Emission Control Technology for
Stationary Internal Combustion Engines

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INTRODUCTION

Reciprocating internal combustion (IC) engines are used in a variety of stationary applications, including gas compression, pumping, power generation, cogeneration, irrigation, and inert gas production. Stationary IC engines can be spark-ignited (natural gas, propane or liquefied petroleum gas [LPG], or gasoline) or compression-ignited (diesel). Diesel engines inherently operate lean, whereas internal combustion engines that use natural gas, propane, or gasoline can be operated in rich or lean modes of operation. The difference between rich-burn and lean-burn engine operation lies in the air-to-fuel ratio. A rich-burn engine is characterized by excess fuel in the combustion chamber during combustion. A lean-burn engine, on the other hand, is characterized by excess air in the combustion chamber during combustion.

Stationary diesel engines are widely used in emergency back up generators and for water pumping, especially when the electrical grid is down. In places where an electrical grid is not accessible or available, diesel engines can be used to generate prime power as a distributed generating source.

Stationary gas engines, typically fuelled by natural gas or propane, are widely used for prime power and for gas compression. In gas compression, the types of engines are either rich-burn or lean-burn. Rich-burn engines have an air-to-fuel ratio that is balanced, resulting in an exhaust O_2 content of about 0.5%. Lean-burn gas engines have an exhaust O_2 content typically >8%. For gas production or gas gathering, the engines can be either rich or lean. For gas transmission, the engines are typically all lean-burning. Gas engines are also used for prime power applications, especially where it is convenient to connect a natural gas line to the engine. Both rich-burn and lean-burn engines are used for decentralized power or distributed generation, cogeneration, and combined heat and power (CHP) applications.

Depending on the application, stationary IC engines range in size from relatively small (approximately 50 hp) for agricultural irrigation purposes to thousands of horsepower for power generation. Often when used for power generation, several large engines will be used in parallel to meet the load requirements.

The operation of stationary IC engines results in the emission of criteria air pollutants, such as hydrocarbons (non-methane hydrocarbons [NMHCs] or volatile organic compounds [VOCs]), carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM). Exposure to these pollutants is associated with numerous effects on human health, including increased respiratory symptoms, hospitalization for heart or lung diseases, and even premature death. The air toxics (i.e., hazardous air pollutants [HAPs]) emitted from stationary engines include formaldehyde (CH_2O), acrolein, acetaldehyde, and methanol. People exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. The actual concentration of all of these varies from engine to engine, mode of operation, and is strongly related to the type of fuel used.

Various emission control technologies exist for stationary IC engines which can afford substantial reductions in all of the pollutants listed above in a cost-effective manner. However, depending on whether the engine is being run rich or lean and on the emission control

technology used, the targeted emissions vary, as do the levels of control. For example, oxidation catalysts can be used to control CO, NMHCs, VOCs, and HAPs from lean-burn gas engines, whereas non-selective catalytic reduction would be used to control emissions (NOx, CO, HCs, and HAPs) from rich-burn gas engines. PM emissions from stationary diesel engines are more of a concern than those for internal combustion engines using other fuels. Several emission control technologies exist for diesel engine PM control. Diesel oxidation catalysts can be used to not only reduce the gaseous emissions associated with the use of diesel engines but also further provide PM control (up to 50%). Likewise, wall-flow diesel particulate filter systems can be used to achieve up to and greater than 90% PM control.

1.0   GASEOUS EMISSION CONTROL OF STATIONARY IC ENGINES

The principle behind a catalyst for control of the gaseous emissions of a stationary IC engine is that the catalyst causes chemical reactions without being changed or consumed. An emission control catalyst system consists of a steel housing – whose size is dependent on the size of the engine for which it is being used – that contains a metal or ceramic structure which acts as a catalyst support or substrate. There are no moving parts, just acres of interior surfaces on the substrate coated with either base or precious catalytic metals, such as platinum (Pt), rhodium (Rh), palladium (Pd), or vanadium (V), depending on targeted pollutants. Catalysts transform pollutants into harmless gases by causing chemical reactions in the exhaust stream. These reactions differ depending on the technology being used, which further depends on whether the engine is operating rich or lean.

Different emission control technologies have to be applied to stationary IC engines depending on their air-to-fuel (A/F) ratio. This is due to the fact that the exhaust gas composition differs depending on whether the engine is operated in a rich, lean, or stoichiometric burn condition. Figures 1-3 highlight the performance of different catalyst systems for a wide range of A/F ratios. Engine operating mode (speed and load) as it affects exhaust gas temperature also has to be considered.

