Hydrogen for the Heat-Treat Shop

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Hydrogen and hydrogen-bearing atmospheres are arguably the most versatile furnace atmospheres employed in the heat-treatment industry. How hydrogen is produced and the various supply options available are important questions that need to be better understood. Let's learn more.

Hydrogen is said to be the highest-volume gas consumed in the heat-treating industry.[1] Its usefulness is due in large part to its unique chemical and physical properties (Table 1). Applications using hydrogen often rely upon its reducing and/or protective atmosphere characteristics. For steel and stainless steels, examples include bright annealing, brazing, metal injection molding, sintering and welding. CVD coatings and crystal growing also utilize hydrogen gas. In general, processing of stainless steels requires a higher purity level than carbon steel, in which the atmosphere is often either blended (e.g., nitrogen/hydrogen) or diluted (e.g., endothermic/nitrogen).

Production Methods

A number of production methods exist for generating hydrogen. These include steam reforming (i.e., collection and extraction of hydrogen from fossil fuels), electrolysis and thermolysis (both of which extract hydrogen from water molecules). Supply modes often depend on consumption (Fig. 1).

Traditionally, hydrogen has been purchased through large-scale reformers at or near the site of use or from industrial-gas suppliers via truck delivery or dedicated pipeline to the site. Steam reforming and similar thermal-cracking techniques have typically been best matched to very large-volume, steady-state processes, such as hydrogen supply for chemical plants and refineries.

Table 1. Physical properties of common gases (@ 25°C, 1 bar)[2]

Gas type and property	Argon	Helium	Hydrogen	Nitrogen
Density @ 15°C, kg/m^3	1.6687	0.167	0.0841	1.170
Density ratio to air	1.3797	0.138	0.0695	0.967
Molar mass, kg/kmole	39.948	4.0026	2.0158	28.0
Specific heat capacity (Cp), kJ/kg-K	0.5024	5.1931	14.3	1.041
Thermal Conductivity (λ), W/m-K	0.0177	0.1500	0.1869	0.0259
Dynamic viscosity (η), N-s/m^2	0.0000226	0.00001968	0.00000892	0.00001774

On-site hydrogen-generation systems (Fig. 2) are becoming a popular choice for the heat-treatment industry and include methods such as water electrolysis, which matches typical industry-required flow-rate ranges and usage patterns. Hydrogen purity is typically 99.9995+% (or better).

With respect to electrolysis, three cell technologies are in use: solid oxide electrolysis cells (SOECs), alkaline electrolytic cells (AECs) operating at high electrolyte (KOH or K_2CO_3) concentrations and polymer electrolyte membrane cells (PEMs). SOECs operate at high temperature (typically at or near 800˚C), while AECs operate in the range of 200˚C. By contrast, PEMs typically operate below 100˚C.

Both approaches have advantages and drawbacks. Large-scale on-site generation provides a reliable supply of hydrogen. Few heat-treating applications require hydrogen in such a large volume to justify the high capital expense of a conventional reforming generator, however, which is the technology most widely used in on-site applications. For most heat treaters, therefore, the option is to rely on delivered hydrogen. The downside of this approach is typically higher total cost of hydrogen, delivery surcharges and the potential for supply disruptions.[4]

On-Site Hydrogen Generation

On-site hydrogen-generation systems employing water electrolysis are a good fit for the needs of the heat-treatment industry because they match the flow-rate range and usage patterns well. Systems employing polymer electrolyte membrane (PEM) water electrolysis technology (Fig. 3) provide the purest hydrogen, at various pressure levels without a compressor, at variable flow rates and within a compact space envelope. The hydrogen produced is very pure at 99.9995+% or better. While hydrogen purity is extremely valuable to some customers, it is less important to others and is primarily based on what the hydrogen is being used for. The most important parameters about hydrogen purity are:

- What are the trace impurities? In particular, heat treaters need to know about nitrogen and carbon compounds.

