Information Sheet # 46

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Your Reliable Guide for Power Solutions

To fulfill our commitment to be the leading supplier in the power generation industry, the Buckeye Power Sales team ensures they are always up-to-date with the current power industry standards as well as industry trends. As a service, our **Information Sheets** are circulated on a regular basis to existing and potential power customers to maintain their awareness of changes and developments in standards, codes and technology within the power industry.

Exhaust Emission After-Treatment Devices for Generator Set Systems

1.0 Introduction

Modern diesel engines are 20 to 40% more efficient than current gasoline engines and also emit less carbon monoxide and carbon dioxide. However, due to the high combustion temperatures of diesels, they do produce more nitrogen oxide than a gasoline engine.

This Information Sheet discusses the various treatment devices available for diesels which are employed to reduce the emissions of both nitrogen oxides (NOx) and particulate matter (PM), hydrocarbons and carbon monoxide.

2.0 Regulations Driving the Requirement for Exhaust After-treatment

The Clean Air Act was introduced in 1955, with five amendments being passed since then. The objective was, and remains, to reduce the air pollutants which contribute to damaging greenhouse gases. There have been major steps forward in this pollutant reduction from diesel engine exhausts. The Environmental Protection Agency (EPA) was charged with the introduction of regulations for highway and off-road engines, in particular to reduce the six common pollutants (ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide and lead).

The first federal clean diesel engine exhaust standards (Tier 1) were put in place in 1996 and since then, improved and more stringent standards have been phased in according to varying ranges of horsepower and cylinder displacement. The final stringent Tier 4 level standards will be in effect, starting in 2012 and completed by 2015.

A huge improvement in lowering diesel emissions has been achieved with primary measures such as cross-flow cylinder heads, improved combustion process, far higher fuel injection pressures (presently up to 33,000 psi – 10 times higher than 17 years ago), common rail injection systems, electronically controlled fuel injection with multiple injection events, charge-air cooling of inlet air, variable geometry turbochargers, exhaust gas recirculation (EGR) to reduce NOx, and electronic engine management controls.

However, in order to meet the new Tier 4 standards, other external devices or secondary measures such as advanced exhaust gas after-treatment (post combustion) technologies and devices have to be employed in order to obtain the required emission reductions. The 2006 introduction of an ultra low sulfur diesel fuel (15 ppm) specification also was a very large assist for both engine and after-treatment devices. The latest internal combustion engines fitted with after-treatment devices, are very close to achieving a zero emission status.

3.0 Diesel Exhaust Fluid (DEF)

Urea is a compound of nitrogen which turns into ammonia when heated. A measured amount (called reductant) of this harmless, non-toxic DEF solution (32.5% urea and 67.5% water) is injected into the exhaust gas stream, which in turn releases ammonia when injected into a catalytic converter. This alters about 80% of the NOx content from the exhaust into nitrogen and water.

DEF begins to freeze at about 12ºF so heating must be provided to the DEF tank and supply lines. Frozen DEF expands by about 7% so the tank must be able to accommodate this. If stored at recommended temperatures (not exceeding 77ºF), shelf life will be two years. As DEF is corrosive to certain metals (aluminum), the system is made of appropriate, heavy-duty plastic.

4.0 Selective Catalytic Reduction (SCR)

NOx levels can only be reduced – it cannot be oxidized by a catalyst. The DEF injected in front of the SCR's ceramic blocks reacts with the NOx and reduces it to N2 and CO2. This system can reduce NOx emissions by up to 98%.

The catalytic converters utilized comprise of a substrate made of metal foil or extruded ceramic with a honeycomb cross-section. A 'wash coat' of alumina slurry is applied to provide a better bonding surface and increase the surface area – the greater to surface area the more effective the catalyst.

5.0 Catalyzed Diesel Particulate Filters (CDPF)

Diesel particulates consist of a carbon core with other combustion elements stuck to them such as unburned fuel and oil particles and traces of metals. The DPF works like an air filter but uses a ceramic filter rather than paper. The CDPF face has many cells – with every cell blocked at the far end and every alternative blocked at the entrance. The exhaust stream therefore must pass through the porous wall into the adjoining chamber which has an opening at the other end. The PM or soot is trapped on the wall and only clean, filtered exhaust gas can exit. Most CDPF's are made of cordierite – a ceramic type of material and silicon carbide. High exhaust temperatures cause the trapped PM to undergo a chemical reaction, where the nitrogen dioxide (NO_2) breaks down the PM converting it to nitrogen and CO_2. This reaction creates heat energy which further assists the oxidation process. However, if the exhaust temperature is too low, the PM will not oxidize and build up in the filter until it increases the back pressure.

The CDPF usually is coated with a platinum coating – an expensive and precious metal. In addition to the benefit of oxidizing CO and HC's, it also lowers the Balance Point Temperature which oxidizes the PM at a lower exhaust temperature. This oxidizing process is known as regeneration.

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The DPF must be sized carefully to suit the specific application. This will be based on the exhaust flow with normal and maximum operating conditions. It may require a single or multiple cDPF (in parallel) be installed so as to maintain an acceptable exhaust back pressure and provide a level of PM storage capacity.

Normally the CDPF is combined with an exhaust silencer to reduce space requirements. Should the engine run on light loads, e.g. powering a standby generator and load circuits cannot be added to reach a suitable engine load to reach adequate operational temperatures, the filter will have to be removed and externally regenerated by a service provider to remove the accumulated PM in order to avoid thermal stressing the filter.

