APBF-DEC

Quarterly Update

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

#4, Winter 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 emissions 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_dec.

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
For further information, contact either Wendy Clark at NREL, phone 303-275-4468, fax 303-275-4415, e-mail Wendy_clark@nrel.gov or Helen Latham at Battelle, phone 614-424-4062, fax 614-424-5601, e-mail lathamh@battelle.org.

APBF-DEC's Phase I Is Well Underway

All five of the APBF-DEC's projects are underway at test laboratories around the country as part of Phase I, which continues into 2003. Members of the APBF-DEC's Steering Committee and working groups have procured the technology systems, fuels, and lubricants to be tested; contracted with test laboratories and other support services; established teams that hold bi-weekly or weekly teleconferences to discuss progress; and regularly visit test sites.

The major tasks during Phase I for each of the five projects are to: develop the test cells and install test engines, optimize emissions reduction performance, conduct durability tests, and determine the effects of various sulfur levels in diesel fuel on regulated and unregulated emissions. Significant in-kind support is being provided by the Engine Manufacturers Association (EMA) and the Manufacturers of Emission Controls Association (MECA). Following are descriptions of the projects' progress through December 2001.

Selective catalytic reduction/diesel particle filter (SCR/DPF) technologies, fuels, engines.

The Southwest Research Institute (SwRI) of San Antonio, TX, was selected as the testing laboratory. Caterpillar supplied the engines (heavy-duty Caterpillar C12), MECA provided the integrated emission control systems (SCR and DPF technologies), and SwRI dedicated a heavy-duty test cell for the duration of the test. STT Emtec of Sweden provided the low-pressure loop exhaust gas recirculation systems (EGR) system, and Robert Bosch supplied the urea injection system.

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.

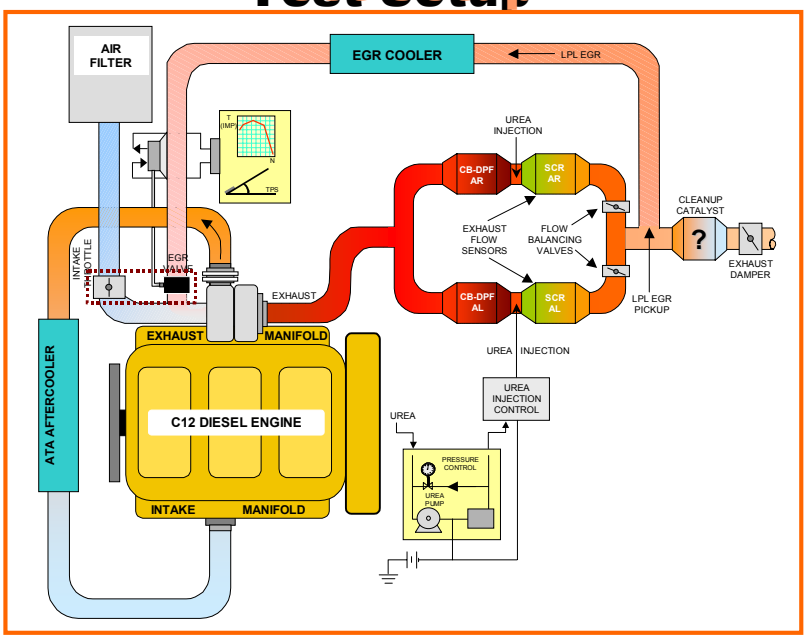
The objectives of the SCR/DPF tests are to:

- Demonstrate the low-emissions performance using advanced diesel engines and SCRs/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.

Fuels with three different sulfur levels (3-, 8-, and 15-ppm) are being evaluated to determine the effects of fuel sulfur levels on each system's performance. The 3-ppm DECSE fuel will be used to establish a baseline, then experimental work will be conducted with fuels containing 8- and 15-ppm sulfur. Other elements are in place, including fuel supplies, urea, and the low-pressure-loop EGR system, whose purpose is to reduce engine-out NO_x.

A heavy-duty engine has been installed in an emission test cell at SwRI to optimize the emission reduction performance of two different emission

Test Setup



This schematic demonstrates how tests of the diesel engine and SCR/DPF emission control systems are being conducted at SwRI.

control systems (DPF and SCR catalysts). Controls are being integrated in both systems to reach the lowest possible emissions of NO_x and PM. The test setup is pictured in the above schematic.

SwRI expects to spend the first 10 months in this integration/optimization phase. The test starts by characterizing the engine-out emissions. The exhaust emission control system is divided into two identical "legs," each comprised of the DPF, followed by urea injection, the SCR catalyst (for oxidizing ammonia slip), and a flow balancing valve.

