Power topic #9001 | Technical information from Cummins Power Generation

EPA emission regulations: What they mean for diesel powered generating systems

> White paper

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Cummins Power Generation

On July 11, 2006, the EPA finalized the New Source Performance Standards (NSPS) to regulate emissions from stationary diesel engines. Starting from January 1, 2007, the NSPS harmonized emissions requirements for stationary diesel engines with the existing EPA nonroad regulations and specified requirements for an interim period through January 1, 2007 to transition to these new stationary engine regulations. EPA also has regulations for stationary spark ignited gas engines which are covered in a separate white paper. This paper explains how the Environmental Protection Agency's (EPA) New Source Performance Standards apply to diesel engines used in generator sets.

Diesel-powered generator sets remain the preferred choice for standby and emergency power systems around the world. With the growth of applications in recent years involving distributed generation, more diesel generator sets are being used for utility peaking and commercial load-shedding due to their proven reliability, low life-cycle cost, high efficiency, ready availability, ease of installation, operational flexibility and high-quality electrical performance.

Cummins Power Generation offers generator sets from 15 kW to 2500 kW that meet all applicable Tier levels established by the EPA for stationary and nonroad applications.

Compared to previous years, NOX and PM emission requirements have reduced significantly as we have moved up the tier levels. It is also worth noting that the fuel that we have been using has undergone some change as well. The sulfur content for example has gone down from 5000 ppm to 500 ppm for low sulfur diesel (LSD) and to 15 ppm for ultra low sulfur diesel (ULSD).

NOX AND PM EMISSION REQUIREMENTS

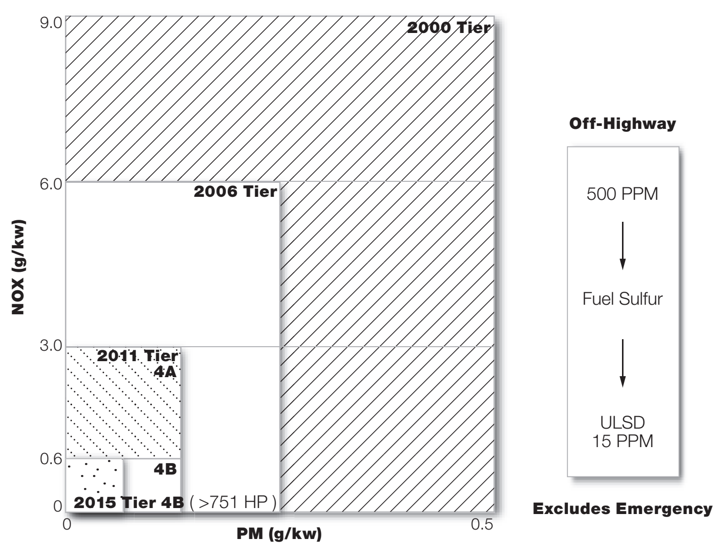


FIGURE 1 – Increasing EPA Nitrogen Oxide and Particulate Matter standards through 2015.

The regulatory landscape

Until the issuance of the final NSPS on July 11, 2006, regulations for stationary diesel engines, primarily used for power generation, were in sharp contrast to regulations for non road diesel engines. Prior to the new standards, there were no federal emissions regulations for stationary diesel engines. Emissions regulations for stationary engines were usually governed by state and local permitting authorities and varied by the annual operating hours for the application. The exact number of permissible operating hours varied by state and locale, but as an example, base-load generators running in excess of 2,000 hours per year in areas with the worst air quality faced the most stringent local emissions standards. Load management or peaking facilities running up to 1,000 hours per year faced slightly less stringent regulations. Standards for emergency standby generators operating only 200 hours per year had the most attainable permitting requirements. These general standards were established by local authorities in response to an EPA requirement for clean air standards. EPA's NSPS stationary emissions standards are intended to help local authorities meet EPA's clean air standards in regions that are non-compliant.

The EPA "non road" category of engines was established to describe engines used in mobile equipment such as farm equipment, construction equipment, generator sets on trailers and other portable industrial engines used in temporary off-road / off-highway applications. The EPA created and established standards for the non road category because local permitting authorities only had jurisdiction over stationary sources.

