OSAR 2024 Conference

Application of the AVL M.O.V.E FT

A New Portable FTIR for In-Vehicle Emissions Measurement

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The Challenge

- Aspects of global emission legislations focus on real driving emissions that are measured on-board during a test drive
- New regulations for additional gas components require new solutions
- The next generation of PEMS systems must be small, lightweight, and easy to handle, while still providing accurate results even within a wide range of ambient conditions

The Solution – AVL M.O.V.E FT

- An FTIR-based multi-component emission measurement system that can measure relevant gas components within one system

- Operates as an ***add-on*** to the well known AVL M.O.V.E iS+ and iX test systems **OR** as a ***stand-alone*** system

Technical Specifications

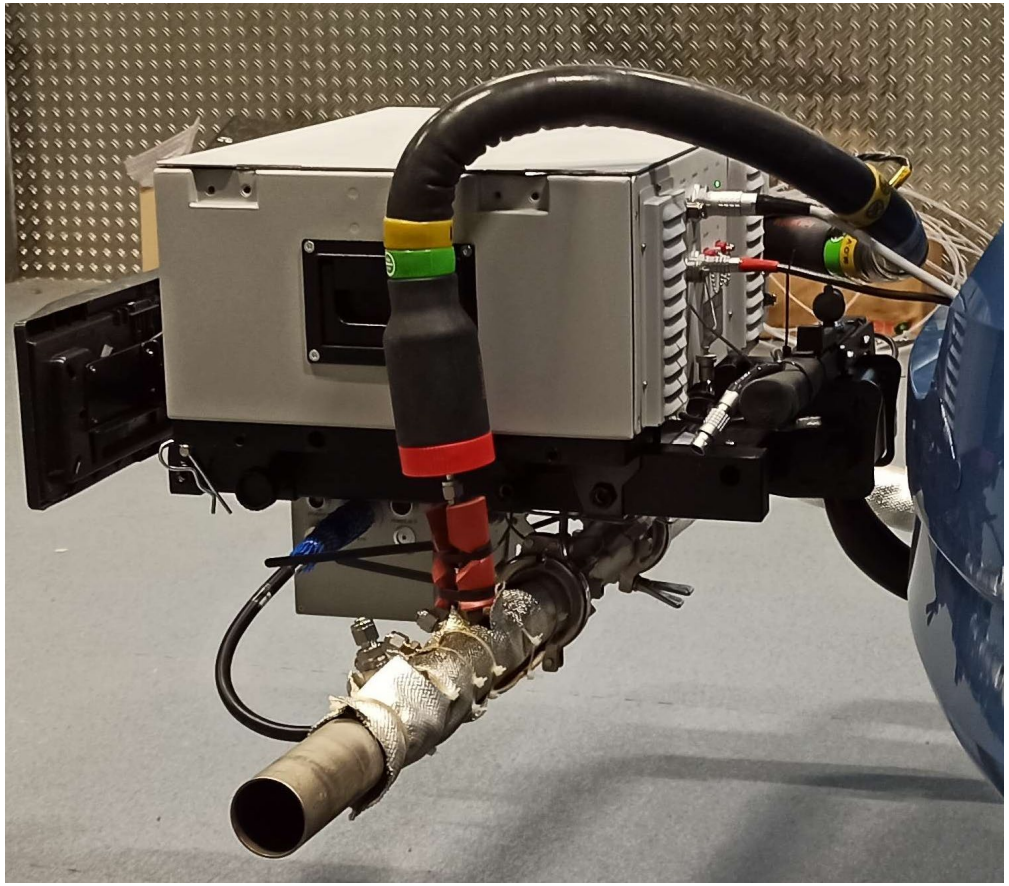
Public

The AVL M.O.V.E FT

- The AVL M.O.V.E FT is based on an FTIR spectrometer that can simultaneously measure multiple pre-calibrated exhaust gas components.
- The system does not require any supply gases, which makes it ideal for mobile on-board measurements.
- The simplicity of the system makes it easy to transport and install, which is essential since these systems must frequently be mounted and dismounted to different vehicles.

General Specification	
Dimensions (W x D x H)	49.5 x 36 x 18.9 cm (~19 x 14 x 7")
Weight	18 kg (~40 lbs)
Power supply	22 – 28 VDC, max 20A, ~150W after warm-up @ 20 °C
Ambient temperature	-10 – +45 °C (14 – 113 °F)
Ambient pressure	800 – 1,100 hPa (~0 – 2,000 m)
Ambient humidity	5 – 90 % rel., non-condensing
Measurement Ranges of Selected Gas Components	
CO_2	0 – 20 Vol.%
CO	0 – 5 Vol.%
NO	0 – 1,500 ppm
NO_2	0 – 1,000 ppm
NOx (NO + NO_2)	0 – 1,500 ppm
NH_3	0 – 1,500 ppm
N_2O	0 – 1,500 ppm
HCHO	0 – 200 ppm
Other Gas Components	
CH_4, $THC_{FTIR\ equiv.}$, NMHC, NMOG and many more	
Analyzer Specification	
Measurement principle	FTIR (Fourier Transform InfraRed)
Detector cooling	Thermoelectric
Optical bench purging	Not required
Communication interface	LAN TCP/IP (AK protocol)

AVL M.O.V.E FT – Highlights



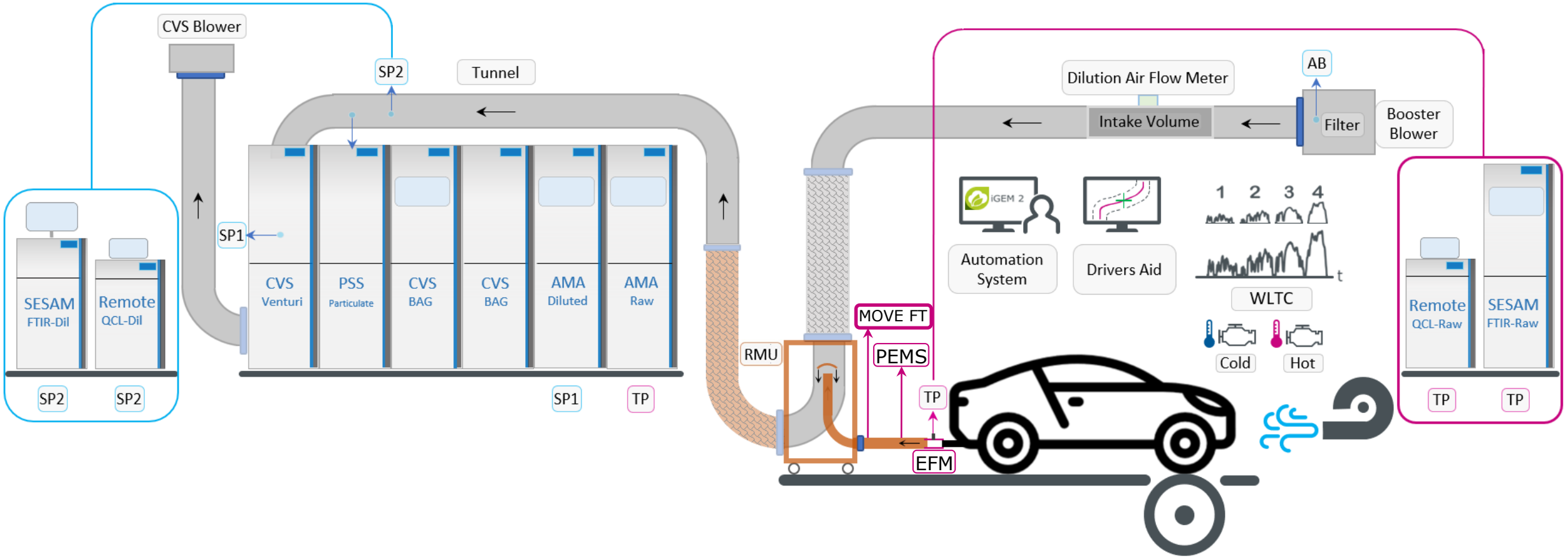
- One box including FTIR, sample pump and everything needed for the measurement
- No liquid nitrogen and no supply gases needed
- Measuring NH_3, N_2O, HCHO and CH_4 functioning as add-on for existing PEMS system
- Optional CO, CO_2, NO and NO_2 to function as a complete alternative to an existing PEMS system
- Other components on request for R&D purposes
- Low power consumption ~150 W after warm-up
- Small footprint and lightweight (~40 lb)

