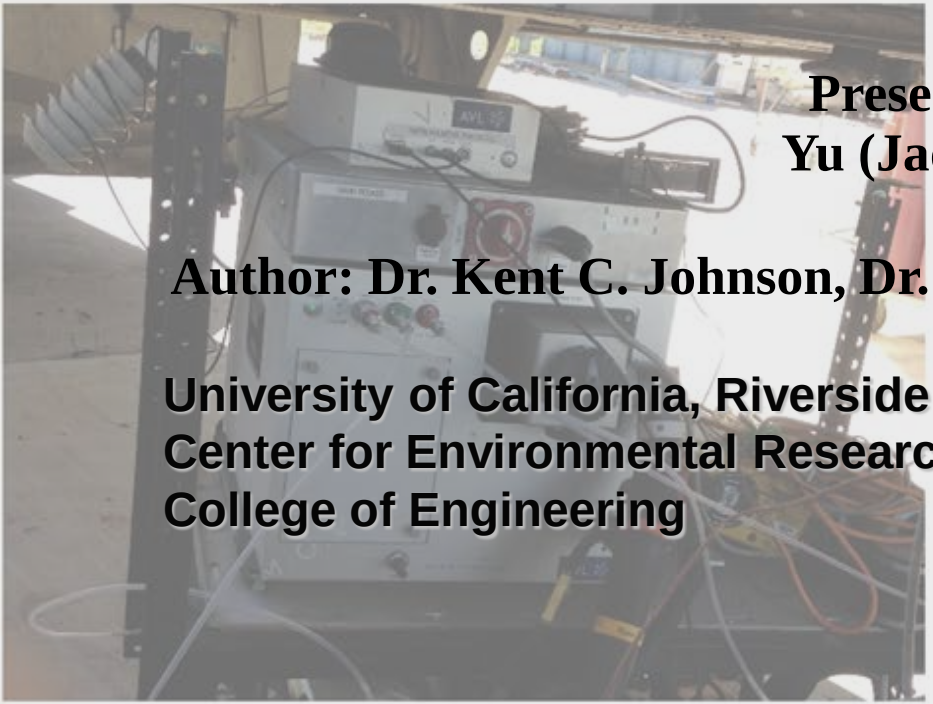
Evaluation of NTK Compact Emission Meter (NCEM)

NGK Spark Plug Co., Ltd



Presented By:
Yu (Jade) Jiang

Author: Dr. Kent C. Johnson, Dr. Tom Durbin, Jiacheng (Joey) Yang

University of California, Riverside
Center for Environmental Research and Technology
College of Engineering

PEMS: Assess Real World Emissions

1065 Compliant PEMS

Compact Emission Meter

Compact NTK unit Accurate Enough?

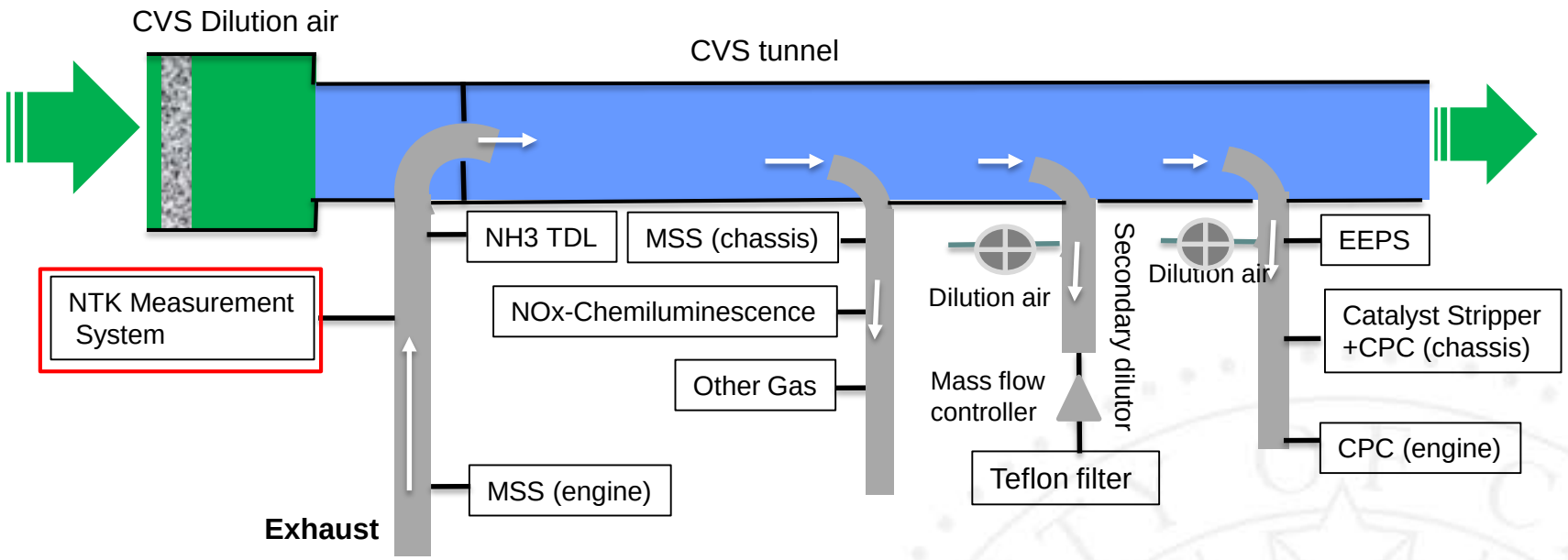
Testing Approach was Comprehensive

Description	Engine dyno	Chassis dyno	Marine engine dyno 3 fuels (DMA, RMA-12, RMG-380)
Model and Year	DDC60, 1991	CUM ISX15, 2014	DDC 671N, 1970
Aftertreatment	None	DOC/DPF/SCR	None
Rated Power (Hp)	350	550	210
Engine Technology	4-Stroke	4-Stroke	2-Stroke
PM/NOx CERT Emissions	0.1/4.0 g/bhp-hr	0.01/0.35 g/bhp-hr	0.2/5.0 g/bhp-hr
PM Composition Estimated	80% EC: 30% EC 20% OC: 70% OC	50% EC 50% OC	30% EC: 5% EC 70% OC: 45%S,50%OC
Measurements	MEL, MSS, CPC, +	MEL, MSS, CSCPC	PG-350, MSS, CPC,
Test Cycles	FTP, UDDS, SET	UDDS, HHDDT	25%, 50% and 75% load

