Emission Measurement System Designed to Meet Euro 7 and U.S. Tier 4 Standards

ECMA 17th International Conference ECT 2026

HORIBA, Ltd.　Tomoshi Yoshimura

Oct 23, 2026

Agenda

1. Regulatory Trends

   EURO 7 and U.S. Tier 4
2. Measurement Systems and Technical Challenges
3. Ultra-Low NOx measurement
4. Low-Mass PM Measurement
5. Low-CO_2 with high moisture measurement
6. Summary

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Euro 7, US Tier 4, and MY2027

Major Changes from the Previous Regulation

Regulation	Category	Date	Main Changes from the Previous Regulation	Requirement for Testing Equipment
Euro 7	LDV	Nov. 29 2026	**Updates** - PN23 to PN10 - PM and PN10 for all PI engines	- PN10 Measurement
Euro 7	HDV	May 29, 2028	**New pollutants** - NMOG(Non-methane organic gas) - HCHO (TBD by 2027) - CH_4, N_2O **Updates** - NH_3 mass emission (Euro VI: ppm) - PN10 (Euro VI: PN23)	- NMOG : Potential for the Impinger-Cartridge Method - HCHO : TBD - NH_3 Mass Measurement - CH_4, N_2O, PN10 Measurement
US Tier 4	LDV	MY2027 postponed to MY2029?	**Emission limit tightened:** - PM (3mg/mi ➔ 0.5mg/mi)	- Analytical Methods for Low-Mass PM measurement
MY2027	HDV	MY2027	**Emission limit tightened:** - NOx (200mg/hp-hr ➔ 35mg/hp-hr)	- Analytical Methods for Ultra-Low Concentrations NOx measurement

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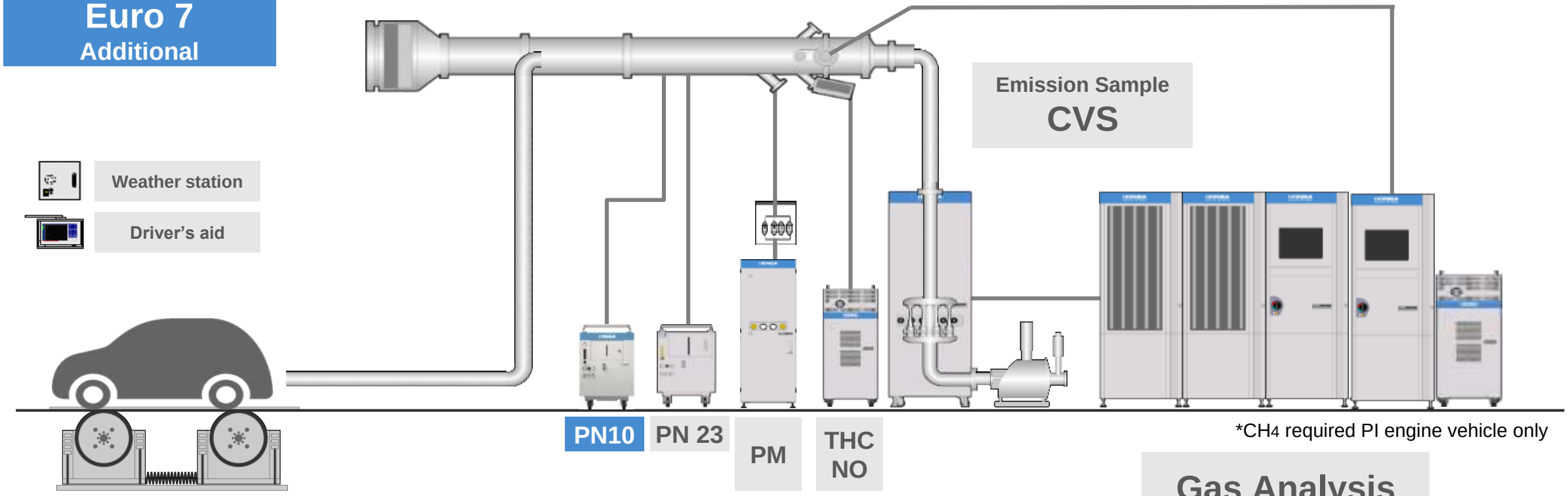
Euro 7 Chassis Test Cell Testing Configuration

LDV

Euro 6e

Euro 7
Additional



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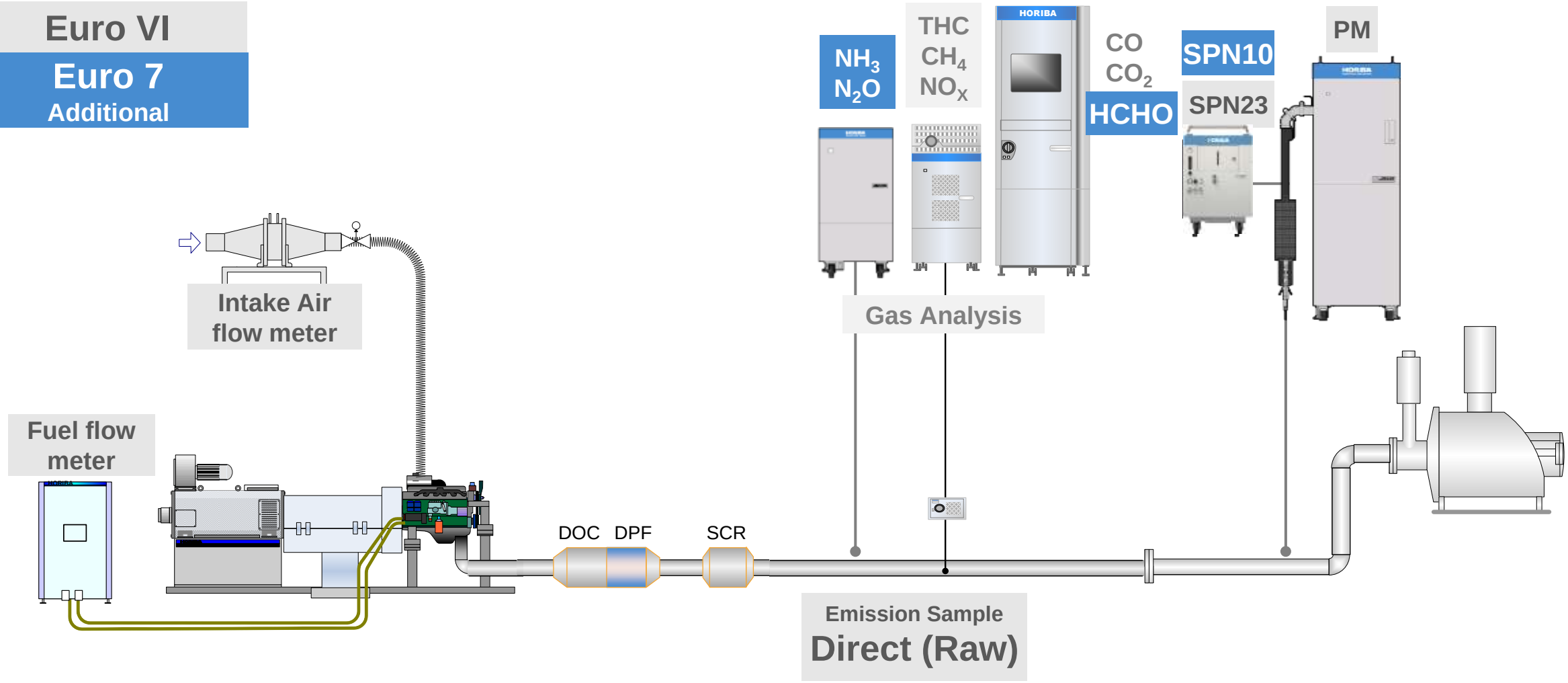
Euro 7 HDD Engine Testing Configuration

HDV

*Whether HCHO measurement is required is TBD
*QCL-IR / FTIR analyzer with type approval must be used according to UNR49.

