

# Standardization and Upgrading of Biodiesel Fuel Quality



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# Trends of Biodiesel standard in Europe and Japan

## Europe

2003 Standard of Fatty acid methyl ester (FAME) for automotive fuel (EN14214)

2004 Revision of Automotive diesel fuel (EN590)

Diesel fuel may contain up to 5% of FAME complying with EN14214

## Japan

2003-2005 Verification test for standardization of biodiesel blended fuel (at METI&AIST)

2006 Fix of biodiesel fuel standard and FAME JIS Standard



## Objective

- **Development of application technology of palm oil methyl ester (PME) for diesel engine.**

# Characteristics of major FAMES in the world

region	material	major species	Production (kton)	stability	low-temperature performance
U.S.	Soybean	Linoleic acid	30,858(1 <sup>st</sup> )	x	0
Asia	Palm	Palmitic acid	29,646(2 <sup>nd</sup> )	0	x
Europe	Rapeseed	Oleic acid	14,361(3 <sup>rd</sup> )		0



# Characteristics of palm oil methyl ester (PME)

## Merits

- Large amount of production (mainly produced in Asia)
- Affordable price than other vegetable oil
- Good oxidation stability

## Demerit

- Easy to congeal (Not good in Japan)

# Properties of major FAME (EN14214)

Property	Unit	Limits		Palm oil methyl ester (PME)	Rapeseed oil methyl ester (RME)	Soybean oil methyl ester (SME)
		Minimum	Maximum			
Ester content	%(m/m)	96.5		100.0	99.7	99.3
Density at 15	kg/m <sup>3</sup>	860	900	874.3	884.9	884.1
Viscosity at 40	mm <sup>2</sup> /s	3.50	5.00	4.404	5.068	4.028
Flash point		120	-	162	174	170
Sulfur content	mg/kg	-	10.0	< 3	< 3	4
Carbon residue	%(m/m)	-	0.3	0.04	0.32	0.15
Cetane number		51.0	-	66.5	52.2	52.7
Sulfated ash content	%(m/m)	-	0.02	<0.001	<0.001	<0.001
Water content	mg/kg	-	500	649	286	249
Total contamination	mg/kg	-	24	1.7	2.6	5.4
Copper strip corrosion	Rating	class1		1a	1a	1a
Oxidation stability	Hours	6.0	-	7.02	4.51	1.28
Acid value	mgKOH/g		0.5	0.10	0.17	0.08
Iodine value			120	50.2	110	128
Linolenic acid methyl ester	%(m/m)		12.0	0.3	7.7	7.2
Methanol content	%(m/m)		0.2	< 0.01	0.07	< 0.01
Monohlyceride content	%(m/m)		0.8	0.024	0.27	0.012
Diglyceride content	%(m/m)		0.2	< 0.001	0.12	< 0.001
Triglyceride content	%(m/m)		0.2	< 0.001	0.19	< 0.001
Free glycerol	%(m/m)		0.02	0.006	0.006	0.008
Total glycerol	%(m/m)		0.25	0.012	0.112	0.011
Sodium(Na)	mg/kg		5.0	< 1	< 1	< 1
Potassium(K)	mg/kg		(Na+K)	< 1	< 1	< 1
Calcium(Ca)	mg/kg		5.0	< 1	< 1	< 1
Magnesium(Mg)	mg/kg		(Ca+Mg)	< 1	< 1	< 1
Phosphorus content	mg/kg		10.0	< 1	< 1	< 1
CFPP				12	-11	-3

# Oxidation stability

Property	Unit	Limits (EN14214)		palm oil methyl ester (PME)	rapeseed oil methyl ester (RME)	soybean oil methyl ester (SME)
		Minimum	Maximum			
<b>Oxidation stability</b>	<b>Hours</b>	<b>6.0</b>	<b>-</b>	<b>7.02</b>	<b>4.51</b>	<b>1.28</b>
<b>Iodine value</b>			<b>120</b>	<b>50.2</b>	<b>110</b>	<b>128</b>
<b>Linolenic acid methyl ester</b>	<b>%(m/m)</b>		<b>12.0</b>	<b>0.3</b>	<b>7.7</b>	<b>7.2</b>

