APBF-DEC

Quarterly Update♦

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

No. 2, Spring 2001

During its first year, the APBF-DEC program concentrated on organizing and planning functions. This included determining the number of groups interested in participating; securing adequate funding and in-kind support; appointing Steering Committee members; determining the number and makeup of work groups; establishing meeting schedules, test support needs and methods, and operating principles; and developing statements of work and reviewing proposals from subcontractors.

The first edition of the *APBF-DEC Quarterly Update* (No. 1, Winter 2000) contains additional background information about the program's organization, study design, schedule, collaborating groups and companies, planning, and startup activities (http://www.ott.doe.gov/apbf_dec). Two of the four emissions control technologies tested in the earlier Diesel Emission Control-Sulfur Effects (DECSE) program are included in the APBF-DEC program, the NO_x adsorber and diesel particulate filters (DPF).

Funding, Participants

The four-year APBF-DEC program is expected to have a 50/50 government/industry cost-share and be funded at about $35 million, including $25 million in funding and $10 million in in-kind contributions. Participants include the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), the Engine Manufacturers Association (EMA), the American Petroleum Institute (API), the Manufacturers of Emission Controls Association (MECA), the American Chemistry Council (ACC), the California Air Resources Board (CARB), and the South Coast Air Quality Management District (AQMD) (see Figure 1). The California Energy Commission (CEC) has also expressed interest in participating. Industry is providing significant in-kind resources, e.g., test engines, urea injection systems, catalyst systems. The program is managed by DOE's National Renewable Energy Laboratory (NREL) and Oak Ridge National Laboratory (ORNL).

Fuels

The focus of the APBF-DEC program is on fuels and lubricants, i.e., the effects of fuel and lubricant composition on emissions from advanced engine-emission control systems. The APBF-DEC program can choose from a group of fuels that DOE and the APBF-DEC Steering Committee have approved for its fuel testing programs. These fuels include DECSE fuels with fuel sulfur content of 3 to 30 parts per million (ppm), refinery fuels of limited batch-production volumes, and a Fischer-Tropsch fuel. The APBF-DEC fuels and lubricants procurement team plans to provide DECSE fuels and a refinery-produced fuel for the first part of testing. A refinery-

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♦ **BACKGROUND:** The APBF-DEC is an industry/government program to identify and evaluate (1) the optimal combinations of low-sulfur diesel fuels, lubricants, diesel engines, and emissions 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). Information about the APBF-DEC program is posted at http://www.ott.gov/apbf_dec. APBF-DEC is the successor to the Diesel Emission Control-Sulfur Effects (DECSE) program, whose objective was to determine the impact of fuel sulfur levels on the performance and short-term durability of emissions control systems, which could lower emissions of NO_x and PM from diesel-powered vehicles in the years 2002 to 2004. The final DECSE reports will be available on the web site this spring at: http://www.ott.doe.gov/decse. The DECSE data show the effects that fuel-borne sulfur has on the performance of emissions control systems and the effects fuel properties (including additives) have on the performance of those systems. For further information, contact Helen Latham at Battelle, phone 614-424-4062, fax 614-424-5601, e-mail lathamh@battelle.org.

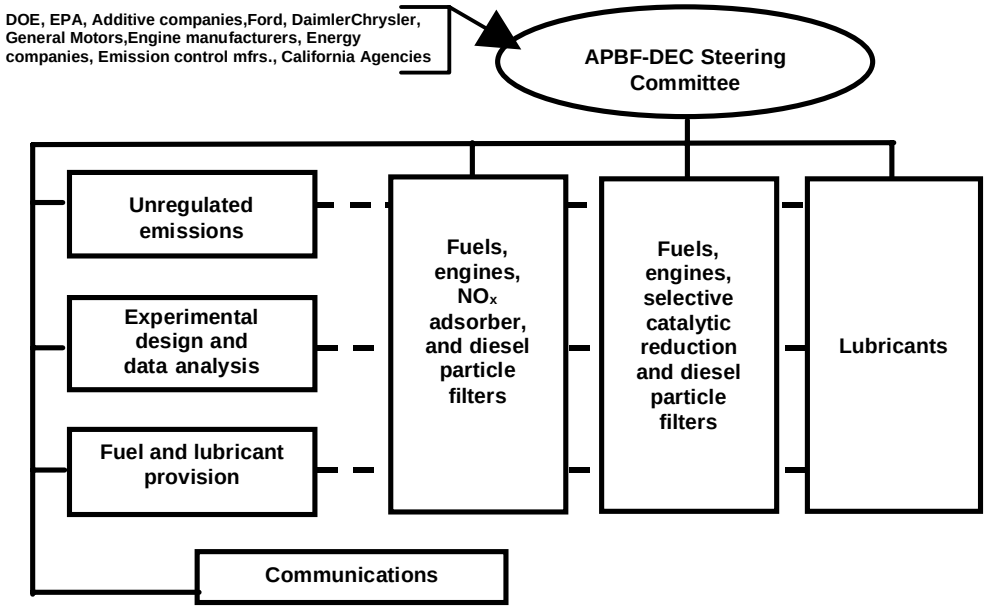

Figure 1. APBF-DEC Systems, Organization

produced fuel is desirable for speciation of unregulated emissions, because its chemical signature will be more complex than the composition of the DECSE base fuel and it should provide more chemical precursors over a broader distribution of carbon numbers. The refinery-produced fuel should be similar to the DECSE fuel in fuel performance and physical properties and similar to the national average diesel (meeting the requirements of ASTM D975), but with very low (<15 ppm) sulfur.