Correlation Testing Results

Chassis Dynamometer

Public

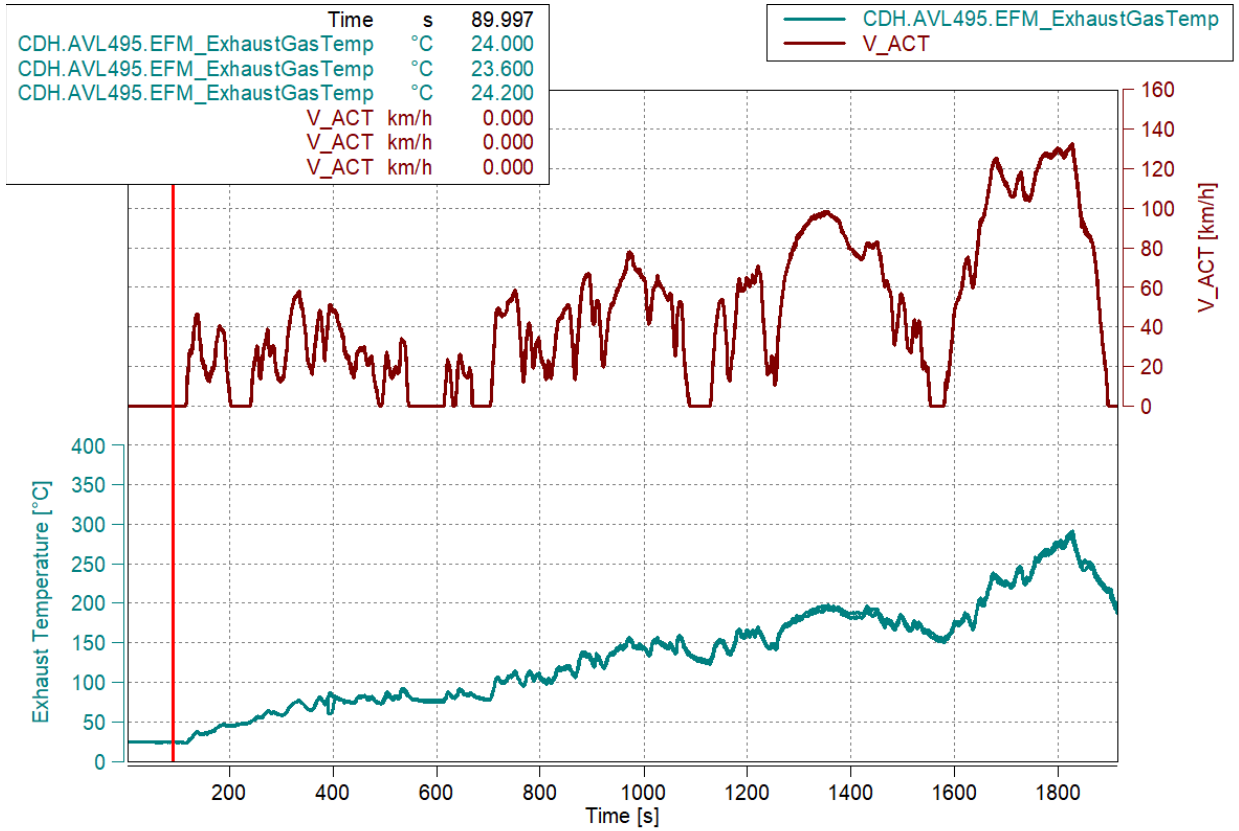
Experimental Setup



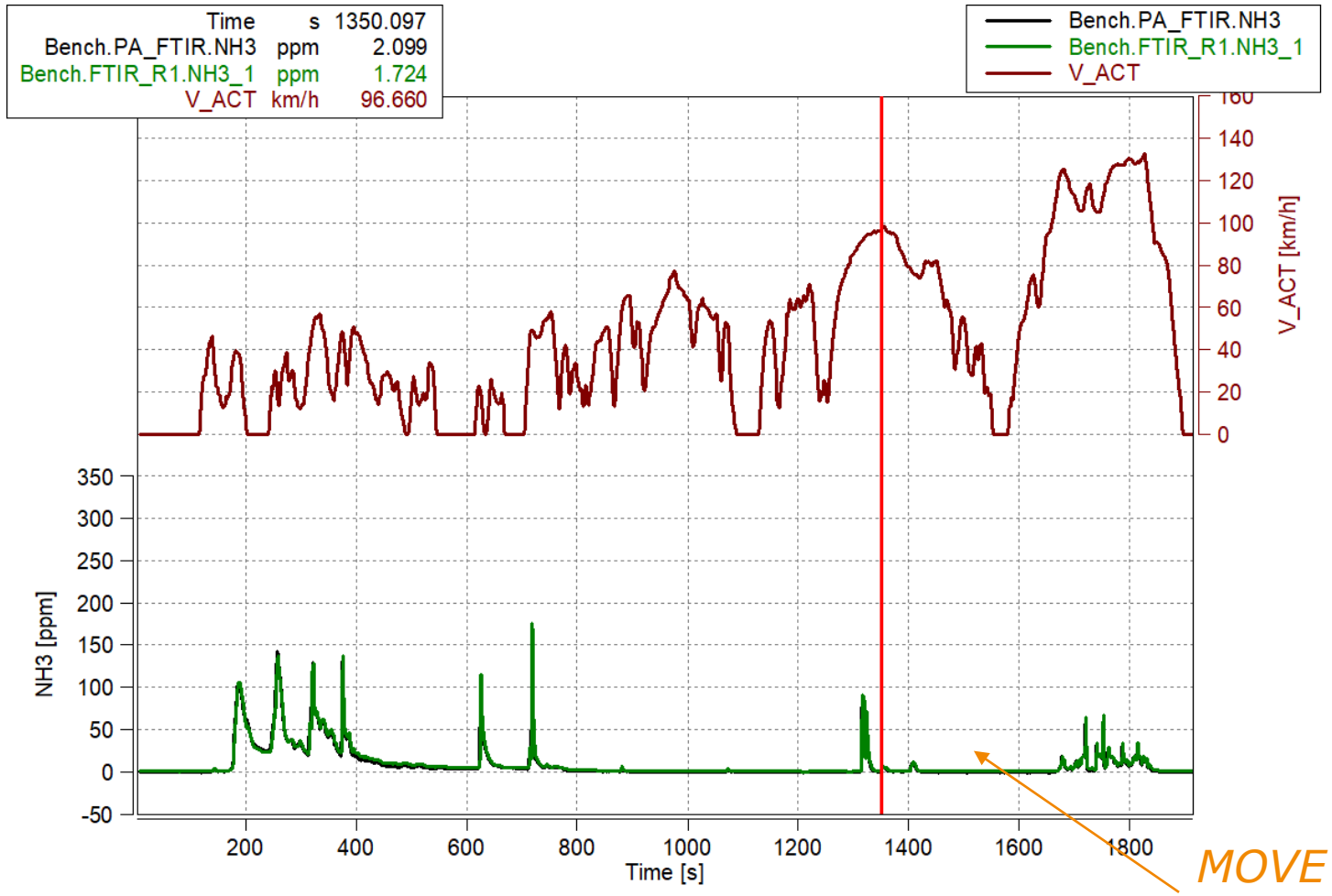
Data Presentation Format

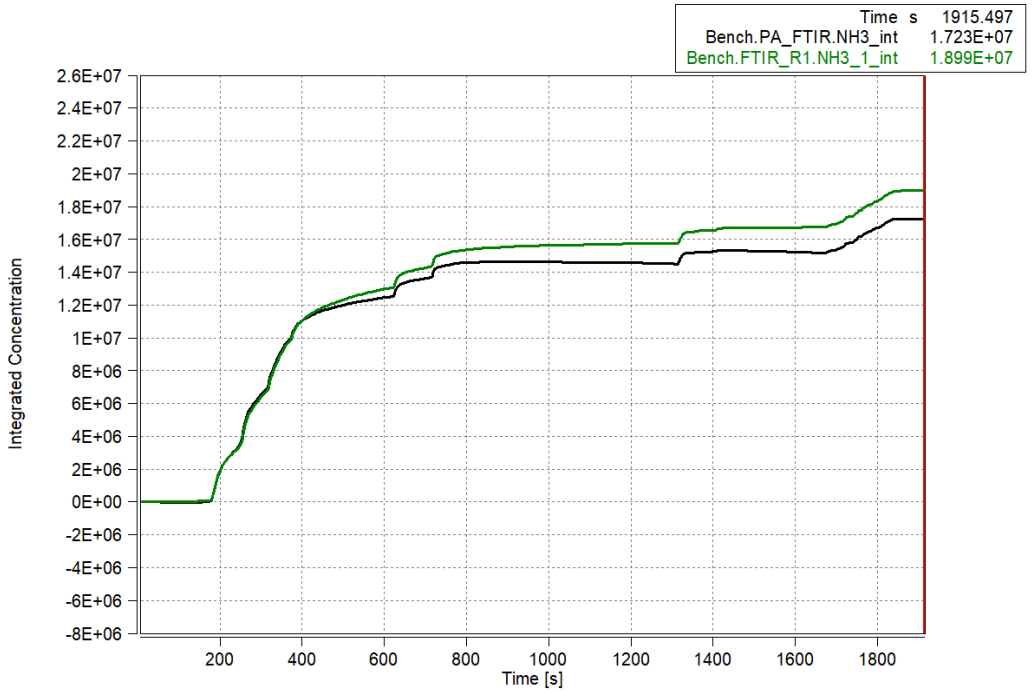
- Comparison of raw emission concentrations over Cold Start WLTCs of a gasoline vehicle

- Legend:
  - **MOVE FT**
  - **AMA SL**
  - **SESAM i60**



Ammonia (NH_3)





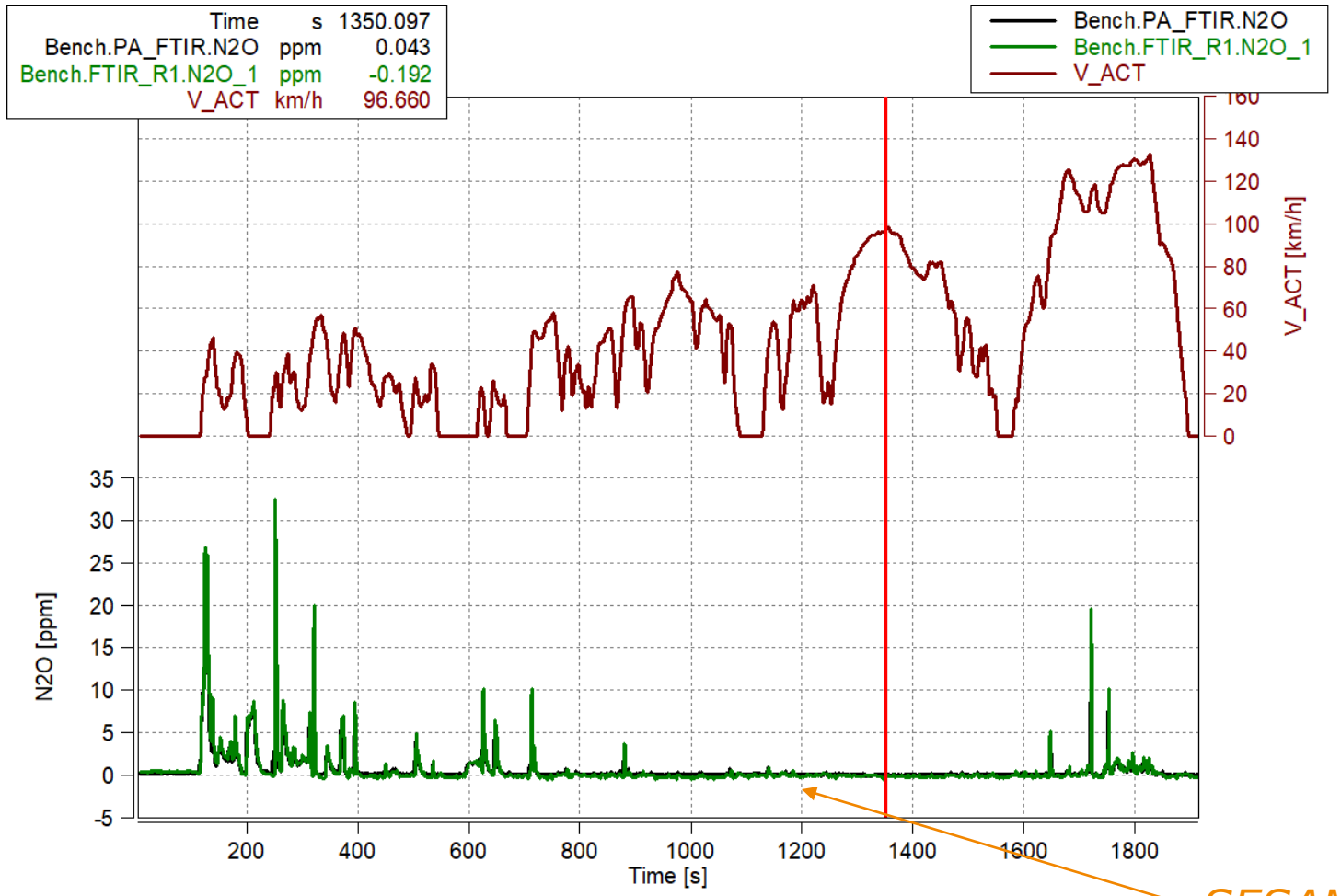
Relative Differences:

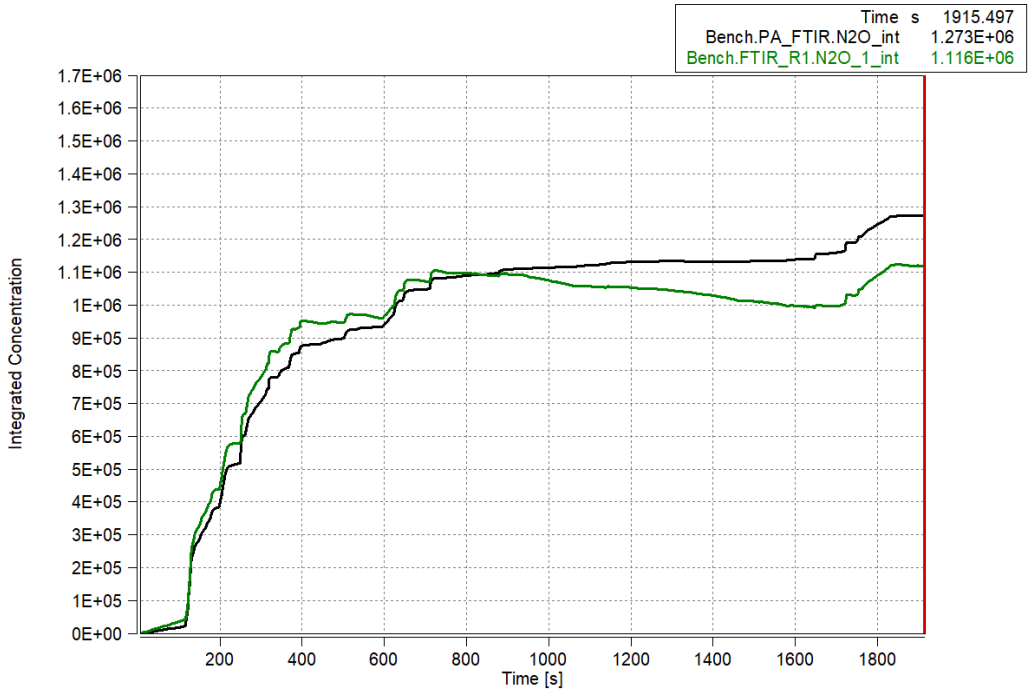
Δ_{AMA} = N/A

Δ_{SESAM} = -9.27%

MOVE FT NH_3 reads ~-1 ppm in Phase 3 (1500 ppm range)

Nitrous Oxide (N_2O)





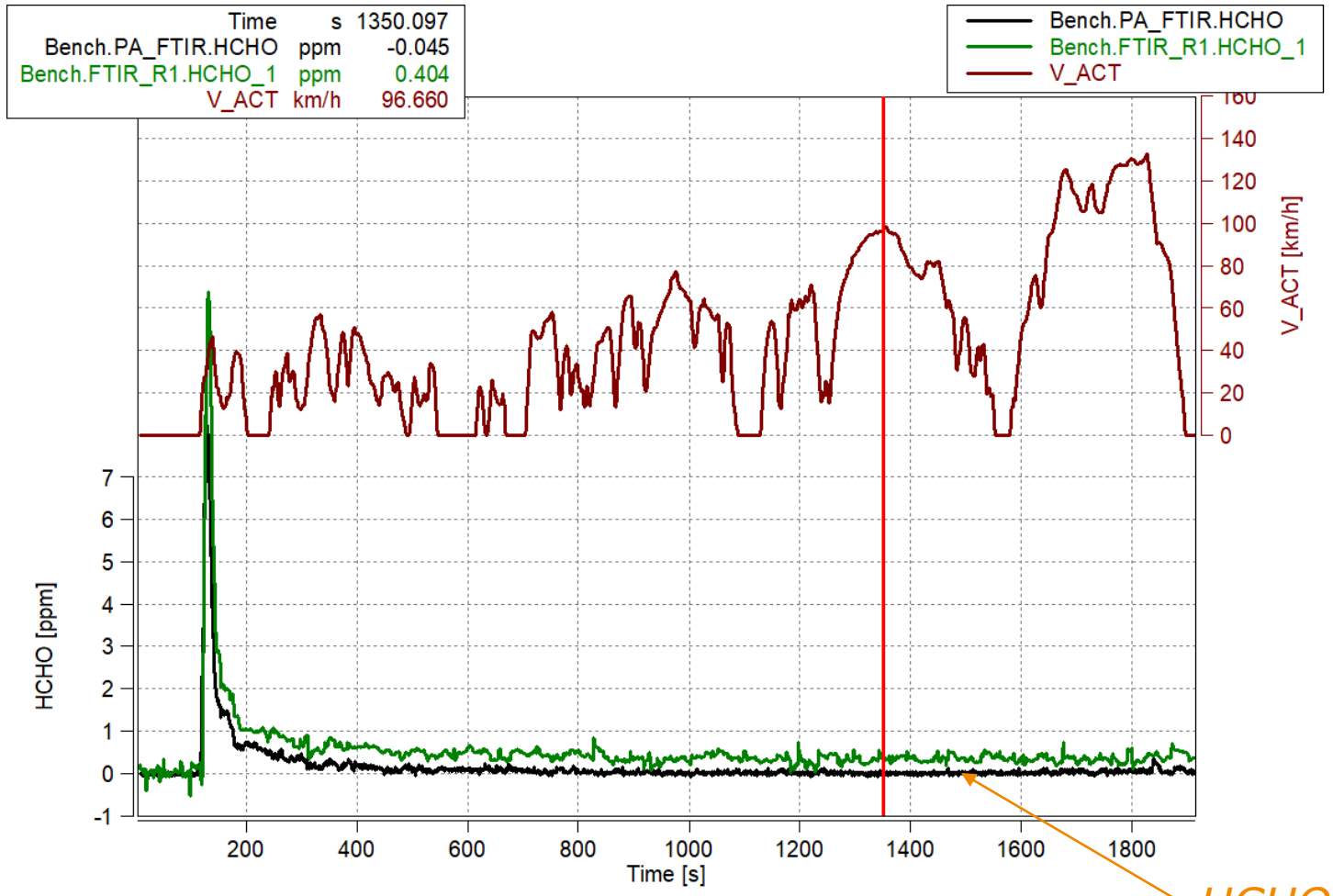
Relative Differences:

