ULTIMATE SERVICE ASSOCIATES
A NORTH AMERICAN SITE SERVICES CO.

*The ultimate solution for maintaining your nationwide generator network*

# Catalytic Converters & Aftertreatment of Exhaust for Engine Driven Generators

## 1.0 Introduction:

Catalytic converters are an emission control device that the general public became aware during the 1970's, as they were introduced into gasoline vehicles. When regulatory bodies within North America and Europe started to implement directives to regulate the level of toxic emissions put into the atmosphere, manufacturers of internal combustion engines looked to adopting bolt on exhaust aftertreatment solutions to existing engines in order to meet the standards set by bodies such as the Environmental Protection Agency (EPA) in the US. One such device was the catalytic converter. The purpose of a catalytic converter is to create a chemical reaction to change harmful substances in exhaust gasses into less harmful substances.

***This information discusses how catalytic converters are used to clean up emissions, the difference between converters for diesel and spark ignition engines used as prime movers on generator systems, and the reduction of particulates using diesel particulate filters.***

## Exhaust Aftertreatment Technology for Engine Driven Generator Systems

*Figure 1* **Diesel Oxidation Catalyst (DOC)**

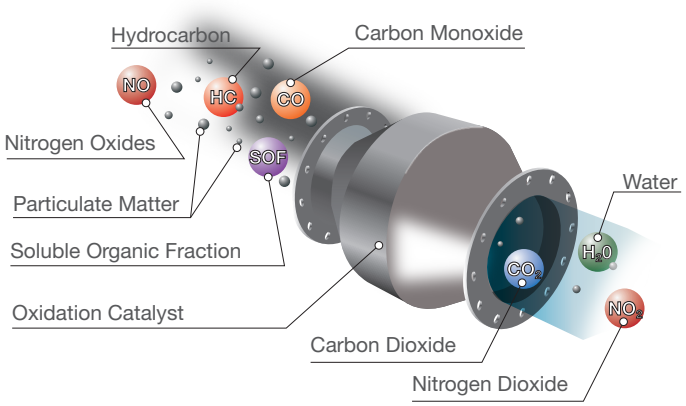



Figure 1, 2 and 3 depict three exhaust aftertreatment technologies employed to reduce the regulated emissions from engine driven generator systems.

Later versions of diesel and gaseous engines employ cleaner combustion technology, for example high pressure fuel injection, as such, whether an engine uses one or more combinations of the depicted technologies along the exhaust stream, depends on model of engine.

Your authorized generator distributor should be consulted regarding exhaust aftertreatment of new and existing installations.

*Figure 2* **Selective Catalytic Reduction (SCR)**

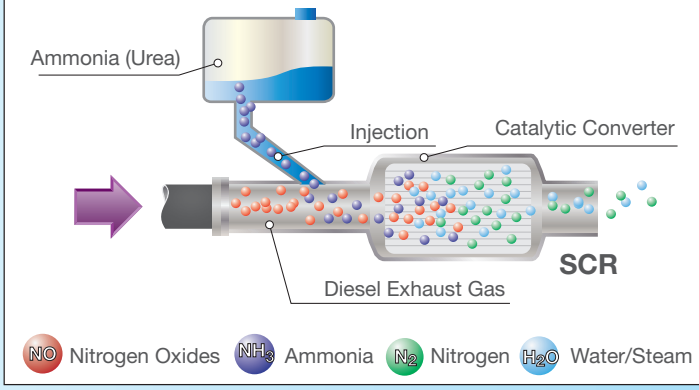
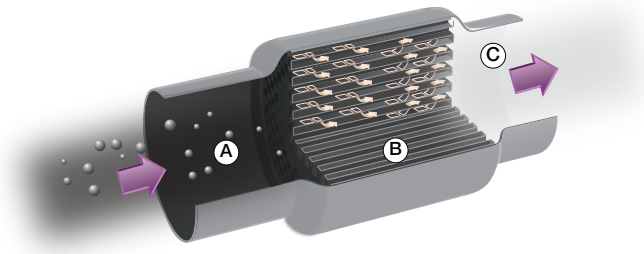



*Figure 3* **Diesel Particulate Filter (DPF)**




A - Exhaust inlet carrying PM
B - Filter extracts PM
C - Outlet exhaust PM within EPA limit

To fulfill our commitment to be the leading network service provider in the Power Generation Industry, the USA, Inc. team maintains up-to-date technology and information standards on Power Industry changes, regulations and trends. As a service, our **Information Sheets** are circulated on a regular basis, to existing and potential Power Customers to maintain awareness of changes and developments in engineering standards, electrical codes, and technology impacting the Power Generation Industry.

## 2.0 Elements of Exhaust Gases Being Regulated:

When the EPA was founded and charged to set standards for exhaust emissions the primary objective was to improve the atmosphere we breath and hence our health. The unhealthy elements of emission were considered to be:

- Carbon monoxide - CO
- Hydrocarbons (unburnt and partially burnt fuel) - $C_xH_{2x+2} + [(3_x+1)/2]\ O_2$
- Nitrous oxide - NO

Particulates - PM

## 3.0 Definition of a Catalyst:

A catalyst is a substance that can be added to a reaction to increase the reaction rate without getting consumed in the process. Catalysts typically speed up a reaction by reducing the activation energy or changing the reaction mechanism.

