VII.3 Hydrogen Recycling System Evaluation and Data Collection

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Project Start Date: January 2013
Project End Date: December 2015

Overall Objectives

The objective of this project is to demonstrate the product readiness and to quantify the benefits and customer value proposition of H2Pump's Hydrogen Recycling System (HRS-100™) by installing and analyzing the operation of multiple prototype 100 kg per day systems in real world customer locations. The data gathered will be used to measure reliability and to demonstrate the value proposition to customers. H2Pump will install, track, and report multiple field demonstration systems in industrial heat treating and semi-conductor applications. The customer demonstrations will be used to develop case studies and showcase the benefits of the technology to drive market adoption. The objectives of the project are to:

- Validate commercial assumptions around the Hydrogen Recycling Agreement including customer assumptions and system performance.
- Build case studies of the HRS-100™ in customer operations that can be used as credible demonstrations quantifying the operating cost savings, emissions reduction and production efficiency improvement.
- Expand the Beta test fleet into additional customer environments to accelerate learning, problem identification, resolution and reduce the risk of product launch.
- Provide data to National Renewable Energy Laboratory (NREL) for in-depth analysis of system performance characteristics and identify areas for improved data gathering and perform causal analysis. All of the data acquired by the systems will be made available to the NREL. The minimum data includes stack voltage and current, system power, and hydrogen flow rate. Data frequency can be no less than a one minute interval. Maintenance and repair logs will also be provided to NREL, specifying time, maintenance item, or reason for repair. NREL will also be provided with gas analyses to help determine whether certain gases result in higher degradation.
- Prepare and test commercial infrastructure elements such as installation, commissioning, reporting, operation, and maintenance.

Fiscal Year (FY) 2014 Objectives

- Modified Statement of Project Objectives will include a new objective: H2Pump will perform extensive furnace exhaust gas stream analyses at each site and implement solutions to mitigate contaminates.
- Execute Go/No-Go review.
- Install and commission the remaining three systems in the fourth quarter of 2014 and provide data to NREL to perform degradation calculations.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

(G) Hydrogen from Renewable Resources

FY 2014 Accomplishments

- Completed the development and deployment of a database tool to track system performance and store lifetime data.
- Identified furnace exhaust contaminates at Pall, Rome Strip Steel, and Ulbrich deployment sites through extensive gas sampling and analysis by an external lab.
- Implemented solutions at Pall and Rome Strip Steel for containment of sulfur compounds, CO, and other contaminates harmful to the pumping stack.
- Implemented automatic controls at Pall, increasing the daily recycle rate by three times.

- Provided data to NREL quarterly to assess system performance. Demonstrated less than 10 kWh/kg at most operating points.

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INTRODUCTION

Hydrogen is used in numerous industrial applications including metallurgical and semiconductor processing. Hydrogen intensive metal heat treating applications include stainless steel annealing, brazing, and metal production from ore. Each industrial application uses hydrogen for different purposes; however, in general, hydrogen is used to create an oxygen-free reducing atmosphere and is not consumed by the industrial process. H2Pump has developed a unique hydrogen recycling solution capable of reclaiming nearly 100 kg per day from such industrial processes.

Figure 1 shows how the HRS integrates with a typical industrial furnace or semi-conductor manufacturing tool. The HRS receives the furnace or tool exhaust that is normally flared or exhausted to atmosphere. The HRS requires certain utilities including electricity, water, and nitrogen. The heart of the HRS system is the electrochemical pump stack. The electrochemical process involves the extraction of hydrogen from a gas stream containing hydrogen, followed by the formation of "new" hydrogen. This transformational approach is accomplished without mechanical compression. The new hydrogen is returned to the original process.

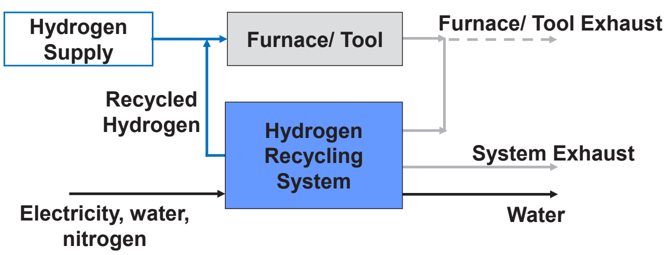


FIGURE 1. Integration of a Hydrogen Recycling System with an Industrial Process

The HRS-100™ system design is shown in Figure 2. The main subsystems and components include incoming gas clean-up, humidification, the pump stack, power supply, heat rejection and the dryer. Most heat treating processes require a very low dew point in the hydrogen supply. To ensure adequate quality of the recycled product, H2Pump measures the dew point of the product before returning the hydrogen to the customer's process.

APPROACH

H2Pump is fortunate to have the support of the New York State Energy Research and Development Authority as a cost sharing partner in this project. The New York State Energy Research and Development Authority award funds 50% of the system material cost, the installation cost, the ongoing operation, and maintenance costs of the demonstration. The DOE award shares the costs of the systems, the database development and the analysis performed by NREL.

