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Short communication

Hercules project: Contributing to the development of the hydrogen infrastructure

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Abstract

A key factor in developing a hydrogen based transport economy is to ensure the establishment of a strong and reliable hydrogen fuel supply chain, from production and distribution, to storage and finally the technology to dispense the hydrogen into the vehicle.

This paper describes how the industrial gas industry and, in particular, Air Products and Carburos Metalicos (Spanish subsidiary of Air Products), is approaching the new market for hydrogen as an energy carrier and vehicle fuel. Through participations in projects aiming to create enough knowledge and an early infrastructure build-up, like The Hercules Project (a project carried out in collaboration with eight partners), we contribute to the hydrogen economy becoming a reality for the next generation.

Keywords: Hydrogen; Hercules project; Hydrogen station; Vehicle fueling; Renewables

1. Introduction

The concept of the hydrogen economy is gaining followers in many sectors of our society. By hydrogen economy we mean its use as an energy carrier in the broadest sense, whatever the method of obtaining, distributing or storing it, as well as whether it is destined for a stationary or portable application or as a transport fuel. This paper describes the contribution that Carburos Metálicos is making to the setting up of this economy, providing its know-how and the strategic focus required to develop the hydrogen infrastructure in our country of Spain, in the form of a project set up with eight partners.

The production and handling of hydrogen is not new. We already have more than 50 years of experience using the product for industrial applications. One of the fundamental advantages of hydrogen use as an energy carrier is its flexibility. Even though the hydrogen needs to be produced, the possibilities are varied, both in terms of the sources and processes for obtaining it and its distribution, storage and end use, as illustrated in Fig. 1.

Furthermore, many of these methods are already currently being used in order to satisfy the requirements of the chemical or pharmaceutical industry, refineries, the food, glass, metal and electronics industries, amongst others; not forgetting its application as a cooling agent in electricity generation turbines, which could be considered to be a precedent for the use of hydrogen in the energy sector.

In terms of hydrogen production, most industrial hydrogen is currently obtained through the process of steam methane reforming (SMR), using natural gas. In the first stages of the hydrogen economy, this technology would supply the requirements of several hydrogen projects in the automotive industry. Fig. 2 shows the Carburos Metálicos reforming plant in Tarragona.

This plant satisfies the hydrogen needs of a medium size refinery, starting from about 26,000 $Nm^3 h^{-1}$ natural gas input.

If all hydrogen production of this plant, with a capacity of some 70,000 $Nm^3 h^{-1}$, was destined for vehicle fueling, it would fulfill the requirements of 270,000 hydrogen cars by providing enough fuel to refuel 34,000 times a day.

Owing to its efficiency and experience in carrying out this process, we believe that this route for hydrogen will continue to be important for many years to come, even though it is subject to changes in the prices of its primary source of energy, natural gas.

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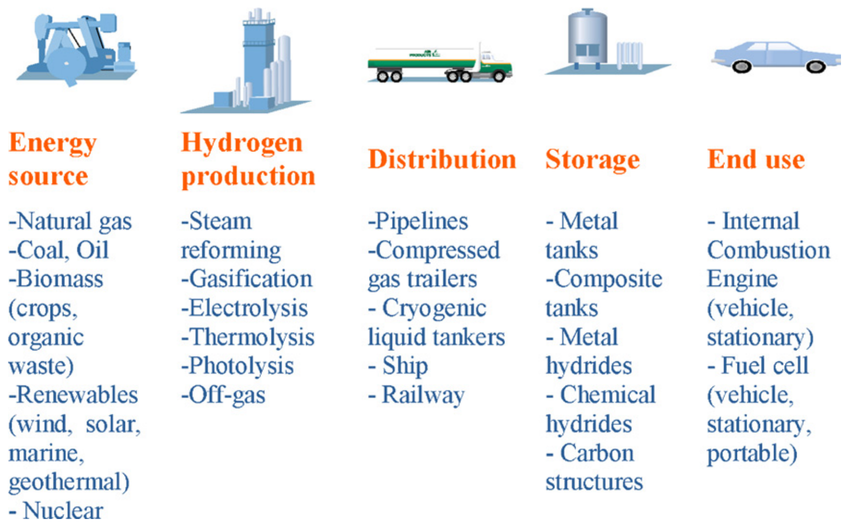

Fig. 1. Flexibility in a hydrogen economy.

On the other hand, we talk more and more frequently about hydrogen as a renewable fuel or about the fuel cells as being "clean" devices. Nevertheless, this is not 100% certain: hydrogen can be produced by fossil fuels or renewable sources, and how 'renewable' you term the power that comes from the fuel cells depends on the source of the hydrogen that supplies them.

