UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCUELA TÉCNICA SUPERIOR INGENIERÍA INDUSTRIAL VALENCIA

INDUSTRIAL ENGINEERING MASTER THESIS

DESIGN OF A HYDROGEN REFUELLING STATION (HRS) AT THE UNIVERSITAT POLITÈCNICA DE VALÈNCIA: PRODUCTION BY MEANS OF PEM ELECTROLYSIS, STORAGE, COMPRESSION AND REFUELLING DISPENSER

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"To my parents and my sister, for their unconditional support during the academic stage that ends today."

"To my supervisor, for all his help, his energy and his support guiding me during the realization of this project."

Abstract

Nowadays, there is an increasing concern about how different energy systems impact on the environment and affect society. Accordingly, the search for alternative solutions to achieve a clean and sustainable energy system is becoming imperative. Specifically, for the transport sector, many technologies are being developed aiming at decarbonising the industry, and hydrogen is among them.

The present work focuses on the technical design of a hydrogen refuelling station (HRS) located at the Polytechnic University of Valencia (UPV). The study deals with the selection of the components that form the hydrogen chain, from its production by Proton Exchange Membrane (PEM) electrolysis, through storage and compression stages, to the point of consumption where hydrogen is supplied to different fuel cell electric vehicles (FCEV). Through the use of this facility, greenhouse effect emissions are expected to be reduced, since the use of hydrogen as a fuel produces water vapor as its main emission by-product.

Keywords: hydrogen, PEM electrolysis, HRS, fuel cell

Resumen

Actualmente, existe una creciente preocupación sobre cómo los diferentes sistemas energéticos impactan en el medio ambiente y afectan a la sociedad. En consecuencia, la búsqueda de soluciones alternativas para lograr un sistema energético limpio y sostenible se está volviendo imprescindible. Específicamente, para el sector del transporte, se están desarrollando varias tecnologías con el objetivo de descarbonizar la industria, siendo el hidrógeno una de ellas.

El presente trabajo se centra en el diseño técnico de una estación de repostaje de hidrógeno (HRS) ubicada en la Universidad Politécnica de Valencia (UPV). El estudio aborda la selección de los componentes que forman parte de la cadena de hidrógeno, desde su producción por electrólisis de membrana de intercambio de protones (PEM), pasando por las sucesivas etapas de almacenamiento y compresión, hasta llegar al punto de consumo donde se suministra hidrógeno a diferentes vehículos eléctricos de pilas de combustible. Mediante esta instalación, se espera que las emisiones de efecto invernadero se reduzcan considerablemente, ya que el uso de hidrógeno como combustible produce vapor de agua como principal subproducto de emisión.

Palabras Clave: hidrógeno, electrólisis PEM, Hidrogenera, pila de combustible

Resum

Actualment, hi ha una creixent preocupació sobre com els diferents sistemes energètics impacten en el medi ambient i afecten la societat. En conseqüència, la recerca de solucions alternatives per aconseguir un sistema energètic net i sostenible s'està tornant imprescindible. Específicament, per al sector del transport, s'estan desenvolupant diverses tecnologies amb l'objectiu de descarbonitzar el sector, sent l'hidrogen una d'elles.

El present treball es centra en el disseny tècnic d'una estació de repostatge d'hidrogen (HRS) situada a la Universitat Politècnica de València (UPV). L'estudi aborda la selecció dels components que formen part de la cadena d'hidrogen, des de la seva producció per electròlisi de membrana d'intercanvi de protons (PEM), passant per les successives etapes d'emmagatzematge i compressió, fins arribar al punt de consum on es subministra hidrogen a diferents vehicles elèctrics de piles de combustible. Mitjançant aquesta instal·lació, s'espera que les emissions d'efecte hivernacle es redueixin considerablement, ja que l'ús d'hidrogen com a combustible produeix vapor d'aigua com a principal subproducte d'emissió.

Paraules clau: hidrogen, electròlisi PEM, Hidrogenera, pila de combustible

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Abbreviations

AEM: Anion-Exchange Membranes
AFC: Alkaline Fuel Cell
APQ: Almacenamiento de Productos Químicos (Chemical Storage)
ASTM: American Society for Testing and Materials
ATEX: Atmósferas Explosivas (Explosive Atmospheres)
BEV: Battery Electric Vehicle
CEPREVEN: Centro de prevención de Daños y Pérdidas (Centre for the Prevention of Damage and Loss)
CTE: Código Técnico de la Edificación (Technical Building Code)
DN: Diámetro nominal (Nominal diameter)
FCEB: Fuel Cell Electric Buses
FCEV: Fuel Cell Electric Vehicle
FCH JU: Fuel Cells and Hydrogen Joint Undertaking (EU)
FCV: Fuel Cell Vehicle
HHV: High Heating Value
HRS: Hydrogen Refuelling Station
IEA: International Energy Agency
IEC: Electrotechnical Commission
ISO: International Organization for Standardization
ITC: Instrucción Técnica Complementaria (Complementary Technical Instruction)
ITC-BT: Instrucción Técnica Complementaria Baja Tensión (Complementary Technical Instruction Low Voltage)
JIVE: Joint Initiative for hydrogen Vehicles across Europe
LHV: Low Heating Value
MBTP: Very Low Protection Voltage (Muy Baja Tensión de Protección)
MBTS: Very Low Safety Voltage (Muy Baja Tensión de Seguridad)
MCFC: Molten Carbonate Fuel Cell
MEA: Membrane Electrode Assembly
MHE: Material Handling Equipment
MIE: Ministerio de Industria y Energía (Ministry of Industry and Energy)
NTE: Normas Tecnológicas de la Edificación (Technological Norms of the Construction)
NTE-IFA: Normas Tecnológicas de la Edificación - Instalaciones de fontanería. Abastecimiento (Technological Norms of the Construction - Plumbing installations. Supply)
NTE-IPF: Normas Tecnológicas de la Edificación - Instalaciones de protección contra el fuego (Technological Norms of the Construction - Fire protection installations)
PAFC: Phosphoric Acid Fuel Cell
PFSA: Perfluorosulfonic Acid
PEM: Proton Exchange Membrane
PEMFC: Polymer Electrolyte Membrane Fuel Cell
PN: Presión Nominal (Nominal Pressure)
RMS: Root Mean Square

RSCIEI: Reglamento de Seguridad Contra Incendios en los Establecimientos Industriales (Fire Safety Regulations in Industrial Buildings)
SAE: Society of Automotive Engineers
SOFC: Solid Oxide Fuel Cell
SPE: Solid Polymer Electrolyte
UPS: Uninterruptible Power Supply
UPV: Polytechnic University of Valencia
WTP: Water Treatment Plant

Part I

Technical Report

Chapter 1

Introduction

Currently, there is a clear tendency to look for clean and renewable energy sources within the ongoing energy transition. With the impending need to take action to address climate change and its impacts, governments and businesses are in the way of implementing solutions to drive the energy paradigm towards clean, safe, reliable and accessible sources of energy. In this context, the use of alternative fuels such as hydrogen could encourage the development of a more sustainable future.

The present project focuses on the design of a hydrogen refuelling station (HRS) at the Polytechnic University of Valencia (UPV), including all the hydrogen chain phases, from hydrogen production through Proton Exchange Membrane (PEM) water electrolysis to the final use of hydrogen in fuel cell vehicles. The installation integrates therefore the necessary intermediate hydrogen storage systems and all the auxiliary components that control the process, in order to ensure a suitable working. The selection of all these components is carried out on the basis of initial consumption assumptions and by analysing the most suitable type of vehicle for visiting the installation. The different phases of the project are considered, simulating as much as possible the development of a real project. Accordingly, apart from the selection of components and the sizing of pipes or electrical conduits, the construction phases of the civil work involved in a project of this type are included. In addition, the main installation technical drawings, the technical specifications and the project budget are given.

On the other hand, the study of the regulations currently applicable is necessary as well as an analysis of current and future trends, to better understand the panorama that arises when implementing the development of this facility.

Chapter 2

Objectives

The objectives of this work are:

1. To analyze the current hydrogen economy scenario and discuss the future trends of this technology.
2. To compile the existing legislation, both at national and European level, as well as the standards applicable to the design of the HRS.
3. To analyse the characteristics of the vehicles that are going to refuel in order to determine the periodic hydrogen consumption of the installation.
4. To analyze the most critical case within the installation and design the system to ensure proper operation.
5. To make the selection of the main components of the HRS: electrolyser, storage systems, compressors/boosters and hydrogen dispensers.
6. To design the layout of the installation, including drawings of the instrumentation and electrical installation.
7. To carry out an economic analysis through the budget in order to assess the economic feasibility of the installation.

Chapter 3

Hydrogen economy

3.1 Current situation

Technologies based on hydrogen as an alternative fuel are currently attracting more and more attention in the search for cleaner solutions focused on a more sustainable future. The World Economic Forum and the World Energy Council already include, for example, this topic as a normal point of discussion, as so does the G20 nations [E4tech, 2019]. The interest in hydrogen lies in its many attractive properties. It is a light, storable and reactive material, it has a high energy content per unit mass and it can be easily produced on an industrial scale, from a diverse range of low-carbon energy sources. Moreover, it is a environmental friendly element whose use does not produce direct emissions of air pollutants or greenhouse gases.

Based on the path that other more environmentally friendly technologies had to overcome, such as photovoltaic panels or battery electric vehicles (BEV), everything indicates that hydrogen has a future within today's society and that its integration will gradually allow its cost to be reduced, despite the fact that is still in its early stages of development. In addition, climate change is leading governments to make changes to meet certain established targets, such as the creation of zero-emission zones within cities. This requires the adoption of cleaner alternative technologies like hydrogen.

In 2019, transport applications of fuel cells were dominant, with fuel cell vehicle (FCV) leading the sales versus fuel cell stationary and portable applications [E4tech, 2019]. Figure 3.1 shows the evolution in the number of units sold and the total megawatts shipped annually from 2015 to 2019 of the above mentioned fuel cell applications.

As can be seen in the Figure 3.1, the trend over the years maintains, being the transport sector with fuel cell vehicles dominant against the other two fuel cell applications. Concretely, the fuel cell vehicles share has increased from 20% to 80% of the MW shipped in the 5 years shown. The transport applications represent over 900 MW of the 1.1 GW total, or in terms of shipments, they reach more than 15000 vehicles of all types, with fuel cell cars making the largest contribution to this capacity. Hundai and Toyota are the leaders in this sector, having shipped 4750 vehicles (or

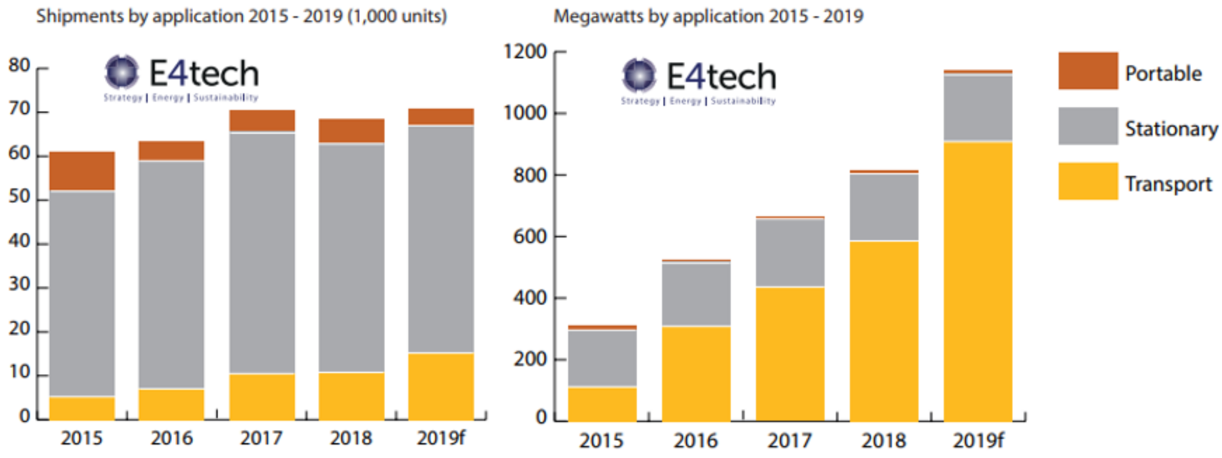


Figure 3.1: Fuel Cell shipments by applications: number of units (left) and total megawatts shipped annually (right) [E4tech, 2019]

450 MW) and 2700 vehicles (or 300 MW) by the end of 2019, respectively. Trucks and buses also represent a substantial amount of 1500 shipped units, especially in China, and material handing shipments have continued to grow, with a representation of more than 5000 vehicles. Finally, a small but growing number of specialist fuel cell vehicles also contributes to transport applications, including commercial vans among others (Renault, in partnership with Michelin/Symbio).

Hence, this picture shows that there are increasingly opportunities for hydrogen to success in the transport sector. Hydrogen is seem to be therefore a potential transport fuel which offers interesting characteristics such as short refuelling time, less weight added for energy stored and zero tailpipe emissions. The potential use of hydrogen in several transport modes is already a reality, with approximately 11200 fuel cell electric vehicles (FCEV), 25000 forklifts, 500 buses, 400 trucks and 100 vans in operation, mostly in California, Europe and Asia (mainly in Japan, with China and Korea increasingly entering in the market) [IEA, 2019].

The global car stock is expected to continue growing, as shown in Figure 3.2, thus giving hydrogen a demand perspective if it is able to capture a part of this market. California is the mayor global leader in car deployment currently, with more than 7500 hydrogen vehicles on public roads and an increasing development in infrastructure [E4tech, 2019]. However, cost reduction and building of refuelling station networks are still needed if more automakers are to be interested in the market.

The case of material handling fuel cell vehicles, such as forklifts, is particularly interesting since they are in a mature stage, competing at the same level with the existing battery electric forklifts, and offering better refuelling times at comparable prices.

Behind these dominant transport applications, there are other types of vehicles such as buses, trucks or vans, which are gaining importance. For instance, fuel cell electric buses (FCEB) are closer to commercial viability due to government measures to reduce emissions in urban areas. Even though cost is still high, initiatives to subsidise the capital and infrastructure costs are growing. Public investments in countries like UK, France or Denmark has been push thanks to strong Fuel Cells and Hydrogen Joint Undertaking (FCH JU) support, and Joint Initiative for hydrogen Vehicles across Europe (JIVE) projects are also becoming an important driver whose

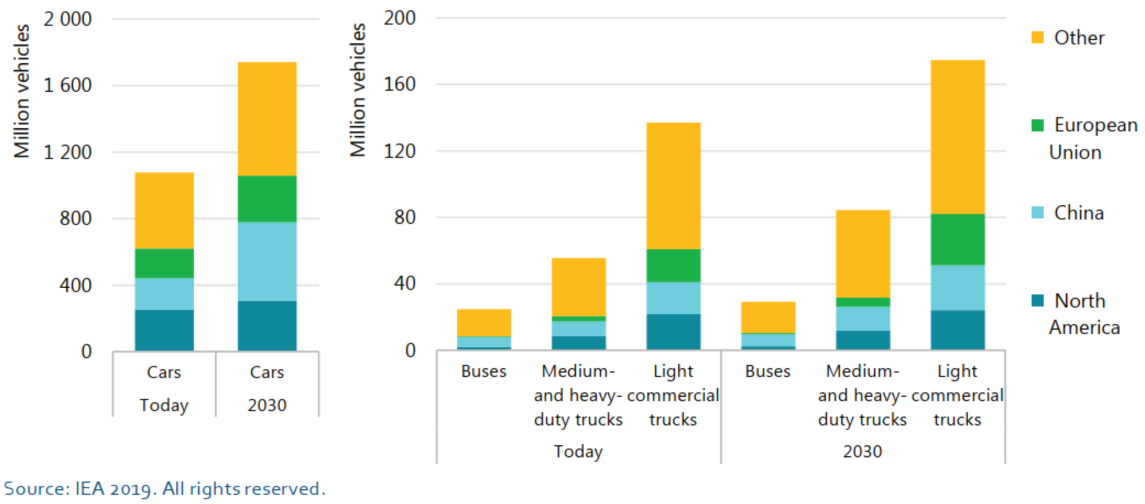


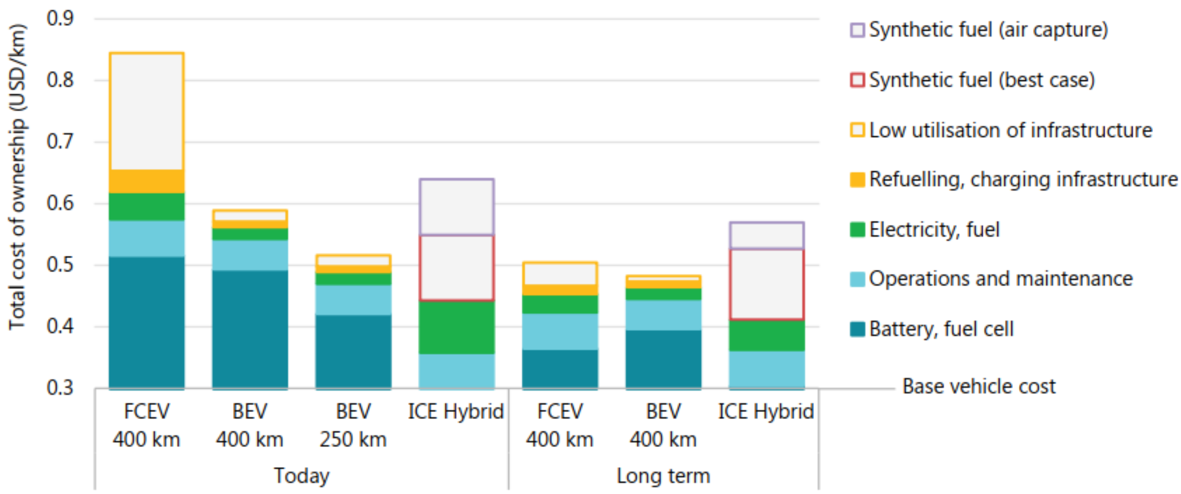
Figure 3.2: Road vehicle fleet growth to 2030 under current trends [IEA, 2019]

target is to put in operation 290 buses across Europe [E4tech, 2019]. These funds are key to boost these technologies, as it has been demonstrated in California through programs such as the California Air Resources Board and the Climate Investment Program, or in China where government subsidies have been shown to be the cause of success in this sector.

On the other hand, hydrogen refuelling stations (HRS) are fundamental for hydrogen based transport, as they make the link between hydrogen production and hydrogen use in the fuel cell vehicle. Therefore, it is essential to align this infrastructure with the FCV demand in order to optimise the costs of both parts. Hydrogen refuelling station utilisation affects in a very sensitive way to the delivered hydrogen prices. The higher the ratio of cars to refuelling stations, the lower hydrogen prices. In addition, different regions need to be homogeneous offering similar vehicle's pace versus station roll-out (i.e. cars per HRS). Nevertheless, the number of HRS is increasing worldwide. In California, the number of stations grew from 39 to 44 in 2019, being the 2025 target of 200 HRS. Japan has now 130 HRS, after addition of 30 new stations in 2019. Across the European countries, 50 HRS have been added in 2019 looking for the 2025 goal of 750 HRS within the national energy and climate plans targets. Apart from these ones, Germany reached a number of 78 HRS in operation at the end of 2019. [E4tech, 2019].

As far as electrolyser technology is concerned, companies continue to grow rapidly, although to a lesser extent than their fuel cell counterpart. With the reduction in the price of renewable energies and their increasing absorption into the electricity grid, the future trend for electrolyser technology is to allow a greater integration of these energies as an storage medium. The signals suggest that the electrolyser industry will be able to respond reasonably quickly to a dramatic increase in demand. Furthermore, although this industry does not currently contribute to a high percentage of hydrogen production methods (less than 0.1% of dedicated hydrogen production globally [IEA, 2019]), its use as an alternative option for the decarbonisation gives it a high advantage in the future energy paradigm. In fact, according to the International Energy Agency (IEA) analysis [IEA, 2019], the cost of producing hydrogen from renewable energy through electrolysis could fall 30 % by 2030 as a result of price reduction and the scaling up of hydrogen production.

In this context, with a positive and growing scenario for hydrogen technology in the transport sector, cost competitiveness is a key factor to achieve real feasibility and depends on three critical cost components: the cost of the fuel cell stack, the cost of on-board storage, and the cost of refuelling [IEA, 2019]. Currently, the commercial cost of a typical fuel cell is around 230 $/kW with a peak power of 80–100 kW per vehicle, and it is expected to be reduced to 180 $/kW soon [IEA, 2019]. Cost reduction can be achieved through the optimization in the design components of the membrane electrode assembly (MEA) and in the bipolar plates, which are one of the main contributors to the high cost of the fuel cell, as well as through economies of scale. On the other side, on-board storage tank cost are likely to fall at a slower rate than fuel cells. As for HRS, investment cost are estimated to be around 0.6-2 million $ (700 bar pressure) and 0.1-1.6 million $ (350 bar pressure), being the compressor and the storage tanks the largest cost components [IEA, 2019]. In spite of this high initial cost, compared for example to the BEV infrastructure, the HRS offer significant advantages if they are deployed at a bigger scale such as faster refuelling times, lower space requirements and cost reductions due to economies of scale. Even though BEV are nowadays cheaper than FCV, total cost of car ownership are expected to be reduced in the long term, as shown in Figure 3.3. This picture shows a future perspective where both types of technology are perfectly compatible and can complement each other as alternative options satisfying different consumer preferences.



Notes: ICE = internal combustion engine. The y-axis intercept of the figure corresponds to base vehicle "glider" plus minor component costs, which are mostly invariant across powertrains. More information on the assumptions is available at www.iea.org/hydrogen2019.

Source: IEA 2019. All rights reserved.

Figure 3.3: Total cost of car ownership by powertrain, range and fuel [IEA, 2019]

Finally, it is important to highlight the key role of governments in the deployment of this technology. Currently, regulations limit the development of viable hydrogen economy. Certain regulations are unclear or not written, hindering the exploitation of this technology. Even though governments are increasingly aware of the urgent necessity of searching for cleaner solutions for the benefit of citizens, the success of a clean hydrogen industry requires planning and coordination between national and local governments, industry and investors. International cooperation is also necessary to accelerate the growth of clean, versatile hydrogen worldwide, and to benefit from common international standards. For example, a "Hydrogen Energy Network" platform has been established across the European Union in order to include hydrogen pathways for achieving carbon neutrality. The Linz Declaration "Hydrogen Initiative", which promotes co-operation on sustainable hydrogen technology, has been signed by 28 European countries, with Spain being one of them, alongside 100 businesses, organisations and institutions [IEA, 2019]. In addition, public policy action can boost the deployment of this technology through measures such as zero-emission vehicle mandates, feebates (taxes the worst performing vehicles in terms of CO_2 emissions and subsidise those which performs best) or purchase subsidies. To summarize, it can be said that governments has a crucial role in hydrogen economy and they must work with the industry sector to ensure that existing regulations are not a barrier to invest.

3.2 Fuel cells

Fuel cells are the main technology for the energy use of hydrogen. As mentioned above, they play a fundamental role in the transport sector being a component of the vehicles housing them, as an alternative to generate the energy needed for their displacement. Fuel cells are electrochemical devices that transform chemical energy into electrical energy in a continuous way, with high efficiency, low emission of pollutants, and no combustion process taking place.

The main elements of a fuel cell are the electrodes (anode or negative electrode and cathode or positive electrode), the electrolyte in charge of conducting the ions produced in the redox reactions (it can be solid or liquid), the matrix that contains the electrolyte, and the bipolar plate that acts as current collector and gas distributor. Normally, the individual cells are grouped together in a stack to produce higher voltage levels (the usable voltage of a cell is approximately 0.7 V). Figure 3.4 shows the diagram of a fuel cell including the above mentioned components.

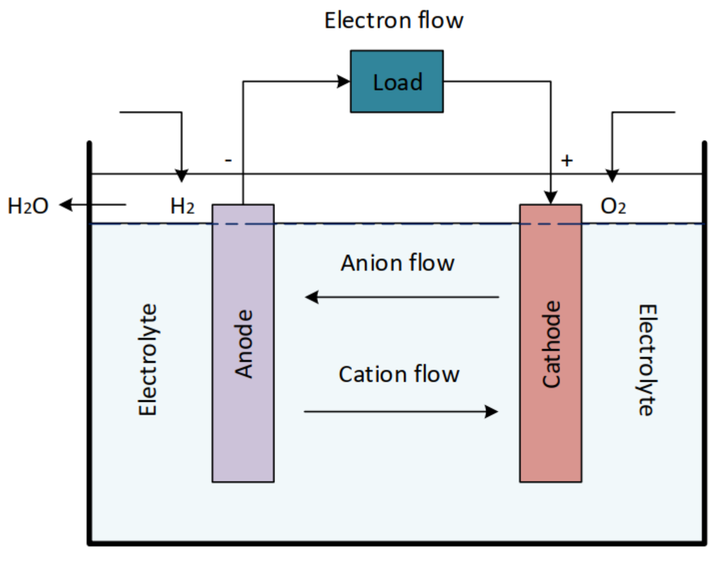


Figure 3.4: Fuel cell diagram

The operating principle of a fuel cell is the opposite to that of an electrolytic cell. In this case, the gaseous fuel (normally hydrogen) is constantly fed to the anodic compartment and an oxidant (normally air) is fed to the cathode compartment. Energy is generated in the form of DC electricity and heat, by the electrochemical oxidation of the fuel at the anode and the electrochemical reduction of the oxidant at the cathode.

There is a variety of fuel cell types, which can usually be classified into the following categories depending on the electrolyte they use:

1. Polymer Electrolyte Membrane Fuel Cell (PEMFC): this type of fuel cell provides a high energy density, and is lightweight and small in size compared to other fuel cells. The electrolyte used is a solid polymer (excellent conductor of protons) and the electrodes are made of carbon and porous. In addition, the cell requires platinum catalysts, which make the system more expensive. It operates at relatively low temperatures (80 °C), which allows faster start-up as they need less time to heat up.
2. Alkaline Fuel Cell (AFC): they were the first fuel cells to be developed. In this type of cell, the electrolyte is concentrated (85 wt%) potassium hydroxide (KOH) for cells operating at temperatures around 250 °C, or less concentrated (35-50 wt%) KOH for cells operating at temperatures below 120 °C. They have a high efficiency (60 % in space applications) due to the speed of the reactions that occur inside them. However, they require a high level of purity of the oxygen and hydrogen used since they are extremely sensitive to carbon dioxide poisoning.
3. Phosphoric Acid Fuel Cell (PAFC): this fuel cell uses 100 % concentrated phosphoric acid as electrolyte, and operates at temperatures between 150 °C and 200 °C. The fuel requires prior external reforming and the cell accepts carbon dioxide in the reformed fuel gas stream and in the air acting as a diluent.
4. Molten Carbonate Fuel Cell (MCFC): the electrolyte of this fuel cell is normally a combination of alkaline carbonates (sodium and potassium) retained in a lithium aluminate ceramic matrix. The high operating temperature (600-700 °C) causes the carbonates to form a molten salt that is highly ion-conductive. In this case, the reforming of the fuel can take place inside the fuel cell (internal reforming) and it is required to feed the cathode with carbon dioxide to form the carbonate ion.
5. Solid Oxide Fuel Cell (SOFC): this type of high temperature fuel cell (650-1000 °C) uses a solid hard ceramic electrolyte consisting of a non-porous metal oxide (usually yttria-stabilized zirconium oxide) where ionic conduction by oxygen ions takes place. Since the electrolyte is solid, problems of corrosion or flooding of the electrolyte in the electrodes are avoided. As in the previous fuel cell, the reforming of the fuel can be carried out internally and it also admits carbon monoxide directly as fuel.

Among the different options existing, the best suitable and standardized technology for the transport sector are the PEMFCs, widely used in FCVs. This type of fuel cell is particularly appropriate for use in passenger vehicles due to the fast start-up, a low sensitivity to orientation, and a favorable ratio of weight to energy produced [Llera Sastresa and Zabalza Bribián, 2011]. A more detailed description of the operation of this type of fuel cell is given below.

3.2.1 PEM Fuel Cells

In PEMFC, hydrogen gas is supplied to the anode (fuel electrode) and it is dissociated into protons and electrons at the electrode surface. Then, the protons diffuse through the polymer electrolyte membrane, which is highly ion-conducting. On the other side, electrons flow through the external circuit (generating electricity) thanks to the electronically conductive electrode, and once they reach the cathode promote the reaction of protons with the oxidant supplied (air) in the cathode in order to form water. Equations 3.1 and 3.2 bellow shows the half cell reactions that occur in this type of fuel cell, and Equation 3.3 is the global reaction:

$$Anode : H_2 \rightarrow 2H^+ + 2e^- \tag{3.1}$$

$$Cathode : \frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O \tag{3.2}$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + electricity + heat \tag{3.3}$$

Figure 3.5 shows a diagram of a PEMFC where the reactants and products directions are indicated as well as the ongoing reactions.

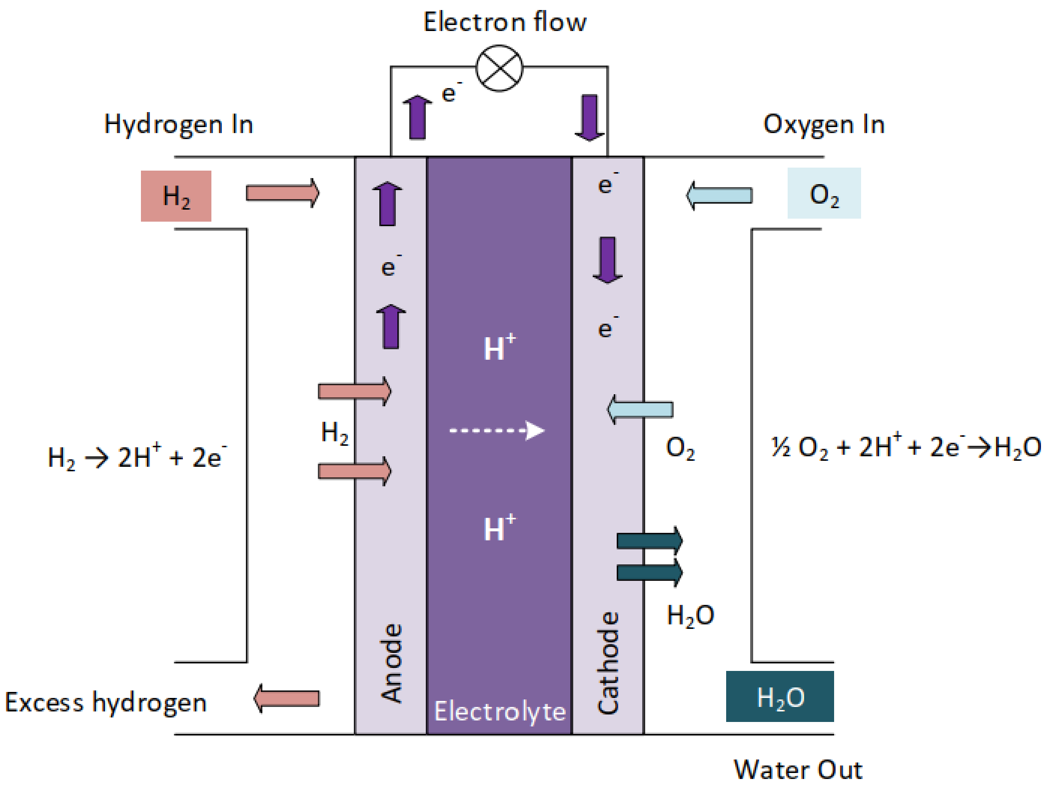


Figure 3.5: PEMFC diagram

In order to have an overall view of how this type of fuel cells are housed inside a vehicle, Figure 3.6 shows the different components necessary for the proper functioning of the vehicle [Toyota, 2015], which are enumerated as follows:

1. Fuel cell stack.
2. Fuel cell boost converter, which is used to obtain an output with a higher voltage than the input.
3. Battery, which stores energy recovered from deceleration, supplemented by energy produced by the fuel cell stack under low load driving conditions, to assist output during acceleration.
4. High-pressure hydrogen tank, which stores hydrogen as fuel. The nominal working pressure is a high pressure level of 70 MPa (700 bars) for cars.
5. Motor, which is driven by electricity generated by fuel cell stack and/or supplied battery.
6. Power control unit, which optimally controls the fuel cell stack output under various operational conditions and drives battery charging and discharging.
7. Auxiliary components, such as hydrogen circulating pump, etc.

Since the HRS will receive different types of FCV, the main vehicles that will visit the facility will be explained below using existing commercial examples. As seen in the Figure 3.6, Toyota has available fuel cells cars, being one of the leaders in the sector. Apart from cars, the facility must be prepared to receive FCV such as vans. Renault, the French company, has recently launched the "Master Z.E. Hydrogen" van model, pictured in Figure 3.7, as part of its electrification strategy. This vehicle is equipped with a 10 kW fuel cell with two hydrogen tanks located under the chassis, that can store 4.18 kg of hydrogen at 700 bar pressure [Gutierrez, 2019].

Figure 3.6: Toyota Mirai Fuel Cell Vehicle. Internal components [Toyota, 2015]

Figure 3.7: Master Z.E. Hydrogen van model [Gutierrez, 2019]

As mentioned before, the material handling equipment sector is quite developed and competitive against the electrical versions. Therefore, it makes sense to include such an equipment as another vehicle that potentially will visit the facility. Among the main manufacturers are Linde, Hyster-Tale, Fronius, or Plug Power [Berger, 2017], which continues to consolidate its leading position including production of its next generation GenDrive systems for Class 1 industrial forklifts [E4tech, 2019]. Figure 3.8 shows a commercial example of a Gendrive Series 1000 fuel cell product made for counterbalanced trucks. This FCV runs at maximum performance as long as the hydrogen tank is filled and it only takes less than 2 minutes to refuel it (in comparison with the 12 minutes that changing batteries take) [PLUG POWER, 2018].

Figure 3.8: Gendrive Series 1000 FCV [PLUG POWER, 2018]

The last vehicle presented in this section is the hydrogen bicycle. Although this type of FCV is one of the newest technologies, there are already some manufactures in the sector such as Gernweit, Linde or Clean Air Mobility [Berger, 2017]. As an example, the Figure 3.9 shows the Linde H_2 bike which is an unique, highly efficient and zero-emissions drive system. This vehicle supports assisted pedalling over a range in excess of 100 kilometres, with a single 34 grams cylinder of hydrogen and with a refuelling time of less than 6 minutes [LINDE, no date].

Figure 3.9: Linde H_2 bike [LINDE, no date]

3.3 Hydrogen production methods

In general, hydrogen can be obtained from any substance containing the element, such as water or hydrocarbons, as well as organic matter of plant or animal origin. Therefore, there are several methods to produce hydrogen which can be classified depending on its primary renewable or non-renewable energy sources. Figure 3.10 shows such a classification where four main ways to produce hydrogen are identified:

1. Hydrocarbon reforming. In this process the molecular structure of a hydrocarbon is rearranged in order to modify its properties. In these thermochemical processes, the compounds are in general in high energy states and the energy contained in the fuel can be used to increase the temperature inside the reactor and to promote reactions for the hydrogen release that is part of its composition. Steam reforming, partial oxidation and autothermal reforming belong to this type of process, providing efficiencies between 60 and 85% (based on hydrogen high heating value) [Shiva Kumar and Himabindu, 2019] and being considered as developed and established technologies.

2. Hydrocarbon pyrolisis. In this process a solid fuel (coal or biomass) is decomposed by action of heat in the absence of an oxidizing medium. It is a CO_2-neutral method with abundant and cheap feedstock, which can make hydrogen production to fluctuate because of feedstock impurities and seasonal availability. The efficiency of the process lies between 35 and 50% [Shiva Kumar and Himabindu, 2019].

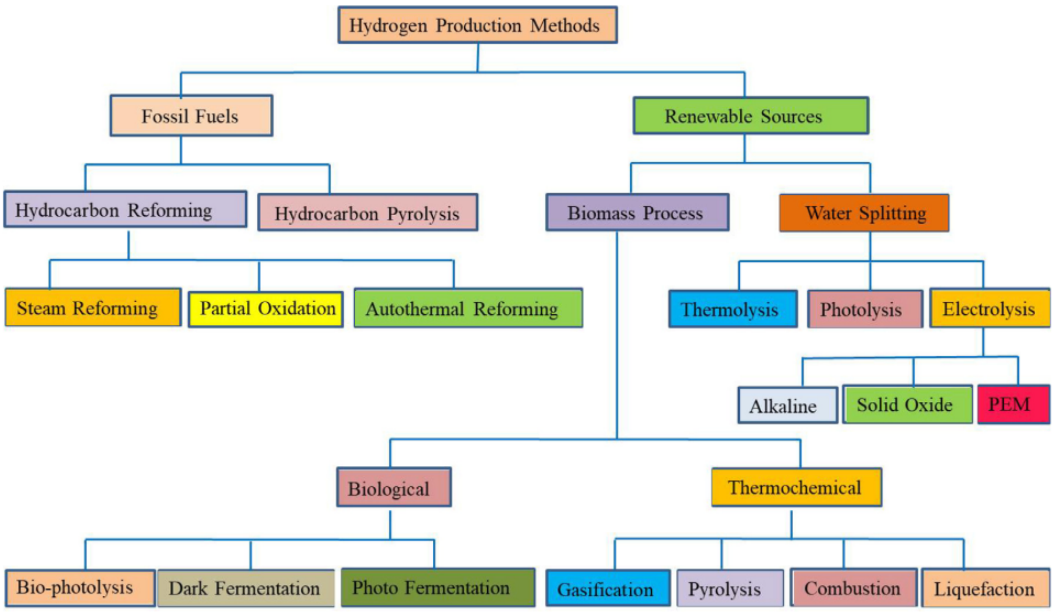


Figure 3.10: Hydrogen production methods classification [Shiva Kumar and Himabindu, 2019]

3. Biomass processes. They can be split into biological and thermochemical processes. Generally, thermochemical processes are used in the production of hydrogen in large-scale centralized systems. In contrast, biological processes are often used in decentralized systems, being slower and more expensive than thermochemicals. The biological processes of hydrogen production depend on the presence of an enzyme that produces hydrogen. Bio-photolysis, dark fermentation and photo fermentation are CO_2-neutral biological processes whose efficiencies are 10–11%, 60-80% and 0.1% respectively [Shiva Kumar and Himabindu, 2019]. As for thermochemical processes, gasification (30-40 %), pyrolysis (35-50%), combustion and liquefaction are within this cathegory. The greatest challenges in obtaining hydrogen from biomass are fundamentally reducing the cost of equipment and the cost of supplying biomass.

4. Water splitting. This process is known as the chemical reaction in which water is broken down into oxygen and hydrogen. There are three different ways of splitting water: thermolysis, photolysis and electrolysis. Their efficiencies are 20-45%, 0.06% and 60-80% respectively [Shiva Kumar and Himabindu, 2019] and they are considered as clean and sustainable methods in which the main byproduct is oxygen.

Currently, the global hydrogen production is around 500 billion cubic meter per year, where around 96% comes from nonrenewable fossil fuels, in particular from steam reforming of methane [Shiva Kumar and Himabindu, 2019]. However, in the long term, the use of fossil fuels to obtain hydrogen is going to be nonsense if the clean and sustainable path of hydrogen as an alternative fuel is to be sustained. Since hydrogen production methods from fossil fuels produces lower purity of hydrogen with high concentration of harmful greenhouse gasses, the water splitting hydrogen production method is having special attention as an environmental friendly option that could replace the fossil fuel based energy production. To do so, the most efficient and mature option among the technologies mentioned above is water electrolysis, which produces clean and high purity hydrogen (99.999%). Therefore, it is worth to explain the principles of water electrolysis, as well as the different technologies available in the market to carry on the water splitting process, as it is done in the following section.

3.3.1 Water electrolysis

Water electrolysis consists in the rupture of the water molecule into hydrogen and oxygen by applying an electric current. The overall electrochemical water splitting reaction is:

$$H_2O \rightarrow H_2(gas) + \frac{1}{2}O_2(gas) \tag{3.4}$$

Figure 3.11 shows a diagram of the basic components on the electrolytic cell necessary to perform the electrochemical water splitting, regardless the type of electrolysis. The cell always includes the positive anode and negative cathode electrodes, an electrolyte for ion transport and a DC power supply. This source of power uses direct current to polarize the electrodes, so that the ions dissolved in the electrolyte can be driven to the electrode of opposite charge where the electrochemical reaction takes place.

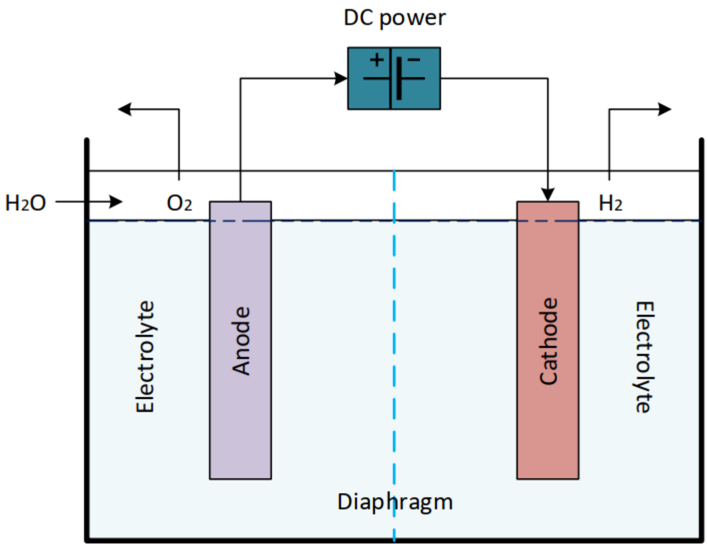


Figure 3.11: Electrolysis cell diagram

As said above, in order to carry on the water electrolysis, electrical energy is added to a low-energy product (water) and two high-energy gases (oxygen and hydrogen) are released. The energy needed is represented by the enthalpy variation ΔH and is given by the thermodynamic expression:

$$\Delta H(T,P) = \Delta G(T,P) + T\Delta S(T,P) \tag{3.5}$$

where ΔG is Gibbs free energy (provided in form of electrical energy), T is the temperature and ΔS is the entropy. The second term represents the part of the energy that comes from the environment in form of heat. These magnitudes depend on the thermodynamic variables of pressure and temperature, and when they vary, so does the amount of electrical work and thermal energy required for the reaction to occur. If the pressure remains constant, when the temperature increases, the electrical demand (ΔG) decreases while the heat required ($T\Delta S$) increases. The combination of both energies makes the total energy (ΔH) to be almost constant over the operating temperature range. In addition, the Gibbs free energy remains positive in the temperature range of interest, which means that the reaction is non-spontaneous and justifies the need of an electric current to activate the reaction. The voltage needed to decompose the water molecule is called reversible potential and is equal to 1.23 V if the electrolysis reaction is carried out under standard conditions (1 bar, 298 K). Figure 3.12 shows the energy balance that takes place in the electrochemical reaction under certain conditions of pressure and temperature (1 atm, 298 K).

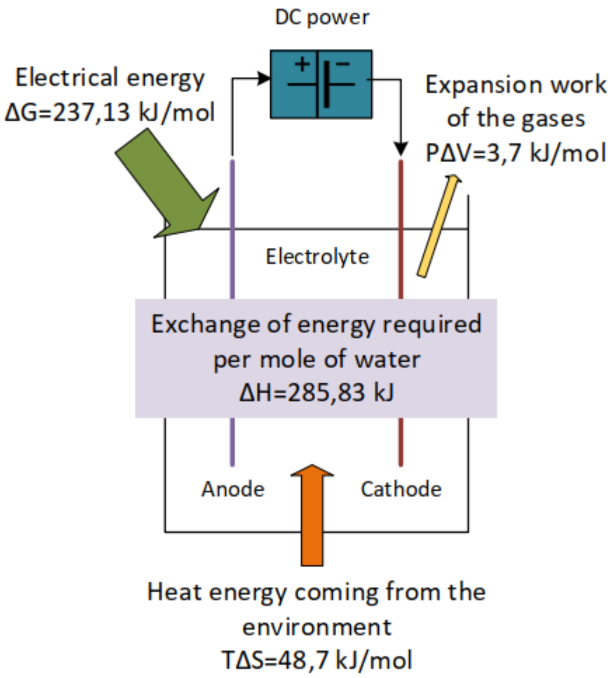


Figure 3.12: Energy balance of water electrolysis (1 atm, 298 K) [Llera Sastresa and Zabalza Bribián, 2011]

There are three different technologies for water electrolysis depending on the type of electrolyte:

- Alkaline electrolysis, in which the reaction takes place under base conditions and normally a liquid electrolyte is used. Recent research has shown that it is also possible to operate the cell with alkaline electrolysis using a solid polymer electrolyte (SPE) such as an anion-exchange membrane (AEM).
- Acidic electrolysis, in which water splitting undergoes in acidic anodic conditions, and normally a SPE is used, such as a PEM, although there is also the option of using a liquid acid electrolyte.
- Solid oxide water electrolysis, in which the reaction is carried out under much higher temperatures (typically around of 1000 °C) and therefore uses ion-conducting ceramics (solid oxide) which can withstand such high temperature operating conditions.

Currently, the most mature and competitive technologies are alkaline and PEM, which operate in near ambient temperature conditions. Even though alkaline water electrolysis is a commercially more developed technology, PEM water electrolysis is more suitable for smaller hydrogen production which fits with the case presented in this project. Furthermore, PEM electrolysis seems to be preferred when coupled with intermittent renewable energy sources in terms of performances, which, as said above, is one of the goals of the present design. Therefore, the option of using alkaline water electrolysis technology is discarded because it is not totally well-adapted to operate with transient power sources, such as renewable energy sources [Godula-Jopek, 2015].

Since the electrolyser chosen to be placed in the installation is PEM technology, its principle of working is briefly described hereafter. In a PEM cell, the main characteristic component is the thin ion-conducting polymeric film used both as a cell separator for the gaseous products and as conductor for the electric charges, which in this case are solvated protons. In this type of cells, there is no liquid electrolyte and the only liquid that flows is deionized water, a fundamental element for the reaction to take place. On both sides of the membrane, two electrocatalytic layers are placed acting as the anodic and cathodic sides. Next to them, thin porous current collectors and bipolar plates are used to convey the electric current through the external DC power source and to separate adjacent cells. Figure 3.13 shows an schematic representation of the electrolytic PEM cell containing all the components mentioned above.

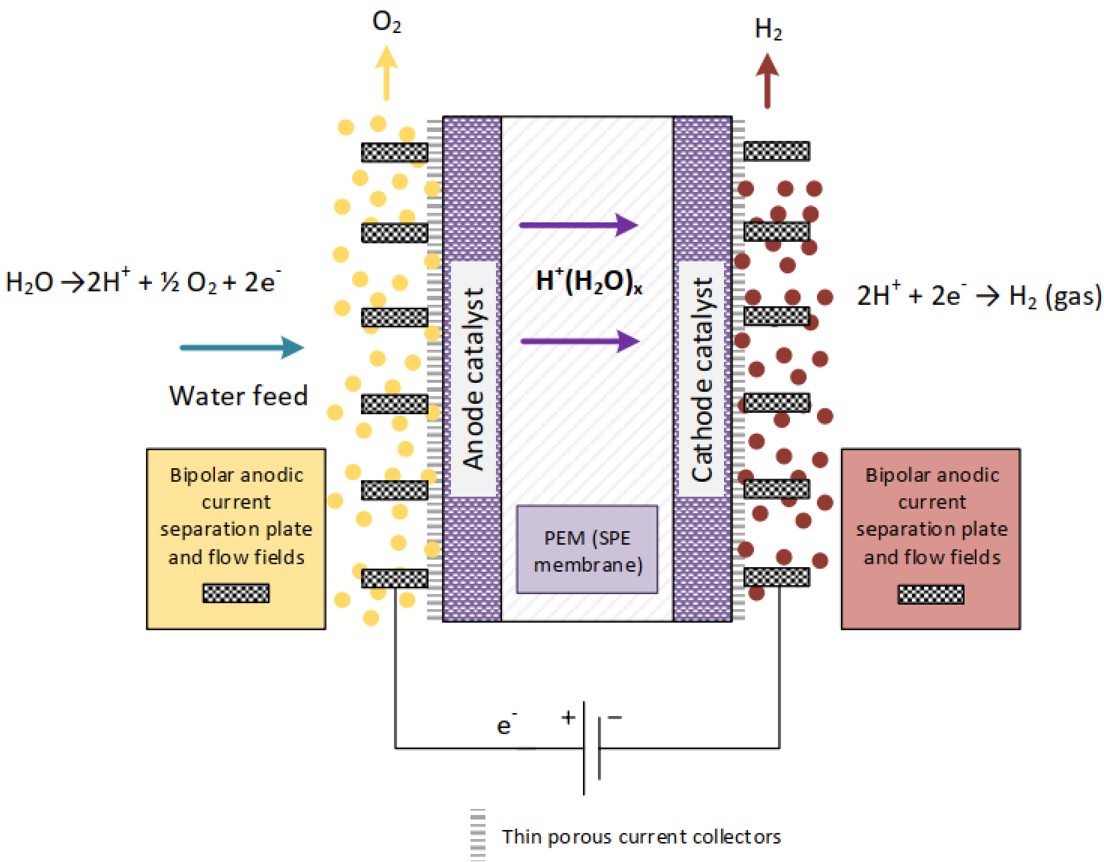


Figure 3.13: PEM cell diagram [Bessarabov and Millet, 2018]

During water electrolysis, the two electrochemical reactions that occurs at the anodic and cathodic sides (half-cell reactions) are

$$Anode : H_2O(l) \rightarrow \frac{1}{2}O_2(g) + 2H^+ + 2e^- \quad (3.6)$$

$$Cathode: 2H^{+} + 2e^{-} \rightarrow H_2(g) \tag{3.7}$$

and provide when combined the global reaction given by Equation 3.4. At the anode, the DC current is used to split the liquid deionized water into protons and gaseous oxygen. Then, the solvated protons make the journey across the polymer electrolyte ion-conduction membrane until they reach the cathode, as a response to the electrical field established through the cell. At the cathode, the protons are desolvated and reduced into molecular hydrogen.

Finally, to further justify the viability to implement the PEM technology within the design, a SWOT analysis is presented in Table 3.1 to review the state of art of this electrolysis process [Bessarabov and Millet, 2018].

STRENGTHS	WEAKNESSES
1. Mature technology (15 MW scale). 2. High purity gas delivery (99.999%). 3. High compactness (commercial 3.0-3.5 A/cm^2; laboratory scale 10-15 A/cm^2) 4. High energy efficiency (70%-80% HHV at 1 A/cm^2). 5. Durability (>60.000 h of continuous operation). 6. Excellent flexibility and reactivity for operation with transient power sources. 7. Operating under pressure (200 bar demonstrated, 350 bar prototypes) or under a pressure difference.	1. CAPEX still higher (1700-2500 €/kW for 300-500 kWe systems) than the one for alkaline technology (900-1700 €/kW for 300 kWe-5 MWe systems) mainly due to expensive cell components. 2. OPEX in kWh/kg_2 is mainly caused by the electricity cost which determines the cost of gas produced by electrolysis. 3. Safety issues.
OPPORTUNITIES	**THREATS**
1. Growing competition with existing water electrolysis technologies is driving R&D investments. 2. Systems operating at even higher current densities are expected to be reached (already 10 A/cm^2). 3. Significant progress has been made with Perfluorosulfonic Acid's (PFSA) short side chain materials to improve resistance to elevated temperature up to 250 °C (reduction of energy consumption).	1. Lack of competitiveness compared to steam methane reforming. Industrial equipment must comply with non-homogeneous international legal frameworks. 2. Today there is increasing competition between the three main technologies for water electrolysis. There is no convincing technical indication to anticipate which technology will dominate in the future.

Table 3.1: PEM technology SWOT analysis [Bessarabov and Millet, 2018]

3.4 Hydrogen storage

In the hydrogen chain, storage is the important step which links the production phase with the consumption phase. There are several options to storage hydrogen, depending on its aggregation state:

1. Gaseous storage. This form of storage requires external energy to compress hydrogen to the appropriate working pressures and to reduce the size of the storage containers as much as possible. It is the most common and developed method, although it involves a considerable consumption of energy. Once pressurized, hydrogen can either be stored in cylindrical tanks or in pipelines. Both possibilities need to make use of high-strength materials to ensure durability and leak resistance.

2. Liquid storage. Hydrogen in this state of matter has a higher gravimetric and energetic density, thus allowing a greater volume reduction when compared to the compression method, and overcoming problems related with the weight and size of gas storage. However, energy is also necessary in this process to liquefy hydrogen, which demands around 30-40% of the chemical energy of the stored hydrogen, based on Low Heating Value (LHV) [Llera Sastresa and Zabalza Bribián, 2011]. Therefore, it is an energy-intensive process which, in addition, causes large evaporation losses (one third of the energy content of hydrogen is lost in the process, especially in small tanks). Hydrogen cryogenic technology is not as widespread as compressed hydrogen. Nevertheless it has reached a high level of maturity and maintains a significant market share with the main application being large-scale storage (transoceanic transport).

3. Solid storage. In this case gaseous hydrogen becomes part of the molecular composition of a solid compound either by reaction and adsorption, as in metal hydrides, or only by adsorption, as in organic compounds. In the metal hydrides, the process takes place under conditions of high pressure and moderate temperature (gas absorption) and releases the hydrogen by heating at low pressure. It has a reasonably price, but still presents major durability problems, and regeneration is costly. As for organic compounds, active carbon conveniently treated under certain temperature conditions can be used to store hydrogen, although the method is still at the laboratory/prototype stage.

Hydrogen gaseous storage seems to be the more suitable method for the present design due to its level of maturity and the fact of being a common practice in HRS. It is interesting to mention that external compression of hydrogen can be done partially with a electrochemical compression inside the electrolysis cell itself. For this purpose, there are two technologies capable to do such an internal compression. The first one is a balanced high-pressure water electrolyser where the anode and the cathode remain at the same pressure and therefore deliver hydrogen and oxygen at the same pressure. The second option is to use the so-called unbalanced high-pressure water electrolyser, where the cathodic side is put under pressure while the anodic side remains at the atmospheric pressure (hydrogen is delivered at high pressure while oxygen is released at atmospheric pressure). This type of compression is possible due to the solid electrolyte of PEM technology, which allows to obtain a compact system design with resistant structural properties. In addition, the membrane is capable of withstanding high pressures, both in the balanced high pressure electrolyser and in the unbalanced (which requires a PEM capable to resist a pressure difference) [Saeba et al., 2017].

Figure 3.14 shows the comparison between the three methods to produce high pressure hydrogen: atmospheric electrolysis with the subsequent use of an external compressor, balanced high-pressure electrolysis, and unbalanced high-pressure electrolysis. As observed, the unbalanced option seems to be the one which requires less energy, up to approximately 40 bar. However, for pressures higher than 40 bar, the electrolyser coupled with a mechanical compressor becomes the least energy consumption option [Bessarabov and Millet, 2018]. This means that unbalanced high-pressure electrolysers appear to be an interesting alternative to increase hydrogen pressure and to reduce the amount of energy that needs to be consumed with only one external compressor. Nevertheless, this type of electrochemical compression is still in early stages of development. In fact, the effect on the membrane thickness of the hydrogen crossover from the cathode to anode that appears at high pressure operation at the cathode, needs to be considered in order to determine the cell performance degradation.

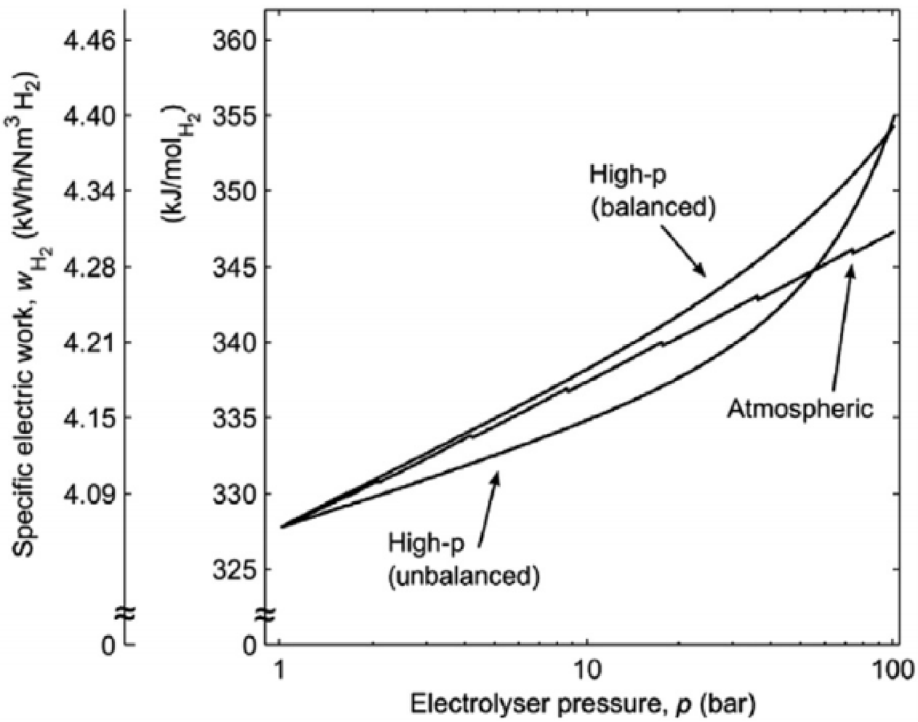


Figure 3.14: Specific energy demand to produce high-pressure hydrogen at 60 °C [Bessarabov and Millet, 2018]

3.4.1 Hydrogen Refuelling Stations

Hydrogen refuelling stations are supply points which allow to transport hydrogen from hydrogen storage tanks to the fuel cells housed inside the vehicles. They are dispensers similar to those used in conventional petrol stations, with the difference that they require some specific safety measures due to the highly flammable nature of hydrogen. Figure 3.15 shows the main components of this structure.

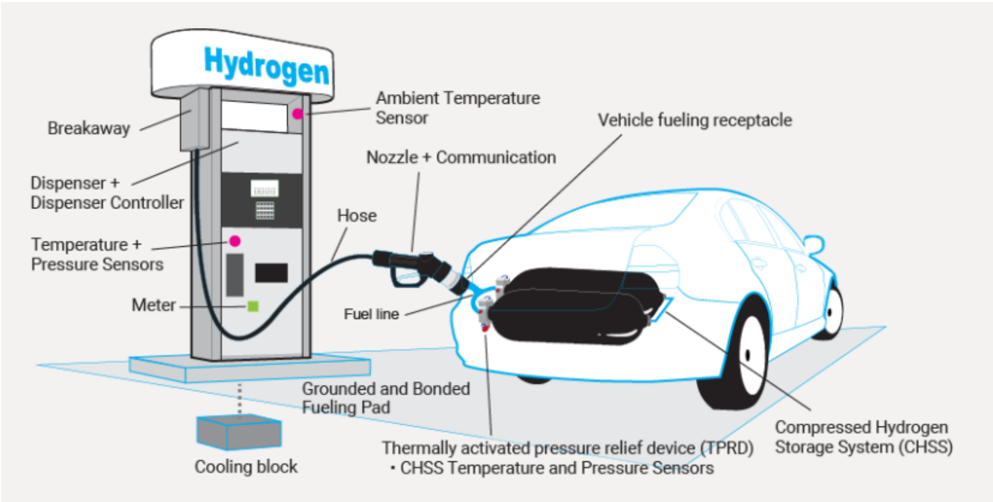


Figure 3.15: HRS main components [ISO 19880-1, 2020]

As commented above, there are few HRS worldwide and it is necessary to build more infrastructure to promote the development of hydrogen-based technologies. In principle, areas with small population, concentrated in the vicinity of a large city and with significant renewable resources are the most suitable areas to build such infrastructures in the early stages of development since in such a way the number of HRS to be built is reduced as well as are the costs [Llera Sastresa and Zabalza Bribián, 2011]. In this sense, an analogy can be made with a university campus where the "population" is small and it is viable to carry out a prototype of HRS for vehicles used on campus and, hence, to achieve a more sustainable place for the university community. This project aims to simulate these characteristics and that is why it was decided to establish the HRS at the Polytechnic University of Valencia (UPV), which is aligned with the objectives of the environmental unit of the university that aims to develop an increasingly sustainable campus.

The HRS implementation should consider three possible production and logistics scenarios:

1. Off shore: the hydrogen is produced in large centralised plants and afterwards transported to the service stations through pipelines or by road, either in liquid form or as compressed gas.
2. On shore: the hydrogen is produced or distributed in a decentralised way. It is possible to use the current infrastructure (natural gas networks, electricity networks and pipelines) to produce hydrogen at the point of supply, either by installing electrolyser or by using reformers from these networks. This is the scheme that the designed installation follows in the present project.
3. On board: in this case a reformer is added on board in the vehicle itself.

Chapter 4

Applicable regulations

The aim of this section is to study the existing regulations on the design and construction of hydrogen installations and HRS. The study is carried out both at national and international level due to the lack of legal development in Spain.

4.1 General applicable regulations

In general, the following regulations apply:

- Law 31/1995, of 8 November, on the Occupational Risk Prevention.
- Royal Decree 186/2016 of 6 May, regulating the electromagnetic compatibility of electrical and electronic equipment.
- Royal Decree 1644/2008 of 10 October 2008, establishing the regulations for the marketing and commissioning of machines.
- Royal Decree 598/2015 of 3 July, amending Royal Decree 39/1997 of 17 January, approving the regulations on prevention services; Royal Decree 485/1997 of 14 April, on minimum provisions for health and safety signs at work; the Royal Decree 665/1997 of 12 May 1997 on the protection of workers against risks related to exposure to carcinogens at work and Royal Decree 374/2001 of 6 April 2001 on the protection of the health and safety of workers against risks related to the chemicals during work.
- Royal Decree 614/2001, of 8 June, on minimum provisions for the protection of the health and safety of workers against electrical risk.
- Royal Decree 842/2002, of 2 August, approving the Low-Voltage Electrotechnical Regulations.
- Royal Decree 1215/1997 of 18 July 1997, establishing the minimum health and safety requirements for the use of work equipment by workers.

- Royal Decree 513/2017 of 22 May, approving the Regulations on Fire Protection Installations.
- Basic Document SI / Security in case of Fire, Technical Building Code (CTE), (approved by Royal Decree 314/2006).

As well as the following technical standards, which serve as a recommendation:

- NTP 40. Fire detection.
- NTP 99. Extinguishing methods and extinguishing agents.

4.2 Regulations for the design of hydrogen installations and HRS

The present project is based on the implementation of Directive 2014/94/EU [Directive 2014/94/EU, 2014], adopted by the European Parliament and the Council on 29 September 2014. The directive was approved by the member states of the European Union with the aim of promoting the development of the infrastructure for alternative fuels, such as hydrogen. It establishes a common framework of measures for this development in order to minimise dependence on oil and to mitigate the environmental impact of transport. Concretely, the directive sets out the technical specifications for hydrogen refuelling points for motor vehicle. It remains in force today and refers to a set of common standards for the design and use of alternative fuel refuelling stations.

Currently, the main problem when legalizing a HRS is the absence of a specific legal framework. At present, there is no harmonization between the different legalization procedures followed in each of the countries. Therefore, the previously mentioned Directive 2014/94/EU [Directive 2014/94/EU, 2014] arouse as an attempt to homogenize such a situation.

In general, the international standards developed, considering the essential requirements set forth in a regulation, are the framework of choice for development and provide rules and criteria for HRS, allowing compliance with regulatory and permit requirements. In fact, a new ISO 19880-1 standard is being developed, based on ISO 20100, which unifies criteria regarding safety distances, taking as a reference the Society of Automotive Engineers (SAE) standard, SAE J2601.

On the other hand, it is worthy to mention that while regulation is developed on the initiative of European regulatory bodies, the standard is built up mainly through contribution by industry, requiring close collaboration between both parts.

As far as the Spanish national legislation is concerned, Royal Decree 639/2016 [Royal Decree 639/2016, 2016], of 9th December, establishes a framework of measures for the implementation of an infrastructure for alternative fuels. This royal decree establishes the minimum requirements for the creation of an infrastructure for alternative fuels, including recharging points for electric vehicles and refuelling points for natural gas and hydrogen.

In addition, in general, the following national regulations should be followed:

- Royal Decree 656/2017 of 23 June, approving the Regulation on the Storage of Chemical Products and its Complementary Technical Instructions MIE (Ministry of Industry and Energy)-APQ (Chemical Storage) from 0 to 10, with application of MIE-APQ 5 (Storage of gases in mobile pressure vessels). According to the ITC (Complementary Technical Instruction) MIE-APQ 5, it will not be applicable to the vessels in use in this project. However, due to the demonstrative nature of the installation, and in order to have as many design considerations/criteria as possible, it will be considered applicable to all vessels, not being strict in its compliance, adapting it to the specific needs of the case in question and considering it as general safety requirements.

- Royal Decree 2060/2008, of 12 December, approving the Pressure Equipment Regulation and its complementary technical instructions.

Taking into account this legislative framework, the technical specifications of the motor vehicle refuelling points to be considered can be found in the following regulations:

- **ISO/TS 20100. Gaseous hydrogen. Fuelling stations.** This technical specification details the characteristics of both public and non-public outdoor hydrogen refuelling stations supplying hydrogen gas used as an on-board fuel for all types of road vehicles [ISO/TS 20100, 2008]. Currently, these regulations constitute a framework of reference, and are included in Royal Decree 639/2016 which must comply with them. However, it must be taken into account that the International Organization for Standardization (ISO) is carrying out an update of this standard, which in the future will be annulled by the ISO/TS 19880 (Gaseous hydrogen. Fuelling stations) [ISO 19880-1, 2020].
- **UNE-EN 17124:2018. Hydrogen fuel. Product specification and quality assurance-Proton exchange membrane (PEM) fuel cell applications for road vehicles**. This standard specifies the quality characteristics of hydrogen fuel and the corresponding quality assurance in order to ensure uniformity of the hydrogen product as dispensed for utilization in PEM fuel cell road vehicle systems [UNE-EN 17124, 2018].
- **UNE-EN 17127:2018. Outdoor hydrogen refuelling points dispensing gaseous hydrogen and incorporating filling protocol**. This document defines the minimum requirements to ensure the interoperability of public hydrogen refuelling points including refuelling protocols that dispense gaseous hydrogen to road vehicles complying with applicable regulations [UNE-EN 17127, 2018]. The ISO standard equivalent to this regulation, to which the Royal Decree 639/2016 also comply, is ISO 17268 (Gaseous hydrogen land vehicle refuelling connection devices). This international standard defines the design, safety and performance characteristics of connectors intended for the refuelling of gaseous hydrogen land vehicles [ISO 17268, 2012].
- **ISO 16528-1:2007. Boilers and pressure vessels. Part 1: Performance requirements**. This part of ISO 16528 defines the performance requirements for the construction of boilers and pressure vessels [ISO 16528-1, 2007].

Chapter 5

System description

5.1 Location of the installation

The construction of the HRS will be carried out on a plot of land at the UPV whose location analysis can be seen on the site plan (see the corresponding drawing number 1 in Part IV). The plot is surrounded by a road to the east, from which it will be possible to access the installation, inhabited buildings to the west, and the UPV greenhouses to the south. The safety distances marked by the different regulations have been taken into account when locating the installation. The data and location of this plot are shown below [Ministerio de Hacienda, no date] (see Figure B.1 of Annex B):

- Cadastral reference: 46900A087000210000FX
- Location: Camí de Vera, 36, 46022, Polytechnic University of Valencia (Valencia, Spain).
- Soil type: Agricultural
- Surface: 6672 m^2

The HRS will be located within this plot and will have a surface of 1580 m^2. It will be for private use with access from the street. Figure 5.1 shows the aerial view of the UPV campus. Within the rectangle marked, arrows appear indicating the road accesses to the facility and the plot that will house the installation is highlighted in red. Complementary, Figure 5.2 makes an aerial zoom on the plot where the HRS is placed, where the surrounding buildings can be seen, such as the greenhouses or the LABDER laboratory of the UPV.

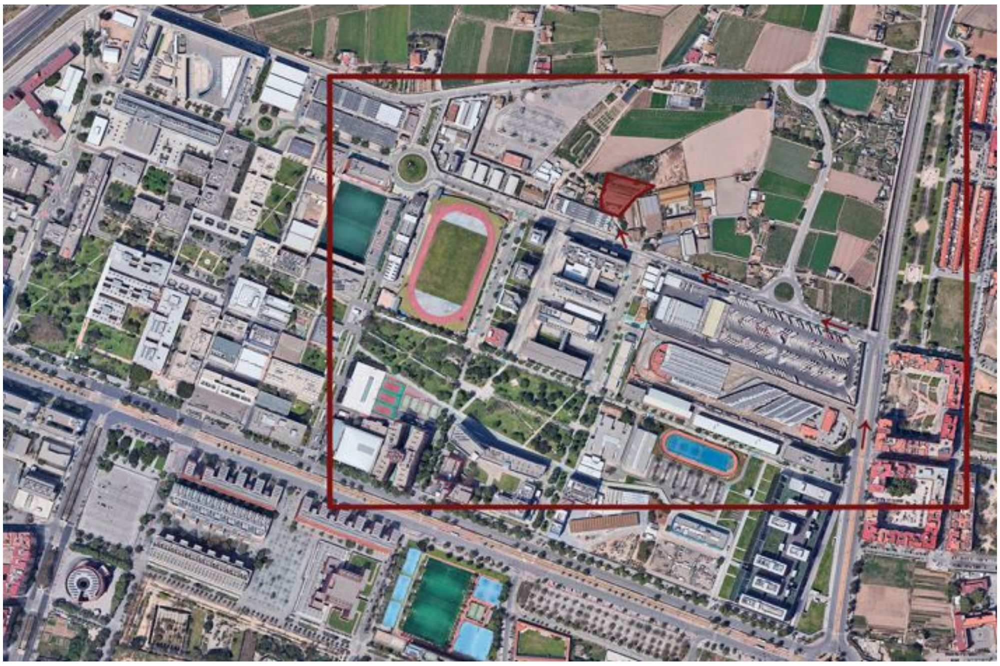


Figure 5.1: Site location at UPV

Figure 5.2: Projection of the proposed HRS volume on the existing plot

5.2 Area classification

5.2.1 Storage classification

Taking into account the expected quantities of gases that will be included in the total storage, the installation will be classified as **Category 4**. The table shown in Figure B.3 in the Annex B establishes the storage limits for this category, according to the ITC MIE-APQ 5 of the Royal Decree 656/2017. This category defines the characteristics that the storage facility must have in terms of location, ventilation, electrical installation, fire protection and personal protection. The storage must comply with general characteristics regarding the following aspects, as well as with some requirements according to its category:

1. Location and construction. Storage systems shall not be located in underground premises or in places with direct communication with basements, except for the case of air bottles only, or in stairwells and lift shafts, corridors, tunnels, under exterior stairs, in specially marked emergency escape routes and in parking lots. Specifically for category 4, it is not allowed to place it inside buildings with commercial uses of public concurrence, administrative, educational, hospital, residential or use by third parties. In addition, according to Table 5.1 for Category 4, the storage area will not contain any activity other than the storage of cylinders. This table also specifies that in storage facilities in open or closed areas, cylinders filled with flammable and other gases (inert, oxidizing, toxic and corrosive) may be stored, provided that there is a distance of at least 6 m between the cylinders of the flammable gases and those of the other gases, or that they are separated by an EI-60 (Fire resistance) wall at least 2 m high and 0.5 m above the cylinders, and that it is horizontally 1.5 m above the stored cylinders.

Table 5.1: Location and safety distances. ITC MIE-APQ 5 (RD 656/2017)

Storage category	1	2	3	4	5
The storage area may accommodate activities other than storage that do not affect the safety of the vessels	Yes	Yes	No	No	No
Distances (meters) between containers of flammable gases to other gases	6 meters or separation wall Figure B.4 and B.5 (Annex B)				
Distances (meters) between containers of flammable gases to inert gases	3 meters or separation wall Figure B.4 and B.5 (Annex B)				
Distances (meters) between flammable gas containers to any ignition source or open fire	6 meters or separation wall Figure B.4 and B.5 (Annex B)				

Moreover, in open storage areas, such as the one covered in this document, if there are cylinders of flammable or oxidizing gases in the storage area, the following distances must be observed in horizontal projection:

- 8 m to public roads.
- 10 m to inhabited buildings or to third parties.
- 10 m to activities classified as fire or explosion risk.

