application.

It defines the construction, safety and performance requirements of modular or factory-matched hydrogen gas generation appliances, herein referred to as hydrogen generators, using electrochemical reactions to electrolyse water to produce hydrogen.

It is applicable to hydrogen generators that use the following types of ion transport medium:

- group of aqueous bases;
- group of aqueous acids;
- solid polymeric materials with acidic function group additions, such as acid proton exchange membrane (PEM);
- solid polymeric materials with basic function group additions, such as anion exchange membrane (AEM).

It is applicable to hydrogen generators intended for industrial and commercial uses, and indoor and outdoor residential use in sheltered areas, such as car-ports, garages, utility rooms and similar areas of a residence.

It has to be considered that hydrogen generators that can also be used to generate electricity, such as reversible fuel cells, are excluded from the scope of this document. Residential hydrogen generators, that also supply oxygen as a product, are excluded from the scope of this document.

IEC 60204-1

It provides requirements and recommendations related to the electrical equipment of machinery so as to promote:

- safety of people and property;
- consistency of control response;
- ease of operation and maintenance.

This standard does not specify additional and special requirements that can apply to the electrical equipment of machinery that:

- are intended for use in open air;
- use, process, or produce potentially explosive material;
- are intended for use in potentially explosive and/or flammable atmospheres;
- have special risks when producing or using certain materials;
- are intended for use in mines.

IEC 60079-10-1

This standard considers that hydrogen can generate a potentially explosive atmosphere. In particular, it investigates the classification of areas where flammable gas or vapour hazards may arise, therefore it can be used as a base to support the proper design, construction, operation and maintenance of equipment in hazardous areas. This standard is intended for areas where an ignition hazard might occur due to the presence of flammable gas or vapour, mixed with air, but it does not apply to:

- mines susceptible to firedamp;
- the processing and manufacture of explosives;
- catastrophic failures or rare malfunctions which are beyond the concept of normality dealt with in this standard;
- rooms used for medical purposes;
- domestic premises;
- where a hazard may arise due to the presence of combustible dusts or combustible flyings but the principles may be used in assessment of a hybrid mixture.

Flammable mists may form or be present at the same time as flammable vapour. In such case, the strict application of the details in this document may not be appropriate. Flammable mists may also form when liquids not strictly considered hazardous due to the high flash point are released under pressure. In these cases, the classifications and details given in this document do not apply.

Atmospheric conditions include variations above and below reference levels of 101,3 kPa (1013 mbar) and 20 °C (293 K), provided that the variations have a negligible effect on the explosion properties of the flammable substances.

In any site, irrespective of size, there may be numerous sources of ignition apart from those associated with equipment. In this context, appropriate precautions will be necessary to ensure safety. This standard is applicable with judgement for other ignition sources, but in some applications other safeguards may be observed (e.g. larger distances may apply for naked flames when considering hot work permits).

This document does not consider the consequences of ignition of an explosive atmosphere, except where the zone is so small that if ignition did occur it would have negligible consequences.

On the same page of the previous matter, two standards must be taken into account:

1. IEC 60079-29-1 specifies general requirements for construction, testing and performance. It describes the test methods that apply to portable, transportable and fixed equipment for the detection and measurement of flammable gas or vapour concentrations with air. The equipment, or parts thereof, is intended for use in explosive atmospheres and in mines susceptible to firedamp.
2. IEC 60079-29-2 gives guidance and recommended practice for selection, installation, safe use and maintenance of electrically operated Group II equipment, intended for use in industrial and commercial safety applications, and Group I equipment in underground coal mines for the detection and measurement of flammable gases complying with the requirements of IEC 60079-29-1 or IEC 60079-29-4.

Nevertheless, dealing with the testing process of hydrogen, three important standards must be mentioned:

EN ISO 15848-1

It specifies testing procedures for evaluation of external leakage of valve stem seals (or shaft) and body joints of isolating valves and control valves intended for application in volatile air pollutants and hazardous fluids. End connection joints, vacuum application, effects of corrosion, and radiation are excluded from this part of ISO 15848. EN ISO 15848-2 concerns classification system and qualification procedures for type testing of valves.

ISO 26142

It defines the performance requirements and test methods of hydrogen detection apparatus, which is designed to measure and monitor hydrogen concentrations in stationary applications. The provisions in ISO 26142:2010 cover the hydrogen detection apparatus used to achieve the single and/or multilevel safety operations, such as nitrogen purging or ventilation and/or system shut-off corresponding to the hydrogen concentration. The requirements applicable to the overall safety system, as well as the installation requirements of such apparatus, are excluded. ISO 26142:2010 sets out only the requirements applicable to a product standard for hydrogen detection apparatus, such as precision, response time, stability, measuring range, selectivity and poisoning. ISO 26142:2010 is intended to be used for certification purposes.

ISO/TR 15916

This standard provides guidelines for the use of hydrogen in its gaseous and liquid forms as well as its storage in either of these or other forms (hydrides). It identifies the basic safety concerns, hazards and risks, and describes the properties of hydrogen safety related. Detailed safety requirements associated with specific hydrogen applications are treated in separate International Standards.

ISO 11114-2:2013.

It is an important guidance for the selection and evaluation of compatibility between non-metallic materials for gas cylinders and valves and the gas contents. It also covers bundles, tubes and pressure drums. ISO

11114-2:2013 can be helpful for composite and laminated materials used for gas cylinders. It does not cover the subject entirely and it is intended to give guidance only in evaluating the compatibility of gas/material combinations.

Only the influence of the gas in changing the material and mechanical properties is considered (for example chemical reaction or change in physical state). The basic properties of the materials, such as mechanical properties, required for design purposes are normally available from the materials' supplier and are not considered. The compatibility data given are related to single component gases but can be used to some extent for gas mixtures. Ceramics, glasses, and adhesives are not covered. Other aspects such as quality of delivered gas are not considered.

ISO 14687

It specifies the minimum quality characteristics of hydrogen fuel as distributed for utilization in vehicular and stationary applications. Although the focus is mainly on the Hydrogen quality for vehicular application (PEM Fuel cell), it provides useful information on the quality need of H_2 for stationary application and related impurities (water, oxygen, etc).

NFPA 2: Hydrogen Technologies Code

This code provides fundamental safeguards for the generation, installation, storage, piping, use, and handling of hydrogen in compressed gas (GH2) form or cryogenic liquid (LH2) form.

Directives

Furthermore, it is worth mentioning the following directives:

- 2014/68/EU Pressure Equipment Directive (PED): This Directive applies to equipment and assemblies subject to a maximum allowable pressure PS exceeding 0,5 bar. Pressure equipment according to the Directive are vessels, piping, safety accessories and pressure accessories. The Directive determines the objectives or "essential requirements" which the above-mentioned equipment must satisfy at the time of manufacture and before its placement on the market. The Directive concerns manufacturers of items such as vessels pressurised storage containers, heat exchangers, steam generators, boilers, industrial piping, safety devices and pressure. The manufacturer must ensure that his products are assessed with regard to conformity to the provisions of the Directive before being placed in the market. Manufacturers, importers and distributors are responsible for the compliance of their products with this law. Manufacturer information must be provided with the product.
- 2006/42/EC Machinery Directive (MD): This Directive aims at the free market circulation on machinery and at the protection of workers and consumers using such machinery. It defines essential health and safety requirements of general application, in addition to more in-depth requirements for specific categories of machinery. The hazards referred to in Annex I of the Directive are wholly or partly covered more specifically by other Community Directives. This

Directive shall not apply, or shall cease to apply, to that machinery in respect of such hazards from the date of implementation of those other directives.

- 2014/35/EU Low voltage Directive (LVD): The directive ensures that electrical equipment within certain voltage limits provides a high level of protection for European citizens, and benefits fully from the single market. It has been applicable since 20 April 2016.
- 2014/30/EU Electromagnetic Compatibility (EMC): The directive regulates the electromagnetic compatibility of equipment – apparatus and fixed installations. In order to achieve this objective, equipment need to comply with the essential requirements of the EMC Directive when it is placed on the market and/or put into service. The requirements limit electromagnetic emissions to a level that will not affect radio and telecommunications or other equipment and require products to have immunity to electromagnetic disturbances. The EMC Directive does not regulate the safety of equipment in respect of people, domestic animals or property, therefore, it is not a safety related Directive.
- ATEX 2014/34/EU Equipment for Potentially Explosive Atmosphere: the directive defines the essential health and safety requirements and conformity assessment procedures, to be applied before products are placed on the EU market. It is aligned with the new legislative framework policy, and it is applicable from 20 April 2016, replacing the previous Directive 94/9/EC.

4.2 HYDROGEN STORAGE

Standards

To ensure the correct and safe operation of the storage unit as well as other equipment in the plant, there are different standards which provides references for control devices and safety systems:

1. UNI 10197: General requirements about calibration benches for safety valves;
2. UNI 764-7: Pressure equipment - Safety systems for pressure equipment not exposed to flame;
3. CEI EN 61508: Functional safety of electrical, electronic and electrotechnical systems programmable for security applications;
4. CEI EN 61511: Functional safety - safety instrumental systems for the process industry;
5. UNI EN ISO 4126: Safety devices against overpressure.
    - ISO 4126-9: Safety devices for protection against excessive pressure - Part 9: Application and installation of safety devices excluding stand-alone bursting disc safety devices;
    - ISO 4126-10: Safety devices for protection against excessive pressure - Part 10: Sizing of safety valves and connected inlet and outlet lines for gas/liquid two-phase flow.