Euro VI

Euro 7
Additional



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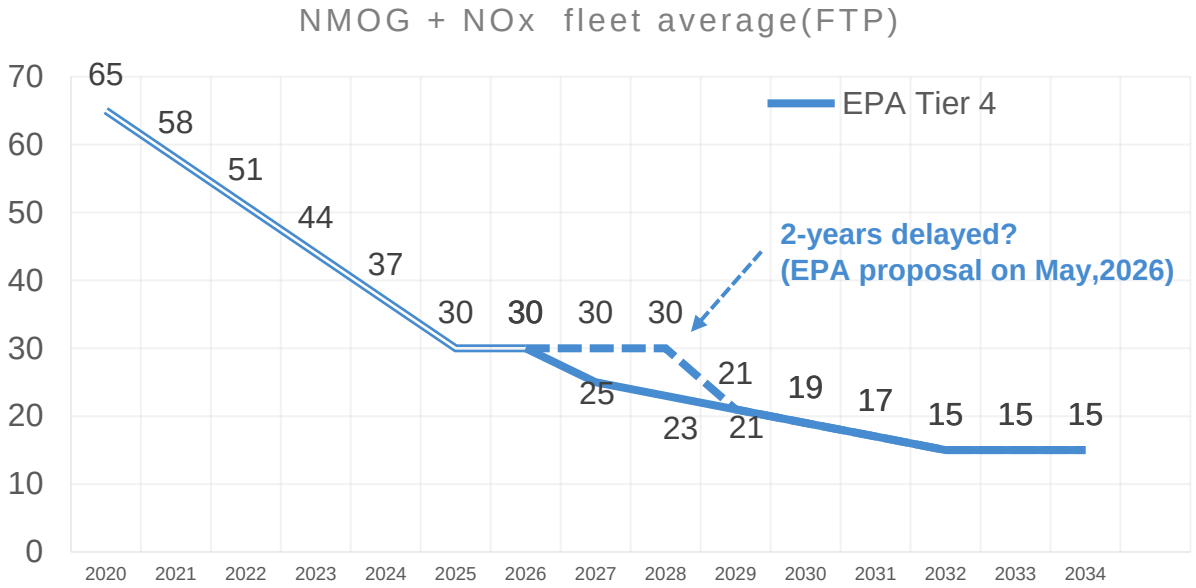
LDV

US Tier 4 NMOG + NOx, PM Emission Standards

LDV

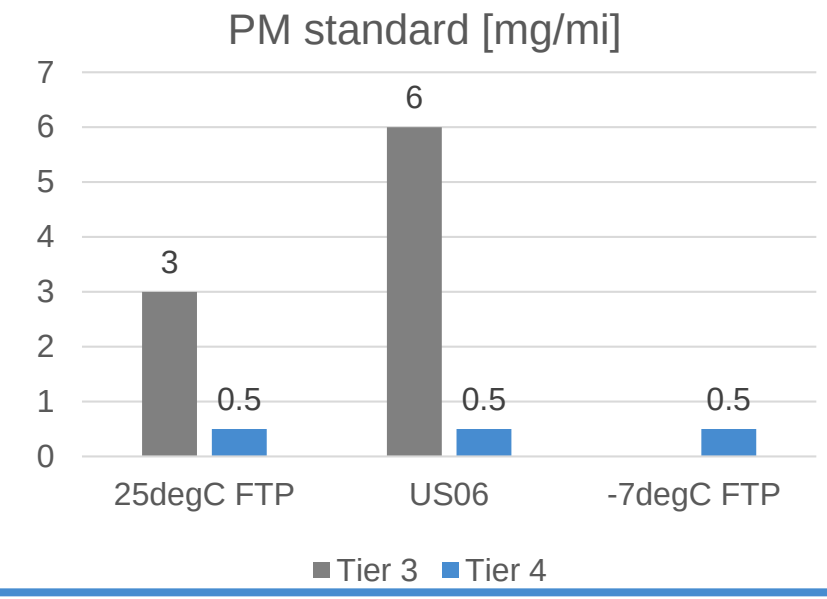
EPA (Environment Protection Agency) proposes to adjust the implementation timeline from model year 2027 to 2029 fir the Tier4 criteria pollutant standards. (May 2026)

NMOG + NOx Fleet average emission limits



PM emission limits

2-years delayed, Phase-in MY2027 to MY2029 ?



Key items

Solution for Low-Mass PM measurements

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HD

US HD Regulation MY2027~

HD Low NOx Standards will be implemented from MY2027.

Current

Compression-Ignition Standards for Duty Cycle Testing

§ 86.007 11(a)

Duty Cycle	NOx mg/hp･hr	NMHC mg/hp･hr	PM mg/hp･hr	CO mg/hp･hr
FTP and SET	200	140	10	15.5

Spark-Ignition Standards for Duty Cycle Testing

§86.008 10(a)

Duty Cycle	NOx mg/hp･hr	NMHC mg/hp･hr	PM mg/hp･hr	CO mg/hp･hr
FTP and SET	200	140	10	14.4

NEW MY2027～

Compression-Ignition Standards for Duty Cycle Testing

§ 1036.104(1)

Duty Cycle	NOx mg/hp･hr	HC mg/hp･hr	PM mg/hp･hr	CO mg/hp･hr
SET and FTP	35	60	5	6.0
LLC	50	140	5	6.0

Spark-Ignition Standards for Duty Cycle Testing

§ 1036.104(2)

Duty Cycle	NOx mg/hp･hr	HC mg/hp･hr	PM mg/hp･hr	CO mg/hp･hr
SET and FTP	35	60	5	14.4
LLC	35	60	5	6.0

Key items

Solution for Ultra-Low NOx measurements

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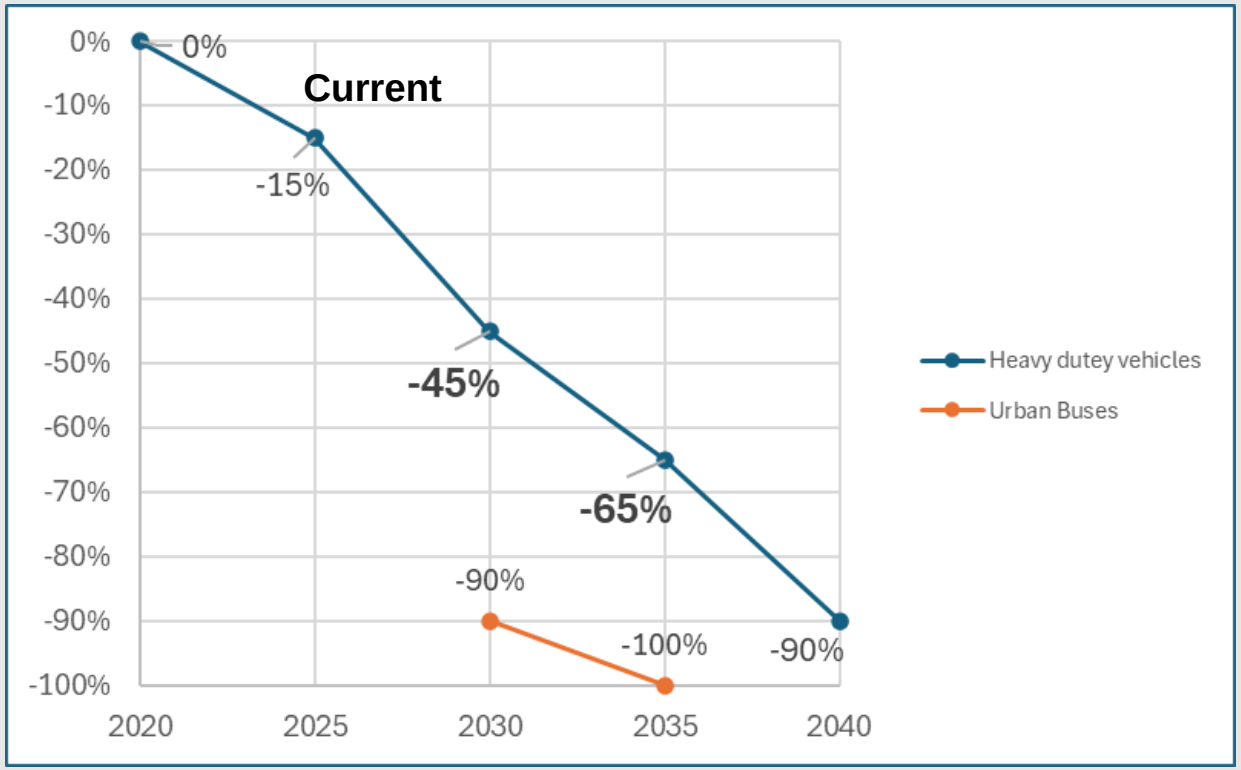
CO_2 Regulatory Trends

HDV and Urban Buses

	EU
Latestregulation	EU 2024/1610
Published	May 14, 2024
CO_2 reduction requirement	
Note	For Urban Buses, 100% reduction will be required from 2035.