- 2 m to internal storage services.

This distance will not be required if they are separated by continuous walls without gaps of REI-180, minimum height 2 m and 0.5 m above the containers and extended 2 m in horizontal projection at both ends (see Figure B.6 in Annex B). The gas storage rooms shall be protected by a fence with a minimum height of 2 m surrounding the whole perimeter, equipped with at least one door. The gate and fence will be metal.

It should be noted that, in addition to the hydrogen stored in open areas, there will be an engine room where the nitrogen (inert gas) installation is located (closed area), which will be equipped with walls of at least REI-30. This building will house a certain amount of nitrogen storage, and as it is an enclosed space the following distances apply for category 4:

- 4 m to public roads.
- 8 m to inhabited buildings or to third parties.
- 8 m to activities classified as fire or explosion risk.
- 2 m to internal storage services.

2. Ventilation. For enclosed storage areas the ventilation will be sufficient and permanent for it to be free of hazardous gases or vapours. For this purpose, openings or gaps with direct communication to the outside must be provided, conveniently distributed in high and low areas. The total surface area of these openings must not be less than 1/18 of the total floor area of the storage area. In the specific case of hydrogen storage, this is considered as an open or semi-open area storage and does not require ventilation. On the other hand, nitrogen storage will be located in a closed storage area with adequate ventilation, as set out above.
3. Electrical installation. It shall comply with the provisions of the applicable high and low voltage electrical regulations.
4. Fire protection. Storage areas will be equipped with at least the fire-fighting equipment listed in Table 5.2 for each category. In all cases, fire extinguishers will be provided, a manual fire alarm system (push-buttons) will be installed and emergency lighting will be set. In accordance with category 4, the storage area will be provided with extinguishing agent compatible with the stored gases, with a minimum of 5 extinguishers, each with a minimum efficiency of 144B, and there shall be required a minimum number of 2 hose reels.

Table 5.2: Fire Protection. ITC MIE-APQ 5 (RD 656/2017)

Storage category	**Fire extinguishers (Minimum number/Effectiveness)**	**Hose reels (Minimal number)**
Category 1	2/89B	-
Category 2	3/89B	-
Category 3	4/89B	-
Category 4	5/144B	2
Category 5	5/144B	$2 + \frac{H_2 Nm^3 - 2000}{2000}$

In the case of storage of flammable gases as the only combustible material, the passive protection measures will be those indicated in Annex II of the RSCIEI (Fire Safety Regulations in Industrial Buildings) with the characterization of the risk level according to the Table 5.3. According to this table, category 4 therefore corresponds to a **medium risk** level classification.

Table 5.3: Characterization of the risk level in flammable gas storage. ITC MIE-APQ 5 (RD 656/2017)

Flammable gas storage category	Risk level characterization
Category 1 and 2	Low risk
Category 3 and 4	Medium risk
Category 5	High risk

5. Personal protective equipment. They will comply with the provisions of Law 31/1995, of 8 November, on the Prevention of Occupational Risks, and implementing regulations, especially Royal Decree 773/1997, of 30 May, on minimum health and safety provisions relating to the use by workers of personal protective equipment and what is indicated in the Safety Data Sheets. For the manipulation of the cylinders it is recommended the use of adequate safety shoes and gloves, as well as specific training for all the personnel who is going to manipulate them.

5.2.2 Study of safety distances

The safety distances will be given by some of the regulations mentioned in the previous sections. Due to the fact that the storage associated with the HRS is classified under RD 656/2017, safety distances are already established to public roads and various buildings in the previous section. Hydrogen storage falls under the scope of application of the Pressure Equipment Regulation (RD 2060/2008), although without any applicable ITC. Therefore, according to this regulation, there is no mandatory regulation that establishes the safety distances that this type of storage must comply with. However, there are rules/regulations that will be studied to establish design criteria:

- ISO/TS 20100. Gaseous hydrogen. Fuelling stations.
- ITC MIE-APQ 5. Storage of Chemical Products and its Complementary Technical Instructions MIE (Ministry of Industry and Energy)-APQ (Chemical Storage).

Both regulations will be taken into account when distributing the elements within the installation, choosing the most restrictive distance if they coincide in any of the cases. Since these distances have already been determined in agreement with the storage category in the previous section, according to ITC MIE-APQ 5, the corresponding distances are defined for the specific case of the facility, in accordance with the ISO/TS 20100 standard. The latter regulation defines four categories of storage, depending on the volume of water in the storage tank, the operating pressure, and the stored amount of hydrogen gas. If there are more than one storage system, as it is the case with this installation, the safety distances are calculated considering the storage systems as a whole according to the regulations, since the failure of a component in a pipeline can result in the release of hydrogen from a set of storage systems. Taking into account the total volume of all the tanks that compose the installation, this volume corresponds to 11700 liters of water, being the amount of volume of hydrogen to be stored of 143.68 kg. Figure 5.3 shows the plot of the standard where the different categories are delimited according to the operating pressure and the storage volume. As can be seen, this case corresponds to category 4 according to the operating conditions.

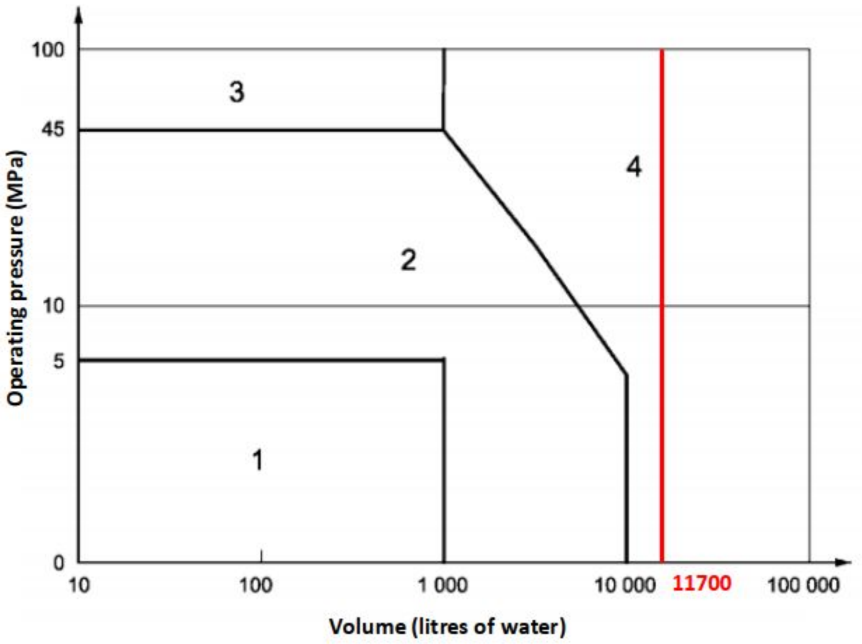


Figure 5.3: Classification of hydrogen gas storage to determine safety distances [ISO/TS 20100, 2008]

The table shown in the Figure B.7 of Annex B indicates the minimum safety distances in meters from hydrogen gas storage systems to different exposures, depending on the storage category. According to this table, the following distances apply for the specific case of this installation (category 4):

- Non-combustible building (resistance 2 hours): 1.5 m. This distance applies to the different engine rooms present in the installation.
- Openings in the wall of the building (door, window) not located above the hydrogen system: 3 m. These distances apply to the various doors and windows in the different engine rooms.
- Air conditioning and compressor air intake: 4 m.
- Public places: 8 m. This distance applies to the nearby places that surround the site such as the greenhouses, the LABDER laboratory or the nearby UPV buildings.
- Public sidewalks and parked vehicles: 4 m.

In addition, Figure B.8 of Annex B indicates the minimum safety distances in metres for the hydrogen gas processing sub-systems including the dispenser. These safety distances should be applied to process subsystems with a maximum operating pressure greater than 5 MPa, where potentially more than 0.1 kg of hydrogen can be released. These subsystems include hydrogen piping and dispensers, and the safety distances should be defined from points where leakage may occur, such as non-welded pipe connections and temporary connections (for example at the dispenser filler neck). These distances are defined according to the service pressure at which the sub-systems work. There are two possible ranges: one for pressures between 5 and 45 MPa and another for pressures greater than 45 MPa. According to this table, the following apply for the specific case of this installation (category 4):

- Non-combustible building (resistance 2 hours): separation needed for access in maintenance and repair operations.
- Openings in the wall of the building (door, window) not located above the hydrogen system: 2 m ($5 < P \leq 45$ MPa) and 3 m ($P > 45$ MPa).
- Flammable liquids or surface hydrogen storage: 4 m ($5 < P \leq 45$ MPa) and 6 m ($P > 45$ MPa).
- Air conditioning and compressor air intake: 3 m ($5 < P \leq 45$ MPa) and 4 m ($P >$ MPa).
- Public places: 4 m ($5 < P \leq 45$ MPa) and 6 m ($P > 45$ MPa).
- Public sidewalks and parked vehicles (excluding vehicles that are going to refuel): 3 m ($5 < P \leq 45$ MPa) and 4 m ($P > 45$ MPa).

5.2.3 Classification of explosive atmospheres

Due to the high explosiveness and flamability of hydrogen, with lower and upper limits of explosiveness of 4% and 75% in air, respectively, it is essential to carry out a classification study of explosive atmospheres (ATEX). In this way, the minimum requirements demanded by the existing regulations and recommendations must be met, for the risk of ATEX formation to be reduced as much as possible. To this end, the following standards are taken into consideration:

- UNE-EN 60079-10-1:2016. Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres.
- UNE-EN 60079-14:2016. Explosive atmospheres - Part 14: Electrical installations design, selection and erection.
- UNE-EN 1127-1:2012. Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology.
- UNE 202007:2006 IN. Application guide of UNE-EN 60079-10. Electrical apparatus for explosive gas atmospheres. Classification of hazardous areas.

The most critical point is the interior of the building in which the hydrogen compressor will be located, since it is an enclosed space in which hydrogen pressures of up to 900 bar will occur. The rest of the hydrogen installation will be outdoors so hydrogen leaks will quickly be diluted in the ambient air. According to the Complementary Low-Voltage Technical Instruction ITC-29 (Special requirements for electrical installations in rooms with a risk of fire or explosion), and taking into account the characteristics of the process, the electrical material to be installed inside the compressor housing must be suitable for operation in a **Zone 2**. This classification indicates that in such location the explosive atmosphere is a mixture consisting of air or hazardous substances in the form of gases, vapours or mist which do not occur in normal operation but for a short period of time in case to occur.

5.3 Vehicles specifications

The facility will receive a certain number of vehicles for them to refuel their hydrogen tanks. Each type of vehicle has an autonomy, requires a certain refuelling pressure and is capable of storing a specific amount of hydrogen in the tank. These vehicles are:

- Van.
  Autonomy: 100-300 km [Berger, 2017]
  Pressure: 700 bar [Gutierrez, 2019]
  Tank capacity: 5 H_2 kg [Berger, 2017]
- Material handling equipment (MHE).
  Autonomy: 8 hours [Berger, 2017]
  Pressure: 350 bar [Berger, 2017]
  Tank capacity: 3.4 H_2 kg [PLUG POWER, 2018]
- Car.
  Autonomy: 385-700 km [Berger, 2017]
  Pressure: 700 bar [Berger, 2017]
  Tank capacity: 5 H_2 kg [Godula-Jopek, 2015]
- Bicycle.
  Autonomy: >100 km [Berger, 2017]
  Pressure: 350 bar [Berger, 2017]
  Tank capacity: 0.034 H_2 kg [LINDE, no date]

In order to know the consumption of each vehicles, it is necessary to determine the refuelling frequency, that is how many days are the vehicle required to go to the HRS to refuel its hydrogen tank. To carry out this calculation, the autonomy of each vehicle is taken into account, choosing a value from the ranges shown above, as well as the kilometres travelled each day. This last data is based on the following assumptions:

- Van: 70 km/day
- Material handling equipment: it is assumed that the material handling equipment needs to refuel every day, due to its lower autonomy.
- Car: 50 km/day
- Bicycle: 20 km/day

Table 5.4 shows a summary of the characteristics of the different types of vehicles selected for the design of the system. The refuelling frequency that appears in the last column of this table is computed by dividing the autonomy of each vehicle by the travelled distance (with the exception of the MHE as it is assumed that the refuelling frequency of this vehicle is daily).

Table 5.4: Vehicles specifications

Type of vehicle	**Number of vehicles**	**Pressure (bar)**	**Tank capacity (kg H_2)**	**Autonomy (km)**	**Travelled distance (km/day)**	**Refuelling frequency (days)**
Van	1	700	5	140	70	2
MHE	1	350	3.4	-	-	1
Car	2	700	5	400	50	8
Bicycle	5	350	0.034	100	20	5

5.3.1 Fuel quality specifications

The fuel quality requirements at the dispenser nozzle shall meet the requirements shown in the table of Figure B.9, included in Annex B, according to the standard UNE-EN 17124:2018 [UNE-EN 17124, 2018]. This table states that the hydrogen used in a PEM fuel cell road vehicle should have a purity of 99.97 %. This will be taken into account when selecting the electrolyser, in order to ensure that such as fuel quality is achieved. In addition, it should be noted that the contaminants listed in the table may introduce impurities into the hydrogen supply chain. Specifically, the contaminants potentially present at each stage of the chain are listed below:

- Production from a PEM electrolyser: mainly O_2 and H_2O.
- Pipeline transportation: contamination of any kind during normal operation is very unlikely. However, during maintenance, the potential sources of contamination are N_2, if insufficiently purged after maintenance, and H_2O, if insufficiently dried after maintenance.
- HRS: contamination during normal operation shall be assessed with consideration of the technology used on a case-by-case basis. During maintenance, the potential sources of contamination are N_2, if insufficiently purged after maintenance, and H_2O, if insufficiently dried after maintenance.
- Special operations (Commissioning, Maintenance): these operations may involve purging/inerting with nitrogen, open to the atmosphere or allowing air into the hydrogen path, cleaning with specific agents including halogenated components or Volatile Organic Compounds. Therefore, the potentially present impurities are N_2, O_2, CO_2, THC and Halogens.
- Whole supply chain: particles may be originated at each level of the supply chain. Therefore, by default, they will be considered as potentially present for each of them, except if specific design measures (filtering) permit demonstrate the opposite.

5.4 Components description

Firstly and more generally, three main sections can be differentiated: production, storage and consumption within the installation. The production system is composed by a PEM electrolyser which receives the energy from different renewable sources to generate hydrogen. Since the university does not have yet a system to take advantage of the renewable energy surpluses to produce hydrogen by electrolysis of water, a constant input from the grid is assumed for the sake of simplicity. The storage area includes several storage phases. The first intermediate tank found in the installation is a pressure vessel which storages the gaseous hydrogen coming directly from the electrolyser output. Since the maximum operating pressure of the electrolyser is 40 bar (see subsection 5.4.1), it is assumed that this storage tank will work at such a pressure (low pressure storage). Afterwards, the hydrogen flow is divided in two high pressure storage subsystems, one for each refuelling pressure. One includes a compression phase from 40 bar up to 900 bar (with the subsequent storage tanks) to deliver hydrogen at 700 bar in the HRS. The other one has also a compression phase from 40 bar up to 450 bar (for the 350 bar HRS) and the subsequent storage system. The last phase of the chain is the consumption point, where the FCEVs can refuel their hydrogen tanks from the two HRS, one delivering pressure at 700 bar and the other one at 350 bar. Figure 5.4 shows the general overview of the installation, where the three different sections are identified.

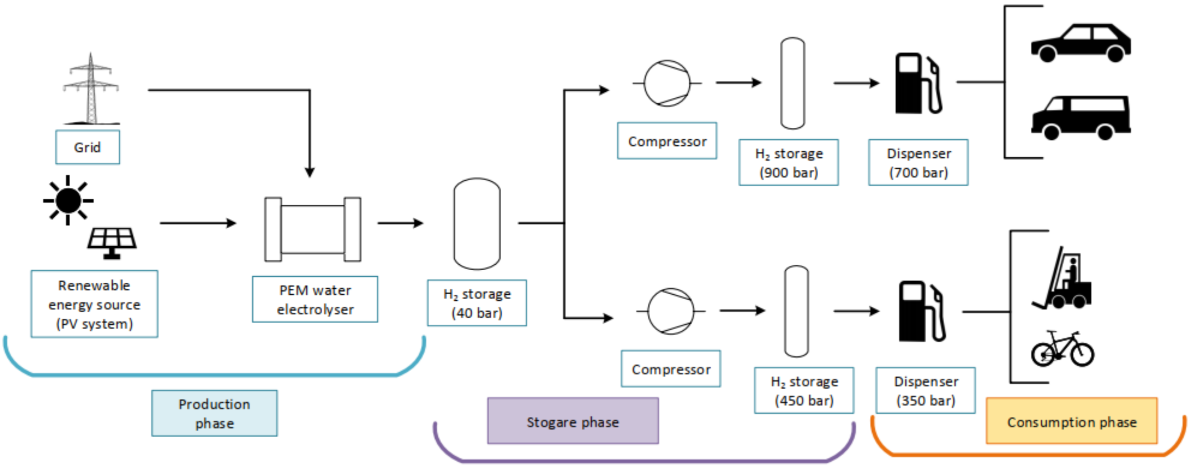


Figure 5.4: General scheme of the installation

5.4.1 Electrolyser

As said above, the electrolyser is the system that allows the conversion of electric energy to chemical energy in order to obtain the hydrogen to be used later within the installation.

The manufacturer selected to provide the electrolyser is *H2B2*, a company incorporated in 2016 and present in the United States and Spain. The enterprise has a reliable product range of electrolysers based on PEM water electrolysis technology.

The first step to determine which electrolyser is suitable within the installation is to calculate the hydrogen consumption. Knowing the consumption of hydrogen by the vehicles, it is possible to deduce the amount of hydrogen that the electrolyser must produce. This consumption can be calculated from the technical specifications of the vehicles summarized in Table 5.4. To carry out this calculation, the following conditions are taken into account:

- The hydrogen consumption is calculated for a period of one month (31 days).
- It is assumed that all the vehicles (Van, MHE, Cars and Bicycles) make their first hydrogen refuelling on the first day of the month. From there, each vehicle visits the HRS to refuel hydrogen according to the refuelling frequency given in Table 5.4.
- In the particular cases of 2 cars and 5 bicycles, it is assumed that each type of these vehicles recharges on the same day. In these two situations, the capacity of the tank should be multiplied by the number of vehicles to find out the total kilograms of hydrogen consumed.

Taking into account the tank capacity of each vehicle, i.e. the kilograms of hydrogen they consume, and the number of vehicle of each type arriving at the facility every day, the daily hydrogen consumption can be estimated, as shown in Figure 5.5.

Refueling cycle					
Days	Van	Material handling equipment	Car	Bicycle	Total consumption (kg of H_2)
1	5	3,4	10	0,17	18,57
2		3,4			3,4
3	5	3,4			8,4
4		3,4			3,4
5	5	3,4			8,4
6		3,4		0,17	3,57
7	5	3,4			8,4
8		3,4			3,4
9	5	3,4	10		18,4
10		3,4			3,4
11	5	3,4		0,17	8,57
12		3,4			3,4
13	5	3,4			8,4
14		3,4			3,4
15	5	3,4			8,4
16		3,4		0,17	3,57
17	5	3,4	10		18,4
18		3,4			3,4
19	5	3,4			8,4
20		3,4			3,4
21	5	3,4		0,17	8,57
22		3,4			3,4
23	5	3,4			8,4
24		3,4			3,4
25	5	3,4	10		18,4
26		3,4		0,17	3,57
27	5	3,4			8,4
28		3,4			3,4
29	5	3,4			8,4
30		3,4			3,4
31	5	3,4		0,17	8,57

Figure 5.5: Hydrogen consumption per day for all the vehicles

To estimate the required hydrogen production, the average monthly hydrogen consumption is taken into account, which has a value of 7.31 kg of H_2 per day. Using the table of equivalences that appears in Figure A.2 of Annex A, kilograms of hydrogen are converted into normal cubic metres. By doing this conversion, a value of 81.28 Nm^3/day is obtained. Finally, to obtain the value in Nm^3/h, it is assumed that the electrolyser works a maximum of 18 hours per day (design condition), and the following calculation is done:

$$Hydrogen\ required\ production(Nm^3/h) = \frac{81.28}{18}(\frac{Nm^3/day}{hours}) = \mathbf{4.52\ Nm^3/h} \tag{5.1}$$

Accordingly, the electrolyser selected must provide at least the hydrogen flow given by Equation 5.1. The model selected is the **EL5N**, from the manufacturer *H2B2* [H2B2, no date], which has a maximum nominal hydrogen flow of 5.2 Nm^3/h, the value immediately above to the calculated value found among the different models of electrolysers. Table 5.5 shows some technical specifications of the model, whereas the rest of specifications can be found in the data sheet of the Figure C.1 included in Annex C.

Table 5.5: Electrolyser Technical specifications. Model EL5N [H2B2, no date]

Max. nominal hydrogen flow ($\mathbf{Nm^3/h}$)	5.2
Operating pressure (bar)	15-40
Hydrogen purity (after gas purification) (%)	99.999
Power (BoP + Stack) (kW)	28.6
Stack consumption ($\mathbf{kWh/Nm^3H_2}$)	4.7
AC power consumption ($\mathbf{kWh/Nm^3H_2}$)	5.5

The electrolyser system is placed inside a cabinet and it includes not only the hydrogen production system (stack) but also auxiliary systems including hydrogen cooling systems, emergency shutdown, overpressure relief system, redundancy on critical safety parameters and heat management system. The system will include a hydrogen detector for possible hydrogen leaks, cutting off the power supply to the electrolyser in a hazardous situation by means of a signal output. Figure 5.6 shows the external aspect of the cabinet that houses the PEM electrolyser and the dimensional views of this component which indicate its measurements in meters.

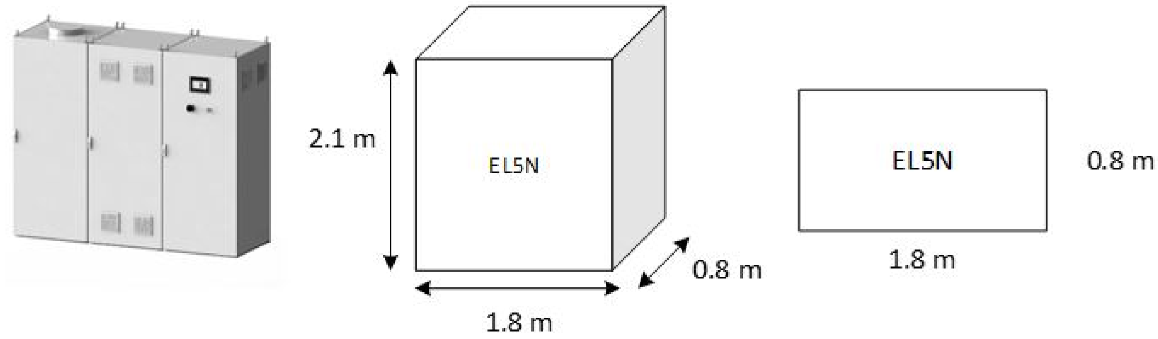


Figure 5.6: PEM electrolyser cabinet and dimensional views [H2B2, no date]

The main equipment can be identified in Figure 5.7, and it is listed bellow with the description of each component.

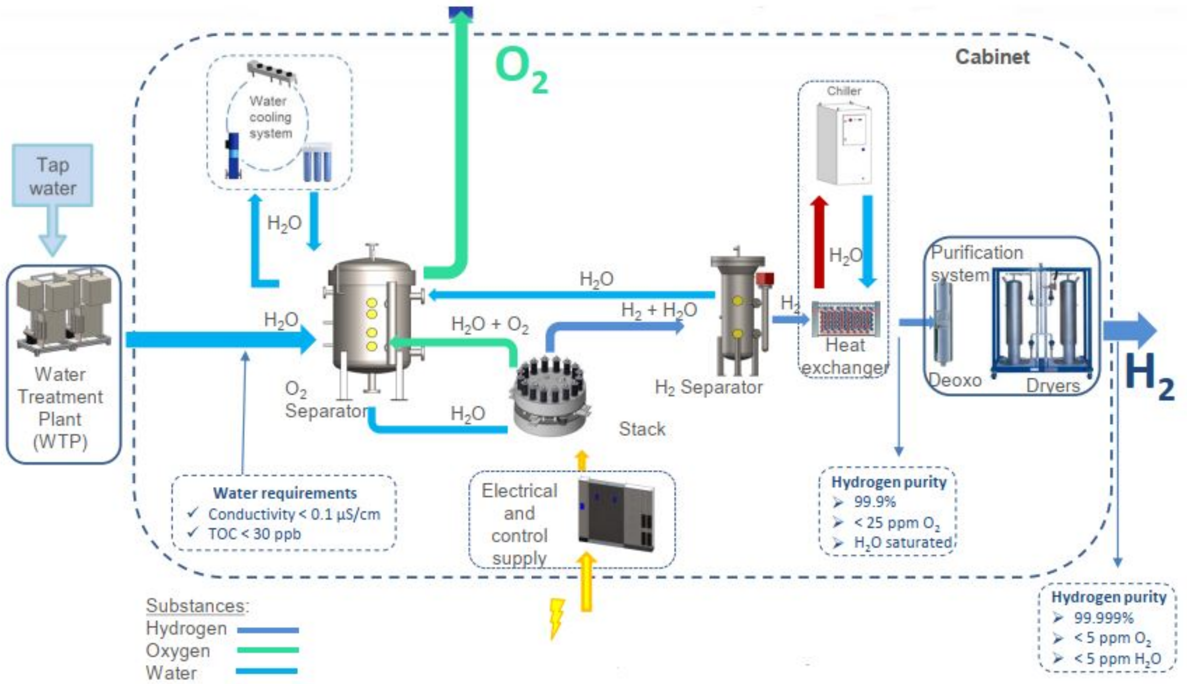


Figure 5.7: General scheme of the electrolyser [H2B2, no date]

- Water treatment plant (WTP). It converts the ordinary water into pure water (2+ type, required for the process). The WTP is only included if deionised water (Conductivity $<$ 0.1 μS/cm, total organic carbon (TOC) $<$ 30 ppb) is not available, and it has a water consumption of less than 10.4 l/h. Therefore, it is included in the system, placed out the cabinet.

- Rectifier (AC/DC converter). Required electricity, which can originate from renewable energy sources, is adapted before powering the stack.

- Stack. Electricity and water enter the system, splitting the water into hydrogen and oxygen molecules.

- Hydrogen separator. Produced hydrogen is a biphasic stream ($H_2 + H_2O$), where steam, hydrogen, and traces of oxygen (in gas phase) and liquid water coexist. Because of this, and due to the hydrogen purity required by downstream applications, this equipment separates water from hydrogen.

- Purification system. It is installed at the outlet of the hydrogen separator, comprising a dryer (to trap humidity) and a deoxo (a catalytic recombiner to collect the oxygen), in line with cathode outlet of the stack. Purification system is included since the hydrogen purity needed should be higher than 99.97%, according to the fuel quality specifications already mentioned (see Figure B.9 of Annex B).

- Gas cooling system (chiller). It is used to cool down the hydrogen stream, improving the efficiency of the complete system.

- Control system. Fully automated PLC for monitoring and control of the electrolyser, and to assure the entire process functions correctly.
- Oxygen separator. Produced oxygen is also a biphasic stream (O_2 + H_2O), where oxygen in gas phase, steam, and traces of hydrogen, as well as a large amount of liquid water, coexist. This equipment recovers the liquid water and vents oxygen to the atmosphere. The recovered water is fed again to the stack in a closed loop (minimizing water consumption).
- General electrical system. It is used to supply electricity to all the instrumentation and equipment. It is included an Uninterruptible Power Supply (UPS), which will supply energy in case of an electrical failure.
- Pumps. There are two pumps in the electrolyser, that impulse the water through the circuit, and give pressure where it is needed.

5.4.2 Low pressure storage system

As mentioned above, the low pressure storage system placed at the electrolyser outlet will storage the hydrogen produced by the electrolyser at a pressure of 40 bar. In order to properly size this first tank, it must be considered that it should store a sufficient amount of hydrogen to be supplied to all vehicles. Therefore, as a minimum, it must be able to store the maximum amount of hydrogen consumed throughout the month. As observed in Figure 5.5, this maximum value corresponds to 18.57 kg of H_2. Using the equivalency ratios given in Figure A.2 (Annex A), these kilograms are equivalent to 206.50 Nm^3. To select this component it is necessary to determine which is the suitable geometric volume to store this quantity of hydrogen at the required pressure. Therefore, an equation that relates the normal volume in Nm^3 with the geometric volume in m^3 must be found. First of all, it is important to define the concept of normal volume as the volume occupied by n moles of a gas under normal conditions of pressure and temperature (P_N=1 bar; T_N=273,15 K), so that it represents an amount of hydrogen. It is also worth noting that hydrogen does not follow the behaviour of an ideal gas, and therefore the Law of Ideal Gases cannot be applied in this case. It is necessary to introduce a correction coefficient, called the compressibility factor Z, to model its behaviour. The equation of the real gases for normal conditions, is therefore given by:

$$P_N \cdot V_N = n \cdot R \cdot T_N \cdot Z_N \tag{5.2}$$

where P_N and T_N have been already defined, V_N is the normal volume, n is the number of moles, R is the universal gas constant and Z_N is the compressibility factor which has a value of 1 in normal conditions as shown in Figure A.3 of Annex A. From this equation, the number of moles will be:

$$n = \frac{P_N \cdot V_N}{R \cdot T_N} \tag{5.3}$$

Since the aim is to find an expression that relates the normal volume to the geometric volume, the equation of state must be expressed as a function of geometric volume, V_g, as follows:

$$P \cdot V_g = n \cdot R \cdot T \cdot Z \tag{5.4}$$

By substituting equation 5.3 in this equation, and assuming that the temperature is constant (T=T_N), the following expression is obtained:

$$V_g(m^3) = \frac{V_N(Nm^3) \cdot Z}{P} \tag{5.5}$$

The compressibility factor for hydrogen is tabulated as a function of the pressure in the table of the Figure A.3 (Annex A). Since we need Z at a pressure of 40 bar, which is not included in the table, a linear adjustment has been carried out providing the equation shown below with an appropriate regression coefficient of 0.9996 (see Figure A.4 in Annex A).

$$Z = 0.0007 \cdot P + 0.9915 \tag{5.6}$$

Introducing in equation 5.5 the minimum amount to be stored (206.50 Nm^3), the minimum geometrical volume can be calculated for a pressure of 40 bar (Z(40 bar)=1.1095), which has a value of 5.26 m^3.

The manufacturer selected to provided this storage tank is *NPROXX*, which is a world leader in high pressure hydrogen storage for both stationary and mobile applications. Since the minimum geometrical volume for the tank is 5.26 m^3, the model tank to be selected should be at least of this size. The most suitable product of the manufacture is the **10" MEGC 300 bar** model with a maximum working pressure of 300 bar. This model is composed by 24 pressure cylinders with a total usable capacity of 170 kg of hydrogen.

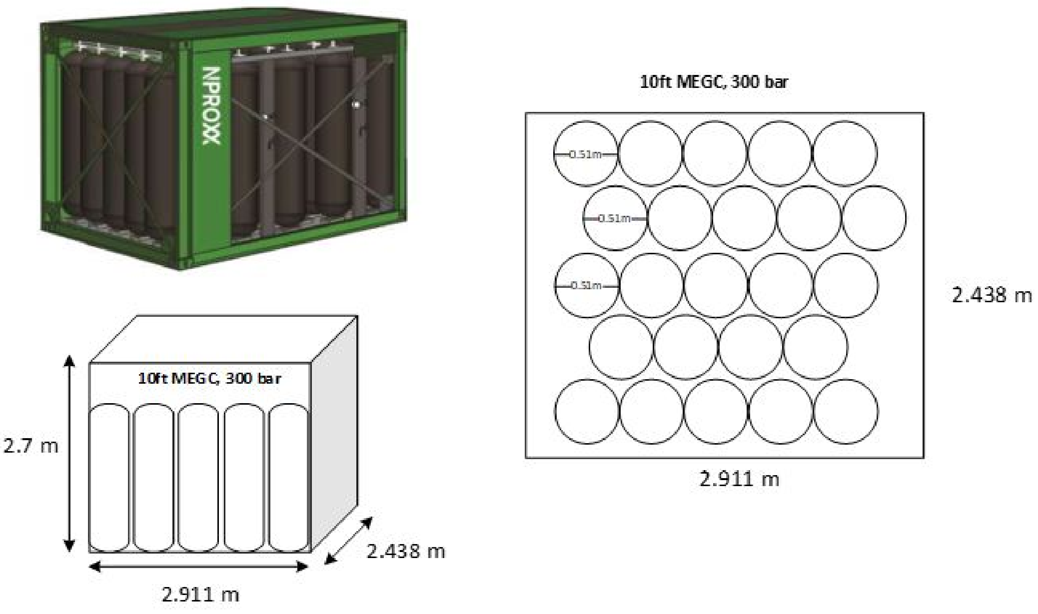


Figure 5.8: Low pressure storage tank and dimensional views [NPROXX, no date]

According to the table in Figure C.2 (Annex C), the geometric volume is 8.4 water m^3, which is greater than the minimum geometrical volume required. In addition, by using again Equation 5.5, the normal volume of the tank can be obtained by introducing the geometrical volume of the commercial model (8.4 m^3), the pressure of 40 bar and its corresponding compressibility factor

(Z(40 bar)=1.1095). A normal volume is obtained of 329.57 Nm^3. Since this value is greater than the minimum volume to be stored according to the estimated hydrogen consumption (206.5 Nm^3), it can be stated that the model selected has sufficient capacity to hold the amount of hydrogen necessary at the imposed pressure. Figure 5.8 shows the aspect of the commercial model chosen and the dimensional views of this component which indicate its measurements in meters.

In order to verify that the size of the tank selected is correct, a simulation of the critical case is carried out, assuming that all the vehicles arrive on day 1 and refuel at the same time. This simulation is performed by taking into account the following aspects:

- The critical case is considered to be that in which all vehicles (Van, MHE, 2 Cars, 5 bicycles) arrive at the HRS at hour 1 on the first day. Figure 5.9 shows the hydrogen consumption of each of the vehicles during that hour.

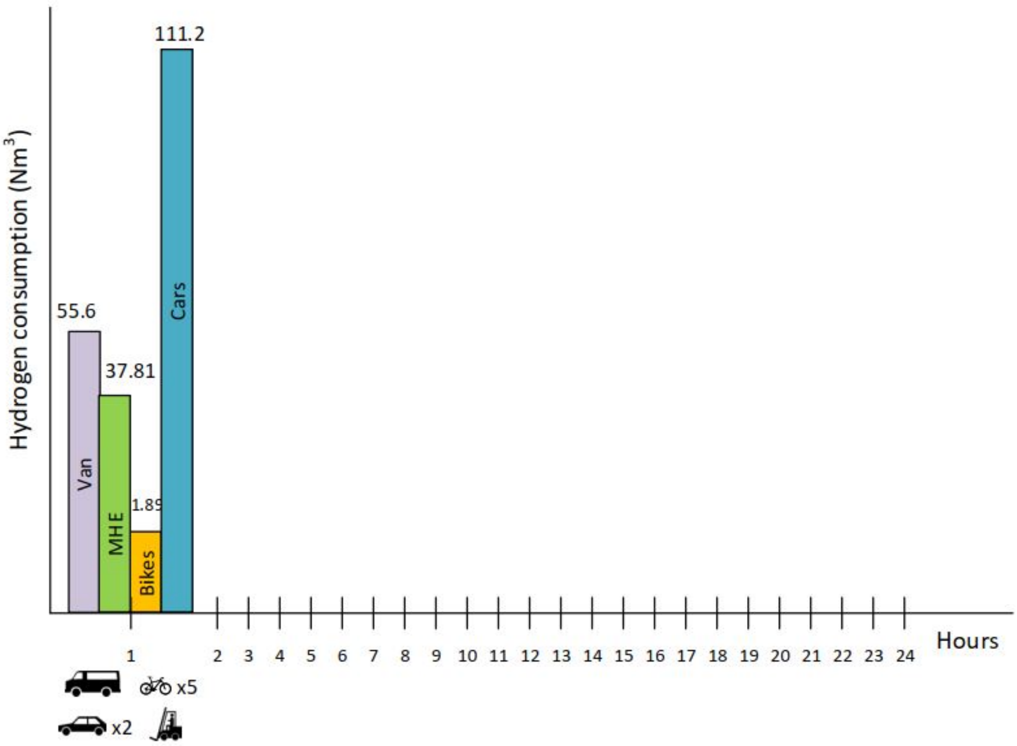


Figure 5.9: Vehicles hydrogen consumption (Day 1)

- The simulation is carried out by hours, during a period of time of one month (31 days).
- From day 1 (day of maximum consumption), a sequence is established in which each vehicle arrives to refuel at a determined hour of the day. The sequence is as follows:
  - Van: 3 a.m
  - Bicycle 1: 9 a.m
  - MHE: 10 a.m
  - Bicycle 2 and 3: 1 p.m
  - Car 1: 2 p.m

  - Bicycle 4 and 5: 5 p.m
  - Car 2: 8 p.m

- This sequence is established on day 2, in which all the inputs are produced sequentially at different times of the day. Figure 5.10 shows the sequence during day 2, where each vehicle comes to refuel at the set time established above.

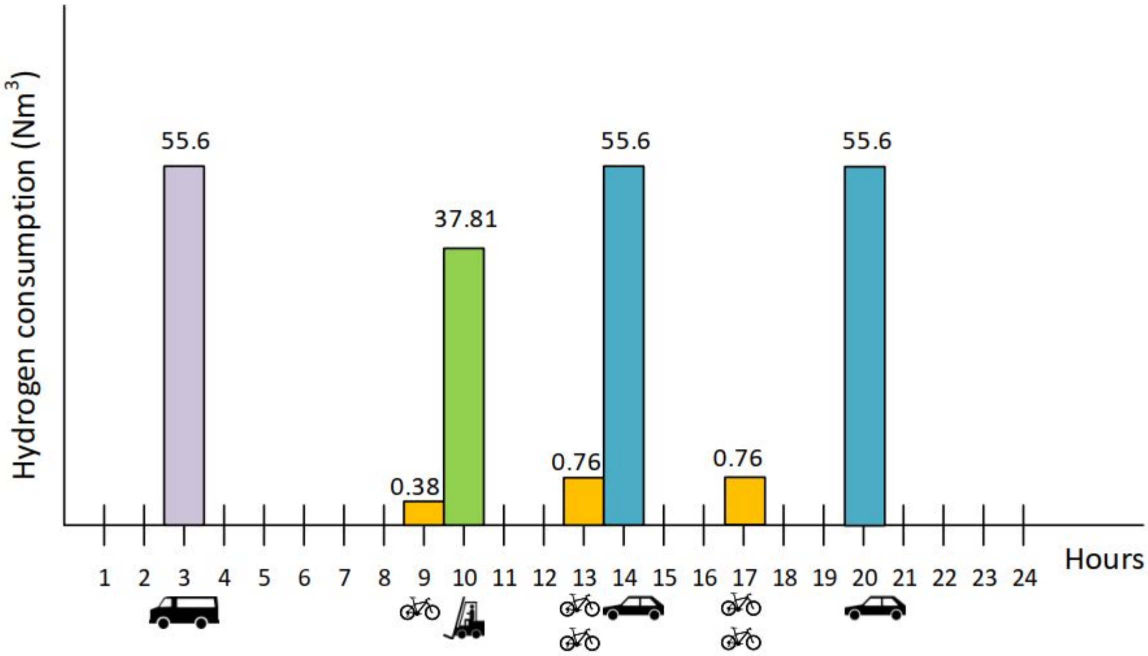


Figure 5.10: Vehicles hydrogen consumption (Day 2)

From there, the refuelling frequency calculated in Table 5.4 is taken into account. Thus, the following days of the month are filled according to the autonomy of each vehicle, with day 1 and day 2 being the most critical days in terms of hydrogen consumption.

- The storage tank is initially supposed to be recharged to its maximum capacity, taking into account a safety margin of 5% with respect to the maximum capacity. Knowing that the maximum capacity of the selected model is 329.57 Nm^3, the tank will initially be recharged with a hydrogen volume of 313 Nm^3.

The calculation to be carried out is the fluctuation of the amount of hydrogen in normal cubic metres, depending on the amount of hydrogen stored in the tank, the amount produced every hour in the electrolyser, and the consumption that takes place when a vehicle is refuelled. As mentioned above, the simulation starts from a maximum capacity value of 313 Nm^3, which takes place in hour 1. From hour 2 onwards, the volume of hydrogen in the tank in the previous hour will be increased by the electrolyser's production in the previous hour and the hydrogen consumption in the previous hour will be subtracted. Therefore, to determine the calculation of the volume of hydrogen inside the tank every hour, the following equation is used:

$$H_2\ volume\ _n = H_2\ volume\ _{n-1} + H_2\ produced\ _{n-1} + H_2\ consumed\ _{n-1} \tag{5.7}$$

A condition is imposed on the hydrogen production so that when the volume of hydrogen in the tank is greater than the maximum capacity (313 Nm^3), the electrolyser stops production. Conversely, as long as the volume inside the tank is less than the maximum capacity, the electrolyser will be producing hydrogen at its nominal maximum hydrogen flow rate (5.2 Nm^3/h). The simulation illustrating the fluctuation of the hydrogen volume inside the low pressure tank is shown in Figures 5.11 and 5.12. The first figure shows the simulation during the 24 hours of the first day, where it can be seen that the maximum volume drop takes place during the first two hours, as mentioned above. The second figure shows the simulation by hours during the whole month where it can be seen that the fluctuation remains stationary with time and that at no moment it exceeds the maximum storage capacity of the tank (329.57 Nm^3). Therefore, it can be concluded that the sizing of the low pressure tank is adequate and that the commercial model selected is correct.

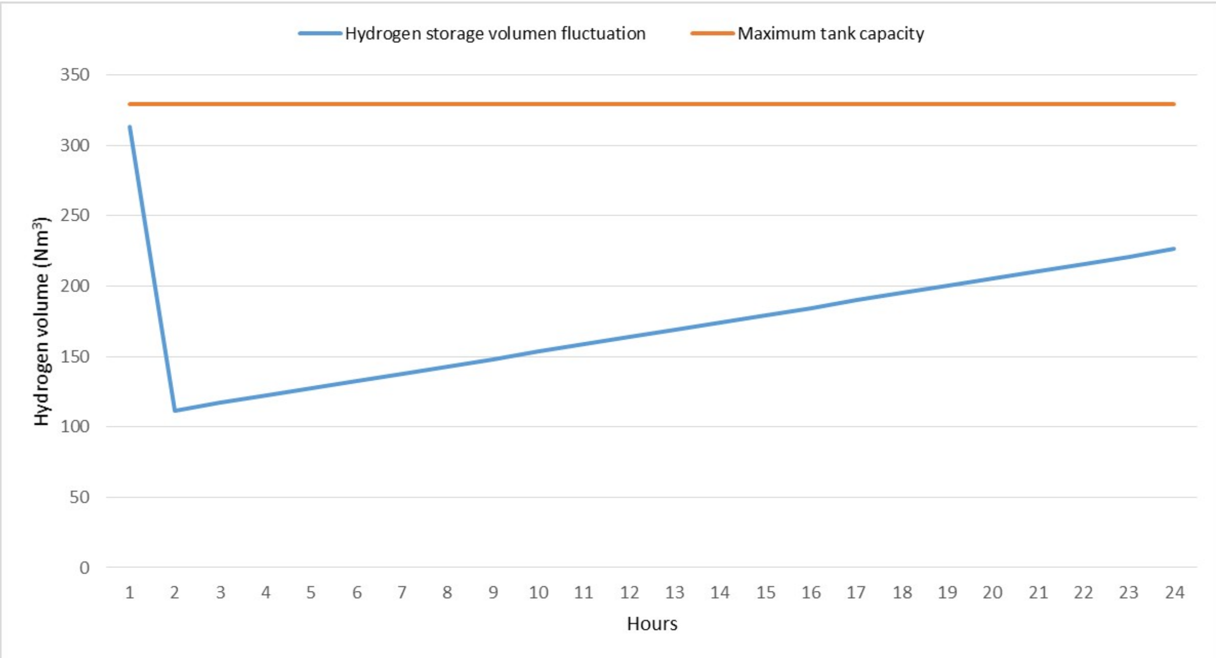


Figure 5.11: Hydrogen storage fluctuation (Nm^3 H_2) in the low pressure tank (Day 1)

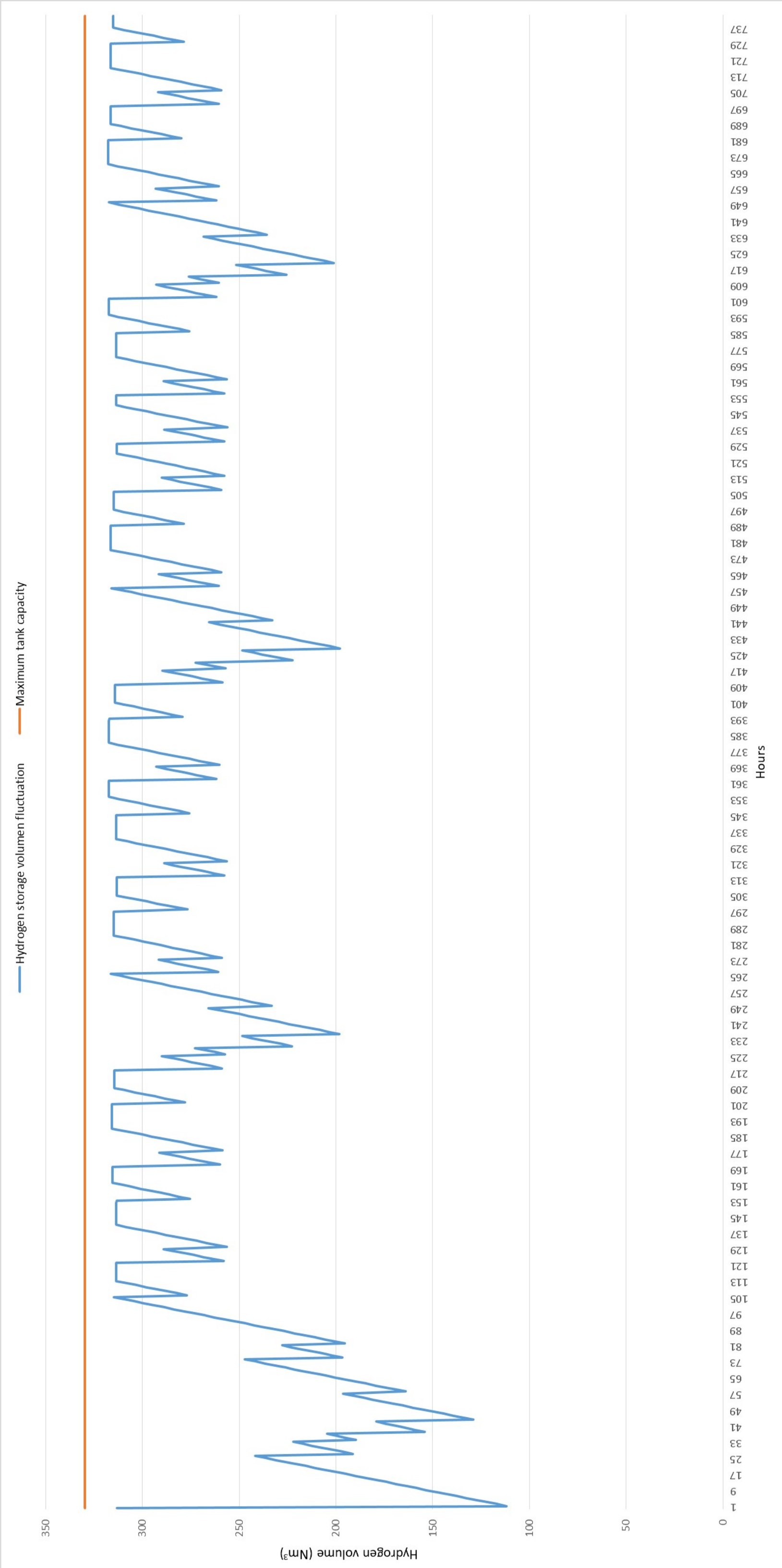


Figure 5.12: Hydrogen storage fluctuation (Nm^3 H_2) in the low pressure tank (31 days)

Besides that, the pressure fluctuation inside the tank is also computed, to determine the maximum pressure drop and ensure that it is not excessive. To calculate the pressure when passing from a condition 1 to another condition 2, it is necessary to calculate the relationship between the two, what is made as follows. Using Equation 5.5 for each condition, the following expressions can be written:

$$P_1 = \frac{V_{N1} \cdot Z_1}{V_g} \tag{5.8}$$

$$P_2 = \frac{V_{N2} \cdot Z_2}{V_g} \tag{5.9}$$

and dividing these two expressions, the following relation between two pressures P_1 and P_2 at constant temperature is obtained:

$$P_2 = \frac{V_{N2} \cdot Z_2 \cdot P_1}{V_{N1} \cdot Z_1} \tag{5.10}$$

As the compressibility factor Z also depends on the pressure according to the Equation 5.6, it is necessary to isolate the pressure term P_2 by entering Equation 5.6 in the above equation. The final expression of pressure P_2 is then:

$$P_2 = \frac{0.9915 \cdot \frac{P_1 \cdot V_{N2}}{V_{N1} \cdot Z_1}}{1 - 0.0007 \cdot \frac{P_1 \cdot V_{N2}}{V_{N1} \cdot Z_1}} \tag{5.11}$$

where P_1 is the initial pressure (40 bar), the compressibility factor Z_1 is computed by using Equation 5.6, V_{N1} is the maximum tank capacity (329.57 Nm^3), and V_{N2} is the volume of hydrogen inside the tank, which is the only parameter that varies according to Equation 5.7. If this equation is applied for all hours of the month, the result is a fluctuation of the pressures inside the tank as shown in Figure 5.13. As can be seen, the maximum pressure drop (13.32 bar) logically corresponds to the moment when the volume inside the tank is minimum.

Finally, since the electrolyser can work a maximum of 18 hours per day, it is necessary to check in the simulation that the average number of hours that the electrolyser has been in operation does not exceed this value. According to the data provided by the simulation, the electrolyser works 517 hours per month out of the total 744 hours in a month. If the daily average of hours worked per month is calculated, this gives a value of 16.67 hours, as shown below, which is lower than the maximum 18 hours that the electrolyser is allowed to work.

$$Daily\ working\ hours = \frac{517}{744} \cdot 24 = 16.67\ hours \tag{5.12}$$

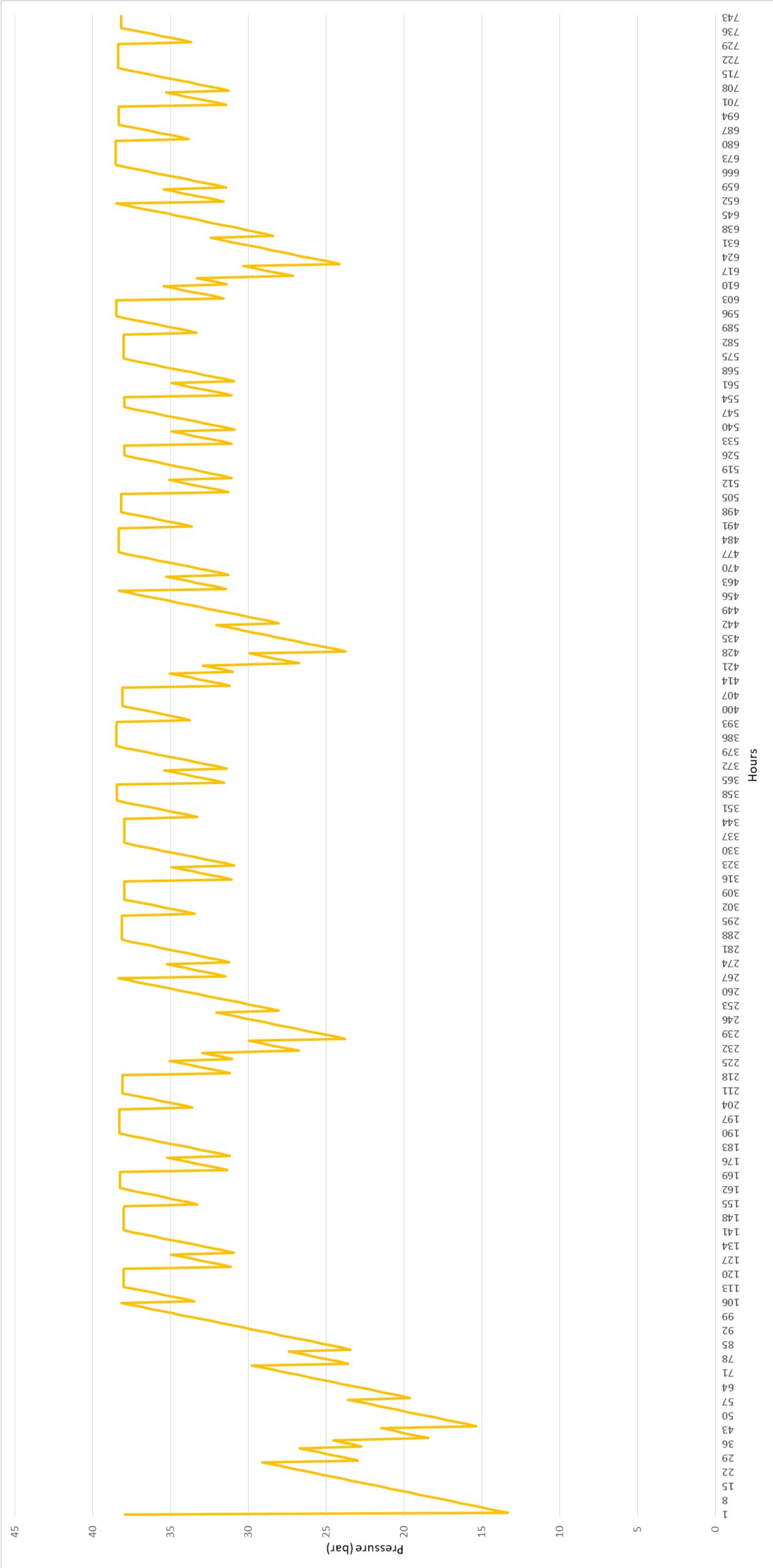


Figure 5.13: Pressure fluctuation (bar) in the low pressure tank (31 days)

5.4.3 High pressure storage system

The selected high pressure storage system is a cascade storage system. This system is usually configured with three vessels considered as low, medium and high pressure containers. In this type of configuration, the refuelling sequence starts with the lowest pressure vessel. When the flow rate reaches a pre-set level in the system, the medium pressure vessel is switched and then the high pressure vessel until filling is complete. However, the sequence of filling the vessels from the compressor is done in reverse, i.e. the high pressure vessel is filled first. This ensures that the high pressure vessel is kept at maximum pressure as long as possible, thus guaranteeing the availability of hydrogen at high pressure.

Two cascade storage systems are set up, one for the HRS of vehicles requiring a pressure of 700 bar and the other for those requiring a pressure of 350 bar. The procedure to determine the amount of hydrogen to be stored is similar to the low pressure system. However, this time each tank system must be sized according to the vehicles they supply. The 900 bar system should supply hydrogen only to the cars and the van, while the 450 bar tank system supplies to the bicycles and the MHE.

In both cases, it should be taken in the calculation the maximum consumption of hydrogen that takes place during a month. The tables in Figure 5.14 give the hydrogen consumption of each of the two tanks. It can be seen that for the 450 bar tank system, at least 3.57 kg of H_2 must be stored, which corresponds to 39.70 Nm^3 using the equivalency ratios given in the table of Figure A.2 (Annex A). On the other hand, for the 900 bar tank system, the maximum consumption that can take place is 15 kg of H_2, which correspond to 166.8 Nm^3, using the aforementioned equivalency ratios.

To justify the chosen cascade storage system, an analysis of two solutions is made, the first in which only a single tank is available where all the hydrogen is stored (similar to the case of the low pressure storage system), and the second where the cascade storage is sized. The objective is to check which of the two solutions waste more hydrogen (non-usable hydrogen). The concept of non-usable hydrogen is as follows. When hydrogen is supplied at a certain pressure, as is the case with HRS, the storage tank must have hydrogen at a higher pressure to carry out the refuelling process. Therefore, the amount of hydrogen to be supplied between these two pressures corresponds to a percentage of the total volume of the storage. As a result, the tank is filled with a greater amount of hydrogen than is actually used, leaving a permanently stored amount of hydrogen (non-usable hydrogen), which acts as a buffer within the tank to ensure that hydrogen is effectively supplied between these two pressures. Firstly, the 900 bar storage system will be analysed and then the storage up to 450 bar, since these two pressures are the ones necessary to guarantee that the hydrogen is supplied at a pressures of 700 bar and 350 bar, respectively.

900 bar Storage Tank System

As mentioned above, the storage system must supply an amount of hydrogen of 166.8 Nm^3, between 900 bar and 700 bar pressures. To select the tank, the geometric volume is first calculated by combining Equations 5.8 and 5.9 as follows:

$$V_{supply} = V_{N1} - V_{N2} = V_g \cdot \left(\frac{P_1}{Z_1} - \frac{P_2}{Z_2} \right) \tag{5.13}$$

Refueling cycle			
Days	Material handling equipment	Bicycle	Total consumption (kg of H_2)
1	3,4	0,17	3,57
2	3,4		3,4
3	3,4		3,4
4	3,4		3,4
5	3,4		3,4
6	3,4	0,17	3,57
7	3,4		3,4
8	3,4		3,4
9	3,4		3,4
10	3,4		3,4
11	3,4	0,17	3,57
12	3,4		3,4
13	3,4		3,4
14	3,4		3,4
15	3,4		3,4
16	3,4	0,17	3,57
17	3,4		3,4
18	3,4		3,4
19	3,4		3,4
20	3,4		3,4
21	3,4	0,17	3,57
22	3,4		3,4
23	3,4		3,4
24	3,4		3,4
25	3,4		3,4
26	3,4	0,17	3,57
27	3,4		3,4
28	3,4		3,4
29	3,4		3,4
30	3,4		3,4
31	3,4	0,17	3,57

Refueling cycle			
Days	Van	Car	Total consumption (kg of H_2)
1	5	10	15
2			0
3	5		5
4			0
5	5		5
6			0
7	5		5
8			0
9	5	10	15
10			0
11	5		5
12			0
13	5		5
14			0
15	5		5
16			0
17	5	10	15
18			0
19	5		5
20			0
21	5		5
22			0
23	5		5
24			0
25	5	10	15
26			0
27	5		5
28			0
29	5		5
30			0
31	5		5

Figure 5.14: Hydrogen consumption per day for vehicles refuelling at 350 bar (left) and at 700 bar (right)

$$V_g = \frac{V_{supply}}{\frac{P_1}{Z_1} - \frac{P_2}{Z_2}} \tag{5.14}$$

where in this case, subscript 1 represents the conditions at a pressure of 900 and subscript 2 represents the conditions at 700 bar (with their respective compressibility factors calculated by the Equation 5.6). Thus, it is obtained a value of 2050.4 litres of water.

Since no manufacturers have been found who provide such capacity in a single tank supporting such pressures, this solution has been discarded to be the most convenient for sizing the storage. Anyway, to have an order of magnitude, the calculation of the non-usable hydrogen has been made assuming that a commercial model of 2100 liters exists. Using Equation 5.5, for the normal volume of hydrogen with a geometric volume of 2100 liters and a pressure of 900 bar, it is estimated that the maximum capacity of the tank at that operating pressure is 1165.59 Nm^3.

If this value is now subtracted to the amount of hydrogen to be supplied (166.8 Nm^3), the value of hydrogen that remains stationary in the tank (non-usable hydrogen) is 998.79 Nm^3.

The other solution proposed is a cascade storage system, in which the appropriate geometric volume for each of the three tanks that make up the system must be selected. Each of these tanks work at a different pressure and are identified as the low pressure tank (LPT), the medium pressure tank (MPT) and the high pressure tank (HPT). First, it is calculated the geometric volume of the reservoir of a vehicle that has to store 5 kg of hydrogen. In this case, we have the maximum consumption when 3 vehicles refuel at the same time (2 cars and 1 van), being the total of hydrogen needed to store 15 kg (166.8 Nm^3), as mentioned above. For a reservoir that has to store 5 kg, it is assumed that the reservoir is almost empty at a pressure of 10 bar ($P_{min,v}$) when the FCV arrives to the HRS. Since the storage system recharges sequentially from the lowest pressure tank to the highest pressure tank, the idea is to calculate which are the appropriate vehicle reservoir recharge pressures for each of the tanks. To find out the two pressure limits between which each storage tank works, an iterative process is used to obtain a similar geometric volume for each of the three tanks. The calculation procedure is represented graphically in Figure 5.15, and for further clarification, the flow chart in Figure 5.16 is included, together with the steps of the procedure presented below, which describe the methodology to be followed.

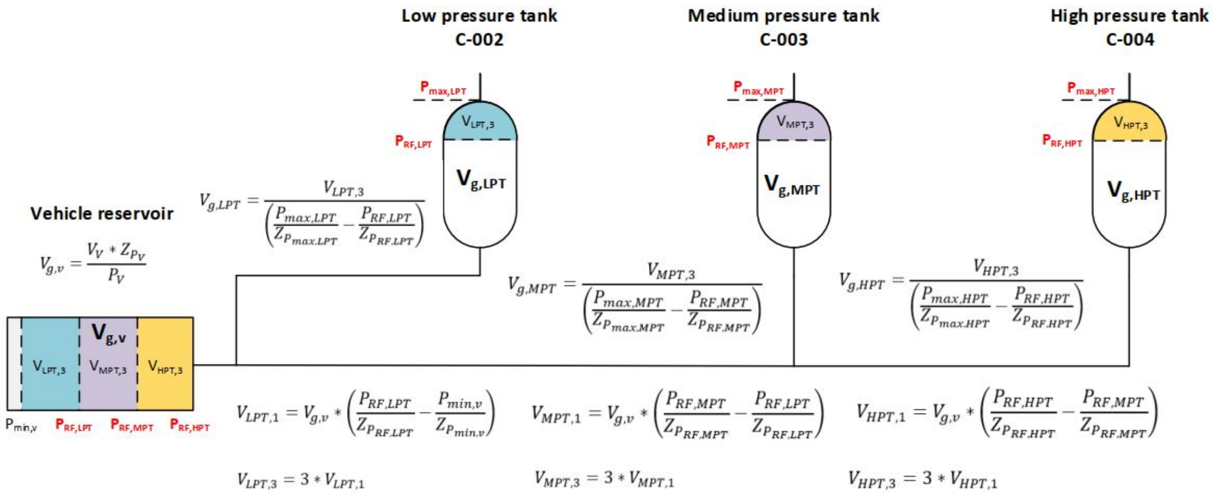


Figure 5.15: Calculation procedure for the hydrogen cascade storage system (900 bar)

1. A tank refuelling pressure $P_{RF,LPT}$ is chosen for the tank that works at the lowest pressure. This tank is called C-002, designated according to the installation drawings.
2. The geometric volume of the vehicle's reservoir $V_{g,v}$ is calculated using Equation 5.5, knowing that it must store V_v= 5 kg (55.6 Nm^3) at P_v=700 bar. The compressibility factor Z_{P_v} can be calculated using the equation 5.6.
3. The volume of hydrogen $V_{LPT,1}$ (Equation 5.5) that the vehicle reservoir will store when the tank is filled from 10 bar to the pressure selected in point 1 ($P_{RF,LPT}$) is calculated taking into account the geometric volume of the vehicle reservoir $V_{g,v}$ obtained in point 2.

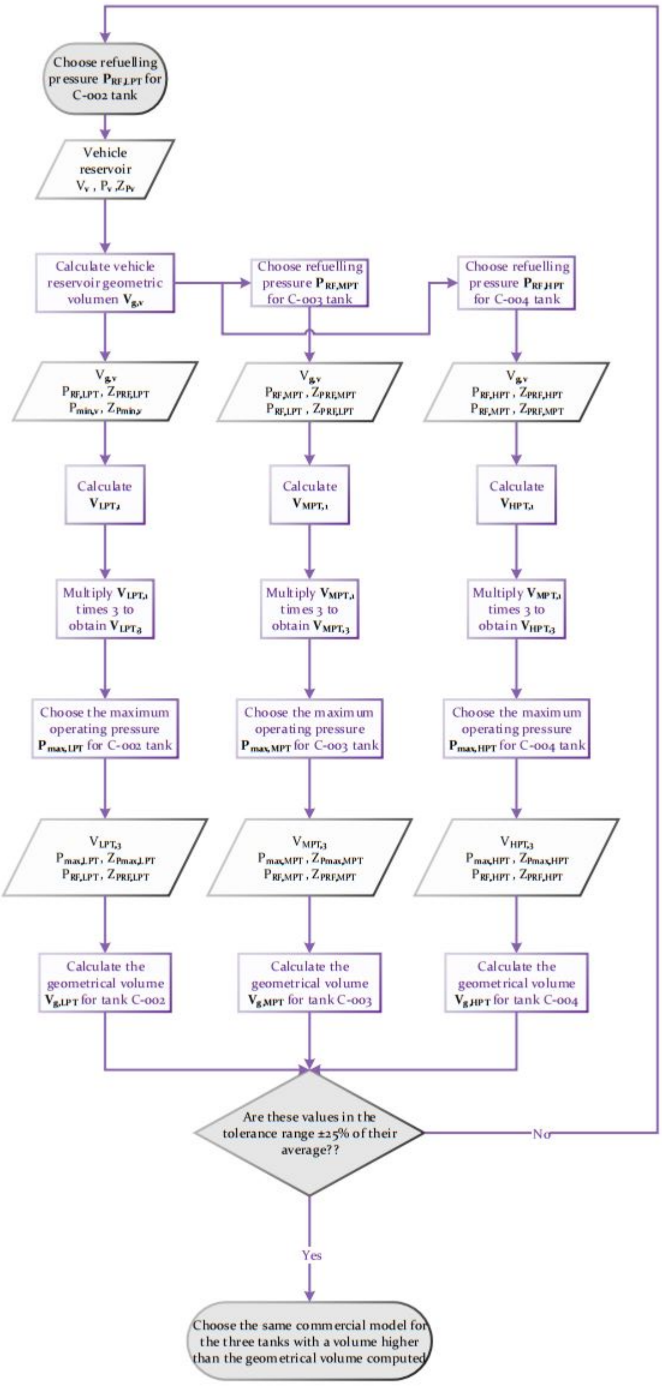


Figure 5.16: Flow chart for calculation procedure of hydrogen cascade storage system (900 bar)

4. This volume is multiplied by 3, as 3 vehicles are actually considered to be refuelled. This volume $V_{LPT,3}$ corresponds to the volume to be supplied by the C-002 tank.

5. The maximum operating pressure $P_{max,LPT}$ of the C-002 tank is chosen. The amount of hydrogen calculated in point 4 ($V_{LPT,3}$) must therefore be supplied between this pressure and the pressure chosen in point 1 ($P_{RF,LPT}$).

6. Using again Equation 5.5, the geometrical volume $V_{g,LPT}$ that tank C-002 must have is now calculated.
7. For the tank storing hydrogen at intermediate pressure (C-003), it is first considered that the tank must supply the vehicle reservoir with hydrogen at a chosen pressure $P_{RF,MPT}$, from the initial pressure at which the tank has remained when the first refuelling from tank C-002 has been carried out ($P_{RF,LPT}$). Taking into account the geometrical volume of the vehicle reservoir calculated in point 2 ($V_{g,v}$), the volume of hydrogen $V_{MPT,1}$ that the vehicle reservoir will store between these two pressures is calculated in the same way as in point 3.
8. This volume is multiplied by 3, as 3 vehicles are actually considered to be recharged. This volume $V_{MPT,3}$ corresponds to the volume to be supplied by the C-003 tank.
9. The maximum operating pressure $P_{max,MPT}$ of the C-003 tank is chosen. The amount of hydrogen calculated in point 8 ($V_{MPT,3}$) must therefore be supplied between this pressure and the pressure chosen in point 7 $P_{RF,MPT}$.
10. Using again Equation 5.5, the geometrical volume $V_{g,MPT}$ that tank C-003 must have is now calculated.
11. The process is repeated for the high pressure tank (C-004), choosing the operating pressures of the tank, $P_{RF,HPT}$ and $P_{max,HPT}$, and calculating in the same way, first the amount of hydrogen that must be supplied to the vehicle's reservoir $V_{HPT,3}$, and then the geometric volume $V_{g,HPT}$ that the C-004 tank must have.

The iterative process ends when the selected pressures, indicated in red in the scheme of Figure 5.15, result in similar geometric tank volumes (in the tolerance range ± 25 % of their average). With these geometric volumes the commercial models of the three tanks are selected, taking into account that they must be of the same size. The chosen manufacturer is again *NPROXX*, which

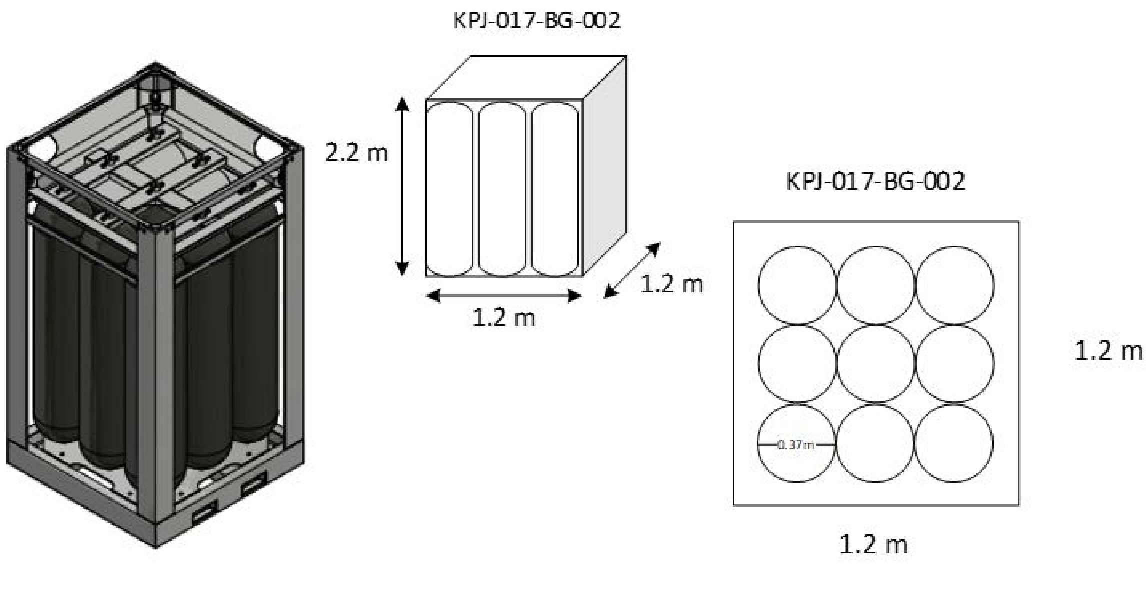


Figure 5.17: High pressure storage tank and dimensional views for cascade storage system (900 bar) [NPROXX, no date]

provides a tank model that can withstand a maximum pressure of 1000 bar. This model is called **KPJ-017-BG-002** and it is formed by a bundle containing 9 cylinders of type 4 whose volume is 100 liters of water each, with a total storage volume of 900 liters. The technical drawings provided by the manufacturer are shown in Figures C.3 and C.4 in the Annex C. Figure 5.17 includes the measurements of these dimensions for the bundle, and a picture of the external appearance of this component.

