DENSO NEWS CONFERENCE REMARKS

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"DENSO'S Current- and Next-Generation Diesel Common Rail Technology"

Allow me to begin by stating, quite plainly – and with apologies to a former GM ad campaign, Oldsmobile, I believe – that the new diesel engine, fueled by DENSO's common rail system, is:

``Not your father's diesel engine."

The image of that engine, with apologies to fathers everywhere, of course, evokes extremely negative adjectives.

``Dirty" and ``noisy" are two that immediately come to mind.

A recent J.D. Power and Associates Clean Diesel Market Assessment Study indicated that one of the major challenges facing diesel acceptance in North America is overcoming the negative perceptions of diesel-powered vehicles held by many consumers.

That's understandable.

So, what would happen if those derogatory adjectives describing diesel-powered cars were, instead, the following phrases:

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``More fuel efficient?"

“More power output?”

``Cleaner?”

``Quieter?”

What if that diesel-powered engine had 30 percent better fuel consumption than a gasoline engine?

What if that diesel-powered engine reached an emissions level of so-called ``zero smoke?”

What if that diesel engine were as quiet as a gasoline engine?

What then?

That very same J.D. Power and Associates study revealed that consumers, intent on not only a better product, but also on reducing dependence on foreign oil, said that, when making a choice for a non-gasoline-powered vehicle, they would select a diesel engine over a hybrid engine.

If that diesel engine were … clean.

The DENSO 1800-bar common rail system removes that ``if.”

And a few others.

Before we proceed to the system itself, allow me to note that DENSO is no newcomer to common-rail diesel technology.

In 1995, DENSO launched the world’s first diesel common rail injection system for trucks, supplying the system to Hino Motors, a Japanese manufacturer. Since then, we have supplied approximately 20,000 common rail injection systems to Hino, Isuzu and Mitsubishi for trucks sold in Japan, the United States and Taiwan.

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In 1996, DENSO began supplying diesel common rail injection systems for passenger cars.

And in 1999, DENSO debuted a common rail system in Toyota cars for the European market.

The new system, with 1800-bar injection pressure, the highest in the world, is simply a natural progression – or, rather, the natural DENSO progression.

Toward excellence.

Faster, cleaner, quieter.

Now, how do we – how did we -- get from here to there?

The Cliffs Notes version is this:

We improved the diesel engine by improving the fuel injection system, engineering it to provide higher injection pressure, better atomization of fuel, with multiple fuel injections, providing, in turn, more power, improved combustion and, ultimately a more powerful vehicle, not to mention a cleaner and quieter one.

To be specific in a single sentence:

By injecting fuel at 1800-bar, regardless of engine speed, DENSO's common rail system raises diesel engine performance, while reducing particulate matter (PM) and nitrogen oxide emissions.

Let's begin with a quick, nuts-and-bolts overview of our common rail system:

DENSO's 1800-bar system is composed of a supply pump, a common rail with a high-pressure sensor, solenoid injectors and a high-speed electronic control unit, or ECU.

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All of the engineering is finely detailed for a specific result – or results.

For example: Using hybrid aluminum and steel for the pump housing reduces the weight of the pump, while producing and maintaining high pressure.

Less weight, smaller size, equals improved efficiency, meaning, of course, improved power.

Most important, the elevated pressure of the injected fuel significantly reduces the concentration of PM and nitrogen oxide in the exhaust emissions.

Now for the specifics.

Prior to the common rail design, standard fuel injection systems were either in-line pump and nozzle systems, or rotary pump and nozzle systems.

In these systems, the injection pressure from the pump depended on the pump speed.

And the pump speed was dependent upon the engine speed.

Remember, too:

The higher the engine speed is in a diesel-powered vehicle, the lower the noise and noxious emissions.

DENSO's 1800-bar common rail system is designed to produce high-pressure fuel – and lower noise and emissions -- even at low engine speeds.

As you can see from this graphic, the 1800-bar pressure is reached at a low idle RPM and remains constant.

This is in contrast to other or ``conventional" or ``in-line pump and nozzle" systems, whose injection pressure increases – but not to 1800 bar; remember; DENSO's 1800-bar common rail system produces the highest pressure in the industry.

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Why is this ultimately so important?

Because, again, the higher the injection pressure, the better the combustion and the less particulate matter and nitrogen oxide in the exhaust, approaching an ultimate benchmark that we call ``zero smoke."

As this graphic depicts, one of the keys to the 1800-bar common rail system is improved fuel atomization.

Improved atomization is dependent on fuel pressure and the size of the nozzle tip hole.

DENSO's 1800-bar system uses a nozzle tip hole reduced in size from 0.15 diameter to 0.13 diameter.

The smaller nozzle ultimately reduces the amount of noxious emissions.

There is a downside, however:

Using a smaller nozzle generally produces a reduction in power.

This is where engineering expertise comes in.

To counter the ramifications of a smaller nozzle, the fuel pressure is increased – 1800-bar, remember – which not only restores the lost power, but also actually increases the engine's performance capability.

