



Advanced Technology Vehicles in Service

Advanced Vehicle Testing Activity



U.S. Department of Energy

Energy Efficiency and Renewable Energy

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City of Los Angeles Bureau of Sanitation

LNG HEAVY-DUTY TRUCKS

THE ROLE OF THE U.S. DEPARTMENT OF ENERGY'S (DOE)

Advanced Vehicle Testing Activity (AVTA) is to bridge the gap between R&D and commercial availability of advanced vehicle technologies. AVTA supports DOE's FreedomCAR and Vehicle Technologies Program in moving these technologies from R&D to market deployment by examining market factors and customer requirements, evaluating performance and durability of alternative fuel and advanced technology vehicles, and assessing the performance of these vehicles in fleet applications.

The Fleet Test & Evaluation team at the National Renewable Energy Laboratory (NREL) supports AVTA by conducting medium- and heavy-duty vehicle evaluations. The team's tasks include identifying fleets to evaluate, mutually agreeing on the type of commercial alternative fuel vehicles to test, designing test plans, gathering on-site data, preparing technical reports, and communicating results on its Web site and in published fact sheets.

THE CITY OF LOS ANGELES

BUREAU OF SANITATION'S decision to acquire Dual-Fuel™ liquefied natural gas (LNG) refuse trucks was guided by research, regulation, and a desire to improve the City's air quality. In 1999, the Bureau of Sanitation conducted a field study on refuse trucks equipped with various types of alternative fuel engines, including dedicated compressed natural gas, dedicated LNG, and Dual-Fuel LNG. The study showed that the trucks with Dual-Fuel engines were best suited to meet the operational requirements of refuse collection. Specifically, the Dual-Fuel trucks had adequate horsepower and torque and could be operated safely over all terrains covered by the Bureau's refuse collection service.

Los Angeles falls within the jurisdiction of the South Coast Air Quality Management District (AQMD), the air pollution control agency for a four-county region in California. The AQMD Multiple Air Toxics Exposure Study suggested that emissions from diesel combustion are carcinogenic. In 2000, AQMD Rule 1193 was adopted, requiring refuse fleets to begin purchasing alternative fuel trucks by July 2001.

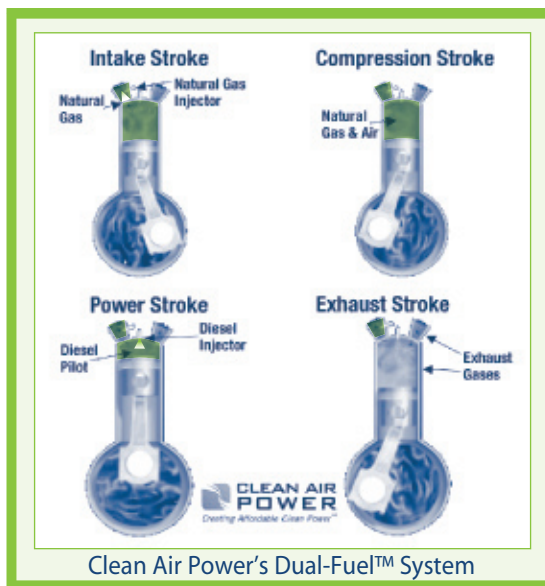
More than a year before the required date, with a partial grant from AQMD, the Bureau of Sanitation took delivery of an initial order of 10 Dual-Fuel refuse trucks. Since then, the Bureau's fleet of Dual-Fuel refuse trucks has

grown to 160, and it will reach 250 by mid-2004. NREL measured emissions from 10 Dual-Fuel trucks and three diesel control trucks¹. This fact sheet compares emissions results from the three diesel control trucks with those from four Dual-Fuel trucks that had the same exhaust aftertreatment as the diesel trucks (the six other Dual-Fuel trucks tested did not have exhaust aftertreatment).

COMMERCIALLY AVAILABLE DUAL-FUEL TECHNOLOGY

used in the refuse trucks was supplied by Clean Air Power, Inc. (formerly Clean Air Partners). The Dual-Fuel engines are based on new commercially available diesel engines, with natural gas injectors installed in the intake manifold

and an additional engine controller connected to the diesel electronic control unit. In a Dual-Fuel engine, natural gas enters the cylinder with the intake air. A small quantity of diesel is injected directly into the cylinder to provide compression ignition. At full load, up to 95% of the engine's operating energy is supplied by natural gas, with the remaining 5% supplied by the diesel charge. Dual-Fuel engines use a skip-fire technique to increase the proportion of natural gas used and reduce emissions at light loads. This technique introduces the fuel mixture into some, but not all, cylinders and continues to use additional cylinders in response to throttle demand until full power is achieved.



The four Dual-Fuel trucks were equipped with the Clean Air Power catalyzed particulate filter (CPF™). The three diesel trucks were equipped with the Engelhard DPX™ catalyzed particulate filter. The CPF is manufactured by Engelhard and uses the same technology as the DPX, but it is certified and marketed for use with natural gas vehicles.

