Challenges and Innovations in Measurement for In-use Compliance:

Advanced emission measurement techniques for low-concentration NOx, alternative fuels, and hybrid powertrains

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Onboard Sensing, Analysis, and Reporting (OSAR) Conference 2024

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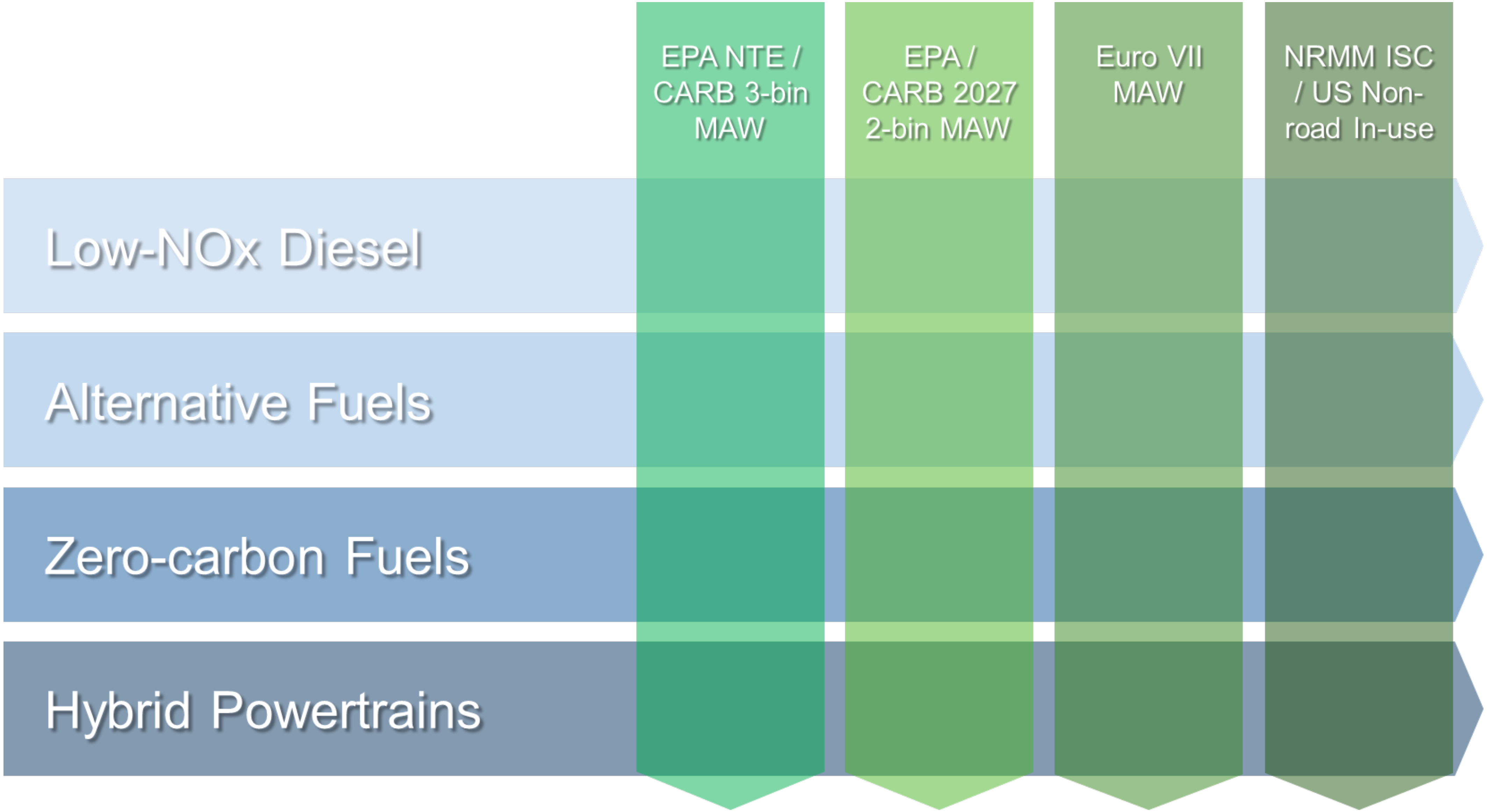
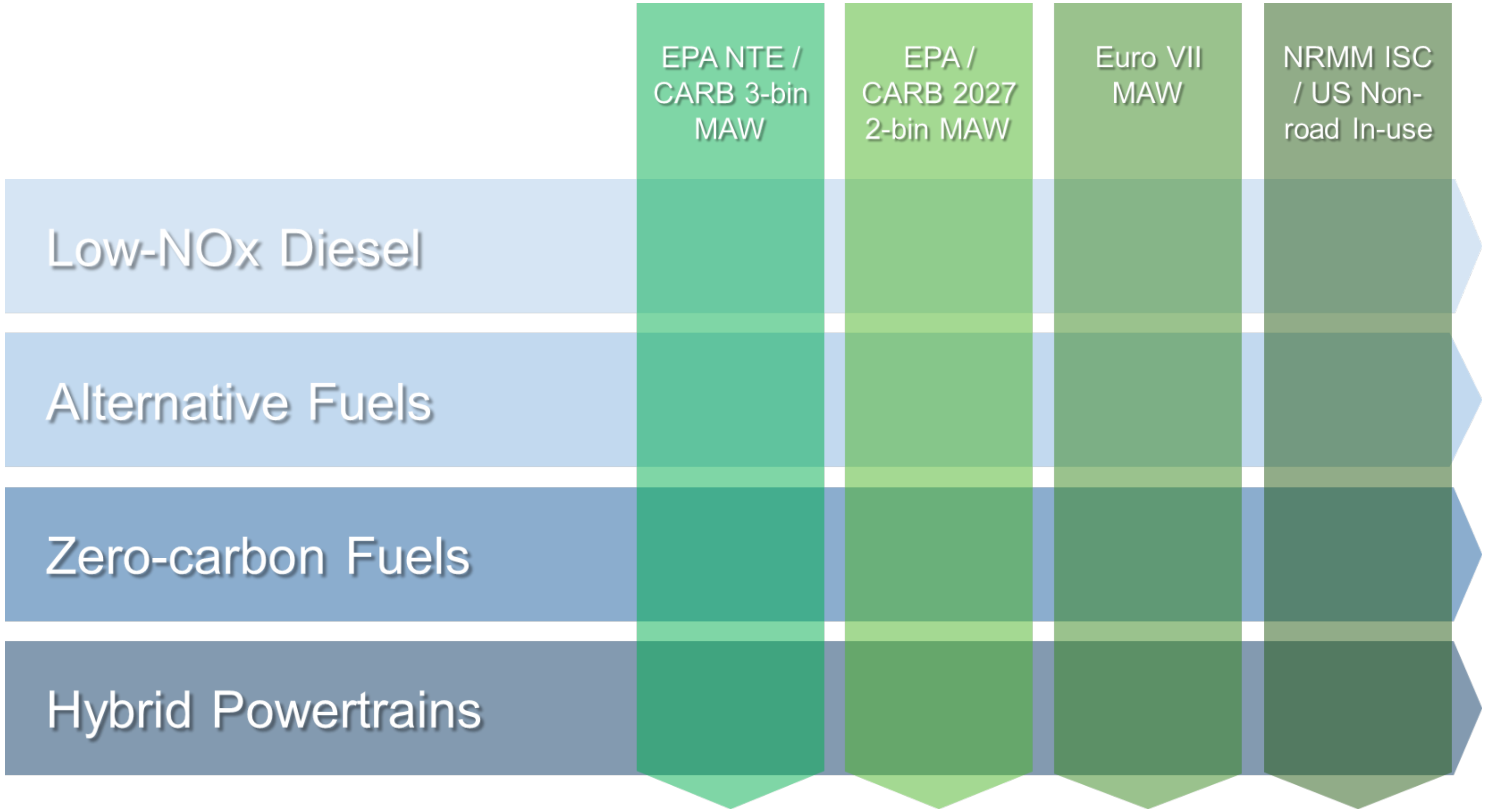
Introduction