Until now, a common rail system would employ only two fuel injections in its combustion cycle – a pilot injection, or the first injection, and a main injection.

The DENSO common rail system employs five injections.

That's five distinct injections during each combustion stroke.

Each with a predetermined and metered fuel quantity.

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The multiple injections are designated as:

The pilot, pre, main, after and post injections.

The pilot injection, occurring well before ignition, provides time for fuel and air to mix.

The ``pre" injection, shortens the ignition delay during the main injection and, as a result, reduces the generation of nitrogen oxide, noise and engine vibration.

The main injection is, well, the main injection, providing the fuel for combustion and power.

The ``after" injection occurs a split-second after the main injection and re-burns any remaining PM.

The ``post" injection helps manage the temperature of the exhaust gases, which makes the exhaust processing in the engine's after-treatment cycle more effective.

Are five injections the limit?

For now perhaps. For this system.

However, our DENSO engineers have developed the capability for up to nine injections during each combustion stroke.

Notice here, too, the depicted decrease in engine noise, for a 2.0-liter engine.

One more note regarding the injection process:

The injectors used in the common rail system are designed for improved response, thereby shortening the interval of injections. In order to increase from two to five injections per stroke, the injectors must be faster.

Ours are.

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Remember, too: A faster injector means a faster injector rate, which means, for the consumer, increased engine power.

Here, you can see, an external view of the solenoid injector. It's characterized by a 0.4 millisecond interval between the end of the pilot injection and the start of the main injection.

Our injector connectors contain chip resistors with different values of resistance. Measuring the operational characteristics of each injector as it comes off the production line, we install the appropriate chip resistor to compensate for any deviation from the target characteristics. That compensation helps achieve an exceedingly accurate injection quantity.

While we currently employ solenoid injectors, in the near future, DENSO will use ``piezo" injectors," which can achieve a lightning-quick, response interval of close to 0.1 milliseconds – a marked improvement over the current, still-impressive, industry leading speed of 0.4 milliseconds.

What we have discussed the past few minutes describes the mechanics of the DENSO 1800-bar common rail system.

The brains behind the operation is a 32-bit electronic control unit or ECU, with accompanying software, which monitors both variations in injection quantity among the injectors, and the variation of each injector during its operation -- and corrects both for optimum engine performance.

Indeed, one of the strong points of our second-generation common rail system is an advanced ECU with what we call ``learning control."

Existing fuel injection systems have what we call ``aging factors," which means that the injection amounts change during the life of the engine, due to aging – use and wear. The result, most obvious to the consumer, is rough idle, or engine noise.

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Thanks to our ``learning control" software, the injection quantities are kept precise for the lifetime of the engine. As a result, the system can keep performing injections with the required small fuel quantities – <u>precisely</u> -- at high accuracy during operation.

To make everything a bit more compact, our 1800-bar system integrates the ECU and EDU – or injector drive unit – into one box.

This graphic ties together DENSO's 1800-bar common rail system.

Note, the five-point injection sequence.

And the ECU-slash-EDU box.

The HP3 supply pump, which is both compact and lightweight and, as such, is one of the most efficient keys for the system, especially in passenger car applications.

Remember the hybrid of aluminum and steel construction.

This, again, is an engineering breakthrough.

The alloy pump, a DENSO signature, is able to withstand the extremely high 1800-bar pressure.

Pumps made exclusively of aluminum cannot withstand that pressure.
In summary, you can see the advantages of our 1800-bar common rail system and the results of our testing with a 2.0-liter, 4-cylinder in-line, intercooler turbo-equipped engine:

- Engine torque was increased by 35 percent.
- Engine power was increased by 24 percent.
- ***Emissions of PM and nitrogen oxide were significantly reduced.***

As a matter of fact, the 1800-bar emission results meet the EURO4 regulations without a Diesel Particulate Filter or DPF– while conventional models are still stretching to meet the old, EURO3 regulations.

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The engine combustion noise at low idle was reduced by 6.5 dB due to the five-cycle multiple injections.

Once, again, here is a final look at how we got here -- to DENSO's 1800-bar common rail system -- from there:

From our developments in 1995 through 1999, from 1200-bar to 1450 bar and a 0.7 millisecond injection interval;

To our current 1800-bar, five injection system, with 0.4 millisecond interval;

To our future plans, which include a 2000-bar system with the aforementioned piezo actuator, which would reduce the interval between injections from 0.4 milliseconds to 0.1 milliseconds.

And, now, in conclusion:

The second-generation DENSO 1800-bar common rail diesel injection system succeeded in meeting EURO4 regulations without a diesel particulate filter.

In regard to U.S. regulations?

We expect, as well, to continue to provide cost effective solutions to government emissions requirements.

The DENSO 1800-bar system is as cutting edge as cutting edge gets.

And the vehicle it powers is, decidedly, not your father's diesel engine.

Not by a long shot.

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