- HDV : By 2030, a 45% reduction in CO_2 mass emissions from 2020 levels will be required.

- Urban buses : 100% reduction in emissions will be required from 2035 onward.

NOx Emission Level

Reference Material : SwRI Research Result

Concentration values for peak, FWMC, and background are very low compared to 2010 engines

Expected Low NOx Concentrations

Gas Condition : Conti-dilute
Test Cycle : FTP Hot-start (HDDTC)
Result : 0.010g/bhp-hr
Peak conc. : < 5ppm
Avg conc. (FWMC) : 0.19 ppm
Back ground : 0.055ppm

***This is the test case of SwRI.**

Some customers would get different results.

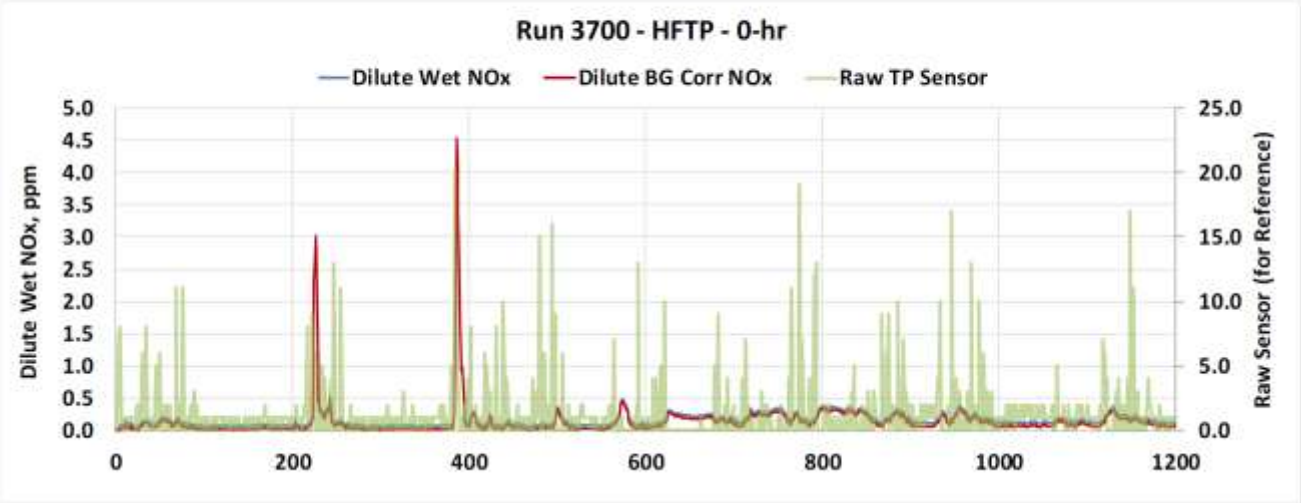
In many cases, minimum 10 ppm range is acceptable, but **2 ppm minimum range is recommended for low-NOx measurement where sub-1 ppm accuracy is necessary**

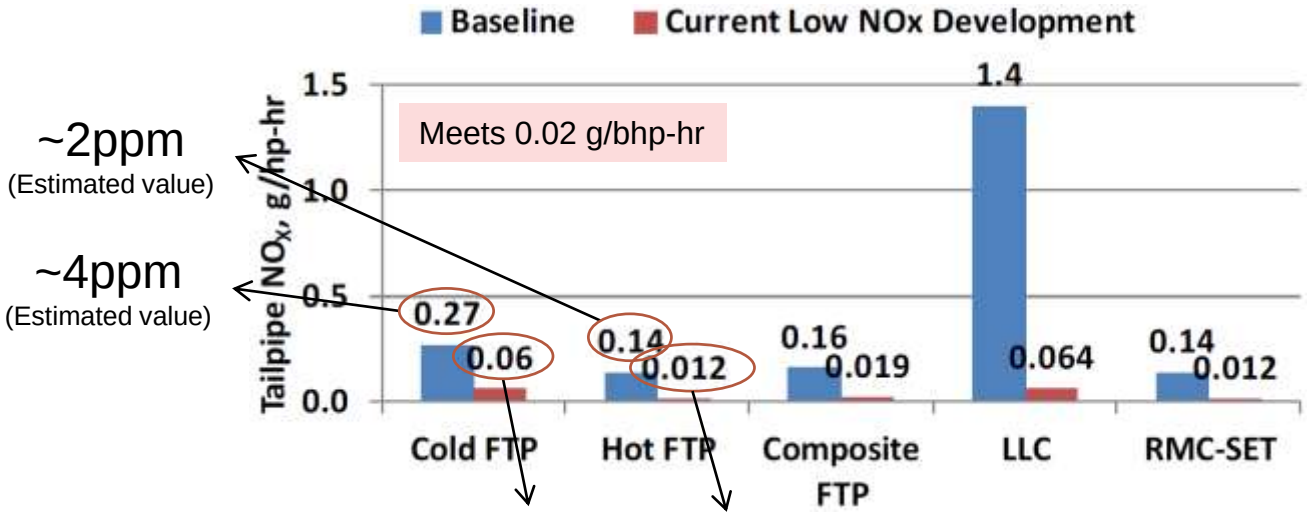
Expected concentration will be as follows:

- **Bag : less than 1ppm (Both cold-start and hot-start)**
- **Dilute-Conti : "meas" would be less than 1ppm (Both hot-start and cold-start)**

"meas" refers to the actual flow-weighted mean measured over any test interval (CFR 1065.205)

Stage 3 Hot-Start at 0.010 g/hp-hr Dilute





~2ppm
(Estimated value)

~4ppm
(Estimated value)

~0.8ppm
(Estimated value)

Average Sample
~ 0.2ppm at 0.010 g/bhp-hr

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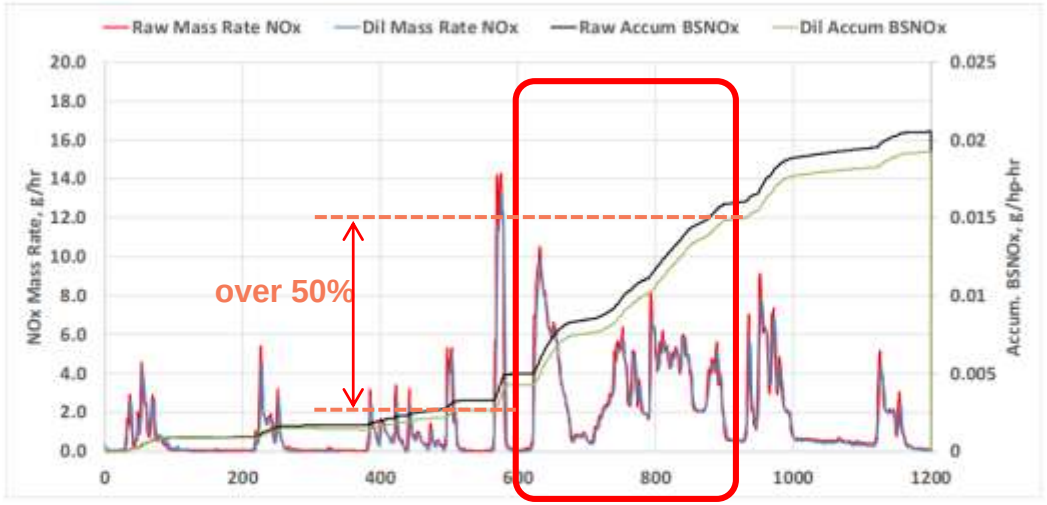
Mass Result Impact Consideration

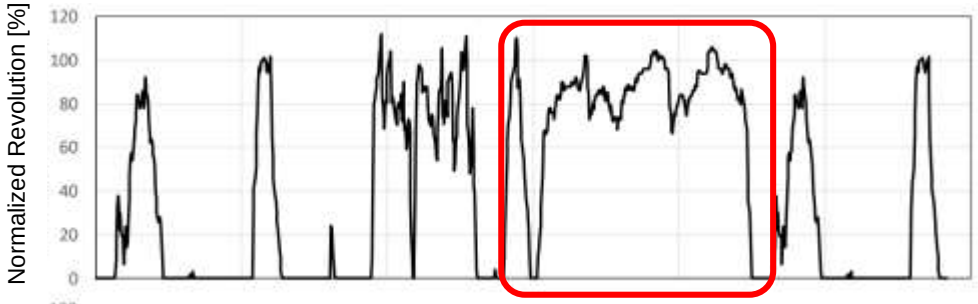
Hot FTP, Dilute Reference Material : SwRI data, reported in EMTC meeting

