

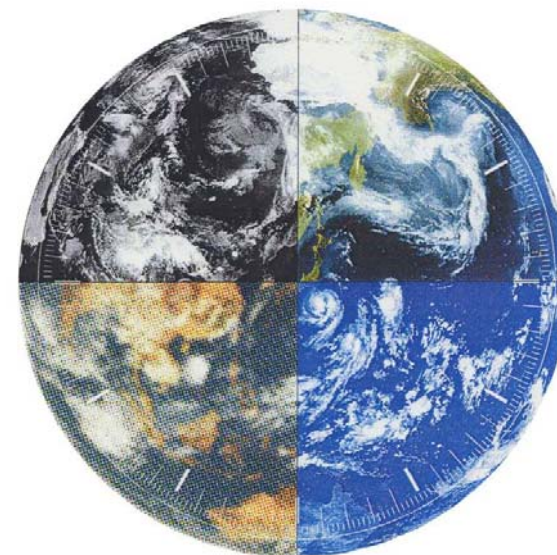


*Further Challenges in  
Automobile and Fuel Technologies  
For Better Air Quality*

**5<sup>th</sup> JCAP Conference**

**Diesel WG Report**

**February 22, 2007**





# Research Objectives

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## ◆ Objectives

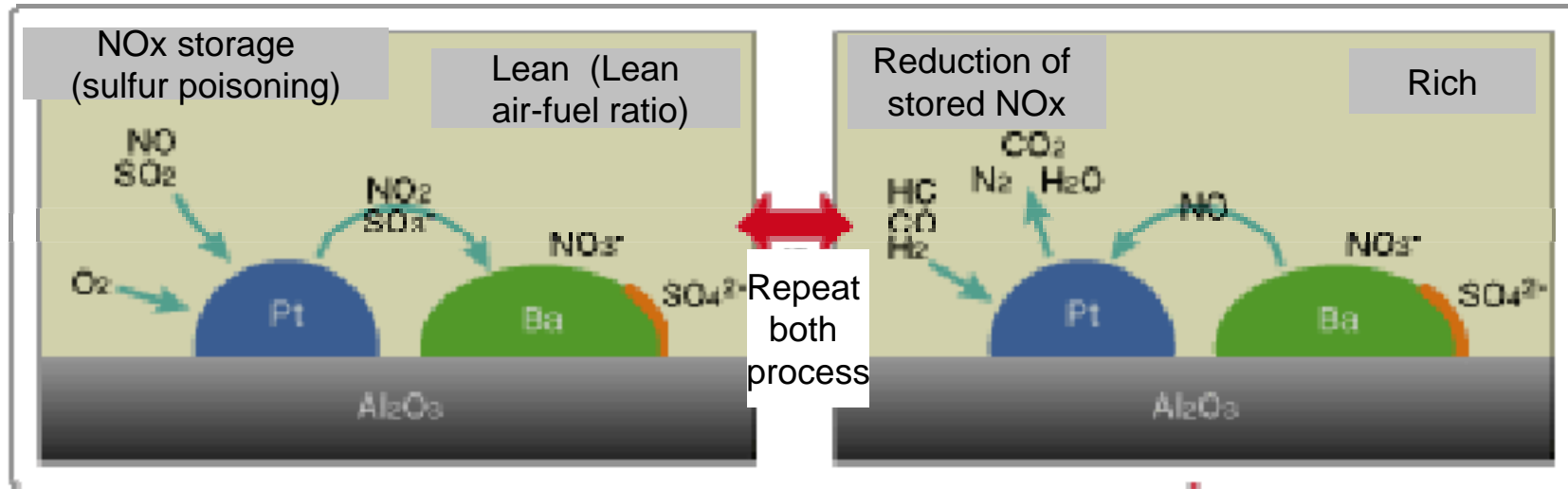
To study effects of fuel properties (sulfur, etc.) on the conversion efficiency of NO<sub>x</sub> reduction catalyst and on CO<sub>2</sub> emissions, and to provide the data-base to clarify the direction of future technologies for both diesel vehicles and their fuel.

## ◆ Technologies to be evaluated

- NO<sub>x</sub> catalyst technologies (including DPF installation)
  - NO<sub>x</sub> Storage-Reduction catalyst (NSR) system
  - Urea-SCR system (SCR: Selective Catalytic Reduction)
- Fuel quality
  - Sulfur: 0—50ppm
  - Properties besides sulfur: Distillation(T90), Aromatics
  - FAME(5% blend), GTL

FAME: Fatty Acid Methyl Ester derived from vegetable oil

## NSR : NO<sub>x</sub> Storage Reduction



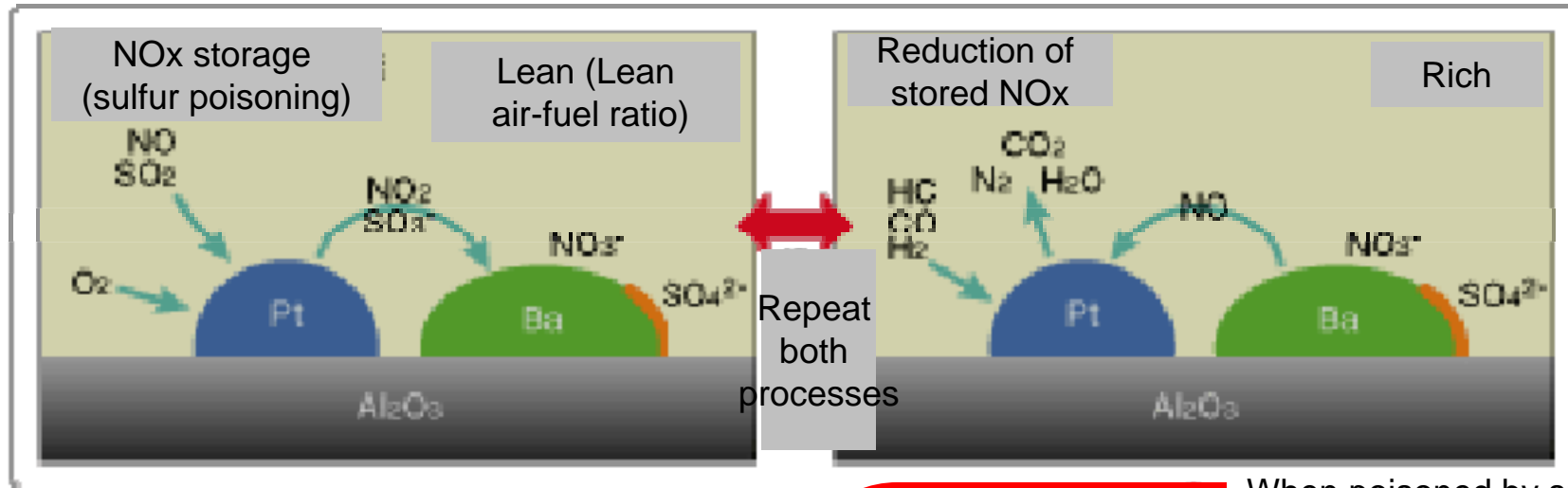
### NO<sub>x</sub> storage

Oxidize NO to NO<sub>2</sub> during lean burn condition, and absorb NO<sub>2</sub> in the form of metallic nitrate by using alkaline earth metals such as Ba.

### NO<sub>x</sub> reduction

Create an fuel rich condition to reduce NO<sub>x</sub> to N<sub>2</sub>.

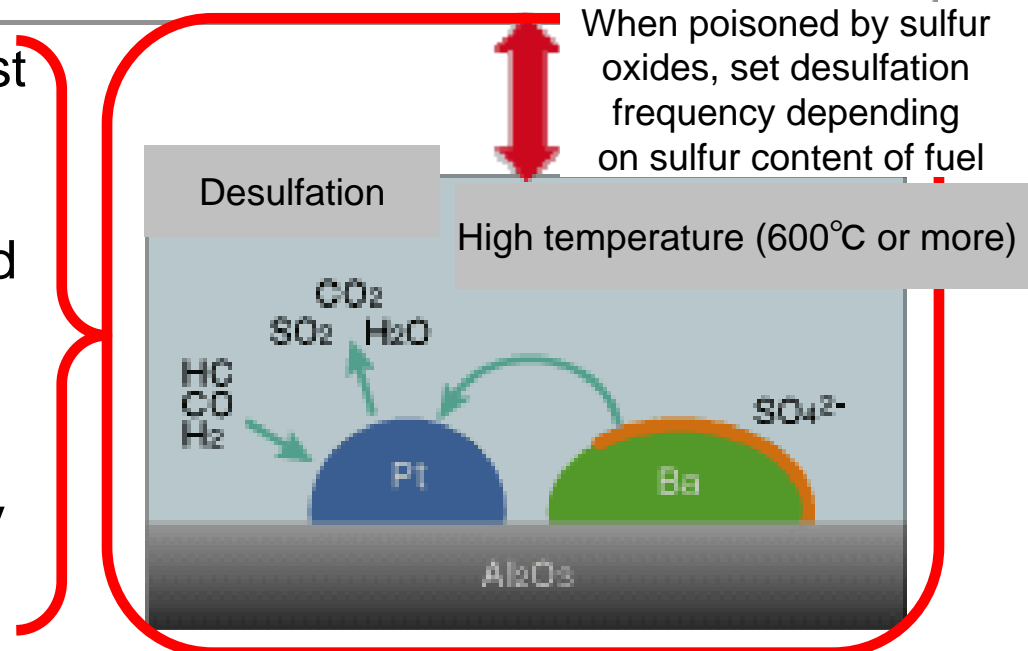
## NSR: NO<sub>x</sub> Storage Reduction



Periodic desulfation (high exhaust gas temp.) is required to recover from sulfur poisoning.

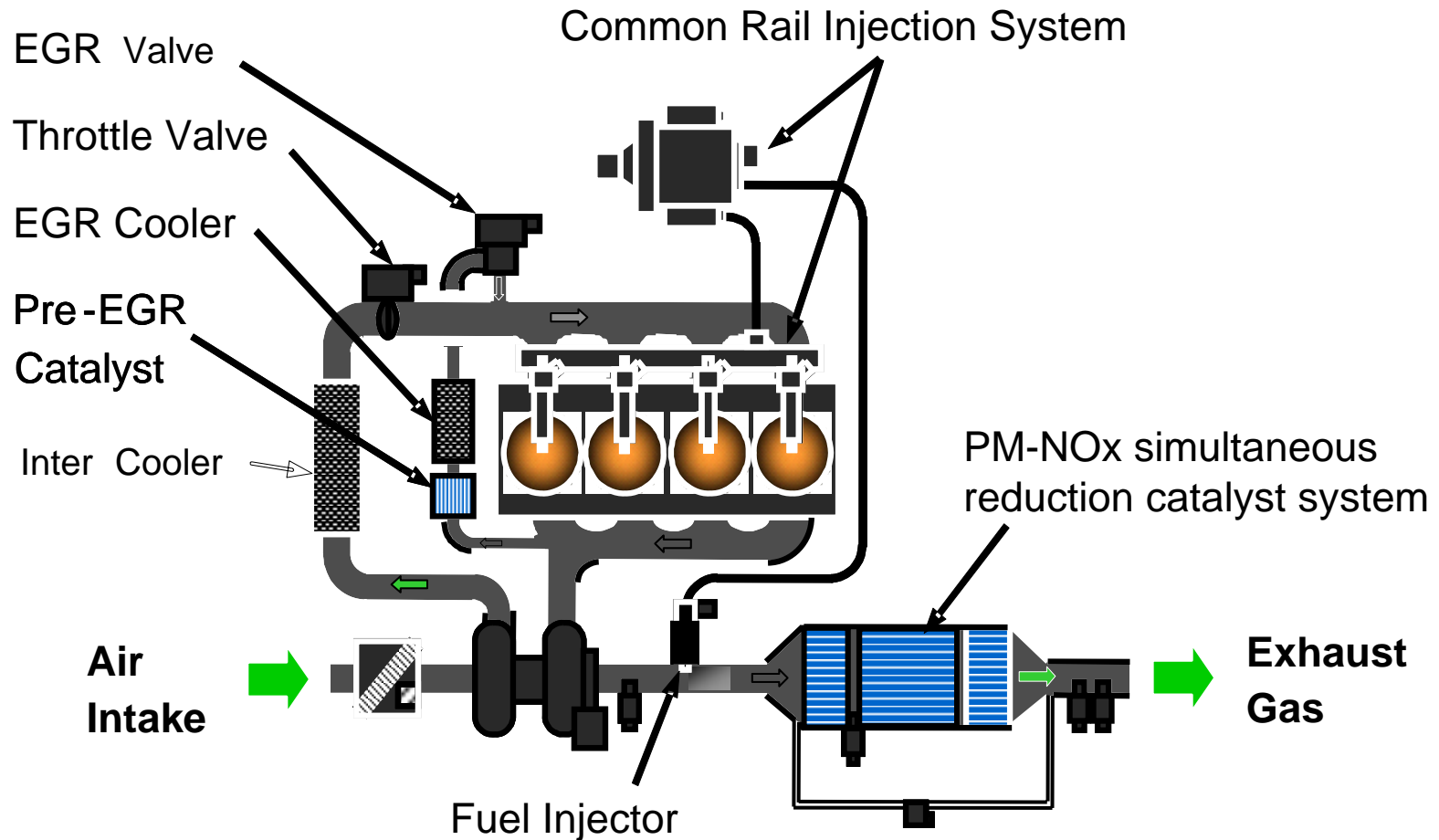
⇒ Worsen both fuel economy and catalyst durability.

Frequency of desulfation can be decreased by reducing sulfur in fuel. ⇒ Improve both fuel economy and exhaust emissions.



