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Low Cost Hydrogen Production Platform

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Abstract

Praxair is in the initial phases of developing the "Low Cost Hydrogen Production Platform" (LCHPP) design in accordance with the DOE cooperative agreement. The overall goal of the program is to develop an on-site hydrogen generation system, based on steam methane reformer technology, which will significantly lower the overall cost to produce hydrogen at low volumes. Praxair has as partners in this program, Boothroyd-Dewhurst Inc. (BDI) and Diversified Manufacturing Inc. (DMI). BDI has expertise in the area of Design For Manufacturing and Assembly (DFMA) and they have worked extensively with the automotive industry to lower the overall cost of production for mass produced systems. DMI is a design and fabrication facility with extensive experience in the areas of high temperature component design for both new designs and refirbishments, tooling design and manufacturing processes. This paper provides background information, an update of the program to date as well as the future plan for the system development.

Introduction

Hydrogen is expected to play a vital role in the transportation sector for fuel cell vehicles (FCVs). A source of low cost hydrogen will be vital to the successful transition to a hydrogen based transportation economy and a key challenge to this goal is to reduce the overall cost for the small scale on-site generation of hydrogen. Praxair is an industry leader in the design, development and operation of hydrogen production facilities and is applying this extensive knowledge base, as well as advanced mass production, design and tooling experience provided by the subcontractors, to this development effort. This program is based on existing SMR and hydrogen purification technologies.

Program Goals

The goal of this program is to design a 1,000 to 5,000 scfh (28 to 140 Nm^3/hr) hydrogen system for the transportation FCV market as well as the small industrial market. The cost goal is to supply hydrogen at $8/MMBtu ($0.26/100 scfh). The system must be small enough to be installed at a typical gas station and be able to operate using available natural gas, water and electricity. The system must meet all applicable safety and operating codes and standards associated with hydrogen and related process equipment.

Process Design

The process used for this program will be a steam methane reformer (SMR) with a PSA or membrane based purification system. The program does not include the hydrogen compression, storage or distribution system required for the high pressure filling of FCVs. A process diagram of the system is shown in Figure 1 below.