A total of seven systems are planned to be installed and monitored during the project. The first step is establishing the site requirements and installation plan. Activities to uncover site specific issues, including potential gas contaminates are undertaken early in the planning process. Mitigation plans are put in place for known contaminates, and the systems are

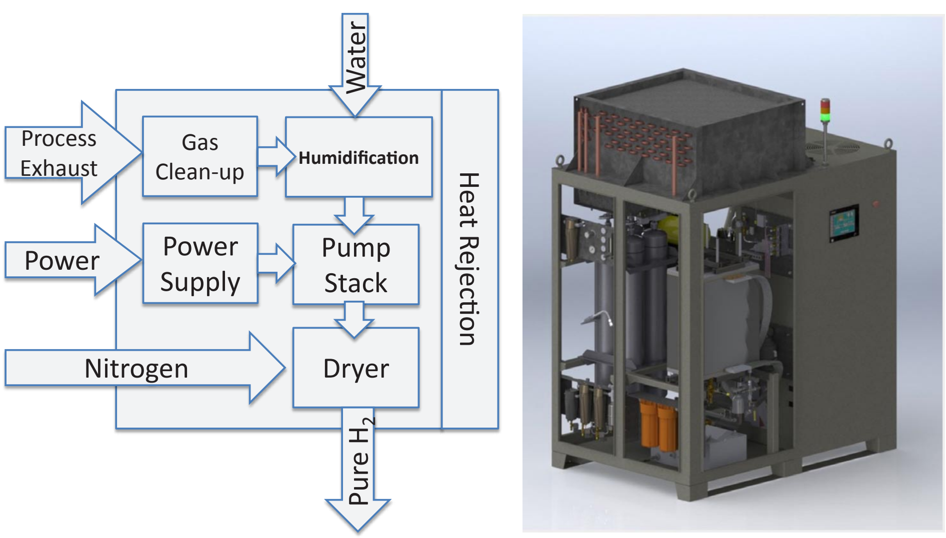


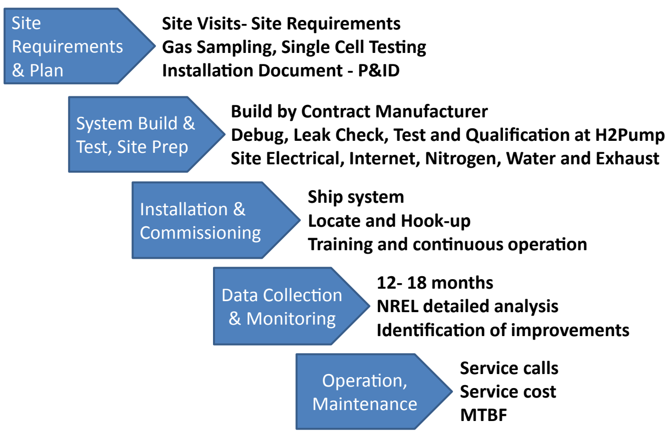
FIGURE 2. HRS-100™ Subsystems and Components

installed and commissioned. Following commissioning, the system will be monitored and the data logs will be given to NREL for analysis (Figure 3).

RESULTS

As of the writing of this report, H2Pump has completed exhaust gas sampling and analyses for the three sites shown in Figure 4 and implemented proprietary solutions for additional gas cleanup prior to the HRS-100™. The solutions include adsorbents for sulfur removal, catalytic CO reduction and oil clean-up. The implementation of control methods for auto-start and ramp-up has greatly increased the recycle rate. Under manual operation, the system at Pall Corporation only operated during daytime hours often missing a second or third shift since the system had to be remotely started and manually ramped up. With the implementation of exhaust sensing and controls, the daily recycle rate has increased 10 fold. The system output still depends on the customer's operating schedule but no longer requires remote intervention. Additionally, the gas sampling showed the presence of trace amounts of sulfur in the exhaust that may have been contaminating the stack. The stack in the Pall system has never been replaced indicating that the solution for sulfur removal was effective and did not permanently damage the stack.

H2Pump has implemented promising gas management solutions at Ulbrich and Rome Strip Steel and is awaiting verification of the efficacy of the solutions.



MTBF - mean time between failure

FIGURE 3. Site Installation and Monitoring Steps

CONCLUSIONS AND FUTURE DIRECTIONS

The site planning and commissioning steps are proving to be the most critical and time intensive part of the project. Revising the Statement of Project Objectives to include greater focus on identifying and mitigating the harmful or poisonous constituents in the furnace exhaust

FIGURE 4. Recycling Demonstration at Pall Corporation, Ulbrich Specialty Strip Mill, and Rome Strip Steel

gas has dramatically improved the system performance. For the remaining three installations in the second budget period of the program, greater emphasis will be placed on understanding the exhaust gas composition and implementing and refining solutions.

SPECIAL RECOGNITIONS & AWARDS/ PATENTS ISSUED

1. Granted US Patent 8,663,448 B2 on March 4, 2014, *Hydrogen Furnace System and Method*, Glenn Eisman.

2. Granted US Patent 8,734,632 B1 on May 27, 2014 *Hydrogen Furnace System and Method*, Glenn Eisman.

FY 2014 PUBLICATIONS/PRESENTATIONS

1. 2014 U.S. DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting, June 16–20, 2014, Washington, D.C.