Other relevant standards are related to all the processes concerning the fabrication of the storage units such as the welding processes, testing and inspections. The following standards can be listed below:

1. UNI EN 287-6:2018: The standard specifies the main requirements, limits, inspection conditions and acceptance requirements for systematic qualification tests of a welder's skills. It also provides a set of technical rules so that these qualifications are uniformly accepted regardless of the type of product, location and examiner.
2. UNI EN ISO 15614-1:2017: The standard, updated in its technical content in a non-substantial way, defines the conditions for the execution of the qualification tests of the welding procedure and the validity limits of a qualified welding procedure for all practical welding operations within the scope of the variables listed. This standard applies to arc welding and gas welding of steels and to arc welding of nickel and nickel alloys.
3. UNI EN ISO 9712:2012: The standard establishes the principles for the qualification and certification of personnel in charge of carrying out non-destructive testing (NDT) in the industrial field.
4. UNI EN ISO 5817:2014: The standard provides guidance on the quality levels of imperfections in welded joints by casting steel, nickel, titanium and their alloys and applies to materials thicker than 0.5 mm.

Furthermore, general standards related to pressure-relief devices for refineries and related industries are listed below, which can be used as reference also for H_2 applications.

API STD 520: Sizing, selection and installation of pressure-relieving devices in refineries

This standard applies to the sizing and selection of pressure-relief devices (PRDs) used in refineries, chemical facilities, and related industries for equipment that has a maximum allowable working pressure (MAWP) of 15 psig (103 kPag) or greater. The pressure-relief devices covered in this standard are intended to protect unfired pressure vessels and related equipment against overpressure from operating and fire contingencies.

This standard includes basic definitions and information about the operational characteristics and applications of various pressure-relief devices. It also includes sizing procedures and methods based on steady-state flow of Newtonian fluids.

Pressure-relief devices protect a vessel against overpressure only; they do not protect against structural failure when the vessel is exposed to extremely high temperatures such as during a fire. See API STD 521 for information about appropriate ways of reducing pressure and restricting heat input.

Atmospheric and low-pressure storage tanks covered in API STD 2000 and pressure vessels used for the transportation of products in bulk or shipping containers are not within the scope of this standard.

API STD 521: Pressure-relieving and depressuring Systems

It provides guidance, recommendations, and alternatives for the design of pressure-relieving and vapor de-pressuring systems at liquefied natural gas terminals, petrochemical facilities, gas plants, and other petroleum production facilities.

NFPA 55: Compressed Gases and Cryogenic Fluids Code

It facilitates protection from physiological, over-pressurization, explosive, and flammability hazards associated with compressed gases and cryogenic fluids.

Directives

Still analyzing the hydrogen storage, the following Directives have been proved to be relevant for the investigation:

- Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances (so-called SEVESO Directive) establishes:
  - general obligations on the operator (Article 5);
  - notification (information on the form and amount of substances, the activity and the surrounding environment) of all concerned establishments (Article 7);
  - the obligation to deploy a major accident prevention policy (Article 8);
  - the obligation to produce a safety report for upper-tier establishments (Article 10);
  - the obligation to produce internal emergency plans for upper tier establishments (Article 12);

- authorities to exert control of the siting of new establishments, modifications to new establishments, and new developments including transport routes, locations of public use and residential areas in the vicinity of establishments (Article 13);
- the obligation to conduct public consultations on specific individual projects that may involve risk of major accidents (Article 15).

- Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment (SEA Directive).
- Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (EIA Directive).
- Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 related to specific environmental analysis.

4.3 GAS GRID CONNECTION AND H_2 PIPELINE

Standards

The outlined regulations [2], reported below, concern the issues related to material compatibility for the transport of mixture and pure H_2 and natural gas:

ASME B31.12: Hydrogen piping and Pipelines

It concerns piping in gaseous and liquid hydrogen service and pipelines in gaseous hydrogen service. The regulation covers materials, brazing, welding, heat treating, forming, testing, inspection, examination, operating, and maintenance. The industrial piping section covers requirements for components, design, fabrication, assembly, erection, inspection, examination, and testing of piping.

This Code is applicable up to and including the joint connecting the piping to associated pressure vessels and equipment but not to the vessels and equipment themselves. It is also applicable to the location and type of support elements, but not to the structure to which the support elements are attached.

ASME B31.3: Process piping

It contains requirements for piping typically found in petroleum refineries; chemical, pharmaceutical, hydrogen, textile, paper and pulp, power generation, semiconductor, and cryogenic plants; and related processing plants and terminals. It covers materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping. Also included is piping that interconnects pieces or stages within a packaged equipment assembly.

ASME B31.8: Gas transmission and distribution piping systems

It covers gas transmission and distribution piping systems, including gas pipelines, gas compressor stations, gas metering and regulation stations, gas mains, and service lines up to the outlet of the customer's meter set assembly. It includes gas transmission and gathering pipelines, including appurtenances that are

installed offshore for the purpose of transporting gas from production facilities to onshore locations; gas storage equipment of the closed pipe type that is fabricated or forged from pipe or fabricated from pipe and fittings; and gas storage lines.

ISO 13623:2017 Petroleum and natural gas industries: Pipeline transportation systems

It specifies requirements and recommendations for the design, materials, construction, testing, operation, maintenance and abandonment of pipeline systems used for transportation in the petroleum and natural gas industries. It applies to pipeline systems on-land and offshore, connecting wells, production plants, process plants, refineries and storage facilities, including any section of a pipeline constructed within the boundaries of such facilities for the purpose of its connection. It is not applicable for flexible pipelines or those constructed from other materials, such as glass-reinforced plastics.

It is applicable to all new pipeline systems and can be applied to modifications made to existing ones, but they can not be applied retroactively to existing pipeline systems.

API-941: Recommended Practice for Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants

This recommended practice (RP) establishes practical operating limits for carbon and low alloy steels in hydrogen service at elevated temperatures and pressures. This RP does not address the resistance of steels to hydrogen at lower temperatures [below about 400 °F (204 °C)], where atomic hydrogen enters the steel as a result of an electrochemical mechanism. This RP applies to equipment in refineries, petrochemical facilities, and chemical facilities in which hydrogen or hydrogen-containing fluids are processed at elevated temperature and pressure.

API-5L: Specification for line pipe

It is an International Standard that specifies requirements for the manufacture of two product specification levels (PSL 1 and PSL 2) of seamless and welded steel pipes for use in pipeline transportation systems in the petroleum and natural gas industries. This International Standard is not applicable to cast pipe.

EN 10208-2: Steel pipes for pipelines for combustible fluids

This European Standard specifies the technical delivery conditions for seamless and welded steel pipes for the on-land transport of combustible fluids primarily in gas supply systems but excluding pipeline applications in the petroleum and natural gas industries.

ISO 11120: Gas cylinders - Refillable seamless steel tubes of water capacity between 150 l and 3 000 1- Design, construction and testing

It outlines the minimum requirements for the material, design, construction and workmanship, manufacturing processes, examinations and tests at manufacture of refillable quenched and tempered seamless steel tubes of water capacities exceeding 150 l up to and including 3 000 l for compressed and liquefied gases exposed to extreme world-wide ambient temperatures, normally between 50 °C and 65 °C. It is applicable to tubes with a maximum tensile strength (Rma) of less than 1100 MPa. These tubes can be used alone or in batteries to equip trailers or multiple element gas containers (ISO modules or skids) for the transportation and distribution of compressed gases.

ISO 15156-1:2020: General principles for selection of cracking-resistant materials

This document describes general principles and gives requirements and recommendations for the selection and qualification of metallic materials for service in equipment used in oil and gas production and in natural-gas sweetening plants in H_2S-containing environments, where the failure of such equipment can pose a risk to the health and safety of the public and personnel or to the environment.

EIGA Doc 121-14 (2014): Hydrogen pipeline systems

This document is for metallic transmission and distribution piping systems carrying pure hydrogen and hydrogen mixtures. It is limited to gaseous products with:

- a temperature range between –40°C (-40°F) and 175°C (347°F);
- total pressures from 1MPa (150 psig) up to 21 MPa (3000 psig) or for stainless steels only partial H2 pressure higher than 0,2 MPa;
- specific concentration criteria defined in the document.

Gas quality issues can be addressed in the following regulation:

EN 16726:2015+A1:2018

This European standard specifies gas quality characteristics, parameters and their limits, for gases classified as group H that are to be transmitted, injected into and from storages, distributed and utilized.

The following standards deal with pipeline technical requirements, such as pressure, external protection or components specification:

EN1594: Gas supply systems- Pipelines for maximum operating pressures over 16 bar

This European Standard is applicable to pipelines with a maximum operating pressure (MOP) over 16 bar for the carriage of processed, non-toxic and non-corrosive natural gas according to EN ISO 13686 (natural gas requirements) in on land gas infrastructure. This European Standard is also applicable to pipelines with a maximum operating pressure (MOP) over 16 bar for the carriage of non-conventional gases such as injected biomethane, for which a detailed technical evaluation of the functional requirements is performed ensuring there are no other constituents or properties of the gases that can affect the integrity of the pipeline.

