Continental
The Future in Motion

# Investigations on the CV Chassis Dynamometer

EMITEC

Powertrain Division

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# Background

- The results described here, are based on the work performed under the dynaCERT Inc. purchase order.
- The intention of the company dynaCERT Inc. was to demonstrate that the use of the dynaCERT HydraGEN system has no, respectively a positive impact on emission performance and fuel consumption of a commercial vehicle with the aim of obtaining an official operating permit (ABE).
- For this purpose, a MAN TGX vehicle was investigated in series configuration and equipped with a dynoCert HydroGEN system on a commercial vehicle chassis dynamometer.
- Following measurements with each of the variants described above were carried out:
  - Full Load curve (according to UN R.49WHSC)
  - Stationary test according to WHSC (World Harmonized Stationary Cycle ) and
  - Transient test according to WHTC (World Harmonized Transient Cycle)
  - Vibration measurement at full load and part load

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# Task and Boundary Conditions

- Objective:
  - Demonstration that the dynaCERT HydraGEN system has no respectively a positive impact on the emission and fuel consumption of a commercial vehicle
- Vehicle under investigation:
  - MAN TGX tractor, 338 kW engine power, 18.000 kg gross vehicle weight
- Variants:
  - Series vehicle configuration (as delievered) (test session 1)
  - Vehicle equipped with dynaCERT HydraGEN system (test session 2)
- Driving cycles considered:
    - Full Load curve (corresponding with UN R.49WHSC)
    - Stationary Test corresponding with WHSC and
    - Transient Test corresponding with WHTC
    - Vibration measurement at full load and part load

# Summary

- Test session 1 – vehicle in series configuration – and test session 2 – vehicle equipped with HydraGen system - were successfully carried out
- With HydraGEN system the EURO VI emission limits were met. Detailed results are shown in the following slides
- The base requirement for the ABE – no emission and fuel consumption deterioration was demonstrated successfully.
- The results of the vibration measurements show a slightly higher vibration load during session 2. This is within the bandwidth of normal engine vibration behavior and is not noticeable to the driver.

# Conclusions

- Comparing the two test sessions
  - A reproducible reduction of NOx Emission and
  - fuel consumption

  was detected during all test cycles for session 2 (vehicle equipped with HydraGen system).
- In accordance with the measurement task, only a limited number of additional variables describing the engine operation could be measured in addition to the measured values relevant for the exhaust emission. Access to engine control data was not possible.
- However, it became obvious, that the engine changed its operation characteristic at the same performance between the two sessions.
- Whether the change in engine operation affected fuel consumption and emissions, and how much the HydraGen system caused the engine to change, could not be conclusively quantified in these studies.

# WHSC

| System Configuration | - | **Orginal** | **with HydraGen** |
|---|---|---|---|
| Date of Measurement | - | 13.06.2018 | 17.07.2018 |
| Test no. | - | 23 | 39 |
| Test Cycle | - | WHSC | WHSC |
| THC | g/kWh | 0.0046 | 0.0022 |
| CO | g/kWh | 0.0010 | 0.0079 |
| NOx | g/kWh | 0.0876 | 0.0283 |
| CO2 | g/kWh | 559.9 | 518.3 |
| Ammonia | ppm | 4.7256 | 3.8746 |
| Particulate Matter | g/kwh | 0.0011 | 0.0005 |
| Particle number | p/kWh*$10^{11}$ | 4.4648 | 1.1484 |
| Fuel Consumption | g/kWh | 188.5 | 173.8 |

# WNTE

| System Configuration | - | **Orginal** | **with HydraGen** |
|---|---|---|---|
| Date of Measurement | - | 13.06.2018 | |
| Test no. | - | 24 | 40 |
| Test Cycle | - | WNTE | WNTE |
| THC | g/kWh | 0.0015 | 0.0010 |
| CO | g/kWh | 0.0000 | 0.0022 |
| NOx | g/kWh | 0.0633 | 0.0071 |
| CO2 | g/kWh | 532.1 | 485.2 |
| Ammonia | ppm | 1.7311 | 2.8237 |
| Particulate Matter | g/kwh | 0.0009 | 0.0009 |
| Particle number | p/kWh*$10^{11}$ | 3.1395 | 0.9639 |
| Fuel Consumption | g/kWh | 178.7 | 162.8 |

