THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

EPA

U.S. Environmental Protection Agency

SOUTHERN RESEARCH INSTITUTE

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**Natural-Gas-Fired Microturbine**
APPLICATION:	**Distributed Electrical Power Generation**
TECHNOLOGY NAME:	**Parallon® 75 kW Turbogenerator With CO Emissions Control**
COMPANY:	**Honeywell Power Systems, Inc.**
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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the purchase, design, distribution, financing, permitting, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups that consist of buyers, vendor organizations, and permitters, and with the full participation of individual technology developers. The program evaluates the performance of technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated, and that the results are defensible.

The Greenhouse Gas Technology Center (GHG Center), one of six verification organizations under the ETV program, is operated by Southern Research Institute, in cooperation with EPA's National Risk Management Research Laboratory. The GHG Center has recently evaluated the performance of the Parallon® 75 kW Turbogenerator (Turbogenerator) which is offered by Honeywell Power Systems, Inc. of Albuquerque, New Mexico. A second test of this technology was repeated after installation of an optional carbon monoxide (CO) emissions control system. This verification statement provides a summary of the test results for the

Turbogenerator with the CO emissions control installed.

TECHNOLOGY DESCRIPTION

Large- and medium-scale gas-fired turbines have been used to generate electricity since the 1950s. Recently, they have become a preferred source of additional generation capacity because of their ability to provide electricity at the point of use. Technical and manufacturing developments have occurred in the last decade that have enabled the introduction of microturbines, with generation capacity ranging from 30 to 200 kW. The Turbogenerator represents a new generation of compact natural-gas-fired microturbines with the capability to produce approximately 75 kW of 3-phase electricity at 275 volts alternating current (VAC). This distributed energy technology generates electricity at a site closer to customers than a central power station, and can be connected directly to the customer and to existing transmission and distribution lines. The power electronics within the standard Turbogenerator allow the system to operate in parallel with the utility grid to provide stand-by generation (i.e., emergency backup power), peak shaving, baseload generation, or cogeneration (combined heat and power generation). A stand-alone or isolated configuration requires an optional "black start" battery to provide starting current to the power system.

The Turbogenerator operates on natural gas at a fuel pressure ranging from 75 to 125 psig. An optional booster compressor is offered which allows low-pressure natural gas to be pressurized to these operating conditions. The Turbogenerator consists of two main sections: an engine and an electrical section. In the engine section, filtered air enters the compressor where it is pressurized. It then enters the recuperator, which is a heat exchanger that adds heat to the compressed air using exhaust heat. The air then enters the combustor where it is mixed with fuel and heated further by combustion. The resulting hot gas is allowed to expand through the turbine section to perform work, rotating the turbine blades to turn a generator that produces electricity. The compressor is mounted on the same shaft as the electrical generator, and consists of only one rotating part. Because of the inverter-based electronics that enable the generator to operate at high speeds and frequencies, the need for a gearbox and associated moving parts is eliminated. The high-speed rotating shaft is supported by airfoil bearings, and does not require lubrication. The exhaust gas exits the turbine and enters the recuperator, which captures some of the energy and uses it to preheat the air entering the combustor, improving the overall efficiency of the system. The exhaust gas then exits the recuperator through a muffler with sufficient heat energy for cogeneration applications, or alternatively, for release to the atmosphere.

The permanent-magnet generator produces high frequency alternating current, which is rectified, inverted, and filtered by the line power unit into conditioned alternating current at 275 volts. This can be converted to the voltage level required by the facility using either an optional internal transformer (120/208 VAC) or external transformers for distribution. The unit supplies a variable electrical frequency of 50 or 60 hertz (Hz). The Turbogenerator is supplied with a control system, which allows for automatic and unattended operation. All operations, including startup, synchronization with the grid, dispatch, and shutdown, can be performed manually or remotely using an optional Supervisory Control and Data Acquisition (SCADA) system.

The optional CO emissions control technology, manufactured by Honeywell, was installed on the test Turbogenerator. This technology is proprietary to Honeywell and a detailed description of the CO emissions control system is not included here, but is identified as Turbogenerator Part Number 721836-0001.

