EXHAUST GAS RECIRCULATION

Exhaust gas recirculation (EGR) is an emission control technology allowing significant NOx emission reductions from most types of diesel engines: from light-duty engines through medium- and heavy-duty engine applications right up to low-speed, two-stroke marine engines. While the application of EGR for NOx reduction is the most common reason for applying EGR to modern commercial diesel engines, its potential application extends to other purposes as well.

The NOx emission benefit of EGR comes at a cost. Other measures are usually required to avoid unacceptable increases in fuel consumption, emissions of PM, HC, and CO, engine wear and reductions in engine durability. In order to address these trade-offs in commercial diesel engine applications, engine manufacturers have had to simultaneously adopt a range of other technological changes such as:

- Reductions in lubricating oil consumption
- Increases in fuel injection pressure
- Increased use of diesel oxidation catalysts
- Increased intake manifold boost pressure

More than one technical route exists to meet a given NOx limit, and EGR can sometimes be used as one of several alternative technologies. Such competition exists, for example, between cooled EGR and urea-SCR technology in heavy-duty Euro IV, Euro V and US 2010 diesel engines.

However, to meet more stringent NOx emission limits, it may be necessary to use EGR in combination with NOx reduction catalysts. Commercial applications of EGR on diesel engines are summarized in the following table. On several occasions, small scale EGR applications occurred earlier than indicated in the table, typically driven by various voluntary incentive programs.

Light-Duty Engines

The introduction of EGR technology to diesel passenger cars in the 1990s went almost unnoticed and was not considered a major breakthrough for several reasons. Because the required NOx reduction was quite modest, the system allowed little EGR back into the cylinder and there was no need for EGR cooling. Typical passenger car engines operate mostly at part load conditions where temperatures are relatively low. It was only the Euro 3/4 legislation that created higher demands on EGR systems and triggered the introduction of increasingly more sophisticated, electronically controlled cooled EGR systems on light-duty engines.

Heavy-Duty Engines

Heavy-duty applications of EGR date back to at least 1977 when the technology was used on some naturally aspirated engines—such as Caterpillar's 3208—to comply with California's 5 g/bhp-hr NOx+HC limit for heavy-duty diesel engines. However, through the 1980s and 1990s the use of EGR on heavy-duty engines remained limited—EGR was not required to meet regulatory emission standards and the application of the technology was driven primarily by incentives such as the US EPA voluntary "low emission vehicle" certification program.

Future Trends

Many advanced combustion concepts under development—like Low Temperature Combustion (LTC)—utilize very high EGR rates for emission control. This is likely to put even more demand on future EGR systems and their components if the application of LTC over a significant portion of the engine operating map becomes commercial.

Urea-SCR after treatment will continue to be an alternative NOx reduction technique competing with EGR. Depending on the stringency of the respective emission standards, on the progress in NOx conversion efficiency and durability of SCR catalysts, and on the relative costs of diesel fuel and urea, three main NOx reduction technology pathways can be used in modern diesel engines:

1. EGR (without NOx after treatment)
2. EGR combined with SCR after treatment
3. SCR only, without EGR