Reduction of Diesel Emission by using High Pressure Loop EGR and Low Pressure Loop EGR

Yuzo aoyagi
Masayuki Kobayashi
New A.C.E. Institute Co., Ltd.
2530 Karima, Tsukuba-shi, Ibaraki Pref.
305-0822, Japan

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Target of Super Clean Diesel (SCD)

No.	Item	Content	
1	NOx PM (g/kWh)	0.2 0.01 w/ After-treatment	1.0 0.10 w/o After-treatment
2	CO_2 (g/kWh)	670~680	
3	Power	Same or Better	
4	Noise	Same or Better	

Explain of the “SCD”

SCD Engine configurations

Engine Type			DI, In-Line 6
Bore × Stroke			Φ122 mm × 150 mm
Displacement			10,520 cm^3
Compression Ratio			15.3
Swirl Ratio			1.0 ~ 9.0
Injection Nozzle			Φ0.139 mm × 8-155°
Target	Max Output	Engine Speed	2000 rpm
		Output	298{405} kW {PS}
		BMEP	1.7 MPa
	Max Torque	Engine Speed	1400 rpm
		Output	1842{188} Nm {kgm}
		BMEP	2.2 MPa

Contents

Combustion Concept

No.	Concept
1	**Lean Combustion** (Burning by much O_2 amount and low combustion temperature)
2	**High Boosting** (Burning in high density air)
3	**Fuel Injection at high Density Air** (Reduction of peak fuel/air ratio)
4	**High Pressure Fuel Injection** (Smoke reduction by fine atomization)
5	**High BMEP** (Reduction of friction and heat loss)
6	**Wide speed range and High Rate of EGR** (Drastic NOx reduction)

