

# Diesel Oxidation Catalyst (DOC) System for PM Control

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ENVIRONMENTAL CATALYSTS AND TECHNOLOGIES

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## Presentation Outlines

- **Background**
  - \* Social requirements in Japan
  - \* Importance to develop robust PM control technology for in use diesels
- **Experimental Procedure**
- **Test Results**
  1. Impact of DOC on PM Emission (work with Kawasaki)
  2. Impact of DOC on Unregulated Hydrocarbons (work with TMG)
  3. Newly Developed DOC + CSF (Catalysed Soot Filter) Using Ceramic Foam
- **Conclusions**

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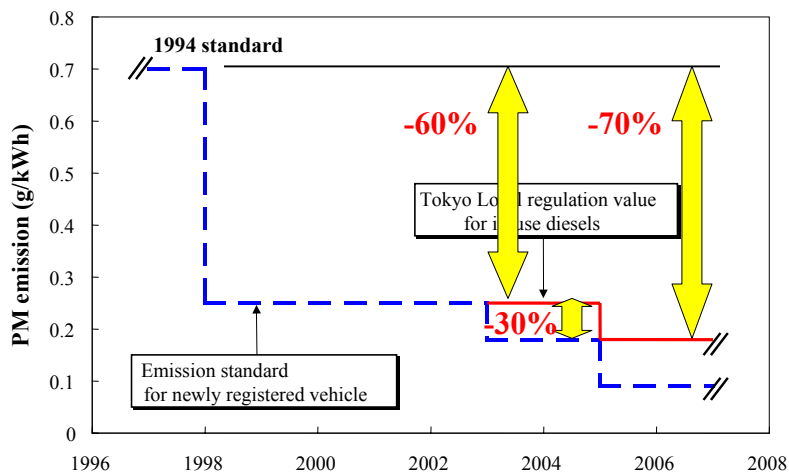
# Comparison of Diesel Emission Control Technologies

++ : very good, + : good, - : not suitable

	Emission Reduction Capability				S tolerance	Practical possibility
	CO	THC	PM	NOx		
<b>DOC</b>	++	++	+	-	++	++
Fuel Additive + DPF	+	+	++	-	++	+
Lean NOx catalyst	++	++	+	+	+	-
NOx trap	++	++	+	++	-	-
CR-DPF (CRT™)	++	++	++	-	-	+
SCR	++	++	+	++	++	-
CRT + SCR (SCRT™)	++	++	++	++	-	-

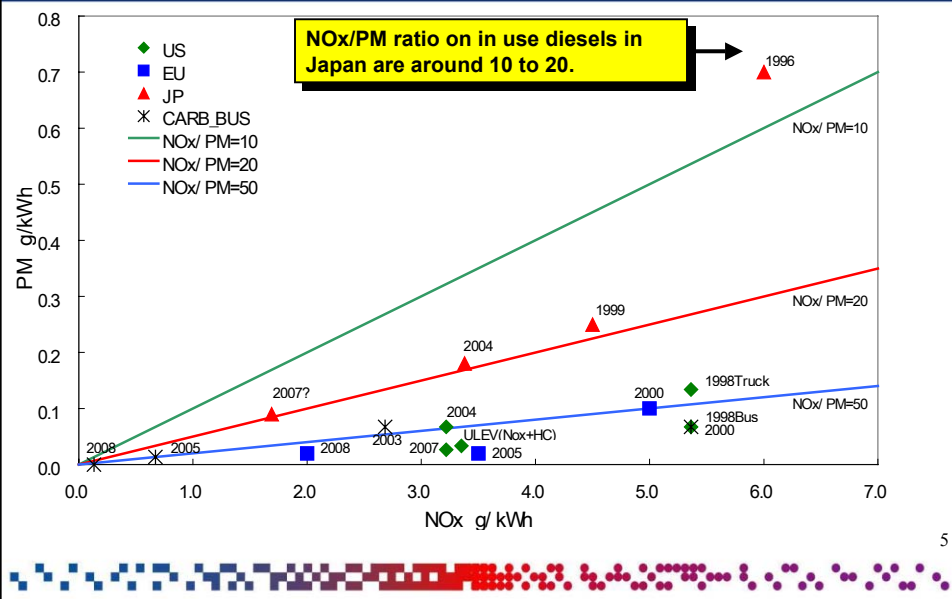
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# Legislation for In-Use HDD Enforced by Tokyo Metropolitan Government