As can be seen in Figure 1, non-selective catalytic reduction systems can achieve substantial NOx reductions for rich-burn engines. This same catalyst technology is referred to as a three-way catalyst when the engine is operated at the stoichiometric point ($\lambda=1$) where not only is NOx reduced but so are CO and NMHC. Conversely, lean NOx catalyst systems and oxidation catalysts provide little, if any, emission control in a rich-burn environment. However, in a lean-burn environment, oxidation catalysts provide significant reductions in both CO and NMHC, and lean NOx catalyst systems provide reductions in NOx, CO, and NMHC.
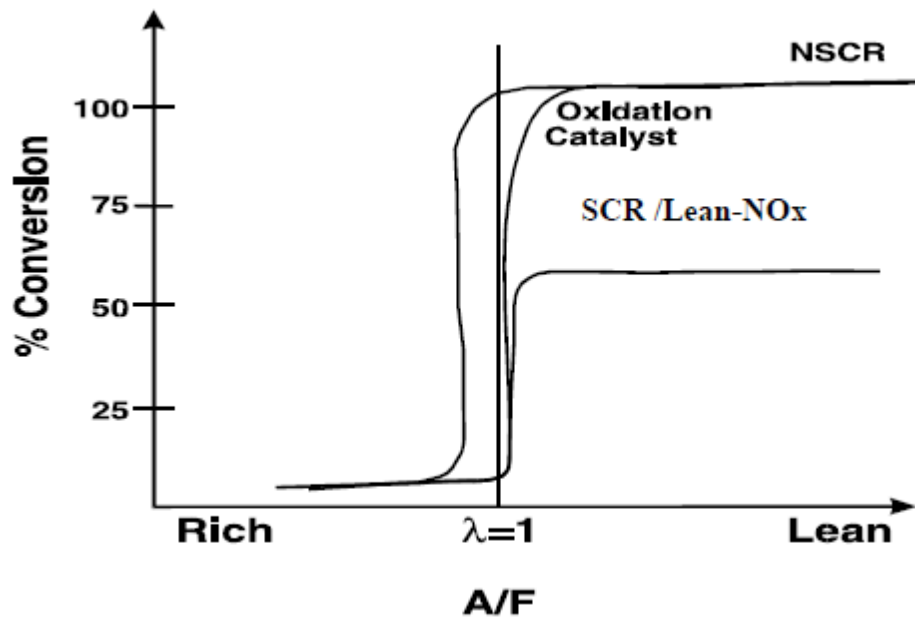
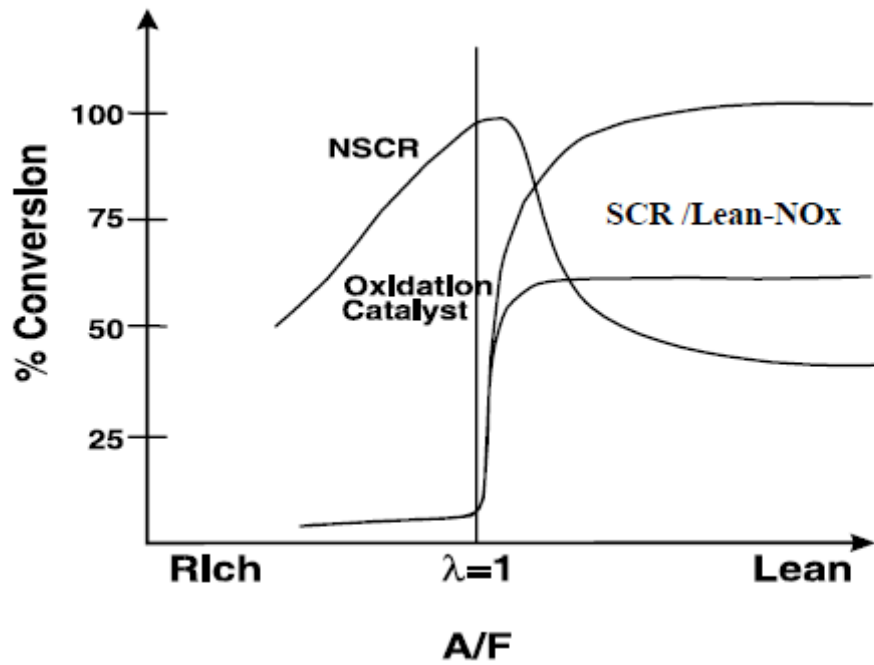**Figure 1. Catalyst performance for carbon monoxide (CO).**

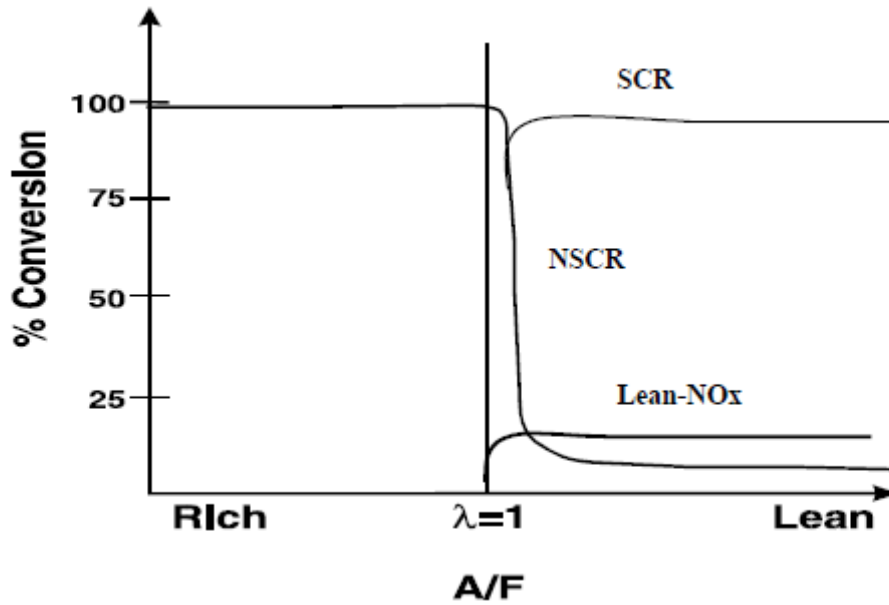**Figure 2. Catalyst performance for non-methane hydrocarbons (NMHCs).**

Figure 3. Catalyst performance for oxides of nitrogen (NOx).

