



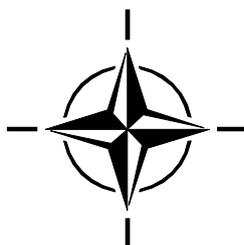
**RTO TECHNICAL MEMORANDUM**

**TM-AVT-ET-073**

# **Proposals for Solutions to Problems Related to the Use of F-34 (SFP) and High Sulphur Diesel on Ground Equipment Using Advanced Reduction Emission Technologies**

(Propositions de solutions aux problèmes liés à l'utilisation de  
F-34 (SFP) et de diesel à haute teneur en soufre pour  
le matériel terrestre disposant de technologies  
avancées de réduction des émissions)

Final Report of Exploratory Team AVT-ET-073.



Published September 2008





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# The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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## AVT-ET-073 Membership List

### Attendance Contributors during the ET-073 meetings:

#### *Chairman*

Petros Kotsiopoulos                      GRE                      AVT Panel Member, ET

#### *Members*

Fabrice Guidotti	BEL	Observer
Bob Hastinos	CAN	Observer
Luc Margotin	FRA	ET Member
Wolfgang Bienenda	DEU	ET Member
Johannes Bader	DEU	ET Member
Euripides Lois	GRE	ET Member
Wim Zijderveld	NLD	Chairman Army NFLWP
Jerzy Walentynowicz	POL	AVT Panel Member, ET
Roland Burberry	GBR	ET Member
Jawed Mugal	GBR	Chairman NFLWG
Philippe Van Exem	NATO IS	Staff Officer NFLWG
Paul Maillardet	GBR	AVT Panel Member, Observer ET – 076
Herbert Dobbs	USA	ET Member
Bob Bondaruk	USA	Observer

**Representing:** 10 countries, 1 NATO IS member, 3 NFLWG members.

**Locations:** The ET-073 met three times during the AVT Panel meetings in Amsterdam, Vilnius and Florence.

# **Proposals for Solutions to Problems Related to the Use of F-34 (SFP) and High Sulphur Diesel on Ground Equipment Using Advanced Reduction Emission Technologies**

**(RTO-TM-AVT-ET-073)**

## **Executive Summary**

The AC/112 NATO Fuels and Lubricants Working Group (NATO FLWG) made an official request at its 2005 meeting to the Research and Technology Organisation (RTO). It requested assistance to solve the problem caused by the stringent European (Euro 4/5) and equivalent US emission legislation imposing advanced emission reduction technologies for all Road Vehicles.

It has been identified that these emission reduction technologies require the use of low sulphur fuels (LSF).

F-34 used under NATO Single Fuel Policy (SFP) is a fuel with high sulphur content when it is compared to European or US compliant diesel fuels. High Sulphur Fuel (HSF) is a potential problem to NATO forces when vehicles and equipment are fitted with advanced emission reduction devices that require Low Sulphur (LS) fuel use. The problems can be either operational, emission related or both.

NATO future operations will be expeditionary; the available local diesel fuel is not likely to be compliant with low sulphur diesel specifications (i.e. EN 590). Therefore NATO forces must have a known worldwide available, standard fuel (F-34) and equipment capable of using such high sulphur fuels (HSF).

### **Recommendations**

- Future equipment fitted with advanced emission reduction technologies should be able to operate on SFP (F-34) and high sulphur diesel fuel.
- Technologies using EGR, DPF and SCR will all be affected when using HSF. However, actions can be taken to overcome problems by by-passing these systems, modifying the ECU or a combination.
- Lean NO<sub>x</sub> Traps (LNT) technology has been identified as unsuitable for military equipment when using HSF.
- Industry should be made aware that the military will prefer the technology that reduces logistic footprint.
- Further investigate the impact of (very) High Sulphur Fuels on current SRC and future technologies. It is recommended that this could be addressed in the programme of work of the AVT-159 – Impact of Changing Fuel upon Land, Sea and Air Vehicles. The acceptance of this report concludes the ET-073 work.

# **Propositions de solutions aux problèmes liés à l'utilisation de F-34 (SFP) et de diesel à haute teneur en soufre pour le matériel terrestre disposant de technologies avancées de réduction des émissions**

## **(RTO-TM-AVT-ET-073)**

### **Synthèse**

Lors de sa réunion 2005, le Groupe de travail AC/112 de l'OTAN sur les carburants et les lubrifiants (NATO FLWG) a soumis une demande officielle à l'Organisation pour la recherche et la technologie (RTO). Il réclamait de l'aide afin de résoudre le problème posé par la rigoureuse législation européenne (Euro 4/5) relative aux émissions et par son équivalent américain, qui imposaient des technologies avancées de réduction des émissions pour tous les véhicules routiers.

Il a été établi que ces technologies de réduction des émissions nécessitent l'utilisation de carburants à faible teneur en soufre (LSF).

Le F-34 utilisé en vertu de la Politique du carburant unique de l'OTAN (Single Fuel Policy, ou SFP) est un carburant à haute teneur en soufre, en comparaison des carburants diesels européens et américains conformes aux normes exigées. Le carburant à haute teneur en soufre (HSF) représente un problème potentiel pour les forces de l'OTAN lorsque les véhicules et le matériel sont équipés de dispositifs avancés de réduction des émissions nécessitant l'utilisation d'un carburant à faible teneur en soufre (LS). Les problèmes peuvent être soit opérationnels, soit liés aux émissions, soit les deux.

Les futures opérations de l'OTAN seront expéditionnaires ; il est peu probable que le carburant diesel disponible sur place soit conforme aux exigences relatives au diesel à faible teneur en soufre (norme européenne EN 590). En conséquence, les forces de l'OTAN doivent disposer d'un carburant standard universellement connu (le F-34) et d'un matériel capable de fonctionner avec de tels carburants à haute teneur en soufre (HSF).

#### **Recommandations**

- Le futur matériel équipé de technologies avancées de réduction des émissions doit pouvoir fonctionner avec du carburant SFP (F-34) et du carburant diesel à haute teneur en soufre.
- Les technologies faisant appel au recyclage des gaz d'échappement (RGE), aux filtres à particules diesel (DPF) et à la réduction catalytique sélective (RCS) seront affectées lors de l'utilisation de HSF. Toutefois, des mesures peuvent être prises pour résoudre ces problèmes : contournement de ces systèmes, modification de l'unité de contrôle électronique (ECU), ou combinaison des deux.
- Il a été établi que la technologie des pièges à NO<sub>x</sub> pauvre (LNT) ne convient pas au matériel militaire lorsque du HSF est utilisé.
- L'industrie doit tenir compte de la préférence des armées pour toute technologie qui limite le soutien logistique.
- Il convient de poursuivre les recherches relatives à l'impact des carburants à (très) haute teneur en soufre sur les SRC actuelles et les futures technologies. Il est suggéré que cela soit traité dans le programme de travail de l'AVT-159 – Impact d'un changement de carburant sur les véhicules terrestres, maritimes et aériens. L'acceptation du présent rapport conclut la tâche de l'ET-073.

# **PROPOSALS FOR SOLUTIONS TO PROBLEMS RELATED TO THE USE OF F-34 (SFP) AND HIGH SULPHUR DIESEL ON GROUND EQUIPMENT USING ADVANCED REDUCTION EMISSION TECHNOLOGIES**

## **1.0 INTRODUCTION**

### **1.1 Background**

#### **1.1.1 Fuel Issues**

The AC/112 NATO Fuels and Lubricants Working Group (NATO FLWG) made an official request at its 2005 meeting to the Research and Technologies Organisation (RTO). It requested assistance to solve the problem caused by the stringent European (Euro 4/5) and equivalent US emission legislation imposing advanced emission reduction technologies for all Road Vehicles.

It has been identified that these emission reduction technologies require the use of low sulphur fuels (LSF).

F-34 used under NATO Single Fuel Policy (SFP) is a fuel with high sulphur content when it is compared to European or US compliant diesel fuels. High Sulphur Fuel (HSF) is a potential problem to NATO forces when vehicles and equipment are fitted with advanced emission reduction devices that require Low Sulphur (LS) fuel use. The problems can be either operational, emission related or both.

NATO future operations will be expeditionary; the available local diesel fuel is not likely to be compliant with low sulphur diesel specifications (i.e. EN 590). Therefore NATO forces must have a known worldwide available, standard fuel (F-34) and equipment capable of using such high sulphur fuels (HSF).

#### **1.1.2 Legislation and Applicability to Military Forces**

The RTO/Applied Vehicle Technology (AVT) Exploratory Team (ET-073) initially considered the legal implications regarding commercial manufacturer formal type approval of vehicles to Euro 4/5 standards. It was found that for military operational road vehicles, the EU current motor vehicle framework emission regulations on type approval of motor vehicles<sup>1</sup> were not applicable. Therefore ET-073 focussed their effort addressing technical and operational issues related to the use of SFP and high sulphur diesel fuel and to give guidance and advice in the procurement of future equipment.

## **2.0 DISCUSSION**

Previous AVT-035 report did not address market solutions especially regarding the use of HSF.

The ET-073 evaluated the current manufacturers' emission reduction technologies by conducting a literature search and by collecting manufacturers and suppliers data from the participating nations. The survey indicated that manufacturers had developed their emission reduction technologies specifically for LS fuel use. It was

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<sup>1</sup> 70/156/EEC and particularly the daughter directives the daughter Directives being 2005/55/EC (88/77/EEC) or (70/220/EEC) or ECE 49/02 and 83/04 as last amended for motor vehicle emissions.

also found that a new technology suitable for HSF is not likely to be developed only for the needs of military users.

Therefore, the ET-073 needed to consider current technologies adapting these to best meet military requirements. As a consequence of this, nations such as Germany conducted work in close relationship with the industry to identify possible solutions.

The ET-073 team agreed following programme of work addressing the short term and long term strategies:

- Considering the need for a quick answer to the NATO Pipeline Committee (NPC), it was decided to provide a guidance and advice document based on current technologies to procurement services.
- To address the long term impact of the use of HSF, it was decided that more work was needed and that this would be best addressed in the new Task Group AVT-159 investigating of “Impact of Changing Fuel on upon Land, Sea and Air Vehicles”.

## **2.1 Possible Current Technology Vehicle Exhaust Emissions Solutions**

The emission control technologies that engine manufacturers currently use are the following:

- 1) Exhaust Gas Recirculation (EGR) to control NO<sub>x</sub> emission accompanied by increased boost pressure and advanced start of injection to control soot.
- 2) Diesel Particulate Filter (DPF) to control soot emissions.
- 3) Oxidation Catalysts to control CO and HC emissions and to meet the high temperatures for regenerating the DPF.
- 4) Selective Catalytic Reduction (SCR) systems to control NO<sub>x</sub>.
- 5) Lean NO<sub>x</sub> Traps (LNT) to control NO<sub>x</sub> emissions.

Most manufacturers use (combinations of) several technological solutions. The ones that specifically require the use of a low sulphur fuel are 2, 4 and particularly 5. Technological solution “5” is so sensitive to high sulphur fuel because its use will lead to absorber poisoning drastically limiting its efficiency.

## **2.2 Effects**

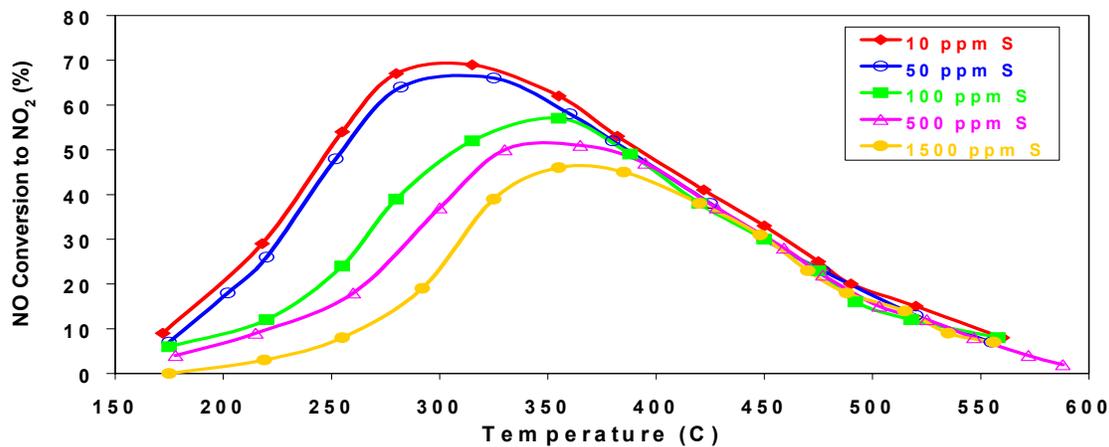
### **2.2.1 Effect of Sulphur Contained in the Fuel**

- Inhibits catalyst performance by strong adsorption on surface and competes for space on the catalyst surface with pollutants.
- Limits the amount of NO<sub>2</sub> formed on an oxidising catalyst – a problem for some particulate DPFs and NO<sub>x</sub> adsorbers that rely on NO<sub>2</sub> for their regeneration.
- Reacts with chemical NO<sub>x</sub> traps more strongly than NO<sub>x</sub> – this decreases NO<sub>x</sub> storage capacity and requires more vigorous and frequent regeneration; increasing fuel consumption.
- Creates sulphate particles that are measured by current sampling and measurement techniques, with any emission control system that includes a precious metal catalyst with an oxidising function.
- Contributes to coating the catalyst surface.

