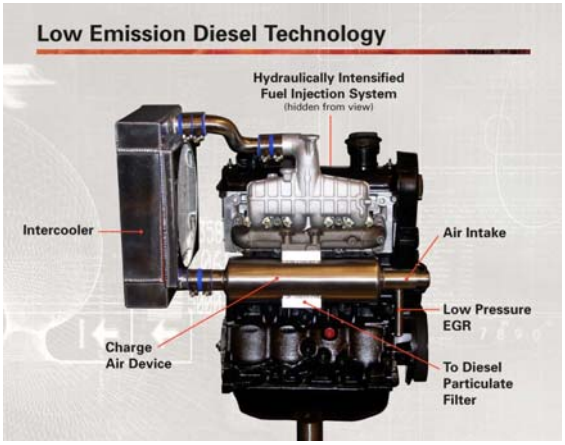
Clean Diesel Combustion –
Clean, Efficient, and Cost Effective Technology

Diesel engines are used worldwide because they achieve better fuel economy, lower carbon dioxide (CO_2) emissions and produce higher levels of power than conventional gasoline engines. However, diesel engines tend to be more costly and emit high levels of oxides of nitrogen (NOx) and particulate matter (PM) emissions. While several technology options exist to decrease these emissions, the U.S. Environmental Protection Agency (EPA) and industry partners are evaluating and developing EPA's Clean Diesel Combustion (CDC) technology , which refines several existing technologies into a unique engine design that is simultaneously clean, efficient, and cost effective.

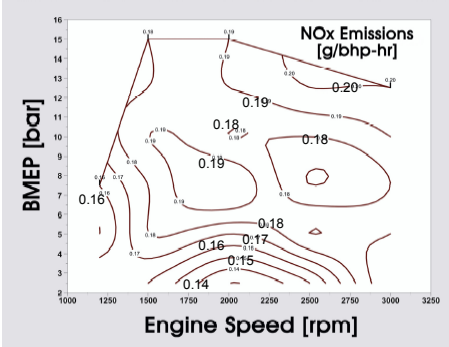


A clean diesel combustion engine with its various components.

What is Clean Diesel Combustion?
The method of CDC encompasses a series of design changes to the diesel engine, which decrease NOx emissions while maintaining or improving engine efficiency. The key concept of CDC technology is the development of in-cylinder NOx control, where NOx emissions are reduced in the engine combustion chamber without penalizing the engine's efficiency. Preliminary EPA research has demonstrated positive results for a design that achieves in-cylinder NOx emissions much lower than levels reported by industry.

Key Features of CDC Technology

- *EPA Fuel System* – Uses a hydraulically intensified fuel system to lower PM and smoke emissions, and improve engine efficiency.
- *Boost System* – Increases the engine power and the efficiency of the combustion process, thus reducing emissions and increasing fuel economy.
- *Low Pressure Exhaust Gas Recirculation (EGR)* – Lowers the peak combustion temperature to reduce the formation of NOx.
- *PM Aftertreatment* – Reduces the remaining smoke, unburned hydrocarbons (HC) and carbon monoxide in the exhaust to levels required for future emissions standards.



This real engine test map shows that NOx emissions are low over the entire engine operating map. Brake mean effective pressure (BMEP) is a measure for comparing performance of one engine to another.

Clean Automotive Technology…

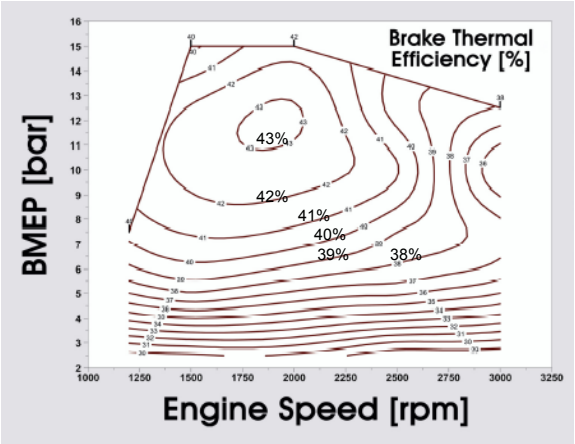
Clean, efficient, cost-effective

Technical challenges include lowering particulate emissions coming directly from the engine, demonstrating the robustness of the technology in real world operation, and keeping cost/durability relative to other approaches for meeting future stringent diesel emission standards. EPA continues to improve the development of this technology by addressing these issues.

Benefits of CDC

CDC, with its unique combination of technology advances, offers benefits such as:

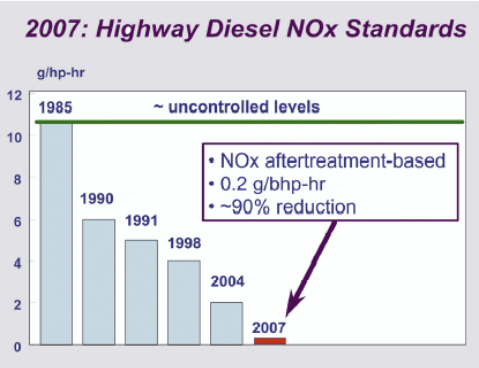
- *Low Cost* – In-cylinder NOx control (where NOx emissions are reduced in the engine combustion chamber) greatly simplifies the aftertreatment system requirements (conventional aftertreatment to reduce smoke, PM, and HC).
- *Low Emissions* – Potential to achieve levels of 2007/2010 Heavy-Duty Engine and Tier 2 emission standards without the use of NOx aftertreatment.
- *Scalable* – Applicable to both light-duty and heavy-duty diesel engines.



This real engine test map shows a high level of engine efficienty at various speeds and ooads. For this test, the boost was externally supplied, simulating a well-matched turbocharger (P exhaust = P input + 1.5 psi)

Technology Advances to Achieve Emission Standard Levels

EPA emission standards – both 2007 heavy-duty engine and the Tier 2 standards for passenger vehicles – call for major reductions (ranging from 77 to 95 percent) in NOx and PM emissions. Although several methods are being examined to meet these future standards, today's primary path option to reduce diesel NOx emissions is through the use of aftertreatment devices. NOx aftertreatment devices control emissions downstream from the engine's combustion chamber, in the exhaust system rather than in the engine.



For model year 2007, NOx emission standards for heavy-duty engines are reduced over 90% of current standards.

Research on CDC technology suggests that cost-effective alternatives for long-term NOx compliance may not need to rely exclusively on NOx aftertreatment methods. CDC technology may be an attractive alternate method to achieve future stringent diesel emissions standard levels.

Currently, EPA is actively discussing CDC technology with potential partners to continue advancing the research and possibly introduce the concept into production in the future.

EPA420-F-04-023
March 2004