CLEAN AIR TASK FORCE

FACT SHEET

Clean Air Task Force Investigations of School Bus Engine Crankcase Emissions and Controls

INTRODUCTION

CATF and its research partners, including Purdue University, have investigated self-pollution of school buses by diesel exhaust in four separate studies in Chicago, IL, Atlanta, GA, Ann Arbor, MI, and Charlotte, NC. CATF's research set out to characterize school bus cabin air quality along residential bus routes, identify sources of particulate matter self-pollution, and assess the benefits of retrofit emissions control devices in reducing diesel exhaust in buses. CATF's work demonstrates that $PM_{2.5}$, ultrafine and black carbon particulate matter can be largely eliminated by today's retrofit emissions controls. One significant finding, that has an important bearing on the selection of emissions controls for existing school buses, is that in addition to tailpipe emissions engine crankcase emissions are a major source of cabin air pollution. This fact sheet briefly summarizes crankcase emissions findings from the study. A January 2005 white paper details the results of research in three of the four cities where CATF has conducted studies to date.[1]

Perhaps most telling, our testing of catalyzed diesel particulate filters (DPFs) combined with ultra-low sulfur diesel fuel (ULSD) reduced ultrafines, black carbon, and particulate polycyclic aromatic hydrocarbons to outdoor ambient levels, but still left substantial $PM_{2.5}$ mass in the cabin. Further investigation indicated that the additional $PM_{2.5}$ mass was entering the buses from the engine crankcase vent ("road draft tube") and not the tailpipe. When DPF-equipped buses were subsequently equipped with a Spiracle™, we observed that cabin $PM_{2.5}$ mass dropped to near ambient levels. In fact, this result was consistent among all conventional and retrofit bus combinations we tested (e.g. conventional buses, buses retrofit with diesel oxidation catalysts, diesel particulate filters, and buses fueled by B99 biodiesel and ultralow sulfur diesel.)

Our findings, replicated in multiple locations and buses, demonstrate that the engine crankcase is, in fact, the *largest* source of $PM_{2.5}$ mass affecting the interior cabin air quality of conventional school buses. The strongest evidence of this is that for every bus tested that was retrofitted with a closed-crankcase filtration device, $PM_{2.5}$ inside the bus was minimized or eliminated. These results document the magnitude of the $PM_{2.5}$ problem from the engine crankcase and the dramatic reduction of $PM_{2.5}$ self-pollution in school buses using the only closed-crankcase filtration retrofit device currently available commercially, the Donaldson Spiracle™. In short, a closed-crankcase device is critical in all applications to reducing cabin $PM_{2.5}$. *The elimination of $PM_{2.5}$ self-pollution inside*

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[1] See: http://www.catf.us/publications/view/82

conventional school buses is only possible with a closed-crankcase filtration retrofit device.[2]

CATF STUDY SYNOPSIS

METHOD
Four continuous particulate matter metrics were monitored inside school bus cabins: $PM_{2.5}$, ultrafine particle number, black carbon and particulate PAH (PPAH). As a control, CATF utilized a lead car to characterize air in front of the bus that potentially could affect the air on the bus. Windows were rolled up at all times. Bus stops along a typical school bus routes were timed with the cabin door open for 60 seconds. Monitors were situated in the front and middle seats of the bus. The progressive testing and retrofitting of conventional buses facilitated assessment of the relative impacts of $PM_{2.5}$ from the engine crankcase and tailpipe; the retrofits effectively turned the two sources “on and off” with the installation 90+% effective DPF and / or the Spiracle™.

BRIEF FINDINGS:

- Along residential routes in conventional buses, with minimal or no external outdoor particulate matter influence, CATF documented significant cabin self-pollution from all four measured PM parameters.
- Diesel exhaust enters the bus at stops when the door is open.
- Two major sources of cabin pollution were documented: 1) the engine crankcase (significant $PM_{2.5}$ mass only, and no detectable ultrafine, black carbon or PPAH) and 2) the tailpipe: (significant ultrafine particles, black carbon and PPAH, but with the surprising result of little or no $PM_{2.5}$ reaching the cabin).
- Wind direction dictated whether tailpipe exhaust (from rear) or crankcase exhaust (from front) entered the bus. Crankcase emissions have been visibly documented entering the cabin from below the cabin door; these emissions are met with a synchronous response from the monitors in the front of the bus.
- A diesel particulate filter (DPF) and ULSD fuel resulted in reducing ultrafine particles, black carbon and PPAH to ambient levels, but failed to substantially reduce $PM_{2.5}$ in the cabin.
- The closed crankcase device in combination with the DPF and USLD reduced all cabin particulate matter parameters to near ambient levels (See data plots below).
- Testing of diesel oxidation catalysts did not result in measurable benefits in PM parameters in-cabin (Note: no quantitative tailpipe tests were undertaken.)
- Closed crankcase ventilation (Spiracle™) in every combination of conventional retrofit bus tested reduced cabin $PM_{2.5}$ levels to ambient.

