DIESEL PARTICULATE FILTERS AND NO$_2$ EMISSION LIMITS

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OUTLINE

- Background
- NO₂ Limits From Retrofit Technologies
- New Air Quality Standards for NO₂
- Diesel Oxidation Catalysts
- Passive Diesel Particulate Filters
- Active Diesel Particulate Filters
- New Oxidation/Reducing Catalysts
- Conclusions
BACKGROUND

- January 1, 2009
- EPA/CARB
- Limit increase in NO$_2$ emissions
- Less than 20% above baseline
- From Retrofit Technologies (DOC, DPF, .. etc)
CARB Verification

NO$_2$ < 20%

- Level 1 -> Level 1 Plus
- Level 2 -> Level 2 Plus
- Level 3 -> Level 3 Plus
BACKGROUND

- June, 2009
- EPA Proposes New Air Quality Standards for NO₂
- EPA Goal is to reduce respiratory illness
BACKGROUND

Health Impact of NO$_2$

- Scientific evidence links short-term NO$_2$ exposures, with increased respiratory effects (asthma)

- Particularly in at-risk areas:
  - Children
  - Elderly
  - Workers in confined spaces
Diesel Oxidation Catalysts

\[
\begin{align*}
\text{CO} + \text{O}_2 & \rightarrow \text{CO}_2 \\
\text{THC} + \text{O}_2 & \rightarrow \text{CO}_2 \\
\text{NO} + \text{O}_2 & \rightarrow \text{NO}_2 \\
\text{SO} + \text{O}_2 & \rightarrow \text{SO}_2 \\
\text{SOF} + \text{O}_2 & \rightarrow \text{CO}_2 + \text{H}_2\text{O} \\
\text{C} + \text{O}_2 & \rightarrow \text{CO}_2 \\
\end{align*}
\]
Diesel Oxidation Catalysts

- CO reduction: 90%
- THC reduction: 80%
- PM reduction: 25%
Diesel Oxidation Catalysts

NO to NO$_2$ Conversion

Conversion in % vs Temperature in °C

Pt Loading
Passive Diesel Particulate Filters

\[
\begin{align*}
\text{CO} + \text{O}_2 & \rightarrow \text{CO}_2 \\
\text{THC} + \text{O}_2 & \rightarrow \text{CO}_2 + \text{H}_2\text{O} \\
\text{NO} + \text{O}_2 & \rightarrow \text{NO}_2 \\
\text{SO} + \text{O}_2 & \rightarrow \text{SO}_2 \\
\text{SOF} + \text{O}_2 & \rightarrow \text{CO}_2 + \text{H}_2\text{O} \\
\text{C} + \text{O}_2 & \rightarrow \text{CO}_2 \\
\end{align*}
\]
Passive Diesel Particulate Filters

Reduction (%)

PM  CO  THC  NO2

Increase (%)
Active Diesel Particulate Filters

- Filters are not coated with oxidation catalysts
- Soot and other particulates are collected as a fluffy layer with high surface area.
- Soot, similar to activated carbon, is able to adsorb hydrocarbons and other gases
- The high surface area increases the reaction probability between carbon and nitrogen dioxide
- Mild diesel oxidation catalysts are used after DPF, thus minimizing the oxidation of NO into NO$_2$. 
Sintered Metal Fibers
Active Diesel Particulate Filters

Electric Regeneration

August 6, 2009
Active Diesel Particulate Filters
PM Reduction

Reduction (%)
0% 20% 40% 60% 80% 100%

After 25 Hours
After 1000 Hours
Active Diesel Particulate Filters

NO\textsubscript{2} Reduction

After 25 Hours

After 1000 Hours

Reduction (%)
Active Diesel Particulate Filters

NO₂ Reduction

<table>
<thead>
<tr>
<th></th>
<th>Reduction (%)</th>
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<tbody>
<tr>
<td>High Face Velocity</td>
<td>40%</td>
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<tr>
<td>Low Face Velocity</td>
<td>100%</td>
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Objectives:

1. Develop washcoats for sintered metal fibers.

2. Develop catalytic topcoats with precious and non-precious metal coating formulations to reduce CO, HC and NO₂.
New Diesel Oxidation/Reducing Catalysts

Emission Reduction Targets

- PM Reduction: >90%
- CO Reduction: >90%
- THC Reduction: >90%
- NO$_2$ Reduction: >90%
New Washcoat

Goals

- Minimize wash-coat material
- Coat individual fibers
- Minimize webbing and shedding
- Minimize the use of precious metals
- Use of non-precious metals
Washcoat C
Washcoat B
Washcoat A
Emission Testing

- Testing was conducted at Intertek Lab.
- Test Engine was 2005 MY Cummins 5.9L engine.
- Rated at 287 HP @ 2600 rpm
- Test Cycles: ISO 8187-C1 and FTP
**ISO 8187-C1 Test Results**

<table>
<thead>
<tr>
<th></th>
<th>PM</th>
<th>NOx</th>
<th>NO\textsubscript{2}</th>
<th>CO</th>
<th>THC</th>
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<tbody>
<tr>
<td>Baseline</td>
<td>0.074</td>
<td>2.195</td>
<td>0.080</td>
<td>0.470</td>
<td>0.027</td>
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<tr>
<td>HDPF2</td>
<td>0.007</td>
<td>2.345</td>
<td>0</td>
<td>0.200</td>
<td>0.005</td>
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<tr>
<td></td>
<td>91%</td>
<td>-3%</td>
<td>100%</td>
<td>58%</td>
<td>82%</td>
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## FTP Test Results

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<thead>
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<th>PM</th>
<th>NOx</th>
<th>NO₂</th>
<th>CO</th>
<th>THC</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>g/hp-hr</td>
<td>g/hp-hr</td>
<td>g/hp-hr</td>
<td>g/hp-hr</td>
<td>g/hp-hr</td>
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<tr>
<td>Baseline</td>
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<td>2.243</td>
<td>0.150</td>
<td>0.780</td>
<td>0.070</td>
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<tr>
<td>HDPF2</td>
<td>0.004</td>
<td>2.345</td>
<td>0</td>
<td>0.360</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>95%</td>
<td>-4%</td>
<td>100%</td>
<td>54%</td>
<td>84%</td>
</tr>
</tbody>
</table>
Summary/Conclusions

- EPA’s New air quality standards for NO₂ will impact future DPF designs
- Passive DPFs increase NO₂ emissions
- Active DPFs reduce NO₂ emissions
- Passive/Active DPFs can provide extra degree of freedom to meet NO₂ limits
- New Oxidation/Reducing Catalysts are needed to reduce CO, THC and NO₂