J a p a n C l e a n A i r P r o g r a m

Activities of Combustion Analysis Working Group in the JCAP

Fumio Okada
Petroleum Energy Center

Naoki Yanagisawa
ISUZU Advanced Engineering Center Ltd.

Yukio Akasaka
JOMO Technical Research Center Co., Ltd.

Representing the Combustion Analysis Working Group Members

Objectives of the Combustion Analysis Working Group

- Scientifically and statistically analyze the data obtained by the Diesel Working Group.
- Technically explain the origin of the differences in emission levels in terms of the engine and fuel technologies applied in the measurements.
- Survey on the mechanisms and performance of after-treatments and the fuel effects on them.

Members in the Combustion Analysis Working Group

Working Groups

Gasoline WG
Diesel WG
Air Modeling WG
Test Methods WG
Cost Study WG

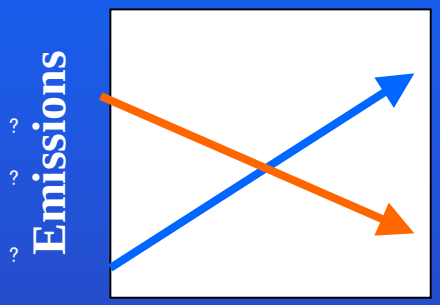
Combustion Analysis WG

Health Effect Study WG
JCAP Coordination WG

Naoki Yanagisawa, Isuzu Advanced Engineering Center
Masahito Shibata, Toyota Motor
Tadakazu Shiozaki, Hino Motors
Yukio Akasaka, JOMO Technical ResearchCenter
Masataka Morinaga, Cosmo Research Institute
Naoki Kono, Tonen
Kenji Tsuchiya, Japan Automobile Research Institute
Masayuki Kagami, Advanced Tech. & Res. Inst., PEC
Eiichi Kikuchi, Waseda University
Kei Miwa, Tokushima University

Analysis Flow Diagram in the JCAP

Emission Test Results



Fuel Properties
(Prepared by Diesel WG)

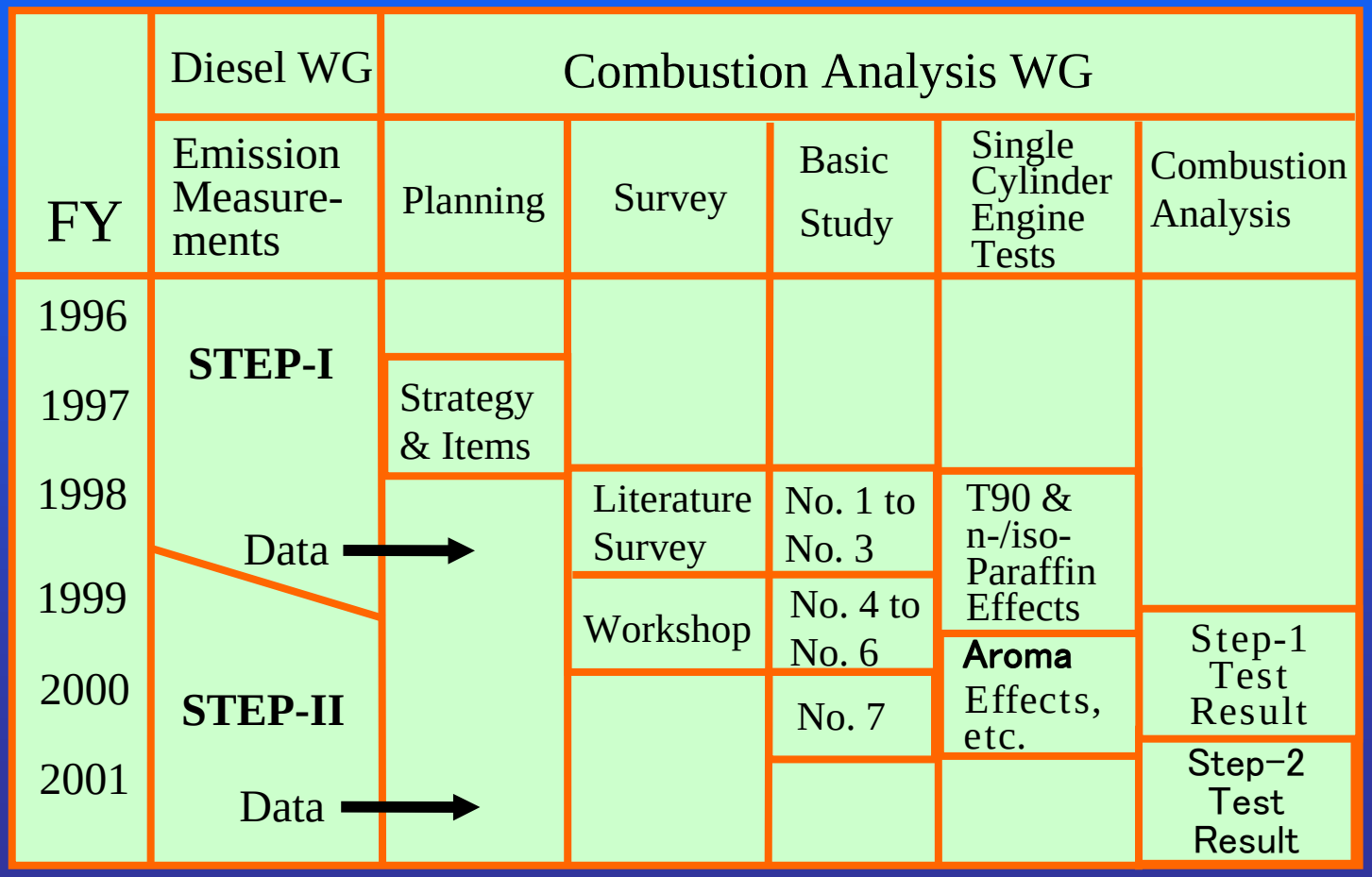
Selection of issues to be resolved?

