Quarterly Update

Advanced Petroleum-Based Fuels–
Diesel Emissions Control (APBF-DEC) Project

#5, Spring 2002

BACKGROUND
The APBF-DEC is an industry/ government project to identify and evaluate (1) the optimal combinations of low-sulfur diesel fuels, lubricants, diesel engines, and emission control systems to meet projected emission standards for the 2001 to 2010 time period and (2) properties of fuels and vehicle systems that could lead to even lower emissions beyond 2010. Sulfur in the fuel is known to interfere with the functioning of most emission control technologies and has been implicated as a possible factor in the formation of ultrafine particulate matter (PM). A systems approach is being used, i.e., simultaneously investigating fuels, lubricants, engines, and emission control systems.

A government/industry steering committee and working groups are guiding the APBF-DEC project. Funding for the project is expected to total $33 million, including $19.3 million in cash ($12 million from the government) and $14 million in in-kind contributions. The project is managed by DOE's National Renewable Energy Laboratory (NREL). Information about the APBF-DEC project is posted at: http://www.ott.doe.gov/apbf.shtml.

APBF-DEC is the successor to the Diesel Emission Control-Sulfur Effects (DECSE) project, whose objective was to determine the impact of fuel sulfur levels on the performance and short-term durability of emission control systems, which could lower emissions of NO_x and PM from diesel-powered vehicles in the years 2002 to 2004. In June 2001, the final edition of the DECSE Program Summary briefly described DECSE's final results. In January 2002, a more detailed summary of the DECSE results was published. These publications and technical reports are available at: http://www.ott.doe.gov/decse/.

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APBF-DEC Projects Are at Full Speed

Activity in the five APBF-DEC projects has increased as Phase I enters its second quarter of test bed setups, deliveries of fuels, development of data protocols, initial data collection, and information-sharing. Phase I continues into 2003. Members of the APBF-DEC Steering Committee and working groups share information about their five projects during regularly scheduled conference calls and a technical Web site.

A base fuel containing 0.6-ppm sulfur has been delivered to test laboratories for the APBF-DEC projects. The base fuel is "doped" to levels required for the tests (8-, 15-, and 30-parts per million [ppm] sulfur). Prior to collecting emissions data, engines and emission controls were set up in test cells. The data analysis team is developing a format for recording data, to ensure consistency. A team is working with urea, selective catalytic reduction technology (SCR), and NO_x adsorber/diesel particle filter groups to develop consistent protocols. Site visits are being scheduled at four test laboratories during May, June, and July.

Lower emission standards will be phased in between 2004 and 2009 for passenger cars and light trucks. For diesel engines to comply with these standards, catalysts will be required.

The recently finalized emission standards for heavy-duty vehicles will go into effect in 2007. These standards (for both PM and NO_x) will require catalytic emission control systems.

Following are summaries of the progress of the five projects (four hardware projects and the lubricants project) through March 2002 at the designated laboratories. Other companies and associations providing engines, systems, and support were identified in the *APBF Quarterly Update #4, Winter 2002*, which is posted on the Web site (http://www.ott.doe.gov/apbf.shtml).

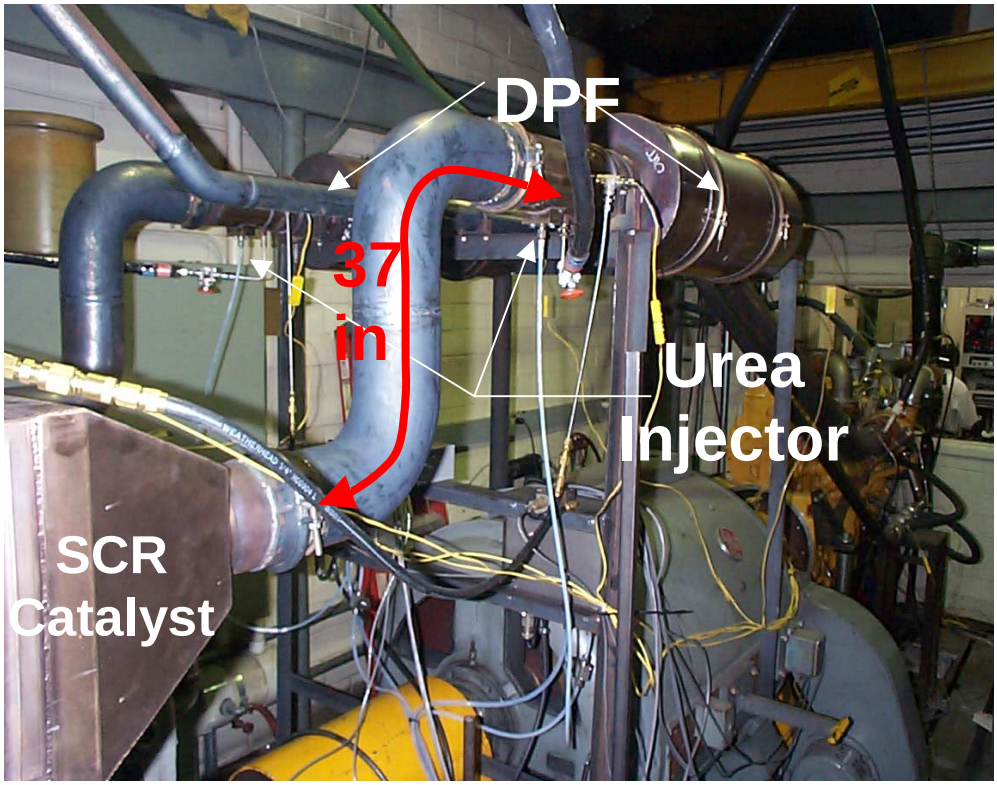
Selective catalytic reduction/diesel particle filter (SCR/DPF) technologies, fuels, engines– Southwest Research Institute (SwRI), San Antonio, TX, testing laboratory, test bed: Caterpillar C-12 engine.

