FY05

BIODIESEL RETROFIT SPECIAL PROJECT

AN

INTERDEPARTMENTAL AGREEMENT

BETWEEN

CITY OF ALBUQUERQUE

ENVIRONMENTAL HEALTH DEPARTMENT

AND

SOLID WASTE MANAGEMENT DEPARTMENT

JULY 2006

FINAL REPORT

City of Albuquerque
Environmental Health Department
Air Quality Division
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www.cabq.gov/airquality

FOREWORD

This FY05 project developed out of an opportunity that the United States Environmental Protection Agency (EPA) provided in a call for special project funding proposals. The deadline for initial proposals was May 7, 2004.

In order to mitigate emissions of ozone precursors and particulate matter in Bernalillo County, New Mexico, the City of Albuquerque, Environmental Health Department, Air Quality Division applied for and was awarded funding from Region 6, United States Environmental Protection Agency. The accepted special project involved retrofitting a small number of City-owned diesel refuse vehicles with an aftermarket emissions reduction component and changeover to biodiesel fuel.

This document will detail the decision-making that took place during development of the project, provide insight to those considering a similar project, and provide estimates of the emissions reductions possible from a similar diesel retrofit project.

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1.0 Diesel Retrofit Project Background

Albuquerque's pollutants of concern are ozone precursors, particulate matter (PM), and toxins. Diesel engines emit fine particulate in the form of carbonaceous soot that is created by pyrolysis in the combustion chamber. Diesels also emit hydrocarbon (unburned fuel) as an aerosol. Hydrocarbons are volatile organic molecules and ground level ozone precursors. Since new technologies had become available to retrofit diesel engines with emissions reduction devices that can be used with standard diesel fuel (D2) to effectively reduce emissions of both hydrocarbons and particulate matter from these engines, the Air Quality Division (AQD) opted for a diesel retrofit project. The installation of a catalytic exhaust muffler (CEM) also simultaneously reduces emissions of carbon monoxide from these vehicles by as much as 70%, a welcome bonus. The CEM is also referred to as a Diesel Oxidative Catalyst (DOC).

AQD drafted a proposal to retrofit selected City-owned diesel vehicles with aftermarket emissions reduction equipment in April 2004. Refuse collection trucks were chosen as the target vehicles because they visit residential and commercial properties in close contact with the public and the stop-and-go nature of their activities reduces the engine's efficiency and consequently increases its emissions relative to other equivalent vehicles. The newer refuse trucks in the City's fleet were already equipped with emissions reduction equipment when purchased and the oldest vehicles in the fleet would be scrapped before the full benefit of a retrofit could be realized. The vehicles that ultimately received the retrofit were 1997 models (Figure 1). These trucks would benefit from this retrofit since the 1997 models were not originally equipped with catalytic converters, yet their projected service lives were thought to be long enough to fully realize the emissions reduction potential of the project.

Figure 1

2.0 Technology

Vehicle catalytic converters are components of a vehicle's exhaust system (Figure 2) that consist of a metal canister filled with a porous ceramic insert (Figure 3) that's coated with certain rare earth elements such as platinum, palladium, or rhodium, depending on the desired chemistry. Using different catalytic coatings, catalytic converters can be formulated to oxidize or reduce pollutants or even both oxidize and reduce in a single unit. Catalytic converters have been used for years, first being applied on passenger vehicles in the mid-1970s, but impurities in traditional diesel fuel have, until recently, prevented use of catalytic converters on diesel vehicles.

