U.S. Army Aberdeen Test Center Support of Heavy Duty Diesel Engine Emissions Testing

Jason A. Jack
U.S. Army Aberdeen Test Center, CSTE-DTC-AT-SL-E,
Aberdeen Proving Ground, MD 21005-5059
jason.jack@atc.army.mil

ABSTRACT

The U.S. Army Aberdeen Test Center (ATC), located at Aberdeen Proving Ground, MD, supports the U.S. Environmental Protection Agency (EPA) in its heavy duty diesel engine emissions compliance program by providing program management, test procedure development, instrumentation application, equipment operation, data collection, reduction, and analysis. Personnel in ATC's Military Environmental Technology Demonstration Center (METDC) work closely with members of the EPA's Certification and Compliance Division (CCD) to plan, perform, and report in-use heavy duty diesel engine compliance testing.

This program originated in 1999 in response to a consent decree settlement between EPA and various heavy-duty diesel engine manufacturers. The settlement resolved claims that manufacturers illegally utilized software control strategies that enabled the engine to comply with emissions standards during laboratory testing, but, not during in-use operations. The manufacturers agreed to pay penalties, meet 2004 standards early, and comply with new in-use not-to-exceed (NTE) standards for Oxides of Nitrogen (NO_x).

Since 2000, under an Inter-Agency Agreement (IAG) with the EPA, ATC has served as the independent tester for EPA CCD. From 2000 – 2002, ATC performed mainly a data collection function in operating EPA's Real-time On-road Vehicle Emissions Reporter (ROVER) and reporting the raw data directly to EPA. Since 2003, this program has developed into a testing program which requires a team of 3-4 technicians, a chemist for data analysis, and scientist test director. Currently, ATC personnel procure test items, schedule testing, instrument and operate the ROVER system during testing, perform data reduction and analysis, and transfer data to EPA and program participants.

ROVER testing by ATC involves non-road test procedure development, technology comparison, idle, variable, durability, and marathon testing. Tests on non-road engines has been conducted mainly to study possible ways of loading a non-road engine and reading emissions during these various engine loads. Technology comparisons were conducted with EPA SmartWay in operating two ROVER systems on two identical tractor trailers over predetermined track scenarios. One of the tractor trailers was the control and the other was tested with various aerodynamic and single wide based tire configurations. Idle testing is conducted in ATC cold room test chambers at various temperatures. Variable testing with ROVER involves testing engines with different drivers, altitudes, and during various seasons (temperature differences). Durability

testing involves testing the same engines each year to determine if there are any changes in emissions of older engines as they are operated over a long period of time. Marathon tests involve testing an engine from ATC, located in Maryland, to points west, including Colorado and New Mexico. These tests result in emissions data from over three thousand total miles of engine operation under various conditions, including different drivers, wide ranges of temperature, altitude, and traffic patterns.

ATC has been an integral part in EPA's heavy-duty in-use emissions compliance efforts and has contributed program oversight, quality testing, and results to EPA. This program has developed into one which EPA can continually monitor engine manufacturer's NO_x NTE compliance under various conditions and use results to verify the progress of the manufacturer's efforts to comply with EPA standards.

This presentation will show the above described testing program in more detail, outlining the current testing and future planned testing, as well as ATC automotive and automotive emissions testing capabilities.

INTRODUCTION

The U.S. Army Aberdeen Test Center (ATC), located at Aberdeen Proving Ground, MD, supports the U.S. Environmental Protection Agency (EPA) in its heavy duty diesel engine emissions compliance program by providing program management, test procedure development, instrumentation application, equipment operation, data collection, reduction, and analysis. Personnel in ATC's Military Environmental Technology Demonstration Center (METDC) work closely with members of the EPA's Certification and Compliance Division (CCD) to plan, perform, and report in-use heavy duty diesel engine compliance testing.

This pilot program was developed in response to the 1998 Department of Justice and EPA settlement with engine manufacturing companies. The settlement resolved claims that manufactures illegally installed computer software on heavy-duty diesel engines that turned off the emission control system during highway driving since the early 1990's. The manufacturers agreed to pay penalties, meet 2004 standards early, and comply with a new in-use standard for Oxides of Nitrogen (NO_x). NO_x leads to the formation of ground level ozone or smog. It can irritate the lungs, lower resistance to respiratory infections such as influenza, and may also impair lung development in young children.

The EPA, developed the Real-time On-road Vehicle Emissions Reporter (ROVER) to sample the emissions of the various heavy duty diesel engines and the EPA has utilized ATC as its testing agency since 2000. ATC conducts ROVER tests on on-highway engines and non-road engines throughout the United States. Working closely with EPA representatives, the ATC ROVER test team locates sponsor requested test items, schedules testing, installs the ROVER system, performs the test, conducts preliminary analysis of data, performs pass/fail analysis, and reports the data to the EPA.

