Selective Catalyst Reduction (SCR) 
For Diesel Engines 

Gus Wright’s
What is SCR?

- **Selective Catalyst Reduction** is an exhaust aftertreatment emission control system used to clean-up oxides of nitrogen (NOx) in the exhaust.
- Used in Europe since 2005.
- Needed in North America to meet 2010 emission standards.
- Implementation October 1st 2009.
2010 Emission standards reducing NOx 90% - again means all HD diesel manufactures are using SCR (Note: Except International)
SCR Better than “In Cylinder Treatment” to Reduce NOx

SCR enables **advanced injection** timing and **lower EGR rates** resulting in:

- Lower fuel costs – At least 5% better
- Reduced active regenerations of soot filter – Advanced injection timing = less soot
- Higher specific power output/cubic inch displacement
- Longer engine life from:
  - Lower cylinder pressures i.e. turbocharger compressor pressure ratio
  - Stroking a block means lower piston speeds
  - i.e. Consider a block developed for 13 L, not a bored & stroked 10.5L

**Increased reliability from**
- Reduced heat loads with lower EGR rates
SCR = Better fuel economy + more power - less PM

LESS EGR | MORE EGR
---|---
LESS FUEL ECONOMY | HIGHER FUEL ECONOMY

LESS EGR | MORE EGR
---|---
LESS HORSEPOWER | MORE HORSEPOWER

LESS EGR | MORE EGR
---|---
MORE DPF REGENERATIONS | FEWER DPF REGENERATIONS

LESS EGR | MORE EGR
---|---
HIGHER COST OF OPERATION | LOWER COST OF OPERATION
<table>
<thead>
<tr>
<th>Less Soot</th>
<th>More Soot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fewer Active Regenerations</td>
<td>More Active Regenerations</td>
</tr>
<tr>
<td>More Passive Regeneration</td>
<td>Less Passive Regeneration</td>
</tr>
<tr>
<td>Less Thermal Cycling of Catalysts</td>
<td>More Thermal Cycling of Catalysts</td>
</tr>
<tr>
<td>Higher Power Density</td>
<td>Lower Power Density</td>
</tr>
<tr>
<td>Less Heat Rejection</td>
<td>More Heat Rejection</td>
</tr>
<tr>
<td>Lower Power Fan</td>
<td>Higher Power Fan</td>
</tr>
<tr>
<td>Higher Residual Value</td>
<td>Lower Residual Value</td>
</tr>
<tr>
<td>Better Fuel Economy</td>
<td>Worse Fuel Economy</td>
</tr>
<tr>
<td>Lower Cost of Operation</td>
<td>Higher Cost of Operation</td>
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</tbody>
</table>

When you dial in more EGR, you affect all these parameters.

From Vovlo PPT 2-09
No Substantial Engine Changes from 2007

2010 Volvo note size of EGR cooler
# Diesel Catalysts

<table>
<thead>
<tr>
<th>Technology</th>
<th>Gasoline Engines</th>
<th>Diesel Engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-way (oxidation) catalytic converters</td>
<td>CO, HC</td>
<td>CO, HC, PM</td>
</tr>
<tr>
<td>3-way catalytic converters</td>
<td>CO, HC, NOx</td>
<td></td>
</tr>
<tr>
<td>Selective catalytic reduction (SCR)</td>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>NOx adsorber catalytic converters</td>
<td></td>
<td>NOx</td>
</tr>
<tr>
<td>Diesel particulate filters</td>
<td></td>
<td>CO, HC, PM</td>
</tr>
<tr>
<td>4-way (combined) diesel catalytic systems (2010)</td>
<td></td>
<td>CO, HC, PM, NOx</td>
</tr>
<tr>
<td>Catalyst Technology</td>
<td>Reaction Type</td>
<td>Reduced Emissions</td>
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<tr>
<td>-------------------------------------------</td>
<td>---------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
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<tr>
<td>Diesel Oxidation Catalyst (DOC)</td>
<td>Oxidation</td>
<td>CO, HC, PM including SOF and odor</td>
</tr>
<tr>
<td>Selective Catalytic Reduction (SCR)</td>
<td>Selective catalytic reduction by ammonia/urea</td>
<td>NOx, PM</td>
</tr>
<tr>
<td>Lean NOx Catalyst (LNC) DeNOx converters</td>
<td>Selective catalytic reduction by hydrocarbons</td>
<td>NOx, CO, HC, PM</td>
</tr>
<tr>
<td>NOx Adsorbers (Lean NOx Trap (LNT))</td>
<td>Adsorption (trapping) of NOx from lean exhaust followed by release and catalytic reduction under rich conditions</td>
<td>NOx, CO, HC</td>
</tr>
</tbody>
</table>
Selective catalyst reduction (SCR) involves injecting urea into the exhaust stream where it breaks down NOx when passing through a catalytic converter.
Components of Typical SCR