Table 1 outlines the gaseous emission control technologies available for rich- and lean-burn stationary IC engines.

Table 1. Catalyst Technologies for Stationary IC Engines

Engine Operation	Catalyst Technology	Target Pollutants
Rich	Non-Selective Catalytic Reduction	NMHCs, CO, NOx, CH_2O
Lean	Oxidation Catalyst	NMHCs, CO, CH_2O
	Selective Catalytic Reduction	NOx
	Lean NOx Catalyst	NMHCs, CO, NOx, CH_2O

Note: NMHCs – non-methane hydrocarbons, CO – carbon monoxide, NOx – oxides of nitrogen, CH_2O – formaldehyde.

1.1 Catalyst Technologies for Stationary Rich-Burn Engines

1.1.1 Non-Selective Catalytic Reduction

Non-selective catalytic reduction (NSCR) is an effective NOx-reduction technology for rich-burn, spark-ignited stationary gas engines. NSCR is currently the most economical and accepted emission control method for rich-burn engines. NSCR systems are similar in design to three-way catalytic converters used on most modern cars and light-duty trucks. Exhaust from the engine is passed through a metallic or ceramic honeycomb covered with a platinum group metal catalyst. The catalyst promotes the low temperature (approximately 850°F) reduction of NOx into nitrogen (N_2), the oxidation of CO into carbon dioxide (CO_2), and the oxidation of HCs into water vapor (H_2O).

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An NSCR system has three simultaneous reactions:

1. Reduction of nitrogen oxides to nitrogen and oxygen:
   $$2NOx \rightarrow xO_2 + N_2$$
2. Oxidation of carbon monoxide to carbon dioxide:
   $$2CO + O_2 \rightarrow 2CO_2$$
3. Oxidation of unburnt hydrocarbons to carbon dioxide and water:
   $$C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO_2 + (x+1)H_2O$$

NSCR catalyst efficiency is directly related to the air/fuel mixture and temperature of the exhaust. Efficient operation of the catalyst typically requires the engine exhaust gases contain no more than 0.5% oxygen. In order to obtain the proper exhaust gas O_2 across the operating range, an air/fuel ratio controller is installed that measures the oxygen concentration in the exhaust and adjusts the inlet air/fuel ratio to meet the proper 0.5% O_2 exhaust requirement for varying engine load conditions, engine speed conditions, and ambient conditions. Precise A/F ratio control is especially important for efficient NOx control, as NOx conversion drops dramatically at lean fuel mixtures. The ratio for natural gas, propane, and gasoline is each slightly different, requiring modified fuel system settings when using each fuel. In general, stationary engines fitted with an NSCR system are equipped with a computerized, closed-loop feedback fuel injection system using one or more oxygen sensors.

Typical NOx conversion efficiencies for NSCR systems range from 90 to 99%, with corresponding reductions in CO (90-99%), HCs (50-90%), and formaldehyde and other HAPs (80-95%).
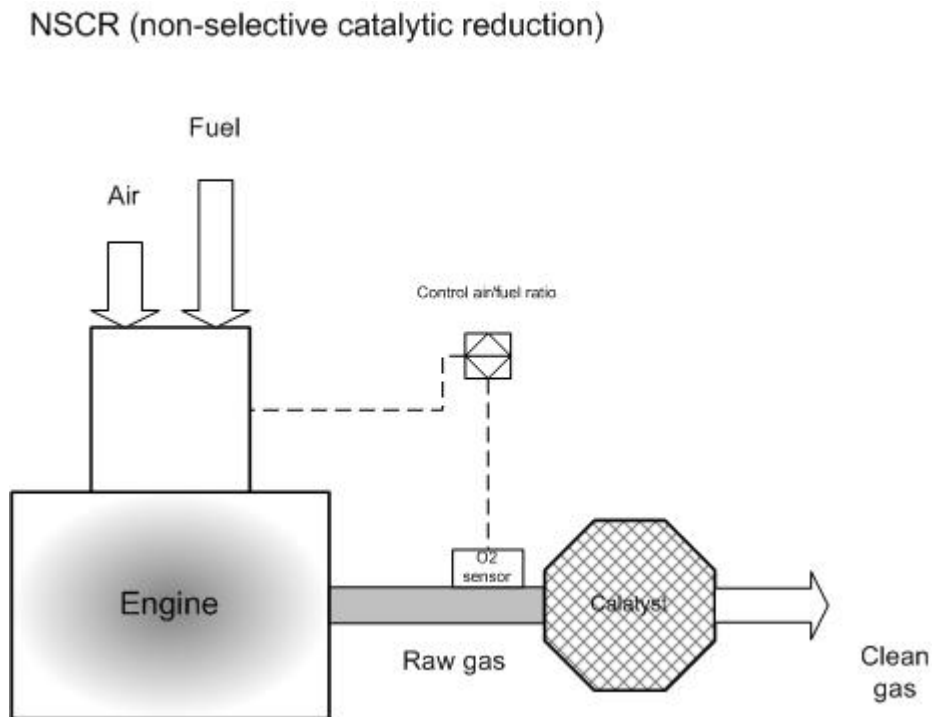

Figure 4. Schematic of an NSCR system.

