Real Time Monitoring of Pilot-Scale Biomass Gasification Using a Molecular Beam Mass Spectrometer

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Thermochemical conversion (i.e. gasification) of biomass to produce renewable transportation fuels is a leading technology option for reducing U.S. dependence on foreign oil while relieving pressure on global food resources. The National Renewable Energy Laboratory (NREL), working with DOE's Biomass Program, has developed conceptual process designs and seeks to enable cost-competitive production of advanced lignocellulosic biofuels. Gasification of biomass produces a CO- and H_2-rich syngas; it also results in the co-formation of volatile, high-molecular-weight "tar" compounds that must be removed before downstream syngas processing. Tars can be catalytically converted into usable H_2 and CO, but quantitative measurement of these compounds is essential to assess the effectiveness of this approach. A transportable molecular beam mass spectrometer (MBMS), designed to be operated remotely, is being used at NREL to provide real-time, continuous monitoring of high-temperature, steam-laden process gas. It is equipped with several integrated system controls that allow it to interface with a variety of chemical process streams. It is able to sample gases and vapors directly from their reactive environment at elevated temperatures and at ambient pressure by using a three-stage, differentially-pumped vacuum system. Samples are extracted through an orifice and undergo free-jet expansion, causing rapid cooling and an abrupt transition to molecular flow sufficient to quench reactions and prevent condensation. The analyte is thus preserved in its original state, allowing light gases to be sampled simultaneously with heavier, condensable or reactive species without loss of sample. Components of the molecular beam are then analyzed with a commercial quadrupole mass spectrometer. Results are presented here from a parametric gasification study that evaluated several feedstocks and process parameters. A multivariate statistical study of the mass spectral data was undertaken to identify aspects of the system's global chemistry that can be used to minimize tar formation for the different feedstocks.