The installation of the ROVER involves attaching a flow meter to the vehicle's exhaust and utilizing a global positioning system (GPS) to track the vehicle location and speed. Data from the flow meter, GPS system and the engine's electronic controls is collected on a laptop computer set up in the cab of the truck. This data is also monitored and collected in a chase vehicle by ROVER team personnel during test runs. This allows personnel to monitor the system performance as well as the safety of the ROVER components on the vehicle. Data collected in a ROVER test includes HC, CO, O_2, NO_x, CO_2, exhaust temperature and pressures, torque, road speed, and the engines data stream. ATC is currently conducting approximately four tests per week to support the EPA.

BODY

ROVER System

The ROVER system is comprised of various off the shelf items. The main components are a computer with the ROVER program, two separate analyzers, a GPS system, an engine control module (ECM) scanner, and a calibrated flow pipe. One of the analyzers is a four gas analyzer for NOx, CO, CO_2, and O_2. A second NOx analyzer is used that produces more real-time data and verifies the NOx readings from the other analyzer. GPS is used to verify position of the vehicle, vehicle speed, and altitude during testing. The ECM scanner is used to monitor and record items necessary in not to exceed (NTE) NOx calculation. The main package contains the analyzers, computer, and the ECM scanner and is placed in the cab of the test item during ROVER installation (Figure 1). The calibrated flow pipe is attached to the test items exhaust using various flex pipes and angled pipes to create an uninhibited flow (Figure 2).

Figure 1. ROVER package in test item cab

Figure 2. Calibrated flow pipe installed

General In-Use Testing

ROVER was developed to test heavy duty diesel engines during their intended use. ROVER is installed on the test item and then test team personnel monitor its operation remotely, observing the real-time data as it's processed and recorded. During early ROVER testing, the system was installed and left on the test item most of the work day, or, at least for an entire truck haul or as it performed a specific task and then the ROVER was removed. Currently, program participants usually volunteer their vehicles for testing purposes and the ROVER testing is completed in less than five hours. Some participants however, still require vehicle use during testing (Figure 3). The ROVER test team at ATC tests engines from state and local governments throughout the United States, private industry, and newer model engines from rental companies.

Figure 3. In-use testing

Types of Testing

ATC supports EPA by performing various types of testing to provide data for the widest range of engine operational situations. This includes variables testing, marathon testing, non-road testing, and new technology comparison testing.

The variables testing program has been in place since EPA began utilizing ATC as its independent testing organization in 2001. In this program, engine families are tested under various conditions with the widest range of operational parameters. Those variables include hot and cold temperatures, driver variation, and altitude. When possible, the same engines in the same vehicles are tested under different conditions. The program has been successful in testing the same engines with various drivers, at various altitudes and under extreme differences in temperature. When the same engine in the same vehicle is not possible, testing is conducted on the same engine family in different vehicles under differing conditions, specifically altitude. Since 2002, data has been collected on specific engine families locally in Maryland, in the summer and winter months, and in Colorado at higher altitudes during extreme temperature scenarios.

Figure 5. Variables testing in Colorado

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Non-road testing has been conducted in various forms in support of EPA efforts to investigate ways to perform emissions testing during in-use applications of non-road engines. In early efforts, tests were conducted on various types of non-road equipment including forklifts, dozers, loaders, tractors, etc. It was determined that it was difficult to load theses engines to the extent needed to perform in-use testing. Currently, a method is used to test tractors only. This method incorporates a power take off (PTO) shaft connecting the PTO of the test item to a PTO generator that is loaded with a generator load bank. In this method, loads can be determined during testing at more precise intervals. This method is only applicable to non-road engines with PTO shafts and has only been performed on tractors. As more testing is performed and data analyzed, this method is being further investigated and developed by ATC and EPA.

Figure 4. Non-road testing

Marathon testing is an effort to test an engine under the most varied conditions possible during a short period of time. Usually, these tests involve renting a test item and operating the vehicle from Maryland to points west into higher altitudes. The normal marathon test will be conducted from ATC to Colorado via Interstate – 70 and return the same route. EPA and ATC have determined this route to be efficient in acquiring data on engines through various altitudes, traffic, and weather conditions in the shortest period of time. During a marathon, it usually takes three days to reach Colorado and three days to

return. This provides over 500 miles of data each day, hauling a known representative load. Over those three days, the engine is tested under a wide range of conditions, some times during the same day.

Figure 6. Marathon testing

Comparison testing has been conducted at various times during ATC support of EPA ROVER testing. This includes testing engines with ROVER and various available in-use emissions testing technology. EPA has been able to verify applicability of available technologies in the emissions compliance program and real-time emissions capabilities of each system. ATC has also performed testing at West Virginia University (WVU) on engines tested using WVU developed technology. ATC performed three tests on engines that WVU tested over the same route and reported the data to EPA. These types of comparison testing have enabled the EPA analyze data from a wide variety of real-time emissions measuring technologies and directly compare them to ROVER data from the same engines over the same routes.