ASME B16.5: Pipe flanges and flanged fitting

It covers pressure-temperature ratings, materials, dimensions, tolerances, marking, testing, and methods of designating openings for pipe flanges and flanged fittings. This standard includes only flanges and flanged fittings made from cast or forged materials, and blind flanges and certain reducing flanges made from cast, forged, or plate materials. Further, it provides recommendations on flange bolting, flange gaskets, and flange joints.

API-1104: Welding of pipelines and related facilities

This standard covers the gas and arc welding of butt, branch, and fillet welds in carbon and low-alloy steel pipe and piping components used in the compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon dioxide, nitrogen, and, where applicable, covers welding on distribution systems.

EN 12954: Cathodic protection of buried or immersed metallic structures

This document describes the general principles for the implementation and management of a system of cathodic protection against corrosive attacks on structures which are buried or in contact with soils, surface fresh waters or underground waters, with and without the interference of external electrical sources. It specifies the protection criteria to be achieved to demonstrate the cathodic protection effectiveness. For structures that can not be electrically isolated from neighbouring influencing structures, it may be impossible to use the criteria defined in the present document.

EN 12732: Gas supply systems. Welding steel pipework- Functional requirements

This document contains requirements for the production and testing of weld joints for the installation and modification, including in-service welding, of onshore steel pipelines and pipework used in gas infrastructure. This includes all pressure ranges and processed, non-toxic and non-corrosive natural gas according to EN ISO 13686 and non-conventional gases such as (injected) biomethane and hydrogen. For injected biomethane or hydrogen a detailed technical evaluation of the functional requirements is required, ensuring there are no other constituents or properties of the gases that can affect the integrity of the pipeline.

EN15001-1 (2023): Detailed Functional Requirements For Design, Materials, Construction, Inspection And Testing:

This standard specifies detailed functional requirements for the design, selection of materials, construction, inspection and testing of industrial gas installation pipework and assemblies with an operating pressure greater than 0.5 bar.

Further, the next Standards will deal mostly with test methods for pipelines connections:

EN ISO 11114-Part 4: Hydrogen Compatibility-Test methods

It specifies test methods and evaluation of results in order to qualify steels suitable for use in the manufacture of gas cylinders (up to 3000 l) for hydrogen and hydrogen bearing embrittling gases. This document only applies to seamless steel gas cylinders. The requirements of this document are not applicable if at least one of the following conditions for the intended gas service is fulfilled:

- the working pressure of the filled embrittling gas is less than 20 % of the test pressure of the cylinder;
- the partial pressure of the filled embrittling gas of a gas mixture is less than 5 MPa (50 bar) in the case of hydrogen and other embrittling gases, with the exception of hydrogen sulphide and methyl mercaptan; in such cases, the partial pressure shall not exceed 0,25 MPa (2,5 bar).

Standard TM0284-96: Evaluation of pipeline and pressure vessel steels for resistance to hydrogen-induced cracking

This standard establishes a test method for evaluating the resistance of pipeline and pressure vessel steels to HIC caused by hydrogen absorption from aqueous sulphide corrosion. Details are provided on the size, number, location, and orientation of test specimens to be taken from each steel product form-pipes, plates, fittings, and flanges.

ASTM G 142: Standard Test method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environment at High pressure, High Temperature or both

This test method covers a procedure for determination of tensile properties of metals in high pressure or high temperature, or both, gaseous hydrogen-containing environments. It includes accommodations for the testing of either smooth or notched specimens. This test method applies to all materials and product forms including, but not restricted to, wrought and cast materials.

ASTM F 1459: Standard test method for determination of the susceptibility of metallic materials to gaseous hydrogen embrittlement

This test method covers the quantitative determination of the susceptibility of metallic materials to hydrogen embrittlement, when exposed to high pressure gaseous hydrogen.

Other types of standards especially regarding user sites:

CGA G 5.4: Standard for hydrogen piping systems at consumer locations

CGA G-5.4 describes the specifications and general principles recommended for piping systems for gaseous (Type I) or liquid (Type II) hydrogen. The standard applies to hydrogen piping in a supply system (to the source valve) and to customer piping from the source valve to the point of use. For the purposes of this standard, high pressure is defined as gaseous hydrogen at service pressures equal to or greater than 3000 psi (20680 kPa). The information in this standard is intended for designers, fabricators, installers, users, and maintainers of hydrogen piping systems as well as for safety personnel, fire departments, building inspectors, and emergency personnel.

CGA G 5.5: Hydrogen vent systems

This publication provides design guidelines for hydrogen vent systems used in gaseous and liquid hydrogen systems at user sites and provides recommendations for safe operation of these vents. It begins at the discharge port of safety devices and other components that control the release of hydrogen and ends at the point where hydrogen concentration in the atmosphere is below the lower flammable limits. It also provides information on the production, transportation, handling, and storage of compressed hydrogen, cryogenic liquid hydrogen, and related products.

Regulations

Furthermore, two important regulations on classification and identification of substances can be outlined as follows:

- Commission Regulation (EU) No 453/2010 of 20 May 2010 on the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH): The Regulation defines the requirement for safety data sheets. It provides detailed requirements for the compilation of safety data sheets, which should include:
  - identification of the substance/mixture and of the company/undertaking;
  - hazards identification;
  - composition/information on ingredients;
  - first aid measures;
  - accidental release measures;
  - handling and storage;
  - exposure controls/personal protection;
  - physical and chemical properties;
  - toxicological information;
  - ecological information;
  - transport information;
  - regulatory information.
- Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances [CLP regulation]: the aim is to ensure a high level of protection of health and the environment, as well as the free movement of substances, mixtures and articles. It includes hydrogen in its list of substances of hazardous substances establishes rules for the harmonized classification and labelling of hydrogen.

Directives

- Directive 2008/68/EC of the European Parliament and of the Council of 24 September 2008 on the inland transport of dangerous goods: This Directive applies to the transport of dangerous goods by road, by rail or by inland waterway within or between Member States, including the activities of loading and unloading, the transfer to or from another mode of transport and the stops necessitated by the circumstances of the transport. (Article 1) This regulation is about how to extend such rules to national transport in order to harmonize across the EC and ensure the proper functioning of the common transport market.
- Directive 2010/35/EU of 16 June 2010 on transportable pressure equipment: The Directive applies to the design, manufacture, conformity assessment and periodic reassessment of transportable cylinders, tubes, cryogenic vessels and tanks for transporting gases as well as hydrogen cyanide, hydrogen fluoride and hydrofluoric acid. It also covers their associated valves

and other pressure equipment. The Directive defines 3 categories for pressure equipment, based on its pressure volume product (P.V) in bar liters.

4.4 BURNER

The current chapter will outline the main standards and directives for the last section of the plant "Burner". Although, there are little to no evidence on regulations about burners operating in hybrid conditions (NG and H_2), therefore mostly normative about regular burners will be reported.

Standards

Different standards are considered relevant for the burner since it is an equipment dealing with high temperature heat. Below are reported normative related to both H_2 or conventional fuel used for burners:

CEN/TR 17924 Safety and control devices for burners and appliances burning gaseous and/or liquid fuels - Guidance on hydrogen specific aspects

This document gives guidance on hydrogen specific safety, design, construction, and performance requirements and testing of safety, control or regulating devices (hereafter referred to as controls) for burners and appliances burning gases with hydrogen content.

The following hydrogen concentrations are covered in this document:

- H2 and NG (hydrogen in natural gas) blends of 20 % hydrogen;
- 100 % hydrogen;
- varying blends / admixtures to natural gas.

Furthermore, it identifies the expected revision needs of the existing CEN/TC 58 standards as well as the need of potential further new standardization deliverables.

ISO 13574:2015

ISO 13574:2015 establishes the vocabulary for all industrial furnaces and associated processing equipment (TPE). It provides terms and definitions which are intended to be applied to the following documents: ISO 13577 (all parts) and ISO 13579 (all parts).

ISO 13579-1:2013 Industrial furnaces and associated processing equipment

ISO 13579-1:2013 specifies a general methodology for measuring energy balance and calculating the efficiency of the process involving industrial furnaces and associated processing equipment as designed by furnace manufacturers. This general methodology includes measurement methods, calculations (general calculation) and an energy balance evaluation report. ISO 13579-1:2013 is not applicable to any efficiencies related to the process itself outside of industrial furnaces and associated processing equipment.

EN 88:2022 Safety and control devices for gas burners and gas burning appliances

This document specifies the safety, design, construction, and performance requirements and testing for pressure regulators and pneumatic gas/air ratio pressure regulators (zero pressure regulators are included as a special type of pneumatic gas/air ratio pressure regulators) for burners and appliances burning one or more gaseous fuels, hereafter referred to as “pressure regulators”.

EN 125:2022 Flame supervision devices for gas burning appliances - Thermoelectric flame supervision devices

This document specifies the safety, design, construction, and performance requirements and testing for thermoelectric flame supervision devices, energized by a thermocouple intended for use with burners and appliances burning one or more gaseous fuels, hereafter referred to as “controls”.

This document is applicable to controls with declared maximum inlet pressures up to and including 500 kPa and of nominal connection sizes up to and including DN 50.

EN 161:2022 Automatic shut-off valves for gas burners and gas appliances

This document specifies the safety, design, construction, and performance requirements and testing for automatic shut-off valves for burners and appliances burning one or more gaseous fuels, hereafter referred to as “valves”. This document is applicable to valves with declared maximum inlet pressures up to and including 500 kPa and of nominal connection sizes up to and including DN 250.

