Vehicle Emissions Team

Report on Diesel Particulate Filter Technology Adoption in Diesel Bus Fleets

Prepared by the
Vehicle Emissions Team
for the
Clean Air Strategic Alliance Board of Directors

Final Report

August 31, 2010

Acknowledgements

Members of the Vehicle Emissions Team showed dedication and commitment to using the CASA process to achieve their objectives. The Vehicle Emissions Team acknowledges the valuable input it received from many stakeholders, especially representatives of the cities of Edmonton (Mike Mellross) and Calgary (Ron Schafer).

About CASA

The Clean Air Strategic Alliance (CASA) is a non-profit association composed of stakeholders from three sectors – government, industry and non-government organizations such as health and environmental groups. All CASA groups and teams, including the board of directors, make decisions and recommendations by consensus. These recommendations are likely to be more innovative and longer-lasting than those reached through traditional negotiation processes. CASA's vision is that the air will have no adverse odour, taste, or visual impact and have no measurable short- or long-term adverse effects on people, animals or the environment.

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Executive Summary

As part of its ongoing interest in exploring ways to reduce vehicle emissions in urban areas, the CASA Vehicle Emissions Team undertook a demonstration project to test the effectiveness of Diesel Particulate Filter (DPF) technology in cold weather. The project demonstrated that DPF technology can contribute to emissions reduction under Alberta's general climatic conditions.

With the new technology proven to reduce emissions, new regulations came into place in 2007. Starting that year, the adoption of DPF technology in public transportation buses in Alberta showed a significant increase. By April 2010, Edmonton and Calgary could count 29% of public transportation buses using DPF technology.

Contents

1 Report Objectives

This document reports on the implementation of two recommendations approved by the CASA Board at their June 16, 2005 meeting:

Recommendation 1: The CASA Vehicle Emissions Team recommends that the Diesel Particulate Filter final report be distributed to Alberta diesel fleet managers and other appropriate parties.

Recommendation 2: The Vehicle Emissions Team will assess the adoption of Diesel Particulate Filter technology in Alberta and report back in 3 years.

2 VET and DPF Background

Alberta has a relatively high consumption of diesel fuel due to its transportation and industrial activities. It is the highest among the Canadian provinces: in 2007, it was 787 litres per habitant, followed by SK (678), MB (553), ON (301), NS (270), QC (254), PEI (230), NL (170), BC (168) and NB (112)[1].

Figure 1 shows the total particulate matter (TPM) emissions for on-road heavy diesel vehicles (HDV)[2] as a percentage of Mobile Sources (excluding off-road vehicles) in different Canadian provinces.

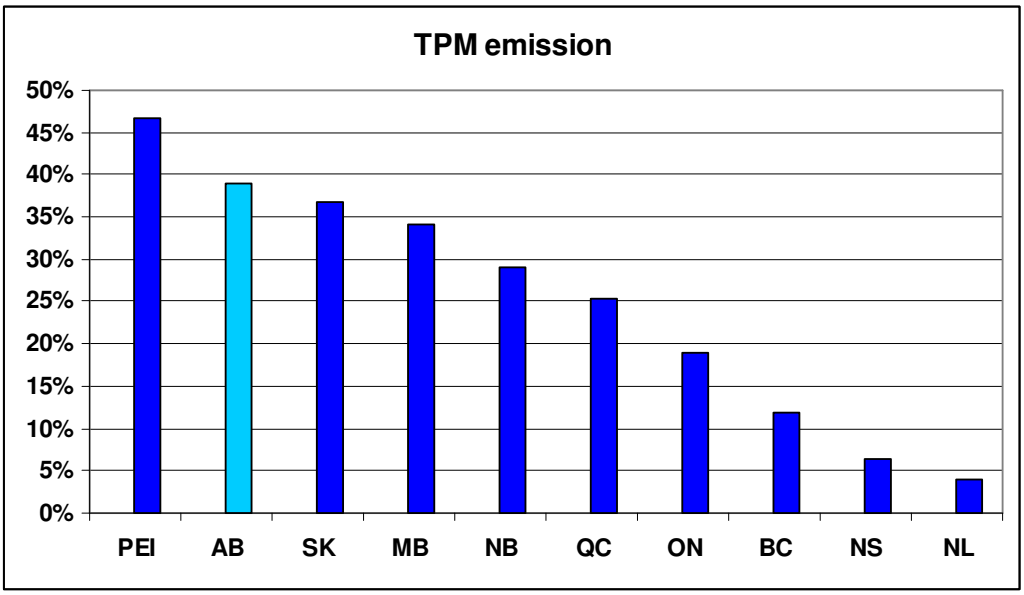

Figure 1: TPM emissions from on-road heavy diesel vehicles as a percentage of Mobile Sources (excluding off-road vehicles).