## 2.2.2 Effect of Sulphur on Advanced Emission Reduction Technologies

### 2.2.2.1 Diesel Oxidation Catalysts (DOCs)

- An oxidation catalyst will reduce the soluble organic fraction (SOF) of the particulate by up to 90%. Destruction of the SOF is important because this portion of the particulate contains numerous chemicals of concern to health experts. Control of the SOF enables the oxidation catalyst to reduce total particulate emissions by 25 to 50 percent, depending on the constituents that make up the total particulate. This technology also reduces diesel smoke and eliminates the pungent diesel exhaust odour. DOC technology has been successfully used on all diesel cars sold in Europe since 1996. DOCs may also be used in conjunction with a DPF, NO<sub>x</sub> absorber, a DeNO<sub>x</sub> catalyst, or SCR to “clean-up” any by-pass of injected hydrocarbons or ammonia. It has been identified that high sulphur reduces the efficiency of the catalyst by reducing its operating temperature and by increasing the formation of sulphated ash. The low operating temperature of the oxidation catalyst reduces the formation of NO<sub>2</sub> needed for the regeneration of the DPF.



### 2.2.2.2 Fuel Sulphur Effects on Diesel Particulate Filter (DPF).

- HSF will cause two different types of negative effects. The first will reduce the catalyst efficiency by reducing the high the operating temperature needed for regenerating the DPF. The second one will be caused by the oxidation of sulphur dioxide resulting in high levels of sulphated ash and total particulate mass. Depending on the DPF design the experienced negative effects will differ as follows:

#### 1) Fuel Sulphur Effects on Wall Flow Diesel Particulate Filter (WF-DPF)

The WF-DPF is a honey comb structure with parallel pipes. These pipes are alternating closed and opened. The inlet pipe at one end and the outlet pipe at the other. Thus gas may only flow through the wall of the filter. Soot particles will be collected in the inlet pipe.

Using HSF will result in an increased loading of the filter and causing frequent regenerating cycles. Additionally, to the reduced performance of the oxidation catalyst will result in an overload and a blocking of the filter. The filter must then be replaced or regenerated externally.

#### 2) Fuel Sulphur Effects on Flow-Through Metallic Particulate Matter Filter (M-PMF)

M-PMF is structured in a layered stack consisting of corrugation foil with shovels and porous fleece. Exhaust gas is introduced to both up and down side of fleeces by shovels, and then soot is trapped

while gaseous components pass the fleece. The nitrogen oxides produced in the oxidation pre-catalyst cause the soot particles to be burned continuously.

As explained in Annex A, the use of HSF will reduce the over all efficiency of the system but will not block the M-PMF.

### 2.2.2.3 Fuel Sulphur Effects on *Selective Catalytic Reduction-System (SCR-System)*

The SCR-System eliminates NO<sub>x</sub> from the exhaust gas for diesel engines by using urea dissolved in water and a catalytic converter for use in trucks and passenger cars. This technology requires no modification of the engine.

The function of the SCR-System (see Annex B page 9) is as follows.

The SCR-System is an integrated exhaust-system. Using the catalytic reduction process the harmful nitrous oxides (NO<sub>x</sub>) are converted into nitrogen (N<sub>2</sub>) and water (H<sub>2</sub>O). The emission of nitrous oxides is consequently reduced by 90%.

In a two-stage process the urea decomposes to ammonia (NH<sub>3</sub>) which then reacts with the nitrogen oxides (NO<sub>x</sub>) and leads to formation of nitrogen and water.

An aqueous urea solution (urea dissolved in water) containing 32.5% of urea used as a reducing agent, which is added to the exhaust gas by injection nozzle after the Oxidation-catalyst and before the SCR-catalyst.

The injection of urea (vol. required approximately 3 – 4% of diesel consumption) is controlled by the Emission Control Unit (ECU) and requires several ECU (engine power, temperature of the engine, etc.) input parameters.

The operation in trucks and passenger cars can be seen in Annex B page 10-13.

It is expected that the use HSF will decrease the efficiency of the oxidation catalyst but more testing is required to qualify the exact impact.

### 2.2.3 Current Emission Technology Solutions

The solution for overcoming the use problem of HSF depends mainly on the emissions control technology; considering the available information from the literature search and assessment testing. It is apparent that the most promising current technological solutions are as follows:

- EGR
  - This solution is less sensitive to HSF usage. It is possible to use fuels with sulphur content up to 3000 ppm. However other longer term maintenance issues still require to be considered and should be proven by projects i.e. durability, wear of valves, liners and compressions rings. A system control option that may help longer term wear using HSF is to enable the system to maintain the EGR valve closed.
- DPF
  - The use of WF-DPF is not recommended because the use of HSF will lead to filter blocking. Systems fitted with such a device will require being by-passed or removed when operating on HSF.
  - The use of M-PMF is more suitable because although efficiency is reduced, the filter will not block.

- Oxidation Catalyst
  - The best option to overcome the adverse impact of HSF on this device is to bypass the catalyst.
  - If not possible to by-pass then action must be taken to address any negative effect to the ECU.
- SCR
  - The use of a HSF will definitely have a very negative effect on the SCR system. But in this case it is relatively easy to bypass the system without significant affect on the engine. When using HSF it would be acceptable not to carry urea product and an ECU may be changed or modified to give the required signals to maintain correct engine operation.
- LNT
  - This is the worst case solution for HSF. The use LNT will lead to severe catalyst poisoning. It is extremely difficult to by pass the catalyst in this case because the ECU utilizes signals form various sensors to adjust the operation of the engine. The engine operates periodically under lean and rich operating modes. Rich operation will require frequent regeneration of the LNT. **Therefore this system is unsuitable for operation on HSF.**
- ECU
  - Stringent emission legislation requires an on board diagnostic system (OBD) integrated in the ECU to control the exhaust gas quality. HSF use will negatively impact on ECU and action must be taken to overcome the engine performance reduction by modifying or replacing the ECU. This has already been successfully applied by the UK and German MODs.

### **3.0 RECOMMENDATIONS**

Evaluating the available information the ET-073 team came to following recommendations:

- Future equipment fitted with advanced emission reduction technologies should be able to operate on SFP (F-34) and high sulphur diesel fuel.
- Technologies using EGR, DPF and SCR will all be affected when using HSF. However, actions can be taken to overcome problems by by-passing these systems, modifying the ECU or a combination.
- LNT technology has been identified as unsuitable for military equipment when using HSF.
- Industry should be made aware that the military will prefer the technology that reduces logistic footprint.
- Further investigate the impact of (very) HSF on current SCR and future technologies. It is recommended that this could be addressed in the programme of work of the AVT-159 – Impact of Changing Fuel upon Land, Sea and Air Vehicles. The acceptance of this report concludes the ET-073 work.

#### **Special Note**

- Where NATO Nations decide to procure and use Commercial off the Shelf (COTS) vehicles, the Euro 4/5 legislation for type approval will apply. They will need to use commercial type approved technology solutions and a service modification may not be legally or contractually available. The UK MOD requires consideration of fuel issues for Military Logistics Vehicles in contracts by reference to a MOD defence Standard<sup>2</sup>.

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<sup>2</sup> MOD Defence Standard 23-6 Issue 4 dated 1 November 2005 (Paragraph 7 Working Fluids).



# Single Fuel Policy

## Compatibility with EURO 4 Diesel Engines

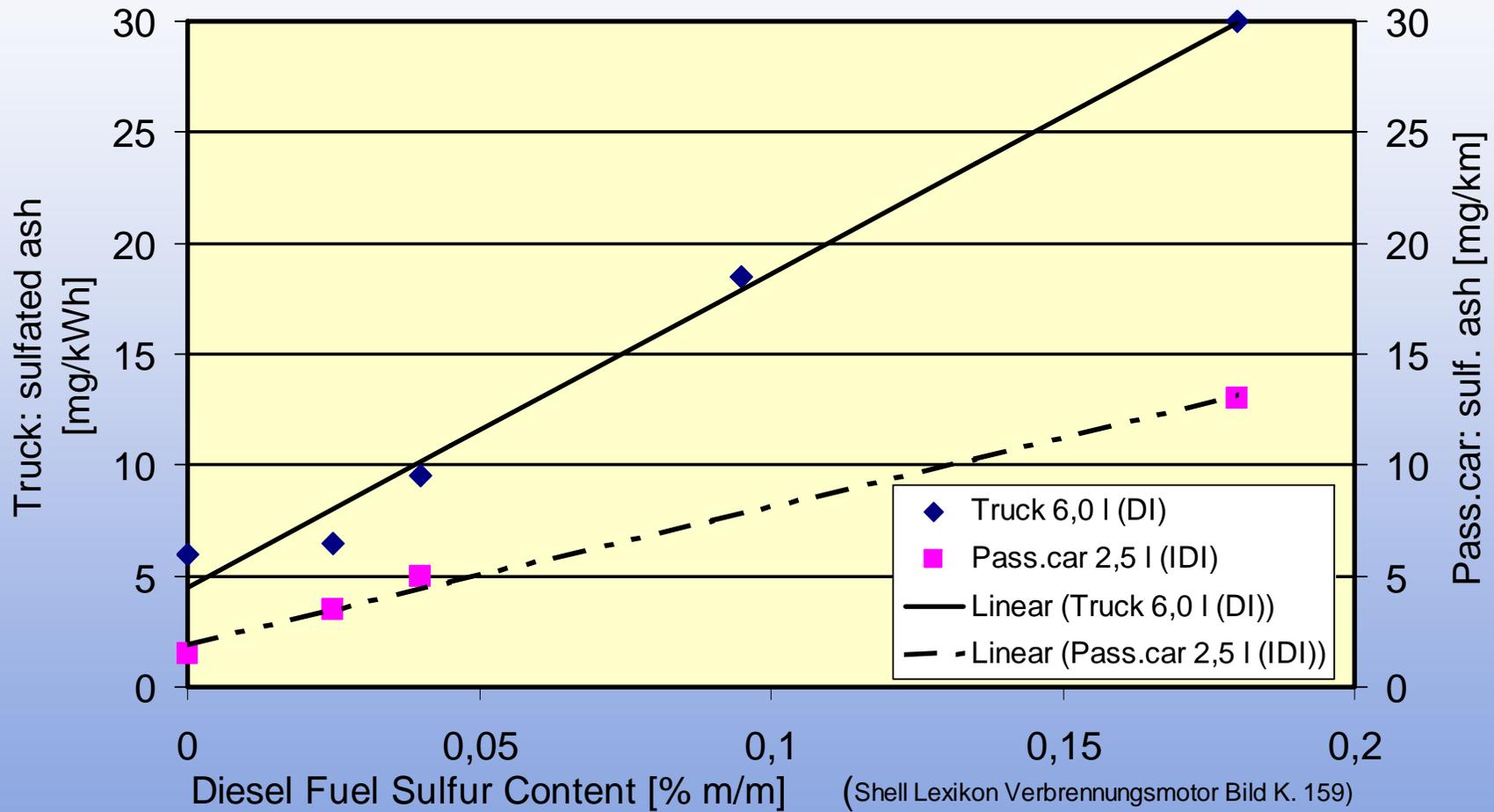
**NATO RTO AVT ET-073 SPRING MEETING 2007**  
(Florence, Italy, May 2007)

**(Dipl.-Ing. (FH) Johannes Bader, WIWEB-420)**

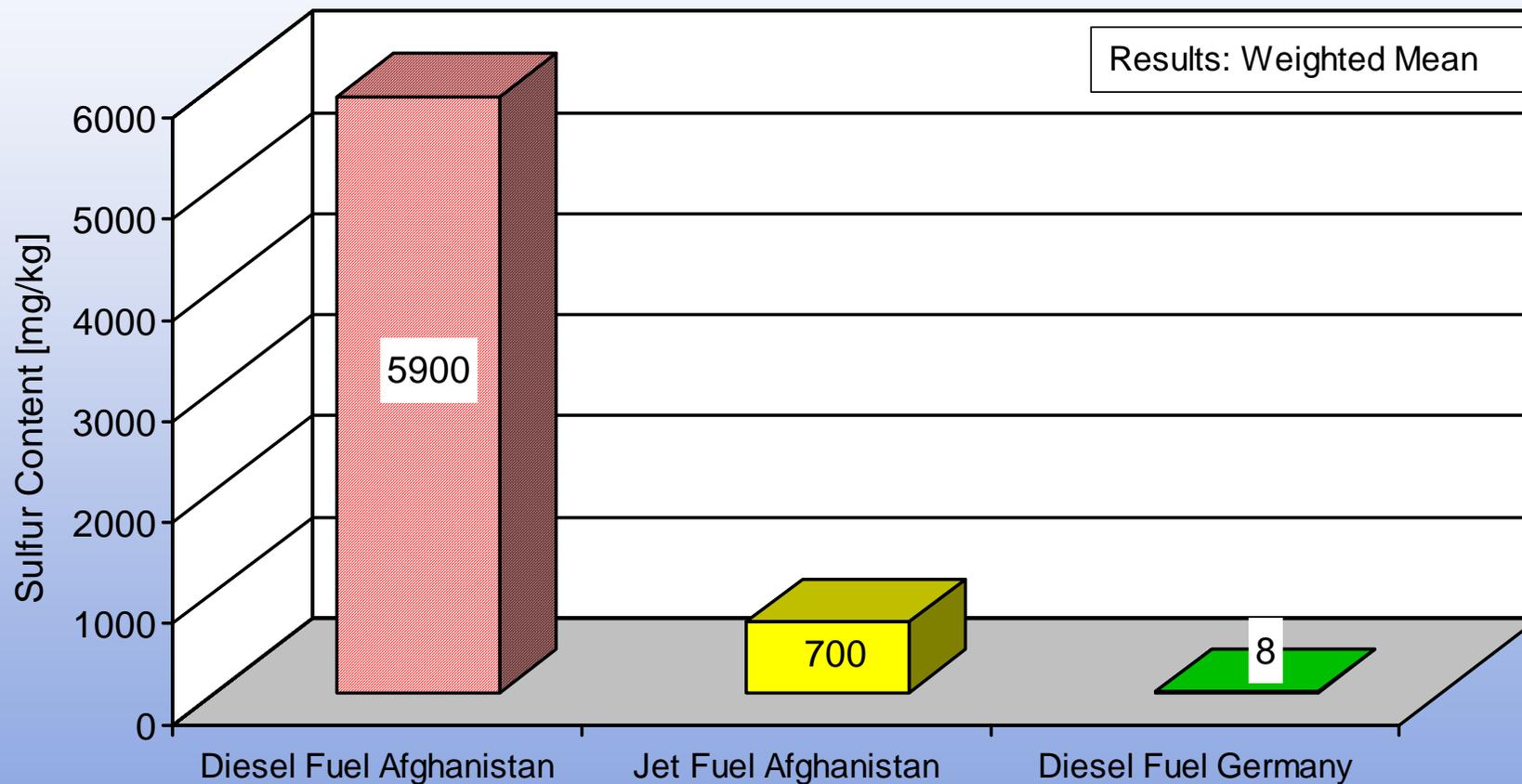
# Content

- Effect of Fuel Sulfur Content on Particulate Emissions
- Sulfur, Aromatic Content and CFPP of Kerosene and Diesel Fuel in Germany and in the ISAF Mission Region
- Technologies to Meet Euro 4/5 Exhaust Gas Legislation Limits with Application Examples
- Compatibility Tests with F-34 and O-236 in an Euro 4 Diesel Engine for Heavy Duty Truck Application

