

**Environmental Performance**



Since selling the world's first buses equipped with a hybrid system in 1991, Hino Motors has consistently taken the lead in the industry as a pioneer of environmental technologies for diesel vehicles. As one example of its efforts to reduce environmental load, Hino Motors began employing its Diesel Particulate active Reduction (DPR) system in 2003—the world's first full-fledged exhaust emission reduction system for commercial vehicles designed to reduce particulate matter (PM).

Compared to gasoline engines, diesel engines burn fuel more efficiently and emit less CO<sub>2</sub> emissions due to better mileage. Despite these advantages, however, cutting down on emissions of nitrogen oxide (NO<sub>x</sub>) and PM from diesel engines has been challenging.

Selective catalytic reduction (SCR) systems that use urea are usually used to control emissions of NO<sub>x</sub> and PM, but their use of urea leads to problems, as described below. Hino Motors, however, has developed a post-processing system for small- and medium-sized engines that successfully reduces NO<sub>x</sub> and PM emissions simultaneously without the use of urea.

Hino Motors has received various awards in recognition of this achievement and the technologies used for the emission reduction system, including the 11th Ministry of Economy, Trade and Industry Minister's Prize for the promotion of the machine industry in February 2014.

Prize name	The period of awarded prize
11th Ministry of Economy, Trade and Industry Minister's Prize for the promotion of the machine industry	2014/2
The Society of Japanese Mechanical Engineers Prize in Fiscal 2013	2014/4
64th the Society of Japanese Automotive Engineers Prize for technology development	2014/5
The prize for an academic society about coal oil in Fiscal 2013	2014/5



The awards ceremony held by the Society of Automotive Engineers of Japan



The awards ceremony held by the Japan Society for Promotion of Machine Industry

Details about Hino Motors' newly developed urea-free NO<sub>x</sub> and PM post-processing system for light- and medium-duty diesel vehicles as well as its future deployment are presented as follows.

## Issues concerning SCR technologies that use urea

Since around 2003 or 2004, selective catalytic reduction (SCR) systems using urea have been applied as a means of reducing exhaust emissions from commercial diesel vehicles in Japan, the U.S and Europe. In these systems, ammonia ( $\text{NH}_3$ ) is used to produce a chemical reaction with nitrogen oxide ( $\text{NO}_x$ ), thereby reducing it to nitrogen ( $\text{N}_2$ ) and water ( $\text{H}_2\text{O}$ ). It works on the same principles as exhaust emission processing systems used at thermal power plants and other similar facilities.

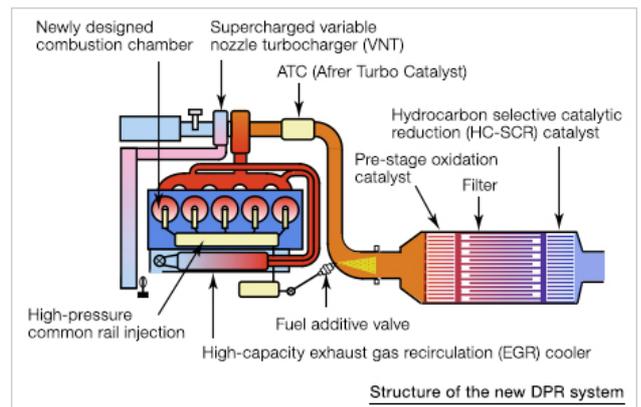
As detailed below, a number of problems arise from the use of urea-based SCR technologies.

### Problems with SCR technologies that use urea:

- The infrastructure for supplying urea fluid is inadequate (only 6% of all gas stations in Japan can supply it)
- Urea-based SCR systems are too large to be installed in small- and medium-sized vehicles (for example, the fire engines and garbage trucks)

Hino Motors has overcome these problems with the development of its new DPR system, the world's first system capable of simultaneously reducing  $\text{NO}_x$  and PM using diesel fuel as a reductant. Recognizing that a catalyst technology capable of reducing exhaust emissions from diesel engines would be needed in the future, Hino Motors began research about 25 years ago to explore the possibility of making a catalyst system that simultaneously reduces  $\text{NO}_x$  and PM. During this research, the Company discovered that by supplying small amounts of fuel in a special catalyst unit, the  $\text{NO}_x$  in the exhaust gas could be reduced through a hydrocarbon selective catalytic reduction (HC-SCR) reaction. It also found that PM collected in a filter could be reduced by means of heat generated by catalytic oxidation. A vast number of issues were solved through repeated trial and error until the technology was finally made feasible.