10. SCD ECU for JE05

3. Injector

7. VVA & High boost 4 valve

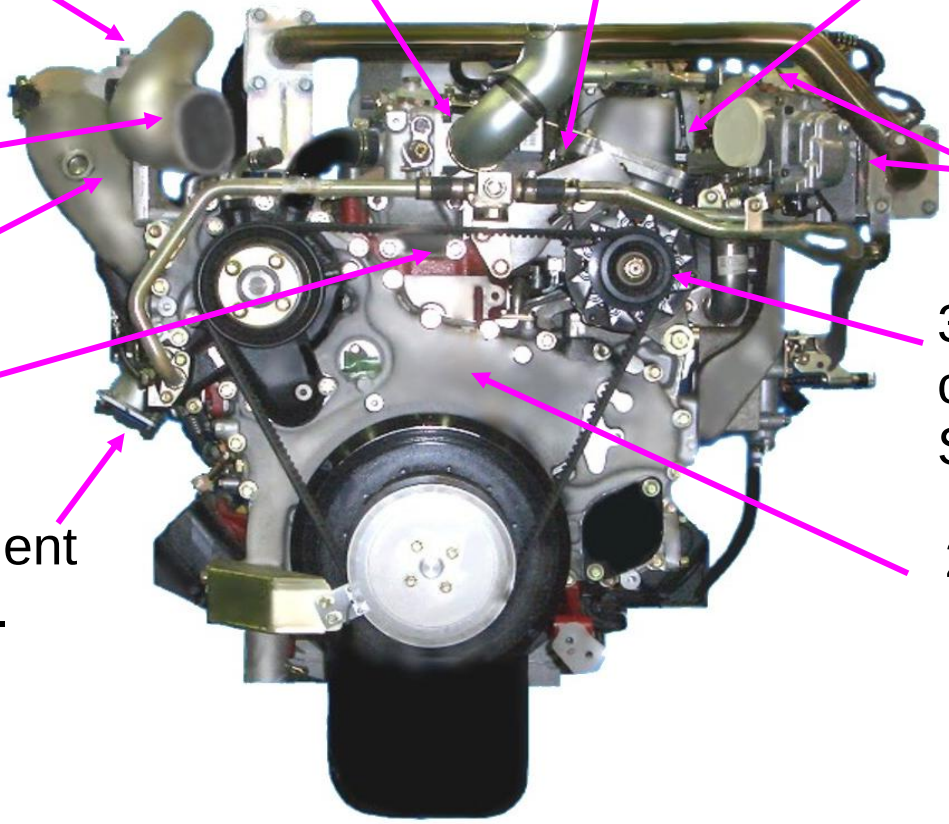
8. Variable swirl

4.5. HP-EGR & LP-EGR

1. SCD T/C

2. Shallow dish C/C

9. After treatment
- De-NOx cat.
- DOC
- DPF
- NOx sensor
- λ Sensor



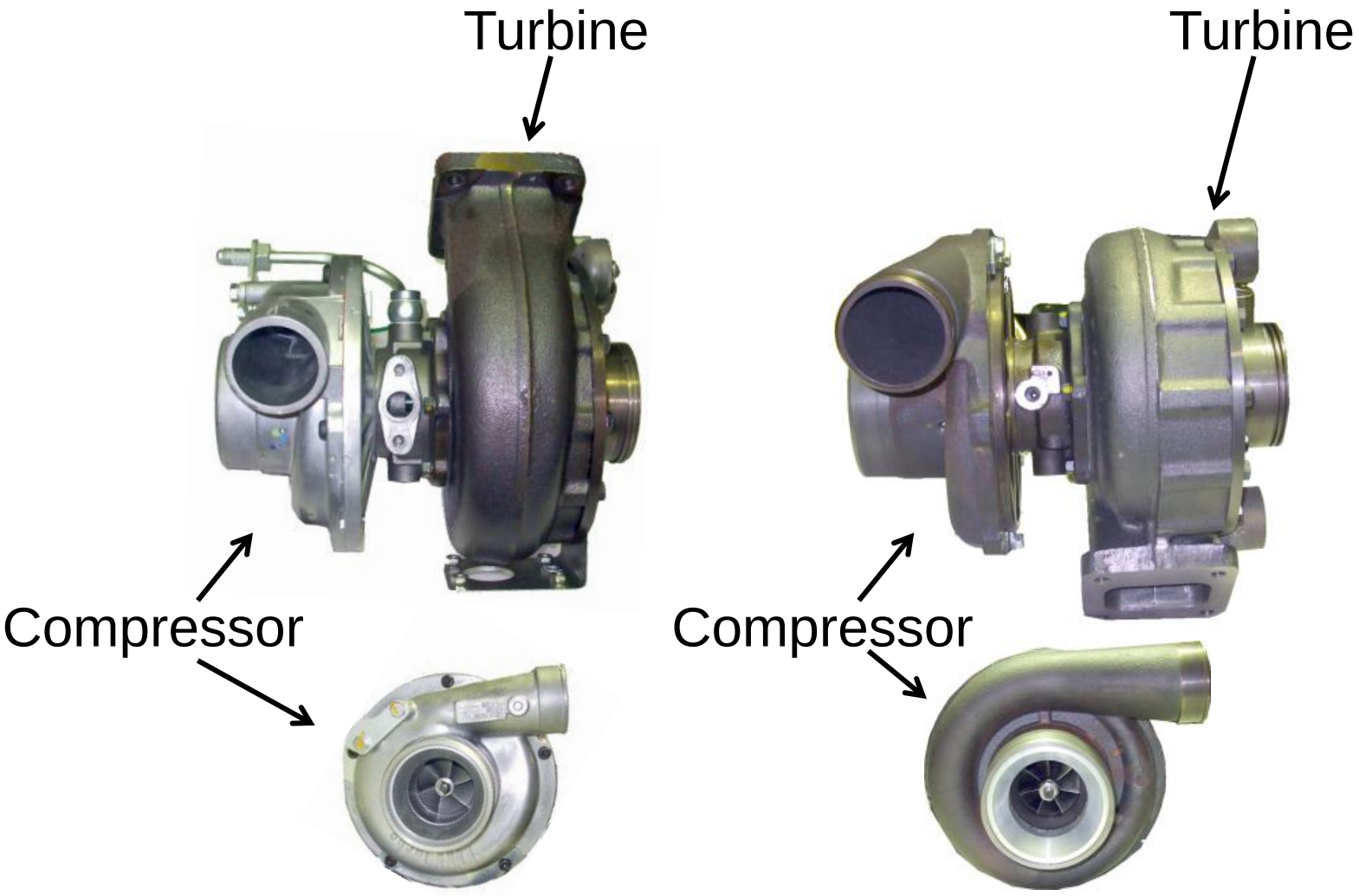
6. Pair of big EGR cooler

3. Pinj=200MPa common rail Supply pump

2. Pmax=20MPa
- Cyl. head
- Cyl. head GKT
- Cyl. Block
- FCD piston

New Technologies Adopted in SCD

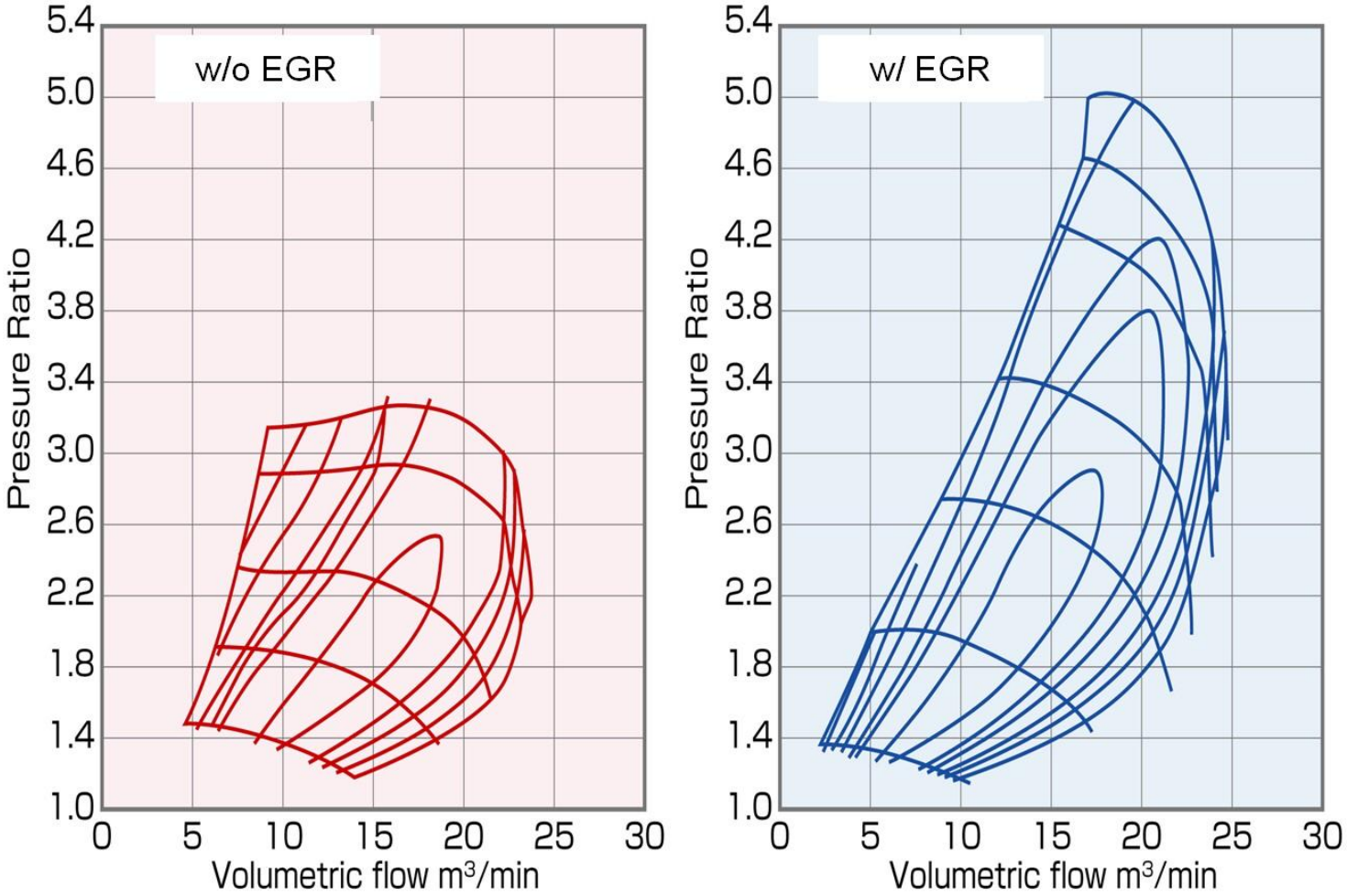
SCD Turbocharger



Current **SCD VGT**

Photos of the VGT

SCD Turbocharger

