391d Thermally Integrated Methane Fuel Processor

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One major issue confronting commercialization of small-scale fuel processors for PEM fuel cell applications is the complexity required to provide thermodynamic conditions for optimal performance of a series of catalytic reactors. Tighter thermal integration is necessary to reduce cost and the number of control elements in such systems. A strategy is presented in which heat is effectively transferred from the fuel processing reactions to a pre-mixed stream using one simple embedded heat exchanger while also maintaining an ideal temperature profile through the reactor.

Typical fuel processors for PEM fuel cell applications employ an autothermal reforming section (ATR) to reform the fuel, water gas shift section (WGS) to reduce CO and increase H2, and a preferential oxidation section (PROX) to further reduce CO to ppm levels. In this series reactor train, the ATR does not require heat integration as it is preferably operated adiabatically. The WGS section however is ideally operated with a decreasing temperature along its length although the reaction is slightly exothermic. The PROX reactor requires close to isothermal conditions while it also releases heat. By premixing fuel, air, and steam into a two-phase fluid and passing it through a counter-flow heat exchanger embedded in the catalyst beds, the energy needs of each reactor can be met while maintaining the desired temperature profile. Furthermore, by altering the vapor fraction of the pre-mixed stream using an external boiler, this profile can be shifted to optimize performance.

Data from a thermally integrated methane fuel processor operated at 2kW and 3kW thermal input is presented. Temperature and concentration of the reformate were measured at several locations along the length of the reactor. From this information, approximate profiles were created and compared with desired trends. An energy balance was done to estimate the amount of heat provided by the external boiler and to calculate the thermal efficiency of the device.