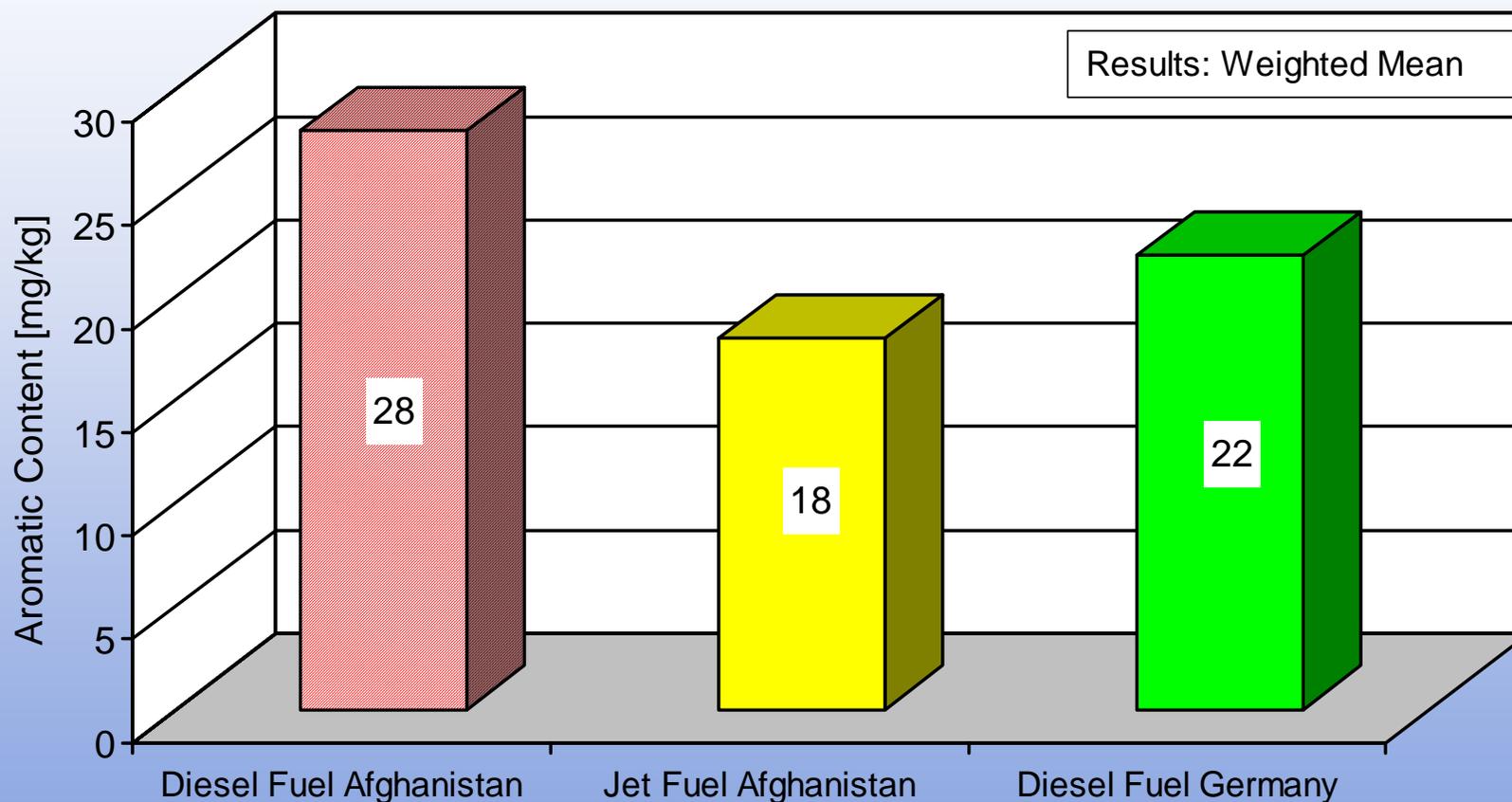
### Fuel Sulfur Content Influences Particulate Emissions