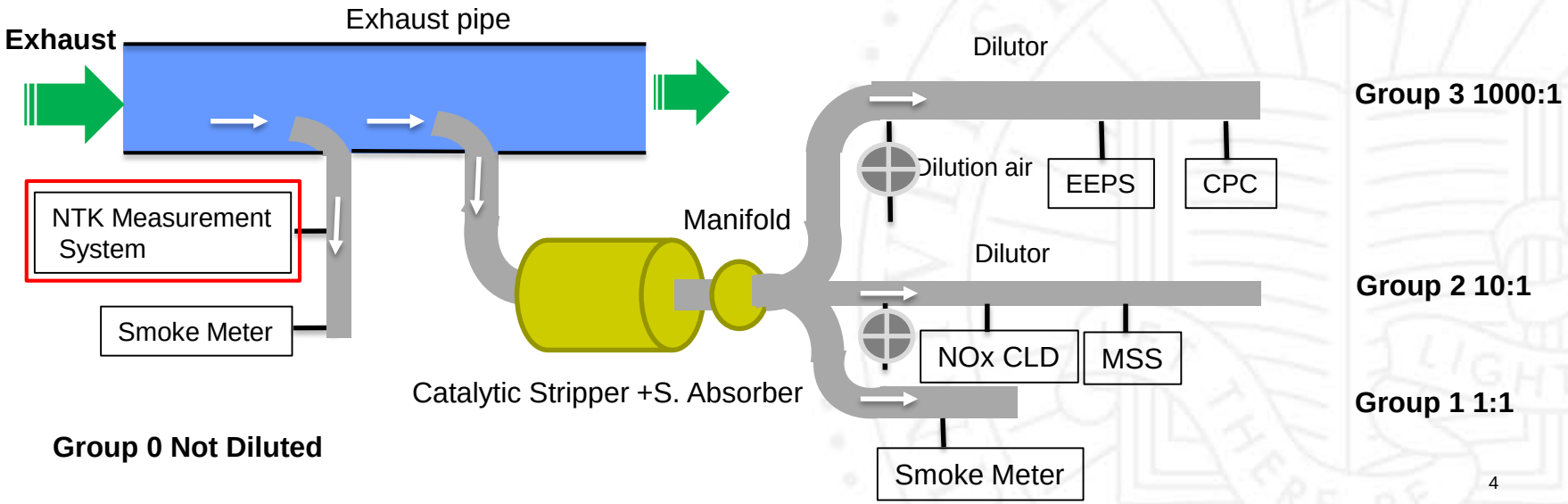
CS: Catalytic Stripper

Experimental Setup

MEL Test

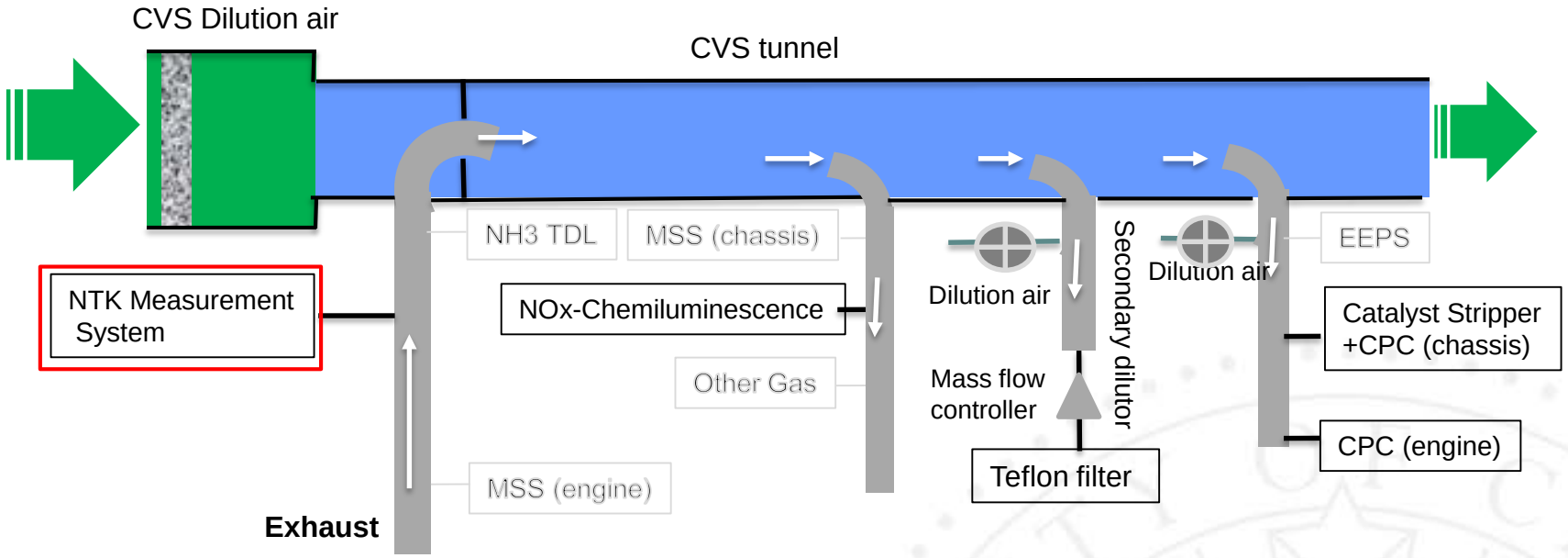


Marine Test

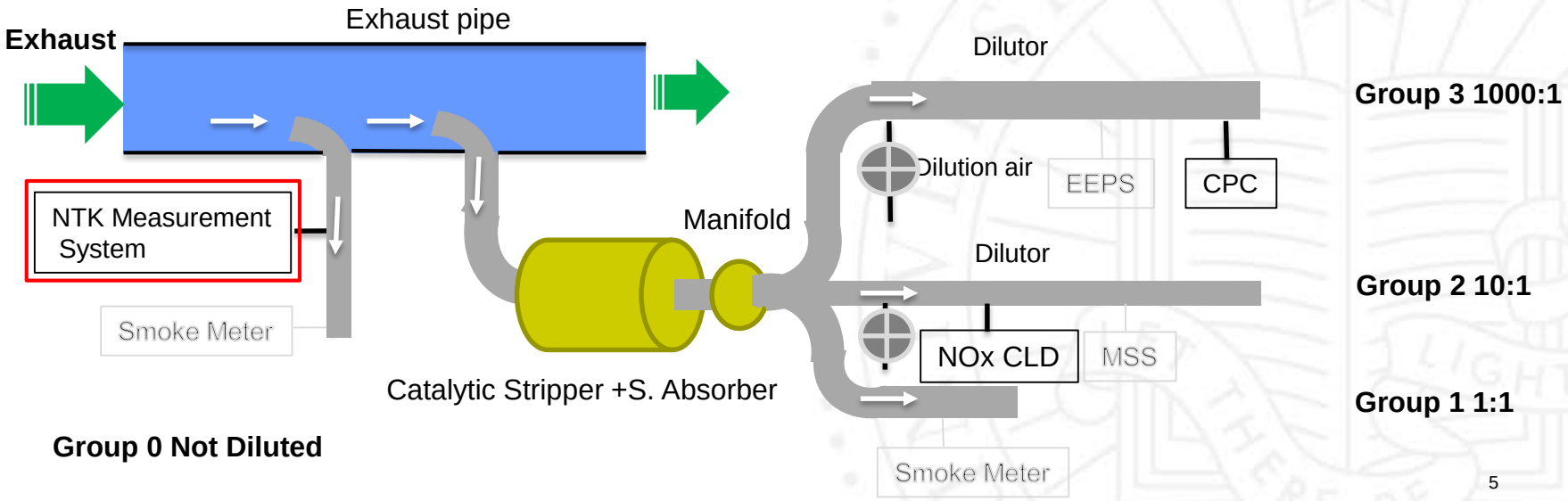


Experimental Setup

MEL Test



Marine Test



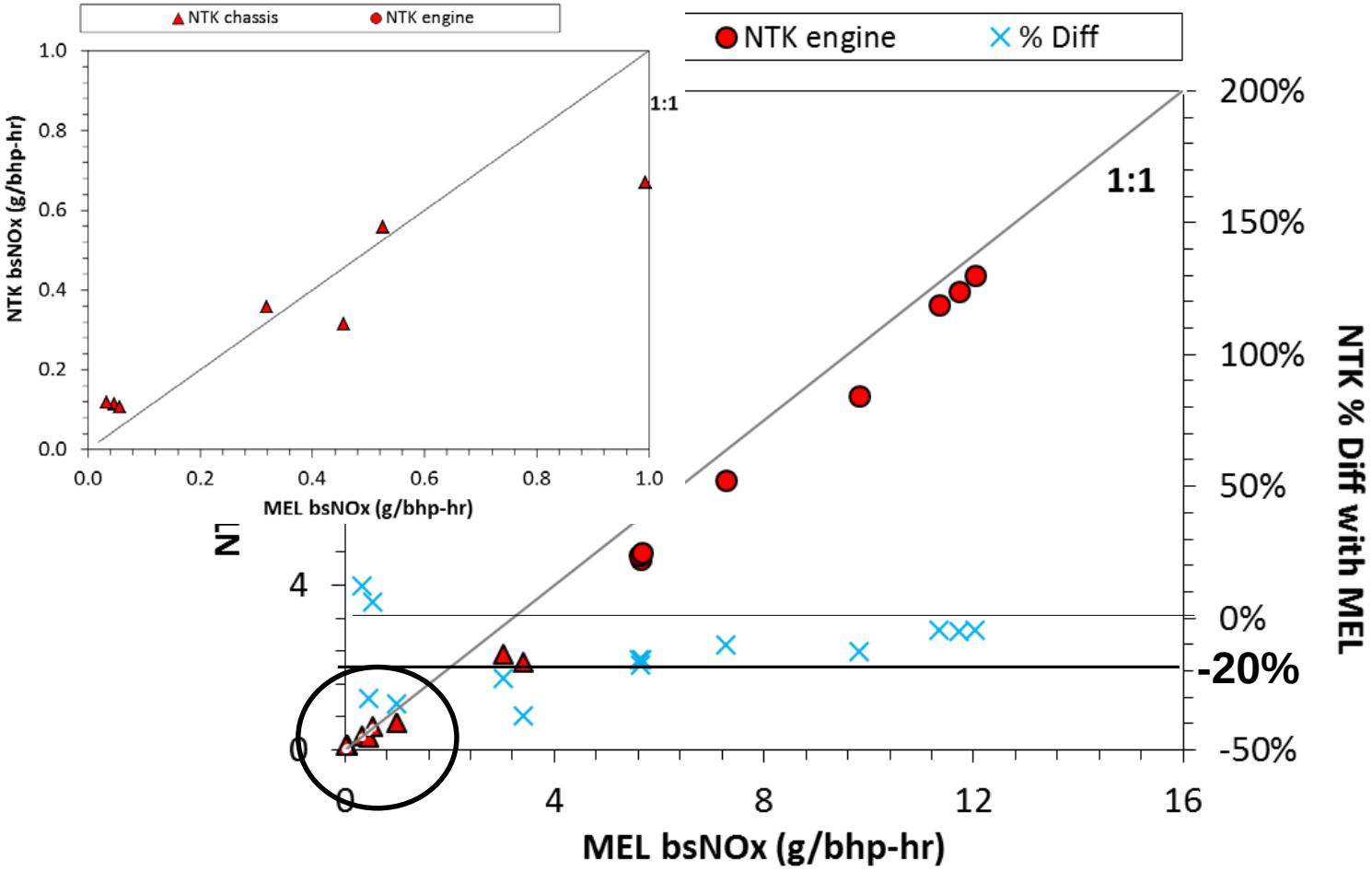
Brake-specific NOx Overall Repeatability is Good

Tests	Trace	Iterations	kNOx (g/bhp-h)		RSD*	PM (mg/bhp-h)		RSD	PN (#/bhp-h)		RSD
Enigne Dyno	FTP	3	4.72 ±	0.08	1.6%	36.02 ±	0.70	2.0%	1.8E+14 ±	3.5E+12	2.0%
	UDDS	3	11.15 ±	0.35	3.1%	86.07 ±	7.05	8.2%	4.3E+14 ±	3.5E+13	8.2%
	SET Low		8.59			27.44			1.4E+14		
	SET		6.54			16.76			8.4E+13		
Chassis Dyno	UDDS	2	0.34 ±	0.03	8.8%	-1.43 ±	0.63	-43.9%	-7.9E+12 ±	3.5E+12	-43.9%
	Creep	2	2.24 ±	0.14	6.1%	-2.21 ±	2.28	-102.9%	-1.2E+13 ±	1.3E+13	-103.0%
	Transient	2	0.62 ±	0.08	12.9%	-1.65 ±	0.68	-41.3%	-9.0E+12 ±	3.8E+12	-42.5%
	Cruise	2	0.11 ±	0.01	4.7%	-0.92 ±	0.14	-14.7%	-5.1E+12 ±	7.5E+11	-14.7%
	SS Cruise	2	0.12 ±	N/A		-0.05 ±	0.02	-49.2%	-2.5E+11 ±	1.2E+11	-48.7%

* Relative Standard Deviation=STDEV/AVG. ×100%

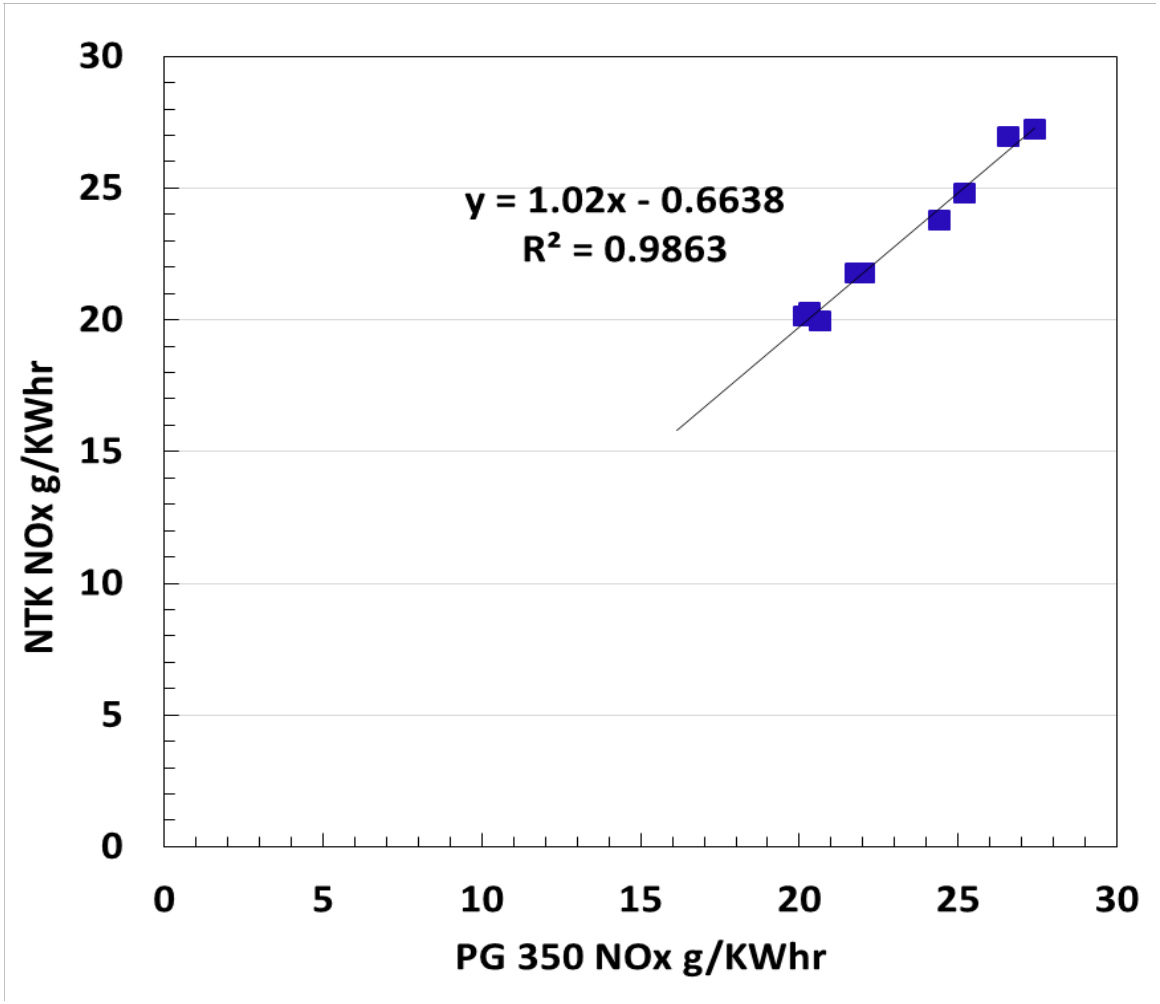
- Note that engine for chassis dyno tests equipped with DOC, DPF and SCR

