ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**LANDFILL GAS CLEANUP AND PHOSPHORIC ACID FUEL CELL SYSTEM**
APPLICATION:	**POWER PRODUCTION FROM WASTE LANDFILL GAS**
TECHNOLOGY NAME:	**GPU AND PC25 ™ 200 kW FUEL CELL**
COMPANY:	**INTERNATIONAL FUEL CELLS CORPORATION**
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PROGRAM DESCRIPTION

The U. S. Environmental Protection Agency's (EPA) Office of Research and Development has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of promising environmental technologies. Under this program, third party performance testing of environmental technology is conducted by independent Verification Organizations. Their goal is to objectively and systematically evaluate technology performance under strict EPA quality assurance guidelines. The EPA's Air Pollution Prevention and Control Division has selected Southern Research Institute as the independent Verification Organization to operate the Greenhouse Gas Technology Verification Center (the Center). With the full participation of the technology developer and users, the Center develops testing plans, and conducts field and laboratory tests. The test results are analyzed, peer reviewed, and then distributed to industry, regulatory, vendor, and other groups interested in the data.

TECHNOLOGY DESCRIPTION

For several years, International Fuel Cells (IFC) Corporation has employed the commercially available phosphoric acid fuel cell (PC25™) to generate electricity from natural gas. This fuel cell unit can also be used at municipal solid waste landfills to convert landfill gas into electric power. This application requires a supplemental gas treatment unit (GPU) to remove sulfur and halide compounds present in the landfill gas (LFG). The combined GPU and PC25™ Fuel Cell system provides a means for utilizing waste landfill gas, thus, reducing methane emissions and other air pollutants.

The design of the GPU is dictated by the gas purity requirements of the fuel cell, and the composition and physical properties of the incoming LFG. The cleaned waste gas is then converted into electric power for on-site use or distribution to an electric grid. In the GPU, hydrogen sulfide is first removed via adsorption on an activated carbon bed, which is used to catalyze the conversion of H_2S into elemental sulfur. Additional water, heavy hydrocarbons, sulfides, and other contaminants are removed through the removal system consisting of a low temperature cooler, carbon bed, dryer bed, and particulate filter. A heat exchanger is used to ensure the gas temperature meets fuel cell inlet requirements. The PC25™ fuel cell consists of a fuel processing system, an electrical conversion system, and a thermal management system. In the fuel processing section, treated LFG is converted to hydrogen and carbon dioxide for introduction into the fuel cell stack. The fuel treatment process consists of a low temperature fuel preprocessor which removes the residual contaminants from the treated gas, a fuel reformer, and a low temperature shift converter where the exhaust from the reformer is further processed. The hydrogen from the process fuel stream is then combined electrochemically with oxygen from the air to produce electricity in the fuel cell stacks. The DC current produced is converted into AC in a power-conditioning package. The PC25™ is designed to produce 200 kW of electric power from natural gas. With LFG, the PC25™ unit generates less power due to lower heating value of LFG.

VERIFICATION DESCRIPTION

This verification statement summarizes the results of tests conducted to verify the performance of a combined GPU and PC25™ fuel cell system operating on LFG. These tests were conducted at two sites where the LFG flow rates, composition, heating value, and contaminant levels are representative of the U.S. landfill population. The performance of the GPU was evaluated by comparing the sulfur and halogen concentrations in the GPU outlet gas with the levels required to effectively operate the fuel cell. The GPU operating availability was determined by dividing the length of time the unit was available by the total operating time of the GPU. The emissions characteristics of the GPU flare, which is used to combust the contaminants collected by the GPU, were measured to evaluate hazardous air pollutants emitted into the atmosphere. The performance of the fuel cell was evaluated by demonstrating the LFG to energy conversion process and by quantifying the power output. Total energy conversion efficiency of the power generation equipment, fuel cell availability, and fuel cell exhaust emissions were also measured.