Raw vs Dilute Example Hot FTP – 0.019 g/hp-hr

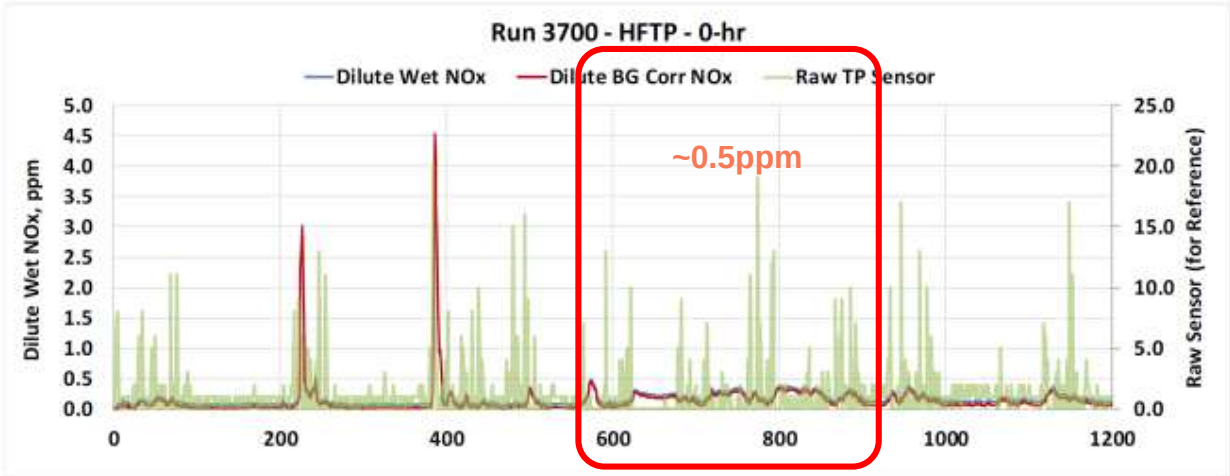


- Stage 1 final matrix – Dilute and Raw in parallel
- Dilute at 0.0189 g/hp-hr
- Raw at 0.0203 g/hp-hr

SwRI Data



Stage 3 Hot-Start at 0.010 g/hp-hr Dilute



NOx mass rates keeps high level from 600-900 sec (continuous high rpm section) of hot-FTP phase.

The mass emission in this section account for much of the total mass emission, though concentration based emission keeps low level, **below 0.5 ppm.**

The analyzed concentration has a proportional impact on mass emission. More accurate analyzer at low concentration range will be helpful for more precise data.

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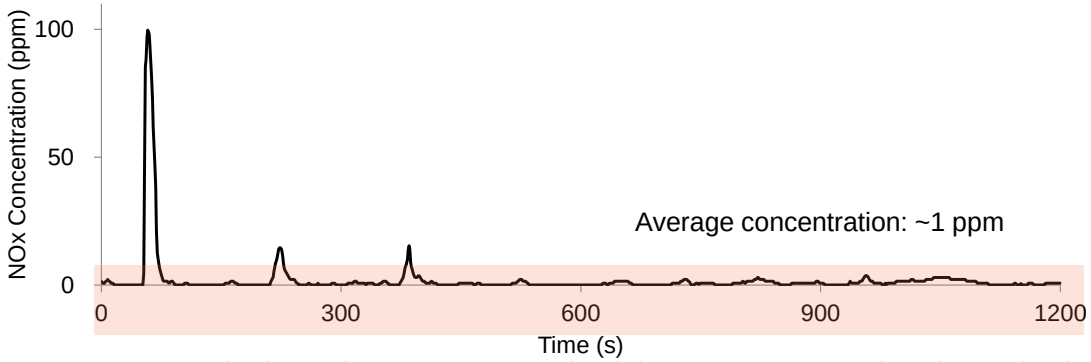
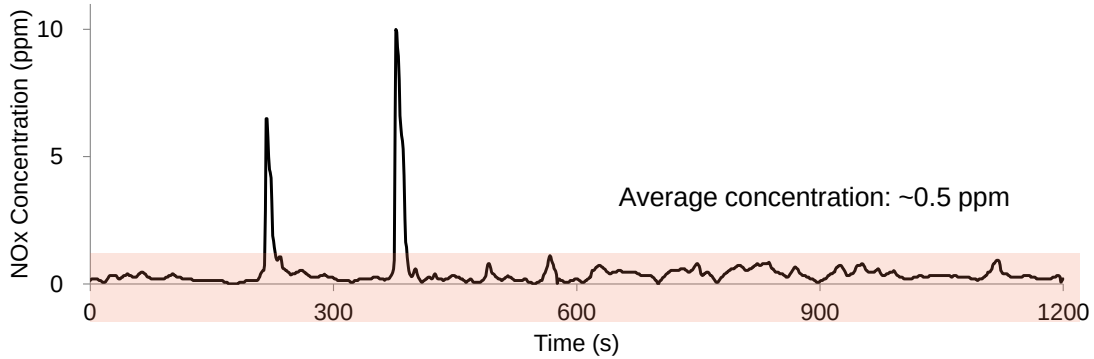
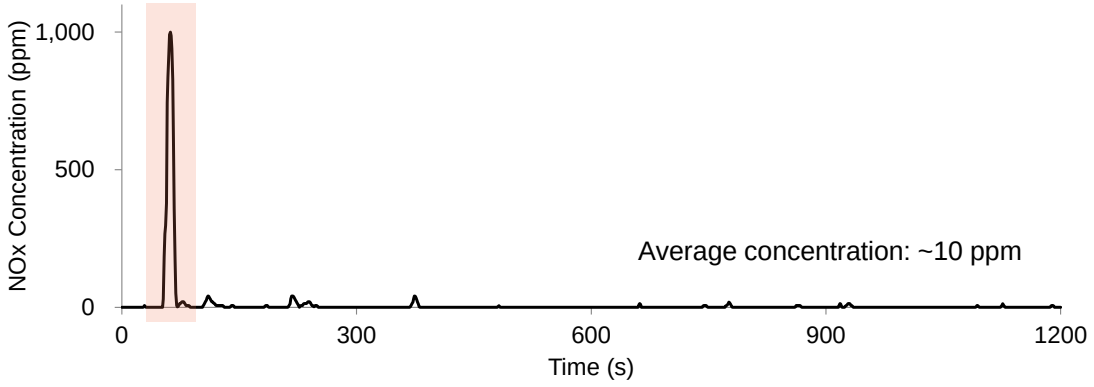
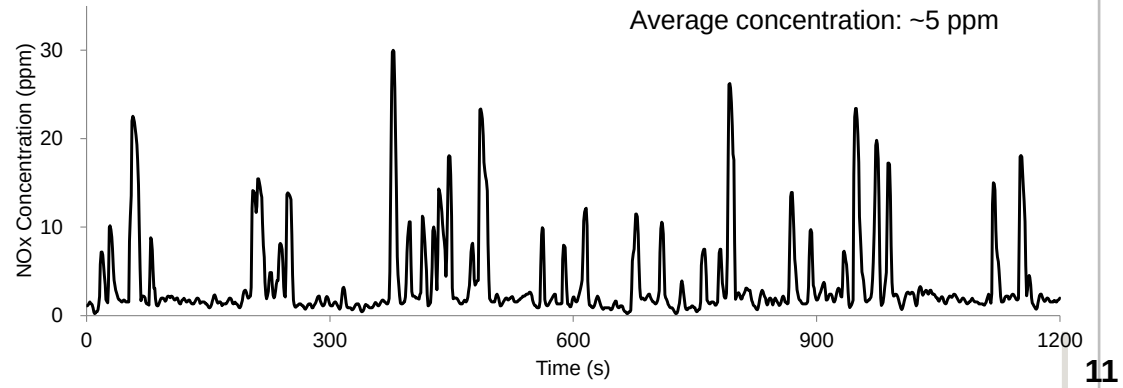
Challenges in Ultra-Low-Concentration NOx Measurement

HD Tier 4, use case

	Cold-Start	Hot-Start
Dilution Gas	Highly accurate measurement of ultra-low-concentration NOx is required. Even slight drift or noise can have a major impact on calculated emissions mass.	
		
	Measurements in the ppb range are required; however, conventional standard analyzers are more susceptible to noise-related effects on calculated emissions mass at ultra-low concentrations.	
Raw Gas	A high-concentration peak occurs initially, followed by low concentrations after catalyst warm-up. A wide measurement range including high concentrations is required. Range switching is not permitted during regulatory testing.	
		

