THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

SOUTHERN RESEARCH INSTITUTE

ETV Joint Verification Statement

TECHNOLOGY TYPE:	Diesel Engine Retrofit Crankcase Ventilation System
APPLICATION:	Heavy Duty Diesel Engine
TECHNOLOGY NAME:	The Condensator
COMPANY:	New Condensator, 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 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. One sector of significant interest to GHG Center stakeholders is transportation - particularly technologies that result in fuel economy improvements and emission reductions. The GHG Center recently evaluated the performance of a technology that is planned for use as a retrofit device for existing light and heavy duty diesel engines. Many on and off-road heavy duty diesel engines have an open crankcase and blow-by tube, especially on older vehicles. On these engines, crankcase blow-by is emitted directly to the atmosphere through the blow-by tube, resulting in emissions of particulate matter (PM), carbon monoxide (CO), hydrocarbons (THC), and other pollutants. The Condensator technology, offered by New Condensator, Inc. of Grass Valley, California (NCI), is applicable to diesel engines that have open crankcase ventilation systems. NCI's Condensator is designed to capture and filter these emissions. This verification statement provides the results of the Condensator performance verification.

TECHNOLOGY DESCRIPTION

The following technology description is based on information provided by NCI and does not represent verified information. This technology is applicable to light- to heavy-duty vehicles, both on- and off-road, and is also available for marine and generator applications. The Condensator is designed to collect and filter the blow-by exhaust from the crankcase and re-route exhaust vapors back to the engine air intake. This removes particulate from the blow-by exhaust and creates a closed crankcase system. NCI claims that enhanced fuel economy, reduced opacity, reduced emissions, and containment of the blow-by gases are the benefits of using this technology. A Model 2DX Condensator was used for this verification.

The Model 2DX Condensator consists of a blow-by manifold, two Condensator containers, and associated tubing to route filtered exhaust gases back to the engine intake. The two Condensator containers are arranged in parallel and hold the collected waste/sludge. Each contains a silica bead separator system that filters the crankcase exhaust. Rubber hoses are used to connect the Condensator containers to the air intake and blow-by tube. Hose clamps keep the hoses in place. NCI requires the Condensator unit to be installed away from extreme heat such as exhaust manifolds.

According to NCI, crankcase exhaust comes in contact with silica bead separators in the Condensator, resulting in a molecular separation process where large, heavier oil molecules condense and collect in the Condensator containers. Water and acid present with the oil will also drop into the containers. Gaseous emissions, including hydrocarbons, continue through the system and are vented back into the engine air intake. Waste oil and condensate collected in the Condensator containers should be emptied during vehicle oil changes. The separators are cleaned periodically in a solvent to dislodge and remove any carbon or sludge that may have attached to the silica beads.

VERIFICATION DESCRIPTION

The verification testing was conducted in January 2005 to evaluate the performance on the Condensator technology on a 1997 Cummins N-14 370 HP turbocharged diesel engine. Verification tests were conducted at Southwest Research Institute's (SwRI) Department of Engine and Emissions Research (DEER) in San Antonio, TX. The testing was planned and executed by the GHG Center to independently verify the change in fuel economy and engine emissions resulting from the use of the Condensator.

The primary verification parameters were changes in fuel economy expressed as brake specific fuel consumption (BSFC) and engine PM emissions. Determination of emissions of NO_X, CO, CO_2, THC, and methane (CH_4), were also conducted as secondary verification parameters. Improvement in engine performance for the primary parameters is expressed as the mean change, or delta (Δ), between results from tests conducted on the engine without the Condensator (baseline tests) and with the Condensator installed (modified engine tests). Modified engine tests include initial testing immediately after installation of the Condensator and cumulative testing after operating the engine with the Condensator installed over a 45-hour durability cycle break-in period. The verification's data quality objective (DQO) for these parameters was to demonstrate a statistically significant delta of 10 percent or greater. A detailed discussion of the data analysis and statistical procedures can be found in the test plan.

The testing was conducted following the approach and procedures specified in the test plan and the ETV *Generic Verification Protocol (GVP) for Diesel Exhaust Catalysts, Particulate Filters, and Engine Modification Control Technologies for Highway and Nonroad Use Diesel Engines*. The GVP makes use of the Federal Test Procedure (FTP) as listed in 40 CFR Part 86 for highway engines as a standard test protocol. Specific details regarding the FTP, measurement equipment, and statistical analysis of results can be found in the test plan titled *Test and Quality Assurance Plan for the New Condensator, Inc. – The Condensator Diesel Engine Retrofit Crankcase Ventilation System* (SRI/USEPA-GHG-QAP-36) and the GVP.

Quality Assurance (QA) oversight of the verification testing was provided following specifications in the ETV Quality Management Plan (QMP). The GHG Center's QA manager conducted an audit of data quality on at least 10 percent of the data generated during this verification and a review of the report. Data review and validation was conducted at three levels including the field team leader (for data generated by subcontractors), the project manager, and the QA manager. Through these activities, the QA manager has concluded that the data meet the data quality objectives that are specified in the Test and Quality Assurance Plan. Both documents can be downloaded from the ETV Program web-site (www.epa.gov/etv).