With the actual geometric volume of the selected tank, the non-usable hydrogen in each tank is calculated in the same way as in the first proposal. Knowing the maximum pressures of each of the three tanks ($P_{max,LPT}$, $P_{max,MPT}$ and $P_{max,HPT}$) and the actual geometric volume, the maximum hydrogen capacity in normal cubic meters that each tank can store under these circumstances can be calculated from Equation 5.5. By subtracting from this value the volumes that each tank must supply to the vehicle reservoir ($V_{LPT,3}$, $V_{MPT,3}$ and $V_{HPT,3}$), the amount of non-usable hydrogen in each tank can be obtained. It should be pointed out that these volumes have had to be slightly adjusted for the sum of all of them to be greater than the minimum amount to be stored (166.8 Nm^3).

Finally, the actual refuelling pressures obtained with the actual geometric volume are also calculated. The volume of non-usable hydrogen is the lower limit to which the pressure falls within the tank. The pressure can be calculated from this volume, isolating it from Equation 5.5, as follows:

$$P_x = \frac{0.9915 \cdot \frac{V_{No\ used\ H_2}}{V_g}}{1 - 0.0007 \cdot \frac{V_{No\ used\ H_2}}{V_g}} \tag{5.15}$$

Table 5.6: Cascade storage system (900 bar) characteristics

	LPT C-002	MPT C-003	HPT C-004
Maximum pressure (bar) $P_{max,\ xPT}$	320	650	900
Refuelling pressure (bar) $P_{RP,xPT}$	200	464	700
Theoretical usable hydrogen (Nm^3) $V_{xPT,3}$	58.86	62.10	42.30
Theoretical geometric volume (l) $V_{g,xPT}$	683.41	642.23	512.45
Actual geometric volume (l)	900	900	900
Maximum storage capacity at $P_{max,\ xPT}$ (Nm^3)	236.94	404.42	478.86
Actual usable hydrogen (Nm^3)	60	64	44
Actual non-usable hydrogen (Nm^3)	176.94	340.42	434.86
Actual refuelling pressure (bar)	226.04	510.0	723.93

Once this pressure is calculated, it must be checked that it does not fall below the theoretical refuelling pressure of each tank. Table 5.6 shows the final characteristics of each tank, as well as the non-usable hydrogen and the actual refuelling pressure calculated from the selected commercial model. As observed in this table, the actual pressure is higher than the theoretical one, which shows that the procedure has been carried out properly and is valid for sizing. Furthermore, if we add up the volumes of non-usable hydrogen of the three tanks (952.23 Nm^3), the resulting volume of wasted hydrogen is less than that obtained with the first solution, which was discarded. Again, this demonstrates that the cascade storage system is more suitable for the facility since less hydrogen is wasted, as the system requires smaller storage tanks.

450 bar Storage Tank System

For the second storage system that will supply the HRS working at a pressure of 350 bar, the procedure is exactly the same as the previous one. Two solutions are again proposed, the first storing the hydrogen in a single tank and the second using a cascade storage.

For the first design solution, an amount of hydrogen of 39.70 Nm^3 must be supplied between pressures of 450 and 350 bar. Using Equation 5.14 for these pressures, the geometric volume of the tank is calculated giving a value of 648.03 liters. The manufacturer *Linde* offers tanks that are suited to these characteristics, so in this case the actual technical data is taken from a tank capable of operating at a maximum pressure of 550 bar with a geometric volume of 1170 litres. As in the previous case, using Equation 5.5, the normal volume is calculated under the actual technical conditions of geometric volume with a maximum pressure to be supported of 450 bar. By performing this calculation, it is estimated that the maximum capacity of the tank at that operating pressure is 402.99 Nm^3. If this value is now subtracted to the amount of hydrogen to be supplied (39.70 Nm^3), the value of hydrogen that remains stationary in the tank (non-usable hydrogen) is 363.29 Nm^3.

The second solution is the cascade storage system, in which in addition to sizing the three tanks needed, the volume of non-usable hydrogen of the actual commercial models is also calculated

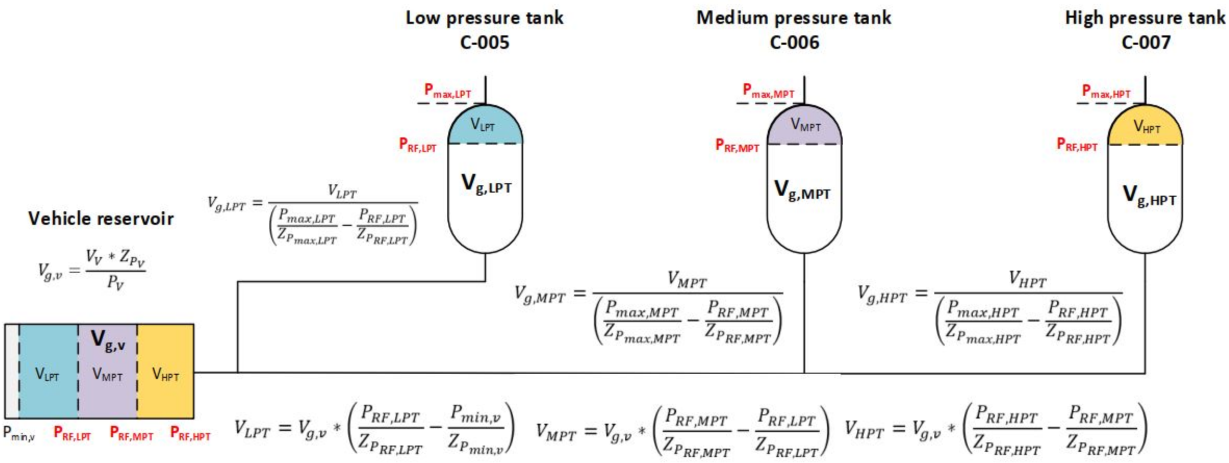


Figure 5.18: Calculation procedure for the hydrogen cascade storage system (450 bar)

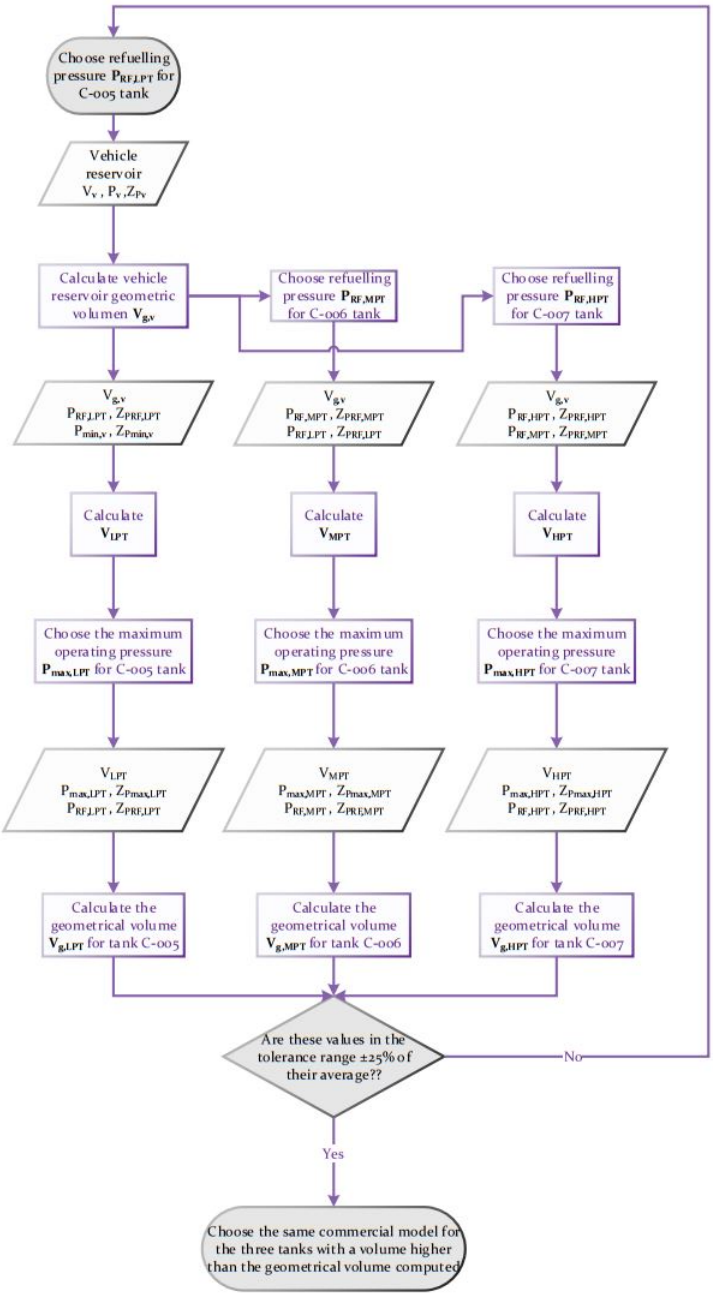


Figure 5.19: Flow chart for calculation procedure of hydrogen cascade storage system (450 bar)

to compare with the previous design solution. In addition, it will also be verified that the actual pressures of the tanks of the selected commercial model are higher than the theoretical ones chosen to carry out the iterative process, as was done in the previous case. As before, three tank will be placed to make up the system, each of them working at low, medium and high pressure (C-005, C-006 and C-007). The calculation procedure is exactly the same, with the small difference that this time only one reservoir of the vehicle will be modelled, which will have to store the total required amount of hydrogen (39.70 Nm^3). This difference is due to the fact that in this case, the type of vehicle that refuels does not have a reservoir of equal capacity, since the bicycle has a reservoir of 0.034 kg and the MHE of 3.4 kg. This makes it difficult to calculate

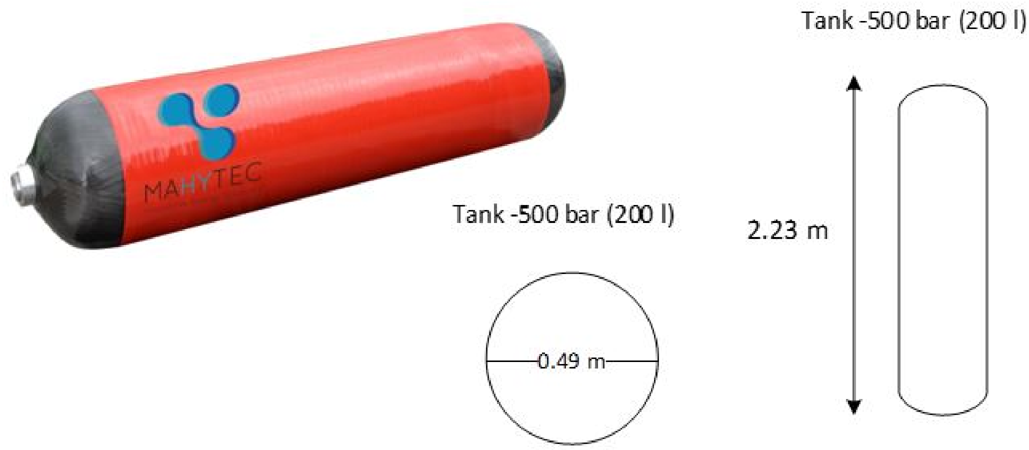


Figure 5.20: High pressure storage tank and dimensional views for cascade storage system (450 bar) [MAHYTEC, no date]

the geometric volume of the tank and the fact that the normal volume to be supplied can be multiplied by a integer, as was done in the previous case. Therefore, the option is to model a single reservoir that can hold all the hydrogen consumption in order to carry out the tanks sizing. Therefore, if the calculation steps of the iterative process of the previous case are followed, the only difference is that steps 4 and 8 are removed, since it is not necessary to multiply by the number of vehicles. The scheme in the Figure 5.18 illustrates the parameters to be determined, with the equations updated for this case. As in the previous case, the parameters that appear in red are the pressures that must be chosen to carry out the iterative process that converges in a similar geometric volume of tanks. Again, the flow chart in Figure 5.19 is included, which provides further clarification on the procedure to be followed.

Once the geometric volumes of the tanks have been calculated through the iterative process, the commercial models are selected. In this case the manufacturer is *MAHYTEC*, a French company that offers inventive solutions in energy storage. The tank model selected is the **Tank - 500 bar 200 L /300 L** [MAHYTEC, no date], which has two storage sizes. For this case, and according to the geometric volumes calculated, the model selected is that with 200 liters water capacity. The technical data sheet for this model can be found in the figure C.5 in the Annex C. Figure 5.20 includes the measurements of the dimensions for the tank, and a picture of the external appearance of this component.

Table 5.7 shows the final calculated characteristics of each tank, as well as the non-usable hydrogen and the actual refuelling pressure calculated from the selected commercial model. As can be seen in this table, the actual pressure is higher than the theoretical one, which shows again that the procedure has been carried out properly and is valid for sizing. Furthermore, if we add up the volumes of non-usable hydrogen of the three tanks (126.11 Nm3), this volume of wasted hydrogen is less than that obtained with the first solution (363.29 Nm^3), and therefore the first solution can be discarded.

Table 5.7: Cascade storage system (450 bar) characteristics

	LPT C-005	**MPT C-006**	**HPT C-007**
Maximum pressure (bar) $P_{max, xPT}$	250	320	450
Refuelling pressure (bar) $P_{RP,xPT}$	120	229	350
Theoretical usable hydrogen (Nm^3) V_{xPT}	14.24	12.19	11.86
Theoretical geometric volume (l) $V_{g,xPT}$	138.64	188.22	193.23
Actual geometric volume (l)	200	200	200
Maximum storage capacity at $P_{max, xPT}$ (Nm^3)	42.86	52.65	68.89
Actual usable hydrogen (Nm^3)	15	12.8	12
Actual non-usable hydrogen (Nm^3)	27.86	39.85	56.89
Actual refuelling pressure (bar)	153.06	229.6	352.12

5.4.4 Hydrogen boosters

For this particular application, the installation of a booster is preferable to the membrane compressor because it is a very compact and less costly system. Its operation is based on a compressed air piston which drives the compression of hydrogen. For a given outlet flow, a higher output pressure is achieved as the pilot air pressure is increased. On the other hand, for the same discharge pressure, the flow that can be treated by the booster is reduced as the compressed air pressure does. The manufacturer chosen for the hydrogen boosters is *Haskel*, a company that designs and manufactures the industry's most reliable and comprehensive range of pneumatic or hydraulic-driven, high-pressure, liquid pumps, gas boosters, air pressure amplifiers and high-pressure valves and system components, with 70 years of high-pressure innovation experience.

When selecting the compressor, the maximum and minimum pressures of the low pressure storage tank must be considered (40 bar and 13.32 bar respectively) since they are the inlet pressures to the booster. Based on these pressures, and on the calculated amount of hydrogen to be supplied to each line of the cascade storage, the manufacturer has proposed a design solution for this installation which is the serial coupling of two of its boosters: **AGD-32** (H_2 model number 86985) feeding into a **AGD-152** (H_2 model number 86988).

These models are Pneumatic Driven Gas Boosters, which consist of a large area reciprocating air drive piston directly coupled by a connecting rod to a small area gas piston. Isolation of the gas compression chambers from the air drive section is provided by three sets of dynamic seals. The intervening two chambers are vented to atmosphere, and air drive contamination is prevented from entering the gas stream. There are two distinct sections in the design: the air drive section and the gas barrel section. The air drive section should perform reliably within a temperature range of -4 °C to 65 °C. Lower temperatures will cause air/gas leakage and higher temperatures will reduce seal life. According to Haskel recommendations, the minimum air class

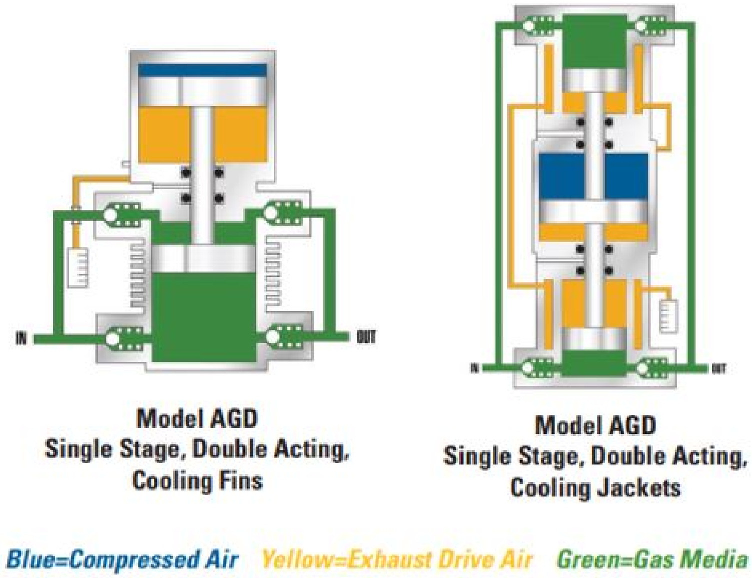


Figure 5.21: AGD Pneumatic Driven Gas Booster Configurations [HASKEL, no date]

should be Class 4 air quality. On the other hand, low temperatures for the gas barrel section normally have little effect on the operation of standard parts and seals. Actually, the heat from the compressing gas helps to balance out an acceptable temperature, being the maximum average acceptable temperature 115 °C [HASKEL, no date]. The models chosen, Double Acting Single Stage (AGD) boosters, boost efficiently large volumes of gas at low to medium compression ratios. Figure 5.21 shows the different configurations for these types of boosters where the different internal chambers through which the different gases flow can be appreciated.

Using the simulation provided by the manufacturer, it is possible to know the hydrogen flow that the booster must supply to each of the cascade storage lines, assuming the most unfavourable

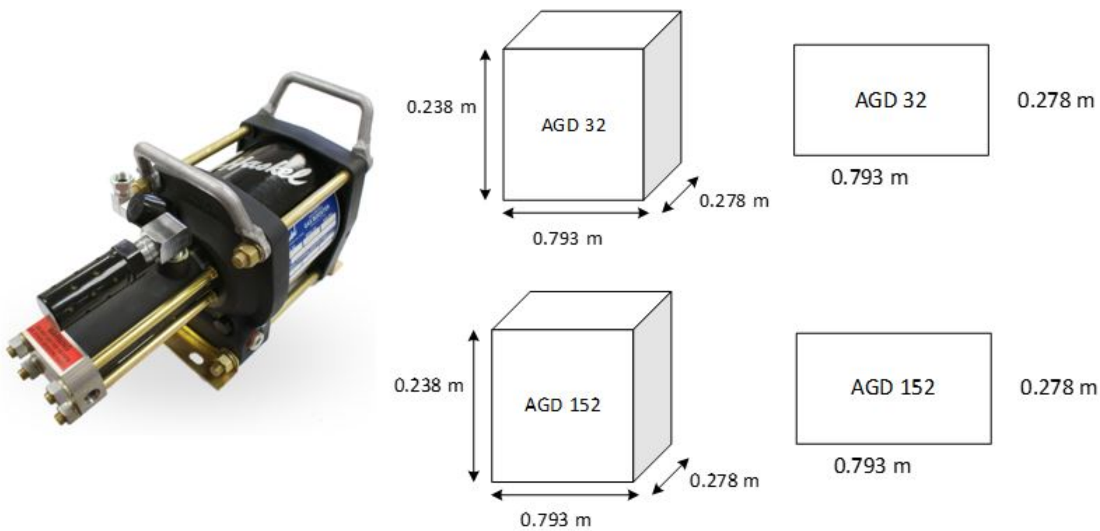


Figure 5.22: AGD Pneumatic Driven Gas Boosters and dimensional views [HASKEL, no date]

Table 5.8: Boosters simulation results by Haskel

	Cascade storage line (900 bar)		Cascade storage line (450 bar)	
Supply pressure (bar)	13.32	40	13.32	40
Interstage pressure (bar)	96.80	196.91	74.80	165.68
Outlet pressure (bar)	900	900	450	450
Gas outlet flow (Nm^3/h)	4.38	9.92	4.8	11.42
Air drive pressure (bar)	7	7	7	7
Air drive quantity for each booster (m^3/h)	50.94	50.94	50.94	50.94
Total system air drive quantity (m^3/h)	101.88	101.88	101.88	101.88
Cycles per minute (AGD-32)	31	24	33	27
Cycles per minute (AGD-152)	24	26	32	33

situation where the inlet pressure is minimum (13.32 bar) and the final outlet pressure, up to which the booster must compress, is 900 bar or 450 bar (depending on the corresponding cascade storage line). As a result of the proposed configuration, the two boosters are connected in series and there must be therefore an intermediate compression pressure between the two compression stages (between the two boosters). The simulation provided by the manufacturer also includes the case where the inlet pressure is maximum (40 bar). Since the intermediate pressure in the case of the cascade storage line at a pressure up to 900 bar is different from the corresponding line at 450 bar, two boosters must be placed in series for each cascade storage lines. This means that

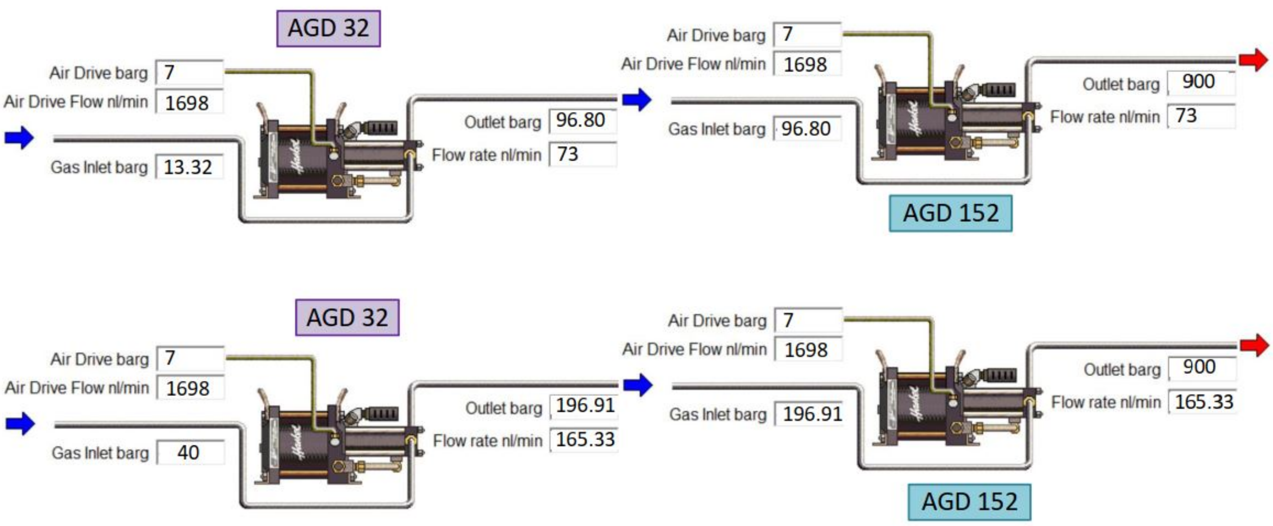


Figure 5.23: AGD Boosters series connection simulations (900 bar line). Minimum supply pressure (top) and maximum supply pressure (bottom) [HASKEL, no date]

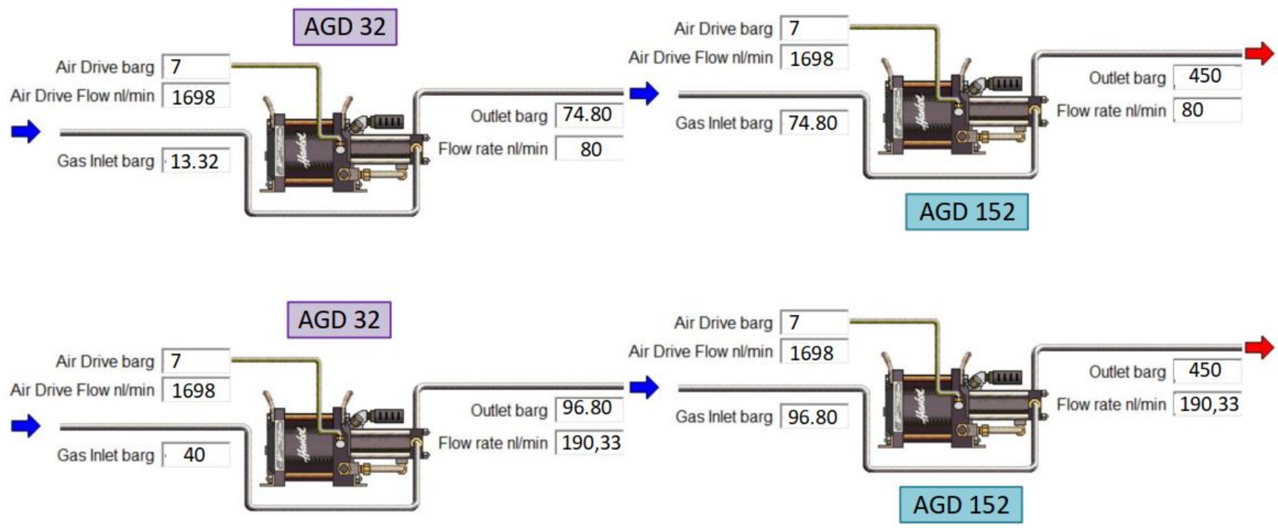


Figure 5.24: AGD Boosters series connection simulations (450 bar line). Minimum supply pressure (top) and maximum supply pressure (bottom) [HASKEL, no date]

there will be a total of 4 boosters, 2 of the AGD-32 model and another 2 of the AGD-152 model. The technical drawings with the dimensions of the boosters models can be found in Figure C.6 in Annex C. Figure 5.22 includes the measurements of the dimensions for both boosters, and a picture of the external appearance of this component.

Table 5.8 contains the results of the simulation carried out by the manufacturer, where the different operation points for the mentioned case of the minimum and maximum inlet pressure and for both lines of the cascade storage are shown. These results are also available in Figures C.7 and C.8 in Annex C. The most relevant data of this table are also shown in Figures 5.23 and 5.24, which visually explain the series connection of both boosters for the 900 bar cascade storage line and the 450 bar cascade storage line.

5.4.5 Air compressor

As mentioned above, the operation of hydrogen boosters requires the supply of compressed air through a compressor. According to the operating specifications provided by the manufacturer of the boosters (see Table 5.8), the pilot air pressure should be 7 bar and each of the boosters require an air quantity of 50.94 m^3/h, making a total of 203.76 m^3/h (3.39 m^3/min). The manufacturer chosen to supply this component is the German family company *Kaeser Kompressoren*, a leading global supplier of compressed air products and services. The company was consulted on the selection of the compressed air compressor and, after assessing the conditions of the installation and the application to the boosters, proposed the following design solution. The facility will have a single screw compressor with a variable speed drive that will be responsible for supplying the appropriate amount of air to each of the boosters through the same compressed air line. The model selected is the **ASK 40 SFC**, of the ASK series that has screw compressors capable of supplying an air flow rate between 0.79 and 4.65 m^3/min, at pressures between 5.5 and 15 bar. This model has low energy consumption, a low noise level, requires little maintenance, is reliable and delivers top quality compressed air. As mentioned above, the ASK 40 SFC is equipped

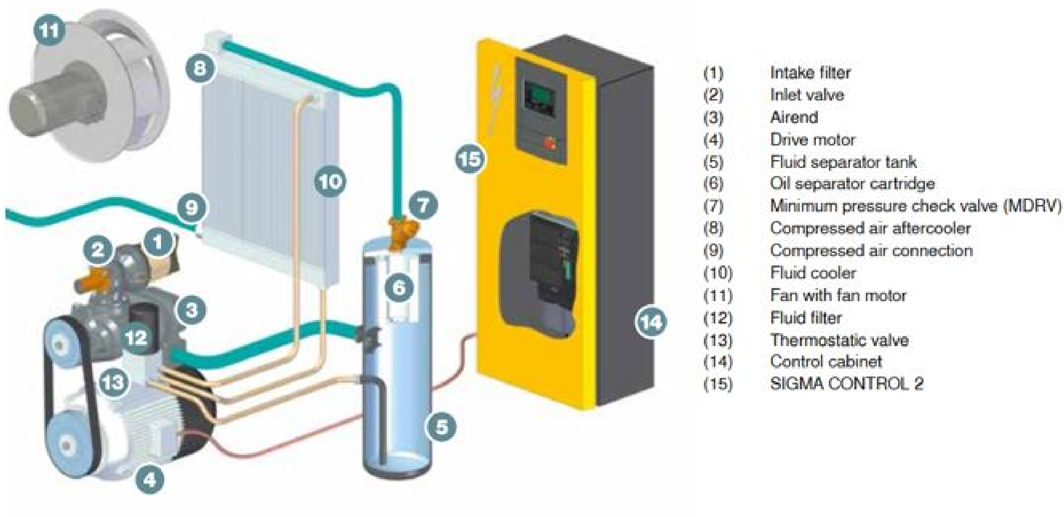


Figure 5.25: Air screw compressor working [KAESER COMPRESSORS AC, no date]

with a SIGMA FREQUENCY CONTROL (SFC) frequency converter. This device allows the volumetric flow rate to be adapted to the actual demand for compressed air by modifying its speed and depending on the pressure. The possibility of reducing the maximum pressure helps to save energy, as each reduced bar means an energy saving of 6-10 %. The different components housed in the compressor cabinet can be seen in Figure 5.25.

The working is as follows. As observed in the figure, the air to be compressed passes through the intake filter (1) and the inlet valve (2) to the compressor airend (3) with SIGMA PROFILE. An efficient electric motor (4) drives the airend (3). The oil injected during compression for cooling purposes is re-separated from the air in the separator tank (5). The compressed air passes through the 2-stage oil separator cartridge (6) and the minimum pressure check valve (MDRV) (7) to the compressed air aftercooler (8). The compressed air without condensate then leaves the unit via the compressed air connection (9). The heat generated in the compression is removed with the cooling oil by means of a heat exchanger installed in the fluid cooler (10) with a separate fan with fan motor (11). The cooling oil is then cleaned in the environmentally friendly fluid filter (12). The thermostatic valve (13) ensures consistent operating temperatures. The control cabinet (14) includes the internal SIGMA CONTROL 2 compressor controller (15) and the frequency converter (SFC) [KAESER COMPRESSORS AC, no date].

Table 5.9 shows a summary of the main technical characteristics of the compressor. In this table it can be confirmed that the selected model is suitable, since both the pressure required and the flow rate demanded by each of the boosters fall within the working ranges offered by this compressor model. The technical specifications of this component can be found on the data sheet in Figure C.9 of Annex C. In addition, Figure 5.26 includes the measurements of the dimensions for the air compressor, and a picture of the external appearance of this component.

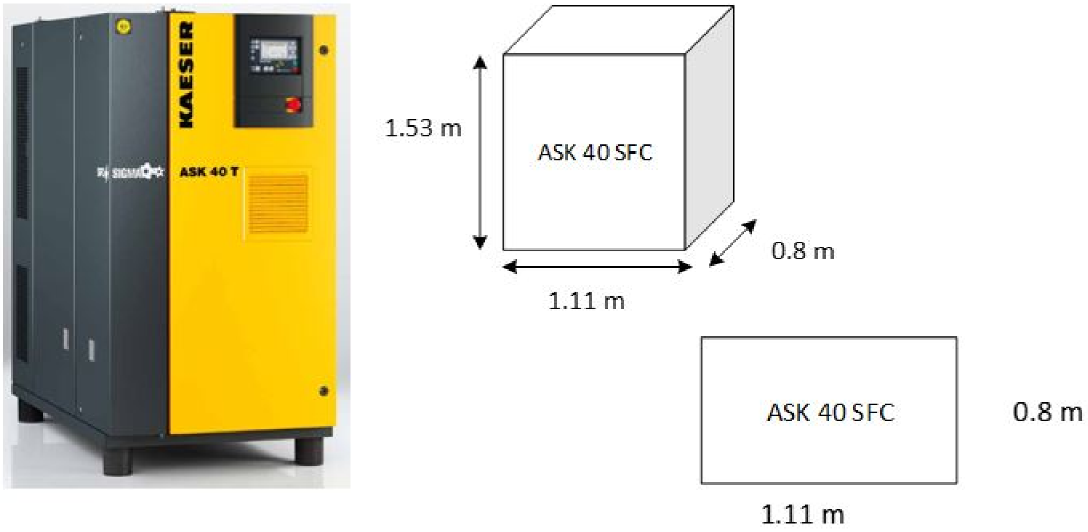


Figure 5.26: Air screw compressor and dimensional views [KAESER COMPRESSORS AC, no date]

Table 5.9: Air screw compressor Technical specifications. Model ASK 40 SFC [KAESER COMPRESSORS AC, no date]

Maximum operating pressure (bar)	8
Drive motor rated power (kW)	22
Full load motor performance (%)	92.7
Flow rate range (m^3/min)	0.94-4.08

5.4.6 Pressure regulators

As seen above, the pilot air, supplied by the selected air compressor, must provide an air intake to each of the boosters at a pressure of 7 bar. Since the air compressor compresses the air up to 8 bar, it is necessary to place a component (pressure regulator) between the compressor outlet and the booster inlet to set the pressure at 7 bar. As there are 4 boosters in the installation, it will be necessary to select 4 pressure regulators, one for each booster. The manufacturer selected to supply these components is *Festo*, a German worldwide leader industrial control and automation company. This enterprise is a global supplier of automation solutions using pneumatics, electronics and networks for all types of industrial processes and activities. The company has an online selection software to choose the right model through a feature search. Entering the operating properties for the particular case of the installation (regulator providing a pressure of 7 bar, working with compressed air, electrically drive), the suitable model is the **MS6-LRE** electrical pressure regulator. The MS series from Festo offers a complete concept for compressed air preparation, suitable for simple standard applications as well as application-specific solutions to the highest quality standards. It is possible to combined the regulator with different function modules, such as on/off and softstart valves with safety function, filter, pressure and flow sensors, dryers, sensors and lubricators. The electrical pressure regulators MS6-LRE series maintain incoming compressed air at the set output pressure. The output pressure is set indirectly via an integrated electrical drive unit, which can be operated either with digital inputs

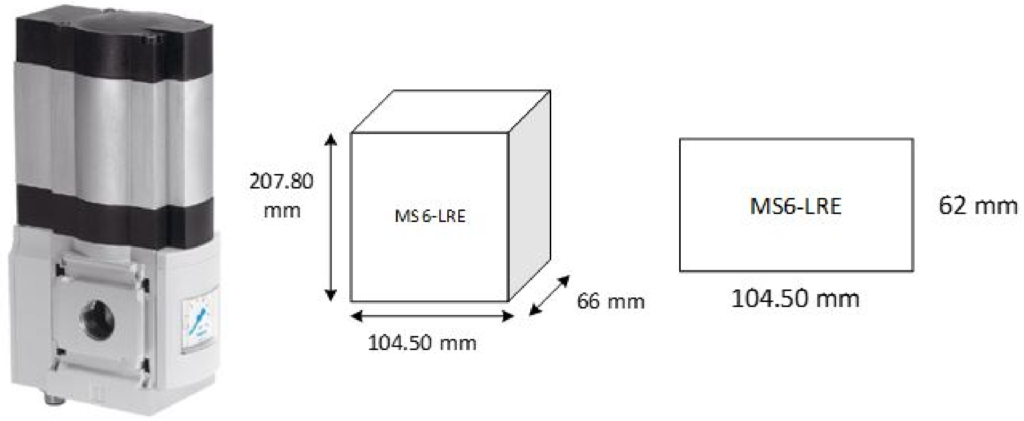


Figure 5.27: Pressure regulator and dimensional views [FESTO, no date]

or using the optional control and display unit [FESTO, no date]. The model data sheet with the technical specifications as well as the technical drawings can be found in Figures C.10 and C.11 of Annex C. In addition, Figure 5.27 includes the measurements of the dimensions for the pressure regulator, and a picture of the external appearance of this component.

5.4.7 Hydrogen dispenser

As mentioned above, two dispensers will supply hydrogen to the vehicles concerned, depending on whether the fuel cells in those vehicles require a pressure of 350 bar or 700 bar. The dispenser will supply the hydrogen from the high pressure storage cascade explained above. The equipment selected is a dispenser from the manufacturer *Haskel*. Figure C.12 of Annex C shows the data sheet of the Standard Hydrogen Refuelling Station model, where different models are available depending on the needs of the installation. Among them, the one selected for this particular case

Figure 5.28: Hydrogen E-dispenser [HASKEL, no date]

will be the E-dispenser, which can fit a heat exchanger in the base of it, and can achieve therefore a fast refuelling time. As can be seen from the specifications in this catalogue, the dispenser allows several dispensing options, including the cases of the present installation. Specifically, this type of dispenser is capable of dispensing at 70 MPa (700 bar) for Light Duty Vehicles up to 10 kg and at 35 MPa (350 bar) for Heavy Duty Vehicles up to 50 kg. It is therefore concluded that it is suitable for the installation. Figure 5.28 includes a picture of the external appearance of this component.

5.5 Hydrogen installation

The hydrogen installation will interconnect all the elements described above, according to the process and instrumentation diagram (see the corresponding drawing number 4 and 5 in Part IV). The installation will be made of 316L stainless steel, with diameters and thicknesses suitable for the pressures and flows of each section, and the instrumentation and valves will be installed using the most suitable joining methods.

For the sizing of the hydrogen pipes, the diameters corresponding to each of the sections, which will depend on the pressure and volumetric flow conditions, must be determined. The procedure used to do this, considering for sake of simplicity an incompressible flow, is described as follows.

1. The necessary starting data is:
   (a) Length of pipe L in metres.
   (b) Pipe roughness ϵ. A roughness of 0.1 mm is assumed.
   (c) Working temperature T_w. A temperature of 30 °C is assumed.
   (d) Pipe working relative pressure P_w. The maximum pressure that the pipe section can withstand will be considered, as this is the most unfavourable case.
   (e) Maximum pressure drop ΔP. A maximum pressure drop of 2 % is assumed.
   (f) Volumetric flow of hydrogen that circulates through each section of pipe Q_N in normal conditions. The maximum value circulating through the pipe will be considered (the most unfavourable case).
   (g) Absolute or dynamic viscosity of the hydrogen μ. This value corresponds to 0.0000084 Pa·s.
   (h) Pressure and temperature in normal conditions. The pressure is the atmospheric one ($P_N = 101337.3$ Pa) and the temperature is 0 °C ($T_N = 273.15$ K).
   (i) Molecular weight of hydrogen (M.W). This value corresponds to 2 g/mol.
2. The R_g gas constant for hydrogen is calculated from the universal gas constant R=8.314 J/K·mol.

$$R_g = \frac{R}{M.W} \tag{5.16}$$

3. The density is determined for the normal conditions and under working conditions. Absolute pressures in Pascals are used which are calculated by adding the atmospheric pressure to

the value of the relative pressure. Absolute pressures are distinguished in the equations by the superscript *.

$$\rho_N = \frac{P_N}{R_g \cdot T_N} \tag{5.17}$$

$$\rho_w = \frac{P_w^*}{R_g \cdot T_w} \tag{5.18}$$

4. The mass flow rate under normal conditions is determined from the volumetric flow rate, expressed in normal cubic metres per second.

$$G = Q_N \cdot \rho_N \tag{5.19}$$

5. From the mass flow, the working volume flow is determined taking into account the previously calculated working density.

$$Q_w = \frac{G}{\rho_w} \tag{5.20}$$

6. The specific weight is determined from the calculated working density and the gravitational constant g.

$$\gamma_w = \rho_w \cdot g \tag{5.21}$$

7. The pressure losses allowed along the pipeline are calculated.

$$h_f = \frac{P_w \cdot \Delta P}{\gamma_w} \tag{5.22}$$

8. The kinematic viscosity at operating temperature is calculated from the absolute viscosity and density under working conditions.

$$\nu = \frac{\mu}{\rho_w} \tag{5.23}$$

9. The diameter is calculated by an iterative process in which the following equations are used:
   - Darcy-Weisbach equation.

$$h_f = \frac{8 \cdot f \cdot L \cdot Q_w^2}{\pi \cdot D_t^5 \cdot g} \tag{5.24}$$

   - Swamee-Jain equation.

$$f = \frac{0.25}{\left(log\left(\frac{\epsilon_r}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right)^2} \tag{5.25}$$

- Relative Roughness equation.

$$\epsilon_r = \frac{\epsilon}{D_t} \tag{5.26}$$

- Reynolds number equation.

$$Re = \frac{4 \cdot Q_w}{\pi \cdot D_t \cdot \nu} \tag{5.27}$$

10. The iterative process starts with the assumption of a coefficient of friction (e.g. f= 0.016), and from it the theoretical diameter D_t is calculated using the Darcy equation 5.24. With the value of this theoretical diameter D_t, the relative roughness and Reynolds number can be calculated from equations 5.26 and 5.27, respectively. Finally, the Swamee-Jain equation 5.25 is used to calculate the new friction factor and compared to the initially assumed value. The process is repeated iteratively until reaching convergence when the estimated f coincides with the calculated f, as shown in flow diagram bellow.

$$f_{est} \rightarrow D_t \ (Eq.\ 5.24) \rightarrow \begin{cases} \epsilon_r \ (Eq.\ 5.26) \\ Re \ (Eq.\ 5.27) \end{cases} \rightarrow f \ (Eq.\ 5.25) \rightarrow f = f_{est}?$$

11. The diameter chosen will be the inner diameter of the commercial catalogue which is immediately higher than the value of the calculated theoretical diameter.

The process described applies to each of the pipe sections ordered below:

- Line 1. Piping from the electrolyser outlet to the low pressure storage.
- Line 2.1. Piping from the outlet of the low pressure storage to the inlet of the K-001 booster.
- Line 2.2. Piping from the outlet of the low pressure storage to the inlet of the K-003 booster.
- Line 3. Piping from the K-001 booster outlet to the K-002 booster inlet.
- Line 4. Piping from the K-003 booster outlet to the K-004 booster inlet.
- Line 5. Piping from the K-002 booster outlet to the 900 bar high pressure storage.
- Line 6. Piping from the K-004 booster outlet to the 450 bar high pressure storage.
- Line 7. Pipe from the outlet of the high pressure storage of 900 bar to the 700 bar HRS.
- Line 8. Pipe from the outlet of the high pressure storage of 450 bar to the 350 bar HRS.

The selected manufacturers for the hydrogen pipelines are Eduardo Cortina and Goodfellow. The first one provides a series of stainless steel ISO pipes, with external diameters from 17.2 mm to 323.9 mm [EDUARDO CORTINA, no date]. The second manufactur has a series of AISI 316L stainless steel tubes, with external diameters from 1 mm to 9.5 mm [GOODFELLOW, no date]. Since each manufacturer provide a different range of diameters, one or the other will be more suitable depending on the theoretical value of the diameter required by the pipe line. Table 5.10 summarizes the characteristics of each of the hydrogen lines, with the input parameters used for the calculation and the commercial diameter chosen from the calculated theoretical one. It is worth to highlight that the flow rate of lines 7 and 8 has been calculated from the vehicle's tank

Table 5.10: Hydrogen installation. Piping diameters.

Line	Lenght (m)	Maximum pressure (bar)	Maximum flow rate (Nm^3/h)	Dint (mm)	Dext (mm)
1	17.1	40	5.2	12.7	21.3
2.1	16.43	40	9.92	19.05	26.9
2.2	15.39	40	11.42	19.05	26.9
3	0.5	197	9.92	3.8	4.2
4	0.5	166	11.42	4	6
5	11.41	900	9.92	3.8	4.2
6	18.59	450	11.42	4	6
7	11.30	900	834	19.05	26.9
8	10.39	450	756.16	25.4	33.7

refuelling time. Accordingly, it has been taken into account for each of the two HRS, the vehicle that has the largest tank (the car in the HRS of 700 bar and the MHE in the HRS of 350 bar). To calculate the necessary flow rate, the amount of hydrogen that fits in the tank is divided by the refuelling time in hours. The amount of hydrogen and the refuelling time are 5 kg (see Table 5.4) and 4 minutes [Berger, 2017] for the car, and 3.4 kg and 3 minutes [Berger, 2017] for the MHE (see Table 5.4). The conversion of the kilograms of hydrogen that can fit in the tank to nominal cubic metres can be carried out using the conversion tables in Figure A.2 of Annex A.

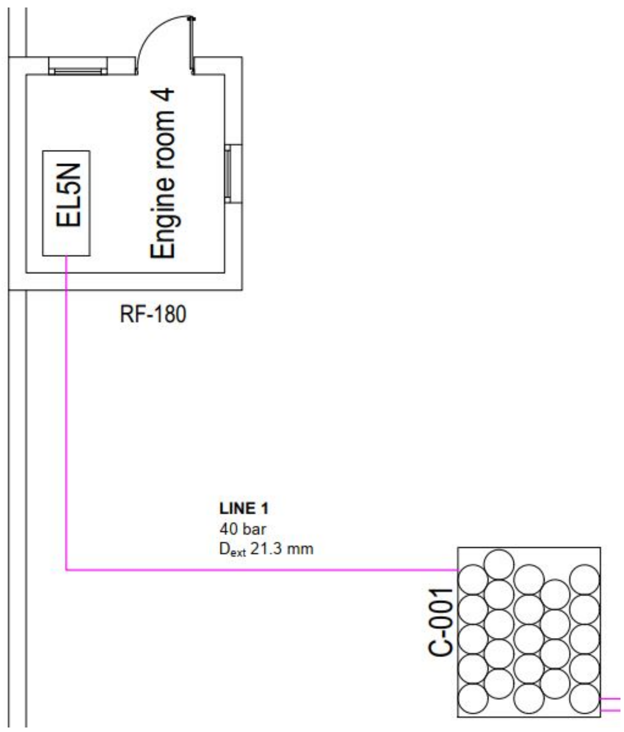


Figure 5.29: Hydrogen installation. Line 1

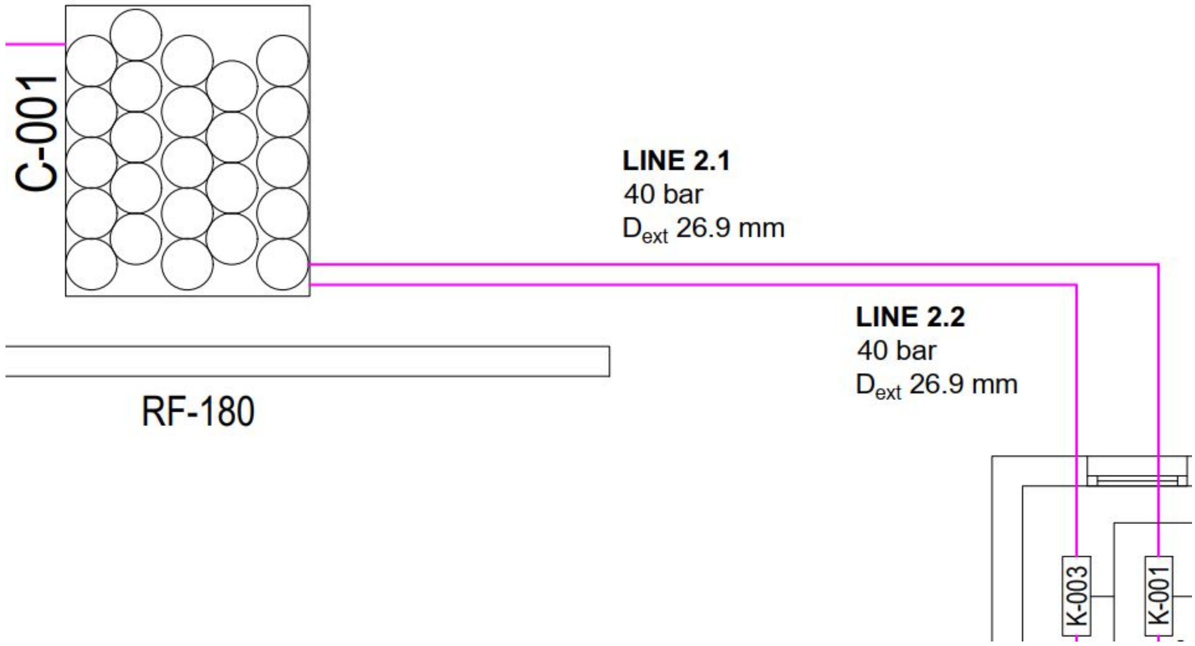


Figure 5.30: Hydrogen installation. Line 2.1 and line 2.2

Figures 5.29, 5.30, 5.31, 5.32 and 5.33 show the captures of technical drawing number 5 (see Part IV), where the name of each of the hydrogen lines, their maximum pressure and the selected outer diameters are indicated.

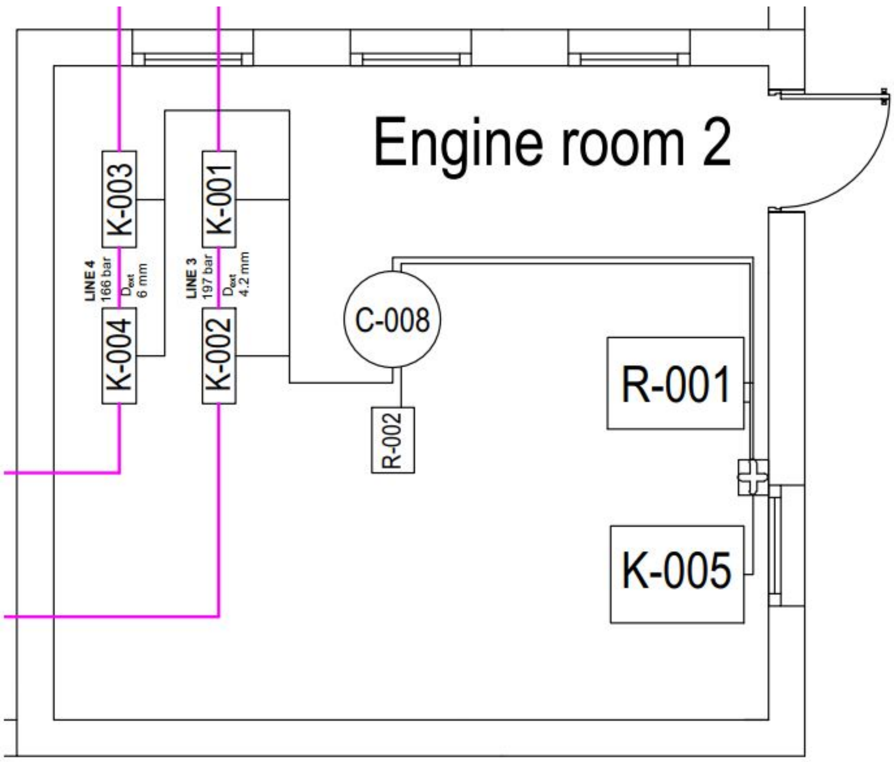


Figure 5.31: Hydrogen installation. Line 3 and line 4

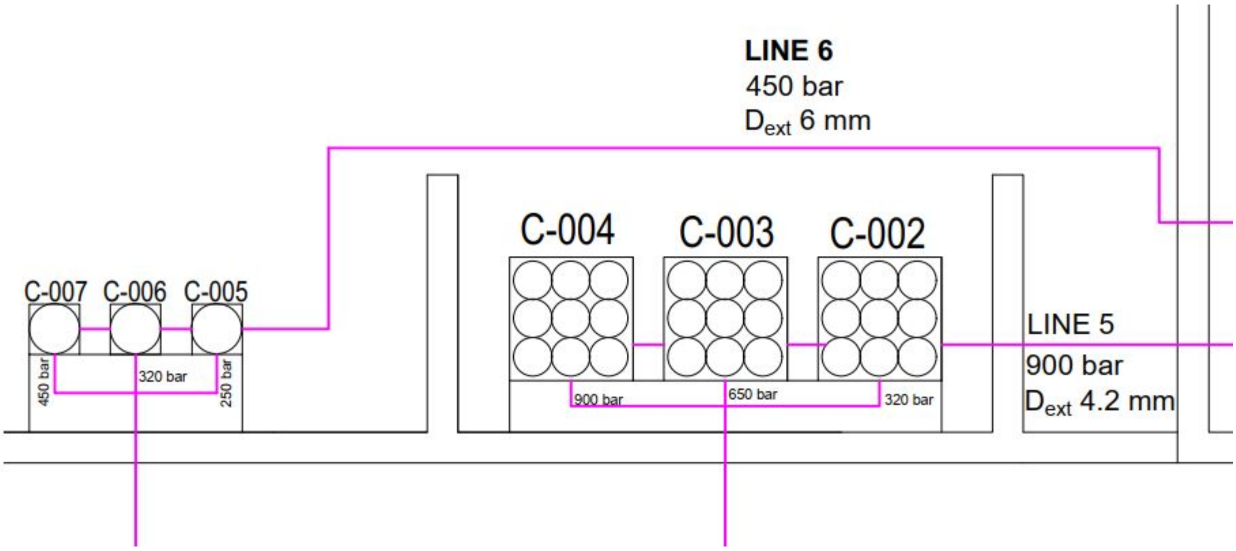


Figure 5.32: Hydrogen installation. Line 5 and line 6

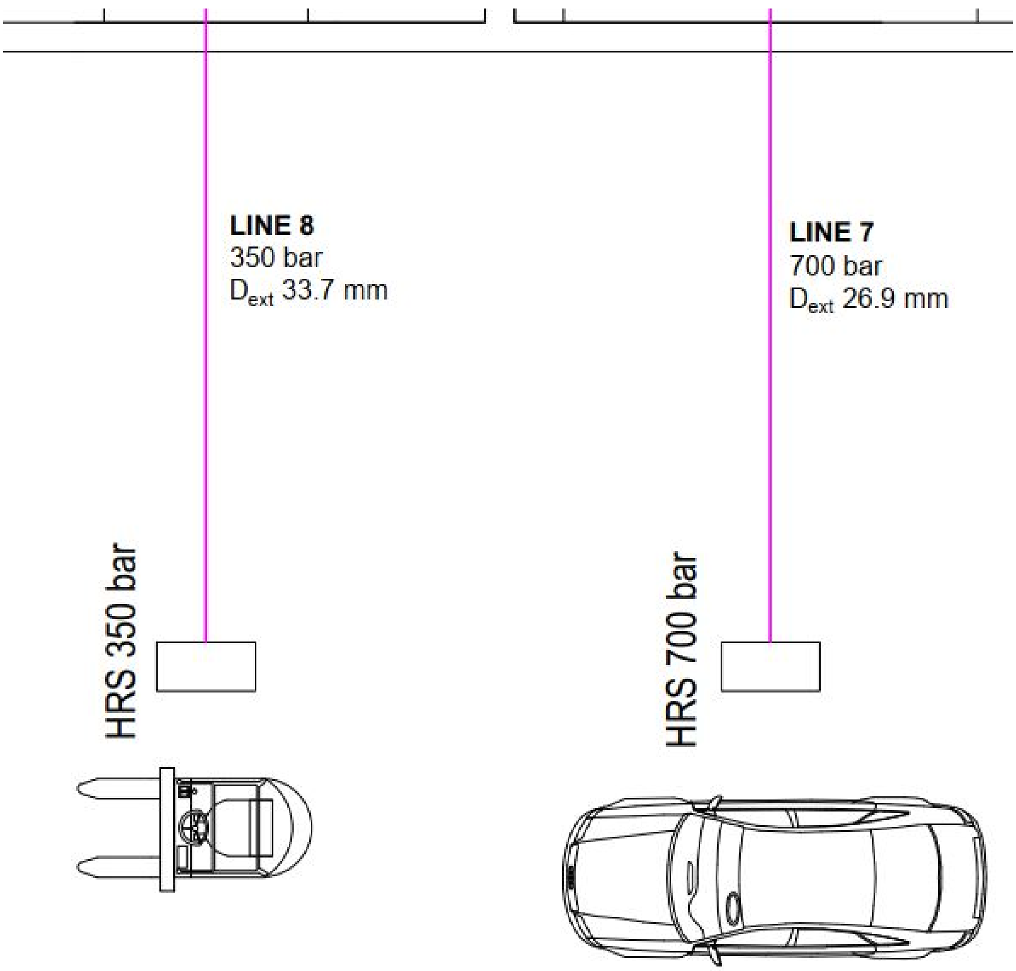


Figure 5.33: Hydrogen installation. Line 7 and line 8

5.6 Civil works

The civil work associated with the HRS will be necessary to comply with those safety requirements in terms of layout, safety distances, as well as the different existing regulations. The enclosure for HRS will be built on a concrete floor with 4 engine rooms: one to house the associated electrical and control panels (Engine room 1), another to house the equipment for carrying out the compression of hydrogen (Engine room 2), a third to house the nitrogen installation (Engine room 3) and finally a last one to house the cabinet containing the electrolyser and the auxiliary systems for the correct production of hydrogen (Engine room 4). All the engine rooms will have sufficient natural ventilation through windows to ensure a safe environment. In addition, both doors and windows will be located at minimum safety distances from the hydrogen storage systems.

A RF-180 separation wall will be installed between the dispensers and the rest of the equipment of the HRS to comply with MIE-APQ 5, for the separation between category 4 storage and activities classified as hazardous and explosive, in addition to adding security to the installation. Likewise, the high pressure storage will be delimited on its sides with RF-180 walls. The low pressure storage will also be protected laterally by an RF-180 wall in the part closest to the high pressure storage to ensure optimum safety conditions. Both storage areas will include a sandwich panel cover to protect the containers from solar radiation and frost. In addition, all the machine rooms will be built with 30 cm RF-180 prefabricated concrete panels. For the construction of the four engine rooms, the necessary structural elements (beams, columns, joists, roofs) made of in-situ concrete or prefabricated panels will be set.

For each installation, the corresponding trench will be made where the type of conduit specified will circulate. The trench is formed by several layers, each with a different thickness. Depending on the type of installation, it will be filled with concrete or with selected soil around the pipe. The trenches will be built to house the foundation slabs and the bracing beams of the engine rooms, as well as the strips footing for the construction of the rest of the walls that delimit the installation. Different types of trenches have been built for this installation. The first type is the trench that is made to house the different layers that make up the soil, as shown in Figure 5.34.

Another type of trench is dug for each Engine Room in order to make the holes that contain the foundations. At each of the corners a trench is built for the foundation slab and filled with the

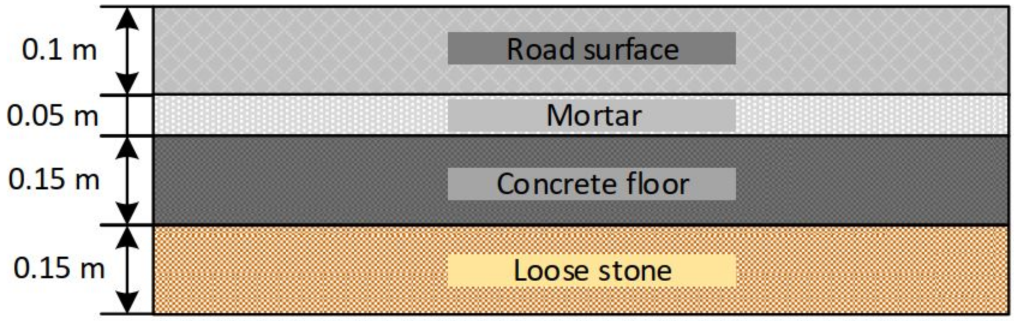


Figure 5.34: Construction detail of the floor trench

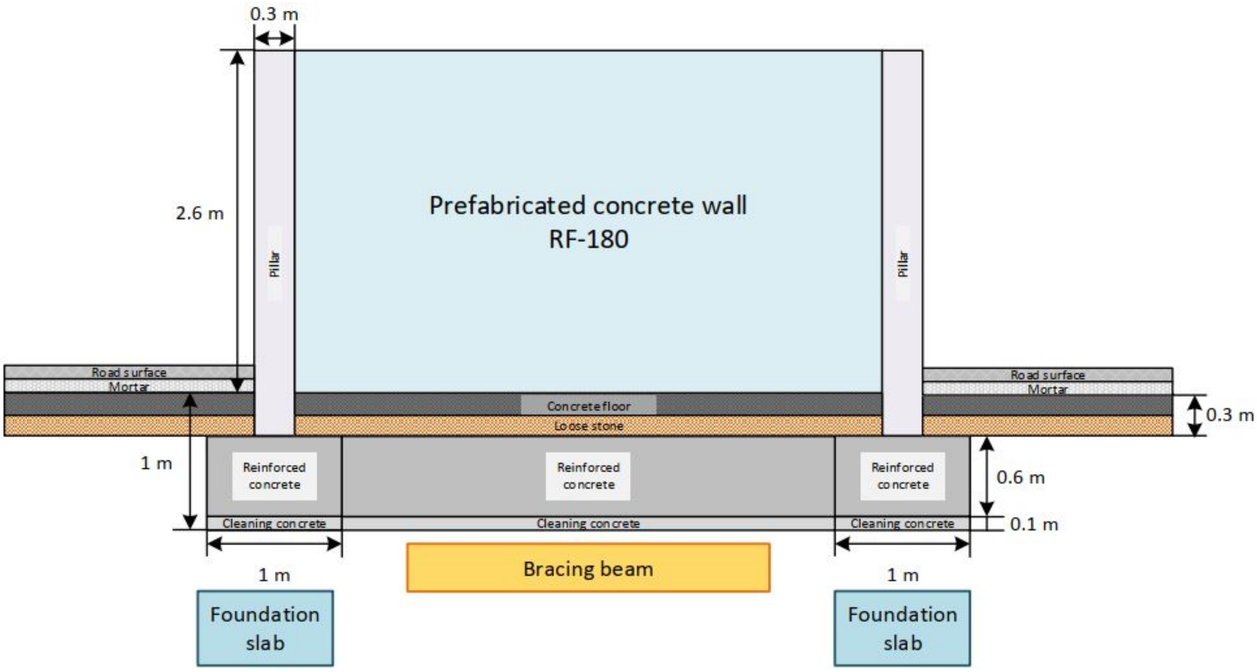


Figure 5.35: Construction detail of the Engine Rooms trench

different layers shown in Figure 5.35. This same figure also shows the bracing beams that are built to join the four foundations together.

In a similar way, trenches are built for the strip footings that will support the rest of the loose walls in the installation. Figure 5.36 shows the construction detail of this trench.

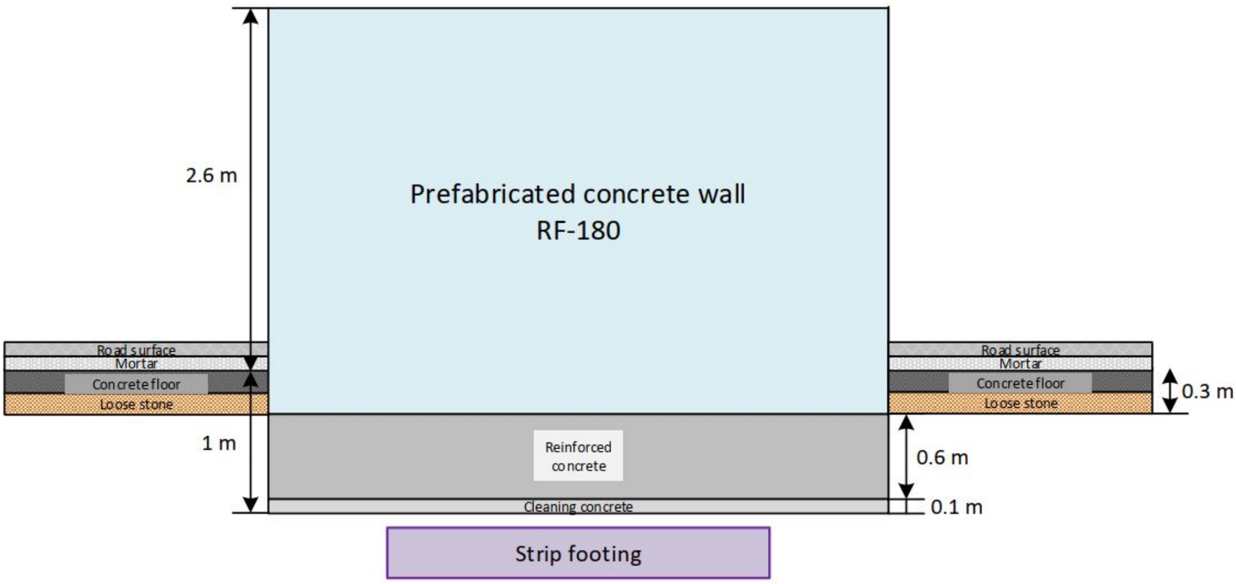


Figure 5.36: Construction detail of the walls trench

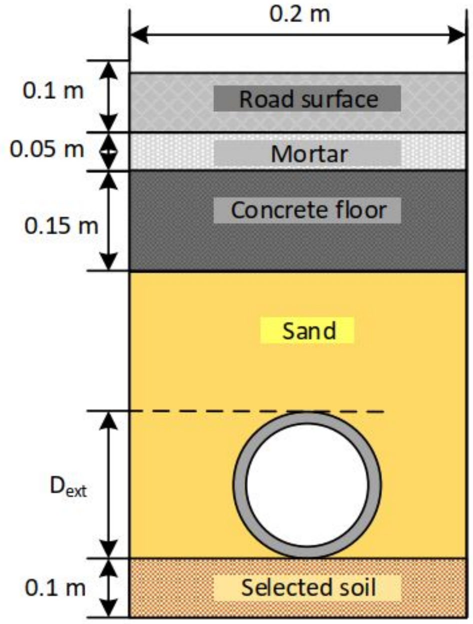


Figure 5.37: Construction detail of the hydrogen pipes trench

In addition, trenches will be built where conduits need to be installed. In this case, the only trench whose function is to house the hydrogen pipes will be built from the outlet of the high-pressure storage to each of the corresponding hydrogen dispensers. Figure 5.37 shows the construction detail of this trench.

The rest of the hydrogen pipelines will circulate in the open air, running through metal structures where these pipes can run aerially. The purpose of these guide structures is to prevent the pipes from being in dangerous areas that could interrupt the passage of personnel. As far as the electrical installation is concerned, it will be not necessary to build trenches to bury the electrical cables since, as will be seen in Section 5.7.1, the electrical mounting will be carried out by means of embedded conduits or conduits that run along the surfaces of the facility. Finally, the nitrogen installation will also circulate aerially, and not being therefore necessary to dig trenches for its installation.

There will be a perimeter fence surrounding the whole area with two automatic gates, one for the entry of vehicles and another for the exit. In addition, each gas storage system will be protected by a fence with a minimum height of 2 m equipped with at least one door, and both (gate and fence) made of metal material. The area where the vehicles stop to refuel will be separated from the rest of the facility by a wall. This space is large enough to allow the minimum turning radius of the vehicles, both at the entrance and exit of the installation. In addition, both hydrogen dispensers will be covered to protect them from the weather. The individual construction elements of the system can be found in the corresponding drawing number 2 in Part IV.

5.7 Auxiliary installations

5.7.1 Low voltage electrical installation

The UPV has a transformer centre that supplies the general low voltage panel located in the installation room. The distribution from the general low-voltage panel is carried out by means of secondary panels up to the storage system and the HRS.

In this case, since the electrical installation runs in a location with a risk of fire or explosion, it is necessary to follow the requirements of the Complementary Low-Voltage Technical Instruction ITC-29 (Special requirements for electrical installations in rooms with a risk of fire or explosion).

Additionally, as general criteria, the following must be met:

- Wherever possible, it should ensured that cables lay always underneath gas pipes carrying flammable gases.
- Connections between conductors and components must be made by suitable means to avoid ignition sources (sparks) as far as possible. In any case, discontinuities in cables must be avoided wherever possible.
- When defining monitoring strategies, it must be borne in mind that if the detector shows the presence of hydrogen above 20 or 40 % of the lower explosion limit, the equipment must be stopped and the power supply cut off as soon as possible.

The electrical diagram of the control and protection electrical panel can be found in Part IV (technical drawing number 6). It contains the main protection elements (automatic switches, magnetic starters, residual-current circuit breakers, engine generators) as well as the different branches that feed the electrical subsystems. There are four three-phase lines connected to the general automatic switch: a line feeding the electrolyser, a line feeding the air compression system, a line feeding the single-phase lighting circuit and a last line feeding the single-phase power circuit. The lighting circuit is arranged by two single-phase lines, each feeding a set of loads electrically. In the same way, the power circuit is made up of three single-phase lines that will in turn supply a series of connection points. The type of grounding follows the TT scheme, in which there is a direct grounding point (service ground). In this scheme, the grounding points of the electrical installation are connected to grounding points electrically independent of the grounding points for the earthing of the system. The electrical wiring is sized according to the maximum admissible current criterion to determine the cable section of the conductors, which are made of copper. The general procedure is described below:

1. The apparent power S of the load connected to the corresponding electric line is calculated, taking into account the active power P and the power factor $cos(\phi)$, according to the equation:

$$S = \frac{P}{cos(\phi)} \tag{5.28}$$

2. From the apparent power S, the RMS (Root Mean Square) current I_{RMS} of the load can be calculated for a three-phase and single-phase current. The equations for both cases are shown:

$$S = 3 \cdot V_{RMS} \cdot I_{RMS} \tag{5.29}$$

$$S = V_{RMS} \cdot I_{RMS} \tag{5.30}$$

where the RMS voltage V_{RMS} is 400 V for the three-phase line and 230 V for the single-phase line.

3. From this current, Table B.10 of Annex B is used to find the cable section corresponding to the maximum admissible current which is higher than the calculated value, according to the following criterion:

$$I_{RMS} < I_{max,ad} \tag{5.31}$$

This table has been taken from the Complementary Low-Voltage Technical Instruction ITC-19 (Installations or receivers. General prescriptions). To choose the appropriate cable section, the column corresponding to the number of conductors in each case must be selected (N=4 in the case of three-phase line and N=2 in the case of single-phase line). Then, the maximum admissible current that meets the criterion set out above is looked for. Since this is an installation with risk of explosion, the provisions of the ITC-29 (Special requirements for electrical installations in rooms with a risk of fire or explosion) must be applied. This ITC establishes that the admissible current of the conductors must be reduced by 15 % with respect to the value corresponding to a conventional installation. Therefore, the cable section must be chosen by applying this percentage to the maximum admissible currents in the table, and checking that it is higher than the calculated RMS current. If this criterion is not met, a higher cable section must be chosen to ensure that the condition for the currents 5.31 is met. The type of mounting and the cable insulation can also be determined from this table.

The criterion of maximum current explained above will be apply for each of the four supply lines:

- **Electrolyser supply line.**

  This three-phase power line supplies electricity to the electrolyser, which requires a power of 28.6 kW according to its technical characteristics (Table 5.5). Since the electrolyser catalogue does not specify the power factor, a power factor of 0.8 is assumed as a safety measure. Applying the procedure described, the RMS current of the line is calculated and has a value of $I_{RMS} = 29.79$ A. Since the number of active conductors is 4 because it is a three-phase line (three phase conductors and the neutral conductor), the maximum admissible current immediately above would be 32 A according to Table B.10, which would correspond to a cable section of 6 mm^2. Applying the above-mentioned 15 % reduction to this current, the maximum permissible current is 27.2 A (recalculated due to the characteristics of this installation of risk and explosion). Since this maximum admissible current is lower than the calculated RMS current (I_{RMS} = 29.79 A), a higher cable cross-section (10 mm^2) is chosen from the table. This section allows a maximum admissible current of 44 A, which, applying the corresponding 15 % reduction, takes a value of 37.4 A. Since the latter current is higher than the calculated RMS current, it is concluded that the cable section of 10 mm^2 is suitable for this line. The table indicates that the conductors will be arranged in tubes in surface mounting or embedded in the construction site (walls, ceilings), with a polyvinyl chloride (PVC) insulation.

As mentioned above, the grounding scheme is a TT scheme. Therefore, the protection cable of each line must also be sized. Table 2.13 of Part II (ITC-19) is used to determine the section of the cable that goes to ground (protective conductors). According to this table, since the section of the chosen phase cables (S=10 mm^2) is less than 16 mm^2, the section of the protective conductor is the same as the load conductors (S_p=S=10 mm^2).

The tubes that house the wiring are made of PVC. The diameter of the tubes can be determined using the tables in the ITC-21 (Protective Tubes and Channels). For the specific case of tubes in fixed surface conduits and tubes in embedded conduits, Tables 2.2 and 2.5 of Part II are used to select the appropriate tube diameter depending on the phase conductor section and the number of conductors. For both types of mounting, the tube diameter is 32 mm, taking into account that there are 4 conductors and that the cable section is 10 mm^2.