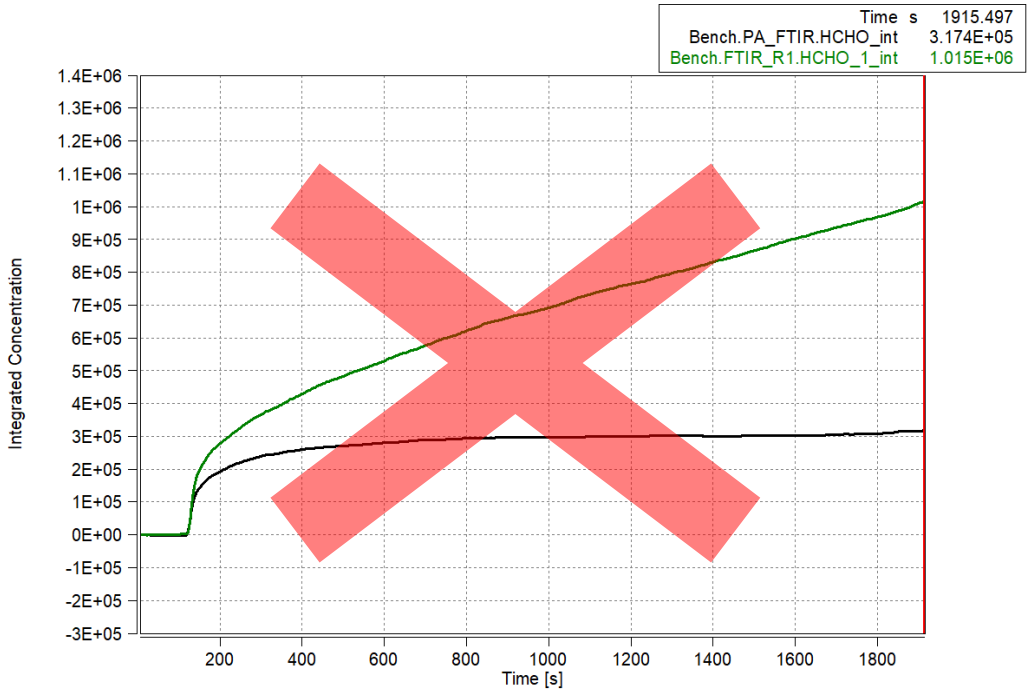
Δ_{AMA} = N/A

Δ_{SESAM} = 14.1%

SESAM N_2O reads negative in Phases 2 and 3

Formaldehyde (HCHO)





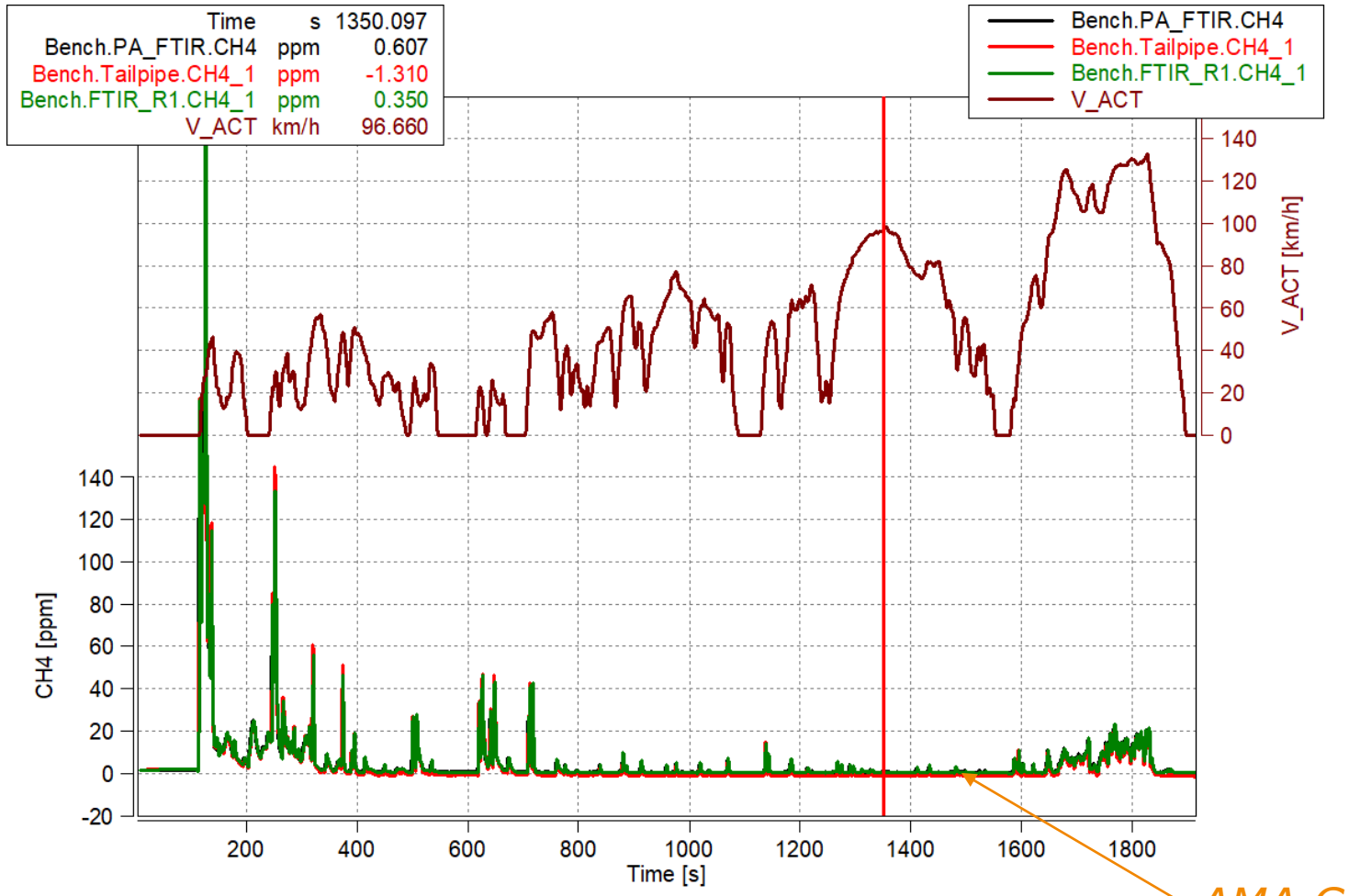
Relative Differences:

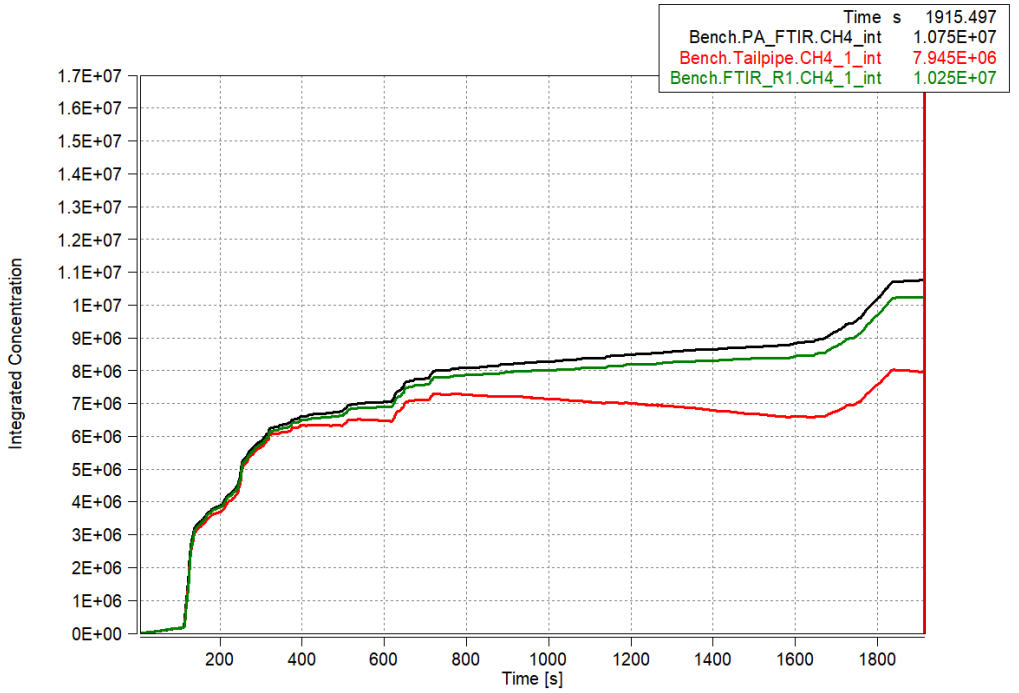
Δ_{AMA} = **N/A**

Δ_{SESAM} = **-212%**

HCHO settles to <1 ppm (200 ppm range)

Methane Hydrocarbons (CH_4)





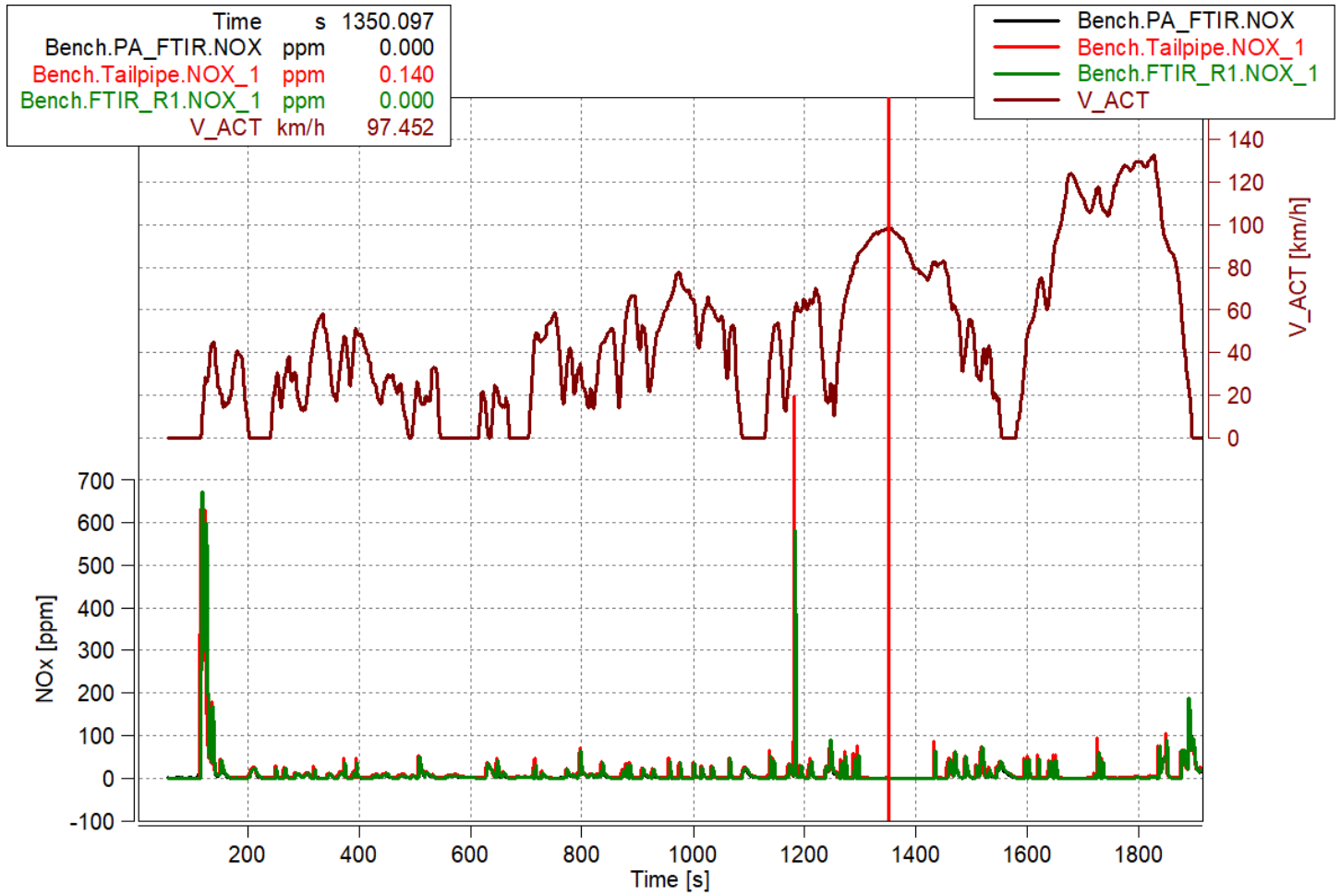
Relative Differences:

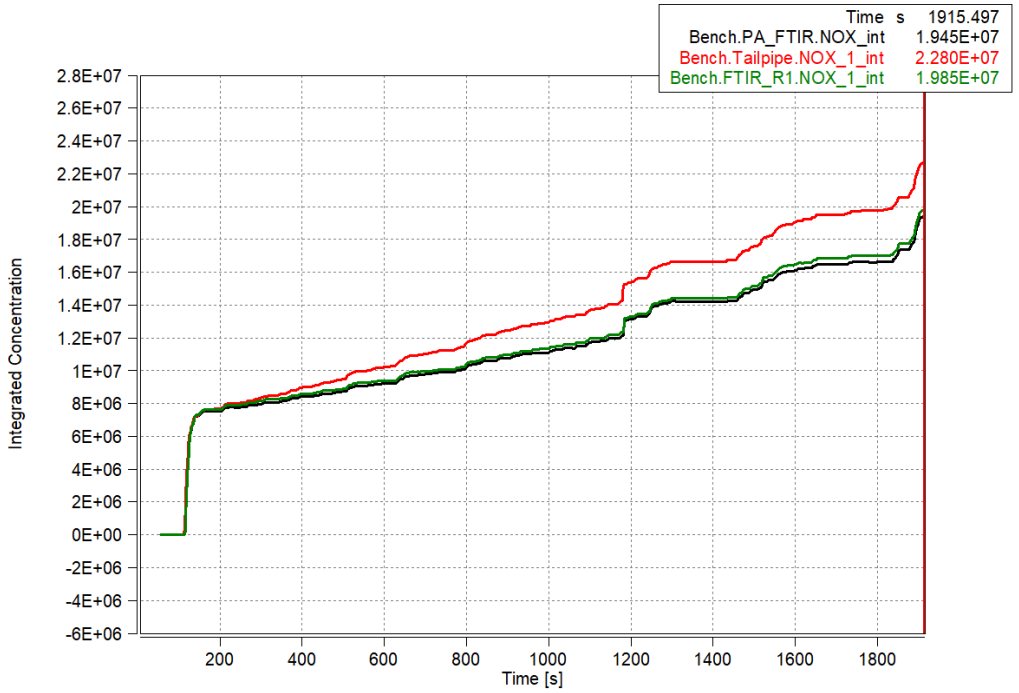
Δ_{AMA} = 35.3%

Δ_{SESAM} = 4.88%

AMA CH4 has drifted negative

Oxides of Nitrogen (NOx)