This document is applicable to:

- electrically actuated valves;
- valves actuated by fluids where the control valves for these fluids are actuated electrically, but not to any external electrical devices for switching the control signal or actuating energy;
- valves where the flow rate is controlled by external electrical signals, either in discrete steps or proportional to the applied signal;
- valves fitted with closed position indicator switches.

EN 126:2012 Multifunctional controls for gas burning appliances

This European Standard specifies the safety, construction and performance requirements for multifunctional controls intended for use with gas burners, gas appliances and similar use, hereafter referred to as MFC. This European Standard is applicable to MFC with declared maximum inlet pressures up to and including 50 kPa (500 mbar) of nominal connection sizes up to and including DN 150 for use with one or more fuel gases.

EN 257:2022 Mechanical thermostats for gas-burning appliances

This document specifies the safety, design, construction, and performance requirements and testing for mechanical thermostats intended for use with gas appliances and similar use, hereafter referred to as “thermostats”. This document is applicable to thermostats with declared maximum inlet pressures up to and including 50 kPa and of nominal connection sizes up to and including DN 50 for use with one or more fuel gases.

EN 437:2021

This document specifies the test gases, test pressures and categories of appliances relative to the use of gaseous fuels of the first, second and third families. It serves as a reference document in the specific standards for appliances.

The document makes recommendations for the use of the gases and pressures to be applied for the tests of appliances burning gaseous fuels (note that procedures for tests are given in the corresponding appliance standards).

The test gases and the test pressures specified in this standard are in principle intended to be used with all types of appliances. However, the use of some test gases and test pressures may not be appropriate in the following cases:

- appliances with nominal heat input greater than 300 kW;
- appliances constructed on site;
- appliances in which the final design is influenced by the user;
- appliances constructed for use with high supply pressures (notably direct use of the saturated vapour pressure).

In these cases, the specific appliance standards may specify other test conditions in order to establish compliance with their requirements.

EN 1106:2022

This document specifies the safety, design, construction, and performance requirements and testing for manually operated taps and presetting taps for burners and appliances burning one or more gaseous fuels, hereafter referred to as "taps". This document is applicable to taps with declared maximum inlet pressures up to and including 50 kPa and of nominal connection sizes up to and including DN 50 for use with one or more fuel gases.

EN 1643:2023 Safety and control devices for burners and appliances burning gaseous and/or liquid fuels - Valve proving systems for automatic shut-off valves

This document specifies the safety, design, construction and performance requirements, and testing for valve-proving systems, hereafter referred to as “VPS”, intended for use with gas burners and gas-burning appliances burning one or more gaseous fuels. This document applies to all types of VPS used for the automatic detection of leakage in a gas burner section having at least two automatic shut-off valves, and which give a signal if the leakage of one of the valves, the piping in-between the valves or of the VPS itself and its components exceeds the detection limit. This document applies to VPS for gases with a maximum inlet pressure up to and including 500 kPa.

EN 1854:2023 Safety and control devices for burners and appliances burning gaseous and/or liquid fuels - Pressure sensing devices for gas burners and gas burning appliances

This document specifies the safety, design, construction, and performance requirements and testing of pressure sensing devices for burners and appliances burning one or more gaseous fuels. This document is

applicable to pressure sensing devices for gaseous fuels, air, or combustion products with declared maximum inlet pressures up to and including 500 kPa. It applies to all types of pressure sensing devices, including electronic, differential and inferential types. It also specifies requirements for pressure sensing devices which are intended to be applied to steam boilers and as such need to meet increased reliability requirements.

EN 1266:2002

This European standard specifies the requirements and test methods for construction, safety, fitness for purpose, rational use of energy, classification and marking of gas-fired convection heating appliances that are fitted with fan-assisted atmospheric burners, and fully pre-mixed burner.

EN 746-2:2010

This European standard specifies the safety requirements for combustion and fuel handling systems that are part of industrial furnaces and associated processing equipment.

EN 676:2020: Forced draught burners for gaseous fuels

This European Standard specifies the terminology, the general requirements for the construction and operation of forced draught gas burners, the provision of control and safety devices and the test procedure for these burners.

This European Standard is applicable to:

- automatic gas burners with a combustion air fan ("burners") and gas line components, intended for use in appliances of different types, and that are operated with gaseous fuels;
- pre-mixed burners and nozzle mixed burners;
- single burners with a single combustion chamber;
- single fuel and dual fuel burners when operating only on gas;
- the gas function of dual-fuel burners designed to operate simultaneously on gaseous and liquid fuels, which, for the latter, the requirements of EN 267 also apply.

Further:

- This European Standard deals with all significant machine hazards, hazardous situations and events relevant to burners, when they are used as intended and under conditions of misuse which are reasonably foreseeable.
- This European Standard specifies the requirements to ensure the safety during commissioning, start-up, operation, shutdown and maintenance.
- This European Standard does not apply to burners specifically designed for use in industrial processes carried out on industrial premises.
- This European Standard deals also with the additional requirements for the burners in the scope with pressurised parts and /or firing pressurised bodies, see Annex K.
- This European Standard deals also with forced draught burners intended to be used with biogenous gaseous fuels, mixtures with line-conveyed gas and special gaseous fuels.

- This European Standard deals also with burners and their equipment to increase the total appliance efficiency.

EN 13611:2021 Safety and control devices for burners and appliances burning gaseous and/or liquid fuels - General requirements

This European Standard specifies the general safety, design, construction, and performance requirements and testing of safety, control or regulating devices (hereafter referred to as controls) for burners and appliances burning one or more gaseous fuels or liquid fuels. This European Standard is applicable to controls with declared maximum inlet pressure up to and including 500 kPa and of nominal connection sizes up to and including DN 250.

ISO 13577-2 Industrial furnaces and associated processing equipment - Safety - Part 2: Combustion and fuel handling systems.

This standard specifies the safety requirements for combustion and fuel handling systems that are part of industrial furnaces and associated processing equipment (TPE). It deals with significant hazards, hazardous situations and events relevant to combustion and fuel handling systems, when used as intended and under the conditions foreseen by the manufacturer.

It covers: fuel pipework downstream of and including the manual isolating valve; combustion air supply (including oxygen and oxygen enriched combustion air) and flue gas system; burner(s), burner system and ignition device; functional requirements for safety related control system. It applies to any oxidation with air or other gases containing free oxygen of gaseous and liquid fuels or any combustion of them to release thermal energy in TPE. For thermal or catalytic post combustion and waste incineration, the standard applies only to auxiliary burners designed to start-up and/or support the process.

EN 298:2012 Automatic burner control systems for burners and appliances burning gaseous or liquid fuels.

This European Standard specifies the safety, construction and performance requirements for automatic burner control systems, programming units and flame detector devices, intended for similar usages, with gas and oil burners and gas and oil burning appliances, with or without fans. These devices are hereafter referred to generally as "automatic burner control systems".

Further:

- This European Standard is applicable to automatic burner control systems that include additional functions.
- This European Standard does not cover automatic burner control systems utilizing thermo-electric flame supervision devices.

EN 416:2020 Gas-fired overhead radiant tube heaters and radiant tube heater systems for non-domestic use - Safety and energy efficiency

This European Standard specifies the requirements and test methods for the construction, safety, classification, marking and efficiency of non-domestic gas-fired overhead radiant tube heaters

incorporating a single burner and multiple burner systems with each burner unit under the control of an automatic burner control system.

EN 549:2019 Rubber materials for seals and diaphragms for gas appliances and gas equipment

The standard specifies requirements and associated test methods for rubber materials used in gas installations, gas equipment and gas appliances in contact with combustible gases classified in EN 437:2018, additionally LPG, bio methane and bio LPG, in the same quality, are covered. It also establishes a classification based on temperature range and hardness.

EN 16129:2013-08 Pressure regulators, automatic change-over devices, having a maximum regulated pressure of 4 bar, with a maximum capacity of 150kg/h, associated safety devices and adaptors for butane, propane, and their mixtures

This European Standard defines the constructional and operational characteristics, the safety requirements, test methods and the marking of regulators and automatic change-over devices having a maximum regulated pressure of 4 bar, with a maximum capacity of 150 kg/h, for use with butane, propane and their mixtures in the vapour phase.

EN 12067-2:2023 Gas/air ratio controls for gas burners and gas burning appliances – Part 2: Electronic types.

This European Standard specifies the safety, construction and performance requirements for electronic gas/air ratio control systems (GARCs) intended for use with gas burners and gas burning appliances. It also describes the test procedures for evaluating these requirements and specifies information necessary for installation and use.

This standard is only applicable to closed loop gas/air ratio controls and does not differentiate into classification by heat input.

This standard applies to electronic GARCs that can be tested independently, as well as part of an appliance or a gas burner.

EN 16340 Safety and control devices for burners and appliances burning gaseous or liquid fuels - Combustion product.

This European Standard specifies the safety, construction and performance requirements for combustion product sensing devices intended to be used in combustion control systems.

This European Standard applies to sensing devices for the measurement of combustion products from burners and appliances for domestic, commercial and industrial use burning:

- gaseous fuels according to EN 437;
- liquid fuels having a viscosity at the burner inlet of 1,6 mm^2/s (cSt) up to 6 mm^2/s (cSt) at 20 °C, higher boiling petroleum based first raffinates (viscosity greater than 6 mm^2/s), that require preheating for proper atomisation.