Table 5.11 summarizes the characteristics of the wiring line that feeds the electrolyser.

Table 5.11: Electrolyser supply line. Wiring characteristics

Phase cables section (mm^2)	10
Neutral cable section (mm^2)	10
Protective cable (mm^2)	10
Wire material	Cu
RMS current (A)	29.79
Maximum admisible current (A)	37.4
Electrical insulation	PVC (VV-K)
Mounting type	Tubes in surface mounting or embedded
Tubes material	PVC
Tubes diameter (mm)	32

Once the wiring characteristics have been determined, it is possible to specify which protection elements are suitable for this line. In this case, since the value of the current circulating on the line is not too high, the use of a magnetic starter followed by a residual-current circuit breaker in series is the most appropriate configuration. In addition, a contactor is added in series to the line that serves to connect the electric line to the emergency lines of the UPV. This safety measure allows electricity to be supplied to the line in the event of a power failure on one of the main lines. To select the appropriate magnetic starter, it must be taken into account that the value of the rated current of the protection device must be between the limits defined by the maximum admissible current and the RMS current, as shown below:

$$I_{RMS} < I_{n,MS} < I_{max,ad} \tag{5.32}$$

The magnetic starter model is a miniature circuit breaker from *Schneider Electric*, a European company operating worldwide, which offers digital energy and automation solutions. This device combines the functions of circuit protection against short-circuit currents, against overload currents and of tripping and electrical fault indication by the addition of auxiliaries [SCHNEIDER ELECTRIC, no date]. The magnetic starter chosen is the model **M9F42335**, whose rated current is 35 A within the limit established by condition 5.32.

On the other hand, to select the residual-current circuit breaker, it must be taken into account that the line rated current must be higher than the rated current of the selected magnetic starter placed in series with it. The selected model is also from *Schneider Electric*. These residual-current circuit breakers offer the functions of protection of persons against electric shock by direct contact (30 mA), protection of persons against electric shock by indirect contact (300 mA), and protection of installations against fire risks (300 mA) [SCHNEIDER ELECTRIC, no date]. The residual-current circuit breaker chosen is model **M9R11240**, whose rated current is 40 A, higher than the rated current of the magnetic starter (35 A) and therefore suitable for placing it on this power line.

Finally, to select the contactor it must be taken into account that its rated current must be equal to or higher than the rated current of the magnetic starter. The contactor selected, also from the manufacturer *Schneider Electric*, is the model **LC1D38P7**, whose rated current is 38 A (higher than the rated current of the magnetic starter of 35 A).

The data sheets for these protection components can be found in Figures C.13, C.14 and C.15 of Annex C.

- **Supply line to the compressed air system.**

  This electrical line supplies electricity to the air compressor, which operates at a nominal power of 22 kW (see Table 5.9). Proceeding in the same way as in the previous case, it is possible to calculate the RMS current circulating on the three-phase line from Equations 5.28 and 5.29, considering a compressor power factor of 0.8 as a safety measure. The RMS current has a value of 22.92 A which, according to Table B.10 (Annex B), would correspond to an immediately higher value of maximum admissible current of 24 A. This current corresponds to the case of 4 conductors, the cross section of each cable being 4 mm^2. However, applying the corresponding 15 % reduction, the recalculated maximum admissible current is 20.4 A, which is lower than the RMS current and makes therefore this cable section not appropriate. If a higher section (6 mm^2) is chosen, the maximum current allowed is 32 A, taking the value of 27.2 A when the reduction factor is applied. Since the current condition 5.31 is met in this case, the cable section of 6 mm^2 is suitable for the sizing of this power line. The table indicates also that the conductors will be arranged in tubes in surface mounting or embedded in the construction site (walls, ceilings), with a polyvinyl chloride (PVC) insulation. The protective earth cable will have a section of 6 mm^2, as set out in Table 2.13 of Part II. The tubes will be made of PVC and will have a diameter of 25 mm, according to Table 2.5 of Part II.

Table 5.12: Air compressor supply line. Wiring characteristics

Phase cables section (mm^2)	6
Neutral cable section (mm^2)	6
Protective cable (mm^2)	6
Wire material	Cu
RMS current (A)	22.92
Maximum admisible current (A)	27.2
Electrical insulation	PVC (VV-K)
Mounting type	Tubes in surface mounting or embedded
Tubes material	PVC
Tubes diameter (mm)	25

Table 5.12 summarizes the characteristics of the wiring line that feeds the compression air system.

In this electric line, the same three protection elements will be placed in series: magnetic starter, residual-current circuit breaker and contactor. The selection criteria set out above are taken into account for their selection. The manufacturer for all three components is again *Schneider Electric*. The selected models of the individual components are shown below:

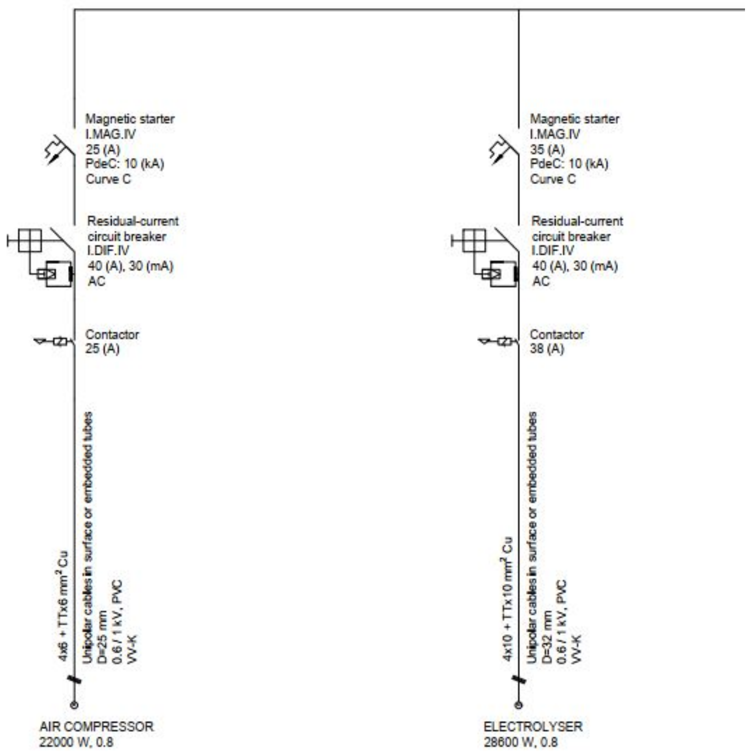


Figure 5.38: One line electric diagram for the electrolyser and the compressed air system

- Magnetic starter. Model **M9F42325** with a rated current of 25 A, meeting the established criteria 5.32.
- Residual-current circuit breaker. Model **M9R11240** with a rated current of 40 A, higher than the magnetic starter rated current.
- Contactor. Model **LC1D25P7** with a rated current of 25 A, equal to the one of the magnetic starter.

The data sheets for these protection components can be found in Figures C.16, C.17 and C.18 of Annex C.

Figure 5.38 shows a capture of the one line electric diagram of the line that supplies the electrolyser and the line that supplies the air compressor (see Part IV, technical drawing number 6). This figure shows the different elements chosen in this section with their technical characteristics.

- **Lighting circuit.**

The lighting circuit consists of a three-phase main line that is divided into two single-phase branches, each feeding a set of loads. For the sizing of these two lines, the general procedure described above for a single-phase line is applied. Both lines are connected to a series of loads totalling 600 W per line, and their section will be therefore the same. The power factor used in this line is 0.88. By using Equations 5.28 and 5.30, an RMS current of the line of $I_{RMS} = 2.96$ A is calculated. The immediately higher maximum admissible current found in Table B.10 (Annex B) is 11.5 A for 2 load conductors, taking a value of 9.775 A when the corresponding reduction of 15 % is applied. Since the current criterion 5.31 is met (the calculated RMS current is less than the recalculated maximum admissible current) the appropriate cable cross-section for this line is 1.5 mm^2. The protective conductor connected to the ground will therefore have an equal section of 1.5 mm^2, according to Table 2.13. The tubes containing the wiring are made of PVC with a diameter of 12 mm according to Table 2.5 of Part II. Table 5.13 summarizes the characteristics of the wiring lines that feeds the lighting circuit.

Table 5.13: Lighting circuit branches. Wiring characteristics

Cables section (mm^2)	1.5
Protective cable (mm^2)	1.5
Wire material	Cu
RMS current (A)	2.96
Maximum admisible current (A)	9.78
Electrical insulation	PVC (VV-K)
Mounting type	Tubes embedded
Tubes material	PVC
Tubes diameter (mm)	12

The protection elements of this line will be a magnetic starter followed by a contactor that allows the connection to the emergency power line. The magnetic starter chosen is the model **M9F42108** of the *Schneider Electric* company, whose nominal current is 8 A, thus fulfilling the established selection criteria 5.32. The selected contactor is the model **LP1K0910BD**, whose rated current is 9 A, meeting the selection criteria 5.31 since it is higher than the rated magnetic starter current. The data sheets for these components can be found in Figures C.19 and C.20 of Annex C.

Figure 5.39 shows a capture of the one line electric diagram of the branches that supply the lighting circuit (see Part IV, technical drawing number 6). This figure shows the different elements chosen in this section with their technical characteristics.

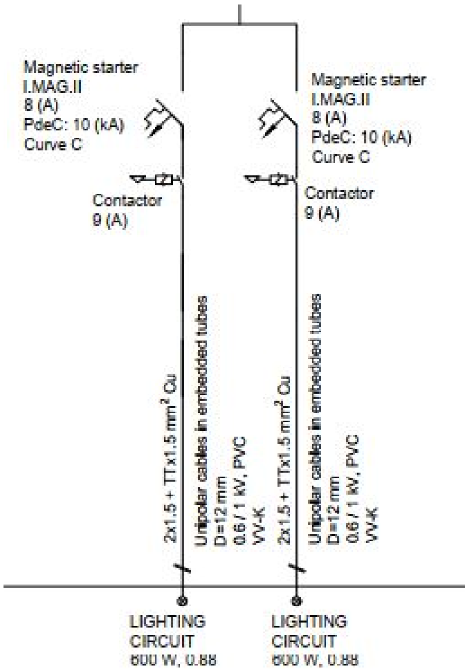


Figure 5.39: One line electric diagram for the lighting circuit

- **Power circuit.**

  The electric line that makes up the power circuit is composed of a three-phase line that feeds three single-phase branches. The power in this circuit is 2500 W for each of the branches with a power factor of 0.9. Using Equations 5.28 and 5.30 with these values, an RMS current of 12.08 A is calculated, the same in all the branches. Choosing the section of 2.5 mm^2 from Table B.10 (Annex B), a maximum admissible current of 16 A is established for 2 conductors, which applying the corresponding 15% reduction is modified to a value of 13.6 A. Since this current meets the established current criterion, it can be concluded that the cable section of 2.5 mm^2 is suitable for this power line. The protective conductor connected to the ground will have an equal section of 2.5 mm^2, according to Table 2.13. The tubes containing the wiring are made of PVC with a diameter of 16 mm according to Table 2.5 of Part II. Table 5.14 summarizes the characteristics of the wiring lines that feeds the lighting circuit.

  The protection elements of each of the branches are a magnetic starter connected in series to a contactor which allows the connection to the emergency power line. Following the selection criteria for these components, the models selected are:

Table 5.14: Power circuit branches. Wiring characteristics

Cables section (mm^2)	2.5
Protective cable (mm^2)	2.5
Wire material	Cu
RMS current (A)	12.08
Maximum admisible current (A)	13.6
Electrical insulation	PVC (VV-K)
Mounting type	Tubes embedded
Tubes material	PVC
Tubes diameter (mm)	16

- Magnetic starter. Model **M9F22113** with a rated current of 13 A, meeting the established criteria 5.32.
- Contactor. Model **LC1K1610B7** with a rated current of 16 A, higher to the one of the magnetic starter.

The data sheets for these components can be found in Figures C.21 and C.22 of Annex C.

Figure 5.40 shows a capture of the one line electric diagram of the branches that supply the power circuit (see Part IV, technical drawing number 6). This figure shows the different elements chosen in this section with their technical characteristics.

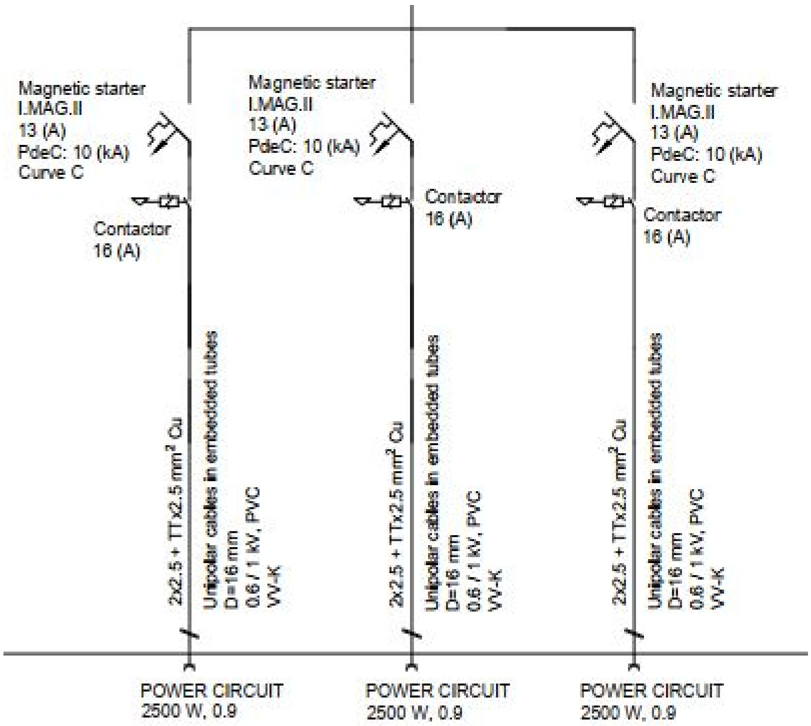


Figure 5.40: One line electric diagram for the power circuit

Finally, the section of the main cable divided into the 4 lines explained above is determined. For this purpose the nominal currents of the magnetic starters of each line are added up, resulting in a total current of 81 A. Going back to Table B.10 (Annex B), a cable section of 50 mm^2 is selected for this three-phase line, with a maximum admissible intensity of 99.45 (15 % reduction applied). The main line protection element is an automatic circuit breaker followed by a relay and a residual current device. The model selected is the **BDL36000S12**, from the manufacturer *Schneider Electric*, whose rated current is 125 A. The technical data sheet can be found in Figure C.23 of Annex C.

5.7.2 Compressed air installation

The compressed air system is required to drive the booster that compresses the hydrogen in the high-pressure storage area. The compressed air system will consist of the air compressor (see section 5.4.5), and a number of systems to achieve optimum air quality and to achieve minimum maintenance of the system. The components to be included in the compressed air line are described below. Again, *Kaeser Kompressoren* is the manufacturer of the selected equipment.

Cyclone separator or cyclone filter

The cyclone separators of the selected series remove the condensate very efficiently, achieving a maximum separation rate of up to 99 % with pressure losses of less than 0.1 bar. According to the manufacturer's recommendations, the most suitable model for installation is the **F46KC**. This component removes the condensate at the compressor outlet, and it is indispensable for the efficient and damage-free operation of downstream dryers and filters. As an advantage, these cyclones separators are maintenance-free [KAESER COMPRESSORS F, no date]. In addition, this separator is supplied with a reliable and economical **ECO-DRAIN 31** condensate drain as standard, which is equipped with a service module to ensure reliable maintenance. ECO-DRAIN condensate drains ensure safe, dependable condensate drainage without air loss [KAESER COMPRESSORS CD, no date], and it is placed at one of the filter exits. Table 5.15 shows the technical specifications of the cyclone filter where it can be seen that both, the flow rate and the pressure, are consistent with the operating conditions required by the installation.

Table 5.15: Cyclone separator Technical specifications. Model F46KC [KAESER COMPRESSORS F, no date]

Maximum operating pressure (bar)	16
Minimum operating pressure (bar)	2
Volumetric flow rate (m^3/min)	4.6
Degree of separation (%)	97-99
Differential pressure in new state (bar)	0.1

Figures C.24 and C.26 of Annex C show the cyclone separator and condensate drain data sheets respectively, and Figure C.25 shows the dimensional drawing of the cyclone separator. In addition, Figure 5.41 includes the measurements of the dimensions for the cyclone separator and the condensate drain, and a picture of the external appearance of both components attached together.

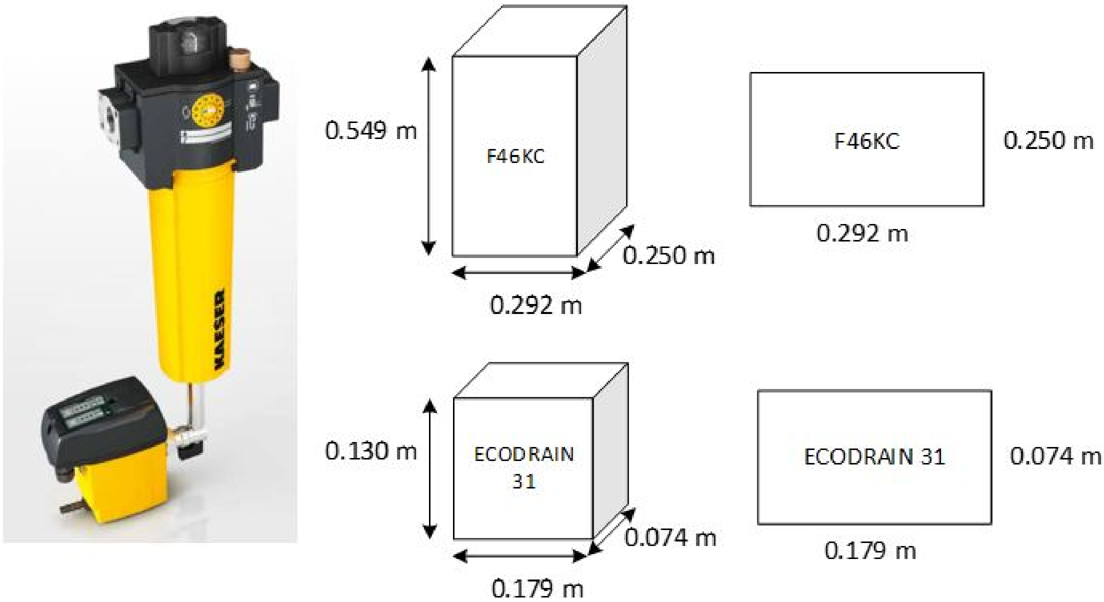


Figure 5.41: Cyclone separator + Condensate drain and dimensional views [KAESER COMPRESSORS F, no date]

Refrigeration dryer

The refrigeration dryers of the selected series (SECOTEC) save a lot of energy compared to conventional dryers during breaks in operation, during phases of lower load and during shutdowns, thanks to their intermittent stop regulation. The integrated cold accumulator ensures constant availability of the refrigeration dryer. In addition, the dryer has a low differential pressure which reduces the maximum overpressure of the compressor and saves energy. According to the manufacturer's recommendations, the most suitable model for installation is the **TD51**. This component is used for drying compressed air down to a pressure dew point of +3 °C, thanks to their highly efficient thermal mass control, which ensures low-wear operation and a stable pressure dew point. SECOTEC refrigeration dryers are equipped as standard with an ECO DRAIN condensate drain. This reliable, electronically regulated drain works according to the level and does not cause any compressed air losses. This means that the ECO DRAIN drain saves even more energy and contributes to the operational reliability of the refrigeration dryer [KAESER COMPRESSORS D, no date]. Figure 5.42 shows the layout of the various components inside the refrigeration dryer cabinet. Table 5.16 shows the technical specifications

Table 5.16: Refrigeration Dryer Technical specifications. Model TD51 [KAESER COMPRESSORS D, no date]

Differential pressure (bar)	0.11
Maximum operating pressure (bar)	16
Volumetric flow rate (m^3/min)	5.65
Refrigerant	R 134-a
Dew point (°C)	+ 3

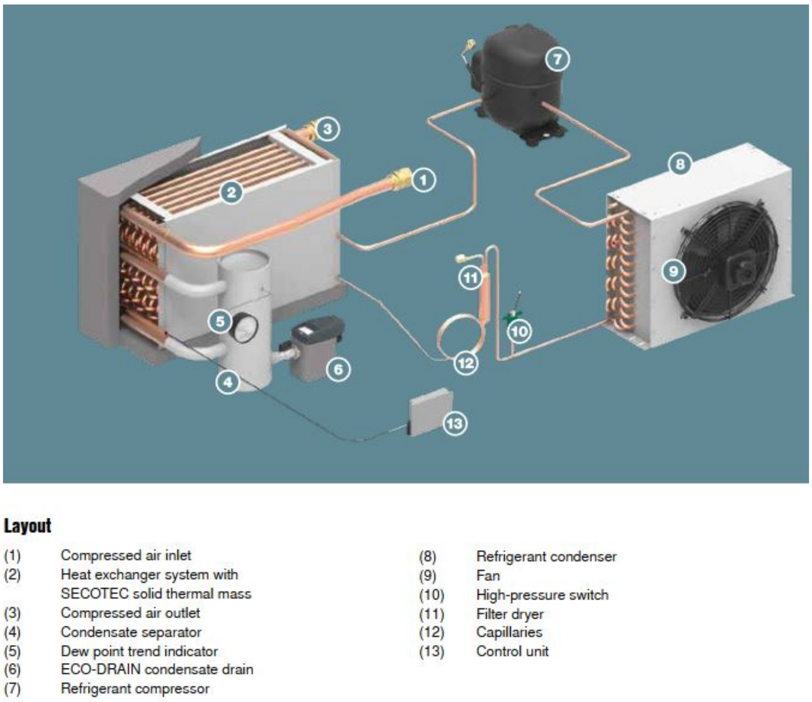


Figure 5.42: Refrigeration dryer layout [KAESER COMPRESSORS D, no date]

of the refrigeration dryer where it can be seen that both the flow rate and the pressure are consistent with the operating conditions required by the installation.

Figure C.27 of Annex C show the component data sheet. In addition, Figure 5.43 includes the measurements of the dimensions for the refrigeration dryer, and a picture of the external appearance of this component.

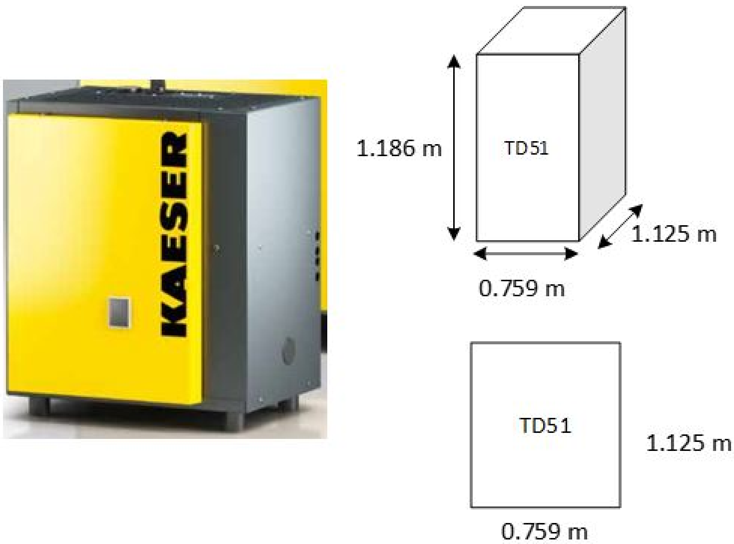


Figure 5.43: Refrigeration dryer and dimensional views [KAESER COMPRESSORS D, no date]

Air receiver

Air receivers play a key role within a compressed air station, since they provide capacity during periods of peak demand and are often used to separate condensate from the compressed air. It is therefore important for receivers to be correctly sized for the specific system and to be resistant against corrosion [KAESER COMPRESSORS AR, no date]. According to the manufacturer's recommendations, the most suitable model for installation is the **1000 L 11 bar** air receiver. The technical specifications can be found on the data sheet shown in Figure C.28 of Annex C. In addition, Figure 5.44 includes the measurements of the dimensions for the air receiver, and a picture of the external appearance of this component.

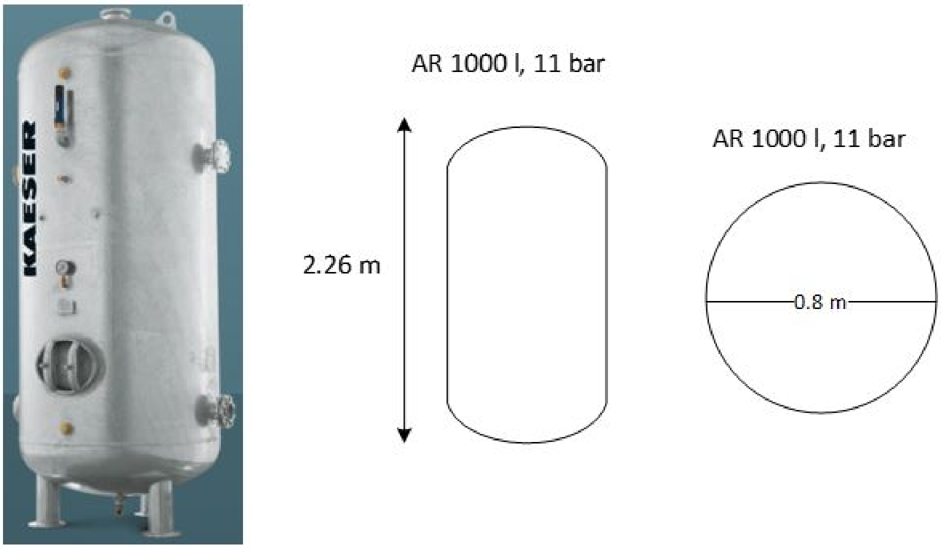


Figure 5.44: Air receiver and dimensional views [KAESER COMPRESSORS AR, no date]

Condensate treatment

The selected AQUAMAT condensate treatment system allows to treat the compressed air condensate within the compressed air installation. In this way, only a small part of the condensate remains for disposal. Compared to the cost of sending the entire condensate to a specialised company for disposal, the AQUAMAT saves approximately 90 % of the cost and has therefore a short payback period [KAESER COMPRESSORS CT, no date]. According to the manufacturer's recommendations, the most suitable model for installation is the **CF9**, suitable for a compressor with a maximum flow of 5.6 m^3/min. The technical specifications can be found on the data sheet shown in Figure C.29 of Annex C. In addition, Figure 5.45 includes the measurements of the dimensions for the condensate treatment, and a picture of the external appearance of this component.

Figure 5.46 shows a diagram specifying the placement order of all the described elements at the compressor outlet. As can be seen, the cyclone separator (or centrifugal separator) is located first, with its corresponding condensate drain. Then the refrigeration dryer is placed, also provided with its condensate drain. Next, a filter with condensate drain is shown, which can be optionally placed in the line. Finally, the air receiver is placed, whose output is connected to the different boosters to which the compressed air line must fed.

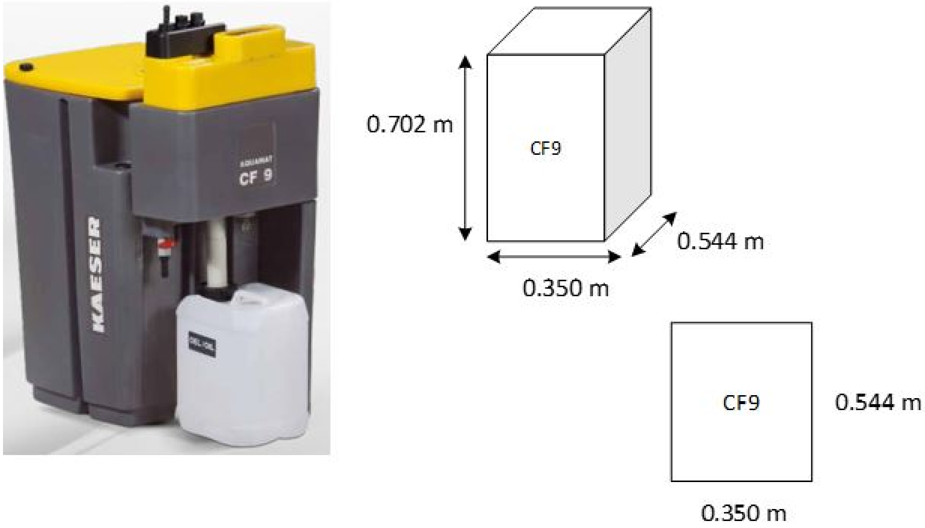


Figure 5.45: Condensate treatment and dimensional views [KAESER COMPRESSORS CT, no date]

At the end of the line there is a protection element (DHS electronic air-main charging system) which provides protection for the compressed air treatment components and help to ensure reliable compressed air quality, even following a complete shutdown of the compressed air supply system. In parallel, the condensate treatment line is drawn in orange colour in the figure. This line collects the output of the different condensate drains to take them to the condensate treatment element. Figure 5.47 shows the layout of all these elements in three dimensions and Annex C includes the different views of the system which incorporate the different dimensions of the entire set (Figure C.30). In addition, Figure 5.48 shows a capture of drawing number 5 (see Part IV), where the Engine Room 2 housing the elements of the compressed air installation is shown. In this drawing the different pipes that are part of the installation are distinguished by colours. The hydrogen pipes are marked in purple, the pipes that take the compressed air to the boosters through the different elements mentioned are orange and the condensate line that goes to the condensate treatment is blue.

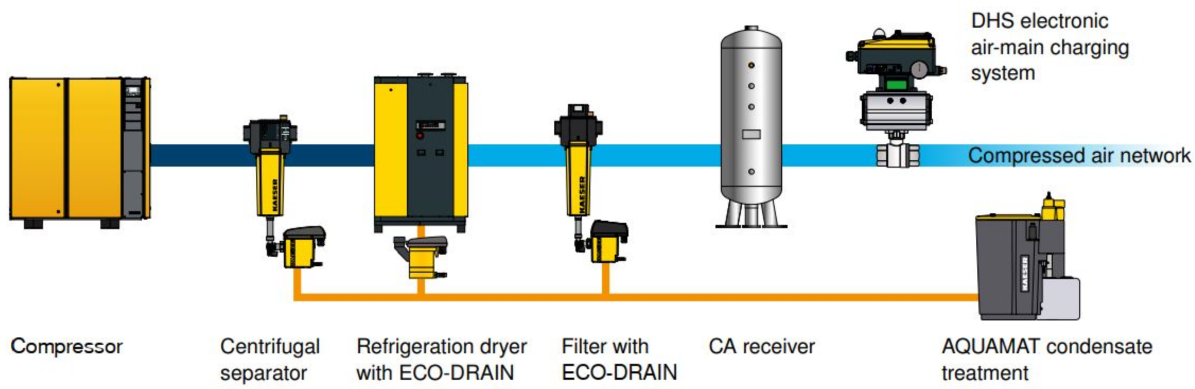


Figure 5.46: Air compressor system components [KAESER COMPRESSORS AC, no date]

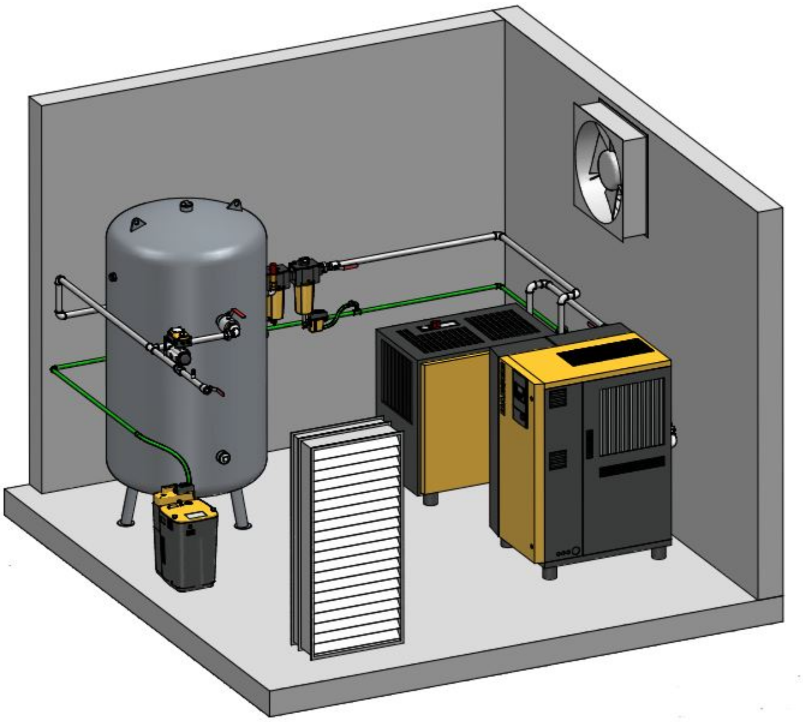


Figure 5.47: Air compressor system layout [KAESER COMPRESSORS AC, no date]

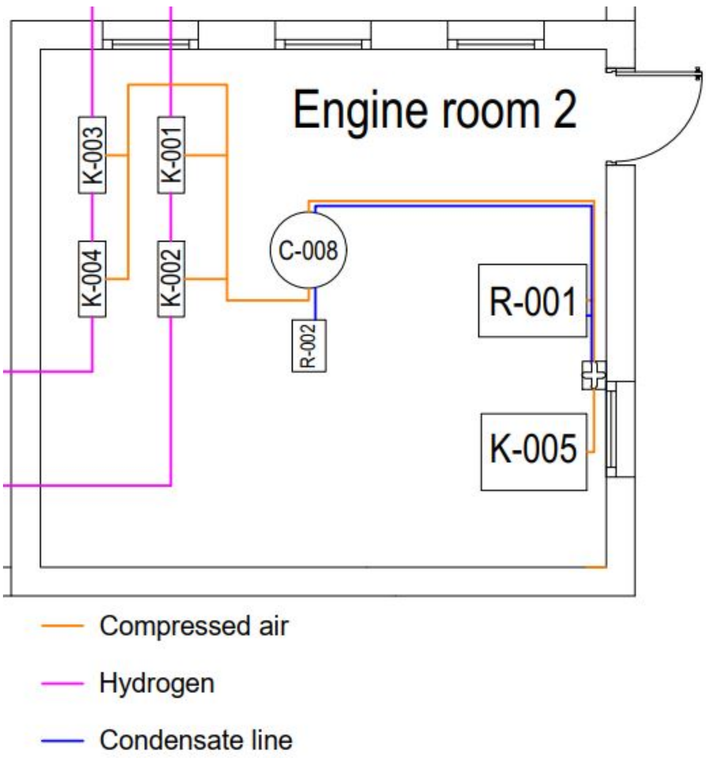


Figure 5.48: Air compressor system technical view

5.7.3 Nitrogen installation

The nitrogen installation will be necessary to carry out the inerting of the installation and the possible piloting of the pneumatic valves present in the process. This installation must ensure an inert distribution which displaces the hydrogen and oxygen contained inside the installation, thus avoiding safety problems and the creation of potentially explosive atmospheres. To this end, there will be pitting in the hydrogen installation that interconnects all the equipment, so that the nitrogen can be connected at these points, as shown in the P&ID drawing number 4 in Part IV. The compressed nitrogen will be transported in storage cylinders to the HRS. These cylinders will be stored in engine room 3, where appropriate connections will be made to the nitrogen lines running through the installation. These pipes run aerially supplying nitrogen at different points distributed throughout the installation.

Chapter 6

Conclusions

This work was aimed at the technical design of the main components that are part of an HRS. The first conclusion to be drawn is that the design has been successfully carried out in compliance with the established design criteria and the adopted assumptions.

A study has been carried out of the consumption characteristics required by the installation, from which it has been possible to develop the technical design specifications. The design of the electrolyser has been carried out based on the average consumption of hydrogen in a month, which has made it possible to know the minimum amount of hydrogen to be produced per hour. Based on this data, the most suitable electrolyser model has been selected. For the design of the different intermediate storage tanks, a distinction has been made between low-pressure storage (at the outlet of the electrolyser) and high-pressure storage (to supply the hydrogen directly to each of the HRS).

The sizing of the low pressure storage tanks takes into account the maximum amount of hydrogen that can be consumed, considering all the consumptions of the different vehicles. To ensure that the commercial tank chosen was suitable, simulations have been carried out of the internal fluctuation of hydrogen within the tank as well as the pressure variation that takes place. According to the results obtained, the system has been designed so that at no time the production of hydrogen could cause an overflow in the tank with no capacity to store all the hydrogen produced. The control of filling and emptying the tank is very important, and its optimization is advantageously in terms of maximum use of hydrogen produced without wasting hydrogen. In the same way, pressure control ensures that overpressures and minimum pressure peaks that may occur within the tank are controlled. Controlling the pressure drop within the tank is important since it affects the successive stages of compression. The lower the pressure drop, the less work the boosters will do as the compression ratio will be lower.

As far as high pressure storage is concerned, two design methods have been evaluated. The first is a single-tank mass storage that can withstand the maximum working pressure, and the second is a cascade storage with three identical tanks working at different pressures. The method chosen is the cascade storage, since it has been demonstrated that it further optimises the amount of non-usable hydrogen that must be permanently stored in the tanks. An iterative calculation method has been developed to determine the most suitable geometric volume for the cascade storage tanks. The process first determines the amount of hydrogen to be supplied to the reservoirs of the vehicles that come to refuel. From this data, it is simulated iteratively which pressure is more adequate to maintain in each of the tanks, obtaining a geometric volume as similar as possible for the three. In this way, it is possible to guarantee the refuelling of the vehicle's deposits (since this is one of the starting data) and to optimise the amount of non-usable hydrogen by achieving similar geometric volumes for the three tanks. This procedure is used for the case of both HRS, being able to identify the geometric volume of the tanks for both cases and being able to select the most suitable commercial model.

The hydrogen compression phase from low pressure storage to high pressure storage is composed of two lines, one for each HRS, and in each of them two boosters are arranged in series. This design solution has been chosen following the recommendations of the manufacturer who has provided the results of the simulation for the case of the installation. Since compression must go from a pressure of 40 bar (or 13.32 bar in the case of minimum inlet pressure) to a maximum pressure of 900 bar or 450 bar (depending on the compression line), the staggered compression solution guarantees better operation of the boosters, by decreasing the compression ratios of each of them. Initially, it was also considered to add a compressor at the outlet of the low pressure storage to compress the hydrogen up to 200 bar. Then, a storage at the intermediate pressure of 200 bar would be placed, connected finally to the lines that would compress up to 900 bar and 450 bar, equipped with a single booster. This design solution was discarded because it added more components (a compressor and another storage tank). However, in the future, an economic and energy analysis could be made to find out which of the two design solutions is more suitable in economic terms. The complementary selection of the compression system, such as the air compressor or the pressure regulators, has been carried out on the basis of the operating data of the boosters.

As far as the hydrogen installation is concerned, a section is dedicated to the sizing of the piping, which are the connection elements between the different components selected. The dimensioning of these pipes has been carried out by an iterative process assuming an incompressible flow to determine the theoretical diameters required. This design is important to ensure that the pipelines can withstand the maximum pressures at which the hydrogen circulates, as well as to establish the ideal connections between the elements of the system.

Among the auxiliary installations, it is worth mentioning the design of the electrical installation that complies with the requirements of the low voltage regulations. The selection of the electrical cables has been carried out with the criterion of maximum admissible intensity. In addition, the main protection elements of the electrical lines have been selected, such as magnetic starters, residual-current circuit breakers or contactors. With all these elements, it is possible to have a first idea of the electrical connections of the installation and the necessary conduits guaranteeing a safe operation of the installation, and to ensure the design criteria of the low voltage regulation applied to installations with risk of fire and explosion. In this section, technical details on the compressed air system are also specified, explaining the various components that ensure optimum air quality. All of them have been selected with the help of the manufacturer to ensure proper operation and taking into account the energy efficiency of the system.

All the drawings have been prepared on the basis of the established design conditions, respecting the minimum safety distances and the structural rules of construction. The inclusion of these plans in the report makes it easier to understand the project, and allows to visualise the calculated parameters, such as the section of the cables in the electrical installation, or the diameters of the hydrogen pipes. In addition, it allows to locate each of the components in the installation and to identify the actual measurements.

The report includes the technical specifications which indicate in detail the considerations to be taken into account when starting the construction of the installation. It includes specifications on the responsibilities of the parties involved in the project, technical characteristics of the assembly of each of the elements of the installation and maintenance conditions to be taken into account. It also refers to a series of updated standards, which can help when installing the components and thus ensure correct installation.

The report also includes the budget, a fundamental part of any engineering project. Although the design of this facility has been based on a technical and safety criterion, rather than on a more economic point of view, it is equally important to evaluate the economic viability of the facility. Therefore, the project is completed with the present budget, which provides an estimate of the cost to carry out this project in real life.

As a general conclusion of this work, it is important to say that despite the current panorama of the hydrogen economy, a project of this type is very attractive to continue developing the constant struggle towards a cleaner and more sustainable future. It is clear that much development is still needed for this technology to reach cost-effective economic maturity, both at the level of infrastructure and at the level of technical improvements in electrolysis technology and fuel cell vehicles. However, with the help of governments increasingly committed to climate change and companies supporting R&D in this technology, the future prospects for the role of hydrogen in a future society cannot go unnoticed, and that is why we must continue to invest in this beneficial technology.

As a personal conclusion, I would like to value the technical character that the development of this work has given me in my formation as an engineer. The design of this project has allowed me to develop my technical knowledge in different disciplines to apply it to a real proposal. I have been able to evaluate all the phases of construction, from the foundation of the installation to the maintenance of the components, which allowed me to learn more in detail about how a project is carried out in real life. Furthermore, the fact that I have been able to be in contact with some companies in the sector, or the in-depth research I have conducted on the current regulations, has helped to improve my transversal skills, which complements perfectly with the technical work carried out.

Annexes

Annexes A

Hydrogen properties

Density	0,0899	gas (kg/Nm3)
	0,0708	liquid (kg/l)
Lower heating value	120	MJ/kg
Higher heating value	141,86	MJ/kg
Explosion limits	4	% (H_2 concentration in air)
	75	
Detonation limits	18,3	% (H2 concentration in air)
	59	
Specific heat capacity	14,199	Cp (KJ/kg·K)
	10,074	Cv (KJ/kg·K)
Diffusion Coefficient	0,61	cm^2/s

Figure A.1: Hydrogen properties

Mass H_2 (kg)	↔	H_2 gas (Nm^3)	↔	H_2 liquid (liters)	↔	Enegy (based in LHV) (MJ)	↔	Energy (based in LHV) (kW·h)
1	=	11,12	=	14,12	=	120	=	33,33
0,0899	=	1	=	1,27	=	10,8	=	3
0,0708	=	0,788	=	1	=	8,495	=	2,359
0,00833	=	0,0926	=	0,1177	=	1	=	0,278
0,03	=	0,333	=	0,424	=	3,6	=	1

Figure A.2: Hydrogen-Energy Equivalences

Pressure (Bar)	1	50	100	150	200	250	300	350	400	500	600	700	800	900	1000
Compressibility factor	1	1,032	1,065	1,089	1,132	1,166	1,201	1,236	1,272	1,344	1,416	1,489	1,56	1,632	1,702

Figure A.3: Compressibility factor as a function of pressure

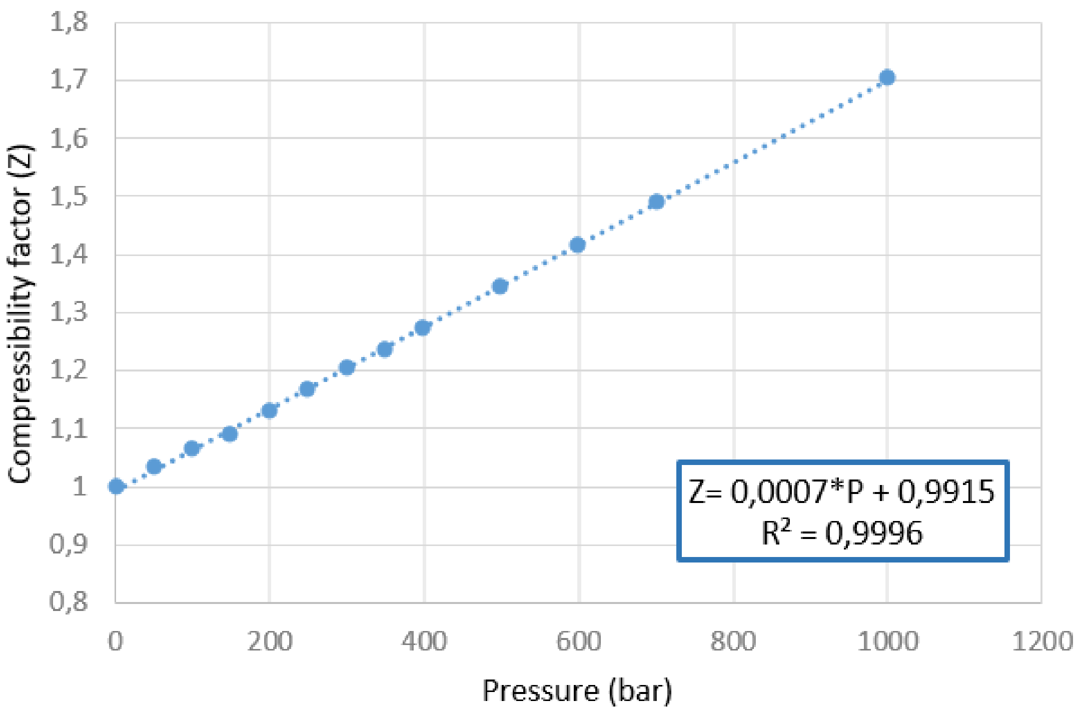


Figure A.4: Linear adjustment of the compressibility factor as a function of pressure

Annexes B

Regulations or Standards Data

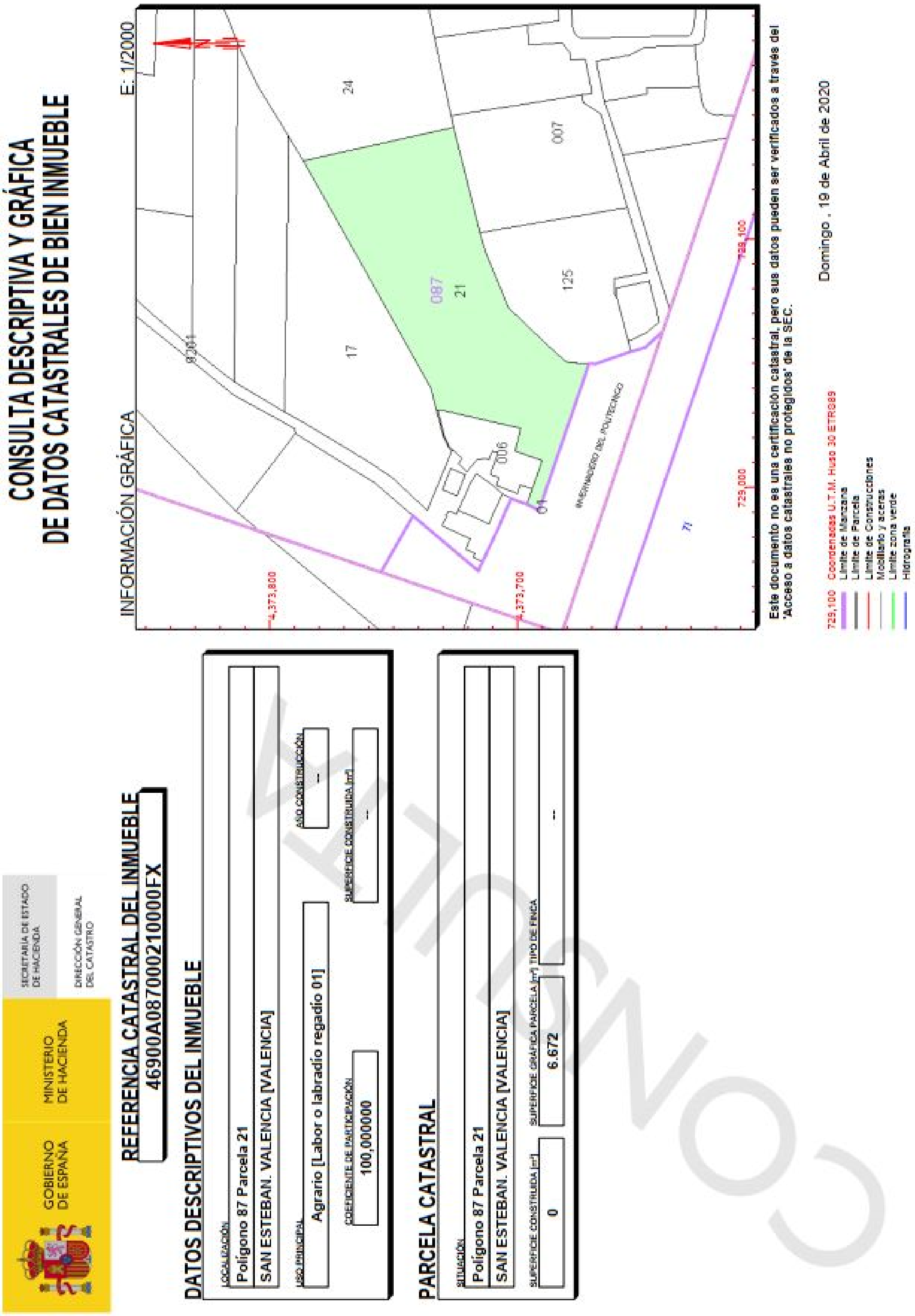


Figure B.1: Cadastral reference of the property [Ministerio de Hacienda, no date]

Categoría del almacén	Gases (Peligrosidad)	Cat. Clp	Indicación de peligro	Cantidad del almacenamiento	
				Kg	Nm^3
1	Inflamables	1	H220		Q ≤ 50
		2	H221		Q ≤ 100
	Comburentes	1	H270		Q ≤ 200
	Gas a presión (1)				
	Gas comprimido		H280		Q ≤ 200
	Gas licuado		H 280		
	Gas licuado refrigerado		H281		
	Gas disuelto		H280		
	Tóxicos	1	H300,H310,H330	Q ≤ 20	
		2	H300,H310,H330	Q ≤ 20	
		3	H301, H311, H331	Q ≤ 30	
		4	H302, H312, H332	Q ≤ 50	
	Amoniaco	3	H331	Q ≤ 150	
	Corrosivos	1A, 1B, 1C	H314	Q ≤ 30	
		1	H290	Q ≤ 30	
2	Inflamables	1	H220		50 < Q ≤ 175
		2	H221		100 < Q ≤ 300
	Comburentes	1	H270		200 < Q ≤ 700
	Gas a presión (1)				
	Gas comprimido		H280		200 < Q ≤ 1000
	Gas licuado		H280		
	Gas licuado refrigerado		H281		
	Gas disuelto		H280		
	Tóxicos	1	H300, H310, H330	20 < Q ≤ 65	
		2	H300, H311, H330	20 < Q ≤ 65	
		3	H301, H311, H331	30 < Q ≤ 65	
		4	H302, H312, H332	50 < Q ≤ 100	
	Amoniaco	3	H331	150 < Q ≤ 400	
	Corrosivos	1A, 1B, 1C	H314	30 < Q ≤ 65	
		1	H290	30 < Q ≤ 65	
3	Inflamables	1	H220		175 < Q ≤ 600
		2	H221		300 < Q ≤ 1000
	Comburentes	1	H270		700 < Q ≤ 2400
	Gas a presión (1)				
	Gas comprimido		H280		1000 < Q ≤ 2400
	Gas licuado		H280		
	Gas licuado refrigerado		H281		
	Gas disuelto		H280		
	Tóxicos	1	H300, H310, H330	65 < Q ≤ 130	
		2	H300, H310, H330	65 < Q ≤ 130	
		3	H301, H311, H331	65 < Q ≤ 130	
		4	H302, H312, H332	100 < Q ≤ 200	
	Amoniaco	3	H331	400< Q ≤ 1000	
	Corrosivos	1A, 1B, 1C	H314	65 < Q ≤ 130	
		1	H290	65 < Q ≤ 130	

Figure B.2: Storage category. ITC MIE-APQ 5 (RD 656/2017)

Categoría del almacén	Gases (Peligrosidad)	Cat. Clp	Indicación de peligro	Cantidad del almacenamiento	
				Kg	Nm³
4	Inflamables	1	H220		600 < Q ≤ 2000
		2	H221		1000 < Q ≤ 3000
	Comburentes	1	H270		2400 < Q ≤ 8000
	Gas a presión (1)				
	Gas comprimido		H280		2400 < Q ≤ 8000
	Gas licuado		H280		
	Gas licuado refrigerado		H281		
	Gas disuelto		H280		
	Tóxicos	1	H300, H310, H330	130 < Q ≤ 650	
		2	H300, H310, H330	130 < Q ≤ 650	
		3	H301, H311, H331	130 < Q ≤ 650	
		4	H302, H312, H332	200 < Q ≤ 900	
	Amoniaco	3	H331	1000 < Q ≤ 2500	
	Corrosivos	1A, 1B, 1C	H314	130 < Q ≤ 650	
		1	H290	130 < Q ≤ 650	
5	Inflamables	1	H220		Q > 2000
		2	H221		Q > 3000
	Comburentes	1	H270		Q > 8000
	Gas A Presión (1)				
	Gas comprimido		H280		Q > 8000
	Gas licuado		H280		
	Gas licuado refrigerado		H281		
	Gas licuado		H280		
	Toxicos	1	H300, H310, H330	Q > 650	
		2	H300, H310, H330	Q > 650	
		3	H301, H311, H331	Q > 650	
		4	H302, H312, H332	Q >900	
	Amoniaco	3	H331	Q > 2500	
	Corrosivos	1A, 1B, 1C	H314	Q > 650	
		1	H290	Q > 650	

Figure B.3: Storage category (Continued). ITC MIE-APQ 5 (RD 656/2017)

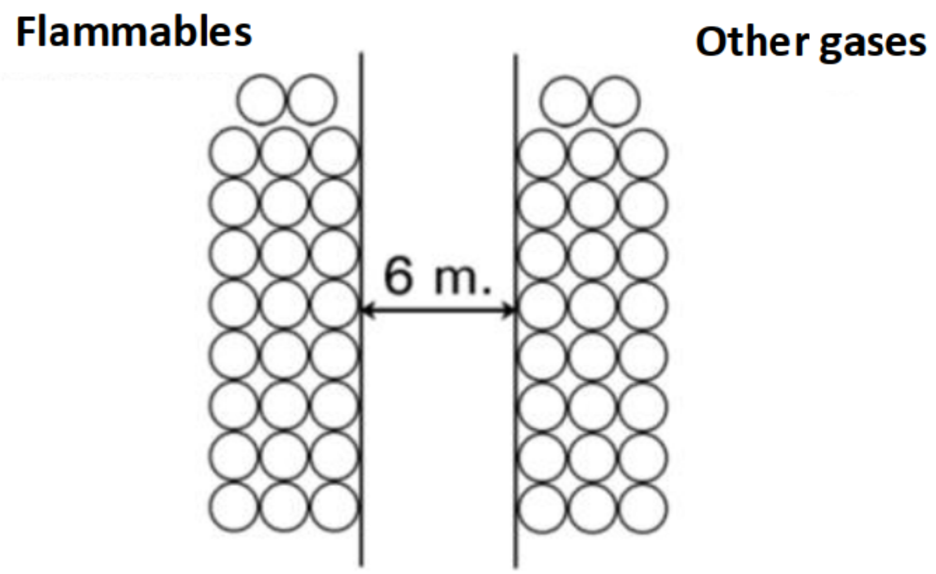
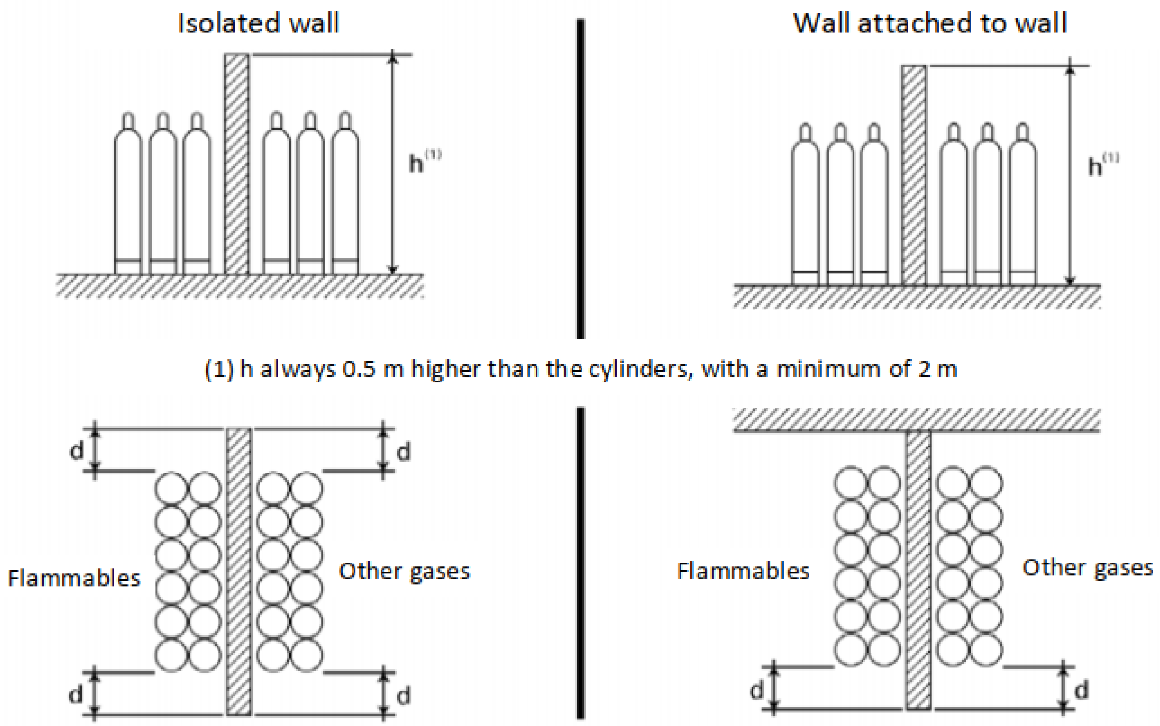


Figure B.4: Separation between cylinders of flammable and other gases (Without separation wall). ITC MIE-APQ 5 (RD 656/2017)
Remark: For separation between containers containing flammable gases and inert gases, a distance of 3 m shall be considered.



Category	d (m)	EI Wall fire resistance (min)
1	0,5	30
2	0,5	30
3	1	60
4	1,5	60
5	2	60

Figure B.5: Separation between cylinders of flammable and other gases (With separation wall). ITC MIE-APQ 5 (RD 656/2017)

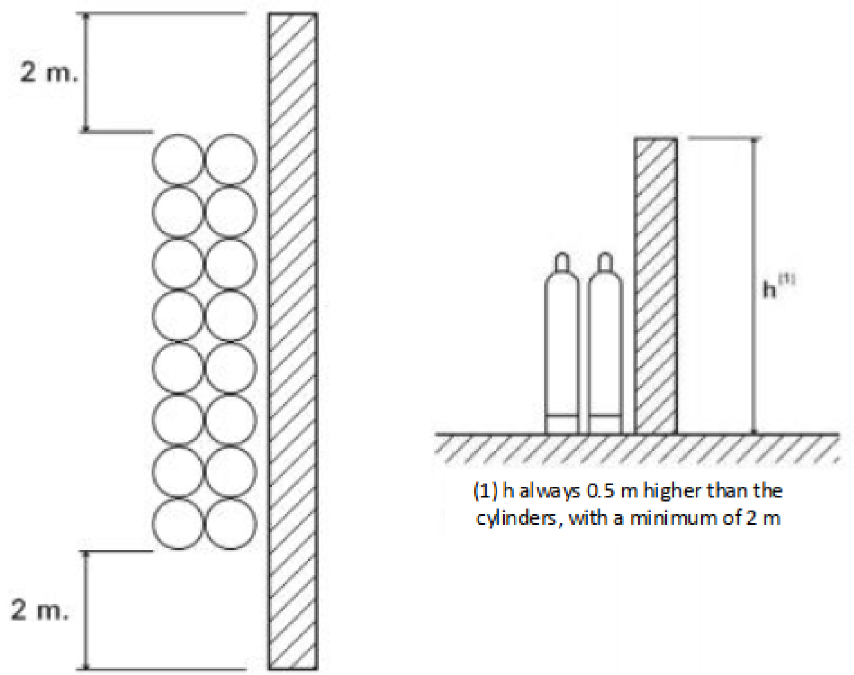


Figure B.6: Separation wall. ITC MIE-APQ 5 (RD 656/2017)

Categoría de almacenamiento		1 V ≤ 1 000 l y P ≤ 5 MPa	2 V ≤ 1 000 l, y P ≤ 5 MPa o 1 000 < V ≤ 10 000 l y Q ≤ 30 kg	3 V ≤ 1 000 l y P > 45 MPa	4 V ≤ 1 000 l y Q > 30 kg o V > 1 000 l	Principal agravamiento del peligro considerado
Exposición	Edificio de material no combustible (resistencia 2 h)	Separación necesaria para el acceso en operaciones de mantenimiento y reparación			1,5	
	Edificio de material combustible	2	4	6	6	1) Extensión del incendio de hidrógeno al edificio 2) Impacto del incendio del edificio sobre gran almacenamiento
	Aperturas en la pared del edificio (puerta, ventana) no situadas por encima del sistema de hidrógeno	1	2	3	3	Atmósfera explosiva en el interior del edificio debido a una fuga de hidrógeno
	Aperturas en la pared del edificio (puerta, ventana) situadas por encima del sistema de hidrógeno	1,5	3	4	4	Atmósfera explosiva en el interior del edificio debido a una fuga de hidrógeno
	Liquidos inflamables en superficie < 4 000 l	1,5	3	4	4	1) Impacto del fuego de hidrógeno dando como resultado un agravamiento de la situación 2) Radiación sobre un almacenamiento de hidrógeno debida a la combustión del liquido inflamable
	Liquidos inflamable en superficie > 4 000 l	2	4	6	8	
	Liquidos inflamables por debajo de la superficie – Orificios de venteo y llenado	2	3	3	4	Radiación sobre un almacenamiento de hidrógeno debida a la combustión del liquido inflamable
	Almacenamiento de gas inflamable (> 500 m³)	1,5	3	4	4	1) Impacto del fuego de hidrógeno dando como resultado un agravamiento de la situación 2) Radiación sobre un almacenamiento de hidrógeno debida a la combustión del liquido inflamable
	Almacenamiento de material combustible, por ejemplo madera	2	3	3	4	
	Fuegos abiertos	1,5	3	4	4	Encendido retardado de una atmósfera explosiva formada a partir de una fuga
	Admisión de aire acondicionado y aire del compresor	1,5	3	4	4	Entrada en el sistema de aire de un edificio de una mezcla explosiva aire/hidrógeno
	Actividades no relacionadas con el repostaje (por ejemplo lavado de vehículos, mantenimiento de vehículos y talleres)	1,5	3	4	4	Atmósfera explosiva/proyección de llama/radiación potencial en caso de fuga
	Lugares de pública concurrencia	2	4	6	8	Exposición inmediata de personas no entrenadas a un incidente importante
	Aceras públicas y vehículos estacionados	1,5	3	4	4	Atmósfera explosiva/proyección de llama/radiación potencial en caso de fuga
	Proyección al suelo de líneas de alta tensión de trenes y tranvías	3	6	8	12	Mayor agravamiento de un incidente de importancia como consecuencia del paso de un tren
	Proyección al suelo de otras líneas eléctricas	1,5	1,5	1,5	1,5	Caída de líneas en el sistema de hidrógeno

Figure B.7: Minimum safety distances in metres from hydrogen gas storage systems [ISO/TS 20100, 2008]

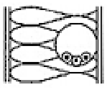
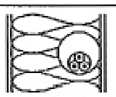
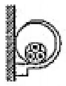
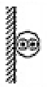
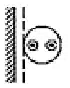
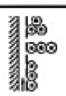
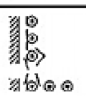
	Presiones de servicio	$5 < P \leq 45$ MPa	$P > 45$ MPa	Principal agravamiento del peligro considerado
Exposiciones	Edificio de material no combustible (resistencia 2 h)	Separación necesaria para el acceso en operaciones de mantenimiento y reparación		Ninguno
	Edificio de material combustible	4	6	Extensión del incendio de hidrógeno al edificio
	Aperturas en la pared del edificio (puerta, ventana) no situadas por encima del sistema de hidrógeno	2	3	Atmósfera explosiva en el interior del edificio debido a una fuga de hidrógeno
	Aperturas en la pared del edificio (puerta, ventana) situadas por encima del sistema de hidrógeno	3	4	Atmósfera explosiva en el interior del edificio debido a una fuga de hidrógeno
	Líquidos inflamables o almacenamiento de hidrógeno en superficie [a]	4	6	Impacto del fuego de hidrógeno dando como resultado un agravamiento de la situación
	Almacenamiento de material combustible, por ejemplo madera	3	3	Impacto del fuego de hidrógeno dando como resultado un agravamiento de la situación
	Fuegos abiertos	3	4	Encendido retardado de una atmósfera explosiva formada a partir de una fuga
	Admisión de aire en el sistema de aire acondicionado y en el compresor	3	4	Entrada en el edificio o en el sistema de aire acondicionado de una mezcla explosiva aire/hidrógeno
	Actividades no relacionadas con el repostaje (por ejemplo lavado de vehículos, mantenimiento de vehículos y talleres)	3	4	Atmósfera explosiva/proyección de llama/radiación potencial en caso de fuga
	Lugares de pública concurrencia (conjunto)	4	6	Exposición inmediata de personas no entrenadas a un incidente importante
	Aceras públicas y vehículos estacionados[b], *lot line*	3	4	Atmósfera explosiva/proyección de llama/radiación potencial en caso de fuga
	Tranvía, tren y líneas de alta tensión en vertical	6	8	Mayor agravamiento de un incidente de importancia como consecuencia del paso de un tren
	Proyección al suelo de otras líneas eléctricas	1,5	1,5	Caída de líneas en el sistema de hidrógeno

a Incluyendo almacenamiento de hidrógeno y almacenamiento ubicado bajo marquesinas.
b Excluyendo vehículos que van a repostar.

Figure B.8: Minimum safety distances in metres for hydrogen gas processing subsystems including the dispenser [ISO/TS 20100, 2008]

Constituent	Characteristics
Hydrogen fuel index (minimum mole fraction)[a]	99,97 %
Total non-hydrogen gases	300 µmol/mol
Maximum concentration of individual contaminants	
Water (H_2O)	5 µmol/mol
Total hydrocarbons (THC)[b] (Excluding Methane)	2 µmol/mol
Methane (CH_4)	100 µmol/mol
Oxygen (O_2)	5 µmol/mol
Helium (He)	300 µmol/mol
Nitrogen (N_2)	300 µmol/mol
Argon (Ar)	300 µmol/mol
Carbon dioxide (CO_2)	2 µmol/mol
Carbon monoxide (CO)[c]	0,2 µmol/mol
Total sulphur compounds (H_2S basis)	0,004 µmol/mol
Formaldehyde (HCHO)[c]	0,2 µmol/mol
Formic acid (HCOOH)[c]	0,2 µmol/mol
Ammonia (NH_3)	0,1 µmol/mol
Halogenated compounds[d] (Halogenate ion basis)	0,05 µmol/mol
Maximum particulates concentration	1 mg/kg
For the constituents that are additive, such as total hydrocarbons and total sulphur compounds, the sum of the constituents shall be less than or equal to the acceptable limit.	
[a] The hydrogen fuel index is determined by substracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mol percent. [b] Total hydrocarbons include oxygenated organic species. Total hydrocarbons shall be measured on a carbon basis (µmolC/mol). [c] Total of CO, HCHO, HCOOH shall not exceed 0,2 µmol/mol [d] All halogenated compounds which could potentially be in the hydrogen gas (for example, hydrogen chloride (HCl), and organic halides (R-X)) should be determined according to the hydrogen quality assurance discussed in Clause 6 and the sum shall be less than 0,05 µmol /mol).	

Figure B.9: Fuel quality specifications for PEM fuel cell road vehicle applications [UNE-EN 17124, 2018]

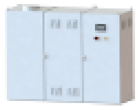
A		Conductores aislados en tubos empotrados en paredes aislantes		3x PVC	2x PVC		3x XLPE o EPR	2x XLPE o EPR					
A2		Cables multiconductores en tubos empotrados en paredes aislantes	3x PVC	2x PVC		3x XLPE o EPR	2x XLPE o EPR						
B		Conductores aislados en tubos[2] en montaje superficial o empotrados en obra				3x PVC	2x PVC			3x XLPE o EPR	2x XLPE o EPR		
B2		Cables multiconductores en tubos[2] en montaje superficial o emprotrados en obra			3x PVC	2x PVC		3x XLPE o EPR		2x XLPE o EPR			
C		Cables multiconductores directamente sobre la pared[3]					3x PVC	2x PVC		3x XLPE o EPR	2x XLPE o EPR		
E		Cables multiconductores al aire libre[4] Distancia a la pared no inferior a 0.3D[5]						3x PVC		2x PVC	3x XLPE o EPR	2x XLPE o EPR	
F		Cables unipolares en contacto mutuo[4] Distancia a la pared no inferior a D[5]							3x PVC			3x XLPE o EPR[1]	
G		Cables unipolares separados mínimo D[5]									3x PVC[1]		3x XLPE o EPR
Cobre		mm²	1	2	3	4	5	6	7	8	9	10	11
		1,5	11	11,5	13	13,5	15	16	-	18	21	24	-
		2,5	15	16	17,5	18,5	21	22	-	25	29	33	-
		4	20	21	23	24	27	30	-	34	38	45	-
		6	25	27	30	32	36	37	-	44	49	57	-
		10	34	37	40	44	50	52	-	60	68	76	-
		16	45	49	54	59	66	70	-	80	91	105	-
		25	59	64	70	77	84	88	96	106	116	123	166
		35		77	86	96	104	110	119	131	144	154	206
		50		94	103	117	125	133	145	159	175	188	250
		70				149	160	171	188	202	224	244	321
		95				180	194	207	230	245	271	296	391
		120				208	225	240	267	284	314	348	455
		150				236	260	278	310	338	363	404	525
		185				268	297	317	354	386	415	464	601
		240				315	350	374	419	455	490	552	711
		300				360	404	423	484	524	565	640	821

1) A partir de 25 mm² de sección.
2) Incluyendo canales para instalaciones -canaletas- y conductos de sección no circular.
3) O en bandeja no perforada.
4) O en bandeja perforada.
5) D es el diámetro del cable.