The SCR/DPF project has completed some transient tests with good results and is ready for baseline testing with the EGR system in place. The urea injection system was installed in December, to be followed by the installation of the first after-treatment devices. SwRI expects two Caterpillar engines to be delivered earlyin January so the durability test cell can be set up. Durability tests lasting 6,000 hours will be conducted simultaneously for the two different systems. Regulated and unregulated emissions will be checked at 2,000-hour intervals.

Notes
(1) The EGR system redirects some of the cooled exhaust gases back into the engine, replacing some fresh air, to be burned a second time.

(2) Urea is an aqueous solution that, when heated, produces ammonia that reacts to reduce NO_x to elemental nitrogen.

NO_x adsorber/diesel particle filter (DPF) technologies, fuels, engines. Three projects using NO_x adsorber/DPF technologies are currently underway to analyze the effects of fuel composition on three types of diesel-powered engines. Contracts were awarded during the last half of 2001 to three separate laboratories where the NO_x adsorber and DPF technologies are being tested:

- FEV Engine Technology, Inc., Auburn Hills, MI, is testing a passenger car—an Audi A4 Avant with a 1.9L TDI engine.
- SwRI, San Antonio, TX, is testing a light-duty truck/SUV—a GMC Sierra, 2500 Series, with a Duramax 6.6L engine.
- Ricardo, Inc., Belleville, MI, is testing a 15L Cummins ISX, DOHC engine.

MECA is providing the NO_x adsorbers, DPFs, other catalysts or emission control system elements, and technical support to all three NO_x/DPF projects. By late 2001, the three laboratories had assembled the engines and appropriate subsystems and instrumentation. The schedule for completing the three projects varies in length from 24 to 30 months.

The baseline fuel to be used for all three projects is the 3-ppm sulfur (DECSE) fuel. The 8- and 15-ppm sulfur fuels will be the focus of the test, with some limited testing of 30-ppm fuel. Limited durability tests will be conducted and additional research work may also be scheduled.

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.

The initial step in all three of the NO_x adsorber/DPF test plans is to optimize the three systems to ensure that the NO_x adsorber and DPF perform as planned, i.e., the technologies achieve regeneration and complete the desulfurization process. The next objective is to determine whether the system (the engine, fuel, lubricant, and emission control technologies), working together, can perform those functions while meeting engine emission targets and without adversely affecting engine performance.

The first task for all three NO_x adsorber/DPF projects is to set up the engine and/or test cell(s), then measure regulated and unregulated engine-out baseline emissions and fuel consumption over cycles using fuel with all four sulfur levels (3-, 8-, 15-, and 30-ppm fuel). Strategies are being developed for regeneration (for both DPF and NO_x adsorber) and desulfurization, which will be triggered while implementing the appropriate evaluation test cycle.

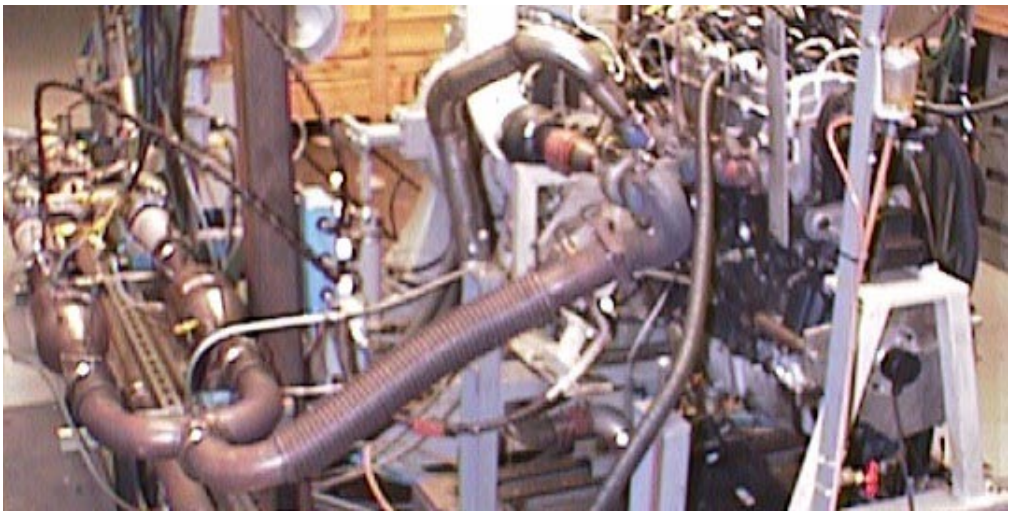
The second task is to evaluate the system's performance, including the integrated, tuned system for regulated and unregulated emissions over the appropriate transient and steady-state evaluation cycles. Each emission control system will be set up and benchmarked using the 3-ppm fuel. Then fresh emission control systems will be aged for at least 300 hours in 50-hour increments using 8- and 15-ppm fuels. A full evaluation of emissions will be conducted at each 50-hour increment. Limited testing is also planned using 30-ppm fuel.