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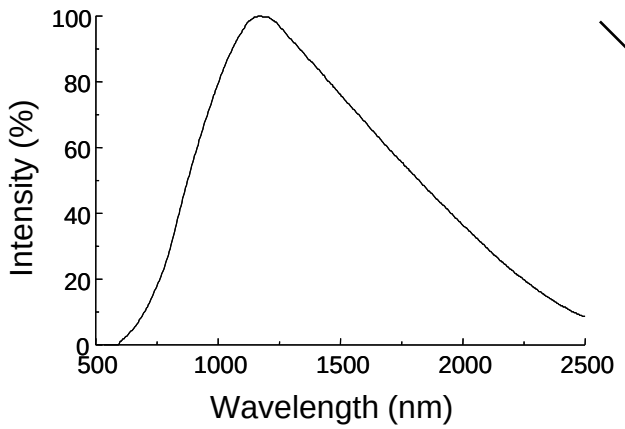
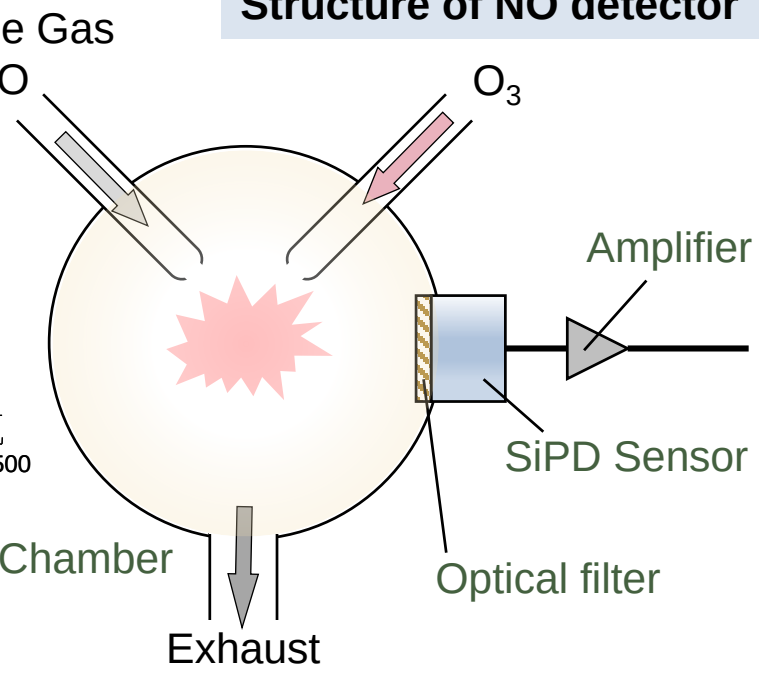
High-Sensitivity CLD

CLD : Chemi-luminescence Detection

Chemi-luminescence Wavelength



Structure of NO detector



- Sample gas (NO) and O_3 gas is introduced into the reaction chamber at the same time.

  NO is oxidized by O_3 to form NO_2.

  $NO + O_3 \rightarrow NO_2 + O_2$ (90%)

  $NO + O_3 \rightarrow NO_2^* + O_2$ (10%)

  10% of the NO_2 is in excited state.

  NO_2^* return to ground state by emitting a photon.

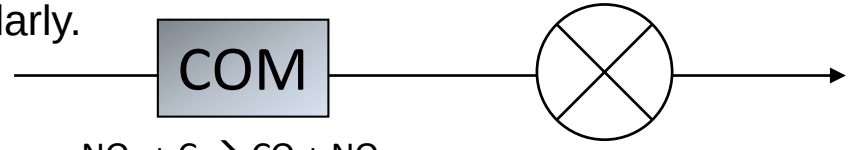
  $NO_2^* \rightarrow NO_2 + hv$

- NO_2 to NO Converter

  NO_2 is reductive to form NO to be detected by CLD.

  This is not a catalyst, material consuming itself.

  NOx converter efficiency check needs to be performed regularly.



$NO_2 + C \rightarrow CO + NO$

$2NO_2 + C \rightarrow CO_2 + 2NO$

To get more Chemi-luminescence:

- Optimal Sample Gas Flow
- Optimal O_3 Flow
- Reaction Chamber Temp.
- Reaction Chamber Press.
- Electrical Processing (Wide Range)

➔ High-Sensitivity CLD

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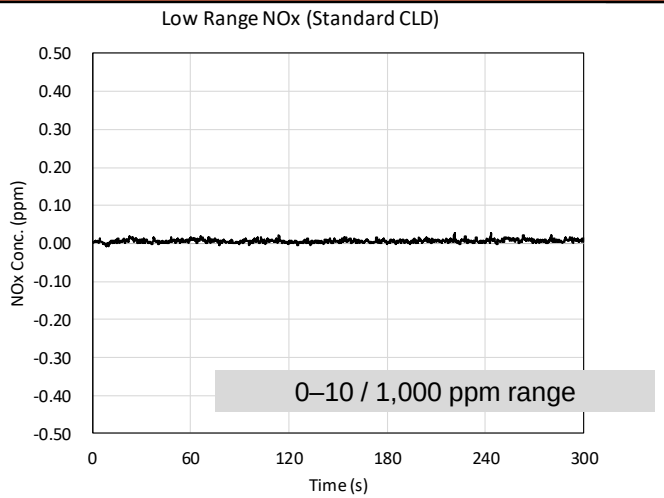
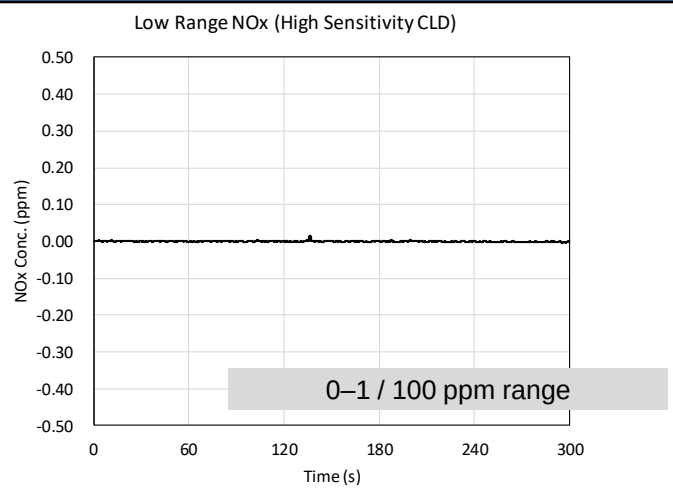
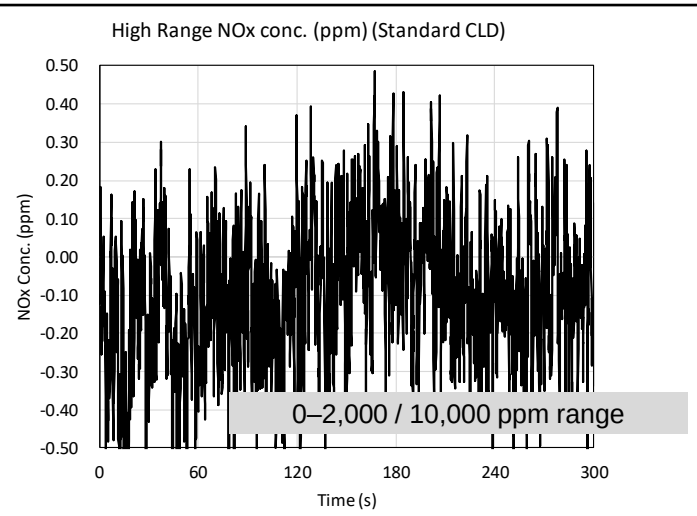
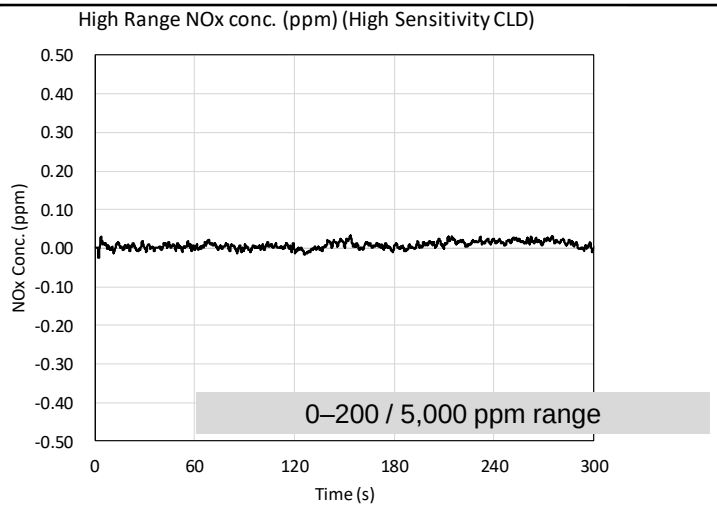
Standard CLD vs. High-Sensitivity CLD

Zero Noise Performance

	Standard CLD	High-Sensitivity CLD
Low range		
High Range		

Compared with the standard NOx analyzer,

the low-concentration NOx analyzer has a lower zero-point noise level.