Figure B.10: Admissible currents (A) in air 40 °C. Number of conductors with load and nature of insulation (ITC-BT 19)

Annexes C

Products catalogues



Main Caracteristics	EL5N
Electrolysis Type	PEM (Proton exchange membrane, caustic free)
Number of Cell Stacks	1
Hydrogen Gas Production	
Max. Nominal Hydrogen Flow	5.2 Nm^3/h
Hydrogen Flow Range	10 -100%
Operating Pressure	15 - 40 barg (217-580 psig)
Hydrogen Purity (before Gas Purification)	> 99.9% ; < 25 ppm O_2; H_2O saturated
Hydrogen Purity (after Gas Purification)	99.999%; < 5 ppm O_2; < 5 ppm H_2O
Electrical Requirements	
Voltage	3 x 400 VAC ± 10% (3Ph+N) / 3 x 480 VAC ± 10% (3Ph+N)
Frequency	50 Hz ± 5% / 60 Hz ± 3%
Power (Bop + Stack)	28.6 kW
Stack Consumption	4.7 kWh/Nm^3 H_2
AC Power Consumption (BoP + Stack)	5.5 kWh/Nm^3 H_2
Feed Water - Tap Water (if Water Treatment Plant is included)	
Consumption	< 10.4 l/hr
Conductivity	< 2,000 uS/cm (T 25 °C (77 °F))
Pressure	2-6 barg (29-87 psig)
Temperature	+5 °C to +40 °C (+41 °F to +104 °F)
Feed Water - Demi Water (if Water Treatment Plant is not included)	
Consumption	< 1 l/Nm^3 H_2
Quality	> 10 MΩcm (< 0.1 uS/cm); TOC < 30 ppb
Control System	
PLC	Fully automated and unattended with 7" color touch screen
Communication	Modbus TCP/IP or Profinet (RJ45 port)
Environmental Conditions	
Ambient Temperature Range	+5 °C to +45 °C (+41 °F to +113 °F)
Humidity	0 to + 95% (non-condensing)
Air Ventilation	Available from a non-hazardous area
Installation Area	Indoor/Outdoor
Dimensions and weight	
Dimensions (LxWxH)	Cabinet (1.8m x 0.8m x 2.1m) (5.9ft x 2.6ft x 6.9ft)
Approx. Weight	950 kg (2,094 lb)
Standards & Regulations	
Compliance	CE, ISO 22734-1 /NFPA 2-2016 & NFPA 70
Other Characteristics	
Duty Cycle	100% (24/7)
Start-up Time (from Stand-by)	< 1 sec
Cold Start Time	< 5 min
Nitrogen Supply System	For each purge, consumption is <0.1 kg at 3 barg (to be supplied by the customer)
Instrumentation air System	Consumption 4 Nm^3/h at 10 barg (to be supplied by the customer)

Included	Additional Options
Hydrogen Cooling System	Oxygen Processing System
Emergency Shutdown System	Instrumentation Air System
Overpressure Relief System	Nitrogen System
Redundancy on Critical Safety Parameters	Hydrogen Purification System (SAE J2719 September 2011)
Heat Management (No Cooling Water is Needed)	Water Treatment System
	Uninterruptible Power Supply (UPS)
	Extreme Environmental Conditions Package (Low and High Temp)

Figure C.1: Electrolyser Data sheet. Model EL5N [H2B2, no date]

NPROXX

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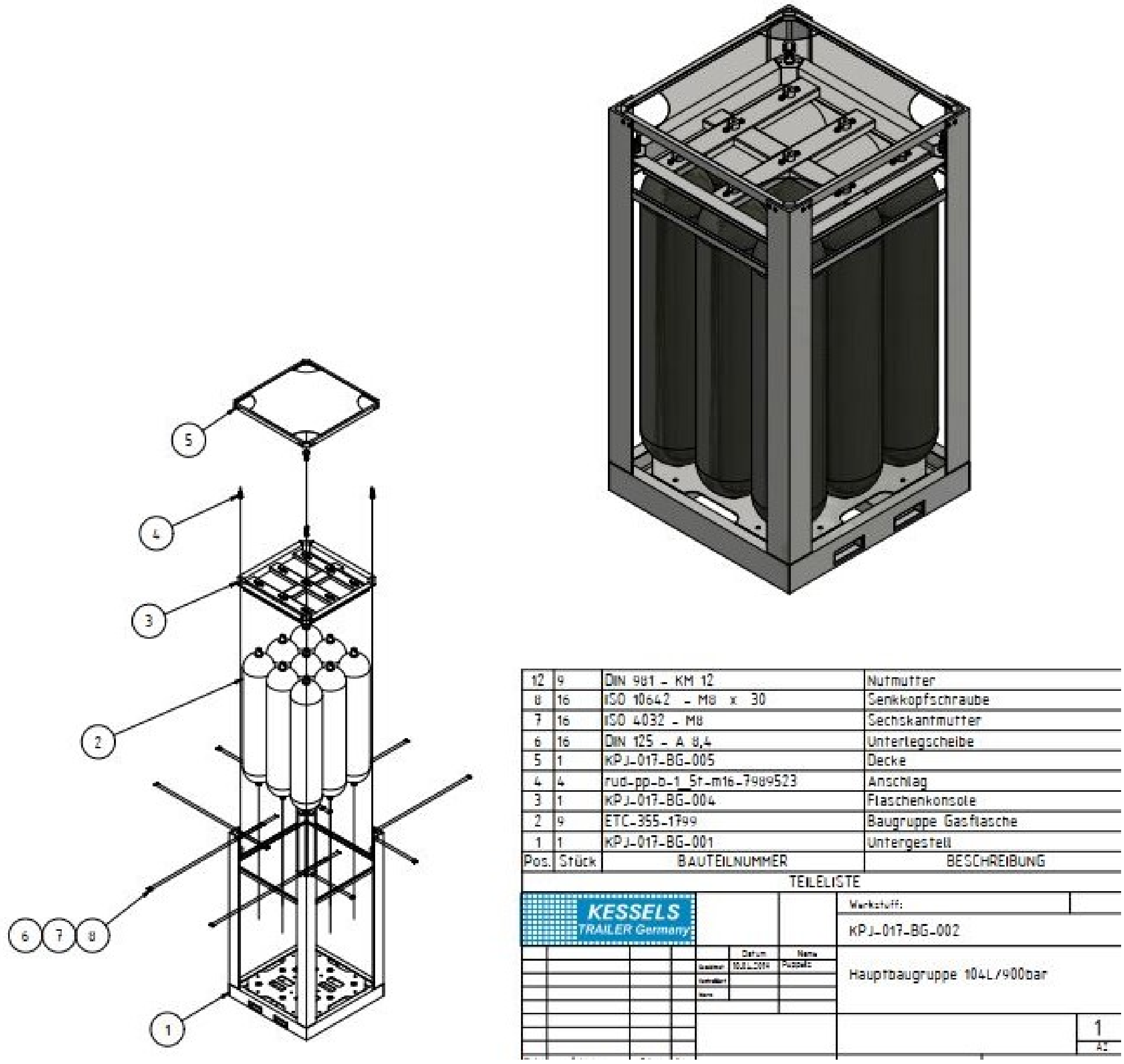
www.nproxx.com

Factsheet 10ft MEGC, 300 bar

Specification MEGC:		
Dimension (L x W x H)	mm	2911 x 2438 x 2700
Certification Storagesystem		MEGC
Usable Storage Capacity (working pressure 10 - 300 bar, 15°C)	Kg H2	170
Volume	Litre	8.400
Weight (empty)	Kg	ca. 9.500
Iso MEGC corner points		Bottom: 4 pcs Top: 4 pcs, lateral holes are closed
No of pressure cylinders/MEGC		24
Sections	Pcs	3
No Modules	Pcs	1
No of PC per section	Pcs	12
Volume per section	Litre	Ca. 2.800
No hand valves per section /total	Pcs	1 / 3
Certification hand valves		TPED
Material Container		Galvanised steel
Housing Sides		Laminated aluminium plates
Top Cover		Stainless steel expanded metal (non-accessible)
Bottom Cover		Galvanized steel support plates for mounting pressure cylinders
Mounting position PC		Vertical
Delivery condition		20 bar nitrogen filling
Specification pressure cylinder:		TH510-30
Dimensions		
Diameter x Length	mm x mm	510 x 2316 mm
Pressure cylinder	Composite	Typ 4
Certification		TPED / EN12245
Water content at 0 bar per cylinder	Litre	350
Usable capacity H2 (300 bar - 10 bar) per cylinder	Kg	7,1
Min. working pressure	Bar	10
Nominal working pressure	Bar	300
Approved temperature range	°C	-20 - + 65

Figure C.2: Low storage tank Data sheet. Model 10“ MEGC 300 bar [NPROXX, no date]



Pos.	Stück	BAUTEILNUMMER	BESCHREIBUNG
12	9	DIN 981 - KM 12	Nutmutter
8	16	ISO 10642 - M8 x 30	Senkkopfschraube
7	16	ISO 4032 - M8	Sechskantmutter
6	16	DIN 125 - A 8,4	Unterlegscheibe
5	1	KPJ-017-BG-005	Decke
4	4	rud-pp-b-1_5t-m16-7989523	Anschlag
3	1	KPJ-017-BG-004	Flaschenkonsole
2	9	ETC-355-1799	Baugruppe Gasflasche
1	1	KPJ-017-BG-001	Untergestell

Figure C.3: 900 bar storage tank system technical drawing. Model KPJ-017-BG-002 [NPROXX, no date]

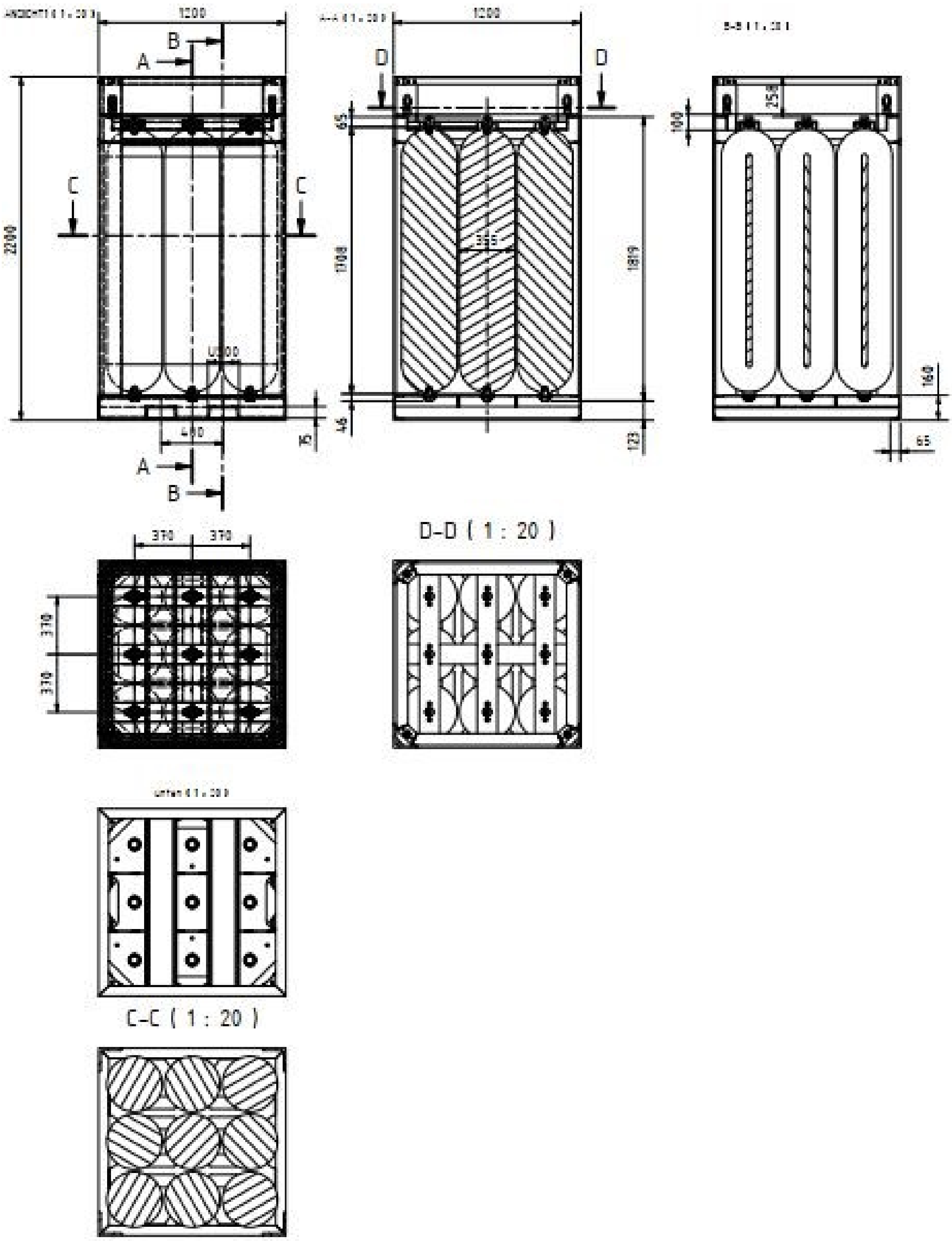


Figure C.4: 900 bar storage tank system technical drawing (views and dimensions). Model KPJ-017-BG-002 [NPROXX, no date]

MAHYTEC
Innovative Energy Solutions

DATASHEET

TANK – 500bar 200L / 300L

High-pressure hydrogen storage

The solution for 350bar hydrogen refilling stations and gas transportation

Can be installed/packaged in a rack by 1, 2, 3…

SERVICE CONDITIONS	
Mass of hydrogen stored at 500bar (15°C)	6.5kg (200L) or 9.5kg (300L)
Temperature of use	From -40°C to 65°C
Maximum working pressure (PS)	500bar
Maximum refilling pressure	500bar
Position of use	Vertical or horizontal
DIMENSIONS	
Inner volume	200L or 300L
Mass of empty tank	188kg (200L) or 260kg (300L)
External dimensions (cm) (without support)	Ø49 x L223 (200L) Ø49 x L307 (300L)
MATERIALS	
Hydrogen tank	Type IV – Polymer liner reinforced with composite material
Nozzle Stainless steel – Aluminum alloy	x2
REGULATION TEST	
Service life	10 years / 5,000 cycles
Hydrostatic test pressure	750bar
Approved according to	EN12245 – PED 2014/68/EU & TPED 2010/35/EU

Figure C.5: 450 bar storage tank system Data sheet. Model Tank - 500 bar 200 L /300 L [MAHYTEC, no date]

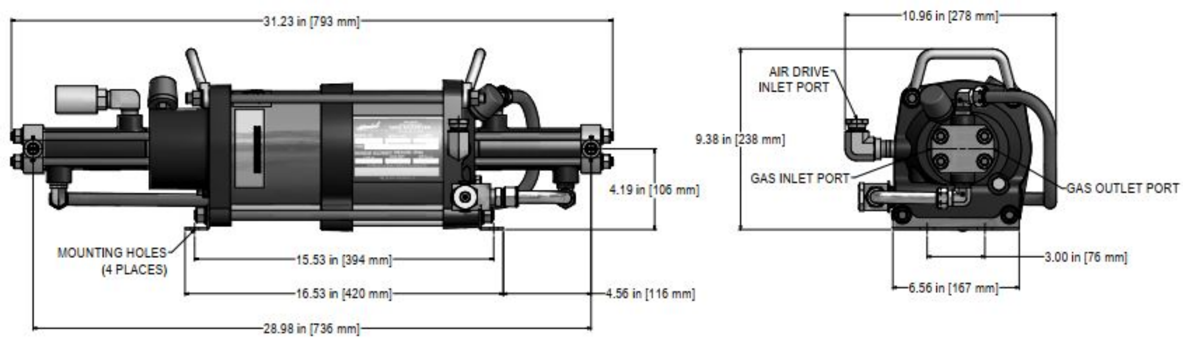
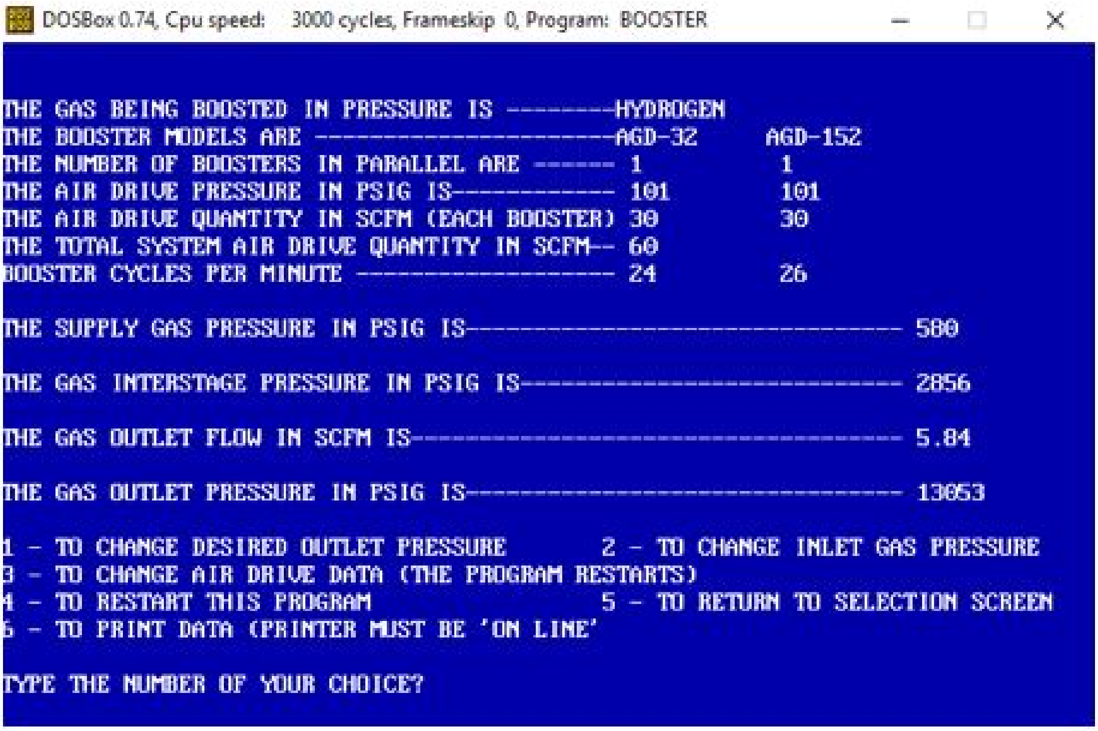


Figure C.6: Pneumatic Driven Gas Booster Dimensional Drawings. Gas Boosters Models: AGD-32, AGD-62, AGD-102, AGD-152 [HASKEL, no date]



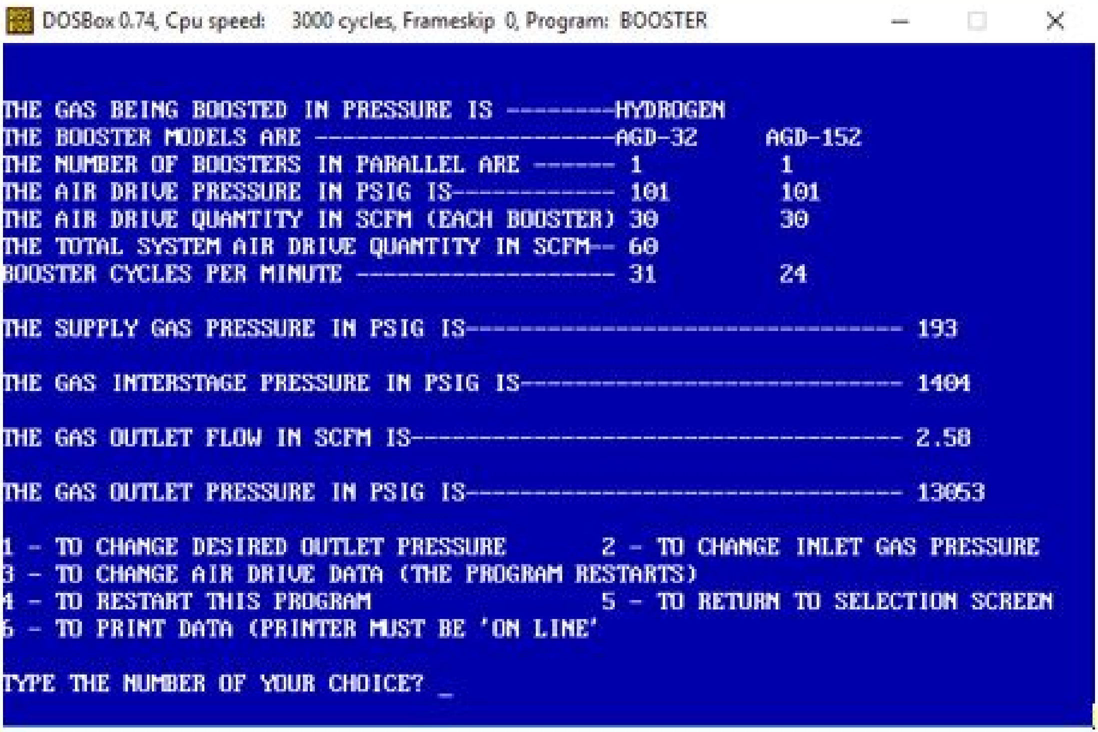
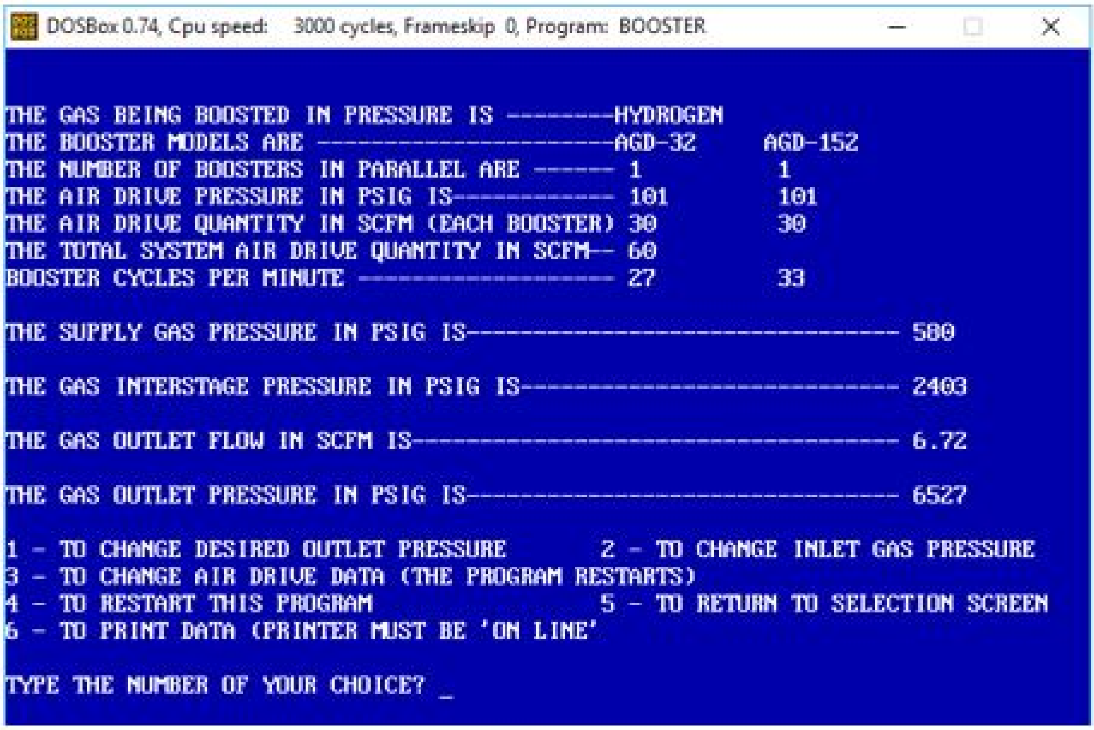


Figure C.7: Boosters simulation results for the minimum and maximum inlet pressure and 900 bar outlet pressure [HASKEL, no date]



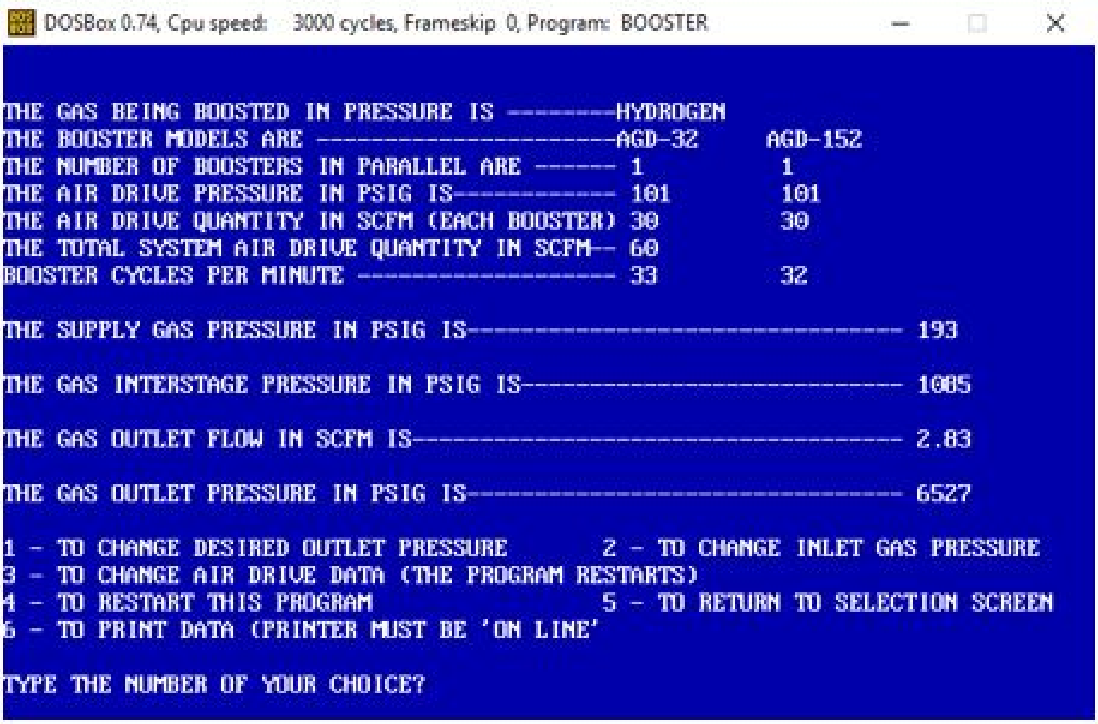


Figure C.8: Boosters simulation results for the minimum and maximum inlet pressure and 450 bar outlet pressure [HASKEL, no date]

SFC - Version with variable speed drive

Model	Working pressure bar	Flow rate [1)] Overall package at operating pressure m^3/min	Max. operating pressure bar	Drive motor rated power kW	Dimensions W x D x H mm	Compressed air connection	Sound pressure level [2)] dB(A)	Mass kg
ASK 34 SFC	7.5	0.94 - 3.60	8	18.5	800 x 1110 x 1530	G 1 ¼	68	530
	10	0.80 - 3.14	11					
	13	0.88 - 2.70	15					
ASK 40 SFC	7.5	0.94 - 4.19	8	22	800 x 1110 x 1530	G 1 ¼	70	550
	10	0.80 - 3.71	11					
	13	0.88 - 3.17	15					

Figure C.9: Air compressor Data sheet. Model ASK 40 SFC [KAESER COMPRESSORS AC, no date]

Data sheet

Overall data sheet – Individual values depend upon your configuration.

Feature	Value
Size	6
Series	MS
Assembly position	Any Preferably vertical
Design structure	Electrically adjustable pressure regulator
Short circuit strength	for all electrical connections
Controller function	Output pressure constant with initial pressure compensation with secondary exhaust
Pressure gauge	Optional With display and control unit with pressure gauge
Operating pressure	0.8 ... 20 bar
Pressure regulation range	0.3 ... 16 bar
Max. pressure hysteresis	0.25 bar
Standard nominal flow rate	2,200 ... 7,500 l/min
Analogue output	0 - 10 V 4 - 20 mA
Duration of control at 25°C	Max. 90 s
Type of inputs	Per IEC 61131-2 No electrical isolation
Nominal operating voltage DC	24 V
Current consumption at nominal operating voltage	Max. 1 A
Current consumption	Max 3.5 A at 24 V DC
Control duration/ interval ratio	1:3
Permissible voltage fluctuation	+/- 10 %
Authorisation	c UL us - Recognized (OL)
CE mark (see declaration of conformity)	to EU directive for EMC
Operating medium	Compressed air in accordance with ISO8573-1:2010 [7:4:4] Inert gases
Note on operating and pilot medium	Lubricated operation possible (subsequently required for further operation)
Corrosion resistance classification CRC	2 - Moderate corrosion stress
Storage temperature	-10 ... 50 °C
Food-safe	See Supplementary material information
Medium temperature	0 ... 50 °C
Protection class	IP65
Ambient temperature	0 ... 50 °C
Product weight	1,820 g
Analogue outputs, absolute accuracy at 25° C	± 3%
Cable interface	Input: M12x1 plug, 5-pin Output: M8x1 plug, 3-pin

Figure C.10: Pressure Regulator Data sheet. Model MS6-LRE [FESTO, no date]

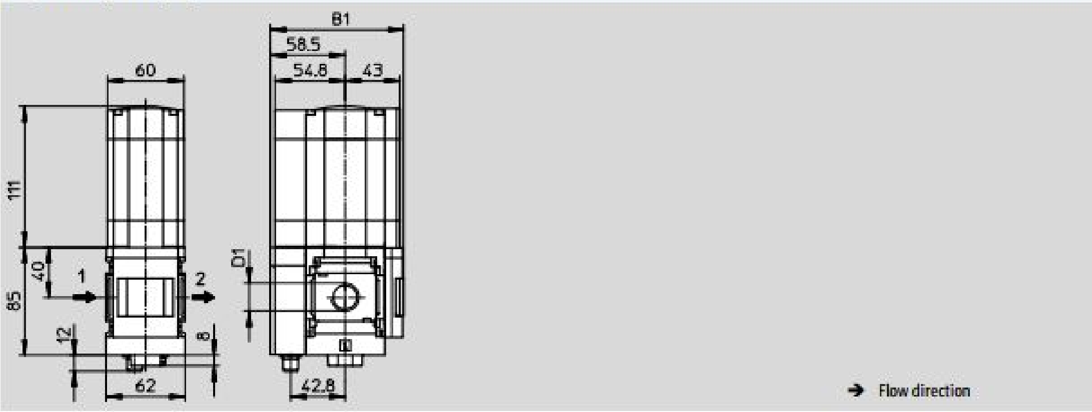
Electrical pressure regulators MS6-LRE, MS series

FESTO

Technical data

Dimensions – Basic version Download CAD data → www.festo.com

Integrated MS pressure gauge



Type	B1 Pressure gauge		D1
	Standard scale	Red-green scale	
MS6-LRE-¼	104.5	106	G¼
MS6-LRE-⅜			G⅜
MS6-LRE-½			G½

- Note: This product conforms to ISO 1179-1 and to ISO 228-1

Figure C.11: Pressure regulator dimensional drawings. Models: MS6-LRE, MS series [FESTO, no date]

Haskel H2 HYDROGEN SYSTEMS

Standard Hydrogen Refuelling Station Datasheet

DISPENSER OPTIONS

FEATURE	STANDARD SPECIFICATION
Hydrogen delivery	In accordance with SAE J2601 refuelling protocol
Hydrogen cooling	Options available down to -40°C
Operating pressure	Up to 100MPa
Dispenser options	Multiple dispenser connection options: - 70MPa for Light Duty Vehicles up to 10kg - 35MPa for Heavy Duty Vehicles up to 50kg - 25MPa & 35MPa for Industrial Vehicles up to 10kg - Nozzle in accordance with customer preference - Multi hose options available
Weather resistance	Suitable for outdoor installation
Operating temperature	-20° C to 40°C
HMI	Haskel proprietary system based on communication requirement. Card swipe and payment options available
Safety equipment	Built in accordance with the authority having jurisdiction compliant with current global safety standards
Electrical power supply	3PH 400V + N 50Hz 200A TN-S

Figure C.12: Standard Hydrogen Refuelling Station Data sheet [HASKEL, no date]

Product data sheet
Characteristics

M9F42335
Multi 9 - C60BP - MCB - 3P - 35 A - C Curve - 480Y/277 V - 10 kA - UL 489

Product availability : Stock - Normally stocked in distribution facility

Price** : 372.00 USD

Main

Range	Multi 9
Product name	Multi 9 C60
Product or component type	Miniature circuit-breaker
Device short name	C60BP
Device application	Distribution
Poles description	3P
Number of protected poles	3
Line Rated Current	35 A 77 °F (25 °C) EN/IEC 60947-2
Network type	AC
Trip unit technology	Thermal-magnetic
Curve code	C
Breaking capacity	6 kA Icu 440 V AC EN/IEC 60947-2 10 kA Icu 415 V AC EN/IEC 60947-2 20 kA Icu 240 V AC EN/IEC 60947-2 6 kA Icu 440 V AC GB 14048.2 10 kA Icu 415 V AC GB 14048.2 20 kA Icu 240 V AC GB 14048.2 14 kA AIR 240 V AC UL 489 10 kA AIR 480Y/277 V AC UL 489 14 kA AIR 240 V AC CSA C22.2 No 5 10 kA AIR 480Y/277 V AC CSA C22.2 No 5
Suitability for isolation	Yes EN/IEC 60947-2
Standards	EN/IEC 60947-2 GB 14048.2 UL 489 CSA C22.2 No 5
Product certifications	IEC CCC CSA UL

Figure C.13: Magnetic starter for electrolyser supply line. Model M9F42335 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

M9R11240

Multi 9 ID - residual current circuit breaker - 2P - 40A - 30mA - type AC

Product availability : Non-Stock - Not normally stocked in distribution facility

Price** : 231.00 USD

Main

Range	Multi 9
Product name	Multi 9 ID
Product or component type	Residual current circuit breaker (RCCB)
Device short name	ID
Device application	Distribution
Poles description	2P
Neutral position	Left
Line Rated Current	40 A
Network type	AC
Earth-leakage sensitivity	30 mA
Earth-leakage protection time delay	Instantaneous
Earth-leakage protection class	Type AC

Figure C.14: Residual-current circuit breaker for electrolyser supply line. Model M9R11240 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

LC1D38P7

TeSys D contactor - 3P(3 NO) - AC-3 - <= 440 V 38 A - 230 V AC 50/60 Hz coil

Product availability : Non-Stock - Not normally stocked in distribution facility

Green Premium

Price** : 193.00 USD

Main

Range	TeSys
Product name	TeSys D
Product or component type	Contactor
Device short name	LC1D
Contactor application	Resistive load Motor control
Utilisation category	AC-3 AC-4 AC-1
Poles description	3P
Power pole contact composition	3 NO
[Ue] rated operational voltage	Power circuit <= 690 V AC 25...400 Hz Power circuit <= 300 V DC
[Ie] rated operational current	50 A 140 °F (60 °C)) <= 440 V AC AC-1 power circuit 38 A 140 °F (60 °C)) <= 440 V AC AC-3 power circuit
Motor power kW	18.5 kW 500 V AC 50/60 Hz AC-3) 18.5 kW 660...690 V AC 50/60 Hz AC-3) 7.5 kW 400 V AC 50/60 Hz AC-4) 18.5 kW 380...400 V AC 50/60 Hz AC-3) 9 kW 220...230 V AC 50/60 Hz AC-3) 18.5 kW 415...440 V AC 50/60 Hz AC-3)
Motor power HP (UL / CSA)	10 hp 230/240 V AC 50/60 Hz 3 phase 10 hp 200/208 V AC 50/60 Hz 3 phase 5 hp 240 V AC 50/60 Hz 1 phase 20 hp 480 V AC 50/60 Hz 3 phase 25 hp 600 V AC 50/60 Hz 3 phase
Control circuit type	AC 50/60 Hz
[Uc] control circuit voltage	230 V AC 50/60 Hz
Auxiliary contact composition	1 NO + 1 NC
[Uimp] rated impulse withstand voltage	6 kV IEC 60947

Figure C.15: Contactor for electrolyser supply line. Model LC1D38P7 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

M9F42325
Multi 9 - C60BP - MCB - 3P - 25 A - C Curve - 480Y/277 V - 10 kA - UL 489

Product availability : Stock - Normally stocked in distribution facility

Green Premium

Price** : 356.00 USD

Main

Range	Multi 9
Product name	Multi 9 C60
Product or component type	Miniature circuit-breaker
Device short name	C60BP
Device application	Distribution
Poles description	3P
Number of protected poles	3
Line Rated Current	25 A 77 °F (25 °C) EN/IEC 60947-2
Network type	AC
Trip unit technology	Thermal-magnetic
Curve code	C
Breaking capacity	6 kA Icu 440 V AC EN/IEC 60947-2 10 kA Icu 415 V AC EN/IEC 60947-2 20 kA Icu 240 V AC EN/IEC 60947-2 6 kA Icu 440 V AC GB 14048.2 10 kA Icu 415 V AC GB 14048.2 20 kA Icu 240 V AC GB 14048.2 14 kA AIR 240 V AC UL 489 10 kA AIR 480Y/277 V AC UL 489 14 kA AIR 240 V AC CSA C22.2 No 5 10 kA AIR 480Y/277 V AC CSA C22.2 No 5
Suitability for isolation	Yes EN/IEC 60947-2
Standards	EN/IEC 60947-2 GB 14048.2 UL 489 CSA C22.2 No 5
Product certifications	IEC CCC CSA UL

Figure C.16: Magnetic starter for air compressor supply line. Model M9F42325 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

M9R11240
Multi 9 ID - residual current circuit breaker - 2P - 40A - 30mA - type AC

Product availability : Non-Stock - Not normally stocked in distribution facility

Price** : 231.00 USD

Main

Range	Multi 9
Product name	Multi 9 ID
Product or component type	Residual current circuit breaker (RCCB)
Device short name	ID
Device application	Distribution
Poles description	2P
Neutral position	Left
Line Rated Current	40 A
Network type	AC
Earth-leakage sensitivity	30 mA
Earth-leakage protection time delay	Instantaneous
Earth-leakage protection class	Type AC

Figure C.17: Residual-current circuit breaker for air compressor supply line. Model M9R11240 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

LC1D25P7

TeSys D contactor - 3P(3 NO) - AC-3 - <= 440 V 25 A - 230 V AC coil

Product availability : Stock - Normally stocked in distribution facility

Green Premium

Price** : 151.00 USD

Main

Range	TeSys
Product name	TeSys D
Product or component type	Contactor
Device short name	LC1D
Contactor application	Resistive load Motor control
Utilisation category	AC-3 AC-4 AC-1
Poles description	3P
Power pole contact composition	3 NO
[Ue] rated operational voltage	Power circuit <= 690 V AC 25...400 Hz Power circuit <= 300 V DC
[Ie] rated operational current	25 A 140 °F (60 °C)) <= 440 V AC AC-3 power circuit 40 A 140 °F (60 °C)) <= 440 V AC AC-1 power circuit
Motor power kW	5.5 kW 220...230 V AC 50/60 Hz AC-3) 11 kW 380...400 V AC 50/60 Hz AC-3) 11 kW 415...440 V AC 50/60 Hz AC-3) 15 kW 500 V AC 50/60 Hz AC-3) 15 kW 660...690 V AC 50/60 Hz AC-3) 5.5 kW 400 V AC 50/60 Hz AC-4)
Motor power HP (UL / CSA)	3 hp 230/240 V AC 50/60 Hz 1 phase 2 hp 115 V AC 50/60 Hz 1 phase 7.5 hp 230/240 V AC 50/60 Hz 3 phase 15 hp 460/480 V AC 50/60 Hz 3 phase 20 hp 575/600 V AC 50/60 Hz 3 phase 7.5 hp 200/208 V AC 50/60 Hz 3 phase
Control circuit type	AC 50/60 Hz
[Uc] control circuit voltage	230 V AC 50/60 Hz
Auxiliary contact composition	1 NO + 1 NC
[Uimp] rated impulse withstand voltage	6 kV IEC 60947

Figure C.18: Contactor for electrolyser air compressor line. Model LC1D25P7 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

M9F42108
Multi 9 - C60BP - MCB - 1P - 8 A - C Curve - 277 V - 10 kA - UL 489

Product availability : Stock - Normally stocked in distribution facility

Green Premium™

Price** : 114.00 USD

Main

Range	Multi 9
Product name	Multi 9 C60
Product or component type	Miniature circuit-breaker
Device short name	C60BP
Device application	Distribution
Poles description	1P
Number of protected poles	1
Line Rated Current	8 A 77 °F (25 °C) EN/IEC 60947-2
Network type	DC AC
Trip unit technology	Thermal-magnetic
Curve code	C
Breaking capacity	3 kA Icu 415 V AC EN/IEC 60947-2 10 kA Icu 240 V AC EN/IEC 60947-2 20 kA Icu 60 V DC EN/IEC 60947-2 3 kA Icu 415 V AC GB 14048.2 10 kA Icu 240 V AC GB 14048.2 20 kA Icu 60 V DC GB 14048.2 10 kA AIR 277 V AC UL 489 14 kA AIR 240 V AC UL 489 14 kA AIR 120 V AC UL 489 10 kA AIR 60 V DC UL 489 10 kA AIR 277 V AC CSA C22.2 No 5 14 kA AIR 240 V AC CSA C22.2 No 5 14 kA AIR 120 V AC CSA C22.2 No 5 10 kA AIR 60 V DC CSA C22.2 No 5
Suitability for isolation	Yes EN/IEC 60947-2
Standards	EN/IEC 60947-2 GB 14048.2 UL 489 CSA C22.2 No 5

Figure C.19: Magnetic starter for the lighting circuit branches. Model M9F42108 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

LP1K0910BD
TeSys K contactor - 3P - AC-3 <= 440 V 9 A - 1 NO aux. - 24 V DC coil

Product availability : Stock - Normally stocked in distribution facility

Price** : 92.00 USD

Main

Range of product	TeSys K
Range	TeSys
Product or component type	Contactor
Device short name	LP1K
Contactor application	Motor control Resistive load
Utilisation category	AC-3 AC-1 AC-4
Poles description	3P
Pole contact composition	3 NO
[Ie] rated operational current	20 A 122 °F (50 °C)) <= 440 V AC AC-1 power circuit 9 A<= 440 V AC AC-3 power circuit 16 A 158 °F (70 °C)) 690 V AC AC-1 power circuit
Auxiliary contact composition	1 NO

Figure C.20: Contactor for the lighting circuit branches. Model LP1K0910BD [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

M9F22113

Multi 9 - C60SP - MCB - 1P - 13 A - C Curve - 277 V - 10 kA - UL 1077

Product availability : Stock - Normally stocked in distribution facility

Green Premium

Price** : 101.00 USD

Main

Range	Multi 9
Product name	Multi 9 C60
Product or component type	Miniature circuit-breaker
Device short name	C60SP
Device application	Distribution
Poles description	1P
Number of protected poles	1
Line Rated Current	13 A 77 °F (25 °C) EN/IEC 60947-2
Network type	AC DC
Trip unit technology	Thermal-magnetic
Curve code	C
Breaking capacity	10 kA AIR 277 V AC UL 1077 14 kA AIR 240 V AC UL 1077 14 kA AIR 120 V AC UL 1077 10 kA AIR 65 V DC UL 1077 10 kA AIR 277 V AC CSA C22.2 No 235 14 kA AIR 240 V AC CSA C22.2 No 235 14 kA AIR 120 V AC CSA C22.2 No 235 10 kA AIR 65 V DC CSA C22.2 No 235 3 kA Icu 415 V AC EN/IEC 60947-2 10 kA Icu 240 V AC EN/IEC 60947-2 20 kA Icu 60 V DC EN/IEC 60947-2 3 kA Icu 415 V AC GB 14048.2 10 kA Icu 240 V AC GB 14048.2 20 kA Icu 60 V DC GB 14048.2
Suitability for isolation	Yes EN/IEC 60947-2
Standards	EN/IEC 60947-2 GB 14048.2 UL 1077 CSA C22.2 No 235

Figure C.21: Magnetic starter for the power circuit branches. Model M9F22113 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

LC1K1610B7
TeSys K contactor - 3P - AC-3 <= 440 V 16 A - 1 NO aux. - 24 V AC coil

Product availability : Non-Stock - Not normally stocked in distribution facility

Price** : 172.00 USD

Main

Range	TeSys
Product or component type	Contactor
Product name	TeSys K
Device short name	LC1K
Device application	Control
Contactor application	Motor control

Complementary

Utilisation category	AC-3 AC-1
Poles description	3P
Power pole contact composition	3 NO
[Ue] rated operational voltage	Power circuit 690 V AC 50/60 Hz Signalling circuit 690 V AC 50/60 Hz
[Ie] rated operational current	16 A<= 440 V AC-3 power circuit 20 A<= 690 V AC-1 power circuit
Control circuit type	AC 50/60 Hz
[Uc] control circuit voltage	24 V AC 50/60 Hz
Motor power kW	4 kW 480 V AC 50/60 Hz 4 kW 500...600 V AC 50/60 Hz 4 kW 660...690 V AC 50/60 Hz 5.5 kW 440 V AC 50/60 Hz 4 kW 220...230 V AC 50/60 Hz 7.5 kW 380...415 V AC 50/60 Hz
Auxiliary contact composition	1 NO
[Uimp] rated impulse withstand voltage	8 kV
Overvoltage category	III

Figure C.22: Contactor for the power circuit branches. Model LC1K1610B7 [SCHNEIDER ELECTRIC, no date]

Product data sheet
Characteristics

BDL36000S12

PowerPact - automatic switch - 600V 125A 3P - Elink

Product availability : Non-Stock - Not normally stocked in distribution facility

Price** : 777.00 USD

Main

Range	PowerPact
Product name	PowerPact B
Product or component type	Automatic switch
Device application	Distribution

Complementary

Line Rated Current	125 A
Number of Poles	3P
Control type	Toggle
Breaking capacity code	D
[Ue] rated operational voltage	600Y/347 V AC 50/60 Hz UL 489
Magnetic hold current	880 A
Magnetic tripping current	1320 A
Mechanical durability	15000 cycles IEC 947-1 Annex K ed 5.2
Electrical durability	10000 cycles IEC 947-1 Annex K ed 5.2 440 V In
Contact position indicator	Yes
Connection pitch	1.06 in (27 mm)
Local signalling	Presence of auxiliary contacts flag green)
Mounting mode	Clip-on 35 x 15 mm symmetrical DIN rail) By screws plate)
Electrical connection	Everlink lug line Everlink lug load
AWG gauge	AWG 6...AWG 2/0 fine stranded aluminium/copper AWG 14...AWG 3/0 rigid or stranded aluminium/copper
Tightening torque	44.25 lbf.in (5 N.m) 0.00...0.02 in² (2.5...10 mm²) 79.66 lbf.in (9 N.m) 0.02...0.15 in² (16...95 mm²)
Number of slots	1 auxiliary switch OF plug-in)

Figure C.23: Automatic circuit breaker for the main electrical line. Model BDL36000S12 [SCHNEIDER ELECTRIC, no date]

Technical specifications

For models F6 to F320 and filter grades KB/KE/KA/KD

Model	Flow rate 1) m³/min	Gauge pressure bar	Ambient temperature °C	Compressed air inlet temperature °C	Maximum mass kg	Electrical supply, ECO-DRAIN
F6	0.60	2 to 16	+3 to +50	+3 to +66	3.3	95...240 VAC ±10% (50...60 Hz) / 100...125 VDC ±10%
F9	0.90				3.3	
F16	1.60	2 to 16	+3 to +50	+3 to +66	4.0	
F22	2.20				4.2	
F26	2.60				4.3	
F46	4.61	2 to 16	+3 to +50	+3 to +66	8.2	
F83	8.25				9.1	
F110	11.00				10.7	
F142	14.20				11.1	
F184	18.40	2 to 16	+3 to +50	+3 to +66	16.2	
F250	25.00				17.9	
F320	32.00				19.9	

1) Performance data at 7 bar gauge pressure relative to 1 bar ambient pressure (absolute) and +20 °C. The flow rate will change for deviating operating conditions.

Degrees of filtration

Degree of filtration	KB Coalescence filter Basic	KE Coalescence filter Extra	KD Particulate filter Dust	KA Activated carbon filter Adsorption	KBE Extra Combination	KEA Carbon Combination
Initial differential pressure at saturation	< 140 mbar	< 200 mbar	< 30 mbar (New, dry)	< 40 mbar (New, dry)	< 200 mbar	< 240 mbar
Aerosol content at inlet	10 mg/m³	10 mg/m³	–	–	10 mg/m³	10 mg/m³
Residual aerosol content at outlet as per ISO 12500-1 1)	< 0.1 mg/m³	< 0.01 mg/m³	–	–	< 0.01 mg/m³	0.003 mg/m³ (Total oil content)
Filter medium	Deep-pleated with support structure and polyester drainage matting		Deep-pleated with support structure	High-efficiency carbon matting	–	–
Application	Filtration of solid and liquid aerosols and solid particles	Same application as KB, but for higher compressed air quality Alternatively: Microparticle filter to KD degree of filtration	Exclusively for filtration of solid particles	Exclusively for removal of oil vapours	Combination of KB and KE; application as KE, but for higher compressed air quality	Combination of KE and KA, filtration of aerosols, solid particles and oil vapours

1) as per ISO 12500-1:06-2007

Figure C.24: Cyclone separator Data sheet. Model F46KC [KAESER COMPRESSORS F, no date]

Dimensions

Model F6 to F320

Model	A G	B mm	C mm	D mm	E mm	F mm	G mm	H mm
F6	½ (¼, ⅜)	283	308	232	155	87	90	≥ 40
F9								
F16	1 (¾)	315	340	259	164	98	100	≥ 40
F22		365	390	308				
F26		365	390	308				
F46	2 (1½, 1¼)	386	411	312	237	153	130	≥ 50
F83		471	496	397				
F110		671	696	597				
F142		671	696	597				
F184	3 (2, 2½)	782	754	643	292	186	150	≥ 50
F250		860	882	771				
F320		1002	1024	918				

G compressed air connections as per ISO 228, optional NPT connections as per ANSI B 1.20.1.

Views

Models shown: F16/F22/F26

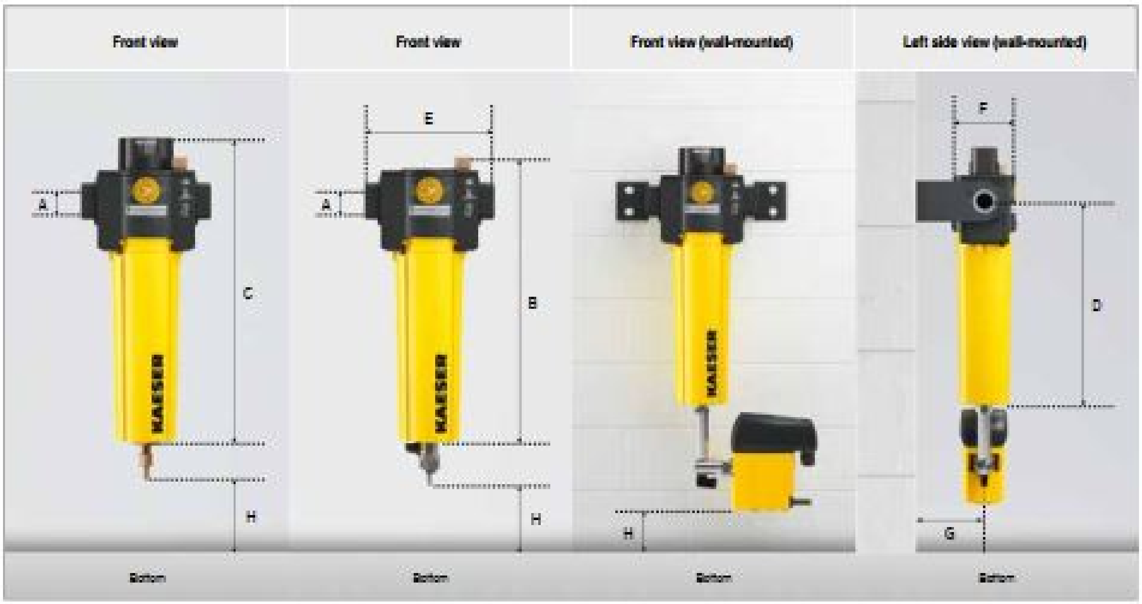


Figure C.25: Cyclone separator dimensional drawings. Model F46KC [KAESER COMPRESSORS F, no date]

Technical specifications

Model	Pressure min. / max. bar(g)	Climate zone [1]	Max. compressor power according to climate zone 1/2/3 m³/min	Dryer power max. 1/2/3 m³/min	Filter performance [2] max. 1/2/3 m³/min	Field of use condensate [3] a/b	Floating contact	Dimensions W x D x H mm	Weight kg	Electrical supply
ECO-DRAIN 30	0.8/16	1/2/3	3/2.5/1.5	6/5/3	30/25/15	a/b	–	164 x 65 x 118	0.8	95...240 VAC ±10% (50...60 Hz) / 100...125 VDC ±10%
ECO-DRAIN 31	0.8/16	1/2/3	6/5/3.5	12/10/7	60/50/35	a/b	•	179 x 74 x 130	0.9	
ECO-DRAIN 32	0.8/16	1/2/3	12/10/7	24/20/14	120/100/70	a	•	211 x 74 x 157	1.6	
ECO DRAIN 32 CO	0.8/16	1/2/3	12/10/7	24/20/14	120/100/70	a/b	•	211 x 74 x 157	1.6	
ECO-DRAIN 12	0.8/16	1/2/3	8/6.5/4	16/13/8	80/65/40	a	•	158 x 65 x 141	0.8	230 V / 1 Ph / 50-60 Hz
ECO DRAIN 12 CO	0.8/16	1/2/3	8/6.5/4	16/13/8	80/65/40	a/b	•	158 x 65 x 141	0.8	
ECO DRAIN 13	1.0/16	1/2/3	35/30/20	70/60/40	350/300/200	a	•	212 x 93 x 162	2.0	
ECO DRAIN 13 CO	0.8/16	1/2/3	35/30/20	70/60/40	350/300/200	a/b	•	212 x 93 x 162	2.0	
ECO-DRAIN 14	0.8/16	1/2/3	150/130/90	300/260/180	1500/1300/900	a	•	252 x 120 x 180	2.9	
ECO DRAIN 14 CO	0.8/16	1/2/3	150/130/90	300/260/180	1500/1300/900	a/b	•	252 x 120 x 180	2.9	
ECO DRAIN 16 CO	0.8/16	1/2/3	1700/1400/1000	3400/2800/2000	–	a/b	•	260 x 280 x 280	5.9	
ECO-DRAIN 12 CP PN 63 [4]	1.2/63	1/2/3	8/6.5/4	16/13/8	80/65/40	a/b	•	146 x 65 x 141	0.9	
ECO-DRAIN 13 CO PN 25 [4]	1.2/25	1/2/3	35/30/20	70/60/40	350/300/200	a/b	•	197 x 93 x 162	2.2	

[1] Climate zone: 1 = **Dry/cool** (Northern Europe, Canada, Northern USA, Central Asia); 2 = **Temperate** (Central and Southern Europe, some parts of South America, North Africa), 3 = **Humid** (South-East Asian coastal regions, Central America, Oceania, Amazon and Congo regions)

[2] Installed downstream of dryer

[3] a = Condensate from fluid-cooled compressors, b = Aggressive condensate

[4] For high pressure applications

► All models can be used in a temperature range from +1 °C to +60 °C

Figure C.26: Condensate drain Data sheet. Model ECO-DRAIN 31 [KAESER COMPRESSORS CD, no date]

Technical specifications

Model		TA Series			TB Series		TC Series			TD Series		
		5	8	11	19	26	31	36	44	51	61	76
Flow rate [1]	m^3/min	0.60	0.85	1.25	2.10	2.55	3.20	3.90	4.70	5.65	7.00	8.25
Pressure loss, refrigeration dryer [1]	bar	0.07	0.14	0.17	0.19	0.20	0.17	0.17	0.18	0.11	0.17	0.17
Elect. power consumption at 100% flow rate [1]	kW	0.30	0.29	0.35	0.44	0.62	0.74	0.89	0.88	0.97	1.25	1.67
Elect. power consumption at 50% flow rate [1]	kW	0.18	0.16	0.19	0.24	0.34	0.34	0.41	0.44	0.55	0.71	0.80
Mass	kg	70	80	85	108	116	155	170	200	251	251	287
Dimensions W x D x H	mm	630 x 484 x 779			620 x 540 x 963		764 x 660 x 1009			1125 x 759 x 1187		
Compressed air connection	G	¾			1		1 ¼			1 ½		2
Condensate drain connection	G	¼			¼		¼			¼		
Electrical supply		230 V/1 Ph/50 Hz			230 V/1 Ph/50 Hz		230 V/1 Ph/50 Hz			400 V/3 Ph/50 Hz		
R-513A refrigerant mass	kg	0.27	0.22	0.36	0.56	0.53	0.80	1.00	1.04	1.25	1.30	1.50
R-513A refrigerant mass as CO_2 equivalent	t	0.17	0.14	0.23	0.35	0.33	0.50	0.63	0.66	0.79	0.82	0.95
Hermetic refrigeration circuit as defined by F-gases reg.		Yes			Yes		Yes			Yes		
Options / Accessories												
Floating contacts: refrigerant compressor running, high pressure dew point		Optional			Optional		Standard			Standard		
Floating contacts: refrigerant compressor running, high pressure dew point, condensate drain alarm		Not available			Optional		Optional			Optional		
Adjustable machine feet		Optional			Optional		Optional			Optional		
Separate autotransformer for adapting to deviating mains voltages		Optional			Optional		Optional			Optional		
Special colour (RAL)		Optional			Optional		Optional			Optional		
Silicone-free version (VW factory standard 3.10.7)		Optional			Optional		Optional			Optional		

Note: Suitable for ambient temperatures of +3 to +43 °C. Max. compressed air inlet temperature +55 °C; gauge pressure min./max. 3 to 16 bar; contains fluorinated greenhouse gas R513A (GWP = 631)

1) As per ISO 7183, option A1: Reference point 1 bar(abs), +20 °C, 0% relative humidity; operating point: pressure dew point +3 °C, working pressure 7 bar(g), inlet temperature +35 °C, ambient temperature +25 °C, 100% relative humidity

Figure C.27: Refrigeration dryer Data sheet. Model TD51 [KAESER COMPRESSORS D, no date]

Technical specifications

Air receiver volume	Max. permitted working pressure	Available versions		Vertical version				Horizontal version			
Litres	bar	Vertical	Horizontal	Height mm	Ø mm	Inlet/outlet connections	Weight kg	Length mm	Ø mm	Inlet/outlet connections	Weight kg
90	11 45	Yes	—	1160 1154	350	2 x G ½ rear	87 88	—	—	—	—
150	11 16	Yes	Yes	1190	450	2 x G ¾ rear	60 67	1050 1346	450 400	2 x G 2	55 75
250	11 16	Yes	Yes	1540 1545	500	2 x G ¾ rear	84 100	1410 1410	500	2 x G 2	84 100
	45		—	1600	500	2 x G 1 rear	195	—	—	—	—
350	11 16	Yes	Yes	1770 1810	550	2 x G 1 rear	100 150	1630 1640	550	2 x G 2	101 164
500	11 16	Yes	Yes	1925 1918	600	2 x G 1 rear	130 210	1776	600	2 x G 2	130 208
	45		—	1925			430	—	—	—	—
900	11	Yes	—	2170 2255	800	2 x G 2; 2 x G 1½	238	—	—	—	—
1000	11 16	Yes	Yes	2265 2255	800	2 x G 1½; 2 x G 2	244 356	2150 2160	800	G 2; 1 x G 1½	240 360
	45			2255		4 x G 1½	670	—	—	—	—
2000	11 16	Yes	Yes	2375 2510	1150 1100	4 x G 2½	470 500	2180	1150	2 x G 2	470 600
	50		—	2480	1100	4 x DN 80	1500	—	—	—	—
3000	11 16	Yes	Yes	2705 2710	1250	4 x G 2½	683 850	2610 3040	1250 1150	2 x G 2½ 2 x G 2	683 810
5000	11 16	Yes	Yes	3570	1400	4 x DN 100	1050 2100	3470 3700	1400	4 x DN 100	1100 1800
8000	11 16	Yes	Yes	4400	1600	4 x DN 200	1850 2350	4440 4400	1600	4 x DN 200	1850 2350
10000	11 16	Yes	Yes	5415	1600	4 x DN 200	2260 2540	5400 5440	1600	4 x DN 200	2200 2650

Figure C.28: Air receiver Data sheet. Model 1000 L 11 bar [KAESER COMPRESSORS AR, no date]

Technical specifications

		AQUAMAT						
		CF 3	CF 6	CF 9	CF 19	CF 38	CF 75	CF 168
Max. flow rate for oil-cooled screw / rotary compressors and oil types in climate zone 1*								
S-460, MOL, MOH, PAO, VCL	m³/min	2.1	4.2	6.5	13	25.9	51.8	80
VDL	m³/min	2.8	5.5	8.5	16.9	33.6	67.3	100
Max. flow rate for oil-cooled screw / rotary compressors and oil types in climate zone 2*								
S-460, MOL, MOH, PAO, VCL	m³/min	1.9	3.8	5.6	11.3	22.5	45	70
VDL	m³/min	2.4	4.9	7.3	14.6	29.3	58.5	90
Max. flow rate for oil-cooled screw / rotary compressors and oil types in climate zone 3*								
S-460, MOL, MOH, PAO, VCL	m³/min	1.6	3.2	4.8	9.6	19.1	38.3	40
VDL	m³/min	2.1	4.2	6.2	12.5	24.9	49.7	50
Max. flow rate from single-/dual-stage reciprocating compressors and oil type in climate zone 1*								
VDL	m³/min	1.9	3.8	5.9	11.7	23.3	46.6	75
PAO	m³/min	1.6	3.2	4.9	9.8	19.4	38.8	–
Ester	m³/min	1.8	3.7	5.6	11.2	22.3	44.6	–
Max. flow rate from single-/dual-stage reciprocating compressors and oil type in climate zone 2*								
VDL	m³/min	1.7	3.4	5.1	10.1	20.3	40.5	52
PAO	m³/min	1.4	2.8	4.2	8.4	16.9	33.8	–
Ester	m³/min	1.6	3.2	4.9	9.7	19.4	38.8	–
Max. flow rate from single-/dual-stage reciprocating compressors and oil type in climate zone 3*								
VDL	m³/min	1.5	2.9	4.3	8.7	17.2	34.4	35
PAO	m³/min	1.2	2.4	3.6	7.2	14.3	28.7	–
Ester	m³/min	1.4	2.8	4.1	8.3	16.5	33	–
Tank size (volume)	l	10	18.6	30.6	61.3	115.5	228.4	720
Filling volume	l	4.3	11.7	22.7	46.3	84.3	158.8	610
Prefilter	l	2.5	4.7	2.5	6.7	18.5	37.2	30
Main filter	l	2.6	4.8	5.9	11.0	20.4	40.3	90
Condensate inlet connection		2x DN 10	2x DN 10	3x DN 10, 1x DN 25	3x DN 10, 1x DN 25	3x DN 13, 1x DN 25	3x DN 13, 1x DN 25	3x DN 13, 1x DN 25
Water outlet connection		DN 10	DN 10	DN 25	DN 25	DN 40	DN 40	DN 30
Service valve connection		–	–	DN 13	DN 13	DN 13	DN 13	DN 13
Connection, oil drain		–	–	DN 25	DN 25	DN 40	DN 40	DN 30
Oil collection container		–	–	2 x 5 l	2 x 5 l	2 x 10 l	2 x 20 l	2 x 30 l
Mass	kg	3,5	5,8	13,5	18,5	36,5	53	90
Dimensions W x D x H	mm	290 x 222 x 538	387 x 254 x 595	350 x 544 x 702	410 x 594 x 872	530 x 764 x 1090	659 x 939 x 1160	1000 x 1200 x 1615
Thermostatically controlled heating								
Heating capacity	W	–	0,4	0,4	1	1	1,4	2,8
Mass	kg	–	0,7	0,7	1	1	1,1	2,2
Electrical connection		–	230 V / 1 Ph / 50-60 Hz	230 V / 1 Ph / 50-60 Hz	230 V / 1 Ph / 50-60 Hz	230 V / 1 Ph / 50-60 Hz	230 V / 1 Ph / 50-60 Hz	230 V / 1 Ph / 50-60 Hz

Figure C.29: Condensate treatment Data sheet. Model CF9 [KAESER COMPRESSORS CT, no date]

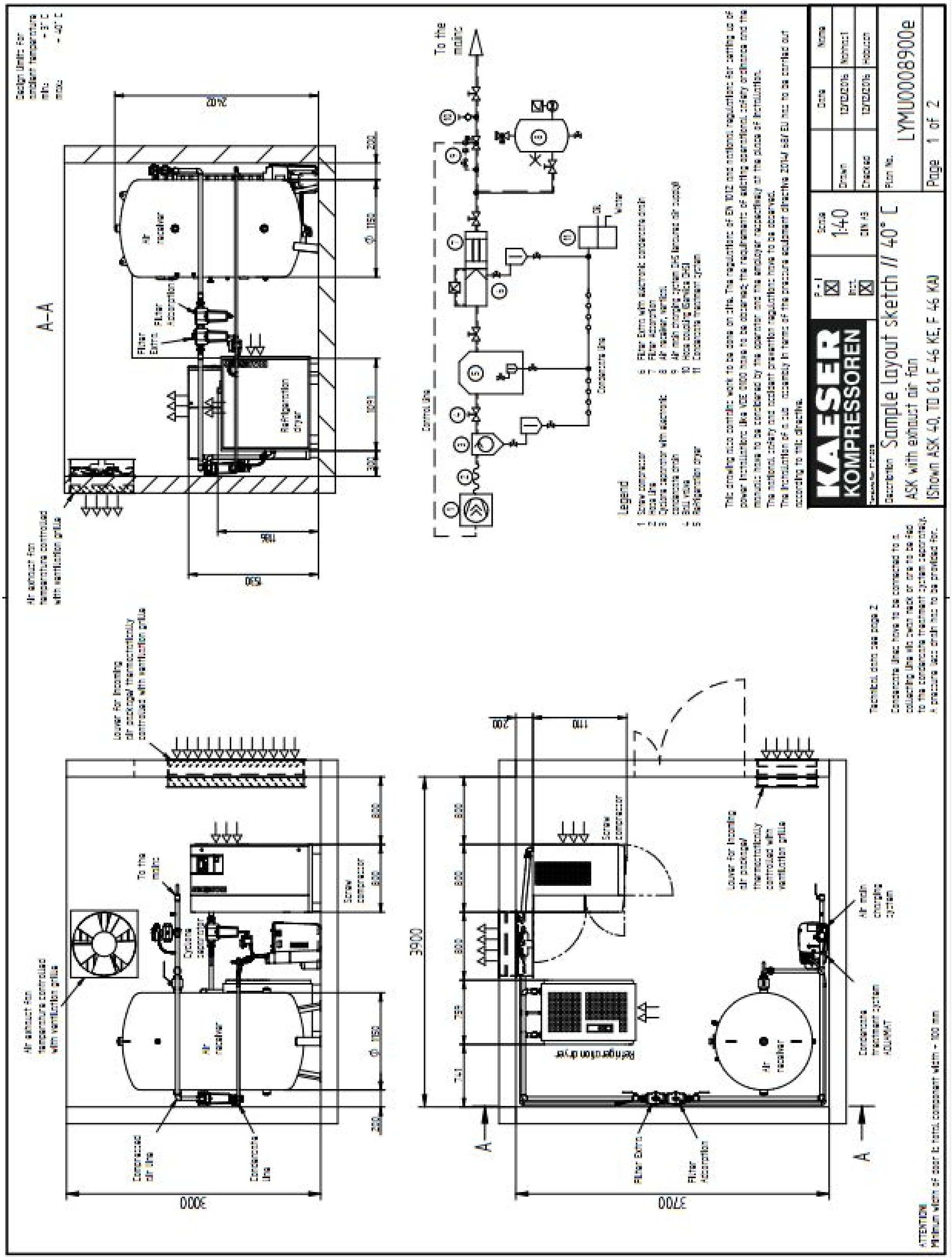


Figure C.30: Air compressor system dimensional drawings [KAESER COMPRESSORS AC, no date]

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Part II

General Technical Specifications

Chapter 1

Project management

1.1 Technical project manager

The following functions/responsibilities correspond to the technical manager:

- To write the complements or rectifications of the project required.
- To attend the works in order to solve the contingencies that may occur and give the complementary orders that may be necessary.
- To approve the partial certifications of work and the final settlement, and to advise the promoter in the act of reception.
- To approve the Health and Safety Plan.
- To carry out the layout of the work and to prepare the corresponding minutes, signing them with the Contractor or Installer.
- To check the provisional installations, the auxiliary means and health and safety systems at work, and to control their correct execution.
- To order and manage the material execution.
- To carry out or arrange for the testing of materials, installations and other work units to ensure construction quality in accordance with the project and with applicable technical regulations.
- To carry out measurements of executed work and to give conformity to the assessed certifications and to the settlement of the work according to the established relations.
- To sign the final certificate of the work.

1.2 Contractor or installer

The following functions/responsibilities correspond to the contractor or installer:

- To organize the work, drawing up the necessary work plans and authorizing the provisional installations and auxiliary means of the work. The contractor will arrange the accesses to the work and the enclosure or fence of it, with the Technical Manager being able to demand his modification or improvement. Likewise, it will be obligatory to place in a visible place, at the entrance of the work, a sign with a metallic panel on an auxiliary structure reflecting the data of the work in relation to its title, the promoter and the names of the competent technicians, whose design must be previously approved by the Project Management. It is the obligation of the Contractor or Installer to keep the site and its surroundings clean.
- To prepare the Health and Safety Plan for the work, when required.
- To sign the act of layout of the work with the Technical Director.
- To be in charge of all the personnel involved in the work and to coordinate the interventions of the subcontractors. The Contractor or Installer is obliged to designate the person acting as Site Manager, with full dedication and faculties to represent him and to adopt all the dispositions that correspond to the contract at all times.
- To ensure the suitability of each and every one of the materials and construction elements used. The Contractor or Installer will transport and place at his own expense the materials coming from the excavations, demolitions, etc., that are not usable on the site, in an orderly manner and in the right place.
- To keep the Book of Orders and to follow up the work.
- To provide the Technical Director with sufficient advance notice of the materials required to carry out his task.
- To prepare the partial certifications of the work and the proposal of final settlement.
- To sign with the Promoter the provisional and definitive reception minutes.
- To arrange insurance against accidents at work and damage to third parties during the work.

1.3 Execution of the work

- **General conditions for the execution of the work:** all the works will be executed with strict subjection to the Project, to modifications of it previously approved and to the orders and instructions that the Technical Manager gives to the Contractor or Installer under his responsibility and in writing, inside the budgetary limitations.
- **Beginning of the work:** the Contractor or Installer shall start the works within the time limit set out in the Particular Technical Specifications, developing them in the necessary form for the work to be carried out within the partial periods stipulated and for the entire process to be completed in accordance with the period required by the contract.The Con-

tractor must give the Technical Manager at least three days' written notice of the beginning of the work.

- **Order of work:** in general, the determination of the order of the work is at the authority of the contractor, except in the cases in which the Project Management considers it appropriate to vary it due to technical circumstances.
- **Extension of the project due to unforeseen circumstances or force majeure:** when it is necessary to extend the project due to unforeseen reasons or any accident, the work will not be interrupted and will continue according to the instructions given by the Technical Manager, while the Reformed Project is being formulated or processed. The Contractor or Installer is obliged to carry out with his personnel and materials as much as the Management of the works arranges for propping up, shoring up, demolition, overhanging or any other work of an urgent nature. If, for reasons of force majeure or beyond the control of the Contractor or Installer, the latter is unable to start the work, has to suspend it, or is unable to finish it within the specified time limits, he will be granted a proportionate extension for the fulfilment of the contract.
- **Hidden works:** of all the work that is to be hidden when the building is finished, the precise plans will be drawn up for them to be perfectly defined. These documents will be prepared in triplicate, being delivered: one to the Technical Manager, another to the Property, and the third to the Contractor, all signed by the three of them. These drawings must be sufficiently dimensioned and will be considered indispensable and unreliable documents for carrying out the measurements.
- **Final work documentation:** the Technical Manager will provide the Property with the final documentation of the works, with the specifications and content established by the legislation in force.
- **Warranty period:** it shall be twelve months long, during which the Contractor shall correct the defects observed, remove the rejected works and repair any faults that may have arisen as a result, all at his own expense and without any right to compensation. In the event of resistance, such works shall be carried out by the Property at the expense of the deposit. After the Final Reception of the work, the Contractor will be relieved of all responsibility, except for hidden defects in the construction.
- **Final Reception:** it shall be verified after the guarantee period has expired. From this date, the obligation of the Contractor or Installer to repair, at his own expense, any defects inherent in the building's conservation regulations will cease, and only responsibilities that might be incurred due to construction defects will remain in force. If, when proceeding with the verification for the final reception of the work, it is not in the proper conditions, this will be postponed. Then, the Technical Manager will set the Contractor or Installer the deadlines and ways in which the necessary works must be carried out. If the work is not carried out within these deadlines, the contract may be terminated with the loss of the deposit.

