

Clean Buses for Kids

TECHNOLOGY OVERVIEW

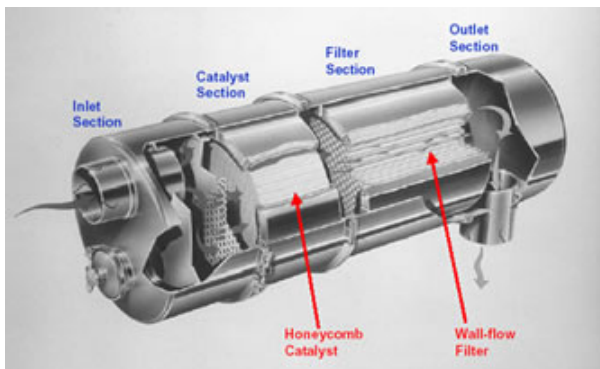
The purpose of the Clean Buses for Kids Program is to provide grants to school districts to retrofit current diesel powered school buses with emission control equipment to reduce particulate (soot) emissions. In order to maximize particulate emission reductions, the Clean Buses for Kids Program is funding only retrofits with diesel particulate filters (DPFs). To use DPFs, ultra-low sulfur diesel (ULSD) fuel must be used. In addition, the Clean Buses for Kids Program will only fund retrofits of Types C and D school buses.

Diesel Particulate Filter

A DPF is a ceramic filter that traps particulates from the engine exhaust. During times of higher exhaust temperatures, these trapped particulates are burned in the particulate filter, resulting in carbon dioxide emissions. The use of catalysts allows this "regeneration" to occur at lower exhaust temperatures. These "passive" filters operate best at or above specific exhaust temperatures; buses should be checked (in a process known as "data logging," discussed more fully beginning on page 8) before installing the filters to ensure that they will function correctly.

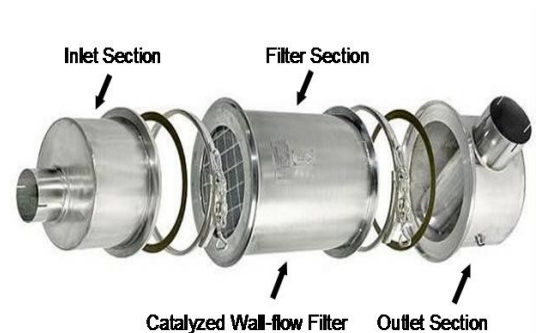
There are two types of catalyzed DPFs currently verified. One type employs an oxidation catalyst ahead of a particulate filter (pictured in Figure 1a). In the second type of DPF, the catalyst is integrated into the surface of the DPF (pictured in Figure 1b). DPFs can be installed on new or used buses, but must be used with ULSD (discussed below).

Figure 1a
Upstream Catalyst Diesel Particulate Filter



Source: <http://www.epa.gov/otaq/schoolbus/retrofit.htm>

Figure 1b
Wall-flow Catalyst Diesel Particulate Filter



Source: Lubrizol Engine Control Systems

This project was undertaken in connection with the settlement of an enforcement action, *United States v. Toyota Motor Corporation*, brought on behalf of the U.S. Environmental Protection Agency under the Clean Air Act.

By using DPFs and ULSD fuel, particulate emissions, as well as hydrocarbon and carbon monoxide emissions, are reduced by 85 to 95 percent. DPFs installed with Program funds must be verified by either the U.S. Environmental Protection Agency (EPA) or the California Air Resources Board (ARB). Both agencies offer technology verification services to ensure the proper operation of the filters with certain engine families and model years and certification of the filters' claimed emission reductions. Each DPF is verified for use only with tested engines that meet minimum exhaust temperature requirements for a specified portion of the bus's duty cycle. Additional conditions of verification include the filters' use with ULSD only and the provision of a backpressure monitor to accompany each filter. EPA-verified DPFs can be found at <http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm>. ARB-verified DPFs can be found at <http://www.arb.ca.gov/diesel/verdev/level3/level3.htm>.

DPFs usually come in a kit that includes mounting brackets, miscellaneous clamps, and an electronic backpressure monitoring system. DPF kits typically cost from \$7,000 to \$8,500 installed. Variances in costs typically relate to the size of the filter required for the specific engine, as well as specific attributes of the DPFs (e.g., the amount of precious metals and whether the DPF is composed of a single DPF substrate or a combination of pre-catalyst with DPF substrate). DPFs have been shown to work best with 1994 or newer highway engines, which characteristically emit lower levels of particulates than older models.