Technology Systems, Lubricants

The two technology systems to be tested in the APBF-DEC program combine the fuels, engines, and catalysts. They are the selective catalytic reduction (SCR) with DPF and the NO_x adsorber with DPF. The base diesel fuel in the test program contains 3 parts per million (ppm) sulfur content, which is essentially "sulfur free." Fuel properties, including additives, may also affect the performance of advanced emissions controls. Therefore, a matrix of fuels will be evaluated along with the emissions reduction technologies. The APBF-DEC work groups have selected the diesel engines and will monitor the projects. The tests will be conducted by subcontractors, with oversight by the work groups.

Member companies of MECA will provide the engine post-combustion emissions control systems (e.g., catalysts), other system elements, and technical support. The following sections describe the technologies, objectives, work plans, and major deliverables for the two technology systems and lubricants to be tested. Table 1 provides a summary of the program.

- **Fuels, engines, SCR/DPF technologies.** The selective catalytic reduction (SCR) technology is an emissions reduction device that, combined with a DPFand advanced fuel formulations, can reduce regulated, unregulated, and toxic emissions. The SCR will use urea as a reductant. Two types of SCR catalysts will be used in the test, along with two types of DPFs—a catalyzed DPF and a continuously regenerated DPF.
  - The **objective** of the test is to demonstrate the low emissions performance attainable with the SCR/DPF technologies and to evaluate the system's sensitivities to fuel variables. The integrated system's performance will be optimized to achieve the maximum reductions of nitrogen oxide (NO_x) and particulate matter (PM) emissions. The system's performance will be monitored, as will engine-out and tailpipe emissions, and regulated, unregulated, and toxic emissions.
  - The **project work plan** describes a two-phase, laboratory demonstration of system performance using a heavy-duty engine. Phase 1 includes laboratory setup, system

optimization and evaluation of engine-out emissions, and aging the catalyst for 10 hours and then 200 hours, while documenting emissions performance. Phase 2 will be the durability phase of the test, which is defined as maintaining emissions reduction performance with acceptable driveability over extended mileage. During the durability phase, the systems are to be aged over a longer term (from ~2,000 to ~6,000 hours) so degradation of the system's performance can be evaluated. The systems will be tested at selected intervals to gauge emissions performance.

- Major **deliverables** will include: a detailed schedule for acquisition, installation, and integration of the engine and the emissions control technologies; a detailed work plan; data from the emissions performance of the two SCR/DPF technologies for one heavy-duty engine; the effects of fuel variables (including sulfur); and an evaluation of the durability and performance after aging. The APBF-DEC work group expects to complete its analysis and report by August of 2003**.**

- **Fuels, engines, NO_x adsorber/DPF technologies.** A NO_x adsorber catalyst is a flow-through exhaust emissions control device with the potential to significantly reduce NO_x, hydrocarbon (HC), and carbon monoxide (CO) emissions from the diesel engine's exhaust. This catalyst is also effective in oxidizing the soluble organic fraction of the diesel particulate matter and other unregulated diesel emissions. In addition to the NO_x adsorber, the integrated system requires an advanced engine, a DPF, and new fuel technologies.

  - The **objective** of the project is to demonstrate the potential of the integrated system to: (1) meet future emissions standards for both light- and heavy-duty engines and (2) help determine the necessary fuel sulfur level and other fuel properties that will enable the system to meet objective (1).

  - The **project work plan** defines the three tasks integrating the selected engines, emissions control system, and development/optimization of the engine management systems for effective operation using the 3-, 8-, 15-, and 30-ppm sulfur fuels. A passenger car and a sport/utility vehicle platform will be used as well as a heavy-duty engine. In Task A, the lab will set up and integrate the system, collect baseline engine-out emissions data, and develop regeneration/desulfurization strategies. Task B will concentrate on systems performance and aging, using fresh catalysts, 50-hour test increments, and a total of 300 hours. Task C will look at other fuel properties (as many as four additional fuels) and the effects of fuel on system performance.

  - Major **deliverables** will include: ongoing data on engine temperatures and flows, performance and aging; optimized NO_x adsorber/DPFsystems for testing one heavy-duty engine and two light-duty vehicles; data from regulated and unregulated emissions performance over transient test cycles; the effects of fuel variables (e.g., sulfur); and an evaluation of the short-term durability of the system. The work group expects to complete the initial program in December 2003.