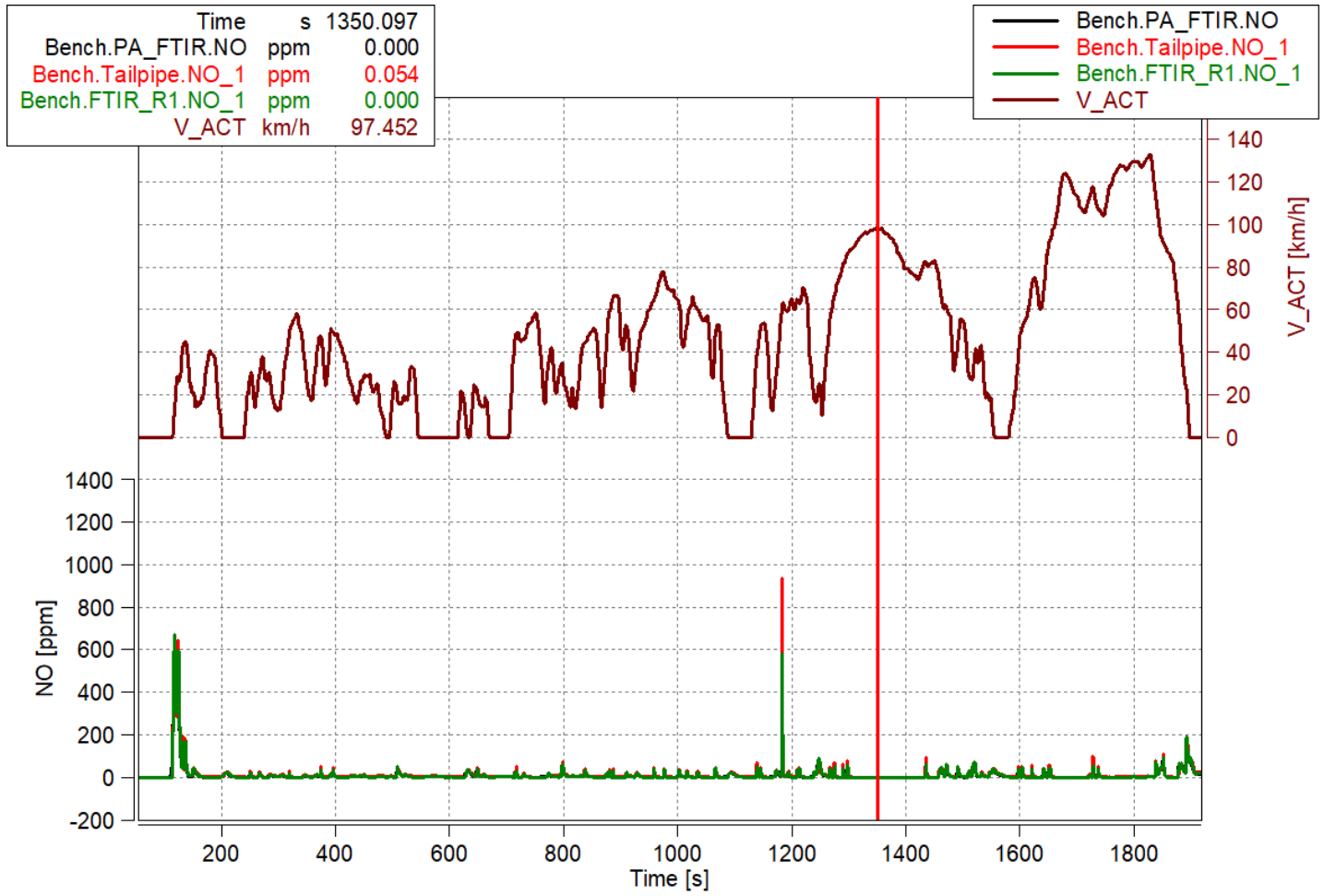


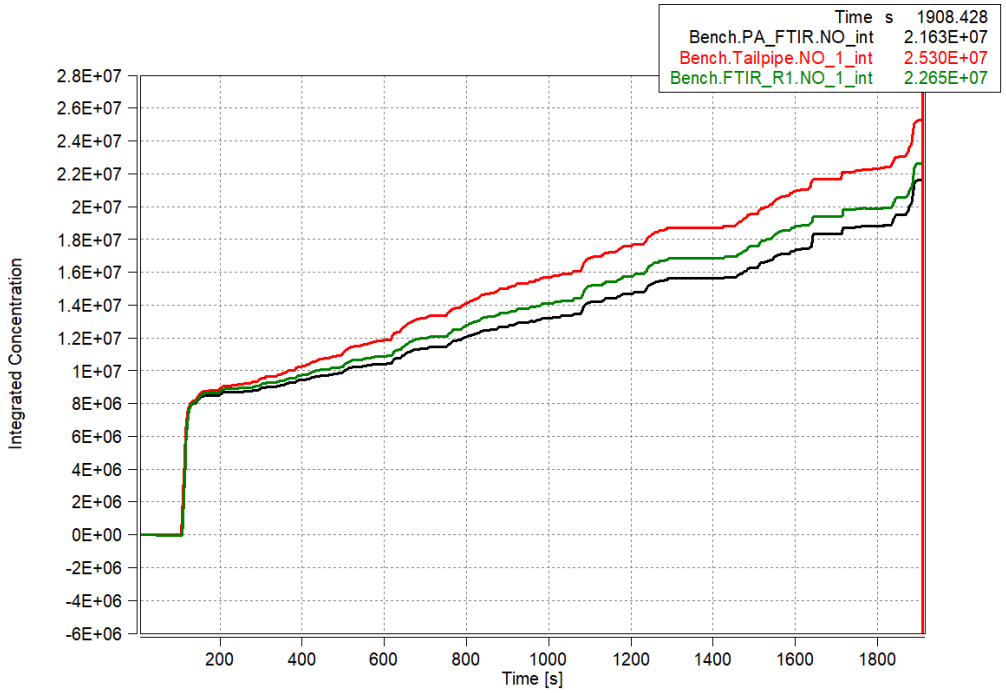
Relative Differences:

Δ_{AMA} = -14.7%

Δ_{SESAM} = -2.02%

Nitric Oxide (NO)



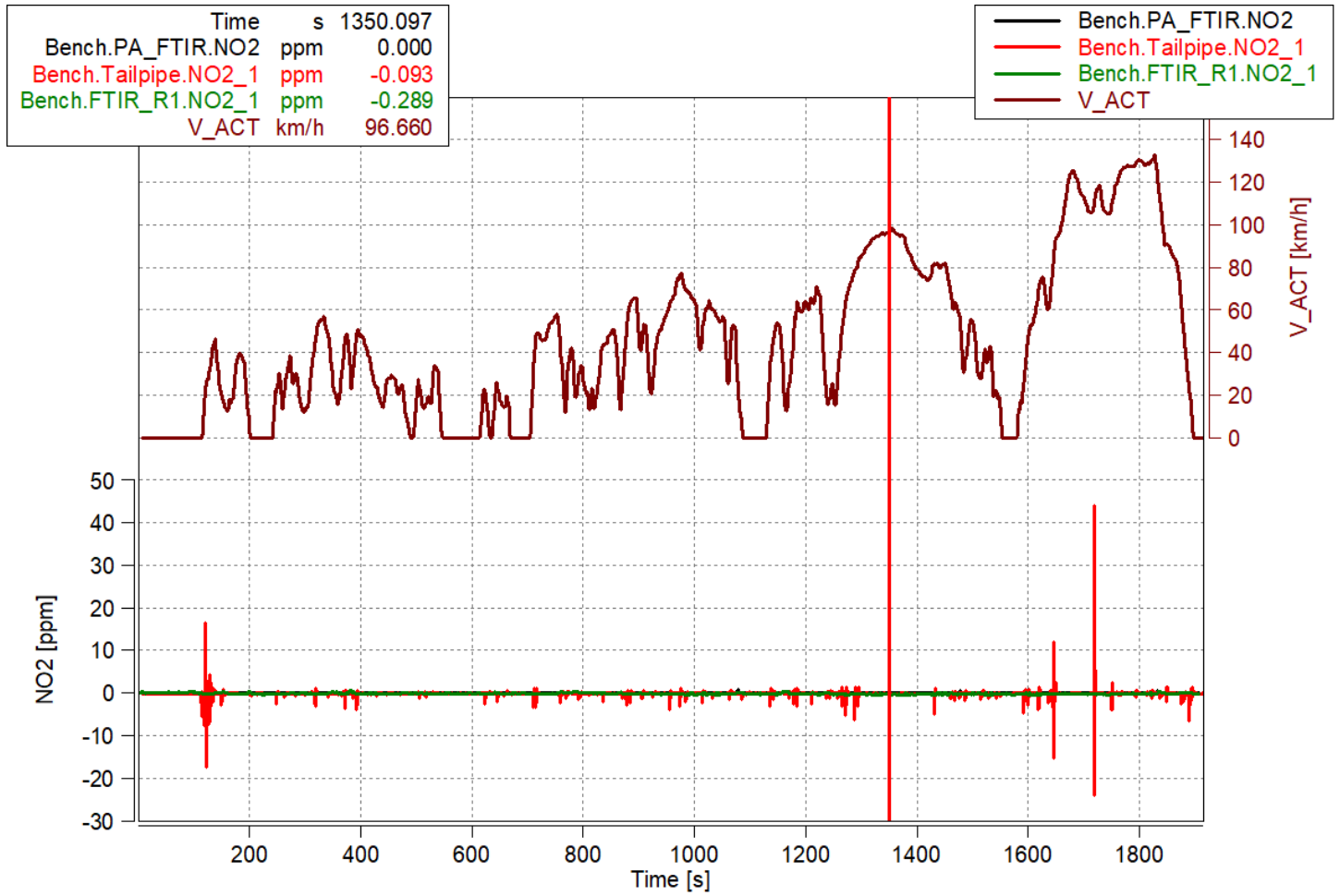


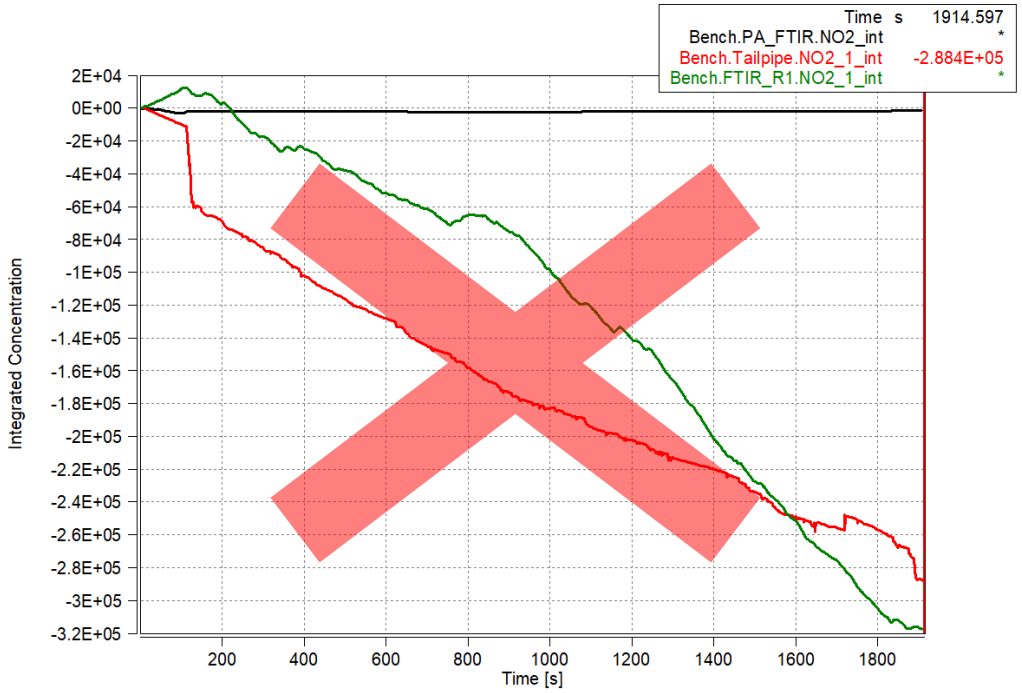
Relative Differences:

Δ_{AMA} = -14.5%

Δ_{SESAM} = -4.50%

Nitrogen Dioxide (NO_2)



