Ultra-low on-road NOx emissions of a 48V mild-hybrid diesel with LNT and dual-SCR

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RDE legislation has improved real-world NOx emissions

RDE requirements ensure that emissions are controlled over wider range of conditions.
RDE legislation has improved real-world NOx emissions

On-road emissions of Euro 6d-Temp cars are well within standards

Source: PEMS results from ACEA and JAMA RDE database
Objective: demonstrate consistent low NOx emissions

- Challenging driving conditions
  - Low speed/load
    e.g. city driving
  - High speed/load
    e.g. motorway driving
  - Transients
    e.g. overtaking
Content

- Demonstrator concept
  - Emissions control technologies combined in integrated approach
  - 48V mild-hybrid to support emissions control
- Emissions tests conducted
- Tailpipe NOx and deNOx efficiency
  - RDE
  - City
  - Motorway
- Conclusions
Vehicle and powertrain characteristics

Vehicle
- C-segment
- 1700 kg

Drivetrain
- Manual gearbox, 6-speed
- 48 Volt mild-hybrid (belt-driven, P0)

Engine
- 1.5l, 4-cylinder, 2-valve
- EGR: uncooled HP and cooled LP

Euro 6b type approval (LNT + DPF)
Emissions control technologies

- LNT + dual-SCR to cover wide range of driving conditions
- Model-based SCR control

EGR: Exhaust Gas Recirculation
HP/LP: High/Low pressure
c: close-coupled
LNT: Lean NOx trap
SCR: Selective Catalytic Reduction
DPF: Diesel Particulate Filter
SDPF: SCR on DPF
uf: underfloor
ASC: Ammonia Slip Catalyst
Emissions control technologies

Components in close-coupled position

Urea mixing section

LNT

SCR

SDPF

Mixing section will also be insulated

Insulation

gas flow
To stabilise LNT regeneration during city driving

- Constant load increase in case of low load conditions
- Transient load compensation in case of unstable driver request

- To cut transient engine-out NOx peaks
- To support active thermal management
  - In addition to late post-injection in ICE when LNT>170°C & ccSCR<220°C
  - Throttle valve used when LNT<170°C
Combination of emissions tests on the road and in the lab

- **RDE**

- **City**

- **Motorway**

Typical SCR light-off temperature
8-40 mg/km achieved on RDE

- 90-96% deNOx efficiency
- No impact of ambient temperature

Results at end of programme with refined calibration
All aftertreatment components contribute to NOx control

- City driving: LNT and close coupled SCR+SDPF
- Motorway driving: underfloor SCR required to secure robust emissions control
Robust NOx control in the city, including cold-start

- LNT regeneration enabled at low load
- Active thermal management to ensure early heat-up
  - Active throughout entire TfL test
  - Typical light-off temperature reached within 300s after cold-start (800s gained)

Thermal management:
- Initial calibration: not active
- Refined calibration: active
24-47 mg/km NOx in the city

- Including challenging Berlin and Transport for London (TfL) tests
- TfL NOx: 80% improvement due to LNT regeneration stabilisation and active thermal management
Ultra-low NOx achieved with low impact on CO₂

- Impact of thermal management implemented
  - CO₂ increase on WLTC and RDE < 3%
- Other technologies are under development for thermal management with minimal CO₂ impact
  - Variable Valve Train (VVT) [1-2]
  - Electrically heated catalyst [3-4]
  - Fuel injection rate shaping [5]
  - P2 / P3 / P4 Hybridisation [6]

3-63 mg/km on the motorway

- 95-99% deNOx efficiency
- Main deNOx by dual-SCR
- Challenge is increase in engine-out emissions
Tailpipe NOx and deNOx efficiency summary

![Graph showing NOx emissions and deNOx efficiency vs. average vehicle speed]

- Euro 6d-temp Not-to-Exceed limit
- Euro 6d Not-to-Exceed limit

Legend:
- TFL
- Berlin
- RDE urban
- WLTC
- RDE total
- Motorway test
- NEDC
- ADAC BAB130

**Average vehicle speed in km/h**

**NOx in mg/km**

**EAT deNOx in %**
Conclusions

- RDE requirements have ensured better control of NOx emissions under most EU driving conditions – these Euro 6d-temp cars are on the road today.

- This demo car shows that diesel NOx emissions can be kept at a very low level in a consistent way, over a wide range of driving conditions.

- Tailpipe NOx measured are 24-47 mg/km in the city and 3-63 mg/km on the motorway.

- This is achieved by combining existing catalyst technologies with improved emissions control functions supported by hybrid technology.
THANK YOU!

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