# WHTC

| System Configuration | - | Original | | | with HydraGen | | |
|---|---|---|---|---|---|---|---|
| Date of Measurement | - | 14.06.2018 | 14.06.2018 | 14.06.2018 | 17.07.2018 | 17.07.2018 | 17.07.2018 |
| Test no. | - | 26 | 27 | | 37 | 38 | |
| Test Cycle | - | cold | hot | Total | cold | hot | Total |
| Weighting factor | - | 0.14 | 0.86 | - | 0.14 | 0.86 | - |
| THC | g/kWh | 0.007867 | 0.002471 | 0.00322644 | 0.006624 | 0.004422 | 0.00473028 |
| CO | g/kWh | 0.089161 | 0.015228 | 0.02557862 | 0.04928 | 0.013632 | 0.01862272 |
| NOx | g/kWh | 0.603154 | 0.056122 | 0.13270648 | 0.487336 | 0.031765 | 0.09554494 |
| CO2 | g/kWh | 603.3187 | 585.4682 | 587.96727 | 559.6342 | 542.635 | 545.014888 |
| Ammonia | ppm | 0.516389 | 0.472988 | 0.4791 | 0.320242 | 0.190114 | 0.20833192 |
| Particulate Matter | g/kwh | 0.0015 | 0.0015 | 0.0015 | 0.0015 | 0.0015 | 0.0015 |
| Particle number | p/kWh*$10^{11}$ | 248.6995 | 8.807838 | 42.3927 | 5.950978 | 1.448322 | 2.07869384 |
| Fuel Consumption | g/kWh | 208.7005 | 203.0532 | 203.843822 | 194.7669 | 189.1959 | 189.97584 |

| System Configuration | - | Original | | | with HydraGen | | |
|---|---|---|---|---|---|---|---|
| Date of Measurement | - | 14.06.2018 | 14.06.2018 | 14.06.2018 | 18.07.2018 | 18.07.2018 | 18.07.2018 |
| Test no. | - | 26 | 27 | | 42 | 43 | |
| Test Cycle | - | cold | hot | Total | cold | hot | Total |
| Weighting factor | - | 0.14 | 0.86 | - | 0.14 | 0.86 | Gesamt |
| THC | g/kWh | 0.007867 | 0.002471 | 0.00322644 | 0.003052 | 0.001114 | 0.00138532 |
| CO | g/kWh | 0.089161 | 0.015228 | 0.02557862 | 0.044265 | 0.01809 | 0.0217545 |
| NOx | g/kWh | 0.603154 | 0.056122 | 0.13270648 | 0.598463 | 0.044372 | 0.12194474 |
| CO2 | g/kWh | 603.3187 | 585.4682 | 587.96727 | 546.4386 | 529.0187 | 531.457486 |
| Ammonia | ppm | 0.516389 | 0.472988 | 0.4791 | 0.641249 | 0.250808 | 0.30546974 |
| Particulate Matter | g/kwh | 0.0015 | 0.0015 | 0.0015 | 0.0011 | 0.0006 | 0.00067 |
| Particle number | p/kWh*$10^{11}$ | 248.6995 | 8.807838 | 42.3927 | 26.06366 | 0.258675 | 3.8713729 |
| Fuel Consumption | g/kWh | 208.7005 | 203.0532 | 203.843822 | 191.1531 | 185.4914 | 186.284038 |

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# Commercial Vehicle Chassis Dynamometer AVL- Zoellner

- 72“ AWD HD Chassis Dynamometer
- Power: 450 kW (max. 600 kW)
  - Max. velocity: 160 km/h
  - Max. axle load: 20.000 kg
  - Traction force: 25.000N (max. 37.500 N)
  - Axle distance between 2.7 m and 8.0 m
  - Two driven axles selectable

# Chassis Dynamometer Automation System and conventional Measuring Equipment

- Automation system: Siemens CATs NT including driver‘s aid
- Exhaust measuring system HORIBA Mexa-7100 for CO, $CO_2$, $O_2$, HC, NO, $NO_2$ and $CH_4$
- Exhaust mass sensor **SEMTECH EFM-HS** (High Speed Exhaust Flow Meter)
- Option: Partial dilution system Control Sistem PSS20 with 3 filter lines for particulate mass

# Exhaust Mass and Fuel Consumption Measurement

1. Exhaust mass measurement with **SEMTECH EFM-HS** Sensor (high speed exhaust flow meter) with AK-interface
2. Air-fuel equivalence ratio (λ) measurement with **ETAS lambdameter LA4_E**, analog signal
3. Fuel consumption via carbon balance based on emission concentration measurement with **HORIBA Mexa-7100** and exhaust mass measurement with **SEMTECH EFM-HS**