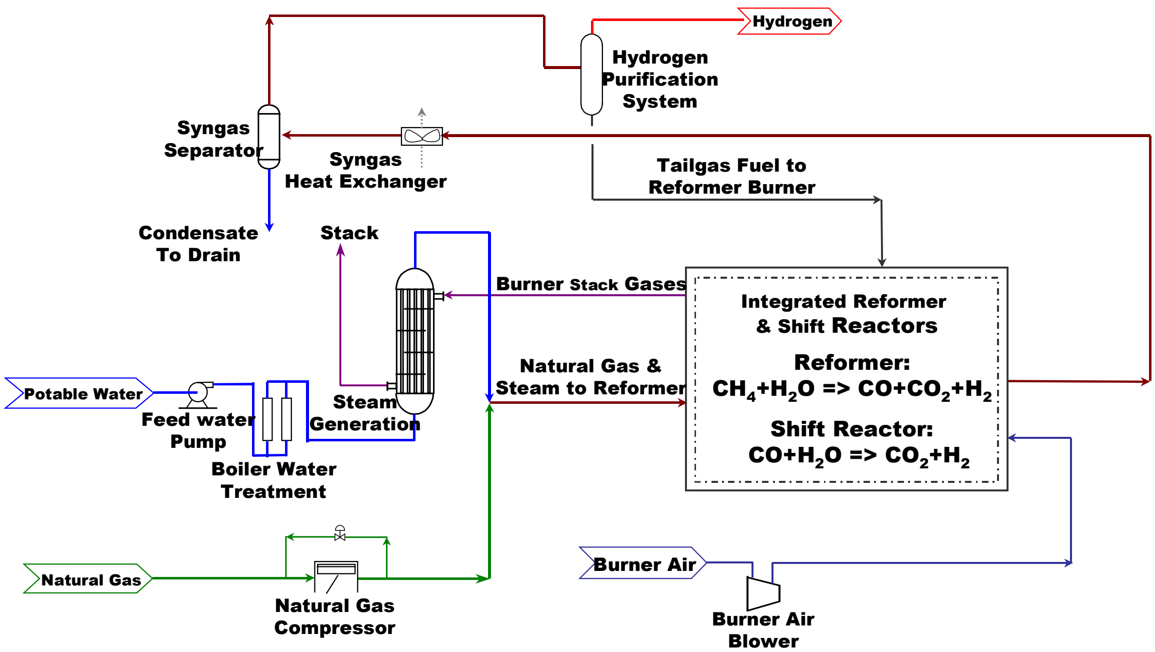

Figure 1. Low Cost Hydrogen Production Platform (LCHPP) Process Diagram

Natural gas consistent with pipeline quality standards will be compressed and combined with steam from the boiler system. Sulfur will be removed from the natural gas prior to being combined with the steam. Steam will be produced from city water using an integrated steam generation system. The system will include water treatment, blowdown and process control required for long term operation. The combined steam and natural gas will then enter the integrated reformer/shift converter system where the hydrogen rich syngas is produced. The syngas is then cooled, the condensate is removed, and sent to the purification system. The purification system will likely be a Pressure Swing Adsorption (PSA) system. The waste gas from the purification system is then combined with air in a burner system to generate the heat required for the reforming process. The usage of this waste gas as a fuel for the burner minimizes local plant emissions. Options of further integrating the steam system and the syngas cooler into the reformer/shift component are currently being evaluated.

The final hydrogen product pressure is expected to be 100 psig. The overall system pressure is limited by the high temperature material properties of the reformer portion of the system. The factors determining the optimum process pressure include optimum reforming temperature, reformer materials stress versus temperature curves, high temperature material costs and the required pressure for the purification system.

Design Background

On-site hydrogen facilities developed by industrial gas companies such as Praxair have typically been designed as large capacity systems and with very low levels of system integration. Generally, the percentage of overall capital required for the installation of a facility remains nearly constant as the capacity, and consequently the cost, increases. Large hydrogen plants arrive at the site as thousands of individual parts requiring significant field cost to assemble and to bring the system on-line. The potential of system integration is hampered by two factors; the first being that the equipment is generally too large to permit system integration and still allow for reasonable shipping charges, the second factor is that large systems are usually one-off systems that do not justify the engineering expense that would be required for significant integration. The DOE sponsored LCHPP program investigates the opportunity associated with small volume hydrogen production and the integration of the system components.

Praxair has previously developed what was then considered to be a small on-site hydrogen plant offering for the industrial market. The system capacity ranges from 18,000 to 30,000 scfh (500 to 850 Nm^3/hr) and generates hydrogen using a SMR with a PSA purification system. The system, although still being multiple skids requiring field assembly, demonstrates some of the potential positive effects of packaging all components on skids and limiting the field installed items to a few miscellaneous components. The installation cost percentage of the overall capital was less than one half of the larger systems and the system was installed in less than 4 weeks. This is a significant improvement over the large plant approach, but the goals for the LCHPP require even more installation and start-up cost reductions. Figures 2 and 3 are diagrams detailing the Praxair HGS small on-site hydrogen generating system.