The verification evaluated baseline engine performance without the Condensator, immediate effect on performance after installation of the Condensator, and cumulative engine performance after operating the engine with the Condensator for a period of 45 hours. The general sequence of test events was as follows:

1. Install and inspect the test engine;
2. Change the engine oil and filter and conduct 25-hour break-in run;
3. Map the baseline engine (develop torque curve);
4. Precondition and soak the baseline engine;
5. Perform baseline engine testing for exhaust emissions, blow-by emission, and fuel consumption;
6. Install the Condensator system;
7. Map the modified engine;
8. Precondition and soak the modified engine;
9. Perform modified engine testing for exhaust emissions and fuel consumption;
10. Perform 45 hour modified engine durability break-in period;
11. Repeat the modified engine testing for exhaust emissions and fuel consumption;
12. Evaluate the test data for data quality; and
13. Complete additional testing as necessary to achieve data quality objectives.

The test runs consisted of operating the test engine over the specified FTP test cycle for one cold-start test, and a minimum of three hot-start tests for both the baseline and modified engine. During each test run, BSFC was evaluated over the FTP transient cycles along with engine emissions of NO_x, PM, THC, CO, CO_2, and CH_4. BSFC is the ratio of the engine fuel consumption to the engine power output expressed in units of pounds mass of fuel per brake horsepower-hour (lb/Bhp-hr). PM samples collected from the blow-by tube during the baseline engine testing were also analyzed for soluble organic fraction (SOF) after the gravimetric particulate determination.

VERIFICATION OF PERFORMANCE

The Condensator system was installed by a Cummins technician without problems, and installation was approved by NCI representatives. The presence of the Condensator did introduce an impact on the engine's crankcase pressure. By routing the crankcase blow-by vent to the engine air intake, the Condensator changed the crankcase pressure from ambient to a vacuum in the range of 8 to 20 inches of water (depending on engine speed and torque). After consulting with the Cummins technician, testing was continued because the engine was operating normally and power output was approximately the same as before installation of the Condensator. No other impacts on engine performance were observed, the open crankcase was closed, and the blow by emissions (essentially all unburned organic material) were successfully routed back into the engine.

Results of the BSFC and PM emissions testing are summarized in Tables S-1 and S-2. Table S-3 summarizes results for the secondary emissions parameters.

Table S-1. BSFC Results

Parameter	Baseline Tests	Initial Condensator Tests	Cumulative Condensator Tests
Mean BSFC (lb/Bhp-hr)	**0.390**	**0.392**	**0.3857**
Standard deviation (lb/Bhp-hr)	0.003	0.004	0.0014
BSFC delta (lb/Bhp-hr)	--	0.002	-0.003
BSFC delta (%)	--	0.4	-0.8
Statistically significant change?	--	No	No

- Installation of the Condensator did not result in statistically significant changes in the test engine's BSFC.

Table S-2. PM Emissions and Statistical Analysis

Parameter	Baseline Tests	Initial Condensator Tests	Cumulative Condensator Tests
Mean PM emissions (g/Bhp-hr)	**0.1133**	**0.1021**	**0.109**
Standard deviation (g/Bhp-hr)	0.0010	0.0009	0.003
PM delta (g/Bhp-hr)	--	-0.011	-0.005
PM delta (%)	--	-9.8	-4.0
Statistically significant change?	--	Yes	No

- By eliminating the crankcase blow-by emissions point, total engine PM emissions were immediately reduced by 9.84 percent, ± 1.8 percent statistical uncertainty, after installation of the Condensator. PM emissions dropped from 0.113 to 0.102 g/Bhp-hr. After the 45 hour break-in period, total engine PM emissions increased slightly to 0.109 g/Bhp-hr, resulting in a reduction from the baseline emission level of 4.04 percent. This change was not statistically significant according to the analysis used here.

- The SOF analyses conducted on the PM samples collection from the blow-by tube indicated that essentially all of the PM collected was soluble organic material (SOF was 100 percent).

Table S-3. Mean Composite Engine Emission Rates

Parameter	Mean Composite Baseline Emissions (g/Bhp-hr)	Mean Composite Initial Condensator Emissions (g/Bhp-hr)	% Decrease (Increase)	Mean Composite Cumulative Condensator Emissions (g/Bhp-hr)	% Decrease (Increase)
NO_X	4.59	4.62	(0.6)	4.51	1.8
CO	0.746	0.721	0	0.708	5
CO_2	561	563	(0.4)	556	0.9
THC	0.203	0.206	(1)	0.226	(11)

- Statistical analyses were not specified for the secondary verification parameters. The data indicate that NO_X and CO_2 emissions were essentially unchanged after installation of the Condensator and CO emissions were reduced by approximately 5 percent after break-in. Emissions of THC were extremely low during all test periods (generally less than 9 parts per million). Emissions of CH_4 were not detected and are considered negligible.

Detailed results of the verification are presented in the final report titled *Environmental Technology Verification Report for New Condensator, Inc. – The Condensator Diesel Engine Retrofit Crankcase Ventilation System* (SRI 2005). Copies of the report or this verification statement can be downloaded from the GHG Center's web-site (www.sri-rtp.com) or the ETV Program web-site (www.epa.gov/etv).

Signed by Sally Gutierrez (8/26/2005)

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