Chapter 2

Technical conditions for the execution and assembly of low-voltage electrical installations

2.1 General conditions

All the materials to be used in this installation shall be of first quality and shall meet the conditions required by the Low Voltage Electrotechnical Regulations and other applicable regulations on construction materials and prototypes. They may be submitted to the analyses or tests, on behalf of the contract, that are considered necessary to accredit their quality. Any others materials that may have been specified and are necessary to be used must be approved by the Technical Management, on the understanding that those which do not meet the conditions required by good practice at the facility will be rejected. The equipment is subjected to a series of tests in the factory to check where is free from mechanical and electrical defects.

In general, based on the Law of Prevention of Labor Risks and the specifications of the NTE norms (Technological Norms of the Construction), the following safety conditions will be fulfilled, among others:

- Whenever intervention in an electrical installation is to be carried out, both in the execution of the same and in its maintenance, the work shall be carried out without voltage.
- A minimum of two operators must always be present at the workplace.
- Gloves and insulating tools must be used.
- When electrical appliances or tools are used, in addition to being grounded where necessary, they shall be fitted with insulation grade II, or supplied with a voltage of less than 50 V by safety transformers.

- Each of the protection, switching and control devices shall be locked in the open position, if possible, with a sign prohibiting operation on the control device.
- The operation will not be restored at the end of the work before checking that there is no danger.
- In general, while working on or near energized circuits or equipment, operators shall wear clothing without metal accessories. They shall carry the tools or equipment in bags and use insulating footwear, without iron fittings or nails in the soles.
- All the general safety provisions to be complied with, must also be complied with concerning safety, hygiene and health at work, and applicable municipal by-laws.

If it is necessary to make any further changes to the system, either due to a fault or because of modifications to the system, all the specifications for execution, control and safety must be taken into account in the same way as for a new system. The opportunity shall be taken to check the general condition of the installation, replacing or repairing those elements that require it.

2.2 Electrical conduits

Cables shall be placed inside tubes or channels, fixed directly to walls, buried, directly embedded in structures, inside building holes, under mouldings, in trays or tray supports. Before the distribution network is set up, the structural elements supporting or embedding it, such as slabs, partitions, etc., must be in place. The location of the mechanism boxes, electrical cabinets and protection boxes, as well as the path of the lines, must be clearly marked on the network, indicating the nature of each element.

- **Insulated cables under protective tubes:** they can be metallic, non-metallic or composite (consisting of metallic and non-metallic materials) tubes and fittings. The tubes are classified according to the following standards:
  - UNE-EN 61386-21:2005. Conduit systems for cable management. Part 21: Particular requirements - Rigid conduit systems.
  - UNE-EN 61386-22:2005. Conduit systems for cable management. Part 22: Particular requirements - Pliable conduit systems.
  - UNE-EN 61386-23:2005: Conduit systems for cable management. Part 23: Particular requirements - Flexible conduit systems.
  - UNE-EN 61386-24:2011: Conduit systems for cable management. Part 24: Particular requirements - Conduit systems buried underground.

  The protective characteristics of the joint between the tube and its fittings must not be less than those declared for the tube system. Also, the inner surface of the tubes must not have any edges, roughness or cracks.

  The dimensions of the unburied tubes with threaded connection are those prescribed in the UNE-EN 60423 standard. For buried tubes, the dimensions correspond to those indicated in the UNE-EN 61386-24 standard. The denomination will be made according to the external diameter. The minimum internal diameter must be declared by the manufacturer.

The minimum external diameter of the tubes, depending on the number and section of the cables, will be obtained from the tables indicated in the ITC-BT-21 (Indoor installations-Protective tubes and channels), as well as the minimum characteristics according to the type of installation.

For the execution of the conduits under protective tubes, the following general prescriptions are to be considered:

- The cables used shall have a rated voltage of not less than 450/750 V.
- The layout of the conduits will be made following vertical and horizontal lines or parallel to the edges of the walls that limit the room where the installation is carried out.
- The tubes will be connected to each other by means of fittings appropriate to their class that will ensure the continuity of the protection they provide to the cables.
- Hot-bendable rigid insulating tubes may be hot-assembled with each other.
- The bends made in the tubes shall be continuous and shall not cause unacceptable reductions in section. The minimum bending radius for each class of tube shall be those specified by the manufacturer in accordance with UNE-EN.
- Electrical cabinets may be intended only to facilitate the insertion and removal of conductors in tubes or serve as junction boxes at the same time.
- Connections between cables shall be made inside suitable boxes made of insulating and non-flame propagating material. If they are metallic, they shall be protected against corrosion. The dimensions of these boxes shall be such that they can comfortably accommodate all the cables that they contain. Their depth shall be at least equal to the diameter of the largest tube plus, 50 % of the tube, with a minimum of 40 mm. Their diameter or inner side shall be at least 60 mm. When tube entries into connection boxes are to be made watertight, suitable compression fittings or glands must be used.
- For metal pipes without internal insulation, the possibility of water condensation must be taken into account. Therefore, the layout of the installation shall be chosen accordingly, providing for drainage and establishing appropriate ventilation by, for example, the use of a "T" of which one of the arms is not used.
- Accessible metal tubes must be grounded. Their electrical continuity must be adequately ensured. In the case of using flexible metal tubes, the distance between two consecutive groundings of the tubes must not exceed 10 meters.
- Metal tubes may not be used as protective or neutral conductors.

Tubes in fixed surface conduits

For surface conduits, the tubes should preferably be rigid and in special cases, bendable tubes may be used. Their minimum characteristics will be those indicated in Table 2.1:

Remark: the codes for compression and impact resistance and for minimum and maximum installation and service temperatures, define the most relevant basic characteristics of the tubes, which are usually represented by a 4-digit code. In the case of tubes in ordinary fixed surface conduits, the minimum codification for the first four characteristics in the table corresponds to 4321. This code, together with the characteristic "Non-flame propagating", defines the product to be installed.

The diameter of the tubes must be such that the cables or insulated conductors can be easily housed and removed. Table 2.2 shows the minimum external diameters of the tubes according to the number and section of the cables to be conducted.

When the tubes are installed in surface assembly, the following requirements must also be taken into account:

- The tubes shall be fixed to the walls or ceilings by means of flanges or clamps protected against corrosion and solidly fastened. The distance between them shall not exceed 0.50 metres.
- The tubes will be placed adapting to the surface on which they are installed, bending or using the necessary fittings.
- In straight alignments, the deviations of the axis of the pipe from the line connecting the end points shall not exceed 2 %.
- The tubes should, whenever possible, be placed at a minimum height of 2.50 metres above the floor, in order to protect them from possible mechanical damage.

Table 2.1: Minimum characteristics for tubes in ordinary fixed surface conduits

Characteristic	Code	Grade
Compression resistance	4	Strong
Impact resistance	3	Medium
Minimum installation and service temperature	2	-5 °C
Maximum installation and service temperature	1	+60 °C
Bending resistance	1-2	Rigid/Bendable
Electrical properties	1-2	Electrical/insulating continuity
Resistance to penetration by solid objects	4	Against objects D $\geq$ 1 mm
Water penetration resistance	2	Against water drops falling vertically when the tube system is tilted 15°
Corrosion resistance of metal and composite tubes	2	Medium internal and external protection
Traction resistance	0	Not declared
Flame propagation resistance	1	Non-propagator
Resistance to suspended loads	0	Not declared

Table 2.2: Minimum external diameters in mm of the tubes in ordinary fixed surface conduits

Single-pole cables nominal section(mm^2)	**Number of cables**				
	1	2	3	4	5
1.5	12	12	16	16	16
2.5	12	12	16	16	20
4	12	16	20	20	20
6	12	16	20	20	25
10	16	20	25	32	32
16	16	25	32	32	32
25	20	32	32	40	40
35	25	32	40	40	50
50	25	40	50	50	50
70	32	40	50	63	63
95	32	50	63	63	75
120	40	50	63	75	75
150	40	63	75	75	-
185	50	63	75	-	-
240	50	75	-	-	-

Tubes in embedded conduits

In embedded conduits, the protective tubes may be rigid, bendable or flexible, with the minimum characteristics indicated below, in Tables 2.3 and 2.4:

Table 2.3: Minimum characteristics for tubes embedded in factory works (walls, ceilings and false ceilings), construction hollows or construction site protective channels

Characteristic	**Code**	**Grade**
Compression resistance	2	Light
Impact resistance	2	Light
Minimum installation and service temperature	2	-5 ºC
Maximum installation and service temperature	1	+60 ºC
Bending resistance	1-2-3-4	Any of those specified
Electrical properties	0	Not declared
Resistance to penetration by solid objects	4	Against objects D $\geq$ 1 mm
Water penetration resistance	2	Against water drops falling vertically when the tube system is tilted 15º
Corrosion resistance of metal and composite tubes	2	Medium internal and external protection
Traction resistance	0	Not declared
Flame propagation resistance	1	Non-propagator
Resistance to suspended loads	0	Not declared

Table 2.4: Minimum characteristics for tubes embedded in concrete or pre-wired conduits

Characteristic	Code	Grade
Compression resistance	3	Medium
Impact resistance	3	Medium
Minimum installation and service temperature	2	-5 °C
Maximum installation and service temperature	2	+90 °C
Bending resistance	1-2-3-4	Any of those specified
Electrical properties	0	Not declared
Resistance to penetration by solid objects	5	Dust-protected
Water penetration	3	Protected against rainwater
Corrosion resistance of metal and composite tubes	2	Medium internal and external protection
Traction resistance	0	Not declared
Flame propagation resistance	1	Non-propagator
Resistance to suspended loads	0	Not declared

1. Tubes embedded in factory works (walls, ceilings and false ceilings), construction hollows or construction site protective channels.
2. Tubes embedded in concrete or pre-wired conduits.

   Remark: tubes with code 3322 correspond to installations that require a product with higher performances, such as installations embedded in concrete in which the tubes are placed during the formwork work and are subject to greater mechanical aggres-

Table 2.5: Minimum external diameters in mm of the tubes in embedded conduits

Single-pole cables nominal section(mm^2)	Number of cables				
	1	2	3	4	5
1.5	12	12	16	16	20
2.5	12	16	20	20	20
4	12	16	20	20	25
6	12	16	25	25	25
10	16	25	25	32	32
16	20	25	32	32	40
25	25	32	40	40	50
35	25	40	40	50	50
50	32	40	50	50	60
70	32	50	63	63	63
95	40	50	63	75	75
120	40	63	75	75	-
150	50	63	75	-	-
185	50	75	-	-	-
240	63	75	-	-	-

sion. Moreover, under these conditions, high setting temperatures can be reached and therefore the performance is higher.

The diameter of the tubes must be such that the insulated cables can be easily accommodated and removed. Table 2.5 shows the minimum external diameters of the tubes according to the number and section of the conductors or cables to be conducted.

When the tubes are embedded, the following requirements must also be taken into account:

- In the installation of the tubes inside the construction elements, the grooves will not jeopardize the safety of the walls or ceilings where they are made. The dimensions of the grooves shall be sufficient to ensure that the pipes are covered by a layer of at least 1 cm thick. At corners, the thickness of this layer may be reduced to 0.5 cm.
- Tubes intended for the electrical installation of the lower floors shall not be installed between the framing and flooring.
- For the installation corresponding to the floor itself, only tubes that must be covered by a layer of concrete or mortar of at least 1 cm thick, may be installed between the framing and the flooring.
- For changes of direction, the tubes shall be suitably bent or fitted with appropriate elbows or "T".
- The covers of the electrical cabinets and junction boxes will be accessible and removable once the work is finished. They will be levelled out with the external surface of the coating of the wall or ceiling, when not installed inside a closed and practicable housing.
- In the case of using tubes embedded in walls, it is convenient to arrange the routes horizontal at a maximum of 50 cm from the floor or ceiling, and vertical at a distance of corner angles no greater than 20 cm.

Table 2.6: Minimum characteristics for tubes in air conduits or with air tubes

Characteristic	Code	Grade
Compression resistance	4	Strong
Impact resistance	3	Medium
Minimum installation and service temperature	2	-5 °C
Maximum installation and service temperature	1	+60 °C
Bending resistance	4	Flexible
Electrical properties	1/2	Continuity/isolation
Resistance to penetration by solid objects	4	Against objects D $\geq$ 1 mm
Water penetration resistance	2	Against water drops falling vertically when the tube system is tilted 15°
Corrosion resistance of metal and composite tubes	2	Medium internal and external protection
Traction resistance	2	Light
Flame propagation resistance	1	Non-propagator
Resistance to suspended loads	2	Light

Tubes in air conduits or with air tubes

In air conduits, intended for feeding machines or elements with restricted mobility, the tubes shall be flexible and their minimum characteristics for ordinary installations shall be those indicated in Table 2.6.

The diameter of the tubes must be such that the insulated cables can be easily accommodated and removed. Table 2.7 shows the minimum external diameters of the tubes according to the number and section of the conductors or cables to be conducted.

Table 2.7: Minimum external diameters in mm of the tubes in air conduits

Single-pole cables nominal section(mm^2)	**Number of cables**				
	1	2	3	4	5
1.5	12	12	16	16	20
2.5	12	16	20	20	20
4	12	16	20	20	25
6	12	16	25	25	25
10	16	25	25	32	32
16	20	25	32	32	40

It is recommended not to use this type of installation for cable cross-sections greater than 16 mm^2.

Tubes in buried conduits

The minimum characteristics of buried tubes shall be as shown in Table 2.8.

Table 2.8: Minimum characteristics for tubes in buried conduits

Characteristic	**Code**	**Grade**
Compression resistance	Not applicable	250 N/450 N/750 N
Impact resistance	Not applicable	Light/Normal/Normal
Minimum installation and service temperature	Not applicable	Not applicable
Maximum installation and service temperature	Not applicable	Not applicable
Bending resistance	1-2-3-4	Any of those specified
Electrical properties	0	Not declared
Resistance to penetration by solid objects	4	Against objects D $\geq$ 1 mm
Water penetration	3	Against rainwater
Corrosion resistance of metal and composite tubes	2	Medium internal and external protection
Traction resistance	0	Not declared
Flame propagation resistance	0	Not declared
Resistance to suspended loads	0	Not declared

Light soil is considered to be uniform soil which is not stony type and with light upper loads, e.g. pavements, parks and gardens. Heavy soil is the stony and hard type with heavy

Table 2.9: Minimum external diameters in mm of the tubes in buried conduits

Single-pole cables nominal section(mm^2)	Number of cables				
	≤ 6	7	8	9	10
1.5	25	32	32	32	32
2.5	32	32	40	40	40
4	40	40	40	40	50
6	50	50	50	63	63
10	63	63	63	75	75
16	63	75	75	75	90
25	90	90	90	110	110
35	90	110	110	110	125
50	110	110	125	125	140
70	125	125	140	160	160
95	140	140	160	160	180
120	160	160	180	180	200
150	180	180	200	200	225
185	180	200	225	225	250
240	225	225	250	250	-

upper loads, such as roads and railways. For tubes embedded in concrete it applies 250 N and Light grade. On the other hand, for tubes in light soil it applies 450 N and Normal grade. Finally, for tubes in heavy soil apply 750 N and Normal grade.

The diameter of the tubes must be such that the insulated cables can be easily accommodated and removed. Table 2.9 shows the minimum external diameters of the tubes according to the number and section of the conductors or cables to be conducted.

- **Insulated cables fixed directly on the walls:** These installations shall be established with cables of rated voltages of not less than 0.6/1 kV, provided with insulation and covering. For the execution of the conduits, the following prescriptions will be taken into account:
  - They shall be fixed on the walls by means of flanges, clamps, or collars in such a way that they do not damage the covers of the walls.
  - The distance between two successive fixing points shall not exceed 0.40 metres.
  - When the cables must have mechanical protection, armoured cables must be used. Otherwise, additional mechanical protection shall be provided on them.
  - Cables should not be bent with a radius that is too small and, this radius should not be less than 10 times the external diameter of the cable unless otherwise is specified in the UNE standard.
  - Crossings of cables with non-electrical conduits may be made at the front or at the rear of the conduit, leaving a minimum distance of 3 cm between the outer surface of the non-electrical conduit and the cable cover when the crossing is made at the front of the conduit.

  - The ends of the cables shall be watertight when the characteristics of the sites so require, using boxes or other suitable devices for this purpose. Watertightness may be ensured by means of cable glands.
  - Joints and connections shall be made by means of boxes or equivalent devices fitted with removable covers, which ensure continuity of mechanical protection, insulation, inaccessibility of connections and allow for verification if necessary.

- **Insulated buried cables:** the conditions for these conduits, in which the insulated conductors must go under a tube unless they have a cover and a rated voltage of 0.6/1 kV, will be established in accordance with ITC-BT-07 (Underground networks for low voltage distribution) and ITC-BT-21 (Indoor installations-Protective tubes and channels).
- **Insulated cables directly embedded in structures:** These conduits require insulated conductors with cover (including armoured or mineral insulated cables). The minimum and maximum installation and service temperature shall be -5 ºC and 90 ºC respectively.
- **Insulated conductors inside the building:** The cables used shall have a rated voltage of not less than 450/750 V. Cables or tubes may be installed directly in building holes under the condition that they are non-flame propagating. Permissible building openings may be in walls, beams, floors or ceilings, or be between two parallel surfaces as in the case of false ceilings or air chamber walls. The section of the holes must be at least four times of that occupied by the cables or tubes, and their smallest dimension must not be less than twice the external diameter of the largest section of the holes, with a minimum of 20 mm. Cable joints and connections shall be accessible, and suitable junction boxes shall be provided for them. Water infiltration, leakage or condensation that could penetrate inside the hole must be prevented, paying particular attention to the impermeability of the outer walls and the proximity of liquid pipelines.
- **Insulated cables under protective trunking:** this is an installation material made up of a profile with perforated or unperforated walls, designed to house cables and closed by a removable cover, that must always be accessible. The cables used shall have a rated voltage of not less than 450/750 V. The protective trunking will have an IP4X rating and will be classified as "channels with access covers that can only be opened with tools". Inside, mechanisms such as switches, sockets, command and control devices, etc., may be placed.

Table 2.10: Minimum characteristics for ordinary surface conduits

Characteristic	**Grade**	
Dimension of the largest side of the cross-section	$\leq$ 16 mm	$>$ 16 mm
Impact resistance	Very light	Medium
Minimum installation and service temperature	+15 ºC	-5 ºC
Maximum installation and service temperature	+60 ºC	+60 ºC
Electrical properties	Insulator	Continuity/Insulator
Resistance to penetration by solid objects	4	Not less than 2
Water penetration	Not declared	Not declared
Flame propagation resistance	Non-propagator	Non-propagator

It will also be possible to make connections between cables inside the trunking and to the mechanisms. The layout of the ducts should preferably follow vertical and horizontal lines or be parallel to the edges of the walls.

Conduits for ordinary surface installations shall have the minimum characteristics indicated in Table 2.10 below, from the tables indicated in the ITC-BT-21 (Indoor installations-Protective tubes and channels). Complying with these characteristics will be done according to the tests indicated in the UNE-EN 50085 standard (Cable trunking systems and cable ducting systems for electrical installations).

- **Insulated conductors under mouldings:** these conduits are made up of cables housed in grooves under the mouldings. They may only be used in locations classified as dry, temporarily wet or dusty. Cables shall have a rated voltage of not less than 450/750 V. They shall meet the following conditions:
  - The dimensions of the grooves shall be such that the cables can be installed through them with no difficulty. In principle, no more than one cable may be fitted in each groove. However, several cables may be fitted if they belong to the same circuit and the groove is of suitable size.
  - The width of the slots intended to receive rigid cables with a cross-section not exceeding 6 mm^2 shall be at least 6 mm.

  For the installation of the mouldings, it will be taken into account the following:
  - The mouldings will not present any discontinuity in the whole length. In changes of direction, the angles of the grooves shall be obtuse.
  - The conduits may be placed at ceiling level or immediately above the skirting boards. In the absence of skirting boards, the lower part of the moulding shall be at least 10 cm above the floor.
  - If grooved skirting boards are used, the lowest insulated conductor shall be at least 1.5 cm above the floor.
  - When crossings of these conduits with those intended for other use (water, gas, etc.) cannot be avoided, a moulding specially designed for these crossings or preferably a rigid embedded tube protruding from both sides of the crossing shall be used. The distance between two ducts crossing shall be at least 1 cm in the case of special mouldings for the crossing and 3 cm in the case of rigid built-in tubes.
  - The connections and derivations of the cables shall be made by means of connecting devices with screw or equivalent systems.
- **Insulated conductors in trays or tray supports:** the material used for manufacturing will be first quality laminated steel, galvanized by immersion. The width of the ducts shall be at least 100 mm, with increments of 100 in 100 mm. The length of the straight sections shall be 2 metres. The trays and their accessories shall be attached to ceilings and walls by means of suspension fittings, at distances such that there are no deflections greater than 10 mm, and shall be perfectly aligned with the walls of the rooms. It is not allowed to join the trays or to fix them to the supports by means of welding. Metal boxes shall be used for line connections or derivations and shall be fixed to the trays.

Only insulated cables with cover shall be used (including armoured or mineral insulated cables), unipolar or multipolar, according to the UNE-HD 60364-5-52:2014 (Low-voltage electrical installations-Part 5-52: Selection and erection of electrical equipment. Wiring systems standard).

In case of proximity of electrical conduits to non-electrical conduits, they shall be arranged so that a minimum distance of 3 cm is maintained between the outer surfaces of the two. In case of proximity to heating ducts, the electrical ducts must be laid in such a way for not to reach a dangerous temperature. They shall therefore be kept apart by a suitable distance or by means of heat shields. In the same way, electric conduits shall not be placed below other conduits which may give rise to condensation, such as those intended to transport steam, water, gas, etc., unless arrangements are made to protect them against the effects of such condensation.

The electrical conduits will be established so that the convenient identification of their circuits and elements, repairs, transformations, etc. can be carried out at any time. Additionally, throughout the length of the conduits through construction elements such as walls, partitions and ceilings, there shall be no cable joints or derivations, and they shall be protected against mechanical deterioration, chemical action and the effects of humidity. The covers, enclosures, controls and buttons for operating the equipment shall be made of insulating material.

2.2.1 Cables

Cables will be of the following types, as indicated in Table 2.11:

Table 2.11: Types of cables

Characteristic	450/750 V nominal voltage	0.6/1 kV nominal voltage
Wire	Copper	Copper (aluminum, when required)
Formation	Unipolar	Uni-bi-tri-polars
Isolation	Polyvinyl chloride (PVC)	Polyvinyl chloride (PVC) or or cross-linked polyethylene (XLPE)
Test voltage	2500 V	4000 V
Installation	Under tube	In the air or on a tray
Applicable legislation	UNE 21031	UNE 21123

The electrolytic copper wires shall be manufactured of uniform quality and mechanical resistance, and their resistivity coefficient at 20 °C shall be 98 % to 100 %. They shall be provided with a tin plating bath and shall be subjected to a verification test. The minimum insulation capacity of the conductors shall be 500 V. In addition, conductors with a cross-section of 6 mm2 or more shall be made up of cable obtained by copper wire braiding of the diameter corresponding to the section of the cable involved.

Sizing of the installation

For the selection of the active wires of the appropriate cable for each load, the most unfavourable of the following criteria will be used:

- **Maximum admissible current.** Take the current of each load as the current. Based on the nominal currents thus established, the cable section that admits this current will be chosen according to the requirements of the Low Voltage Electrotechnical Regulations ITC-BT-19 (Indoor or receivers installations) or the manufacturer's recommendations, adopting the appropriate correction coefficients according to the conditions of the installation. As for load enlargement coefficients, the Instructions ITC-BT-44 for lighting receivers and ITC-BT-47 for motor receivers should be taken into account.
- **Voltage drop during operation.** The cross-section of the cables to be used shall be determined so that the voltage drop between the source of the installation and any point of use is less than 3 % of the nominal voltage at the source of the installation for lighting, and 5 % for other uses, considering all receivers capable of operating simultaneously to be supplied. For the individual branch, the maximum permissible voltage drop shall be 1.5 %. The value of the voltage drop may be compensated between that of the indoor installation and that of the individual branch, so that the total voltage drop is less than the sum of the limit values specified for both.
- **Transient voltage drop.** The voltage drop in the entire system during motor starting must not lead to conditions that prevent the motor from starting, contactors from switching off, lighting from flashing, etc.

Table 2.12: Minimum cross-section of the neutral cable as a function of the cross-section of the phase cables

Phase cables cross section (mm^2)	**Neutral cable cross section (mm^2)**
6 (Cu)	6
10 (Cu)	10
16 (Cu)	10
16 (Al)	16
25	16
35	16
50	25
70	35
95	50
120	70
150	70
185	95
240	120
300	150
400	185

The section of the neutral cable will be the one specified in Instruction ITC-BT-07 (Underground networks for low voltage distribution), according to the section of the phase or polar cables of the installation, shown in Table 2.12. The protection conductors will be of the same type as the active conductors specified in the previous section, and will have a minimum section equal to that fixed by Table 2.13 of the ITC-BT-18 (Grounding installations), depending on the section of the phase or polar cables in the installation.

Table 2.13: Relation between the sections of the protective cables and phase cables

Phase cables cross section S (mm^2)	**Protective cables minimum cross section S_p (mm^2)**
$S \leq 16$	$S_p = S$
$16 < S \leq 35$	$S_p = 16$
$S > 35$	$S_p = S/2$

Identification of the installations

The electrical conduits will be established in such a way that convenient identification of their circuits and elements, repairs, transformations, etc. can be carried out at any time.

The cables of the installation must be easily identifiable, especially with regard to the neutral and the protective cables. This identification shall be carried out by the colours of their insulation. When there is a neutral cable in the installation, or when a phase cable is to be passed on to the neutral cable, these shall be identified by the colour light blue. The protective cable shall be identified by the colour green-yellow. All phase conductors, or where applicable, those for which there is no provision for subsequent connection to the neutral cable, shall be identified by the colours brown, black or grey.

Insulation resistance and dielectric

The installations must have an insulation resistance at least equal to the values given in Table 2.14, according to ITC-BT-19 (Indoor or receivers installations).

Table 2.14: Insulation resistance

Nominal installation voltage	**Direct current test voltage (V)**	**Insulation resistance (MΩ)**
Very Low Safety Voltage (MBTS) Very Low Protection Voltage (MBTP)	250	≥ 0.25
Up to and including 500 V (except for the above case)	500	≥ 0.5
More than 500 V	1000	≥ 1.0

The dielectric strength shall be such that, when the operating equipment (receivers) is disconnected, it shall withstand a voltage test of 2U + 1000 (V) at industrial frequency for 1 minute, U being the maximum service voltage expressed in volts, with a minimum of 1500 V. The leakage currents shall not exceed the sensitivity of the differential switches installed to protect against indirect contacts.

2.3 Electrical cabinets

Connections between wires shall be made inside suitable boxes (electrical cabinet) of non-combustible resistant plastic material or metal, in which case they shall be internally insulated and protected against oxidation. Their depth shall be at least one and a half times the diameter of the largest tube, with a minimum of 40 mm; the side or diameter of the box shall be at least 80 mm. When tube entries in connection boxes are to be made watertight, suitable cable glands must be used. Under no circumstances cables may be joined by simply twisting or winding the cables together, but always using connection terminals.

The ducts shall be firmly attached to all outlet, junction and passage boxes by means of locknuts and sleeves. The ducts and boxes will be fastened with hollow brick toggle bolts, concrete and solid brick expansion toggle bolts and split nails on metal. Screw type toggle bolts will be used in permanent installations, nut type toggle bolts when the installation needs to be dismantled, and expansion toggle bolts will be effective opening. They shall be of solid construction and capable of resisting a minimum traction of 20 kg.

2.4 Devices and sockets

The switches and circuit breakers shall cut off the maximum current of the circuit in which they are placed, without giving rise to permanent electric arc, with no possibility of taking an intermediate position. They shall be of the closed type and made of insulating material. The dimensions of the contact parts shall be such that the temperature cannot exceed 65 °C in any of its parts. Their construction shall be such as to allow a total number of 10000 opening and closing operations, with their nominal load at working voltage. They shall be marked with their nominal current and voltage, and shall be tested at a voltage of 500 to 1000 volts.

The sockets shall be made of insulating material, shall be marked with their nominal working current and voltage and, as a general rule, shall all be grounded. All of them shall be installed inside boxes embedded in the walls, so that only the fully insulated control and the cover shall be visible from the outside.

2.5 Control and protection switchgear

2.5.1 Control electrical panels

All electrical panels shall be new and delivered to the site without any defects, and constructed in accordance with the Low Voltage Electrotechnical Regulations and the recommendations of the International Electrotechnical Commission (IEC).

Each circuit in the panel output will be protected against overloads and short circuits. Protection against ground fault currents shall be provided by means of differential switches with appropriate sensitivity, in accordance with ITC-BT-24 (Indoor or receiving installations; Protection against direct and indirect contacts). The panels shall be suitable for continuous service. The maximum permitted voltage variations and frequency shall be + 5 % above the nominal value.

The panels shall be designed for indoor service, completely dust and moisture proof, and shall consist of a metal structure made of cold laminated profiles, and enclosure panels made of thick, mechanically resistant, non-flammable steel sheets. Alternatively, the panel cabin may be made up of modules of plastic material, with the transparent front. The doors shall be provided with a sealing gasket of neoprene or similar material, to prevent dust entry. All cables will be installed inside cable conduit with removable covers. The power cables will go in different cable conduits along the entire length of the ones for the control cables.

The equipment shall be assembled so to be a minimum distance between it and adjacent parts of other equipment of at least one quarter of the size of the equipment in the direction considered. The depth of the frames shall be 500 mm and their height and width shall be that required for the positioning of the components and equal to a whole multiple of the manufacturer's module. Indicating devices (lamps, ammeters, voltmeters, etc.), control devices (pushbuttons, switches, commutators, etc.), synoptic panels, etc., shall be installed on the front of the panels. All internal components, devices and cables shall be accessible from the front from the outside.

The construction and design of the electric panels must provide safety for the personnel and guarantee perfect operation under all operating conditions, and in particular:

- Compartments which are to be accessible for operation or maintenance while the panel is in service shall not have exposed uncovered voltage.
- The switchboard and all its components shall be capable of withstanding short-circuit currents (kA).

2.5.2 Automatic switches

At the origin of the installation and as close as possible to the point of electrical supply, the general control and protection panel shall be fitted with a general omnipolar circuit breaker, as well as overcurrent protection devices for each of the circuits starting from this panel. Overcurrent protection shall be provided by magneto-thermal or automatic omnipolar circuit breakers. In general, devices intended to protect circuits shall be installed at the source of the circuit and at the points where the admissible current decreases due to changes in section, installation conditions, execution system or type of cables used.

The switches shall be air circuit breaker and free trip and have a position indicator. Actuation shall be direct pole-operated with energy storage shut-off mechanisms. The actuator shall be manual, or manual and electric, as indicated in the diagram or as required for automation needs. They shall be marked with the nominal operating current and voltage, as well as the sign indicating their disconnection. The input switch to the panel, with omnipolar cut-off, will be selective with the switches located downstream, behind it. The protection devices of the circuit-breakers shall be direct-acting relays.

2.5.3 Magnetic starters

Magnetic starter contactors shall be suitable for direct motor starting with a maximum starting current of 600 % of the nominal current, and a cut-off current equal to the nominal current. The useful life of the device will be at least 500,000 cycles. Overload protection will be provided by thermal relays for the three phases, with manual reset that can be activated from inside the panel. In case of long duration hard start, thermal relays with delayed characteristic shall be installed. In no case shall it be permitted to short-circuit the relay during startup. The thermal relay shall be checked by rotating the motor at full load in single-phase; disconnection shall take place after a few minutes.

2.5.4 Fuses

Fuses shall be of high breaking capacity, current limiting and slow acting when installed in motor protection circuits. Fuses for the protection of control circuits or ohmic consumers shall be of high breaking capacity and fast acting. They shall be mounted on insulating, non-combustible material, mounted on a handle that can be easily removed from the base. They shall be constructed in such a way that no metal can be ejected during melting and shall be marked with the nominal working current and voltage.

2.5.5 Residual-current circuit breaker

Protection against direct contact shall be ensured by taking the following precautions:

- **Isolation protection of active parts.** The active parts must be covered with insulation that can only be removed by destroying it.
- **Protection by means of barriers or enclosures.** The active parts must be located inside the enclosures or behind barriers having, at least, the IP protection degree according to UNE-EN 60529:2018/A1:2018 (Degrees of protection provided by enclosures; IP Code). The barriers or enclosures must be securely fixed and sufficiently robust and durable to maintain the required degrees of protection, with sufficient separation of the active parts under normal operating conditions, taking into account external influences. Removing the barriers, opening the enclosures or removing parts of them, when necessary should be made in the following situations:
  - With the help of a wrench or a tool.
  - After removing the voltage from the protected active parts, the voltage cannot be restored until after the barriers or enclosures have been replaced.
  - If there is a second barrier which requires a minimum degree of protection and can only be removed with the help of a tool, preventing all contact with the active parts.
- **Complementary protection by differential-residual current devices.** The use of residual-current devices, whose rated operating differential current value is less than or equal to 30 mA, is recognised as a supplementary protection measure in the event of failure of another protection measure, or in the event of negligence on the part of the user.

Protection against indirect contact will be achieved by "automatic power cut-off". This measure consists of preventing, after the occurrence of a failure, a given contact voltage from being maintained for such a time as to result in a risk. The conventional limit voltage is 50 V, root mean square (RMS) value in alternating current, under normal conditions, and 24 V in wet rooms. All the masses of the electrical equipment protected by the same protective device must be interconnected and connected by a protective cable to the same ground. The neutral point of each generator or transformer must be grounded. The following condition shall be fulfilled:

$$R_a * I_a \leq U \tag{2.1}$$

where R_a is the sum of the resistances of the grounding system and the mass protection cables, I_a is the current that ensures the automatic operation of the protection device, and U is the conventional limit contact voltage (50 or 24 V).

2.5.6 Disconnector

The disconnectors in load will be of connection and sudden disconnection, both independent of the action of the operator. Disconnectors shall be suitable for continuous service and shall be capable of opening and closing the rated current at rated voltage with a power factor equal to or less than 0.7.

2.5.7 Busbars

The main busbar will consist of three bars for the phases and one, with half of the section for the neutral. The neutral busbar shall be sectionable at the entrance to the electric panel. The busbars shall be of high conductivity electrolytic copper and suitable to withstand full load and short circuit currents. An independent ground bus shall also be provided, of an adequate section to allow the grounding of non-conductive metal parts of the appliances, the frame housing and, if any, the protective conductors of the outgoing cables.

2.5.8 Cable glands and labels

The panels will be completely wired up to the input and output power strips. Cable glands shall be provided for all cable entries and exits of the panel, which shall be double-locked for armoured cables and single-locked for unarmoured cables.

All equipment and terminals shall be properly identified inside the electroc panel by numbers corresponding to the designation on the diagram. The labels shall be indelibly and easily legible. Circuit identification labels, consisting of aluminium sheet plates, will be provided firmly attached to the front panel. In any case, the labels shall be marked with black letters 10 mm high on a white background.

2.6 Lighting receivers

The luminaires will comply with the requirements established in the standards of the UNE-EN 60598 series (Luminaires).

The weight of the luminaires suspended exceptionally from flexible cables must not exceed 5 kg. The cables, which must be able to withstand this weight, must not have any intermediate joints and the stress must be placed on an element other than the connection terminal. Accessible metal parts of luminaires which are not Class II or Class III, must have a connection element for grounding.

The use of gas lamps with high voltage discharges will be allowed when their location is outside the accessibility volume or when barriers or separating enclosures are installed. In lighting installations with discharge lamps where machines with fast rotating or reciprocating movement are operated, necessary measures must be taken to avoid the possibility of accidents caused by optical illusion due to the stroboscopic effect. For receivers with discharge lamps, the minimum expected load in volt-amperes shall be 1.8 times the power in watts of the lamps. In the case of single-phase distributions, the neutral conductor shall have the same cross-section as the phase ones. A different coefficient for the calculation of the conductor section shall be acceptable, as long as the power factor of each receiver is greater than or equal to 0.9, and if the load of each element associated with the lamps and the starting currents are known. In the case of receivers with discharge lamps, power factor compensation shall be mandatory up to a minimum value of 0.9. In installations with very low voltage lamps (e.g. 12 V), the use of suitable transformers must be provided.

For luminous signs and for installations supplying them with rated no-load output voltages between 1 and 10 kV, the specifications of standard UNE-EN 50107 (Signs and luminous-discharge-tube installations operating from a no-load rated output voltage exceeding 1 kV but not exceeding 10 kV) shall apply.

2.7 Motors receivers

The motors must be installed so that the approach to their moving parts cannot cause an accident, and they must not come into contact with easily combustible materials. The connecting cables supplying a single engine must be designed for 125 % of the full load current of the engine. On the other hand, those feeding several engines must be designed for a current of not less than the sum of 125 % of the full load current of the engine with the greatest power, plus the full load current of all the others.

Motors must be protected against short circuits and overloads on all phases, so as to cover, in three-phase motors, the risk of a voltage failure on one of their phases. In the case of motors with a star-delta starter, protection must be provided for both star and delta connection. The motors must be protected against the lack of voltage by an automatic power supply cut-off device, when the spontaneous start of the motor can cause accidents as a consequence of the restoration of the voltage, or damage the motor, in accordance with the UNE 20460-4-45 standard (Electrical installations of buildings-Protection for safety. Protection against undervoltage).

The motors must have limited current absorption on startup, when effects could occur that might be detrimental to the installation. In general, engines above 0,75 kilowatt must be equipped with starting rheostats that do not allow the current ratio between the starting period and the normal running period, corresponding to their full load, to exceed the following:

- From 0.75 kW to 1.5 kW: 4.5
- From 1.50 kW to 5 kW: 3.0
- From 5 kW to 15 kW: 2
- Over 15 kW: 1.5

All motors with a power of more than 5 kW shall have six connection terminals, with mains voltage corresponding to the delta connection of the winding (230/400 V motor for 230 V phase-to-phase networks and 400/693 V for 400 V phase-to-phase networks), so that star-delta starting of the motor is always possible.

The motors must comply with the following UNE standards, both in terms of dimensions and construction shapes, as well as in the allocation of power to the various casing sizes:

- UNE-EN 50347:2003. General purpose three-phase induction motors having standard dimensions and outputs - Frame numbers 56 to 315 and flange numbers 65 to 740.
- UNE-EN 60034-5:2003. Rotating electrical machines - Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) - Classification.
- UNE-EN 60034-7:1997. Rotating electrical machines - Part 7: Classification of types of construction and mounting arrangements (IM code).
- UNE-EN 60034-1:2011. Rotating electrical machines - Part 1: Rating and performance.
- UNE-EN 60034-2-1:2014. Rotating electrical machines - Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles) (Endorsed by AENOR in November of 2014.)
- UNE-EN 60529:2018/A2:2018. Degrees of protection provided by enclosures (IP Code).

For floor installation, the B-3 construction form is normally used, with two support plates, a free shaft end and casing with feet. For vertical installation, the motors shall be fitted with bearings designed to support the weight of the rotor and the pulley.

The protection class is determined in the UNE-EN 60529:2018/A2:2018 standard. All motors must have protection class IP 44 (protection against accidental contact with tools and against the penetration of solid bodies with a diameter greater than 1 mm, protection against water splashes from any direction). For installation outdoors or in a humid or dusty environment and inside air handling units, the motors must have protection class IP 54 (total protection against accidental contacts of any kind, protection against dust deposits, protection against water splashes from any direction). The motors with IP 44 and IP 54 protection are completely enclosed and surface cooled. All motors must have at least insulation class B, which admits a maximum temperature increase of 80 °C above the reference ambient temperature of 40 °C, with a maximum winding temperature limit of 130 °C.

The quality of the materials from which the motors are made shall be as follows:

- Housing: high quality cast iron, with solidary legs and cooling fins.
- Stator: magnetic plate package and electrolytic copper winding, mounted in close contact with the housing to reduce thermal resistance to transfer of heat to the outside of the housing.
- Rotor: slotted magnetic plate package, where the secondary winding is housed in a single or double aluminium alloy cage.
- Shaft: made of hard steel.
- Fan: internal (for classes IP 44 and IP 54), made of cast aluminium, solidary with the rotor, or injected plastic.
- Bearings: ball bearings, of a type suitable for the rotor speed and capable of supporting light axial thrusts on horizontal axis motors.
- Terminal boxes and cover: made of cast iron with cable entry through threaded holes with stuffing box.

For the correct selection of a motor, all the following factors should be considered:

- Maximum power absorbed by the driven machine, including transmission losses.
- Rotation speed of the driven machine.
- Characteristics of the electrical supply (number of phases, voltage and frequency).
- Protection class (IP 44 or IP 54).
- Insulation class (B or F).
- Constructive form.
- Maximum temperature of the cooling fluid (ambient air) and height above sea level of the location.
- Moment of inertia of the driven machine and transmission in relation to the speed of rotation of the engine.
- Resistant torque curve as a function of speed.

The motors may allow for deviations from the nominal supply voltage of ± 5 %. If downward deviations greater than the above value are expected, the motor power must be decreased proportionally, taking into account that the starting torque, proportional to the square of the voltage, will also decrease. Before connecting a motor to the main supply line, the insulation resistance of the stator winding must be checked to ensure that it is greater than 1.5 megaohms.

The number of motor poles will be chosen according to the rotation speed of the driven machine. In the case of coupling of equipment (such as fans) by means of pulleys and V-belts, the number of motor poles shall be chosen so that the ratio between motor and fan rotation speeds is less than 2.5.

All motors shall have a nameplate, located in a visible place and written in an indelible manner, on which at least the following data shall appear:

- Engine power.

- Rotation speed.
- Current at operating voltage(s).
- Starting current.
- Operating voltage(s).
- Manufacturer's name and model.

2.8 Grounding

The grounding is mainly established in order to limit the voltage that the metallic masses can present at a given moment with respect to the ground to ensure the performance of the protections and to eliminate or diminish the risk of a breakdown in the electrical materials used. Grounding is the direct electrical connection, without fuses or protection, of a part of the electrical circuit by means of an earth connection with an electrode or group of electrodes buried in the ground. The choice and installation of materials to ensure grounding must be such that:

- The value of the grounding resistance is in agreement with the protection and operating regulations of the installation.
- Ground fault currents and leakage currents can flow safely, particularly from the point of view of thermal, mechanical and electrical stresses.
- Robustness or mechanical protection is ensured regardless the estimated conditions of external influences.
- Consider the possible risks due to electrolysis that could affect other metal parts.

2.8.1 Ground connections

1. Grounding points. The following electrodes can be used:

    - Bars, tubes.
    - Platen, bare cables.
    - Plates.
    - Rings or metallic meshes made up of the above elements or their combinations.
    - Buried concrete reinforcements; with the exception of pre-stressed reinforcements.
    - Other buried structures which are proven to be appropriate.

    The type and depth of burial of the grounding points must be such that possible loss of soil moisture, the presence of ice or other climatic effects do not increase the resistance of the grounding point above the expected value. The depth should never be less than 0,50 m.

2. Grounding wires. The section of the earth cables, when buried, must be in agreement with the values indicated in Table 2.15, according to ITC-BT-18 (Grounding installations). The section will not be less than the minimum required for the protection cables.

Table 2.15: Conventional minimum cross-sections of ground cables

Type	Mechanically protected	Not mechanically protected
Protected against corrosion	According to Table 2.13	16 mm^2 Copper 16 mm^2 Galvanized steel
Not protected against corrosion	25 mm^2 Copper 50 mm^2 Iron	25 mm^2 Copper 50 mm^2 Iron

When making connections between ground cables and ground electrodes, great care must be taken to ensure that they are electrically correct.

3. Grounding connection terminals. Every grounding system must have a main ground terminal, to which the following cables must be connected:

   - The ground cables.
   - The protective cables.
   - The main equipotential connection cables.
   - The functional ground cables, if necessary.

   A device must be provided to measure the resistance of the corresponding earth electrode. This device may be combined with the main ground terminal, must necessarily be removable by means of a tool, must be mechanically safe and must ensure electrical continuity.

4. Protective cables. Protective cables are used to connect electrically the masses of an installation to the ground terminal in order to ensure protection against indirect contact. Protective cables must have a minimum cross-section equal to that given in Table 2.13. In all cases, the protective cables which are not part of the supply line shall be made of copper with a section of at least:

   - 2.5 mm^2, if the protective cables are mechanically protected.
   - 4 mm^2, if the protective cables are not mechanically protected.

   As protective cables, these can be used:

   - Conductors in multi-conductor cables.
   - Insulated or bare conductors having a common sheath with the active cables.
   - Separate bare or insulated conductors.

   No device should be inserted into the protective cable. The masses of the equipment to be connected to the protective cables must not be connected in series in a protective circuit.

Chapter 3

Technical conditions for the construction and assembly pipelines systems

3.1 Conditions and technical characteristics of the pipes

The pipes are identified by the material class, the type of connection, the nominal diameter DN (in mm or inches), the internal diameter (in mm) and the nominal working pressure PN (in bar), on which the material thickness depends.

The pipes shall be indelibly marked with the name of the manufacturer and the standard to which they are manufactured. The pipes must be stored in places where they are protected against the atmospheric agents. When handling them it should be avoid friction, rolling and dragging that could damage the mechanical resistance, and the calibrated surfaces of the extremities or the anti-corrosion protections.

Coupling fittings for all types of pipes may be of the threaded, flanged, electrofusion (PE only) or socket weld or butt weld type, with suitable adhesives (except PE), according to the manufacturer's recommendations. Joints with compression fittings, such as Gibault and others, can also be used.

3.1.1 Materials and applications

The quality of the different materials for pipes and fittings is defined by the following standards:

- **Uncoated steel.** The applicable UNE standards for uncoated steel pipes and their accessories are as follows:
  - UNE-EN 1333:2006. Flanges and their joints - Pipework components - Definition and selection of PN.
  - UNE-EN ISO 6708:1996. Pipework components. Definition and selection of DN (Nominal Size).
  - UNE-EN 10226-1:2004. Pipe threads where pressure tight joints are made on the threads. Part 1: Taper external threads and parellel internal threads. Dimensions, tolerances and designation.
  - UNE-EN 10220:2004. Seamless and welded steel tubes - Dimensions and masses per unit length.
  - UNE-EN 10255:2005+A1:2008. Non-Alloy steel tubes suitable for welding and threading - Technical delivery conditions.
  - UNE 19046:1993. Seamless carbon steel tubes for threading. Tolerance and characteristics.
  - UNE 19049-1:1997. Stainless steel tubes for the conveyance of hot/cold water. Part 1: Tubes.
  - UNE 19050:1975. Welded plain end pipe made from unalloyed steel and with no quality requirements.
  - UNE 19052:1985. Seamless steel tubes for waterworks.
  - UNE-EN 10297-1:2004. Seamless circular steel tubes for mechanical and general engineering purposes - Technical delivery conditions - Part 1: Non-alloy and alloy steel tubes.
  - UNE 19062:1956. Unwelded pipe. Quality standard.
  - UNE-EN 10253-1:2000. Butt-welding pipe fittings - Part 1: Wrought carbon steel for general use and without specific inspection requirements.
  - UNE-EN 1092-1:2019. Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, PN designated - Part 1: Steel flanges.
  - UNE-EN 1092-2:1998. Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, PN designated - Part 2: Cast iron flanges.
  - UNE-EN 10242:1995. Threaded pipe fitting in malleable cast iron.

  If no indication in the measurements is given, the pipes to be used shall be of the normal series, according to UNE-EN 10255.

  Applications: hot, cooled and overheated water, steam and condensate, liquid fuels (fuel oil and diesel), combustible gases, cooling gases, condensation water, wet fire-fighting systems, high temperature waste water.

- **Galvanized steel.** The applicable standards for galvanized pipes are as follows:
  - UNE-EN 10255:2005+A1:2008. Non-Alloy steel tubes suitable for welding and threading - Technical delivery conditions.
  - UNE 19048:1985. Galvanised seamless steel tubes for water supply (Hot and cold).

  The threaded fittings will always be made of malleable cast iron, according to UNE-EN 10242:1995.

  Galvanization will consist of an interior and exterior coating obtained by immersion in a hot zinc bath, with a coating of not less than 400 g/m^2, in accordance with the following UNE standards:
  - UNE-EN ISO 1461:2010. Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods (ISO 1461:2009).
  - UNE-EN 10240:1998. Internal and/or external protective coating for steel tubes. Specification for hot dip galvanized coatings applied in automatic plants.

  In no case shall the galvanized pipe be joined by welding.

  Applications: water for sanitary use, cold and hot water up to 55ºC, condensation from batteries, condensation water, waste water with a temperature above 40ºC and below 60ºC, rain water.

- **Copper.** The characteristics of the pipes will comply with the following UNE standards:
  - UNE-EN 12451:2013. Copper and copper alloys - Seamless, round tubes for heat exchangers.
  - UNE-EN 1057:2007+A1:2010. Copper and copper alloys - Seamless, round copper tubes for water and gas in sanitary and heating applications.
  - UNE-EN 12735-1:2016. Copper and copper alloys - Seamless, round tubes for air conditioning and refrigeration - Part 1: Tubes for piping systems.

  Annealed copper pipe may only be used up to outer diameters of 18 mm, when flexibility is required for bending and the pipe is embedded in the floor or wall.

  Applications: hot and cold sanitary water, diesel fuel, vacuum, cooling fluids and compressed air.

- **Cast iron.** The characteristics of the pipes will meet the requirements of the following UNE standards:
  - UNE-EN 545:2011. Ductile iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods.

  The pipes and special parts shall have a corrosion protection, both externally and internally, consisting of a black bituminous type paint. For sewage, waste and rainwater disposal pipes and for ventilation systems, cast iron pipes complying with ISO 6594:2006 may also be used, with a steel strip seal and elastomer sealing gasket, suitable for pressures up to at least 5 bar.

  Applications: sewage, rainwater and mixed water, external or internal water networks for sanitary use.

- **Plastic materials.** Pipes made of plastic materials such as polyvinyl chloride (PVC), polyethylene (PE), acrylonitrile-butadiene-styrene (ABS), polypropylene (PP), polybutylene (PB), etc.

  1. PVC pressure pipes. Its quality will be as defined by the following UNE standards:

     – UNE-EN ISO 1452:2010. Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure - Unplasticized poly(vinyl chloride) (PVC-U) - Part 1: General (ISO 1452-1:2009).
     – UNE-EN ISO 1452-2:2010. Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure - Unplasticized poly(vinyl chloride) (PVC-U) - Part 2: Pipes (ISO 1452-2:2009).
     – UNE-EN ISO 1452-3:2011. Plastics piping systems for water supply and for buried and above-ground drainage and sewerage under pressure - Unplasticized poly(vinyl chloride) (PVC-U) - Part 3: Fittings (ISO 1452-3:2009, corrected version 2010-03-01).

     Applications: cold water for sanitary use, condensation water (up to 45 °C).

  2. PVC pipes for evacuation. They will comply with the quality required by the following UNE standards:

     – UNE-EN 1329-1:2014+A1:2018. Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure - Unplasticized poly(vinyl chloride) (PVC-U) - Part 1: Specifications for pipes, fittings and the systems.
     – UNE-EN 1401-1:2009. Plastics piping systems for non-pressure underground drainage and sewerage - Unplasticized poly(vinyl chloride) (PVC-U) - Part 1: Specifications for pipes, fittings and the system.

     Applications: sewage, rain and mixed water drains.

  3. PE pipes (rigid and flexible) of high, medium and low density. The quality will be as defined by the following UNE standards:

     – UNE-EN 12201-1:2012. Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 1: General.
     – UNE-EN 12201-2:2012+A1:2020. Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 2: Pipes.
     – UNE-EN 1555:2011. Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE).
     – UNE-EN ISO 15875-1:2004. Plastics piping systems for hot and cold water installations - Crosslinked polyethylene (PE-X) - Part 1: General (ISO 15875-1:2003).
     – UNE 53389:2001 IN. Plastics pipes and fittings. Combined chemical-resistance classification table.
     – UNE-EN ISO 3458:2015. Plastics piping systems - Mechanical joints between fittings and pressure pipes - Test method for leaktightness under internal pressure (ISO 3458:2015).

- UNE-EN ISO 3459:2015. Plastic piping systems - Mechanical joints between fittings and pressure pipes - Test method for leaktightness under negative pressure (ISO 3459:2015).
- UNE-EN ISO 3503:2015. Plastics piping systems - Mechanical joints between fittings and pressure pipes - Test method for leaktightness under internal pressure of assemblies subjected to bending (ISO 3503:2015).

Applications: cold water for sanitary use, irrigation, water up to 45°C, gaseous fuels.

4. PP pipes. The polypropylene pipes will comply with the characteristics established in the following UNE standard:
   - UNE-EN ISO 15874-1:2013. Plastics piping systems for hot and cold water installations - Polypropylene (PP) - Part 1: General (ISO 15874-1:2013).

   Applications: sanitary water.

5. PB pipes. The polybutylene pipes will comply with the characteristics set out in the following UNE standard:
   - UNE-EN ISO 15876:2017. Plastics piping systems for hot and cold water installations - Polybutene (PB).

   Applications: sanitary water.

6. ABS pipes. Quality is defined in ASTM (American Society for Testing and Materials) standards D2239-12a, D2661-14e1, D2680-01(2014).

   Applications: sewage, rainwater and mixed water.

3.2 Particular conditions according to the fluid

3.2.1 Hydrogen pipe

The material used in the hydrogen piping will be 316/316L stainless steel, according to ASTM A269/A269M-15a(2019) (Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service), due to the high resistance to hydrogen embrittlement provided by this type of material and the fact that they are capable of withstanding high pressures.

3.2.2 Nitrogen pipe

A nitrogen distribution system will be available for the different inerting points which are distributed throughout the plant. In the case of nitrogen piping, polyamide or polyethylene pipes could be used. However, for greater rigidity of the system, 316/316L stainless steel will be used, according to ASTM A269 standard.

3.2.3 Compressed air pipe

A compressed air distribution system shall be provided to supply the hydrogen compressor (booster). The material used in the compressed air pipes shall be carbon steel, according to ASTM A179/A179M-19 (Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes).

3.2.4 Vents and drains

The Contractor shall pay special attention to the correct location of the vents and drains, ensuring that they are located at the highest or lowest point of the pipe path. The collector pipes of the respective vents will collect both the discharge pipes of the proportional vent valves distributed throughout the plant and the various vents of each of the equipment, all of which will be safely directed to the outside.

When defining the vent pipes, it should be taken into account the premise that there should be the least number of mechanical elements in these lines that could prevent the free circulation of a fluid to the atmosphere. It is recommended to install vent protectors at the ends of the line to prevent the obstruction of these lines. The vents shall be directed to points not less than 1 metre above the operating position or platforms and then oriented to the atmosphere, or taken to the torch collector line. Care shall be taken not to relieve flammable fluids near air intakes from ventilation systems. As for the drainage pipes, they will be polyethylene pipes directed to the drainage points closest to the point of production.

3.3 Installation

The pipes shall be installed in an orderly manner, using, whenever possible, three axes perpendicular to each other and parallel to the structural elements of the building, except for the slopes that must be given to the pipes. The pipes shall be installed as close as possible to the walls, leaving just enough space to handle the thermal insulation, if any, and valves, traps, etc. The minimum distance between pipes and structural elements or other pipes shall be 5 cm. The pipes shall always run under the electric conduits, whatever the fluid they carry.

Depending on the type of pipe used and the function to perform, the joints may be made by welding, electric or oxyacetylene, gluing, threading, flanging or by compression or mechanical joints. The ends of the pipe shall be prepared in the appropriate manner for the type of joint to be made. The pipes shall always be installed with as few joints as possible. Joints between steel and copper pipes shall be made by means of dielectric joints. The direction of water flow shall always be from steel to copper.

3.3.1 Closed and open circuit pipes

- **Connections.** Connections of equipment and devices to pipe networks shall always be made in such a way that the pipe does not transmit any mechanical stress to the equipment, due to its own weight, or the equipment to the pipe, due to vibrations. The connections to equipment and devices must be easily removable by means of flange coupling for diameters equal to, or greater than DN 65, or threaded for diameters less than or equal to DN 50.
- **Joints.** The material required for a perfect and long-lasting seal will be placed in the threaded joints. When the joints are made by flanges, a sealing gasket shall be placed between them. This gasket shall be made of asbestos for pipes that transport fluids at temperatures above 80 degrees. No joints may be made inside the bushing sleeves, at the crossing of walls, floors, etc.

  The cinching of the pipes, either hot or cold, is recommended because it is more economical, easy to install, and reduces both the number of joints and friction losses. The curves can be made corrugated to give greater flexibility. Bends made by cinching the pipes will be made cold up to DN 50 and hot for larger diameters, or by using special pieces. The bending radius will be as large as possible, depending on the space available. The use of 90º bends will be allowed only when the space available leaves no other alternative.

  Bypasses shall always be made with the axis of the branch at 45º to the axis of the main pipe before joining, except when the space available prevents it or when the circuit needs to be balanced. When changing the section of horizontal pipes, the reduction sleeves shall be eccentric and the pipes will be leveled by the upper generatrix to prevent air pockets from forming. Similarly, in the case of welded joints in horizontal sections, the upper generatrices of the main tube and the branch line will be leveled. The coupling between pipes of different materials shall be made by means of flanges; if both materials are metallic, the joint shall be dielectric.
- **Slopes.** The distribution network of the heat transfer fluid must always be installed so to avoid the formation of air pockets. The horizontal sections shall have a minimum slope of 0,2 % towards the nearest deaerator (0,5 % in the case of natural circulation). When the slope has to be reduced due to the characteristics of the work, the diameter of the pipe immediately above shall be used. The slope will be upwards towards the nearest trap and/or the expansion vessel, when the latter is of the open type, and preferably in the direction of the fluid flow.
- **Traps.** The air removal in the circuits will be different depending on the type of circuit. In open type circuits, such as water distribution or cooling tower circuits, the pipes will have a slight slope, of the order of 0.2 %, towards the "openings" of the circuit (taps and tower), so that the air is favoured in its tendency to move towards the upper parts of the circuit and, also helped by the movement of the water. However, in closed circuits, high points are created due to the circuit layout (column ends and terminal unit connections) or the slopes mentioned in the previous point. A trap valve must then be fitted at all high points, either manually or automatically, to remove any air that accumulates there. When automatic traps are used, they shall be of the DN 15 float type, suitable for the operating pressure of the system.

The traps shall be accessible and, except when installed on certain terminal units, the outlet of the air-water mixture shall be led to a visible place. A ball or cylinder valve DN 15 (preferable to the male tap) shall be installed on the bleed line. In engine room, traps should preferably be of the manual type with ball or cylinder valves as drain taps. Their discharge shall be led to a common, open-type manifold where the bleed valves, in a visible and accessible place.

- **Expansion.** Expansion of the pipes when the temperature of the fluid varies must be compensated for in order to avoid breakage at the weakest points, which are usually the joints between the pipes and the equipment. In engine rooms, it should be taken advantage of frequent changes of direction, with long radius curves, so that the pipe network is sufficiently flexible and can withstand variations in length. However, when laying long pipes, horizontally or vertically, it will be necessary to compensate the movements of the pipe by means of axial dilators.
- **Filtration.** All pumps and automatic valves must be protected, upstream, by the installation of a mesh filter, or metallic cloth. Once the cleaning of the circuit has been satisfactorily completed, and after a few days of operation, the filters which protect the pumps may be removed.
- **Relation to other services.** Pipelines shall always be installed underneath electrical conduits that cross or run parallel except when the fluid they carry is hydrogen. In the case of hydrogen, their pipes shall be located above the electric lines. In the case of combustible gases, the minimum distance between the electrical lines shall be 3 cm. The pipes shall not pass through chimneys or air conditioning or ventilation ducts, with no exceptions allowed.

Table 3.1: Maximum PVC pipes support distances in cm at 20 °C

External diameter DN (mm)	**Nominal pressure PN=4 bar**	**Nominal pressure PN=6 bar**	**Nominal pressure PN=10 bar**
40	-	75	75
50	-	80	80
63	-	90	95
75	100	100	110
90	100	115	130
110	115	130	150
125	125	140	165
140	135	150	175
160	145	165	195
180	155	180	210
200	165	190	225
250	185	215	260
315	210	245	295
400	240	280	320
500	280	320	360

Table 3.2: Maximum PE pipes support distances in cm at 45 °C

External diameter DN (mm)	High density polyethylene (PE.50)	Low density polyethylene (PE.32)
16	50	35
20	55	35
25	60	40
32	65	45
40	75	50
50	80	60
63	90	65
75	100	70
90	110	80
110	120	90

- **Protections.** All metallic elements which are not properly protected against corrosion by the manufacturer, such as black steel pipes, supports and accessories, shall be coated with two coats of anti-rust paint based on synthetic acrylic resins multipigmented with lead minium, zinc chromium and iron oxides. Hot water distribution circuits for sanitary purposes shall be protected against corrosion by means of sacrificial anodes made of magnesium, zinc, aluminium or alloys of the three metals.

3.4 Supports

For plastic pipes, depending on the type of material used, the maximum distances between supports will be those indicated in Tables 3.1 and 3.2.

3.5 Hydrostatic tests

All the networks including those of water distribution for sanitary use, evacuation of sewage and rain water, circulation of heating fluids, water against fires, etc, must be hydrostatically tested before being hidden by masonry works, filling material or by the insulating material, in order to prove its watertightness. Testing inevitably requires plugging the ends of the network when terminal units are not installed. The corresponding plugs must be installed during the installation of the network, so that they serve at the same time to prevent the entry of dirt.

Chapter 4

Conditions and technical characteristics of the valves

The valves are identified by the following functional characteristics which, in turn, depend on their physical characteristics:

- Flow rate, which depends, among other conditions, on the free area of passage.
- The pressure loss to the open valve plug, which depends,among other conditions, on the shape of the fluid passage.
- The tightness of the valve to a closed plug or maximum differential pressure, which depends on the type of closure and the materials used.
- The maximum working pressure, which depends on the material of the valve body, the dimensions and the thickness of the material.
- The type and diameter of the connections, by thread, flanges or welding.

The different types of valves differ in terms of pressure loss when the plug is open, for the same flow rate and diameter, and in terms of tightness when the plug is closed, for the same maximum differential pressure. The importance of these characteristics depends on the function that the valve must perform in the circuit. In any case, the finish of the seat and plug surfaces must ensure that the valves are leak-proof when they are closed for the specified operating conditions. The surfaces of the seat and plug must be replaceable. The packing must be replaceable in service, with the valve fully open, without disassembly.

The nominal pressure PN, expressed in bar (or kg/cm^2), and the nominal diameter DN, expressed in mm (or inches), shall be stamped on the valve body, at least when the diameter is 25 mm or more.

4.1 Connections

Except when otherwise is stated in the Particular Technical Specifications or in the Measurements, the valve connections shall be of the type indicated below, depending on the nominal diameter (DN) of the valve:

- Up to and including DN 20: Female threads.
- From DN 25 to DN 65 included: Female threaded or flanged.
- DN 80 onwards: By flanges

The following instructions must be followed for the safety valve connections:

- The connection pipe between the protected equipment and the safety valve must not be longer than 10 times the nominal diameter of the safety valve.
- The discharge pipe must be routed in a visible place in the engine room.
- The discharge pipe must be sized to allow the total discharge flow of the valve without creating an appreciable counter-pressure.

4.2 Applications

The valves will generally be chosen taking into account the extreme operating conditions, pressure and temperature, and the function that they perform in the circuit. Specifically, the choice of the type of valve should be made by following, in order of preference, these criteria:

- For insulation: ball, butterfly, poppet, piston and gate valves.
- For circuit balancing: seat valves, needle or punch valves, plug valves.
- For discharge: cylindrical, ball and plug valves.
- For filling: ball valves, poppet valves.
- For air bleeding: automatic valves or manual cylinder or ball valves.
- For safety: spring valves.
- For retention: disc valve, double gate, seat valve.

Unless expressly authorised by the project manager, the applications described below shall be avoided:

- Single wedge gate valves for isolating sections of the circuit where the differential pressure is greater than 1 bar.
- Poppet valves for interception in circuits with water in forced circulation.
- Gate valves for filling and emptying the system.
- Safety valves of the lever and counterweight type.
- Taps without cable glands.
- Check valves of the flap type, at least for diameters equal to or greater than DN 25.

Chapter 5

Conditions and technical characteristics of vibration insulators

Machinery in motion must be isolated from the base on which it rests and from the pipes connected to it, to prevent the transmission of vibrations and to eliminate reciprocal stresses between the machinery and the pipes at the same time. The installation of insulators between the machinery and the base may be avoided only when the base is directly supported on the ground.

5.1 Materials and construction

5.1.1 Benches

- **Concrete bench.** A concrete bench consists of a rectangular frame made of standardized U-shaped steel profiles, welded together, with a height equal to 8 % of the maximum distance between support points, with a minimum of 150 mm. Steel rods are welded to the frame, at a distance of 200 mm in both directions. The bench shall be equipped with brackets for the attachment of the elastic supports, welded to the frame so that the total height of assembly is as low as possible. It shall be fitted with sleeves for housing the equipment's fixing bolts, in the form of groove. The dimensions of the bench in floor plan shall be at least 100 mm larger than the projection in floor plan of the polygon delimited by the position of the fixing bolts. The frame of the bench shall have a corrosion-resistant finish. The filler concrete shall be poured "in situ".
- **Steel bench.** It will be constructed from standardized steel profiles, welded together and designed to provide a rigid and distortion-free frame. The height of the bench shall be at least 8 % of the maximum distance between support points, with a minimum of 150 mm. It shall be equipped with brackets for the attachment of elastic supports, welded to the base so that the overall installation height is as low as possible, and provided with slotted

holes for the passing through the fixation bolts of the equipment. The bench shall have a corrosion-resistant finish.

5.1.2 Elastic supports

- **Steel spring supports.** Elastic support consisting essentially of a special steel spring welded to two end plates. The spring will have the following characteristics:
  - Horizontal stiffness equal to at least 1.3 times the vertical stiffness.
  - Outer diameter equal to at least 0,8 times the height under load.
  - Overload capacity of 50 % before reaching non-deformability.

  The lower surface of the baseplate shall be covered by a cushioning pad of ribbed neoprene at least 6 mm thick or of glass fibre at least 12 mm thick. Each insulator shall include a fixing bolt, equipped with a nut and washers. When the equipment to be supported is subject to external loads or when its own weight varies, the elastic support shall have a device to limit the vertical stroke, consisting of a steel plate fixed to the spring and guided by means of insulated bolts with neoprene covers.
- **Neoprene pads.** The pad will be single or double sided, in this case with the interposition of a steel mesh reinforcement. The neoprene shall be oil resistant and capable of withstanding a permanent load of at least 40 N/cm^2 and 20 N/$cm2$ under impact.
- **Fibreglass pads.** It shall be made of pre-compressed glass fibre, protected by an elastomeric membrane which is impermeable to moisture and at the same time allows the movement of air between the fibres to be contained. The pad thus acts as a viscous shock absorber.
- **Hanging supports.** The elastic pipe supports consist of a metal frame and a damping element. The damping element may be a steel spring, a fibreglass or neoprene pad or both. The technical characteristics of the materials shall be as stated above. The frame shall resist an overload equal to 5 times the maximum load of the elastic element, without breaking or deforming, and allow for a bolt misalignment of up to 15 degrees without metal contact with metal.

5.2 Selection and assembly

For the choice of the number of damping supports and their location, the instructions of the equipment manufacturer should be followed. The selection of the damping supports will depend on the disturbing frequency of the machine, the type and weight of the machine, and the rigidity of the structural element supporting the machine.

Anti-vibration joints must not be made to work by traction or torsion. To avoid these efforts, it is necessary to drive the pipe sections connected to the joint by means of sliding supports.

The selection of the joint will be based on the nominal diameter of the pipe, the maximum working pressure and the maximum permissible deformations in compression, traction and misalignment. When a machine is mounted on elastic supports, the electrical connections should be made by means of flexible conduits.

Chapter 6

Fire extinction

Fire protection installations must generally comply with the requirements of the following standards:

- Royal Decree 513/2017 of 22 May, approving the Regulations on Fire Protection Installations.
- Royal Decree 314/2006, of 17 March, approving the Technical Building Code. Basic Document SI "Security in case of fire".
- Royal Decree 2267/2004, of 3 December, approving the Fire Safety Regulations for industrial buildings.
- Building Technology Standards NTE IPF (Fire protection installations) and NTE-IFA (Plumbing installations. Supply).
- Technical Rules of CEPREVEN (Centre for the Prevention of Damage and Loss).
- UNE-EN 671:2013. Fixed firefighting systems - Hose systems.
- UNE 23091-1:1989. Fire fighting equipment. Impulsion hose. Part 1: General specifications.
- UNE 23400:1998. Fire fighting systems. Coupling for fire hose of 25, 45, 70 and 100 mm.
- UNE 23410-1:1994. Water nozzles for fire fighting. Part 1: Conventional nozzles.
- UNE 23500:2018. Water supplies systems for fire fighting.
- UNE-EN 12845:2016. Fixed firefighting systems - Automatic sprinkler systems - Design, installation and maintenance.
- UNE-EN 12259-1:2002. Fixed firefighting systems - Components for sprinkler and water spray systems - Part 1: Sprinklers.
- UNE-EN 12259-2:2000. Fixed firefighting systems - Components for sprinkler and water spray systems - Part 2: Wet alarm valve assemblies.

- UNE-EN 12259-3/A1:2001. Fixed firefighting systems - Components for sprinkler and water spray systems - Part 3: Dry alarm valve assemblies.
- UNE-EN 12259-4:2000. Fixed firefighting systems - Components for sprinkler and water spray systems - Part 4: Water motor alarms.
- UNE-EN 12259-5:2003. Fixed firefighting systems - Components for sprinkler and water spray systems - Part 5: Water flow detectors.
- UNE-EN 14384:2006. Pillar fire hydrants.
- UNE-EN 14339:2006. Underground fire hydrants.
- UNE 23032:2015. Fire safety. Graphical symbols for use on plans: design, protection plans and evacuation plans.
- UNE 23033-1:2019. Fire safety. Safety signs. Part 1: Signals and beacons for fire protection systems and equipment.
- UNE 23034:1988. Fire safety. Safety signs. Means of egress.
- UNE 23035-4:2003. Equipment for fire protection. Longtime afterglowing signs. Part 4: General conditions. Measurement and classification.
- UNE-EN 1363:2015. Fire resistance tests.
- UNE-EN 1364:2019. Fire resistance tests for non-loadbearing elements.
- UNE-EN 1365-2:2016. Fire resistance tests for loadbearing elements.
- UNE-EN 1366. Fire resistance tests for service installations.
- UNE-EN 1634-1:2016+A1:2018. Fire resistance and smoke control tests for door and shutter assemblies, openable windows and elements of building hardware - Part 1: Fire resistance test for door and shutter assemblies and openable windows.
- UNE-EN 13381. Test methods for determining the contribution to the fire resistance of structural members.
- UNE-EN 13501. Fire classification of construction products and building elements.
- UNE-EN ISO 1182:2011. Reaction to fire tests for products - Non-combustibility test (ISO 1182:2010).
- UNE-CEN/TS 1187:2013. Test methods for external fire exposure to roofs.
- UNE-EN ISO 1716:2011. Reaction to fire tests for products - Determination of the gross heat of combustion (calorific value) (ISO 1716:2010).
- UNE-EN ISO 9239-1:2011. Reaction to fire tests for floorings - Part 1: Determination of the burning behaviour using a radiant heat source (ISO 9239-1:2010).
- UNE-EN ISO 11925-2:2011. Reaction to fire tests - Ignitability of products subjected to direct impingement of flame - Part 2: Single-flame source test (ISO 11925-2:2010).
- UNE-EN 13823:2012+A1:2016. Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item.