## Overview of Hino Motors' new DPR system and its benefits



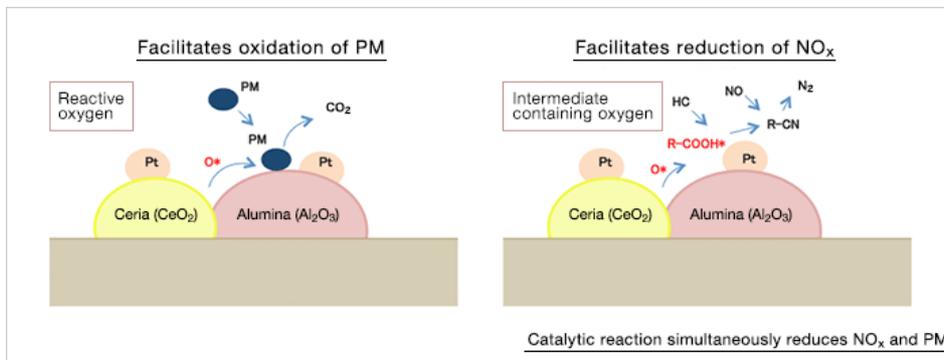
The following diagram shows the structure of Hino Motors' new DPR system, which simultaneously reduces  $\text{NO}_x$  and PM.

PM contained in exhaust gas is collected via a filter fitted to the catalytic converter. The collected PM is combusted in an exothermic reaction via the oxidation catalyst using the fuel supplied from a periodically opening fuel additive valve. The system also maximizes the reduction of  $\text{NO}_x$  by measuring the catalyst usage environment via a heat sensor and  $\text{NO}_x$  sensor attached to the catalytic converter, while adding limited amounts of fuel.

In this way,  $\text{NO}_x$  and PM can be simultaneously reduced using a single catalytic converter, allowing a more compact system to be utilized.

By utilizing cerium oxide ( $\text{CeO}_2$ ) containing high levels of reactive oxygen in the catalytic components, the system successfully accelerates the reaction that simultaneously reduces  $\text{NO}_x$  and PM in the exhaust emissions.

A small oxidation catalyst fitted directly under the high-temperature exhaust turbocharger accelerates the temperature increase of the oxidation catalyst, thereby improving the effectiveness of filter recovery. This makes it possible to recover filter in a short time, even when driving at slow speeds.



The biggest advantage of the system is that it completely eliminates the need for a regular supply of urea fluid since it uses diesel fuel as the NO<sub>x</sub> reductant and the means to recover filter.

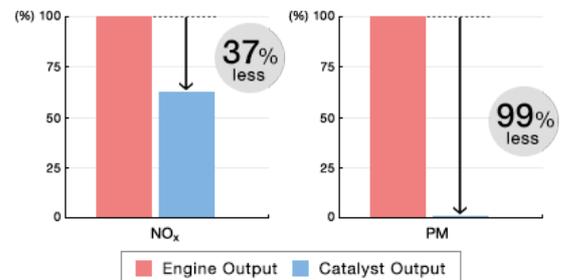
As a result, the system can be readily used for vehicles in areas that have been late in setting up urea fluid supply facilities.

Furthermore, since no urea tank or related equipment is necessary, the exhaust emission reduction system can be made much more compact compared to vehicles equipped with urea-based SCR systems. That gives users a broader choice of vehicle options.

#### Benefits of the new DPR system

- **A supply of urea fluid is completely unnecessary**
- Emission reduction systems can be made compact enough to be equipped in light- and medium-duty diesel vehicles

## Exhaust emission reduction results from using the system, and its deployment in the future



Exhaust emission reduction results from using the recently developed new DPR system are shown in the chart below. While diesel engines are known for high NO<sub>x</sub> and PM levels, use of the new system reduced emissions of NO<sub>x</sub> by 37% and PM by 99% (based on the scenario of urban driving).

To date, over 100,000 vehicles equipped with the new system have been sold. By utilizing recovered filter, the system has reduced fuel consumption by 28%, which also contributes to lowering CO<sub>2</sub> emissions.