# Oxidation Stability Test



Fuel Tank (Upper)

Fuel Tank (Lower)

2000hr Fuel Circulation Test Result

# Low temperature performance

Property	Unit	Palm oil methyl ester (PME)	Rapeseed oil methyl ester (RME)	Soybean oil methyl ester (SME)
CFPP		12	-11	-3

	Jan.	Feb.	Mar.	Apl.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tokyo	5.2	5.6	8.5	14.4	18.6	21.7	25.2	27.1	23.2	17.6	12.6	7.9
Thailand	25.2	27.1	28.5	29.6	28.7	28.6	28.4	27.6	27.3	27.3	26.6	26.5

**Japan : necessity prevent the congelation in winter (f.e. cold flow improver)**

**Thailand : no problem**

# Vehicle performance and emission

## Test fuels

Diesel oil

PME blended fuel

(mixing rate : 5, 20, 50%)

## Test condition

Steady state mode test

① Idling

② Engine speed 1620rpm, load 20%

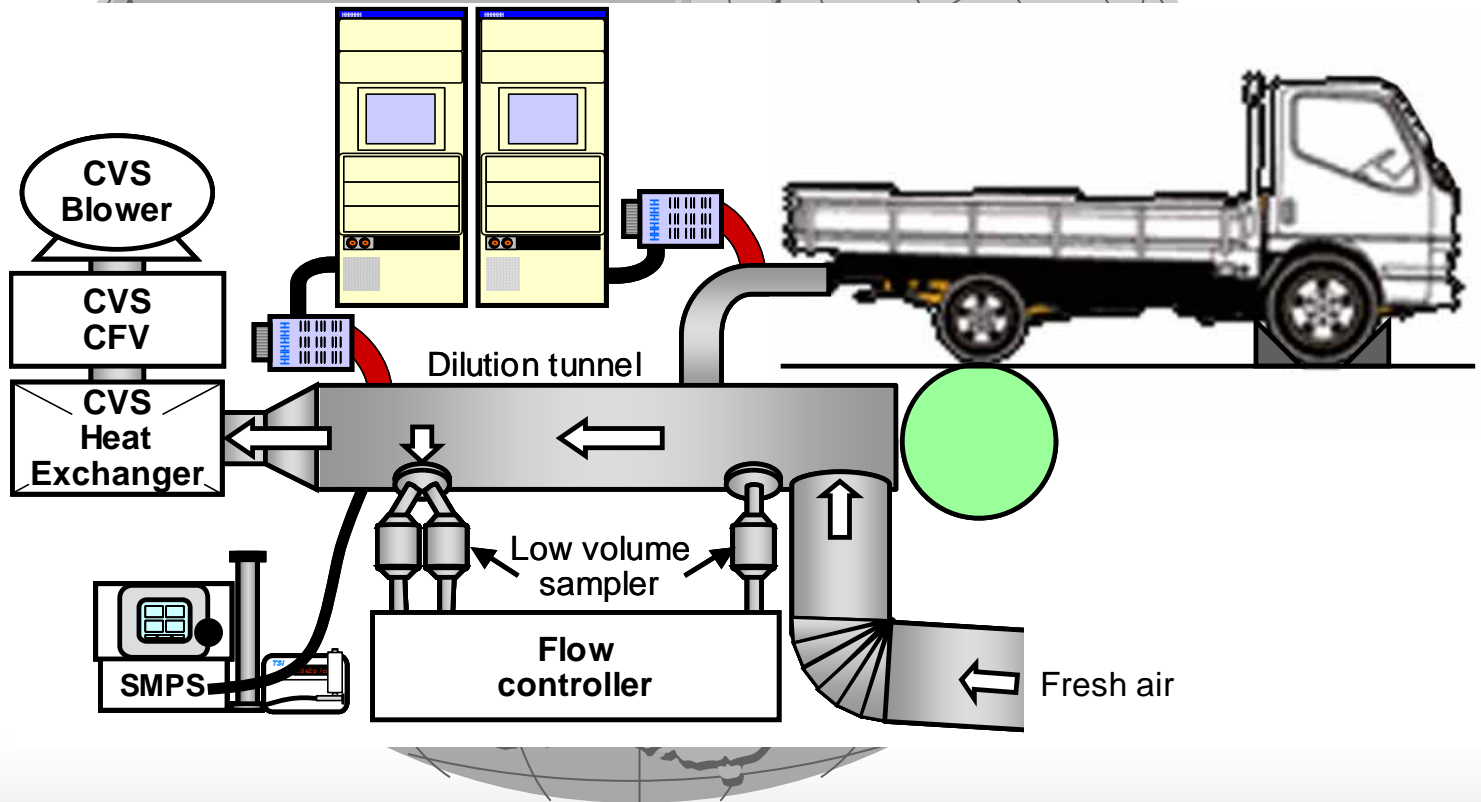
③ Engine speed 1620rpm, load 60%

④ Engine speed 1620rpm, load 80%

## Measurement items

CO, THC, NOx, PM

# Experimental apparatus



# Enigne Test Facility in AIST

25ton Vehicle Test Bench:2set  
450kW Engine Teat Bench:1set



# Vehicle and Engine specification

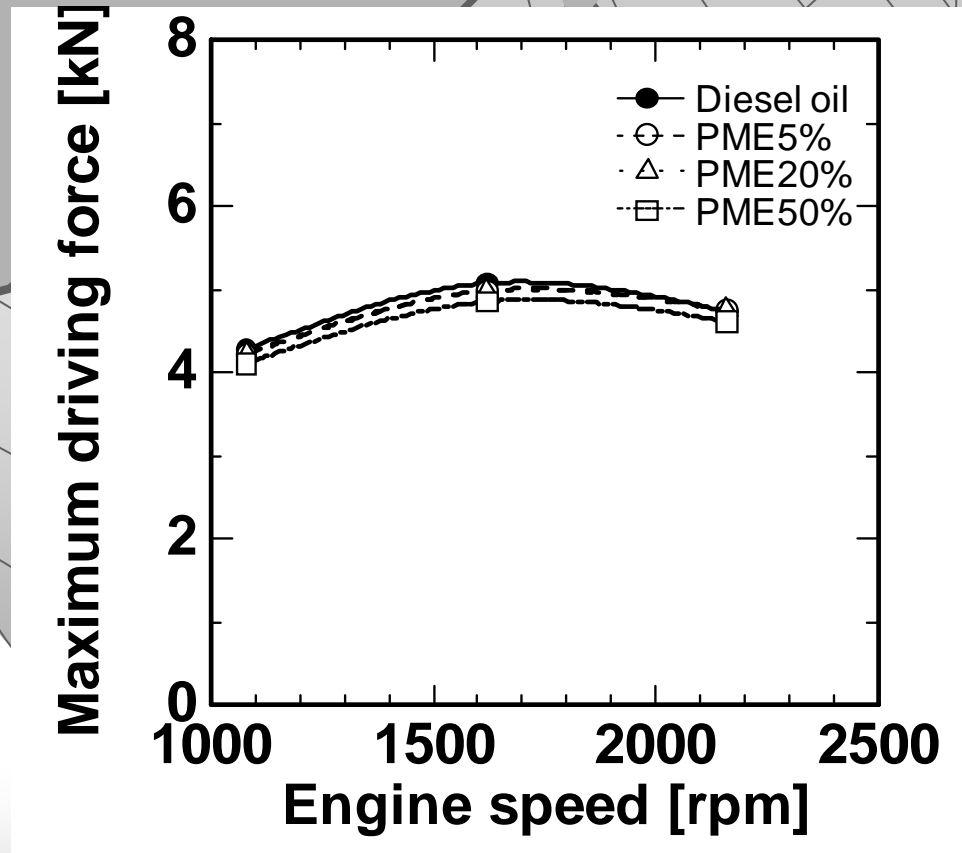
Vehicle	Model	PA-FE82DE(0A3)
Gross vehicle weight	kg	<b>4,695</b>
Unladen vehicle weight	kg	<b>2,530</b>
Total length	mm	6,130
Total width	mm	2,000
Total height	mm	2,195
Wheel base	mm	3,350
Maximum output	kW (rpm)	103 (2,700)
Maximum torque	Nm (rpm)	412 (1,600)

