VII. LOW PRESSURE EXHAUST GAS RECIRCULATION (EGR)

A. Technology Overview and Description

OVERVIEW

EGR reduces engine-out NO_x emissions by recirculating a portion of the engine's exhaust and then introducing it upstream of the engine in order to dilute the oxygen content of the ambient air entering the engine combustion chamber. Reducing the oxygen content lowers the combustion temperature, which in turn results in less NO_x being formed. EGR systems can reduce NO_x by up to 40% or more. Two types of EGR systems exist: high-pressure EGR, which is currently used in new engine applications and low-pressure EGR, which is used in retrofit applications. In OE applications, high-pressure EGR systems are being installed to help meet EPA's current on-road HDE 2.0 g/bhp-hr NO_x standard and are a leading candidate for use in meeting the more stringent NO_x reduction requirements that take effect in 2007.

In retrofit applications, low-pressure EGR is being combined with DPF technology and applied to on-road and offroad engines applications. The EGR/DPF system is an application specific technology. The types of factors that must be considered in applying this technology are the same as with a stand-alone DPF system (See Volume 2, Section III, "Selection and Use Criteria"). Over 3,000 EGR/DPF systems have been installed in Europe and the U.S. System performance, in general, has been quite good; retrofit applications have not experienced the type of problems encountered with OE high-pressure EGR/DPF systems. This technology has been verified by CARB (www.arb.ca.gov/diesel/verdev/verdev.htm).

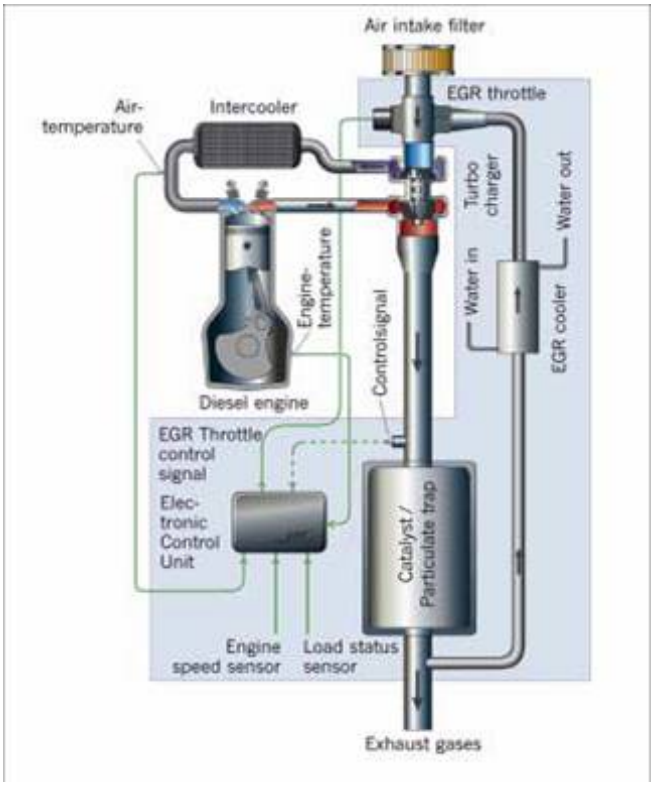
A number of projects involving low-pressure EGR/DPF systems are now underway. Few problems have been reported. In some applications, as with any retrofit technology being introduced, there were some start-up issues such as properly configuring the system on a given vehicle application. Also, as is the case with stand-alone DPF installations, some issues with premature filter plugging have occurred due in large measure to issues related to inadequate exhaust temperatures to ensure that the filter regenerates properly. This resulted in some unscheduled downtime to remove and clean the filter.

Other than the items mentioned above, no reported adverse impacts on vehicle/equipment operation were reported. Information on the possible impact of low-pressure EGR/DPF technology on fuel economy is very limited. One study reported a 1% to 4% fuel economy penalty, depending on the particular engine and test cycle used. The degree of fuel economy impact, if any, is likely influenced by such factors as level of NO_x control efficiency, the engine, the application and the operating duty-cycle.

