

# Development of Current and Future Diesel After Treatment Systems

*Pakorn Bovonsombat, Byung-Sun Kang, Paul Spurk,  
Harald Klein, Klaus Ostgathe*

Degussa Metals Catalysts Cerdec AG  
Rodenbacher Chaussee 4, P.O.Box 1351  
D-63403 Hanau-Wolfgang, Germany

**AVECC2001**

## Content:

---

- 1. Overview**
  - 1-1. Legislation
  - 1-2. PM & NO<sub>x</sub> trade-off
  - 1-3. Requirement of NO<sub>x</sub> conversion efficiency for EU-IV
- 2. Diesel Oxidation Catalyst**
- 3. NO<sub>x</sub> adsorber**
- 4. Diesel Particulate Filter**
- 5. Urea-SCR**
- 6. Summary**

---

**AVECC2001**

## Content:

1. Overview
  - 1-1. Legislation
  - 1-2. PM & NO<sub>x</sub> trade-off
  - 1-3. Requirement of NO<sub>x</sub> conversion efficiency for EU-IV
2. Diesel Oxidation Catalyst
3. NO<sub>x</sub> adsorber
4. Diesel Particulate Filter
5. Urea-SCR
6. Summary

**AVECC 2001**

## Diesel Legislation

Legislation	Total cycle emissions in NEDC-cycle in [g/km]				
	CO	HC + NO <sub>x</sub>	HC	NO <sub>x</sub>	PM
EURO III	0.64	0.56	0.06	0.50	0.05
EURO IV	0.50	0.30	0.05	0.25	0.025

*EURO III and EURO IV legislation for diesel passenger cars in NEDC - cycle.*

Legislation		Total cycle emissions in [g/kWh]				
		CO	NMHC	HC	NO <sub>x</sub>	PM
ESC-Test Cycle	EURO III	2.10		0.66	5.00	0.10
	EURO IV	1.50		0.46	3.50	0.02
ETC-Test Cycle	EURO III	5.45	0.78		5.00	0.16
	EURO IV	4.00	0.55		3.50	0.03

*EURO III and EURO IV legislation for heavy-duty trucks.*

**AVECC 2001**

# Thailand Diesel Legislation

## Legislation for Light Duty Diesel

Vehicle Category	Total Cycle Emissions in R-83 Cycle (g/km)		
	CO	HC+NOx	PM
Less than 6 passengers	1.0	0.70 (0.90)	0.08 (0.10)
More than 6 passengers Less than 2,500 Kg GW	1.0 - 1.5	0.7 - 1.2 (0.9 - 1.6)	0.17 - 0.8 (0.10 - 0.20)

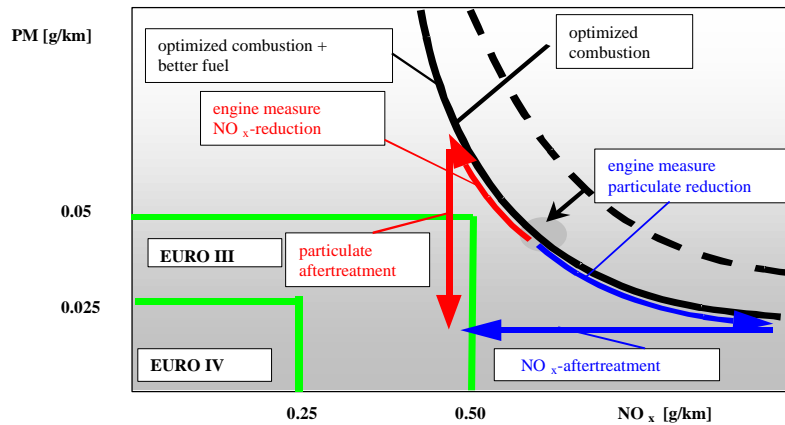
( ) = Values for Direct Injection

## Legislation for Heavy Duty Diesel (Euro II)

Vehicle Category	Total Cycle Emissions in R-49 Cycle (g/ kwh)			
	CO	HC	NOx	PM
More than 9 passengers GW greater than 3,500 Kg.	4.0	1.1	7	0.15