- UNE-EN 13773:2003. Textiles and textile products - Burning behaviour - Curtains and drapes - Classification scheme.
- UNE-EN 13772:2011. Textiles and textile products - Burning behaviour - Curtains and drapes - Measurement of flame spread of vertically oriented specimens with large ignition source.
- UNE-EN 1101:1996. Textiles and textile products - Burning behaviour - Curtains and drapes - Detailed procedure to determine the ignitability of vertically oriented specimens (small flame).
- UNE-EN 1021-1:2015. Furniture - Assessment of the ignitability of upholstered furniture - Part 1: Ignition source smouldering cigarette.
- UNE-EN 1021-2:2015. Furniture - Assessment of the ignitability of upholstered furniture - Part 2: Ignition source match flame equivalent.
- UNE 23727:1990. Reaction to fire test of building materials. Classification of building materials.
- UNE-EN 26184:1993. Explosion protection systems. Part 1: Determination of explosion indices of combustible dust in air (ISO 6184-1:1985).
- UNE-EN 3-7:2004+A1:2008. Portable fire extinguishers - Part 7: Characteristics, performance requirements and test methods.
- UNE 23501:1988. Water spray fixed systems. General provisions.
- UNE 23502:1986. Water spray fixed systems. System components.
- UNE 23503:1989. Water spray fixed systems. Design and installation.
- UNE 23504:1986. Water spray fixed systems. Acceptance test.
- UNE 23505:1986. Water spray fixed systems. Periodic testing and maintenance.
- UNE 23506:1989. Water spray fixed systems. Drawings, specifications and hydraulic calculations.
- UNE 23507:1989. Water spray fixed systems.Automatic fire detection equipment.
- UNE-EN 13565-1:2019. Fixed firefighting systems - Foam systems - Part 1: Requirements and test methods for components.
- UNE-EN 1568:2019. Fire extinguishing media - Foam concentrates.
- UNE-EN 12416:2001+A1:2008. Fixed firefighting systems - Powder systems.
- UNE 23585:2017. Fire safety. Smoke and heat control systems. Requirements, calculation and design methods for temperature control systems and smoke exhaust systems projecting in case of stationary fire.
- UNE-EN 1125:2009. Building hardware - Panic exit devices operated by a horizontal bar, for use on escape routes - Requirements and test methods.
- UNE-EN 179:2009. Building hardware - Emergency exit devices operated by a lever handle or push pad, for use on escape routes - Requirements and test methods.

- UNE-EN 1154:2003. Building hardware - Controlled door closing devices - Requirements and test methods.
- UNE-EN 1155:2003. Building hardware - Electrically powered hold-open devices for swing doors - Requirements and test methods.
- UNE-EN 1158:2003. Building hardware - Door coordinator devices - Requirements and test methods.
- UNE-EN 54-1:2011. Fire detection and fire alarm systems - Part 1: Introduction.
- UNE 23007-2:1998/1M:2008. Fire detection and fire alarm systems - Part 2: Control and indicating equipment.
- UNE-EN 54-3:2016. Fire detection and fire alarm systems - Part 3: Fire alarm devices - Sounders.
- UNE 23007-4:1998/2M:2007. Fire detection and fire alarm systems - Part 4: Power supply equipment.
- UNE-EN 54-5:2017+A1:2019. Fire detection and fire alarm systems - Part 5: Heat detectors - Point heat detectors.
- UNE-EN 54-10:2002. Fire detection and fire alarm systems - Part 10: Flame detectors - Point detectors.
- UNE-EN 54-11:2001/A1:2007. Fire detection and fire alarm systems - Part 11: Manual call points.
- Particular and standardization norms of the Water Supply Company.
- Law 31/1995, of 8 November, on the Prevention of Labour Risks.
- Royal Decree 1627/1997 of 24 October 1997 on minimum health and safety provisions on construction sites.
- Royal Decree 485/1997 of 14 April 1997 on minimum provisions for health and safety signs at work.
- Royal Decree 1215/1997 of 18 July 1997 on minimum health and safety provisions for the use of work equipment by workers.
- Royal Decree 773/1997 of 30 May 1997 on minimum health and safety requirements for the use by workers of personal protective equipment.
- Conditions imposed by the affected Public Bodies and Municipal Ordinances.

6.1 Facade water intakes

In dry column installations, there will be a supply point on the façade for each column, located in a place easily accessible by the fire brigade tank and preferably next to the accesses to the building, embedded in vertical walls with the centre of their outlets 90 cm from the floor. The dimensions of the niche will be 60x45x30 cm (width x height x depth).

The supply port will have a DN 25 drain plug for emptying the column after use. Each port shall consist of a Siamese connection, with a cast iron or aluminium alloy or bronze body, equipped with stainless steel, aluminium or bronze ball valves, operated by a 1/4 turn lever. It will have threaded "Barcelona" type fittings on its outlets, provided with a cover (threaded and male) and a chain, in accordance with Royal Decree 824/1982. It will be prepared for pipe threading (female gas thread).

The maximum working pressure will be 20 bar and the diameters of the pipe connection will be DN 80 and to the hoses DN 70. The niche will be closed by means of a 30x3 mm L-profile metal frame with two anchorage pins on each side, 25x1 mm welded square pipe sheet and 0,5 mm thick steel plate with an indelible red inscription EXCLUSIVELY FOR FIRE FIGHTERS on a white background.

6.2 Dry column hose reels

They will be used for the coupling of the fire hoses to the dry column. They will be embedded in a vertical wall with the center of their mouths at 90 cm from the ground, in a 60x35x30 cm niche (width x height x depth).

The constitution of each fire hose is the same as that described in the previous section, the diameter of the connection to the pipe being DN 65 and to the hoses DN 45. The dry column installation will be carried out with DN 80 galvanised steel pipe and will be subjected to a test pressure of 20 bar for two hours, without any leaks appearing at any point of the installation.

6.3 Fire hydrant

Used to have fire fighting water outlets being connected to the supply network. External hydrants are distinguished by their dimensions (column diameter and outlets and number of outlets), construction (wet or dry column) and implantation (buried or surface).

- **Underground hydrants.** Each fire hydrant will consist of a DN 100 PN 16 ball shut-off valve, a DN 100 drawn steel pipe sleeve and elbow, and a DN 100 threaded fitting with cover and chain. The catch basin will have the dimensions of 1,00x0,80 m in floor plan, with a depth of 0,70 m, provided with a cover of 1,10x0,90 m according to NTE-IPF.
- **Surface hydrants.** Each hydrant shall consist of a cast column, DN 100 or 150 (dry column) or seamless drawn steel (wet column) DN 80, 100 or 150, with a flange for connection to the PN 16 network, arranged vertically or horizontally, with two outlets of DN 45 or DN 70 fitted with "Barcelona" type fittings with cover and chain and, if necessary, another outlet DN 100. and the outlets will be fitted with seat valves. The working pressure will be

10 bar and the test pressure 20 bar. The exterior finish will be red weatherproof enamel. The buried part of the dry column fire hydrant shall be painted with an anti-corrosion paint. The coupling pipe will end with a flange and will be received in a concrete die. The hydrant will protrude from the ground level by approximately 600 mm.

6.3.1 Hose reels (45 mm)

Hose stations shall be arranged in vertical walls in common areas of the building and shall be placed with the lower side of the box at 120 cm from the floor. Each hose kit shall consist of the following elements:

- Threaded angle valve, poppet or ball valve, DN 40 PN 16, in bronze or brass.
- Manometer with dial graduated from 0 to the maximum pressure that can be reached on the network.
- Barcelona type fitting, DN 45, with male gas thread DN 40.
- Hose holder made of metal material protected against corrosion, with horizontal pivot axis, of the coil or folding type, to keep the hose rolled up or bent respectively.
- Hose holder with vertical pivot axis, equipped with fastening elements to vertical wall.
- Hose of 40 mm diameter made of flexible and resistant fabric, internally covered with synthetic rubber, capable of resisting a pressure of at least 15 bar, of 15, 20 or 30 m length.
- A set of Barcelona type fittings for the hose ends, with a diameter of 45 mm, coupled by means of galvanized wire ties.
- Brass lance and nozzle with 12 mm diameter outlet, with jet, mist and close positions, threaded to Barcelona type fitting DN 45 for coupling to the hose.
- Set of chrome-plated brass lance supports.
- Metallic cabinet of 800x600x250 mm provided with drawn glass of 3 mm of thickness, with triangular recesses in opposite angles and indelible inscription in red BURST IN CASE OF FIRE and with chrome frame.

At the minimum dynamic pressure of 3.5 bar at the outlet orifice, the equipment shall be capable of delivering a flow rate of 3.3 l/s with the lance in the full jet position. The minimum effective range, under these conditions and for a 30 degree slope and quiet air, shall be 18 m. When the dynamic pressure upstream of the equipment is higher than 5 bar, a pressure reducing orifice plate shall be installed at the start of the bypass to the equipment, according to NTE-IPF. The installation of equipped fire hydrants shall be subjected to a leakage test at the pressure of 10 bar or at the operating pressure plus 3.5 bar, whichever is higher, for two hours, without any leakage being observed at any point of installation.

6.3.2 Hose reels (25 mm)

The equipment shall be equipped with an automatic or manual opening valve and a semi-rigid hose with a reduced diameter that allows water to be made available immediately, without having to unwind the whole hose, to untrained persons. The valve is opened and closed simply by rotating the hose reel. The equipment shall essentially consist of the following elements:

- Automatic opening valve, with cast alloy body, DN 25, equipped with hydraulic closing rings.
- Pressed steel coil protected against corrosion and painted in red, with a diameter of about 600 mm and variable width according to the length and diameter of the hose, mounted on nylon bearings.
- Hose made of non-self-collapsible semi-rigid material, 25 mm in diameter, with a length of 15, 20, 25 or 30 m, with an operating pressure of 15 bar and a minimum breaking load of 15000 N.
- Connection fitting of 25 mm.
- Water lance with three-position nozzle (jet, mist and seal) made of impact resistant plastic.
- Metallic cabin or fence for overhanging or recessed installation respectively.

At the minimum dynamic pressure of 3.5 bar, the equipment shall be capable of delivering a flow rate of 1.6 l/s with the lance in the jet position. The minimum effective range shall be 12 m. When the dynamic upstream pressure of the equipment exceeds 5 bar, a pressure reducing orifice plate shall be installed at the start of the bypass to the equipment. The installation of fitted fire hydrants shall be subjected to a leakage test at a pressure of 10 bar, or at the operating pressure of more than 3.5 bar, whichever is the greater, for two hours without any leakage being observed at any point in the installation.

Chapter 7

Technical conditions for the construction of compressed air and nitrogen systems

Equipment intended for the production, storage, transport and use of fluids under pressure shall be subject to the requirements, technical inspections and tests laid down in the Pressure Equipment Regulation, if the maximum allowable pressure exceeds 0.5 bar. The manufacturer shall ensure the correct implementation of the provisions laid down at the design stage by applying appropriate techniques and methods, in particular as regards the following aspects:

- **Preparation of components:** must not cause defects or cracks or changes in mechanical characteristics which could endanger the safety of the pressure equipment.
- **Permanent joints:** they must be free of surface or interior deficiencies detrimental to the safety of the equipment. The properties of the permanent joints shall correspond to the minimum properties specified for the materials to be joined. For pressure equipment, permanent joints of elements contributing to the pressure resistance of the equipment and elements that are directly integrated must be made by qualified personnel with the appropriate level of competence and using qualified procedures.
- **Non-destructive testing:** must be carried out by qualified personnel with the appropriate level of competence.
- **Thermal treatment:** where there is a risk that the manufacturing process will change the properties of the materials to such an extent so as to endanger the integrity of the pressure equipment, an appropriate heat treatment shall be applied at the appropriate stage of manufacture.
- **Final inspection:** the pressure equipment must be subjected to a final inspection to visually check, using the accompanying documents, that all the regulatory requirements have been met.

- **Testing:** the final verification of the pressure equipment must include a pressure resistance test which will normally take the form of a hydrostatic pressure test at a pressure at least equal, where appropriate, to the higher of the following two values:
  - The pressure corresponding to the maximum load the equipment can withstand in operation, taking into account its maximum permissible pressure and its maximum permissible temperature, multiplied by the coefficient 1.25.
  - The maximum allowable pressure multiplied by 1.43.

7.1 Materials

Materials intended for parts under pressure:

1. They must have characteristics appropriate to the set of reasonably foreseeable operating and test conditions and, in particular, must be sufficiently ductile and tough. In addition, an appropriate selection of materials must be made to prevent, where necessary, brittle fracture.
2. They must have sufficient chemical resistance to the fluid contained in the pressure equipment.
3. They must not be significantly sensitive to ageing.
4. They must be suitable for the intended processing methods.
5. They must be chosen in such a way so as to avoid significant adverse effects when they are combined different materials.

The pressure equipment manufacturer must properly define the values required for the design calculations specified in the Royal Decree 709/2015 of 24 July establishing the essential safety requirements for the marketing of pressure equipment. The manufacturer of the equipment must take appropriate measures to ensure that the material used meets the required specifications. In particular, documents drawn up by the material manufacturer certifying conformity with a given specification must be obtained for all materials. For the main pressure parts of equipment in categories II, III and IV, the certificate must be a specific product control certificate.

7.2 Marking and labelling

The following information should be provided:

- Manufacturer's identification.
- Year of manufacture.
- Identification of the pressure equipment.
- Essential maximum and minimum allowable limits.
- Depending on the type of pressure equipment, additional information necessary for safe installation, operation or use and, where appropriate, also for maintenance and periodic inspection.

- Where appropriate, the warnings fixed to the pressure equipment shall draw attention to errors in use demonstrated by experience.

7.3 Installation plate and periodic inspections

All pressure equipment in installations subject to periodic inspections must have a plate made of durable materials, indicating the identification number given by the competent body of the autonomous community, the test pressure of the equipment or assembly, its category and group, the maximum service pressure, as well as the inspection dates, the level of inspection carried out and the seal of the entity responsible for the inspection.

The plate models will be in accordance with the Royal Decree 2060/2008, of December 12, which approves the Regulation of pressure equipment and its complementary technical instructions. The large plate model will have dimensions of 70x55 mm. The small plate model may be used in small pressure equipment and will have dimensions of 70x55 mm.

7.4 Installation requirements

For pipes containing gases whose vapour pressure at the maximum allowable temperature is more than 0.5 bar above atmospheric pressure, and where the DN is greater than 32 and the product PS(Maximum Allowable Pressure)x DN(Nominal Diameter) is greater than 1000 bar, the design and manufacture must ensure that:

- The risk of permanent deformation resulting from inadmissible free movement or excessive stress is adequately controlled by means of clamps, straps, fasteners, adjustments and pre-tensioners.
- Where there is the possibility of condensation of gaseous fluids inside the pipes, the necessary means are provided for purging and expelling deposits and incrustations on the bottoms and sides to prevent damage due to water hammer or corrosion.
- The risk of fatigue due to vibrations in the pipes is duly taken into account.
- The risk of accidental discharge is minimised.
- The position and route of underground pipes and pipelines shall be registered at least in the technical documentation in order to facilitate maintenance, inspection or repair in conditions of total security.

7.5 Maintenance of installations

The following maintenance operations will be carried out annually:

- Interior oil and ashes cleaning.
- Safety valves. Checking its status as a control device suitable for this type of function. In case of necessity of replacing them, only new valves will be used.
- Manometers. Their good condition and operation will be checked.

- Inspection and cleaning devices. Accessibility to cleaning holes and registers shall be checked. In the case of purgers, their operation shall be checked. Likewise, the operation of the cooling and oil collection devices of the supplied air shall be checked.
- Lubrication. The oil used shall be free of resin-bearing materials. Oil with antioxidant properties with a flammability point higher than 125 °C shall be used. When the working pressure exceeds 20 kg/cm^2, only oils with a flammability point higher than 220 °C should be used.

7.6 Repairs

Repairs affecting the parts of the equipment which are subject to pressure must be carried out by pressure equipment repair companies registered with the competent body of the Autonomous Community, and which, in accordance with Law 21/1992, of 16 July, on Industry, may carry out their activity throughout Spain. Pressure equipment must continue to meet the design characteristics defined by the manufacturer after repair. All pressure equipment must be inspected by an approved inspection body after repair. Before the commissioning of a repaired pressure equipment, the periodic inspection of level C must be carried out. Repairs made must be certified by the repair company by issuing the corresponding repair certificate.

7.7 Pressurized air reconditioning

The compressors intake moist air and their intake filters cannot change this, nor can they completely remove the particles contained in the atmospheric air from the place where the compressor itself is located. The service life and operational safety of a pneumatic system depends on the condition of the compressed air. Dirt in the compressed air (oxides, dust, etc.) and liquid particles in the air cause great damage to the pneumatic system and all its components, reducing the service life of the various components of the system.

To avoid this type of problem, it is recommended to use compressed air maintenance units on each control or output for consumption. In these, compressed air filters will retain the solid particles and moisture drops contained in the air. The filters called Cyclones will have a double mission:

1. The air entering will pass through plates that force a rotary circulation, so that the large solid particles and the liquid will be deposited on the walls of the vessel or cup, by the centrifugal action.
2. The air will pass through a main filtering element made of metal mesh, paper or sintered metal. This filter, between 20 and 40 microns, retains the solid particles. This filtering action is called "mechanical" since it affects the mechanical pollution of the air, and not its humidity.

The larger particles will be retained by the sinter filter, while the liquids will be diverted to the filter cup. The finest filters, down to 0.01 micron, will filter out the smallest particles and even the smallest drops of water that may remain in the compressed air.

The Pressure Regulator or Control Valve will maintain a constant working pressure on the user side. To achieve this, the inlet pressure to the regulator must always be higher than the working pressure. As long as the valve is preceded by a correct filtering system, it will not require any maintenance other than checking for leaks.

The important function of the compressed air lubricator is to sufficiently lubricate all the pneumatic elements, especially the active ones. The oil used for lubrication is sucked from a small tank in the same maintenance unit, mixed with the compressed air stream, and distributed in the form of "mist" or micro-spray. The use of lubricated air should be avoided by using different plugs for the connection of these elements. The oil level in the lubricator must be checked and, if necessary, added up to the marked level. Plastic filters and lubricator containers should not be cleaned with solvents, as they may be damaged. For lubricators, only mineral oils of the appropriate viscosity and components should be used.

Part III

Budget

The budget is calculated on the basis of the unit/measurement prices of each of the elements of the installation. It is structured by chapters among which are distinguished those corresponding to the necessary civil work, the elements of carpentry and locksmithing, the electrical network, the hydrogen network, the fire protection and the components of the installation. The prices of the different items have been obtained thanks to the information provided by the manufacturer, the database *Generador de Precios de la Construcción* [CYPE INGENIEROS S.A., no date] or taking as a reference budgets elaborated in other similar projects. The calculation of the prices of the different units of the work is the result of adding up the direct costs, indirect costs, general expenses and industrial profit.

They will be considered as **direct costs**:

- The labour, with its bonuses, charges and social security, directly involved in the execution of the unit of work.
- Materials, at the resulting cost of the work, which are integrated into the unit concerned or which are necessary for its execution.
- Technical health and safety equipment and systems for the prevention and protection of accidents and occupational diseases.
- Expenditure on staff, fuel, energy, etc., incurred in connection with the operation of the machinery and installations used in the execution of the work unit.
- The cost of depreciation and maintenance of machinery, installations, systems and equipment previously cited.

They will be considered as **indirect costs**: the costs of installing offices on site, communications, building warehouses, workshops, temporary workers' quarters, laboratories, insurance, etc., those of the technical and administrative staff assigned exclusively to the work, and unforeseen costs. All these expenses will be calculated as a percentage of the direct costs (5 %). The result obtained by the sum of the above concepts will be called the Material Execution Price.

The following will be considered as **general expenses**: general company costs, financial costs, tax charges and fees of the administration legally established. They shall be calculated as a percentage of the sum of the direct costs and indirect (in public administration works contracts this percentage is set at 13 %).

The Contractor's **industrial profit** is set at 6 % of the sum of the above items.

The contract price is the sum of direct costs, indirect costs, general expenses and industrial profit. Value-added tax (VAT) is added to this sum and with this percentage (21 %) included the final budget of the project is set.

The breakdown of the budget prepared by the PRESTO software is shown below. In the following pages there is a summary of the budget, which shows the total of the general budget (with the corresponding percentages applied), equal to **1,989,888.54 €**. The budget is also included with the measurements of each item and the decomposed price table where the breakdown of direct and indirect costs of each item is presented.

Chapter 1

Final budget summary

RESUMEN DE PRESUPUESTO

Hidrogenera UPV

CAPITULO	RESUMEN	EUROS	%
1	DEMOLICIONES Y TRABAJOS PREVIOS	2.861,86	0,21
2	MOVIMIENTO DE TIERRAS	6.080,27	0,44
3	CIMENTACIONES, ESTRUCTURAS Y MUROS	110.407,55	7,99
4	PAVIMENTO	72.520,07	5,25
5	CUBIERTAS	8.582,01	0,62
6	CERRAJERÍA Y CARPINTERÍA	42.257,93	3,06
7	RED ELÉCTRICA DE BAJA TENSIÓN	29.847,77	2,16
8	RED DE HIDRÓGENO	1.742,66	0,13
9	PROTECCIÓN CONTRA INCENDIOS	1.212,82	0,09
10	COMPONENTES INSTALACIÓN	1.106.450,07	80,06

PRESUPUESTO DE EJECUCIÓN MATERIAL		**1.381.963,01**
13,00% Gastos generales	179.655,19	
6,00% Beneficio industrial	82.917,78	
SUMA DE G.G. y B.I.		262.572,97
21,00% I.V.A.		345.352,56
PRESUPUESTO DE EJECUCIÓN POR CONTRATA		**1.989.888,54**
TOTAL PRESUPUESTO GENERAL		**1.989.888,54**

Asciende el presupuesto a la expresada cantidad de UN MILLÓN NOVECIENTOS OCHENTA Y NUEVE MIL OCHOCIENTOS OCHENTA Y OCHO EUROS con CINCUENTA Y CUATRO CÉNTIMOS

Valencia, a 29 de abril de 2020.

Chapter 2

Budget and measurements

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 1 DEMOLICIONES Y TRABAJOS PREVIOS								
1.1	**m² Desbroce y limipieza terreno por medios mecánicos**								
	Desbroce y limpieza del terreno, con medios mecánicos. Comprende los trabajos necesarios para retirar de las zonas previstas para la edificación o urbanización: árboles, plantas, tocones, maleza, broza, maderas caídas, escombros, basuras o cualquier otro material existente, hasta una profundidad no menor que el espesor de la capa de tierra vegetal, considerando como media 40cm. incluye retirada de material sobrante, carga sobre camión, el transporte a acopio intermedio cuando resulte necesario, y la descarga, y sin incluir transporte de escombros a vertedero autorizado. Se incluyen los apeos, apuntalamientos, arriostramientos, andamios y plataformas que resulten necesarios para realizar estas operaciones, y que no serán de abono independiente.								
	Total cantidades alzadas						1.580,00		
							1.580,00	0,90	1.422,00
1.2	**u Traslado modulo caseta prefabricada**								
	Traslado módulo caseta prefabricado, de la zona de la hidrogenera a menos de 50m de distancia, fuera de ésta, incluso carga sobre camión, el transporte a acopio intermedio cuando resulte necesario, y la descarga. Se incluyen los apeos, apuntalamientos, arriostramientos, andamios y plataformas que resulten necesarios para realizar estas operaciones, y que no serán de abono independiente.								
	Total cantidades alzadas						1,00		
							1,00	160,06	160,06
1.3	**m² Levantamiento valla simple torsión**								
	Levantado de valla simple torsión, incluso retirada de escombros, carga sobre camión, el transporte a acopio intermedio cuando resulte necesario, y la descarga, y sin incluir transporte de escombros a vertedero autorizado. Se incluyen los apeos, apuntalamientos, arriostramientos, andamios y plataformas que resulten necesarios para realizar estas operaciones, y que no serán de abono independiente.								
	Total cantidades alzadas						1.580,00		
							1.580,00	0,81	1.279,80
	TOTAL CAPÍTULO 1 DEMOLICIONES Y TRABAJOS PREVIOS								**2.861,86**

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 2 MOVIMIENTO DE TIERRAS								
2.1	**m³ Excavación zanja solera**								
	Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.								
	Total cantidades alzadas						711,00		
							711,00	7,43	5.282,73
2.2	**m³ Excavación zanjas canalización H2**								
	Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.								
	Total cantidades alzadas						2,24		
							2,24	7,43	16,64
2.3	**m³ Excavación zanjas zapatas + vigas riostras**								
	Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.								
	Total cantidades alzadas						38,48		
							38,48	7,43	285,91
2.4	**m³ Excavación zanjas zapatas corridas**								
	Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.								
	Total cantidades alzadas						66,62		
							66,62	7,43	494,99
	TOTAL CAPÍTULO 2 MOVIMIENTO DE TIERRAS								**6.080,27**

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 3 CIMENTACIONES, ESTRUCTURAS Y MUROS								
3.1	**m² Hormigón de limpieza 150/B/20 e=10 cm**								
	Capa de hormigón de limpieza HL-150/B/20 preparado, de consistencia blanda, tamaño máximo del árido 20 mm. y 10cm. de espesor, en la base de la cimentación, transportado y puesto en obra, según EHE.								
	Total cantidades alzadas						105,10		
							105,10	8,20	861,82
3.2	**m³ Hormigón armado 25/B/40/IIa zapatas + vigas riostras**								
	Hormigón HA-25/B/40/IIa para armar preparado en cimentaciones de zanjas, zapatas y riostras, de consistencia blanda y tamaño máximo del árido 40 mm, transportado y puesto en obra según EHE-08 vertido por cualquier medio.								
	Total cantidades alzadas						23,09		
							23,09	96,83	2.235,80
3.3	**m³ Hormigón armado 25/B/40/IIa zapatas corridas**								
	Hormigón HA-25/B/40/IIa para armar preparado en cimentaciones de zanjas, zapatas y riostras, de consistencia blanda y tamaño máximo del árido 40 mm, transportado y puesto en obra según EHE-08 vertido por cualquier medio.								
	Total cantidades alzadas						39,97		
							39,97	96,83	3.870,30
3.4	**m² Encofrado metálico**								
	Encofrado metálico a 2 caras para muros de altura menor 1.5m mediante paneles metálicos de pequeñas dimensiones, estimándose 25 usos, incluso desencofrado, limpieza y almacenamiento.								
	Total cantidades alzadas						340,47		
							340,47	23,13	7.875,07
3.5	**m² Paneles hormigón prefabricado Em=30 cm**								
	Muro de contención de tierras formado por paneles prefabricados texturados con gomas rekli o similar, textura a elegir por DF, de hormigón arquitectónico armado de espesor variable de entorno a 30 cm de espesor medio. Esta partida incluye hormigón, encofrados, (acero medido aparte) fabricación, transporte, colocación sobre el hormigón de limpieza, alineación de los módulos, sellado de juntas, y colocación correcta de las esperas del trasdós, para realizar un correcto empalme por solapo con las armaduras de la cimentación.								
	Total cantidades alzadas						798,67		
							798,67	94,57	75.530,22
3.6	**m Vigas prefabricada de hormigón armado**								
	Viga prefabricada de hormigón armado tipo T invertida, de 30 cm de anchura de alma, 30 cm de altura de talón, 45 cm de anchura total y 45 cm de altura total, con un momento flector máximo de 360 kN·m..								
	Total cantidades alzadas						41,00		
							41,00	139,36	5.713,76
3.7	**kg Pilares HEB Acero 14x14 marquesina**								
	Acero UNE-EN 10025 S275JR, en pilares formados por piezas simples de perfiles laminados en caliente de las series IPN, IPE, HEB, HEA, HEM o UPN, acabado con imprimación antioxidante, colocado con uniones atornilladas en obra, a una altura de hasta 3 m. El precio incluye los tornillos, los cortes, los despuntes, las piezas especiales, las placas de arranque y de transición de pilar inferior a superior, los casquillos y los elementos auxiliares de montaje.								
	Total cantidades alzadas						208,26		
							208,26	1,63	339,46
3.8	**kg Viga HEB Acero 14x14 marquesina**								
	Acero UNE-EN 10025 S275JR, en vigas formadas por piezas simples de perfiles laminados en caliente de las series IPN, IPE, HEB, HEA, HEM o UPN, acabado con imprimación antioxidante, con uniones atornilladas en obra, a una altura de más de 3 m. El precio incluye los tornillos, los cortes, los despuntes, las piezas especiales, los casquillos y los elementos auxiliares de montaje.								

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	Total cantidades alzadas						324,41		
							324,41	1,62	525,54
3.9	**m Pilares hormigón 30x30 HA 30/B/20/IV+Qa <3.5 met**								
	Soporte de hormigón armado de 30 N/mm2 (HA 30/B/20/IV+Qa) confeccionado en central, con una cuantía media de 120 kg. de acero B 500 S, de sección 30x30 cm., para una altura de menor de 3.5 m., incluso encofrado metálico, desencofrado y curado, según EHE.								
	Total cantidades alzadas						46,40		
							46,40	161,27	7.482,93
3.10	**m² Losa de placas alveolares prefabricadas de hormigón pretensado**								
	Losa de 12 + 5 cm de canto, realizada con placas alveolares prefabricadas de hormigón pretensado, de 12 cm de canto y 60 cm de anchura, con momento flector último de 12 kN·m/m, con altura libre de planta de hasta 3 m, apoyada directamente sobre vigas de canto o muros de carga; relleno de juntas entre placas alveolares, zonas de enlace con apoyos y capa de compresión, realizados con hormigón HA-25/B/20/IIa fabricado en central, y vertido con cubilote, acero B 500 S en zona de negativos, con una cuantía aproximada de 4 kg/m², y malla electrosoldada ME 15x15 Ø 5-5 B 500 T 6x2,20 UNE-EN 10080. Incluso piezas de acero UNE-EN 10025 S275JR tipo Omega, en posición invertida, laminado en caliente, con recubrimiento galvanizado, 1 kg/m², para el apoyo de las placas en los huecos del forjado, alambre de atar y separadores. El precio incluye la elaboración de la ferralla (corte, doblado y conformado de elementos) en taller industrial y el montaje en el lugar definitivo de su colocación en obra, pero no incluye los apoyos ni los pilares.								
	Total cantidades alzadas						95,00		
							95,00	62,87	5.972,65

TOTAL CAPÍTULO 3 CIMENTACIONES, ESTRUCTURAS Y MUROS.. 110.407,55

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 4 PAVIMENTO								
4.1	**m² Pavimiento de hormigón + mortero**								
	Pavimento realizado con losa prefabricada de hormigón para tráfico rodado, de color de DIMENSIONES 600x400x15cm tipo Fenollar Metropolitan bio-innova color claro a elegir por DF o equivalente, acabado antideslizante R3, sentada sobre subbase rígida resistente, colocado en capa de 10 cm de mortero y adhesivo cementoso mejorado con deslizamiento reducido y tiempo abierto ampliado (C2TES1) y rejuntado con mortero de juntas cementoso mejorado (CG2), totalmente terminado, incluso cortes y limpieza.								
	Total cantidades alzadas						1.155,33		
							1.155,33	28,62	33.065,54
4.2	**m² Solera Hormigón Armado 25/B/20/IIa**								
	Solera de hormigón HA-25/B/20/IIa de consistencia blanda y tamaño máximo del árido de 20mm, con un espesor de 25 cm, armada con una malla 15.15.5 de acero corrugado B 500 T, elaborado, transportado, vertido y compactado en obra, medido el volumen a excavación teórica llena. Incluso corte de capilaridad con lámina de plástico impermeable reforzado, y pequeños encofrados para los escalonamientos. En la descomposición se incluye un exceso de m3 hormigón, y 1kg/m2 de acero, para la formación y el refuerzo de los escalones.								
	Total cantidades alzadas						1.155,33		
							1.155,33	30,91	35.711,25
4.3	**m³ Relleno extendido gravas**								
	Relleno y extendido de gravas con medios mecánicos, motoniveladora, incluso compactación, con rodillo autopropulsado, en capas de 25cm de espesor máximo, según NTE/ADZ-12.								
	Total cantidades alzadas						173,30		
							173,30	21,60	3.743,28
	TOTAL CAPÍTULO 4 PAVIMENTO.......								**72.520,07**

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 5 CUBIERTAS								
5.1	**m² Cubierta inclinada de paneles sándwich aislantes, de acero.**								
	Cubierta inclinada de paneles sándwich aislantes de acero, de 30 mm de espesor y 1150 mm de ancho, alma aislante de lana de roca, con una pendiente mayor del 10% .								
	Total cantidades alzadas						65,35		
							65,35	43,04	2.812,66
5.2	**m² Cubierta plano no transitable, ventilada, autoprotegida**								
	Cubierta plana no transitable, ventilada, autoprotegida, tipo convencional, pendiente del 1% al 15% . FORMACIÓN DE PENDIENTES: tablero cerámico hueco machihembrado de 80x25x3,5 cm con capa de regularización de mortero de cemento, industrial, M-5, de 3 cm de espesor, acabado fratasado, sobre tabiques aligerados de ladrillo cerámico hueco de 24x11,5x9 cm, recibido con mortero de cemento, industrial, M-5, dispuestos cada 80 cm y con 20 cm de altura media, rematados superiormente con maestras de mortero de cemento, industrial, M-5; AISLAMIENTO TÉRMICO: fieltro aislante de lana mineral; IMPERMEABILIZACIÓN: tipo monocapa, adherida, formada por lámina de betún modificado con elastómero SBS, LBM(SBS)-50/G-FP previa imprimación con emulsión asfáltica aniónica con cargas tipo EB. El precio no incluye la ejecución y el sellado de las juntas ni la ejecución de remates en los encuentros con paramentos y desagües.								
	Total cantidades alzadas						95,00		
							95,00	60,73	5.769,35
	TOTAL CAPÍTULO 5 CUBIERTAS								**8.582,01**

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 6 CERRAJERÍA Y CARPINTERÍA								
6.1	**m² Vallado metálico almacenamiento**								
	Celosía metálica para cierre de huecos de fachada mediante elementos fijos o puertas abatibles, de dimensiones y geometría según planos de proyecto, formado por bastidor metálico de perfil hueco laminado en frío, de sección cuadrados y/o rectangulares, galvanizados, cierre de hueco mediante tela metálica para enrejado de simple torsión 25/25, acabado galvanizado, tensada y atornillada al bastidor, conjunto anclado a fábrica de fachada mediante casquillos y tornillería, incluso parte proporcional de elementos de cuelgue y cierre de seguridad en puertas de acceso. Totalmente terminado y montado, eliminación de restos y limpieza final.								
	Total cantidades alzadas						60,14		
							60,14	29,55	1.777,14
6.2	**m Puertas correderas**								
	Puerta corredera para vallado H=1'8m, con módulos compuestos de bastidor perimetral de perfil 80.60.3, 80.80.3, UPE80. Entrepaño formado por pletinas de 6mm en disposición vertical mayoritariamente, con algunas en disposición horizontal. Estas pletinas se sueldan con TIG en su base y su cabeza al bastidor perimetral, incluso entre si, con las formas en Z del diseño, con la preparación de bordes necesaria para que la soldadura no sobresalga de las secciones del material. Se incluye el material de cerrajería para puerta corredera, que incluye rail-guía, tirador, ruedas, rodamientos, rodillos superiores guiadores, pescante limitador de vuelco, cremallera, cerradura,...etc, y todo el material necesario para dejar la puerta terminada, comprobada y en funcionamiento.								
	Total cantidades alzadas						8,00		
							8,00	584,73	4.677,84
6.3	**m Vallado General TIG H=1'8m**								
	Vallado altura entorno a 1.8m, ejecutado con módulos compuestos de bastidor de perfil tubular de 80.60.3mm en horizontales, y pletina 80.10mm en verticales. Entrepaño formado por pletinas de 6mm en disposición vertical mayoritariamente, con algunas en disposición horizontal, según planos de detalle. Estas pletinas se sueldan con TIG en su base y su cabeza al bastidor perimetral, incluso entre si, con las formas en Z del diseño, con la preparación de bordes necesaria para que la soldadura no sobresalga de las secciones del material. Este módulo de vallado se atornilla a los pilares formados a base de perfiles laminados con sección en T, o en H, o tubulares. Cualquier tipo de tornillería deberá quedar enrasada a la superficie del vallado. Las vallas se cierran con pilares metálicos tubulares rectangulares en los puntos donde se ubican las puertas las cuales van fijadas a dichos pilares. Ver plano PM48 detalle 1. Material acero acero S-275 JR, Acabado: galvanizado con pintura de poliuretano, acabado color marrón RAL 8022. Fijación a soporte: Mecánica.								
	Total cantidades alzadas						147,00		
							147,00	227,13	33.388,11
6.4	**u Puertas 90x205cm**								
	Puerta de paso de una hoja abatible de 90x205cm, formada por dos planchas de acero galvanizado ensambladas entre si y relleno de espuma de poliuretano, marco de plancha de acero galvanizado de 1.2mm de espesor, bisagras y cerradura embutida con manivela, incluso aplomado, colocación y eliminación de restos.								
	Total cantidades alzadas						5,00		
							5,00	118,63	593,15
6.5	**m² Ventanas aluminio**								
	Suministro y colocación de carpinterías de aluminio de dimensiones y diseño según planos de proyecto, abatibles, oscilobatientes, correderas, fijas, etc., realizada con perfiles con rotura de puente térmico de aluminio lacado de 60 micras con sello de calidad Qualicoat con canal europeo, junta de estanquidad interior, sellante en esquinas del cerco y accesorios que garanticen su correcto funcionamiento, acabada lacado color imitación acero corten para recibir acristalamiento de hasta 38mm, recibido sobre premarcos de aluminio atornillados a elementos de fachada y/o cerramientos, sellado de juntas por medio de silicona aplicada con pistola, incluso replanteo, colocación, aplomado y nivelado, montaje y regulación, listo para recibir acristalamiento, eliminación de restos y limpieza final, según NTE-FCL.								
	Total cantidades alzadas						7,80		
							7,80	233,55	1.821,69

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	TOTAL CAPÍTULO 6 CERRAJERÍA Y CARPINTERÍA								**42.257,93**

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 7 RED ELÉCTRICA DE BAJA TENSIÓN								
7.1	**m Cable con aislamiento 1.5 mm2**								
	Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 1,5 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V).								
	Total cantidades alzadas						2.200,00		
							2.200,00	1,09	2.398,00
7.2	**m Tubo PVC D=12 mm**								
	Suministro e instalación fija en superficie de canalización de tubo rígido de PVC, enchufable, curvable en caliente, de color negro, de 12 mm de diámetro nominal, resistencia a la compresión 1250 N, con grado de protección IP547.								
	Total cantidades alzadas						2.000,00		
							2.000,00	2,59	5.180,00
7.3	**m Cable con aislamiento 2.5 mm2**								
	Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 2,5 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V)								
	Total cantidades alzadas						3.200,00		
							3.200,00	1,82	5.824,00
7.4	**m Tubo PVC D=16 mm**								
	Suministro e instalación fija en superficie de canalización de tubo rígido de PVC, enchufable, curvable en caliente, de color negro, de 16 mm de diámetro nominal, resistencia a la compresión 1250 N, con grado de protección IP547.								
	Total cantidades alzadas						3.000,00		
							3.000,00	2,59	7.770,00
7.5	**m Cable con aislamiento 10 mm2**								
	Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 10 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V)								
	Total cantidades alzadas						500,00		
							500,00	2,81	1.405,00
7.6	**m Tubo PVC D=32 mm**								
	Suministro e instalación empotrada en elemento de construcción de obra de fábrica de canalización de tubo curvable de PVC, transversalmente elástico, corrugado, forrado, de color negro, de 32 mm de diámetro nominal, resistencia a la compresión 320 N, con grado de protección IP547.								
	Total cantidades alzadas						500,00		
							500,00	1,73	865,00
7.7	**m Cable con aislamiento 6 mm2**								
	Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 6 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V).								
	Total cantidades alzadas						500,00		
							500,00	2,81	1.405,00
7.8	**m Tubo PVC D=25 mm**								
	Suministro e instalación empotrada en elemento de construcción de obra de fábrica de canalización de tubo curvable de PVC, transversalmente elástico, corrugado, forrado, de color negro, de 25 mm de diámetro nominal, resistencia a la compresión 320 N, con grado de protección IP547.								
	Total cantidades alzadas						500,00		
							500,00	1,38	690,00
7.9	**u Interruptor magnetotermico 8 A**								
	Multi 9 - C60BP - MCB - 1P - 8 A - C Curve - 277 V - 10 kA								

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	Total cantidades alzadas						3,00		
							3,00	115,93	347,79
7.10	u **Contactor 9 A**								
	TeSys K contactor - 3P - AC-3 <= 440 V 9 A								
	Total cantidades alzadas						2,00		
							2,00	94,83	189,66
7.11	u **Interruptor diferencial 25 A, 30 mA**								
	Interruptor diferencial instantáneo, de 2 módulos, bipolar (2P), intensidad nominal 25 A, sensibilidad 30 mA, poder de corte 6 kA, clase AC.								
	Total cantidades alzadas						2,00		
							2,00	66,24	132,48
7.12	u **Interruptor magnetotermico 13 A**								
	Multi 9 - C60SP - MCB - 1P - 13 A - C Curve - 277 V - 10 kA								
	Total cantidades alzadas						4,00		
							4,00	104,32	417,28
7.13	u **Contactor 16 A**								
	TeSys K contactor - 3P - AC-3 <= 440 V 16 A								
	Total cantidades alzadas						3,00		
							3,00	172,91	518,73
7.14	u **Interruptor magnetotermico 35 A**								
	Multi 9 - C60BP - MCB - 3P - 35 A - C Curve - 480Y/277 V - 10 kA								
	Total cantidades alzadas						1,00		
							1,00	367,08	367,08
7.15	u **Contactor 38 A**								
	Contactor TeSys D - 3P(3 NO) - AC-3 - <= 440 V 38 A								
	Total cantidades alzadas						1,00		
							1,00	192,96	192,96
7.16	u **Interruptor diferencial 40 A, 30 mA**								
	Multi 9 ID - residual current circuit breaker - 2P - 40A - 30mA - type AC								
	Total cantidades alzadas						2,00		
							2,00	229,90	459,80
7.17	u **Interruptor magnetotermico 25 A**								
	Multi 9 - C60BP - MCB - 3P - 25 A - C Curve - 480Y/277 V - 10 kA								
	Total cantidades alzadas						1,00		
							1,00	351,25	351,25
7.18	u **Contactor 25 A**								
	TeSys D contactor - 3P(3 NO) - AC-3 - <= 440 V 25 A								
	Total cantidades alzadas						1,00		
							1,00	151,81	151,81
7.19	u **Interruptor automático 125 A**								
	PowerPact - automatic switch - 600V 125A 3P								
	Total cantidades alzadas						1,00		
							1,00	763,85	763,85
7.20	u **Sistema de alimentación ininterrupida (SAI)**								
	Sistema de alimentación ininterrumpida Off-Line, de 0,8 kVA de potencia, para alimentación monofásica.								
	Total cantidades alzadas						1,00		
							1,00	418,08	418,08

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	TOTAL CAPÍTULO 7 RED ELÉCTRICA DE BAJA TENSIÓN...								**29.847,77**

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 8 RED DE HIDRÓGENO								
8.1	**m Tubería H2 gas Dext=21.3 mm**								
	Total cantidades alzadas						17,10		
							17,10	17,64	301,64
8.2	**m Tubería H2 gas Dext=26.9 mm**								
	Total cantidades alzadas						43,12		
							43,12	21,39	922,34
8.3	**m Tubería H2 gas Dext=4.2 mm**								
	Total cantidades alzadas						11,91		
							11,91	8,45	100,64
8.4	**m Tubería H2 gas Dext=6 mm**								
	Total cantidades alzadas						19,09		
							19,09	9,56	182,50
8.5	**m Tubería H2 gas Dext=33.7 mm**								
	Total cantidades alzadas						10,39		
							10,39	22,67	235,54
	TOTAL CAPÍTULO 8 RED DE HIDRÓGENO..								**1.742,66**

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 9 PROTECCIÓN CONTRA INCENDIOS								
9.1	**u Pulsador alarma convencional**								
	Pulsador de alarma convencional de rearme manual, de ABS color rojo, protección IP41, con led indicador de alarma color rojo y llave de rearme. Incluso elementos de fijación.								
	Total cantidades alzadas						2,00		
							2,00	32,43	64,86
9.2	**u Alumbrado de emergencia en zonas comunes**								
	Suministro e instalación en superficie en zonas comunes de luminaria de emergencia, con tubo lineal fluorescente, 6 W - G5, flujo luminoso 155 lúmenes, carcasa de 245x110x58 mm, clase II, IP42, con baterías de Ni-Cd de alta temperatura, autonomía de 1 h, alimentación a 230 V, tiempo de carga 24 h. Incluso accesorios y elementos de fijación.								
	Total cantidades alzadas						1,00		
							1,00	52,67	52,67
9.3	**u Extintor**								
	Extintor portátil de polvo químico ABC polivalente antibrasa, con presión incorporada, de eficacia 21A-144B-C, con 6 kg de agente extintor, con manómetro y manguera con boquilla difusora. Incluso soporte y accesorios de montaje.								
	Total cantidades alzadas						5,00		
							5,00	46,69	233,45
9.4	**u Boca de incendio equipada**								
	Suministro e instalación en superficie de Boca de incendio equipada (BIE), de 25 mm (1") y de 680x480x215 mm, compuesta de: armario construido en acero de 1,2 mm de espesor, acabado con pintura epoxi color rojo RAL 3000 y puerta semiciega con ventana de metacrilato de acero de 1,2 mm de espesor, acabado con pintura epoxi color rojo RAL 3000; devanadera metálica giratoria fija, pintada en rojo epoxi, con alimentación axial; manguera semirrígida de 20 m de longitud; lanza de tres efectos (cierre, pulverización y chorro compacto) construida en plástico ABS y válvula de cierre tipo esfera de 25 mm (1"), de latón, con manómetro 0-16 bar. Incluso accesorios y elementos de fijación.								
	Total cantidades alzadas						2,00		
							2,00	430,92	861,84

TOTAL CAPÍTULO 9 PROTECCIÓN CONTRA INCENDIOS.. 1.212,82

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
	CAPÍTULO 10 COMPONENTES INSTALACIÓN								
10.1	**u Electrolizador PEM EL5N**								
	Total cantidades alzadas						1,00		
							1,00	288.264,44	288.264,44
10.2	**u Almacenamiento hidrógeno gas 10" MEGC 300 bar**								
	Total cantidades alzadas						1,00		
							1,00	155.151,66	155.151,66
10.3	**u Almacenamiento hidrógeno gas KPJ-017-BG**								
	Total cantidades alzadas						3,00		
							3,00	108.720,66	326.161,98
10.4	**u Almacenamiento hidrógeno gas Tank-500 bar (200 l)**								
	Total cantidades alzadas						3,00		
							3,00	6.889,04	20.667,12
10.5	**u Booster AGD 32**								
	Total cantidades alzadas						2,00		
							2,00	26.411,16	52.822,32
10.6	**u Booster AGD 152**								
	Total cantidades alzadas						2,00		
							2,00	26.411,16	52.822,32
10.7	**u Standard Hydrogen Refuelling Station**								
	Total cantidades alzadas						2,00		
							2,00	93.947,16	187.894,32
10.8	**u Compresor de tornillo 30 CV kaeser ASK 40 SFC con variador de f**								
	Total cantidades alzadas						1,00		
							1,00	13.235,31	13.235,31
10.9	**u Secador frigorifico kaeser TD 51**								
	Total cantidades alzadas						1,00		
							1,00	4.816,38	4.816,38
10.10	**u Filtro centrifugo en línea kaeser F46KC con manómetro**								
	Total cantidades alzadas						1,00		
							1,00	587,92	587,92
10.11	**u Depósito aire vertical kaeser 1000 litros 11 bar galvanizado**								
	Total cantidades alzadas						1,00		
							1,00	1.449,98	1.449,98
10.12	**u Purgador capacitativo de condensados kaeser ECO-DRAIN 31**								
	Total cantidades alzadas						1,00		
							1,00	254,92	254,92
10.13	**u Griferia deposito**								
	Total cantidades alzadas						1,00		
							1,00	249,13	249,13
10.14	**u Separador de condensados kaeser CF 9**								
	Total cantidades alzadas						1,00		
							1,00	749,91	749,91

CÓDIGO	RESUMEN	UDS	LONGITUD	ANCHURA	ALTURA	PARCIALES	CANTIDAD	PRECIO	IMPORTE
10.15	u **Regulador de presión electrico MS6-LRE**								
	Total cantidades alzadas						4,00		
							4,00	330,59	1.322,36
	TOTAL CAPÍTULO 10 COMPONENTES INSTALACIÓN								**1.106.450,07**
	TOTAL								**1.381.963,01**

Chapter 3

Breakdown price table

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE

CAPÍTULO 1 DEMOLICIONES Y TRABAJOS PREVIOS

1.1		**m²**	**Desbroce y limipieza terreno por medios mecánicos**			
			Desbroce y limpieza del terreno, con medios mecánicos. Comprende los trabajos necesarios para retirar de las zonas previstas para la edificación o urbanización: árboles, plantas, tocones, maleza, broza, maderas caídas, escombros, basuras o cualquier otro material existente, hasta una profundidad no menor que el espesor de la capa de tierra vegetal, considerando como media 40cm. incluye retirada de material sobrante, carga sobre camión, el transporte a acopio intermedio cuando resulte necesario, y la descarga, y sin incluir transporte de escombros a vertedero autorizado. Se incluyen los apeos, apuntalamientos, arriostramientos, andamios y plataformas que resulten necesarios para realizar estas operaciones, y que no serán de abono independiente.			
MO1.1_1	0,010	h	Peón ordinario construcción	17,31	0,17	
MQ1.1_1	0,010	h	Pala cargadora de oruga 128cv 1,5m3	69,13	0,69	
%	0,500		Costes directos complementarios	0,90	0,00	
			Suma la partida........			0,86
			Costes indirectos........		5,00%	0,04
			TOTAL PARTIDA........			**0,90**

Asciende el precio total de la partida a la mencionada cantidad de CERO EUROS con NOVENTA CÉNTIMOS

1.2		**u**	**Traslado modulo caseta prefabricada**			
			Traslado módulo caseta prefabricado, de la zona de la hidrogenera a menos de 50m de distancia, fuera de ésta, incluso carga sobre camión, el transporte a acopio intermedio cuando resulte necesario, y la descarga. Se incluyen los apeos, apuntalamientos, arriostramientos, andamios y plataformas que resulten necesarios para realizar estas operaciones, y que no serán de abono independiente.			
MO1.1_1	1,000	h	Peón ordinario construcción	17,31	17,31	
MO1.2_2	2,000	h	Oficial 1ª construcción	18,12	36,24	
MQ1.2_1	0,500	h	Camión de transporte 10T 8m3 2ejes	21,06	10,53	
MQ1.2_2	2,000	h	Camión grúa autocargante 13 T s/JIC	43,80	87,60	
%	0,500		Costes directos complementarios	151,70	0,76	
			Suma la partida........			152,44
			Costes indirectos........		5,00%	7,62
			TOTAL PARTIDA........			**160,06**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO SESENTA EUROS con SEIS CÉNTIMOS

1.3		**m²**	**Levantamiento valla simple torsión**			
			Levantado de valla simple torsión, incluso retirada de escombros, carga sobre camión, el transporte a acopio intermedio cuando resulte necesario, y la descarga, y sin incluir transporte de escombros a vertedero autorizado. Se incluyen los apeos, apuntalamientos, arriostramientos, andamios y plataformas que resulten necesarios para realizar estas operaciones, y que no serán de abono independiente.			
MO1.3_1	0,005	h	Aprendiz 2º carpintería	12,09	0,06	
MO1.3_2	0,005	h	Peón ordinario construcción	17,31	0,09	
MQ1.3_1	0,015	h	Retro de neum s/palafrtl 0,8m3	41,38	0,62	
%	0,500		Costes directos complementarios	0,80	0,00	
			Suma la partida........			0,77
			Costes indirectos........		5,00%	0,04
			TOTAL PARTIDA........			**0,81**

Asciende el precio total de la partida a la mencionada cantidad de CERO EUROS con OCHENTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 2 MOVIMIENTO DE TIERRAS						
2.1		**m³**	**Excavación zanja solera**			
			Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.			
MO2.1_1	0,120	h	Peón ordinario construcción	17,31	2,08	
MQ2.1_1	0,120	h	Retroexcavadora de neumaticos c/palafrtl 0,34m3	41,31	4,96	
%	0,500		Costes directos complementarios	7,00	0,04	
			Suma la partida..			7,08
			Costes indirectos............................		5,00%	0,35
			TOTAL PARTIDA..			**7,43**

Asciende el precio total de la partida a la mencionada cantidad de SIETE EUROS con CUARENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
2.2		**m³**	**Excavación zanjas canalización H2**			
			Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.			
MO2.4_1	0,120	h	Peón ordinario construcción	17,31	2,08	
MQ2.4_1	0,120	h	Retroexcavadora de neumaticos c/palafrtl 0,34m3	41,31	4,96	
%	0,500		Costes directos complementarios	7,00	0,04	
			Suma la partida..			7,08
			Costes indirectos............................		5,00%	0,35
			TOTAL PARTIDA..			**7,43**

Asciende el precio total de la partida a la mencionada cantidad de SIETE EUROS con CUARENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
2.3		**m³**	**Excavación zanjas zapatas + vigas riostras**			
			Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.			
MO2.4_1	0,120	h	Peón ordinario construcción	17,31	2,08	
MQ2.4_1	0,120	h	Retroexcavadora de neumaticos c/palafrtl 0,34m3	41,31	4,96	
%	0,500		Costes directos complementarios	7,00	0,04	
			Suma la partida..			7,08
			Costes indirectos............................		5,00%	0,35
			TOTAL PARTIDA..			**7,43**

Asciende el precio total de la partida a la mencionada cantidad de SIETE EUROS con CUARENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
2.4		**m³**	**Excavación zanjas zapatas corridas**			
			Excavación para la formación de zanja, en terrenos medios, con retroexcavadora, incluso ayuda manual en las zonas de dificil acceso, limpieza y extración de restos a los bordes, incluso carga, transporte a acopio intermedio cuando resulte necesario, descarga, y sin incluir transporte de escombros a vertedero autorizado.			
MO2.4_1	0,120	h	Peón ordinario construcción	17,31	2,08	
MQ2.4_1	0,120	h	Retroexcavadora de neumaticos c/palafrtl 0,34m3	41,31	4,96	
%	0,500		Costes directos complementarios	7,00	0,04	
			Suma la partida..			7,08
			Costes indirectos............................		5,00%	0,35
			TOTAL PARTIDA..			**7,43**

Asciende el precio total de la partida a la mencionada cantidad de SIETE EUROS con CUARENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 3 CIMENTACIONES, ESTRUCTURAS Y MUROS						
3.1		**m²**	**Hormigón de limpieza 150/B/20 e=10 cm**			
			Capa de hormigón de limpieza HL-150/B/20 preparado, de consistencia blanda, tamaño máximo del árido 20 mm. y 10cm. de espesor, en la base de la cimentación, transportado y puesto en obra, según EHE.			
MO3.1_1	0,050	h	Oficial 1ª construcción	18,12	0,91	
MO3.1_2	0,100	h	Peón especializado construcción	17,62	1,76	
M3.1_1	0,110	m3	HL-150/B/20	46,34	5,10	
%	0,500		Costes directos complementarios	7,80	0,04	
			Suma la partida			7,81
			Costes indirectos		5,00%	0,39
			TOTAL PARTIDA			**8,20**

Asciende el precio total de la partida a la mencionada cantidad de OCHO EUROS con VEINTE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.2		**m³**	**Hormigón armado 25/B/40/IIa zapatas + vigas riostras**			
			Hormigón HA-25/B/40/IIa para armar preparado en cimentaciones de zanjas, zapatas y riostras, de consistencia blanda y tamaño máximo del árido 40 mm, transportado y puesto en obra según EHE-08 vertido por cualquier medio.			
MO3.2_1	0,700	h	Oficial 1ª construcción	18,12	12,68	
MO3.2_2	1,050	h	Peón especializado construcción	17,62	18,50	
M3.2_1	1,150	m3	HA-25/B/40/IIa	51,93	59,72	
MQ3.2_1	0,300	h	Vibrador gasolina aguja ø30-50mm	2,87	0,86	
%	0,500		Costes directos complementarios	91,80	0,46	
			Suma la partida			92,22
			Costes indirectos		5,00%	4,61
			TOTAL PARTIDA			**96,83**

Asciende el precio total de la partida a la mencionada cantidad de NOVENTA Y SEIS EUROS con OCHENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.3		**m³**	**Hormigón armado 25/B/40/IIa zapatas corridas**			
			Hormigón HA-25/B/40/IIa para armar preparado en cimentaciones de zanjas, zapatas y riostras, de consistencia blanda y tamaño máximo del árido 40 mm, transportado y puesto en obra según EHE-08 vertido por cualquier medio.			
MO3.3_1	0,700	h	Oficial 1ª construcción	18,12	12,68	
MO3.3_2	1,050	h	Peón especializado construcción	17,62	18,50	
M3.3_1	1,150	m3	HA-25/B/40/IIa	51,93	59,72	
MQ3.3_1	0,300	h	Vibrador gasolina aguja ø30-50mm	2,87	0,86	
%	0,500		Costes directos complementarios	91,80	0,46	
			Suma la partida			92,22
			Costes indirectos		5,00%	4,61
			TOTAL PARTIDA			**96,83**

Asciende el precio total de la partida a la mencionada cantidad de NOVENTA Y SEIS EUROS con OCHENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.4		**m²**	**Encofrado metálico**			
			Encofrado metálico a 2 caras para muros de altura menor 1.5m mediante paneles metálicos de pequeñas dimensiones, estimándose 25 usos, incluso desencofrado, limpieza y almacenamiento.			
MO3.4_1	0,460	h	Oficial 1ª construcción	18,12	8,34	
MO3.4_2	0,460	h	Peón especializado construcción	17,62	8,11	
M3.4_1	0,080	l	Desencofrante líquido	2,24	0,18	
M3.4_2	0,200	kg	Alambre reco n.13ø2.0mm mazos5kg	2,48	0,50	
MQ3.4_1	8,000	u	Amtz pl met encf 30x50cm 25us	0,41	3,28	
MQ3.4_2	0,040	m3	Amtz mad encf tabl 6 us	37,78	1,51	
%	0,500		Costes directos complementarios	21,90	0,11	
			Suma la partida			22,03
			Costes indirectos		5,00%	1,10
			TOTAL PARTIDA			**23,13**

Asciende el precio total de la partida a la mencionada cantidad de VEINTITRES EUROS con TRECE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.5		m²	**Paneles hormigón prefabricado Em=30 cm**			
			Muro de contención de tierras formado por paneles prefabricados texturados con gomas rekli o similar, textura a elegir por DF, de hormigón arquitectónico armado de espesor variable de entorno a 30 cm de espesor medio. Esta partida incluye hormigón, encofrados, (acero medido aparte) fabricación, transporte, colocación sobre el hormigón de limpieza, alineación de los módulos, sellado de juntas, y colocación correcta de las esperas del trasdós, para realizar un correcto empalme por solapo con las armaduras de la cimentación.			
MO3.5_1	0,220	h	Oficial 1ª construcción	18,12	3,99	
MO3.5_2	0,220	h	Ayudante construcción	17,81	3,92	
MO3.5_3	0,120	h	Peón ordinario construcción	17,31	2,08	
M3.5_1	1,000	m2	Pnl pref H e=30 cm aci col	62,00	62,00	
M3.5_2	1,000	kg	Masilla en frío de asf+caucho	1,51	1,51	
MQ3.5_1	0,050	me	Grúa móvil s/plat 50T	175,04	8,75	
MQ3.5_2	1,000	u	Puntal met 3.00m	7,37	7,37	
%	0,500		Costes directos complementarios	89,60	0,45	
			Suma la partida			90,07
			Costes indirectos		5,00%	4,50
			TOTAL PARTIDA			**94,57**

Asciende el precio total de la partida a la mencionada cantidad de NOVENTA Y CUATRO EUROS con CINCUENTA Y SIETE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.6		m	**Vigas prefabricada de hormigón armado**			
			Viga prefabricada de hormigón armado tipo T invertida, de 30 cm de anchura de alma, 30 cm de altura de talón, 45 cm de anchura total y 45 cm de altura total, con un momento flector máximo de 360 kN·m..			
MO3.6_1	0,050	h	Oficial 1º montador	19,67	0,98	
MO3.6_2	0,100	h	Ayudante montador	18,63	1,86	
M3.6_1	1,000	m	Viga prefabricado de hormigón armado tipo T invertida	123,93	123,93	
MQ3.6_1	0,050	h	Grúa autopropulsada de brazo telescopico	67,00	3,35	
%3.6	2,000		Costes directos complementarios	130,10	2,60	
			Suma la partida			132,72
			Costes indirectos		5,00%	6,64
			TOTAL PARTIDA			**139,36**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO TREINTA Y NUEVE EUROS con TREINTA Y SEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.7		kg	**Pilares HEB Acero 14x14 marquesina**			
			Acero UNE-EN 10025 S275JR, en pilares formados por piezas simples de perfiles laminados en caliente de las series IPN, IPE, HEB, HEA, HEM o UPN, acabado con imprimación antioxidante, colocado con uniones atornilladas en obra, a una altura de hasta 3 m. El precio incluye los tornillos, los cortes, los despuntes, las piezas especiales, las placas de arranque y de transición de pilar inferior a superior, los casquillos y los elementos auxiliares de montaje.			
MO3.7_1	0,012	h	Oficial 1ª montador de estructura metálica	19,67	0,24	
MO3.7_2	0,012	h	Ayudante montador de estructura metálica	18,63	0,22	
M3.7_1	1,000	kg	Acero laminado	1,06	1,06	
%3.7	2,000		Costes directos complementarios	1,50	0,03	
			Suma la partida			1,55
			Costes indirectos		5,00%	0,08
			TOTAL PARTIDA			**1,63**

Asciende el precio total de la partida a la mencionada cantidad de UN EUROS con SESENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.8		kg	**Viga HEB Acero 14x14 marquesina**			
			Acero UNE-EN 10025 S275JR, en vigas formadas por piezas simples de perfiles laminados en caliente de las series IPN, IPE, HEB, HEA, HEM o UPN, acabado con imprimación antioxidante, con uniones atornilladas en obra, a una altura de más de 3 m. El precio incluye los tornillos, los cortes, los despuntes, las piezas especiales, los casquillos y los elementos auxiliares de montaje.			
MO3.8_1	0,015	h	Oficial 1ª montador de estructura metálica	19,67	0,30	
MO3.8_2	0,008	h	Ayudante montador de estructura metálica	18,63	0,15	
M3.8_1	1,000	kg	Acero laminado	1,06	1,06	
%3.8	2,000		Costes directos complementarios	1,50	0,03	
			Suma la partida			1,54
			Costes indirectos		5,00%	0,08
			TOTAL PARTIDA			**1,62**

Asciende el precio total de la partida a la mencionada cantidad de UN EUROS con SESENTA Y DOS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.9		**m**	**Pilares hormigón 30x30 HA 30/B/20/IV+Qa <3.5 met**			
			Soporte de hormigón armado de 30 N/mm2 (HA 30/B/20/IV+Qa) confeccionado en central, con una cuantía media de 120 kg. de acero B 500 S, de sección 30x30 cm., para una altura de menor de 3.5 m., incluso encofrado metálico, desencofrado y curado, según EHE.			
MO3.9.2_1	0,063	h	Oficial 1ª construcción	18,12	1,14	
MO3.9.1_2	0,063	h	Peón ordinario construcción	17,31	1,09	
M3.9_1	0,147	m3	HA-30/B/20/IV+Qa	75,13	11,04	
MQ3.9_1	0,042	h	Vibrador gasolina aguja ø30-50mm	2,87	0,12	
%	0,500		Costes directos complementarios	13,40	0,07	
3.9.1	120,000	kg	Acero p/hormigón B 500 S ø6-25	1,05	126,00	
3.9.2	1,500	m2	Encf met plr <3.5m 40x50 75us	9,42	14,13	
			Suma la partida..			153,59
			Costes indirectos...........................		5,00%	7,68
			TOTAL PARTIDA..			**161,27**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO SESENTA Y UN EUROS con VEINTISIETE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
3.10		**m²**	**Losa de placas alveolares prefabricadas de hormigón pretensado**			
			Losa de 12 + 5 cm de canto, realizada con placas alveolares prefabricadas de hormigón pretensado, de 12 cm de canto y 60 cm de anchura, con momento flector último de 12 kN·m/m, con altura libre de planta de hasta 3 m, apoyada directamente sobre vigas de canto o muros de carga; relleno de juntas entre placas alveolares, zonas de enlace con apoyos y capa de compresión, realizados con hormigón HA-25/B/20/IIa fabricado en central, y vertido con cubilote, acero B 500 S en zona de negativos, con una cuantía aproximada de 4 kg/m², y malla electrosoldada ME 15x15 Ø 5-5 B 500 T 6x2,20 UNE-EN 10080. Incluso piezas de acero UNE-EN 10025 S275JR tipo Omega, en posición invertida, laminado en caliente, con recubrimiento galvanizado, 1 kg/m², para el apoyo de las placas en los huecos del forjado, alambre de atar y separadores. El precio incluye la elaboración de la ferralla (corte, doblado y conformado de elementos) en taller industrial y el montaje en el lugar definitivo de su colocación en obra, pero no incluye los apoyos ni los pilares.			
MO3.10_1	0,150	h	Oficial 1º montador de estructura prefabricada de hormigón	19,67	2,95	
MO3.10_2	0,150	h	Ayudante montador de estructura prefabricada de hormigón	18,63	2,79	
MO3.10_3	0,069	h	Oficial 1º ferrallista	19,67	1,36	
MO3.10_4	0,061	h	Ayudante ferrallista	18,63	1,14	
MO3.10_5	0,013	h	Oficial 1º estructurista	19,67	0,26	
MO3.10_6	0,054	h	Ayudante estructurista	18,63	1,01	
M3.10_1	1,000	m2	Placa alveolar prefabricada de hormigón pretensado	26,20	26,20	
M3.10_2	1,000	kg	Acero laminado para apoyo de placa prefabricada	2,64	2,64	
M3.10_3	3,000	u	Separador homologado para malla electrosoldada	0,08	0,24	
M3.10_4	1,150	m2	Malla electrosolada	1,67	1,92	
M3.10_5	4,000	kg	Ferralla con acero en barras corrugadas	0,81	3,24	
M3.10_6	0,064	kg	Alambre galvanizado para atar	1,10	0,07	
M3.10_7	0,063	m3	Hormigón HA-25/N/20/IIa, fabricado en central	76,88	4,84	
MQ3.10_1	0,150	h	Grúa autopropulasada de brazo telescópico	67,00	10,05	
%3.10	2,000		Costes directos complementarios	58,70	1,17	
			Suma la partida..			59,88
			Costes indirectos...........................		5,00%	2,99
			TOTAL PARTIDA..			**62,87**

Asciende el precio total de la partida a la mencionada cantidad de SESENTA Y DOS EUROS con OCHENTA Y SIETE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 4 PAVIMENTO						
4.1		**m²**	**Pavimiento de hormigón + mortero**			
			Pavimento realizado con losa prefabricada de hormigón para tráfico rodado, de color de DIMENSIONES 600x400x15cm tipo Fenollar Metropolitan bio-innova color claro a elegir por DF o equivalente, acabado antideslizante R3, sentada sobre subbase rígida resistente, colocado en capa de 10 cm de mortero y adhesivo cementoso mejorado con deslizamiento reducido y tiempo abierto ampliado (C2TES1) y rejuntado con mortero de juntas cementoso mejorado (CG2), totalmente terminado, incluso cortes y limpieza.			
MO4.2.1_1	0,200	h	Oficial 1ª construcción	18,12	3,62	
MO4.3_1	0,200	h	Peón ordinario construcción	17,31	3,46	
M4.1_1	0,035	m3	Mto cto M-5 CEM ind	57,81	2,02	
M4.1_2	5,000	kg	Adh cementoso C2 TE S1	1,01	5,05	
M4.1_3	1,000	kg	Mto juntas cementoso CG2	1,02	1,02	
M4.1_4	1,050	m2	Losa hormigón 600x400x15cm	11,37	11,94	
M4.1_5	0,010	m3	Agua	1,19	0,01	
%	0,500		Costes directos complementarios	27,10	0,14	
			Suma la partida...			27,26
			Costes indirectos..........................		5,00%	1,36
			TOTAL PARTIDA...			**28,62**

Asciende el precio total de la partida a la mencionada cantidad de VEINTIOCHO EUROS con SESENTA Y DOS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
4.2		**m²**	**Solera Hormigón Armado 25/B/20/IIa**			
			Solera de hormigón HA-25/B/20/IIa de consistencia blanda y tamaño máximo del árido de 20mm, con un espesor de 25 cm, armada con una malla 15.15.5 de acero corrugado B 500 T, elaborado, transportado, vertido y compactado en obra, medido el volumen a excavación teórica llena. Incluso corte de capilaridad con lámina de plástico impermeable reforzado, y pequeños encofrados para los escalonamientos. En la descomposición se incluye un exceso de m3 hormigón, y 1kg/m2 de acero, para la formación y el refuerzo de los escalones.			
MO4.2.1_1	0,200	h	Oficial 1ª construcción	18,12	3,62	
MO4.2.1_2	0,200	h	Peón especializado construcción	17,62	3,52	
M4.2_1	0,300	m3	HA-25/B/20/IIa	53,93	16,18	
M4.2_2	1,150	m2	Mallazo ME 15x15 ø 5-5	1,33	1,53	
M4.2_3	1,150	m2	Lámina PE e=0.10mm	0,09	0,10	
M4.2_4	1,000	kg	Acero corru B 500 S ø6-25	0,57	0,57	
%	0,500		Costes directos complementarios	25,50	0,13	
4.2.1	0,200	m2	Encf met <1.5 1cr pq dim	18,93	3,79	
			Suma la partida...			29,44
			Costes indirectos..........................		5,00%	1,47
			TOTAL PARTIDA...			**30,91**

Asciende el precio total de la partida a la mencionada cantidad de TREINTA EUROS con NOVENTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
4.3		**m³**	**Relleno extendido gravas**			
			Relleno y extendido de gravas con medios mecánicos, motoniveladora, incluso compactación, con rodillo autopropulsado, en capas de 25cm de espesor máximo, según NTE/ADZ-12.			
MO4.3_1	0,021	h	Peón ordinario construcción	17,31	0,36	
M4.3_1	1,700	t	Grava caliza 10/25 s/lvd 10km	10,07	17,12	
MQ4.3_1	0,020	h	Motoniveladora 140 CV	52,00	1,04	
MQ4.3_2	0,020	h	Rodll autpro 10 T	51,88	1,04	
MQ4.3_3	0,020	h	Pala crgra de neum 179cv 3,2m3	45,67	0,91	
%	0,500		Costes directos complementarios	20,50	0,10	
			Suma la partida...			20,57
			Costes indirectos..........................		5,00%	1,03
			TOTAL PARTIDA...			**21,60**

Asciende el precio total de la partida a la mencionada cantidad de VEINTIUN EUROS con SESENTA CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 5 CUBIERTAS						
5.1		**m²**	**Cubierta inclinada de paneles sándwich aislantes, de acero.**			
			Cubierta inclinada de paneles sándwich aislantes de acero, de 30 mm de espesor y 1150 mm de ancho, alma aislante de lana de roca, con una pendiente mayor del 10%.			
MO5.1_1	0,081	h	Oficial 1ª montador de cerramientos industriales.	18,13	1,47	
MO5.1_2	0,081	h	Ayudante montador de cerramientos industriales	16,43	1,33	
M5.1_1	1,050	m2	Panel sándwich aislante de acerO	34,18	35,89	
M5.1_2	3,000	u	Tornillo autorroscante de 6,5x70 mm de acero inoxidable	0,50	1,50	
%5.1	2,000		Costes directos complementarios	40,20	0,80	
			Suma la partida			40,99
			Costes indirectos		5,00%	2,05
			TOTAL PARTIDA			**43,04**