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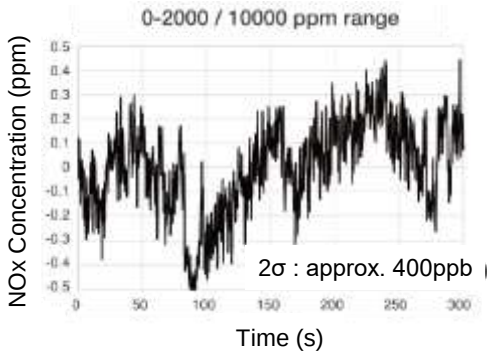
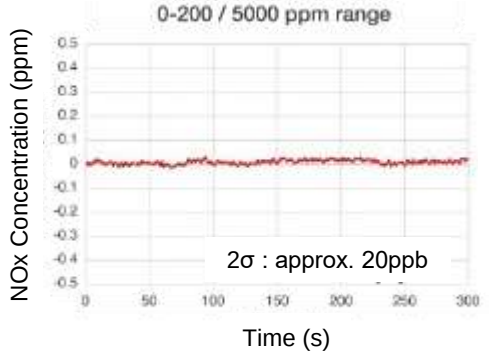
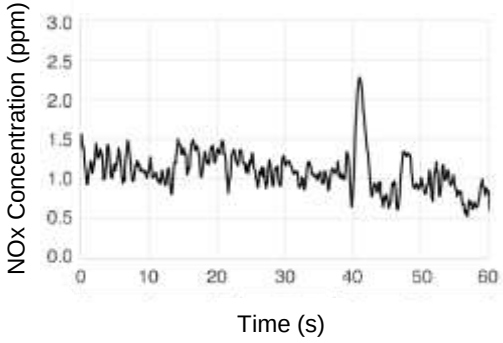
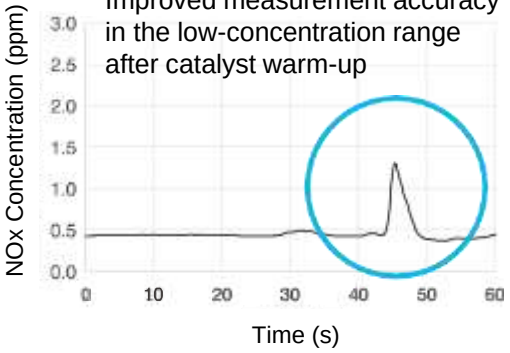
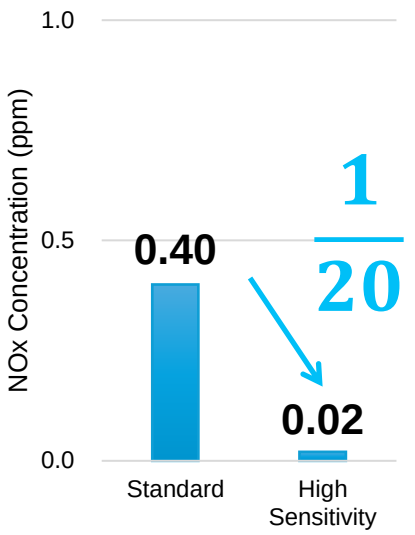
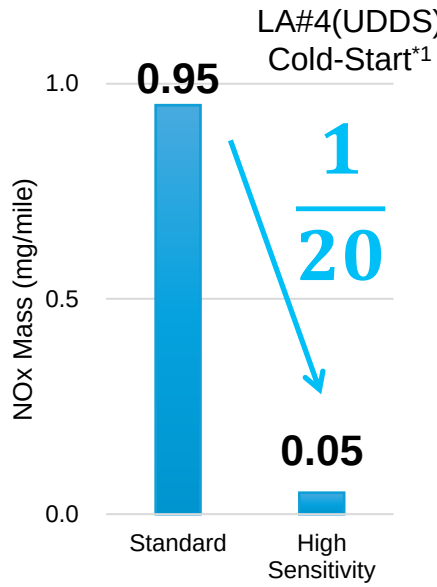
Measurement Using High-Sensitivity CLD

Zero Stability and Impact on Mass Emission

	Standard-CLD	High Sensitivity CLD
Stability of Zero Point		
Low Conc. Emission Measurement		



Comparison of Zero-Point Stability



Impact on Emission Mass

Effect on Emission Mass

Standard NOx analyzer: 6%*2

Low-concentration NOx analyzer: 0.3%*2

*2 Impact relative to the 15 mg/mile regulatory limit

➤ The low-concentration NOx analyzer greatly improves the repeatability of emissions-mass measurement.

*1 LA#4 (UDDS): Los Angeles Urban Dynamometer Driving Schedule
A dynamometer driving mode simulating urban driving in Los Angeles

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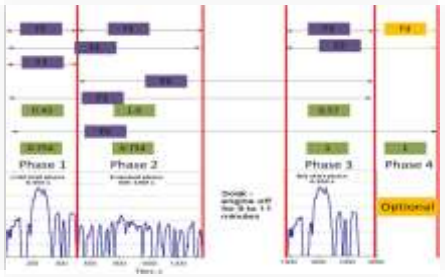
System Overview for 0.5mg/mile U.S. Tier 4 PM Standard

Combination of several technical optimization is possibly required

Single PM filter over multiple-phase tests



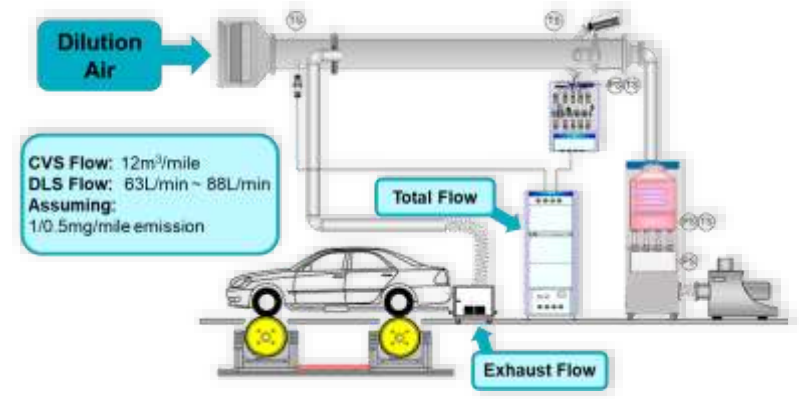
Tunnel temp. management with CVS

Increased face velocity (140cm/s)

with advanced Dilution Sampler

Tier 4 Upgrade for PM 0.5mg/mile

Tunnel flow rate flexibility with CVS



Automated filter weighing

with Robot weighing system

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Measurement of Low-Mass PM

Ensure sufficient PM collection and minimize variations in the measurement and weighing systems

Classification	Control Point
Dilution Ratio Control	Maintain sufficient PM mass on the filter by using a low dilution ratio.
PM Sampling Method	Use a single filter for three-phase sampling.
Flow Rate and FFV Control	Combine flow weighting with a high filter face velocity (FFV).
Background PM Control	Measure tunnel background PM before and after each test.
Exhaust Line and Flow-Path Control	Minimize PM losses, condensation, and electrostatic effects in the exhaust line.
Filter Selection	PTFE, reducing EC/OC effect but careful static-charge required. TX40 is less static-charge but EC/OC background effect must be considered.
Weighing Accuracy Control	Reduce weighing errors by using the ABBA method and automated weighing.
Environmental and Cleanliness Control	Continuously control temperature, humidity, dew point, and cleanliness.