Thus, as part of its ongoing interest in exploring ways to reduce vehicle emissions in urban areas, the CASA Vehicle Emissions Team undertook a demonstration project to test the effectiveness of the

[1] 2007 Canadian Vehicle Survey, Natural Resources Canada.
[2] HDV is a motor vehicle that is rated at more than 3,856 kg (8,500 lbs.) Gross Vehicle Weight Rating (GVWR).

Johnson Matthey Continuously Regenerating Technology® (CRT; i.e., Diesel Particulate Filter (DPF)) under cold weather conditions. The project involved a one-year test of the filter on two diesel buses in the Edmonton Transit System (ETS) fleet, between January 2003 and January 2004.

The project was also an opportunity to assess the impacts of using ultra-low sulphur diesel (ULSD) fuel, which was mandated in Canada starting in June 2006. In this project, vehicle exhaust emissions were tested for total hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide, and particulate matter.

This pilot program was based on actual tests with production model buses during revenue operations in a cold weather environment, which is something that virtually all Canadian transit systems experience. Several technical presentations were made at Canadian Urban Transportation Association meetings, and the test program and its results generated substantial interest among transit-related organizations across the country.

The project also had considerable public exposure in the Edmonton area through newspaper articles and radio news broadcasts following the kick-off event. Attendance at special events, handing out information brochures, and displaying the two vinyl-wrapped test buses provided additional community exposure to the technology and clean air issues.

The test, conducted by the Edmonton Transit System, evaluated the performance of DPF technology while gaining experience with installing and maintaining the device. The filter did not impair bus performance, in terms of fuel economy and driving performance, but it does require annual cleaning to ensure proper continued operation; the cleaning process will add about three hours to the annual maintenance inspection for each bus.

2.1 DPF Project Objectives

The objectives of the Diesel Particulate Filter (DPF) Project were to:

1. Demonstrate the effectiveness of diesel engine emissions reduction technology in an Alberta context (i.e., under local cold weather conditions).
2. Provide an opportunity for Alberta's transportation and transit industries to acquire hands-on experience with the installation, use and performance characteristics of CRT technology.
3. Increase public and transportation industry awareness of existing and emerging DPF emissions reduction technology.
4. Stimulate the transportation and transit industry's interest in and adoption of air pollution reduction devices.
5. Increase public awareness of air quality issues.
6. Improve urban air quality.

2.2 DPF Project Remarks

The project's main conclusion is that the DPF worked with ULSD fuel and in modern engines with high combustion temperatures in Alberta's climate. By using diesel particulate filters, it is possible to

advance emissions reductions that would otherwise take longer to occur through fleet turnover. The results showed specifically that:

1. There were major reductions in emissions of three pollutants, but no significant change in the emission rate of nitrogen oxides. A range in reductions is given to reflect the differences observed in the two phases:
   - Total hydrocarbons: 51 – 87%
   - Carbon monoxide: 67 – 89%
   - Total particulate matter: 60 – 75 %
2. The CRT performed effectively even in the very cold weather experienced during the test period.
3. The use of ULSD on its own did not show any significant emission reductions for the pollutants that were measured. ULSD is an enabling fuel for the implementation of new advanced emission control devices, like the CRT.

Based on test results, the use of this technology on transit fleets has the potential to help improve local air quality, particularly in transit operational facilities and along diesel bus routes.

3 Addressing Recommendation 1 – Report Distribution

During July 2005, a summary letter and the Diesel Particulate Filter Pilot Project Final Report were distributed to more than 250 stakeholders, fleet managers and other appropriate parties in Alberta as well as federal government representatives in Alberta and Ottawa. Appendix C shows an example of the letter. The Diesel Particulate Filter Pilot Project Final Report is available from CASA and Government of Alberta web sites[3].