Introduction

Part 1
Challenges

Part 2
Advances and Innovations



Measurement Challenges: Low-NO_X Diesel

NOx measurement <10 ppm

Direct measurement

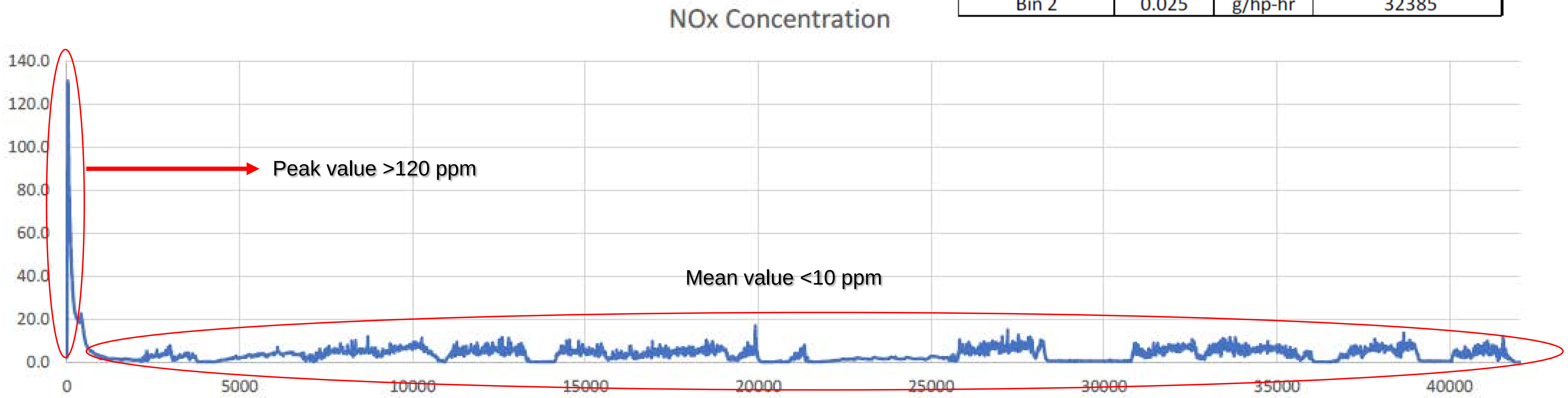
- Turndown ratio
- Time Alignment
- Stability / high H_2O content exhaust

Typical concentrations

NOx 3.7 ppm (post SCR light-off)
H_2O ~4.6% [1]

EPA Vehicle 7 [2]

			# windows
Bin 1	0.8	g/hr	9163
Bin 2	0.025	g/hp-hr	32385

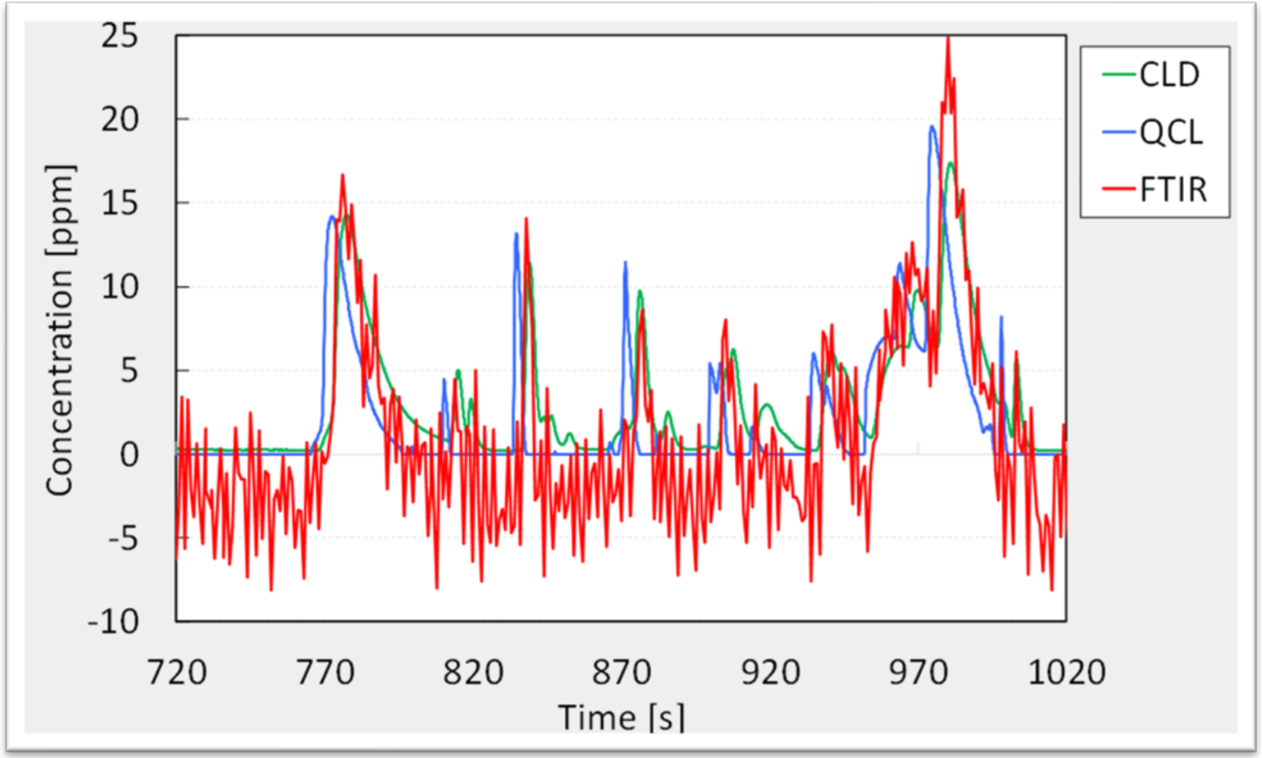


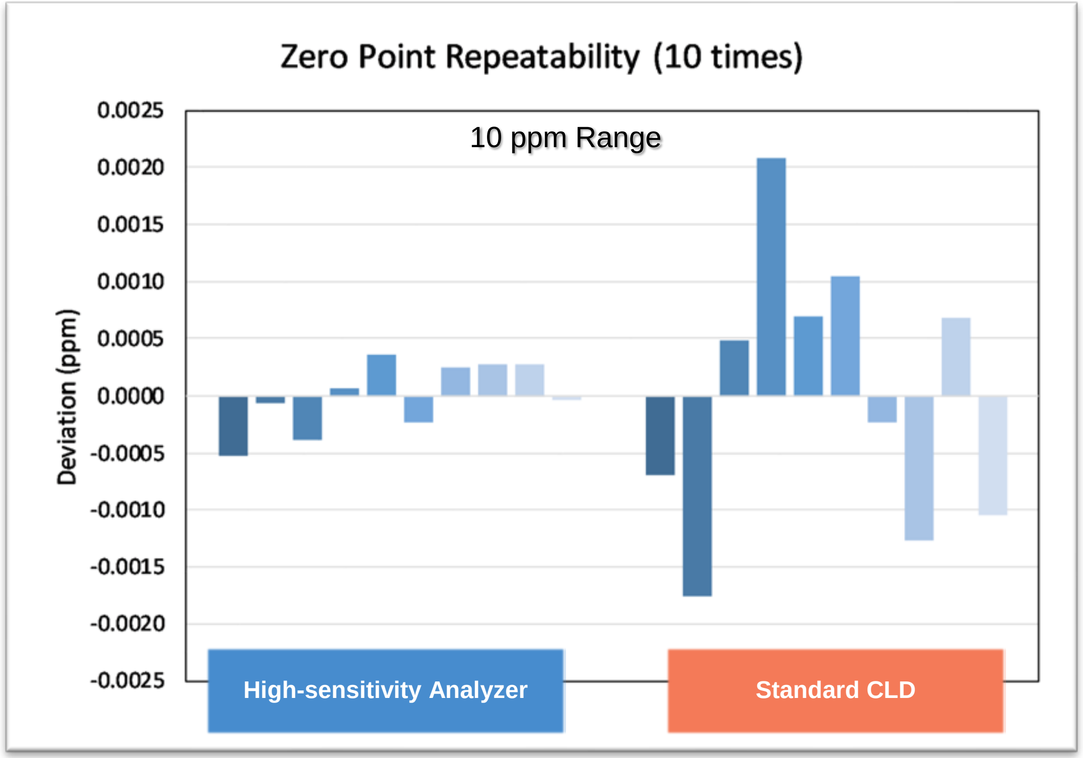
Source: Southwest Research, 2024 [1]