Figure 7.WVU comparison testing

ATC has also performed testing to support other EPA divisions and private industry utilizing ROVER. In FY05, ATC performed testing for EPA SmartWay. This testing was conducted at ATC and allowed EPA SmartWay to directly compare various technologies and their affect on fuel economy and emissions when applied to a tractor and trailers. In this testing, two identical tractor and trailers were used and tested simultaneously on a track with a predetermined sequence of driving at different speeds to simulate stop and go and line haul scenarios. One of the tractor trailers remained unaltered for baseline comparisons. Various combinations of aerodynamic and single wide based tire packages were added to the second tractor trailer and run a minute apart on the track with the other tractor trailer. A ROVER system was run on each tractor and all ROVER data was recorded and analyzed by ATC and reported to SmartWay in an ATC Test Record for their emissions and fuel economy study.

In FY06, ATC conducted testing in support of the American Bus Association to study engine idle emissions. ATC performed emissions testing on six different buses during idle and over predetermined stop and go scenario on an ATC test track. The results of this test were also documented in an ATC Test Record.

Procurement of Test Items

ATC procures test items from a variety of sources in support of the EPA heavy duty diesel engine emissions testing. These sources include federal, state, and local governments, private industry, and rental companies. At the start of each fiscal year, ATC and EPA personnel meet to discuss the testing for that year and determine the specific engines to be tested in the above referenced test scenarios. That is, the engines to be used during variables testing, marathon testing, and non-road tests. Each year it is understood that ATC will attempt to locate the newest model year engine families for testing and test as many of these different engine families as possible. This allows EPA to create a larger inventory of emissions data for there analysis of engine family compliance. ATC will contact the sources of these test items directly and ask them to participate in the program. If they agree to participate, ATC schedules the test and travels to the location of the test item and conducts the test. ATC and EPA will provide the data to each participant after the testing is complete upon their request. In order to conduct marathon testing, ATC usually rents newer model year engines from various rental companies, as determined by EPA.

Typical ROVER Test

Most testing of rented vehicles is conducted locally on public roads around APG. The typical ATC ROVER tests involve ATC ROVER test team personnel traveling to various program participants to test engines. ATC personnel arrive on site at a designated time and begin installation of the ROVER. A typical ROVER installation requires approximately one to two hours, depending on the vehicle and exhaust location. The program participant provides a driver and if possible, loads the vehicle. The test is conducted over a predetermined route on public roads of approximately 40-50 miles, incorporating highway, stop and go, and hills, if possible. The ROVER team follows the test vehicle in a chase vehicle and remotely monitors the real-time data being generated. At the end of the test run, ATC personnel remove the ROVER and return to ATC. The entire test, depending on the route, lasts around four hours.

Data Analysis

ATC also performs preliminary data analysis on test data. The data is kept in a database filed under each test day and fiscal year. ATC personnel analyze the data with respect to NTE NOx in grams per brake horsepower hour over various periods within each test. This is done to analyze if the engine is in compliance with its engine family NTE NO_x

limits. A quick pass/fail analysis is usually done before data is submitted to EPA. This allows EPA personnel to analyze the data after ATC has assured its quality and validity. In cases when ATC conducts testing on many engines of one participant and they ask for the data, ATC provides a fleet report with various types of analysis of NTE NO_x, fuel economy, and engine data for each engine tested from that participant.

ATC Reporting

ATC transfers analyzed data to EPA at the completion of each test. ATC reports progress on procurement, scheduling, testing, and data analysis monthly to EPA. ATC personnel interact daily with EPA personnel to support them in continuation of data analysis and to ensure that the program achieves its goals with respect to variety and number of engine families, number of tests, and cost. As noted above, ATC has provided individual Test Records to both EPA SmartWay and American Bus Association for their individual test programs at ATC.

Other ROVER Testing

EPA has allowed ATC to conduct ROVER emissions testing in other Department of Defense (DoD) programs. ATC has conducted emissions testing using ROVER in partnerships with other DoD organizations and services, academia, and private industry. ATC has used ROVER in an Environmental Security Technology Certification Program (ESTCP) program that investigated emissions data in the use of various concentrations of biodiesel. This program was headed by the Naval Facilities Engineering Service Center (NFESC) and partnered ATC with the University of California at Riverside and various participating DoD bases throughout the United States. ROVER is also utilized by ATC in an ESTCP sponsored project investigating various diesel engine emission reduction technologies. This program is also managed by the NFESC and partners ATC with the University of California at Riverside and Cummins.

ATC Testing and Capabilities

ROVER testing at ATC allows EPA to utilize ATC expertise and capabilities to conduct various in-use testing missions. ATC also possesses various other capabilities with respect to vehicle and engine testing. This includes many tracks that simulate various road conditions and the world's largest Roadway Simulator. This facility can test up to and 80,000 lb tractor trailer, simulating driving scenarios. ATC is also in the process of constructing a high speed test track that will allow vehicles to maintain speeds of 70 mph over a 4.5 mile tri oval track with paved and gravel traffic lanes. With current and future capabilities, ATC personnel can conduct numerous testing scenarios for DoD, EPA, other government organizations, and private industry.