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Choosing the right emission standard and the right technology for emergency standby power systems:

EPA tiers, emissions and reliability in emergency standby power systems

White Paper

By Gary Johansen, Executive Director, Worldwide Engineering

Tier 1. Tier 2. Tier 3. Tier 4 interim. Tier 4 Final. As the emissions standards of the Environmental Protection Agency (EPA) have moved up, the mandated emission reductions for most diesel engines have moved dramatically lower, especially in 2011 with the Tier 4 interim standards taking effect. It is understandable that many people would conclude that the highest possible tier is preferable for all applications. But it's not that simple, as the EPA (website: http://www.epa.gov) itself has recognized. In choosing the appropriate EPA tier, it is important to consider the application and to choose the right technology for the job.

Background

Exhaust emissions from diesel engines have been reduced exponentially since 1996, when the first U.S. rules for stationary equipment were implemented. The power generation industry has made great strides in reducing emissions to meet these requirements.

The development of EPA emission standards

The current phase of the EPA requirements for many stationary non-emergency and nonroad diesel engines is Tier 4 interim, or Tier 4i, which mandates substantial reductions in certain pollutants, especially particulate matter (PM) and oxides of nitrogen (NOx).

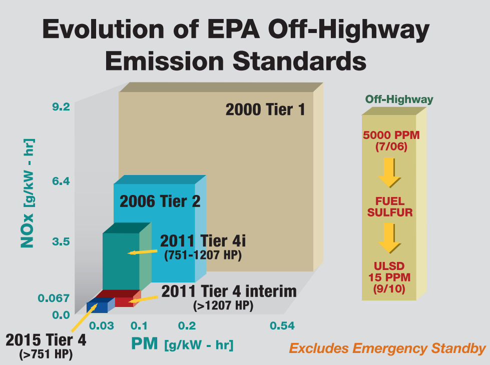
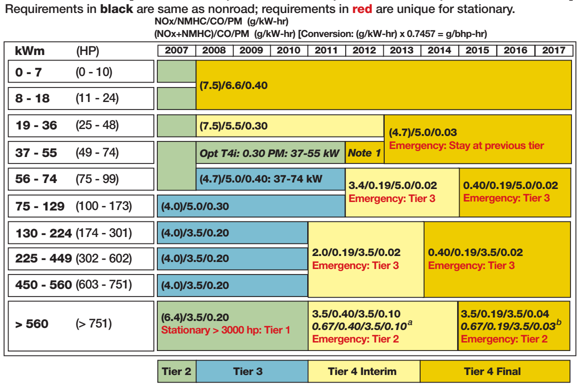


Figure 1 - This chart illustrates the dramatic emissions reductions mandated by Tier 4 phases relative to previous stages of emissions reduction.

Figure 2 shows how the EPA emission standards are applied. Notice that there are different emission limits and effective dates for different engine power levels. Equally important, the requirements vary with the application. The EPA requirements for stationary *emergency* standby applications, the subject of this white paper, are different from the requirements for all other applications.

EPA CI NSPS for Stationary Engines Standards (60.4201, 60.4202, 60.4204, & 60.4205)

Requirements in **black** are same as nonroad; requirements in red are unique for stationary.



a. Applies to non-emergency power gen engines >900kW (>1207 hp)
b. Applies to non-emergency power gen engines >560kW (>751 hp)

(1) Compliance with optional 'Option 1' 0.30 g/kW-hr PM limit in 2008 allows 1-year delay of T4 until 2013. Option 1 engines in 2008 are T4i engines, not T3 engines.
(2) Fire pump requirements for 2007+ generally delayed three years.
(3) Engines ≥ 10 L/cyl must meet T2 marine requirements of 40 CFR 94.8.
(4) There is NO TPEM program for engines in stationary applications.
Rev 14 April 2009

Figure 2 - The EPA's tiered schedule for stationary and mobile diesel engines, by engine size and application. Local and state environmental codes may override these federal regulations. Contact the environmental agency having jurisdiction in your area to determine local or regional requirements. These agencies can be very helpful in understanding the emission requirements as well as permitting and enforcement practices in each state or locality.