Stationary engines are defined as any engine that is permanently installed or located on site for a minimum period of 12 months. This category includes standby generator sets, on-site prime and distributed energy power systems, and a wide variety of industrial engines mounted on permanent bases or foundations.

It is worth noting that to accommodate for inventory, the EPA allows 2 years from the date of tier level change to install the previous tier engine. For example, engines between 49 and 99 HP are required to be tier 3 compliant starting 2008. So any engines in the same power band built before this date would have to be installed before end of 2009.

FIGURE 2 below summarizes the EPA emissions regulations for both EPA nonroad and stationary diesel engine generators out to 2017.

Note that the requirements for stationary engines above 3000 hp are T1 for 2007-2010, and when emergency engine requirements become unique by not forcing aftertreatment.

USA EPA

<table>
<tr><th>kW</th><th>HP</th><th>'96</th><th>'97</th><th>'98</th><th>'99</th><th>'00</th><th>'01</th><th>'02</th><th>'03</th><th>'04</th><th>'05</th><th>'06</th><th>'07</th><th>'08</th><th>'09</th><th>'10</th><th>'11</th><th>'12</th><th>'13</th><th>'14</th><th>'15</th><th>'16</th><th>'17</th></tr>
<tr><td>0–7</td><td>(0–10)</td><td colspan="4"></td><td colspan="5">(10.5) / 8.0 / 1.0</td><td colspan="3">(7.5) / 8.0 / 0.80</td><td colspan="10" rowspan="2">(7.5) / 6.6 / 0.40</td></tr>
<tr><td>8–18</td><td>(11–24)</td><td colspan="4"></td><td colspan="5">(9.5) / 6.6 / 0.80</td><td colspan="3">(7.5) / 6.6 / 0.80</td></tr>
<tr><td>19–36</td><td>(25–48)</td><td colspan="3"></td><td colspan="5">(9.5) / 5.5 / 0.80</td><td colspan="4">(7.5) / 5.5 / 0.60</td><td colspan="5">(7.5) / 5.5 / 0.30 *</td><td colspan="5">(4.7) / 5.0 / 0.03</td></tr>
<tr><td>37–55</td><td>(49–74)</td><td colspan="2"></td><td colspan="6" rowspan="2">9.2 / – / – / –</td><td colspan="4" rowspan="2">(7.5) / 5.0 / 0.40</td><td colspan="4">(4.7) / 5.0 / 0.30</td><td colspan="3">(4.7) / 5.0 / 0.03
(T3 for emergency)</td><td colspan="3">(4.7) / 5.0 / 0.03
(T3 for emergency)</td></tr>
<tr><td>56–74</td><td>(75–99)</td><td colspan="2"></td><td colspan="4">(4.7) / 5.0 / 0.40</td><td colspan="3" rowspan="2">3.4 / 0.19/5.0 / 0.02
(T3 for emergency)</td><td colspan="3" rowspan="2">.40 / 0.19 / 3.5 / 0.02
(T3 for emergency)</td></tr>
<tr><td>75–129</td><td>(100–173)</td><td></td><td colspan="6">9.2 / – / – / –</td><td colspan="4">(6.6) / 5.0 / 0.30</td><td colspan="5">(4.0) / 5.0 / 0.30</td></tr>
<tr><td>130–224</td><td>(174–301)</td><td colspan="7">9.2 / 1.3 / 11.4 / 0.54</td><td colspan="3">(4.0) / 3.5 / 0.20</td><td colspan="5">(4.0) / 3.5 / 0.20</td><td colspan="3" rowspan="3">3.5 / 0.40 / 3.5 / 0.10
(T3 for emergency)</td><td colspan="4" rowspan="3">3.5 / 0.19 / 3.5 / 0.04
(T3 for emergency)</td></tr>
<tr><td>225–449</td><td>(302–602)</td><td colspan="5">9.2 / 1.3 / 11.4 / 0.54</td><td colspan="4">(6.4) / 3.5 / 0.20</td><td colspan="6">(4.0) / 3.5 / 0.20</td></tr>
<tr><td>450–560</td><td>(603–751)</td><td colspan="6">9.2 / 1.3 / 11.4 / 0.54</td><td colspan="3">(6.4) / 3.5 / 0.20</td><td colspan="6">(4.0) / 3.5 / 0.20</td></tr>
<tr><td>561–2237</td><td>(752–3000*)</td><td colspan="4"></td><td colspan="6">9.2 / 1.3 / 11.4 / 0.54</td><td colspan="5">9.2 / 1.3 / 11.4 / 0.54</td><td colspan="4" rowspan="2">3.5 / 0.40 / 3.5 / 0.10
(T2 for emergency)
0.67 / 0.40 / 3.5 / 0.10 [a]</td><td colspan="3" rowspan="2">3.5 / 0.19 / 3.5 / 0.04
(T2 for emergency)
0.67/ 0.19 / 3.5 / 0.03 [b]</td></tr>
<tr><td>> 2237</td><td>(>3000)</td><td colspan="4"></td><td colspan="11">9.2 / 1.3 / 11.4 / 0.54</td></tr>
</table>

