NO_2 Emissions from Diesel Engine Powered Vehicles in Underground Mines

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NIOSH

CDC — Department of Health and Human Services — Centers for Disease Control & Prevention

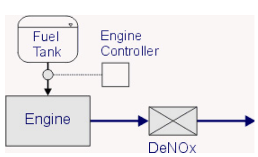
1

This presentation reviews the effects of diesel control technologies on nitrogen dioxide (NO_2) emissions in underground mining applications

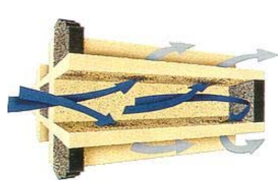
Diesel engine

NO_2 MSHA ceiling limit
5 ppmV
Coal - MNM mines

$NO_x = NO + NO_2$
NO = Nitrogen oxide
NO_2 = Nitrogen dioxide



NO_x control strategies

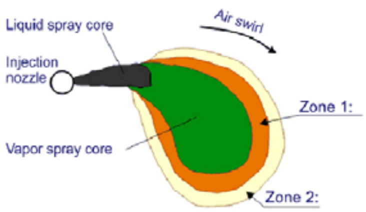


DPM control strategies

2

NO_2 is not a direct product of combustion, but can be formed from NO in a diesel combustion chamber

$NO + HO_2 \leftrightarrow NO_2 + OH$



High temperature: NO is stable

Lower temperature: NO_2 is stable

The formation of NO_2 is generally promoted in **low fuel-air conditions, lower loads** and **lower temperatures**

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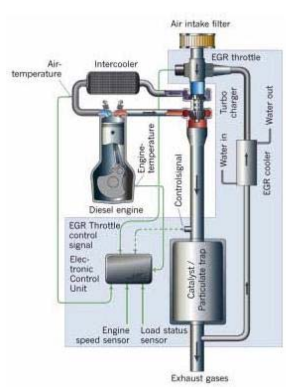
Modern turbocharged **engines reduce overall NO_x emissions but increase the NO_2 emissions**

3

EGR is a very efficient NO_x control strategy but ...

EGR (Exhaust Gas Recirculation): A portion of the engine's exhaust gas is returned to the combustion chamber via the inlet system, resulting in a reduction in both combustion chamber temperature and oxygen concentration.



Several EGR technologies are currently used for NOx control

An optimized EGR can reduce the NOx produced by a diesel engine up to 70%

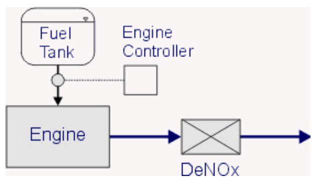
Downsides

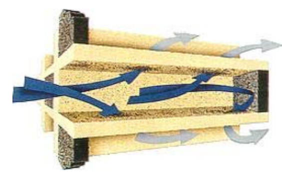
1. **Increase of** DPM concentration
2. **Increase** of the NO_2/NO due to a lower combustion chamber temperature

4

From the manifold through the tailpipe….

The NO_2 concentration doesn't change significantly in the tailpipe unless aftertreatment strategies are employed





NOx control strategies

DPM control strategies

5

Tailpipe NO_x control strategies: extensive use of applied chemistry

SCR

Selective Catalytic Reduction

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Catalytic conversion of NO_x via injection of urea or ammonia

LNC

Lean NO_x catalyst

↓

Catalytic conversion of NO_x via injection of gaseous hydrocarbons, similar to SCR

LNT

Lean NO_x trap

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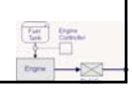
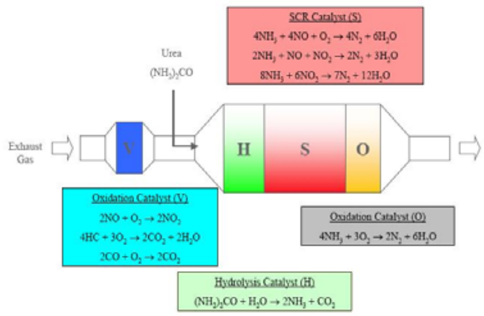
Catalytic adsorption of NO_x on active sites and conversion in fuel rich conditions



6

SCR

NO_2 plays a crucial role for this control strategy, but there can be a downside effect