1.2   Catalyst Technologies for Stationary Lean-Burn Engines

1.2.1   Oxidation Catalysts

Oxidation catalysts (or two-way catalytic converters) are widely used on diesel engines and lean-burn gas engines to reduce hydrocarbon and carbon monoxide emissions. Specifically, oxidation catalysts are effective for the control of CO, NMHCs, VOCs, and formaldehyde and other HAPs from diesel and lean-burn gas engines. Oxidation catalysts consist of a substrate made up of thousands of small channels. Each channel is coated with a highly porous layer containing precious metal catalysts, such as platinum or palladium. As exhaust gas travels down the channel, hydrocarbons and carbon monoxide react with oxygen within the porous catalyst layer to form carbon dioxide and water vapor. The resulting gases then exit the channels and flow through the rest of the exhaust system.

An oxidation catalyst has two simultaneous reactions:

1. Oxidation of carbon monoxide to carbon dioxide:
   $$2CO + O_2 \rightarrow 2CO_2$$
2. Oxidation of hydrocarbons (unburnt and partially burnt fuel) to carbon dioxide and water:
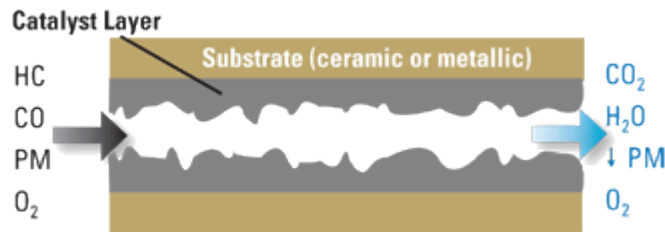 $$C_xH_{2x+2} + [(3x+1)/2]O_2 \rightarrow xCO2 + (x+1)H_2O$$

Figure 5. Diagram of an oxidation catalyst.

Using an oxidation catalyst, CO emissions can be reduced by 70-99%, NMHCs by 40-90%, VOCs by 60-99%, and formaldehyde and other HAPs by 60-99%. Oxidation catalysts are also used to reduce particulate emissions of diesel engines by oxidizing the soluble organic fraction of the particulate – reductions of up to 50% can be achieved (see Section 2.1 below).

1.2.2   Selective Catalytic Reduction

Selective catalytic reduction (SCR) is used to reduce NOx emissions from diesel and lean-burn gas engines. Rather than using a three-way catalyst in a low-oxygen environment as with an NSCR system, SCR systems inject ammonia or a compound such as urea, which is decomposed into ammonia, into the lean-burn exhaust stream as a reducing agent. Pure anhydrous ammonia, aqueous ammonia, or urea can be used as the reductant, but, in stationary gas engine applications, urea is most common because of its ease of use. As it hydrolyzes, each mole of urea decomposes into two moles of ammonia. The ammonia then reacts with the NOx to convert it into nitrogen and water.

The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is:

1. $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$
2. $2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$
3. $NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

The reaction for urea instead of either anhydrous or aqueous ammonia is:

$4NO + 2(NH_2)_2CO + O_2 \rightarrow 4N_2 + 4H_2O + 2CO_2$
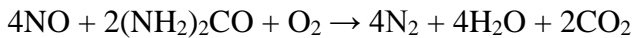
An oxidation catalyst must be added to the SCR design if hydrocarbons and carbon monoxide need to be controlled in addition to NOx on a lean-burn engine. The oxidation catalyst first oxidizes the exhaust stream to convert CO to CO_2 and hydrocarbons to CO_2 and water. The CO_2, water, and NOx then enter the SCR catalyst where the NOx reacts with the ammonia.
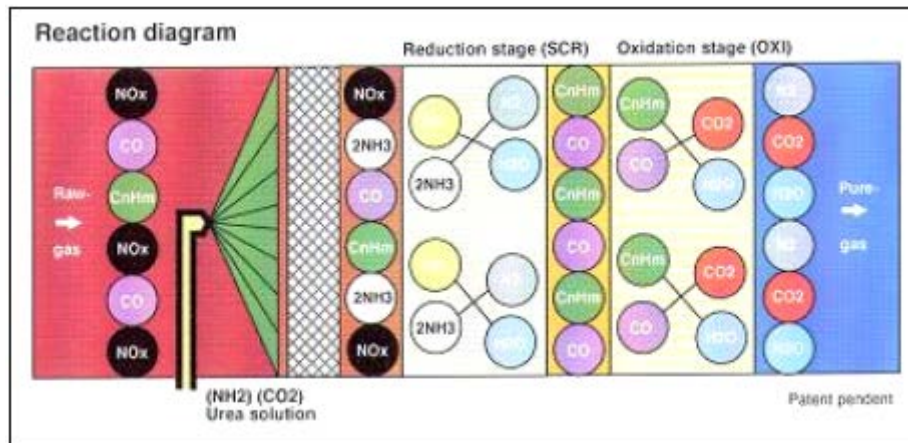
Figure 6. Diagram of an SCR catalyst system.

Catalyst selection is somewhat based on the expected temperature range of the engine exhaust and is sized to achieve the desired amount of NOx reduction. Both precious metal and base metal catalysts have been used in SCR systems. Base metal catalysts, typically vanadium and titanium, are used for exhaust gas temperatures between 450°F and 800°F. For higher temperatures (675°F to 1100°F), zeolite catalysts may be used. Precious metal SCR catalysts are also useful for low temperatures (350°F to 550°F).

The catalyst can be supported on either ceramic or metallic substrate materials (e.g., cordierite or metal foil) constructed in a honeycomb configuration. In some designs, the catalyst material is extruded directly into the shape of a honeycomb structure. The reagent injection system is comprised of a storage tank, reagent injector(s), reagent pump, pressure regulator, and electronic controls to accurately meter the quantity of reagent injected as a function of engine load, speed, temperature, and NOx emissions to be achieved.