* Stationary Only

Tier 1 | Tier 2 | Tier 3 | Tier 4 Interim | Tier 4 Final

a: Applies to portable power generations > 1200hp
b: Applies to portable power generations > 751hp

FIGURE 2

Nonattainment areas

In the U.S., certain state and local emissions standards for diesel-powered generator sets require an additional level of control, primarily for NOX and PM. While EPA designated "nonattainment areas" represent a fraction of the land area of the country, they are typically heavily populated areas

The U.S. metropolitan areas that meet the National Ambient Air Quality Standards (NAAQS) are said to be in "attainment" for specific contaminants. Those areas not meeting the standards are said to be in "non attainment." States having nonattainment areas must develop State Implementation Plans (SIPs) showing how those areas will be brought into attainment. The EPA's Office of Air Quality Planning and Standards (OAQPS) provides guidance for stationary source emissions reductions upon which the SIPs can be based.

Generator set applications in these nonattainment areas face the most stringent emissions regulations and may require the Best Available Control Technology (BACT) to be in compliance with state and local permits. These BACT measures generally include aftertreatment devices like Selective Catalytic Reduction (SCR) and particulate traps.

Also, for nonattainment areas, a more extensive New Source Review (NSR) is required for major new sources, or modifications to sources, having the potential to emit more than designated thresholds.

Some of the control strategies

Engine emissions are affected by three factors: fuel, combustion and aftertreatment.

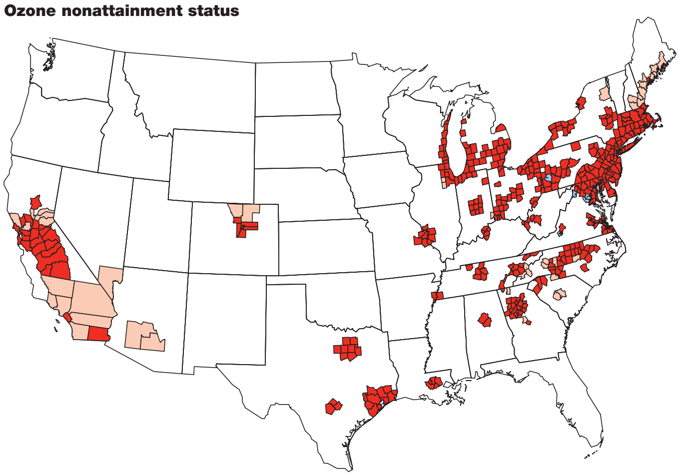
Fuel:

Understandably, it is difficult to get a clean output from any process with a dirty input. Fuel quality has changed greatly over the years thereby increasing power output and decreasing its adverse effects on aftertreatment devices. The sulfur content for example affects the functioning of aftertreatment devices As can be seen from the first graphic, the sulfur content has reduced from 5000 ppm to 15 ppm over the past 10 years or so enabling us to extend the useful life of catalyst used in the aftertreatment devices.