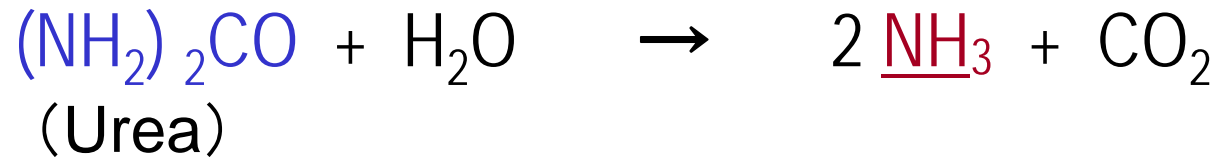
# DPF+NSR System Configuration

## PM-NOx simultaneous reduction catalyst system

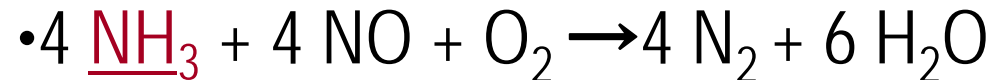
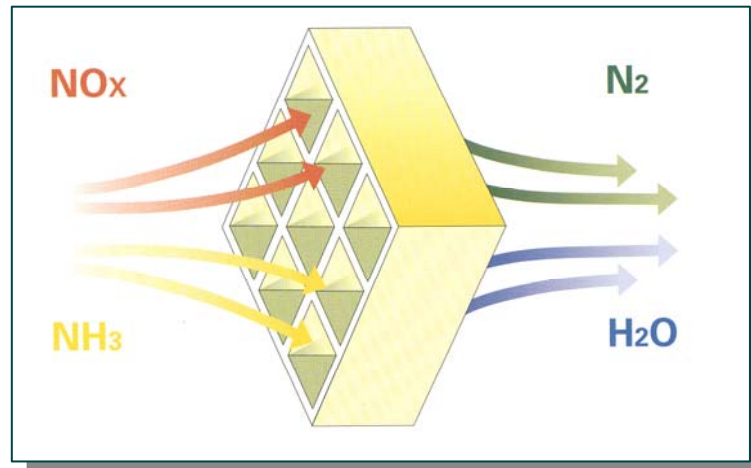


## SCR: Selective Catalytic Reduction

### ◆ Hydrolysis of urea



### ◆ Reduction reaction (Reduction of NO<sub>x</sub> by NH<sub>3</sub>)

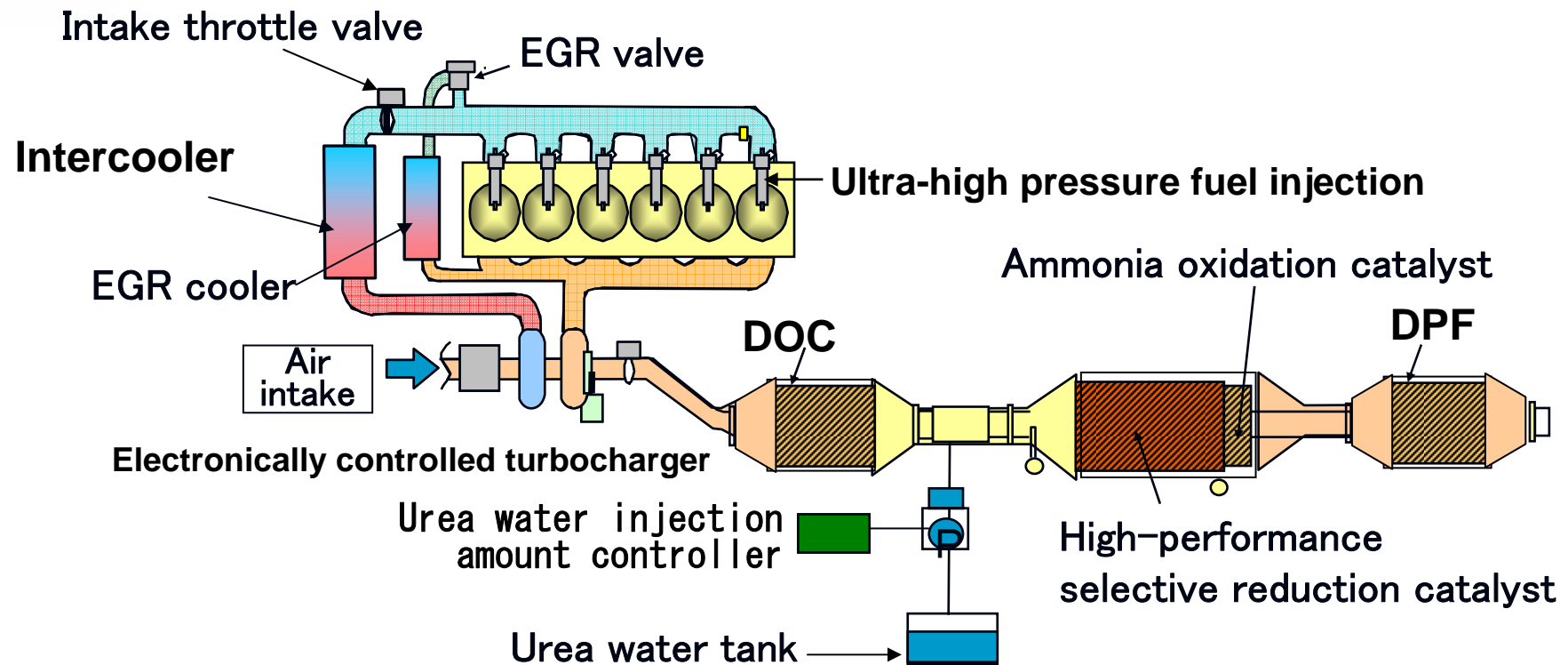


The reaction depicted below is active at low temperature.



(Effective NO<sub>2</sub>/NO<sub>x</sub> ratio= approx. 0.5)

# System Configuration of Engine E (Urea-SCR)



**DPF is placed after urea-SCR system**  
**Insulating exhaust system to prevent exhaust gas temperature drop**



**Average exhaust gas temperature at SCR inlet is approx. 20°C higher compared with in production engine case.**



# Contents of Report

1. Effects of sulfur content	1.1 Mileage accumulation test Engine D (NSR), Vehicle B (NSR)
	1.2 Urea-SCR test Engine B (Urea-SCR)
2. Effects of distillation and aromatics	Matrix test Engine D (NSR), Vehicle B (NSR) Engine E (Urea-SCR)
3. Effects of FAME/GTL	FAME/GTL test Engine D (NSR), Vehicle B (NSR)

			Fuel properties		
			Sulfur content	T90/Aromatics	FAME/GTL
NO <sub>x</sub> Catalyst technology	NSR	Engine D	1.1	2	3
		Vehicle B			
	Urea-SCR	Engine B	1.2		
		Engine E			



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			Fuel properties		
			Sulfur content	T90/Aromatics	FAME/GTL
<b>NO<sub>x</sub> Catalyst technology</b>	NSR	Engine D	1.1	2	3
		Vehicle B			
	Urea-SCR	Engine B	1.2	2	
		Engine E			



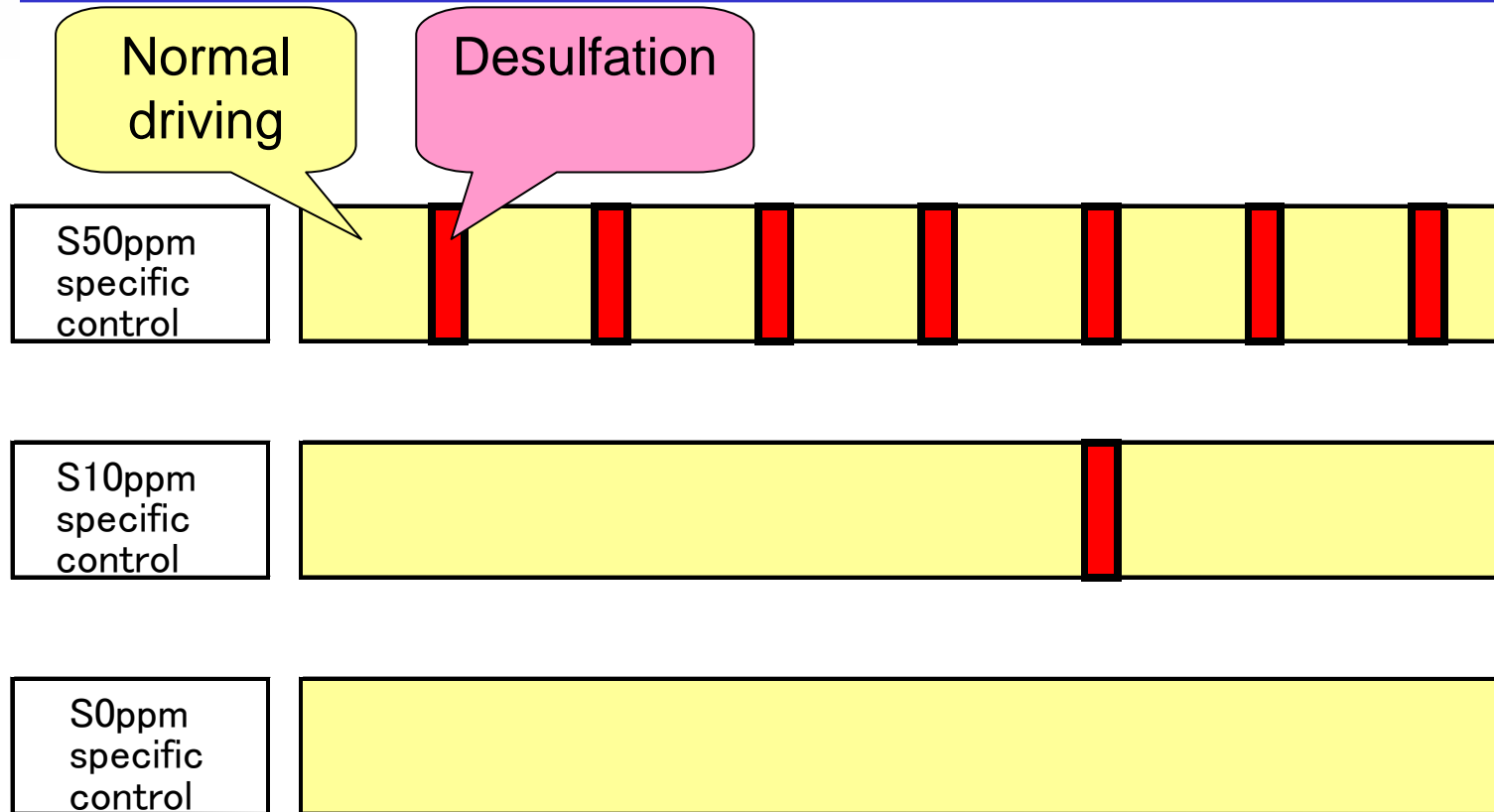
# Mileage Accumulation Test (Effects of Sulfur)

## Test Fuel Properties

		J2D25 <b>(S0)</b>	J2D01 <b>(S10)</b>	J2D02 <b>(S50)</b>
Density	gr/cm <sup>3</sup>	0.822	0.828	0.827
Distillation °C	10%	216	220	219
	50%	262	288	288
	90%	301	337	337
Aromatics	vol%	12.7	15.6	15.9
<b>Sulfur content</b>	mass ppm	<b>&lt;1</b>	<b>7</b>	<b>46</b>
Cetane number		52.2	59.0	58.9
Cetane index		57.1	60.5	60.6

Note) Since the S0 fuel uses a different base fuel than ordinary diesel fuels, its properties differ from those of S10 and S50.

# Frequency of Desulfation (Concept)



Frequency (interval) of desulfation was designed as a function of the sulfur content of fuel. Namely desulfation is conducted more frequently as sulfur content increases.

Desulfation results in worsening in fuel economy because fuel is injected into exhaust pipes to maintain exhaust gas temperature at as high as 700 °c.



# Influence of Sulfur in Fuel on Fuel Economy

## Mileage accumulation test results for Engine D (NSR) (Fuel economy)

S0 fuel/S0 control	S10 fuel/S10 control	S50 fuel/S50 control
Avg. fuel economy 6.33km/L <b>(+1.1%)</b>	Avg. fuel economy 6.26km/L <b>(Base)</b>	Avg. fuel economy 5.97km/L <b>(-4.6%)</b>

Driving distance : 50,000 km (modified 11 laps)

4.6% improvement in fuel economy when sulfur content is reduced from 50 to 10ppm.



