HyRadix: Reliable Production Technology for the Hydrogen Economy

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Abstract (in Times New Roman 12pt Bold)

HyRadix small-scale on-site hydrogen generating technology has two very different applications. Both the Adéo™ Hydrogen Fuel Generator and the Aptus™ On-Site Hydrogen Generator are based on the same auto-thermal reforming (ATR) platform. Both provide high-purity hydrogen to the customer, whether the customer is installing a hydrogen refueling station for fuel cell vehicles or requires hydrogen for an industrial process such as metals treating or fats and oils hydrogenation. HyRadix technology provides a low-cost option for hydrogen production with the operational flexibility that both refueling and industrial customers require.

An Adéo™ Hydrogen Fuel Generator has been providing fuel for vehicles at SunLine Transit in Thousand Palms, California since April 2004. The vehicles include SunLine's fleet of HCNG blended-fuel buses as well as fuel cell cars being tested by most of the major automakers. This was the first reformer based hydrogen refueling station in the State of California. The Adéo Hydrogen Fuel Generator operates unattended in varying modes from daily start/stop to 24/7 continuous operation.

The same technology is being used to provide an economical alternative to delivered hydrogen and electrolysis produced hydrogen in the metals, electronics and fats and oils industries.

Keywords: hydrogen, hydrogen fuel, natural gas reforming, LPG reforming

1. Introduction

Interest in using hydrogen as a fuel has been steadily increasing over the last decade. Significant investment and effort has gone into researching the methods and developing the devices by which hydrogen can be used for powering many products. As the transportation sector is the major consumer of the worlds hydrocarbon resources, no product has received more research and development attention than automobiles and buses. However, it is also well recognized that the success of such products depends on the customer's ability to use them as they currently use their gasoline and diesel powered vehicles. This means the required hydrogen fuel infrastructure must be widely available before hydrogen powered vehicles will represent a significant portion of the transportation market.

Current hydrogen markets are dominated by the production model of central production facilities with hydrogen gas delivery by pipeline or tube-trailer, or liquid delivery by cryogenic trailer. While this system is most suited for the incumbent hydrogen generation technology, this model of hydrogen supply is not the only or always the most economic method of supplying hydrogen to all locations. On-site production has historically been limited to large scale users or very remote locations. However, with its Adéo and Aptus products, HyRadix is showing that on-site production can be a sensible and economic means of hydrogen supply for industrial users and hydrogen fuel retailers. This has been demonstrated at a fuelling station in California, where hydrogen fuel cell vehicles (HFC) and internal combustion engine vehicles using either hydrogen (HICE) or a blend of hydrogen and natural gas (HCNG) are operated.

2. Technology Advancement

The process technology most widely used for large scale production is steam methane reforming. To make plants economic they are built with very large capacities well beyond the need for most individual consumers. Such large scale plants produce the hydrogen for low cost at the plant site, but transportation costs add significantly to the delivered product cost. In order to avoid incurring such costs, the consumer must consider on-site generation of hydrogen. Until now, the alternatives for such on-site hydrogen production were economic in only very few or special cases. The Aptus unit represents the future in on-site hydrogen generation and provides a solution which is economic to many hydrogen consumers.

To avoid transportation costs, some large hydrogen consumers (>800 Nm3/h) have been compelled to purchase large on-site generators. This equipment is essentially a scaled-down version of the large centralized hydrogen generation plants. These reformers require a long delivery, require a site construction and erection effort, often require integration with existing process plants, and do not provide a wide operating range. As these units are scaled down further these items become even more of a burden for the project. These types of plants also operate at very high temperatures due to the indirect heat transfer from the furnace to the reformer reaction zone. The import of steam and export of low quality fuel gases from such on-site reformers can complicate the design and installation of the system. For the large scale consumer these may offer an alternative to purchasing large amounts of delivered gas. For many industrial users and refuelling stations, however, these reformers do not meet the needs well because they do not scale down well to capacities below 500 Nm3/h.

Another alternative for some consumers is to use electrolysis of water to generate the required hydrogen. However, the consumption of electric power for such devices is 4.5 to 5.0 kWh per normal cubic meter of hydrogen produced. As the equipment ages, this high power consumption increases further. Except in special circumstances, where power is especially inexpensive and other hydrogen sources are not available, the production of hydrogen by electrolysis for industrial applications is not most economic. Examining the relative cost of producing hydrogen from the alternative on-site hydrogen generation systems brings out this point. In Southeast Asia, as in other parts of the world, the local natural gas and electricity prices vary somewhat according to location. However, it can be seen from Figure 1 that the operating costs for producing hydrogen via the HyRadix on-site generator is lower than producing hydrogen from an electrolyzer in every reasonable utility cost scenario examined.