Engine	Model	4M50(T3)
Cylinder arrangement		<b>In-line 4</b>
Bore x Stroke	mm	<b>114 x 120</b>
Displacement	cc	<b>4,899</b>
Compression ratio		17.5
Combustion		Direct injection
Injection system		Common rail injection system
Aspiration		Intercooler turbocharger
Emission reduction		<b>DPF with oxidation catalystr</b>

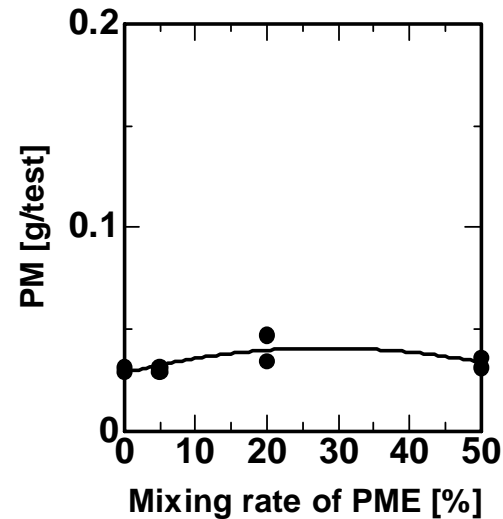
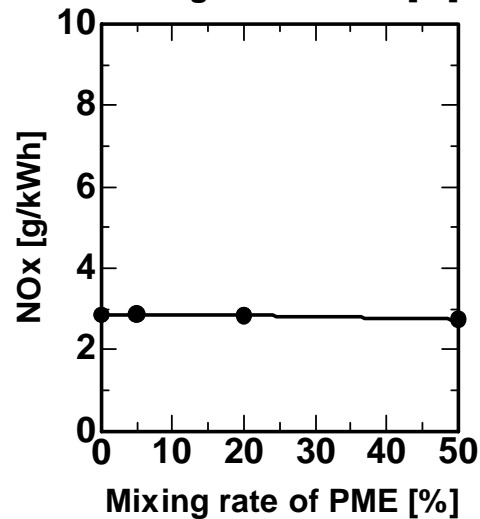
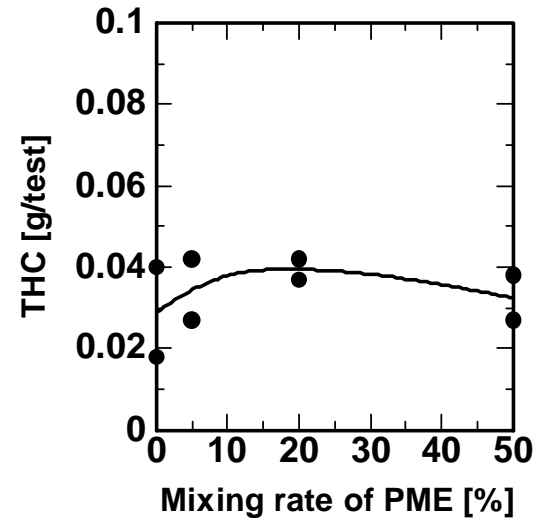
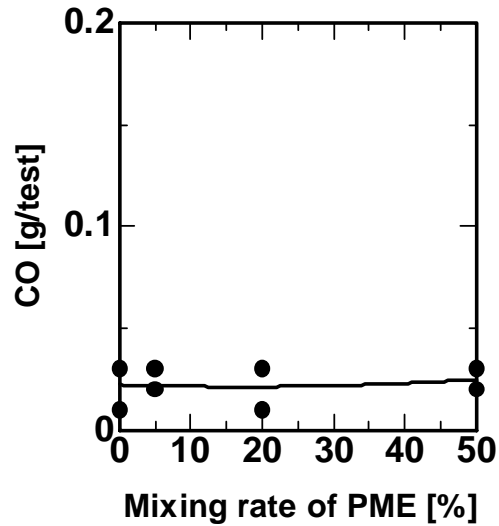
# Fuel properties