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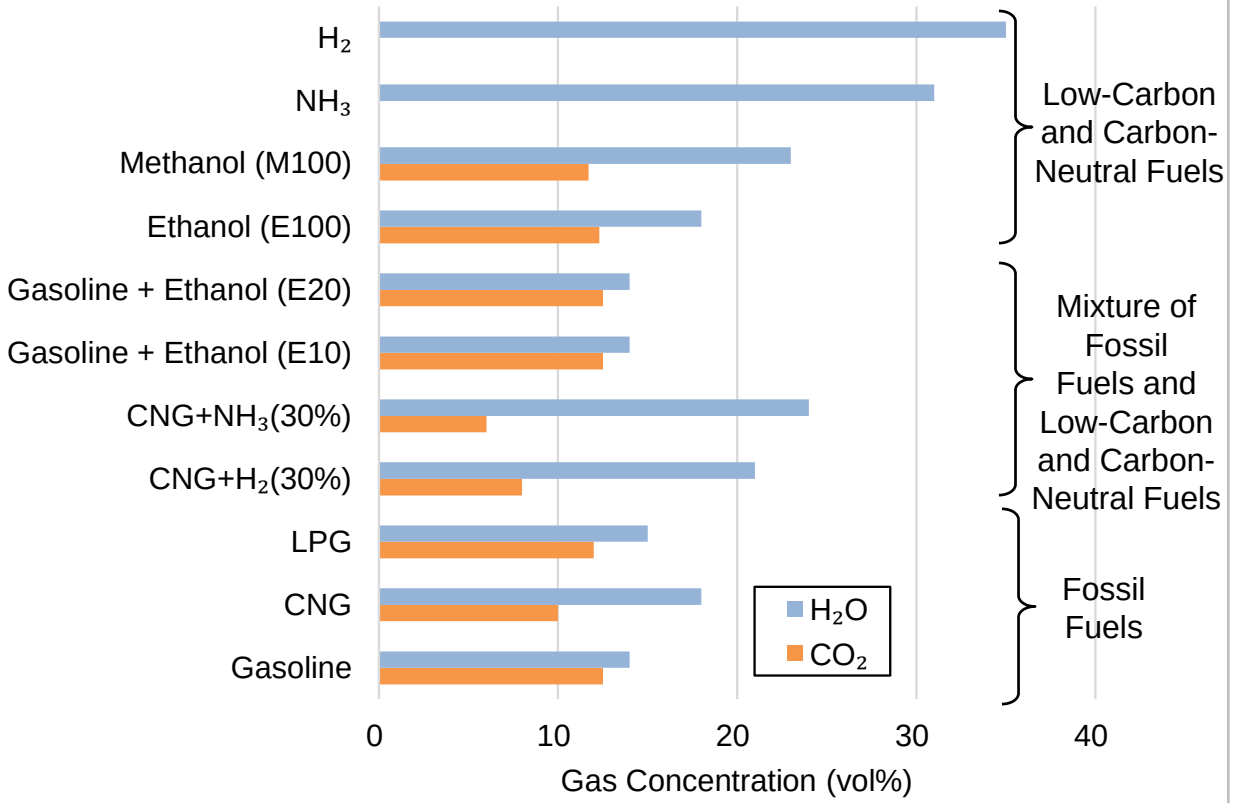
CO_2 Measurement Challenges

Low CO_2 Concentration with High Moisture

Characteristics of Low-Carbon and Carbon-Neutral Fuels

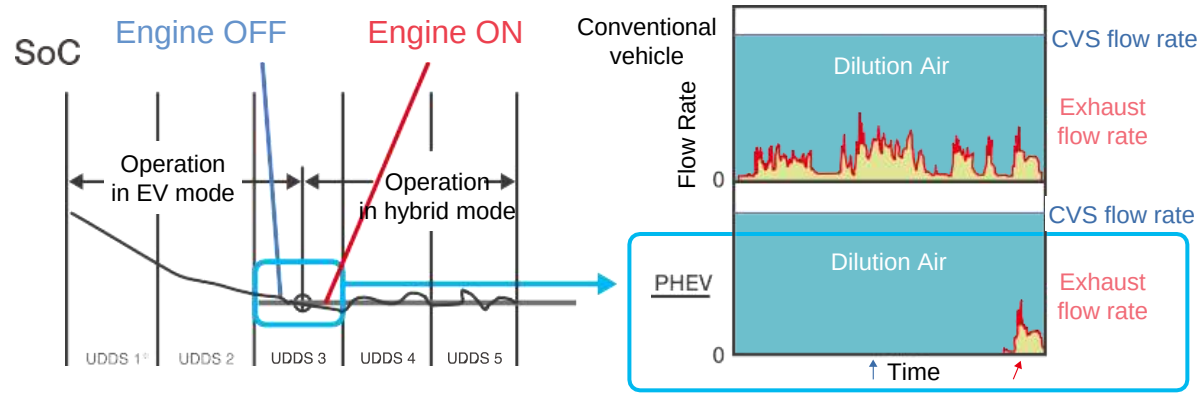
Increased moisture content in exhaust gases



Comparison of Moisture Content in Exhaust Gases Between Fossil Fuels and Low-Carbon and Carbon-Neutral Fuels

Characteristics of PHEVs

Decreased CO_2 concentration in the CVS bag



UDDS : Urban Dynamometer Driving Schedule
(Driving cycle on a dynamometer simulating urban driving)

Comparison of exhaust emissions between a conventional vehicle and a PHEV

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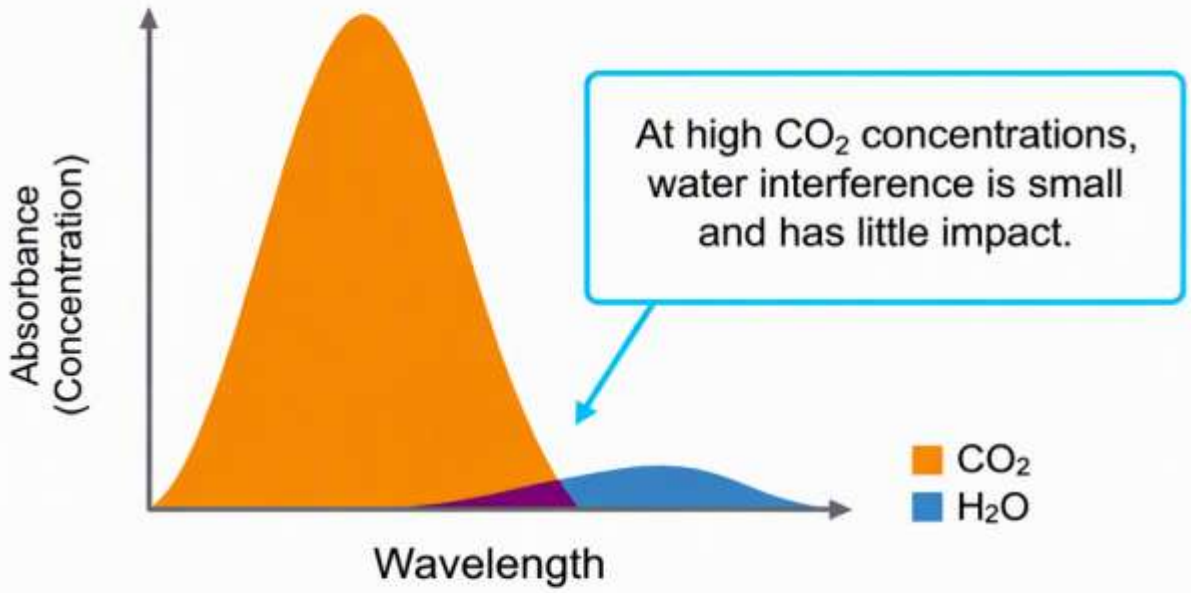
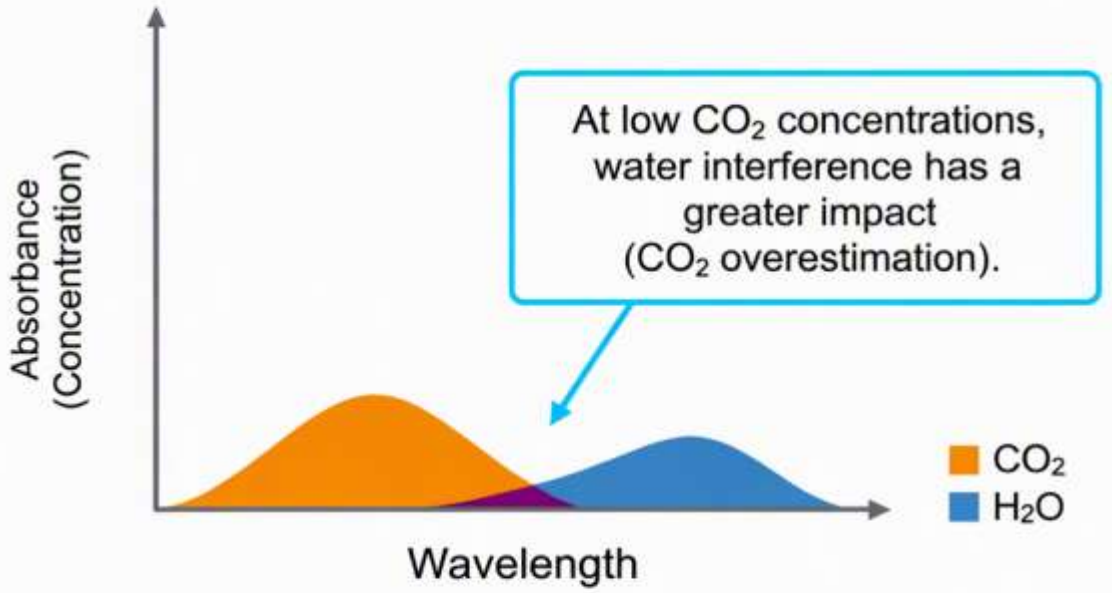
CO_2 Measurement Challenges (NDIR)