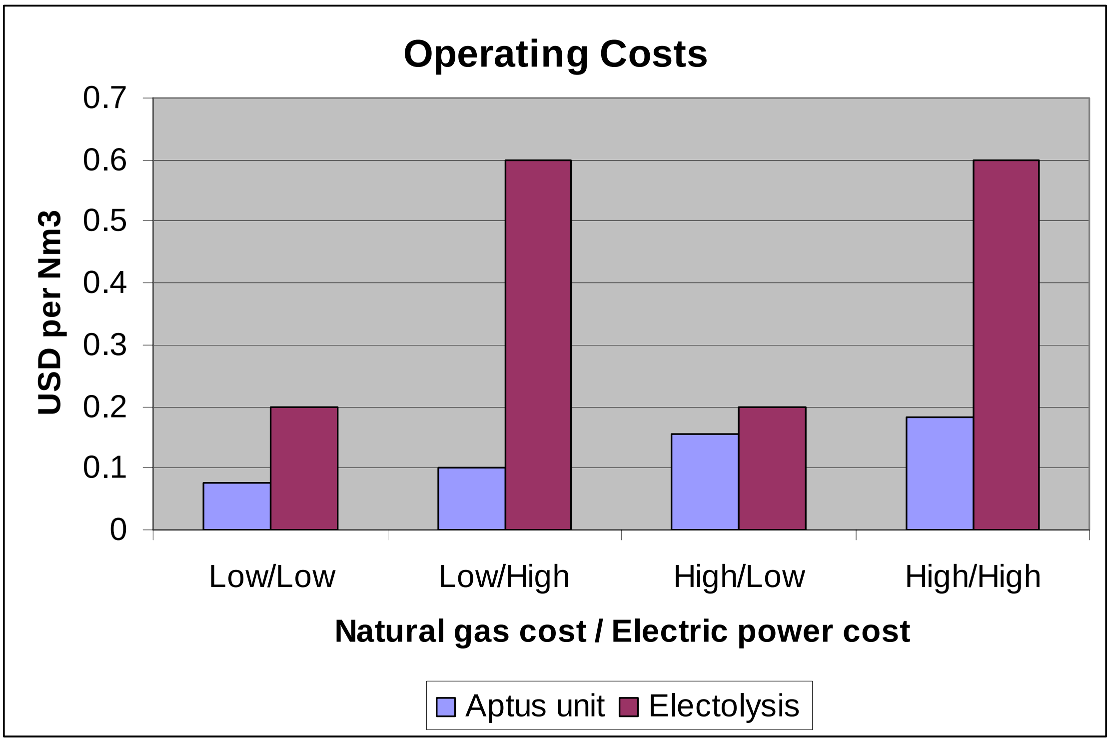

Figure 1: Cost of inputs to produce hydrogen on-site by reforming compared to electrolysis.

Input data assumed for Figure 1:	*Low Range*	*High Range*
Natural gas, USD per Nm3	*0.11 to 0.14*	*0.26 to 0.30*
Electricity, USD per kWh	*0.03 to 0.05*	*0.11 to 0.13*

Notwithstanding the above noted cost advantage, several refuelling stations have been completed using electrolysis equipment for hydrogen generation. One of the intentions with such systems is to reduce the production of carbon dioxide caused by the production of the hydrogen fuel. However, in making this evaluation, the carbon dioxide released at the central power generating facility should not be ignored. A comparison of carbon dioxide emission when producing hydrogen with electrolysis and reforming are presented in Figure 2. From this data, it is clear that producing hydrogen using the HyRadix on-site hydrogen generator produces less carbon dioxide than does electrolysis when the electricity production is considered. This is true even in California, USA where a higher proportion of renewable energy is supplied to the grid.

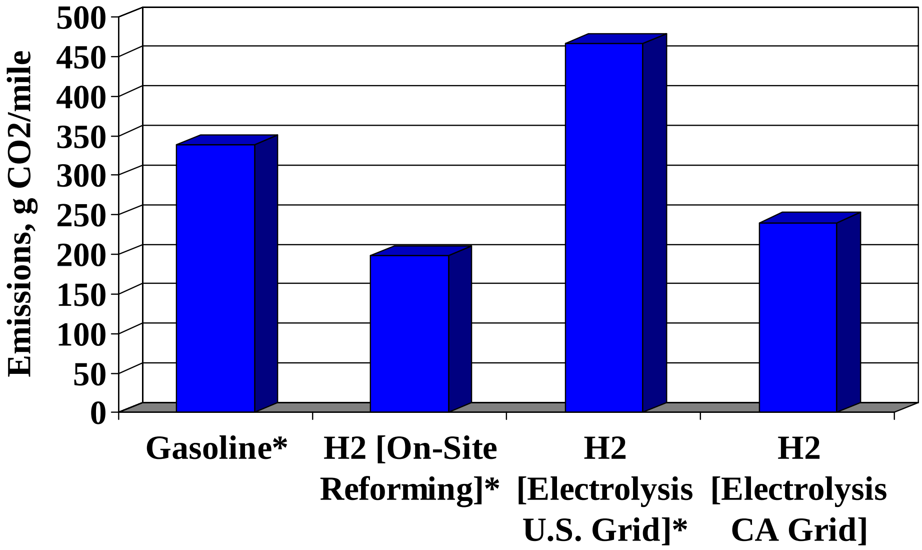

Figure 2: Grams of carbon dioxide released per mile driven using various fuels.
[*Source: 2001 Study by Argonne National Laboratory, extension to CA Grid by HyRadix.*]

3. Case Study: Hydrogen Fuel Supply

For those considering installation of a hydrogen fuelling station, it will be interesting to review a case study of the installation of an Adéo hydrogen fuel generator in California, USA. HyRadix installed an Adéo unit at SunLine Transit Agency in California, USA and has been producing hydrogen fuel for their commercial operations since April 2004. The transit group operates their own HCNG buses, is a frequent test site for HFC and HICE buses, and serves as a fuelling site for fuel cell vehicles of most major automotive manufacturers.