Further:

- This European Standard applies to all types of stationary sensing devices measuring flue gas components O_2, CO, CO_2, H_2, C_xH_y, NO_X, SO_2 or for a combination of them (multiple gasses).
- This European Standard applies also to sensing devices for extractive systems.
- This European Standard does not cover sensor requirements for combustible gas, combustible gas mixture and oil quality.

Regulations

Regulation (EU) 2016/426 of the European Parliament and of the Council of 9 March 2016 on appliances burning gaseous fuels

This Regulation concerns appliances burning gaseous fuels used for cooking, refrigeration, air-conditioning, space heating, hot water production, lighting or washing, further with forced draught burners and heating bodies to be equipped with such burners and to safety devices, controlling devices or regulating devices and sub-assemblies thereof, designed to be incorporated into an appliance or to be assembled to constitute an appliance (fittings).

Articles in the standard describe the responsibilities of manufacturers, importers and distributors as follow:

- Article 7 sets the obligations of manufacturers which should:
  - ensure that appliances and fittings meet the essential requirements set out in Annex I;
  - draw up the technical documentation referred to in Annex III ('technical documentation');
  - carry out the relevant conformity assessment procedure;
  - keep the technical documentation and the EU declaration of conformity for 10 years;
  - ensure that procedures are in place for series production to remain in conformity;
  - carry out sample testing of appliances made available on the market;
  - investigate, and, if necessary, keep a register of complaints, of non-conforming appliances and fittings and recalls of such appliances and fittings, and shall keep distributors informed of any such monitoring;
  - ensure that their appliances and fittings bear a type, batch or serial number or other element allowing their identification, and the inscriptions provided for in Annex IV;
  - indicate on the appliance their name, registered trade name or registered trademark, and the postal address at which they can be contacted;
  - ensure that the appliance or fitting is accompanied by instructions and safety information;
  - ensure that the fitting is accompanied by a copy of the EU declaration of conformity containing, inter alia, instructions for incorporation or assembly, adjustment, operation and maintenance;
  - take corrective measures necessary to bring that appliance or fitting into conformity, to withdraw it or recall it, if appropriate.
- Article 9 sets obligations for importers which should:
  - ensure that the appropriate conformity assessment procedure has been carried out;

- ensure that the manufacturer has drawn up the technical documentation, that the appliance bears the CE marking and is accompanied by instructions and safety information and that the manufacturer has complied with the requirements set out in Article 7(5) and (6);
- indicate on the appliance their name, registered trade name or registered trademark, and the postal address at which they can be contacted;
- ensure that the appliance is accompanied by instructions and safety information in a language which can be easily understood by consumers and other end-users, as determined by the Member State concerned;
- ensure that the fitting is accompanied by a copy of the EU declaration of conformity containing instructions for incorporation or assembly, adjustment, operation and maintenance in accordance, in a language which can be easily understood by appliance manufacturers, as determined by the Member State concerned;
- ensure that, while an appliance or a fitting is under their responsibility, storage or transport conditions do not jeopardize its compliance with the essential requirements;
- carry out sample testing of appliances made available on the market, investigate, and, if necessary, keep a register of complaints, of non-conforming appliances and fittings and recalls of such appliances and fittings, and shall keep distributors informed of any such monitoring;
- for 10 years after the appliance or the fitting has been placed on the market, keep a copy of the EU declaration of conformity at the disposal of the market surveillance authorities and ensure that the technical documentation can be made available to those authorities, upon request;
- further to a reasoned request from a competent national authority, provide it with all the information and documentation necessary to demonstrate the conformity of an appliance or a fitting in a language which can be easily understood by that authority.

- Article 10 sets the obligations of distributors which should:
  - verify that the appliance bears the CE marking and that it is accompanied by instructions and safety information and that the manufacturer and the importer have complied with the requirements set out in Article 7(5) and (6) and Article 9(3) respectively;
  - not make the appliance or the fitting available on the market until it has been brought into conformity;
  - ensure that, while an appliance or a fitting is under their responsibility, storage or transport conditions do not jeopardise its compliance with the essential requirements;
  - make sure that the corrective measures necessary to bring that appliance or fitting into conformity, to withdraw it or recall it, if appropriate, are taken;
  - furthermore, where the appliance or the fitting presents a risk, distributors shall immediately inform the competent national authorities of the Member States in which they made the appliance or the fitting available on the market to that effect, giving details of the non-compliance and of any corrective measures take.

Additionally, the Regulation contains rules on:

- conformity assessment procedures for appliances and fittings;

- rules and conditions for affixing the CE marking;
- requirements relating to notifying authorities;
- procedure at national level for dealing with appliances or fittings presenting a risk.

5. ITALIAN VS EUROPEAN FRAMEWORK

As of now in Europe, as well as in the rest of the world, there is a “limited" experience on the production and usage of Hydrogen for all sectors (mobility, hard to abate, etc). This situation may lead to different normative and standards to be applied in each European country.

This section has the goal to:

- report the main Italian decree related to the hydrogen system to be considered for the Tenova democase of HyTecHeat project;
- compare Italian norms related to H_2 system with the ones from the other UE members partners in the project, in order to provide further useful insights applicable to the other democases.

5.1 Italian Decree: 7th July 2023

The decree 7 July 2023 [5] has approved the new standard related to the fire prevention for the identification of methodologies for risk analysis and fire safety measures to be adopted for the design, construction and operation of hydrogen plants.
The standard has been shown to be more appropriate for H_2 plants rather than the previous DM 23/10/2018, reported in the next chapter for completeness, since it can be applied to all the hydrogen systems and not only for H_2 refuelling station.

First, this standard classifies the H_2 production plant based on the operating pressure PH_2:

- $PH_2 < 0,5$ barg
- $0,5 \text{ barg} < PH_2 < 50$ barg
- $50 \text{ barg} < PH_2 < 100$ barg
- $100 \text{ barg} < PH_2 < 300$ barg
- $300 \text{ barg} < PH_2 < 500$ barg
- $500 \text{ barg} < PH_2 < 700$ barg
- $700 \text{ barg} < PH_2 < 1000$ barg

For operating pressures greater than 1000 barg or in the case of adoption of storage systems other than those listed in this decree, the designer, following the assessment of the fire risk, must implement specific fire safety measures also determined by methodologies envisaged with an engineering approach to fire safety pursuant to Ministerial Decree of 9 May 2007.

Second, it classifies as dangerous the following equipment:

- electrolysis module;
- buffer tank;
- compression system;
- hydrogen storage;
- loading station (loading bays);
- pressure reduction and stabilisation group;
- connecting pipes (connecting elements a., b., c., d., e. and f. for hydrogen transfer);

giving more accurate definition for each element.

Third, it specifies that the Verification of the eligibility of an electrolyser to the D.P.R. 151/2011 must be conducted if the Hydrogen produced is higher than 25 Nm^3/h. The D.P.R. 151/2011 identifies the activities subject to fire prevention controls and regulates, for the submission of projects, for the examination of projects, for technical visits, for the approval of derogations from specific regulations, the verification of fire safety conditions which, according to current legislation, are attributed to the competence of the Italian National Fire Corps.

Moreover, at least one access to the site must be provided with the following minimum requirements to allow the intervention of the emergency vehicles of the Fire Brigade:

- width: 3.50 m;
- free height: 4 m;
- turning radius: 13 m;
- slope: no more than 10%;
- load resistance: at least 20 tons (8 on the front axle and 12 on the rear axle: wheelbase 4 m).

Moreover, the normative reports specific instructions for each part of the plant:

a. H_2 production:
   - the plant must be subject to a specific risk assessment, conducted accordingly to the procedures set out in Annex I of the Decree of the Minister of the Interior of 7 August 2012;
   - the plant must be designed and built in accordance with the rule of art. Plants that comply with ISO 22734 are considered to be state-of-the-art;
   - the risk assessment shall include the risk of formation of explosive atmospheres.

b. H_2 storage:
   - storage unit must be designed and manufactured in accordance with the rule of art;
   - the operating pressure PH_2 must not exceed 1000 bar;
   - the storage units shall be placed in a box and if the total volume of the deposit is greater than 6000 Nm^3, the box must be divided into portions delimited by walls built in reinforced concrete, or in other non-combustible material of adequate mechanical strength, with construction characteristics of the artifacts such as to guarantee only perimeter the mitigation of the effects due to accidents;

- the support structure, if present, must be non-combustible and have fire resistance characteristics at least R60 or be protected so as to guarantee performance equivalent to R60;
- should have safety devices that prevent pressure from exceeding the design value, regardless of the storage temperature;
- should have a safety device, thermally activated, which intervenes if the design temperature is exceeded;
- each storage unit must be isolable from the rest of the system by means of emergency shut-off valves;
- each storage unit must be equipped with a pressure measuring system.

c. H_2 compression:

- compressors must be designed and manufactured in accordance with the rule of art;
- the compressor shall be equipped with an emergency shut-off device to stop operation when the pressure on the suction side falls below the minimum supply pressure;
- each compressor shall be equipped with a safety system to prevent overpressure as well as a drain valve system for emergency depressurization. In addition, each compressor must be connected with the rest of the system through the use of appropriate vibration damping systems;
- compressors must be equipped with suitable emptying and inerting systems to allow maintenance operations;
- any safety accessories (safety valves) installed downstream of the compressors, to ensure that the maximum operating pressures are not exceeded, must be mounted independently of those existing in the compressors themselves;
- compressors, including any relevant devices (e.g. pressure pulsation tanks) shall be placed in boxes as done for storage unit. For compressors with pressures not exceeding 300 bar, any barriers must be identified using risk analysis methodologies.

d. Loading docks:

- These are areas used to house the tube trailers.
- During the loading/unloading of hydrogen gas, the tube trailers are considered part of the installation;
- the route provided for the tube trailers, from the entrance of the plant to the point of loading/unloading, must be free of obstacles;
- any loading of the tube trailers without the tractor unit must be carried out within the time strictly necessary; In this case, the tube trailers must be parked so that the tractor unit can hook and tow it even in an emergency without making maneuvers (in the direction of exit from the system);
- the loading bay shall be equipped with a stop-off device which interrupts the flow of hydrogen both on the plant side and on the tube trailers side as soon as the emergency button is pressed, located near the loading station.

e. Gas plant:

- It is the system consisting of the set of pipes, shut-off, exhaust and safety valves, as well as equipment that make up the supply, compression, damping, accumulation, gas distribution and emergency system.
- The materials used must meet the requirements of Legislative Decree no. 26 of 15 February 2016;
- the design pressures of the system must be at least 10% higher than the maximum nominal operating pressures and, in any case, not lower than the switching pressures of the safety valves;
- the overpressure in the supply line of loading bays with pressures above 300 bar shall not be more than 1% of the supply pressure, with pressure pulsations not exceeding 4%.