Measurement Challenges: Low-NO_X Diesel

"Slight variations" meaningful

- Drift, Noise, Background, Response, Interference / quench





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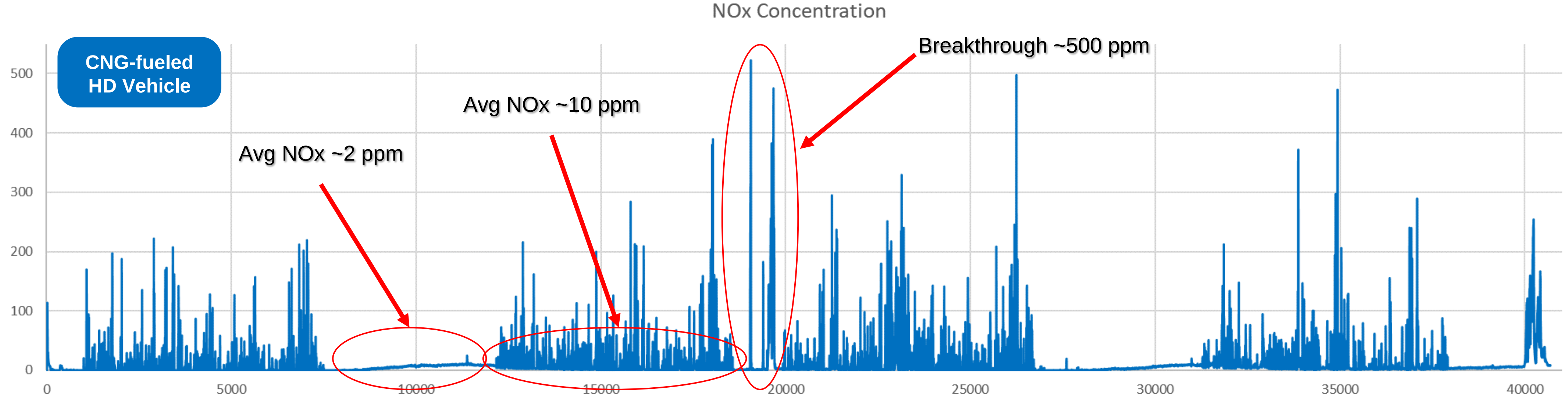
Measurement Challenges: Alt Fuels, Carbonized

NOx measurement <10 ppm

Interference gases: H_2O, NH_3, CO_2, etc.

Avg Concentrations

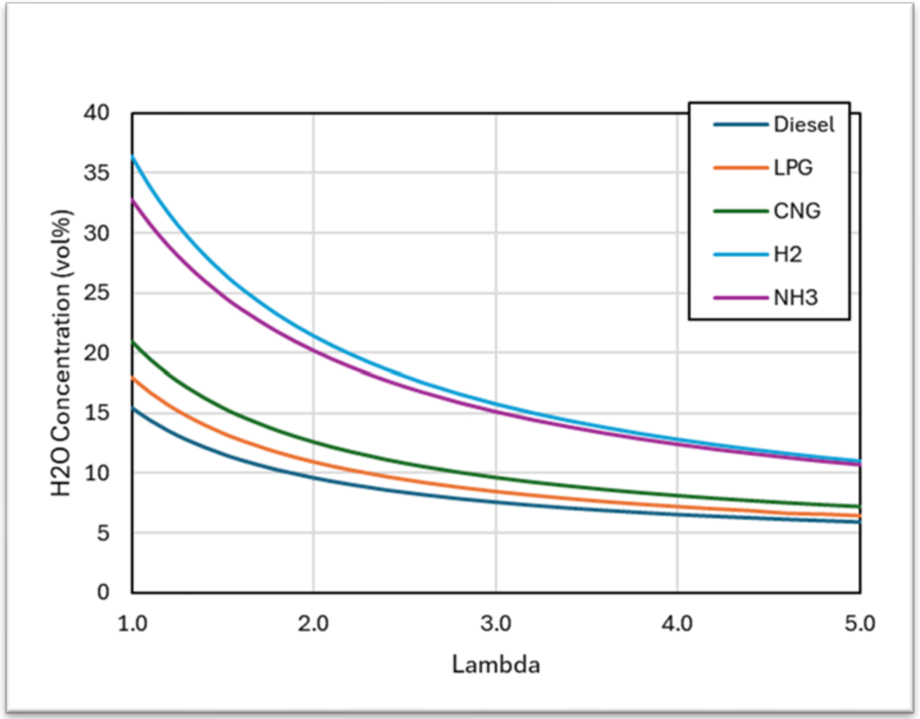
NOx 9.7 ppm (0.2 g cert level)
H_2O ~22.9%
[3]

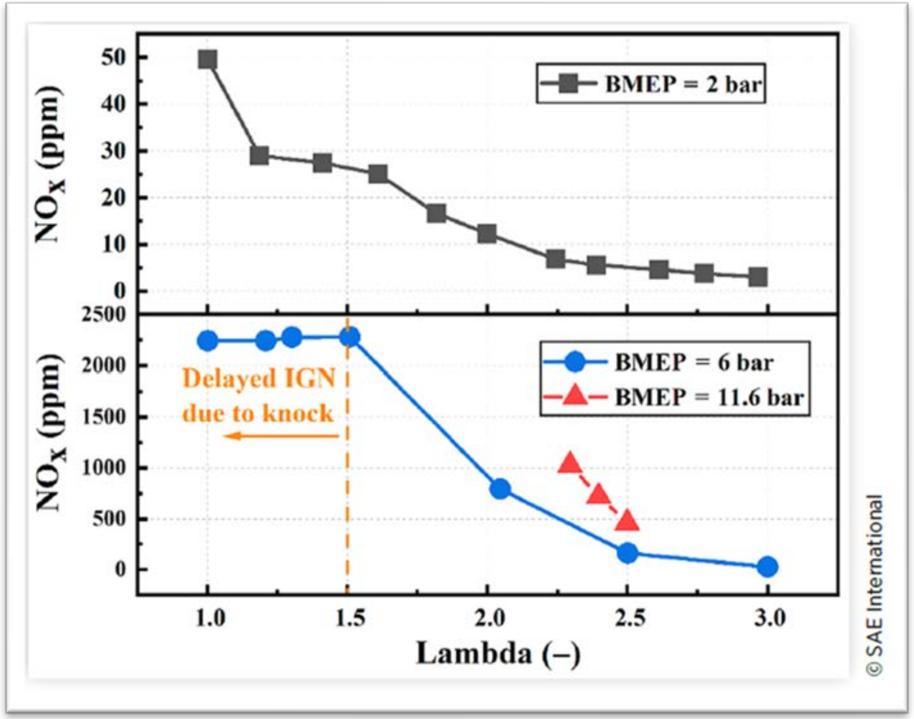


Renewable / Bio / Ethanol Fuels (E98+)