Confirmation of measures to resolve the issues

1) Survey (Literature & Workshop)
2) Basic studies carried out by universities
3) Single-cylinder engine tests performed by varying fuel properties and engine parameters.
4) Statistical Analysis

Conclusions

Schedule of Combustion Analysis WG



Statistical Analysis of the Diesel Emission Data

Objective: To evaluate effects of fuel properties other than T90 and Aroma., and engine technologies and parameters on emissions.

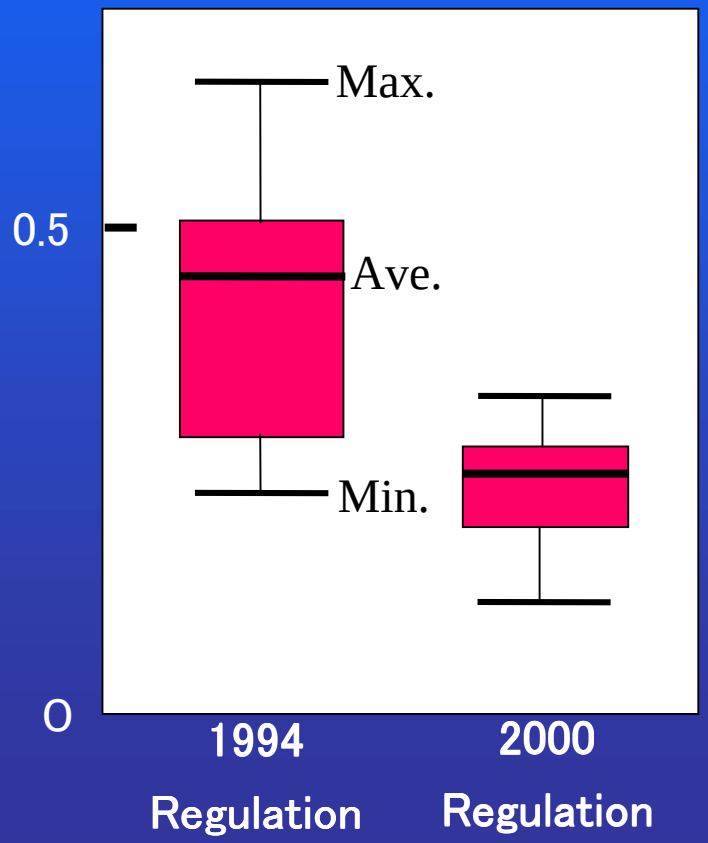
Example: Regression of Diesel Engine Emission Data

Substances	Parameters	R^2 Ave.	R^2 Variance
PM	Dens., CN, Sulfur	0.8054	0.03547
NOx	T90, CN, Single-Aroma	0.8046	0.05170
CO	T90, CN, Sulfur	0.8165	0.03903
THC	T90, CN	0.8535	0.03006

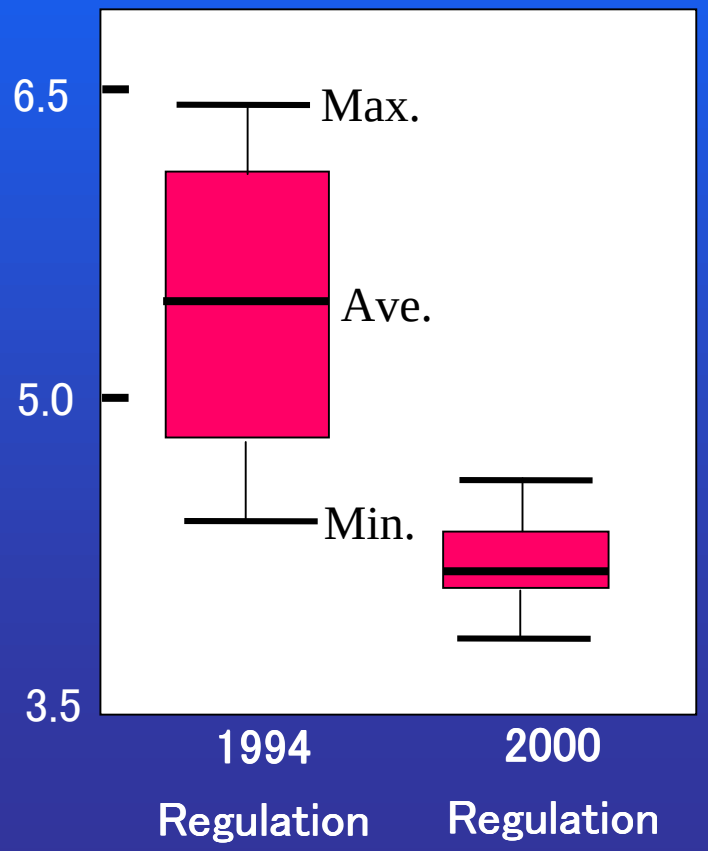
Emissions from Diesel Engines Produced under Different Regulations

Years

PM (g/kWh)



NOx (g/kWh)



