



EPA Emission Regulations:

What they mean for diesel powered generating systems

On July 11, 2006, the Environmental Protection Agency (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 non-road regulations and specified requirements for an interim period through January 1, 2007 to transition to these new stationary engine regulations. The EPA also has regulations for stationary spark-ignited gas engines, which are covered in a separate white paper. This paper explains how the 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.

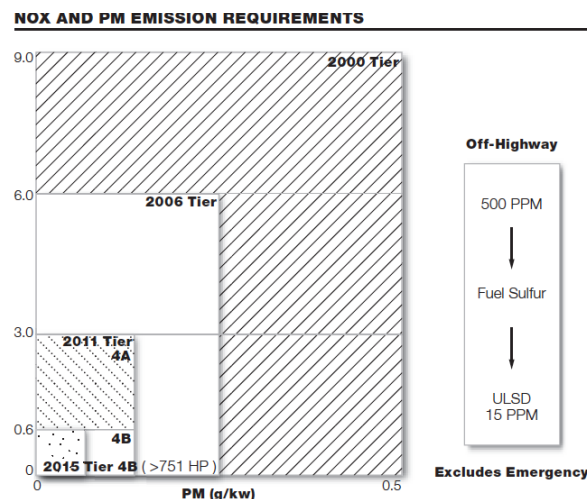


Figure 1. Increasing EPA Nitrogen Oxide and Particulate Matter standards through 2015

USA EPA		'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17
kW	HP																						
0-7	(0-10)							(10.5) / 8.0 / 1.0			(7.5) / 8.0 / 0.80												
8-18	(11-24)							(9.5) / 6.6 / 0.80			(7.5) / 6.6 / 0.80												
19-36	(25-48)							(9.5) / 5.5 / 0.80			(7.5) / 5.5 / 0.60												
37-55	(49-74)																						
56-74	(75-99)							9.2 / - / -			(7.5) / 5.0 / 0.40												
75-129	(100-173)							9.2 / - / -			(5.6) / 5.0 / 0.30												
130-224	(174-301)							9.2 / 1.3 / 11.4 / 0.54			(4.0) / 3.5 / 0.20												
225-449	(302-602)							9.2 / 1.3 / 11.4 / 0.54			(5.4) / 3.5 / 0.20												
450-560	(603-751)							9.2 / 1.3 / 11.4 / 0.54			(5.4) / 3.5 / 0.20												
561-2237	(752-3000*)							9.2 / 1.3 / 11.4 / 0.54			9.2 / 1.3 / 11.4 / 0.54												
> 2237	(>3000)							9.2 / 1.3 / 11.4 / 0.54															

* Stationary Only

Tier 1	Tier 2	Tier 3	Tier 4 Interim	Tier 4 Final
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a: Applies to portable power generations > 1200hp
b: Applies to portable power generations > 751hp

Figure 2. The regulatory landscape

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 non-road applications.

Compared to previous years, NOx and PM emission limits 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 changes 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).

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. The EPA's NSPS stationary emissions standards are intended to help local authorities meet the EPA's clean air standards in regions that are non-compliant.

The EPA's "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.

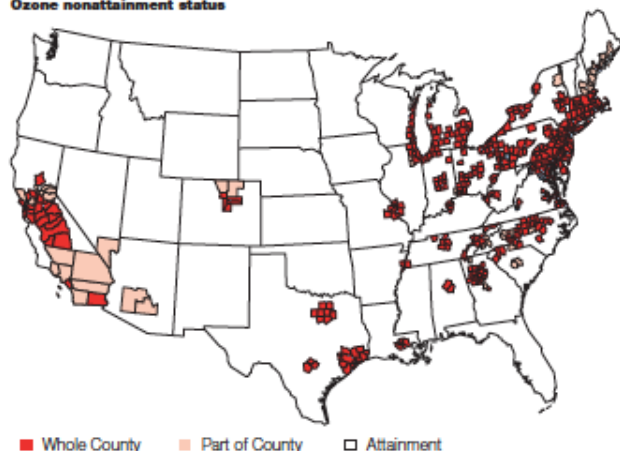
NATIONAL AMBIENT AIR QUALITY STANDARDS**Ozone nonattainment status**

Figure 3. Shows counties designated nonattainment for the 8-hour ozone standard. NO_x—a recognized precursor to ozone—is more strictly controlled in areas with higher ozone levels.

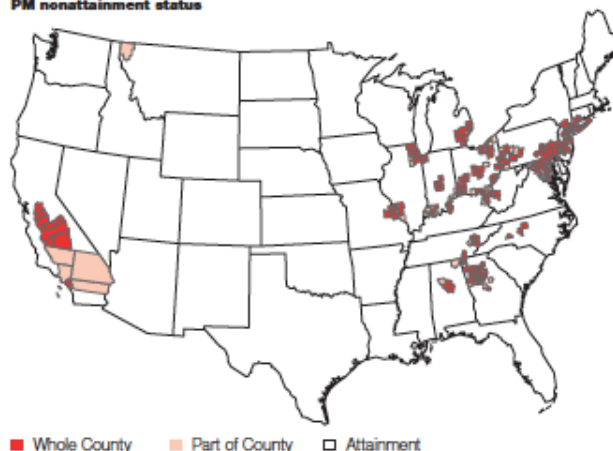
PM nonattainment status

Figure 4. Shows counties designated nonattainment for particulate matter (PM_{2.5}). PM_{2.5} designates particulate matter (primarily soot particles) that is less than 2.5 microns in size.

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 NO_x 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 “nonattainment.” 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 catalysts 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 of 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 next to 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 cylinder temperatures and pressures. Advancements in this field allow for multiple injections which help engines cope with varying load demands in an efficient way.

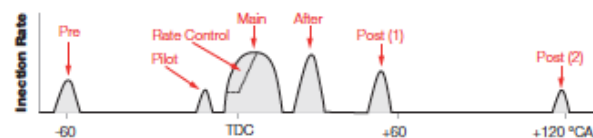


Figure 5. Fuel injection timing

Other advancements include:

- Exhaust gas recirculation (EGR): A well-proven method of reducing NO_x 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 NO_x 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 VGTs: 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 NO_x and PM. Retardation of injection timing, along with increased injection pressure, has been shown to reduce NO_x 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 NO_x 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 reduces 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 aim 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 NO_x emissions and is basically aqueous urea injection into the exhaust stream passing over a suitable catalyst. SCR can reduce NO_x up to 98 percent. Systems consist of an SCR catalyst, urea injection

system, urea tank, pump and a control system. See Figure 6.

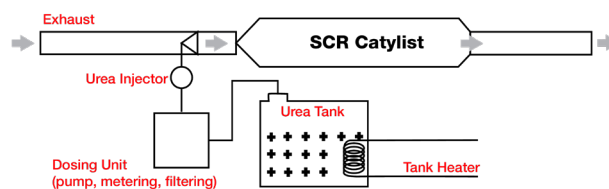


Figure 6. Selective catalytic reduction (SCR)

- 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 led to the demise of diesel engines on a non-commercial scale in this country. DPFs 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 CO₂. 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.

The aftertreatment options selected should consider the emissions constituents to be reduced, the engine operating load, the exhaust temperatures which the aftertreatment equipment will be exposed to and the engine's back pressure limitation.

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 these solutions are becoming more applicable to a wide range 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 cumminspower.com.



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