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An investigation into water and thermal balance for a liquid fueled fuel processor

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Abstract

To better understand the sizing and performance issues associated with water and energy balances of a fuel processor for a PEM fuel cell, a process flow system has been programmed into the ASPEN® simulator for a reference system supplying 600 W electrical power. The fuel processor consists of an autothermal reformer (ATR), single-stage water gas shift (WGS), dual-stage PROX reactors and an anode gas burner (AGB) operating on sulfur-free JP8. The reactor components were modeled using RGIBBS for the ATR and actual experimental kinetics for the WGS and PROX reactors. Simulations investigating thermal management, ATR and WGS performance and system efficiencies were done. Using realistic temperature approaches for heat exchangers it is likely that integrated systems will have to discard heat to the surroundings. Also, depending on the operating conditions, water will either be in surplus or deficit. At 1 atm pressure there is no condition that will enable complete water capture. The minimum pressure where water independence can be achieved is at 1.23 atm with a fuel cell utilization of 60% and a S/C = 1.5 and O/C = 1.0. The complete fuel processor is expected to be 0.46 L and 2.02 kg. This paper will expand on these findings with suggestions for optimal operating efficiencies and sizing for JP8 fuel processors.
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Keywords: Water balance; Thermal management; Liquid fuel processor; Pressure effect

1. Introduction

The continued interest in fuel cells for many applications has typically been separated into two categories; the fuel cells themselves and the systems that will deliver the hydrogen. Currently those hydrogen delivering systems are fossil fuel based fuel processors that operate on either gaseous or liquid fuels. While there are many issues that still need to be understood and developed for liquid fuel processors, one issue that has only received limited attention thus far is the water and heat balance issues for the entire processor and fuel cell system. Until there is a reliable storage technology for pure hydrogen and renewable energy such as solar, wind or nuclear are developed, the deployment of PEM fuel cell applications will rely on hydrocarbon fuel processing for hydrogen generation. As research continues on the development of fuel cells and fuel processors, attention must be given to the thermal and water integration issues. This pertains particularly to mobile applications, but is very relevant for stationary applications if hydrocarbons are to be used. To obtain a high efficiency and relatively autonomous fuel cell power system, one must ensure a high level of thermal integration and reduce the human interactions. High efficiency makes sense and reduction of human interaction would likely lead to wide acceptance. For example, if a fuel cell system were to require the user to add water every time the system needed fuel, that would be an added burden, and could be a logistical problem, that would give all but the most enthusiastic users reason to not choose the technology. To that extent, an investigation was undertaken using an ASPEN® simulation to understand the issues associated with thermal integration and water balance for a liquid fueled fuel processor system. There have been a considerable number of studies done looking at water balance issues [1–3]. Yet, only a limited number have conducted investigations using real performance curves of the units. To provide insight into how the various units (reactors and heat exchangers) will integrate an ASPEN® flow sheet has been set up which incorporates kinetic rate expressions for the water gas shift (WGS) and preferential oxidation (PROX) reactors. In addition, real heat exchanger parameters were

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