# Exhaust Mass Flow Measurement

Exhaust mass sensor **SEMTECH EFM-HS** (high speed exhaust flow meter) with AK-interface

Source: www.sensors-inc.com

## Theory of Operation

Mass flow determination via Bernoulli and continuity equation

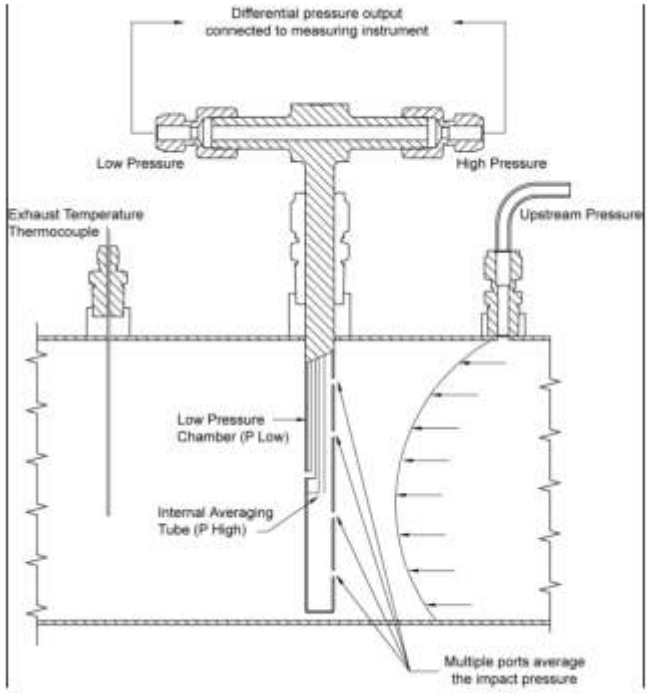
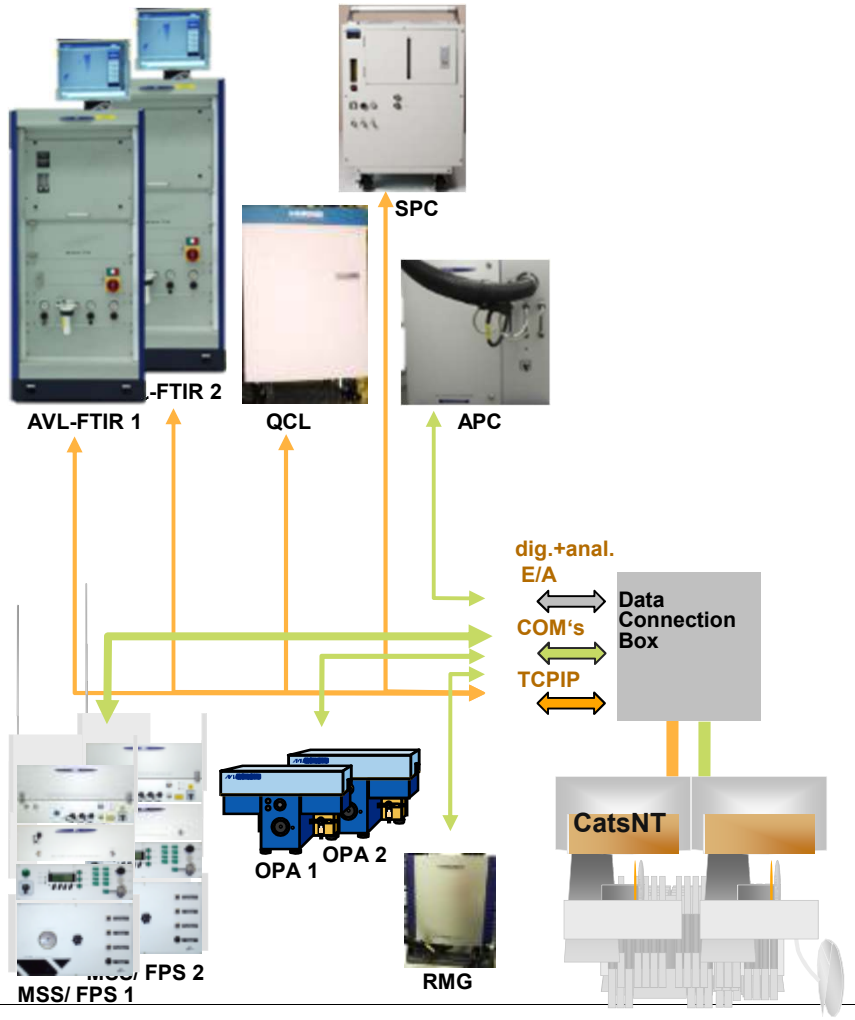