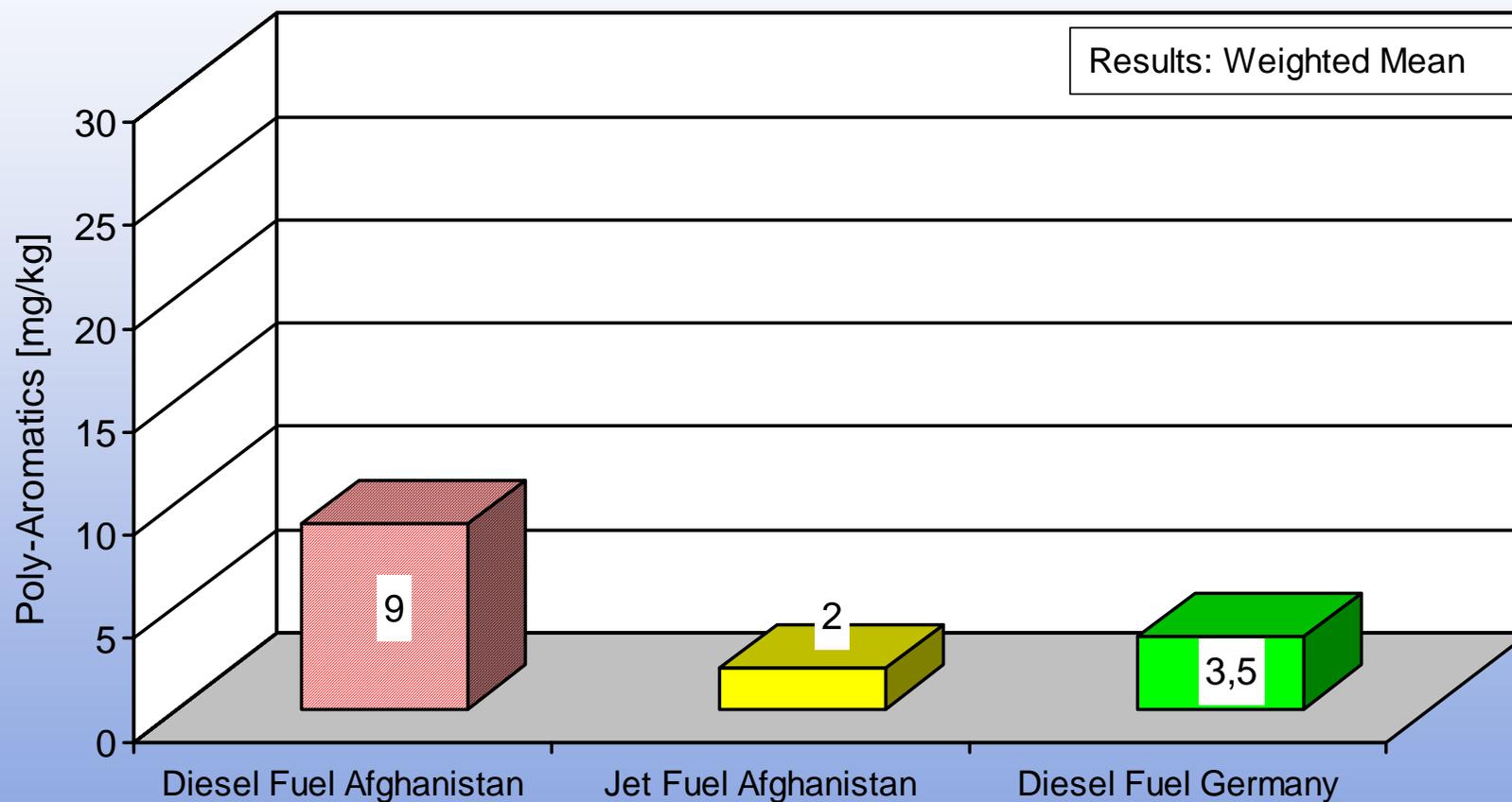
### Fuels: Total Sulfur Content



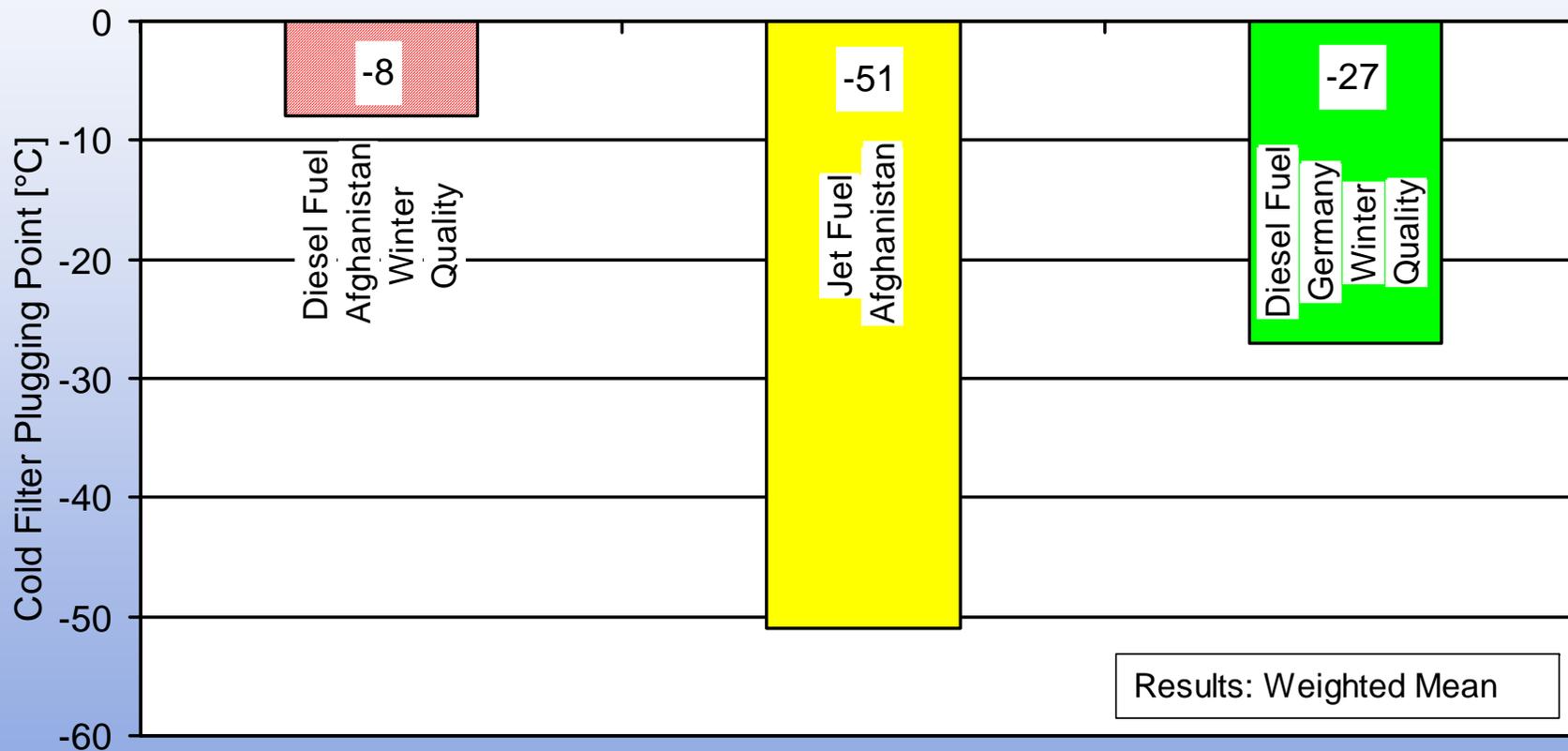
## Fuels: Total Aromatic Content



## Fuels: Poly-Aromatic Content



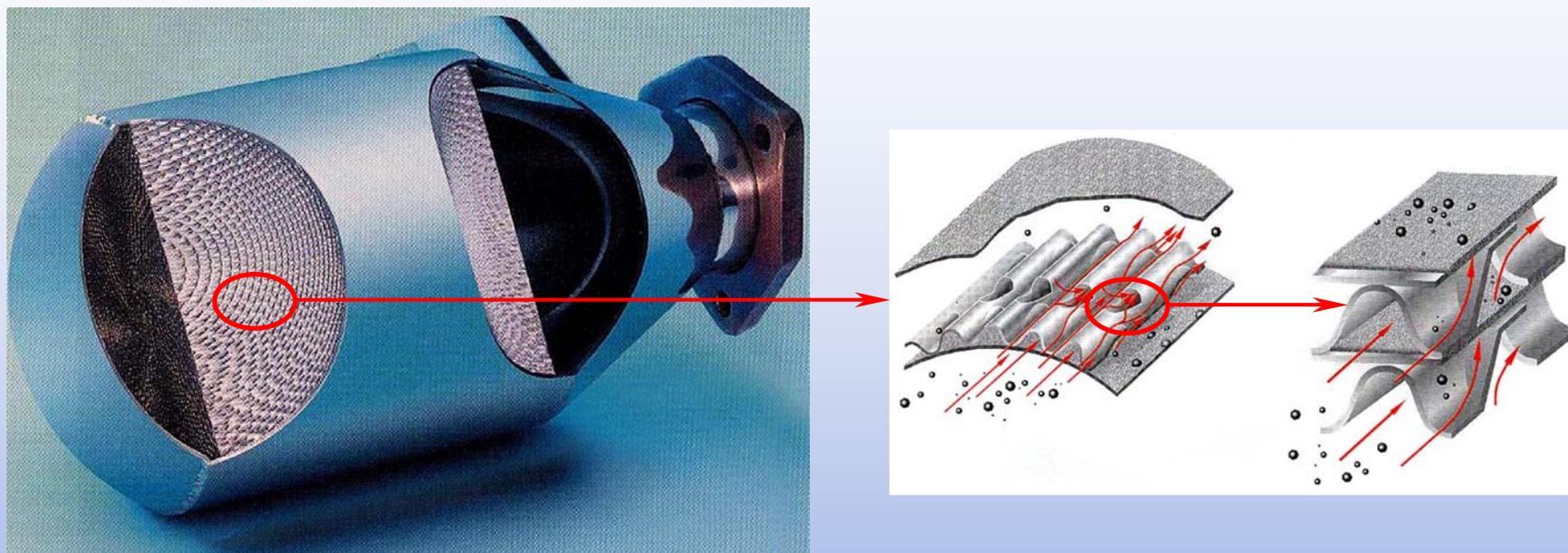
## Fuels: Cold Temperature Behavior



## Technologies To Meet EURO 4/5 Exhaust Gas Limits

- **Homogeneous Charge Compression Ignition (HCCI):**  
Combustion principle with external air-fuel mixture formation to avoid soot **and** nitrogene-oxide formation;  
Today not available for series application!
- **Exhaust Gas Recirculation (EGR)** to avoid nitrogene-oxide formation in combination with exhaust gas aftertreatment via **Particulate Matter Filter (PMF)**.
- High temperature combustion to avoid soot formation combined with exhaust gas aftertreatment to reduce nitrogene-oxides [DeNOX-Catalyst or **Selective Catalytic Reduction (SCR)**];  
Detailed explanation by Mr Bienenda.

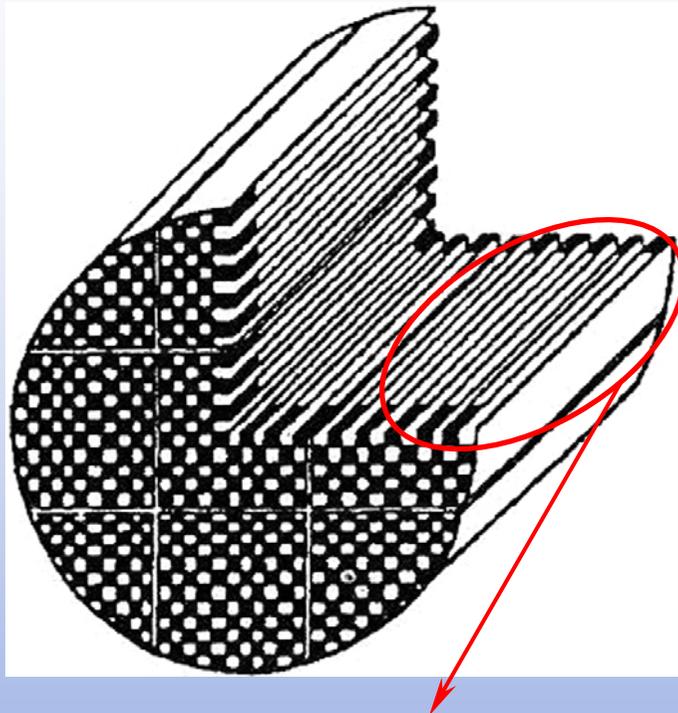
## Flow-Through Metallic PM Filter (M-PMF)



### Principle of the M-PMF

M-PMF is structured as layers stack consisting of corrugation foil with shovels and porous fleece. Exhaust gas will be introduced to up and down side of fleeces by shovels, and then soot can be trapped while gaseous components pass the fleece. With the help of the nitrogene oxides produced in the oxidation pre-catalyst the soot particles will be burned continuously.

## Wall Flow Diesel Particulate Filter (DPF)



### Principle of the DPF

The DPF is structured like a honey comb with parallel pipelines. These pipelines are alternating closed. The inlet pipeline at the end and the outlet pipeline at the front. Thus the gas flow has only the chance to go through wall of filter. Soot particles will be collected in the inlet pipeline.

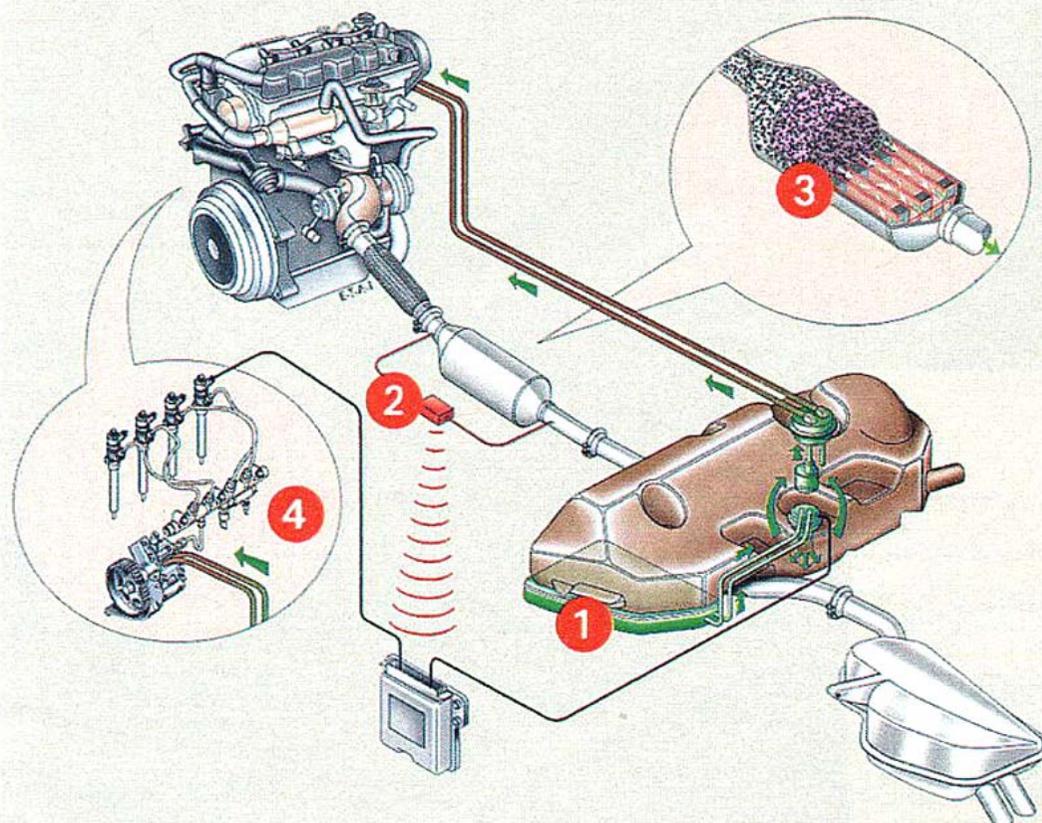
When the difference pressure limit between DPF-inlet and -outlet is exceeded a regenerating process has to be carried out by arising the exhaust gas temperature for soot oxidation. In order to remove the therefore needed temperature some OEM especially the French use a catalytic additive. But depending on the fuel and engine oil quality and the operating profile, the durability of this filter type is limited. If the inlet pipelines will be clogged by sulphated ash or reaction products of other ash forming components (e.g. engine oil additives) the DPF has to be replaced.

**→ Not suitable for military use!**

## Diesel Particulate Filter (DPF) Application Example 1

### Filtersystem mit Additiv bei Peugeot und Citroën

*Das erste System am Markt hält nahezu 100 Prozent der Partikel zurück*



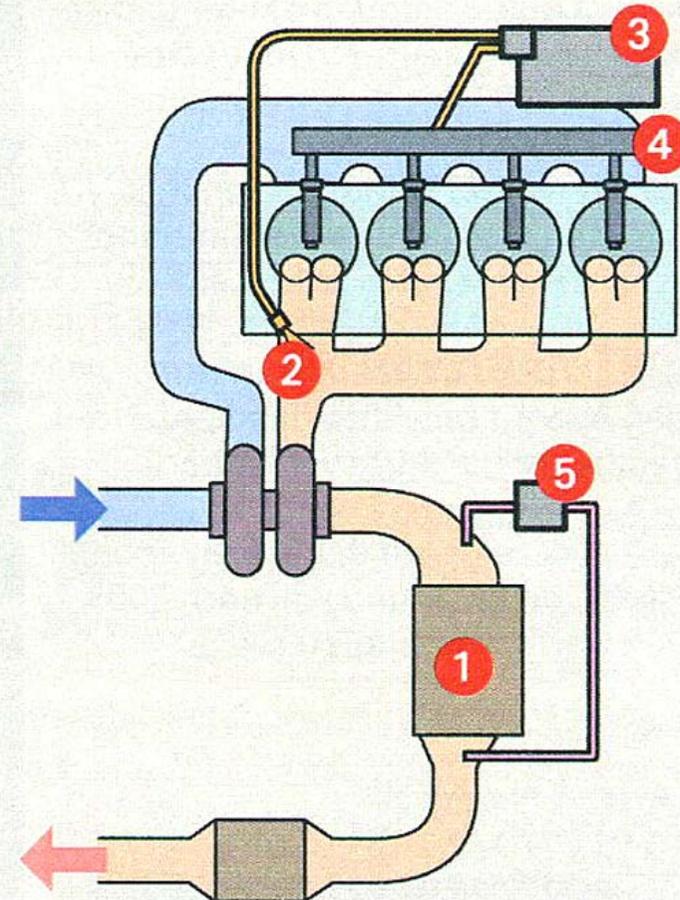
Beim PSA-System wird das Additiv Cer in einem eigenen Tank **1** mitgeführt und dem Dieselkraftstoff vom Motorsteuergerät permanent beigemischt. Ein Drucksensor **2** erkennt die Ruß-Beladung des Filters **3** und gibt über die Motorelektronik den Befehl an das Common-Rail-System **4** für eine Nacheinspritzung. So steigt die Abgastemperatur, und die heißeren Gase führen zusammen mit Cer zum Abbrennen des Rußes.