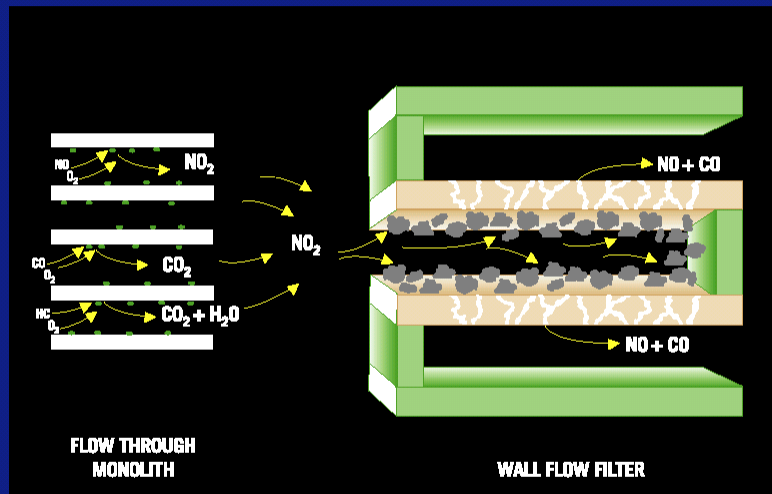


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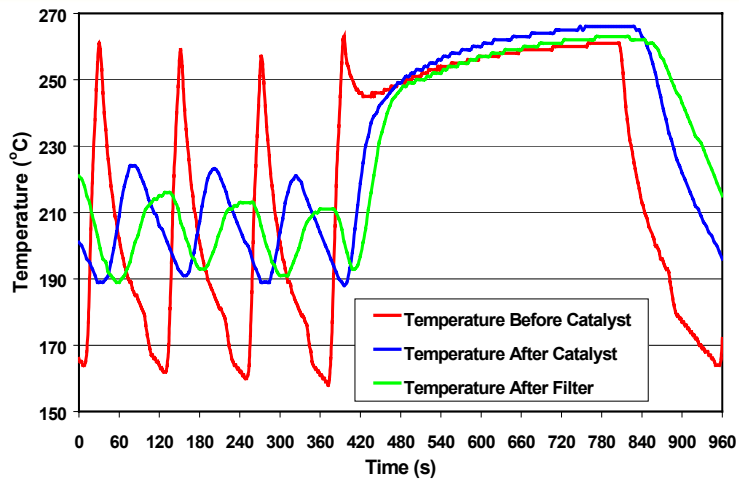
# Past and Future NOx and PM Legislations



# How to Improve ? -DOC + CSF System Principle-

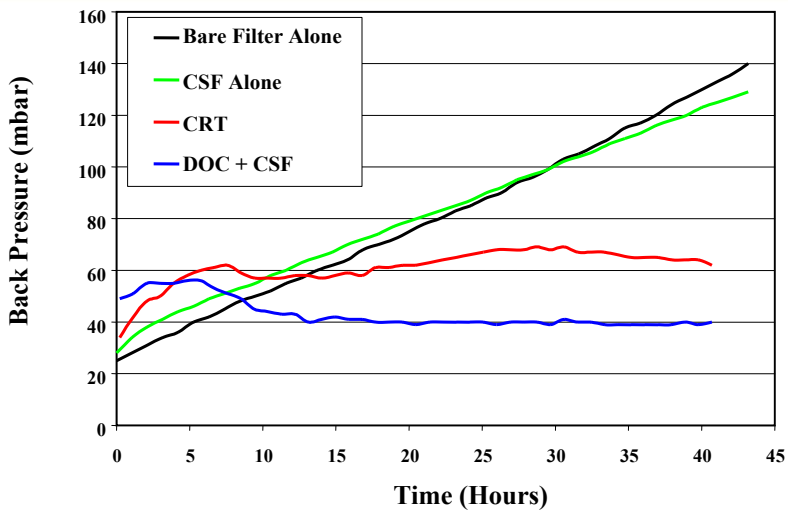


## Temperatures Conditions During Low Temperature Cycle



Ref : R. Allansson et.al., SAE Paper 2002-01-0428

## Low Temperature Cycle (40 hrs) Performance in MK1 Fuel



Ref : R. Allansson et.al., SAE Paper 2002-01-0428

# Experimental Conditions

\*Less than 50 ppm S fuel was used for all test.