Definition of key terms

Before going further, let's define the terms involved. The EPA refers in its documents and charts to "emergency engines" and "emergency power." The agency defines emergency power installations as those that operate only when the normal power source, e.g., a local utility, is lost, or when operation is required for testing and exercise purposes. Typically, an automatic transfer switch senses the loss of normal power, starts the emergency generator set and transfers the electrical loads to the generator set. When normal power is restored, the transfer switch reconnects the loads to the normal power source and shuts down the generator set. The synonymous term *emergency standby power* is often used in the power generation industry, and this white paper follows that industry practice.

The EPA requires that emergency standby power systems have a non-resettable meter to record the hours of operation. Outside of actual emergencies, standby power systems are usually operated for only short periods, e.g., less than 100 hours a year for testing and maintenance. As a result, the emissions impact from these engines is low compared with those of high-hour applications. It is important to note that the hours of operation during actual power failures are not counted as part of the 100-hour limit.

Different requirements for emergency standby power

Returning to Figure 2, the yellow and gold boxes — for engines larger than 18 kWm — specify the different standards for emergency standby applications. Engines larger than 560 kWm are to remain at Tier 2, while smaller engines are required to meet Tier 3 standards.

Getting the technology right

To understand the EPA's decision and how to comply with the different standards, it is useful to know what technology options are available to meet Tier 4 standards, besides the use of ultra low sulfur diesel (ULSD) fuel. These technologies fall into two categories: in-cylinder and exhaust aftertreatment. To achieve optimal reliability and performance, these two sets of technologies must be designed and implemented in tandem.

If not properly matched to the engine, in-cylinder and exhaust aftertreatment technologies may cause engine power loss and possible derating. Factory-approved and -certified designs assure proper power levels.

In-cylinder technologies, which may include new combustion system geometry and advanced, high-pressure fuel injection, are sufficient to meet Tiers 2 and 3 requirements. Reliable exhaust aftertreatment technologies are required for an optimal solution to meet Tier 4i requirements.

Taking the current state of emission-reduction technologies into consideration, the EPA decided that if an application is strictly emergency standby, the appropriate standard that maximizes reliability and emission reduction, while constraining costs and complexity, is Tier 2 or Tier 3, depending on the engine power. Applications such as prime power, peaking power, storm avoidance (reverse standby), cogeneration — anything other than just emergency standby — are required to meet Tier 4i standards as of 2011, because these other applications are considered stationary *non*-emergency uses.

Adaptation of proven aftertreatment technologies

The available aftertreatment technologies that satisfy Tier 4i requirements have a long track record in other applications. Consider, for example, selective catalytic reduction (SCR). This technology has been used in a variety of applications to effectively control NOx, most recently in on-highway commercial vehicles. SCR is now being adapted for use in industrial and power generation applications. For stationary non-emergency use, where Tier 4i emission standards come into play, SCR can be used to greatly reduce NOx without sacrificing generator engine and electrical performance. To address high levels of particulates in the exhaust, some engine manufacturers utilize diesel particulate filter (DPF) systems, which may also be used to meet Tier 4 Final emission standards in 2015.

DPF filters are designed to remove the accumulated particulate, either through the use of a passive diesel oxidation catalyst (DOC), or through an active regeneration method that heats the filter sufficiently to enable oxidation of the soot.

Selective catalytic reduction (SCR)

SCR is a proven NOx-reduction technology that utilizes diesel exhaust fluid (DEF), an ammonia-based solution that is introduced into the engine's exhaust system. SCR technology has advanced greatly to achieve very low NOx levels, while potentially contributing to enhanced generator performance and fuel consumption. The DEF solution, when injected in precise amounts into the exhaust flow at regulated temperatures, can reduce NOx by 90% or more. In fact, this technology fully achieves, and in many cases exceeds, EPA Tier 4i requirements for stationary non-emergency high-hour applications.

The importance of the right temperature

The SCR technology used to meet Tier 4 requirements relies on proper mixing and decomposition of the DEF in the exhaust piping upstream of the catalyst. This decomposition also relies on exhaust conditions, such as temperature and flow, to be at specified conditions.

As an engine starts up after time at ambient or "cold" conditions, it takes time for the exhaust to reach the optimum temperature, depending on the ambient conditions and the engine load. Operating the engine and aftertreatment system at optimum temperatures is required to achieve the lower emission levels desired in the implementation of the aftertreatment system. Or to put it another way, NOx emissions won't be reduced until the optimal temperature for DEF injection is reached.

To minimize the time to achieve effective NOx reductions, some Tier 4 system designs include an additional heat source such as an electric exhaust heater or a fuel burner in the exhaust to ensure that the chemical reaction occurs.