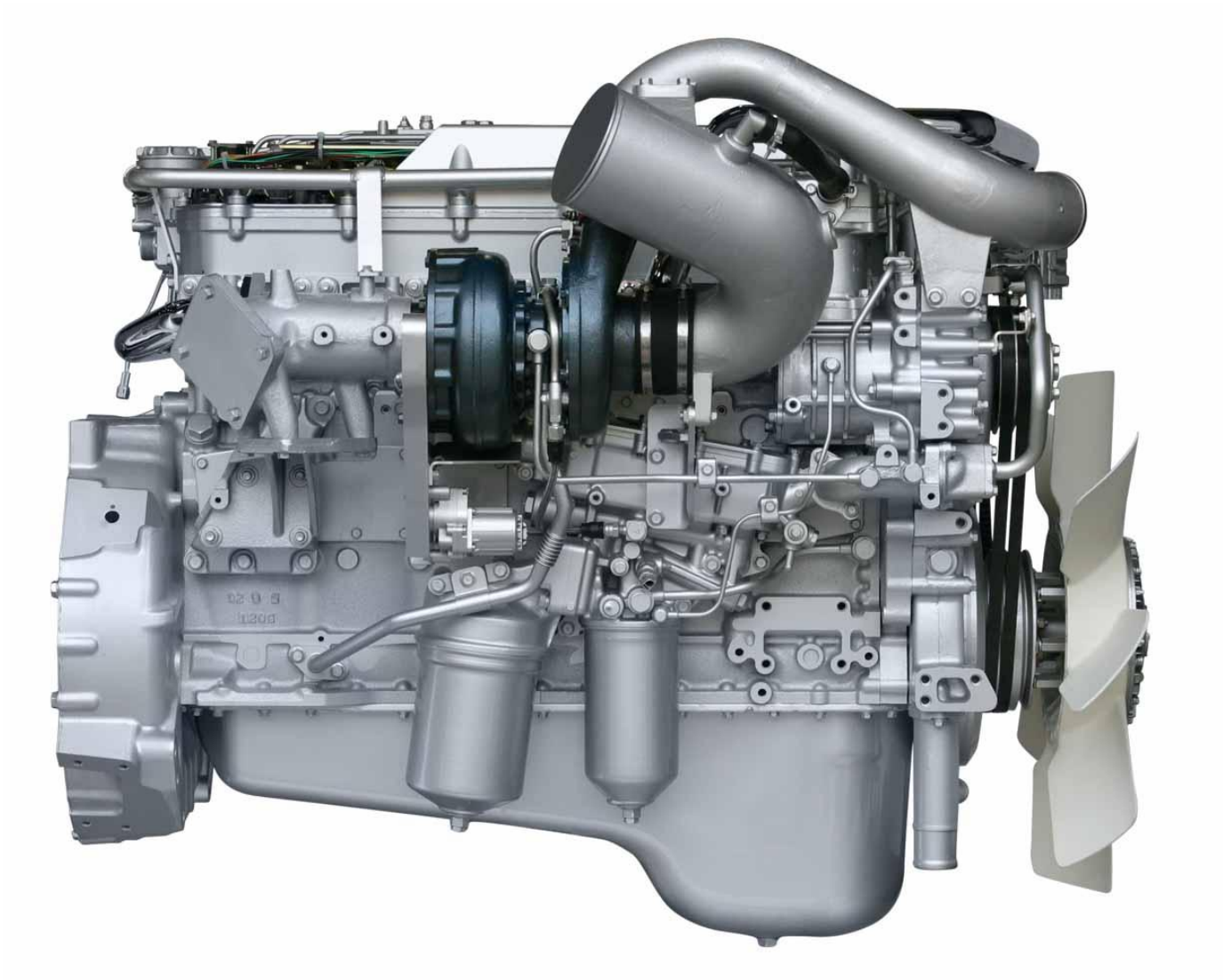


Current **SCD VGT**

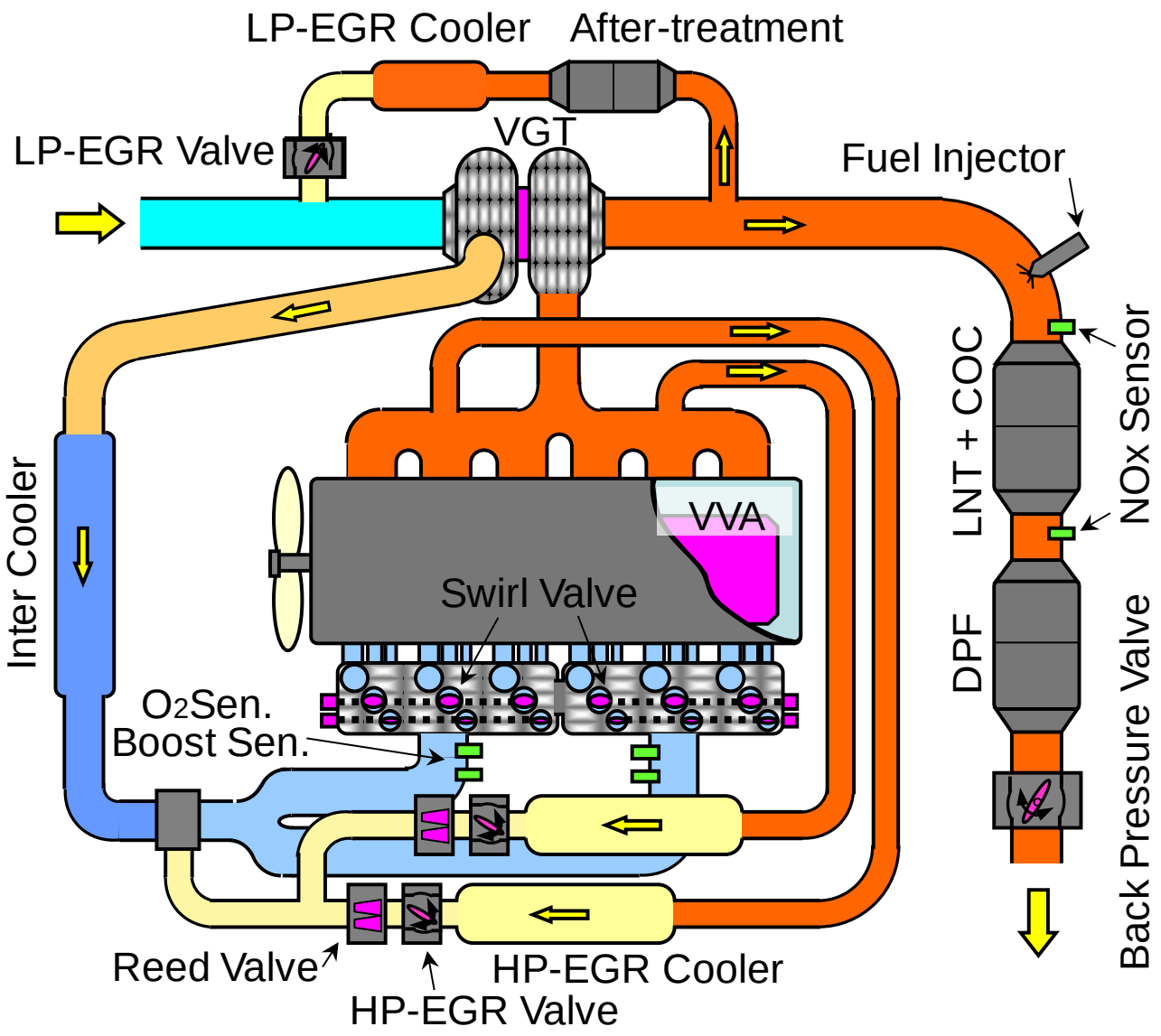
Comparison of Compressor Map

VGT compressor map

SCD Engine at Exhaust Side

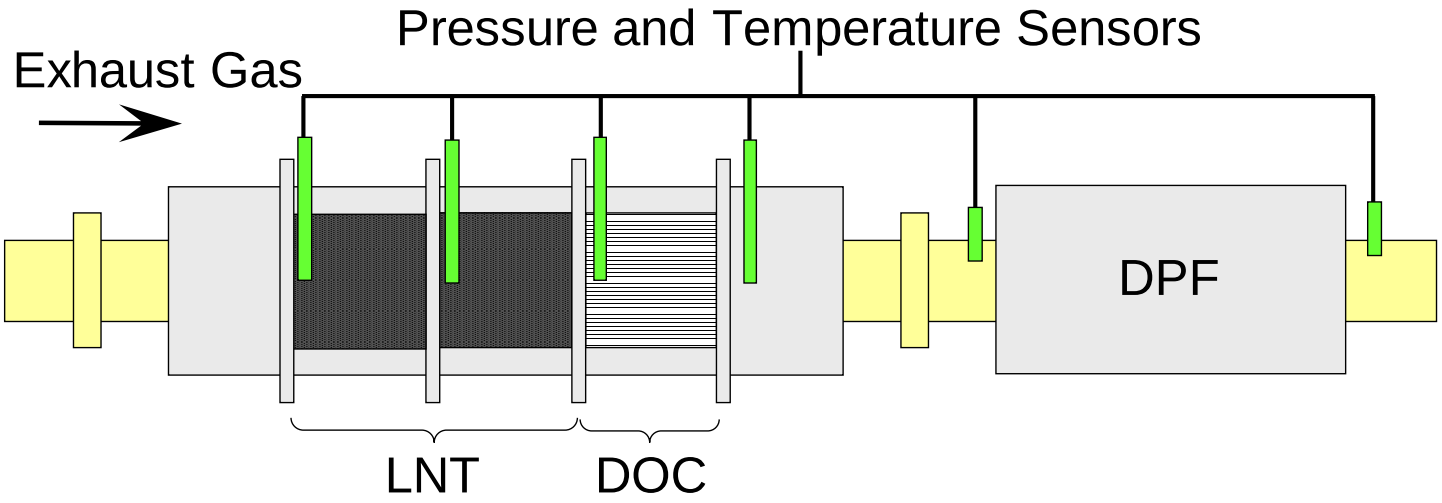


TI Engine Layout



New ENG Block diagram

SCD After-treatment system



Type	Volume	Quantity
De-NOx Catalyst	8.5L（Φ10.5”×6”）	2
Diesel Oxidation Catalyst	8.5L（Φ10.5”×6”）	1
Diesel Particulate Filter	17.0L（Φ10.5”×12”）	1

Contents

Fuel Properties

Category		Property	Category		Property
Density 15° C g/cm3		0.8212	Elements mass %	C	86.1
Kinematic H 13.8 mm2/s Viscosity 30℃		3.244		H	13.8
				O	-
Flash Point ° C		66.0		N	<0.1
Cetane Index （JIS K2280）		59.0	Components vol. %	Saturates	81.3
				Olefins	0.0
Cetane Number		**58.2**		Aromatics	18.7
Distillation	IBP	170.5		Mono-	17.5
	5%	190.5		Di-	1.0
	10%	201.5		Tri-	0.2
	50%	273.0	Calorific Value	kJ/kg	45990
	90%	333.0	Lower Calorific Value	kJ/kg	43100
	EP	360.5			
Sulfur ppm	mass	**7**	Lubricity HFRR（WS1.4）	*μ*m	272

Lubricant oil Properties

Category		Properties
Density 15° C g/cm3		0.859
Flash Point (COC) ° C		226
Kinematic Viscosity	40° C	68.82
	100° C	10.55
Pour Point ° C		-35.0
Sulfuric Ash Content mass %		1.00
Sulfur mass %		0.26