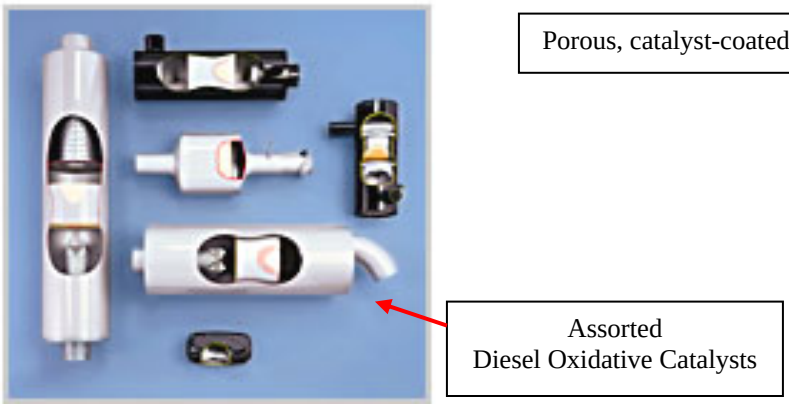

Figure 2

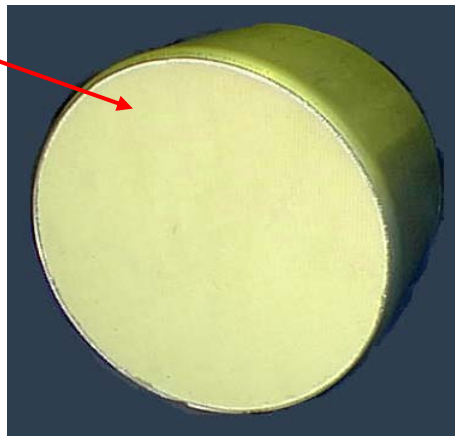

Figure 3

So-called Catalytic Exhaust Mufflers (CEM), otherwise known as Diesel Oxidative Catalysts (DOC) are now available that can be constructed and simply installed as a replacement for the vehicle's existing muffler. No other modifications to the vehicle are required, though, to extend the life of the catalyst, only vehicles with engines in a good state of tune were chosen for the project. The CEM contains an oxidation catalyst/muffler combination that reduces particulate emissions up to 25%, and hydrocarbon and carbon monoxide emissions as much as 70%. Unlike particle traps, which have a tendency to plug, a catalyst tends not to clog if the vehicle's duty cycle is adequate to keep the catalyst hot.

The effectiveness of the retrofit and the expected service lifetime of the catalyst are tied to how the vehicles are used, so care should be taken to ensure that the type of technology chosen matches the vehicle's duty cycle. While our refuse vehicles do a lot of stop-and-go driving during collection, they make frequent extended excursions on the freeway at highway speeds to discharge their loads at the City's somewhat distant landfill. The extended trips on the highway at sustained high speeds are adequate in our situation to give the catalyst time to regenerate and to prevent clogging.

3.0 Verification

Since EPA will not fund a project that does not use "verified" technology, the AQD consulted EPA's verification webpage at http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm for clarification. Manufacturers wishing to have their products verified must put those products through a rigorous testing

program to ensure that the product will perform as advertised. For details about EPA's verification program, point your browser to http://www.epa.gov/etv.

The trucks chosen for our project were manufactured by Volvo and equipped with Cummins 4-stroke diesel engines. The Solid Waste Department (SWD) ultimately chose to retrofit the selected trucks with a Fleetguard™ diesel oxidative catalyst (DOC). Fleetguard™ is a wholly owned subsidiary of Cummins Diesel and manufactures a catalytic exhaust muffler (CEM) that has been verified through the EPA's Environmental Technology Verification program. By choosing a CEM manufactured by a subsidiary of the vehicle engine manufacturer, the City of Albuquerque was able to sidestep the inevitable question of whether or not installation of an "aftermarket device" might void the manufacturer's engine warranty.

4.0 Bio-diesel Fuel

The Fleetguard™ CEM chosen for our project is compatible with standard diesel fuel (D2), provided the sulfur content of the fuel is below 500 ppm. Fuel with a higher concentration of sulfur can be damaging to a catalyst. The D2 marketed in and around Albuquerque is typically below 400 ppm sulfur, which was considered adequate for our project. But the effectiveness of the catalyst is increased as the sulfur content of the fuel is reduced. Therefore, to maximize the benefits of the retrofit project, the City of Albuquerque, at Cummins' suggestion, chose to fuel the modified vehicles with biodiesel fuel. The product chosen was B20, a hybrid blend of 80% D2 and 20% biodiesel fuel. Biodiesel fuel contains less sulfur than D2, so, by blending biodiesel and D2 together the total sulfur content of the fuel is reduced. B20 reduces PM emission by about 10%, even when used without a CEM. Therefore, using B20 in conjunction with a CEM should yield additional PM emissions reductions.