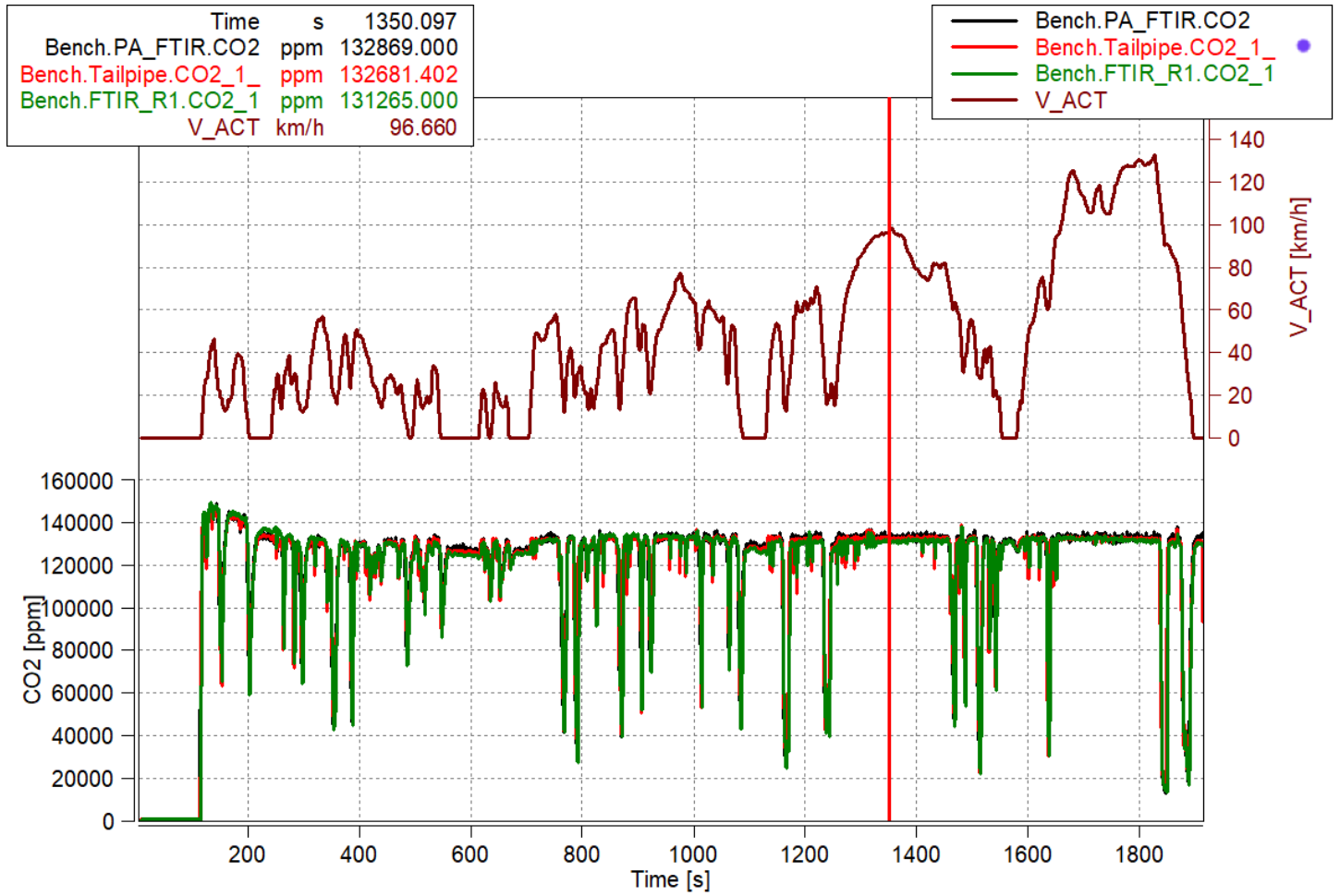


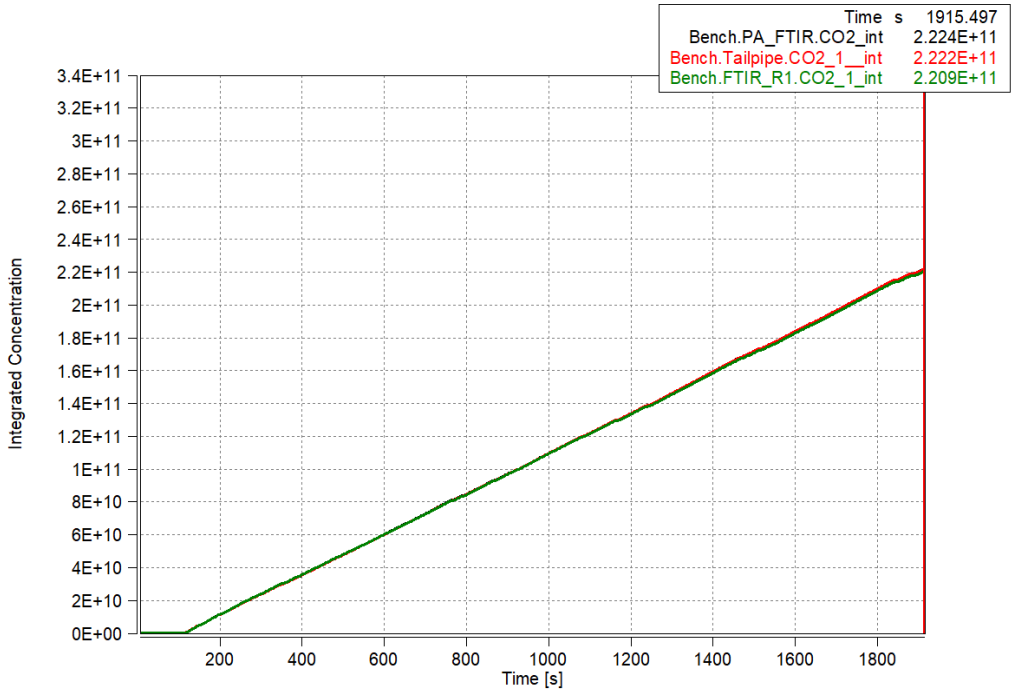
Relative Differences:

Δ_{AMA} = **N/A**

Δ_{SESAM} = **N/A**

Carbon Dioxide (CO_2)



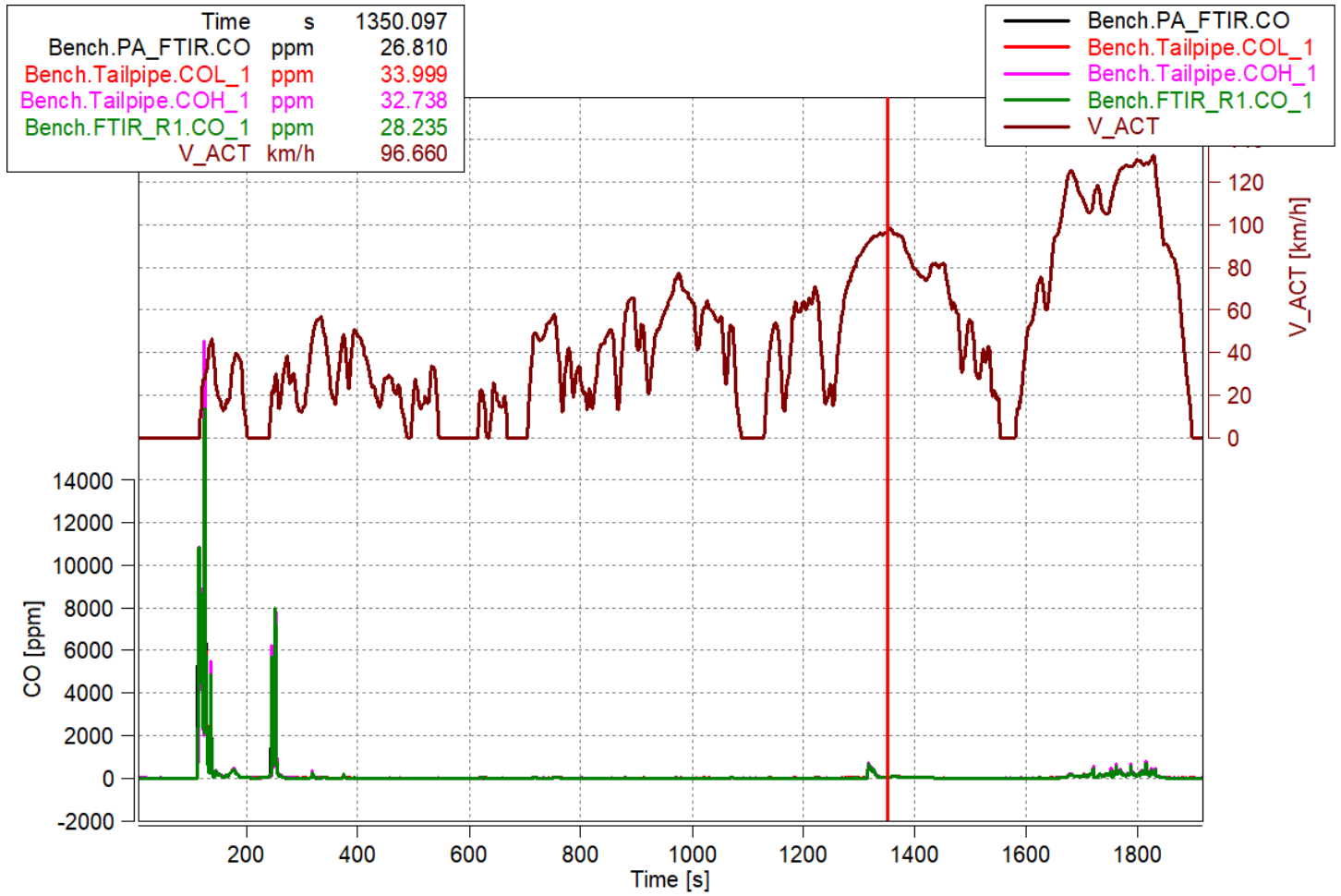


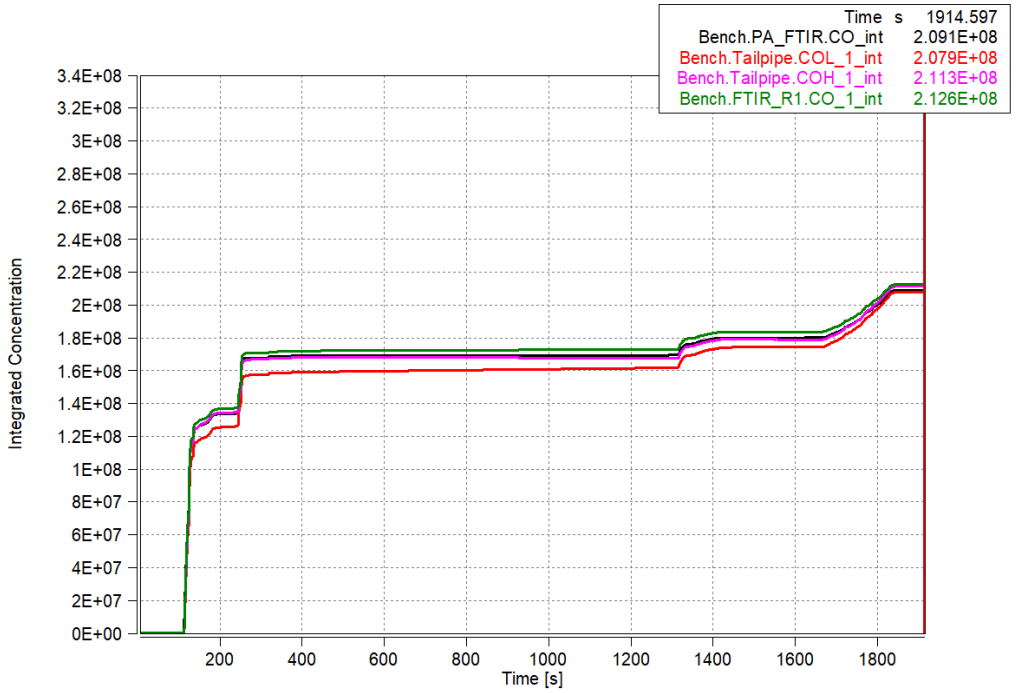
Relative Differences:

Δ_{AMA} = 0.0900%

Δ_{SESAM} = 0.679%

Carbon Monoxide (CO)





Relative Differences:

Δ_{AMA} = **0.577%** (CO_{low})
Δ_{AMA} = **-1.04%** (CO_{high})

Δ_{SESAM} = **-1.65%**

Chassis Dynamometer Testing Findings

	Rel Δ		Abs Δ / Range		$Range_{MOVE\ FT}$ (ppm)
	AMA	SESAM	AMA	SESAM	
NH_3	-	-9.27%	-	0.0623%	1500
N_2O	-	14.1%	-	0.00580%	1500
HCHO		-212%	-	0.187%	200
CH_4	35.3%	4.88%	1.49%	0.268%	*100*
NOx	-14.7%	-2.02%	0.121%	0.0145%	1500
NO	-14.5%	-4.50%	0.122%	0.00853%	1500
NO_2	-	-	-	-	1000
CO_2	0.0900%	0.679%	0.0337%	0.389%	200000
CO	0.577%	-1.65%	0.00152%	0.00352%	50000