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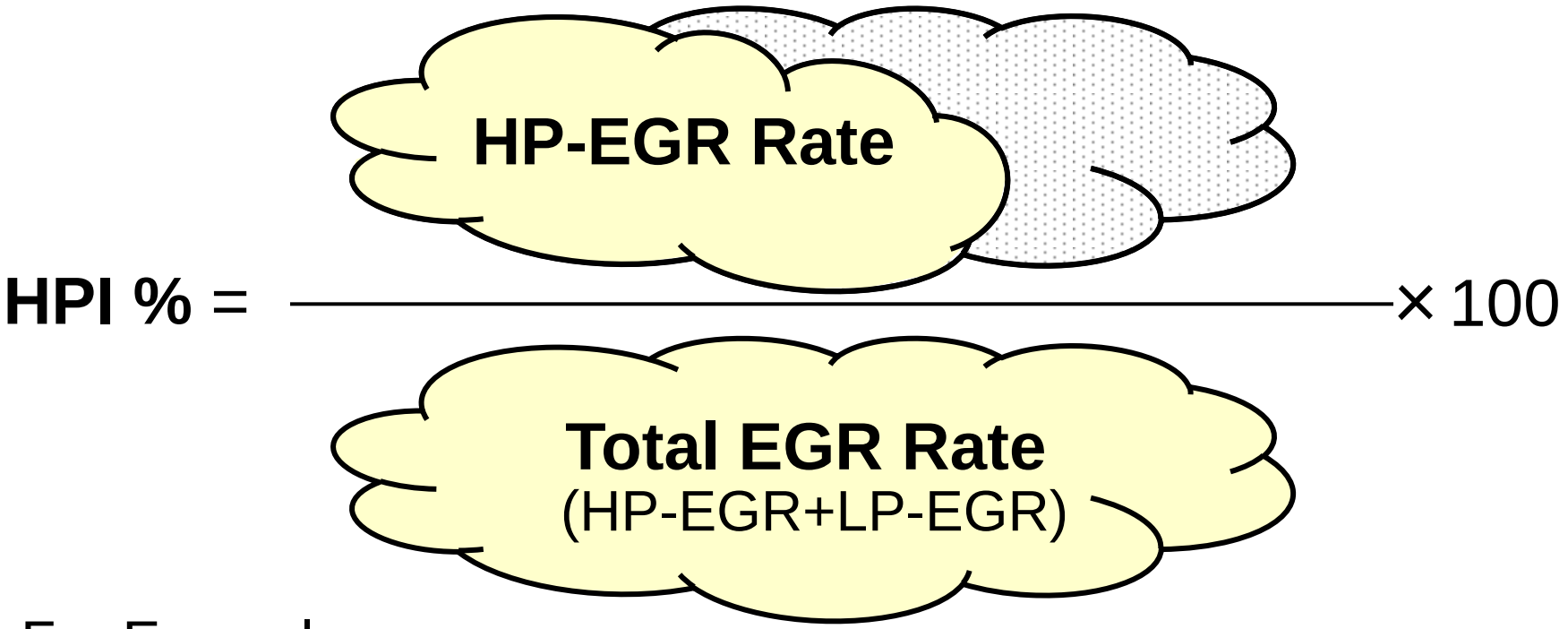
Explanation of High Pressure EGR Index (HPI)



For Example

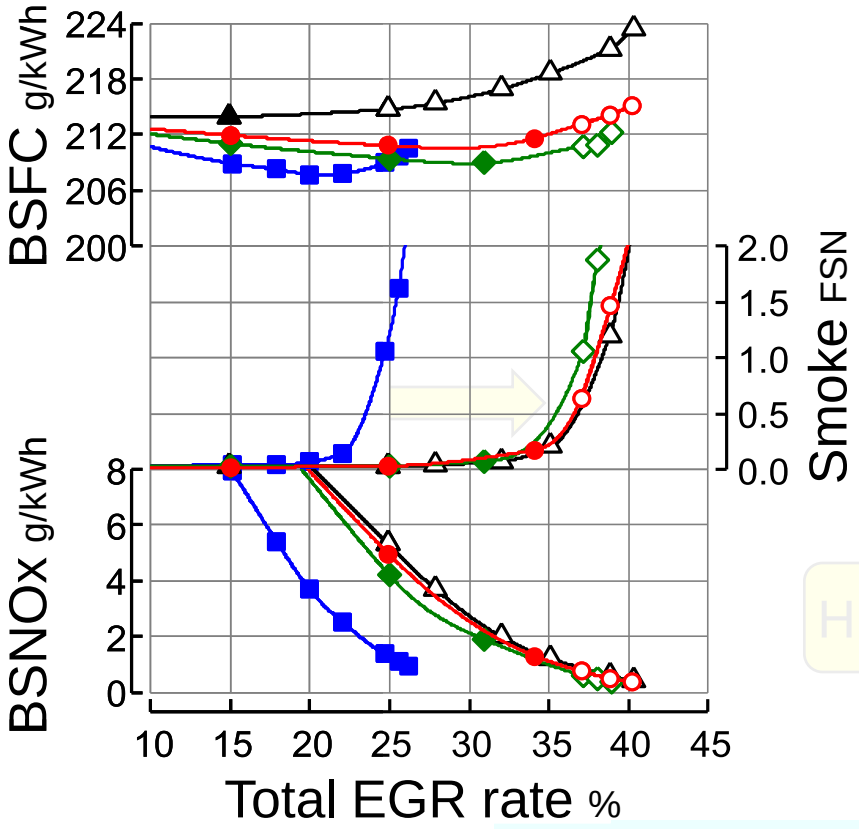
HPI =100% ; HP-EGR only
HPI = 70% ; HP-EGR 70% + LP-EGR 30%
HPI = 0% ; LP-EGR only