## Diesel Particulate Filter (DPF) Application Example 2

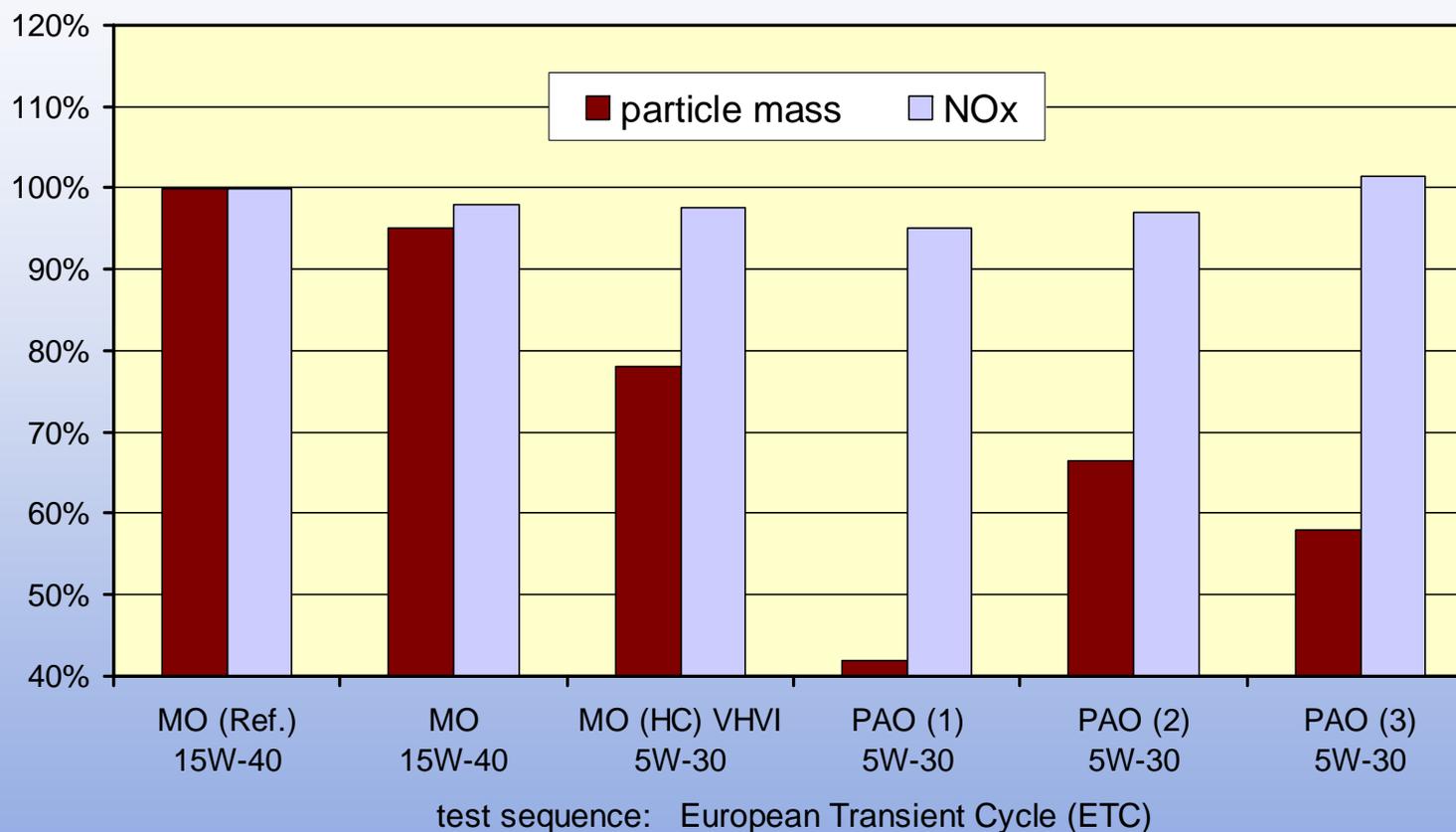
### Toyota arbeitet mit einer zusätzlichen Einspritzdüse

*Extradiesel im Abgastrakt reinigt den Filter*

Auch Toyota erhöht zum Regenerieren des Filters **1** die Abgastemperatur, allerdings kann hier zum Verbrennen des Rußes auf ein Additiv verzichtet werden. Im Auspuffkrümmer des Motors sitzt eine zusätzliche Einspritzdüse **2**. Wann aus ihr eine Zusatzportion Diesel in den Abgasstrom gemischt wird, entscheidet die Steuerelektronik **3** der Common-Rail-Einspritzung **4**. Auch hier liefert ein Drucksensor **5** die notwendigen Informationen. Er misst die Druckverhältnisse vor und nach dem Filter. Ist der Unterschied zu groß, wird regeneriert.



## Influence of Engine Oil on to the Emission Quality



**MO:** Mineral Oil    **HC:** Hydrocrack Oil    **VHVI:** Very High Viscosity Index    **PAO:** Poly-Alpha-Olefine (Synthetic Oil)

Quelle: Bleimschein, Fotheringham, Plomer, Reboul: „Lubricant Base Oil Effects on Regulated Euro 2 Heavy Duty Diesel Engine“  
published in Mineralöl Technik, Ausgabe 5/2003

## Compatibility Test with F-34 and O-236 in an Euro 4 Engine

Full Scale Engine Test in Cooperation with MAN and WTD 41

**Duration: 1000 h (2,5x 400 h Test according to NATO AEP 5)**

### Test Item:

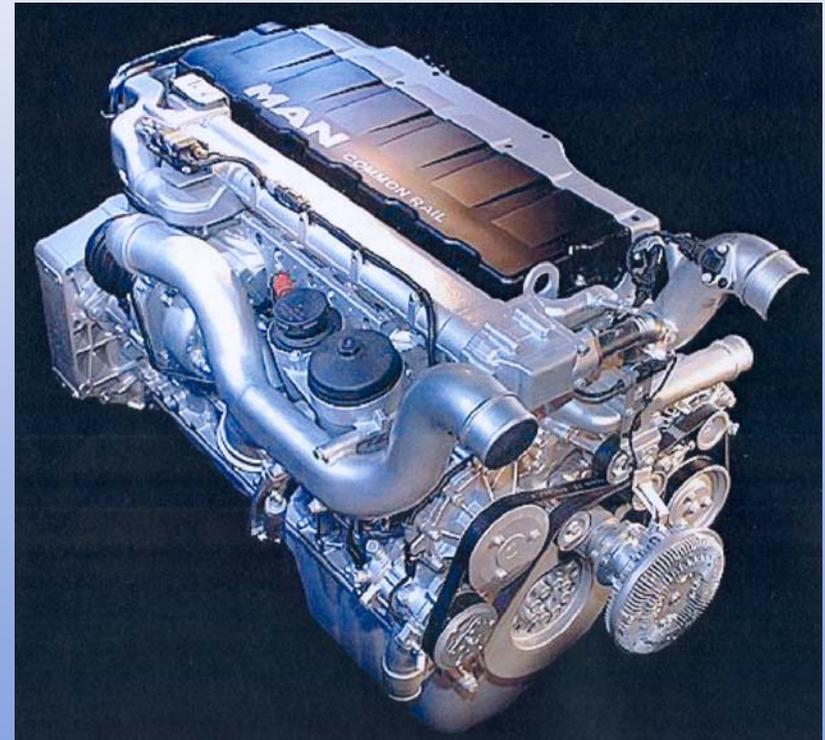
MAN D2066 LF 11 6-Cyl. (in-line)  
turbocharged intercooled DI Engine,  
with EGR and PM-Catalyst (M-PMF)

Inject.-System: Common-Rail, fuel-  
lubricated, hardened  
for military application

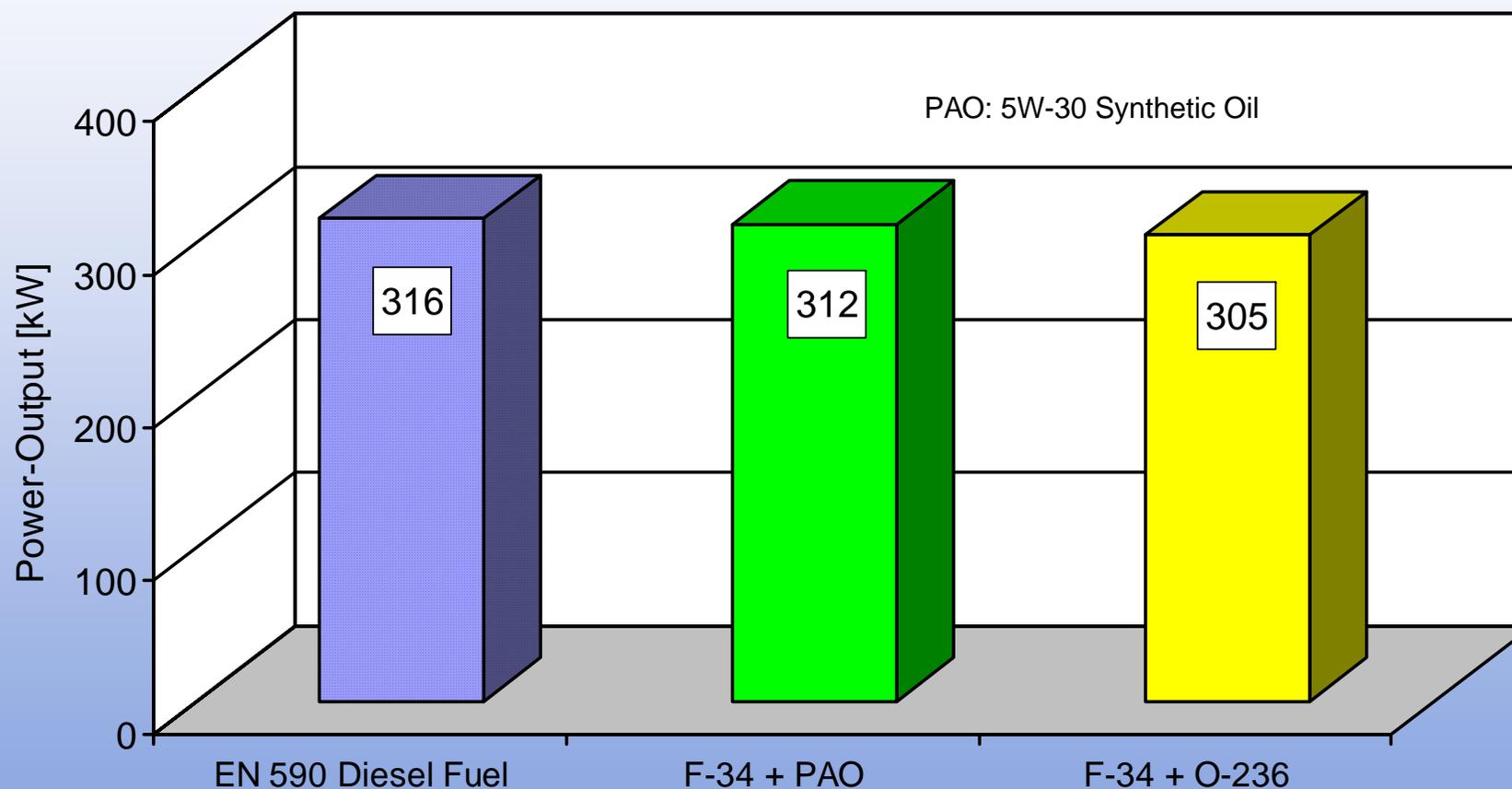
Stroke Volume: 10,52 ltrs

Rated Torque: 2100 Nm (1000-1400)

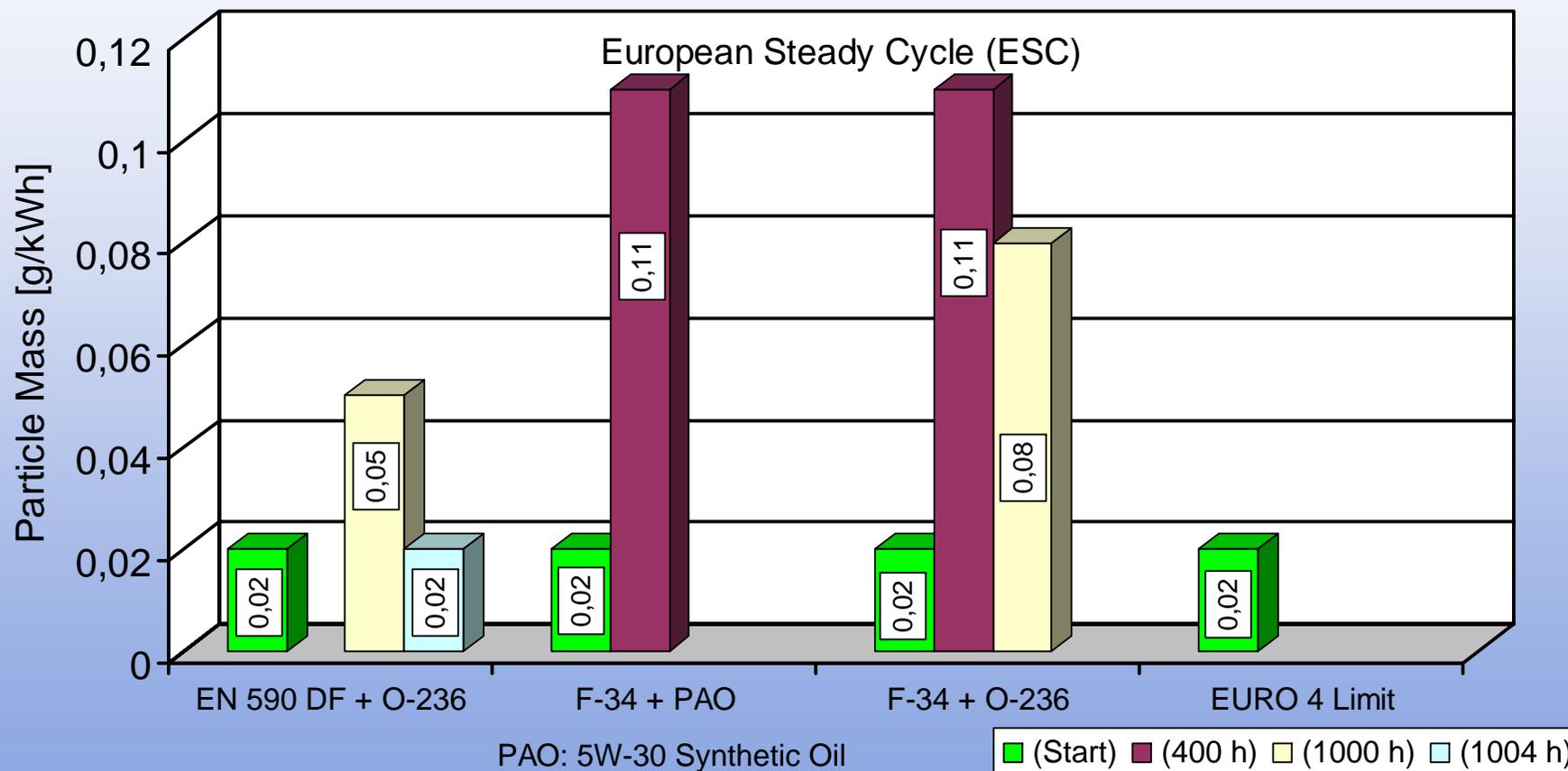
rpm Rated Power: 316 kW (1900 rpm)