In-cylinder Studies on Diesel Combustion

Combustion Mechanisms in Diesel Engines

- Literature Surveys on Combustion
- Single-cylinder experiments (JARI)

Diagnoses of Fuel Effects on Combustion (Contractual basis Studies)

- Chemical reaction of fuels
- NOx and PM formation during ignition and main combustion

Diesel Engine Technologies

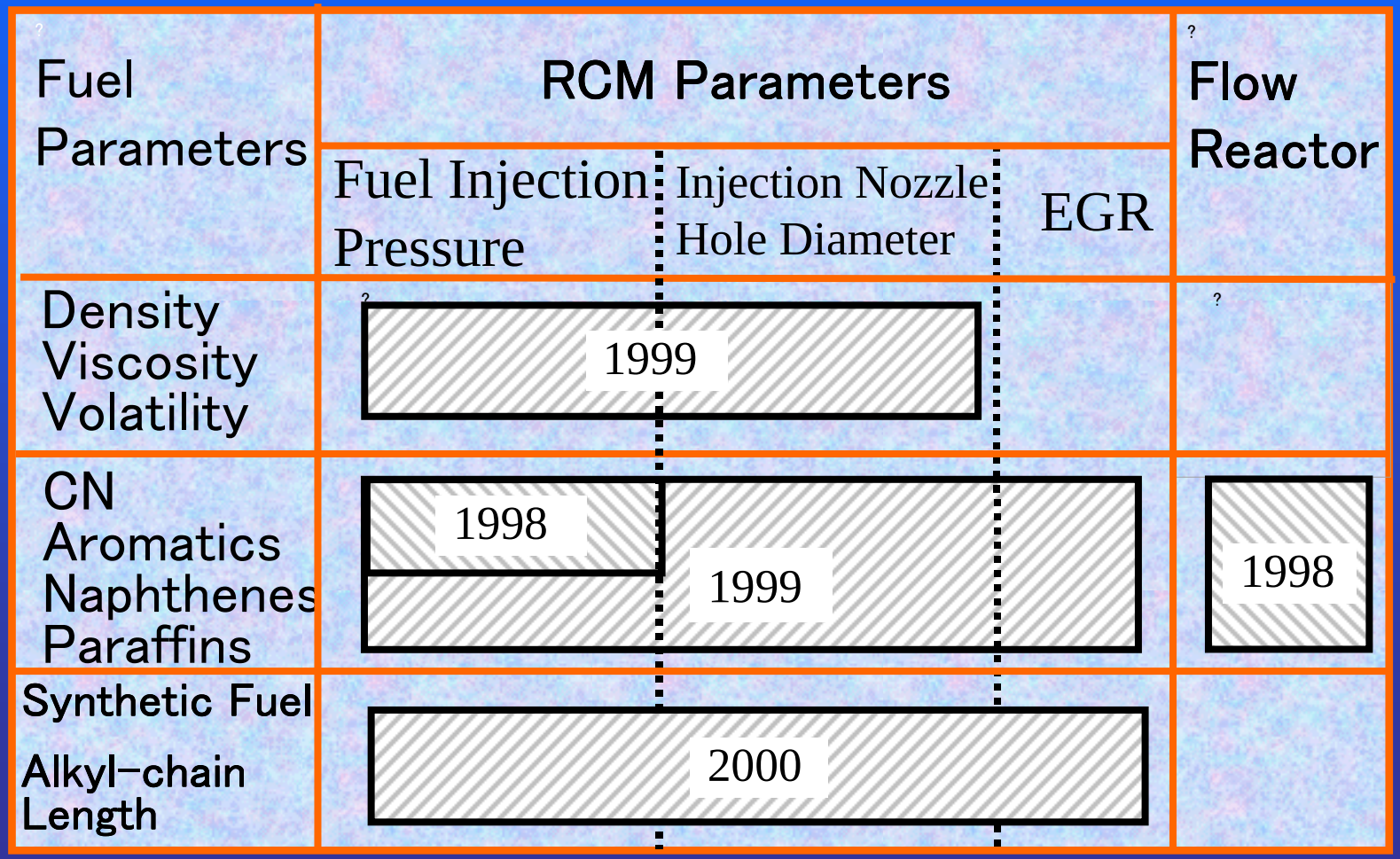
Reciprocal Volume
Injection Pressure
EGR
TC, etc.

In-cylinder Combustion

Fuel Technologies

T90
Aroma. Content
Cetane Number
Sulfur, etc

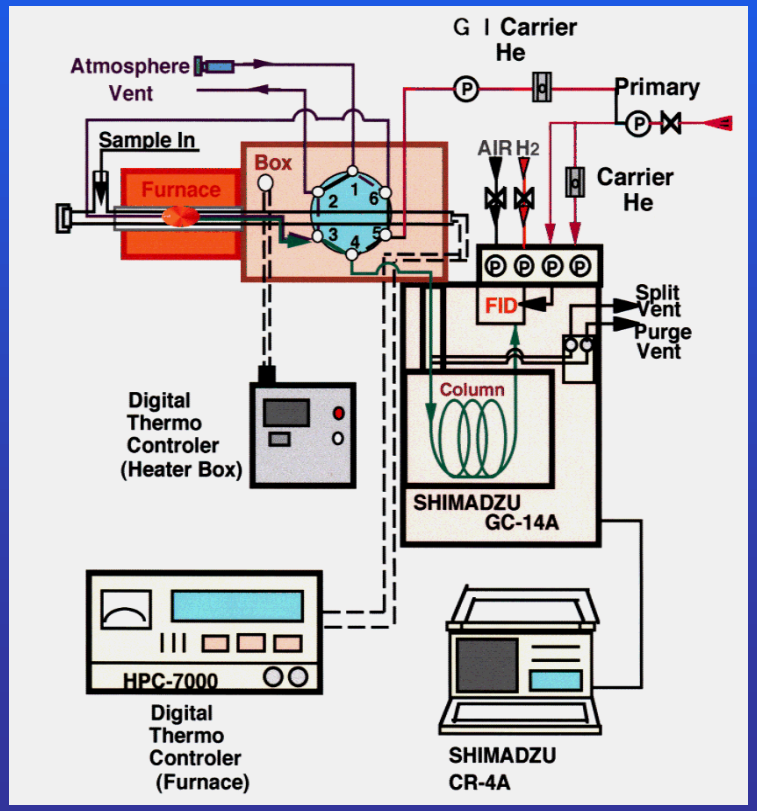
Contractual Basic Studies in Universities