Items	Unit	Diesel oil	PME5%	PME20%
Density	g/cm <sup>3</sup>	0.8191	0.8212	28294
Flash point		66.5	65	69
Distillation	IBP	167.0	167.5	167
	10%	197.0	197.5	200.5
	50%	271.0	274	287.5
	90%	329.0	330.5	334
Pour point		-25.0	-17.5	-7.5
CFPP		-15	-13	-6
10% carbon residue	wt%	<0.01	<0.01	<0.01
Cetane number		59.3	60	60.7
Viscosity at 30	mm <sup>2</sup> /s	3.118	3.162	3.458
Sulfur content	ppm	4	4	3
Cloud point		-8	-7	-6
C	wt%	87.0	85.4	83.9
H		12.9	13.8	13.6
O		<0.1	0.5	2.2
N	ppm	<1	<1	<1
Lower heating value	J/g	43120	43100	43000
Ash	wt%	<0.001	<0.001	<0.001
Water content	ppm	23	32	52

## Comparison of maximum driving force

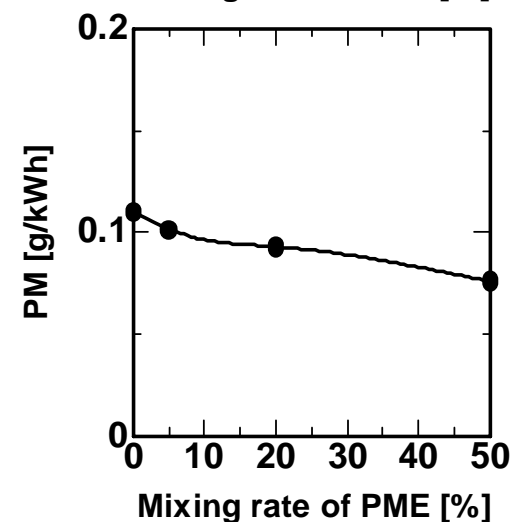
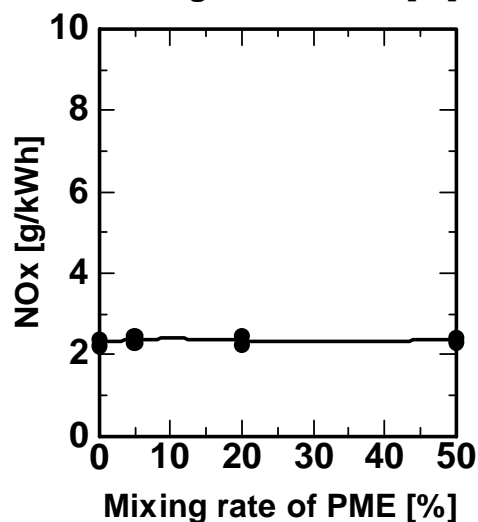
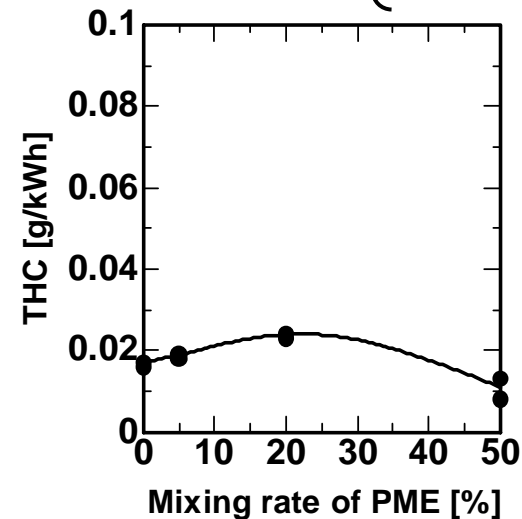
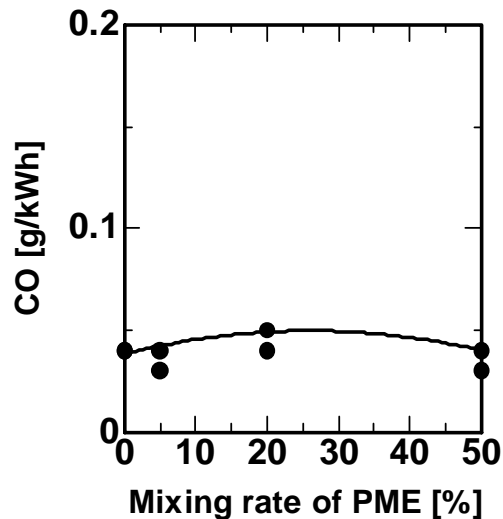
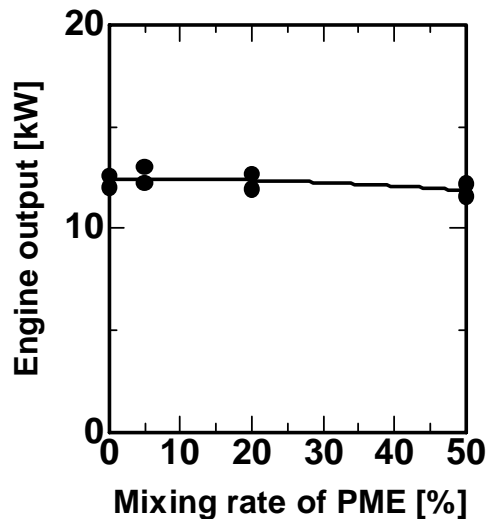