6.0 Three-Way Catalysts

These can only be used for rich burn gasoline and many natural gas (NG) engines, where less than 0.5% oxygen is present in the exhaust gas stream.

7.0 Diesel Oxidation Catalysts (DOC)

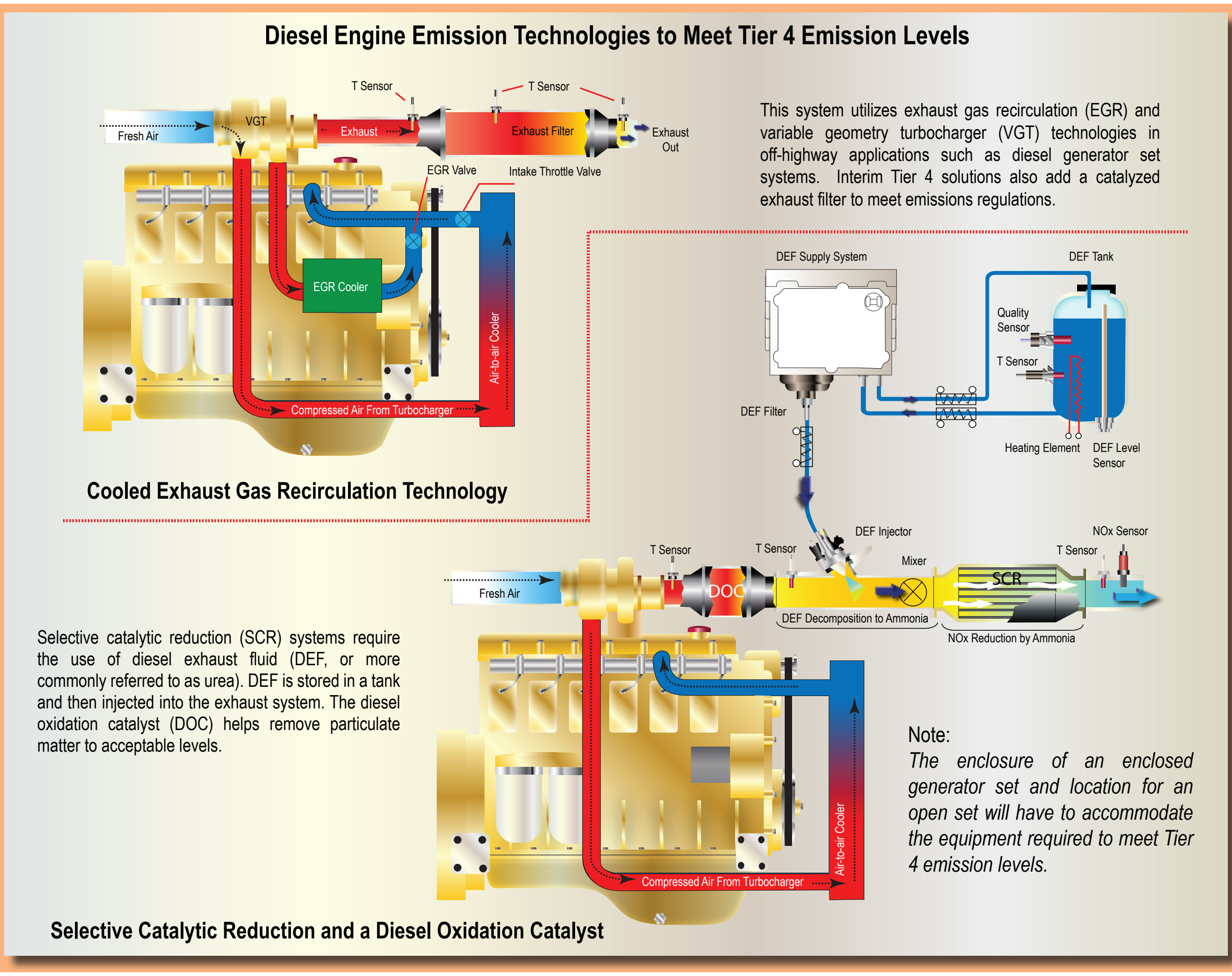
Diesel and many NG engines are considered to be ‘lean burn’ as there is little or no restriction of the amount of air that goes into the combustion chamber, resulting in more than 5% oxygen in the exhaust gas stream. This type of catalyst can easily reduce the carbon oxide (CO) and non-methane hydrocarbons (NMHC) – up to about 95%, dependent on the exhaust temperature. The catalyst converts the CO to CO_2 and O_2. The NMHC is converted to harmless CO_2 and H_2O.

8.0 Dimensions Considerations of Exhaust After-treatment Devices

One issue that has to be addressed by equipment manufacturers is that of the increased bulk and weight of the above devices. While they do not normally pose a problem for stationary installations, it can create difficulties for the manufacturer particularly for designs of small machines, where tight enclosures and weight are important requirements.

9.0 Reduction Results in Air Pollutants to Note

a) Ozone. An 11% decrease nationally from 2001 to 2008.
b) Particulate Matter. A 17% national average improvement between 2001 and 2008.
c) Carbon Monoxide. Over 40% reduction since the 1970’s
d) Nitrogen Oxides. A 46% decrease in national average from 1980 to 2008.
e) Sulfur Dioxide. A 71% decrease from 1980 to 2008.
f) Lead. Declined by 95% in transportation sector between 1980 and 1999.



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