Water Interference



Conventional vehicle exhaust



Hybrid vehicle x low-carbon / decarbonized-fuel exhaust

- CO_2 concentration in the bag decreases while the relative proportion of water increases, which makes the measurement more susceptible to water interference.
- Therefore, in BAG measurements without sample dehumidification, low-concentration CO_2 is relatively susceptible to water interference.

* In direct measurements with sample-gas dehumidification, water-interference effects are not an issue.

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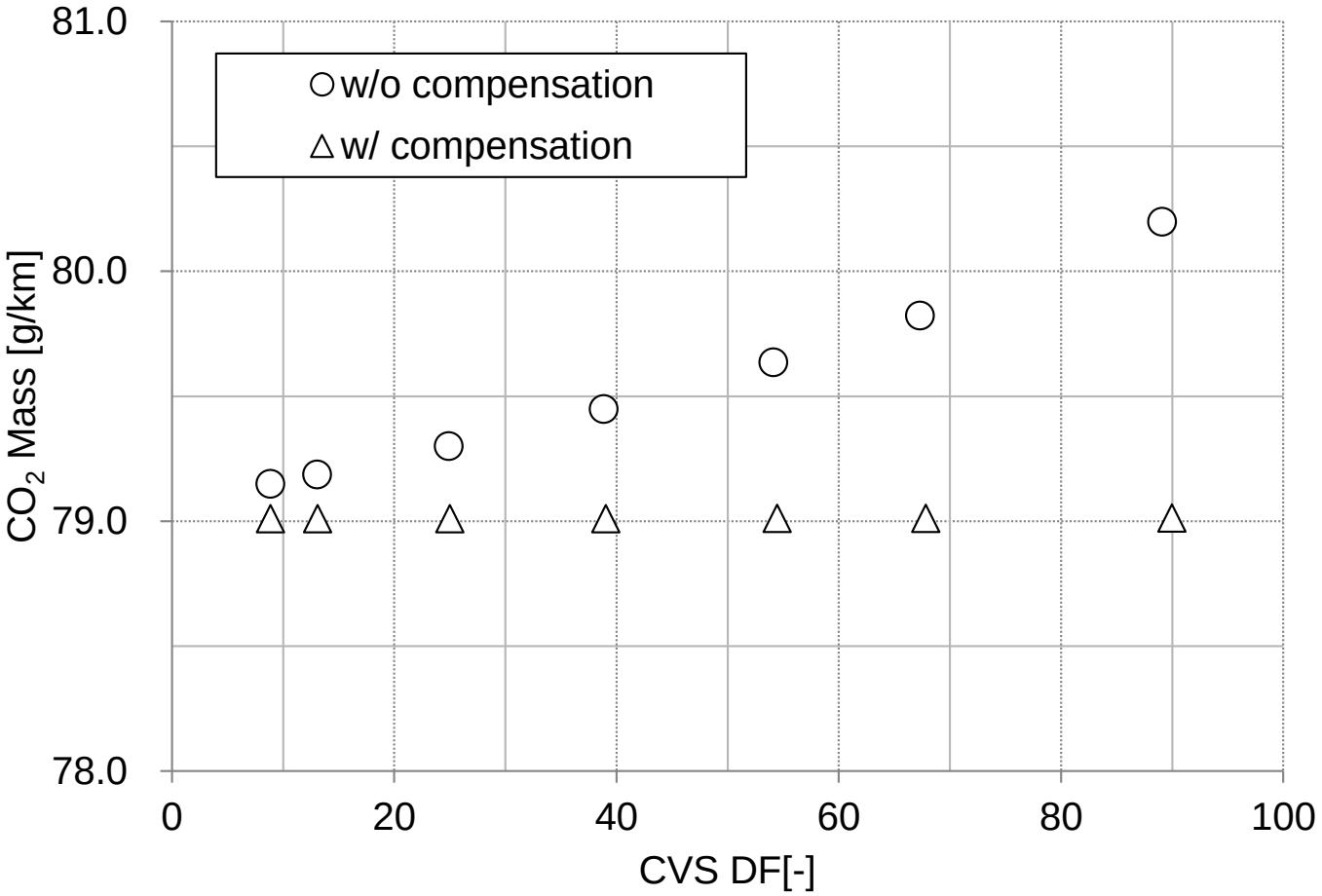
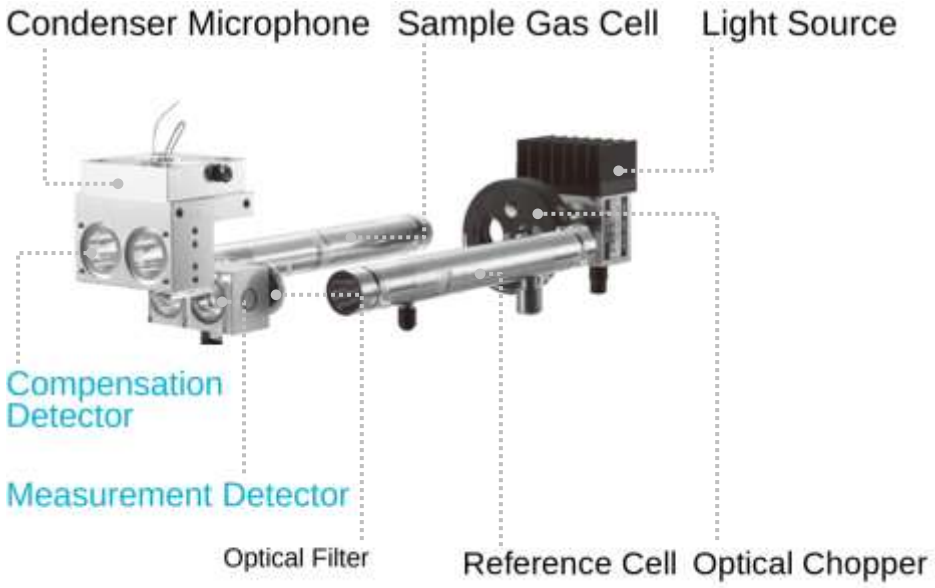
Measurement Using a Moisture Compensated CO_2 Analyzer

Compensation Function





Structure of an NDIR (Non-dispersive Infrared) analyzer with compensation detector

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Summary

New Measurement Technology and Response Strategies for Euro 7 and U.S. Tier 4

Item	Summary
Background	As emissions requirements become increasingly stringent, the following new measurement requirements are emerging:
1. Ultra-low NOx measurement	Provide excellent zero-point stability, high sensitivity, low noise, and a wide dynamic range for ppb-level measurements.
2. Low-mass PM measurement	Ensure sufficient PM collection and minimize variations in the measurement and weighing systems to support measurements at the 0.5 mg/mile level.
3. Low-CO_2 with high moisture measurement	Use an analyzer with water-interference compensation to address lower CO_2 concentrations and increased water content in exhaust gas.

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Thank you

Cảm ơn

감사합니다

ありがとうございました

Dziękuję

धन्यवाद

Grazie

Merci

谢谢

நன்றி

ขอบคุณครับ

Gracias

Obrigado

Σας ευχαριστούμε

Děkuji

Teşekkürler

شكرا

Tack ska ni ha

Danke

Большое спасибо

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