# Emission characteristics (idling condition)

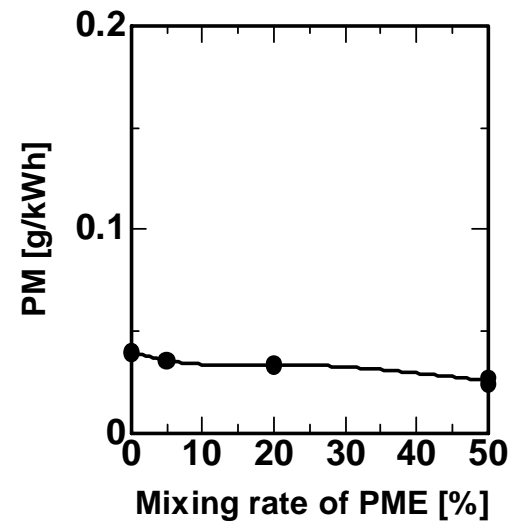
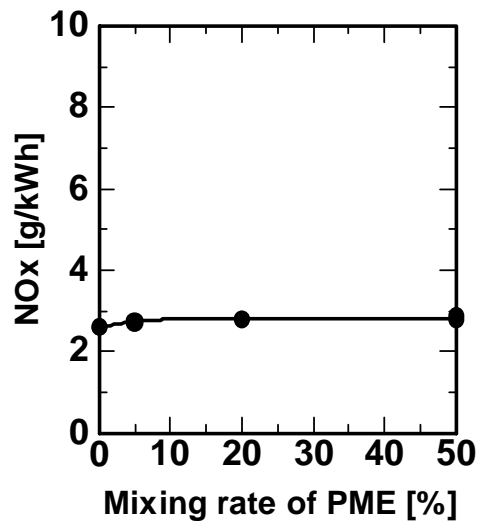
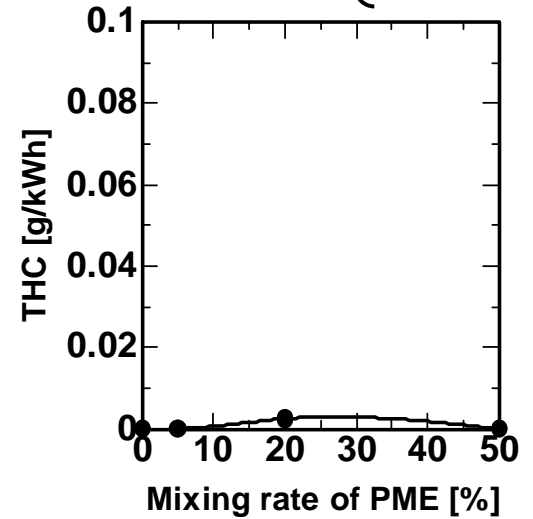
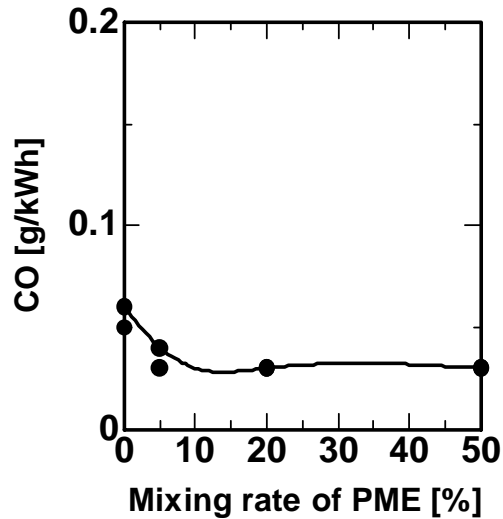
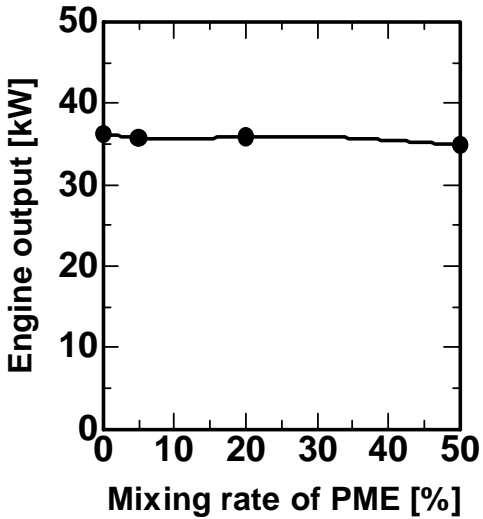