- DEF – Diesel Exhaust Fluid (Generic name) 32.5% urea, 67.5% de-mineralized water
- DEF is safe to handle and store
  - Non-toxic
  - Non-polluting
  - Non-flammable
- When stored at extreme temperatures, neither DEF nor Urea become toxic
- Poses no serious risk to humans, animals, equipment or the environment when handled properly
- The product is slightly alkaline with a pH of approximately 9 (Neutral water is 7, a can of acidic coke is 3, baking soda is alkaline at 9)
DEF Freezes at -12°F -11°C

Freezing Point of Urea/Water Solutions

- Tank and line heaters required. DEF evacuated from lines during shut-down.
- Ammonia produced at high-temperatures
In-Tank Heater DEF Pickup

- Fits inside DEF tank from top
- Circulates engine coolant through the Diesel Exhaust Fluid to maintain proper temperature – 60°F
- All stainless steel, high-quality
- DEF level gage float (in center), with wiring harness
- DEF pickup with intake filter
- No tank insulation is required
A Dash Gauge Indicates DEF Level
The tank cap for the DEF tank is blue to further differentiate from the diesel tank.
DEF Dispensed in Bulk or at Pump Island
How much DEF Used?

- DEF consumption is expected to be approximately 2% of fuel consumption, depending on vehicle operation, duty cycle, geography, load ratings, etc.

  OR

- 50 to 1 ratio with diesel. (For every 50 gallons of diesel fuel burned, you will use 1 gallon of DEF). If you know the average fuel consumption of a vehicle, you can calculate the amount of DEF that will be used.

- Price @ ½ to 1/3 the price of a liter/gallon of diesel fuel
How Many fill-ups?

Annual miles for average truck = 120,000 miles
MPG for average truck = 6 mpg
120,000 miles / 6 mpg = 20,000 gallons diesel fuel per year

DEF usage @ 2% of fuel consumption = 400 gallons of DEF / year

400 gallons / 20 gallon tank (average size) = 20 DEF fill-ups / year
What happens if the vehicle runs out of DEF?

- **A.** Vehicles that will use DEF will have indicators on the dash that will alert the driver to quantity of DEF on board. A gauge similar to a fuel gauge today will indicate level of DEF. There will be a DEF low level warning lamp that illuminates when DEF is low. If the vehicle is operated such that one would run completely out of DEF vehicle power will be reduced enough to encourage the operator to refill the DEF tank. Once the tank has been refilled the engine will resume normal power levels.

- **Note** – two NOx sensor are used to detect DEF quality. NOx in and out of the exhaust. If NOx reductions are not sensed, the engine will de-rate thinking it is out of DEF.
Smaller Standardized Filler Opening

- The standard nozzle diameter for dispensing DEF has been designed at 19mm versus the standard diesel fuel nozzle diameter which is 22mm.
“Two Box” System

The DPF and SCR catalysts are separate in a 2-box system (2010 Volvo)
“One Box” System

- DPF & SCR are integrated into a single unit
One Box Side View
Basic Principle – Spraying DEF into the exhaust stream to promote NOx-reducing catalyst activity.

Compressed air spray DEF into the exhaust stream
DEF breaks down into Ammonia in the decomposition chamber due to exhaust heat.
NH3 Reaction

- Ammonia (NH3) in conjunction to the SCR catalyst, converts the NOx to harmless nitrogen (N2) and water (H2O).
N0x Reduction

- Decreased Levels of EGR
- Diesel Particulate Filter
- DEF Injected Into Exhaust Stream
- DEF Tank

DEF Decomposes Into Ammonia and Mixes with Exhaust Gases, Including NOx

Catalyst Converts Ammonia/NOx Mix To Nitrogen and Water
N0x Sensors Monitor SCR Operation

N0x In

N0x Out
Ultra-Low Sulphur Fuels Req’d

EPA Diesel Emissions Standards 1994 to 2010

- Diesel Sulfur Content (ppm)
- Particulate Matter (g/hp-hr)
- Nitrogen Oxide (g/hp-hr)

- 1994
- 1998
- 2002
- 2007
- 2010
### 2007 Rule: Basic Program Requirements

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<th>2012</th>
</tr>
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<tbody>
<tr>
<td>avPM</td>
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<td></td>
<td></td>
<td>100% at 0.01-g/hp-hr</td>
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<tr>
<td>NOx</td>
<td></td>
<td></td>
<td></td>
<td>50% at 0.2-g/hp-hr</td>
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<td>100% at 0.2-g/hp-hr</td>
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<td>Fuel</td>
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<td>80% at 15-ppm maximum sulfur (under voluntary compliance option)</td>
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<td>100% at 15 ppm</td>
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What is BlueTec?

- BlueTec is Chrysler/MBE name for its two nitrogen oxide (NOx) reducing systems used in their European and North American diesel engines. One uses a urea based reductant called AdBlue, the other is called DeNOx and uses an oxidizing catalytic converter and particulate filter combined with a NOx adsorber.
• LD Diesel also use SCR
DEF (AdBlue) Filler Door
MB Diesel Exhaust System