For emergency standby applications, some precautions should be taken regarding DEF storage, in order to prevent the solution from freezing, which occurs below 12°F (-11°C), and from becoming contaminated. If freezing does occur, the tank and lines simply need to be thawed.

The importance of correct operation and maintenance

As with any technology, proper operation and maintenance of the engine and aftertreatment are required to ensure that the systems perform reliably. Failure to follow the manufacturer's recommendations can result in engine and aftertreatment system damage, which can adversely affect the reliability of a system. Proper operation and maintenance will help ensure that these systems perform properly in their critical applications.

Figure 3 - A high-range generator set with an SCR system (gray insulated equipment) installed above it.

Costs, performance and reliability: a balanced approach

Optimizing cost, performance and reliability can be achieved only by an integrated in-cylinder and aftertreatment solution. The key to such optimization is to focus on the requirements of the application. For instance, a user with a critical power application that places a higher importance on being able to operate a generator set for storm avoidance or planned outages may prefer a higher initial capital cost to enable the lower emissions required to meet the Tier 4i standards. On the other hand, an organization with a data center application that requires very high power density may prefer a solution with exhaust aftertreatment to deliver higher power output than a purely in-cylinder solution might provide. Regardless of the application, an integrated solution provided by a manufacturer with the ability to optimize both in-cylinder and aftertreatment technologies will ensure the optimum cost, performance and reliability for the application.

Cummins commitment to research and development of advanced technologies

Cummins Power Generation is continuing to work on advanced, industry-leading power generation and engine technologies. Cummins on- and off-highway engines provide customers with industry-leading performance, fuel economy and environmental sustainability by providing the right combination of engine in-cylinder advances, coupled with Cummins turbochargers, fuel systems, filtration, and exhaust aftertreatment technologies. These technologies are developed and matched to our customers' requirements.

Additionally, Cummins has been doing research on fuel cells since the 1960s, and this work has accelerated through our association with the Solid State Energy Conversion Alliance (SECA) program of the Department of Energy (DOE). This work exemplifies the answers we are developing to the crucial questions of how to provide the electrical energy needed to support a growing global economy, with less environmental impact and more efficient use of vital energy resources.

Conclusions and recommendations

Because emergency standby power systems operate in a very different and limited cycle compared with continuous duty machines, the EPA has decided that these emergency standby systems need to comply with Tier 2 or 3. These standards maximize emission reductions for this operating cycle while minimizing costs and complexity.

Nonetheless, in some locations, Tier 4i compliance might be required due to local ordinances. And some users may opt to install Tier 4i systems even where they are not required by law, perhaps to have greater flexibility in deciding on the number and timing of operating hours for their system, or to allow for nonemergency applications. In those applications, it is important to install a system that is well matched to the engine to enable the DPF and SCR systems to work effectively and reliably.

More broadly, it is advisable to look for solutions that properly balance in-cylinder and aftertreatment technologies and that are developed, approved and supported by a reputable manufacturer. As we look down the road 10 or 20 years into the future, these and new technologies will have evolved further, providing ever greater value and sustainability to end users and society.

John Wall, Chief Technical Officer at Cummins, noted that "Cummins and Cummins Power Generation have employed a comprehensive set of technologies that offer significant improvements in several areas: engine electronics, airflow management, fuel efficiency and exhaust aftertreatment. We have been working on these enhancements for a number of years, and we are confident that they represent a combined approach that enhances reliability, performance and cost-effectiveness, while substantially reducing emissions."

Cummins Power Generation is committed to providing reliable, green and cost-effective power systems. For applications other than emergency standby, this means Tier 4-compliant systems that use an optimal balance of in-cylinder and aftertreatment measures. For emergency standby power applications, this means providing systems that meet Tier 2 or Tier 3 standards. It also means continuing our investment in new technologies to develop Tier 4 solutions that optimize effectiveness and system reliability in emergency standby applications.

About the author

Gary Johansen is Executive Director, Worldwide Engineering at Cummins Power Generation. He has worked for Cummins for 19+ years, 17 of which were in the Engine Business Unit, and all in Engineering and Product Development. Much of his early career was focused on engine performance and emissions development to meet a variety of global on- and off-highway emissions regulatory requirements. He has 25 years' experience working in product development, purchasing, and strategy, functioning as both a supplier and an OEM. He has a BSME from Trine University.

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