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Doosan Portable Power's G325 is the first in a series of new models that meet Tier 4i emissions standards. Photo courtesy Doosan Portable Power.

By Todd Howe, Manager of Global Generator Products, Doosan Portable Power

Tier 4 has become the talk of the industry and with good reason. Engine and machine manufacturers alike have made design changes to their product offerings to meet the standards set in place by the Environmental Protection Agency (EPA).

Tier 4 interim (Tier 4i) standards are a part of the EPA national program to reduce emissions from nonroad diesel engines through engine controls and reduced-sulfur fuel. The regulations require a 90 percent reduction in diesel particulate matter (PM) and a 50 percent reduction in nitrogen oxide (NO_x) from Tier 3 regulations. At the beginning of 2011, Tier 4i focused on diesel engines with power greater than 173 horsepower, which was the beginning of the gradual phase-in to Tier 4 final (Tier 4f) regulations, which are set to take



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Since then, diesel engine manufacturers have met Tier 1 and Tier 2 exhaust emissions with in-engine design changes and new technologies such as high-pressure common rail fuel injection, multistage turbocharging and upgrading the electronic control unit. Because these were all done within the engine, the generator package did not significantly change.

Tier 3 was the first stage to enforce standards on PM reduction. To account for that, exhaust gas recirculation (EGR) and variable turbocharging were introduced to make engines cleaner and more fuel efficient without changing overall machine design.

Engine Upgrades

Engine manufactures began communicating the implications of Tier 4i on machine design to equipment manufacturers in 2009. Two technology pathways have been developed in making the shift to Tier 4i. The preferred pathway improves upon technology introduced in the Tier 3 phase with exhaust gas recirculation (EGR), which effectively reduces the NO_x emissions, with an addition of an aftertreatment system composed of an oxidation catalyst and exhaust filter, which reduces PM.

The second development path is not as common at Tier 4i, but may be more prevalent in the upcoming shift to Tier 4f (where "f" denotes "final") when manufacturers plan to integrate an after-treatment system that includes selective catalytic reduction (SCR) to control NO_x



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- The engine control unit improved to integrate the engine and exhaust filter control system and optimize the overall operation of the machine.
- Advanced turbocharging, either through a single variable geometry turbocharger (VGT) or multiple turbochargers in series, added to vary the speed and volume of airflow into the engine. This not only optimizes an engine's power output, but also lowers emissions.
- A cooled exhaust gas recirculation (EGR) system added or improved to reduce NO_x emissions.
- A high-pressure common rail (HPCR) fuel system improved to allow for more complete and efficient combustion and can ultimately lower PM.
- An exhaust after-treatment system added to the engine, which includes a diesel oxidation catalyst (DOC) and diesel particulate filter (DPF). The DPF uses a ceramic filter to trap and incinerate solid PM and is periodically cleaned via a process called regeneration which oxidizes the solid PM and converts it to carbon dioxide to pass through the filter and restore its performance.
- An exhaust muffler can be added after the after-treatment system to achieve lower noise levels.
- To make the transition to Tier 4 final, it is expected that the aftertreatment system will ultimately include a DOC plus a decomposition reactor and SCR catalyst, augmented with further enhanced electronic controls and an onboard reservoir for DEF storage.



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In Tier 4i compliant mobile generators from Doosan Portable Power, the power train is in a sealed compartment with a small electric-drive cooling fan to cool convection heat. The radiator and charge air cooler for the engine are housed in a separate compartment.

Photo courtesy Doosan Portable Power.

However, with all of these additions and improvements comes additional expense.

Along with the increase in price of the machines, generator operators will also need education on regeneration indicators. While the regeneration process typically occurs without disruption to operation, power or productivity, a series of light indicators and switches correlate to the engine regeneration process. If manual regeneration is required, lights will indicate when it's needed and when to stop the machine operation if the process is not performed. A switch to inhibit automatic regeneration is available, but overuse may lead to higher maintenance costs and equipment downtime, so operator training on proper use of regeneration controls will be critical for Tier 4i products.

Design Starts with the Engine



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of new product introductions. Engine manufacturers work closely with original equipment manufacturers to determine what new testing measurements are required, to better understand how the aftertreatment and the engine regeneration process affect temperature and performance of the generator. That, and field trials, allows manufacturers to quickly learn about any design issues or areas to focus on to improve the machine.

Preparing for Tier 4f

Engine manufacturers have only recently shared information on the new technology needed to meet the upcoming Tier 4 final emissions standards. The technology of choice for most engine manufacturers will likely implement the selective catalytic reduction technology. Following the lead of what's been done in on-highway trucking, an additional after-treatment system may be required to meet the 50 percent decrease in NOx emissions.

In terms of overall package design, generator manufacturers will need to continue to find space for the new treatment devices and upgraded technology. Manufacturers will also need to account for a reservoir or tank to hold diesel exhaust fluid (DEF), a fluid that combines with exhaust moving through the SCR system to create a chemical reaction to further reduce emissions. Typically, the SCR system runs at a rate of about 5 percent of the fuel capacity, so if the generator has a 100-gallon tank on board, a 5-gallon DEF reservoir would be needed. But it's still early in the Tier 4f game.



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packages will be built with the operator in mind and will continue to be reliable, durable and quality high-performance machines.

Doosan Portable Power's Tier 4i Approach

In improving overall value in the Doosan Portable Power generators to meet the Tier 4i regulations, there was also the opportunity to meet the needs of the customer , resulting in substantial redesign of the mobile generators. Feedback on current models and customer surveys were important in designing for Tier 4i, as owners and operators expressed what they wanted to see in the new generators to improve work conditions and to solve day-to-day operational pitfalls.

Reducing noise levels and water ingress while increasing fuel efficiency were also addressed throughout design development. The Doosan Portable Power generator package in the larger Tier 4i generators is sealed to prevent hazardous liquid spillage if something were to malfunction inside the machine. The challenge with a sealed machine, however, is having enough airflow through the package without excessive rainwater intake, which would also lead to increased maintenance time.

To reduce water ingress in all working conditions, Doosan took a compartmentalized approach with the cooling system, separating the generator into two sides. The power train is housed in the sealed compartment with a small electric-drive cooling fan to move a small volume of air to cool convection heat. The radiator and charge air



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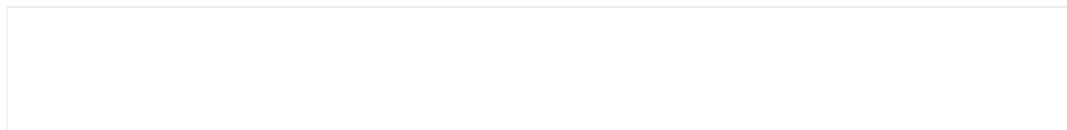
Using direct ambient air through the open radiator compartment — instead of warm air that’s been moved across the engine — provides better cooling performance against the Tier 4i engine’s 30 percent heat load increase without significantly increasing the radiator size. And it’s done with a minor increase to the generator package footprint.

The Tier 4i technology being used today in the Tier 4i generators from Doosan Portable Power is anything but exotic. The components used, while they’ve never been used in a generator before, are not brand new components. The engine changes are similar to those that took place when the DPF technology was introduced through the on-highway engine emission regulations.—TH

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