The objectives of the SCR/DPF tests are to:

- Demonstrate the low-emissions performance using advanced diesel engines and SCR/diesel particle filters (DPFs).
- Determine the regulated and unregulated emissions with and without emission controls.
- Examine the durability of the emission control systems.
- Determine toxic and unregulated emission levels.
- Evaluate the sensitivities of the emission controls to fuel variables.

SCR/DPF. The selective catalytic reduction technology (SCR) is an emissions reduction device that, combined with a diesel particle filter (DPF) and advanced fuel formulations, has the potential to reduce regulated, unregulated, and toxic emissions. Two types of SCRs and DPFs are being evaluated.

The purpose of the test is to demonstrate the low diesel emissions possible by using the SCR/DPF and to evaluate the sensitivity of emission controls to fuel variables.



The effects of urea on the SCR/DPF technologies are being tested on the Caterpillar C-12 test engine at SwRI's laboratory in San Antonio.

Test Engine: Caterpillar C12, 12L

The Caterpillar C-12 test engine, received in September, has been installed and passed break-in and validation tests. This project is using four test fuels (3-, 8-, 30-ppm sulfur) and a fifth fuel, "BP 15"—called the refinery processed fuel. Some fuels were delivered by mid-March, allowing work to begin on the first emission control system (labeled "System A"). Also in March, SwRI began to calibrate the urea injection system. Urea is an aqueous solution that, when heated, can produce ammonia that can react in an SCR device to reduce NO_x to elemental nitrogen. A study is being conducted by Arthur D. Little (ADL) to estimate the potential demand for urea, the costs of production and distribution infrastructure, and the environmental impacts of using urea.

The first durability engine has been installed in the test cell and completed its break-in schedule. SwRI has also received and is calibrating two exhaust gas recirculation systems. Four groups of currently unregulated ("toxics") emissions samples will be analyzed by a third-party lab. Emissions testing at the 200-hour point, including sampling of special toxic emissions, is expected to be completed by early June.

NO_x adsorber/diesel particle filter (DPF) technologies, fuels, engines – Three projects using NO_x adsorber/DPF technologies are currently underway at three laboratories to analyze the effects of fuel composition on three types of diesel engines. Similar tasks are planned for the three NO_x adsorber/DPF projects: (1) set up the engine(s) and/or test cell(s), measure regulated and unregulated engine-out baseline emissions and fuel consumption, using fuel with four sulfur levels; (2) evaluate the system's performance over transient and steady-state evaluation cycles; (3) use the results from the previous tasks to determine the best ECSs and sulfur levels for testing of up to 1,000 hours; and (4) examine the effects of fuel properties, other than sulfur content, on regeneration and desulfurization strategies. Protocols for sampling unregulated emissions are being updated and have been defined for the three test labs.

NO_x Adsorber/DPF. The NO_x adsorber catalyst is a flow-through exhaust emissions control device with the potential to significantly reduce nitrogen oxide (NO_x), hydrocarbon (HC), and carbon monoxide emissions in the exhaust from diesel engines. When combined with a DPF, the system also can oxidize the diesel particulate matter (PM) and other unregulated emissions.

The purpose of these tests is to demonstrate the potential to achieve stringent emission reductions from diesel engines using a system that includes the engine, fuel, NO_x adsorber, DPF, and thermal management technologies.

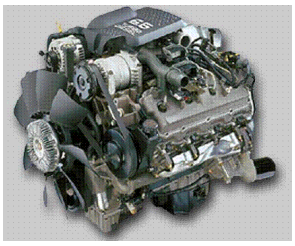
- **FEV Engine Technology, Inc., Auburn Hills, MI, test bed: a light-duty passenger car** (Audi A4 Avant with a 1.9L TDI engine). The first test engine has completed the break-in period and has been installed in a development test cell for calibration. Testing will be split into different branches, rapid warm-up techniques and raw NO_x reduction. Steady-state tests will be conducted to evaluate the effects of increases in exhaust temperature on fuel consumption and the engine's operating mode. A second engine was to be delivered in April. The third and fourth engines are awaiting break-in and engine calibration work. Dual wall exhaust manifolds have been fabricated. The emission control system's (ECS) pre-catalyst geometry and under-body elements have been defined, and the first set of ECS components were to be delivered in April, when testing is to begin. The engine management software is being developed in parallel with the ECS schedule.