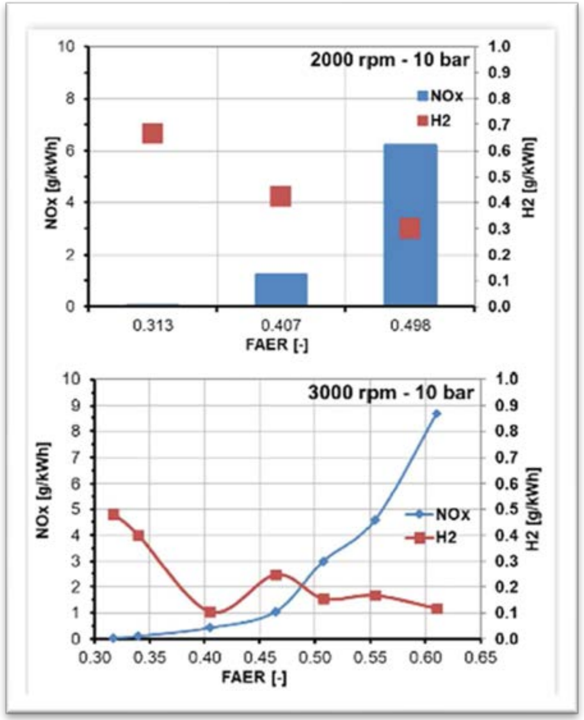
- TP emissions comparable to low-NOx diesel; Elevated levels of H_2O
- Potential new species: NMHCe, HCHO

Measurement Challenges: Alt Fuels, Zero-carbon





Source: SAE 2023 [4]



Source: SAE 2021 [5]

Low-level concentrations of all criteria emissions

Elevated H_2O content in exhaust (?)

Potential new measurement species: Hydrogen (?), H_2O, NH_3 (fuel slip)

Summary of Challenges

Themes common to all technologies / fuels

Measurement Challenges

- NOx measurement <10 ppm, Low-level concentrations of criteria emissions
- New species: Hydrogen, H_2O, NH_3 (fuel slip), HCHO, CH_4
- H_2O content in exhaust, other interferents
- “Slight variations” meaningful
  - Drift
  - Noise
  - Response
  - Interference

Measurement System Requirements

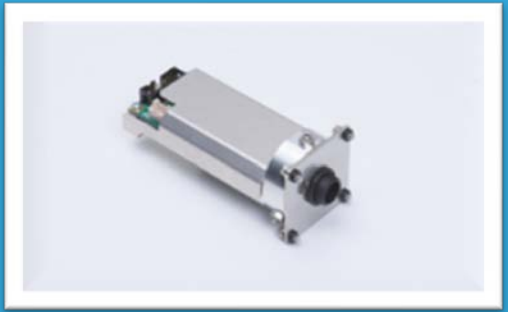
- Consistent, accurate NOx measurement at single-digit concentration levels
- Long-term zero drift stability and noise performance
- Additional measurements: H_2, N_2O, NH_3, HCHO, H_2O
- Robust to measurement interference: H2O, NH3
- Robust to the environment & conditions that can impact the sampling system, e.g. ammonia, acidic condensates, high HC

HORIBA Advances and Innovations

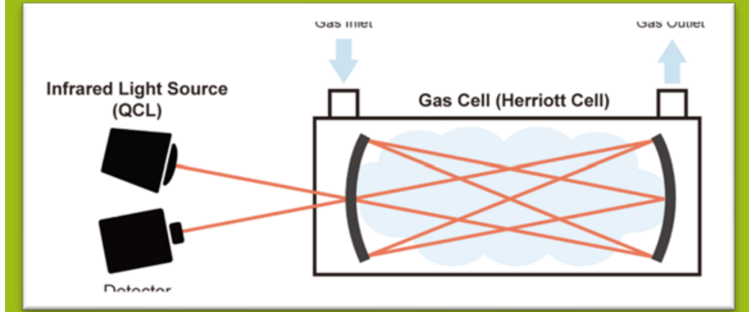
IRLAM by HORIBA

Innovative approach: Advanced IR

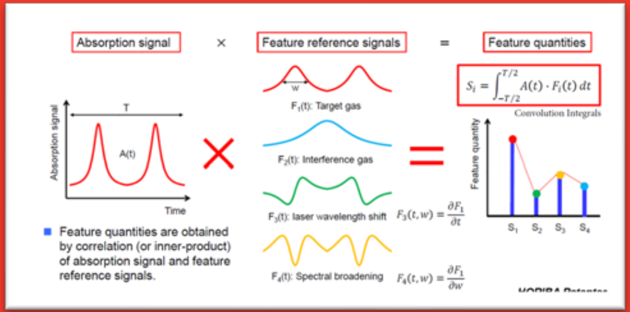
Quantum Cascade Laser (QCL)



Herriot Cell



Calculation Algorithm

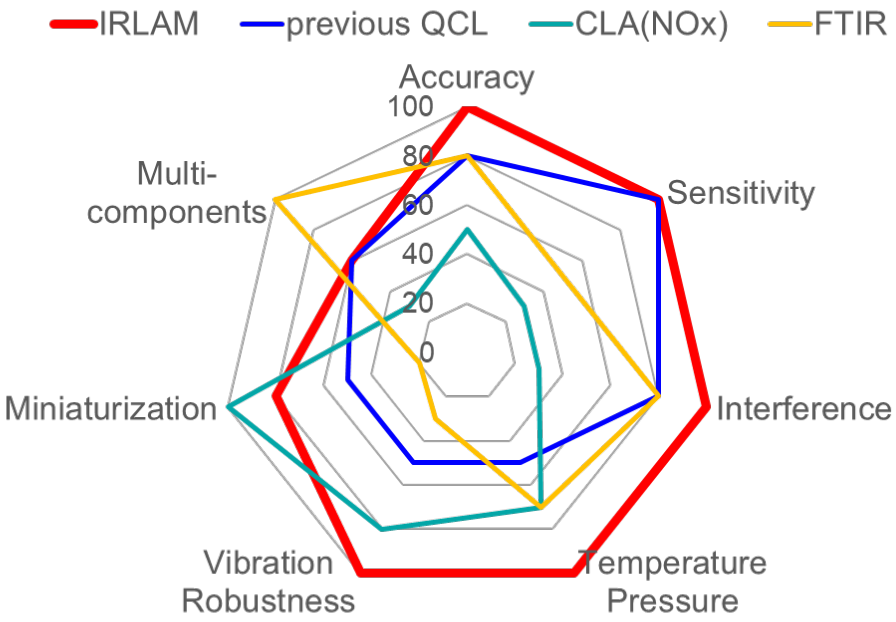


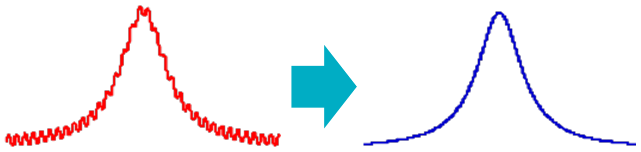
High Sensitivity | **Low Interference** | **Small Size** | **High Reliability**

HORIBA Advances and Innovations

IRLAM by HORIBA

Accuracy at low concentrations; New species





Absorption signal of conventional QCL

Absorption signal of HORIBA's QCL

Add-on Module

OBS-ONE-XL01

(NH_3, N_2O)

OBS-ONE-GS02

(CO, CO_2, NO, NOx)