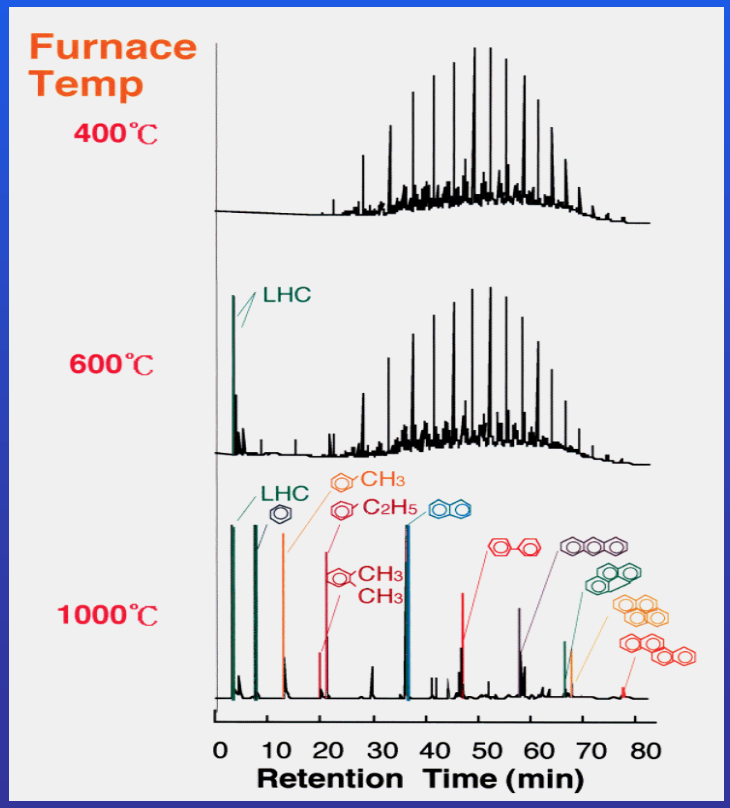


Flow Reactor Studies (1998)

Soot forming tendency

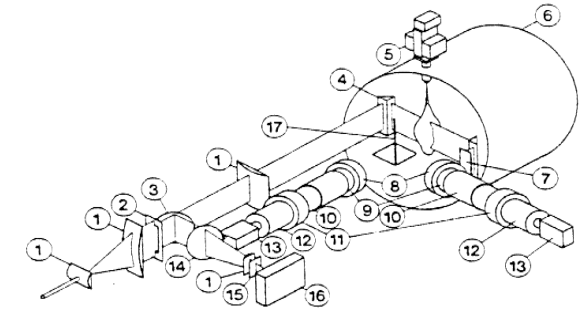
Aromatics > Olefins ≧ Naphthenes > Paraffins





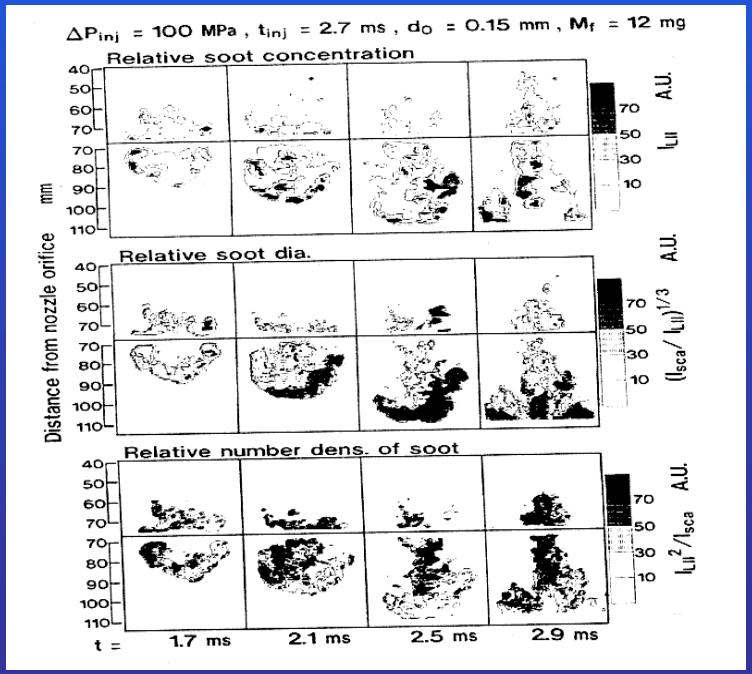
The RCM Test Results (1998)

The concentration and area of soot formation in the RCM chamber emitted from fuel with a high aromatic content are larger than that from a low aromatic content fuel. However, the difference between fuels tends to decrease with increasing fuel injection pressure.