Determining the age of the engine, the engine type, and the bus duty cycle will be important in evaluating whether a given bus will be a candidate for a DPF. Applicants should work closely with qualified DPF installers to make this determination. DPFs can take anywhere from two to eight hours to install on a bus, depending on the filter and engine configuration. More information on DPFs can be obtained from the EPA Fact Sheet: "Questions and Answers on Using a Diesel Particulate Matter Filter in Heavy-Duty Diesel Trucks and Buses," June 2003, EPA420-F-03-017 (<http://www.epa.gov/otaq/retrofit/documents/f03017.pdf>). Currently verified DPFs eligible for funding under this program are listed in Table 1.

In addition to the passive DPFs described above, a new active DPF was verified by ARB in late 2005 for use on 1994 through 2005 model year engines. Instead of using exhaust heat to regenerate, the Cleaire Horizon system uses electricity to regenerate while the bus is parked overnight. As such, this system requires no data logging as the heat comes from an electric heater instead of the engine exhaust. Particulates are trapped in this system until it is plugged into a 220V outlet, at which time regeneration begins. Therefore this system will work on buses that are too cold to work with normal passive DPFs. This system's estimated cost is approximately \$13,000 installed versus \$7,000 to \$8,500 for a passive DPF. In addition, a 220V outlet needs to be made available near where buses park to allow regeneration, which may result in additional infrastructure costs.

Table 1
Diesel Particulate Filters Eligible under this Program

| MANUFACTURER | TECHNOLOGY | APPLICABILITY |
|---------------------------------|--|---|
| Cleaire | Longview System | Highway, heavy-duty, 4 stroke 1994 - 2003 non-EGR diesel engines |
| Cleaire | Horizon System | Highway, heavy-duty, 4 stroke 1994 - 2005 model year engines |
| Donaldson | DPM Diesel Particulate Filter | Highway, heavy-duty, 4 stroke 1994 - 2004 model year non-EGR diesel engines |
| Engelhard International | DPX Catalyzed Diesel Particulate Filter | Highway, heavy-duty, 4 stroke 1994 - 2004 model year non-EGR diesel engines |
| Lubrizol Engine Control Systems | Purifilter - Diesel Particulate Filter | Highway, heavy-duty, 4 stroke 1994 - 2003 model year non-EGR diesel engines |
| Johnson Matthey | Continuously Regenerating Technology (CRT) Particulate Filter | Highway, heavy-duty, 4 stroke 1994 - 2006 model year diesel engines |
| Johnson Matthey | Catalytic Continuously Regenerating Technology (CCRT) Particulate Filter | Highway, heavy-duty, 4 stroke 1994 - 2006 model year non-EGR diesel engines |

See <http://www.arb.ca.gov/diesel/verdev/level3/level3.htm> or <http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm> for details.

Note that the Donaldson LTF is no longer verified on any buses





Ultra-Low Sulfur Diesel Fuel

ULSD fuel is available in most parts of the country as of October 2006. To be eligible for this program, buses retrofitted with particulate filters must use ULSD with a sulfur content of 15 parts per million (ppm) or less. The primary purpose of ULSD fuel is to enable or improve the performance of after-treatment technologies such as DPFs. The quantity of emission reductions from the use of ULSD fuel alone varies depending upon application, level of sulfur reduction, and other characteristics of the replacement fuel. In some cases, use of ULSD fuel can reduce particulate matter (PM) emissions by 5 to 9 percent.

School Bus Types

School buses are built in four different types: A, B, C, and D. Type C buses account for about 65 percent of bus sales, Type D accounts for about 25 percent, and Types A and B combined account for 10 percent. Descriptions of these bus types are given in Table 2.

**Table 2
School Bus Types**

| SCHOOL BUS TYPE | GROSS VEHICLE WEIGHT RATING | DESCRIPTION | EXAMPLE |
|-----------------|---|--|--|
| A | <p>A1 – Less than or equal to 10,000 lbs</p> <p>A2 – 10,000 to 14,000 lbs</p> | <p>Van conversion or bus constructed utilizing a cutaway front-section vehicle with a left side driver's door.</p> <p>The entrance door is behind the front wheels.</p> <p>Designed for carrying more than 10 persons.</p> |  |
| B | <p>B1 – Less than or equal to 10,000 lbs</p> <p>B2 – 10,000 to 16,000 lbs</p> | <p>Constructed utilizing a stripped van or truck chassis.</p> <p>The entrance door is behind the front wheels.</p> <p>Designed for carrying more than 10 persons.</p> <p>Part of the engine is beneath and/or behind the windshield and beside the driver's seat.</p> |  |
| C | <p>19,500 to 28,000 pounds</p> | <p>Constructed utilizing a truck chassis with a hood and front fender assembly.</p> <p>The entrance door is behind the front wheels.</p> <p>Designed for carrying more than 10 persons</p> <p>All of the engine is in front of the windshield</p> |  |
| D | <p>More than 28,000 pounds</p> | <p>Transit school bus is constructed utilizing a stripped chassis.</p> <p>The entrance door is ahead of the front wheels.</p> <p>Designed for carrying more than 10 persons</p> <p>The engine mounted in the front, midship, or rear. The engine may be behind the windshield and beside the driver's seat; it may be at the rear of the bus, behind the rear wheels; or midship between the front and rear axles.</p> |  |