- **Lubricants.** The DECSE program quantified the impact of sulfur in the fuel on the performance and short-term durability of selected emissions control systems. The APBF-DEC program is studying the effects of lubricant properties and composition on the performance and durability of the emissions control systems and the impacts of aging. The potential effects of sulfur and other constituents in the lubricants can become increasingly important as the percentage of sulfur in the fuel is reduced. As the lubricants are burned, they can contribute as much as 7 to 10 ppm of fuel-equivalent sulfur and mask the effectiveness of some emissions control systems using low-sulfur diesel fuel.

  - The **objective** is to determine which, if any, lubricant-derived emissions components are detrimental to the performance or the durability of diesel emissions control systems. This includes the effects of the lubricant additive on engine-out oil, the effects of the lubricant basestock on engine-out emissions, and how the lubricants may affect the performance of the emissions control systems.

  - The **project work plan** describes a three-task test to evaluate the lubricant formulation's effects on emissions. A multi-cylinder diesel engine, fueled by 3-ppm sulfur diesel fuel, will be used in the test. In Task 1, engine emissions (without a catalyst) will be measured for PM, NO_x, and HC to determine the impact of the lubricant on engine-out emissions. In Task 2, the lab will conduct a bench scale analysis to evaluate the impact of lubricant-

derived species (identified in Task 1) on the emissions control systems. Task 3 will consist of tests to confirm results found in Tasks 1 and 2, as well as durability testing.

Tests will be performed on four different oil basestocks and approximately 12 additive packages containing various levels of ash, sulfur, phosphorous, selected metals, and other key components. The basestock packages will be provided by additive companies, according to the experimental design. The tests will measure PM, including sulfate and nitrate fractions; metal content; unregulated emissions; size distribution; and HC, NO_x, and sulfur dioxide (SO_2).

- **Deliverables** will include the lubricant test matrix, which outlines the work and tests to be completed; protocols for data handling and management; and measurements of emissions for HC, PM, CO, NO_x, and SO_2 from test cycles conducted with lubricants specified in the experimental design. The APBF-DEC lubricants work group expects to complete its analysis and the final report by the December of 2003.

Table 1. Summary of APBF-DEC Technology Systems

Technologies	Test Lab	Engines/ Vehicles	Fuel Base fuel: 3-ppm sulfur	Projects Start/Finish		Final Products
SCR/DPF (2 SCR catalysts—selected from 3 [Vanadium, zeolite, base metal])	Subcontractor-TBD	1 heavy-duty engine	3- and/or 8-, 15-, 30-ppm sulfur content; Fischer-Tropsch, refinery fuel	4/01	8/03	Optimized SCR/DPF systems for heavy-duty engines; evaluations of emissions performance; effects of fuel variables (e.g., sulfur and aromatics) on emissions and performance; data on engine durability and performance after aging from field demonstrations; and assessment of urea infrastructure barriers.
NO_x adsorber/DPF	Subcontractors-TBD	1 heavy-duty engine & 2 light-duty vehicles	3-, 8-, 15-, 30-ppm sulfur content; refinery fuel	3/01	12/03	Optimized NO_x adsorber/DPF systems for testing heavy- and light-duty engines using late-cycle injection; emissions performance of the two technologies over transient test cycles, including unregulated emissions; effects of fuel variables such as sulfur, aromatics, and additives; durability of system,; emissions performance with acceptable driveability at extended mileage; examination of other fuel properties after demonstrating ultra-low emissions.
Lubricants	Subcontractor-TBD	International T444E engine	3-ppm sulfur content	4/01	12/03	Guidance to lubricant providers on lubricant formulation, to additive developers based on tests of the effects on emissions control system, and to engine manufacturers and emissions comtrol systems suppliers; an evaluation of the matrix of combinations of additives and basestocks.

Support Work Groups

Three APBF-DEC support work groups will provide assistance to the APBF-DEC system work groups in the following areas: unregulated emissions, provision of fuel and lubricants, and experimental design.

- **Unregulated emissions.** The unregulated emissions support group will identify and develop methods to monitor for and analyze “unusual” and potentially problem compounds (other than CO_2, CO, and NO_x) that can be present in trace amounts in tailpipe emissions from both SCR and NO_x adsorber systems. The group will also specify measurements and methods for use by the three systems work groups and perform unregulated emissions analyses.

- **Provision of fuel and lubricants.** The fuels and lubricants support group will provide the fuels and selected lubricants, along with related analytical data. NREL has contracted with Chevron-Phillips for low-sulfur fuels, from which the systems work groups can select.

- **Experimental design and data analysis.** The experimental design and data analysis support group will prepare a detailed experimental design for use by the test laboratories, to ensure consistency in the test protocols and data collection. The data to be collected include engine-out emissions, emissions control performance, tailpipe emissions reduction potential, correlations of fuel properties with NO_x and PM emissions, the impact of sulfur on fuel lubricity, and the effects of lubricants.

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