Test 1 : Collaboration work with Kawasaki-city.

Test 2 : Collaboration work with Tokyo metropolitan Research Institute for Environmental Protection.

	Vehicle/Engine		DOC			CSF			
	Vehicle type	Engine size (L)	Size (mm)	Cell density (cpsi)	PGM (g/L)	Size (mm)	Cell density (cpsi)	Pt (g/L)	Memo
<b>Test 1</b>	Garbage truck	5	D:191 X L:178	400	2	/	/	/	/
<b>Test 2</b>	City bus	10	D:267 X L:152	400	2.6	D:267 X L:305	200	0	Non-coat Cordielite Wall-through
<b>Test 3</b>	Engine Bench	13	D:267 X L:152	400	2.6	OD:240 X ID:120 X L : 200	30 cpi	0.7	Catalyzed Cordielite foam filter

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## Specifications of Tokyo Metropolitan City Bus

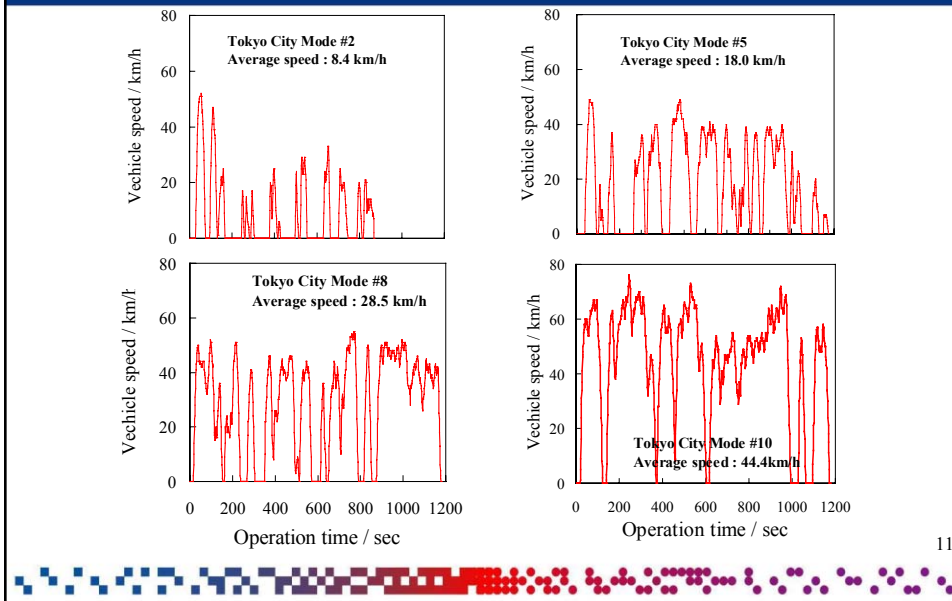


### Vehicle Specifications

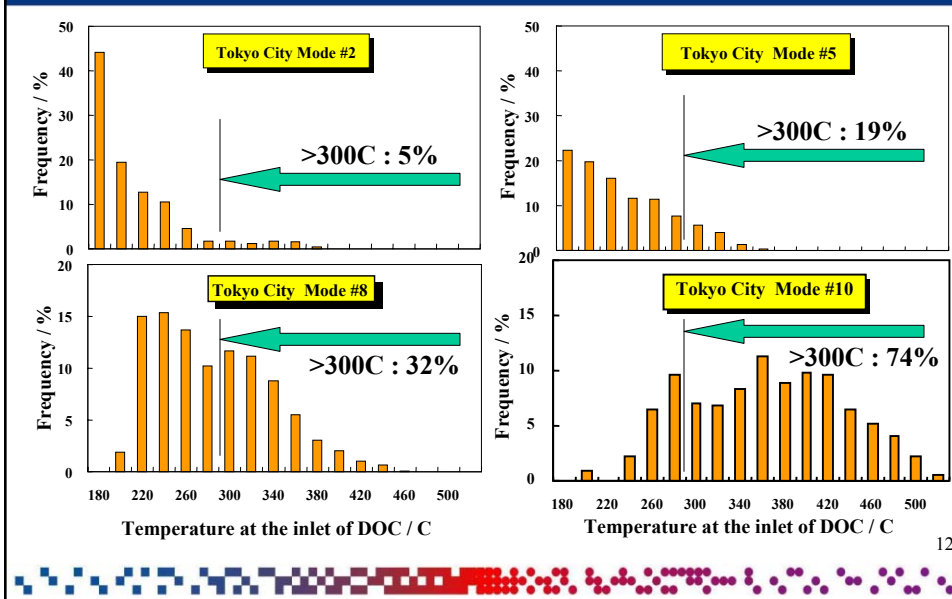
Engine Maker	Hino
Engine Type	M10U (DI, 6 cylinders)
Engine Displacement	9.88 L
Maximum Power	230 PS / 2500 rpm
Maximum Torque	70 kgm / 1500 rpm
Registration	Feb., 1993 (HT2MLA41043)