NOx Values within 20% of MEL Results

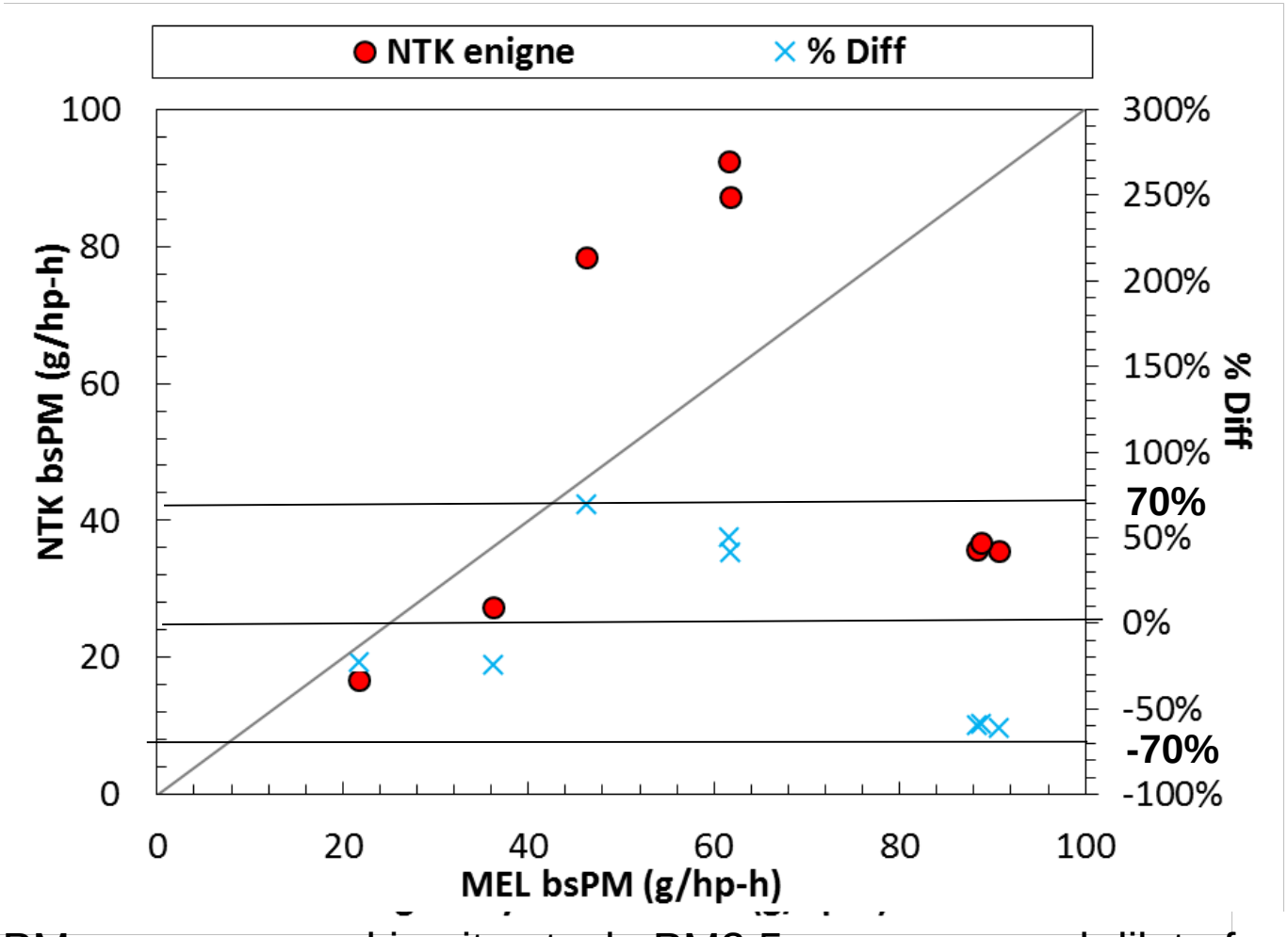


- NTK NOx measurements were lower than the MEL reference method
- NOx values within 20% of MEL results for engine test

Marine Engine NOx Results Show A Good Correlation with CLD-NOx for By Pass Mode

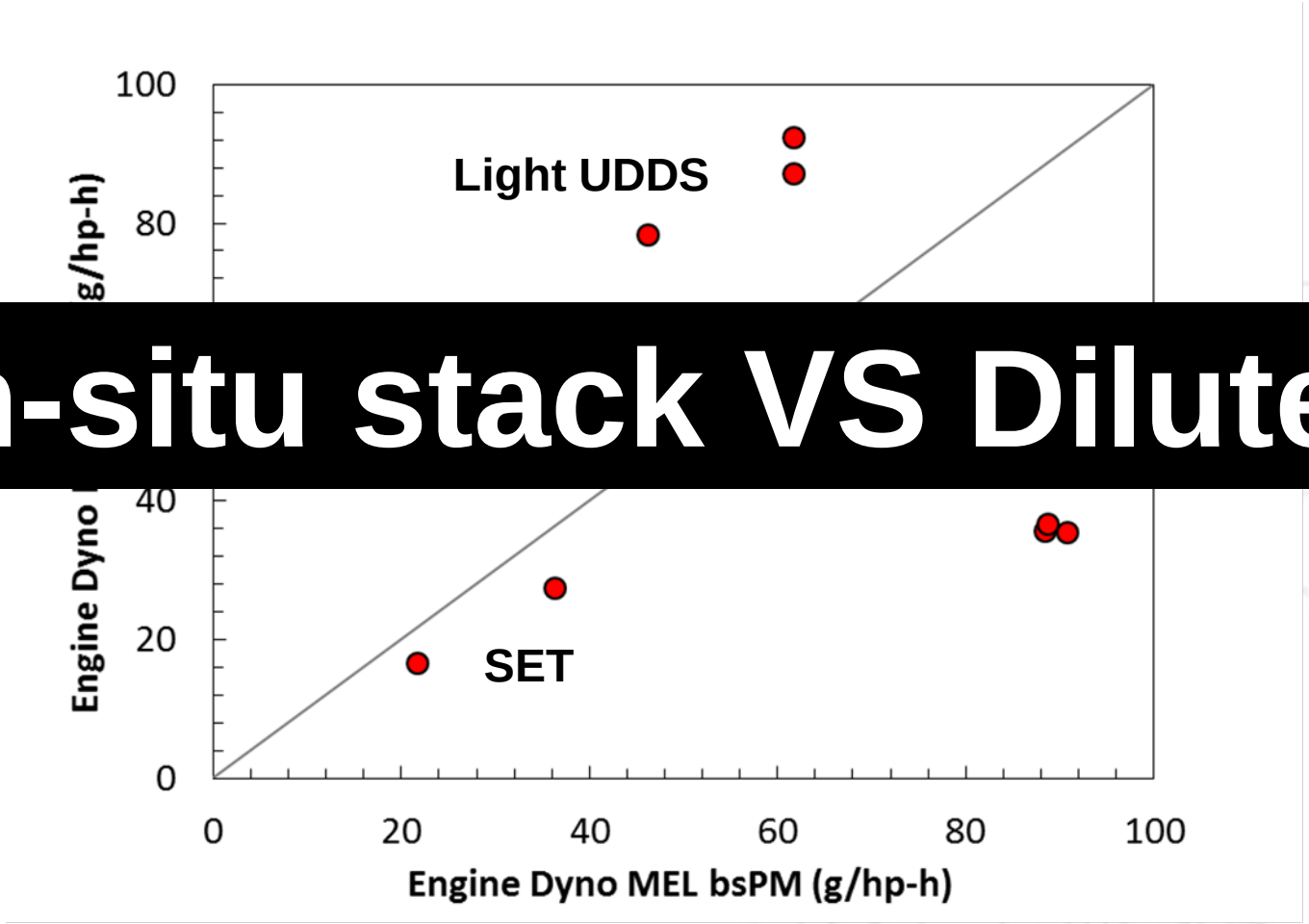


PM Values within 70% with $PM_{2.5}$



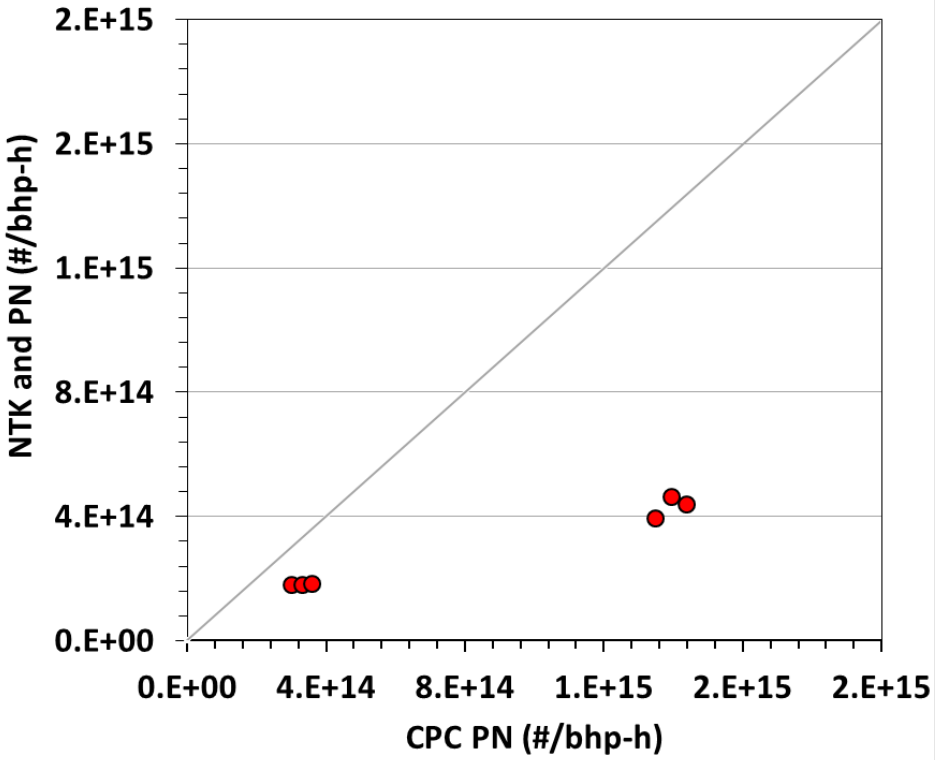
- NTK PM was measured in-situ stack, PM2.5 was measured dilute from a CVS without a catalytic stripper
- PM values were within 70% with $PM_{2.5}$ for engine dyno test

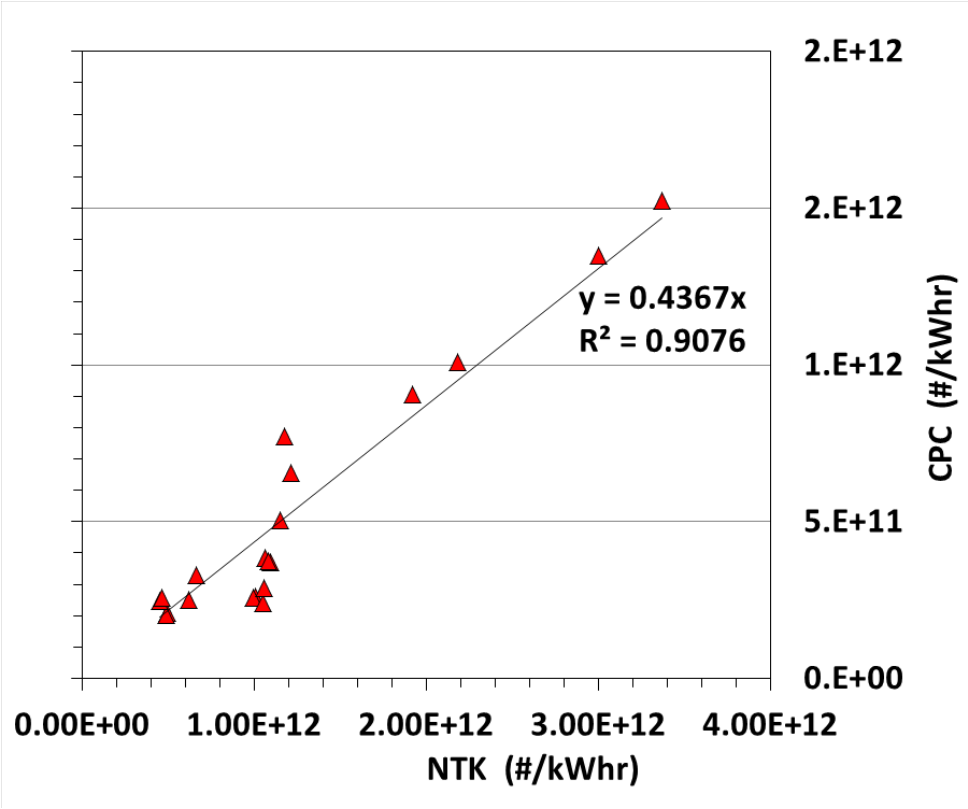
PM Values Varies with Driving Cycles



In-situ stack VS Diluted

PN Compared Well with CPC Results of Marine for Catalytic Stripper Mode





- CPC measured in diluted CVS exhaust, NTK was an in-situ stack measurement.
- NTK vs CVS PN Differences resulted from organic condensation formation in CVS.
- NTK measurement represents a solid PN.
- **NTK PN compared well with CPC results for marine engine test.**

NTK Compact Gas, PM, and PN System:

- Required no startup calibrations or corrections
- Operated continuously without interruption
- NOx compared well for both on-road and marine engines
- PM values were within 70% with $PM_{2.5}$ for engine dyno test
- NTK PN compares well with CPC results for marine engine with CS condition.