# Mileage Accumulation Test Results for NSR Catalyst (List)

## Effects of sulfur on **fuel economy during driving**

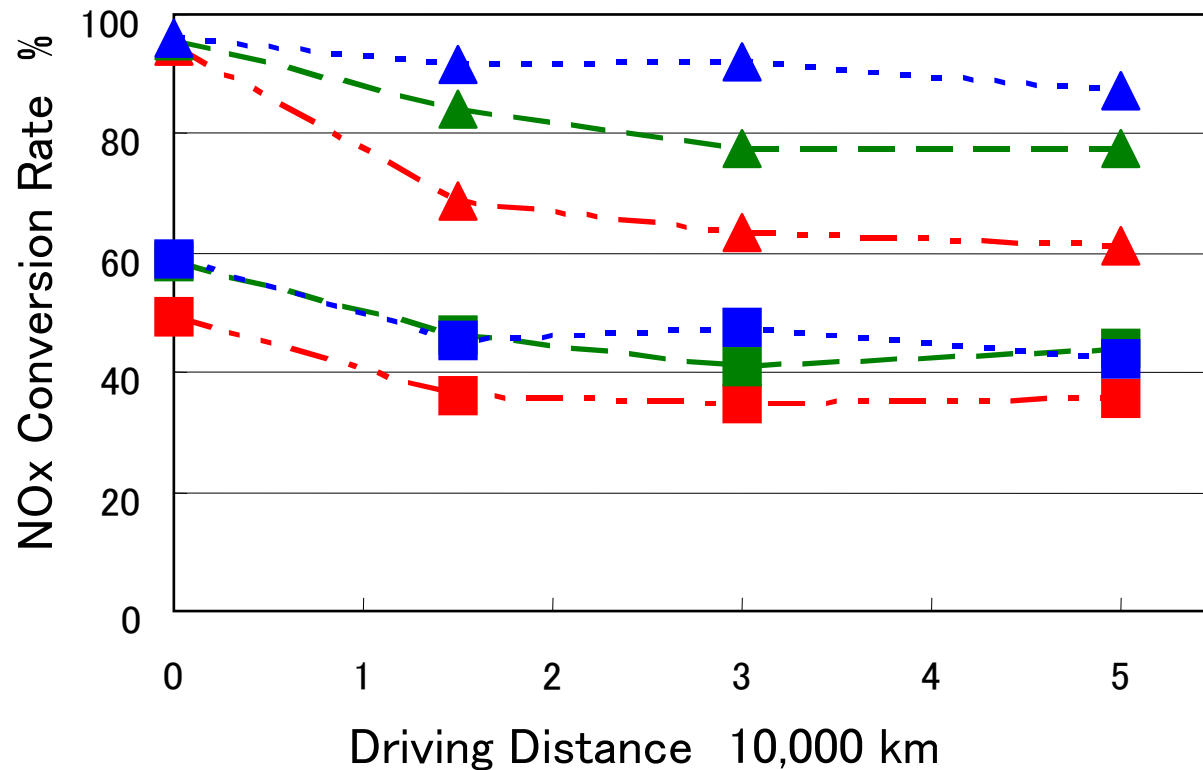
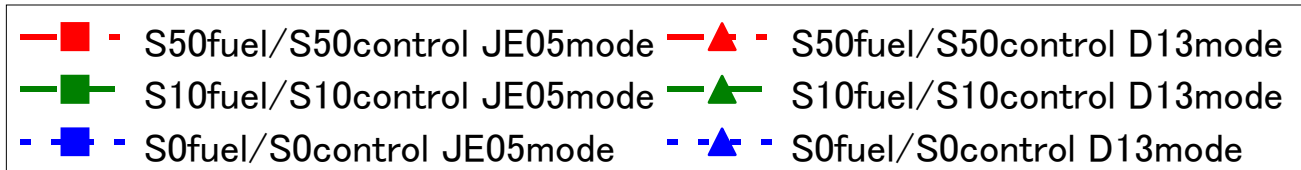
Engine and vehicle			Driving condition		Fuel economy change rate		
Name	Disp.	After treatment	Driving mode	Driving distance	S50ppm	S10ppm	S0ppm
Engine A	3.8L	NSR	Modified 11 laps	10000km	-3.9%	Baseline	1.2%
Engine D	4.0L	NSR+DPF	Modified 11 laps	50000km	-4.6%	Baseline	1.1%
Vehicle B (Passenger car)	2.0L	NSR+DPF	11 laps	30000km	-4.9%	Baseline	0.7%
Vehicle C (Medium-duty vehicle)	3.0L	NSR+DPF	11 laps	80000km	-9.1%	Baseline	2.0%

Influence of sulfur content on fuel economy is larger with Vehicle C.

Effects of desulfation conditions are a likely cause.



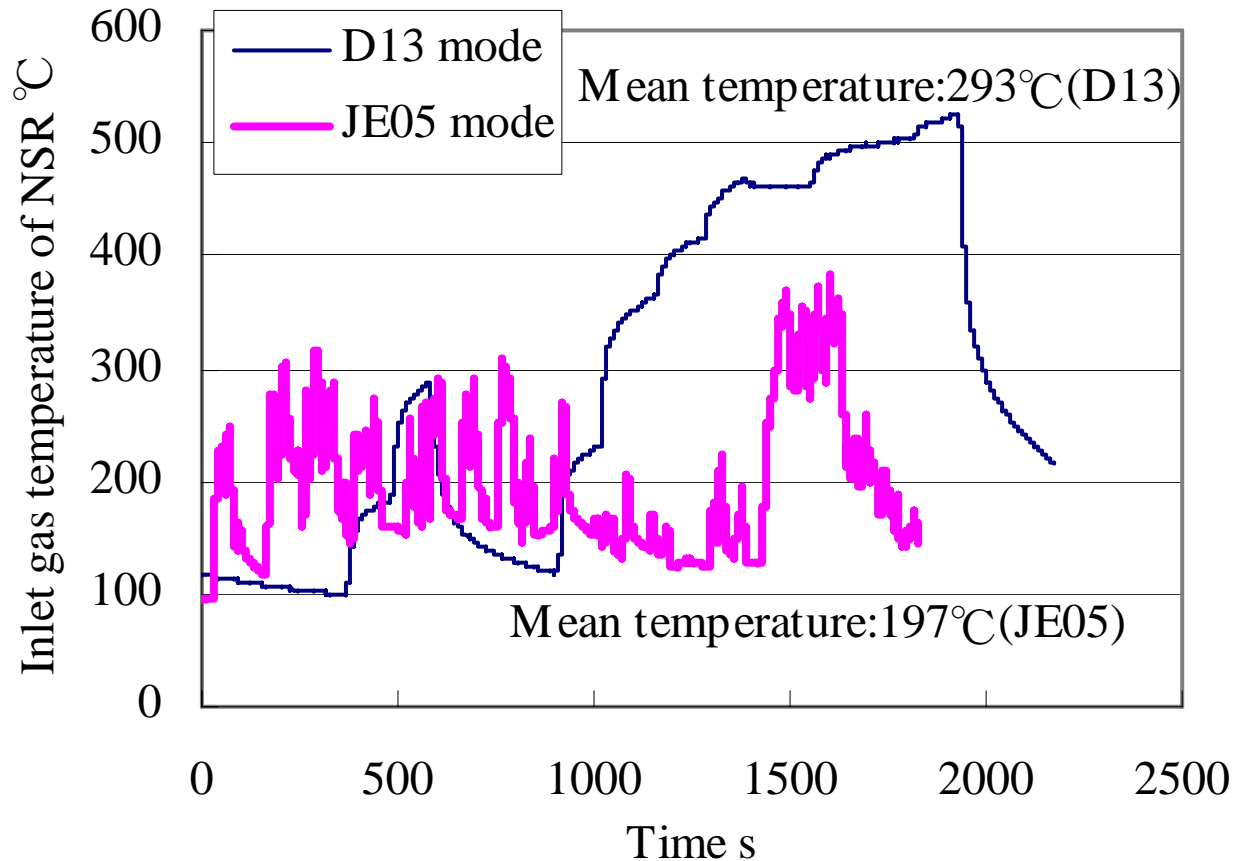
# Mileage Accumulation Test for Engine D (NSR) NOx Conversion Efficiency Time History



Difference in NOx conversion efficiency between D13 and JE05 modes is assumed to result from difference in exhaust gas temperature at catalyst inlet.

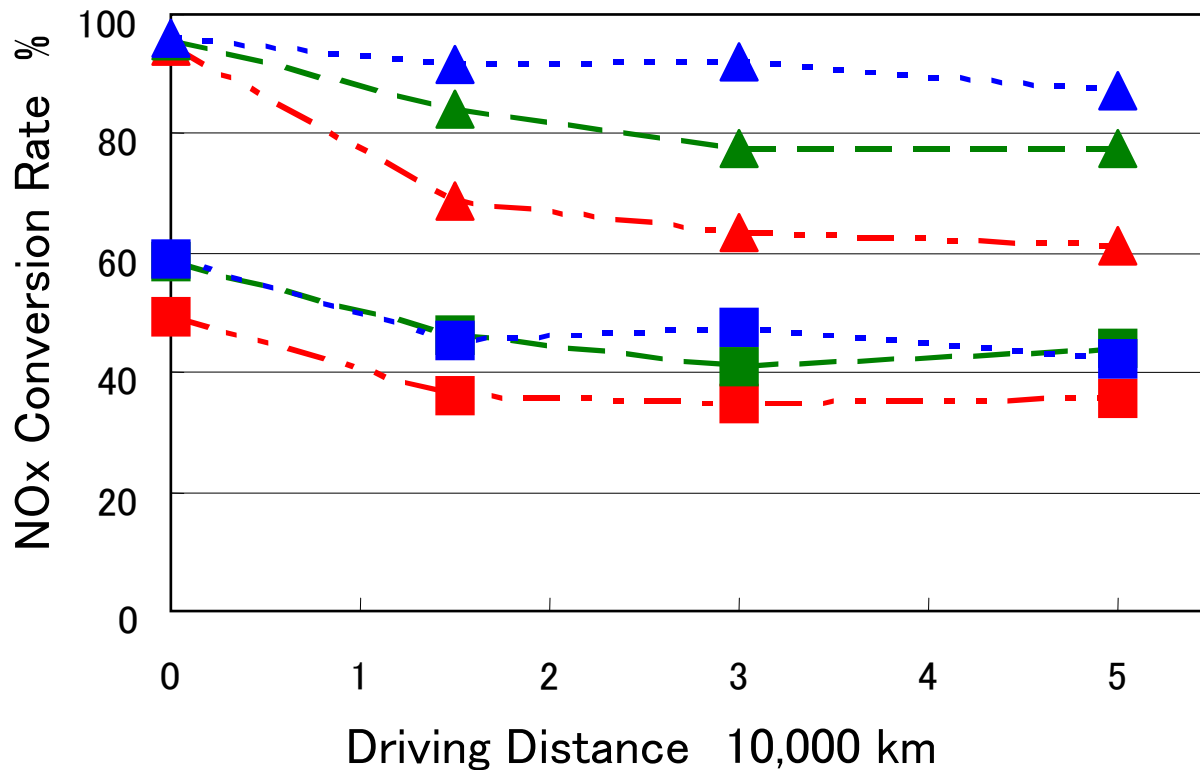
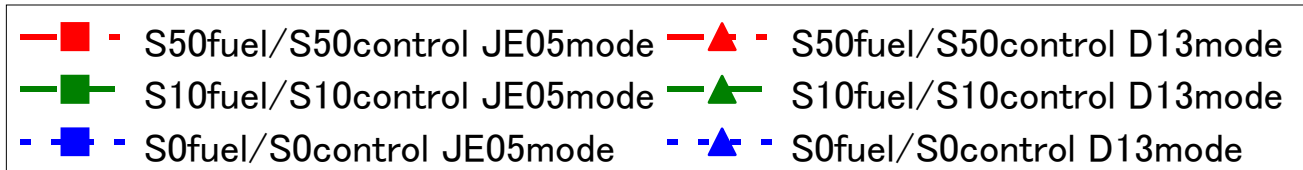


# Exhaust Gas Temperature during Test Cycles



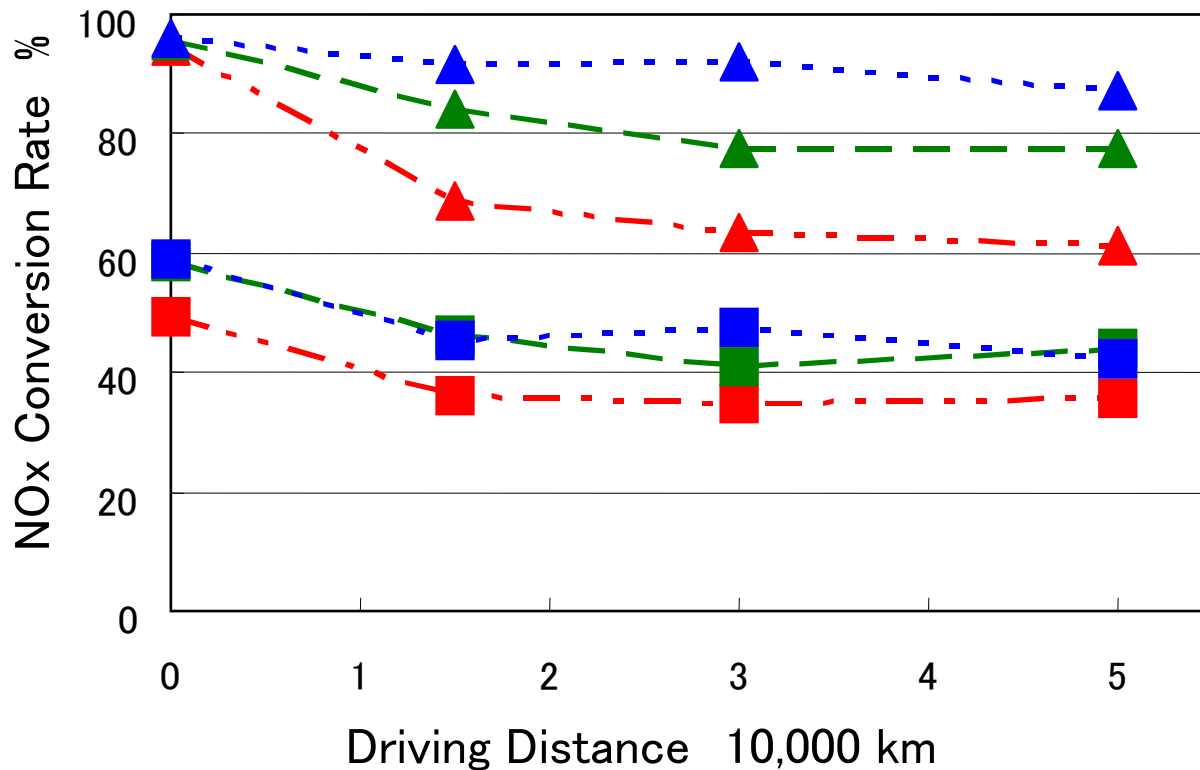
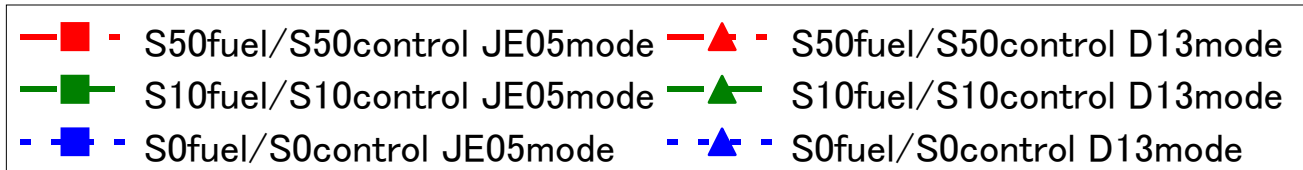
Average exhaust gas temperature at JE05 mode test cycle is approx. 100 °C lower than that of D13 mode.