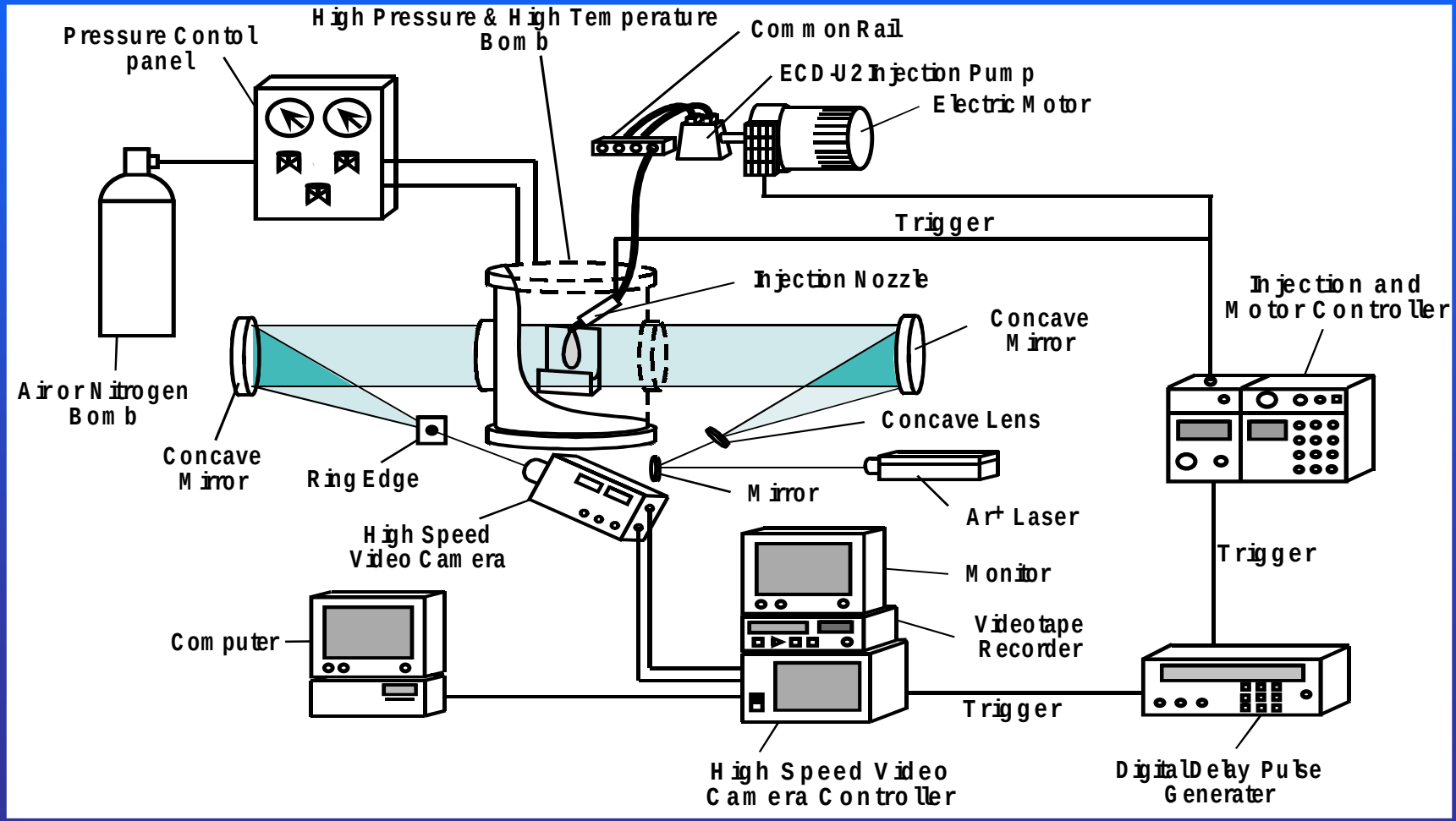
① Cylindrical lenses
② Slit
③ Beam splitter
④ Prism
⑤ Injector
⑥ R. C. M.
⑦ Beam stopper
⑧ Band pass and ND filters
⑨ Doubling prism
⑩ Lens
⑪ Gated image intensifier
⑫ Relay lens
⑬ CCD camera
⑭ Lens
⑮ ND filter
⑯ Photo-diode array
⑰ Half mirror

Fig. 1 Optical set-up for soot imaging and combustion chamber of a rapid compression machine