Acknowledgements

Funding Support

NGK Spark Plug Co., Ltd

Technical Staff

Don Pacocha, Eddie O’Neil, Mark Villella and Kurt Bumiller

Thank You for Your Attention

Introduction of NGKNTK compact size PM/PN, NOx/O2 multi gas measurement unit
NTK Compact Emissions Meter (NCEM)

Presented by :Wenjing Ma

NGK SPARK PLUG CO., LTD.

Report No.: RELAE-1249
Prepared on: Mar. 17th, 2016

Background

NGK SPARK PLUGS | NTK TECHNICAL CERAMICS
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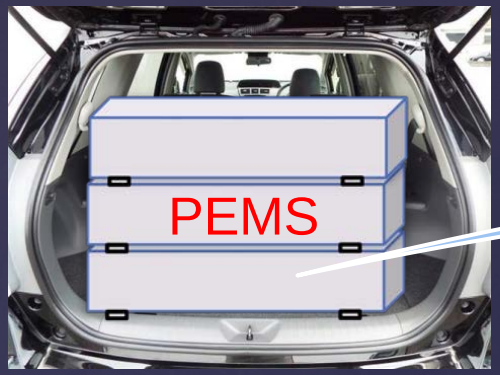


NTK OEM Sensors

Target Applications	・Emission certification
Features	・Same origin as standard emissions analyzers ・Equivalent of accuracy with standard emission analyzers
Demerits	・Too heavy and large ・Long set-up times ・Slower response due to sampling measurement ・Expensive

NTK Sensor Control Technology

NCEM

Target Applications	・Vehicle R&D ・Engine & vehicle test facilities
Features	・**Light weight and compact size** ・**Fast ready to measure** ・**Fast response with real time measurement** ・**Easy to use** ・**Vehicle battery operation**

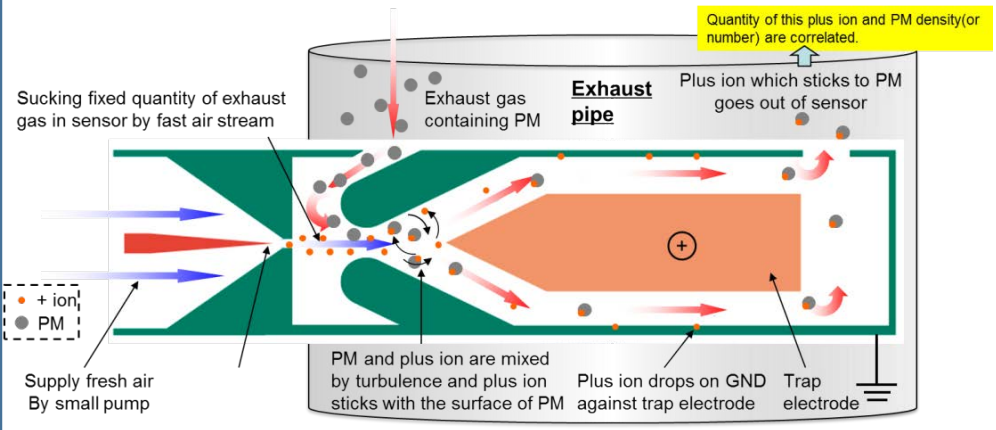
➢ NCEM Functions

- *Features*

✓ *Light-weight (Max.12kg) and Compact size (W340 × D280 × H270mm)*
✓ *Fast ready to measure(Up to 5 minutes wait)*
✓ *Fast response and REAL TIME measurement*
✓ *Simple and EASY USE for emissions analyze and data-logging*
✓ *Selectable Slots for module and sensors : Maximum 8 slots*
✓ *GPS and OBD2 data synchronization*
✓ *DC12/24V vehicle battery operation (Less than 10Amp Max.)*

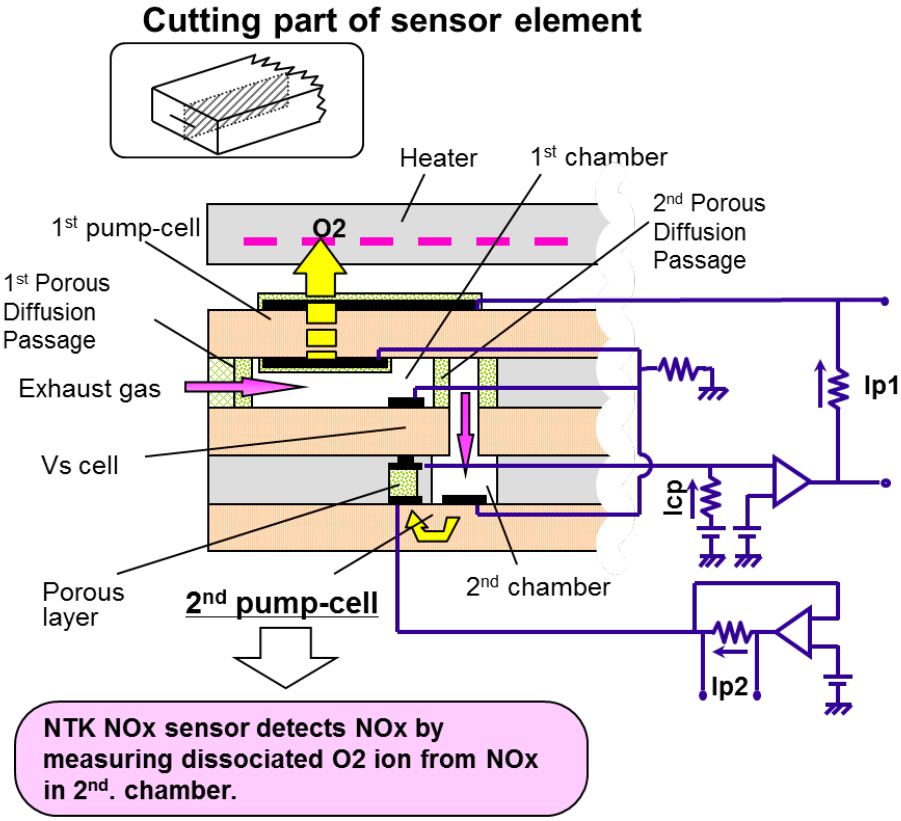
NTK PM/PN Sensor

NTK PM/PN sensor technology is based on the Pegasor.



NTK_NOx_Sensor

Production released from 2010 for OEM sensor



NTK NOx sensor detects NOx by measuring dissociated O2 ion from NOx in 2nd. chamber.

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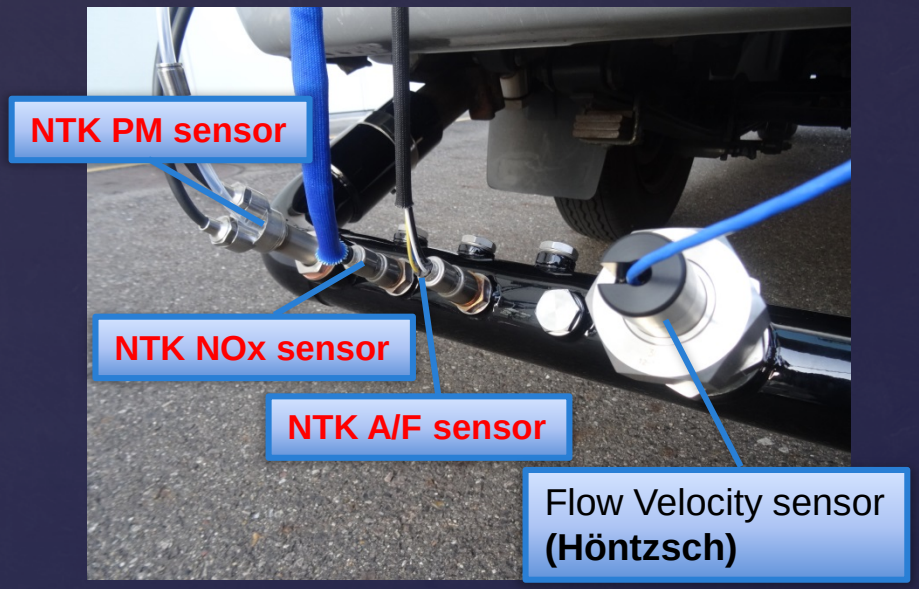
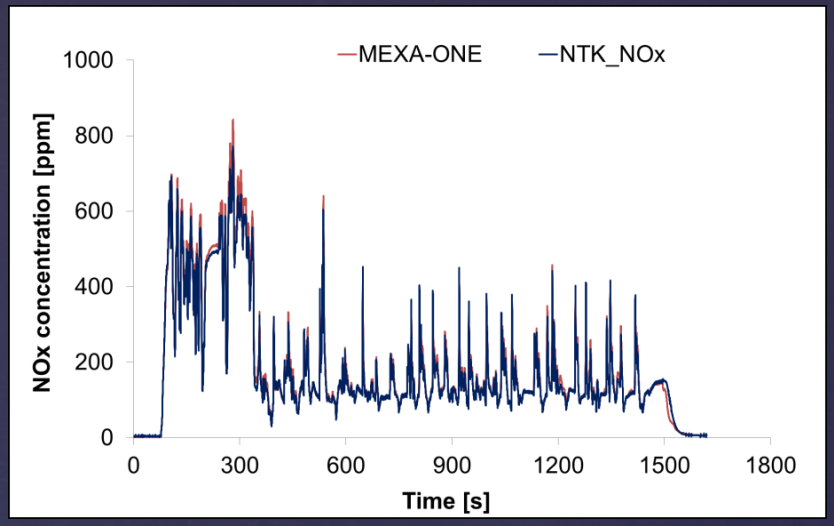
- *Vehicle Measurement Condition*



Item	Detail
Test cycles	FTP
Standard measurements	AVL MSS, TSI EEPS, HORIBA MEXA-ONE
Measurement component	PM. PN, NOx at tail pipe
Engine	1.8L Diesel
After treatment	DOC/DPF/SCR (using damaged DPF)

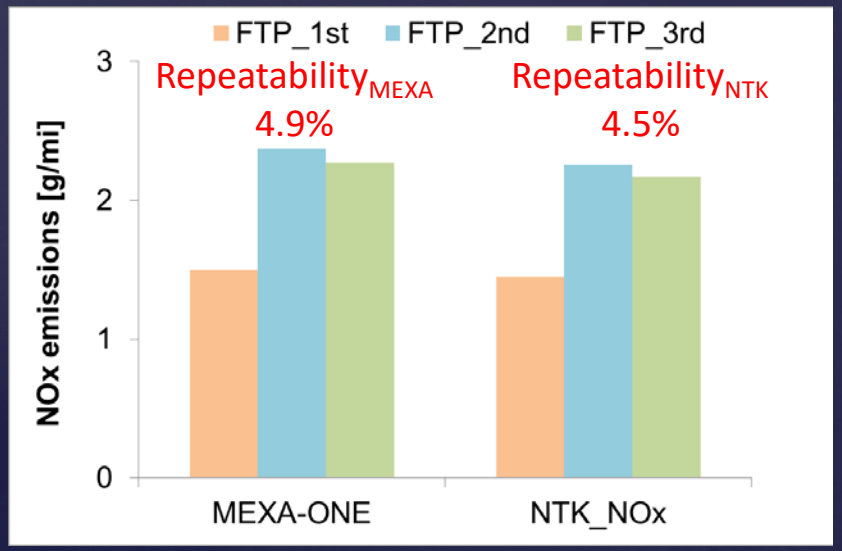
➢ *Performance of NOx Measurement (Dynamic)*

- **Real Time NOx Data for FTP**



✓ NTK_NOx and MEXA-ONE had good correlation.