5.0 Planning for the Future

AQD staff worked closely with the manufacturer of the catalyst, fuel suppliers, and the Solid Waste Management Department to become as knowledgeable about our project as possible in order to anticipate and avoid potential pitfalls. We learned that B20 fuel tends to act as a detergent in older vehicles' fuel systems and can loosen varnish that has built up in the fuel tanks and fuel lines over time, resulting in clogged fuel filters. In anticipation of that issue, some project funds were earmarked to purchase replacement fuel filters to be available, as necessary, in the event of problems.

6.0 Supplemental Project

Our initial request was for funding to retrofit 21 refuse collection trucks with a CEM plus pay the cost differential between B20 and traditional diesel fuel for a period of one year. After reviewing our proposal the EPA decided to directly sponsor a supplemental retrofit of an additional 14 trucks, resulting in a total of 35 trucks having CEMs installed. Since EPA was able to directly pay the vendor for the supplemental retrofits, effectively streamlining the work, Cummins Rocky Mountain retrofitted the additional 14 trucks by September 2004. The 21 trucks chosen for the initial project were retrofitted by Roberts Trucking and completed by June 2005.

7.0 Availability of Biodiesel Fuel

Hurricane Katrina struck in August 2005, seriously disrupting supplies of fuels, particularly biodiesel, from the gulf coast refineries. Supply of biodiesel fuel to the City of Albuquerque was suspended in late August 2005. Fortunately the catalyst chosen for our project would still function by fueling with D2, so the unavailability of biodiesel did not cause a disruption of the project or affect continued use of the CEM.

In the interim, the City of Albuquerque made the independent decision to use ultra low-sulfur diesel fuel for its public transportation fleet and B20 fuel for the remainder of its diesel fleet. So, once supplies of B20 were resumed, all City-owned diesel vehicles where back to using ultra low-sulfur diesel fuel and B20.

8.0 Estimated Emissions Reductions

Fleet emissions reductions anticipated over the course of a year are based on a standard weekly schedule for a typical refuse vehicle using the fuel/mileage records of 18 of the 35 retrofitted trucks whose service histories were free of interruption during the course of the project.

Anticipated emissions reductions include the benefit of additional PM reductions utilizing the CEM with biodiesel.

9.0 Calculations

Given:

Cummins M11 engines are rated at 350 brake horse power (bhp)

DOC or CEM = Diesel Oxidative Catalyst or Catalytic Exhaust Muffler

8 hours/day ; 5 days/week ; 52 weeks/year ; 2,080 hours/year (Standard annual refuse vehicle operation)

1997 federal emissions standards for heavy-duty diesel engines are as follows:

Carbon Monoxide (CO) - 15.5 grams/brake horsepower-hour (g/bhp-hr)

Hydrocarbons (HC) - 1.3 g/bhp-hr

Particulate Matter (PM) - 0.1 g/bhp-hr

Estimated percent of pollutant reductions are as follows:

10% PM reduction from B20 (0.1 factor for calculations)

25% PM reduction from DOC (0.25 factor for calculations)

70% CO reduction from DOC (0.7 factor for calculations)

70% HC reduction from DOC (0.7 factor for calculations)

PARTICULATE MATTER (Reduction estimate from use of B20)

(0.1 g /bhp-hr) (350 hp	*	2,080 hrs/yr/truck)	=	72,800 g/yr/truck
72,800 g/yr/truck	*	0.1 (factor) Reduction (B20)	=	7,280 g/yr/truck Reduction (B20)
7,280 g/yr/truck Reduction (B20)	*	0.002204623 lb/g	=	16.05 lb/yr/truck Reduction (B20)

PARTICULATE MATTER (Reduction estimate from use of DOC)

72,800 g/yr/truck	-	7,280 g/yr/truck Reduction (B20)	=	65,520 g/yr/truck
65,520 g/yr/truck	*	0.25 (factor) Reduction (DOC)	=	16,380 g/yr/truck Reduction (DOC)
16,380 g/yr/truck	*	0.002204623 lb/g	=	36.11 lb/yr/truck Reduction (DOC)

PARTICULATE MATTER (Reduction estimate total)

