

Thinking Inside the Box

This technical paper presents an overview of the 2007 emission regulation challenges facing the trucking industry and highlights the key elements of Hino's response.

The Challenge

In October 1997, the EPA adopted new emission standards for heavy and medium duty diesel truck and bus engines beginning with model year 2004. Figure 1 shows the movement of US EPA regulations in gray boxes starting with the 1998 Nitrogen Oxides (NOx) level of 4 g/bhp-hr and Particulates (PM) level of 0.1 g/bhp-hr. Moving to the darker gray box of 2004, maintained the Particulate levels but further reduced NOx to 2 g/bhp-hr.

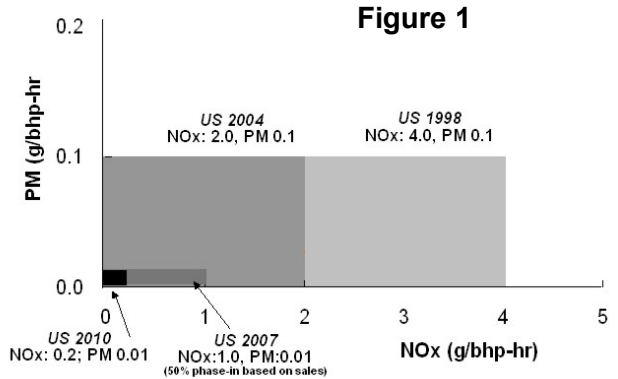
As we approach the 2007 engine introduction it is interesting to see the graphic depiction of the change in both PM and NOx. The 90% reduction of PM to 0.01 g/bhp-hr coupled with a 50% reduction in NOx (phased-in based on sales at 50% each year from 2007 through 2010) will require a combination of both engine changes and the introduction of particulate filter technology. These changes come in conjunction with a phased in reduction of the sulfur content of fuel from the current levels of 500 parts per million (PPM) to the 2007 goal of 15 PPM. At the terminal level, highway diesel fuel sold as low sulfur fuel must meet the 15 ppm sulfur standard as of September 1, 2006. For retail stations and wholesale purchasers, highway diesel sold as low sulfur fuel must meet the 15 ppm sulfur standard by October 15, 2006.

Hino's Advantage

Japan has required tighter NOx and PM levels than the US law starting in October 2005. Hino, the largest producer of medium and heavy duty trucks in Japan for 32 consecutive years, introduced its 2005 emission changes in May 2005 getting a jump on commercial application experience on the key technology changes that will be used on its J-Series engines to meet the US 2007 levels. This production experience gives Hino an advantage over US and European engine producers who have not been in production with their 2007 designs. Additionally, Hino's key components such as its Cooled EGR System, Common Rail Fuel System and Variable Nozzle Turbocharger have been in production since 2003. These items, with some

modification for 2007, provide a strong base of experience for meeting the new regulations.

Figure 1 serves to explain the title of this paper – the emission regulation challenge is largely an exercise of thinking “inside the box” –inside the box of performance tradeoffs of emissions versus fuel economy; inside the box of component reaction to low sulfur fuel; and inside the box of NOx and Particulate tradeoffs.



Engine designers are taking a variety of approaches to the new regulation challenges. Figure 2 shows the key technologies emerging as responses to the challenge. For the 2007 levels, Hino is utilizing Diesel Particulate Reduction (DPR) technology in conjunction with engine controlled oxidation or “regeneration” of the particulate content. The regeneration eliminates the need to change or regularly service the DPR filter.

Figure 2

Catalyst Technology	Reaction Type	Reduced Emissions
Diesel Particulate Reduction (DPR)	Oxidation	HC, PM, odor
Diesel Oxidation Catalyst (DOC)	Oxidation	CO, HC, PM, odor
Selective Catalytic Reduction (SCR)	Catalytic reduction by ammonia or urea injection	NOx
Lean NOx Catalyst (LNC)	Selective catalytic reduction by hydrocarbons	NOx, HC, PM
Lean NOx Trap (LNT)	Adsorption (trapping) of NOx from lean exhaust followed by release and catalytic reduction under rich conditions	NOx, CO, HC



Thinking Inside the Box

The key to meeting emission regulations is not limited to understanding the science of NOx and Particulate reduction – it is more focused on establishing solutions that are robust enough to live in a wide variety of applications and that impact the cost of the truck as little as possible.

Hino's Response

Our experience in Japan has shown that we can meet the US 2007 emission regulations with four modifications of current components and the addition of one new feature:

Current Component Enhancements

- **Common Rail Injection System**
 - o Increased pressure and multiple injection points
- **Cooled EGR**
 - o Increased cooling capacity
- **Variable Nozzle Turbocharger**
 - o Increased efficiency and surge margin
- **Piston Design**
 - o Changes to handle higher pressures

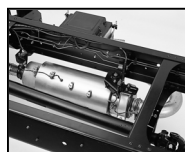
New Features

- **Diesel Particulate Reduction (DPR)**
 - o Post combustion system using active regeneration control and particulate filter (Figure 3 – components as configured for current trucks running in Japan)

Figure 3



J-Series Engine



2007 DPR System



2007 Particulate Filter

Figure 4 shows the primary features of Hino's 2007 emissions solution. As shown, the new system utilizes technology common with today's engine plus the addition of a diesel particulate reduction (DPR) system. The variable nozzle turbocharger (VNT) and electronically controlled common rail fuel system combine to optimize the air-fuel mixture to reduce particulates by improving the completeness of the combustion cycle. The increase in the exhaust gas recirculation (EGR) system reduces NOx emissions. The DPR system then relies on post injections (multiple injections per cycle from the common rail system) to heat the exhaust gases for the particulate filter. Active regeneration adds oxygen to periodically burn and vaporize the particulates trapped in the DPR filter. Controlling both the engine and the DPR system with a common computer assures optimization of emission control.

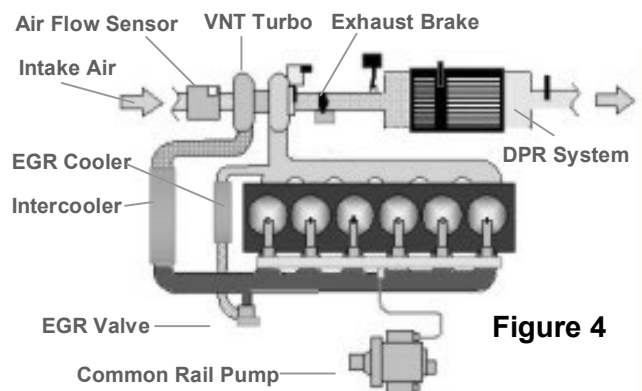


Figure 4

The challenge, of course, is to meet the regulations while maintaining both the reliability and the fuel economy of the engine, and that is the goal we set for our engineers. Their response is typical of the designs of Hino trucks -- **simple, straightforward and dependable**. The approach is simple in the fact that it uses proven production pieces from other Hino engines; it is straightforward based on its optimization of control through the use of a common computer system for both the engine and DPR; it is dependable because we have taken the time to thoroughly test every facet of the design both in the lab and the field. We're confident that our approach to 2007 will maintain Hino's reputation for building high quality trucks.

For more information on Hino Trucks go to www.hino.com

Every report of this type needs some fine print – so here it is. Our idea in publishing these papers is to keep you informed on our engineering direction and product design. The contents are as accurate as possible at the time of publishing. But everything may change if we get a better idea.