Figure 7. Schematic of a typical SCR system for stationary IC engines.

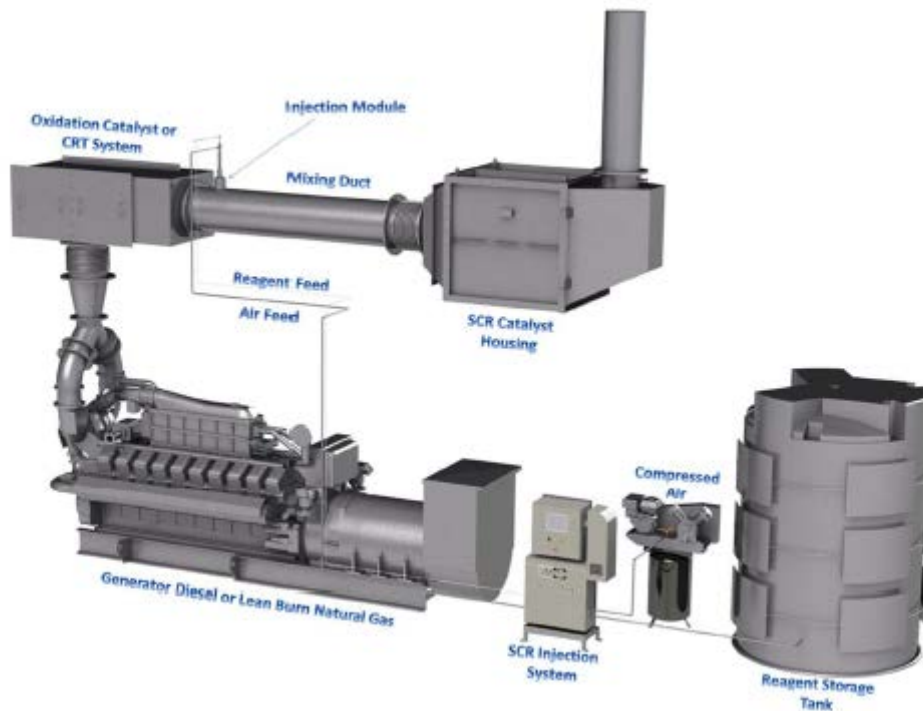SCR systems can attain NOx conversion efficiencies of 95% or greater, but ammonia/urea requirements tend to increase with higher NOx conversion efficiencies, creating the potential to slip more ammonia. Ammonia cleanup catalysts can be installed behind the SCR catalyst to collect any excess ammonia that slips through (converting it into nitrogen and water). The ideal ratio of ammonia to NOx is 1:1 based on having ammonia available for reaction of all of the exhaust NOx without ammonia slip. However, SCR efficiency can be less than ideal at low temperatures (potential low SCR activity) and at higher temperatures with high exhaust flow rates (high space velocities). Optimizing the ammonia to NOx ratio is shown to lead to potential improvements in overall NOx conversion efficiency with little additional ammonia slip.

1.2.3   Lean NOx Catalysts

Lean NOx catalyst (LNC) technology is a technology that has recently emerged that has demonstrated NOx emission reductions from stationary diesel and lean-burn gas engines. LNCs control NOx emissions by injecting a small amount of diesel fuel or other hydrocarbon reductant into the exhaust upstream of a catalyst. The fuel or other hydrocarbon reductant serves as a reducing agent for the catalytic conversion of NOx to N_2. Because the mechanism is analogous to SCR but uses a different reductant, LNC technology is sometimes referred to as hydrocarbon selective catalytic reduction, or HC-SCR. Other systems operate passively without any added reductant at reduced NOx conversion rates.

The typical LNC is constructed of a porous material made of zeolite (a micro-porous material with a highly ordered channel structure), along with either a precious metal or base

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metal catalyst. The zeolites provide microscopic sites that attract hydrocarbons and facilitate NOx reduction reactions. Without the added fuel and catalyst, reduction reactions that convert NOx to N_2 would not take place because of excess oxygen present in the exhaust.

For diesel engines over transient cycles, peak NOx conversion efficiencies are typically around 25 to 40% (at reasonable levels of diesel fuel consumption), although higher NOx conversion efficiencies have been observed on specially designed HC-SCR catalysts that employ an ethanol-based reductant. For stationary lean-burn gas engines, two types of lean NOx catalyst formulations have emerged: a low temperature catalyst based on platinum and a high temperature catalyst utilizing base metals (usually copper). Each catalyst is capable of controlling NOx over a narrow temperature range. A copper-exchange zeolite-based catalyst is active at temperatures between 350-450°C, resulting in 60% NOx conversion, while a platinum catalyst is active at lower temperatures of approximately 200-300˚C, with 50% NOx conversion capability.

2.0 PARTICULATE MATTER EMISSION CONTROL OF STATIONARY IC ENGINES

Particulate matter emission control of stationary IC engines is a concern for diesel engines, which emit a relatively high amount of particulate compared to engines using other fuels. Diesel particulate emissions are composed of a variety of compounds from fuel and lube oil combustion, as well as engine wear and sulfate from diesel fuel sulfur. The majority of the particulate consists of carbon and the soluble organic fraction consisting of unburned fuel and unburned lube oil. Both diesel oxidation catalysts and diesel particulate filters can be used to substantially reduce diesel PM emissions.