More details on piping (rigid or flexible) and safety system are reported in the normative.

f. Electrical system:

- Electrical constructions must be carried out in accordance with the provisions of Law no. 186 of 1 March 1968 considering the classification of the electrical risk of the places to be conducted according to the reference technical standards, ensuring the achievement of the following fire safety objectives:
  - limit the likelihood of causing fire or explosion;
  - limit the spread of a fire through its components;
  - allow occupants to leave the rooms safely;
  - enable rescue services to operate safely.

More details on the requirements for the electrical system are reported in the normative.

g. Prevention of formation of explosive mixtures:

In order to minimize the formation of potentially explosive hydrogen-air mixtures, it is considered necessary to carry out a risk assessment and adopt protective measures in accordance with Chapter V.2 of Ministerial Decree of 3 August 2015 and subsequent amendments. Further, it is advised to adopt the following additional measures:

- in case of deviation of the flow rate and pressure of hydrogen gas from the limits of the regular operation of the plant as declared by the manufacturer, a process control system must be provided that allows the interruption of the power supply of electrical equipment not classified according to Directive 2014/34/EU (ATEX) and the start of ventilation; the ventilation system must be such as to maintain an average concentration of hydrogen gas inside the electrolyser system below 1%;
- a hydrogen detection system capable of activating automatic ventilation in case of concentrations equal to or greater than 1% shall be provided. The selection of the number, location and type of hydrogen detectors must be carried out in accordance with the rule of the art with particular reference to the CEI EN 60079-29-1 standard. The installation, use and maintenance of hydrogen gas detectors comply with IEC EN 60079-29-2;
- in addition, in order to prevent the formation of oxygen-enriched atmospheres (with a concentration of O_2 greater than 23.5% in air), if the electrolyser is designed to release oxygen inside closed areas/environments, an oxygen detection system must be provided, subservient to the ventilation system.

h. Detection and alarm systems:

The dangerous equipment of the installation mentioned above must be monitored by installation of the following systems:

1. Temperature monitoring and control system: the dangerous equipment where high temperature values can be reached must be subject to temperature monitoring and control.
2. Gas leak detection and control system: a system must be provided for the detection and control of gas leaks in all areas of the plant likely to be affected by the possible formation of a hazardous explosive atmosphere according to the results of the risk assessment to be conducted in accordance with chapter V.2 of the Ministerial Decree of 3 August 2015 and subsequent amendments. The plant, where necessary, must be built according to the reference technical standards.
3. Flame detection system: a flame detection system must be provided for in all areas of the system likely to be affected by the ignition of any hydrogen leaks. The plant, where necessary, must be built according to the reference technical standards.

It is also required the installation of a fire detection and alarm system (IRAI) to protect the entire activity. More details can be found in the normative.

i. Extinguishing and cooling systems:

- the dangerous equipment of the system must be protected with a hydrant network designed and built in accordance with the provisions of the decree of the Ministry of the Interior of 20 December 2012. For the design of the network you can refer to the UNI 10779 standard, assuming for the activity a level of danger not lower than 2;
- compressed hydrogen storage that may be exposed to fire must also be protected by rain cooling systems.

j. Fire extinguishers:

- portable fire extinguishers must be installed to protect against any hazardous element of the installation;
- at least one fire extinguisher must be provided for every 100 m^2 of floor area for technical rooms and each enclosed area within the plant.

k. Emergency System (EES):

- the production plant must be equipped with an Emergency Shutdown System (ESS) in order to immediately cut off the supply of the hazardous elements of the plant in the event of a real and imminent danger that cannot be eliminated by the intervention of the process control systems alone;
- the ESS system may be activated following intervention by the automatic detection systems mentioned above. In any case, emergency shutdown devices (ESD), with manual reset, must be provided for located near the dangerous elements of the system.
- The ESS system must intervene at least in the following cases:

- exceeding concentration of H_2 in the atmosphere equal to or greater than 1%;
- fire alarm activated by the IRAI system;
- stop or lack of mechanical ventilation in the electrolyser cabinet, or in the case of a flow rate of less than 75% of the design flow rate;
- activation of an ESD emergency button;
- differential pressure within the cells (stack) between O_2 and H_2 beyond the limits indicated by the manufacturer;
- high pressure and high temperature at the outlet of the compressors;
- low suction pressure inlet to the compressors.

- Once activated, the ESS system must provide at least the following functions:
  1. stop the production of hydrogen (electrolyser);
  2. depressurising equipment containing H_2 under pressure and conveying it to a safer place;
  3. completely isolate the delivery pipes at the loading docks;
  4. completely isolate the low-pressure line from the suction and the delivery line of the compressors;
  5. completely isolate storage;
  6. interrupt the electrical circuit of the installation and ancillary installations, except the lines supplying the security installations.
- The ESS system shall be equipped with reboot locks that require intentional recovery before hydrogen generation is allowed to restart. In any case, the system must be designed in such a way that it does not create a dangerous condition at the time of recovery.

Lastly, the Decree reports the safety distances that must be respected between the dangerous equipment of the plant. Compared to DM 23/10/2018, the safety distances depend on the operating hydrogen pressure of the equipment as reported in Table 3:

Pressure [bar]	External safety distance [m]	Protection safety distance [m]	Internal safety distance [m]
$700 < PH_2 \leq 1000$	30	15	15
$500 < PH_2 \leq 700$	25	15	15
$300 < PH_2 \leq 500$	20	15	15
$100 < PH_2 \leq 300$	17	12	12
$50 < PH_2 \leq 100$	12	8	8
$30 < PH_2 \leq 50$	8	6	6
$10 < PH_2 \leq 30$	7	5	5
$PH_2 \leq 0,5$	5	3	3

Table 1: Safety distances according to Italian DM 07/07/2023

5.2 Italian Decree: DM 23rd October 2018

The DM 23/10/2018 states the Fire prevention technical rule for design, construction and operation for H_2 system. Even though it is intended for Hydrogen refuelling station (HRS), the decree is addressed when designing an H_2 system, since it provides regulations on the same equipment used for other purposes (electrolyzers, storages, tube trailers and compressors).

The provisions reported in the document aim to:

- minimize the causes of fire and explosions;
- limit, in the event of an accident, damage to people;
- limit, in the event of an accident, damage to buildings or adjoining premises;
- allow rescuers to operate in safe conditions.

The decree is dived into the following 6 main sections:

1. GENERAL PROVISIONS: where terms, definitions, dimensional tolerances, materials used and system equipment are outlined. This section reports the equipment of the plant classified as dangerous and subjected to specific provisions in the decree (f.i. specific safety distances must be kept). In particular, the following are considered dangerous elements of the system:
    - hydrogen production unit, if present;
    - pressure reduction and hydrocarbon gas measurement cabin (only in the case of production units consisting of reformers with hydrocarbons);
    - compressors;
    - storage units;
    - gas trailers, if present;
    - delivery units;
2. CONSTRUCTION MODES: where relevant information on the construction mode of different equipment are exploited. A summary of the full list of equipment is reported below:
    a. Fence: Areas dedicated to the dangerous elements of the plant, except delivery units, must be demarcated by a fence characterized by a minimum height of 1.8 m.
    b. H_2 production plant:
        - the plant for the on-site production of hydrogen, where applicable, must be the subject of a specific risk assessment, to be conducted according to the procedures set out in Annex I of the decree of the Minister of the August 7, 2012 DM 07/08/2012.
        - H2 production plant by means of electrolysis must follow the ISO 22734-1 and be placed in a box (made of concrete);
        - be compliant to other requirements (see DM for more information).
    c. Compressors:
        - compressors must be designed and manufactured in compliance to the rule of art (compliant with the standard EN 1012-3);

- vessels used to dampen pressure pulsations must have geometric volume not exceeding 0.4 m3;
- be compliant to other requirements (see DM for more information).