- **NOx emissions comparisons on g/mi for FTP**



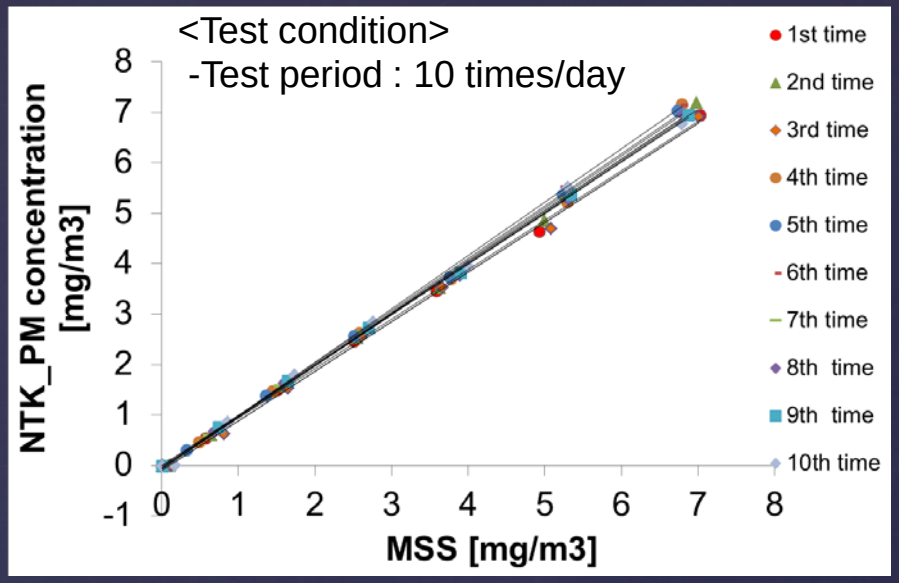
✓ $\%\text{Repeatability}_{MEXA} = \frac{MEXA - MEXA\_Ave}{MEXA\_Ave} \times 100\%$

✓ $\text{Repeatability}_{NTK} = \frac{NTK - NTK\_Ave}{NTK\_Ave} \times 100\%$

✓ The repeatability of three times measurement for NTK_NOx was same level as MEXA-ONE.

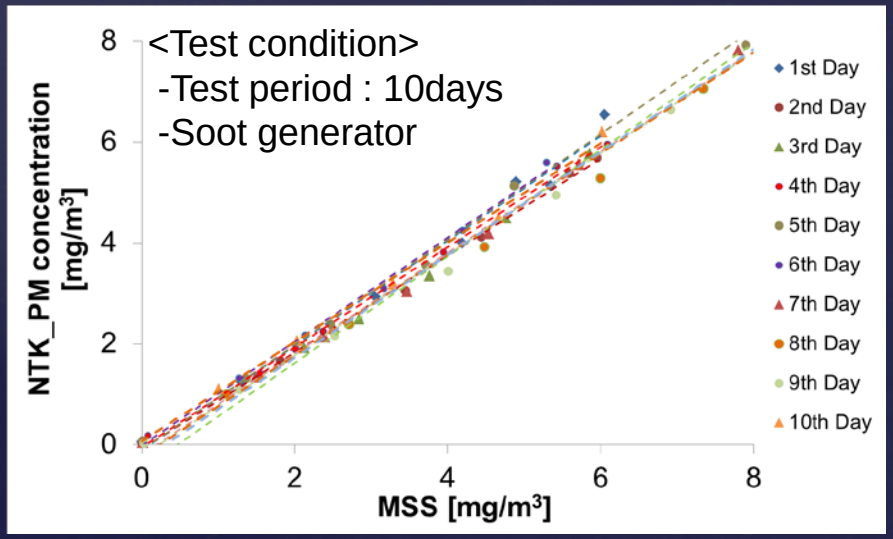
➢ NTK_PM Repeatability(Static Bench)

▪ NTK_PM repeatability (N=10 times)



- ✓ $\%\ \text{Repeatability} = \frac{\text{NTK\_PM} - \text{MSS}}{\text{MSS}} \times 100\%$
- ✓ The repeatability of PM measurement under one day toward MSS was less than 5%.
- ✓ This result includes MSS repeatability.

▪ NTK_PM Repeatability (10 days)

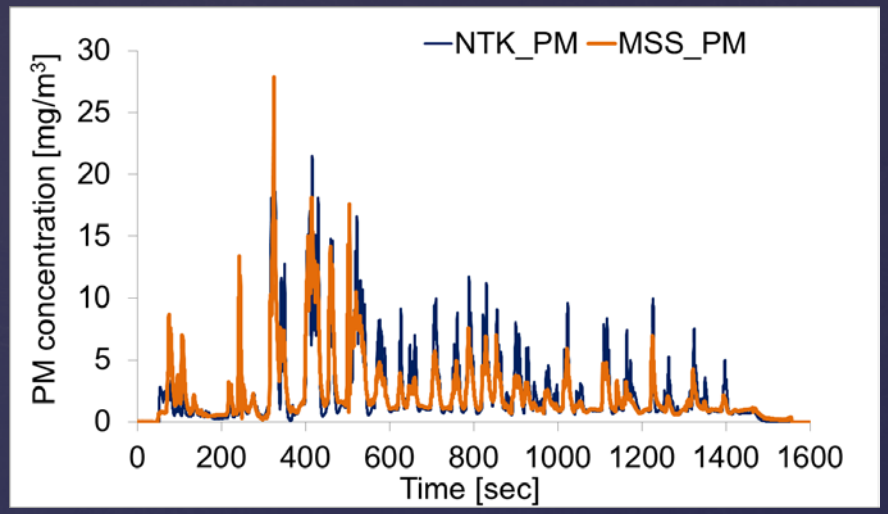


- ✓ The day to day repeatability of PM measurement toward MSS was less than 6%.
- ✓ This result includes MSS repeatability.

➢ Performance of PM Measurement (Dynamic)

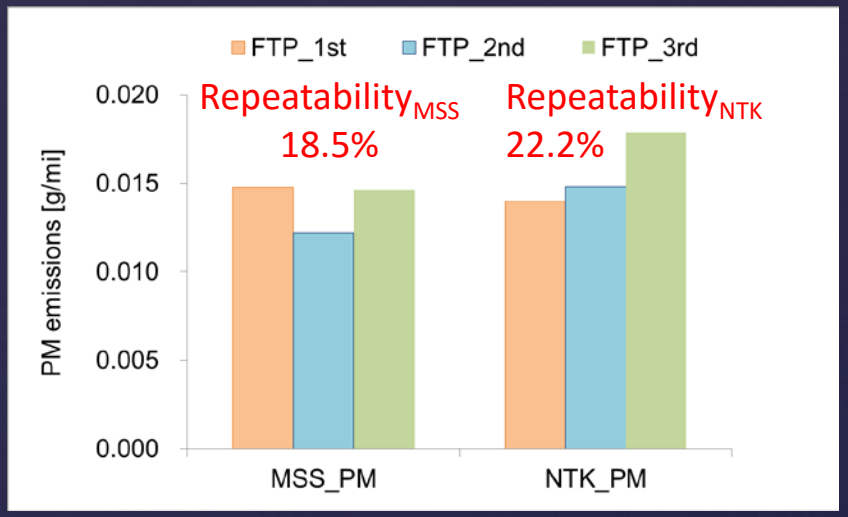
NTK NCEM has selectable gain for PM measurement toward particle size.
NTK tested using 60nm of default particle size gain at this time.

Real Time PM Data for FTP



✓ NTK_PM output showed the same behavior as MSS.

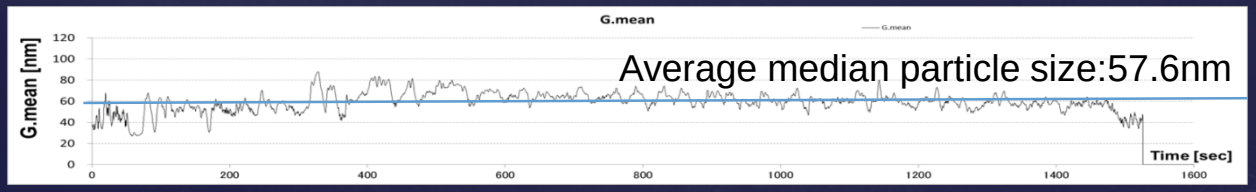
PM emissions comparisons on g/mi



✓ NTK_PM showed similar repeatability as MSS.

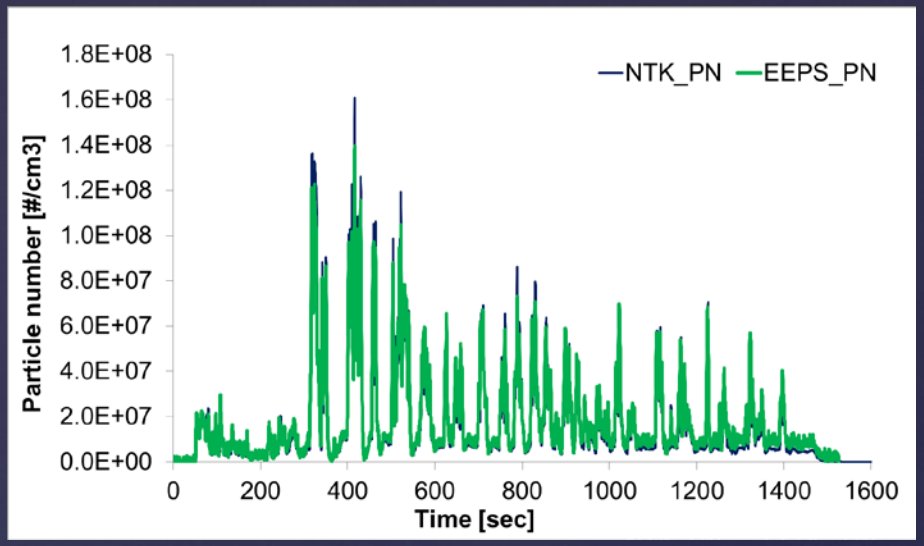
✓ This result includes actual vehicle emission repeatability.

Real Time averaged particle size for test car measured by EEPS



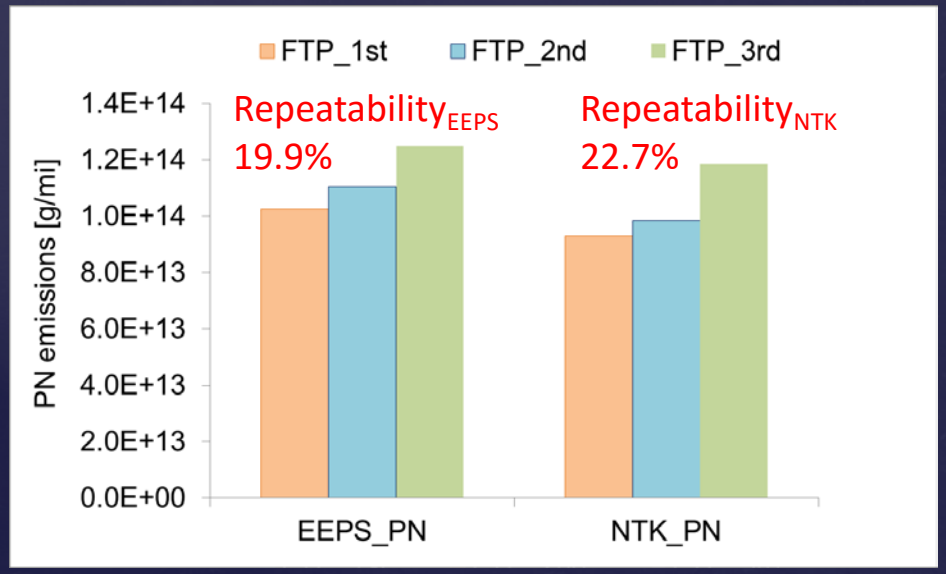
➢ Performance of PN Measurement (Dynamic)

- **Real Time PN Data for FTP**



✓ NTK_PN output showed the same behavior as EEPS.

