

IV. LEAN NO_x CATALYST (LNC)

A. Technology Overview and Description

OVERVIEW

LNC technology is a relatively new and emerging technology. The technology has been successfully applied to new passenger cars in Europe and as a retrofit technology on transit buses, refuse trucks, utility vehicles and offroad equipment such as backhoes. LNC systems are currently capable of achieving NO_x reductions in the range of 10% to 25%. LNC designs that use diesel fuel as the reducing agent to facilitate NO_x control performance have about a 3% fuel economy penalty.

LNC is an application specific technology and care should be taken in selecting vehicle/equipment applications. In retrofit applications, LNCs can be combined with DOCs, DPFs and crankcase emission control technologies. A LNC/DPF system has been verified by CARB as a retrofit technology achieving at least a 25% NO_x reduction and at least an 85% PM reduction (See www.arb.ca.gov/diesel/verdev/verdev.htm).

LNC/DPF systems have, in general, performed very well in retrofit applications in the U.S. Some systems have been operating for up to several years with little or no problems. A small percentage of LNC/DPFs have experienced instances of premature plugging of the DPF, requiring unscheduled cleaning. Also, in limited cases, plugging also has occurred on the front face of the LNC. The technology manufacturer has made modifications to the system software to alleviate the problem. Finally, as with stand-alone DPF systems, the LNC/DPF system in a few instances had a backpressure monitor malfunction due to the overly sensitive components. The technology supplier has made modifications to the system design to correct the problem.

TECHNOLOGY DESCRIPTION

Controlling NO_x emissions from a diesel engine is difficult because diesel engines are designed to run in a lean mode that results in high levels oxygen (“oxygen rich”) in the exhaust. In the oxygen-rich environment of diesel exhaust, it is difficult to chemically reduce the NO_x molecules over the catalyst to nitrogen. A LNC conversion of NO_x to nitrogen requires a reductant (HC, CO, or H₂) and under typical diesel engine operating conditions, sufficient quantities of the reductant are not present. As a result, the conventional three-way catalyst used on gasoline-powered vehicles/equipment cannot be used in diesel engine applications.

The LNC was developed to address the issue of catalytic NO_x control in the oxygen-rich exhaust environment of diesel engines. Some LNC systems inject a small amount of diesel fuel or other reductant into the exhaust. The fuel or other reductant serves as a reducing agent for the catalytic conversion of NO_x to nitrogen. Other LNC designs operate passively to reduce NO_x. The LNC support is a porous material, often made of zeolites and encased in a stainless steel container similar to what is used to hold a DOC substrate or a DPF filter. The support or substrate provides catalytic sites that are fuel/HC rich where NO_x reductions can take place. An HC/NO_x ratio of up to 6:1 is needed to achieve good NO_x reductions. The LNC/DPF system

includes a backpressure monitor and monitor for the fuel injection dosing system. Figure 4-1 is a photograph of the CARB-verified LNC/DPF system

Figure 4-1, Example of a Lean-NO_x Catalyst system



Courtesy of Cleaire

B. Emission Reduction

LNC technology is capable of achieving anywhere from 10% to 25% depending on the system design and vehicle/equipment applications. To some extent, NO_x control efficiency is dependent on the temperature of the duty cycle; if temperatures are low, the NO_x conversion is reduced. Passive systems, such as those used on passenger cars in Europe, achieve NO_x reductions of 10±%. Active LNC systems employing a reductant such as those used in retrofit applications in the U.S. have achieved a 25% or greater NO_x emission control efficiency. Since the diesel fuel used in active LNCs to reduce the NO_x does not produce mechanical energy, active LNC typically operates at a fuel penalty of about 3%. The additional fuel consumption results in a slight increase in CO₂ emissions. The CARB-verified LNC includes a catalyst-DPF as part of the system. The DPF is verified to achieve at least an 85% reduction in PM emissions, and will also reduce HC and CO emissions, as well as virtually eliminate diesel smoke and odor.

C. Status and Availability

STATUS

Passive LNC technology has been successfully employed on new diesel-powered passenger cars in Europe as original equipment since the mid-1990s. Retrofit applications of LNCs are a relatively recent development, but the application experience in both the on-road and offroad sectors is growing rapidly. A combined active LNC/DPF system has been used for retrofit applications in the U.S.

In on-road applications, the LNC/DPF system has been applied to transit buses, refuse trucks, and highway maintenance trucks. For example, over a three year period that began in 2004, up to 2,700 LNC/DPF systems will be installed on transit buses in the San Francisco area of California. A number of other transit agencies throughout California are also equipping LNC/DPF on buses. The California Department of Transportation (CALTRAN) has retrofitted LNC/DPF systems on approximately 120 vehicles with 1994 and later model year engines..

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Applications include dump trucks with spreaders and plows, as well as trucks with hoists and trash compactors. In offroad applications, the LNC/DPF system is designed to be installed on offroad equipment with EPA Tier 1 compliant engines rated at 100 horsepower or greater. LNC/DPFs have been installed on backhoes, graders, wheel loaders and back-up generators.



AVAILABILITY

There is currently one manufacturer of a CARB-verified LNC/DPF system.

D. Selection and Use Criteria

The LNC/DPF retrofit system, due in large part to the catalyst-based DPF component of the system, is an application specific technology. The same criteria that apply when evaluating DPFs as a stand-alone technology apply to the LNC/DPF system as well and include:

- 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 retrofit system.
- The level of sulfur in the diesel fuel.

These criteria are discussed in detail in Section III, DPF Selection & Use Criteria. The LNC/DPF systems have typically been retrofitted on 1994 and later model years, but in at least one instance the system was retrofitted on a 1988 model year offroad engine. According to the CARB verification, application of this technology requires exhaust temperatures of at least 260°C for at least 25% of the daily duty cycle. Also, the requirements for available space on the vehicle/equipment are increased as the dimensions of the LNC/DPF system can be greater than a DPF stand-alone technology.

E. Installation and Vehicle Modifications

Just as is the case when a DPF is used by itself, the application and use of the LNC/DPF system requires the same care in selecting and preparing the vehicle for retrofit, properly configuring and performing the installation, and properly maintaining the system and vehicle/equipment (see Section II, DPF Installation & Vehicle Modifications).

The LNC/DPF system can be installed as a muffler replacement. However, because the dimensions (both diameter and length) may be larger than the OE muffler being replaced, care must be taken to insure that adequate space exists to properly install the system. Installation of the system is performed by the technology provider. The retrofit process typically takes up to two days, and in some cases more if a custom fit is required.

F. Fuel Requirements

This system is verified to operate only on ULSD (less than 15 ppm sulfur) fuel. This requirement exists to support application of a catalyst-based DPF in the system as well as to maximize the effectiveness of the LNC component.

G. Maintenance

In addition to the maintenance performed on the DPF, on occasion in some applications, the front face of the LNC plugs. In cases where plugging occurs, the LNC element can be removed and cleaned. The injector system providing the diesel fuel as the reductant for the LNC should be inspected periodically and recalibrated or repaired as needed.

H. Costs

The installed cost of the CARB-verified LNC/DPF technology ranges from less than \$15,000 to over \$20,000 depending on the vehicle/equipment application, the engine horsepower rating, and the number of vehicles/equipment being retrofitted. Maintenance costs are related primarily to DPF filter cleaning (See Volume 2, Section II, DPF Maintenance Costs). Since this verified system uses diesel fuel as the reducing agent, a small fuel economy penalty (up to approximately 3%) could result in a slight increase in operating costs.