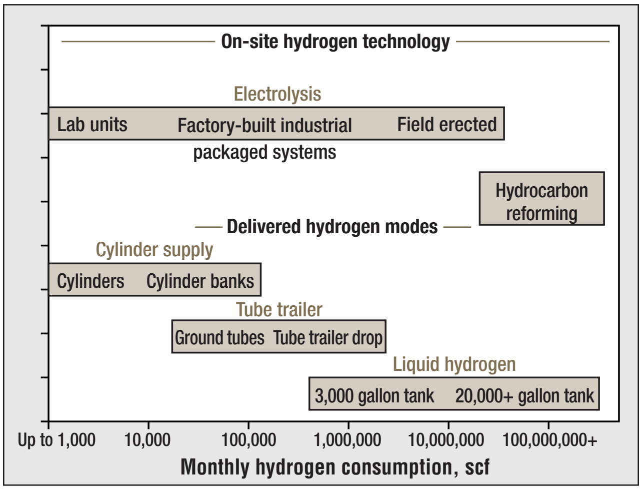

Fig. 1. Typical U.S. hydrogen supply modes[1]

- How dry is the gas? Often, water content is not always specified. One wants the driest hydrogen possible for the best results on the broadest range of metallurgical applications. If humidification is required for certain processes, the heat treater should add moisture through use of a saturator (bubbler).

The technology illustrated here typically employs a platinum catalyst in combination with a membrane separator to split deionized water into its constituent parts (hydrogen and oxygen) and the hydrogen sent off as a process gas. When a DC voltage is applied to the electrolyzer, water molecules at the anode are oxidized to oxygen and protons (H^+ ions) while electrons are released. The protons pass through the membrane to the cathode, where they combine with electrons from the other side of the circuit and are reduced to hydrogen gas. Once generated, the hydrogen is dried and supplied to the desired process application. It is produced at the same rate that it is used, requiring no storage of hydrogen.

Fig. 2. Typical on-site hydrogen generator *(courtesy of Nel Hydrogen)*

Hydrogen Supply Choices

Which is best; a delivered product or on-site generation? In North America, hydrogen is widely available in a variety of supply options and delivery methods, so the choice is up to the individual user. A broad consensus of those using on-site technology points to the following advantages:

- Safety and compliance – often cited as less hazardous than storage sources
- Site utilization – ease of compliance to NFPA safety guidelines, especially those related to hydrogen storage
- Materials flexibility – versatility to process a wider variety of alloys
- Atmosphere cost predictability – cost of on-site-generated hydrogen becomes a fixed cost of operation

Summary

The need for hydrogen in the heat-treatment industry continues to grow, and on-site hydrogen production capability is an intriguing alternative that should be explored by heat treaters.

References online at http://tinyurl.com/jkwm6tl

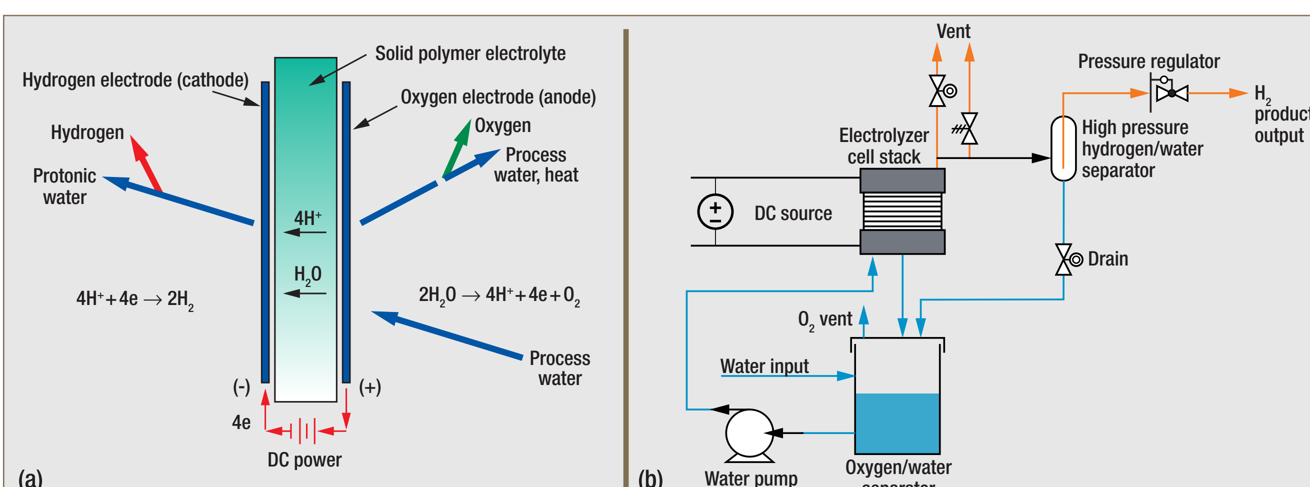

Fig. 3. PEM electrolysis method for producing hydrogen; (a) electrolysis process; (b) electrolysis system