- **PN emissions comparisons on #/mi for FTP**

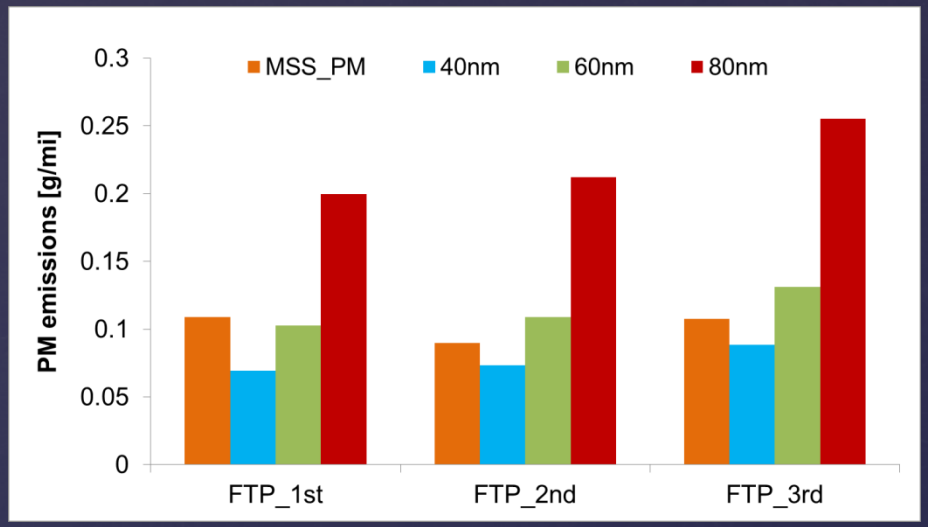


✓ NTK_PN showed similar repeatability as EEPS.

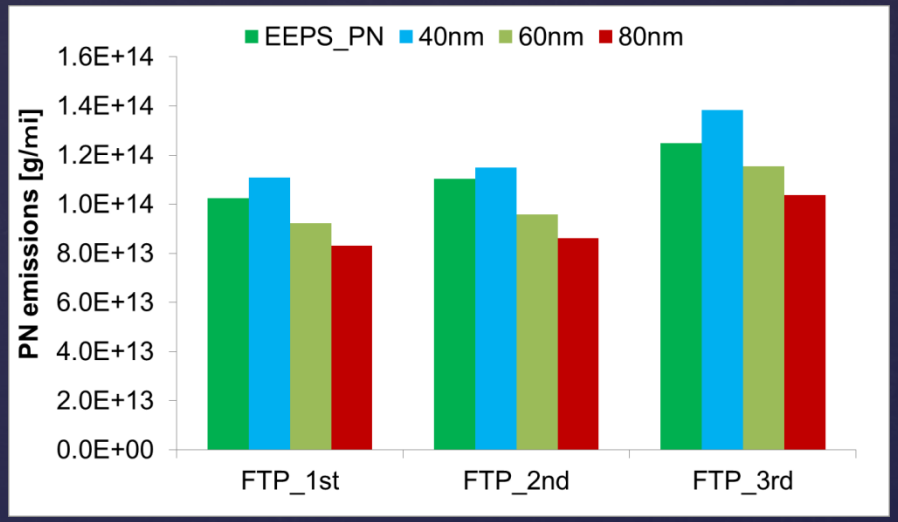
✓ This result includes actual vehicle emission repeatability.

➢ *Particle size effecting on PM/PN emissions*

- **Particle size effect for PM**



- **Particle size effect for PN**



- ✓ Different selectable gain (40 and 80nm) were adapted then compared differences.
- ✓ Error by selecting larger side particle size gain is larger for PM measurement.
- ✓ Much smaller effect of particle size exists for PN measurement than PM.
- ✓ But the error could be improved by selecting suitable selectable gain according to actual particle size even PM.

➢ Comparison of PM between 1st and 2nd sample

PM result of NCEM 1st sample for FTP by UCR

Test Details			PM (mg/bhp-h)		
FTP	PEMS	MSS	68.8	±	0.4
FTP	NTK		36.0	±	0.7

Difference between MSS and NTK_PM was 47.7%.

* Effect of semi-volatile particle may also includes

Improvement from 1st. to 2nd.sample

- **Precise calibration by multiple point measurement**
- **Better accuracy/repeatability by total re-design of HW**

PM result of NCEM 2nd sample for FTP

Test details		Interations	PM [g/mi]
FTP	MSS	**3**	0.014 ± 0.0012
FTP	NTK_PM	**3**	0.016±0.0017

The difference between MSS and NTK_PM was 14.3%.

➢ *Summary*

NGK SPARK PLUGS | NTK TECHNICAL CERAMICS
NGK SPARK PLUG CO., LTD.

- ✓ NTK_NOx and MEXA-ONE had good correlation.
- ✓ NTK_NOx showed same level repeatability as MAXA-ONE.
- ✓ NTK_PM and NTK_PN output showed the same behavior as MSS and EEPS.
- ✓ NTK_PM/PN showed similar repeatability as MSS and EEPS .
- ✓ The particle size effect for PM is larger for larger particle size, but it was much smaller for PN.
- ✓ NTK NCEM has selectable PM/PN gain for various particle size, so accuracy could be more optimized by using the features.
  (Future improvement will be also considered)

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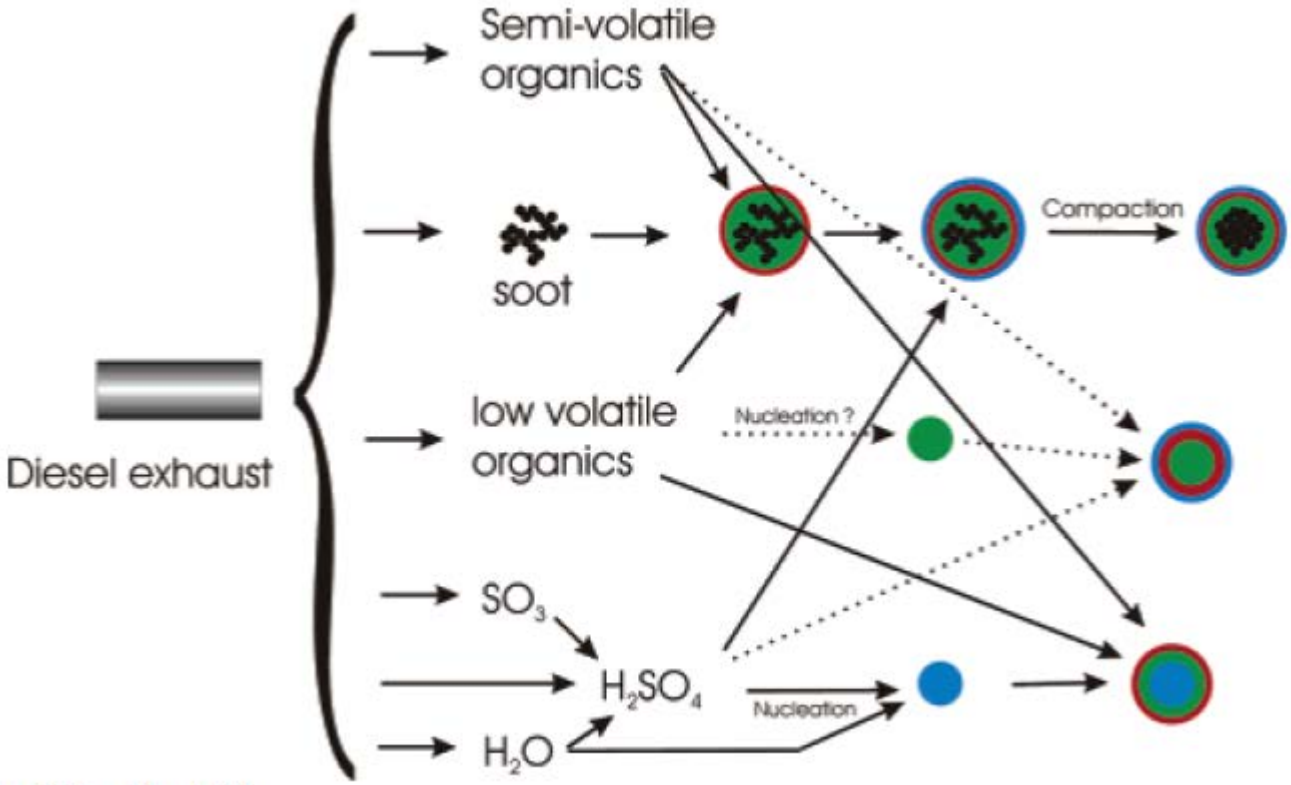
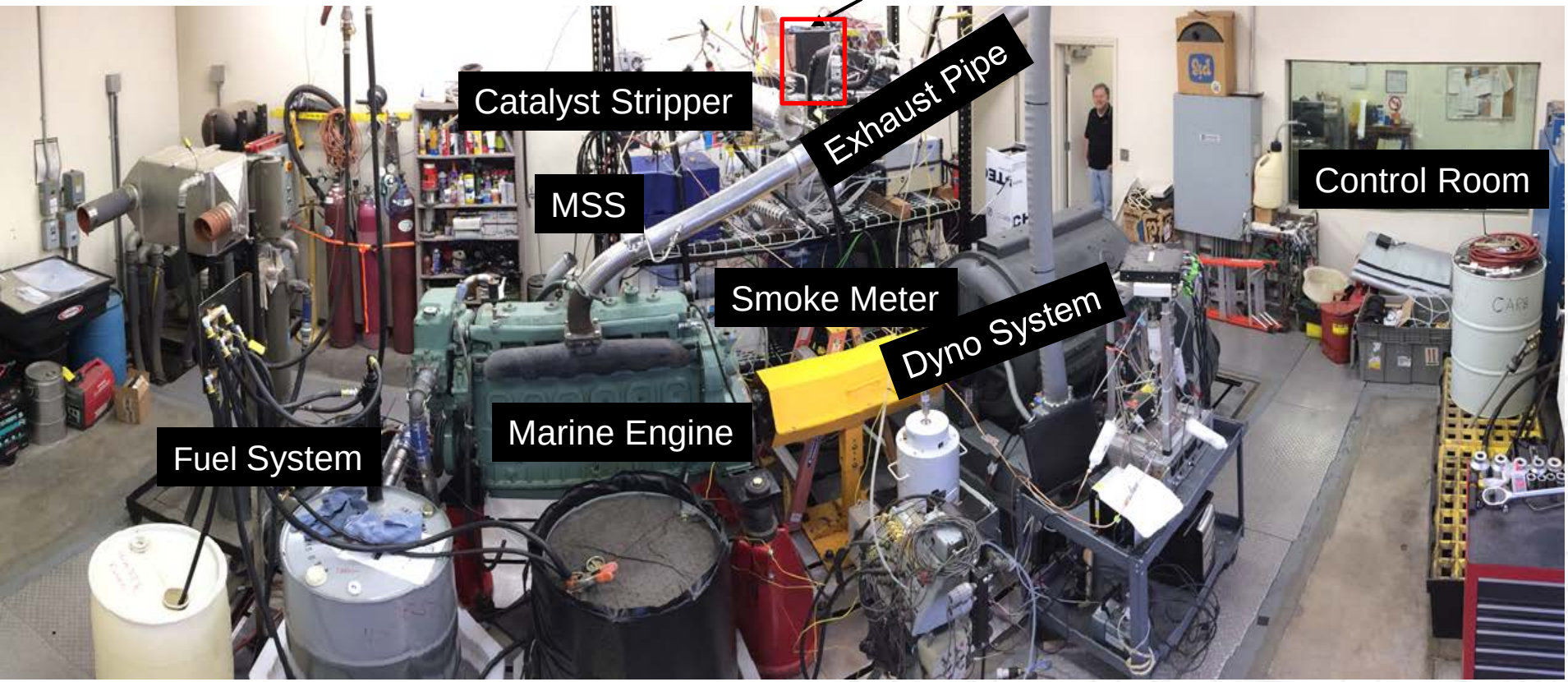
THANK YOU !