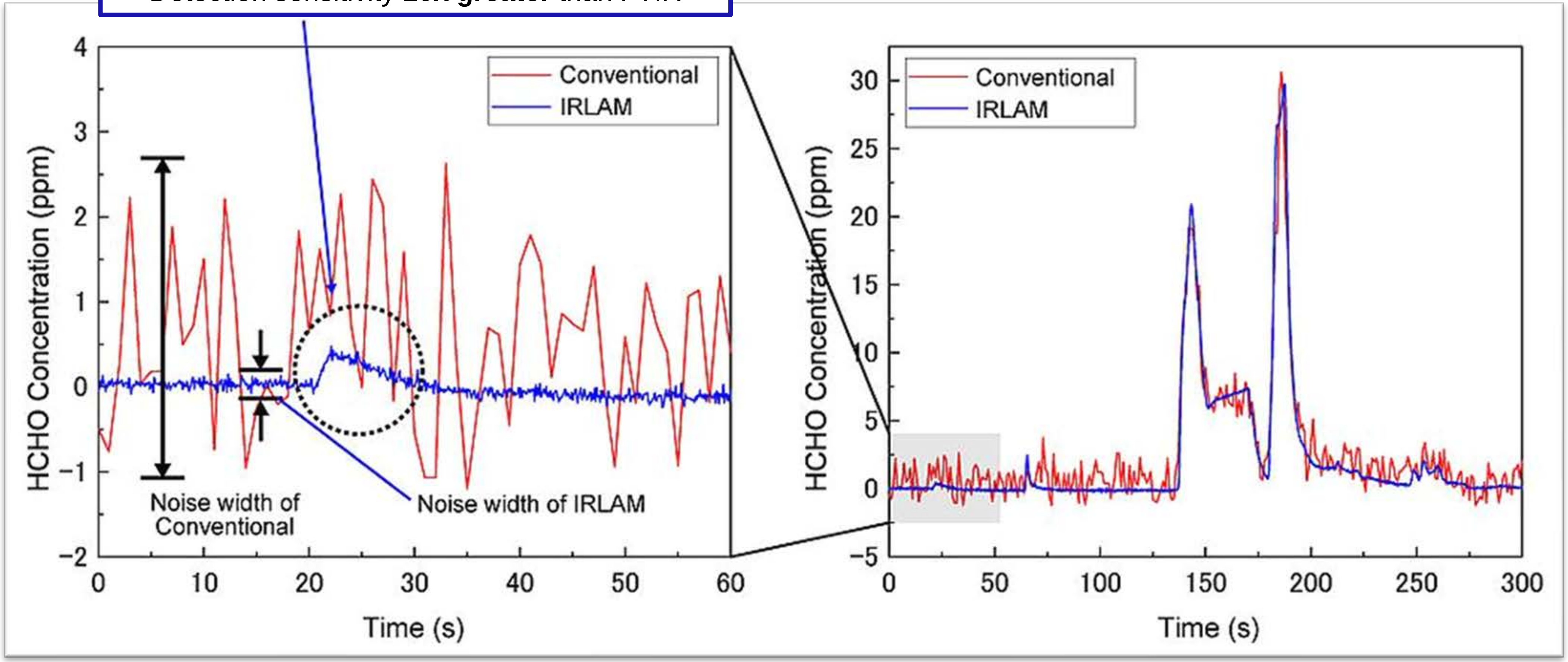
CO Low / High, CO_2, NO, NO_2, NH_3, N_2O, HCHO, CH_4 Low / High [QCL-IR], THC [FID]

New PEMS

HORIBA Advances and Innovations

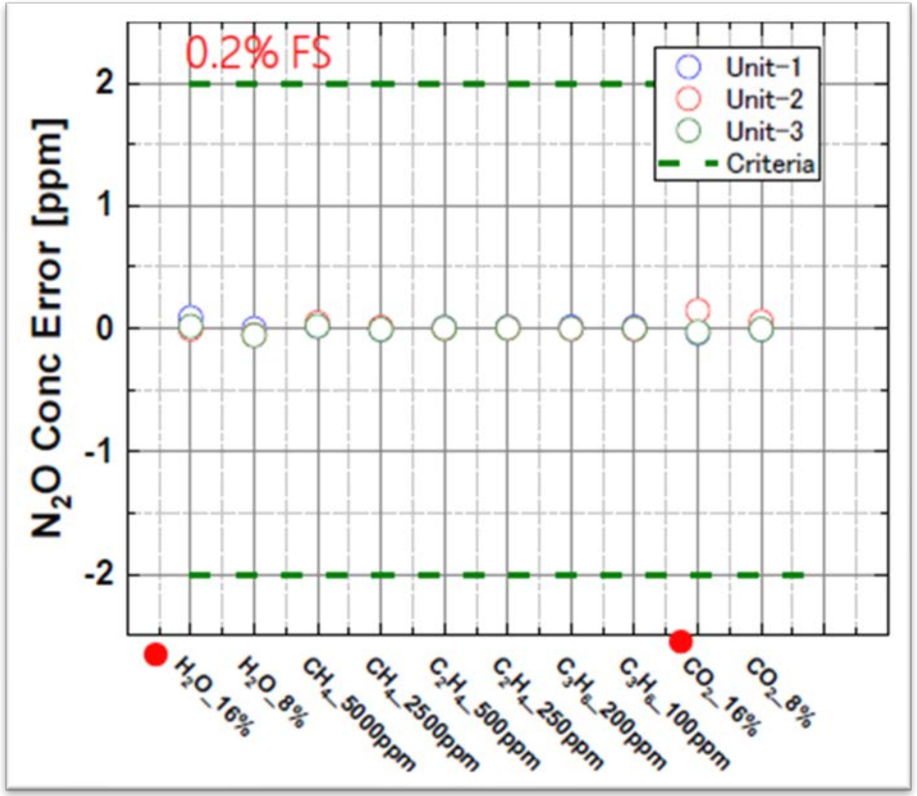
Accuracy at low concentrations, ultra-low noise