Effect of EGR on Steady State Test

Fixed VGT nozzle position

Ne = 1200 rpm
BMEP = 0.83 MPa
SOC = TDC
Pinj. = 160 MPa
VGT/N = 78% Close

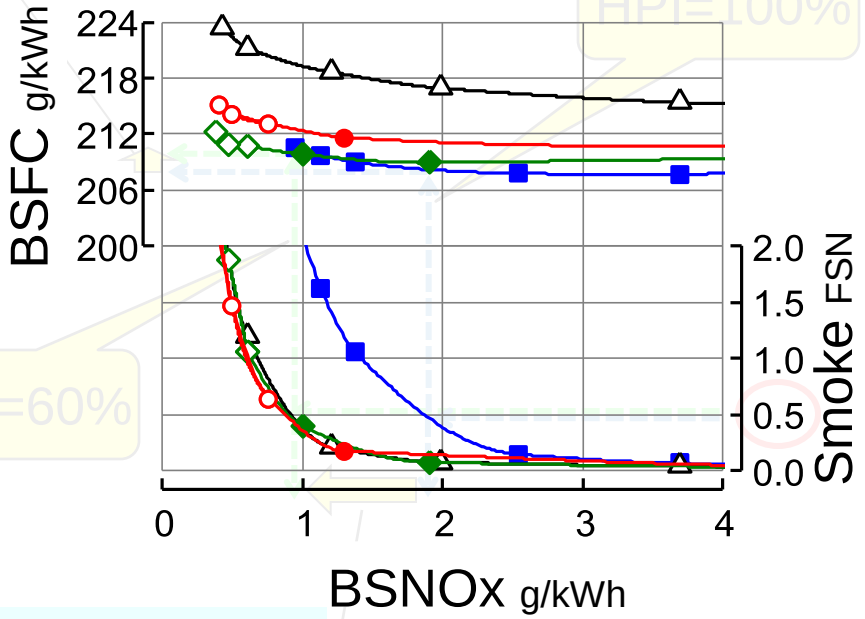
HPI=100%
HPI= 60% with BPCV
HPI= 30% with BPCV
HPI= 0% with BPCV