4 Addressing Recommendation 2 – Provide an Update

Recommendation 2 required that an update on the current status of DPF technology adoption in Alberta be provided to the CASA Board three years after the CASA DPF report was issued. This update is provided in the following paragraphs.

Alberta has two large urban areas, Edmonton and Calgary, as well as several medium urban areas (e.g. Red Deer, Lethbridge, Fort McMurray, and Grande Prairie). City development and density factors have supported the development of public transportation in these cities. In these urban areas, the larger on-road heavy diesel vehicle fleets are made up of the public transit system and the school bus fleet. The transit system fleet is more than five times larger than the school bus fleet. In addition, transit systems (a public asset) pursue different outcomes and initiatives than the school bus system (a private asset). Thus, the focus in the analysis of the adoption of the DPF technology in Alberta was on the public transit system.

[3] Alberta Transportation http://www.transportation.alberta.ca/Content/docType57/Production/DieselFilter.pdf , and http://www.CleanBus.ca

In 2007, the Environmental Protection Agency (EPA) and Transport Canada set stringent limits on Nitrogen Oxide and Particulate Matter emissions from on-road trucks and buses. Through a combination of engine redesign, ultra-low sulphur diesel fuel and engine oils, new vehicle technologies will significantly cut emissions. Combined, the new regulations and technologies made it feasible for bus manufacturers to develop an Original Equipment Manufacturer (OEM) DPF technology for their buses.

In 2007, with the new regulation in place, the owners of the bigger bus fleets in Alberta started to purchase modern diesel buses that fulfill the regulation requirements. These modern diesel buses have incorporated different DPF technologies, mainly active filters.

4.1 Edmonton Transit System

Edmonton Transit System (ETS) developed a DPF retrofit program in 2007. This program was discontinued because:

- The turnover of the fleet was accelerated to remove the GMC Bus Fleet from Service by 2009. This left around 585 buses that did not have DPF in the ETS fleet.
- The pilot project to test the DPFs provided information concerning the reliability of the product. The DPFs were creating maintenance issues for the ETS fleet, which in turn impacted operations. It was determined the technology was not suitable for Transit operations.

The Edmonton Transit System (ETS) buses purchased in 2007 /2008 are modern diesel buses[4]. These buses are equipped with engines that have electronically controlled fuel systems, fuelled by ultra low sulphur diesel to achieve the best fuel economy. DPF and Exhaust Gas Recirculation have also been installed to reduce the release of pollutants to the environment. The DPF used on the new buses is an active filter system which re-burns particulate matter in the muffler system. The following table presents the adoption of DPF technology in the ETS fleet.

Table 1: Use of the DPF technology in ETS fleet (last update, April 2010)

ETS active diesel fleet	Total	With DPF technology	Penetration
Buses (40', 60', shuttles)	**943**	**358**	**~ 38%**

This represents a range in reductions for the public transportation sector in Edmonton[5]:

- Total hydrocarbons: 19 – 33% (4.4 to 7.6 tonnes/year)
- Carbon monoxide: 25 – 34% (39.5 to 52.5 tonnes/year)
- Total particulate matter: 23 – 29% (7.0 to 8.7 tonnes/year)

Rather than retro-fitting existing buses, turnover in new buses may address the implementation of the DPF technology in the ETS fleet. Bus turnover is about 25 years. ETS has established a program for the replacement of the remaining 585 buses over the next 14 years; this represents an average rate of 40 per year. The new buses have DPF technology as OEM.

[4] The City of Edmonton. Retrieved August 10, 2010 from http://www.edmonton.ca/transportation/ets/about_ets/current-ets-initiatives.aspx

5 Base on the Diesel Particulate Filter Pilot Project, Final Report. CASA, December 2004.

4.2 Calgary Transit

To reduce particulate matter, all new Calgary Transit (CT) buses purchased from 2007 on, have Diesel Particulate Filters (DPFs) installed[6]. This new engine technology significantly reduces Calgary Transit's vehicle emissions into the environment. CT Technical Services has just finished gathering data on the first delivery of EPA 2007 engines. They reported a 74% initial failure rate of the OEM DPF system while under warranty.