d. Storage unit:
   - the accumulation of gaseous hydrogen, both process intermediate and for storage within the plant, can take place in storage units, also made up of several containers, with variable operating pressure, not exceeding 1000 bar, and maximum quantity of hydrogen in storage not exceeding 6000 Nm^3;
   - storage unit must be designed and manufactured in compliance to the rule of art (compliant with the standard ISO 19884);
   - storage units must be placed in a special box (made of concrete). If the total volume of the storage unit is greater than 6000 Nm^3, the box must be divided into portions bounded by walls built in reinforced concrete or other material incombustible of adequate mechanical strength, with construction characteristics of the artifacts such as to guarantee mitigation only at the perimeter the effects of accidents;
   - be compliant to other requirements (see DM for more information).

e. H_2 trailers:
   - H_2 trailers must comply with ADR [3] regulations;
   - the planned route for the trailer, from the entrance to the plant of distribution up to the point of discharge, must be free of obstacles;
   - the trailers must be parked so that drivers can hook up the trailer and tow it even in case of emergency without performing maneuvers (in the direction of exit from the lift);
   - be compliant to other requirements (see DM for more information).

f. Gas system:
   - It includes the system of pipes, shut-off, discharge and safety valves, as well as equipment that compose the supply network, compression, damping, accumulation, gas distribution and emergency system. See DM for more information.

g. See DM for other equipment requirements

3. SAFETY DISTANCES: where the safety distances between the equipment of the plant are reported. In particular, the following distances must be respected:

   a. Dangerous equipment:

Element	Protection distance* [m]	Internal safety distance** [m]	External safety distance*** [m]
Compressor	15	-	30
Storage	15	15	30
Gas trailer box	15	15	30

Table 2: Safety distances according to Italian Ministerial decree 23/10/2018

* Minimum value, established by the standard, of the distances measured horizontally between the border of each dangerous element of an activity and the fence (where prescribed) or the border of the area on which the activity itself stands. [4]

** Minimum value, established by the standard, of the distances measured horizontally between the respective plan perimeters of the various dangerous elements of an activity. [4]

*** Minimum value, established by the standard, of the distances measured horizontally between the plan perimeter of each dangerous element of an activity and the perimeter of the closest building external to the activity itself or other works public or private or with respect to the boundaries of building areas towards which these distances must be observed [4]

b. Dispenser (for HRS, only):

Element	Protection distance* [m]	Internal safety distance** [m]	External safety distance*** [m]
Dispenser	15	12	30

Table 3: Safety distances for dispenser according to Italian DM 23/10/2018

c. Other distances: Among the dangerous elements referred in general provisions and the premises listed below, intended for ancillary services, the following safety distances must be observed:
   - manager's office, warehouse, toilets, workshop without use of open flames and washing system: safety distances reported in Tables 1 and 2;
   - electricity substation: 22 m;
   - between the dangerous elements of the installation and the grid power lines, with voltage values greater than 1000 V_{rms} (AC) and 1500 V (DC), must be observed, with respect to plan projection, a distance of 45 m.

d. See DM for other safety distances.

Note that safety distances different from the above mentioned can eventually be identified by applying the methodologies of the engineering approach to fire safety envisaged by decree of the Minister of the Interior 9 May 2007.

4. OPERATING STANDARDS: where information on operation of the plant, general emergency prescriptions, needed technical documents, safety signs and emergency call are reported.
5. PROVISIONS FOR INSTALLATIONS FOR THE REFUELING OF COMPANY FLEETS: not deep dived as out of HyTecHeat project.
6. MIXED DISTRIBUTION PLANTSROAD FOR AUTOMOTIVE: not deep dived as out of HyTecHeat project.

5.3 Italian Decrees: Safety and Fire Prevention

In this section, a list of Italian Ministerial Decree, provisions and Legislative Decrees will be reported concerning fire prevention and safety regulations on workplaces and construction sites. Although they are not specifically related to hydrogen/natural gas plants, these regulations are deemed valuable during the engineering of every plant with fire hazard:

D.P.R. 151/11, Regulations simplifying the regulation of procedures related to fire prevention.

D.P.R. 151/2011 is the current decree that identifies activities subject to fire prevention inspections and regulates the verification of fire safety conditions under the responsibility of the National Fire Department. It imposes the obligation to maintain fire-fighting equipment, facilities and all active and passive protection systems present within the specific subject activity.

D.M. 08/12, "Provisions on how to submit applications concerning fire prevention procedures and the documentation to be attached"

The D.M. regulates the contents and related attachments for each of the following instances:

- Instance of project evaluation;
- segnalazione certificata inizio attività (SCIA);
- certificate of periodic renewal of fire compliance;
- application for exemption;
- application for a Nulla Osta di Fattibilità (NOF);
- application for verification in progress;
- petition for turn-over.

D. Lgs. 81/08 "safety measurements in workplaces"

D. Lgs 81/2008 prescribes measures aimed at protecting the health and safety of "workers" and "users" in private and public workplaces through the implementation of EU directives.
The objectives of the decree concern the systematic search for occupational and non-occupational hazards (indicated in the "Risk Assessment Report") and their elimination or containment before they produce undesirable effects.

D.M. 08/15 "Approval of technical standards for fire prevention."

D.M. 08/2015 regulates industrial and manufacturing activities that do not yet have technical regulations on fire prevention, including:

- Workshops and laboratories with welding operations;
- workshops or laboratories for painting with flammable paints;
- establishments and plants where bricks and other are produced;
- cement factories;
- others.

D.M. 03/03, "Requirements for reaction to fire of materials constituting the air distribution and recovery ducts of air conditioning and ventilation systems."

The Decree establishes the fire reaction requirements of materials constituting air distribution and recovery ducts of air conditioning and ventilation systems serving activities subject to fire prevention controls.

D.M. 10/22 "Amendments to regulations on the reaction to fire of materials and the fire prevention code."

D.M. 10/2022 introduces important changes regarding reaction-to-fire classification and approval of materials for fire prevention purposes. The Decree, among the new features, repeals the Italian classification of reaction to fire according to Ministerial Decree June 26, 1984, and leaves the European classes of reaction to fire for construction products valid, providing, a single European classification system.

D.M. 02/07 "Fire resistance classification of products and construction elements of construction works."

D.M. 02/2007 applies to products and construction elements for which the fire resistance requirement is prescribed for the works in which they are incorporated.

D.M. 01/08 n. 37 "Regulation on the reorganization of the provisions on the activity of installation of systems inside buildings"

The decree introduces new provisions on the safety of systems in buildings, both for their certification when being installed and/or modified (transformation, extension, extraordinary maintenance), and for the obligations to be fulfilled by the owner in the case of the transfer of the property. The certification consists of the issuance, by licensed companies, of precise documentation, namely the project, declaration of conformity, use and maintenance booklets and, only for systems installed or modified before 27/3/08, the "declaration of compliance."

D.M. 10/03/2005 "Classes of fire reaction for construction products to be used in works for which the fire resistance requirement is prescribed"

The decree classifies fire reaction to construction products, flooring, linear shape products intended for thermal insulation and electrical cables.

D.M. 15/03/2005 "Reaction-to-fire requirements for construction products installed in activities governed by specific technical provisions for fire prevention according to the accordance with the European classification system."

The decree introduces installation requirements and classifies fire reaction to such products:

- non-combustible products
- unclassified products
- products installed along escape routes
- products installed in other environments
- insulating products

5.4 Dutch guideline: PGS 15:2016 (version 1)

PGS 15 (2016 version 1.0) is included into the Publicatiereeks Gevaarlijke Stoffen (Dangerous substances publication) and it provides guidelines on the method of (temporary) storage of packaged hazardous substances on fire safety, occupational safety and environmental safety.

This guideline provides indications for:

a) Gas type and quantity:
   - It applies to all storage of refillable gas containers of class 2 of the ADR with a total amount greater than 125 liters of water capacity. These packages must be stored in a dedicated storage facility, where no other goods may be present that are not functional for the management of the gas cylinders.
   - Storage should preferably be carried out outdoors and applies to both full and empty gas cylinders with the following hazard properties: suffocating, oxidizing and/or flammable; including the following specific gases: compressed air, ammonia (toxic/corrosive), refrigerant gases and ethylene oxide (toxic/flammable).
   - Gas cylinders containing gases with similar hazard properties must be stored together. Combustible and fire-promoting gases may be stored next to each other without a partition because the chance that two gas cylinders will fail at the same time, the gases will mix with each other and be ignited is considered negligible.

b) Material and position:
   - For storage of gas cylinders containing flammable gases heavier than air such as propane and butane, a distance of at least 5 m must be maintained from basement openings, wells and street gullies that are in open connection with the sewerage system and from at least 7.5 m to suction openings of ventilation systems located less than 1,5 m above ground level.
   - The floor of the storage facility shall not be lower than the surrounding floor or that of adjacent rooms. This floor must be flat and made of non-combustible material. In the case of an open storage facility, the floor must be draining and no gas must be able to accumulate under this floor.
   - The outdoor storage facility must be made of non-fire material, but a roof is not necessary. The location of the outdoor gas cylinder storage must comply with the distance rules below (Table 4), regardless of the type of gas:

	Total water content stored gas cylinders < 2500 liters			Total water content stored gas cylinders > 2500 liters		
RFPFS* [min]	60	30	N/A	60	30	N/A
Safety distance from establishment boundary [m]	0	1	3	0	3	5
Safety distance from construction or combustible object within the establishment [m]	0	3	5	0	5	10

Table 4: Safety distances from specific boundaries and RFPFS from guideline PGS 15:2016.