[2] The Donaldson Spiracle is presently the only commercially available closed-crankcase filtration retrofit device we are aware of.

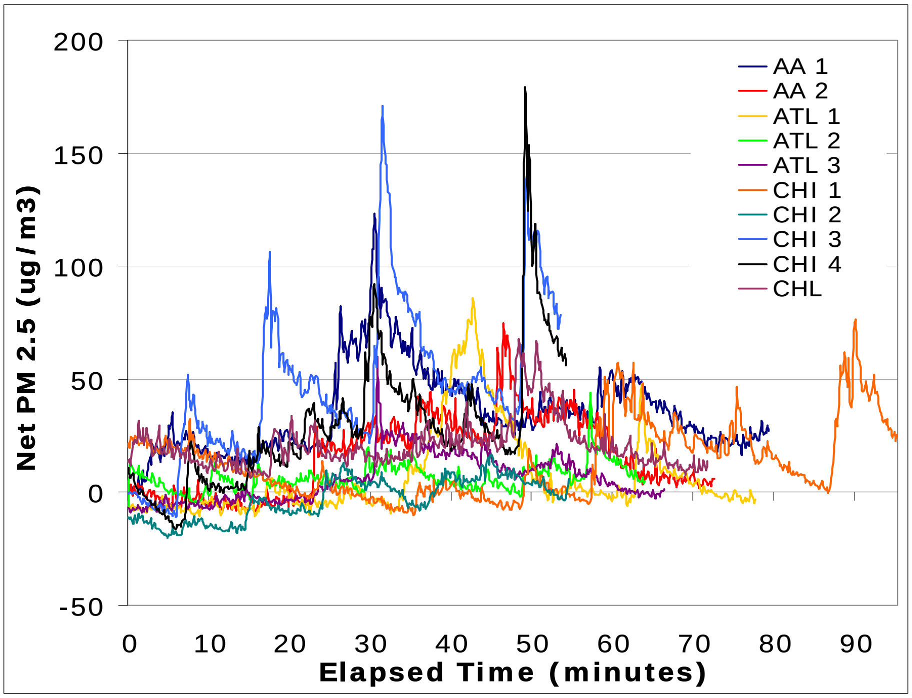

Figure 1: Conventional Buses. Significant $PM_{2.5}$ pollution from the engine crankcase was documented inside the cabins of all test scenarios when a closed crankcase device (Spiracle) was not used.