Detection sensitivity **10x greater** than FTIR

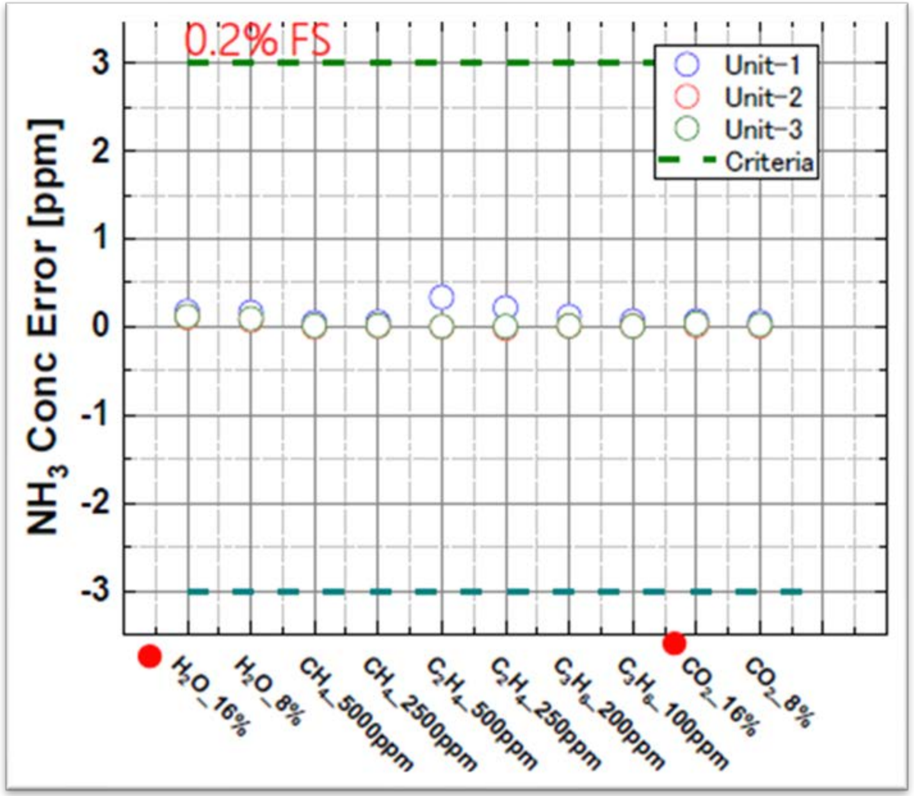


HORIBA Advances and Innovations

Robust against interference



Interference <0.3 ppm



Interference <0.5 ppm

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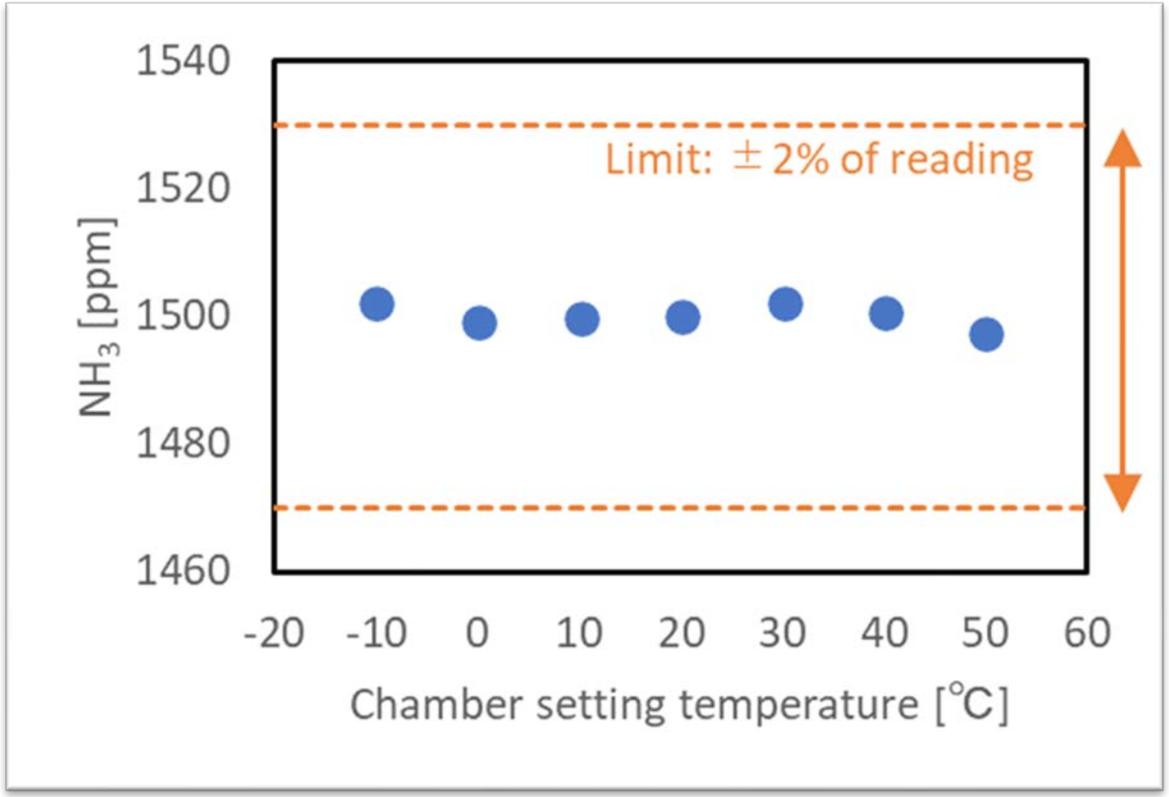
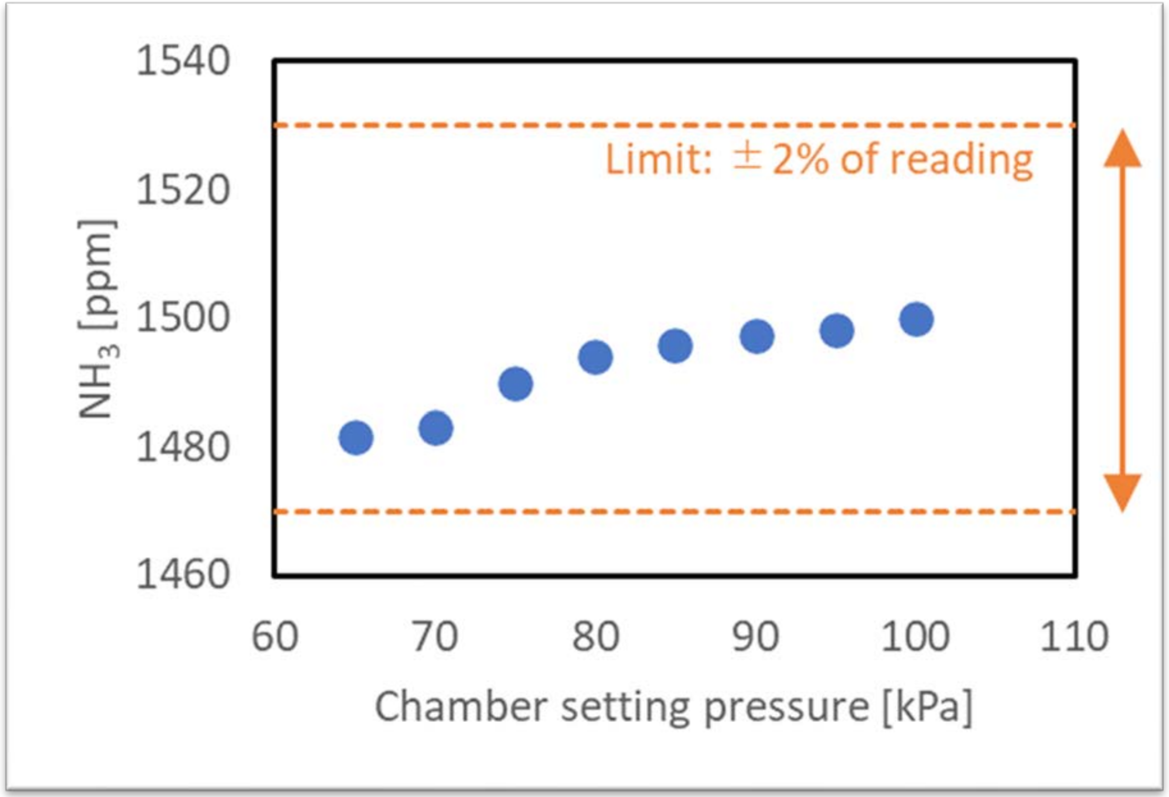
IRLAM by HORIBA

Robust against Pressure / Temperature



Temperature -10 to 50 °C

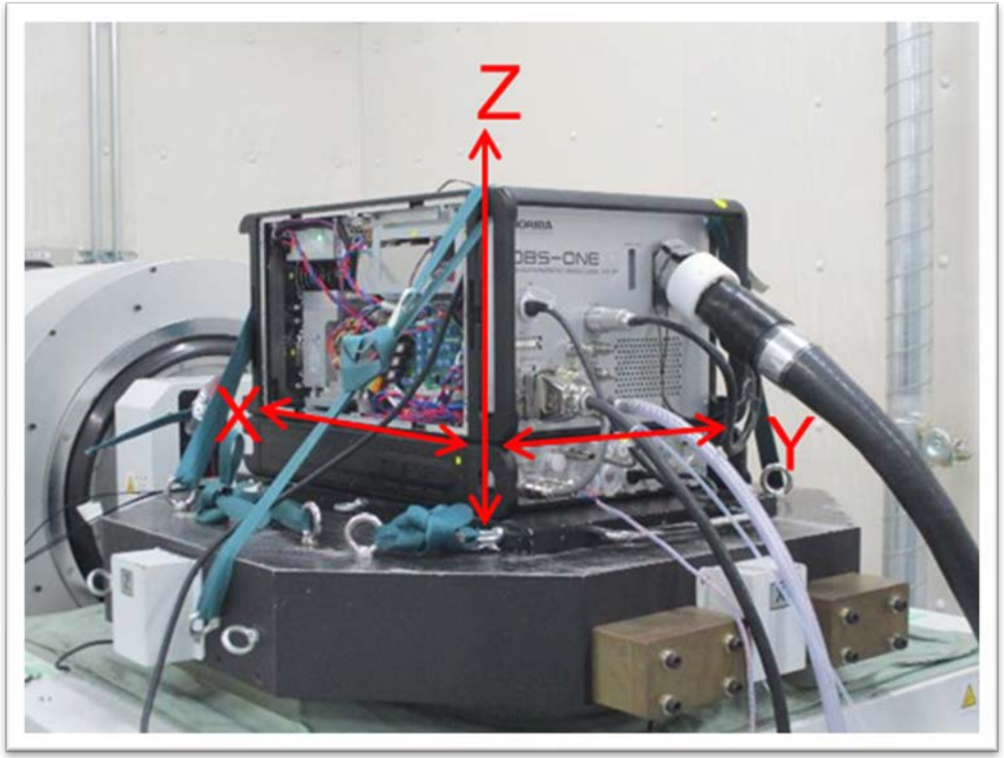


Pressure 100 kPA to 65 kPA
(Altitude 0 to 3000 m)