**AVECC 2001**

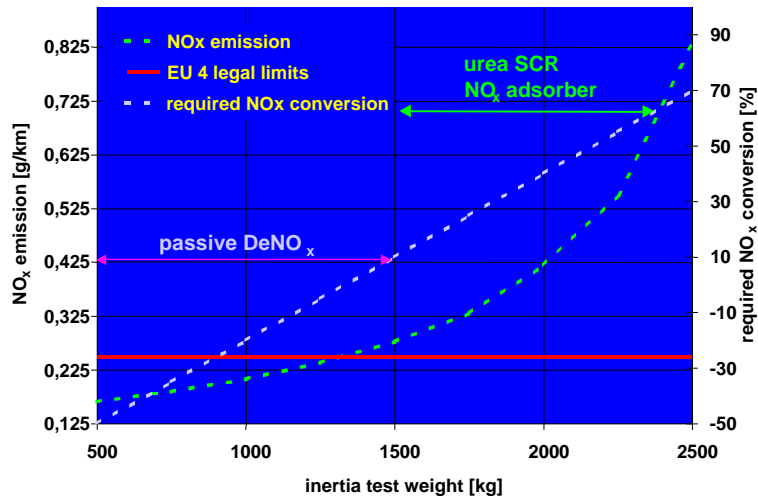
# NOx-PM Trade-off



*NO<sub>x</sub>/PM trade-off-curve for passenger cars. Emission values refer to NEDC- cycle. Similar principle is valid for heavy-duty trucks.*

**AVECC 2001**

## Requirement of NO<sub>x</sub> Conversion Efficiency for EU-IV



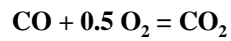
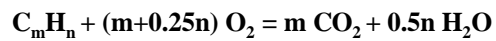
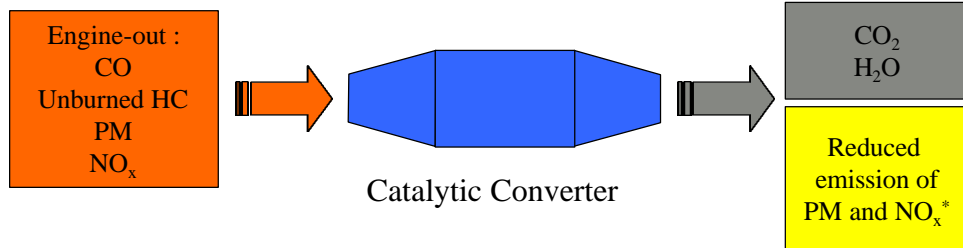
AVECC 2001

## Content:

1. Overview
  - 1-1. Legislation
  - 1-2. PM & NO<sub>x</sub> trade-off
  - 1-3. Requirement of NO<sub>x</sub> conversion efficiency for EU-IV
2. Diesel Oxidation Catalyst
3. NO<sub>x</sub> adsorber
4. Diesel Particulate Filter
5. Urea-SCR
6. Summary

AVECC 2001

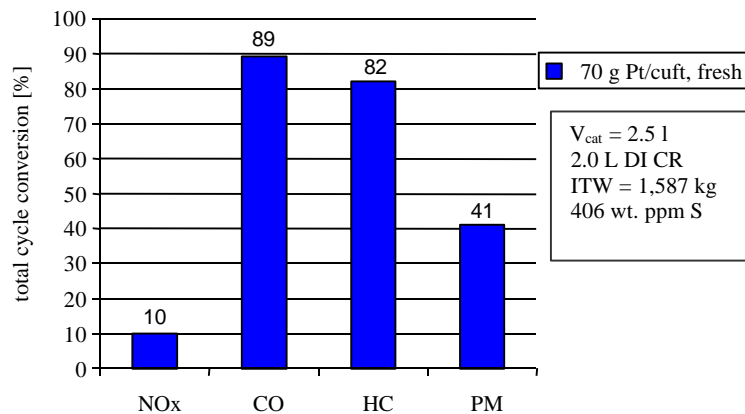
## Function of Diesel Oxidation Catalyst