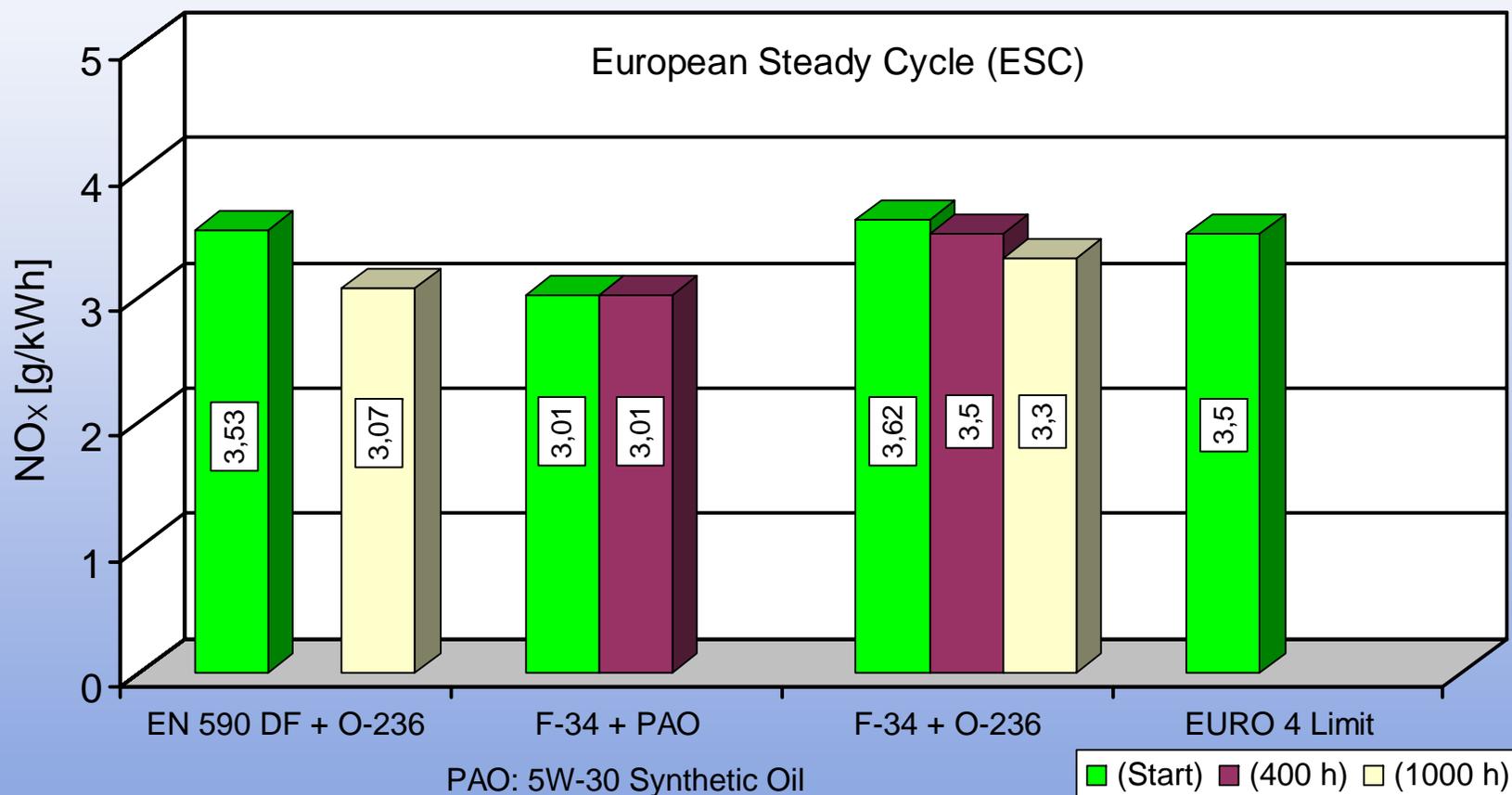
## MAN D2066LF11 Engine: Power-Output



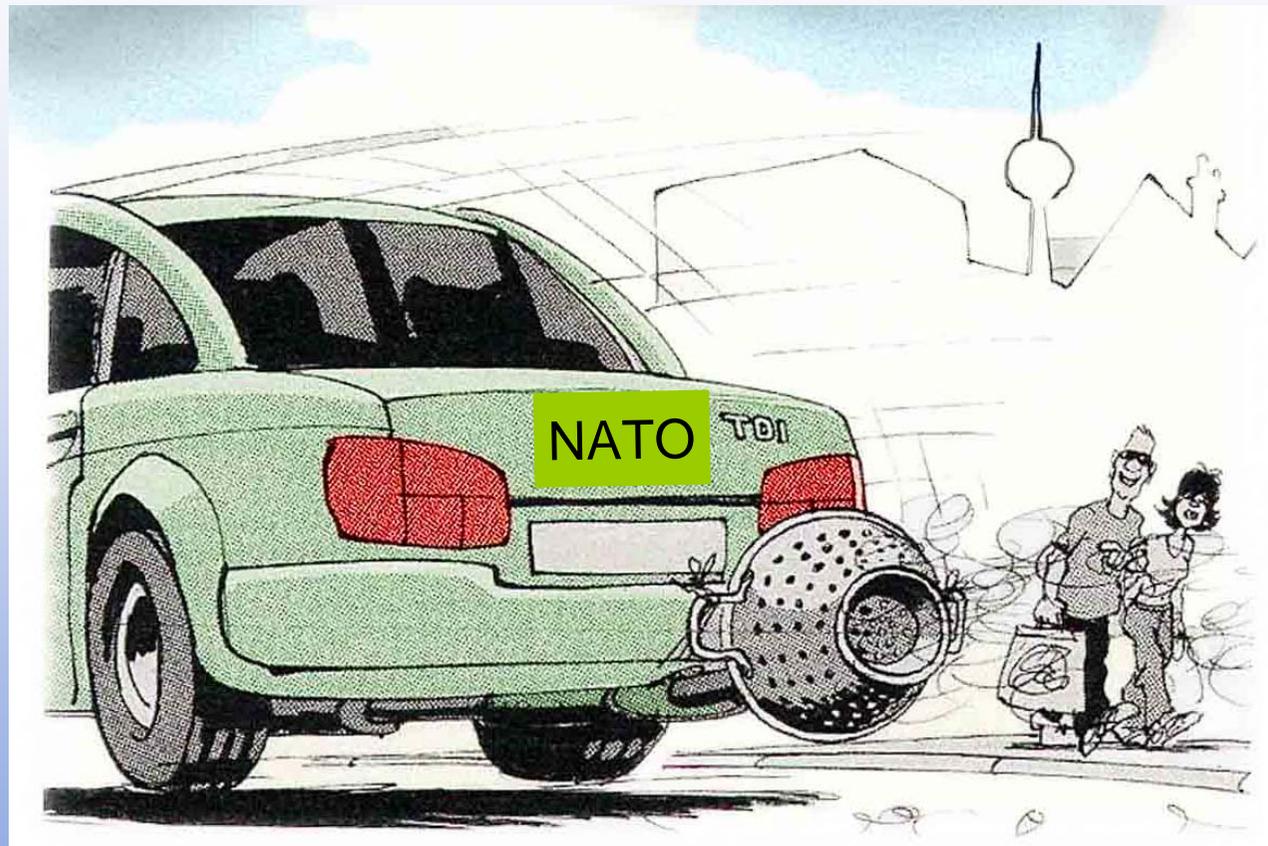
### MAN D2066LF11 Engine: Particle Mass



## MAN D2066LF11 Engine: NO<sub>x</sub> Emission



This solution is quite doubtfully.



Thank you for attention !

**AVT ET-073**

**14.-18. May 2007 Florence**

# **The Impact of F-34 (SFP) and high Sulphur Diesel on Ground Equipment using Advanced Reduction Emission Technologies**



## **The SCR-System in Military Application**

## Content

- Introduction
- Development of the exhaust threshold values standard from 1990 to 2008 in europe
- Present Technologies to reduce diesel exhaust emission for EURO 4/5
- What is the SCR-System?
- Effect of the SCR-System
- How works the SCR-System ?
- The SCR-System realised in Trucks
- The SCR-System realised in passenger vehicles
- Dieselquality ( Sulphur Content) worldwide
- Influece of Dieselquality for the SCR-System
- Next stepps for the Industry and military User

## Introduction

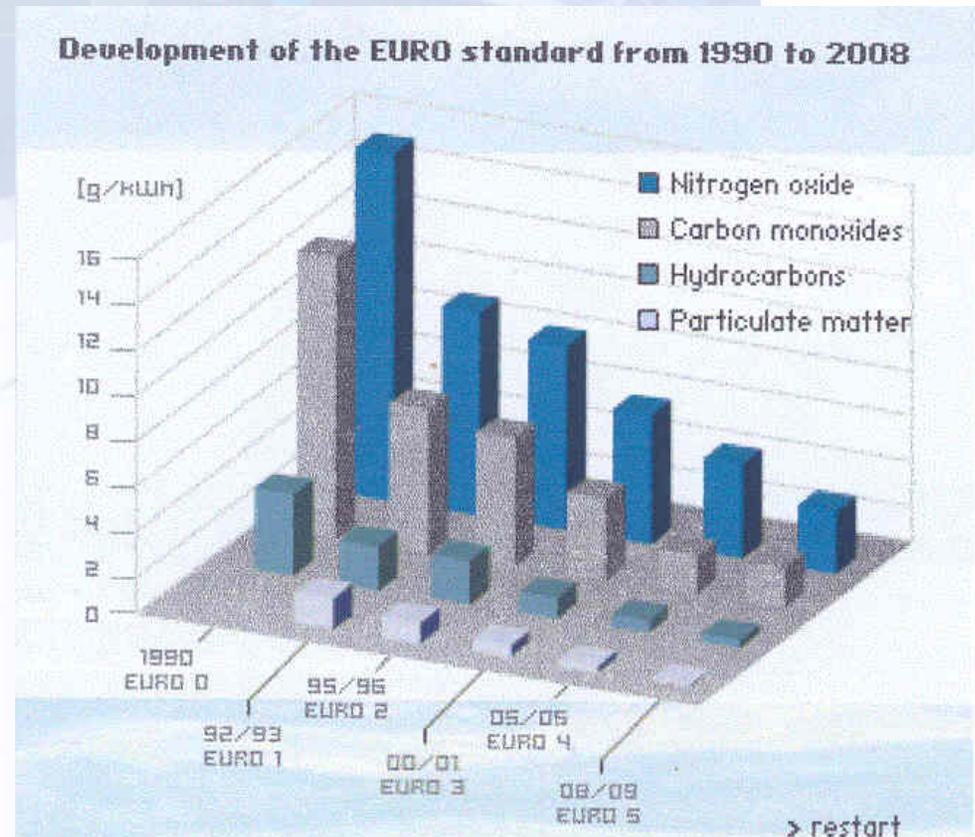
The development of new technologies for the exhaust threshold values EURO4/5 in Europe has the consequence that we will have higher requirements for diesel quality for these systems.

So it will be necessary to investigate the effects of diesel with high sulphur or F-34 for military application.

## Development of the exhaust threshold values standard from 1990 to 2008 in europe

The reduction percentage in the periode 1990-2008:

- Nitrogen oxide (NO<sub>x</sub>): 86%
- Carbon monoxide (CO): 87%
- Hydrocarbon (HC): 81%
- Particle emission (PM): 94%



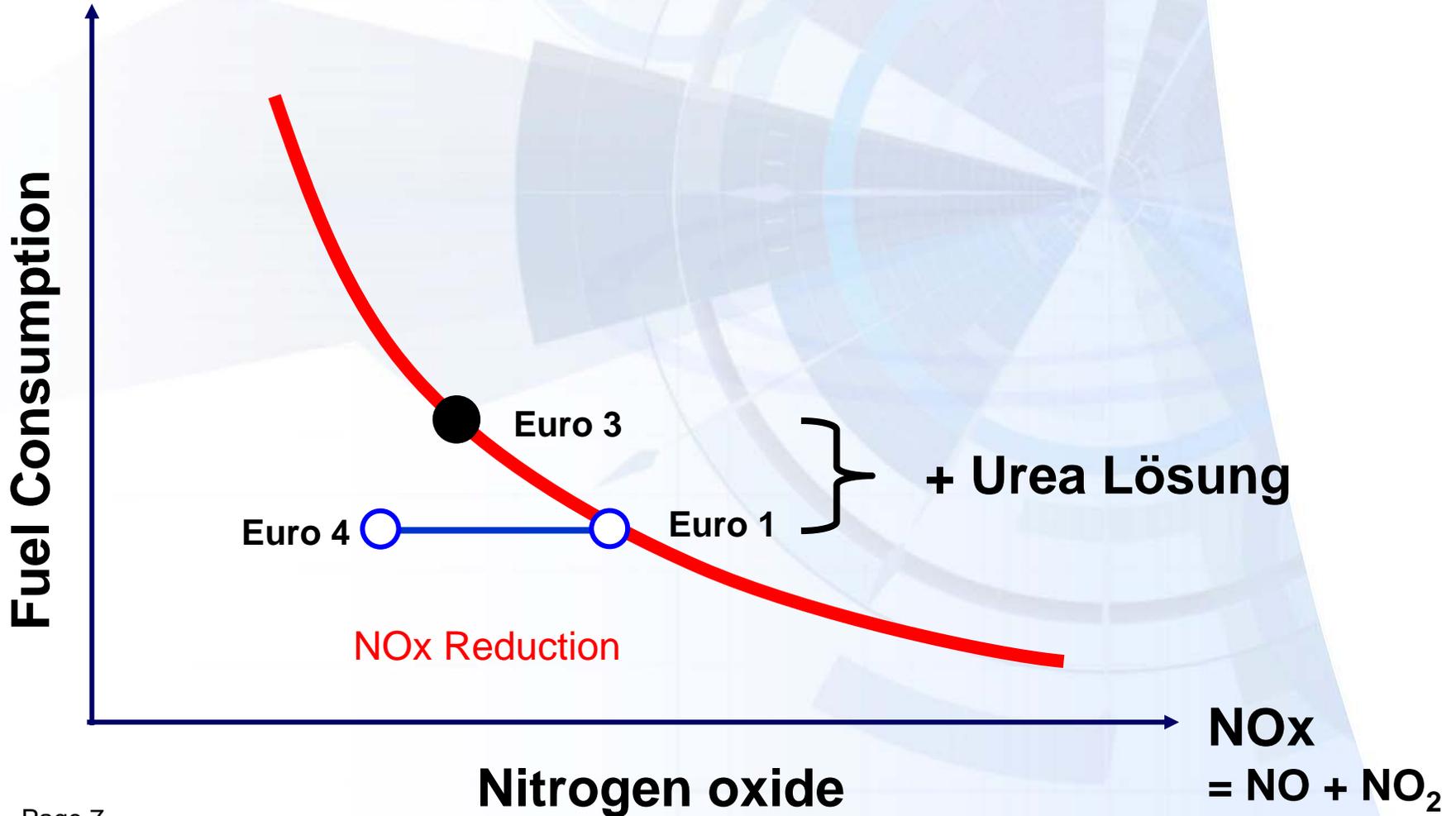
## **Present Technologies to reduce diesel exhaust emission for EURO 4/5**