THE WEST VIRGINIA UNIVERSITY TRANSPORTABLE HEAVY-DUTY VEHICLE EMISSIONS TESTING LABORATORY

was used to collect emissions data. The laboratory consists of two trailers: one with rollers, flywheels, and power absorbers for the dynamometer function and the other with controls and emissions measurement equipment. The trucks were driven onto the chassis dynamometer and positioned on two sets of rollers. The outer wheel

¹Walkowicz, K.A. et al., "Chassis Dynamometer Emission Measurements from Refuse Trucks Using Dual-Fuel™ Natural Gas Engines," SAE International Truck & Bus Meeting & Exhibition, November 2003, Ft. Worth, TX, paper no. 2003-01-3366.

	Dual-Fuel Trucks	Diesel Trucks
Truck	Peterbilt Model 320	Peterbilt Model 320
Model Year	2003	2000-2001
Wheelbase	164 in.	164 in.
GVWR	51,000 lbs.	51,000 lbs.
Curb Weight	32,077 lbs.	32,077 lbs.
Service	Curbside refuse pickup, automated side loader	Curbside refuse pickup, automated side loader
Engine	Caterpillar C10	Caterpillar C10
Model Year	2002	2000
Rating	315 hp, 1,050 ft.-lbs.	315 hp, 1,050 ft.-lbs.
Displacement	10.3 L	10.3 L
Ignition	Compression ignition	Compression ignition
Fuels	LNG and Ultra-Low Sulfur Diesel*	Ultra-Low Sulfur Diesel*
Storage	LNG: 110 gal. Diesel: 48 gal.	65 gal.
Range	80-110 miles	80-110 miles
Emissions on Simulated Curbside Pickup Cycle	Clean Air Power CPF Aftertreatment	Engelhard DPX Aftertreatment
CO**	0.60 g/mile	0.94 g/mile
NO _x	94.6 g/mile	122 g/mile
NMHC/THC***	0.30 g/mile	0.0 g/mile
PM**	0.07 g/mile	0.01 g/mile
CO ₂	8,875 g/mile	10,620 g/mile

* Less than 15-ppm sulfur
** Differences in CO and PM measurements between the Dual-Fuel and diesel trucks were not statistically significant
*** NMHC reported for Dual-Fuel trucks, THC reported for diesel trucks

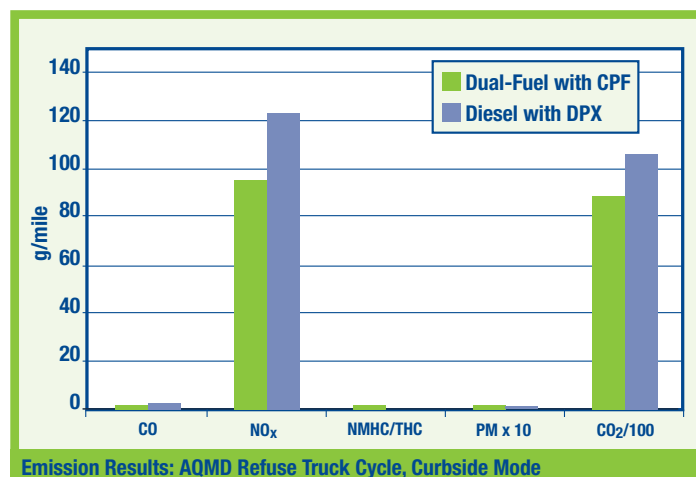
of the dual wheel set on each side of the vehicle was removed and replaced with hub adapters that couple the drive axle directly to the dynamometer units on each side of the vehicle.

A driver operated the vehicles through the AQMD Refuse Truck Cycle. This cycle is based on the William H. Martin Cycle. It includes highway operation (to represent driving between the pickup area and dump site), curbside refuse

pickup operation, and refuse compaction. Results over the curbside mode are shown in this fact sheet because typical residential refuse trucks spend most of their time and consume most of their fuel in this mode.

All tailpipe exhaust was ducted to a full-flow exhaust dilution tunnel, where it was mixed with filtered dilution air. The quantity of diluted exhaust was measured precisely with a critical flow venturi system. Samples of the diluted exhaust were analyzed for carbon monoxide (CO), carbon dioxide (CO₂), oxides of nitrogen (NO_x), total hydrocarbons (THC), non-methane hydrocarbons (NMHC), and total particulate matter (PM).

During the curbside mode, the Dual-Fuel trucks reduced average emissions of NO_x by 23% and CO₂ by 16% compared with the diesel trucks. Because all trucks used catalyzed particulate filters, emissions of PM and CO were very low (near detectable limits), and differences in these average emissions between the Dual-Fuel and diesel trucks were not statistically significant.



OVERALL, THE LOS ANGELES BUREAU OF SANITATION HAS BEEN SATISFIED with the ability of the Dual-Fuel trucks to meet the operational requirements of residential refuse collection. As with most new technologies, some initial problems were encountered, such as engine overheating and loss of fuel from on-board LNG tanks. The problems were overcome, and the Bureau continues to add Dual-Fuel trucks to its fleet.

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Web Sites

City of Los Angeles Bureau of Sanitation: www.ci.la.ca.us/SAN
Clean Air Power: www.cleanairpower.com
Advanced Vehicle Testing Activity: www.ott.doe.gov/otu/field_ops

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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