The third task will use the results from 300 hours of testing during the second task to determine the best combination of emission control systems and fuel sulfur level for further testing of up to 1,000 hours. This is intended to indicate the longer term performance and durability of at least one of the emission control systems.

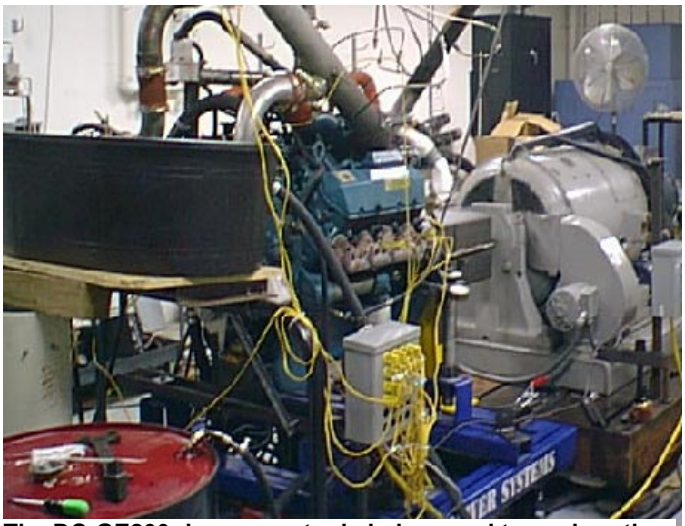
The final task will examine the effects of other fuel properties (i.e., besides sulfur content) on the previously developed regeneration (filter and adsorber) and desulfurization strategies. The emission control system's performance and the fuel economy impact on the system will be investigated, but extensive aging cycles will not be included in the testing. The specific fuels and properties to be used in this portion of the project will be determined by the APBF-DEC's fuels and lubricants provision working group.

By late December, the three sites had made significant progress. One medium-duty test vehicles (GMC Sierra, 2500 Series, with Duramax 6.6L engine) was delivered to SwRI. One vehicle is being road-tested and receiving initial analysis. A second engine is being installed in the test cell. FEV is completing the engine build, installing the test cell for the Audi A4 Avant/TDI engine, procuring hardware and engine control software, and developing the emission control system. The Cummins ISX engine has been installed at the Ricardo test cell and baseline runs are being conducted.

Lubricants. APBF-DEC's fifth project is studying the effects of lubricant formulations (basestocks and additives) on the performance and durability of advanced diesel emission control systems. The properties and composition of lubricants can affect the performance, durability, and aging of emission control systems.



One of the three NO_x adsorber/DPF systems is being tested in this FEV test cell.



The DC-GE200 dynamometer is being used to analyze the effects of lubricants in the fuel on emission control systems.

As lubricants are burned, they may contribute to the levels of sulfur in exhaust gases and impair the effectiveness of emission control systems. The predecessor to APBF-DEC—the Diesel Emissions Control-Sulfur Effects project—demonstrated the acute sensitivity to sulfur and other potential poisons of some of the diesel emission control systems tested. Thus the results of this project will be important in defining future lubricant formulations for both light- and heavy-duty diesel engines.

Testing of lubricant formulations is being conducted in a heavy-duty engine test cell by the Automotive Testing Laboratory (ATL) in East Liberty, OH (see photo at left). The test engine is installed on a dynamometer constructed by ATL. This setup combines a double-ended GE DC-electric brake (200 hp) with a Go-Power DT2000 water brake (800 hp) to provide 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. The ultra-low sulfur test fuel being used is stored in a 10,000-gallon underground tank that is protected from contamination.

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. Gaseous emissions are sampled according to federal guidelines, including carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), nitrogen oxides (NO_x) and sulfur dioxides (SO_2). Particulate matter (PM) in the exhaust from the test engines is collected simultaneously on three separate filters and analyzed separately.

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.

The objectives of the initial setup were to determine the set points for each steady-state operating condition, select the proper speed and load conditions, and establish suitable settings of the exhaust gas recirculation (EGR) system. Proper EGR rate settings are necessary to ensure meaningful NO_x reductions without significant effects to PM, HC, or other gaseous pollutants. Another purpose of this initial testing was to gauge preliminary estimates of repeatability of the setup prior to the start of actual testing.

Repeatability data collected in September 2001 suggested that the system and associated retrofit hardware were stable and fit for beginning the testing. 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
- Evaluate whether there are meaningful differences in the engine's emissions when using two oils of widely different properties.

Phase 1 testing began in December and is expected to be completed by April 2002. Initial emissions data have been collected and are being analyzed.

Fuel. Chevron Phillips Chemical Co., LP, is blending the fuel.