# Mileage Accumulation Test for Engine D(NSR)



NOx conversion efficiency deteriorates with driving distance. The trend is more critical when using higher sulfur fuel.

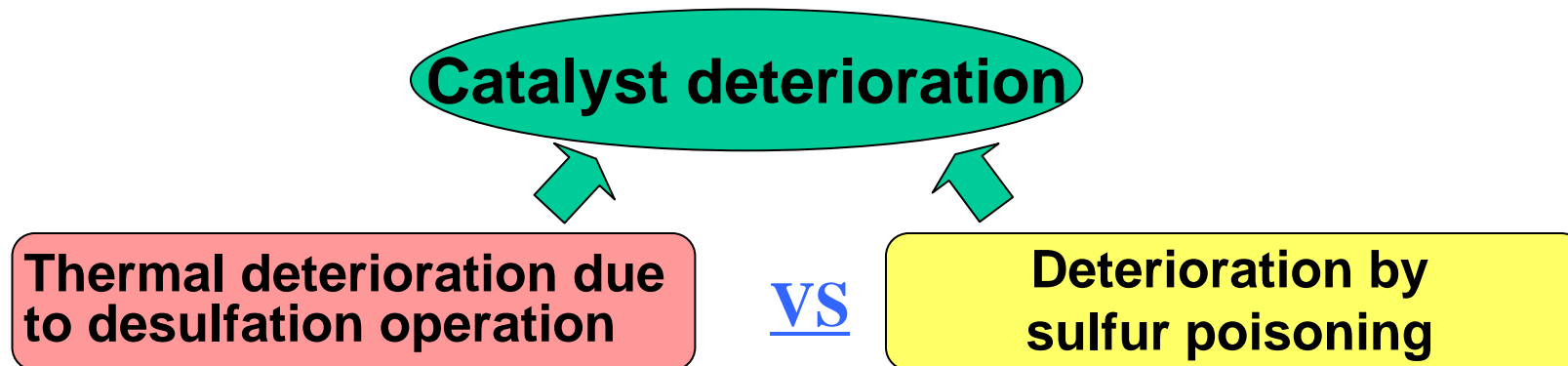
# Mileage Accumulation Test for Engine D(NSR)



Effect of fuel sulfur is smaller in JE05 mode. The likely cause is that SV of JE05 is low and the effect of NOx storage performance deterioration on NOx conversion does not become apparent.

# Estimated Mechanisms and Evaluation Method for Catalyst Deterioration

## Estimated mechanisms of NO<sub>x</sub> storage performance deterioration (catalyst deterioration)



### 【Evaluation methods】

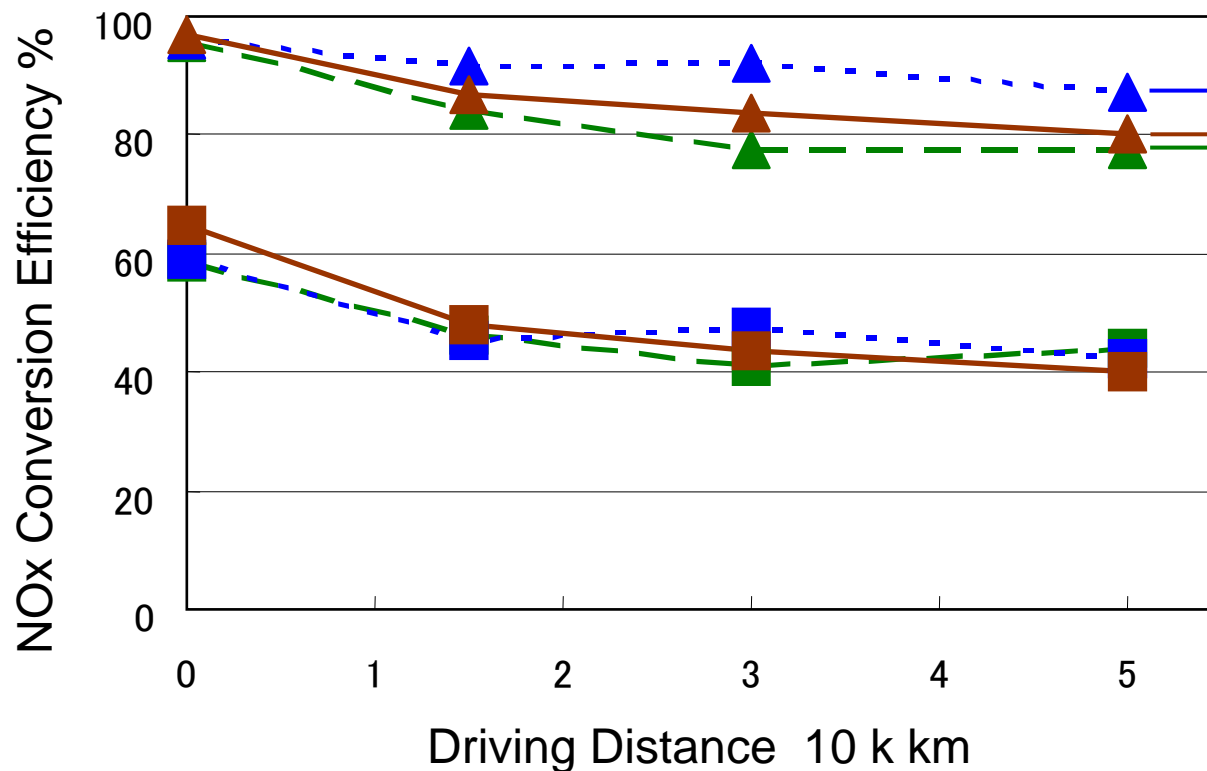
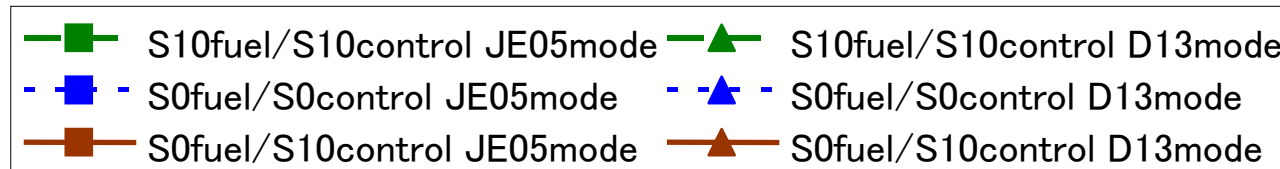
Newly add "S0 fuel/S10 control" mileage accumulation test

**Thermal deterioration** ☞ Compare the results of S0 fuel/S0 control and S0 fuel/S10 control tests.

**Deterioration by sulfur poisoning** ☞ Compare the results of S10 fuel/S10 control and S0 fuel/S10 control tests.



# Mileage Accumulation Test for Engine D(NSR)



Thermal deterioration

Sulfur poisoning

Difference between the **S0/S0 control** and the **S0/S10 control** is bigger than that between the **S0/S10 control** and the **S10/S10 control**. The main cause of catalyst deterioration is assumed to be **thermal deterioration**.



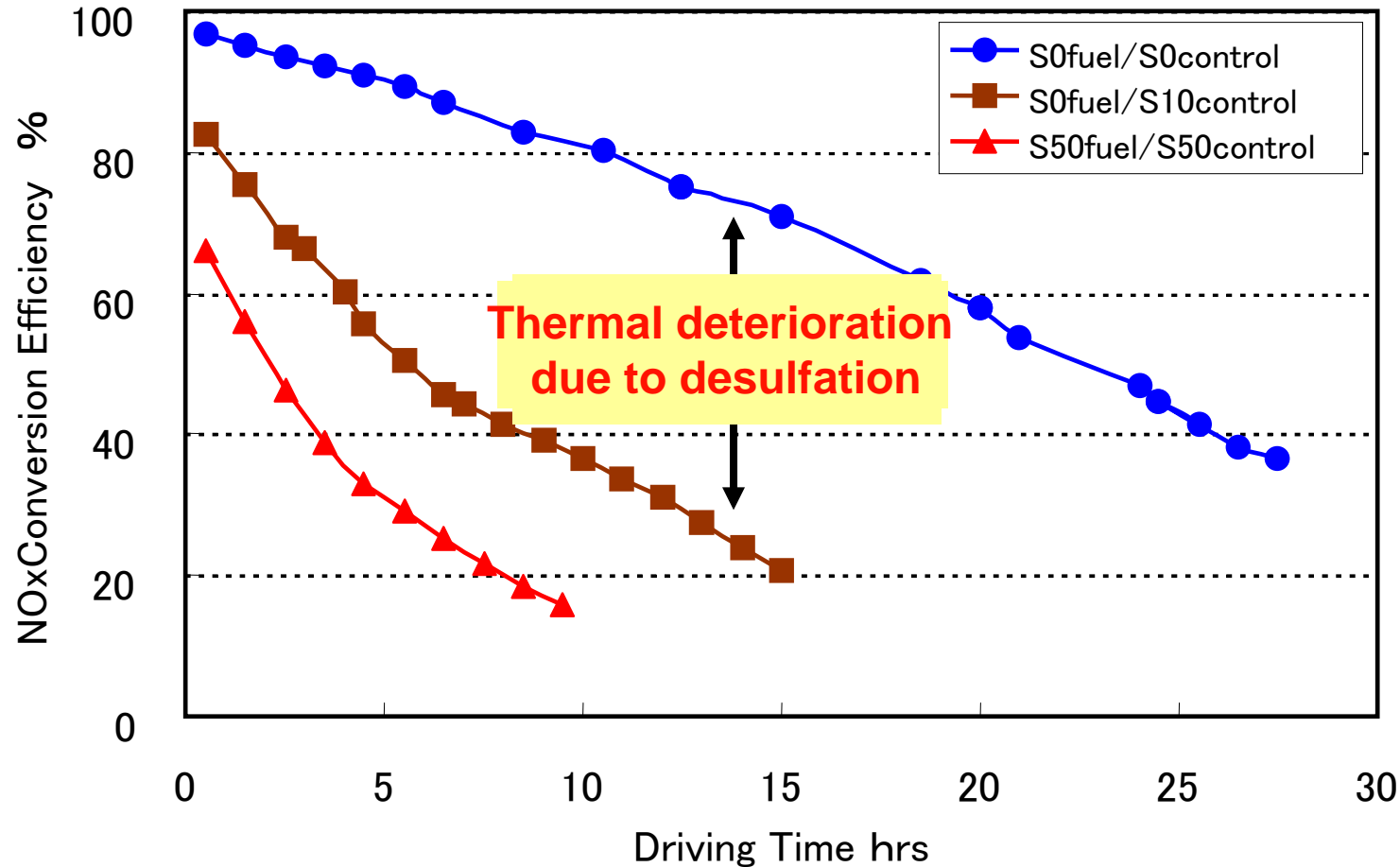
# Method of Evaluating NOx Storage Performance

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NOx storage capacities of NSR catalysts after mileage accumulation are measured by the following process.

1. Reversibly poisoned absorbents on the catalyst surface are activated by manually controlled desulfation .
2. After the desulfation, desulfation control is suspended, and only “rich-spike” for reducing NO<sub>2</sub> to nitrogen is activated. The engine start operation with high speed and load, which means high space velocity for the catalyst, using S50 fuel. In accordance with the engine operation, absorbents are gradually poisoned by sulfur and deactivated.
3. In the case of a catalyst which enough active absorbents exist on the surface, NOx reduction performance is maintained high and need longer period for losing NOx conversion ability, while in the case number of active absorbents is small the catalyst loses the ability within a short period.