Source: 2000 National School Specifications and Procedures



TIPS FOR INSTALLATION

This document is intended to provide school districts with additional background on DPFs and some key tips to help them through the installation phase of their projects completed in conjunction with the Clean Buses for Kids Program.

Disclaimer

Please note that your DPF manufacturer and/or installation vendor is the primary source of information regarding the filters and their installation. School districts should check with their vendor about important technical issues.

Technical Assistance

The Clean Buses for Kids program is available to answer school district questions during the installation phase of this project. Please contact your Account Manager by phone or email and/or Lou Browning at lbrowning@icfi.com with your installation questions. You may also contact the Program via the hotline (703.934.3040) or email (info@cleanbusesforkids.com), and a program representative will respond to your message.

Filter Verification

DPFs are verified for use on school buses only if the engine exhaust temperature exceeds a certain level for a given period of its duty cycle. The duty cycle is the normal route that a bus drives during a given day. If the duty cycle is not severe enough (e.g., no high speeds or hilly terrain), the bus may not reach the necessary exhaust temperatures to burn up the trapped soot in the filter. This is why data logging is so important to determine whether the bus can reach those conditions over its normal route. If the minimum temperature requirement is not met, the filter is not verified for that bus and, therefore, not eligible for funding under the Clean Buses for Kids Program.

Operating conditions under which each filter is verified are listed in Table 3. To receive EPA or ARB verification, the exhaust temperature where the filter will be mounted must meet the minimum exhaust temperature for at least the percent of the duty cycle listed in Table 3. **We will not fund the installation of filters on any buses that do not meet the appropriate temperature profile as certified by the vendor in the Certification of Installation Form.** In addition, each filter must be installed with a backpressure monitor to notify the bus operator when maintenance is required. DPFs are verified for use with ULSD only.

This project was undertaken in connection with the settlement of an enforcement action, *United States v. Toyota Motor Corporation*, brought on behalf of the U.S. Environmental Protection Agency under the Clean Air Act.

Table 3
Operating Conditions for Eligible Diesel Particulate Filters

| FILTER | EXHAUST TEMPERATURE | PERCENT OF DUTY CYCLE |
|-----------------------------|------------------------------------|-----------------------|
| Claire Longview | 260°C | 25% |
| Claire Horizon | No minimum temperature requirement | |
| Donaldson DPM | 250°C | 30% |
| Engelhard/International DPX | 225°C | 50% |
| | 300°C | 10% |
| Lubrizol Purifilter | 280°C | 25% |
| Johnson Matthey CRT | 240°C | 40% |
| Johnson Matthey CCRT | 200°C | 40% |

Data Logging

In order to determine whether a bus meets the minimum exhaust temperature requirements for the selected DPF to be installed, data logging must be conducted. Data logging measures the exhaust temperature profile of the engine during its normal route. The portion of the school bus fleet that is going to be retrofitted with filters must be data logged. The vendor will install a temperature probe at the approximate location of the filter kit installation on the exhaust pipe. For front engine buses, effort should be made to install the temperature probe closer towards the engine provided that the filter could be installed at that location. Sometimes insulating the exhaust pipe is necessary.

You should work closely with your vendor to identify routes that may be problematic (mostly urban driving with no hills and a lot of stop-and-go driving). For each of the buses that drive these potentially problematic routes, the vendor will place a data logger on the bus to measure the exhaust temperature during normal operation. The vendor will also data log other representative buses in your fleet. The drivers must not be informed of the data logging as they may tend to modify their normal driving patterns if they know they are being monitored.

Data loggers are normally placed on buses at the beginning of a week and record exhaust temperature during the week of driving. You must identify routes that the buses might drive over the next five years to make sure that the bus will meet the minimum temperature requirements during normal operation.

Program Requirements Related to Data Logging

The Clean Buses for Kids program requirements state that each bus retrofitted under the Program operate for 10,000 miles or more per year for a minimum of 4 days per week during the school year so that the duty cycles are likely to be suitable for DPF installation. All applicants have included a statement in Table 4, row (i) of their Funding Application that states all buses included in this project meet the minimum program requirements.