HORIBA Advances and Innovations

IRLAM by HORIBA

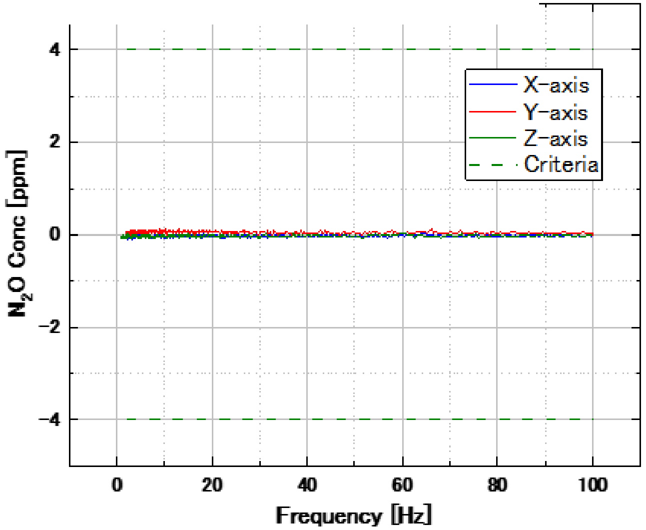
Little to zero vibration effects



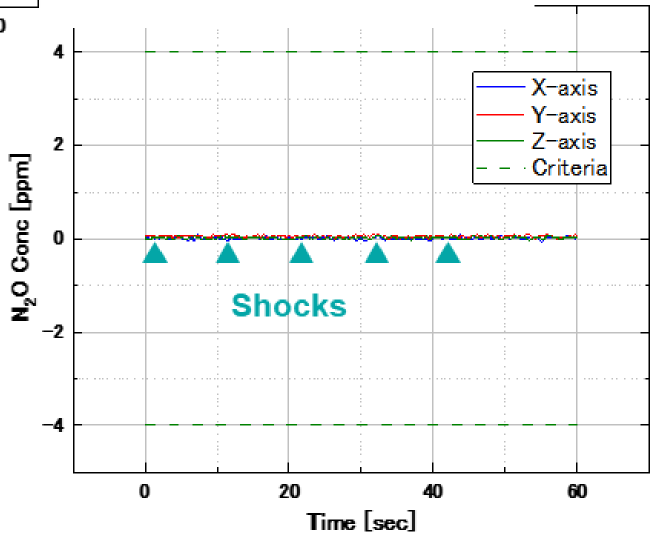
Sweep: 1-100 Hz, 9.8 m/s^2

Shock: 50 m/s^2

N_2O Sweep Zero

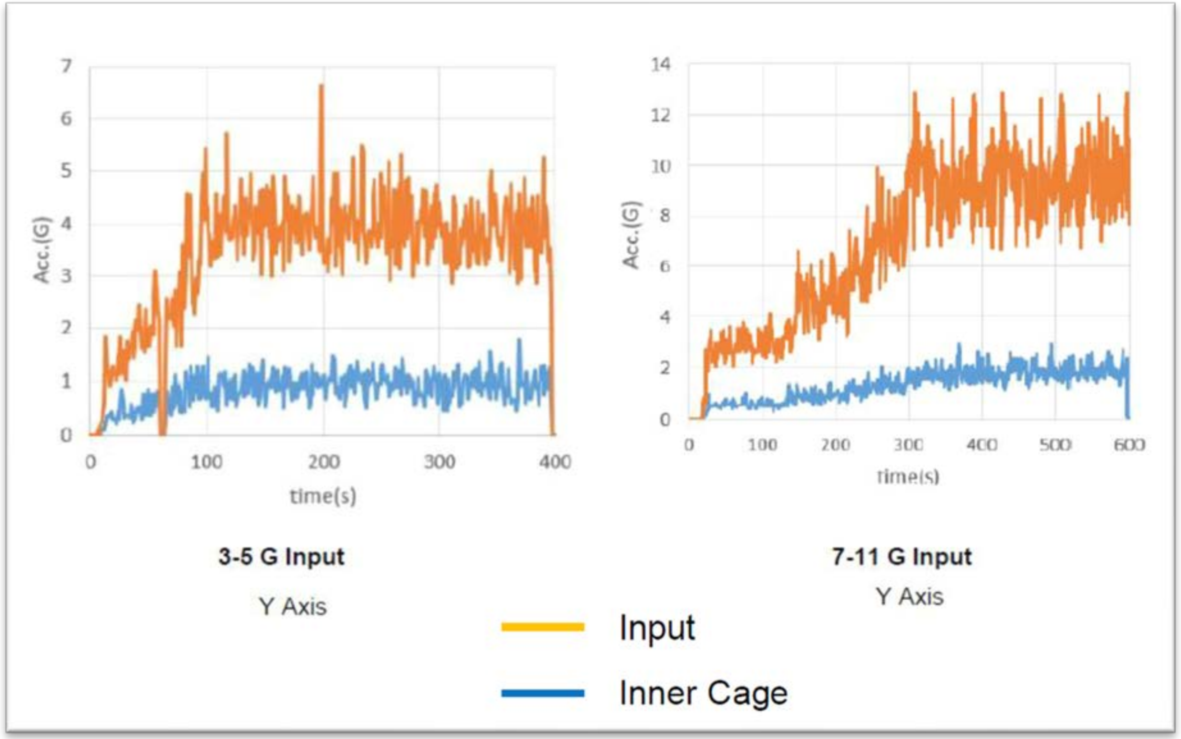


Shock Zero



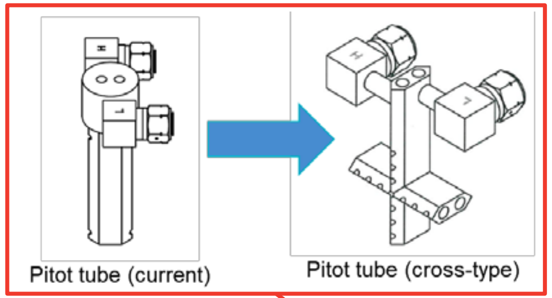
HORIBA Advances and Innovations

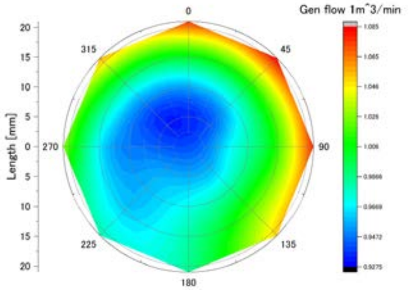
Vibration / environment

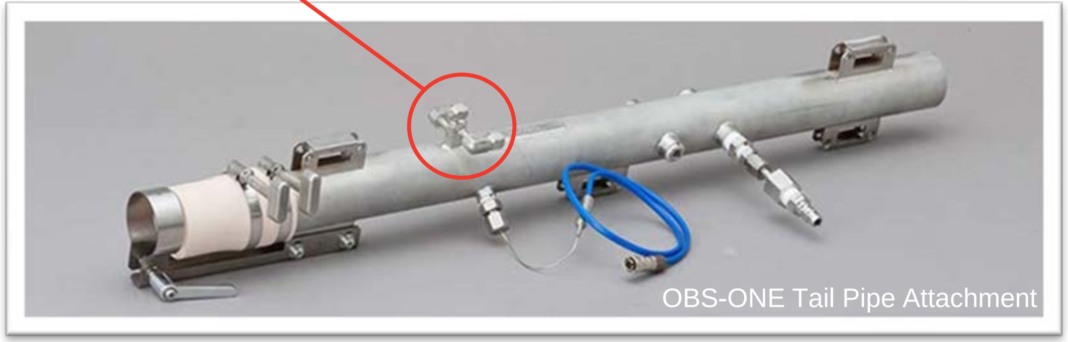


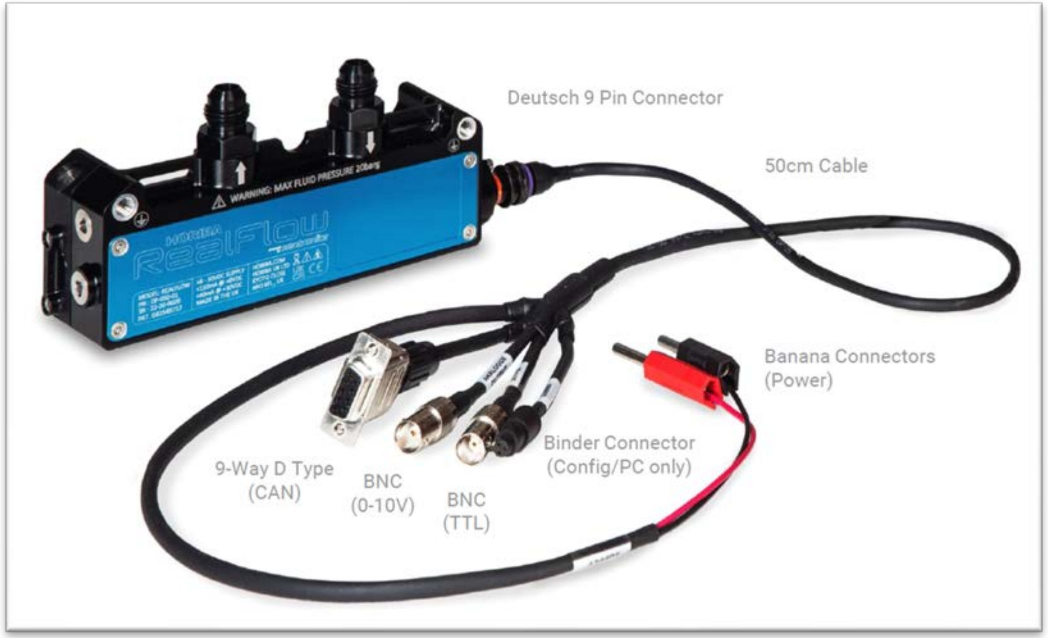
HORIBA Advances and Innovations

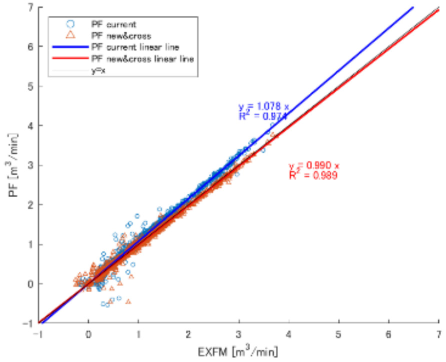
Exhaust flow / fuel flow

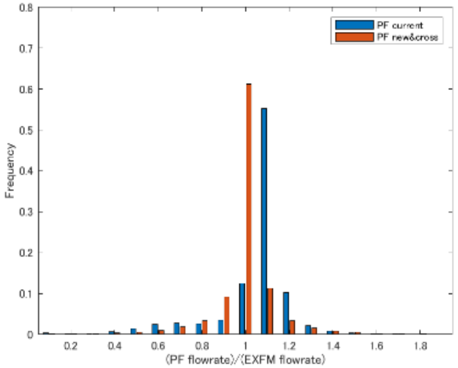


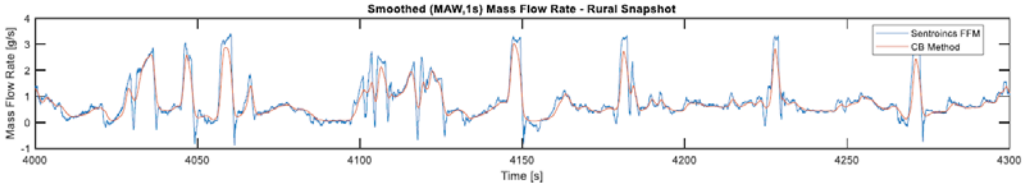










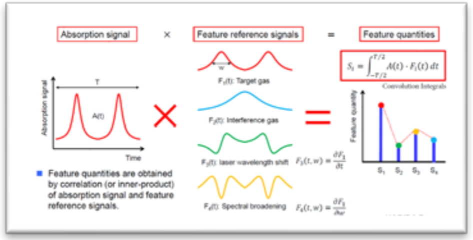


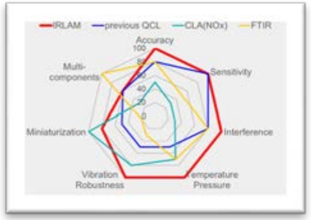
Summary: Continued Innovation

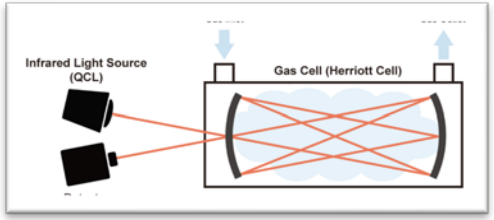
Measurement System Requirements

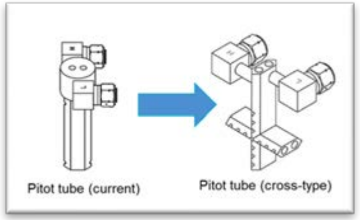
- Consistent, accurate NOx measurement at low concentration levels
- Long-term zero drift stability and noise performance
- Additional measurements
- Robust to measurement interference
- Robust to the environment & conditions that can impact the sampling system

Innovative Solutions









References and Acknowledgement