VERIFICATION DESCRIPTION

An initial verification of the Turbogenerator focused on evaluation of electrical power production and emissions performance at four load conditions within the normal operating range of the unit including 100, 90, 75, and 50 percent of rated power [*Environmental Technology Verification Report for the Honeywell Power Systems, Inc. Parallon® 75 kW Turbogenerator* (SRI 2001)]. The verification goal was to compare electrical efficiency and emissions performance after installation of the CO control system with data collected during the initial testing. Emissions testing was conducted at 75 and 50 percent load because CO emissions were not detected at 100 and 90 percent loads during earlier testing of the uncontrolled unit. CO was detected only at the lower loads. The testing also included determination of electrical power output and electrical efficiency for comparison with the power production and efficiency values measured during the initial verification. The specific verification factors associated with the testing are:

- **Electric Power Production**
- **Electrical Efficiency**
- **Emissions Performance (NO_x, CO, THCs, CO_2, and CH_4)**

Evaluation of power production performance includes the verification of power output, heat input, and electrical efficiency at the selected loads. Electrical efficiency was determined according to the ASME Performance Test Code on Gas Turbines (PTC-22), and consisted of direct measurements of fuel flow rate, fuel heating value, and power output. Ambient temperature, barometric pressure, and relative humidity measurements were also collected to characterize the condition of intake air.

Emissions performance evaluations occurred simultaneously with electrical efficiency determinations at the two lower load points. Pollutant concentration and emission rate measurements for nitrogen oxides (NO_x), carbon monoxide (CO), total hydrocarbons (THCs), carbon dioxide (CO_2), and methane (CH_4) were conducted in the turbine exhaust stack. All test procedures used in the verification were U.S. EPA Federal Reference Methods, and followed the NSPS guidelines for stationary gas turbines. Pollutant concentrations in the exhaust gas are reported as parts per million (ppm) corrected to 15 percent oxygen (O_2), and mass emission rates are reported as pounds per hour (lb/hr). The mass emission rates are also normalized to turbine power output and reported as pounds per kilowatt hour (lb/kWh).

The verification test was conducted at a commercial office facility operated by the University of Maryland, College Park. The University's Center for Environmental Energy Engineering (CEEE) has established a test facility at the office building. The CEEE test facility examines distributed energy conversion systems and heating, ventilation, and air-conditioning (HVAC) systems for buildings in cooperation with private industry and government groups. The Turbogenerator was connected to the electric grid system and provided about 30 percent of the electricity requirements for the 55,000 ft^2 office building. It was equipped with an optional booster compressor and a 480-volt transformer. The unit was programmed to operate during normal business hours (9:00 am to 5:00 pm weekdays), at full load (75 kW nominal).

VERIFICATION OF PERFORMANCE

Power Production Performance

- During the initial verification, all load tests occurred near standard conditions (ambient temperature: 62 to 66 ^oF; barometric pressure: 14.64 to 14.65 psia; relative humidity: 55 to 63 percent). During the repeat testing with CO control, the temperature ranged from 52 to 56^oF and relative humidity was steady at approximately 91 percent.

- Power delivery by the Turbogenerator after installation of the CO control was consistent with power delivered by the standard Turbogenerator.

- Electrical efficiency after installation of the CO control was approximately 2 percent lower than efficiency measured on the standard Turbogenerator as a result of higher fuel consumption rates at each load tested.

Honeywell has cited a weak permanent-magnet generator, combined with lower ambient temperatures encountered during the tests, as the reasons for lower efficiencies. The weak generator in the test unit produced lower voltage such that the system could not be run to its maximum turbine exit temperature. The lower ambient temperatures observed during the CO control test magnified this weakness, and resulted in further reduction in cycle efficiencies.

Test Condition		Standard Turbogenerator		Turbogenerator with Optional CO Emissions Control	
% of Rated Power	Power Command (kW)	Power Delivered[a] (kW)	Electrical Efficiency[a] (%)	Power Delivered[a] (kW)	Electrical Efficiency[a] (%)
100	75	71.26	23.45	71.15	21.53
90	68	64.71	23.22	64.66	21.40
75	56	53.36	22.71	53.04	20.63
50	38	35.90	19.81	35.69	17.87
[a] Includes energy consumed by booster compressor and 480 volt transformer					

Emissions Performance

- CO emissions were essentially eliminated after installation of the CO control. Emission rates were below the lower detection limit of the sampling system (approximately 2 ppm).

Test Condition		Standard Turbogenerator Emissions (lb/kWh)				Turbogenerator Emissions with Optional CO Control (lb/kWh)			
% of Rated Power	Power Command (kW)	NO_x	CO	THCs	CO_2	NO_x	CO	THCs	CO_2
75	56	0.0015	0.0019	< 0.0001	1.77	0.0017	< 0.0002	< 0.0001	1.81
50	38	0.0026	0.0295	0.0011	2.10	0.0026	< 0.0002	0.0036	2.37

- NO_x emissions were not significantly changed by use of the CO control system. Emissions of hydrocarbons increased slightly at the lowest power command. Emissions of CO_2 increased by approximately 2 percent at 75 percent of capacity power and 13 percent at the lowest power command after installation of the CO control. Emissions of THCs also increased at low load. Increases in CO_2 and THCs emissions are likely related to the higher fuel consumption rates that occurred during these tests.

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