AMA Detector
-
-
-
HFID
HCLD
HCLD
HCLD
NDIR
NDIR

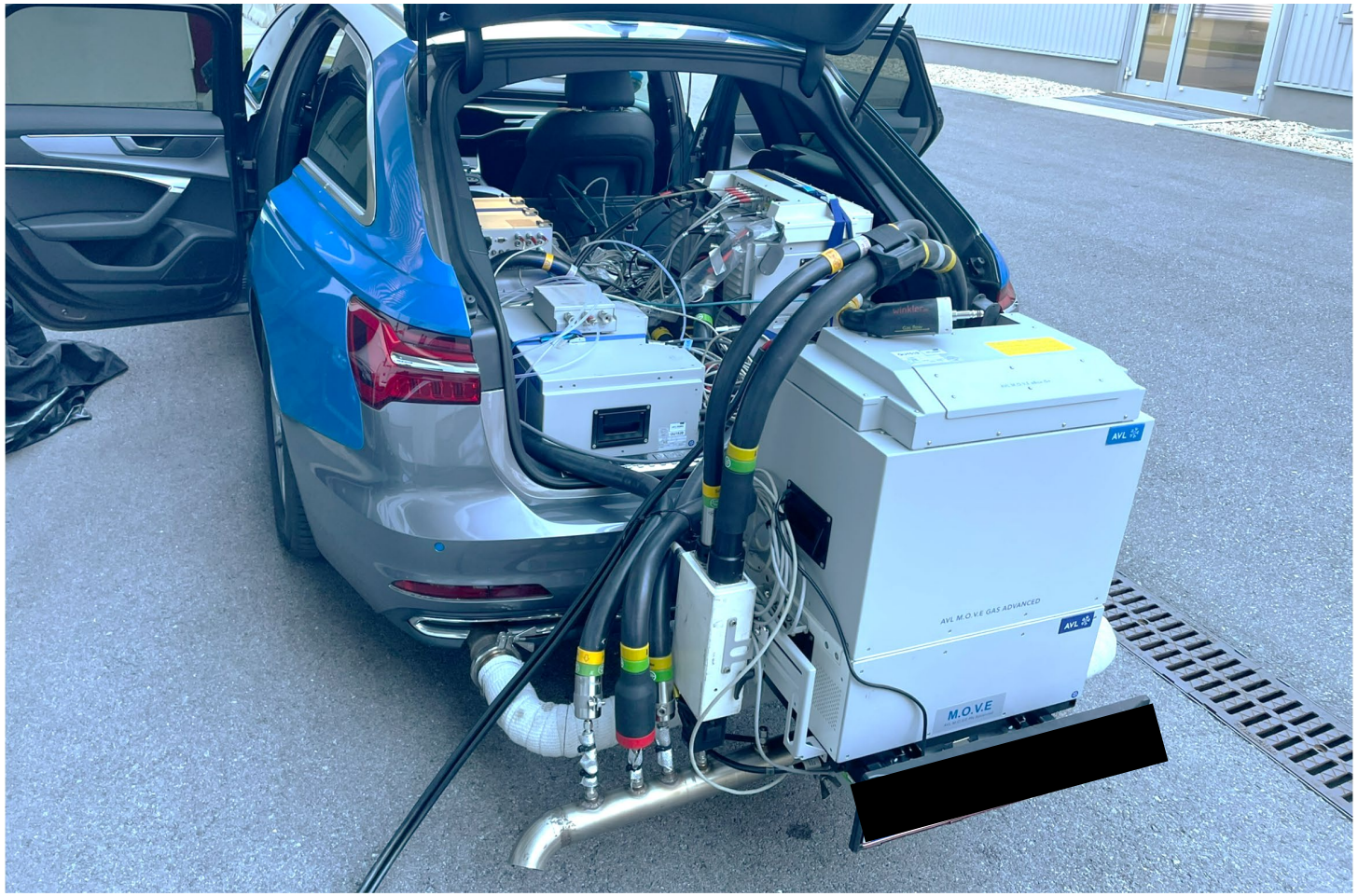
Note: CH_4 range of 100 ppm is shown for calculation purposes only.

- The M.O.V.E FT correlates well with reference laboratory analyzers
  - For species where relative difference is >2% where the concentrations are quite low, the absolute difference compared to full scale range of the M.O.V.E FT is <2%

Correlation Testing Results

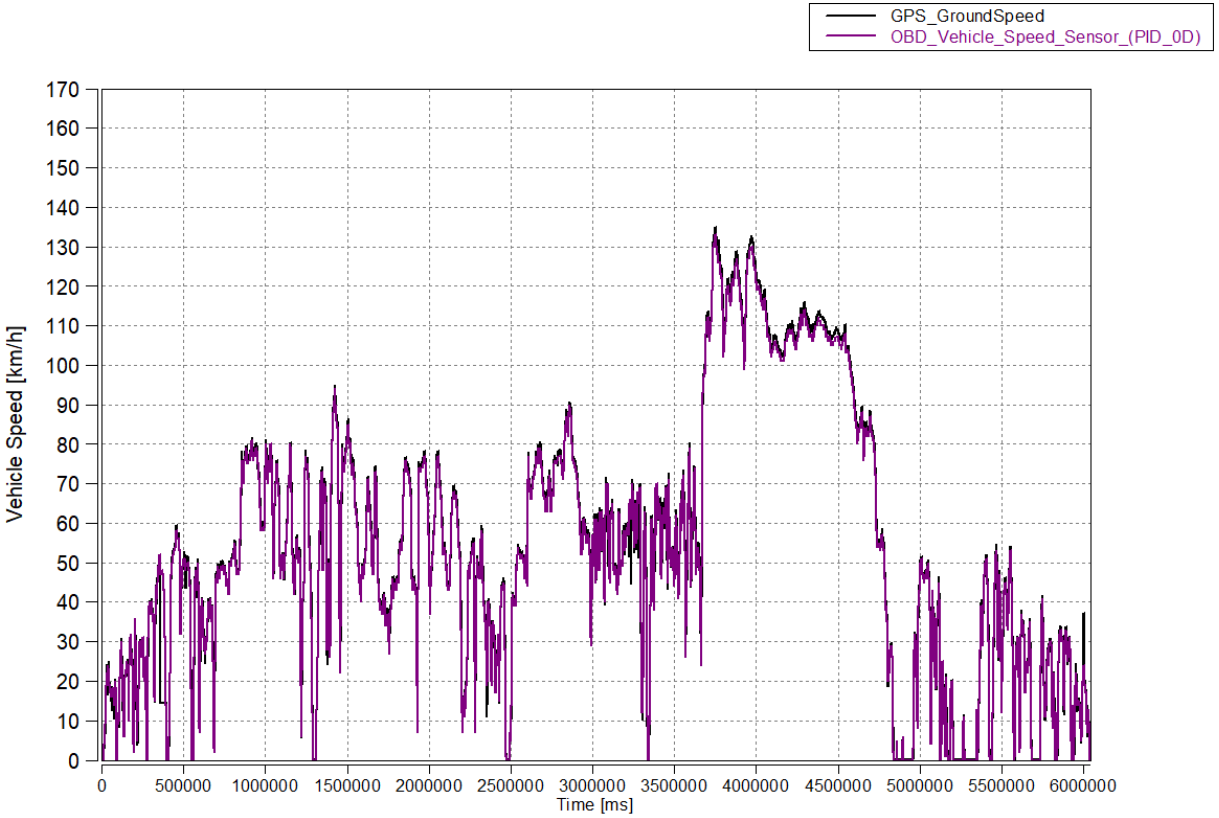
In-Vehicle (RDE)

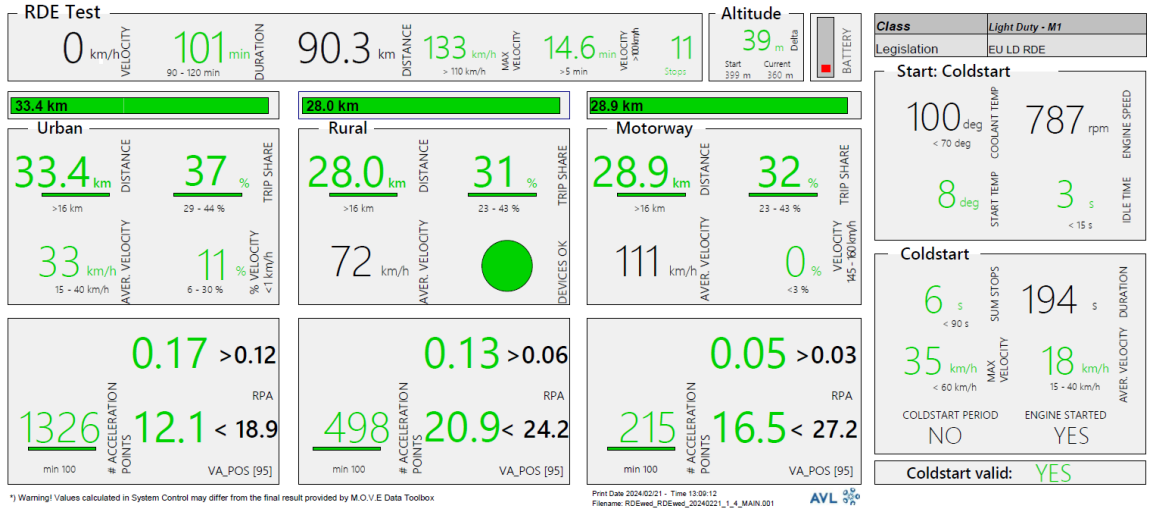
Instrumented Test Vehicle



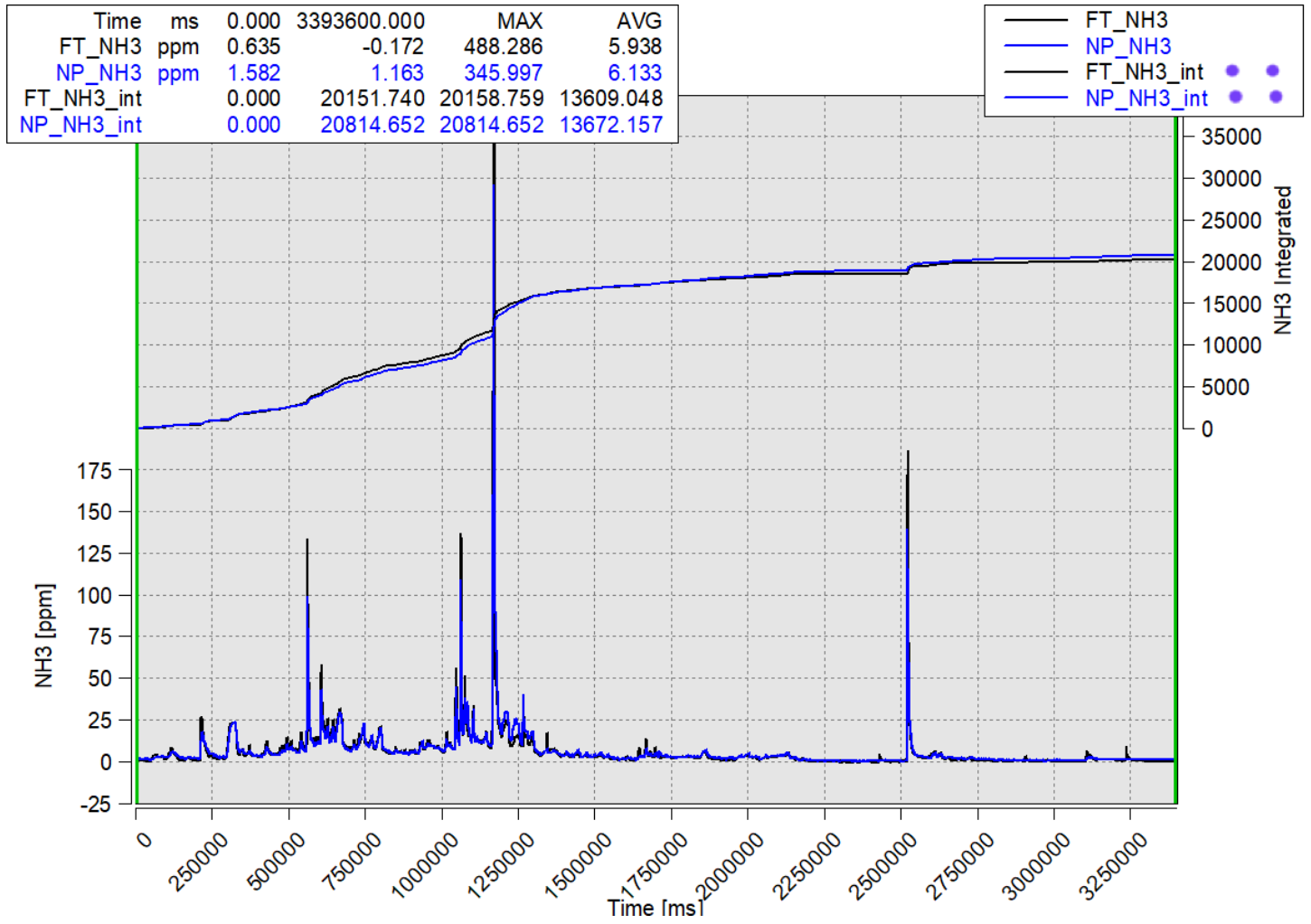
Vehicle Speed and RDE Validation

- Testing of a *different* gasoline vehicle



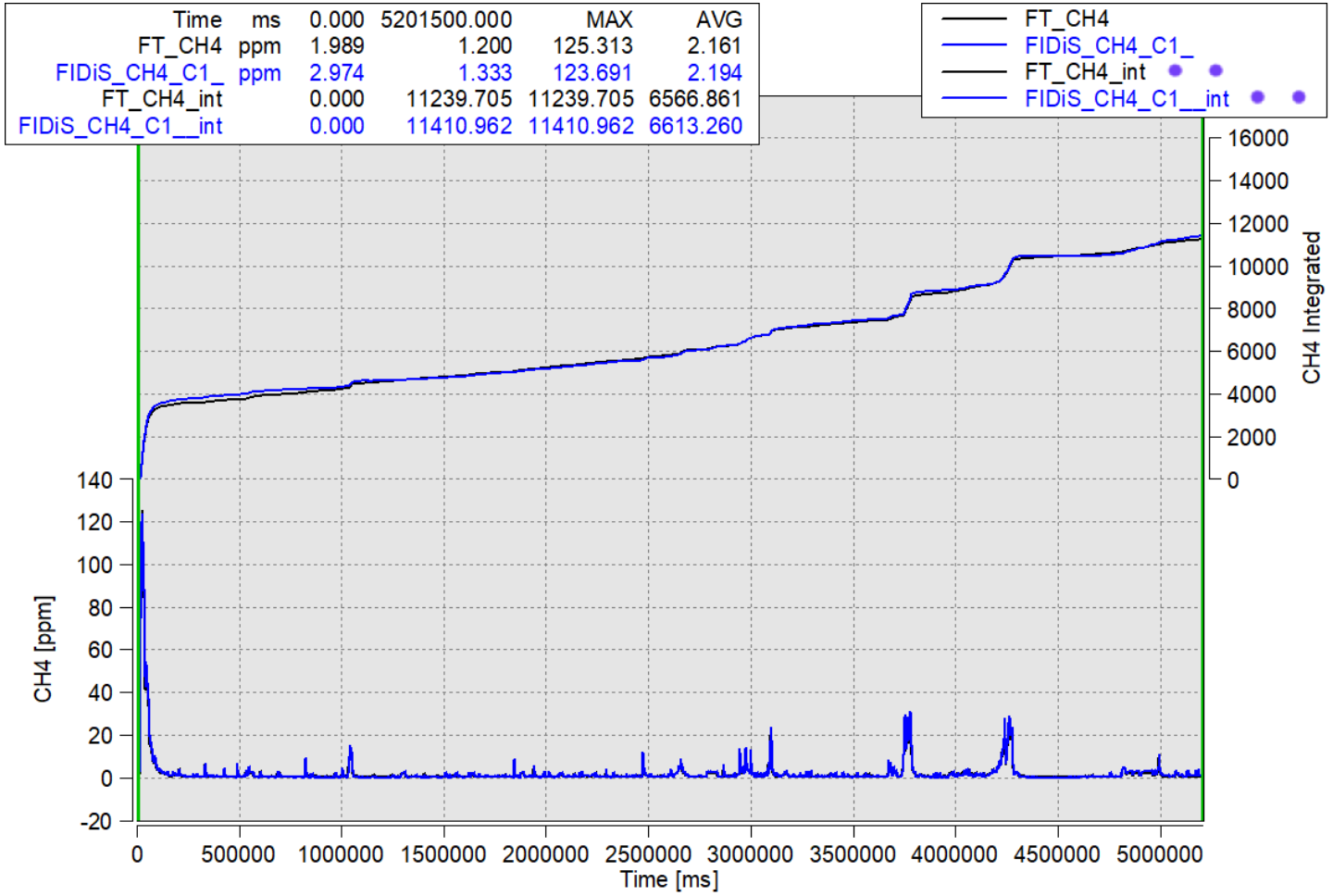


Ammonia (NH_3)