\* Passive NO<sub>x</sub> conversion rate: Max. 10 %

**AVECC 2001**

## Performance of Diesel Oxidation Catalyst



*Diesel oxidation catalyst for passenger car – performance in NEDC – cycle.*

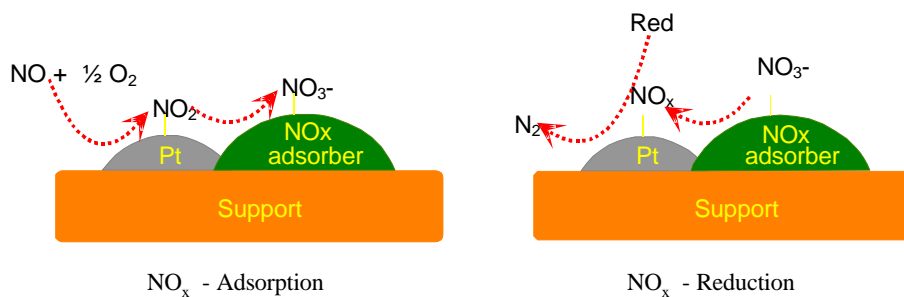
**AVECC 2001**

## Content:

1. Overview
  - 1-1. Legislation
  - 1-2. PM & NO<sub>x</sub> trade-off
  - 1-3. Requirement of NO<sub>x</sub> conversion efficiency for EU-IV
2. Diesel Oxidation Catalyst
3. NO<sub>x</sub> adsorber
4. Diesel Particulate Filter
5. Urea-SCR
6. Summary

AVECC 2001

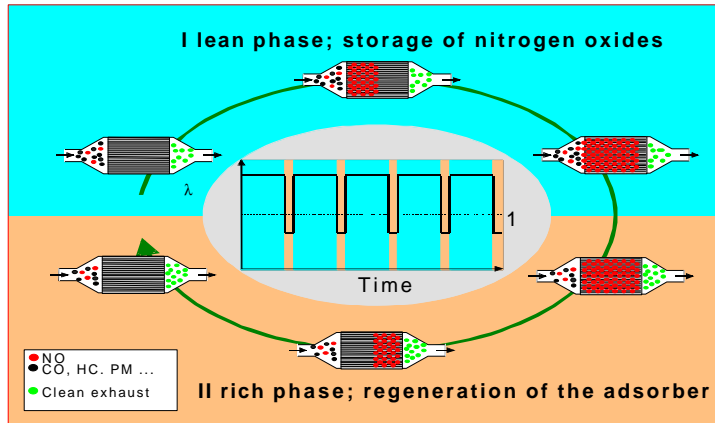
## Basic Concept of NO<sub>x</sub> Adsorber



*Chemical model of NO<sub>x</sub> storage catalyst*  
*Source: N. Miyoshi et al, SAE 950809 (1995)*

AVECC 2001

## Operation Concept of NO<sub>x</sub> Adsorber



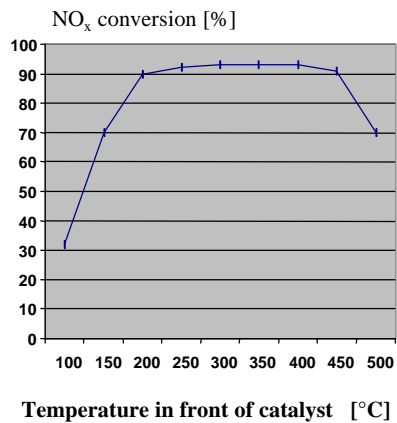
*Operation principle of diesel NO<sub>x</sub>-storage catalyst.*

**AVECC 2001**

## Conversion Efficiency of NO<sub>x</sub> Adsorber

### Model Gas composition:

- Simulation of typical diesel exhaust gas composition
- Adjustment lean / rich simulation: 60 s lean / 10 s rich setting; SV = 30,000



*NO<sub>x</sub> conversion as function of temperature in front of diesel No<sub>x</sub>-storage catalyst  
Model gas test*

**AVECC 2001**

## Content:

---

1. Overview
    - 1-1. Legislation
    - 1-2. PM & NO<sub>x</sub> trade-off
    - 1-3. Requirement of NO<sub>x</sub> conversion efficiency for EU-IV
  2. Diesel Oxidation Catalyst
  3. NO<sub>x</sub> adsorber
  - 4. Diesel Particulate Filter**
  5. Urea-SCR
  6. Summary
- 