Carburos Metálicos has for some time been involved in hydrogen and renewable energy-related projects. We should therefore list the facilities that are available for compressing and storing the hydrogen for the projects (some still being developed), which are spread across various points in Spain:

- INTA: Photovoltaic solar pilot plant (Huelva).
- BESEL: Aeropila Project (Valladolid).
- ITE (Instituto de Tecnología Eléctrica): Pilot plant (Valencia).
- TECNALIA: Hidrotec Project (Bilbao).

Fig. 2. Carburos Metálicos SMR Plant in Tarragona.

- ITC (Instituto Tecnológico de Canarias): Hydrohybrid Project (Gran Canaria).
- GAS NATURAL: Sotavento windfarm (Lugo).

The philosophy behind these projects is to compensate for the fluctuating nature of renewable energy by using an energy storage system, such as hydrogen. This hydrogen can be used at a later date either within a stationary fuel cell to return electricity to the grid, or as a clean transport fuel. Fig. 3 below includes the basic outline for a system of this type.

Unlike California Hydrogen Highway, the most ambitious plan for deploying hydrogen infrastructure in the earth, whose focus is not in the production side but in the deployment of many hydrogen fuelling stations, in Hercules project (much more modest project in size), Carburos Metálicos, forming a partnership with seven companies, Hynergreen and Solúcar R&D (both from Abengoa), Santana Motor, INTA, Aicia, Greenpower and Agencia Andaluza de la Energía, has taken on the challenge of putting its effort into a renewable hydrogen and clean fuel cell project.

The Hercules project has a dual objective: on the one hand, to demonstrate the technical and financial viability of the production of renewable hydrogen from an inexhaustible resource, which is widely distributed across the surface of the Earth: the Sun. On the other, to validate the use of fuel cells, as a clean and efficient method of converting hydrogen into electricity in one of the most promising, but also the most demanding, fields at present: land transport. It will be the first time in Spain that an all-purpose vehicle prototype running on a fuel cell is being developed.

Both objectives have a clear synergy, as they will in turn contribute to the success of a far-reaching objective: the development of the hydrogen economy in Spain, by setting up the first point of the future "hydrogen virtual network" in this country in Andalucía. This will, furthermore, be the most southerly of Europe's hydrogen stations.

The Project therefore plans, on the one hand, to use photovoltaic panels to generate electrical energy, which will be used in an electrolyser for the production of renewable hydrogen. The

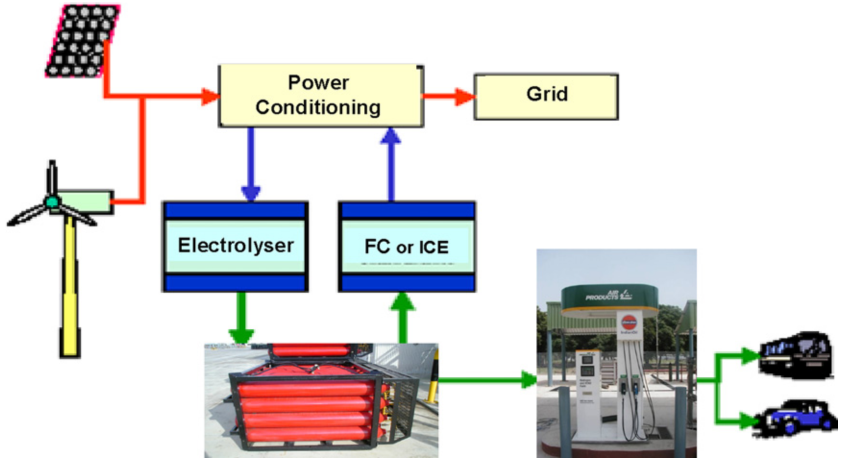

Fig. 3. Basic diagram of a hydrogen renewable energy system [1].

equipments for compressing and storing the gas will be installed, as well as the refuelling station required to supply the electrical vehicle with hydrogen. To summarise, a renewable hydrogen service station will be developed. There is also a plan to develop a prototype, to be included in the plant, that produces hydrogen based on high temperature thermal solar energy.

On the other hand, the second of the Hercules project objectives consists in the design, development and construction of a hybrid electrical vehicle that runs on batteries and a fuel cell supplied by pure hydrogen. This vehicle will be designed in order to refuel at the above mentioned hydrogen station. This objective is not described in this paper, but is the subject of an independent report by INTA.

2. Project description

The plant is located in Sanlúcar La Mayor (Seville), and is next to the existing Abengoa photovoltaic and thermoelectrical solar installations (Fig. 4).