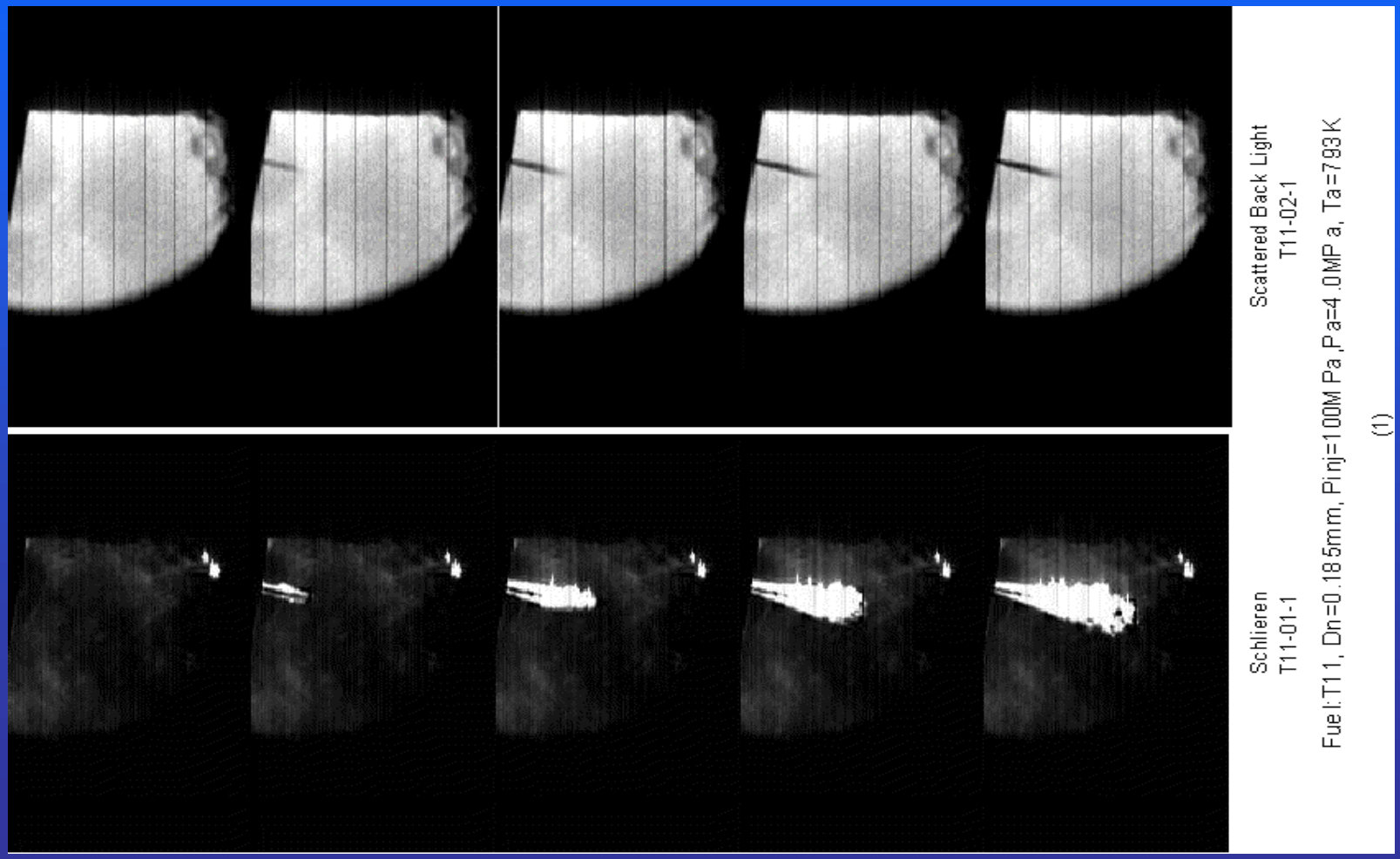


Petroleum Energy Center

Effects of Physical Properties of Fuels on Mixture Formation

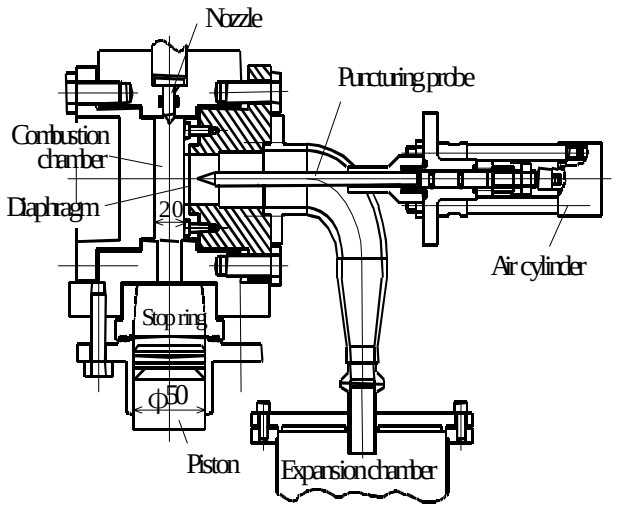


T90 and density of fuels play important roles for liquid phase penetration lengths, but spray tip penetration lengths are not affected significantly by these parameters.



Total Gas Sampling Studies (1999)

Analysis of hydrocarbon species during the combustion process in a RCM improve the quantification methods used for fuels and their decomposed species.



Total Gas Sampling System

Heat Release and formation of Small Hydrocarbons

Objectives of Single-cylinder Engine Tests

Engine Side

Operation of a single-cylinder engine by changing engine specifications and conditions independently.

Fuel Side

Usage of test fuels whose properties are independently changed.

Obtain fundamental data to understand effects of engine and fuel parameters on diesel tailpipe emissions.