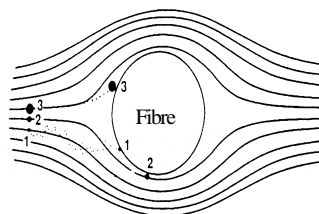
**AVECC 2001**

## Particulate Filter System

---



*Surface filter*

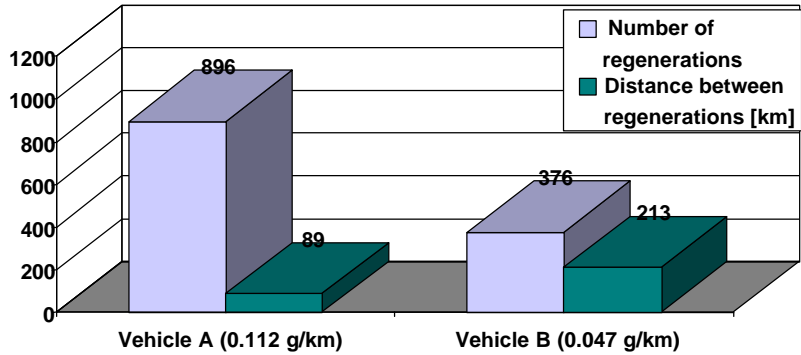


1. Diffusion 2,3. Inertia effects

*Fibre filter*

**AVECC 2001**

## Number of Regenerations vs. PM Raw Emission

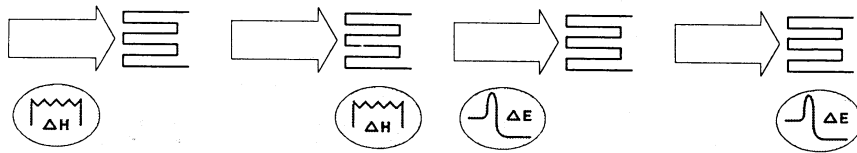


PM raw emissions measured in NEDC-cycle

Calculation of required filter regeneration cycles during 80,000 km in NEDC-cycle. Particulates loading in the filter: 10 g.

**AVECC 2001**

## Type of Filter Regeneration



- Exhaust gas heating
- Exhaust gas throttling
- Electrical heating
- Filter heating
- Electrical heating
- Burner systems
- Microwave heating
- Lowering soot ignition temperature before the filter
- Fuel additives
- Lowering soot ignition temperature in the filter
- Catalytic coating

Examples of filter regeneration methods.

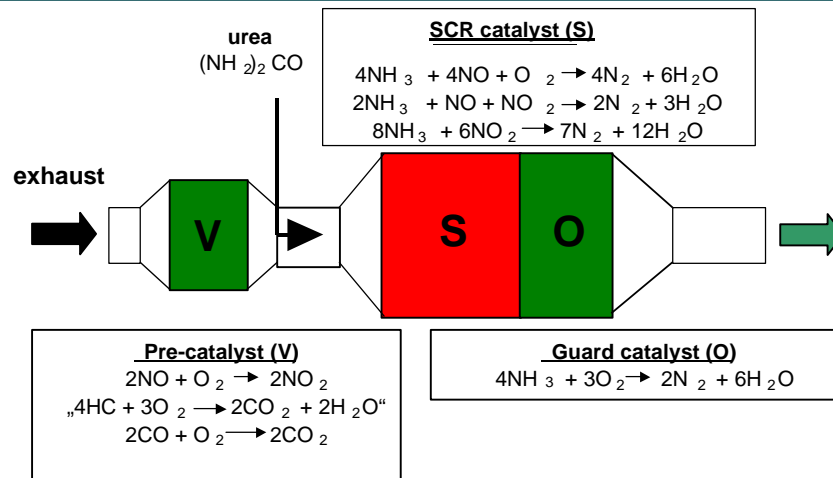
**AVECC 2001**

## Content:

1. Overview
  - 1-1. Legislation
  - 1-2. PM & NO<sub>x</sub> trade-off
  - 1-3. Requirement of NO<sub>x</sub> conversion efficiency for EU-IV
2. Diesel Oxidation Catalyst
3. NO<sub>x</sub> adsorber
4. Diesel Particulate Filter
5. Urea-SCR
6. Summary