The development of fuels for compression ignited (C.I.) engines does not stop at reduced sulfur percentages though. Manufacturers continue to look at alternative fuels, innovative fuel systems and new control strategies to improve the overall efficiency of the engine. Biodiesel is one such viable option. It is a fuel comprised of methyl/ethyl ester-based oxygenates of long chain fatty acids derived from the transesterification of vegetable oils, animal fats, and cooking oils. These fuels are commonly known as Fatty Acid Methyl Esters (FAME). Biodiesel properties are similar to that of diesel fuel, as opposed to gasoline or gaseous fuels, and thus are capable of being used in compression ignition engines. Due to certain challenges associated with the fuel (Fuel quality, oxidation stability, contamination, microbe growth, etc), engine manufacturers are skeptical

NATIONAL AMBIENT AIR QUALITY STANDARDS

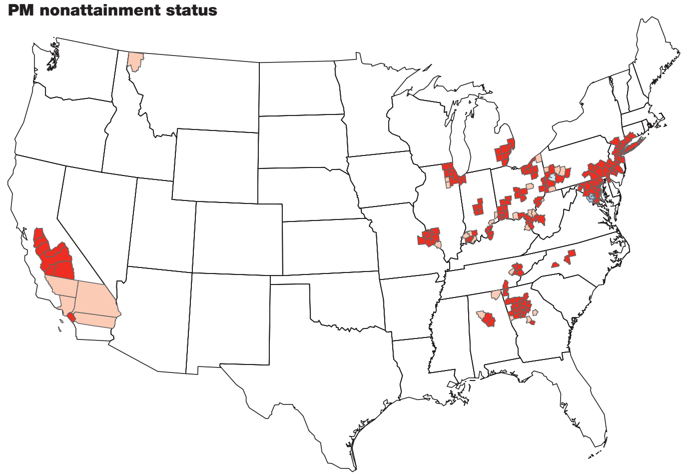
Ozone nonattainment status



■ Whole County ■ Part of County □ Attainment

FIGURE 3 – Shows counties designated nonattainment for the 8-hour ozone standard. NOx—a recognized precursor to ozone—is more strictly contolled in areas with higher ozone levels.

PM nonattainment status



■ Whole County ■ Part of County □ Attainment

FIGURE 4 – Shows counties designated nonattainment for particulated matter (PM25). PM25 designates particulate matter (primarily soot particles) that is less than 2.5 microns in size.

on the use of 100 percent biodiesel (B100) blends of biodiesel with regular diesel are therefore widely used with B5 and B20 being highly popular in the market depending on complexity of the engine and the application. The number in front of the letter 'B' indicates the percentage of biodiesel in the blend. B5 would have 5 percent biodiesel; B20 would have 20 percent, and so on.

Combustion:

In essence this is a process where chemical energy from fuel is converted into mechanical energy at the crankshaft. Of the exhaust contents a small part by volume are major pollutants which are controlled by regulatory bodies like the EPA. For diesel engines, combustion is a constant pressure heat addition and therefore the method of adding fuel and the injection timing in relation to the crank position plays an important part in addition to the in cylinder temperatures and pressures. Advancements in this field allow for multiple injections which help engines cope with varying load demands in an efficient way.

FUEL INJECTION TIMING

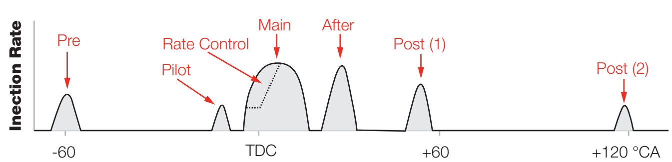


FIGURE 5

Other advancements include:

- **Exhaust gas recirculation (EGR):** A wellproven method of reducing NOX in internal combustion engines. By recycling a portion of the inert gases of the exhaust gas stream with incoming engine air, combustion temperatures are reduced and, therefore, so is NOX formation. While not employed widely in stationary diesel engines at the present time, EGR may be used on selected engines to achieve compliance with EPA regulations.
- **Variable geometry turbo chargers (VGT) with inter-coolers VGT's:** Allows for variable boost by changing the angle of the vanes. This greatly reduces the turbo lag at low speed without compromising on maximum boost at higher speeds.
- **Combustion chamber geometry:** Design goals include achieving the optimum compression ratio and thorough mixing of fuel and air prior to combustion. Designs that optimize the air swirl and turbulence provide the best mixing and therefore the lowest emissions consistent with high power output.
- **Common rail injection systems with fuel pressures up to 1,800 bars (26,000 psi):** Injection timing, injection pressure, nozzle design and electronic injection systems have all proved significant in controlling both NOX and PM. Retardation of injection timing along with increased injection pressure has been shown to reduce NOX without significantly increasing the production of hydrocarbons (HC) or PM. Higher injection pressures and multiple injection events per cycle improve fuel atomization and combustion chamber penetration that simultaneously improve fuel economy while reducing PM.
- **Electronic engine management:** The addition of electronic sensors and microprocessor-based controls has greatly improved fuel efficiency and power output while decreasing the production of both NOX and PM. By controlling fuel quantity, injection timing, turbocharger boost pressure and other factors, electronic engine controls maintain optimum combustion efficiencies by compensating for load, temperature, fuel energy content, barometric pressure and even engine wear.

