THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

EPA
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SOUTHERN RESEARCH INSTITUTE

ETV Joint Verification Statement – Phase II

TECHNOLOGY TYPE:	**Air/Fuel Ratio Controller**
APPLICATION:	**Gas-fired, Lean-burn Reciprocating Engines**
TECHNOLOGY NAME:	**GECO™ 3001 Air/Fuel Ratio Controller**
COMPANY:	**MIRATECH Corporation** **(Manufactured by Woodward Governor Company)**
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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 ETV 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 and Quality Assurance Plans (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 ETV, is operated by Southern Research Institute, in cooperation with EPA's National Risk Management Research Laboratory. The GHG Center has recently completed the Phase II evaluation of 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/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 preprogrammed valve learn table. The Controller will operate in open-loop mode until the preprogrammed 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 preprogrammed 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 characterize, during two phases of testing, the following verification parameters:

PHASE I:

- 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)

PHASE II:

- Lubrication oil degradation (extended evaluation)

The Phase I evaluation was conducted over a 4-day period after completion of Controller installation, shakedown, and start-up activities. Installation and programming of the Controller was completed on June 19, 2001, and Phase I field testing for fuel consumption and engine emissions was conducted from June 20 to 23, 2001. Results of the Phase I evaluation were previously reported in a separate Verification Report and Statement, which can be obtained online at the GHG Center Web site (www.sri-rtp.com) or the U.S. EPA ETV Web site (www.epa.gov/etv). Primary conclusions from the Phase I evaluation are listed below.

- Little or no reduction in fuel consumption rates occurred with use of the GECO 3001 controller,
- NO_x emission reductions of about 30 percent occurred over a range of load conditions with use of the controller, and
- Total installed cost of the controller at the host site was $11,652 in 2001.

The Phase II evaluation of oil degradation continued over an extended 8-month period, beginning with an initial fresh oil charge in June 2001. Lubrication oil degradation was evaluated by comparing the oil characteristics of one engine equipped with the Controller (Test Engine) to the oil characteristics of a second but identical engine without the Controller (Control Engine).

Both engines were equipped with fresh oil in June 2001, 2 weeks prior to the Phase I testing. The first set of oil samples was collected on June 23 immediately after completion of the Phase I testing, and sampling continued through February 6, 2002. The Test Engine was operated while the Controller continuously controlled air/fuel ratios. Engine lubrication oil samples were collected on a monthly basis for the duration of the 8-month verification period, and these samples were sent to a laboratory where the key lubrication oil properties listed below were measured. Differences in these oil properties between the Test and Control Engines were assessed in an effort to examine the Controller's impact on lubrication oil quality.

Lubrication Oil Analyses

Verification Parameter	Reference Method	Principle of Analysis	Reporting Units
Oxidation	Not Specified	Fourier-Transform Infra-red Spectroscopy	absorbance per centimeter (cm)
Nitration	Not Specified	Fourier-Transform Infra-red Spectroscopy	absorbance per centimeter (cm)
Viscosity @ 40^{o}C	ASTM-D445	Kinematic	centistokes (cSt)
Total Acid Number	ASTM-D974	Potentiometric Titration	mg KOH/g

Station operating logs were used to document the operating hours of both engines during the verification period. In order to make a meaningful comparison of oil degradation rates on the two engines, operating hours needed to be similar. The engines operated on the same schedule and for a similar number of hours throughout the verification period.

Differences in the Test and Control Engines' oil properties listed above were characterized and these differences were used to determine if the Controller helps reduce lubrication oil quality degradation.

VERIFICATION OF PERFORMANCE

Both engines received fresh charges of engine oil on June 2, 2001, and again on October 11, 2001. The testing was concluded after the second charge of oil was removed in February 2002. During the 8-month verification period, engine operating hours were nearly identical with the Test Engine logging 5,790 hours and the Control Engine logging 5,859 hours. The Controller continuously controlled the air/fuel ratios on the Test Engine during the entire period while, during the same period, the Control Engine operated normally.

After removing outliers from the sampling results, differences between the Test and Control Engines' oil properties were examined. For each sample pair collected on the same day, the GHG Center subtracted oil properties measured for the Test Engine from the same oil properties measured for the Control Engine. The Overall Average Percent difference between the Test and Control Engines was then calculated as shown below and used to assess the significance of differences found between the two engines.

Overall Average Percent Difference for Viscosity =

100*[average of all viscosity differences/average of all control engine viscosity values]

Any significant differences found were examined to assess if use of the Controller was a likely cause of the differences observed.

- **Nitration**: The amount of lubrication oil nitration in the Test Engine was 21 percent less than the level of nitration associated with the Control Engine. This improvement in oil quality is consistent with the Phase I finding that NO_x emissions were reduced by about 30 percent, and that exposure of lubrication oil to acid gases like NO_x increases nitration as combustion gases or "blow-by" mix with lubrication oil in the crank case.

- **Oxidation, Viscosity, and Total Acid Number**: There appear to be no consistent and significant difference between the oxidation, viscosity, and total acid numbers for the Control Engine, and the values of these parameters for the Test Engine. Overall Average Percent Difference values for all three parameters were 2 percent or less.

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Notice: GHG Center verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. The EPA and Southern Research Institute make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate at the levels verified. The end user is solely responsible for complying with any and all applicable Federal, State, and Local requirements. Mention of commercial product names does not imply endorsement or recommendation.