AVECC 2001

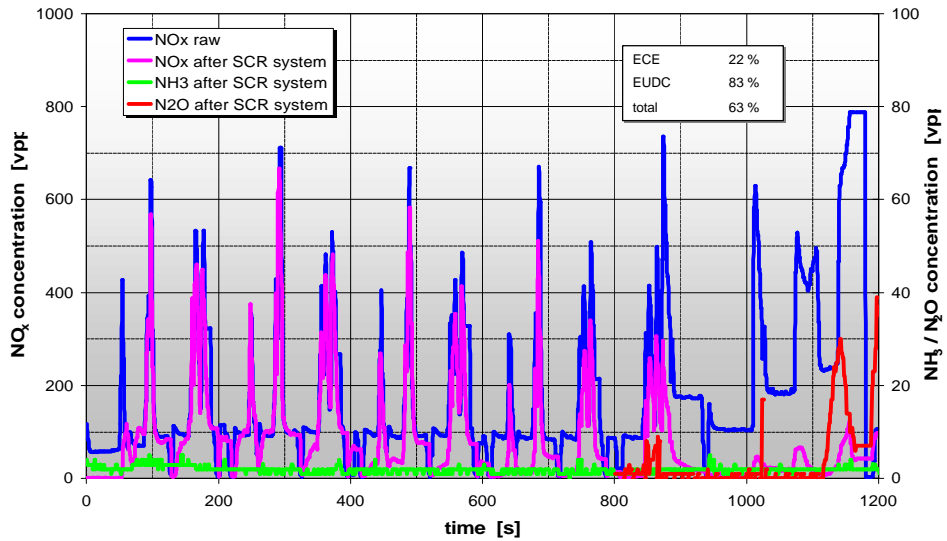
## Basic System of SCR



Operation principle of urea-SCR system.

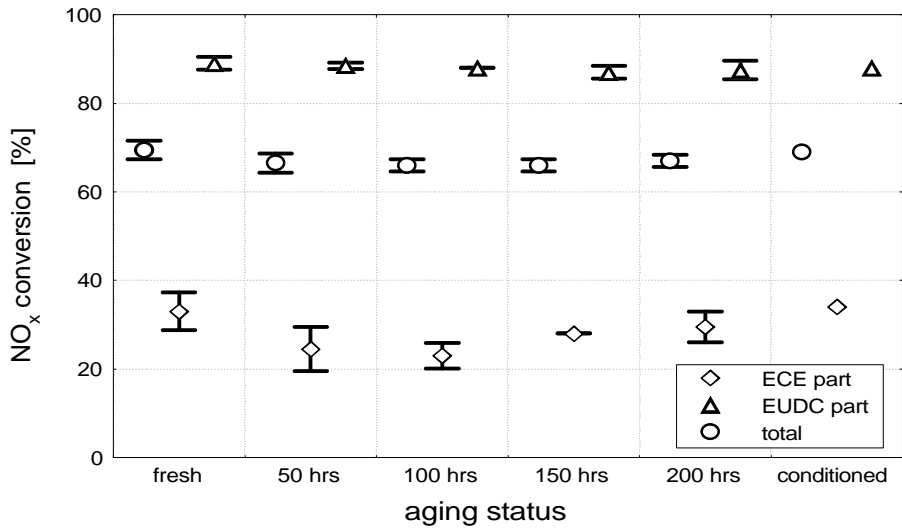
AVECC 2001

## Engine Test Result of Urea-SCR (MVEG A)



**AVECC 2001**

## Durability of Urea-SCR (MVEG A)



**AVECC 2001**

## Content:

---

1. Overview
  - 1-1. Legislation
  - 1-2. PM & NO<sub>x</sub> trade-off
  - 1-3. Requirement of NO<sub>x</sub> conversion efficiency for EU-IV
2. Diesel Oxidation Catalyst
3. NO<sub>x</sub> adsorber
4. Diesel Particulate Filter
5. Urea-SCR
6. Summary

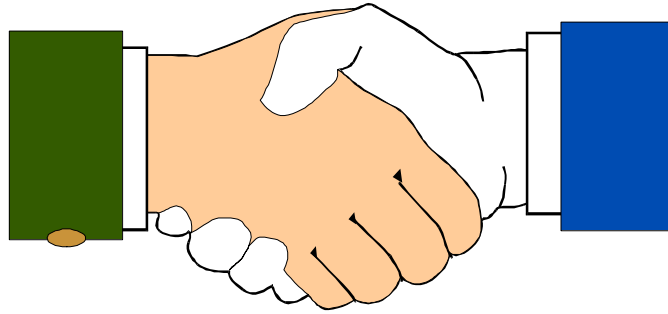
**AVECC 2001**

## Summary:

---

1. From 2000 onwards, diesel emission legislation based on modified EU-I & -II has been enforced in China, India and Thailand .
2. Diesel oxidation catalyst as the basic technology for diesel aftertreatment, combined with engine calibration can fulfill EU-III limits.
3. For EU-IV, diesel oxidation catalyst with NO<sub>x</sub> aftertreatment and/ or with particulate filter, combined with improved engine technology could be required.
4. System developments of reducing NO<sub>x</sub> over 50 %, e.g., NO<sub>x</sub> adsorber and Urea-SCR, are ongoing.
5. Particulate filter can trap PM with efficiency over 90 %.  
To develop filter regeneration method is a main challenge.

**AVECC 2001**



**Thank you for your attention !!!**

---

***AVECC 2001***