# Engine output and emission characteristics

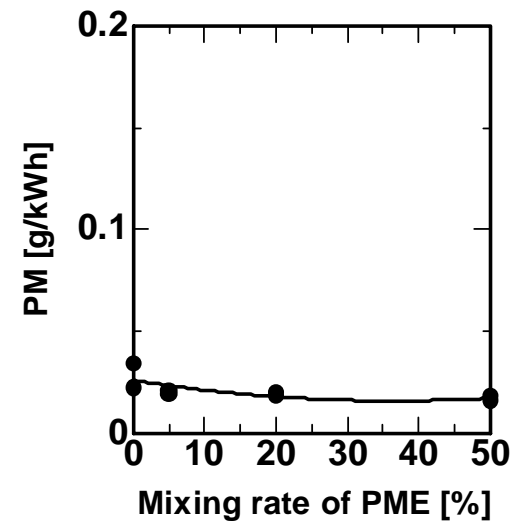
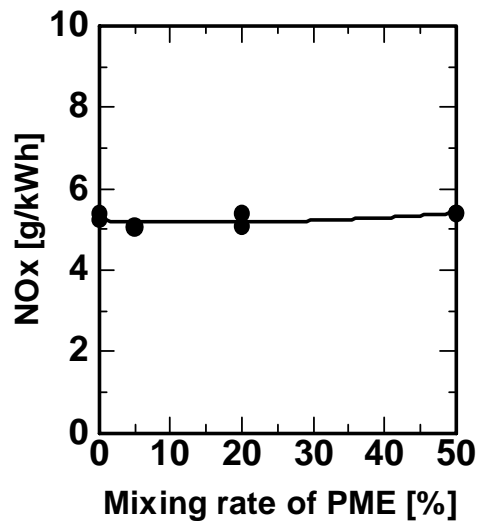
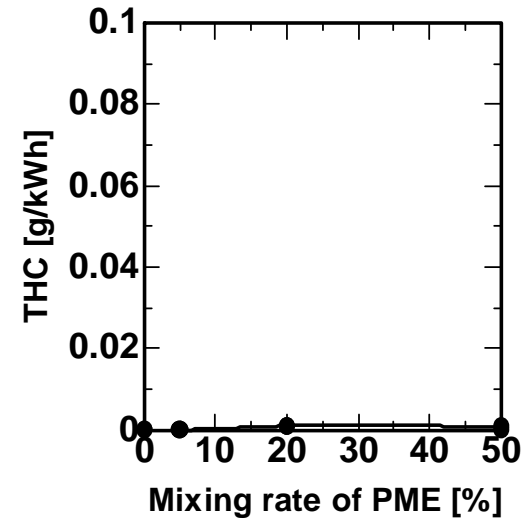
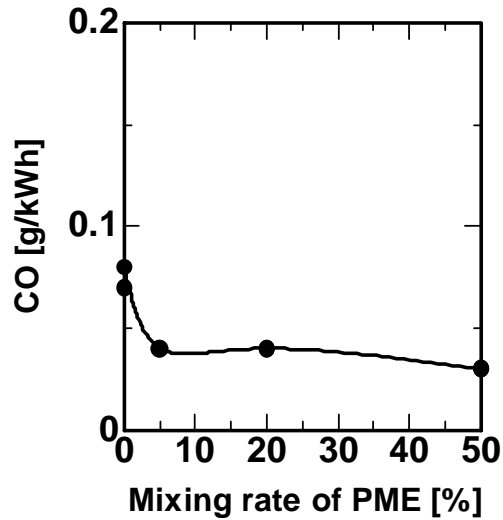
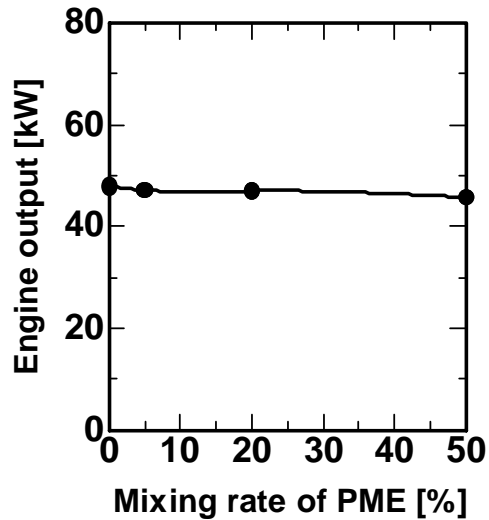
(1620rpm  
20%load)



# Engine output and emission characteristics (1620rpm 60%load)



# Engine output and emission characteristics (1620rpm 80%load)



# Summary

- **PME shows good oxidation stability .**
- **PME is easy to congeal. Cold flow improver is necessary in Japan.**
- **Engine performance is almost same.**
- **Exhaust Emission is also no problem for new engines (with DPF and Oxidation Catalyst).**
- **Japanese FAME JIS standard may show the good direction when using various FAME.**

# Future Work

- More stable FAME manufacturing method is important.
- Endurance vehicle TEST with PME is necessary to verify the FAME percentage.
- Cold flow improver development is necessary to import PME to Japan.
- More lower emission research is appreciated.

## Extra Other News

- **Bio Ethanol contamination regulation** will be decided as JASO **Standard** in March 2006.
- **J-SAE, Japan Alcohol Association and AIST contributed the standard. (The committee chair person is Goto.)**
- **At the next conference, I will report the JASO standard. In the future, it will grade up to JIS standard.**