2.1 Diesel Oxidation Catalysts

The use of diesel oxidation catalyst (DOC) devices is one of the common forms of reducing particulate matter (PM) in diesel exhaust. In most stationary applications, a DOC consists of a stainless steel canister that contains a honeycomb structure called a substrate or catalyst support. There are no moving parts, just large amounts of interior surface area. The interior surfaces are coated with catalytic metals such as platinum or palladium. As with oxidation catalysts for lean-burn gas engines, a DOC converts exhaust gas pollutants into harmless gases by means of chemical oxidation. In the case of diesel exhaust, the catalyst oxidizes CO, HCs, and the liquid hydrocarbons adsorbed on carbon particles to CO_2 and water. Liquid hydrocarbons adsorbed on the carbon particles in engine exhaust are referred to as the soluble organic fraction (SOF) – the soluble part of the PM in the exhaust. DOCs are efficient at converting the SOF of diesel PM into carbon dioxide and water.

The level of total particulate reduction is influenced in part by the percentage of SOF in the particulate. Oxidation catalysts can reduce the SOF of the particulate by 90% under certain operating conditions, and can reduce total particulate emissions by up to 50% by mass. Destruction of the SOF is important since this portion of the particulate emissions contains numerous hazardous air pollutants. DOCs can also reduce CO emissions by 70-95% and hydrocarbons by 70-90%. DOCs can also reduce smoke emissions and virtually eliminate the

characteristic odor associated with diesel exhaust by oxidizing the aldehyde and acrolein emissions. DOCs do not generally oxidize or reduce the elemental carbon or black carbon constituents of diesel PM.
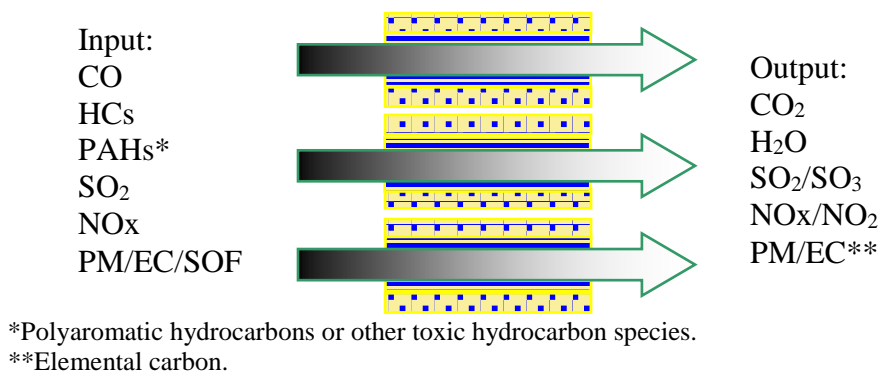

Input:
CO
HCs
PAHs*
SO_2
NOx
PM/EC/SOF

Output:
CO_2
H_2O
SO_2/SO_3
NOx/NO_2
PM/EC**

*Polyaromatic hydrocarbons or other toxic hydrocarbon species.
**Elemental carbon.

Figure 8. Diagram of a diesel oxidation catalyst.

Like diesel particulate filters (see Section 2.2 below), DOCs are affected by sulfur in diesel fuel. Hence, the sulfur content of diesel fuel is critical to applying catalyst technology. Catalysts used to oxidize the SOF of particulate emissions can also oxidize sulfur dioxide to form sulfates, which are counted as part of total particulate emissions. This reaction is not only dependent on the level of sulfur in the fuel but also on the temperature of the exhaust gases. Catalyst formulations have been developed which selectively oxidize the SOF while minimizing oxidation of the sulfur dioxide. However, the lower the sulfur content in the fuel (typically less than 50 ppm for DOCs), the greater the opportunity to maximize the effectiveness of oxidation catalyst technology for both better total control of PM and greater control of toxic hydrocarbons.

Diesel oxidation catalysts are virtually maintenance-free. Periodic inspection by engine owners to ensure that cell plugging is not occurring is advisable. This would usually only occur in the case of an engine malfunction and, in that event, the catalysts can easily be cleaned and reinstalled.

The popularity of DOCs is due to their flexibility and reliability. Because they are a completely passive, flow-through device, they can be installed on a wide range of applications as long as the exhaust temperatures remain above approximately 150°C. DOCs can be used not only with conventional diesel fuel but have also been shown effective with biodiesel and emulsified diesel fuels, ethanol/diesel blends, and other alternative diesel fuels.

2.2 Diesel Particulate Filters

Wall-flow diesel particulate filters (DPFs) remove particulate matter in diesel exhaust by filtering exhaust from the engine. They can be installed on both stationary and mobile engines. The structure of a wall-flow DPF is similar to that of an oxidation catalyst, except every other channel is blocked with a dense plug. To remove the soot, raw exhaust enters an open channel at the front of the DPF. The walls of the filter are engineered to be semipermeable, allowing gases to pass through but trapping the soot particles inside. The DPF contains a thin layer of catalyst