- SCR ( **S**elective **C**atalytic **R**eduction )
- HCCI ( **H**omogeneous **C**harge **C**ompression **I**gnition )  
Detailed explained by Mr. Bader
- EGR ( **E**xhaust **G**as **R**ecirculation )  
Detailed Explained by Mr. Bader

## What is the SCR-System ?

- The SCR-System ( **S**elective **C**atalytic **R**eduction-System) is the specific elimination of Nitrogen-Oxides from the exhaust gas for diesel engines by using “AdBlue” ( Urea dissolved in water ) and a catalytic converter realised in trucks and passenger cars.

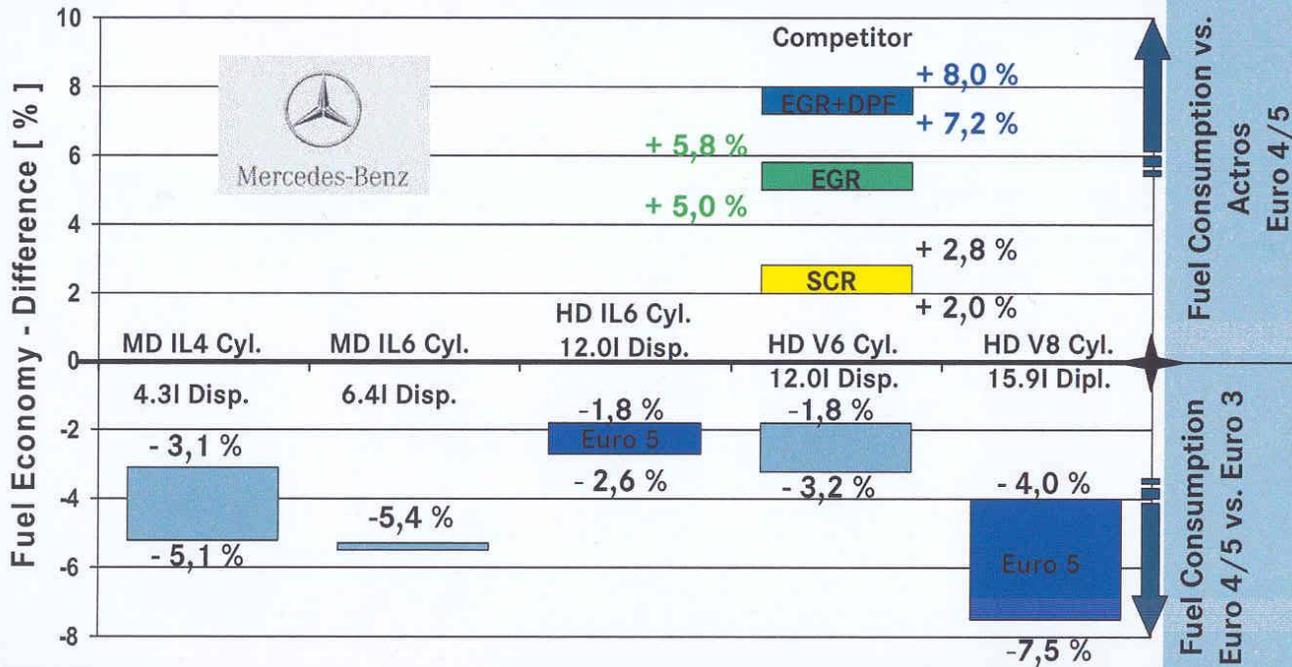
## Effect of the SCR-System



# Effect of the SCR-System

An Main Effect of the SCR-System is the lower fuel Konsumtion

**Mercedes-Benz Actros  
ggü. Wettbewerb**

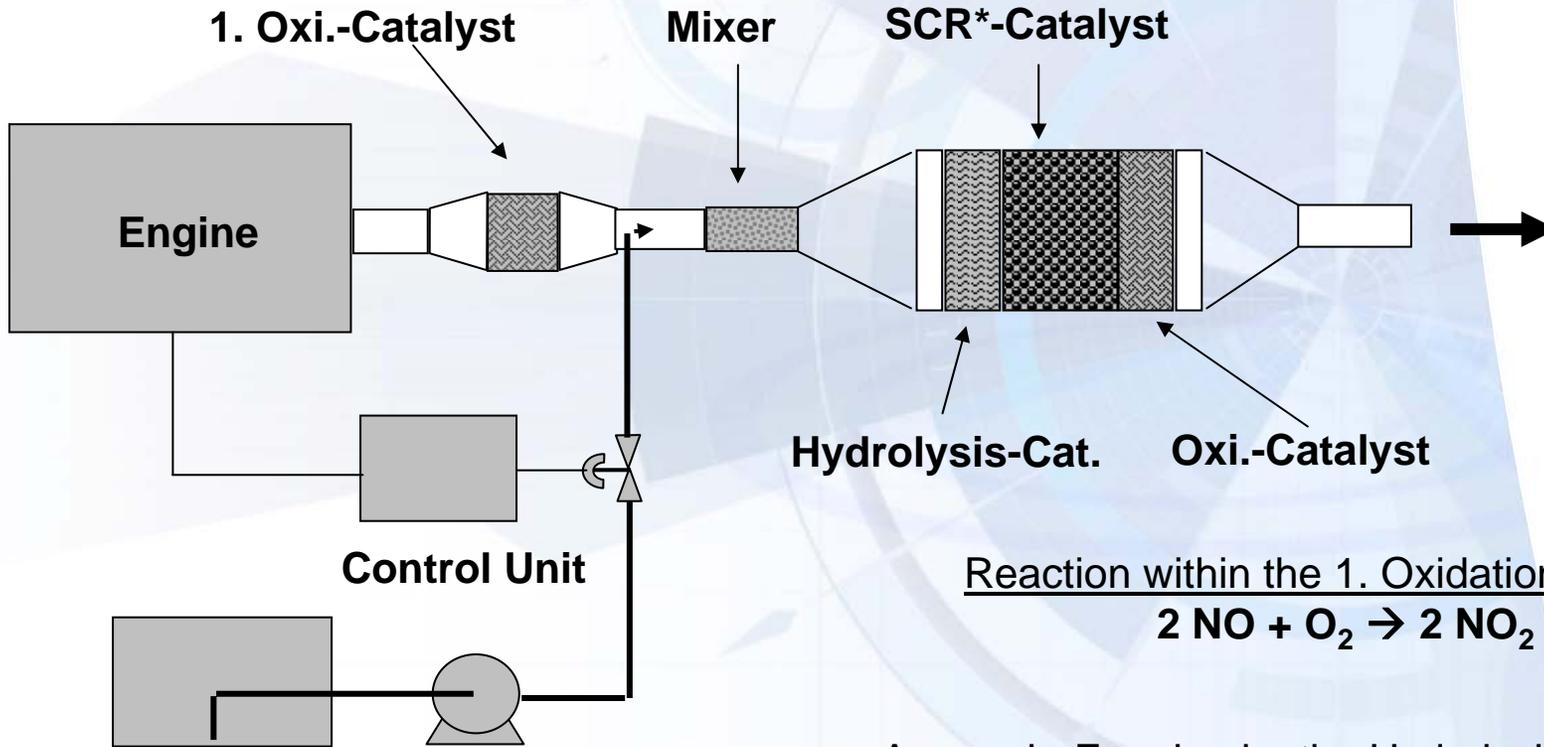


**Vorteil  
EURO IV/V SCR  
vs.  
EURO IV EGR**

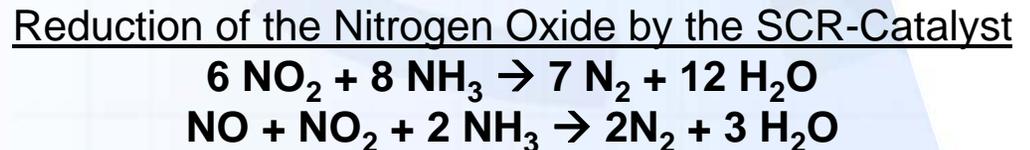
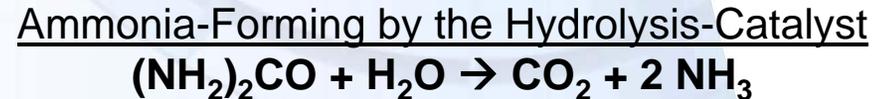
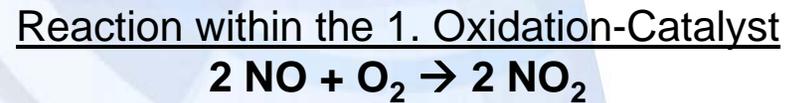
**Vorteil  
EURO IV/V SCR  
vs.  
EURO III**