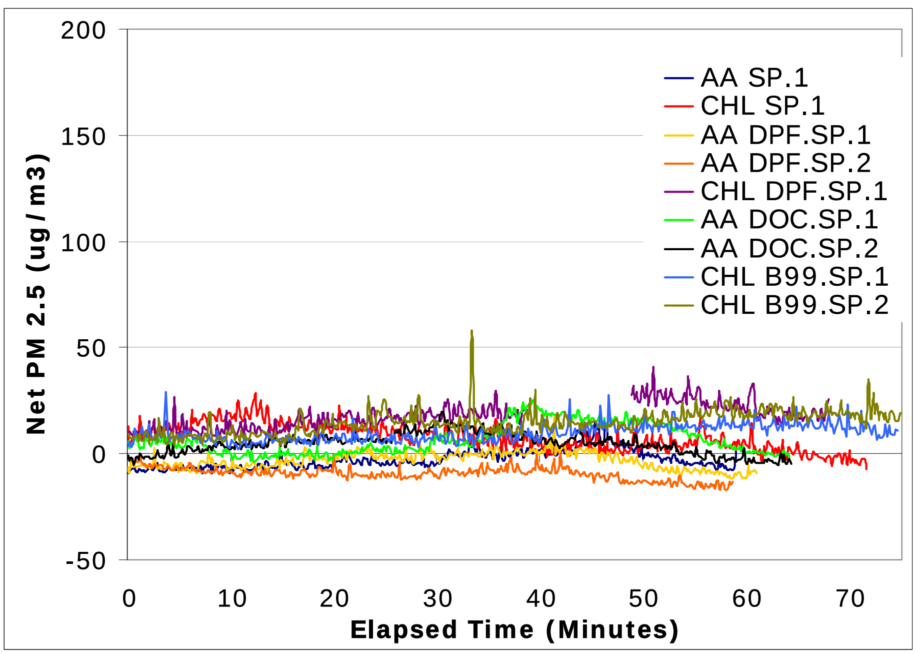

Figure 2: Buses retrofit with Closed-Crankcase Device. For all buses retrofitted with closed crankcase filtration device (Donaldson Spiracle™), in-cabin $PM_{2.5}$ pollution was reduced to near ambient levels, regardless of whether the bus was a conventional bus, or retrofit with a DPF or DOC or running on B99 biodiesel or ULSD fuels.

APPENDIX: DISCUSSION OF INTERNATIONAL AND CATF FINDINGS

A January 4, 2006 fact sheet published by International Truck and Engine Co., *Diesel Vehicles Crankcase Emissions Fact Sheet* cites a study by International[3] as well as the Clean Air Task Force's 2003 Atlanta school bus study, and questions CATF's conclusion that the crankcase is an important source of cabin particulate matter pollution.[4] However, consistent findings from Clean Air Task Force's (CATF) four-city study, conducted from 2003-2005, robustly document that engine crankcase $PM_{2.5}$ pollutes conventional (engine in front) school bus cabins.[5] More importantly, our studies document that the elimination of cabin $PM_{2.5}$ is only possible by retrofitting the buses with a closed-crankcase filtration device.

Although there are fundamental differences in the CATF and International study designs and methods, we believe that the results of the two studies are consistent with each other as well as with the U.C. Riverside study findings that the International fact sheet cites.[6] International's study, conducted in Los Angeles, found minimal (<1 ug/m^3) in-cabin $PM_{2.5}$ mass from the tracer-doped tailpipe emissions, despite an average 72 ug/m^3 $PM_{2.5}$ on the bus. The International study attributes the in-cabin $PM_{2.5}$ to the influence of external pollution sources (based on a documented average 114 ug/m^3 in the roadway in front of the bus as measured by a lead car five minutes ahead.) Alternatively, based on our study observations, we suspect that some portion of this in-cabin $PM_{2.5}$ may have also originated from the crankcase at times when the bus door was open, such as during initial bus idling or at the seven or eight bus stops made in the International study.

There are some important contrasts between the International and CATF studies and conclusions:

a) International employed single-filter-per-run measurements and a fuel-doped iridium tracer in contrast to CATF's continuous measurements. Continuous monitors allowed us to immediately identify changes in pollutant levels during idling, during bus stops, and in traffic. Despite the difference in method, our measurements agree with International's finding that there is very little $PM_{2.5}$ in-cabin mass coming from the tailpipe. (As noted above, our results document that the in-cabin $PM_{2.5}$ mass comes from the engine crankcase.)

b) We have consistently documented high ultrafine particle counts from the tailpipes of conventional buses running on conventional fuel. We find that ultrafine particle numbers are reduced to near ambient outdoor levels by retrofitting these buses with DPFs and running ULSD fuel. This result is consistent with cited U.C. Riverside's results that show major reductions in *particle number* with a DPF retrofit.

d) CATF's study was conducted on actual bus routes largely in quiet residential areas while International's route followed busy roadways. Higher $PM_{2.5}$ levels in their lead car led International to conclude that external diesel sources were responsible for substantial

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[3] See: http://www.greendieseltechnology.com/TRR1880pp21-28.pdf
[4] See: http://www.greendieseltechnology.com/News.asp?ID=361&link=
[5] See: http://www.catf.us/publications/view/82
[6] See: http://www.donaldson.com/en/exhaust/news/005687.html

cabin pollution. The residential areas where CATF's studies have been undertaken have resulted in minimal confounding by external diesel sources, making it easier to identify self-pollution. CATF's study documented significant $PM_{2.5}$ pollution spikes in the bus cabin at bus stops, despite low ambient outdoor particulate matter concentrations in the roadway in front of the bus.

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