Test Fuels in 1999 Experiments

		Test Fuels Used in 1999 Experiments					
		Base	T90 Series		n/i-Paraffin Series		
		T1	T9	T10	T6	T7	T8
Density	(15°C)g/cm^3	0.7880	0.7852	0.7916	0.7846	0.7820	0.7880
Viscosity	(30°C)mm^2/s	3.630	3.322	4.946	3.560	3.470	3.630
Distillation	°C						
10%		229.5	230.5	233.0	232.0	234.5	229.5
50%		249.0	247.5	254.5	253.5	256.5	249.0
90%		307.0	275.0	387.5	311.0	313.0	307.0
Cetane Number		48.8	48.6	48.5	60.4	70.7	61.0
Composition	Vol %						
n-Paraffins		36	35	24	50	63	36
i-Paraffins		57	58	70	44	32	57
Naphthenes		7	7	6	6	5	7
Total Aroma.		0	0	0	0	0	0
Sulfur Conc.	mass%	0	0	0	0	0	0
Cetane Improver	mg/L	none	none	none	none	none	T1+5000

Engine Conditions in 1999 Experiments

Basic Engine Conditions

Engine Revolution : 1800rpm

Injection Timing : 1～4 point

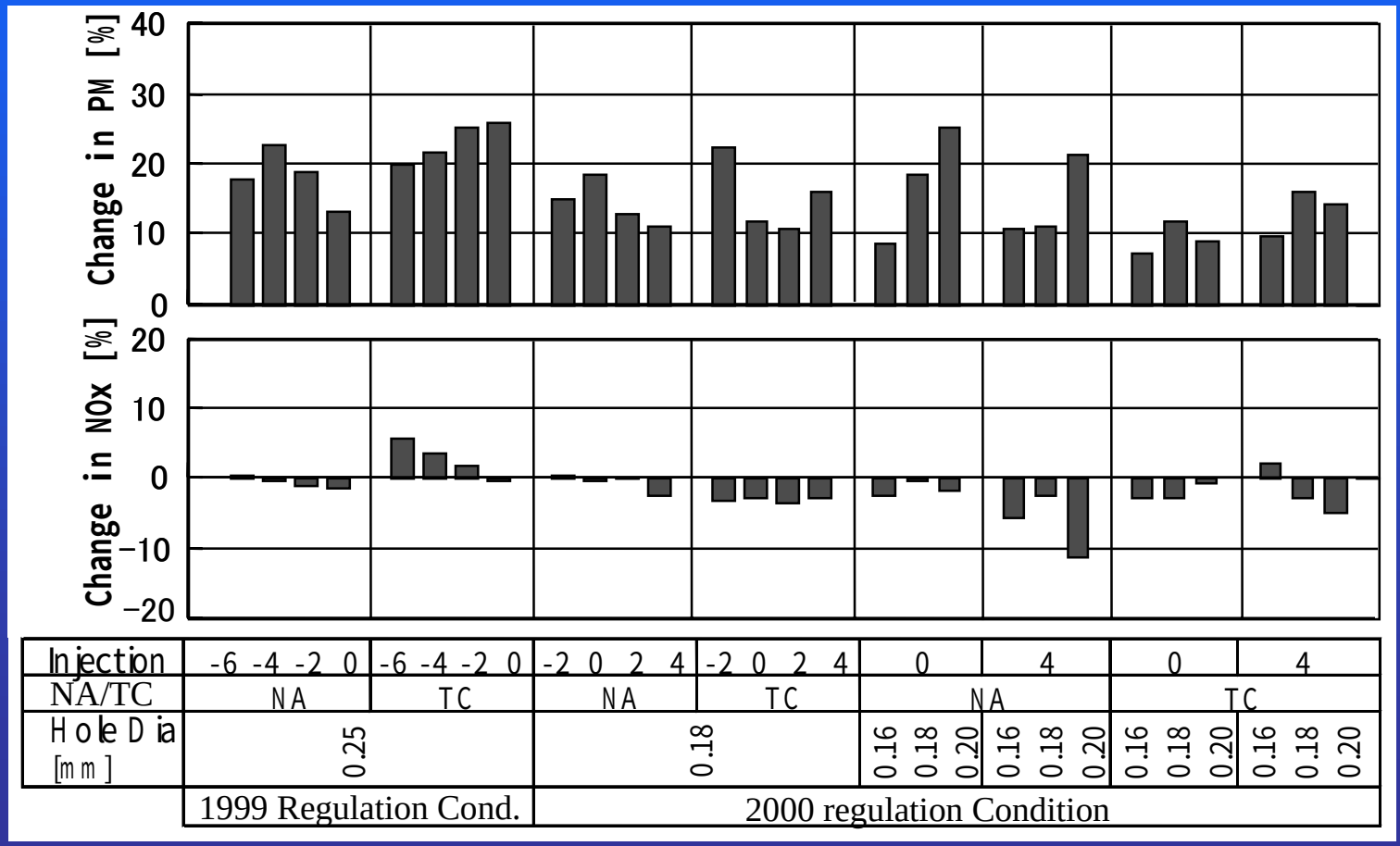
NA Conditions

λ	Intake [kg/cm²]	Injection [MPa]	Hole Dia. [mm]	EGR [%]	Regulation
1.4	NA	60	0.25	-	1994
		100	0.16	-	2000
			0.18		
			0.20		
4.0	NA	30	0.25	0	1994
		40	0.18	0	2000
		50			
		60			
		50	0.18	20	
				40	