*Resistance to Fire Penetration and Fire Spread

NB1: If storage of gas cylinders takes place against the façade of a building belonging to the establishment, that part of the wall, and the wall up to a maximum of 4 meters above and 2 meters on either side of the gas cylinders, must have a fire resistance of at least 60 minutes.

NB2: Distance provisions apply for safety on private property. External security has not been taken into account, because this is laid down in the External Security Establishments Regulation.

c) Security:
- Gas cylinders with a stable construction, such as propane gas cylinders, do not need to be secured. All other gas cylinders and gas cylinders must be secured to the back wall or wall by means of a chain, bracket or clamping strap. Gas cylinders of different sizes should have an equal level of protection. The usual transport pallets for gas cylinders also meet this requirement of securing.
- An open storage facility must not be accessible uncontrolled to unauthorised persons. An access door to an accessible storage facility must be lockable from the outside with a lock, but can be opened from the inside without a key.
- The storage device should preferably not be placed in the driving route of a forklift or other means of transport. If this is the case, collision protection is mandatory in situations where there is a risk of damage to gas cylinders as a result of frequent vehicle movements.

d) Set:
- Each storage facility shall contain at least one portable 6 kg ABC powder extinguisher, capable of extinguishing an incipient fire from the stored gases and protected from weather influences.
- If a storage facility presents or may present a risk to the safety or health of a worker, personal protective equipment, such as safety glasses and work gloves, must be available to workers exposed or likely to be exposed to that hazard.

e) Indoor storage facility:

- At least one wall must be an external wall in which there is at least one door. In the case of a fire safety cabinet/gas cylinder cabinet, this storage device must comply with standard EN 14470-2. The facility must not be located in an escape route.
- The implementation of the indoor storage facility must offer resistance to fire penetration and fire spread for at least 60 m.
- Indoor storage facilities may contain a maximum of 2,5 kg of hazardous substance, unless there is a NEN 2535 recognized fire alarm system with notification to the alarm center of the (company) fire brigade, then this may be a maximum of 10,000 kg. Facilities up to 250 kg or litres may be located on one floor.
- If a ventilation opening is installed in an architectural structure that has requirements with regard to RFPFS or fire resistance, flame-retardant grilles must be fitted and the installation of the ventilation must not impair the RFPFS of the storage facility. This requirement does not apply to a fire safety cabinet.

f) Other indications:

- A difference is made between outdoor storage facilities up to and above 10,000 kg.
- Gas cylinders that have been removed from the approved must be removed or replaced immediately.
- Gas cylinders must have the correct inspection, ADR and GHS hazard labels during storage.
- The same storage rules apply to full gas cylinders as to empty gas cylinders.
- The requirement of RFPFS applies from the inside out and from the outside in.
- Fixed bulk tanks do not fall under PGS15.
- Semi-detached storage facilities with a fire-resistant separation are seen as multiple individual storage facilities.

g) Lastly, PGS15 does not apply to:

- Gas cylinders with a total of up to 125 liters of water capacity;
- aerosols with a total of up to 50kg net capacity;
- working stock (gas cylinders placed on a welding trolley or gas cylinders connected to a collection line; of the latter group, the cylinders and the pipe must be protected from damage if applicable and the valves must be easily accessible in the event of an emergency);
- extinguishing agents (also larger quantities from an emergency response training center);
- connected carbon dioxide cylinders of beer taps;
- gas cylinders installed for an extinguishing gas installation.

5.5 Safety distances comparison

Country	Normative	Identification dangerous equipment				Notes
			External Distance [m]	Protection distance [m]	Internal distance [m]	From hazardous components
ITALY	DM 23/10/2018	Electrolyzer Storage Compressor Tube trailer etc	15	15	15	Independent from pressure
ITALY	DM 07/07/2023	Electrolyzer Storage Compressor Tube trailer etc	30	15	15	700<P≤1000 barg
			25	15	15	500<P≤700 barg
			20	15	15	300<P≤500 barg
			17	12	12	100<P≤300 barg
			12	8	8	50<P≤100 barg
			8	6	6	30<P≤50 barg
			7	5	5	10<P≤30 barg
			5	3	3	P≤10 barg
			RFPFS 60 min	RFPFS 30 min	RFPFS N/A	
NETHERLANDS	PGS 15:2016	Storage	0	1	3	From estab. boundary (capacity < 2500 liters)
			0	3	5	From estab. boundary (capacity > 2500 liters)
			0	3	5	From haz. objects within estab. boundary (capacity < 2500 liters)
			0	5	10	From haz. objects within estab. boundary (capacity > 2500 liters)

Table 5: Comparison between Safety distances for H2 plant in Europe

6. STANDARDS SUMMARY TABLE

This chapter will give a better visualization of the different standards/directives/regulations and Ministerial decrees, previously depicted in the full document, by organizing them in Table 6 depending on the impact they had on each section of the HyTecHeat system.

Standard, Directive and Regulation	H_2 production	H_2 storage	Gas grid connection	Burner	Cross cutting
ISO 22734:2019	x				
IEC 60204-1:2016+AMD1:2021	x				
IEC 60079-10-1:2020	x				
IEC 60079-29-1:2016/AMD1:2020	x				
IEC 60079-29-2:2015	x				
EN ISO 15848-1:2015/A1:2017	x				
EN ISO 15848-2:2015	x				
ISO/TR 15916:2015	x	x			
ISO 26142:2010	x	x	x	x	x
ISO 11114-2:2021	x	x			x
ISO 14687	x				
2014/68/EU (PED)	x	x		x	x
2006/42/EC (MD)	x			x	
2014/35/EU (LVD)	x				
2014/30/EU (EMC)	x				
ATEX 2014/34/EU	x	x	x	x	x
API STD 520		x			
API STD 521		x			
API STD 2000		x			
UNI EN 287-6:2018		x			
UNI EN ISO 15614-1:2017		x			
UNI EN ISO 9712:2012		x			
UNI EN ISO 5817:2014		x			
UNI 10197	x	x	x	x	x
UNI 764-7	x	x	x	x	x
CEI EN 61508	x	x	x	x	x
CEI EN 61511	x	x	x	x	x
UNI EN ISO 4126	x	x	x	x	x
Directive 2012/18/EU		x			
Directive 2001/42/EC	x	x	x	x	x
Directive 2011/92/EU	x	x	x	x	x
Directive 2014/52/EU	x	x	x	x	x
ASME B16.5			x		
ASME B31.12			x		

ASME B31.3			x		
ASME B31.8		x	x		x
EN 16726:2015+A1:2018	x	x	x		
API-5L			x		
API-941			x		
API-1104			x		
ASTM G 142		x	x		
CGA G 5.4			x		
CGA G 5.5			x		
ISO 13623:2017			x		
ISO 11114-4:2021		x	x		
ISO 11120:2015			x		
EN1594			x		
EN 10208-2			x		
EN 12954			x		
EN 12732			x		
ISO 15156-1:2020			x		
TM0284-96		x	x		
Directive 2008/68/EC			x		
Directive 2010/35/EU		x	x		x
Directive EU No 453/2010	x	x	x		x
Directive EC No 1272/2008	x		x		
CEN/TR 17924				x	
ISO 13574:2015				x	
ISO 13579-1:2013				x	
EN 88:2022				x	
EN 125:2022				x	
EN 126:2012				x	
EN 161:2022				x	
EN 257:2022				x	
EN 437:2021				x	
EN 1106:2022				x	
EN 1643:2023				x	
EN 1854:2023				x	
EN 1266:2002				x	
ISO 13577-2				x	
EN 298:2012				x	
EN 416:2020				x	
EN 549:2020				x	
EN 16129:2013				x	
EN					
EN 12067-2:2023				x	
EN 13611:2021				x	
EN 16340				x	
Regulation (EU) 2016/426				x	
EN15001-1:2023			x		
EN 746-2:2010				x	

EN 676:2020				x	
EIGA Doc 121-14:2014			x		
NFPA 2	x	x	x		x
NFPA 55		x	x		x

Table 6: Summary of Standards for the H2 system

Normative	Country	H2 production	H2 storage	Gas connection	Burner	Cross cutting
DM 23/10/2018	Italy	x	x	x	x	x
DM 07/07/2023		x	x	x	x	x
D.P.R. 151/11						x
D.M. 08/12						x
D. Lgs. 81/08						x
D.M. 08/15						x
D.M. 03/03						x
D.M. 10/22						x
D.M. 02/07						x
D.M. 01/08 n. 37						x
D.M. 10/03/2005						x
D.M. 15/03/2005						x
PGS 15:2016	Netherlands		x			

Table 7: Summary of European normative/regulations for H2 system specific to country

7. CONCLUSIONS

This report had the aim to identifying and gathering the relevant normative and standards that can be applicable in the European Union to the safety design and operation of H_2 system.

In order to do so, the HyTecHeat system has been dived into 4 main sections: H_2 production, Hydrogen storage, Gas grid connections/Pipe connection, Hybrid combustion systems. For each section the relevant normative and standards has been optimally identified and described, in such a way that the gathered information can be adopted to accomplish the next project deliverables.

It is important to state that all the information and normative reported in this document, does not replace the specific reading of each document as well as the investigation of other normative during the design and implementation phase of the project.

8. LIST OF FIGURES

9. LIST OF TABLES

10. BIBLIOGRAPHY / REFERENCES

[1] FCHObservatory
[2] HyLAW European commission
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