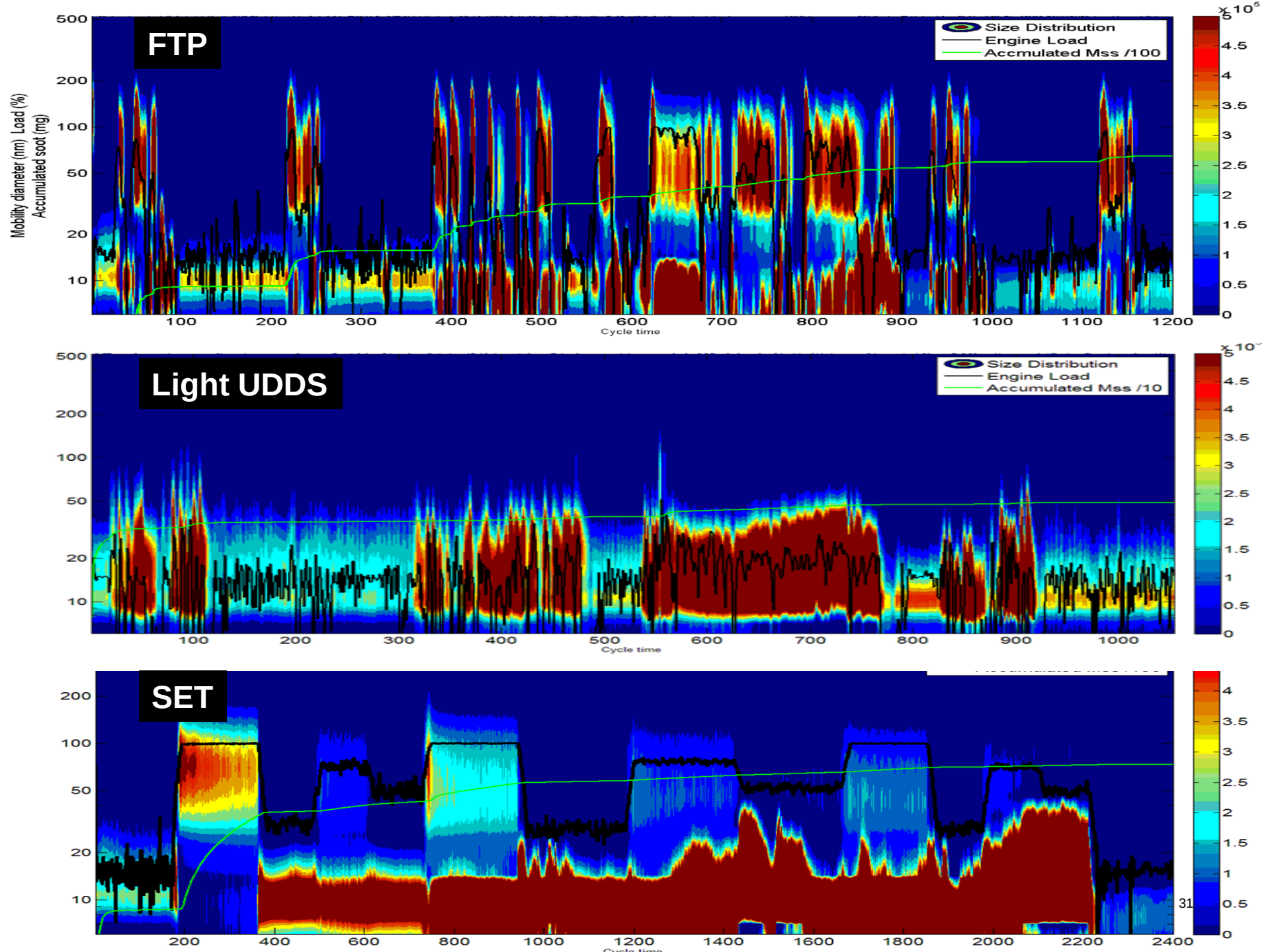
PM formation resulting in the exhaust stack and during dilution



After Schneider [26]

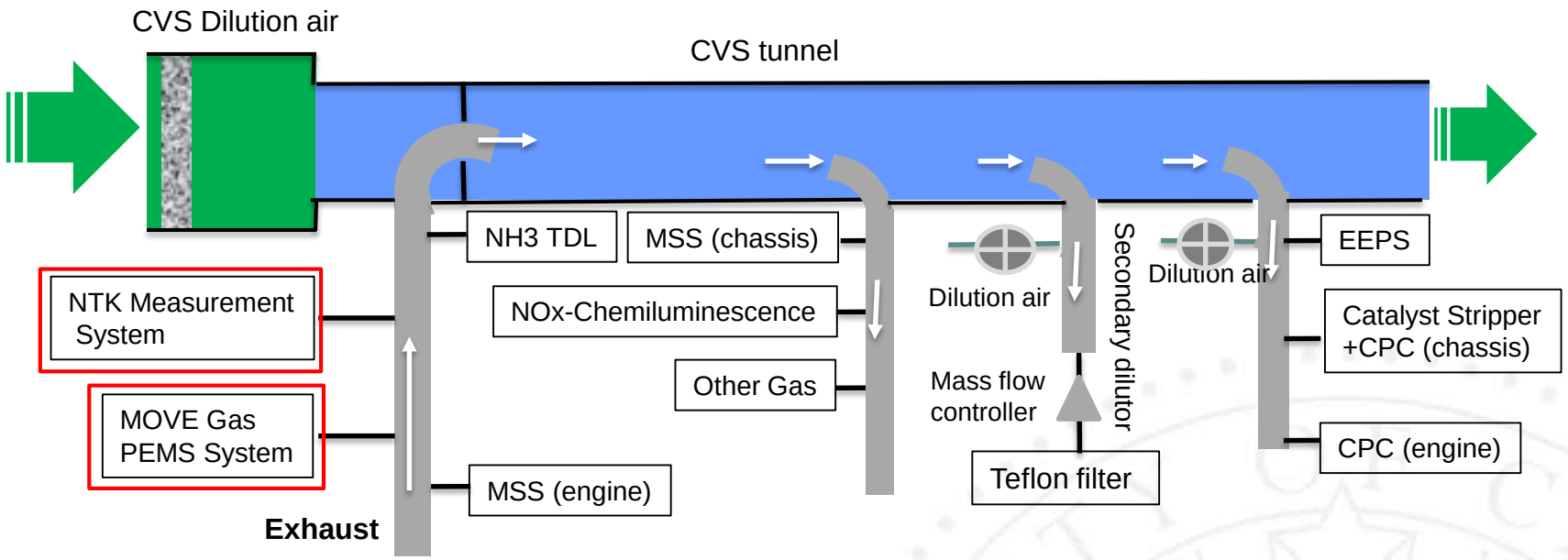
Comprehensive Marine Engine Testing with NTK-system



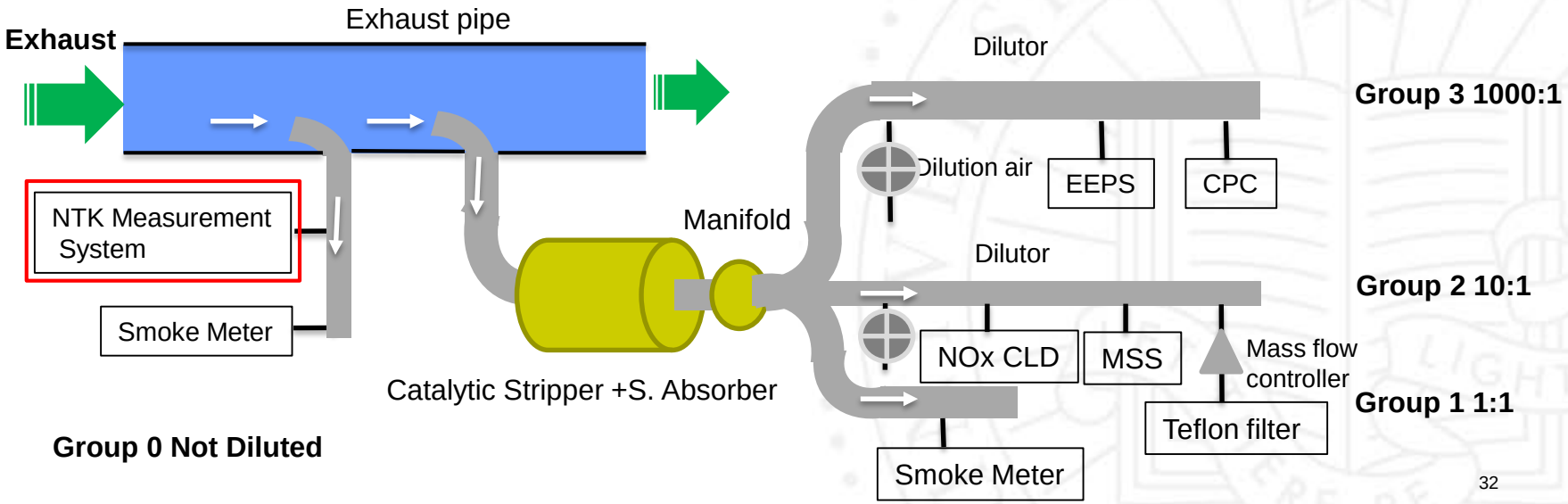

FTP
Size Distribution
Engine Load
Accmulated Mss /100
Mobility diameter (nm) Load (%)
Accumulated soot (mg)
Cycle time
Light UDDS
Size Distribution
Engine Load
Accumulated Mss /10
Cycle time
SET
Cycle time