36.11 lbs/yr/truck Reduction (DOC)	+	16.05 lbs/yr/truck Reduction (B20)	=	52.16 lbs/yr/truck Reduction (DOC + B20)
52.16 lbs/yr/truck Reduction (DOC + B20)	÷	2,000 lbs/ton	=	~ 0.03 tons/yr/truck Reduction (DOC + B20)
0.03 tons/yr/truck Reduction (DOC + B20)	*	18 trucks	=	~0.5 tons/yr Reduction (DOC + B20)

CARBON MONOXIDE (Reduction estimate from use of DOC)

(15.5 g /bhp-hr)	(350 hp *	2,080 hrs/yr/truck)	=	11,284,000 g/yr/truck
11,284,000 g/yr/truck	*	0.7 (factor) Reduction (DOC)	=	7,898,800 g/yr/truck Reduction (DOC)
7,898,800 g/yr/truck Reduction (DOC)	*	0.002204623 lb/g	=	~17,414 lbs/yr/truck Reduction (DOC)
17,414 lbs/yr/truck Reduction (DOC)	÷	2,000 lbs/ton	=	~ 8.7 tons/yr/truck Reduction (DOC)
8.7 tons/yr/truck Reduction (DOC)	*	18 trucks	=	157 tons/yr Reduction (DOC)

HYDROCARBON (Reduction estimate from use of DOC)

(1.3 g /bhp-hr)	(350 hp *	2,080 hrs/yr/truck)	=	946,400 g/yr/truck
946,400 g/yr/truck	*	0.7 (factor) `Reduction (DOC)	=	662,480 g/yr/truck Reduction (DOC)
662,480 g/yr/truck Reduction (DOC)	*	0.002204623 lb/g	=	~1,460.5 lbs/yr/truck Reduction (DOC)
1,460.5 lbs/yr/truck Reduction (DOC)	÷	2,000 lbs/ton	=	~ 0.73 tons/yr/truck Reduction (DOC)
0.73 tons/yr/truck Reduction (DOC)	*	18 trucks	=	13 tons/yr Reduction (DOC)

10.0 Conclusion

The intent of this project was to apply verified emissions reductions equipment to a class of vehicles whose emissions have a regular impact throughout the residential community. The estimated air pollutant reduction anticipated by the installation of CEM's and changeover to alternative fuel suggests that significant emissions reductions could be extrapolated from the potential results associated with this

project's small pool of vehicles retrofitted, which was further reduced for calculating reductions due to unanticipated changes in vehicle service requirements, or down time for special repairs.

11.0 - References

EPA (1997), Emission Standards Reference Guide for Heavy-Duty and Nonroad Engines. Environmental Protection Agency, Air and Radiation, www.epa.gov/otaq/cert/hd-cert/stds-eng.pdf.

Chevron (1998), Diesel Fuel and Air Quality. Chevron Products, http://www.chevron.com/products/prodserv/fuels/bulletin/diesel/L2_3_6_rf.htm

Fleetguard™ (2006), Diesel Oxidation Catalyst. Fleetguard Products, http://www.fleetguard.com/fleet/en/products/en_prod_ems)docatslyst.jsp

Acronyms and Special Terms

DOC	–	Diesel Oxidative Catalyst – A muffler-like component of a diesel engine exhaust system consisting of a container filled with a catalytic material supported on a porous ceramic substrate. The catalyst promotes oxidation of pollutants into less toxic emissions in the vehicle's exhaust stream.
CEM	–	Catalytic Exhaust Muffler (see DOC).
ppm	–	Parts per million.
Biodiesel Fuel	–	Refers to alkyl esters made from the transesterification of both vegetable oils and/or animal fats. Biodiesel is biodegradable, non-toxic, and has significantly fewer emissions than petroleum-based diesel when burned.
B20	–	A hybrid motor fuel which consists of 80% D2 and 20% biodiesel fuel.
bhp	–	Brake horsepower can be defined as the measure of an engine's horsepower without the loss in power caused by the gearbox, generator, differential, water pump and other auxiliaries. The actual horsepower delivered to the driving wheels is less.
g/bhp-hr	–	Grams per brake horsepower – hour.