IMPROVE AIR QUALITY: Reduce Emissions from Diesel-Fuelled Buses

Diesel-fuelled buses can be an important source of air pollutants. They can emit significant amounts of nitrogen oxides (NO_X), particulate matter ($PM_{2.5}$ and PM_{10}) [1], sulphur dioxide (SO_2), sulphates (SO_4), carbon monoxide (CO), and volatile organic compounds (VOCs). These air pollutants can contribute to the formation of smog and have been linked to a variety of acute and chronic health outcomes, including respiratory illnesses, heart disease, and premature death.

Owners and operators of diesel-fuelled buses can take steps to significantly reduce the emission of air pollutants from their vehicles. This fact sheet provides information about the steps that they can take—which include using cleaner fuels, replacing older vehicles with new buses equipped with more advanced emission control systems, and retrofitting existing engines with improved emission control systems—and the benefits associated with these actions.

Use Low-Sulphur Diesel Fuel

Sulphur levels in diesel fuels can affect vehicle exhaust emissions in two ways. First, there is a direct relationship between the sulphur levels in the fuel used and the tailpipe emissions of SO_2 and SO_4 particulates. Second, sulphur emissions can impair the effectiveness of exhaust emission control devices such as conventional diesel oxidation catalysts and more advanced systems such as diesel particulate filters and NO_X adsorbers.

The Canadian *Diesel Fuel Regulations*, which came into effect in 1998, limited sulphur levels in on-road diesel fuel to a maximum of 500 parts per million (ppm). [2] In 2002, these regulations were revoked and replaced by the *Sulphur in Diesel Fuel Regulations*, which will reduce sulphur levels in on-road diesel fuel to a maximum of 15 ppm starting in June 2006. The goal of the *Sulphur in Diesel Fuel Regulations* is to enable engine manufacturers to use the advanced emission control devices that are likely to be needed in order to achieve the stringent emission standards that will apply to heavy-duty diesel engines beginning with the 2007 model year.

Diesel fuel with low levels of sulphur is currently available in some areas of the country. By using diesel fuel that contains low levels of sulphur instead of conventional diesel (which contains, on

1 Particulate matter less than or equal to 2.5 microns ($PM_{2.5}$) and particulate matter less than or equal to 10 microns (PM_{10}).

2 Sulphur levels in fuel can also be reported in milligrams per kilogram (e.g., 500 ppm is equivalent to 500 mg/kg).

average, about 320 ppm sulphur in Canada [3]), vehicle emissions can be substantially reduced. When New York City transit buses equipped with diesel oxidation catalysts were fuelled with 30 ppm sulphur diesel instead of 300 ppm sulphur diesel, emissions of PM and CO were reduced by about 30%, and emissions of hydrocarbons (HC) and SO_4 were reduced to an even greater extent (Table 1).

The Region of Waterloo, Ontario, which began purchasing diesel fuel with less than 30 ppm sulphur for its transit fleet in May 2003, is paying a premium of $0.05 or $0.06 per litre for this fuel. This cost premium is expected to be less where larger volumes of diesel fuel are purchased and in regions that have ready access to low-sulphur fuels. [4]

Replace Older Buses with New Buses

Significant reductions in air emissions can be achieved by replacing older diesel-fuelled buses with newer ones that comply with more progressive emission standards. Since the 1970s, the federal government has established increasingly stringent emission standards for new on-road vehicles. Exhaust emission standards for heavy-duty diesel vehicles, which are engine-based and expressed in grams per brake horse power-hour (g/bhp-h), have been significantly tightened over the last two decades. This is particularly true for the emission standards applied to NO_x and PM for new on-road heavy-duty diesel engines, which are summarized in Table 2. The new emission standards, which will be phased in beginning in 2007, will reduce emissions of NO_x and PM from new on-road diesel engines by 95% and 90%, respectively, compared with the 1998 standards. [5]

Retrofit with Diesel Oxidation Catalysts

When heavy-duty diesel vehicles are retrofitted with diesel oxidation catalysts, emissions of toxic air pollutants can be substantially reduced. Diesel oxidation catalysts can be used to retrofit in-use buses and trucks to produce substantial emission reductions with relatively little investment. While these devices can operate on conventional diesel (which contains, on average, about 320 ppm sulphur in Canada [6]), they operate more efficiently when used with fuel that has a low sulphur content. As part of its Voluntary Diesel Retrofit Program, the U.S. Environmental Protection Agency (EPA) identifies specific diesel oxidation catalysts that have been "verified," the engines with which they have been verified, and the emission reductions that can be achieved with the various combinations. While the emission reductions vary depending upon the engine type, model year, retrofit technology applied, pollutant, and vehicle operation, the reductions can be as high as 26% for PM, 41% for CO, and 66% for HC. [7]

The Region of Waterloo, Ontario, which plans to retrofit 86 of its existing buses with diesel oxidation catalysts, estimates that it will cost about $3,500 to $5,000 per bus for parts and installation. It has targeted the 1989 to 1999 model year buses for retrofitting. [8] According to vendors, there is no additional maintenance involved with the use of diesel oxidation catalysts.

Retrofit with Diesel Particulate Filters

Catalyzed diesel particulate filters are very efficient emission control devices that can be installed on in-use buses by replacing the existing muffler. They are, however, very sensitive to sulphur emissions and must be used with diesel fuels containing low levels of sulphur. When New York City buses were retrofitted with diesel particulate filters and fuelled with 30 ppm sulphur diesel fuel, emissions of a broad array of smog-forming and toxic air pollutants were reduced by 70 to 99% relative to buses equipped with diesel oxidation catalysts and fuelled with diesel containing 300 ppm sulphur (see Table 3).