# Comparison of NOx Storage Performance of Catalyst after 50000km mileage accumulation



Use catalyst after 50,000km mileage accumulation  
 Fuel: S50 ppm diesel fuel (T90=280°C)  
 Driving conditions: Constant driving at 2400rpm/190Nm (No desulfation during driving)



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<b>3. Effects of FAME/GTL</b>	<b>FAME/GTL test</b> Engine D (NSR), Vehicle B (NSR)

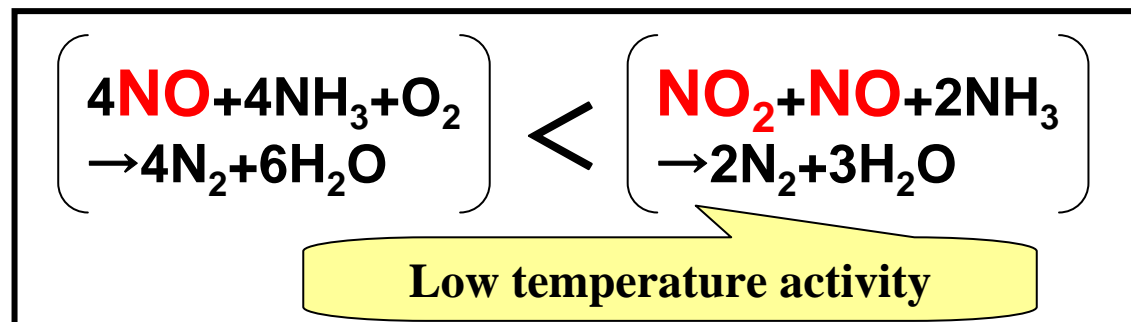
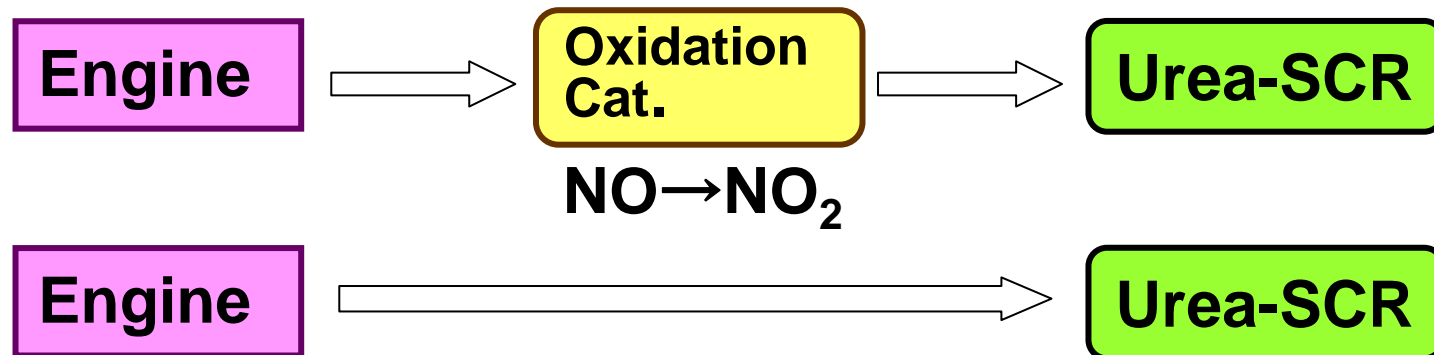
			<b>Fuel properties</b>		
			Sulfur content	T90/Aromatics	FAME/GTL
<b>NO<sub>x</sub> Catalyst technology</b>	NSR	Engine D	<b>1.1</b>	<b>2</b>	<b>3</b>
		Vehicle B			
	Urea-SCR	Engine B	<b>1.2</b>		
		Engine E		<b>2</b>	

# Effects of Sulfur on Urea-SCR system-Overview

Evaluate the difference in NO<sub>2</sub>/NO<sub>x</sub> ratio and NO<sub>x</sub> conversion ratio with/without oxidation catalyst before Urea-SCR at low exhaust gas temp.



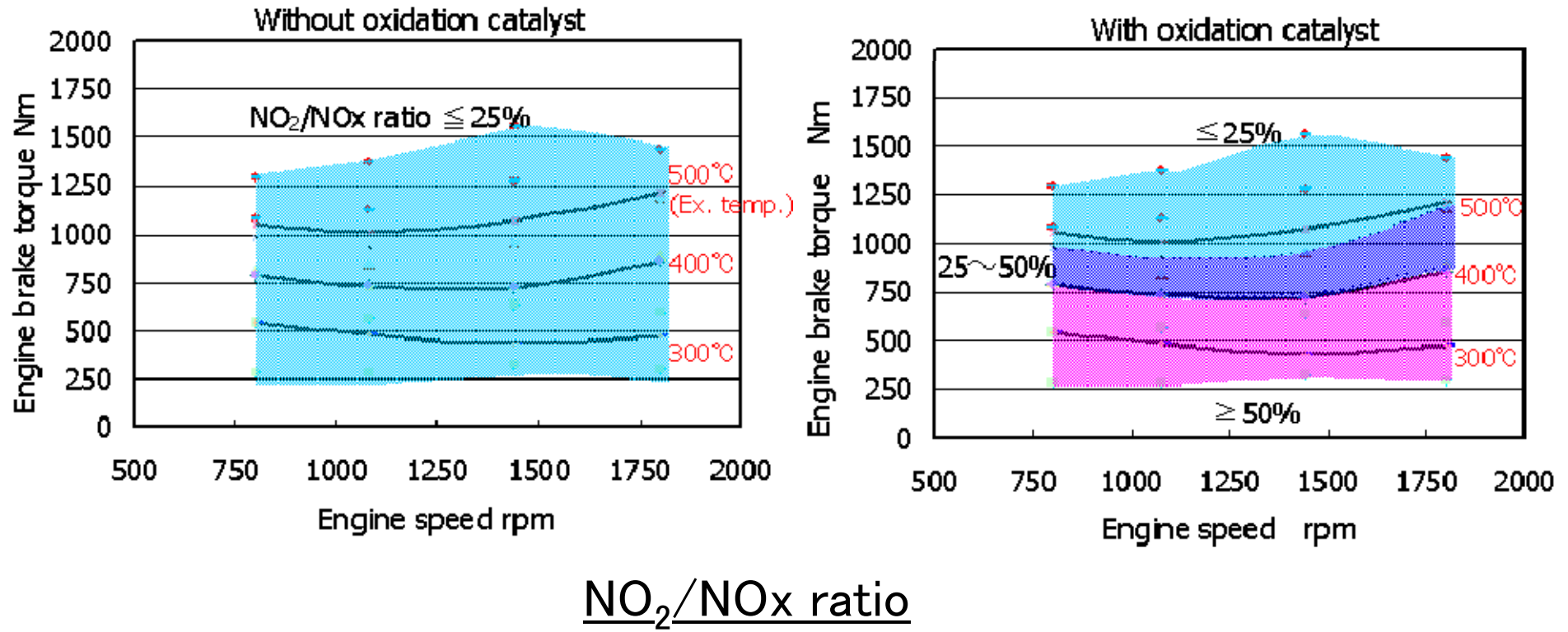
Without oxidation catalyst case is simulated that oxidation catalyst deteriorated by sulfur poisoning,





# Urea-SCR Test: Results and Considerations

## Evaluation results of NO<sub>2</sub> formation rate for with/without oxidation catalyst before Urea-SCR

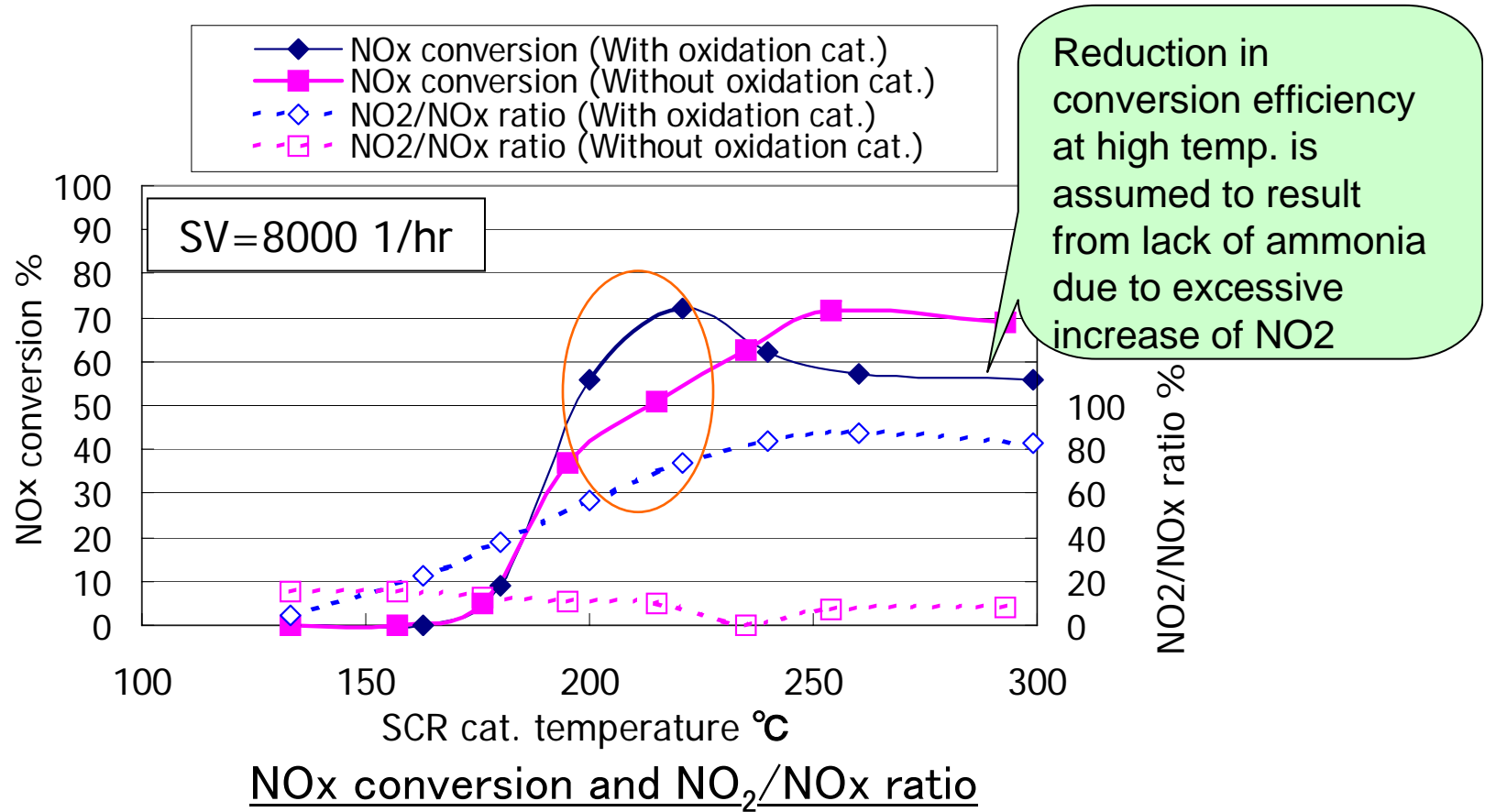


NO<sub>2</sub>/NO<sub>x</sub> ratio increases at low temperature due to installation of oxidation catalyst.



# Urea-SCR Test: Results and Considerations

Evaluation results of NO<sub>x</sub> conversion efficiency and NO<sub>2</sub>/NO<sub>x</sub> formation rate for with/without oxidation catalyst



NO<sub>x</sub> conversion efficiency in low temperature range (approx. 200°C) increased due to installation of oxidation catalyst



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3. Effects of FAME/GTL	FAME/GTL test Engine D (NSR), Vehicle B (NSR)

			Fuel properties		
			Sulfur content	T90/Aromatics	FAME/GTL
NO <sub>x</sub> Catalyst technology	NSR	Engine D	1.1	2	3
		Vehicle B			
	Urea-SCR	Engine B	1.2		
		Engine E			



# Matrix Test – Test Fuel Properties

		J2D35	J2D41	J2D42	J2D43	J2D44
		Base	90% distillation temp.		Aromatics	
			T300	T280	A10	A5
Density	gr/cm <sup>3</sup>	0.828	0.809	0.803	0.816	0.808
Distillation °C	10%	219	182	175	218	212
	50%	273	216	210	277	279
	90%	331	298	276	336	335
Aromatics cont.	vol%	19.2	17.4	19.0	9.9	5.9
Sulfur cont.	/mass ppm	3	7	7	7	7
Cetane number		56.6	56.7	54.3	51.7	65.7
Cetane index		57.4	49.2	48.9	63.6	68.1
Nitrogen cont.	/mass ppm	6	155	157	2	1

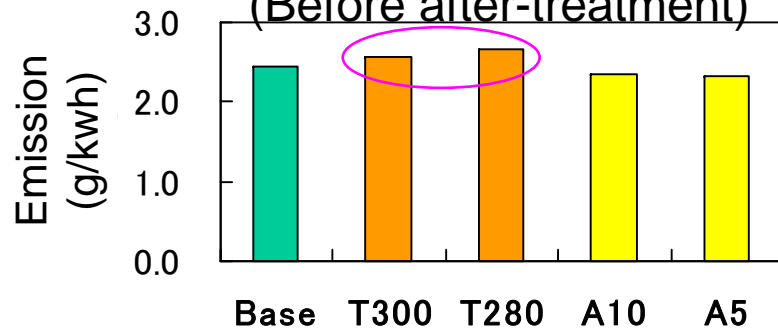


# Matrix Test Results - NO<sub>x</sub>

## Engine D (NSR)

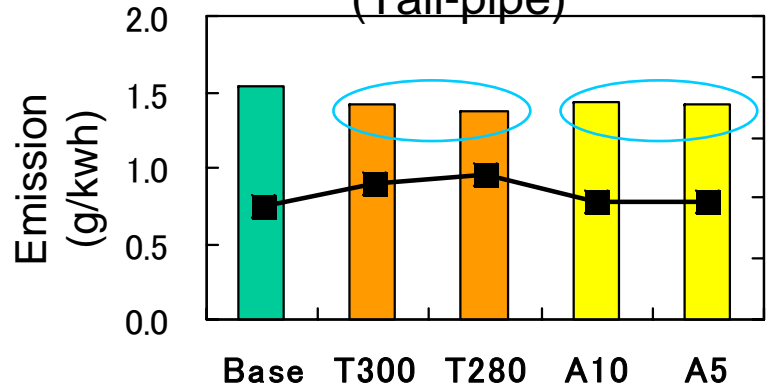
Engine outlet

(Before after-treatment)



Post after-treatment

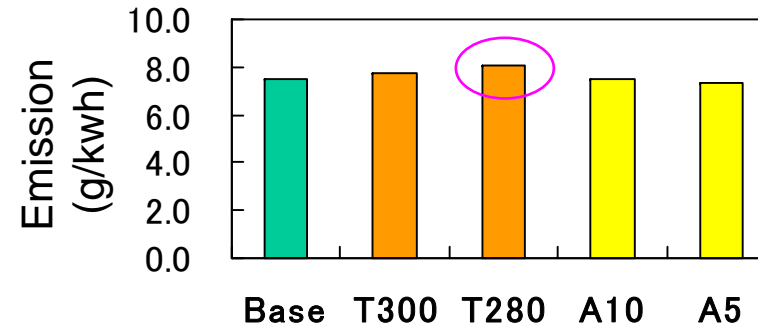
(Tail-pipe)