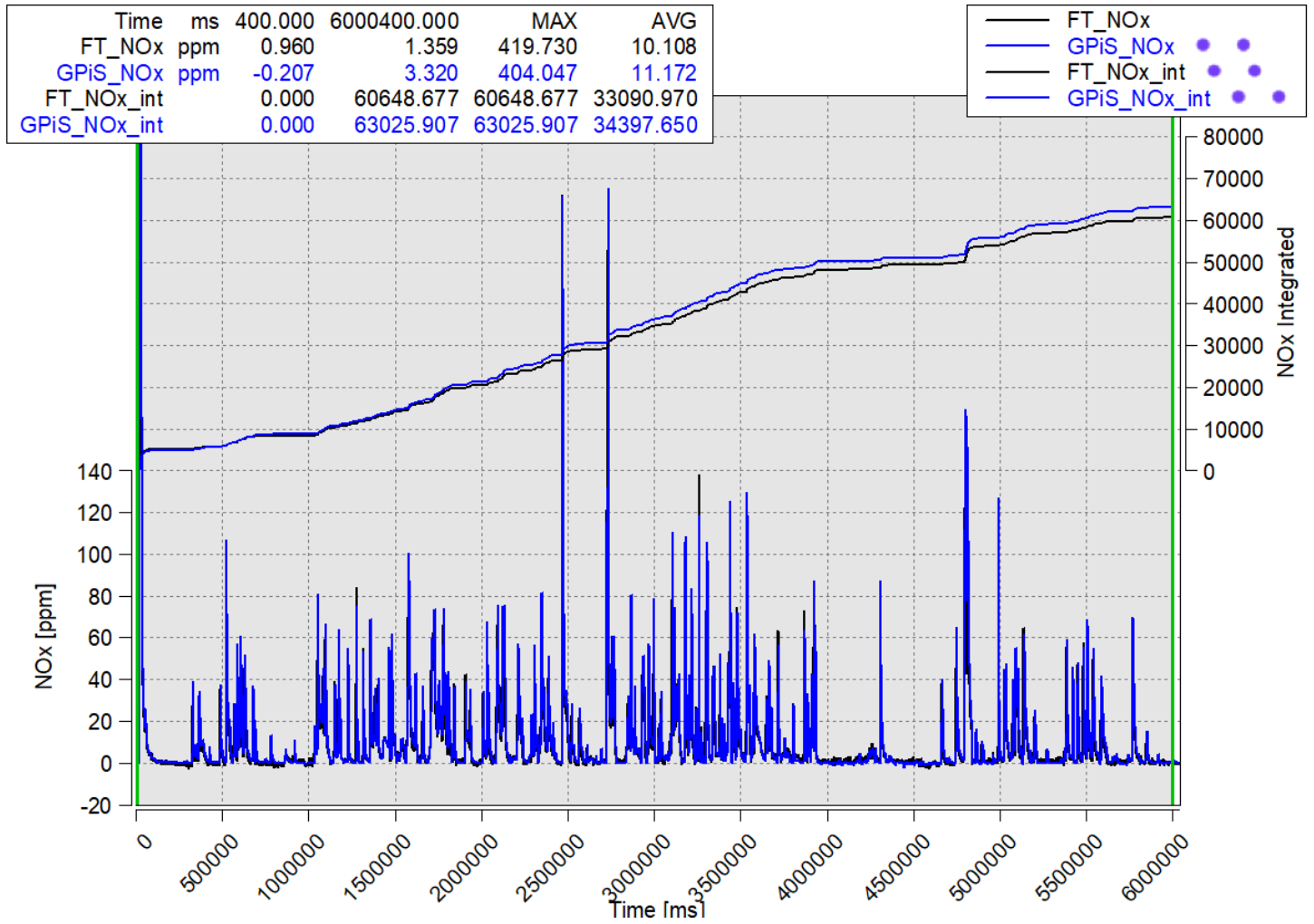
- **Relative Differences:**
  - $\Delta_{M.O.V.E}$ **= -3.15%**

Methane (CH_4)



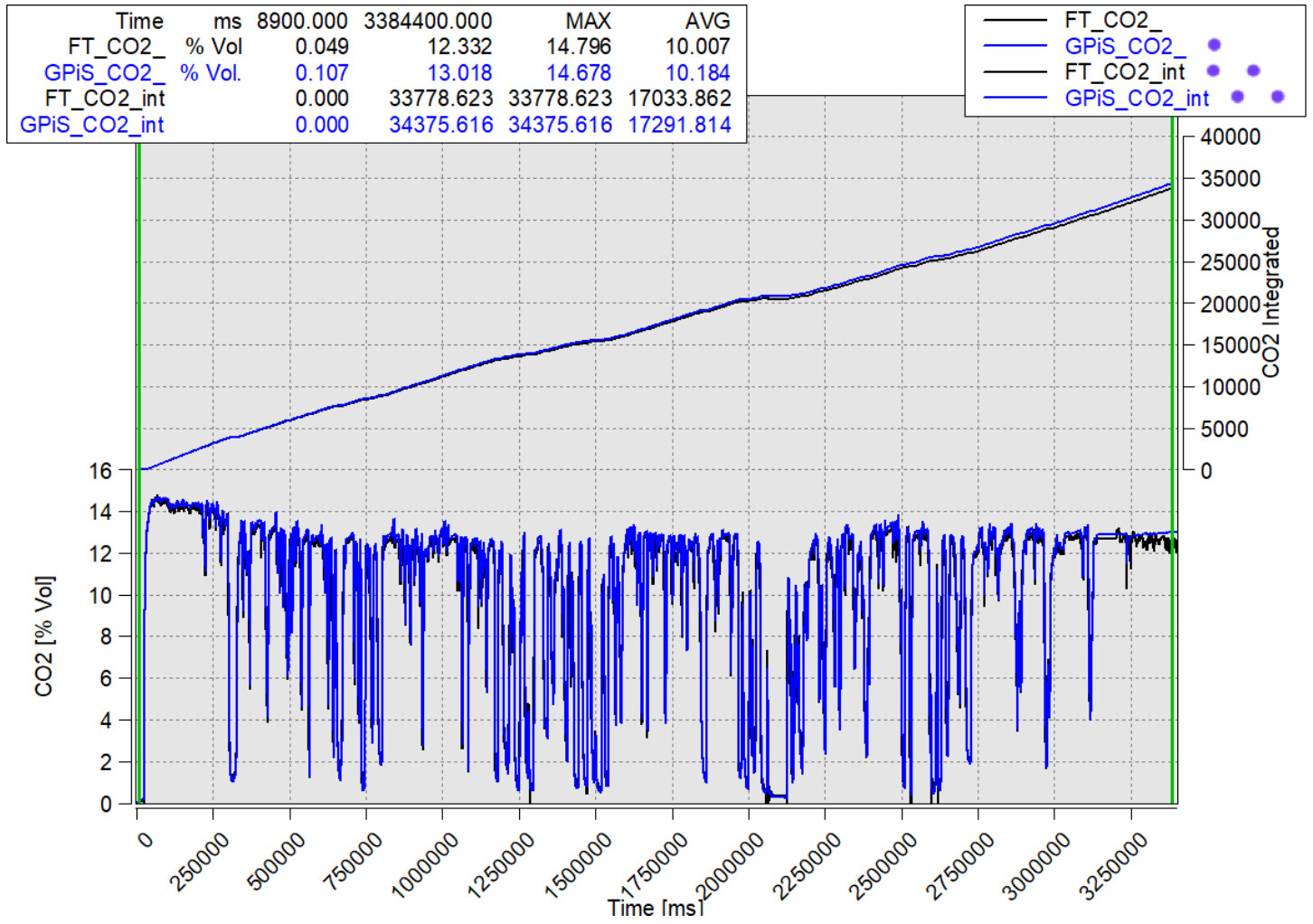
- **Relative Differences:**
  - $\Delta_{M.O.V.E}$ **= -1.50%**

Oxides of Nitrogen (NOx)



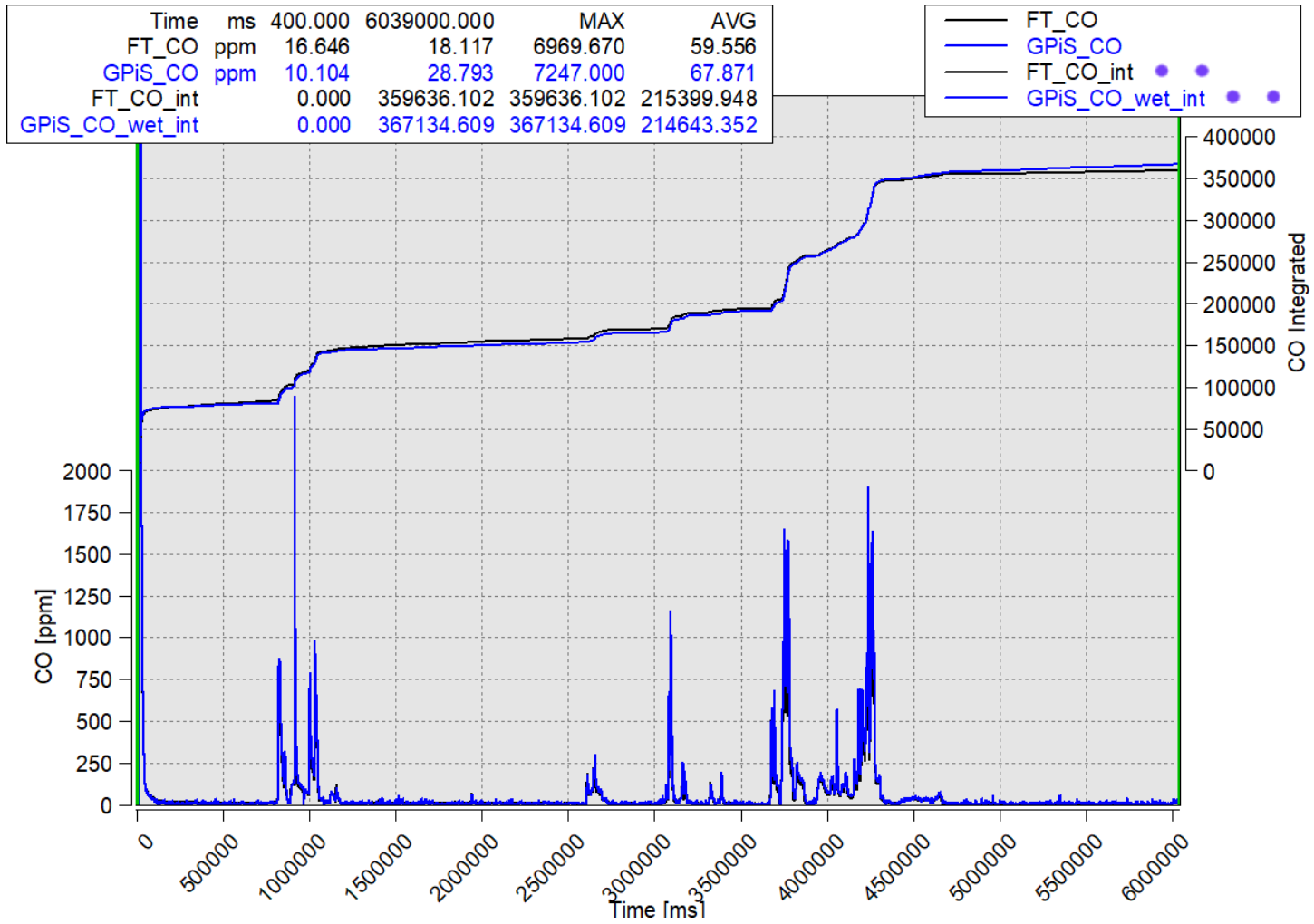
- **Relative Differences:**
  - $\Delta_{M.O.V.E}$ = **-3.77%**

Carbon Dioxide (CO_2)



- **Relative Differences:**
  - $\Delta_{M.O.V.E}$ = **-1.74%**

Carbon Monoxide (CO)