The new DPR system can contribute to environmental technical solutions not only in Japan but also in emerging countries. Since urea fluid supply networks are generally insufficient in Asian nations and other countries around the world, the utilization of Hino Motors' new system is generating considerable interest.

## Comments

**This system is a completely original Hino Motors technology that nobody else had worked on before.**



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## Discussion leader: What motivated Hino Motors to develop its new DPR system?

### Hosoya:

The new DPR system came from research that began in the 1980s. At that time, we thought that a post-processing system for reducing NO<sub>x</sub> and PM would eventually be needed in the future. Then in 1999, Tokyo Governor Shintaro Ishihara raised the issue of exhaust emissions from diesel vehicles, even showing diesel soot in a plastic bottle. That raised public awareness of the need to make exhaust gas cleaner, and, understandably, we became certain that such a system was absolutely necessary.

### Kobayashi:

My job involved listening to the concerns and needs of customers and relaying them to production development departments. While customers wanted vehicles that complied with regulations, they also recognized that meeting these regulations meant equipping the vehicles with complicated equipment that could be hard to handle. Therefore, I wanted the Company to produce something that would greatly help reduce the problems involved in complying with the regulations.

### Hosoya:

Our new technology came from collaboration between engineers working on both engines and exhaust systems. Both groups aimed to improve the performance of each of these operations. But the successful development of a system that decreases NO<sub>x</sub> and PM simultaneously is what really separates their efforts from past endeavors.

### Minamikawa:

At the time of development, I was responsible for integrating the technologies developed up to that time in the mass production system. To turn the technology into a product, it was necessary to incorporate the needs of customers, such as making the system compact enough to fit under the floor of a truck cab.

Because the system was designed to be extremely compact, it was easy for us to assemble it into a product. I was rather anxious about whether or not we would be able to actually assemble everything properly, since it was a completely original Hino Motors technology that nobody else had worked on before.

Despite my concerns, however, I was confident that Mr. Hosoya's team could handle the development work.

### Kobayashi:

In the Sales and Marketing Division, we wondered whether the Company would make a system using urea, like those of other manufacturers. But, I had heard that such systems do not have a great reputation because they add so much weight to the vehicle, and obtaining a supply of urea can be difficult. Therefore, if a system that didn't use urea could be developed, I certainly wanted the Company to go ahead with it.

## Discussion leader: How did customers react after the system was released?

### Kobayashi:

Presently, the release is driving up unit sales of medium-duty trucks, which are commonly used by households and vehicle rental agents. Customers renting trucks from the agents are not professional drivers, so they are generally not aware of systems that use urea. But, in fact, there have been cases in which customers unknowingly rented a vehicle with such a system, and the vehicle shut down because they forgot to replenish it with urea. As a result, rental customers have been requesting vehicles that do not need urea, so our share of the vehicle rental market has been increasing.



### Minamikawa:

Another response from outside the Company was the prize we received for promoting new machinery from the Minister of the Economy, Trade and Industry. Hino Motors had never received an award from a government minister before.

### Hosoya:

Indeed, that was very surprising. These days, measures are needed to deal with air pollution in newly developing countries. If we provide a system that does not depend on an urea supply network, we can easily enter those markets. I hope the Company will take this perspective into account.

**Discussion leader: Please tell us about your ambitions going forward.**

**Kobayashi:**

To improve the safety of trucks nowadays, they must be equipped with various parts besides exhaust emission systems, like heavy bumpers. As a result, people say that trucks themselves have become heavier, and less cargo can be loaded compared with trucks ten years ago.

With the release of our new system, I think we have addressed commercial needs and made customers aware of its many advantages.

In the future, if there are efforts to keep weight increases down as much as possible, we in sales will be very grateful. That's because trucks are primarily vehicles for transporting cargo.

**Minamikawa:**

I would also like to see more compactness. We chose the new system on the basis of its better user-friendliness for customers, so from now on, I think we should pursue convenience for customers when proceeding with development.

**Hosoya:**

I completely agree with you. These days, to fight against global warming, we must try to reduce CO<sub>2</sub> emissions and also make exhaust emissions cleaner. Furthermore, from the customer's standpoint, good trucks are those that cut down on fuel expenses as much as possible. The challenge we face is whether we can release new technologies that make vehicles cheaper, cleaner, and more fuel efficient.