THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

SOUTHERN RESEARCH INSTITUTE

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**Air/Fuel Ratio Controller**	
APPLICATION:	**Gas-fired, Lean-burn Reciprocating Engines**	
TECHNOLOGY NAME:	**GECO™ 3001 Air/Fuel Ratio Controller**	
COMPANY:	**MIRATECH Corporation**	
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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 GECO 3001™ Air/Fuel Ratio Controller (Controller) which is offered by MIRATECH Corporation of Tulsa, Oklahoma. This verification statement provides a summary of the results obtained during testing of the controller

TECHNOLOGY DESCRIPTION

As engine operations and conditions change over time, engine performance and emissions can be affected by these changes. Variables such as engine speed and load, fuel gas quality, and ambient air conditions can have significant effects on engine operation and the air/fuel ratio in the cylinders. The GECO Controller is an air/fuel ratio controller designed to improve performance of natural-gas-fired, four-cycle, lean-burn reciprocating engines by optimizing and stabilizing the air/fuel ratio over a range of engine operations and conditions.

The technology uses a closed-loop feedback system that automatically and continuously optimizes the air/fuel mixture introduced to the engine. This function provides the potential to improve engine fuel consumption and reduce engine emissions, particularly when changes in engine load, fuel quality, or ambient conditions occur. The Controller can be configured to operate based on engine exhaust oxygen (O_2) feedback, or generator output (kW) feedback for engines used to drive electrical generators. Using either approach, the controller monitors the O_2 or kW sensor inputs and controls the air-to-fuel ratio generated by the carburetor.

The Controller uses relationships between excess air in the combustion chamber, measured exhaust gas O_2 concentrations, and engine emissions to calculate optimum air/fuel ratios at various engine loads. Using exhaust gas O_2, intake air manifold pressure (MAP), intake air manifold temperature (MAT), and engine speed (MAG-pickup) as primary indicators of engine operation, the Controller continuously adjusts air/fuel ratios in the engine by adjusting and controlling fuel flow to the carburetor. Fuel flow is adjusted using a full authority fuel valve supplied by the vendor and installed directly into the engine fuel line upstream of the carburetor/mixer. After all system components are installed on an engine and confirmed to be functional, the Controller must then be programmed to control air/fuel ratios to the levels most desirable for a specific engine and application.

The Controller can be used in three different modes of operation: open-loop, closed-loop, and manual. When the engine is started, the Controller sets the fuel valve to a crank default position that can be preset as desired. The valve remains in this position until the engine reaches 400 rpm, at which point the Controller goes into open-loop mode and sets valve positions according to a pre-programmed valve learn table. The Controller will operate in open-loop mode until the pre-programmed target air/fuel ratio is surpassed, at which point the Controller will go into closed-loop mode of operation. Once in closed-loop mode, the Controller uses input signals for engine speed and air pressure (the MAG-pickup and MAT sensors) to look up the target valve positions from the pre-programmed valve table, and set the valve at that position to optimize the air/fuel ratio. Manual mode is primarily a troubleshooting tool that allows the user to disable the Controller and manually control the fuel valve to program the controller during system installation and setup and to observe the sensor and emissions responses.

VERIFICATION DESCRIPTION

This verification test was designed to quantify changes in engine fuel consumption rates, criteria pollutant and greenhouse gas (GHG) emissions, and oil degradation rates that occur with the use of the Controller. The evaluation was designed to characterize, via measurements and other means, the following verification parameters:

- Changes in fuel consumption rates (Btu/BHp-hr)
- Changes in nitrogen oxide (NO_x), carbon monoxide (CO), total hydrocarbon (THC), carbon dioxide (CO_2), and methane (CH_4) emissions (g/BHp-hr)

- Controller installation requirements (labor and capital)
- Lubrication oil degradation rates (extended Phase II evaluation)

Evaluations of changes in fuel consumption rates and engine emissions were conducted over a 4-day period after completion of Controller installation, shake-down, and start-up activities. Evaluation of oil degradation rates will continue over an additional 3- to 4-month period and be reported separately. To verify the effects of the Controller on engine performance, each of the parameters was evaluated with and without the use of the Controller on the Test Engine. The verification parameters were evaluated using the following comparisons:

- Engine fuel consumption rate, engine emissions, and emissions reductions were evaluated by conducting a series of tests at different engine operating setpoints. During each test, measurements were collected with the Controller enabled, and then repeated with the Controller disabled.

- An extended evaluation of lubrication oil degradation rates will be conducted by comparing the oil characteristics of the engine equipped with the Controller (Test Engine) to the oil in another identical engine (Control Engine) that is not equipped with a Controller.

Evaluation of fuel consumption rate includes the verification of engine power output and fuel heat input during each test period. Fuel consumption rate was determined according to the ASME Performance Test Code for Reciprocating Internal Combustion Engines, and consisted of direct measurements of fuel flow rate, fuel heating value, and power output. Ambient temperature and relative humidity measurements were also collected to characterize the condition of intake air. Emissions performance evaluations occurred simultaneously with fuel consumption rate determinations during each test period. Pollutant concentration and emission rate measurements for NO_x, CO, THCs, CO_2, and CH_4 were conducted in the engine exhaust stack during the tests. All test procedures used in the verification were U.S. EPA Reference Methods for emissions measurements. Pollutant emission rates are reported in units of grams per brake horsepower-hour (g/BHp-hr).