Instructions on Data Logging

If not all engines are data logged, a representative sample must be data logged. Vendors must data log any 'worst case' buses. In this instance, 'worst case' refers to buses where the duty cycle, i.e., the bus route, may not be sufficient to attain the required temperature profile. For buses where data logging is not individually conducted, a simple explanation, such as "same engine and similar route schedule as bus X that was data logged," must be included on the Certification of Installation Form.

- ✓ Vendor will work with the school district to identify routes that are mostly stop-and-go and do not contain any hilly sections. These routes are most likely to be problematic in terms of temperature profile, and buses that drive these routes must be data logged.
- ✓ Vendors will identify potentially problematic engine/vehicle configurations, such as front engine buses or engines that are known for low exhaust temperatures.
- ✓ Vendor will eliminate any buses that, through experience, will not meet the temperature requirements for proper regeneration (i.e., won't burn up the trapped particulates).
- ✓ Vendor will provide data log traces (i.e., a graph of the temperature profile) to the Clean Buses for Kids Program as part of the installation documentation, along with an explanation of where the temperature probe was placed, the data log interval, and which buses were data logged.
- ✓ Vendor will include a statement on the Certification of Installation Form that any buses not data logged will meet the minimum exhaust temperature requirements for which the filter was verified by either the EPA or CARB.

If the school district needs to change which buses are included in the actual project, the school district will need to resubmit an amended Table 4-2 from its Funding Application. For all buses that were eliminated from the initial installation list, please provide an explanation to document why they were eliminated.

Maintenance

School districts are strongly encouraged to work with their vendors to understand the proper maintenance requirements for DPFs.

Under 'normal' conditions, vendors usually predict that the maintenance requirements are a once-a-year cleaning. Given specifics of engine configuration or condition, bus route, and individual drivers' behavior, more frequent cleaning may be required.

When maintenance is required, an LED indicator light (installed during filter installation) will light, indicating the filter needs cleaning. It is okay to finish the route before having the filter cleaned. Some units have two lights, a yellow and a red light. If the yellow light is lit, you should do maintenance on the filter within a couple of weeks. If the red is lit, you should do maintenance on the filter within a week.

To clean the filters, school districts will remove the filter and either blow them out with pressurized air and/or bake them in specially designed baking units supplied by your vendor. Check with your specific filter manufacturer for their recommended procedures and cleaning frequency. The filter is usually held in with v-band clamps that can be dismantled to remove the filter.

Soot/ash removed from the DPF after cleaning must be properly disposed of according to all applicable federal, state, and local laws.

Warranty Guarantees

The Clean Buses for Kids Program only offers funding for installation of verified DPFs. The 'verified' part of the requirement also means that the filter must be warranted. Warranties can only be offered if the filter is installed on a bus that passes the data logging test and is demonstrated to have a sufficient minimum temperature profile.

Filter Problems

School districts should work with vendors to make themselves aware of any problems they may experience with the filters. If filter maintenance is required too frequently, it may be an indication of a problem with the filter, its application, and/or the engine.

If the filter fails to operate correctly, school districts must ask the vendor to address the problem immediately. School districts are expected to assume full responsibility in maintaining the filter as required by the warranty.

Forms/Documentation Districts Should Expect From Vendor

School districts need to work with vendors up front to make sure that they receive a fully documented invoice for the installation. Included with the invoice should be copies of the vendor's Certificate of Installation Form (for each bus) and copies of the filter warranty.

The Program Administrator will work with vendors to ensure that the Certificate of Installation Form required for each bus can be as close as possible to the vendor's standard form that they provide to the filter manufacturer.

ULSD Fueling Practices

In order for the DPFs to operate effectively, ULSD must be used in all retrofitted school buses. If school districts are converting an existing fuel tank to store the ULSD, the tank should be drained as completely as possible prior to filling with ULSD. Effort should be made to refill the tank at least twice before using ULSD in the retrofitted buses to ensure that no residual sulfur from the regular grade diesel remains in the tank.

Unless the school district's entire fleet runs on ULSD or the school district uses a card lock system to fuel its buses with the appropriate fuel, ULSD tanks and retrofitted school buses must be clearly labeled "Use Only Ultra-Low Sulfur Diesel (ULSD) fuel." Prolonged use of fuel other than ULSD may damage the DPFs and will result in significantly more frequent cleanings of the filters.

Other

Some vendors may endeavor to sell school districts extra products, such as filter cleaning kits or crankcase filters. School districts should check with vendors about the cost, maintenance, warranty, and installation requirements of those extra products.