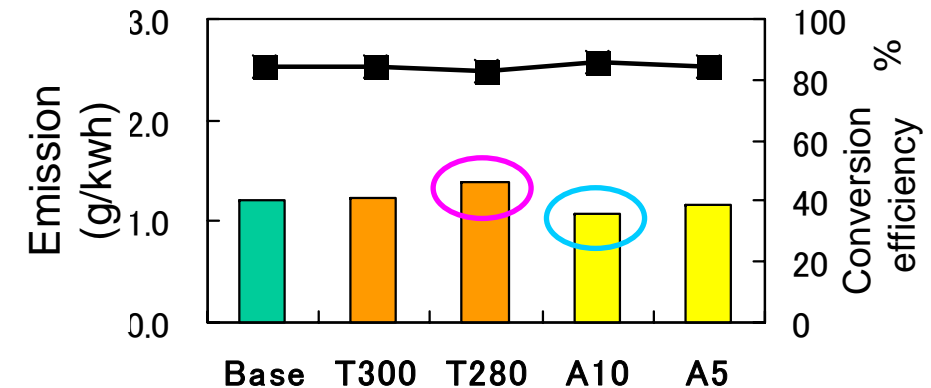
JE05 Mode

## Engine E (Urea-SCR)

Engine outlet



Post after-treatment



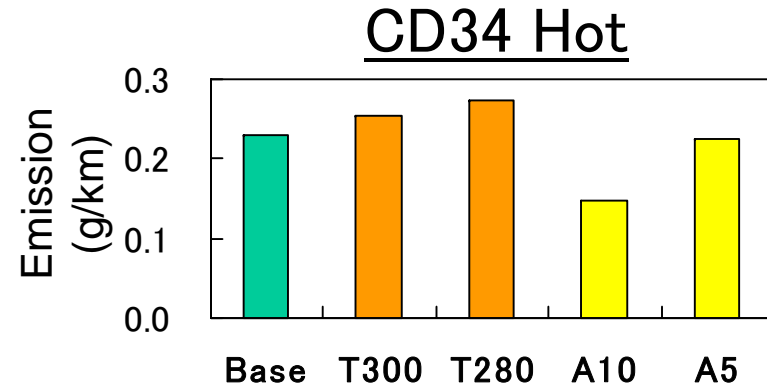
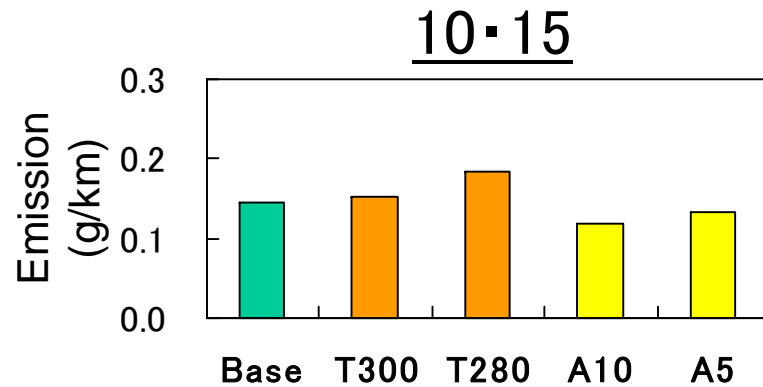
For Engine D (NSR), Post after-treatment NO<sub>x</sub> decreased due to conversion efficiency improvement with lighter T90.

For Engine E (Urea-SCR), NO<sub>x</sub> increased at engine outlet and post after-treatment with lighter T90.



# Matrix Test Results for Vehicle B (NSR)

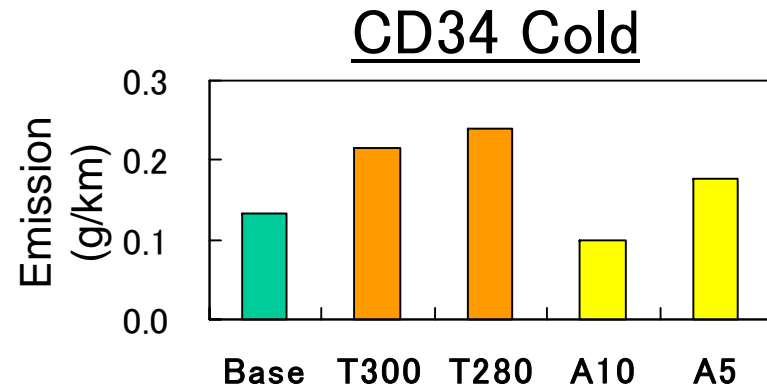
## NO<sub>x</sub>



For Vehicle B(NSR), Post after-treatment NO<sub>x</sub> did not decrease with lighter T90.

This is likely a result of :

1. Effect of change in pilot injection-combustion. (Pilot combustion reduces by lowering T90)
2. Change in EGR rate by a difference in fuel density. (EGR rate is designed as a function of acceleration pedal position)

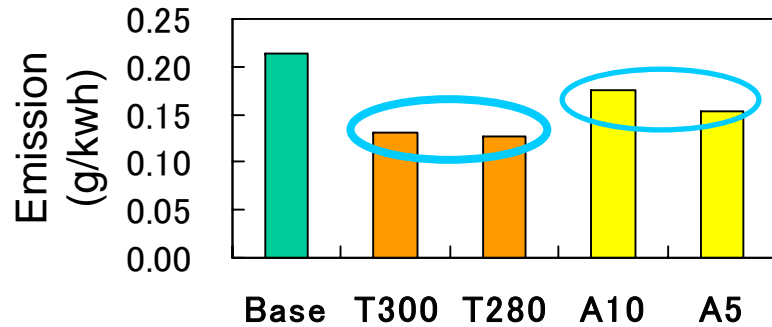




# Matrix Test Results - PM

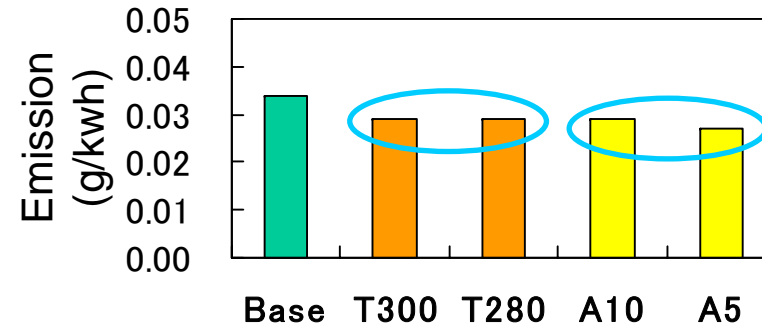
## Engine D (NSR)

### Engine outlet



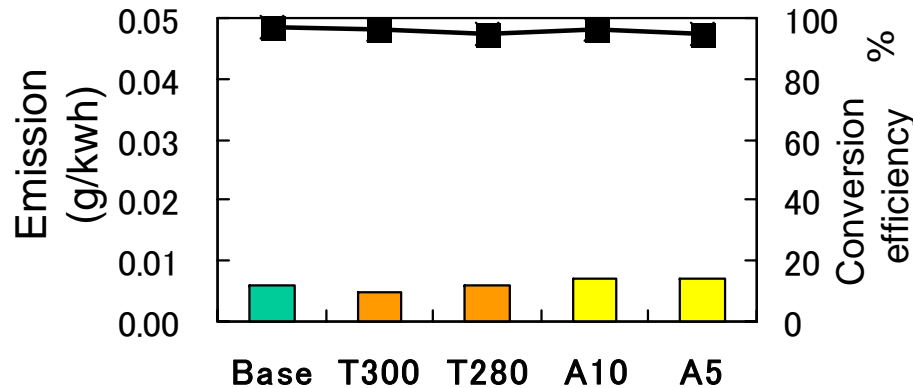
## Engine E (Urea-SCR)

### Engine outlet

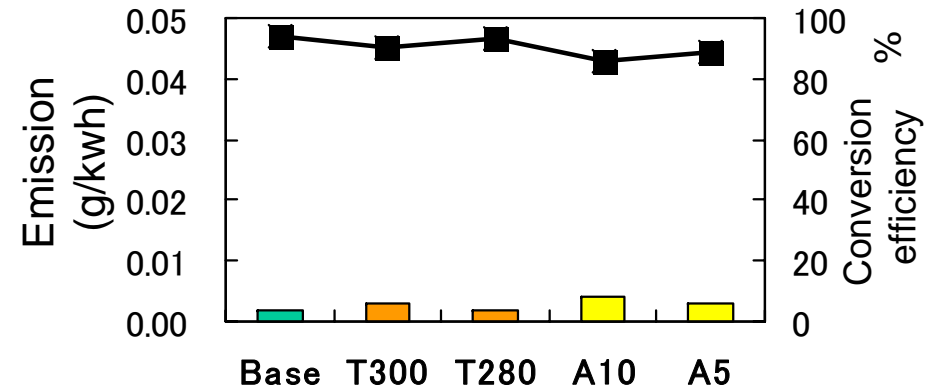


### JE05 Mode

### Post after-treatment



### Post after-treatment

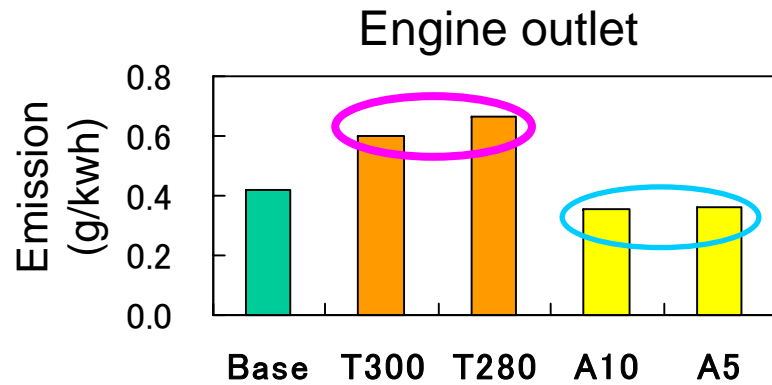


Both Engines showed a decrease in PM emissions at engine outlet due to the use of lighter T90 and less aromatics. All fuels had high conversion efficiency and low emission levels following after-treatment.

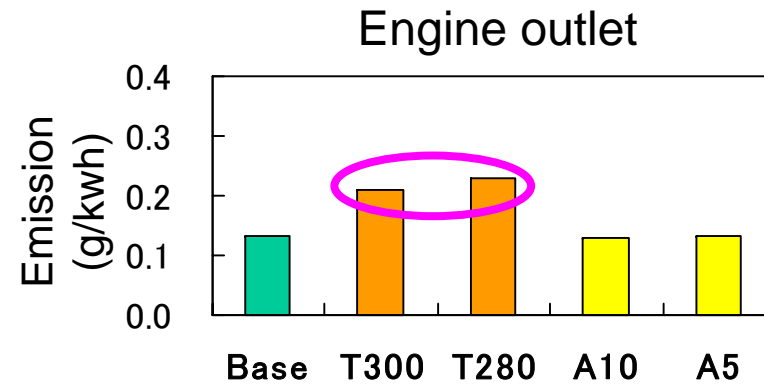


# Matrix Test Results - HC

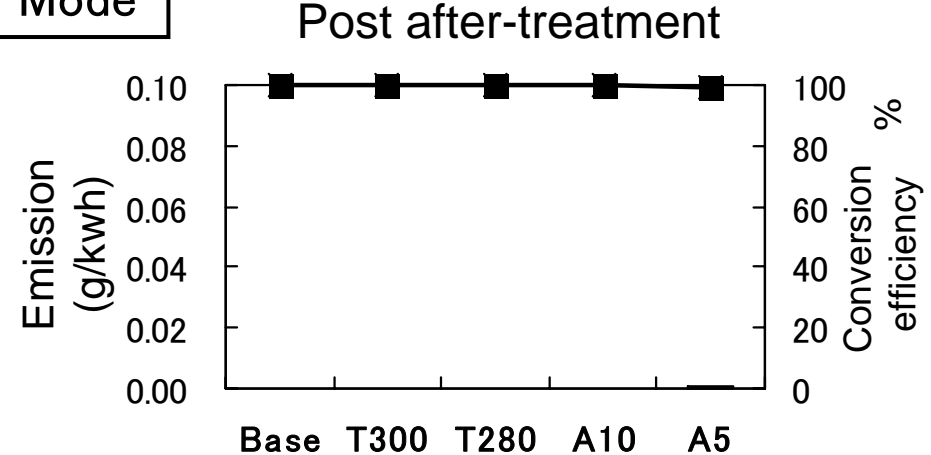
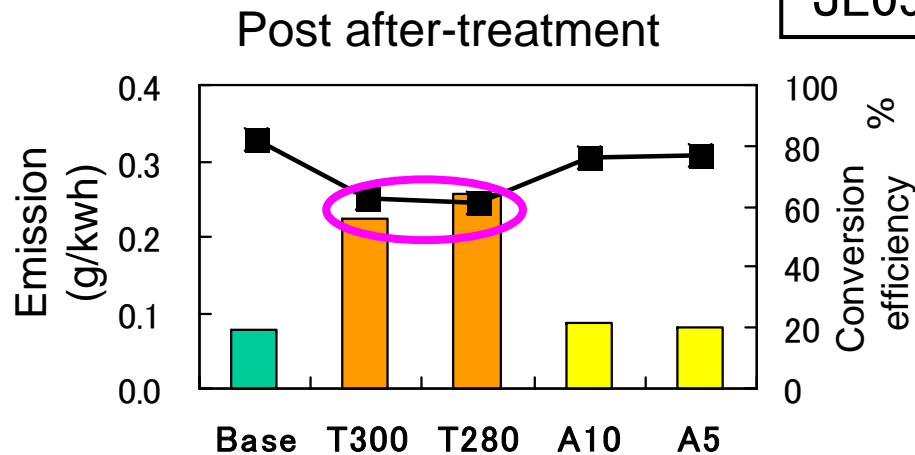
## Engine D (NSR)



## Engine E (Urea-SCR)



JE05 Mode



For both Engines, HC at engine outlet increased with lighter T90. For Engine D (NSR), post after-treatment HC also increased, while Engine E (Urea-SCR) showed high conversion efficiency and low post after-treatment emission level.



