Continuous and Precise Metering of Reactants and Solvents into Supercritical Water Gasification

Using a Teledyne ISCO Syringe Pump and Extractor

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Syringe Pump Application Note AN36

Doug Hendry[1], Malithi Wickramathilaka[2], Nikolas Wilkinson[2], Andrew Miller[1], and William Jacoby[1,2],
Department of Biological Engineering[1], Department of Chemical Engineering[2], University of Missouri, Columbia, MO

Abstract and Introduction

Gasification of biomass involves thermal decomposition of organic components in the absence of oxygen. Supercritical water (SCW) is an excellent reaction media to gasify biomass. Water above its critical point (temperature of 374°C and a pressure of 22.1 MPa) has thermo-physical properties that are intermediate between gas and liquid phases. This note illustrates a compilation of several studies conducted with the supercritical water gasification (SCWG) apparatus. Teledyne ISCO 260D syringe pumps [see note] are essential parts of the apparatus, which is located in the Carbon Recycling Center in the Department of Biological Engineering at the University of Missouri. The pumps provide precise metering of a variety of high-pressure, ambient temperature fluids into the SCW environment at flow rates sufficient to create turbulent flow of supercritical fluid mixtures at elevated temperatures in the reactors.

Experimental Procedure

The design schematic for the supercritical water gasification (SCWG) reactor and apparatus in the Carbon Recycling Center is depicted in Figure 1. The pressure in the apparatus for all experiments was between 26 and 30 MPa. The furnace temperature was between 700 and 750° C. A Teledyne ISCO 260D syringe pump was used to deliver water, at high pressure and ambient temperature, directly into the preheat stream. A second ISCO pump was used to feed the carbon loading stream, which for these experiments, was a liquid carbon source, namely alcohols and sugars, also at high pressure and ambient temperature. Both pumps were used in constant flow mode. In the mixing tee, the carbon feed reached supercritical conditions nearly instantaneously due to mixing with SCW from the preheat stream.The temperature range in the mixing tee is between 475 and 525 °C. The reactor reached steady state quickly due to its low volume (13 ml).

Downstream of the reactor is a cooling coil to quench the reaction and cool the supercritical fluid mixture and a high pressure equilibrium phase separator. The separator is at the same pressure as the rest of the system and close to ambient temperature. The separator removes liquid water and any solids from the permanent vapor product (hydrogen, methane, carbon dioxide). The reactor reached steady state quickly due to its low volume (~13 ml). Reaching steady state in the separator took about 20 minutes. Several references describe the procedure for measuring gasification efficiency, gasification rate, and vapor product composition (Hendry 2012, Miller 2012, Hendry 2011).

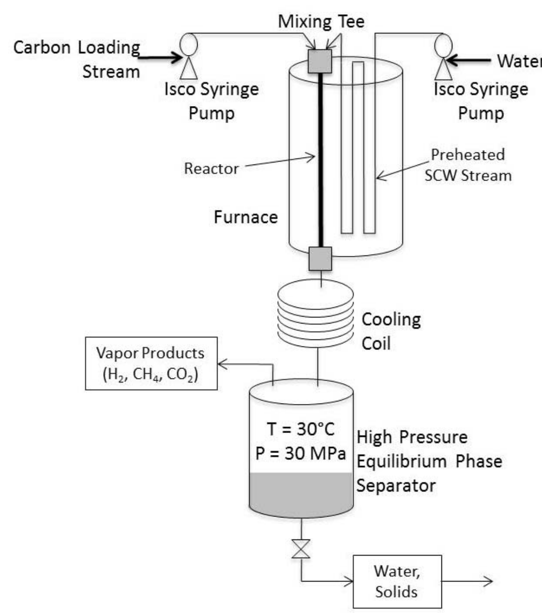

Figure 1: Schematic of the supercritical water reactor apparatus in the Carbon Recycling Center at MU

Results and Discussion

Studies on SCWG of alcohol showed that maximum gasification rates occurred when $\tau \leq 1.2$ s, corresponding to high Reynolds numbers, turbulent flow, and effective axial mixing, allowing observation of intrinsic reaction rate (Hendry 2012). Additional, experiments were performed under turbulent, plug flow conditions which were achieved in part because of the capabilities of the ISCO syringe pumps. The gasification rates observed at turbulent conditions are the highest SCWG rates ever reported. Such high gasification rates present the potential for SCWG as a viable, high throughput process. In another study, the SCWG continuous apparatus was used to gasify glucose and nearly six times faster rates were observed (Hendry 2012).

Conclusion

Experiments were performed in the supercritical water gasification apparatus at the University of Missouri. These were the first such experiments to achieve turbulent plug flow and maximize gasification rates. The gasification apparatus operates at high pressures (>26 MPa) and is dependent on ISCO syringe pumps to feed water and liquid carbon streams. The results from these experiments show that supercritical water gasification is a high throughput process to convert low value carbon wastes into high value fuel gases.

References

1. D. Hendry, A. Miller, W. Jacoby, 2012. Turbulent operation of a continuous reactor forgasification of alcohols in supercritical water. Ind. Eng. Chem. Res. 51, 2578–2585.
2. D. Hendry, C. Venkitasamy, N. Wilkinson, W. Jacoby, 2011. Exploration of the Effect of Process Variables on the production of High-value Fuel Gas from Glucose via Supercritical Water Gasification. Bioresour. Technol. 102, 3480-3487.
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Note:

The 260D model pump, which was used during the original experiment, is discontinued. Current model 260x is the recommended replacement for the older 260D model.

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Product model names have been updated in this document to reflect current pump offerings.

Teledyne ISCO
P.O. Box 82531, Lincoln, Nebraska, 68501 USA
Toll-free: (800) 228-4373 • Phone: (402) 464-0231 • Fax: (402) 465-3091
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