$NO_2/NO = 0.5$ provides the maximum SCR efficiency

Common use of a DOC to increase the NO_2/NO ratio

↓

Over production of NO_2 can promote NO_2 slip

LNC

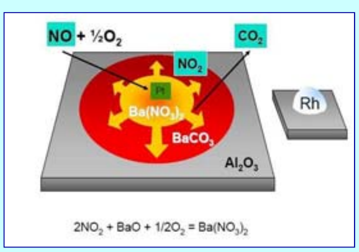
Same conversion for NO and NO_2. No specific concerns regarding NO_2 emission

7

LNT

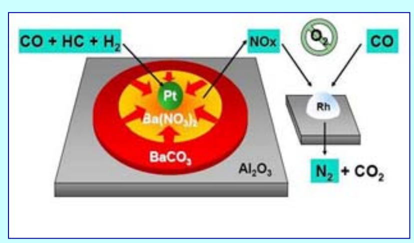
Controls NO_2 emissions by capturing NO_2 during the lean conditions and destroying in rich condition.

FUEL LEAN CONDITION



Use of a metal catalyst (Pt) to increase NO_2 and then trap it on catalyst's active sites

FUEL RICH CONDITION

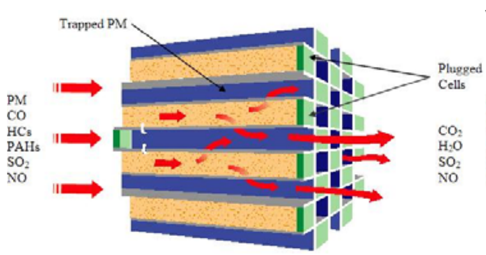


Release of NO_x (mainly NO_2) and conversion on a second catalyst

In fuel rich conditions perfect conversion rate of NO_x is necessary to avoid NO_2 slip

8

The Diesel Particulate Filter (DPF) by itself does not play a specific role in NO_2 conversions



The wall filtration of DPM is a physical process and it does not effect the concentration of gas components: no effect on NO_2

The DPM trapped in the filter can react with NO_2

Adsorption of NO_2 on DPM as nitrates

Oxidation of DPM by NO_2. Helps with DPF regeneration

Any filter needs to be regenerated, periodically or continuously: usually DPM is removed through combustion.

Regeneration at reduced temperature through the use of a catalyst, may result in an increase in the NO_2 concentration in the exhaust

9

The catalytic regeneration is efficient but can make things worse for NO_2

The regeneration of a DPF requires ENERGY (high exhaust temperatures)

Energy means fuel penalties – Money

An oxidation catalyst improves the regeneration and thus it helps to reduce fuel penalties

Oxidation Catalyst
- Fuel additives: added to the fuel before the combustion
- Solid catalyst washcoated over the DPF wall

Downside: An oxidation catalyst can also convert NO to NO_2.

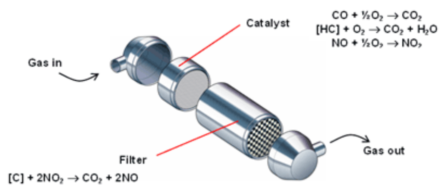
- Catalyst chemical composition
- Temperature
- Catalyst load
- Regeneration strategy

10

NO_2 can assist with DPF regeneration

The regeneration of a DPF requires a GOOD OXIDANT AGENT.
NO_2 is a stronger oxidant agent than oxygen at lower temperature.

DOC + DPF = NO_2 regeneration



The use of a diesel oxidation catalyst (DOC) is necessary to increase the NO_2 concentration - which otherwise would be too low to induce a proper DPF regeneration

The NO_2 is then used to oxidize the DPM, a process called **non catalytic** DPF regeneration. During regeneration, NO_2 is converted into NO.

Forcing the NO_2 conversion in the DOC increases the possibility of NO_2 slip. Even though the DPM collected on the filter should use all of the NO_2 during regeneration, a secondary NO_2 control should be used.

NO_2: an open issue. Do not underestimate

- Modern turbocharged diesel engines **emit higher NO_2 concentrations** than old diesel engines
- EGR and other NO_x aftertreatment strategies reduce the overall NO_x concentration: However **NO_2reduction efficiency may be lower than NOx reduction efficiency**.
- The use of a **catalyst** for DPF regeneration **might increase the NO_2** concentration in the exhaust.
- **DPF regeneration** based on increasing the **NO_2 concentrations** ahead of the DPF via an oxidation catalyst is possible but NO_2 slip is a **an issue to be considered.**
- Integrated systems - NO_x control and DPM control strategies – have to be explored and studied with the specific target of reduced DPM and NO_2 emissions

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Questions??

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13

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14