While diesel particulate filters have been used in a large number of communities in the United States, there has been less experience with them in Canada. Diesel particulate filters are currently being tested on two Edmonton Transit buses to see how they perform in extreme Canadian weather conditions. With nine months of testing completed, Edmonton Transit reports that the diesel particulate filters appear to

3 Sulphur in Liquid Fuels 2002 (Environment Canada).

4 Rob Bromley, Public Health Department, Region of Waterloo, March 2003.

5 On-Road Vehicle and Engine Emission Regulations, *Canada Gazette*, Part II, January 1, 2003.

6 Sulphur in Liquid Fuels 2002 (Environment Canada).

7 U.S. EPA, Verified Technologies, Website http://www.epa.gov/otaq/retrofit/retrofittech.htm.

8 Rob Bromley, Public Health Department, Region of Waterloo, March 2003.

Table 1 Measured Emissions (g/km) and Emission Reductions (%), 1999, Buses with Diesel Oxidation Catalysts (DOC), 300 ppm Sulphur Diesel Fuel Relative to 30 ppm Sulphur Diesel Fuel [a]

	HC	CO	NO_x	PM	SO_4
DOC & 300 ppm sulphur	0.135	1.23	14.9	0.122	0.0385
DOC & 30 ppm sulphur	0.030	0.876	15.5	0.086	0.00174
Emission reduction	**-78%**	**-29%**	**+4.0%**	**-29.5%**	**-95%**

a Tested in the Central Business District cycle.

Source: Lanni *et al.*, "Performance and Durability Evaluation of Continuously Regenerating Particulate Filters on Diesel Powered Urban Buses at NY City Transit," Society of Automotive Engineers (2001-01-0511).

Table 2 Summary of Emission Standards (g/bhp-h) Applied to NO_x and PM Emissions from New On-Road Heavy-Duty Diesel Engines (1990 to 2007)

Model year	NO_x	PM
1990	6.0	0.60
1991 [a]	5.0	0.25
1994 [a]	5.0	0.10 (0.07) [b]
1998	4.0	0.10 (0.05) [b]
2004	2.0 [c]	0.10 (0.05) [b]
2007+	0.2	0.01

a Compliance in Canada based on voluntary initiative of engine manufacturers.
b Tighter standard (in parentheses) applies only to engines used in urban buses.
c Approximate level, as actual emission standard applies to combined emissions of NOx + non-methane HC.

Table 3 Measured Emissions and Emission Reductions, 1999, Buses with Diesel Oxidation Catalysts (DOC) and 300 ppm Sulphur Diesel Fuel Relative to Diesel Particulate Filters (DPF) and 30 ppm Sulphur Diesel Fuel [a]

	HC (g/km)	CO (g/km)	NO_x (g/km)	PM (g/km)	Carbonyl [b] (mg/km)	PAHs [c] (mg/km)	NO_2-PAH (mg/km)	SO_4 (mg/km)	SO_2 (mg/km)
DOC & 300 ppm sulphur	0.135	1.23	14.9	0.122	46.6	39.8	2.73	38.5	182
DPF & 30 ppm sulphur	0.009	0.075	15.5	0.015	0.31	9.01	0.621	8.08	4.47
Emission reduction	**-93%**	**-94%**	**+4%**	**-88%**	**-99%**	**-77%**	**-77%**	**-79%**	**-98%**

a Tested in the Central Business District cycle.
b Carbonyl is a family of chemicals that includes formaldehyde.
c PAHs stands for polycyclic aromatic hydrocarbons.

Source: Lanni *et al.*, "Performance and Durability Evaluation of Continuously Regenerating Particulate Filters on Diesel Powered Urban Buses at NY City Transit," Society of Automotive Engineers (2001-01-0511).

be operating very well. Tailpipe emissions testing conducted when temperatures dropped below 0°C indicate that the filters were reducing PM, CO, and HC emissions by 60 to 80% despite the cold weather conditions. [9] For maintenance, the U.S. EPA recommends cleaning diesel particulate filters every 48,000 kilometres. [10]

The Region of Waterloo, which has purchased 18 new 2004 model year buses equipped with continuously regenerating diesel particulate filters, will pay about $10,000 to $12,000 more per bus for these advanced emission control devices. The Regional Council of Waterloo considers this cost increase to be acceptable given that the overall cost of a new transit bus approaches $500,000. [11]

Calculating Emission Reductions

The U.S. EPA has developed a website that is designed to assist fleet managers and others to calculate the emission reductions associated with various retrofit scenarios. This site, which can be accessed at http://www.epa.gov/otaq/retrofit/aqcreditcalc.htm provides equations with which to calculate reductions, information on the various combinations of technologies and fuels, and a calculator that can be used to determine the emission reductions.

9 Rick Paul, Edmonton Transit, Canadian Urban Transit Association (CUTA) Presentation, November 2003.

10 Anthony Erb, U.S. EPA Voluntary Diesel Retrofit Program, November 2003.

11 Rob Bromley, Public Health Department, Region of Waterloo, October 2003.

For further information

Ontario Public Health Association (OPHA)
Air Quality Project

http://www.opha.on.ca/projects/air.html

For additional information

Oil, Gas and Energy Branch
Environment Canada
351 St. Joseph Blvd.
Gatineau, QC K1A 0H3

or visit Environment Canada at

http://www.ec.gc.ca/energ/main_e.htm and click on **Library/Reports**

The internet Web site addresses in this fact sheet were current at the time of printing and are subject to change.

Additional information can be obtained at Environment Canada's Web site at **www.ec.gc.ca** or at the Inquiry Centre at **1-800-668-6767**.