that chemically converts the soot particles to carbon dioxide. This allows the filter to function continuously during engine operation. The catalyst also allows the DPF to function as an oxidation catalyst, reducing HC and CO in addition to PM. Once converted, the gases pass through the filter's porous walls and into a much cleaner exhaust stream.
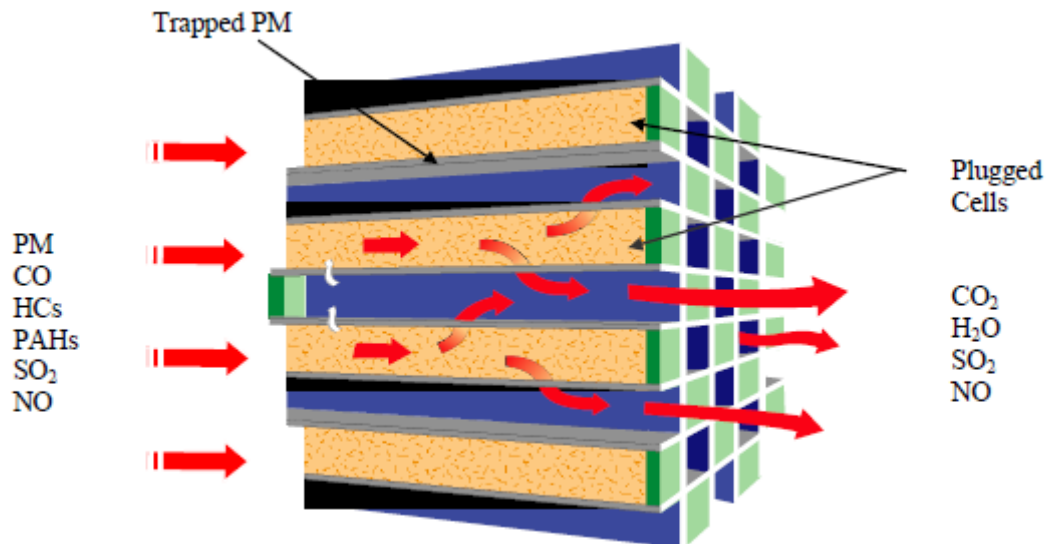

Figure 9. Diagram of a wall-flow diesel particulate filter.

Wall-flow filters have the highest level of filtration efficiency (>90%) for particulate matter (including ultrafine particles) and can reduce black carbon by as much as 99%. In addition, CO emissions can be reduced by 90% and hydrocarbons by 60-80%. Experience with catalyst-based filters indicates that they can achieve a virtually complete reduction in odor and in the soluble organic fraction of particulate emissions.

Since a filter can fill up over time, these systems must provide a means of burning off or removing accumulated particulate matter. A convenient means of accomplishing this is to burn or oxidize accumulated particulate matter on the filter when exhaust temperatures are adequate. By burning off trapped material, the filter is cleaned, or "regenerated." Many techniques can be used to regenerate a diesel particulate filter. Some of these techniques are used together in the same filter system to achieve efficient regeneration.

The major filter regeneration techniques are listed below:

- Catalyst-based regeneration using a catalyst applied to the surfaces of the filter. A base or precious metal coating applied to the surface of the filter reduces the ignition temperature necessary to oxidize accumulated particulate matter.

- Catalyst-based regeneration using an upstream oxidation catalyst. In this technique, an oxidation catalyst is placed upstream of the filter to facilitate oxidation of nitric

oxide (NO) to nitrogen dioxide (NO_2). The nitrogen dioxide adsorbs on the collected particulate, substantially reducing the temperature required to regenerate the filter.

- Fuel-borne catalysts. Fuel-borne catalysts reduce the temperature required for ignition of trapped particulate matter.

- Air-intake throttling. Throttling the air intake to one or more of the engine cylinders can increase the exhaust temperature and facilitate filter regeneration.

- Post top-dead-center fuel injection. Injecting small amounts of fuel in the cylinders of a diesel engine after pistons have reached the top-dead-center position introduces a small amount of unburned fuel in the engine's exhaust gases. This unburned fuel can then be oxidized in the particulate filter to combust accumulated particulate matter.

- On-board fuel burners or electrical heaters. Fuel burners or electrical heaters upstream of the filter can provide sufficient exhaust temperatures to ignite accumulated particulate matter and regenerate the filter.

- Off-board electrical heaters. Off-board regeneration stations combust trapped particulate matter by blowing hot air through the filter system.

A number of substrate materials have been used in DPFs, including: ceramic and silicon carbide materials, fiber wound cartridges, knitted silica fiber coils, ceramic foam, wire mesh, and sintered metal substrates. Filter materials capture particulate matter by interception, impaction, and diffusion. Filter efficiency has rarely been a problem with the filter materials listed above, but work has continued to: 1) optimize filter efficiency and minimize back pressure, 2) improve the radial flow of oxidation in the filter during regeneration, and 3) improve the mechanical strength of filter designs. Technological developments in DPF design include advancements in cell shape and cell wall porosity optimization aimed at minimizing engine backpressure and extending the interval between filter service. Advances such as higher pore volume and increased pore connectivity, along with thinner web designs, facilitate catalyst coating while maintaining longer times between soot regeneration events.

Sulfur in diesel fuel significantly affects the reliability, durability, and emissions performance of catalyst-based DPFs. Sulfur affects filter performance by inhibiting the performance of catalytic materials upstream of or on the filter. Sulfur also competes with chemical reactions intended to reduce pollutant emissions and creates particulate matter through catalytic sulfate formation. Catalyst-based diesel particulate filter technology works best when fuel sulfur levels are less than 15 ppm. In general, the less sulfur in the fuel, the better the technology performs. The use of ultra-low sulfur diesel fuel (15 ppm sulfur maximum) greatly facilitates filter regeneration at lower temperatures in passive DPF devices. The performance of uncatalyzed filters, such as those used in many actively regenerated devices, is not affected by fuel sulfur. Therefore, when using diesel particulate filter technology, a careful assessment of its suitability should be made based on fuel sulfur content, engine type, filter system, operating conditions, and desired control levels.