It is worth noting that all these advancements have pushed the thermal efficiency of the diesel engine from about 33 percent to over 40 percent.

Aftertreatment:

Exhaust aftertreatment reduce emissions by a great margin. Optimizing engine design, fuel systems and advanced control strategies certainly help a great deal and aftertreatment strategies can be seen as the next step. This level of emission control is what the EPA tier 4 regulations aims to achieve. The following methods have already gained practical levels of commercialization in various applications:

- **Selective catalytic reduction (SCR):** This is a very effective method for curbing NOX emissions and is basically aqueous urea injection into the exhaust stream passing over a suitable catalyst. SCR can reduce NOX up to 98 percent. Systems consist of an SCR catalyst, urea injection system, urea tank, pump and a control system. See FIGURE 6.

SELECTIVE CATALYTIC REDUCTION SYSTEM

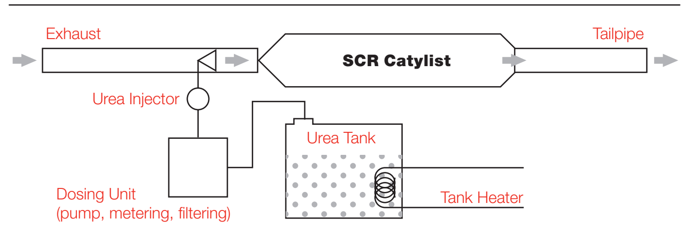


FIGURE 6

About the author

Aniruddha Natekar started with Cummins Power Generation in 2007. As a Sales Application Engineer, he provides technical recommendations on installations, engineering support to customers, assists the sales force with technical training, and supports technical seminars.

Aniruddha has M.S. in Automotive Engineering from Lawrence Technological University (Southfield, MI) and B.S. in Mechanical Engineering from University of Pune (India). He has held positions in R&D, market research, engineering, and product development with various automotive companies.

- **Diesel oxidation catalyst (DOC):** DOC is a flow through device that consists of a canister containing a honeycomb-like structure or substrate. The substrate has a large surface area that is coated with an active catalyst layer. DOC is capable of achieving over 95 percent reduction in CO and HC. More specifically, DOCs utilize palladium and platinum catalysts to reduce the particulate matter (PM), hydrocarbon based soluble organic fraction (SOF), and carbon monoxide content of diesel exhaust by simple oxidation.
- **Diesel Particulate filter (DPF)**: Particulate matter is the most visible form of pollutant coming out of an exhaust pipe. It is the main constituent of black smoke or soot which has lead to the demise of diesel engines on a non commercial scale in this country. DPF's or Diesel particulate matter (PM) traps are designed to physically capture PM from the exhaust stream. They can either be simple mechanical filters requiring frequent replacement, or they can be catalytic filters that provide periodic or continuous oxidation (regeneration) of the trapped particulates into CO_2. PM traps with continuous regeneration have already reached a high level of commercialization and are being employed on stationary diesel engines in areas with strict PM emissions regulations. Ultra-low sulfur diesel fuel is needed to prevent contamination of the conversion catalysts. However, filtration efficiencies up to 90 percent have been demonstrated.

Conclusion

Since January 1, 2007, the NSPS harmonized emissions requirements for stationary diesel engines with the existing EPA non road regulations. These regulations keep getting tighter and as we move towards tier 4 requirements, we will see a steeply rising use of aftertreatment strategies bringing significant reduction in NOX and PM levels. Some installation locations are already familiar with the aftertreatment strategies used to cope with the best available control practises, but now these solutions will be applicable to a much larger population of generator sets. Thanks to the technological refinements taking place today, the electric power industry will continue to enjoy the performance advantages that diesel generators offer well into the foreseeable future.

For additional technical support, please contact your local Cummins Power Generation distributor. To locate your distributor, visit www.cumminspower.com.

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