Asciende el precio total de la partida a la mencionada cantidad de CUARENTA Y TRES EUROS con CUATRO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
5.2		**m²**	**Cubierta plano no transitable, ventilada, autoprotegida**			
			Cubierta plana no transitable, ventilada, autoprotegida, tipo convencional, pendiente del 1% al 15%. FORMACIÓN DE PENDIENTES: tablero cerámico hueco machihembrado de 80x25x3,5 cm con capa de regularización de mortero de cemento, industrial, M-5, de 3 cm de espesor, acabado fratasado, sobre tabiques aligerados de ladrillo cerámico hueco de 24x11,5x9 cm, recibido con mortero de cemento, industrial, M-5, dispuestos cada 80 cm y con 20 cm de altura media, rematados superiormente con maestras de mortero de cemento, industrial, M-5; AISLAMIENTO TÉRMICO: fieltro aislante de lana mineral; IMPERMEABILIZACIÓN: tipo monocapa, adherida, formada por lámina de betún modificado con elastómero SBS, LBM(SBS)-50/G-FP previa imprimación con emulsión asfáltica aniónica con cargas tipo EB. El precio no incluye la ejecución y el sellado de las juntas ni la ejecución de remates en los encuentros con paramentos y desagües.			
MO5.2_1	0,780	h	Oficial 1º construcción	18,89	14,73	
MO5.2_2	0,980	h	Peón ordinario construcción	17,67	17,32	
MO5.2_3	0,050	h	Oficial 1º montador de aislamientos	19,42	0,97	
MO5.2_4	0,050	h	Ayudante montador de aislamientos	17,90	0,90	
MO5.2_5	0,100	h	Oficial 1º aplicador de láminas impermeabilizantes	18,89	1,89	
MO5.2_6	0,100	h	Ayudante aplicador de láminas impermeabilizantes	17,90	1,79	
M5.2_1	8,000	u	Ladrillo cerámico hueco doble	0,13	1,04	
M5.2_2	0,014	m3	Agua	1,50	0,02	
M5.2_3	0,075	t	Mortero industrial para albañilería de cemento	33,86	2,54	
M5.2_4	0,010	m2	Panel rígido de poliestireno expandido	1,34	0,01	
M5.2_5	1,200	m2	Fieltro aislante de lana mineral	5,26	6,31	
M5.2_6	5,000	u	Tablero cerámico hueco machihembrado	0,39	1,95	
M5.2_7	1,100	m2	Lámina de betún modificado con elastómero SBS	6,18	6,80	
M5.2_8	0,300	kg	Emulsión asfáltica aniónica	1,46	0,44	
%5.2	2,000		Costes directos complementarios	56,70	1,13	
			Suma la partida			57,84
			Costes indirectos		5,00%	2,89
			TOTAL PARTIDA			**60,73**

Asciende el precio total de la partida a la mencionada cantidad de SESENTA EUROS con SETENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 6 CERRAJERÍA Y CARPINTERÍA						
6.1		**m²**	**Vallado metálico almacenamiento**			
			Celosía metálica para cierre de huecos de fachada mediante elementos fijos o puertas abatibles, de dimensiones y geometría según planos de proy ecto, formado por bastidor metálico de perfil hueco laminado en frío, de sección cuadrados y /o rectangulares, galv anizados, cierre de hueco mediante tela metálica para enrejado de simple torsión 25/25, acabado galv anizado, tensada y atornillada al bastidor, conjunto anclado a fábrica de fachada mediante casquillos y tornillería, incluso parte proporcional de elementos de cuelgue y cierre de seguridad en puertas de acceso. Totalmente terminado y montado, eliminación de restos y limpieza final.			
MO6.5_1	0,250	h	Oficial 1ª construcción	18,12	4,53	
MO6.1_2	0,500	h	Peón especializado construcción	17,62	8,81	
MO6.5_3	0,500	h	Oficial 1ª metal	12,19	6,10	
M6.1_1	1,100	m2	Tela metálica 25/25 enrejados	2,27	2,50	
M6.1_2	6,000	kg	Acero perfil hueco A-42b	1,01	6,06	
%	0,500		Costes directos complementarios	28,00	0,14	
			Suma la partida..			28,14
			Costes indirectos...........................		5,00%	1,41
			TOTAL PARTIDA...			**29,55**

Asciende el precio total de la partida a la mencionada cantidad de VEINTINUEVE EUROS con CINCUENTA Y CINCO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
6.2		**m**	**Puertas correderas**			
			Puerta corredera para v allado H=1'8m, con módulos compuestos de bastidor perimetral de perfil 80.60.3, 80.80.3, UPE80. Entrepaño formado por pletinas de 6mm en disposición v ertical may oritariamente, con algunas en disposición horizontal. Estas pletinas se sueldan con TIG en su base y su cabeza al bastidor perimetral, incluso entre si, con las formas en Z del diseño, con la preparación de bordes necesaria para que la soldadura no sobresalga de las secciones del material. Se incluy e el material de cerrajería para puerta corredera, que incluy e rail-guía, tirador, ruedas, rodamientos, rodillos superiores guiadores, pescante limitador de v uelco, cremallera, cerradura,...etc, y todo el material necesario para dejar la puerta terminada, comprobada y en funcionamiento.			
M6.3_1	1,000	m	Perfil hueco rect 80.60.3 (Pesa 6,07Kg/m)	5,03	5,03	
M6.2_2	1,000	m	Perfil UPE80 (Pesa 7'9Kg/m)	6,50	6,50	
M6.2_3	1,540	m	Perfil hueco rect 80.80.3 (Pesa 7'01Kg/m)	5,81	8,95	
M6.3_2	70,000	kg	Acero S275JR en pletina	1,30	91,00	
M6.3_3	160,000	u	Rep soldadura TIG kg/est L=25mm	0,08	12,80	
M6.3_4	6,000	u	Rep soldadura TIG kg/est L=100mm	0,32	1,92	
M6.3_5	0,095	t	Repercusión galv anizado por t est metálica	432,24	41,06	
MO6.5_3	4,000	h	Oficial 1ª metal	12,19	48,76	
MO6.3_2	4,000	h	Especialista metal	10,37	41,48	
M6.2_8	0,333	u	Material de cerrajería para puerta corredera	182,01	60,61	
M6.2_9	0,333	u	Motor para puerta corredera	542,01	180,49	
%	0,500		Costes directos complementarios	498,60	2,49	
6.3.1	90,000	Kg	Rep Esmalte poliuret bic s/Kg v allado	0,62	55,80	
			Suma la partida..			556,89
			Costes indirectos...........................		5,00%	27,84
			TOTAL PARTIDA...			**584,73**

Asciende el precio total de la partida a la mencionada cantidad de QUINIENTOS OCHENTA Y CUATRO EUROS con SETENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
6.3		**m**	**Vallado General TIG H=1'8m**			
			Vallado altura entorno a 1.8m, ejecutado con módulos compuestos de bastidor de perfil tubular de 80.60.3mm en horizontales, y pletina 80.10mm en verticales. Entrepaño formado por pletinas de 6mm en disposición vertical mayoritariamente, con algunas en disposición horizontal, según planos de detalle. Estas pletinas se sueldan con TIG en su base y su cabeza al bastidor perimetral, incluso entre si, con las formas en Z del diseño, con la preparación de bordes necesaria para que la soldadura no sobresalga de las secciones del material. Este módulo de vallado se atornilla a los pilares formados a base de perfiles laminados con sección en T, o en H, o tubulares. Cualquier tipo de tornillería deberá quedar enrasada a la superficie del vallado. Las vallas se cierran con pilares metálicos tubulares rectangulares en los puntos donde se ubican las puertas las cuales van fijadas a dichos pilares. Ver plano PM48 detalle 1. Material acero acero S-275 JR, Acabado: galvanizado con pintura de poliuretano, acabado color marrón RAL 8022. Fijación a soporte: Mecánica.			
M6.3_1	2,100	m	Perfil hueco rect 80.60.3 (Pesa 6,07Kg/m)	5,03	10,56	
M6.3_2	45,000	kg	Acero S275JR en pletina	1,30	58,50	
M6.3_3	160,000	u	Rep soldadura TIG kg/est L=25mm	0,08	12,80	
M6.3_4	2,000	u	Rep soldadura TIG kg/est L=100mm	0,32	0,64	
M6.3_5	0,062	t	Repercusión galvanizado por t est metálica	432,24	26,80	
MO6.5_3	3,000	h	Oficial 1ª metal	12,19	36,57	
MO6.3_2	3,000	h	Especialista metal	10,37	31,11	
%	0,500		Costes directos complementarios	177,00	0,89	
6.3.1	62,000	Kg	Rep Esmalte poliuret bic s/Kg vallado	0,62	38,44	
			Suma la partida..			216,31
			Costes indirectos...........................		5,00%	10,82
			TOTAL PARTIDA..			**227,13**

Asciende el precio total de la partida a la mencionada cantidad de DOSCIENTOS VEINTISIETE EUROS con TRECE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
6.4		**u**	**Puertas 90x205cm**			
			Puerta de paso de una hoja abatible de 90x205cm, formada por dos planchas de acero galvanizado ensambladas entre si y relleno de espuma de poliuretano, marco de plancha de acero galvanizado de 1.2mm de espesor, bisagras y cerradura embutida con manivela, incluso aplomado, colocación y eliminación de restos.			
MO6.5_1	0,600	h	Oficial 1ª construcción	18,12	10,87	
MO6.5_2	0,600	h	Peón ordinario construcción	17,31	10,39	
M6.4_1	1,000	u	Puerta 1hj a galv 90x205cm	91,16	91,16	
%	0,500		Costes directos complementarios	112,40	0,56	
			Suma la partida..			112,98
			Costes indirectos...........................		5,00%	5,65
			TOTAL PARTIDA..			**118,63**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO DIECIOCHO EUROS con SESENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
6.5		**m²**	**Ventanas aluminio**			
			Suministro y colocación de carpinterías de aluminio de dimensiones y diseño según planos de proyecto, abatibles, oscilobatientes, correderas, fijas, etc., realizada con perfiles con rotura de puente térmico de aluminio lacado de 60 micras con sello de calidad Qualicoat con canal europeo, junta de estanquidad interior, sellante en esquinas del cerco y accesorios que garanticen su correcto funcionamiento, acabada lacado color imitación acero corten para recibir acristalamiento de hasta 38mm, recibido sobre premarcos de aluminio atornillados a elementos de fachada y/o cerramientos, sellado de juntas por medio de silicona aplicada con pistola, incluso replanteo, colocación, aplomado y nivelado, montaje y regulación, listo para recibir acristalamiento, eliminación de restos y limpieza final, según NTE-FCL.			
MO6.5_1	0,350	h	Oficial 1ª construcción	18,12	6,34	
MO6.5_2	0,650	h	Peón ordinario construcción	17,31	11,25	
MO6.5_3	0,650	h	Oficial 1ª metal	12,19	7,92	
M6.5_1	1,050	m2	Carpintería aluminio rpt lacada	185,95	195,25	
M6.5_2	0,150	u	Cartucho masilla caucho silicona	3,74	0,56	
%	0,500		Costes directos complementarios	221,30	1,11	
			Suma la partida..			222,43
			Costes indirectos...........................		5,00%	11,12
			TOTAL PARTIDA..			**233,55**

Asciende el precio total de la partida a la mencionada cantidad de DOSCIENTOS TREINTA Y TRES EUROS con CINCUENTA Y CINCO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 7 RED ELÉCTRICA DE BAJA TENSIÓN						
7.1		**m**	**Cable con aislamiento 1.5 mm2**			
			Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 1,5 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V).			
MO7.1_1	0,015	h	Oficial 1º electricista	19,42	0,29	
MO7.1_2	0,015	h	Ayudante electricista	17,86	0,27	
M7.1_1	1,000	m	Cable unipolar VV-K 1.5 mm2	0,46	0,46	
%7.1	2,000		Costes directos complementarios	1,00	0,02	
			Suma la partida..			1,04
			Costes indirectos...........................		5,00%	0,05
			TOTAL PARTIDA..			**1,09**

Asciende el precio total de la partida a la mencionada cantidad de UN EUROS con NUEVE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.2		**m**	**Tubo PVC D=12 mm**			
			Suministro e instalación fija en superficie de canalización de tubo rígido de PVC, enchufable, curvable en caliente, de color negro, de 12 mm de diámetro nominal, resistencia a la compresión 1250 N, con grado de protección IP547.			
MO7.6_1	0,035	h	Oficial 1º electricista	19,42	0,68	
MO7.6_2	0,050	h	Ayudante electricista	17,86	0,89	
M7.4_1	1,000	m	Tubo rígido de PVC	0,85	0,85	
%7.2	2,000		Costes directos complementarios	2,40	0,05	
			Suma la partida..			2,47
			Costes indirectos...........................		5,00%	0,12
			TOTAL PARTIDA..			**2,59**

Asciende el precio total de la partida a la mencionada cantidad de DOS EUROS con CINCUENTA Y NUEVE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.3		**m**	**Cable con aislamiento 2.5 mm2**			
			Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 2,5 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V)			
MO7.7_1	0,015	h	Oficial 1º electricista	19,42	0,29	
MO7.7_2	0,015	h	Ayudante electricista	17,86	0,27	
M7.7_1	1,000	m	Cable unipolar VV-K 6 mm2	1,14	1,14	
%7.3	2,000		Costes directos complementarios	1,70	0,03	
			Suma la partida..			1,73
			Costes indirectos...........................		5,00%	0,09
			TOTAL PARTIDA..			**1,82**

Asciende el precio total de la partida a la mencionada cantidad de UN EUROS con OCHENTA Y DOS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.4		**m**	**Tubo PVC D=16 mm**			
			Suministro e instalación fija en superficie de canalización de tubo rígido de PVC, enchufable, curvable en caliente, de color negro, de 16 mm de diámetro nominal, resistencia a la compresión 1250 N, con grado de protección IP547.			
MO7.6_1	0,035	h	Oficial 1º electricista	19,42	0,68	
MO7.6_2	0,050	h	Ayudante electricista	17,86	0,89	
M7.4_1	1,000	m	Tubo rígido de PVC	0,85	0,85	
%7.2	2,000		Costes directos complementarios	2,40	0,05	
			Suma la partida..			2,47
			Costes indirectos...........................		5,00%	0,12
			TOTAL PARTIDA..			**2,59**

Asciende el precio total de la partida a la mencionada cantidad de DOS EUROS con CINCUENTA Y NUEVE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.5		**m**	**Cable con aislamiento 10 mm2**			
			Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 10 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V)			
MO7.7_1	0,040	h	Oficial 1º electricista	19,42	0,78	
MO7.7_2	0,040	h	Ayudante electricista	17,86	0,71	
M7.7_1	1,000	m	Cable unipolar VV-K 6 mm2	1,14	1,14	
%7.5	2,000		Costes directos complementarios	2,60	0,05	
			Suma la partida..			2,68
			Costes indirectos...........................		5,00%	0,13
			TOTAL PARTIDA..			**2,81**

Asciende el precio total de la partida a la mencionada cantidad de DOS EUROS con OCHENTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.6		**m**	**Tubo PVC D=32 mm**			
			Suministro e instalación empotrada en elemento de construcción de obra de fábrica de canalización de tubo curvable de PVC, transversalmente elástico, corrugado, forrado, de color negro, de 32 mm de diámetro nominal, resistencia a la compresión 320 N, con grado de protección IP547.			
MO7.6_1	0,016	h	Oficial 1º electricista	19,42	0,31	
MO7.6_2	0,020	h	Ayudante electricista	17,86	0,36	
M7.6_1	1,000	m	Tubo curvable PVC	0,95	0,95	
%7.6	2,000		Costes directos complementarios	1,60	0,03	
			Suma la partida..			1,65
			Costes indirectos...........................		5,00%	0,08
			TOTAL PARTIDA..			**1,73**

Asciende el precio total de la partida a la mencionada cantidad de UN EUROS con SETENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.7		**m**	**Cable con aislamiento 6 mm2**			
			Cable unipolar VV-K, siendo su tensión asignada de 0,6/1 kV, reacción al fuego clase Eca, con conductor de cobre clase 5 (-K) de 6 mm² de sección, con aislamiento de PVC (V) y cubierta de PVC (V).			
MO7.7_1	0,040	h	Oficial 1º electricista	19,42	0,78	
MO7.7_2	0,040	h	Ayudante electricista	17,86	0,71	
M7.7_1	1,000	m	Cable unipolar VV-K 6 mm2	1,14	1,14	
%7.7	2,000		Costes directos complementarios	2,60	0,05	
			Suma la partida..			2,68
			Costes indirectos...........................		5,00%	0,13
			TOTAL PARTIDA..			**2,81**

Asciende el precio total de la partida a la mencionada cantidad de DOS EUROS con OCHENTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.8		**m**	**Tubo PVC D=25 mm**			
			Suministro e instalación empotrada en elemento de construcción de obra de fábrica de canalización de tubo curvable de PVC, transversalmente elástico, corrugado, forrado, de color negro, de 25 mm de diámetro nominal, resistencia a la compresión 320 N, con grado de protección IP547.			
MO7.8_1	0,016	h	Oficial 1º electricista	19,42	0,31	
MO7.8_2	0,020	h	Ayudante electricista	17,86	0,36	
M7.8_1	1,000	m	Tubo curbavle de PVC	0,61	0,61	
%7.8	2,000		Costes directos complementarios	1,30	0,03	
			Suma la partida..			1,31
			Costes indirectos...........................		5,00%	0,07
			TOTAL PARTIDA..			**1,38**

Asciende el precio total de la partida a la mencionada cantidad de UN EUROS con TREINTA Y OCHO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.9		**u**	**Interruptor magnetotermico 8 A**			
			Multi 9 - C60BP - MCB - 1P - 8 A - C Curve - 277 V - 10 kA			
MO7.17_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.9_1	1,000	u	Interruptor magnetotermico 8 A	105,00	105,00	
%	0,500		Costes directos complementarios	109,90	0,55	
			Suma la partida..			110,41
			Costes indirectos...........................		5,00%	5,52
			TOTAL PARTIDA..			**115,93**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO QUINCE EUROS con NOVENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.10		u	**Contactor 9 A**			
			TeSys K contactor - 3P - AC-3 <= 440 V 9 A			
MO7.19_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.10_1	1,000	u	Contactor 9 A	85,00	85,00	
%	0,500		Costes directos complementarios	89,90	0,45	
			Suma la partida..			90,31
			Costes indirectos...........................		5,00%	4,52
			TOTAL PARTIDA..			**94,83**

Asciende el precio total de la partida a la mencionada cantidad de NOVENTA Y CUATRO EUROS con OCHENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.11		u	**Interruptor diferencial 25 A, 30 mA**			
			Interruptor diferencial instantáneo, de 2 módulos, bipolar (2P), intensidad nominal 25 A, sensibilidad 30 mA, poder de corte 6 kA, clase AC.			
MO7.16_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.11_1	1,000	u	Interruptor diferencial 25 A, 30 mA	56,99	56,99	
%7.11	2,000		Costes directos complementarios	61,90	1,24	
			Suma la partida..			63,09
			Costes indirectos...........................		5,00%	3,15
			TOTAL PARTIDA..			**66,24**

Asciende el precio total de la partida a la mencionada cantidad de SESENTA Y SEIS EUROS con VEINTICUATRO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.12		u	**Interruptor magnetotermico 13 A**			
			Multi 9 - C60SP - MCB - 1P - 13 A - C Curve - 277 V - 10 kA			
MO7.17_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.12_1	1,000	u	Interruptor magnetotermico 13 A	94,00	94,00	
%	0,500		Costes directos complementarios	98,90	0,49	
			Suma la partida..			99,35
			Costes indirectos...........................		5,00%	4,97
			TOTAL PARTIDA..			**104,32**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO CUATRO EUROS con TREINTA Y DOS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.13		u	**Contactor 16 A**			
			TeSys K contactor - 3P - AC-3 <= 440 V 16 A			
MO7.19_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.13_1	1,000	u	Contactor 16 A	159,00	159,00	
%	0,500		Costes directos complementarios	163,90	0,82	
			Suma la partida..			164,68
			Costes indirectos...........................		5,00%	8,23
			TOTAL PARTIDA..			**172,91**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO SETENTA Y DOS EUROS con NOVENTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.14		u	**Interruptor magnetotermico 35 A**			
			Multi 9 - C60BP - MCB - 3P - 35 A - C Curve - 480Y/277 V - 10 kA			
MO7.17_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.14_1	1,000	u	Interruptor magnetotermico 35 A	343,00	343,00	
%	0,500		Costes directos complementarios	347,90	1,74	
			Suma la partida..			349,60
			Costes indirectos...........................		5,00%	17,48
			TOTAL PARTIDA..			**367,08**

Asciende el precio total de la partida a la mencionada cantidad de TRESCIENTOS SESENTA Y SIETE EUROS con OCHO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.15		u	**Contactor 38 A**			
			Contactor TeSys D - 3P(3 NO) - AC-3 - <= 440 V 38 A			
MO7.19_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.15_1	1,000	u	Contactor 38 A	178,00	178,00	
%	0,500		Costes directos complementarios	182,90	0,91	
			Suma la partida..			183,77
			Costes indirectos...........................		5,00%	9,19
			TOTAL PARTIDA..			**192,96**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO NOVENTA Y DOS EUROS con NOVENTA Y SEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.16		**u**	**Interruptor diferencial 40 A, 30 mA**			
			Multi 9 ID - residual current circuit breaker - 2P - 40A - 30mA - type AC			
MO7.16_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.16_1	1,000	u	Interruptor diferencial 40 A, 30 mA	213,00	213,00	
%	0,500		Costes directos complementarios	217,90	1,09	
			Suma la partida..			218,95
			Costes indirectos...........................		5,00%	10,95
			TOTAL PARTIDA..			**229,90**

Asciende el precio total de la partida a la mencionada cantidad de DOSCIENTOS VEINTINUEVE EUROS con NOVENTA CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.17		**u**	**Interruptor magnetotermico 25 A**			
			Multi 9 - C60BP - MCB - 3P - 25 A - C Curve - 480Y/277 V - 10 kA			
MO7.17_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.17_1	1,000	u	Interruptor magnetotermico 25 A	328,00	328,00	
%	0,500		Costes directos complementarios	332,90	1,66	
			Suma la partida..			334,52
			Costes indirectos...........................		5,00%	16,73
			TOTAL PARTIDA..			**351,25**

Asciende el precio total de la partida a la mencionada cantidad de TRESCIENTOS CINCUENTA Y UN EUROS con VEINTICINCO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.18		**u**	**Contactor 25 A**			
			TeSys D contactor - 3P(3 NO) - AC-3 - <= 440 V 25 A			
MO7.19_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.18_1	1,000	u	Contactor 25 A	139,00	139,00	
%	0,500		Costes directos complementarios	143,90	0,72	
			Suma la partida..			144,58
			Costes indirectos...........................		5,00%	7,23
			TOTAL PARTIDA..			**151,81**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO CINCUENTA Y UN EUROS con OCHENTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.19		**u**	**Interruptor automático 125 A**			
			PowerPact - automatic switch - 600V 125A 3P			
MO7.19_1	0,250	h	Oficial 1º electricista	19,42	4,86	
M7.19_1	1,000	u	Interruptor automatico	719,00	719,00	
%	0,500		Costes directos complementarios	723,90	3,62	
			Suma la partida..			727,48
			Costes indirectos...........................		5,00%	36,37
			TOTAL PARTIDA..			**763,85**

Asciende el precio total de la partida a la mencionada cantidad de SETECIENTOS SESENTA Y TRES EUROS con OCHENTA Y CINCO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
7.20		**u**	**Sistema de alimentación ininterrupida (SAI)**			
			Sistema de alimentación ininterrumpida Off-Line, de 0,8 kVA de potencia, para alimentación monofásica.			
MO7.20_1	1,000	h	Oficial 1º electricista	19,42	19,42	
MO7.20_2	1,000	h	Ayudante electricista	17,86	17,86	
M7.20_1	1,000	u	Sistema de alimentación ininterrupida	353,08	353,08	
%7.20	2,000		Costes directos complementarios	390,40	7,81	
			Suma la partida..			398,17
			Costes indirectos...........................		5,00%	19,91
			TOTAL PARTIDA..			**418,08**

Asciende el precio total de la partida a la mencionada cantidad de CUATROCIENTOS DIECIOCHO EUROS con OCHO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 8 RED DE HIDRÓGENO						
8.1		**m**	**Tubería H2 gas Dext=21.3 mm**			
MO8.2_1	0,380	h	Oficial 1º instalador de gas	19,42	7,38	
MO8.2_2	0,380	h	Ayudante instalador de gas	17,86	6,79	
M8.2_1	1,000	u	Material auxiliar para montaje y sujección a la obra	0,23	0,23	
M8.3_2	1,000	m	Tubo de acero inoxidable de 4.2 mm	2,07	2,07	
%8	2,000		Costes directos complementarios	16,50	0,33	
			Suma la partida........			16,80
			Costes indirectos........		5,00%	0,84
			TOTAL PARTIDA........			**17,64**

Asciende el precio total de la partida a la mencionada cantidad de DIECISIETE EUROS con SESENTA Y CUATRO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
8.2		**m**	**Tubería H2 gas Dext=26.9 mm**			
MO8.2_1	0,390	h	Oficial 1º instalador de gas	19,42	7,57	
MO8.2_2	0,390	h	Ayudante instalador de gas	17,86	6,97	
M8.2_1	1,000	u	Material auxiliar para montaje y sujección a la obra	0,23	0,23	
M8.2_2	1,000	m	Tubo de acero inoxidable de 26.9 mm	5,20	5,20	
%8	2,000		Costes directos complementarios	20,00	0,40	
			Suma la partida........			20,37
			Costes indirectos........		5,00%	1,02
			TOTAL PARTIDA........			**21,39**

Asciende el precio total de la partida a la mencionada cantidad de VEINTIUN EUROS con TREINTA Y NUEVE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
8.3		**m**	**Tubería H2 gas Dext=4.2 mm**			
MO8.1_1	0,150	h	Oficial 1º instalador de gas	19,42	2,91	
MO8.1_2	0,150	h	Ayudante instalador de gas	17,86	2,68	
M8.1_1	1,000	u	Material auxiliar para montaje y sujección a la obra	0,23	0,23	
M8.3_2	1,000	m	Tubo de acero inoxidable de 4.2 mm	2,07	2,07	
%8	2,000		Costes directos complementarios	7,90	0,16	
			Suma la partida........			8,05
			Costes indirectos........		5,00%	0,40
			TOTAL PARTIDA........			**8,45**

Asciende el precio total de la partida a la mencionada cantidad de OCHO EUROS con CUARENTA Y CINCO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
8.4		**m**	**Tubería H2 gas Dext=6 mm**			
MO8.1_1	0,150	h	Oficial 1º instalador de gas	19,42	2,91	
MO8.1_2	0,150	h	Ayudante instalador de gas	17,86	2,68	
M8.1_1	1,000	u	Material auxiliar para montaje y sujección a la obra	0,23	0,23	
M8.4_2	1,000	m	Tubo de acero inoxidable de 6 mm	3,10	3,10	
%8	2,000		Costes directos complementarios	8,90	0,18	
			Suma la partida........			9,10
			Costes indirectos........		5,00%	0,46
			TOTAL PARTIDA........			**9,56**

Asciende el precio total de la partida a la mencionada cantidad de NUEVE EUROS con CINCUENTA Y SEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
8.5		**m**	**Tubería H2 gas Dext=33.7 mm**			
MO8.1_1	0,390	h	Oficial 1º instalador de gas	19,42	7,57	
MO8.1_2	0,390	h	Ayudante instalador de gas	17,86	6,97	
M8.1_1	1,000	u	Material auxiliar para montaje y sujección a la obra	0,23	0,23	
M8.5_2	1,000	m	Tubo de acero inoxidable de 33.7 mm	6,40	6,40	
%8	2,000		Costes directos complementarios	21,20	0,42	
			Suma la partida........			21,59
			Costes indirectos........		5,00%	1,08
			TOTAL PARTIDA........			**22,67**

Asciende el precio total de la partida a la mencionada cantidad de VEINTIDOS EUROS con SESENTA Y SIETE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 9 PROTECCIÓN CONTRA INCENDIOS						
9.1		**u**	**Pulsador alarma convencional**			
			Pulsador de alarma convencional de rearme manual, de ABS color rojo, protección IP41, con led indicador de alarma color rojo y llave de rearme. Incluso elementos de fijación.			
MO9.1_1	0,500	h	Oficial 1º instalador de redes y equipos de deteción	19,42	9,71	
MO9.1_2	0,500	h	Ayudante instalador de redes y equipos de deteción	17,86	8,93	
M9.1_1	1,000	u	Pulsador de alarma convencional de rearme manual	11,64	11,64	
%9.1	2,000		Costes directos complementarios	30,30	0,61	
			Suma la partida			30,89
			Costes indirectos		5,00%	1,54
			TOTAL PARTIDA			**32,43**

Asciende el precio total de la partida a la mencionada cantidad de TREINTA Y DOS EUROS con CUARENTA Y TRES CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
9.2		**u**	**Alumbrado de emergencia en zonas comunes**			
			Suministro e instalación en superficie en zonas comunes de luminaria de emergencia, con tubo lineal fluorescente, 6 W - G5, flujo luminoso 155 lúmenes, carcasa de 245x110x58 mm, clase II, IP42, con baterías de Ni-Cd de alta temperatura, autonomía de 1 h, alimentación a 230 V, tiempo de carga 24 h. Incluso accesorios y elementos de fijación.			
MO9.2_1	0,200	h	Oficial 1º electricista	19,42	3,88	
MO9.2_2	0,200	h	Ayudante electricista	17,86	3,57	
M9.2_1	1,000	u	Luminaria de emergencia	41,73	41,73	
%9.2	2,000		Costes directos complementarios	49,20	0,98	
			Suma la partida			50,16
			Costes indirectos		5,00%	2,51
			TOTAL PARTIDA			**52,67**

Asciende el precio total de la partida a la mencionada cantidad de CINCUENTA Y DOS EUROS con SESENTA Y SIETE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
9.3		**u**	**Extintor**			
			Extintor portátil de polvo químico ABC polivalente antibrasa, con presión incorporada, de eficacia 21A-144B-C, con 6 kg de agente extintor, con manómetro y manguera con boquilla difusora. Incluso soporte y accesorios de montaje.			
MO9.3_1	0,100	h	Peón ordinario construcción	17,67	1,77	
M9.3_1	1,000	u	Extintor portátil de polvo químico ABC	41,83	41,83	
%9.3	2,000		Costes directos complementarios	43,60	0,87	
			Suma la partida			44,47
			Costes indirectos		5,00%	2,22
			TOTAL PARTIDA			**46,69**

Asciende el precio total de la partida a la mencionada cantidad de CUARENTA Y SEIS EUROS con SESENTA Y NUEVE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
9.4		**u**	**Boca de incendio equipada**			
			Suministro e instalación en superficie de Boca de incendio equipada (BIE), de 25 mm (1") y de 680x480x215 mm, compuesta de: armario construido en acero de 1,2 mm de espesor, acabado con pintura epoxi color rojo RAL 3000 y puerta semiciega con ventana de metacrilato de acero de 1,2 mm de espesor, acabado con pintura epoxi color rojo RAL 3000; devanadera metálica giratoria fija, pintada en rojo epoxi, con alimentación axial; manguera semirrígida de 20 m de longitud; lanza de tres efectos (cierre, pulverización y chorro compacto) construida en plástico ABS y válvula de cierre tipo esfera de 25 mm (1"), de latón, con manómetro 0-16 bar. Incluso accesorios y elementos de fijación.			
MO9.4_1	1,100	h	Oficial 1º fontanero	19,42	21,36	
MO9.4_2	1,100	h	Ayudante fontanero	17,86	19,65	
M9.4_1	1,000	u	Boca de incendio equipada 25 mm	361,34	361,34	
%9.4	2,000			402,40	8,05	
			Suma la partida			410,40
			Costes indirectos		5,00%	20,52
			TOTAL PARTIDA			**430,92**

Asciende el precio total de la partida a la mencionada cantidad de CUATROCIENTOS TREINTA EUROS con NOVENTA Y DOS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
CAPÍTULO 10 COMPONENTES INSTALACIÓN						
10.1		u	**Electrolizador PEM EL5N**			
MO10.15_1	2,000	h	Oficial 1ª instalador	19,42	38,84	
MO10.15_2	0,800	h	Ayudante instalador	17,86	14,29	
M10.1_1	1,000	u	Electrolizador PEM EL5N	273.118,57	273.118,57	
%	0,500		Costes directos complementarios	273.171,70	1.365,86	
			Suma la partida			274.537,56
			Costes indirectos		5,00%	13.726,88
			TOTAL PARTIDA			**288.264,44**

Asciende el precio total de la partida a la mencionada cantidad de DOSCIENTOS OCHENTA Y OCHO MIL DOSCIENTOS SESENTA Y CUATRO EUROS con CUARENTA Y CUATRO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.2		u	**Almacenamiento hidrógeno gas 10" MEGC 300 bar**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.2_1	1,000	u	Almacenamiento hidrógeno gas 10 " MEGC 300 bar	147.000,00	147.000,00	
%	0,500		Costes directos complementarios	147.028,40	735,14	
			Suma la partida			147.763,49
			Costes indirectos		5,00%	7.388,17
			TOTAL PARTIDA			**155.151,66**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO CINCUENTA Y CINCO MIL CIENTO CINCUENTA Y UN EUROS con SESENTA Y SEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.3		u	**Almacenamiento hidrógeno gas KPJ-017-BG**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.3_1	1,000	u	Almacenamiento hidrógeno gas KPJ-017-BG	103.000,00	103.000,00	
%	0,500		Costes directos complementarios	103.028,40	515,14	
			Suma la partida			103.543,49
			Costes indirectos		5,00%	5.177,17
			TOTAL PARTIDA			**108.720,66**

Asciende el precio total de la partida a la mencionada cantidad de CIENTO OCHO MIL SETECIENTOS VEINTE EUROS con SESENTA Y SEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.4		u	**Almacenamiento hidrógeno gas Tank-500 bar (200 l)**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.4_1	1,000	u	Almacenamiento hidrógeno gas Tank-500 bar (200 l)	6.500,00	6.500,00	
%	0,500		Costes directos complementarios	6.528,40	32,64	
			Suma la partida			6.560,99
			Costes indirectos		5,00%	328,05
			TOTAL PARTIDA			**6.889,04**

Asciende el precio total de la partida a la mencionada cantidad de SEIS MIL OCHOCIENTOS OCHENTA Y NUEVE EUROS con CUATRO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.5		u	**Booster AGD 32**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.5_1	1,000	u	Booster AGD 32	25.000,00	25.000,00	
%	0,500		Costes directos complementarios	25.028,40	125,14	
			Suma la partida			25.153,49
			Costes indirectos		5,00%	1.257,67
			TOTAL PARTIDA			**26.411,16**

Asciende el precio total de la partida a la mencionada cantidad de VEINTISEIS MIL CUATROCIENTOS ONCE EUROS con DIECISEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.6		**u**	**Booster AGD 152**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.6_1	1,000	u	Booster AGD 152	25.000,00	25.000,00	
%	0,500		Costes directos complementarios	25.028,40	125,14	
			Suma la partida			25.153,49
			Costes indirectos		5,00%	1.257,67
			TOTAL PARTIDA			**26.411,16**

Asciende el precio total de la partida a la mencionada cantidad de VEINTISEIS MIL CUATROCIENTOS ONCE EUROS con DIECISEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.7		**u**	**Standard Hydrogen Refuelling Station**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.7_1	1,000	u	Standard Hydrogen Refuelling Station	89.000,00	89.000,00	
%	0,500		Costes directos complementarios	89.028,40	445,14	
			Suma la partida			89.473,49
			Costes indirectos		5,00%	4.473,67
			TOTAL PARTIDA			**93.947,16**

Asciende el precio total de la partida a la mencionada cantidad de NOVENTA Y TRES MIL NOVECIENTOS CUARENTA Y SIETE EUROS con DIECISEIS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.8		**u**	**Compresor de tornillo 30 CV kaeser ASK 40 SFC con variador de f**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.8_1	1,000	u	Compresor de tornillo 30 CV kaeser ASK 40 SFC con variador de f	12.514,00	12.514,00	
%	0,500		Costes directos complementarios	12.542,40	62,71	
			Suma la partida			12.605,06
			Costes indirectos		5,00%	630,25
			TOTAL PARTIDA			**13.235,31**

Asciende el precio total de la partida a la mencionada cantidad de TRECE MIL DOSCIENTOS TREINTA Y CINCO EUROS con TREINTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.9		**u**	**Secador frigorifico kaeser TD 51**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	1,000	h	Ayudante instalador	17,86	17,86	
M10.9_1	1,000	u	Secador frigorifico kaeser TD 51	4.526,93	4.526,93	
%	0,500		Costes directos complementarios	4.564,20	22,82	
			Suma la partida			4.587,03
			Costes indirectos		5,00%	229,35
			TOTAL PARTIDA			**4.816,38**

Asciende el precio total de la partida a la mencionada cantidad de CUATRO MIL OCHOCIENTOS DIECISEIS EUROS con TREINTA Y OCHO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.10		**u**	**Filtro centrifugo en línea kaeser F46KC con manómetro**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.10_1	1,000	u	Filtro centrifugo en línea kaeser F46KC con manómetro	528,78	528,78	
%	0,500		Costes directos complementarios	557,10	2,79	
			Suma la partida			559,92
			Costes indirectos		5,00%	28,00
			TOTAL PARTIDA			**587,92**

Asciende el precio total de la partida a la mencionada cantidad de QUINIENTOS OCHENTA Y SIETE EUROS con NOVENTA Y DOS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.11		**u**	**Depósito aire vertical kaeser 1000 litros 11 bar galvanizado**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.11_1	1,000	u	Depósito aire vertical kaeser 1000 litros 11 bar galvanizado	1.345,71	1.345,71	
%	0,500		Costes directos complementarios	1.374,10	6,87	
			Suma la partida..			1.380,93
			Costes indirectos..........................		5,00%	69,05
			TOTAL PARTIDA..			**1.449,98**

Asciende el precio total de la partida a la mencionada cantidad de MIL CUATROCIENTOS CUARENTA Y NUEVE EUROS con NOVENTA Y OCHO CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.12		**u**	**Purgador capacitativo de condensados kaeser ECO-DRAIN 31**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.12_1	1,000	u	Purgador capacitativo de condensados kaeser ECO-DRAIN 31	213,22	213,22	
%	0,500		Costes directos complementarios	241,60	1,21	
			Suma la partida..			242,78
			Costes indirectos..........................		5,00%	12,14
			TOTAL PARTIDA..			**254,92**

Asciende el precio total de la partida a la mencionada cantidad de DOSCIENTOS CINCUENTA Y CUATRO EUROS con NOVENTA Y DOS CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.13		**u**	**Griferia deposito**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.13_1	1,000	u	Griferia deposito	207,74	207,74	
%	0,500		Costes directos complementarios	236,10	1,18	
			Suma la partida..			237,27
			Costes indirectos..........................		5,00%	11,86
			TOTAL PARTIDA..			**249,13**

Asciende el precio total de la partida a la mencionada cantidad de DOSCIENTOS CUARENTA Y NUEVE EUROS con TRECE CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.14		**u**	**Separador de condensados kaeser CF 9**			
MO10.15_1	1,000	h	Oficial 1ª instalador	19,42	19,42	
MO10.15_2	0,500	h	Ayudante instalador	17,86	8,93	
M10.14	1,000	u	Separador de condensados kaeser CF 9	682,30	682,30	
%	0,500		Costes directos complementarios	710,70	3,55	
			Suma la partida..			714,20
			Costes indirectos..........................		5,00%	35,71
			TOTAL PARTIDA..			**749,91**

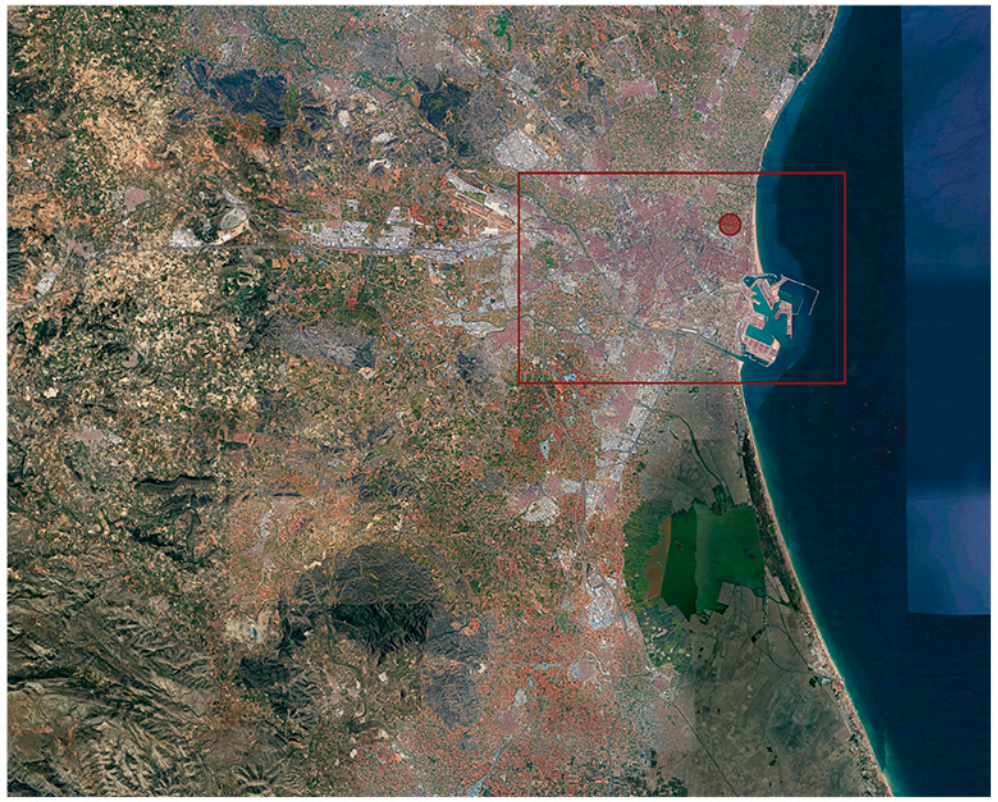
Asciende el precio total de la partida a la mencionada cantidad de SETECIENTOS CUARENTA Y NUEVE EUROS con NOVENTA Y UN CÉNTIMOS

CÓDIGO	CANTIDAD	UD	RESUMEN	PRECIO	SUBTOTAL	IMPORTE
10.15		**u**	**Regulador de presión electrico MS6-LRE**			
MO10.15_1	0,500	h	Oficial 1ª instalador	19,42	9,71	
MO10.15_2	0,200	h	Ayudante instalador	17,86	3,57	
M10.15_1	1,000	u	Regulador de presión electrico MS6-LRE	300,00	300,00	
%	0,500		Costes directos complementarios	313,30	1,57	
			Suma la partida..			314,85
			Costes indirectos..........................		5,00%	15,74
			TOTAL PARTIDA..			**330,59**

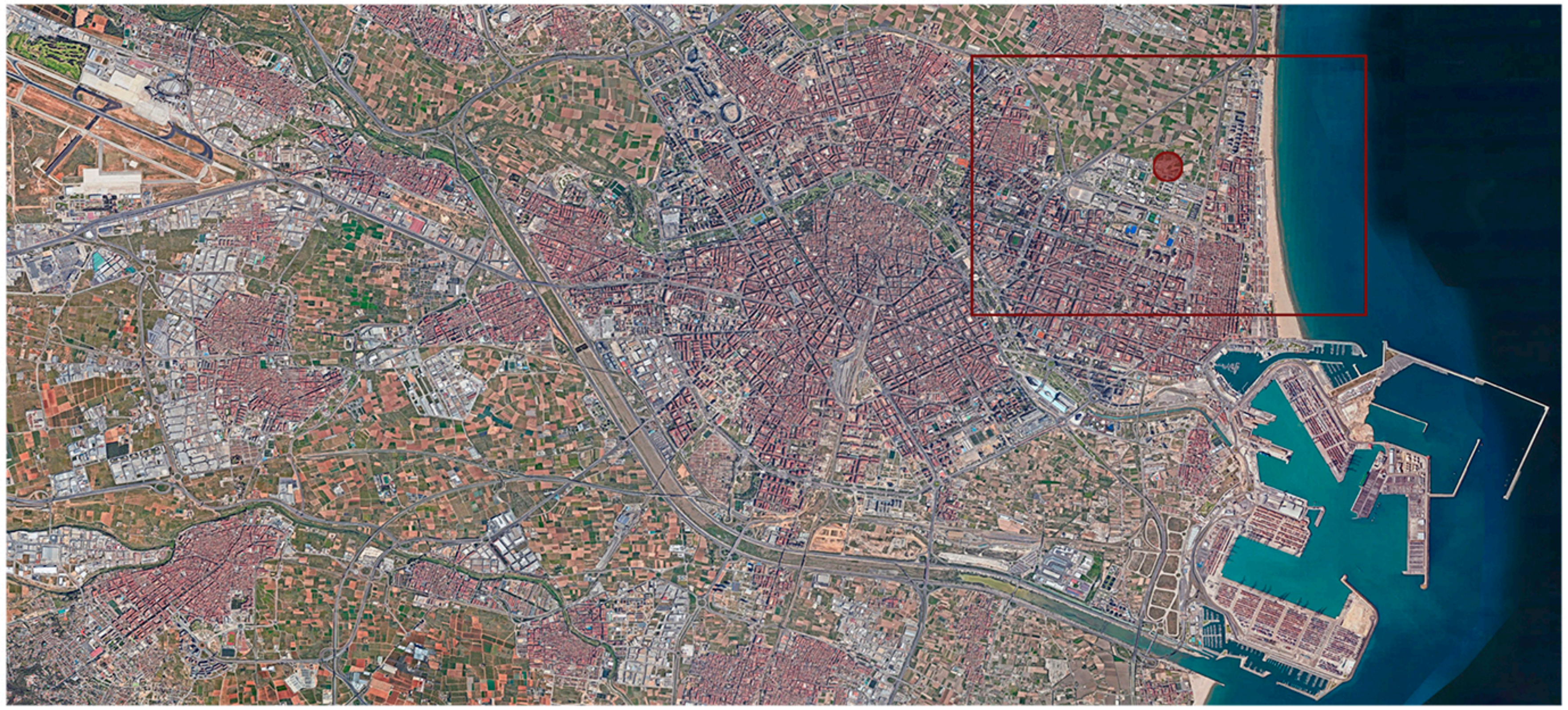
Asciende el precio total de la partida a la mencionada cantidad de TRESCIENTOS TREINTA EUROS con CINCUENTA Y NUEVE CÉNTIMOS

Part IV

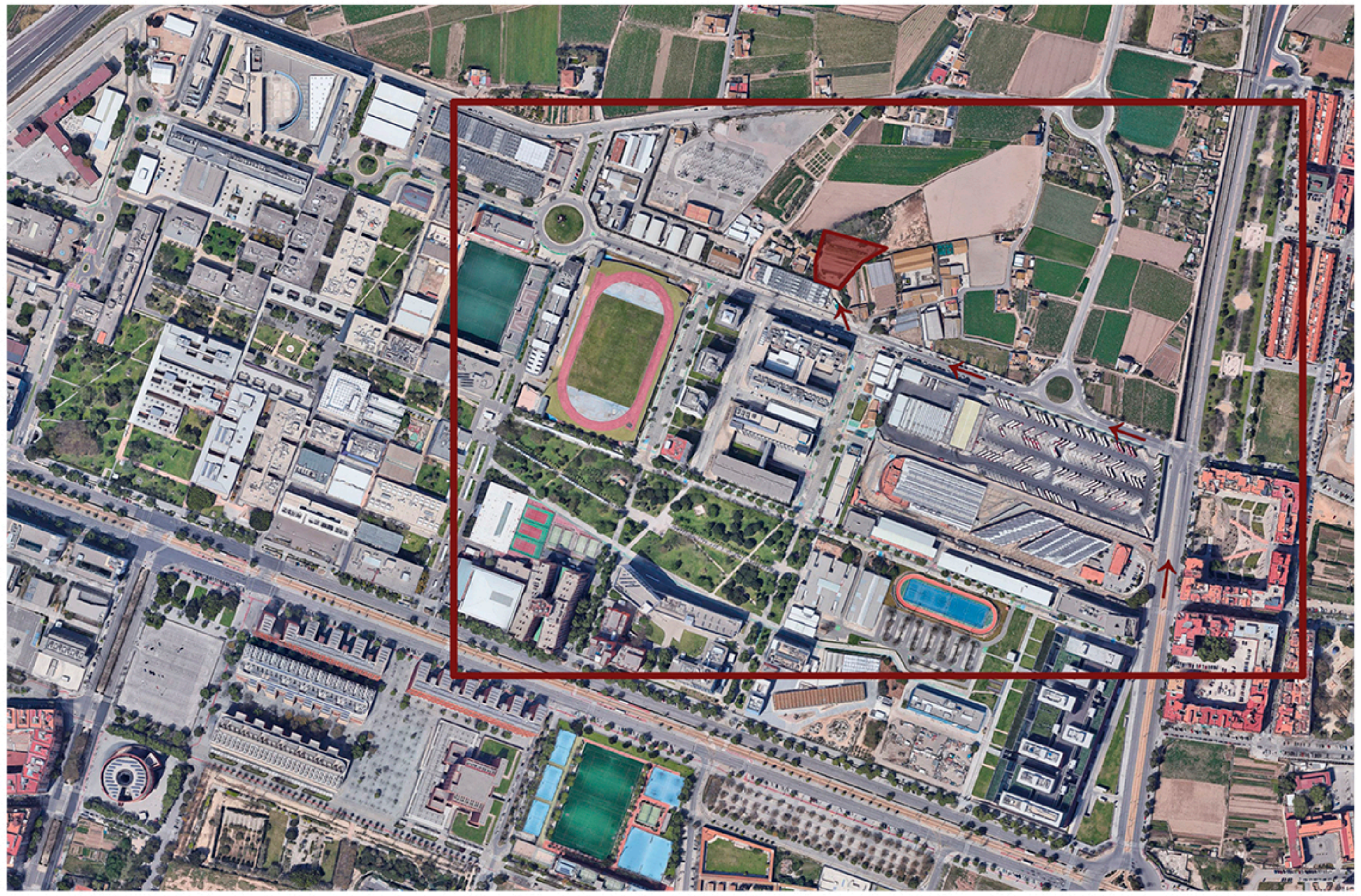
Technical drawings



1. Location: Valencia (Valencian Community)



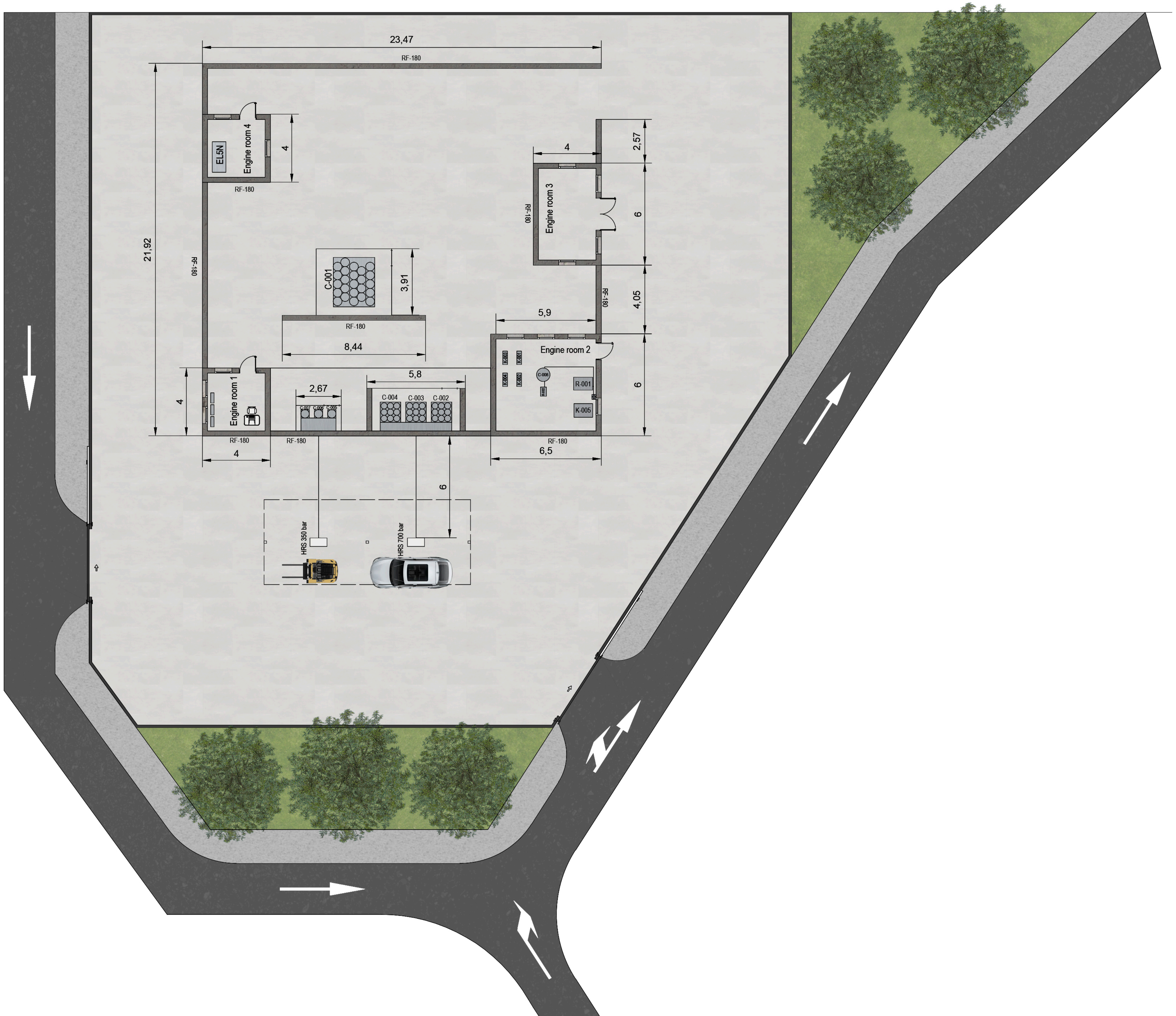
2. Site location: Camí de Vera, 36, 46022 València, Valencia



3. Environment: signposting of accesses and buildings close to the plot

4. Insertion: projection of the proposed HRS volume on the existing plot

TRABAJO FIN DE MÁSTER EN INGENIERÍA INDUSTRIAL UNIVERSITAT POLITÈCNICA DE VALÈNCIA ESCUELA TÉCNICA SUPERIOR INGENIEROS INDUSTRIALES VALENCIA	Proyecto: DESIGN OF A HYDROGEN REFUELLING STATION (HRS) AT THE UNIVERSITAT POLITÈCNICA DE VALÈNCIA: PRODUCTION BY MEANS OF PEM ELECTROLYSIS, STORAGE, COMPRESSION AND REFUELLING DISPENSER	Plano: Site plan Autor: Paloma Zúñiga Saiz	Fecha: May 2020 Escala: SE	Nº Plano: 1



TRABAJO FIN DE MÁSTER EN INGENIERÍA INDUSTRIAL

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCUELA TÉCNICA SUPERIOR INGENIEROS INDUSTRIALES VALENCIA

Proyecto: DESIGN OF A HYDROGEN REFUELLING STATION (HRS) AT THE UNIVERSITAT POLITÈCNICA DE VALÈNCIA: PRODUCTION BY MEANS OF PEM ELECTROLYSIS, STORAGE, COMPRESSION AND REFUELLING DISPENSER

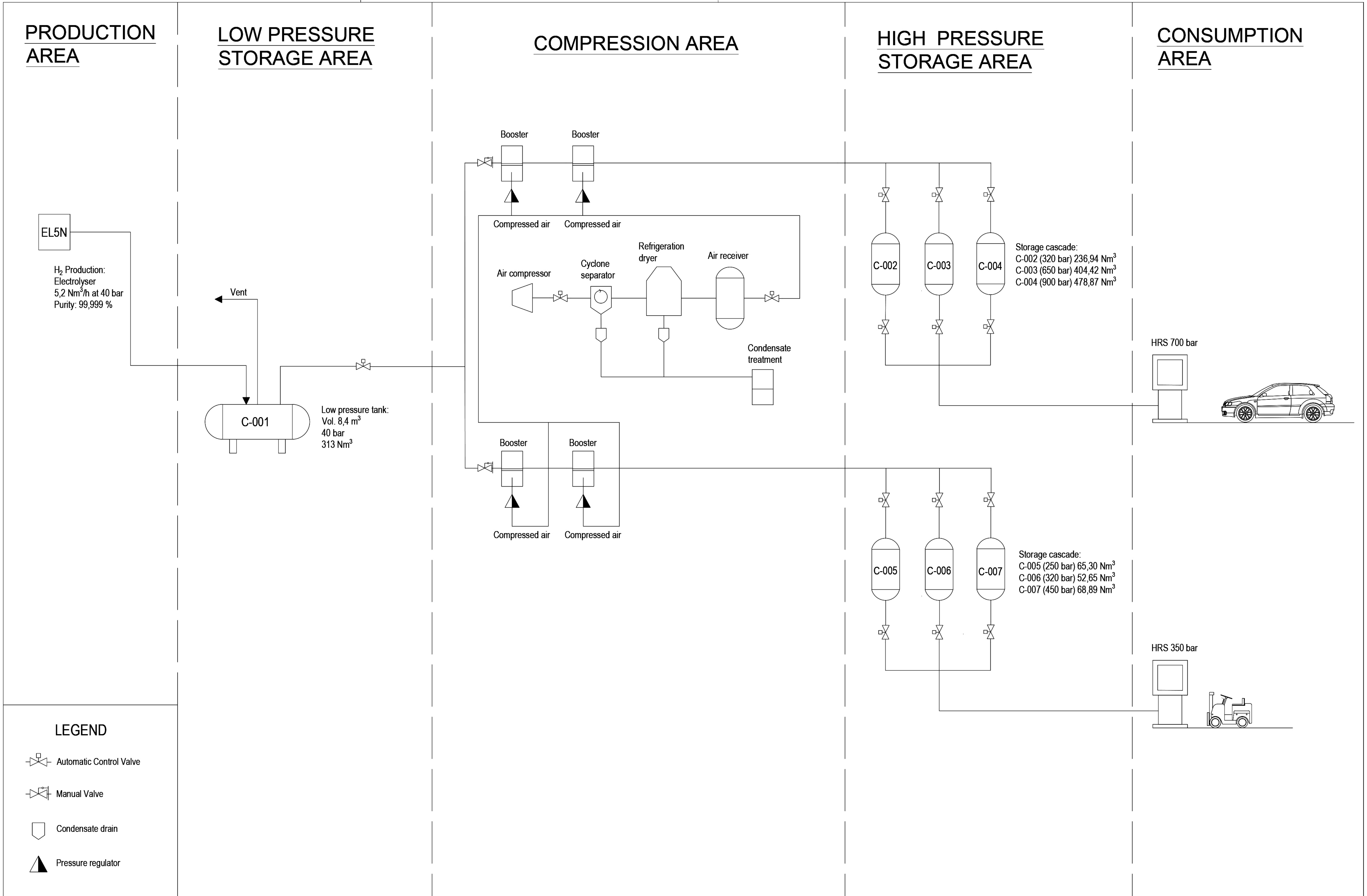
Plano: Floor plan

Autor: Paloma Zúñiga Saiz

Fecha: May 2020

Escala: 1:250

Nº Plano: 2



TRABAJO FIN DE MÁSTER EN INGENIERÍA INDUSTRIAL

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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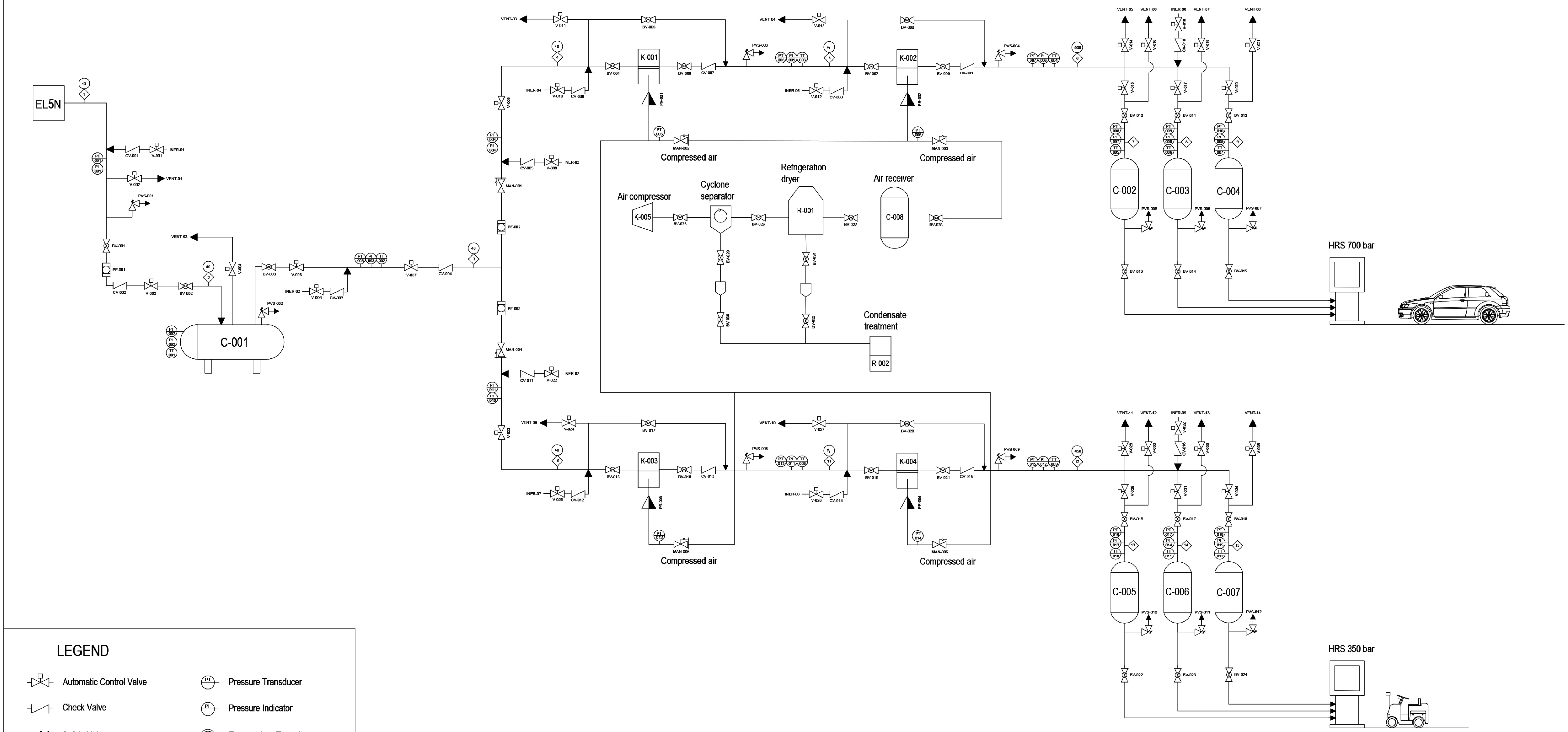
Plano: Flow diagram

Autor: Paloma Zúñiga Saiz

Fecha: May 2020

Escala: SE

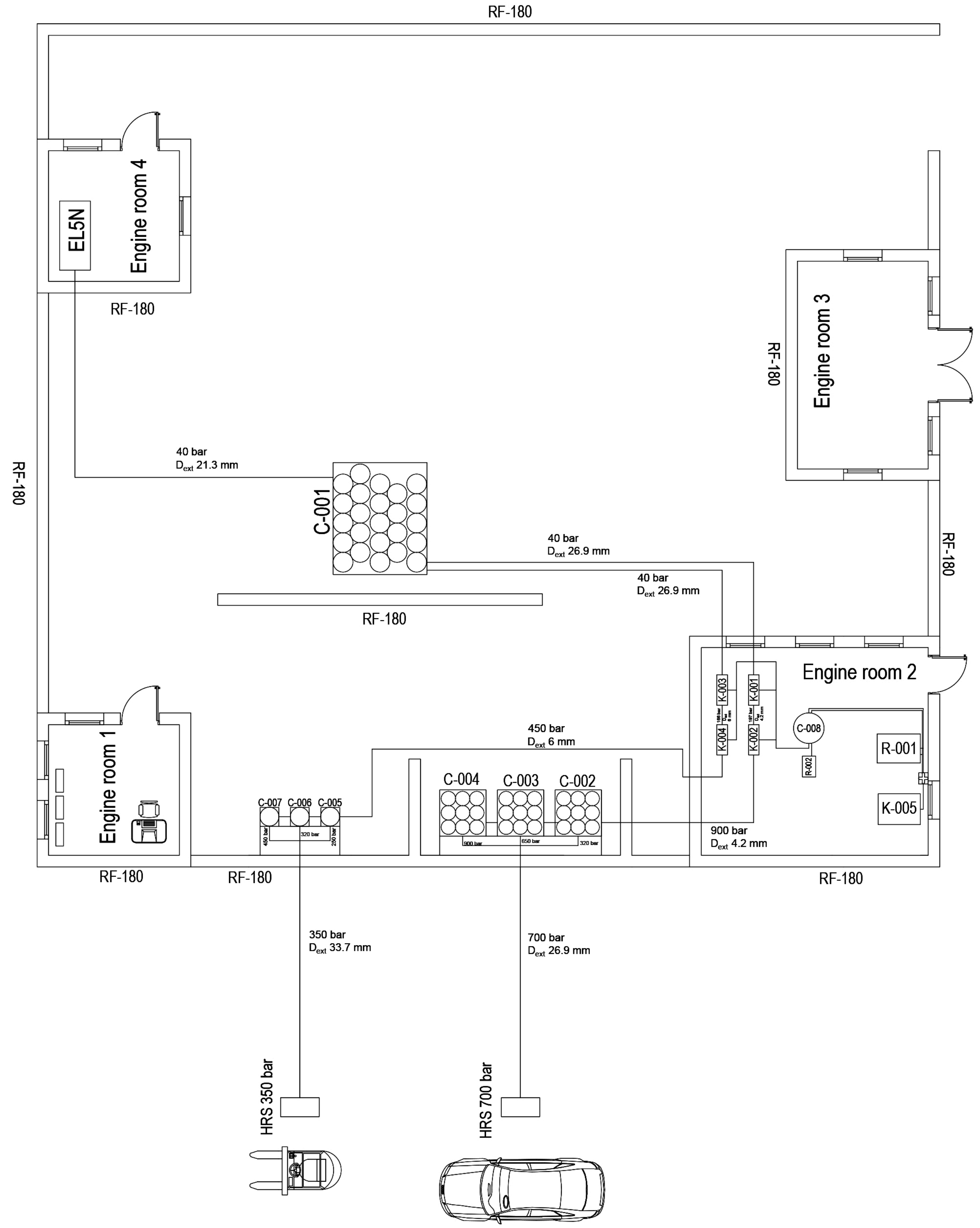
Nº Plano: 3



LEGEND

- Automatic Control Valve
- Check Valve
- Safety Valve
- Ball Valve
- Flow meter
- Manual Valve
- Pressure Transducer
- Pressure Indicator
- Temperature Transducer
- Condensate drain
- Pressure regulator

TRABAJO FIN DE MÁSTER EN INGENIERÍA INDUSTRIAL UNIVERSITAT POLITÈCNICA DE VALÈNCIA ESCUELA TÉCNICA SUPERIOR INGENIEROS INDUSTRIALES VALENCIA	Proyecto: DESIGN OF A HYDROGEN REFUELLING STATION (HRS) AT THE UNIVERSITAT POLITÈCNICA DE VALÈNCIA: PRODUCTION BY MEANS OF PEM ELECTROLYSIS, STORAGE, COMPRESSION AND REFUELLING DISPENSER	Plano: Process and instrumentation diagram (P&ID) Autor: Paloma Zúñiga Saiz	Fecha: May 2020 Escala: SE	Nº Plano: 4



TRABAJO FIN DE MÁSTER EN INGENIERÍA INDUSTRIAL

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCUELA TÉCNICA SUPERIOR INGENIEROS INDUSTRIALES VALENCIA

Proyecto:
DESIGN OF A HYDROGEN REFUELLING STATION (HRS) AT THE UNIVERSITAT POLITÈCNICA DE VALÈNCIA: PRODUCTION BY MEANS OF PEM ELECTROLYSIS, STORAGE, COMPRESSION AND REFUELLING DISPENSER

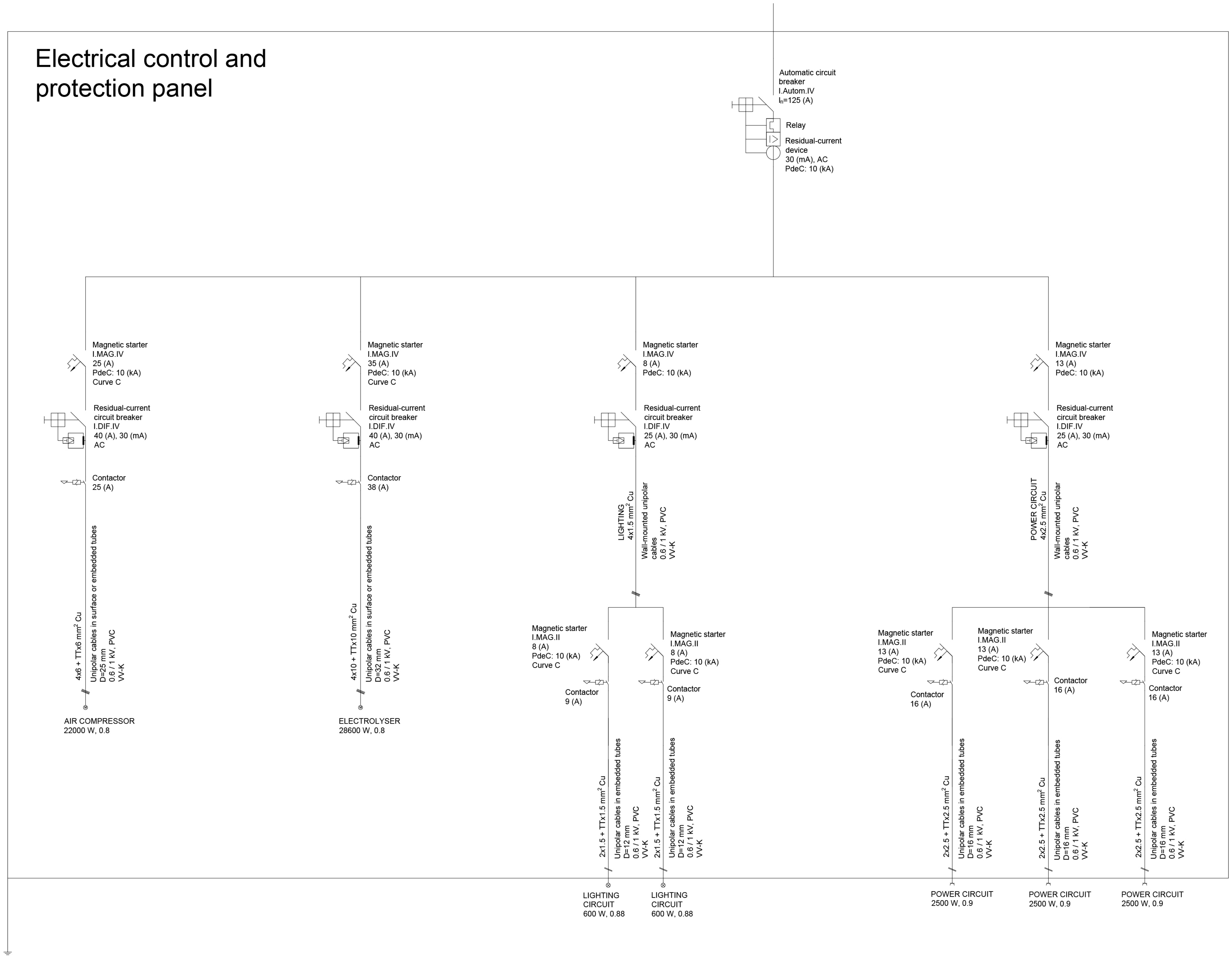
Plano:
Hydrogen installation

Autor:
Paloma Zúñiga Saiz

Fecha:
May 2020

Escala:
1:150

Nº Plano:
5



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Plano: Electrical one-line diagram

Autor: Paloma Zúñiga Saiz

Fecha: May 2020

Escala: SE

Nº Plano: 6