The first verification test was executed at the Penrose site in Los Angeles, California. This test addressed contaminant removal efficiency by the GPU, flare destruction efficiency, and the operational availability of the cleanup system. The system was then relocated to the Groton Landfill in Connecticut where its performance was verified under different operating conditions. Details of the verification may be found in the report titled *Electric Power Generation Using A Phosphoric Acid Fuel Cell On A Municipal Solid Waste Landfill Gas Stream* (EPA-600/R-98-105). The verification report may be ordered through the National Technical Information Service or downloaded from the ETV Program or Center websites (www.epa.gov/etv or www.sri-rtp.com).

VERIFICATION OF PERFORMANCE

Performance Factors for the GPU:

- Halide and Sulfur Removal Efficiency: The fuel cell requires total halogen and total sulfur levels to be <3 ppmv in the GPU outlet stream. At Penrose, the GPU exceeded the removal requirements of both contaminants, with total halides reduced from 60 ppmv to ≤0.032 ppmv, and total sulfur reduced from 113 ppmv to ≤0.047 ppmv. The Groton performance results were similar, with total sulfur levels reduced to ≤0.022 ppmv and total halides to ≤0.014 ppmv.

- Estimated Flare Destruction Efficiency and CO/NO_X Concentrations: The destruction efficiencies of non-methane organic compounds and volatile organic compounds were estimated to be 99 percent. The conversion efficiency of sulfur compounds is also estimated to be about 99 percent. These efficiencies are based on an estimation of flare gas exhaust flow because the measured flow rate was below the EPA Method 2 detection limit. The NO_X and CO concentrations at the flare outlet averaged 10.4 ppmv and 3.0 ppmv, respectively.

- Operational Availability: The GPU logged 2,297 hours at Penrose and 4,168 hours at Groton (6,465 hours total). The GPU availability for the Penrose test was 87 percent. At Groton, the GPU availability decreased to 45 percent because of leaks caused by relocating the test equipment from California to Connecticut, and a malfunctioning gas compressor added at Groton to provide pressurized inlet gas. Once these mechanical failures were corrected, the GPU availability increased to 70 percent.

Performance Factors for the PC25™ Fuel Cell:

- Electrical Output: At the Penrose site, a nominal output of 140 kW was expected to be generated from the waste gas containing 44 percent methane (heating value of 446 BTU/scf). The test verified a maximum output of 137 kW. The heating value of the Groton LFG was higher, 581 BTU/scf and 57 percent methane, resulting in higher power production from the fuel cell (165 kW).

- Energy Conversion Efficiency: The fuel cell system energy conversion efficiency, based on lower heating values, was determined to be 37.1 percent at Penrose and 38.0 percent at Groton.

- Operational Availability: The adjusted availability for the fuel cell, which compensates for shutdowns not caused by the fuel cell, was over 96 percent at both test sites.

- Stack Emissions: The emissions from the fuel cell exhaust are consistent with the data measured from 16 other PC25™ units operating on natural gas. The average emissions were measured as follows (dry gas, corrected to 15 percent O_2): NO_X = 0.12 ppmv or 0.29 g/hr, SO_2 = non detectable (0.23 ppmv detection limit) or <0.78 g/hr, and CO = 0.77 ppmv or 1.15 g/hr.

The results of these tests satisfy the requirements set forth in the testing plan for the GPU and the fuel cell system. The GPU functioned according to its design specifications, purifying LFG to a level which was more than suitable for fuel cell use. The fuel cell produced power with no forced outages and provided consistently low secondary emissions. The electricity produced at both sites were connected to a local grid system and sold to utility companies.

Although the PC25™ 200 kW fuel cell system has been used on natural gas, this verification was the first application on LFG. This required the process design and engineering of a new GPU system to clean up the contaminants not present in natural gas. The costs for the GPU were higher at Penrose ($2,450/kW), and lower at Groton ($1,655/kW) due to reduced labor and start-up requirements. The cost for the PC25™ fuel cell was $3,000/kW. The vendor estimates that, with system simplifications, dedicated production facilities, and other cost reduction options, the GPU costs may eventually be reduced to $264/kW ($180/kW for equipment and material, $84/kW for labor). Similarly, the vendor estimates that $1,500/kW may eventually be the mature phase cost of the fuel cell. These cost estimates have not been independently verified.

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