Around 1% increase

HPI=100%

HPI=60%



Around 50% reduction

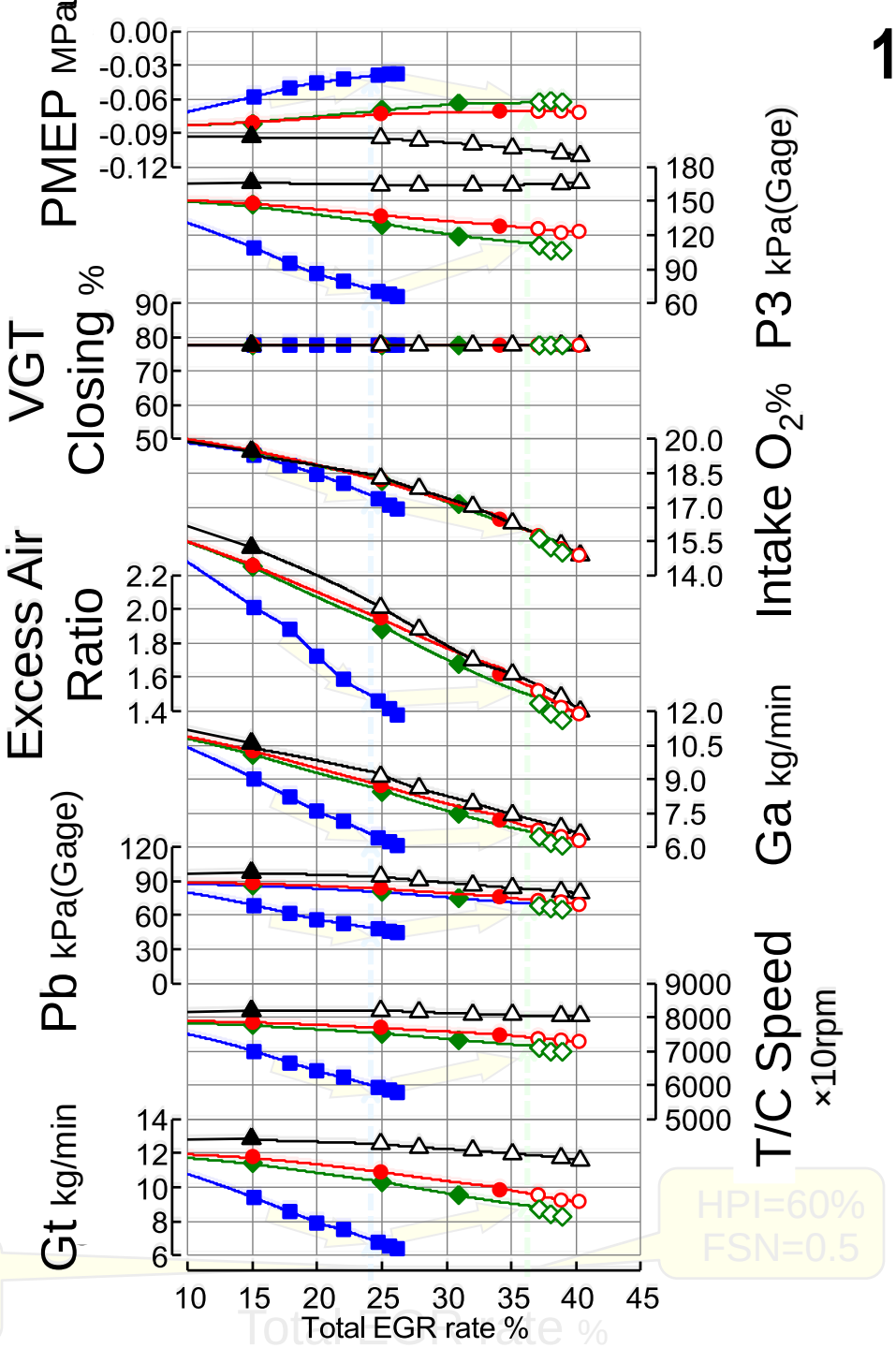
Steady state test with fixed VGT 1

Combination of HP & LP EGR

Fixed VGT nozzle position

Ne = 1200 rpm
BMEP = 0.83 MPa
SOC = TDC
Pinj. = 160 MPa
VGT/N = 78% Close

HPI=100%
HPI= 60% with BPCV
HPI= 30% with BPCV
HPI= 0% with BPCV

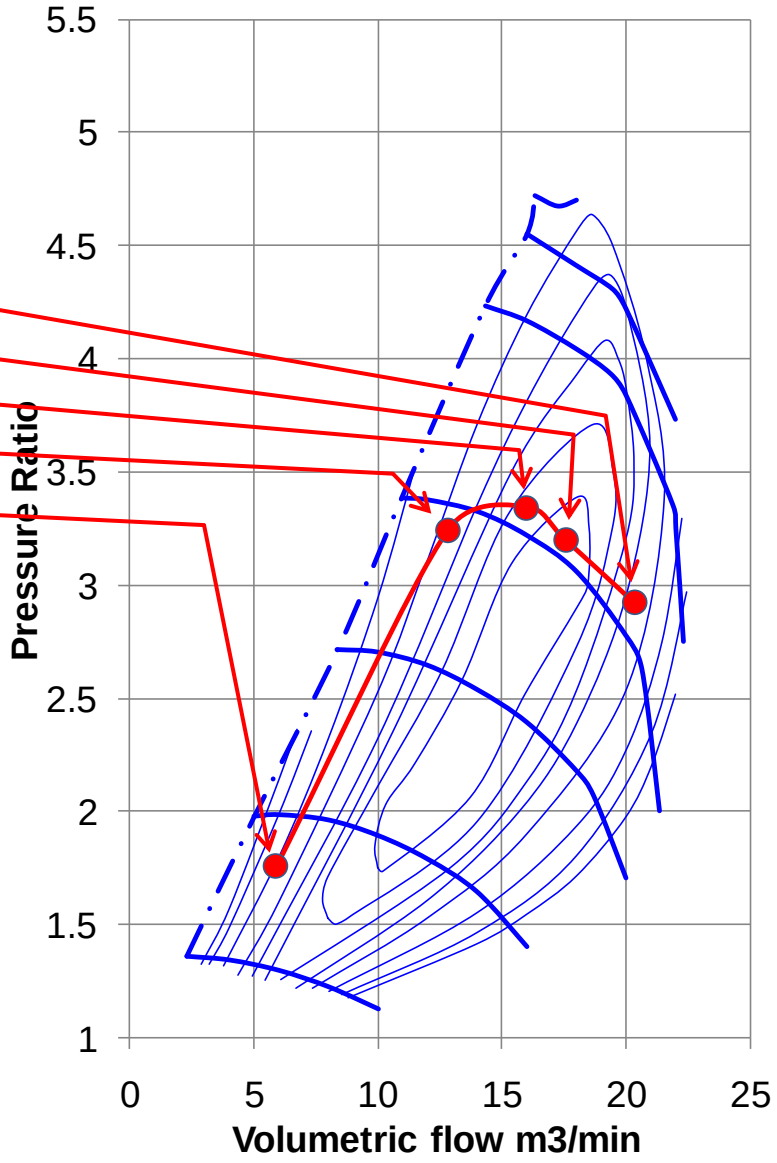


Steady state test with fixed VGT 2

Combination of HP & LP EGR

Ne = 800,1000,1200
1400,2000 rpm
Load = 100%

EGR rate 15%
19%
21%
25%
23%
(HPI=10~42%)



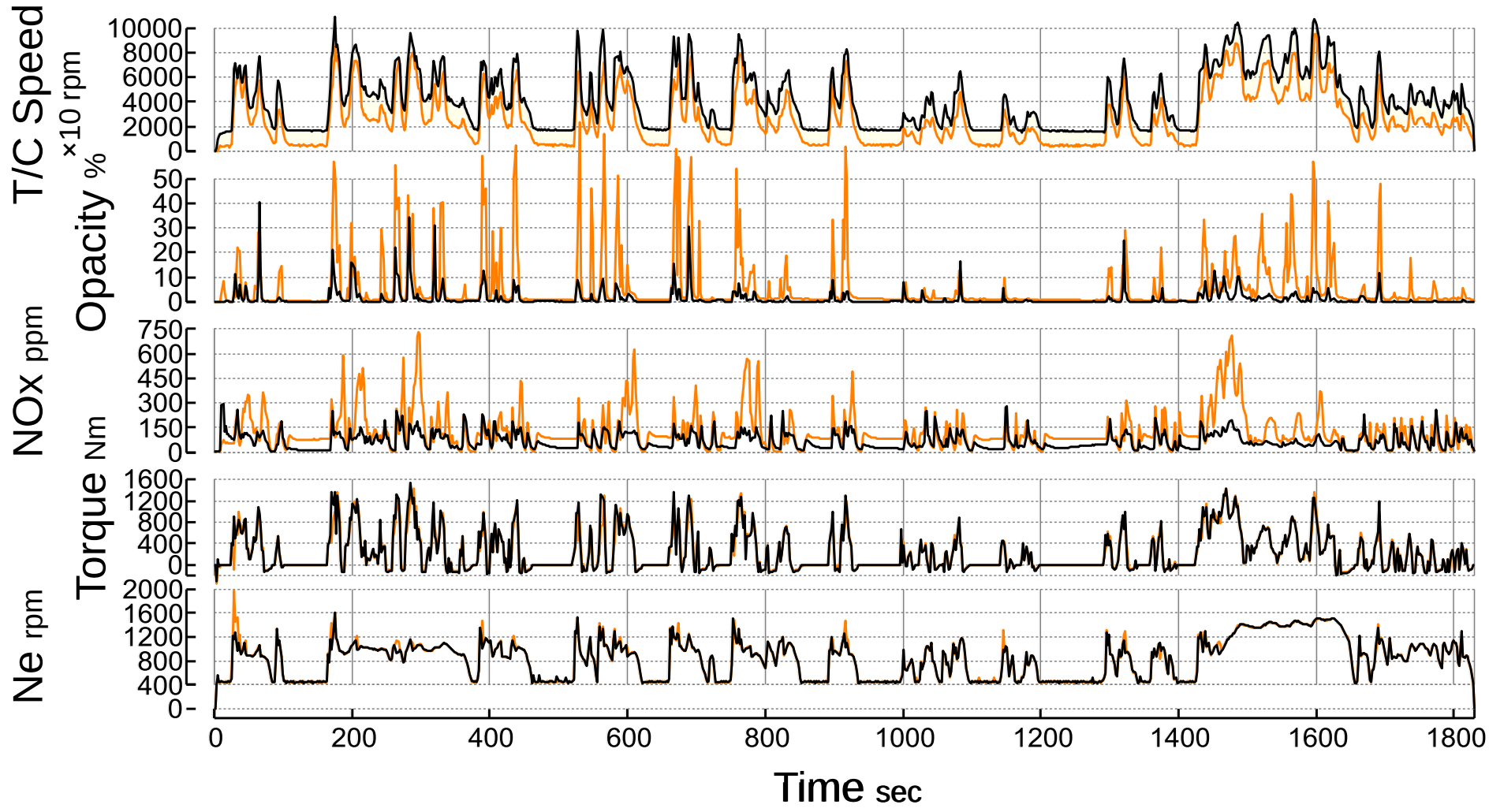
Operating points on the compressor map 2