References:

[1] Jonathan Leonard, Patrick Couch, Thomas D. Durbin, Ph.D., Kent Johnson, Ph.D. et al, Arvind Thiruvengadam, Ph.D., Marc Besch, Ph.D.et al, Sam Cao, Ph.D. et al, “In-Use Emissions Testing and Activity Profiles for On-Road Heavy-Duty Vehicles”, California Energy Commission, March 2023

[2] Southwest Research Institute, *Modeling Stochastic Error Between PEMS and Bench Measurement,* January 2024

[3] Arvind Thiruvengadam, Ph.D., Marc Besch, Ph.D.et al; WVU Final Report to SCAQMD, CEC-500-2023-002 Appendix B, March 2023

[4] Hu, Z., Ma, W., Ma, J., Zhou, L. et al., “Experimental Research on Performance Development of Direct Injection Hydrogen Internal Combustion Engine with High Injection Pressure,” SAE Int. J. Engines
16(7):957-969, 2023, doi:10.4271/03-16-07-0053.

[5] Rouleau, L., Duffour, F., Walter, B., Kumar, R. et al., “Experimental and Numerical Investigation on Hydrogen Internal Combustion Engine,” SAE Technical Paper 2021-24-0060, 2021, doi:10.4271/2021-24-0060.

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អរគុណ
Terima kasih
Gracias
谢谢
Tack ska du ha
Danke
Σας ευχαριστώ πάρα πολύ
धन्यवाद
Grazie
THANK YOU
شُكْرًا
ขอบคุณครับ
Большое спасибо
ありがとうございました
Obrigado
Cảm ơn
Merci
감사합니다
Dziękuję