TECHNOLOGY DESCRIPTION

EGR technology involves recirculating a portion of an engine's exhaust back into the turbocharger inlet, or the intake manifold of a naturally aspirated engine. In most EGR systems, an intercooler lowers the temperature of the recirculated exhaust. The recirculated exhaust, which has a higher heat capacity and contains less oxygen than the ambient air lowers the combustion temperature of the engine, thereby reducing NO_x formation. In retrofit applications,

a low-pressure EGR system has been combined with a catalyst-based DPF. The DPF collects PM from the exhaust, including exhaust that is recirculated. Preventing the PM in the exhaust from being re-introduced into the combustion process is critical to the proper functioning of the retrofit EGR system. Unlike high-pressure EGR that is integrated as part of the engine system, low-pressure does not require engine modifications.



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B. Emission Reduction

Retrofit low-pressure EGR systems can achieve NO_x emission reductions of 25% to over 50%. The level of NO_x control is influenced by the EGR system design, the engine application, engine calibration, and the operating duty-cycle.

EGR systems do not reduce other exhaust pollutants, but in retrofit applications, low-pressure EGR is combined with a catalyst-based DPF. Therefore, the system provides up to over 90% reduction in PM, up to 90% reduction in CO and HC (including toxic HCs), and virtually eliminates diesel smoke and odor. It has been reported that the EGR component of the system helped reduce the NO_2 formed by the DPF. Where the DPF portion of the system is installed as a muffler replacement, the noise attenuation of the DPF is comparable to, or better than, the muffler it replaces.

C. Status and Availability

STATUS

Low-pressure EGR/DPFs have been retrofitted on approximately 3,000 on-and off-road engines in the U.S. and Europe. Applications include transit buses, refuse trucks and utility vehicles. For example, over 700 transit buses have been retrofitted with low-pressure EGR systems in Texas. Current experience with low-pressure EGR/DPF systems is in the range of 180 horsepower to 450 horsepower, with new, larger EGR/DPF system being offered to cover applications up to 1,000 horsepower.

AVAILABILTY

There are currently at least two suppliers of low-pressure EGR systems for retrofit applications, one of which has received CARB verification.

D. Selection and Use Criteria

Since the retrofit low-pressure EGR system incorporates a catalyst-based DPF, it is an application specific application. The criteria that must be evaluated are the same as when considering the application of a catalyst-based DPF as a stand-alone technology. Briefly, in making the decision whether a low-pressure EGR/DPF system can be applied, the following criteria must be considered:

- The level of engine-out emission levels, including those from the engine lubricating oil.
- The engine operating exhaust temperature profile.
- Available space to equip the low pressure EGR/DPF system.
- The level of sulfur in the diesel fuel.

These criteria are discussed in detail above in Volume 2, Section III, “DPF Selection and Use Criteria”.

E. Installation and Vehicle Modifications

Given the complexity of the low-pressure EGR/DPF system, care should be taken in selecting and preparing the vehicle/equipment to be retrofitted and in installing, monitoring, and maintaining the system. The issues related to these factors are generally the same as when a DPF is retrofitted as a stand-alone technology. (See Volume 2, Section III, “DPF Installation and Vehicle Modification”). Installing the low-pressure EGR/DPF is performed by the technology provider and typically takes a two-person team up to eight hours to install the system.

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F. Fuel Requirements

Since catalyst-based DPF technology is used as part of the system, ULSD must be used. (See Volume 2, Section III, "DPF Fuel Requirements").

G. Maintenance

The issues related to these factors are generally the same as when a DPF is retrofitted as a stand-alone technology. (See Volume 2, Section III, "DPF Maintenance").

H. Costs

The installed cost of the low-pressure EGR/DPF systems have ranged from $15,000 to $18,000, depending the engine application to be retrofitted. The maintenance costs are primarily for DPF filter cleaning (See Volume 2, Section III, "DPF Costs").