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Performance and Efficiency of a Biogas CHP System Utilizing a Stirling Engine

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Abstract A Stirling engine utilizes external combustion to produce heat and electricity. Due to the external combustion chamber, the engine can utilize a multitude of fuels including biogas or natural gas. The system used in this study is capable of producing about 7 kW of heat and 1 kW of electricity. Nitrogen is used as the "working fluid" in the engine. The heat from the combustion chamber is circulated through a cooling system making use of the thermal energy. The system includes a battery bank for energy storage and has been equipped with various instruments used to measure temperatures, pressures and flow rates of the fuel, the combustion air and the coolant. The engine is operated using natural gas as well as biogas and the engine characteristics for each are compared. The data collected is used to determine the system performance, thermal and electrical power outputs, individual and overall efficiencies, as well as exhaust emissions (O_2, CO, CO_2, NO_x and HC). This paper will present a detailed description of the CHP system, the instrumentation, the test procedures, the test data, analysis of the results and comparison of the biogas and natural gas test results.

Key Words

Stirling engine, CHP, Power Station, Biogas, external combustion, alternative fuels

1. Introduction

In 2010, Kettering University received a research grant from the United States Department of Energy (DOE) through the Michigan Economic Development Corporation (MEDC) to verify and improve process parameters for the production of biogas at the Flint Wastewater Treatment Plant and to determine the feasibility of utilizing biogas in transportation and power generation applications. A part of this project involved the selection, installation, instrumentation and testing of a Stirling engine combined heat and power (CHP) system. After considering numerous systems, a 24V DC WhisperGen Personal Power Station PPS16-24LG was selected, purchased and installed in the Automotive Laboratory at Kettering University.

One of the advantages of a Stirling engine is its external combustion. This allows the engine to run on a multitude of fuels where other engines cannot. The Stirling engine can be run on any fuel that will combust within the combustion chamber. These include gasoline, diesel, natural gas, propane, and biogas. Another advantage with the external combustion chamber is that the fuel does not have to be refined as it does for other types of engines. The external combustion also provides for more complete combustion resulting in less unburned hydrocarbons emitted in the exhaust.

One of the fuels we used for testing the Stirling engine was natural gas which is piped into the building from the local utility company. It consists of 96.4% methane, 1.5% ethane, 1.4% carbon dioxide, and trace amounts of nitrogen and propane.

The other fuel we used for our testing was biogas which consists of 62% methane, 37% carbon dioxide and 1% nitrogen (by volume). This blend of biogas is what the City of Flint Waste Water Treatment Plant will produce from their anaerobic digesters. Bio-methane is upgraded biogas and is close to natural gas in its composition and can be used in everyday applications. The Stirling engine can run on biogas which eliminates the need for further upgrading, process time and costs.