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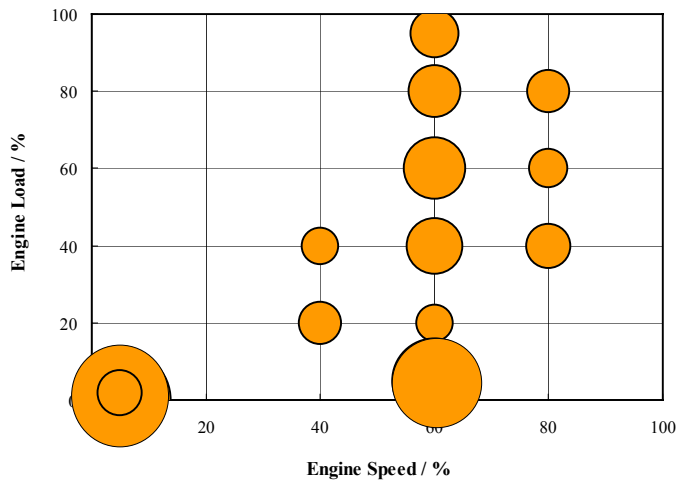
# Tokyo City Mode 2, 5, 8 and 10



# Temperature Frequency on Tokyo City Modes



# Engine Map Points with Weighting Factor on Japanese D13 Mode



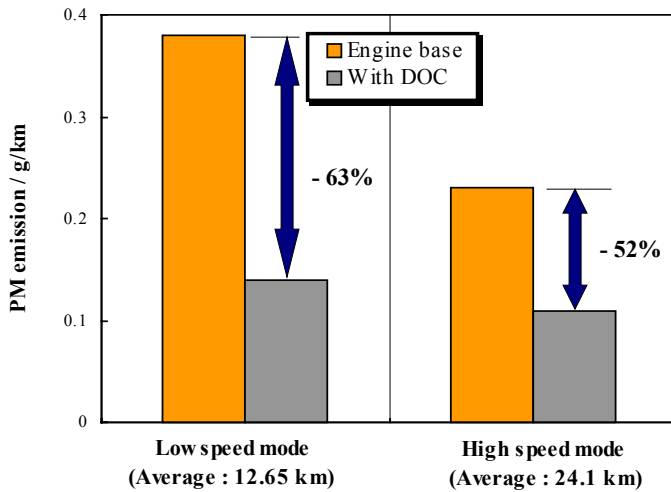
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## Test Results

- PM reduction Efficiency over DOC -

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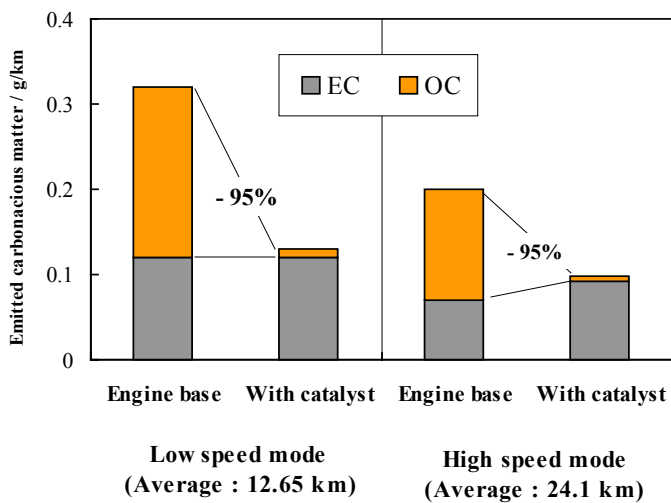
## PM Reduction Efficiencies on DOC over Kanagawa-Prefecture Modes



Conventional  
DOC testing on  
Garbage Truck  
(5L engine)