The plant will be designed on a demonstration scale (>100 kWe, >10 $Nm^3 h^{-1}$ H_2) [3]. The plan is to have it in operation in 2008, and to collect data for approximately a year.

Carburos Metalicos has proposed a series of goals as part of the Hercules project, based on the following premises:


Fig. 4. Abengoa solar plants in Sanlúcar La Mayor [2].

1. Generating hydrogen by water electrolysis is a known method that is used in industrial processes, but which tends to be a process that operates on an uninterrupted basis, using an electrical supply that is available on a permanent basis.
2. The industrial hydrogen is stored and transported in tanks at pressures of 200 bar.
3. The process for pouring or discharging the hydrogen at the industrial clients' installations is a slow operation.
4. The hydrogen is handled by specialist staff, who have received the appropriate training, and are familiar with the risks involved.

The goals are therefore respectively:

1. To study the viability of integrating an industrial electrolyser in an intermittent energy generating environment–solar energy. In principle, the choice has been made for an alkaline electrolyser, as these days these are the main ones that run reliably in the industry.
2. Set up the electrolysis plant and hydrogen compressor in order to operate on an almost uninterrupted basis, filling up the storage tanks to a pressure of 400 bar—double the standard pressure for hydrogen storage in an industrial installation.
3. Design hydrogen refuelling equipment to fill a vehicle's tank quickly, with gas that is always available on demand.
4. Prepare the said hydrogen station with future public hydrogen fuelling in mind, equipping it with a simple, safe and reliable operating system.

In order to achieve these goals, a series of operational modules linked to a high pressure storage tank will be set up, in order to discharge the hydrogen in a cascade to the vehicle's tank at 350 bar. With this configuration we can reconcile two clearly different worlds, hydrogen generation – slow with long cycles – with the supply to the vehicle, quick and occasional operation.

Furthermore, the hydrogen station will be designed with a compression and storage system at 400 bar, independent from the main storage tank and compressor. We will therefore be able to improve the vehicle refuelling times so that it is not subject to pressure fluctuations of the main circuit.

The modular design of the plant will allow operationally related areas to be established, which will be able to be built, reproduced and optimised with greater ease.

The hydrogen station will have a control panel in order to activate the whole refuelling process, and will include its own microcontroller, trip relays, an emergency stoppage device, solenoid valves, circuit breakers and engine start-up devices.

Both the hydrogen generator and the main storage tank, as well as the fuelling station, will have individual and joint safety and emergency stoppage systems. Therefore, depending on the problem, it will be possible for one module or for the whole plant to be stopped. There will undoubtedly be a huge emphasis on safety, not only in terms of the refuelling operation, but also in the whole hydrogen production and storage plant.

3. Expected results and discussion

In order to evaluate the economic viability of the project, the experimental part will be complemented by monitoring and controls in order to establish the performance of the unit, by means of the material and energy balances.

The most important input will be from:

- Electrical photovoltaic energy.
- Water.
- Electrical energy from the grid.
- Nitrogen.

The photovoltaic energy and water are the main energy and material, respectively. As indicated above, the plan is to provide energy in excess of 100 kWe, in order to generate approximately 1 kg h^{-1} of hydrogen at 400 bar [3].

The predicted efficiency of the electrolyser is approximately 70%, for continuous and in optimum operating conditions, and its energy consumption lower than 5.25 kWh Nm^{-3}. Nevertheless, special attention will be paid to its effective output over the long-term, given that its operation would be interrupted during a real application. In the same way, the estimative data of solar hydrogen production cost, of about 3 € Nm^{-3}, will be recalculated integrating the costs of all relevant equipment.

In terms of water, although it is normally considered to be a "consumable", we must begin to get used to treating it carefully as a material due to its scarcity in the environment where the plant will be located. The hydrogen generator also needs purified water in order to prevent the bath from being damaged. Therefore a variety of data will have to be considered, such as the quantity of the water, the quality, losses in purification, losses through accumulation, etc. Bearing in mind the supply of the generator alone, the initial water data is approximately 11 l h^{-1}.

The electrical energy from the grid and the nitrogen work as auxiliary energy and material in the plant, the first as a service electrical supply (lighting and safety) and the second as an inert fluid, compression driver and regenerator for the electrolyser's purification system. These materials and auxiliary energies will also be measured in detail in order to calculate the overall output.

In conclusion, in the same way that the current industrial infrastructure of hydrogen plays an important role in the development of future energy solutions, the energy market will, in turn, influence the way in which the industrial gas companies serve existing customers. A couple of examples within the Hercules project are:

- The supply of hydrogen at higher pressures.
- Generating hydrogen using new methods, such as renewable energy, that could supply both the industrial and energy market.

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