Contents

JE05 Transient Test Result

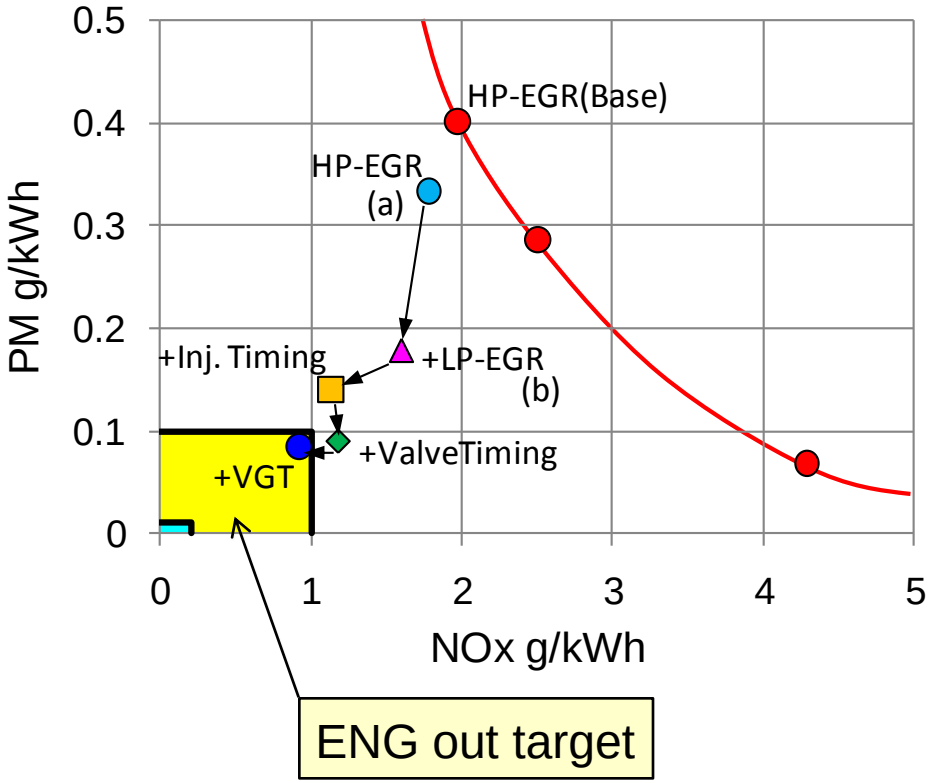
Previous Setting (HP-EGR)
Improved Setting (HP-EGR and LP-EGR)

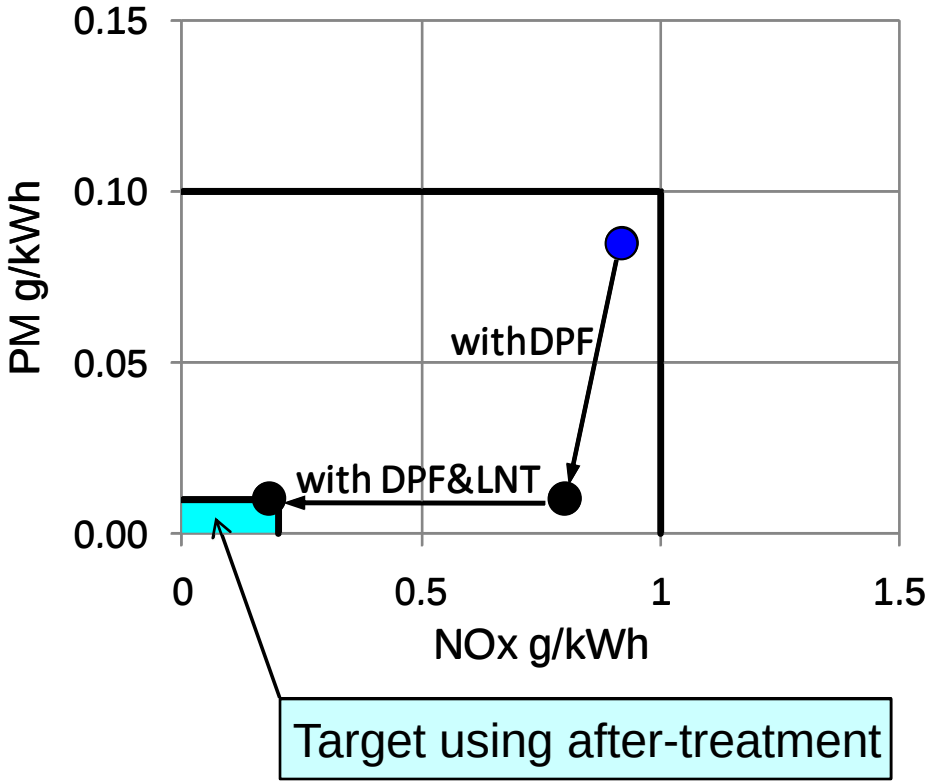
* without after-treatment



Result of the emissions at transient test cycle with after-treatment

JE05 Transient Test Result





Result of the emissions at transient test cycle with after-treatment

Summary (1/2)

The effects of VGT, HP-EGR, LP-EGR, and each device on steady state and transient operations were verified using a super clean diesel engine. The following results are obtained.

1) Important technologies such as high-pressure fuel injection of 200 MPa, a high boost pressure ratio up to 5 with the new VGT, and an EGR system of HP-EGR and LP-EGR, which enables a large amount of EGR, were selected as effective measures to reduce exhaust emissions by the JE05 transient test.

Summary (2/2)

2) Combining HP-EGR and LP-EGR, as in this study's EGR system, is proposed.
It increases the EGR rate at a medium load up to 35%. Finally, a low NOx value such as NOx=1.0 g/kWh without an aftertreatment is obtained.

3) The EGR system of HP-EGR and LP-EGR used for this study has performance that increases EGR while maintaining BSFC and the boost pressure and decreases NOx and PM simultaneously, not only in the steady-state condition but also in the transient condition.

Acknowledgements

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