## 4.0 Types of Generator System Prime Movers:

Engine drive generator systems primarily employ three types of prime movers (engines) having various types of fuel and fuel ignition systems, which are:

**4.1 Spark Ignition Gaseous Fuel –** A four-stroke engine running on natural gas or liquid petroleum with fuel combustion/burn initiated by a spark ignition (SI) engine.

**4.2 Spark Ignition Gasoline Fuel –** A four-stroke engine running on gasoline with fuel combustion/burn initiated by a spark ignition (SI) engine.

**4.3 Compression Ignition Diesel Fuel –** A four-stroke engine running on diesel with fuel combustion/burn initiated by a compression (CI) engine.

## 5.0 Types of Converters for Different Gas/Gaseous Engine Types:

Converters were originally introduced on automotive gasoline engines, but these are the same engine blocks used on generator gaseous and gasoline SI engines. SI engines employ one of two types of converters:

**5.1 Two-way Converter –** A 2-way catalytic, or oxidation converter, controls two elements of regulated exhaust emissions carbon monoxide and hydrocarbons. Functions works as follows:

- Oxidation of Carbon Monoxide -
  Oxidation of Carbon Monoxide to Carbon Dioxide written as: $2 \times CO + 0_2 \rightarrow 2\ CO_2$
- Oxidation of Hydrocarbons -
  Oxidation of Hydrocarbons to Carbon Dioxide and Water written as: $C_xH_{2x+2} + [(3_x+1)/2]\ O_2 \rightarrow x\ CO_2 + (x+1)\ H_2O$

This type of catalytic converter is still widely used on diesel engines where the primary purpose is to reduce hydrocarbon and carbon monoxide emissions. However, they were replaced by 3-way converters when the EPA started to regulate nitric oxide (NO), also commonly referred to as NOX.

**5.2 Three-way Converter –** A 3-way catalytic, or oxidation converter, in addition to having the functions of a 2-way converter, has the advantage of controlling Nitric Oxide (N0). Since the business of regulating exhaust gases has changed over time. Once the main pollutant was seen to be Carbon Monoxide and Hydrocarbons. In Europe there was a change to diesel automobiles from gasoline. However, Nitric Oxide (NO) is now recognized as a major pollutant in cities as regards human breathing, therefore diesel engines have there Nitric Oxide subject to much lower emission levels. As such the 3-way catalyst is used over the 2-way catalyst.

The third element of regulated exhaust emission, Nitric Oxide (NO) functions as follows:

- Oxidation of Nitric Oxide -
  Oxidation of Nitric Oxide to Nitrogen written as: $2 \times NO + 0_2 \rightarrow N_2 + 2O_2$

## 6.0 Catalytic Converters for Diesel Engine - Diesel Oxidation Catalyst (DOC):

The exhaust emissions of diesel engines have different concentrations of pollutants to that of spark ignition engines, primarily higher nitric oxide (NO) and particulates (PM). To address these two elements the most commonly employed catalytic converter is the Diesel Oxidation Catalyst (DOC). DOC has the ability to promote oxidation of exhaust gas components by oxygen, which is present in ample quantities in diesel exhaust. This process is similar to that described for a gasoline engine. (See figure 1)

In a modern diesel engine aftertreatment system the DOC is used to oxidize Nitric Oxide (NO) to Nitrogen Dioxide ($NO_2$)

## 7.0 Technologies Employed to Achieve Tier 4 Final Diesel Emissions:

Over time the EPA has tightened the exhaust emission components of NOX and particulates. In addition $NO_2$ is now considered more of a pollutant, even though not as unhealthy as NO. As aftertreatment for diesel generators had to meet more stringent exhaust emission standards two additional technologies were added to stream of exhaust aftertreatment devices:

**7.1 Selective Catalytic Reduction (SCR) –** The SCR is placed after the DOC. SCR uses ammonia or urea ($NH_3$) injected into the exhaust stream leaving the DOC. The SCR functions most efficiently when there is a higher concentration of $NO_2$, which is produced in quantity by the DOC as it converts NOX to $NO_2$. The SCR functions as follows:

- Oxidation of Nitric Oxide using Ammonia and Nitrogen Dioxide from the DOC (See figure 2) -
  Oxidation of Nitrogen Dioxide to Nitrogen (an inert gas making up 75% of the earth's atmosphere) and Water: $NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

**7.2 Diesel Particulate Filter (DPF) –** A diesel particulate filter, or DPF, is an exhaust aftertreatment device that traps particulate matter such as soot and ash. A DPF typically uses a substrate made of a ceramic material that is formed into a honeycomb structure. The manufacture will recommend the hours between operation before the filter has to be cleaned. (See figure 3)

USA ULTIMATE SERVICE ASSOCIATES A NORTH AMERICAN SITE SERVICES CO.

Ultimate Service Associates, LLC.
5514 South Lewis Ave.
Tulsa, OK 74105

Ph: 918.836.8701
Fx: 918.835.2748

www.usa-svc.com

MEMBER EGSA Electrical Generating Systems Association