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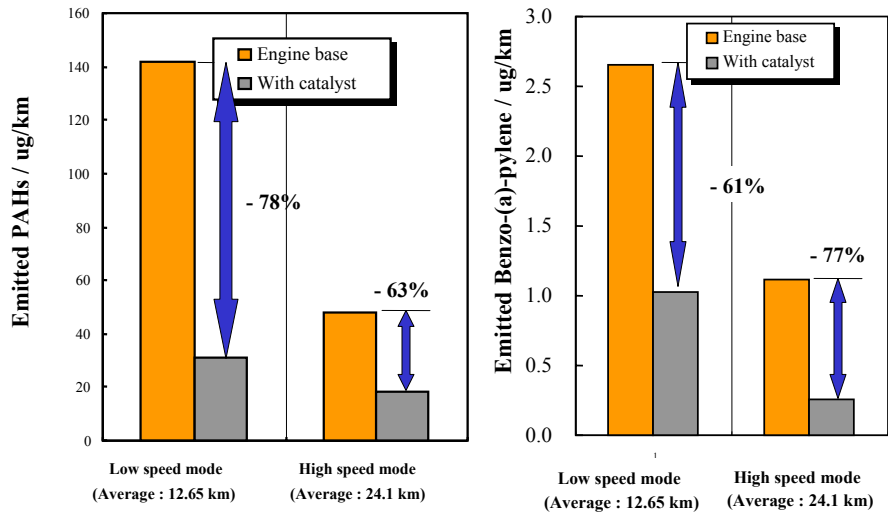
## Emitted Carbonaceous Matter over Kanagawa-Prefecture Modes



Garbage Truck  
(5L engine)

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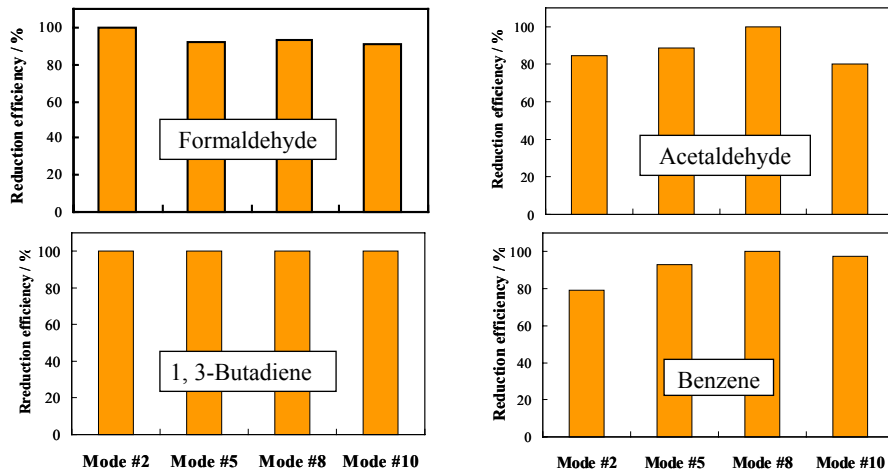
# Emitted PAHs and Benzo-(a)-Pylene over Kanagawa-Prefecture Modes



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# Unregulated Hydrocarbons Reduction Efficiencies over Tokyo City Modes

\* City Bus test : 10L engine



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## Vehicle Test Summary

1. DOC installed on garbage truck can reduce more than 40% PM. The reduction efficiency depends upon the vehicle driving condition.
2. DOC mainly reduced organic carbons (SOF) into PM and no effective function to reduce elementary carbons (Soot).
3. DOC effectively reduced many kinds of unregulated hydrocarbons at various driving condition.

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- PM reduction Efficiency over DOC + CSF -

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# How to Improve ?

$$[\text{PM combustion rate}] \geq [\text{PM accumulation rate}]$$



Increase NO<sub>x</sub> concentration  
(Out of control)

**Improve temperature condition**  
(Dual skin tube)

**Catalyzed filter**  
(Pt base catalyst)



Reduce PM emissions  
(Out of control)

**Low efficiency filter**  
(Wire mesh, Foam type)

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# System Concept of DOC+CSF Using Foam Filter

1. Use NO many times in the unit  
Frame by frame reaction of NO<sub>2</sub> with C
2. Larger geometrical surface area (GSA) than wall-through type DPF, and can increase number of contact point with PM

	Foam filter	Wall-through filter	
	#30	12/200	8/300
GSA(cm <sup>2</sup> /cm <sup>3</sup> )	43	9	12