The following table presents the adoption of DPF technology in the CT fleet.

Table 2: Use of the DPF technology in CT fleet (last update, April 2010)

CT active diesel fleet	Total	With DPF technology	Penetration
Total	**969**	**175**	**18 %**

This represents a range in reductions for the public transportation sector in Calgary[5]:

- Total hydrocarbons: 9 – 16% (2.2 to 3.7 tonnes/year)
- Carbon monoxide: 12 – 16% (19.3 to 25.6 tonnes/year)
- Total particulate matter: 11 – 14% (3.4 to 4.3 tonnes/year)

Turnover in new buses is also addressing the adoption of DPF technology as OEM in the CT fleet. CT has not made public its plan for the fleet renovation; CT has purchased 65 new buses in 2008 and 50 in 2009, and its goal is to replace as many old two-stroke technology engines as soon as capital funding becomes available.

4.3 St. Albert Transit

St. Alberta Transit (StAT) incorporated 13 new buses in 2007 with engines designed under EPA 2007 regulations which include the particulate filter as standard technology. In 2008 StAT incorporated 3 buses, and in 2009, 15 new buses also under EPA 2007 engine regulations. Based on this trend, the following table presents the adoption of the DPF technology in the StAT fleet.

Table 3: Use of the DPF technology in St. Albert Transit (last update, July 2010)

StAT diesel fleet	Total	With DPF technology	Penetration
Total	**58**	**31**	**53 %**

This represents a range in reductions for the public transportation sector in St. Albert[5]:

- Total hydrocarbons: 27 – 47% (0.4 to 0.7 tonnes/year)
- Carbon monoxide: 36 – 48% (3.4 to 4.5 tonnes/year)
- Total particulate matter: 32 – 40% (0.6 to 0.8 tonnes/year)

[6] Calgary Transit. Retrieved August 10, 2010 from http://www.calgarytransit.com/environment/emissions.html

Turnover in new buses is also addressing the adoption of DPF technology as OEM in the StAT fleet. StAT has not made public its plan for the fleet renovation.

4.4 Private Sector

In the private sector, the adoption of DPF technology is slower and dependent on fleet renovation, but the bus turnover in the private sector is lower than in the public sector. For example, Southland Transportation, one of the biggest school buses transportation companies operating in Alberta, currently operates 151 buses in the Edmonton area. By April 2010, eight of these units were equipped with OEM DPF technology (5.3%).

5 Conclusions

Many projects around the world have demonstrated the effectiveness of DPF technology in emissions reduction when it is applied to diesel engines. In Canada, weather conditions present particular constraints for every technology dealing with emissions reduction. The demonstration project developed by CASA was successful in that it assessed DPF technology in Alberta's conditions.

Over time, several factors have contributed to expand the use of DPF technology:

- Demonstration projects have proven the efficacy of the adoption of DPF technology in the emission reduction; and
- EPA and Transport Canada regulations have decreased the allowable rate of emissions from on-road trucks and buses.

Thus, we can conclude:

- The DPF report was an important piece for understanding DPF technology in Alberta's conditions, however, the report is now outdated;
- Regulation, DPF technology evolution, and successful results in its use reducing emissions have combined to improve the adoption of DPF technology as OEM; nevertheless, technical challenges remain in order to decrease failures in the operation of DPF as OEM.
- Because the use of retrofits resulted in maintenance issues and was not viable, the current trend of adoption of DPF technology follows the same rate as the turn-over of the transportation fleet;
- Starting in 2007, public transportation started to show an increase in the use of DPF technology in Alberta;
- The rate of DPF adoption in private transportation in Alberta appears to be lower than that for the public sector because of slower fleet turn-over; and
- As of April 2010, in the two biggest cities in Alberta, 28% of the public transportation buses are equipped with DPF technology. This represents a range in reductions for the public transportation sector as follows[5]:
    - Total hydrocarbons: 14 – 24% (7.0 to 11.9 tonnes/year)
    - Carbon monoxide: 19 – 25% (62.2 to 82.6 tonnes/year)
    - Total particulate matter: 17 – 21% (11.0 to 13.7 tonnes/year)