- **Relative Differences:**
  - $\Delta_{M.O.V.E}$ = **-2.04%**

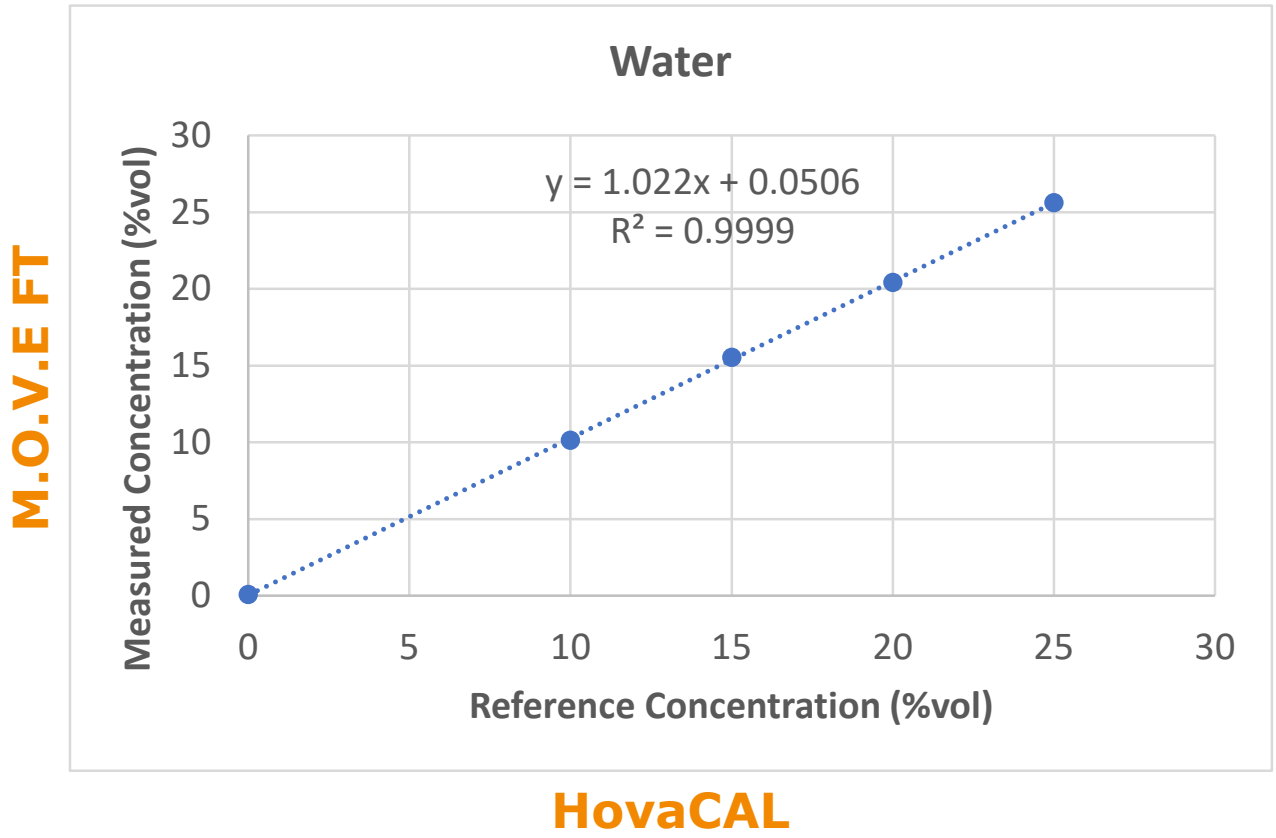
In-Vehicle (RDE) Testing Findings

	Rel Δ	M.O.V.E Detector
	M.O.V.E	
NH_3	-3.15%	TDLAS
CH_4	-1.50%	HFID
NOx	-3.77%	NDUV
CO_2	-1.74%	NDIR
CO	-2.04%	NDIR

- The M.O.V.E FT correlates well with the conventional M.O.V.E analyzers with all species being <4% relative difference
- There appears to be a negative bias which can be investigated further for reproducibility

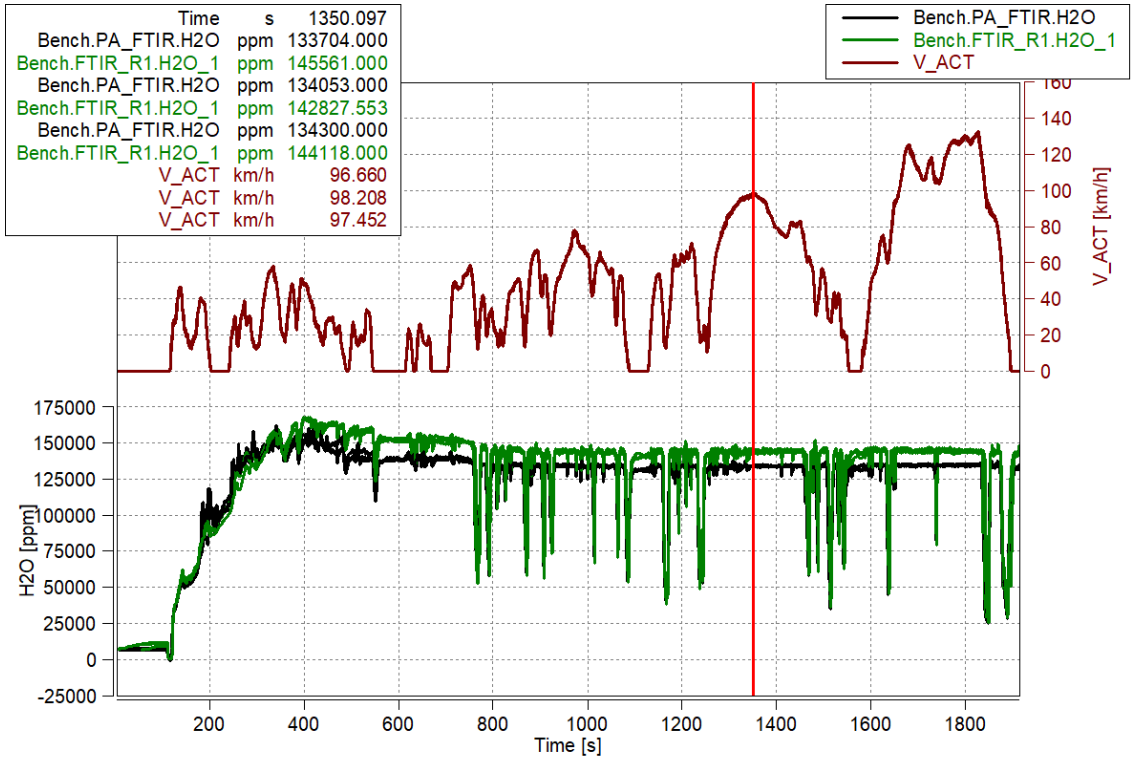
What about H_2O?

Water (H_2O) – Bench Experiment

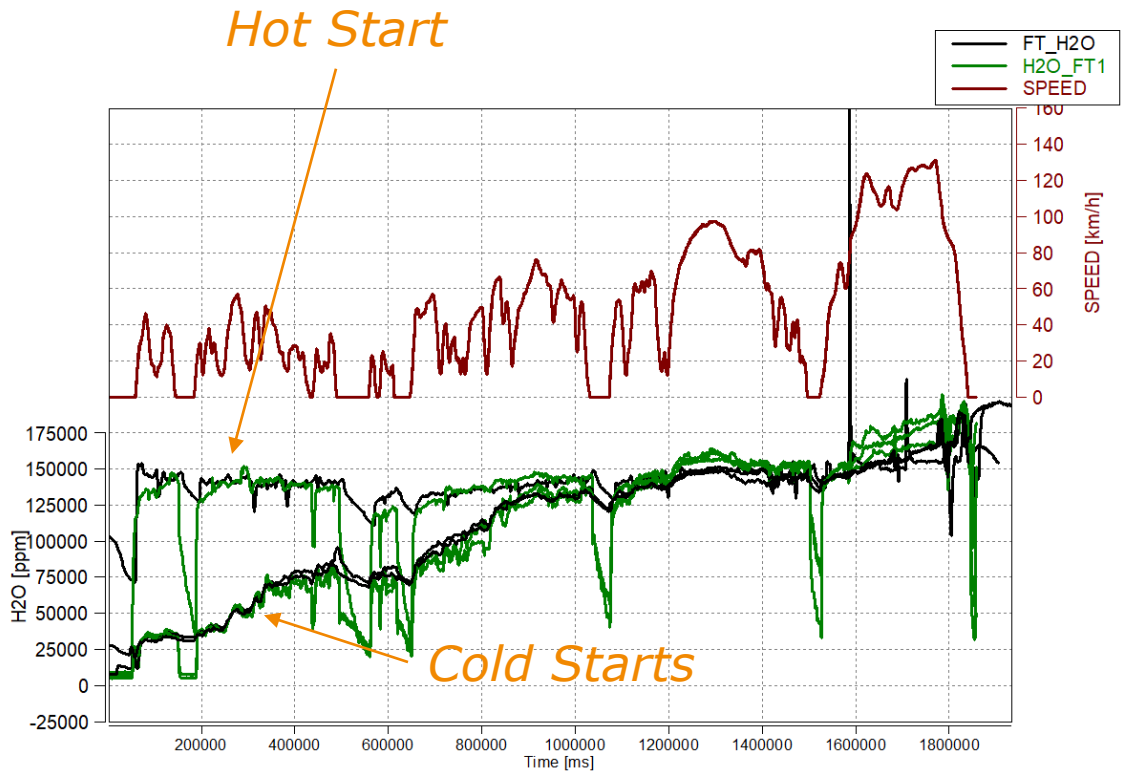


- Driven by current in H_2 ICE, we will continue to investigate correlation between the M.O.V.E FT H2O measurement and the reference HovaCAL

Water (H_2O) over Cold Start WLTC Tests

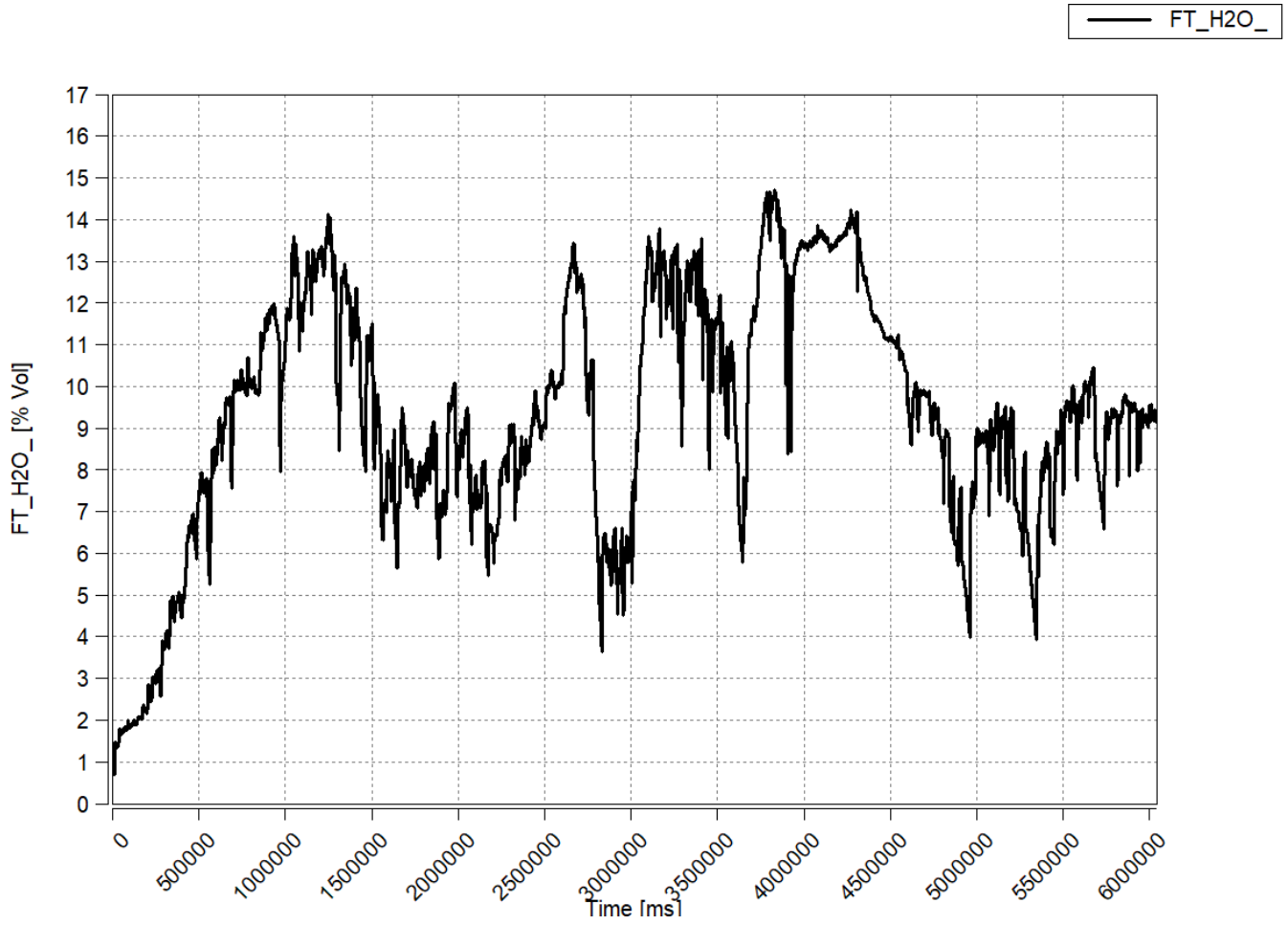


Laboratory A Results



Laboratory B Results

Water (H_2O) over RDE Test



Conclusions and Recommendations

Conclusions and Recommendations

- The AVL M.O.V.E FT performed well as a measurement instrument in both laboratory (chassis dynamometer) and real-world, in-vehicle (RDE) environments
  - At low concentrations where relative comparisons can be misleading, the instrument performs well when considering the available range of the measured constituent

- The portable system is lightweight and user-friendly without the need for on-board gases

- The H_2O measured by the M.O.V.E FT compares well to the laboratory SESAM FTIR giving confidence to future in-use testing (potentially) of non-carbon containing fuels where H2O measurement is crucial

- Additional data collection (both laboratory and real-world) from exhaust from a variety of fuel types (e.g., diesel, CNG, H2, and blends) may pursue qualification the M.O.V.E FT as an alternative measurement device for in-use emissions measurement

Thank you

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