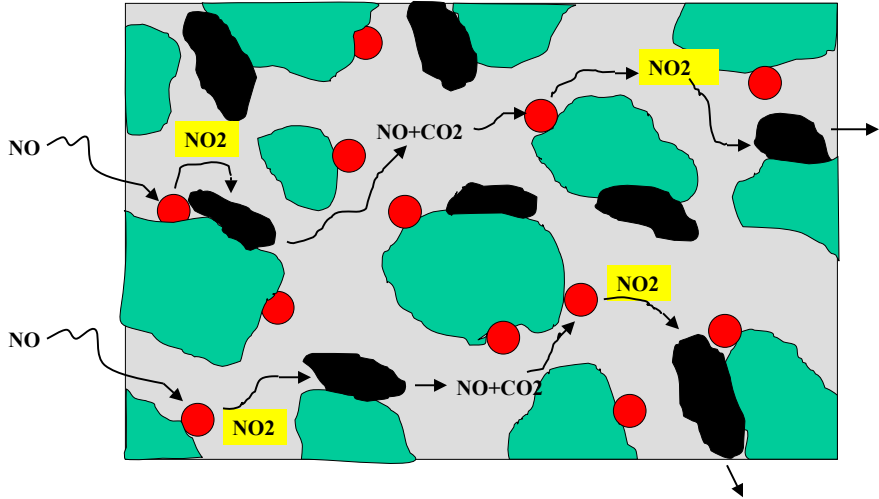
3. Acceptable backpressure level as CSF

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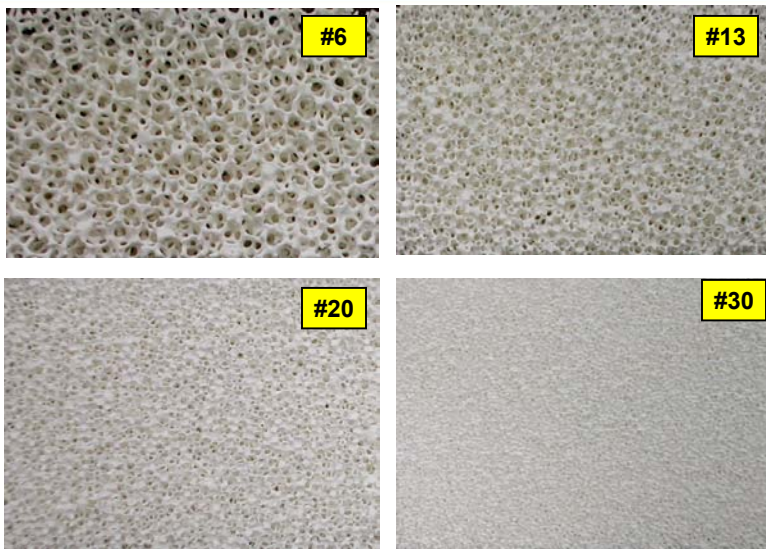
# NO<sub>2</sub> Reaction with C in Coated Foam Filter

- Pt
- Soot
- Frame

\* Frame by Frame Reaction of NO<sub>2</sub> with C



# Outward of Cordielite Ceramic Foams



## Plate Stack and Cylindrical Design

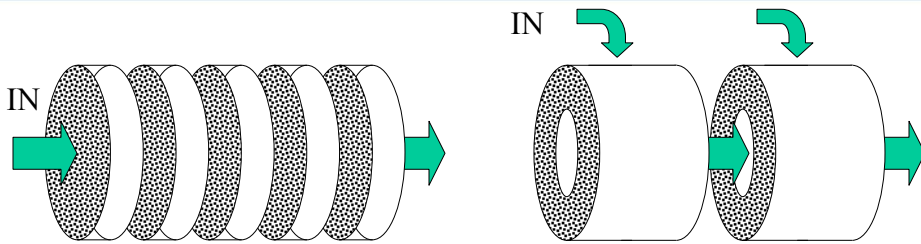
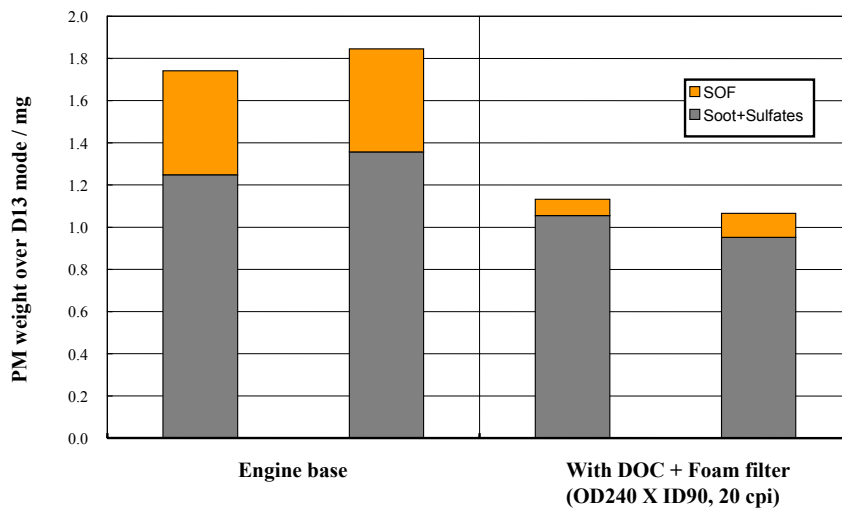