Appendix A: VET Current Members

Name	Membership
Rob Bioletti	Government (Alberta Environment)
Maureen Brown	Government (City of Calgary)
Peter Dzikowski	Government (Alberta Transportation)
Gustavo Hernandez	CASA
Myles Kitagawa	NGO (Toxics Watch Society)
Mike Mellross	Government (City of Edmonton)
Mayne Root	Industry (Alberta Motor Transport Association)
Petra Rowell	CASA
Ron Schafer	Government (City of Calgary)
Ted Stoner	Industry (CPPI)
Don Szarko	NGO (Alberta Motor Association)
Kyle White	Government (City of Calgary)
Scott Wilson	NGO (Alberta Motor Association)

Appendix B: VET - Terms of Reference

Mission Statement: Recommend initiatives to reduce vehicle emissions and support the CASA vision of clean air.

Objectives:

1. Identify, evaluate and recommend areas of further action to reduce vehicle emissions.
2. Implement initiatives approved by the CASA board.
3. Influence/advocate implementation of policies and programs that reduce transportation emissions.
4. Serve as a resource/provide expertise to CASA teams and other organizations.
5. Identify and recommend communication/public education on vehicle emissions.
6. Identify gaps and make recommendations to fill gaps.

Priority Actions:

1. Identify potential reduction opportunities for on- and off-road heavy-duty vehicles.
2. Upgrade modelling for current and future vehicle emissions forecasts.
3. Identify and promote transportation demand management measures.
4. Review the list of emission reduction opportunities for passenger vehicles considered by the VEWG in 1998.
5. Implement initiatives already approved by the CASA board.
6. Promote the idea of CASA sponsoring an integration workshop for constituent groups and teams.
7. Influence/advocate implementation of policies and programs that reduce transportation emissions.
8. Gather information on travel demand patterns.
9. Understand driving behaviour and attitudes of Albertans.
10. Promote the team's initiatives and projects.

Appendix C: DPF Distribution Letter

July 28, 2005

Myles Kitagawa
Toxics Watch Society of Alberta
2nd Floor 6328 104 Street
Edmonton AB T6H 2K9

Dear Myles,

As part of its ongoing interest in exploring ways to reduce vehicle emissions in urban areas, the CASA Vehicle Emissions Team undertook a demonstration project to test the effectiveness of Diesel Particulate Filters (DPF) (specifically the Johnson Matthey Continuously Regenerating Technology®) under cold weather conditions. The project involved a one-year test of the filter on two diesel buses in Edmonton Transit System's (ETS) fleet, between January 2003 and January 2004.

The project's main conclusion was that the DPF worked in Alberta's climate. Operationally they require ultra low sulphur diesel fuel (ULSD), and are applicable in modern engines with high combustion temperatures. By using diesel particulate filters, it is possible to advance emissions reductions that would otherwise take longer to occur through fleet turnover. The results showed specifically that:

There were major reductions in emissions of three pollutants, but no significant change in the emission rate of nitrogen oxides. A range in reductions is given to reflect the differences observed in the two phases:

- Total hydrocarbons: reductions of 51 – 87%
- Carbon monoxide: reductions of 67 – 89%
- Total particulate matter: reductions of 60 – 75 %

The DPF performed effectively even in the very cold weather experienced during the test period.

The test was very useful to ETS in evaluating the performance of the DPF technology and gaining experience with installing and maintaining the device. The filter did not impair bus performance, in terms of fuel economy and driving performance, but it does require annual cleaning to ensure proper continued operation; the cleaning process will add about three hours to the annual maintenance inspection for each bus.

This pilot program was based on actual tests with production model buses during revenue operation in a cold weather environment, which is something that virtually all Canadian transit properties experience.

We hope that you find the enclosed final report from the Diesel Particulate project useful. If you have any questions or would like to learn more about using the DPF technology to reduce the emissions from your fleet, please contact CASA at casa@casahome.org or visit www.cleanbus.ca.

Alan Brownlee
Government Co-chair
Vehicle Emissions Team

Gerry Ertel
Industry Co-chair
Vehicle Emissions Team

Enclosure