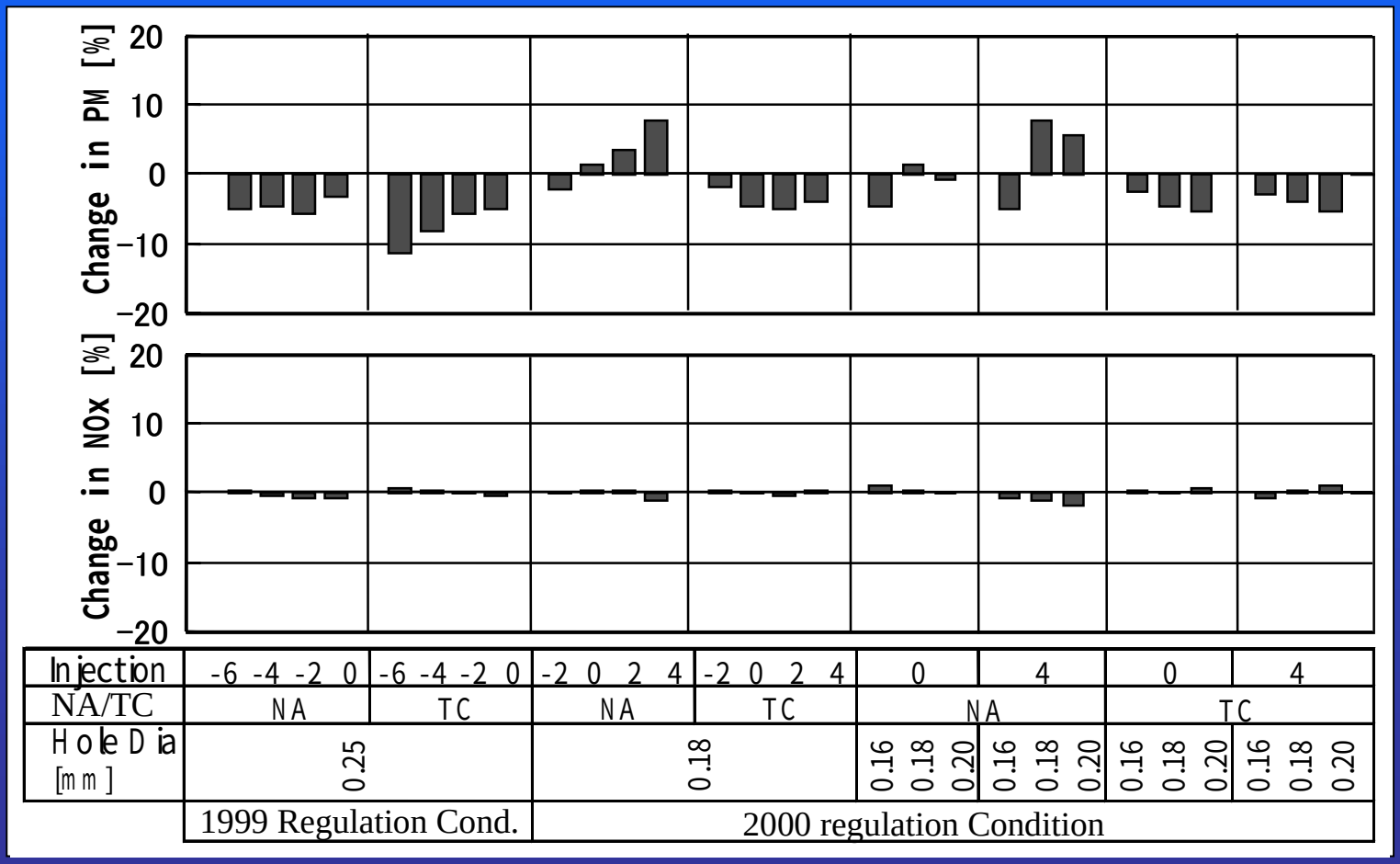
TC Conditions

λ	Intake [kg/cm²]	Injection [MPa]	Hole Dia. [mm]	EGR [%]	Regulation
1.8	0.4	60	0.25	-	1994
		100	0.16	-	2000
			0.18		
			0.20		
4.0	0.1	30	0.25	0	1994
		40	0.18	0	2000
		50			
		60			
		50	0.18	20	
				40	

Changes [%] in PM and NOx with Increasing T90 by 100 ℃ at High Load



Changes [%] in PM and NOx with Increasing n-Paraffin Content by 10 % at High Load



Injection	-6 -4 -2 0		-6 -4 -2 0		-2 0 2 4		-2 0 2 4		0		4		0		4
NA/TC	NA		TC		NA		TC		NA				TC		
Hole Dia [mm]	0.25				0.18				0.16	0.18	0.20	0.16	0.18	0.20	0.16	0.16	0.18	0.20	0.16	0.18	0.20
	1999 Regulation Cond.				2000 regulation Condition										

Survey on After-treatment Systems (1)

- Literature survey on after-treatment systems (1998).
- Workshop on after-treatment technologies and influence of fuel properties on them (8th of November, 1999).

Guest Speakers:

- Johnson Matthey
- Engelhard
- AVL
- FEV

Survey on After-treatment Systems (2)

3. Survey on C (soot) + NO_2 reaction

Following a recent request from Diesel WG, Combustion Analysis WG has just started a survey on the reaction.

- Mechanisms, rate constant and temperature dependence of the reaction
- Influence of SO_2 and H_2O on the reaction

Results of the survey may lead us to the next contractual basis studies in a university.

Summary (1)

In-cylinder Studies

- Contractual basis studies and single-cylinder engine tests have been carried out in pursuit of fundamental understanding of the in-cylinder combustion mechanisms and influences of engine parameters and fuel properties on emissions.
- All of the information obtained through those studies and results of the statistical analysis will be compiled for the analysis and interpretation of the Diesel WG's data.
- The technical report will be published in March, 2000 (firstly in Japanese).

Summary (2)

Surveys on After-treatment Systems

- Surveys and studies on technologies and reactions in after-treatment systems have become major tasks in the Combustion Analysis WG.
- The WG is contributing in this field by gathering information, holding workshops, discussion with academic authorities and probable contractal basis studies.

FIN