Verification testing was conducted on lean-burn internal combustion engines (Caterpillar Model 3516-LE), with a rated power output of 1,085 BHp. The engines were equipped with reciprocating gas compressors (Ariel Model JGK) that elevated pipeline gas pressure from 250 to 850 pounds per square inch.

VERIFICATION OF PERFORMANCE

Twelve comparison test runs were conducted during the field testing. Of these, three were conducted under normal engine operations with the unit at full load, and another three were conducted at reduced engine load (approximately 80 percent of capacity). The remaining six comparisons were conducted during abnormal station and engine operation and were invalidated (the fuel heating value was atypically high during these periods). Results of the tests conducted during system installation and normal engine operations are summarized below.

Engine Fuel Consumption Rate

During each of the comparison test periods, changes in fuel consumption rates were so small that the GHG Center is unable to state with certainty the level of fuel use change that occurs with the use of the Controller. Because fuel consumption rates were so similar with the Controller enabled and disabled, any differences observed during the test periods are within the overall uncertainty of the measurements.

Summary of Fuel Consumption Rate Test Results					
Test Number	**Controller Mode of Operation**	**Engine Power Output (BHp)**	**Heat Input (MMBtu/hr)**	**Fuel Consumption Rate (Btu/BHp-hr)**	**Percent Reduction[a]**
1	Enabled	831	7.318	8805.7	(0.4)
	Disabled	856	7.510	8772.8	
10	Enabled	843	7.628	9049.2	(1.5)
	Disabled	843	7.514	8913.7	
11	Enabled	817	7.524	9209.8	(0.6)
	Disabled	813	7.442	9153.7	
Average change in fuel consumption rate at full load with normal LHV[b]					**(0.8)**
2	Enabled	722	6.558	9082.4	0.8
	Disabled	739	6.765	9153.6	
12	Enabled	724	6.856	9469.5	(2.3)
	Disabled	722	6.680	9251.8	
13	Enabled	724	6.885	9509.4	(1.2)
	Disabled	720	6.766	9397.0	
Average change in fuel consumption rate at reduced load with normal LHV					**(0.9)**

[a] Values in parentheses indicate percent increases
[b] LHV = fuel lower heating value

Emissions Performance

With the Controller enabled, significant reductions in NO_x emissions were evident during all of the test periods with reductions averaging 30.5 and 31.5 percent lower at full and reduced operating loads, respectively. Variability in NO_x emissions was also reduced when the Controller was enabled. At the same time, small reductions in CO emissions were also achieved through use of the Controller. Emissions data collected during abnormal station operations are not included in the summary table, but indicated that, potentially, reduction of NO_x emissions is even greater during these periods. THC, CH_4, and CO_2 emissions increased during the test periods.

Summary of Changes in Engine Emission Rates						
Test ID	**Engine Operation**	**Reduction[a] in Engine Emissions (%)**				
		NO_x	**CO**	**THC**	**CH_4**	**CO_2**
1	Full Load	18.1	9.9	22.3	23.0	(0.9)
10		38.6	3.1	(11.6)	(11.7)	(1.1)
11		34.9	2.3	(4.3)	(4.0)	(0.2)
Average Change		**30.5**	**5.1**	**(2.1)**	**(2.4)**	**(0.7)**
2	Reduced Load	19.1	3.6	(9.2)	(8.8)	0.6
12		38.2	2.2	(14.0)	(13.8)	(1.9)
13		32.7	1.5	(9.9)	(9.9)	(1.2)
Average Change		**30.0**	**2.4**	**(11.0)**	**(10.8)**	**(0.8)**

[a] Values in parentheses indicate percent increases

Controller Installation Requirements

Four technicians from the installation contractor were on site to install the system components, a power supply, and conduit. A total of 24 man-hours were spent installing the system. A significant portion of this time (approximately 60 percent) was involved in cutting, bending, and installing the conduit around the engine components to run the signal cables to the Controller. Programming of the Controller required approximately 4 hours of labor for the MIRATECH engineer. Additionally, emissions measurements were required during programming activities. In this case, the emissions testing contractor was on-site for the verification testing and provided this service. Otherwise, a portable emissions analyzer and operator would be required to assist with the programming. Capital costs associated with procurement and installation of the Controller were provided by MIRATECH and are summarized as follows:

Controller and all system components	$9,750
24-volt DC power supply (application specific):	$750
Conduit and other miscellaneous materials (application specific):	no charge
Installation contractor labor (24 hours at $48/hr)	$1,152
Total system installation cost:	$11,652

The labor and capital costs reported here represent installation at the test facility only. Other applications where power is previously available, or conduit installation is less complicated, may reduce the total cost.

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