Experimental Setup Schematic

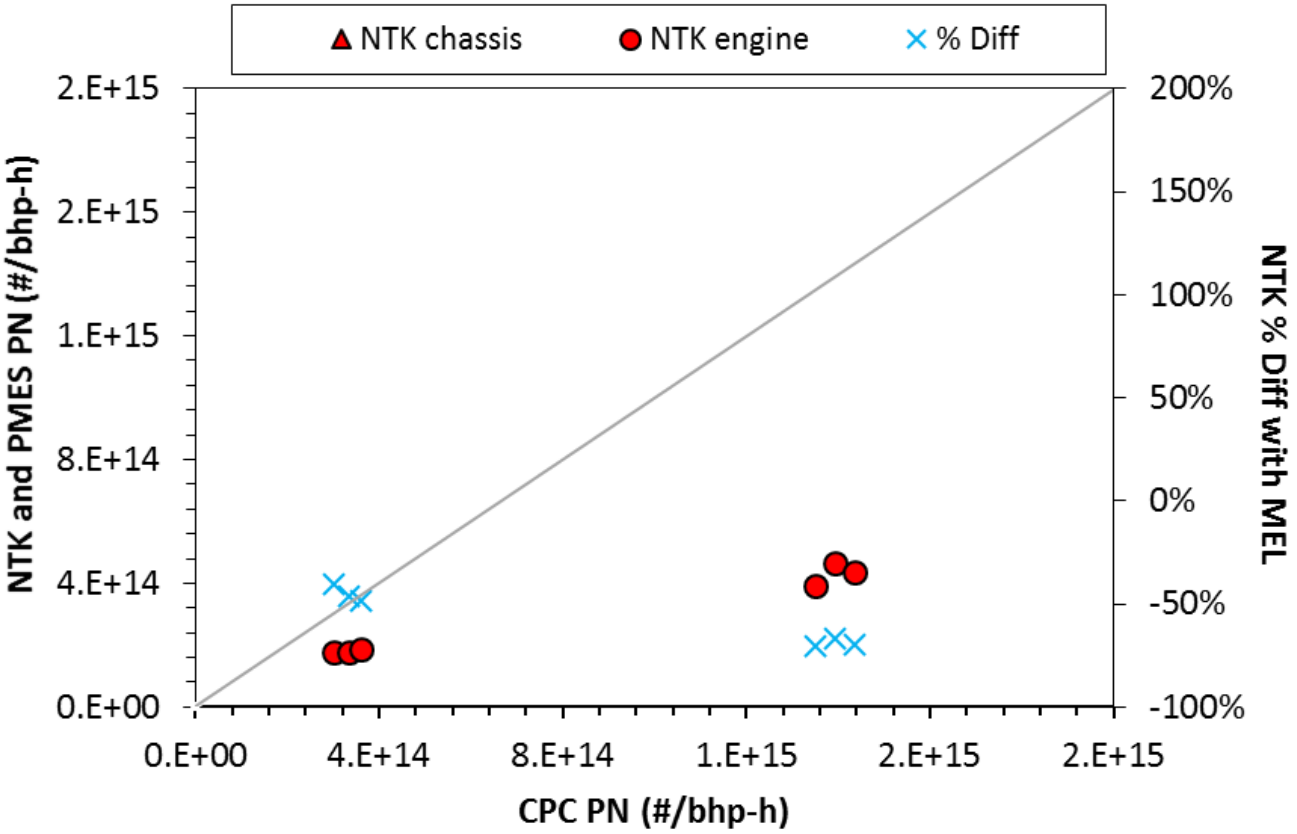
MEL Test



Marine Test

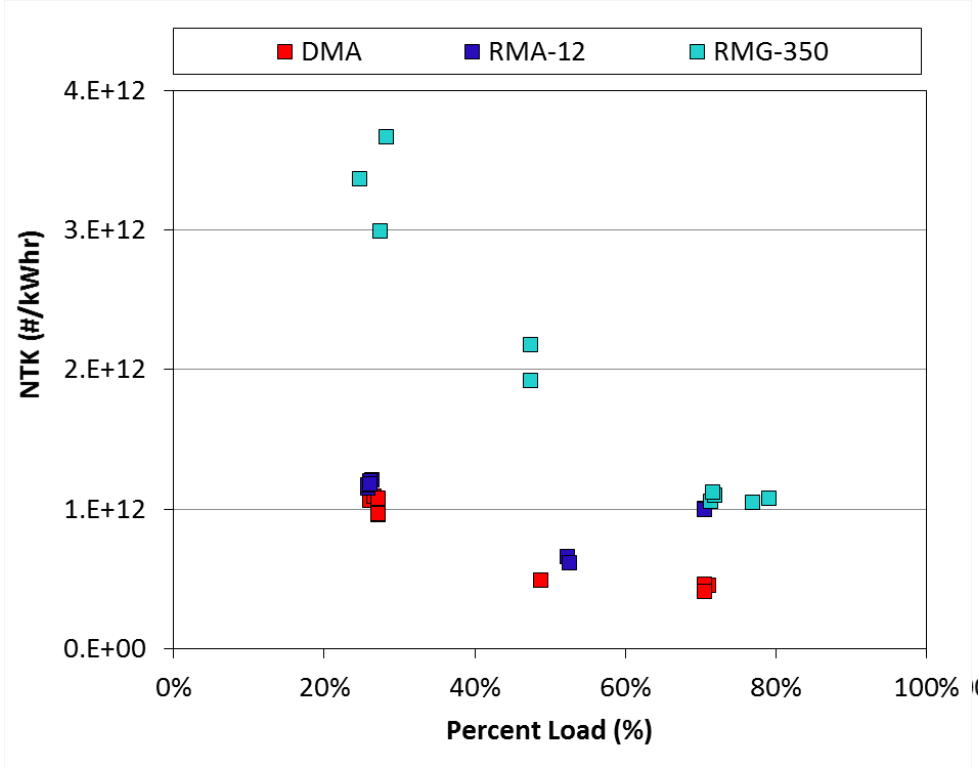


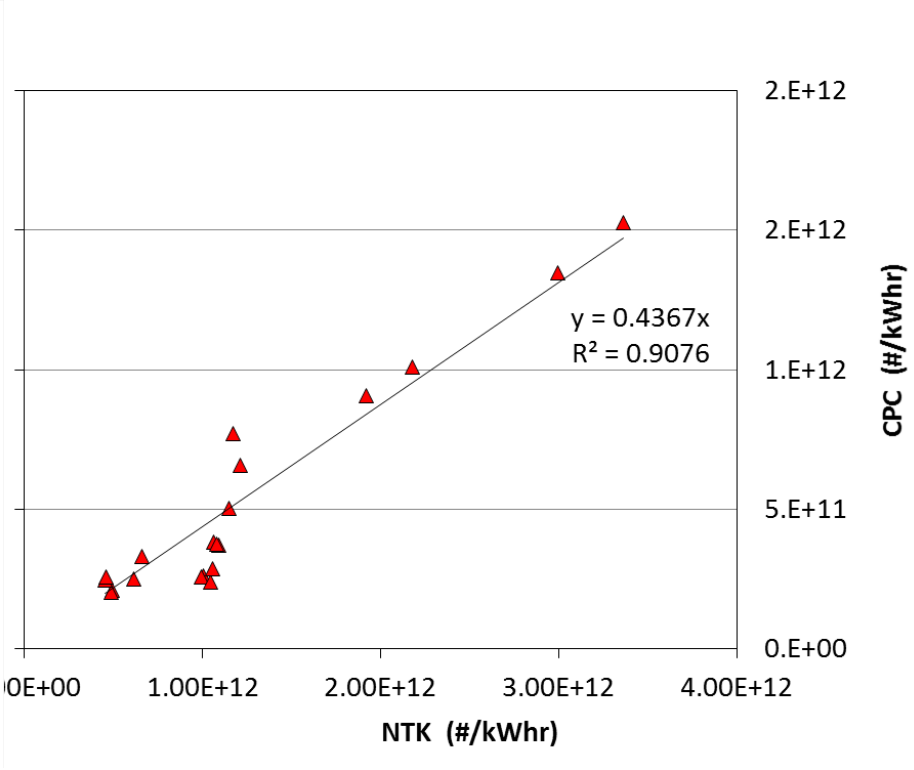
PN Results was Lower Than CPC



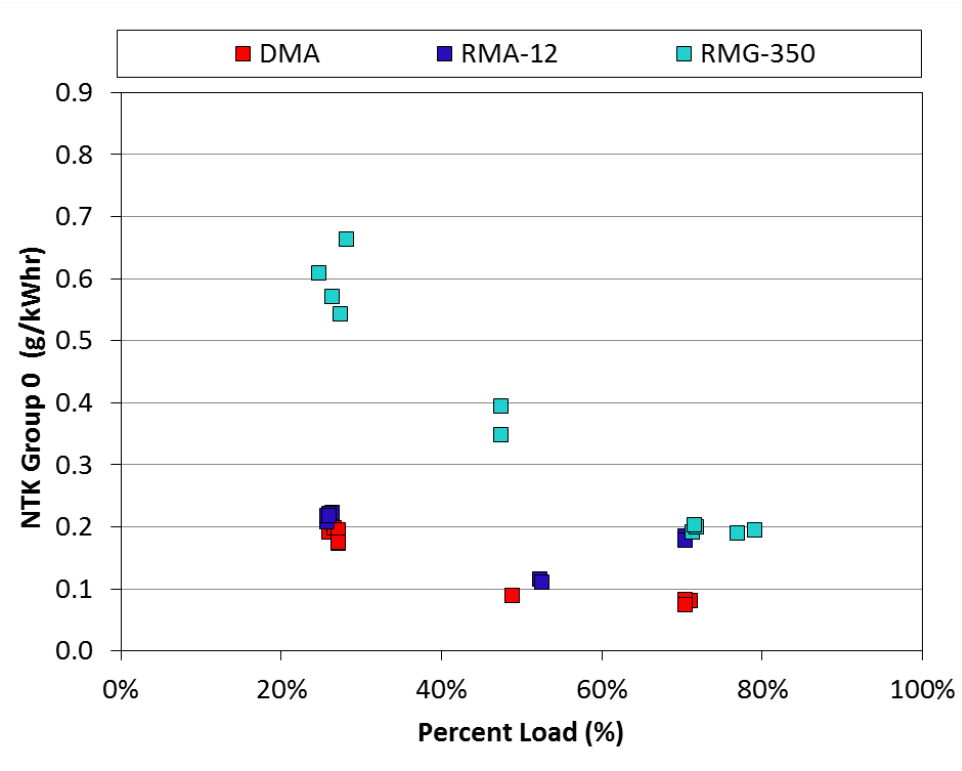
- CPC measured in diluted CVS exhaust, NTK was an in-situ stack measurement.
- NTK vs CVS PN Differences resulted from organic condensation formation in CVS.
- NTK measurement represents a solid PN.

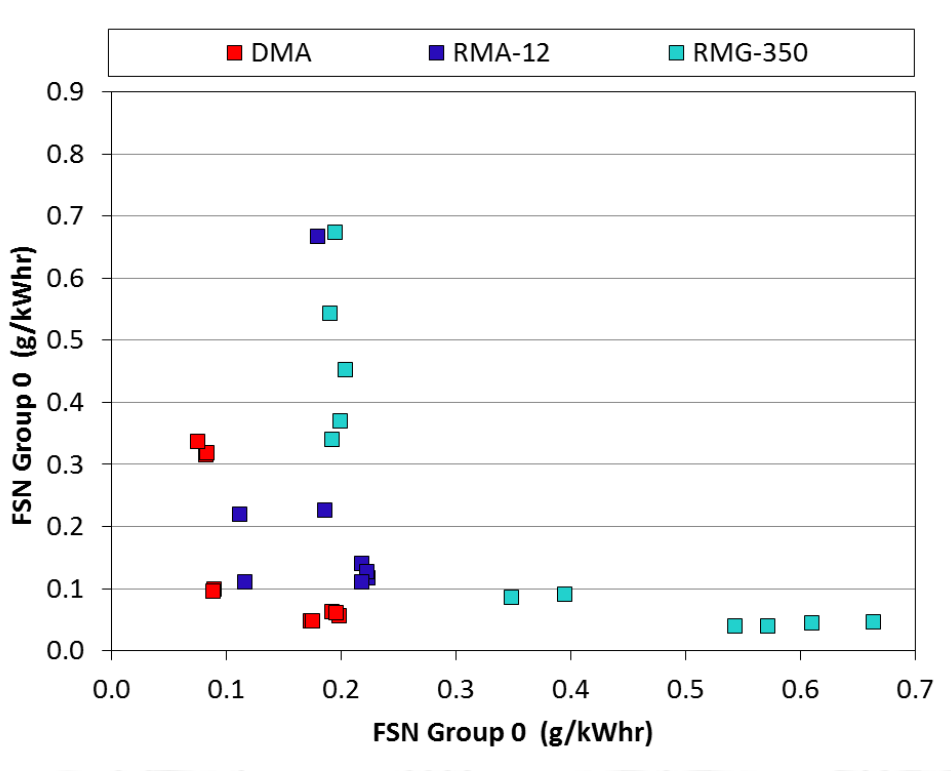
Marine PN Results Show A Good Correlation with CPC for CS Mode



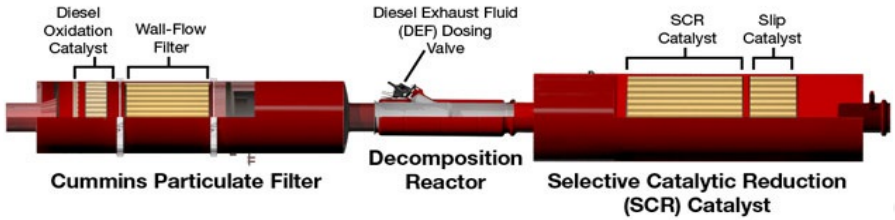


- NTK PN was measured raw, CPC PN was measured dilute with CS
- NTK shows how PN varies with load.
- NTK PN Compares well with CPC results.


DMA
RMA-12
RMG-350
NTK Group 0 (g/kWhr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0%
20%
40%
60%
80%
100%
Percent Load (%)


DMA
RMA-12
RMG-350
FSN Group 0 (g/kWhr)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
FSN Group 0 (g/kWhr)

Diesel Engines After-treatment Systems



After-treatment system	Remove emissions	Remove efficiencies
Diesel particulate filter (DPF)	PM	85% or more of the soot
Selective catalytic reduction (SCR)	NO_X	70%-95% NO_X
Diesel oxidation catalysts (DOCs)	PM, CO and hydrocarbons (HC)	20%-40% PM, 40%-75% HC, 10%-60% CO

Real Time PSD Data for SET