# Comparison of Matrix Test Results

		Engine D NSR+DPF		Engine E Urea-SCR+DPF	
		Lighter T90	Less aromatics	Lighter T90	Less aromatics
NO <sub>x</sub>	Engine outlet	= / ↑	=	= / ↑	=
	Post after-treatment	↓ ↓ / ↓	↓	= / ↑	↓
PM	Engine outlet	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓
	Post after-treatment	—	—	—	—
HC	Engine outlet	↑ ↑ ↑	↓ / ↓ ↓ ↓	↑ ↑ ↑	=
	Post after-treatment	— / ↑ ↑ ↑	= / —	—	—
CO	Engine outlet	↑ / =	↓ / ↓ ↓ ↓	↓ / =	=
	Post after-treatment	↓ ↓ ↓ / —	—	—	—

No increase or decrease (less than  $\pm 5\%$ ) : =

Slight increase ( $5\% \leq$  and  $< 10\%$ ): ↑ , Increase ( $10\% \leq$  and  $< 25\%$ ): ↑ ↑ , Significant increase ( $25\% \leq$ ): ↑ ↑ ↑

Slight decrease ( $5\% \leq$  and  $< 10\%$ ): ↓ , Decrease ( $10\% \leq$  and  $< 25\%$ ): ↓ ↓ , Sig. decrease ( $25\% \leq$ ): ↓ ↓ ↓

Absolute change value is below the Back-to-Back repetition criteria: —

High conversion efficiency:  $95\% \leq$



# Comparison of Matrix Test Results

		Engine D NSR+DPF		Engine E Urea-SCR+DPF	
		Lighter T90	Less aromatics	Lighter T90	Less aromatics
NO <sub>x</sub>	Engine outlet	= / ↑	=	= / ↑	=
	Post after-treatment	↓ ↓ / ↓	↓	= / ↑	↓
PM	Engine outlet	↓ ↓ ↓	↓ ↓	↓ ↓ ↓	↓ ↓ ↓
	Post after-treatment	—	—	—	—
HC	Engine outlet	↑ ↑ ↑	↓ / ↓ ↓	↑ ↑ ↑	=
	Post after-treatment	— / ↑ ↑ ↑	= / —	—	—
CO	Engine outlet	↑ / =	↓ / ↓ ↓	↓ / =	=
	Post after-treatment	↓ ↓ ↓ / —	—	—	—

Effect of fuel properties on Urea-SCR system was small compared to that on NSR.



# Comparison of Matrix Test Results

		Engine D NSR+DPF		Engine E Urea-SCR+DPF	
		Lighter T90	Less aromatics	Lighter T90	Less aromatics
NO <sub>x</sub>	Engine outlet	= / ↑	=	= / ↑	=
	Post after-treatment	↓ ↓ ↓ / ↓	↓	↓	↓
PM	Engine outlet	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓
	Post after-treatment	—	—	—	—
HC	Engine outlet	↑ ↑ ↑	↓ ↓ ↓	↑ ↑ ↑	=
	Post after-treatment	— / ↑ ↑ ↑	= / —	—	—
CO	Engine outlet	↑ / =	↓ ↓ ↓	↓ ↓ ↓	=
	Post after-treatment	↓ ↓ ↓ / —	—	—	—

## Effect of lighter T90 on post after-treatment NO<sub>x</sub> level

Post after-treatment NO<sub>x</sub> level is reduced by the use of lighter fuel. This is because the NSR has adopted a system in which fuel is injected into the exhaust pipes, and the use of lighter fuel facilitates a formation of rich exhaust conditions.



# Comparison of Matrix Test Results

		Engine D NSR+DPF		Engine E Urea-SCR+DPF	
		Lighter T90	Less aromatics	Lighter T90	Less aromatics
NO <sub>x</sub>	Engine outlet	= / ↑	=	= / ↑	=
	Post after-treatment	↓ ↓ / ↓	↓	= / ↑	↓
PM	Engine outlet	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓
	Post after-treatment	—	—	—	—
HC	Engine outlet	↑ ↑ ↑	↓ ↓ ↓ ↓	↑ ↑ ↑	=
	Post after-treatment	— / ↑ ↑ ↑	— / —	—	—
CO	Engine outlet	↑ / =	↓ ↓ ↓ ↓	↓ / =	=
	Post after-treatment	↓ ↓ ↓ / —	—	—	—

## Effect of lower aromatics content on HC and CO at engine outlet

Effect of fuel properties on emissions is considered to become more apparent with Engine D because it has greater timing retardation.



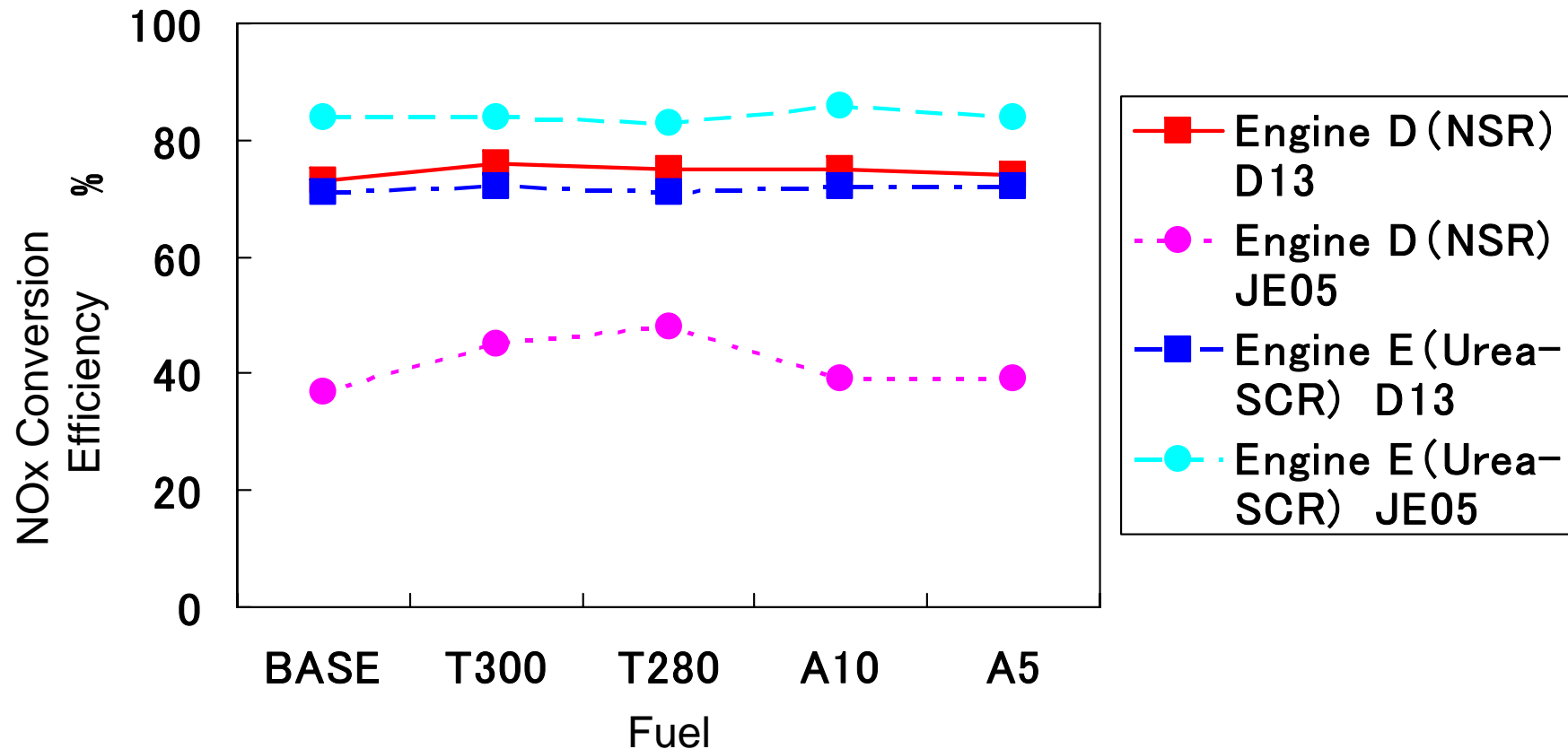
# Comparison of Matrix Test Results

		Engine D NSR+DPF		Engine E Urea-SCR+DPF	
		Lighter T90	Less aromatics	Lighter T90	Less aromatics
NO <sub>x</sub>	Engine outlet	= / ↑	=	= / ↑	=
	Post after-treatment	↓ ↓ / ↓	↓	= / ↑	↓
PM	Engine outlet	↓ ↓ ↓	↓ ↓	↓ ↓ ↓	↓ ↓ ↓
	Post after-treatment	—	—	—	—
HC	Engine outlet	↑ ↑ ↑	↓ / ↓ ↓	↑ ↑ ↑	=
	Post after-treatment	— / ↑ ↑ ↑	= / —	—	—
CO	Engine outlet	↑ / =	↓ / ↓ ↓	↓ / =	=
	Post after-treatment	↓ ↓ ↓ / —	—	—	—

Effect of lower aromatics on Post after-treatment HC emissions  
 HC emissions significantly increase with Engine D in JE05 mode (large amount of HC emissions are discharged during acceleration). It is assumed that lighter fuel may easily evaporate from catalyst surface during acceleration.



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



Engine E showed high NO<sub>x</sub> conversion efficiency in JE05 mode. This is assumed to result from 20°C higher exhaust gas temperature\* as well as JE05 mode-specific matching.

\* See slide 7



# Contents of Report

1. Effects of sulfur content	1.1 Mileage accumulation test Engine D (NSR), Vehicle B (NSR)
	1.2 Urea-SCR test Engine B (Urea-SCR)
2. Effects of distillation and aromatics	Matrix test Engine D (NSR), Vehicle B (NSR) Engine E (Urea-SCR)
3. Effects of FAME/GTL	FAME/GTL test Engine D (NSR), Vehicle B (NSR)

			Fuel properties		
			Sulfur content	T90/Aromatics	FAME/GTL
NO <sub>x</sub> Catalyst technology	NSR	Engine D	1.1	2	3
		Vehicle B			
	Urea-SCR	Engine B	1.2	2	
		Engine E			



# FAME/GTL Test – Test Fuel Properties

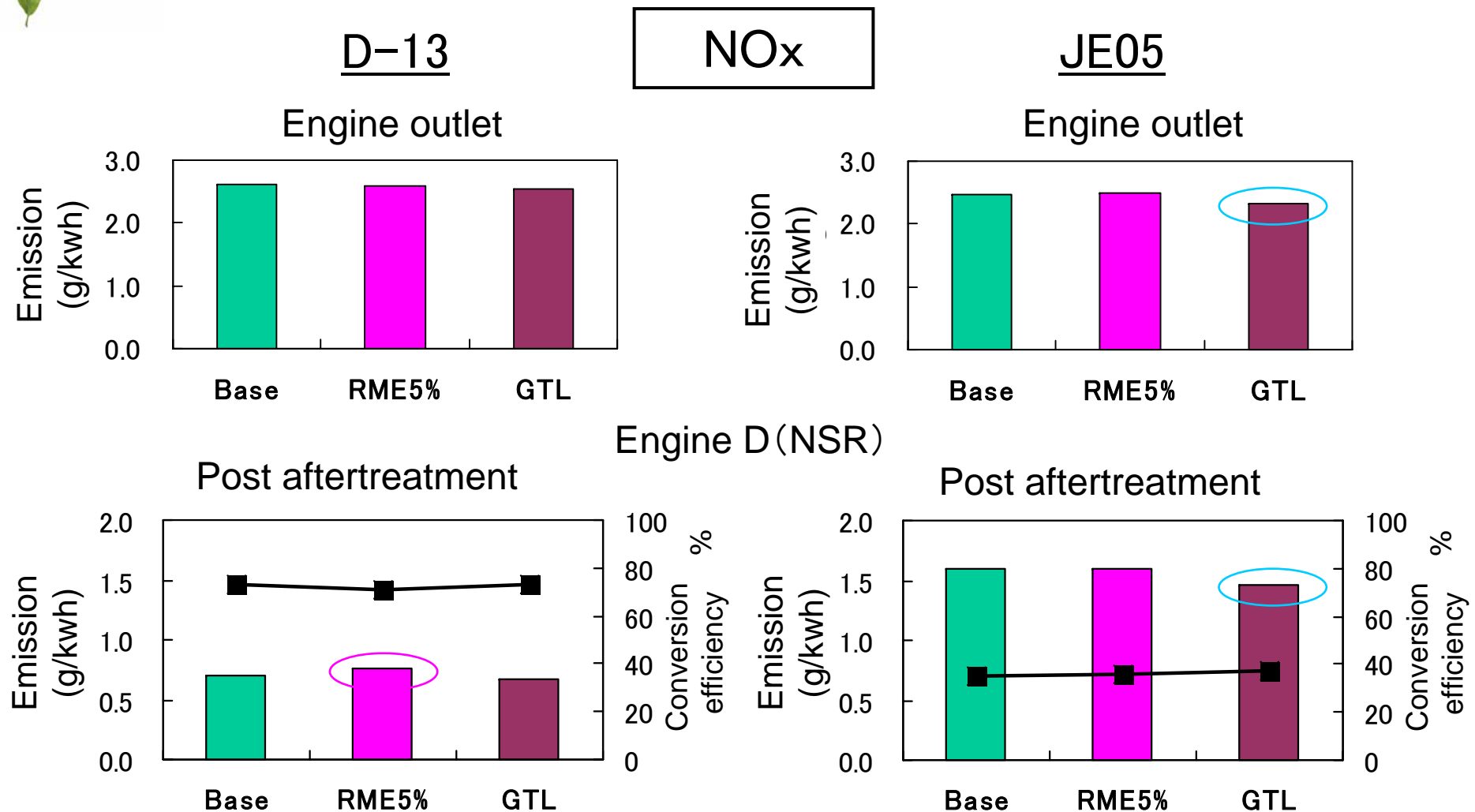
		J2D35	J2D47A	J2D45
		Base	RME5%	GTL
Density	gr/cm <sup>3</sup>	0.828	0.831	0.785
Distillation °C	10%	219	225	246
	50%	273	278	296
	90%	331	333	342
Aromatics cont.	vol%	19.2	17.8	0.0
Sulfur cont.	mass ppm	3	3	<1
Cetane Number		56.6	56.4	78.9
Cetane index		57.4	57.7	90.3
Nitrogen cont.	mass ppm	6	<1	<1

FAME (RME5%) is blended with RME (rapeseed methyl ester) by 5% to base fuel.