In addition to the Adéo unit, the fuelling station includes two stages of hydrogen gas compression to reach the pressures necessary, product storage facilities, and hydrogen dispensing equipment. Figure 3 shows a block flow diagram of the fuelling station. The hydrogen compression is split into two stages due to the multiple uses of the hydrogen fuel. It is compressed to about 200 bar for blending with natural gas and use in the HCNG buses. A portion of the hydrogen fuel is compressed to about 400 bar for use in hydrogen ICE and HFC vehicles. The dispensing equipment can dispense either HCNG or high purity hydrogen fuel.

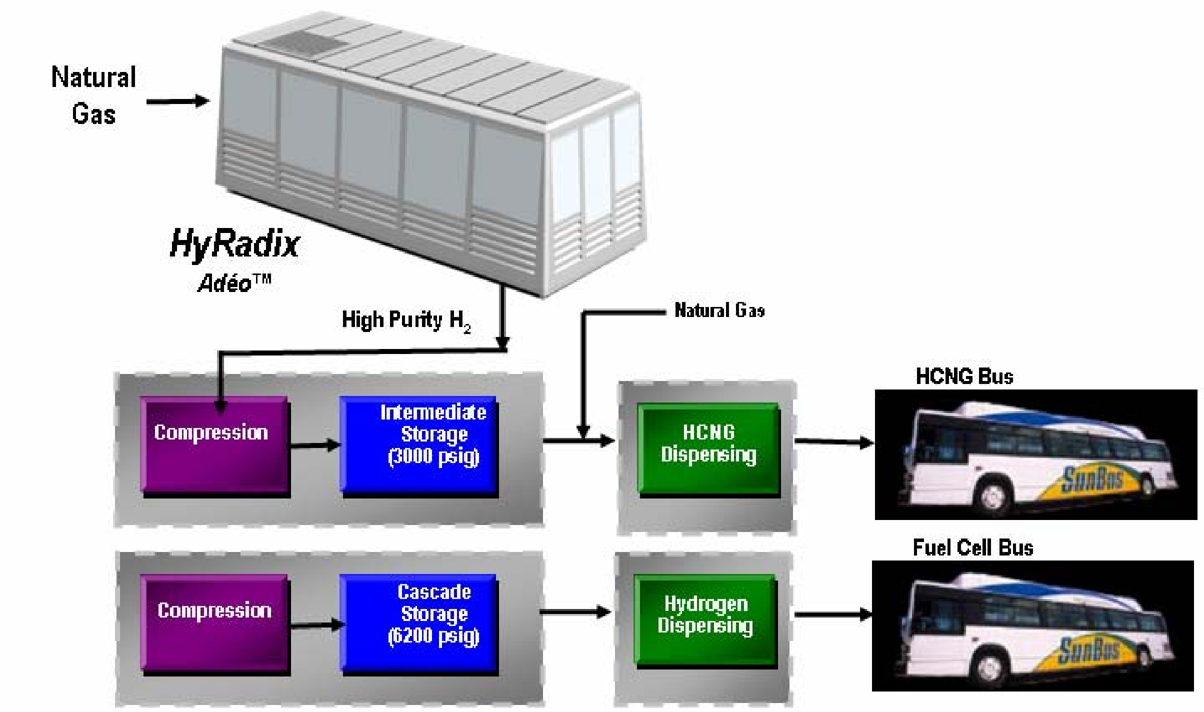

FIGURE 3: Block flow diagram of fuelling station at SunLine Transit Agency.

Using utility basis costs of $4.50/MMBtu and 0.085 $/kWh provided by the U.S. Department of Energy (DOE), the fully loaded cost of producing hydrogen with the configuration used at SunLine Transit is $3.68 per kg ($0.33/Nm3). This cost includes a capital loading to account for all capital equipment required including the reformer, compression, storage and dispensing equipment. The operating cost of producing the hydrogen at 7 barg pressure from the Aptus unit is less than $0.15 per normal cubic meter of high purity product.

4. Conclusion

Economic on-site generation of hydrogen is now possible for fuelling stations industrial users consuming between 30 and 500 Nm3/h. By incorporating innovative advances in process technology into its hydrogen generators, HyRadix is commercializing this equipment to provide customer with effective on-site hydrogen solutions. Customers are able to avoid transport costs for their hydrogen and control this critical input to their own manufacturing processes.