**Mercedes-Benz  
EURO IV/V vs. EURO III**

# How works the SCR-System ?

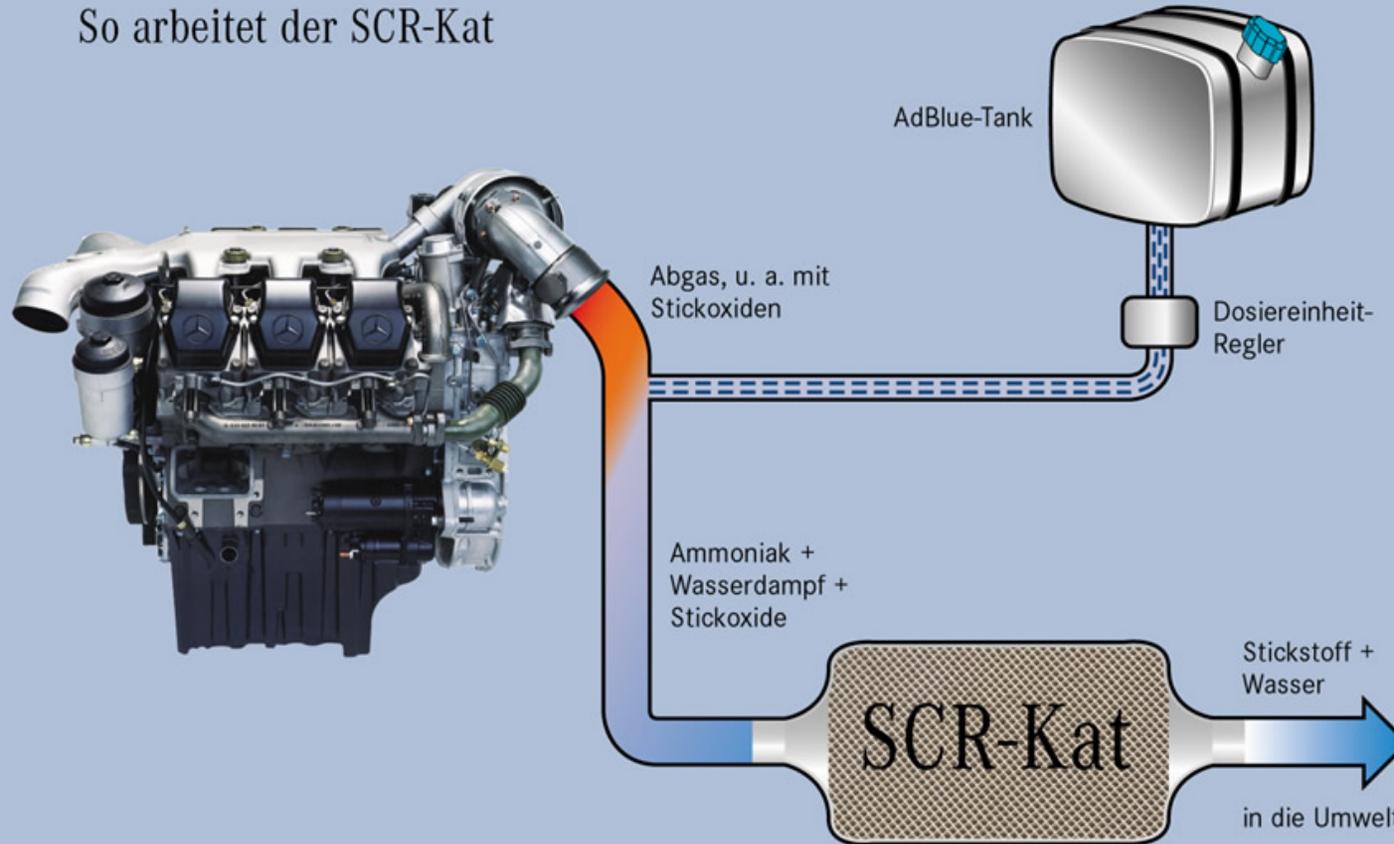


**Tank and Pump for Adblue\***  
 (\* urea dissolved in water )

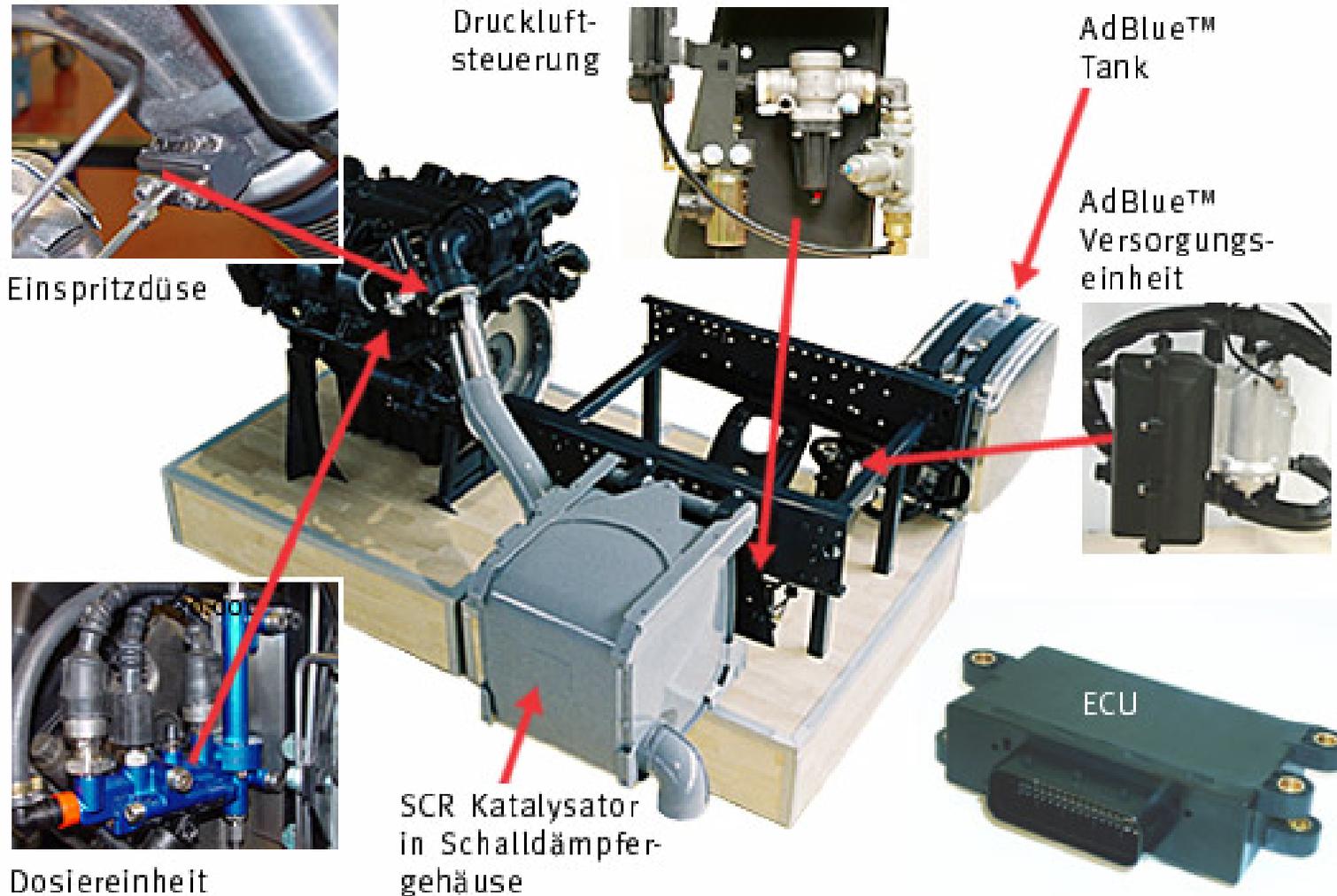


# The SCR-System realised in Trucks

So arbeitet der SCR-Kat

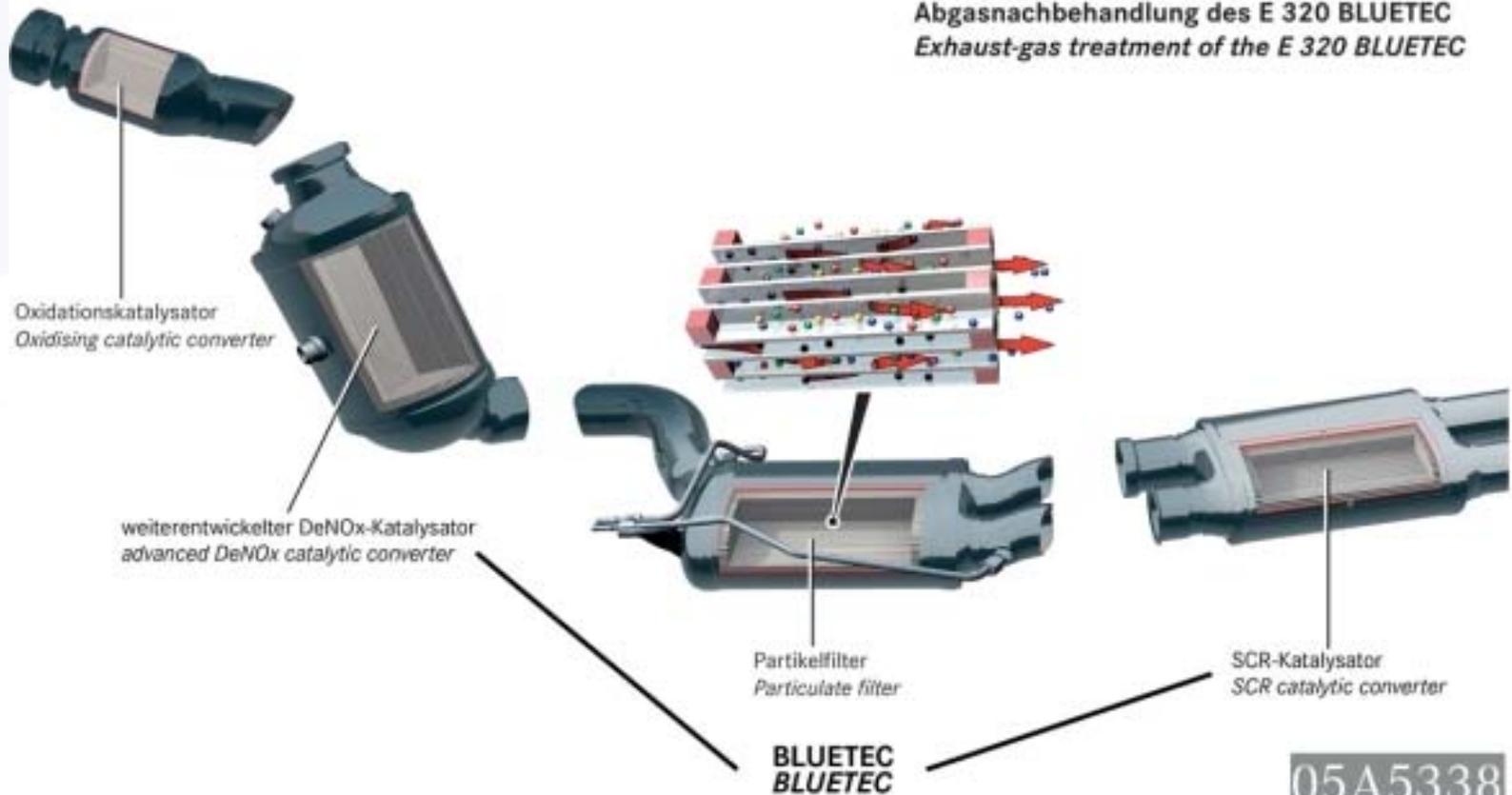


# The SCR-System realised in Trucks

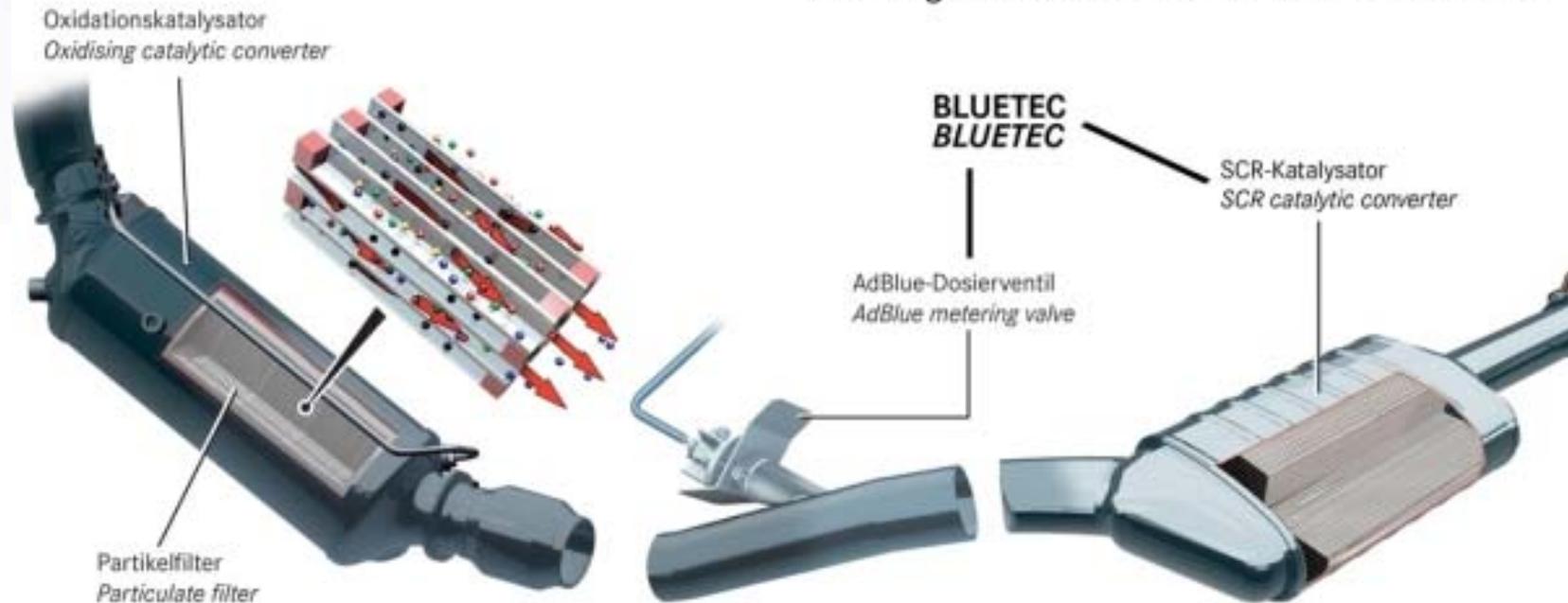


# The SCR-System realised in passenger vehicles

Exhaust gas treatment in the E 320 BLUETEC. Self-sufficient operation thanks to an improved nitrogen oxide storage catalytic converter



## Exhaust gas treatment in the Vision GL 320 BLUETEC



## **Dieselquality ( Sulphur Content ) worldwide**

- The sulphur content in diesel fuel depends on the local deposit of crude oil and refining technology.
- Sulphur in diesel fuels can range from 10 – 10.000 ppm
- Sometimes national diesel fuel with more sulphur than F-34

## Influence of Dieselquality for the SCR-System

- The SCR-System is in principle a system which has only influence of the exhaustsystem. No Modification of the Engine is necessary.
- In case of use bad fuel or F-34 the function of the ECU has to be modified because the NOx-Sensor after the Catalytsystem will send the unecceptable exhaust gas datas and the ECU will reduce the torque about 40% by heavy trucks and about 25% by light trucks. This will be also the case if the engine is running without “AdBlue“.

**This will be for military application not acceptable**

## Next steps for the Industry and military User

- Tests with an DC-Engine with SCR-System under military conditions by WIWEB ( with F-34 / high sulphur fuel / no AdBlue ).
- Solve the problem with the ECU  
for ex.: special military ECU  
Softwaremodification  
swith version: Military-Civil



**EmissionControlUnit**



**Thank You for Your Attention !**



<b>REPORT DOCUMENTATION PAGE</b>																	
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<b>14. Abstract</b>	<p>The Applied Vehicles Technology Panel (AVT) of the NATO Research and Technology Organisation (RTO) commissioned exploratory team ET-073 to address technical and operational issues related to the use of SFP and high Sulphur Diesel Fuel on Ground Equipment Using Advanced Reduction Emission Technologies and to give guidance and advice in the procurement of future equipment.</p>																





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