Filter systems do not appear to cause any additional engine wear or affect engine maintenance. The systems are designed with engine displacement as a key parameter in order to ensure that appropriate backpressures are encountered during engine operation. Concerning maintenance of the filter system itself, manufacturers are designing systems to minimize maintenance requirements during the useful life of the engine. In some cases, however, accumulated lubricating oil ash may have to be periodically removed. Generally, manufacturers provide the end-user with appropriate removal procedures.

Determining whether a given filter system is appropriate for a given engine in a specific stationary application depends on the fuel sulfur level and exhaust gas temperature during operation. The steady-state operation of these engines makes this determination relatively simple. For example, a manufacturer may specify that, when using diesel fuel containing 15 ppm of sulfur, regeneration of the filter will occur at temperatures in excess of 300°C. Running the engine at the load condition in which it will be used and measuring the exhaust gas temperature will indicate whether the filter system is suitable.

3.0   SUMMARY OF FEDERAL REGULATIONS FOR CONTROLLING EMISSIONS FROM STATIONARY IC ENGINES

Current U.S. EPA air quality requirements for stationary IC engines differ according to:

- whether the engine is new or existing, and
- whether the engine is located at an area source or a major source and whether the engine is a compression-ignition (CI) engine or a spark-ignition (SI) engine. SI engines are further subdivided by power cycle, i.e., two-stroke vs. four-stroke, and whether the engine is rich-burn or lean-burn.

The EPA regulations that apply to stationary IC engines are:

- New Source Performance Standards (NSPS) – Standards of Performance for Stationary Compression-Ignition Internal Combustion Engines (40 CFR Part 60 Subpart IIII)
- New Source Performance Standards (NSPS) – Standards of Performance for Stationary Spark-Ignition Internal Combustion Engines (40 CFR Part 60 Subpart JJJJ)
- National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines (40 Code of Federal Regulations Part 63, Subpart ZZZZ)

The NSPS regulation addresses emissions of NOx, CO, and VOCs from new stationary IC engines. The final rule NSPS for new stationary CI engines was promulgated on July 11, 2006. The emission standards are generally modeled after EPA's standards for nonroad and marine diesel engines. The nonroad diesel engine standards are phased in over several years and have tiers with increasing level of stringency. The engine model year in which the tiers take effect varies for different size ranges of engines. Tier 4 limits for nonroad diesel engines were phased in beginning in 2008. The final rule NSPS for new stationary SI engines was

promulgated on January 18, 2008. The rule limits NOx, CO, and NMHC from new stationary spark-ignited internal combustion engines that are manufactured or ordered after June 12, 2006, and manufactured after July 1, 2007, for engines greater than or equal to 500 horsepower, and after January 1, 2008, for engines less than 500 horsepower.

The NESHAP regulation addresses emissions of toxic air pollutants (formaldehyde, acetaldehyde, acrolein, and methanol emissions) from new and existing stationary IC engines. EPA has determined that carbon monoxide can be used as an appropriate surrogate for formaldehyde. Since testing for CO emissions has many advantages over testing for emissions of HAPs, most of the emission standards have been finalized in terms of CO as the only regulated pollutant. The final rule NESHAP for existing stationary CI engines was promulgated on March 10, 2010, and went into effect in May 2013. The final rule NESHAP for existing stationary SI engines was promulgated on August 20, 2010, and went into effect in September 2013.

For more information on EPA's regulatory actions to control emissions from stationary IC engines, go to: www.epa.gov/airtoxics/icengines/.

Separate from EPA, the California Air Resources Board (ARB) has adopted an airborne toxic control measure (ATCM) to reduce public exposure to diesel particulate matter and to control criteria pollutants emitted from new and existing stationary diesel-fueled, compression-ignition engines. The control measure reduces diesel PM and controls criteria pollutant emissions through a combination of limits on annual operating hours and application of best available control technology. For more information on ARB's regulatory actions to reduce emissions from stationary IC engines, go to: www.arb.ca.gov/diesel/statport.htm.

4.0   CONCLUSION

With heightened concerns about the emissions of gaseous air pollutants and particulate matter from stationary internal combustion engines, post-combustion emission control technology is becoming increasingly important in the operation of these engines at various stationary sources. The implementation of EPA's New Source Performance Standards and the agency's National Emission Standards for Hazardous Air Pollutants are significantly tightening emission control requirements on these stationary sources.

Applying exhaust gas aftertreatment controls to stationary engines can be challenging because of the vast array of applications, with different duty cycles, durability demands, packaging constraints, and regulatory requirements. However, reliable solutions are available for both rich-burn and lean-burn stationary engines that provide high conversion efficiencies to reduce emissions of oxides of nitrogen, carbon monoxide, volatile organic compounds, hazardous air pollutants, and, where applicable, particulate matter. Generally, these technologies are well developed and have been successfully commercialized. Thus, the chief issues when evaluating emission control policies for stationary engines are likely to be issues of cost and cost-effectiveness, rather than technical feasibility.

When selecting an emission control technology, it is important to ensure that the technology is compatible with the duty cycle of the engine and the desired emission reductions. Properly maintained engines ensure that emission control technologies will perform optimally. End-users also need to follow maintenance procedures specified by the technology supplier to ensure continued performance of the emission control device.