**Figure A.1 Example of Averaging Pitot Tube Cross Section**

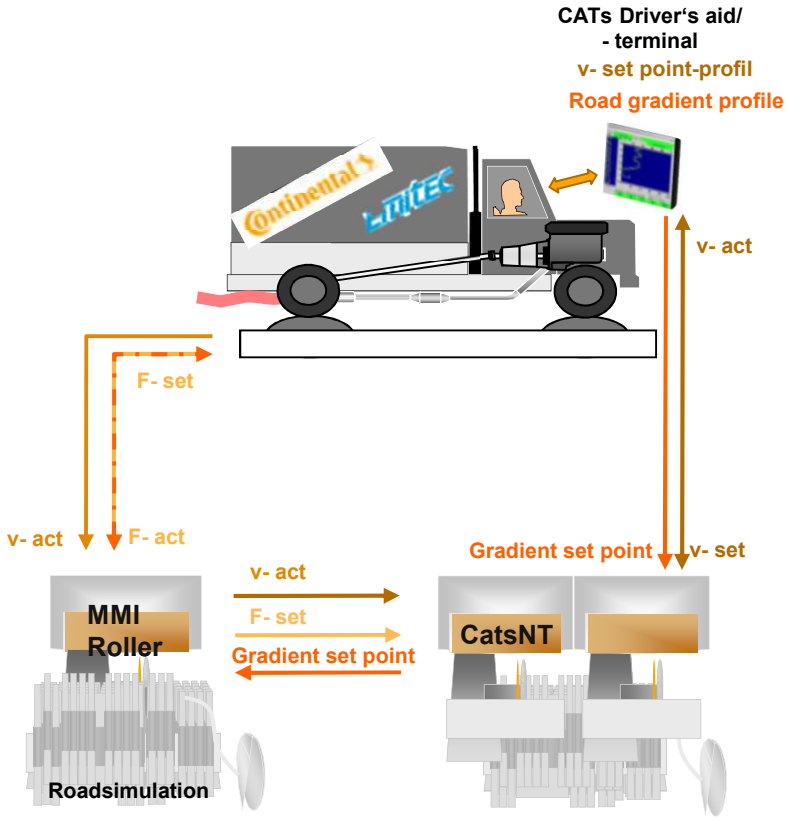
# Commercial Vehicle Chassis Dynamometer
# Optional Exhaust Measuring Equipment

- Simultaneous measurement of multiple gaseous species
  2x SESAM FTIR (AVL)
- Simultaneous measurement of $NO$, $NO_2$, $N_2O$, $NH_3$
  1x Horiba Mexa-1400QCL-NX
- Measurement of Particle number
  1x AVL APC 489
  1x Horiba SPCS 2100
- Measurement of Soot (transient)
  2x Micro Soot Sensor 483 (AVL, with dilution system FPS 400, Dekati)
- Measurement of opacity
  2x AVL opacimeter 439
- Measurement of Soot (steady state)
  1x smokemeter 415S (AVL)



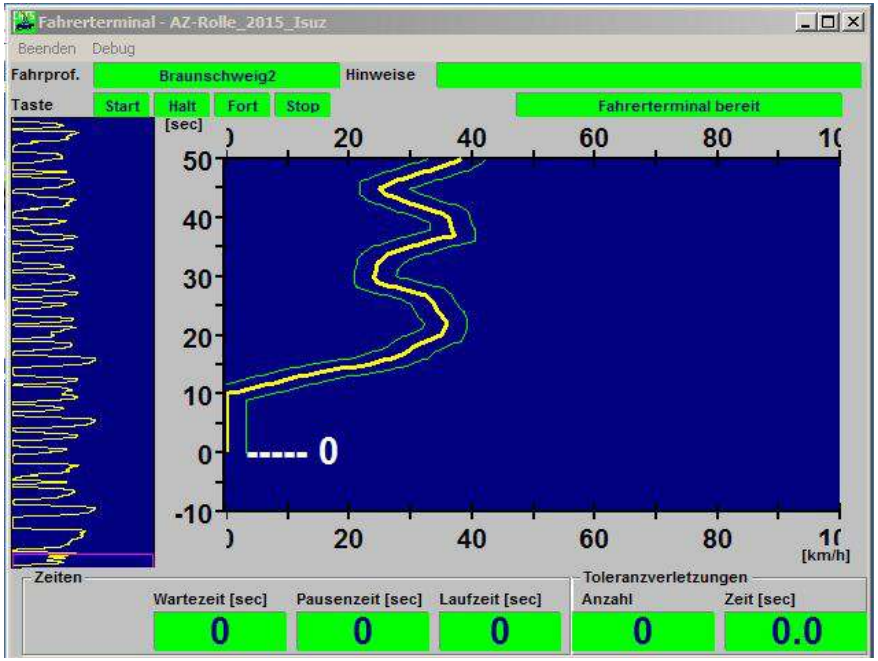
# Commercial Vehicle Chassis Dynamometer Operation Modes – Extended