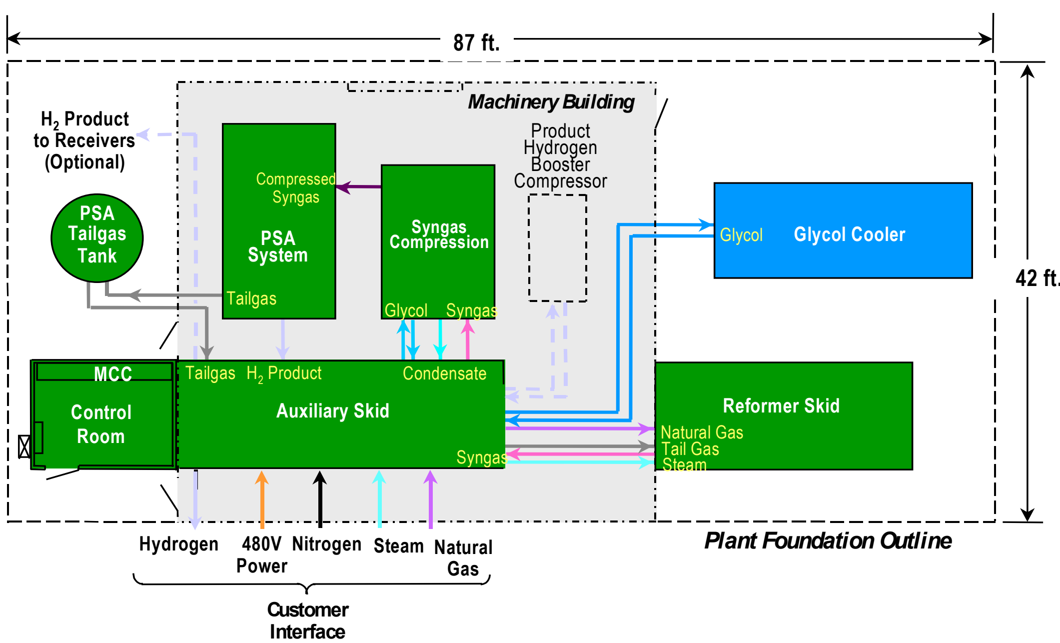

Figure 2. Praxair HGS On-Site Supply System

Figure 3. Praxair HGS On-Site Supply System (Seymour, Indiana)

Although the HGS system has been a success in the industrial market with the system being over 97% reliable, the goals for the LCHPP program require a step change. The LCHPP will be approximately one sixth the capacity, about one fifth the footprint, while lowering the hydrogen product cost to about one half of the HGS system.

Program Approach

As detailed above, the requirement for industrial on-site hydrogen plants has been larger volumes than that of the LCHPP program. Achieving a competitive, lower volume plant offering has dictated the need to modularize plant components and streamline the installation and start-up process. The cost target of the LCHPP program is significantly lower than any previous goal set for the industrial market and to approach this goal, further integration, scale of economies and design optimization will need to be implemented. Rather than designing a system from a block flow process engineering approach, the system will be designed from the ground floor using DFMA techniques as well as a much higher level of system integration. The system will also be designed for mass production and therefore require the development of tooling and fixtures to aid in the assembly process. It will not be possible to build 0 – 10 of these units and approach the DOE cost goal. The economic viability of the system will only be achieved in large volume production runs.

The LCHPP program is structured in 3 distinct phases. Phase I is the engineering study and feasibility phase which is scheduled to be completed in October 2002. A business plan and economic model will be developed as part of phase I and will be updated as required during phases II and III. Phase II is the system detail design, tooling development and prototype phase and is currently scheduled to begin in December 2002. Phase III is the final phase where a demonstration unit will be developed and tested. The tooling required for the mass production of the system will also be developed in phase III. Phase III is currently scheduled to begin in September 2004 and last for 1.5 years.

Phase I Progress and Future Work

Phase I of the program began in January 2002 and is scheduled to be completed in October 2002. As of this report date, approximately 20-30% of the phase I work has been completed. Progress to date includes development of the process flow computer models, development of the mechanical design concepts, setting the product and utility design parameters and developing a preliminary cost model for the system. The subcontractors for this program (BDI and DMI) have been involved in the development and selection of potential concepts. For the system to meet the design goals, it is critical that new design, fabrication and optimization techniques be instituted in the early stages of the program. Meeting the program goals will also require that codes and standards be developed to allow for the safe operation of a small on-site hydrogen facility without being excessively stringent and a major cost component to the overall system.

Future work for phase I includes further refinement of the mechanical design concepts, selection of one or two of the highest potential concepts, development of the techno-economic study and development of the business model. A report summarizes the phase I effort and providing a go/no-go recommendation for phase II will be developed and submitted to the DOE by the end of October 2002.

Conclusions

There are clearly enhanced approaches to designing a small on-site hydrogen system from both the component and system level. The cost goals from the DOE are aggressive (75 to 80% of cost target required for utilities), but with introducing design optimization into an integrated small-scale system, it should allow the overall cost to approach the target goal. A report summarizing the finding of phase I, as well as recommendations for phase II will be developed by the end of October 2002.

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Subcontractors

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