	Plate stack Type	Cylindrical Type
Efficiency	High	Low(in parallel)/High(in series)
D.Pressure	High	Low
Canning (Mechanical strength)	Difficult	Easy

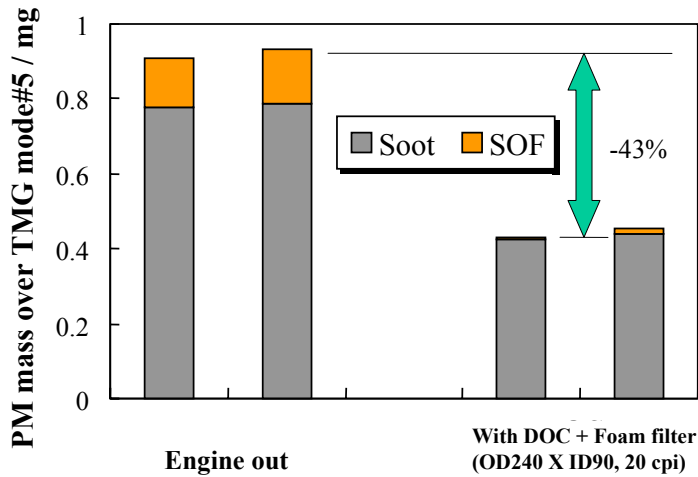
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## PM Emissions over D13 mode



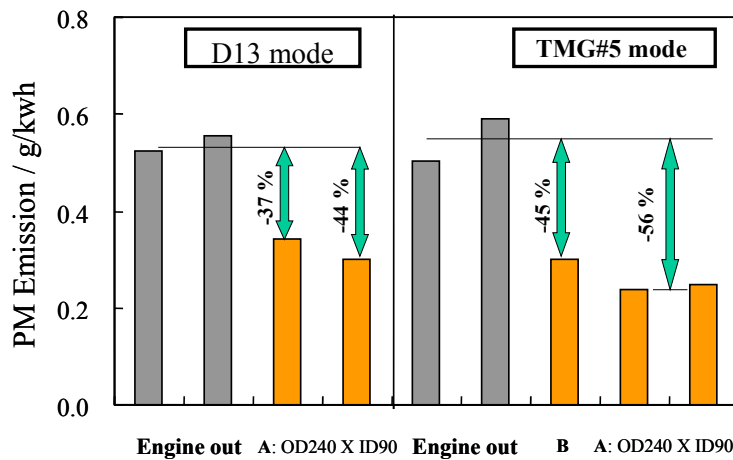
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## PM Emissions over Tokyo City Mode #5 - Blow-Off Effect while Transient Test -



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## PM Emissions over D13 Mode and Tokyo City Mode#5



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## Conclusions

1. DOC can reduce part of the PM, especially organic carbons. The reduction efficiency depends upon the SOF content and temperature at driving condition.
2. DOC effectively reduced unregulated hydrocarbons emitting from diesel engines. This is additional advantage to use DOC, not only for reducing PM mass.
3. System performance of newly developed DOC + catalyzed foam filter was demonstrated and showed promising results.
  - \* On this system, around 50% PM reduction efficiency was confirmed on both steady state mode and transient modes.
  - \* This system enable to cover the specific PM reduction target in between DOC and conventional wall-through DPF.

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**Thank you !**