- **Road simulation/ velocity profile** (standard)
  - Set-speed  profile on driver monitor, (speed curve with tolerance band)
  - By means of road coefficients the roller bench simulates and controls the load resp. traction force depending on the speed
- **Road simulation/ velocity profile and road gradient profile** (extended)
  - Road gradient profile parallel to the speed profile on driver monitor
  - Continuously sending via AK as set value to the MMI
  - MMI changes the load according to the speed and the gradient value



# Driver‘s Aid – Velocity Cycles

- **Velocity cycles are freely programmable** (standard)
  - Braunschweig cycle
  - FIGE cycle
  - WHVC
  - SORT 1,2,3
  - HBEFA
  - TNO cycle „urban“, “rural“, “motorway“
  - JE05 speed cycle
  - Tokyo mode  n° 2, 5 and 10
  - ….
- **Generated velocity cycles (extended)**
  - **E. g. Braunschweig cycle with gradient** to optimize ECU calibration regarding fuel consumption



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# Technical Data Vehicle

| Topic | Details |
|---|---|
| Commercial designation | TGX  Tractor |
| Manufacturer | MAN TRUCK & BUS |
| Licence Platte | ROW RY 806 |
| FIN-No. | WMA06XZZ2JP100928 |
| Emission Class | EURO VI; C; M; N |
| Fuel | Diesel |
| Power | 338 kW @ 1800 rpm |
| Displacement | 12419 ccm |
| Length | 5983 mm |
| Width | 2500 mm |
| Heigth | 3877 mm |
| maximum weight allowed | 18000 kg |
| EC type-approval number | e4*2007/5*0229*28 |


# dynaCERT HydraGEN HG1-45B Specification

## SUITABLE FOR

Turbo Engine: 10-15L

- POWER GENERATION
- DELIVERY TRUCKS
- OFF-ROAD CONSTRUCTION
- RAIL TRANSPORTATION
- MARINE APLICATIONS

## FEATURES & BENEFITS

REDUCTION IN FUEL CONSUMPTION BY 6%-19.2%*

*6% certified by PIT Group, 19.2% from performance testing at UOIT

REDUCES GREENHOUSE GASES THAT ARE PRODUCED

REDUCES $NO_X$ UP TO 46.1% | $CO_2$ UP TO 19.2% | CO UP TO 51% | THC UP TO 50.1%

REDUCES PARTICULATE MATTER BY OVER 65%

LONGER ENGINE LIFE

INCREASED POWER AND TORQUE

LONGER OIL LIFE +25%

REDUCTION OF DPF BY 33%

REDUCTION OF DEF USAGE BY 60%

## TECHNICAL DATA

| | |
|---|---|
| HG1 Engine: | 4.5L |
| Current: | 15-20A at 12VDC |
| | 7.5-10A at 24VDC |
| Power Usage: | 180-240W |
| Electrical Supply: | 12VDC / 24VDC |
| Water Reservoir: | 6.2L |
| KOH: | 4.5L |
| Communication: | GPRS, Bluetooth, (GPS in future) |

## WEIGHT / DIMENSIONS

| | |
|---|---|
| Unit size (h x w x d): | 24" x 20" x 10" |
| Unit weight: | 50 lbs |
| Carton size: | 29" x 22.5" x 19.5" |
| Carton weight: | 74 lbs (includes installation package) |
| Unit size (h x w x d): | 61 x 51 x 25 cm |
| Unit weight: | 23 kg |
| Carton size: | 74 x 57 x 50 cm |
| Carton weight: | 33.5 kg (includes installation package) |
| Units per pallet: | 6 |

Source: https://fs.go.iopw.com/FileServer/sites/169/spec-sheets/AUGUST2018/HG1_45B_Spec_Sheet_16AUG2018.pdf