Test Engine: Diesel Future II, 1.9L

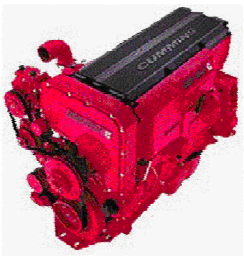

Test Vehicle

- **SwRI, San Antonio, TX, test bed: a light-duty truck/SUV** (a 2500 Series Chevrolet Silverado, with a Duramax 6.6 liter [L] engine). A simulation engine dynamometer test of a light-duty vehicle on a chassis dynamometer was developed to duplicate the Duramax engine in the test vehicle's operation. This test cell is being used to examine accelerating aging and evaluating regeneration strategies and for comparisons to the actual vehicle's performance on the dynamometer. Comparisons can be made of the NO_x and carbon dioxide (CO_2) emission results, exhaust gas temperatures, smoke opacity, manifold absolute pressure, and intake airflow. A test system was set up to evaluate the use of two preliminary pre-catalysts and supplemental fuel injection. The system will also be examining post injection mapping. The vehicle's test bed has been developed, the engine's break-in phase is completed, and the exhaust gas recirculation system (EGR) is being developed and mapped. The ECS components have been delivered and the second vehicle was expected in April. A site visit was planned for mid-April.


Test Vehicle


Test Engine: GM Duramax 6600, 6 6L

- **Ricardo, Inc., Burr Ridge, IL, test bed: a heavy-duty engine** (15L Cummins ISX, DOHC engine). The engine with integrated EGR and control systems was delivered in January. The Cummins engine was installed in the test bed in March and integrated with Ricardo's control system. Initial tasks have included collecting baseline data and exploring the lower air fuel ratio engine capabilities. The monitoring algorithm for the diesel particle filter was completed. A wiring harness has been designed to incorporate all signal requirements. An intake throttle was selected to improve air management (i.e., increase EGR flow). An in-cylinder secondary fuel injection system has been installed. ECS systems A and B (single and dual path) are expected to be delivered in May. The test plan was approved by the project co-chairs.



Test Engine: Cummins ISX, 15L

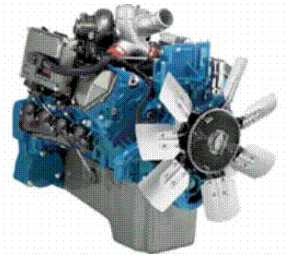
Lubricants – Automotive Testing Laboratory (ATL), East Liberty, OH, test bed: Navistar T444E, 7.3L V8 engine, with retrofits installed. The objective of this project is to determine which, if any, lubricant-derived components in emissions are detrimental to the performance or durability of emission control systems. The study of lubricants (basestocks and additives) will assess the effects on the performance and durability of advanced diesel emission control systems. Lubricants (e.g., lube oil sulfur and ash) may interfere with the performance of catalysts, impacting the durability of NO_x adsorbers, and plug diesel particle filters.

The test cell is fully equipped with an electronic interface that provides full control of the engine's operation and facilitates data acquisition, storage, and analysis. The test plan calls for evaluating a matrix of additives in combination with four different basestocks. The test fuel contains 3-ppm sulfur. Gaseous emissions are sampled according to federal guidelines for carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), and

Lubricants. Testing of lubricant formulations is being conducted in a heavy-duty engine test cell. The test engine is installed on a dynamometer combining a double-ended GE DC-electric brake (200hp) with a Go-Power DT-2000 water brake (800hp), which provides precise control and high torque/power absorption capability on a single in-line assembly. Longer duration testing for aging and oil consumption is to be conducted on a DT-2000 water brake dynamometer.

sulfur dioxides (SO_2). Particulate matter (PM) in the exhaust from the test engines is collected simultaneously on three separate filters and analyzed separately.

Prior to starting the test, an initial evaluation was conducted to characterize the oil consumption rate; compare the baseline oil consumption data with subsequent evaluations to determine if any change has occurred in the engine that may influence emission results; and evaluate whether there are meaningful differences in the engine's emissions when using two oils of widely different properties. A demonstration test was conducted in October to identify emissions of PM, HC, S, and SO_2 and metals. Initial data and calculations have included oil consumption and mass balance, metals, PM/gases, oil analysis, statistical analysis of demonstration test data, comparisons of emissions of two types of oils during demonstration runs. Phase l testing is scheduled for completion in May.



Test Engine: Navistar T444E, 7.3L

The effects of lubricant-derived components on the performance and durability of emission control systems are being tested on the heavy-duty Navistar T444E, 7.3L engine at ATL's East Liberty, OH, laboratory.