GTL is the product of a commercial plant.



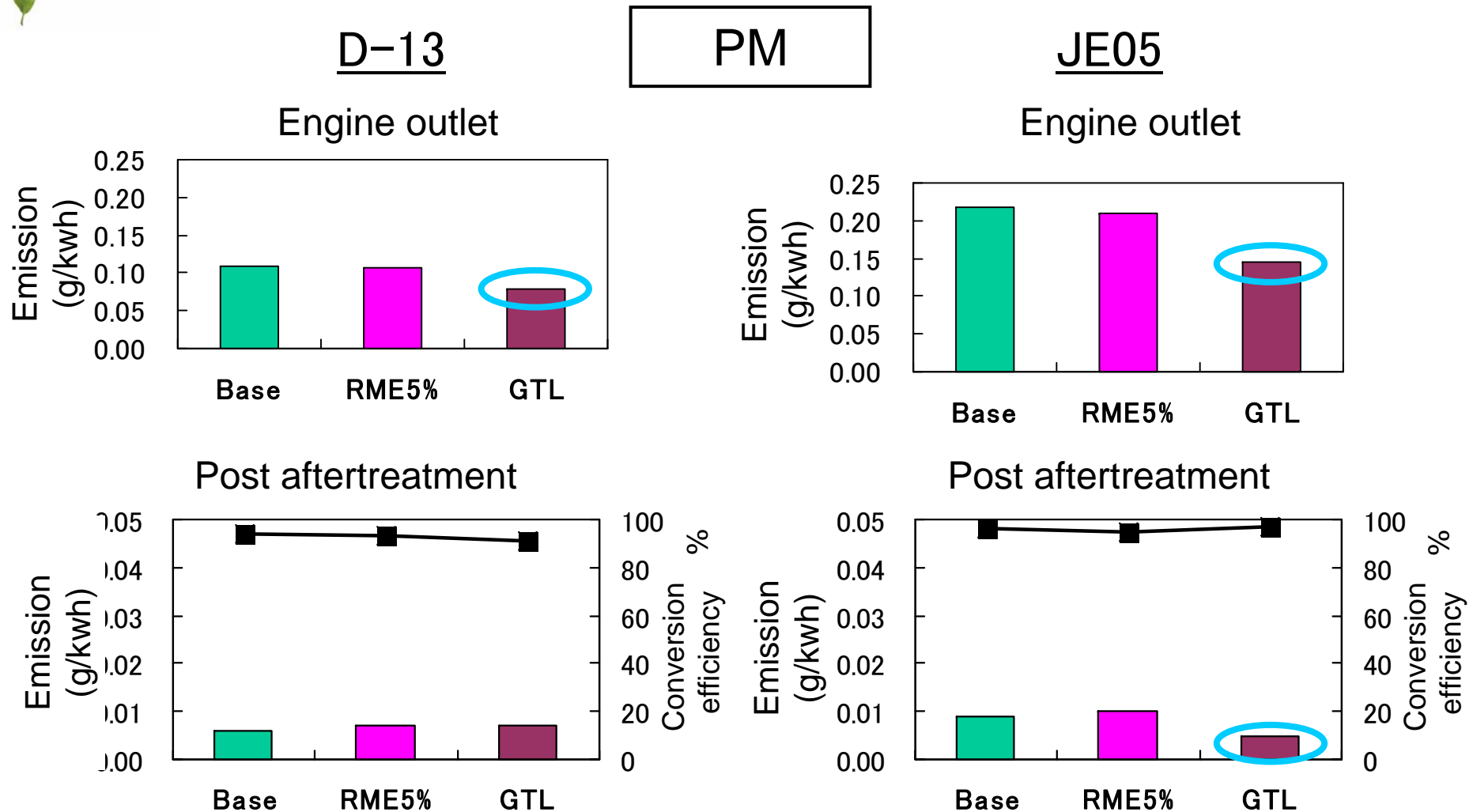
# FAME/GTL Test Results for Engine D(NSR)



For RME5% fuel, NO<sub>x</sub> emissions increased slightly in D13 mode, but there was no difference in JE05 mode. As for GTL, NO<sub>x</sub> emissions decreased especially in JE05 mode, both at engine outlet and post after-treatment.



# FAME/GTL Test Results for Engine D (NSR)



There was no difference in PM emissions between the both driving modes when using RME5% fuel. As for GTL, PM emissions decreased especially in JE05 mode, both at engine outlet and post after-treatment.



# Summary of FAME/GTL Test Results for Engine D

		RME5%		GTL	
		D-13	JF05	D-13	JF05
NO <sub>x</sub>	Engine outlet	=	=	=	↓
	Post after-treatment	↑	=	=	↓
PM	Engine outlet	=	=	↓ ↓ ↓	↓ ↓ ↓
	Post after-treatment	—	(High conversion efficiency)	—	(High conversion efficiency)
HC	Engine outlet	↑	=	↓ ↓ ↓	↓ ↓ ↓
	Post after-treatment	—	—	↓ ↓	↓ ↓ ↓
CO	Engine outlet	=	=	↓	↓ ↓ ↓
	Post after-treatment	(High conversion efficiency)	(High conversion efficiency)	(High conversion efficiency)	(High conversion efficiency)

No increase or decrease (less than  $\pm 5\%$ ) : =

Slight increase ( $5\% \leq$  and  $< 10\%$ ): ↑ , Increase ( $10\% \leq$  and  $< 25\%$ ): ↑ ↑ , Significant increase ( $25\% \leq$ ): ↑ ↑ ↑

Slight decrease ( $5\% \leq$  and  $< 10\%$ ): ↓ , Decrease ( $10\% \leq$  and  $< 25\%$ ) ): ↓ ↓ , Sig. decrease ( $25\% \leq$ ): ↓ ↓ ↓

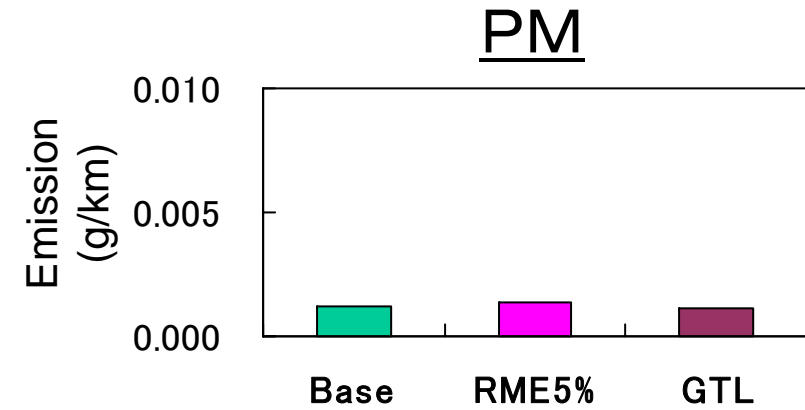
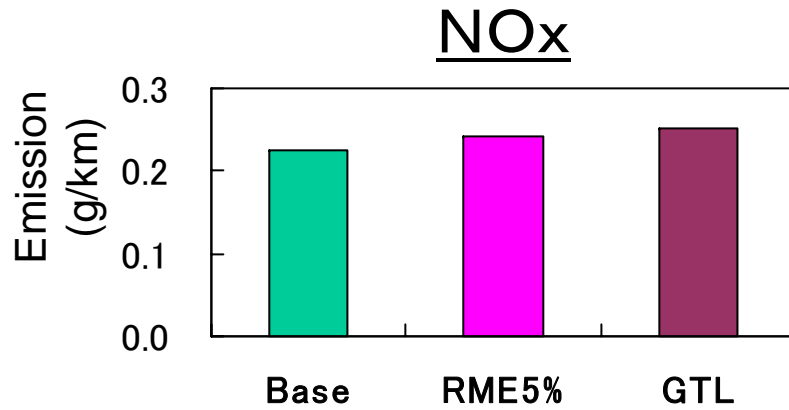
Absolute change value is below the Back-to-Back repetition criteria: —

High conversion efficiency:  $95\% \leq$

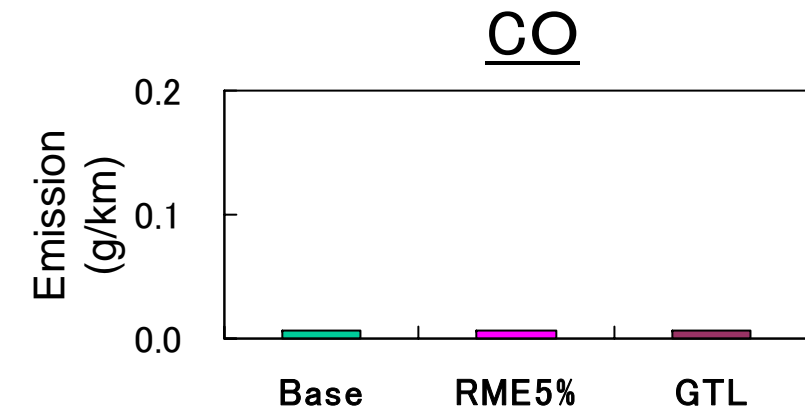
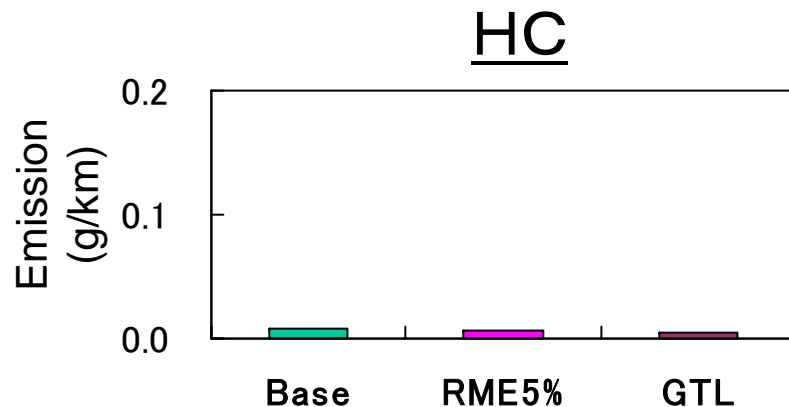


# FAME/GTL Test Results for Vehicle B (NSR)

CD34 Hot



Vehicle B(NSR)



Vehicle B (NSR) showed increase in NO<sub>x</sub> emissions due to the use of GTL. PM, HC and CO emission levels were extremely low for all types of fuel.



# Summary



# Diesel WG – Summary (1)

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Effects of fuel properties on NOx storage reduction catalyst (NSR catalyst) and Urea-SCR are investigated, Obtained conclusions are;

## **【Effects of sulfur in fuel】**

### **<NSR catalyst>**

· Reduction in sulfur content reduces worsening of fuel economy (increase of CO<sub>2</sub>) due to desulfation of the NSR catalyst.

E.g.: Reduction in sulfur content from 50 to 10 ppm results in 4 to 5 % improvement in fuel economy.

· Reduction in sulfur content is also effective for maintaining NOx conversion efficiency because it reduces thermal deterioration of NSR catalyst due to desulfation.

### **<Urea-SCR>**

· Improvement in NOx conversion efficiency at low exhaust gas temp. as in urban driving can be expected. This is because reduction in sulfur content may reduce poisoning of former stage oxidation catalyst.



# Diesel WG – Summary (2)

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## **【Effects of T90】**

- **Lighter diesel fuel (reduction of T90) may improve conversion efficiency of the NSR catalyst.**
- **On the other hand, optimization of engine system is required because NOx and HC emissions at engine outlet have increased due to the use of lighter fuel.**
- **Lighter diesel fuel can reduce PM emissions at engine outlet, but effect on post after-treatment emissions is small because PM emissions are reduced substantially by DPF. However it is noticed that, reduction of PM emissions at engine outlet can generally improve reliability of DPF device.**

## **【Effects of aromatics】**

- **Lower aromatics content of diesel fuel can reduce PM emissions at engine outlet, but effect on post after-treatment emissions is small because PM emissions are reduced substantially by DPF.**



# Diesel WG – Summary (3)

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## **【Effects of FAME】**

- **No significant change in exhaust emissions was observed for NSR catalyst system due to the use of FAME (RME5%).**

## **【Effects of GTL】**

- **Possibility of reduction in emission components, especially at engine outlet, was shown due to the use of GTL.**