23rd ETH-Conference on Combustion Generated Nanoparticles

June 17th-20th, 2019
ETH Zurich, Switzerland

KNUT
KOREA NATIONAL UNIVERSITY OF TRANSPORTATION

# Emissions characteristics for data analysis methods of Light-Duty vehicle on Real Diving Emissions Test


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## RDE-LDV Timeline

Source : "The European Commission's science and knowledge service", Joint Research Centre, European Commission

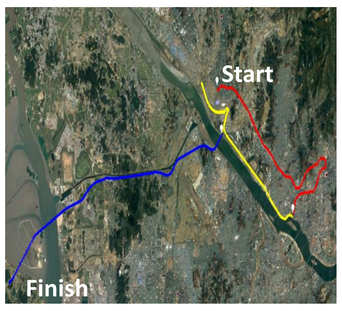
| 2011 | 2014 | May 2015 | Oct 2015 | Jan 2016 | Dec 2016 | 2017 |
|---|---|---|---|---|---|---|
| RDE-LDV Working Group (kick off) | RDE data evaluation methods assessment | 1st proposal of RDE test procedure adoption | 2nd proposal of RDE test procedure adoption | Reporting and monitoring test | 3rd proposal of RDE test procedure adoption | 4th proposal of RDE test procedure |

- RDE 1st package (Reg. 2016/427) : test procedures, instrumentation requirements, evaluation method
- RDE 2nd package (Reg. 2016/646) : complementary boundary conditions, conformity factors
- RDE 3rd package (Reg. 2017/1154) : extended condition, PEMS PN, cold start, regeneration
- RDE 4th package : In-service conformity, method revision

## Test vehicles

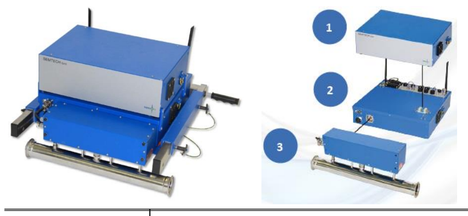
| NO | Vehicle type | Model year | Max. Power [hp] | Disp. [cc] | After-treatment | Emission limit |
|---|---|---|---|---|---|---|
| Veh. 01 | Small SUV | 2015 | 89 hp | 1,500 cc | LNT + DPF | Euro 6 |
| Veh. 02 | SUV | 2015 | 199 hp | 2,200 cc | LNT + DPF | Euro 6 |
| Veh. 03 | Small SUV | 2015 | 113 hp | 1,600 cc | LNT + DPF | Euro 6 |
| Veh. 04 | Small SUV | 2015 | 133 hp | 1,600 cc | LNT + DPF | Euro 6 |
| Veh. 05 | SUV | 2016 | 129 hp | 1,600 cc | LNT + DPF | Euro 6 |
| Veh. 06 | Passenger car | 2016 | 139 hp | 1,700 cc | LNT + DPF | Euro 6 |
| Veh. 07 | SUV | 2016 | 183 hp | 2,000 cc | LNT + DPF | Euro 6 |
| Veh. 08 | SUV | 2016 | 180 hp | 2,400 cc | LNT + DPF | Euro 6 |
| Veh. 09 | Passenger car | 2015 | 187 hp | 2,000 cc | DPF + SCR | Euro 6 |
| Veh. 10 | Passenger car | 2015 | 168 hp | 2,100 cc | DPF + SCR | Euro 6 |
| Veh. 11 | SUV | 2015 | 246 hp | 3,000 cc | DPF + SCR | Euro 6 |
| Veh. 12 | Small SUV | 2016 | 118 hp | 1,600 cc | DPF + SCR | Euro 6 |
| Veh. 13 | SUV | 2016 | 177 hp | 2,000 cc | DPF + SCR | Euro 6 |
| Veh. 14 | Passenger car | 2016 | 271 hp | 3,000 cc | DPF + SCR | Euro 6 |
| Veh. 15 | SUV | 2017 | 168 hp | 2,000 cc | DPF + SCR | Euro 6 |
| Veh. 16 | SUV | 2017 | 256 hp | 3,000 cc | DPF + SCR | Euro 6 |
| Veh. 17 | SUV | 2018 | 187 hp | 2,000 cc | DPF + SCR | Euro 6d-temp |
| Veh. 18 | Passenger car | 2017 | 187 hp | 2,000 cc | LNT + DPF + SCR | Euro 6 |
| Veh. 19 | SUV | 2018 | 186 hp | 2,000 cc | LNT + DPF + SCR | Euro 6d-temp |
| Veh. 20 | Passenger car | 2018 | 202 hp | 2,200 cc | LNT + DPF + SCR | Euro 6d-temp |

## RDE route




| | Urban | Rural | Motorway | Total |
|---|---|---|---|---|
| Trip distance (Trip share) | 26.5 km (36.0 %) | 19.7 km (26.8 %) | 27.4 km (37.2%) | 73.6 km (100 %) |
| Trip duration | 4,308 sec | 951 sec | 930 sec | 6,188 sec (103.1 min) |
| Avg. vehicle Speed | 22.1 km/h | 74.6 km/h | 106.1 km/h | |

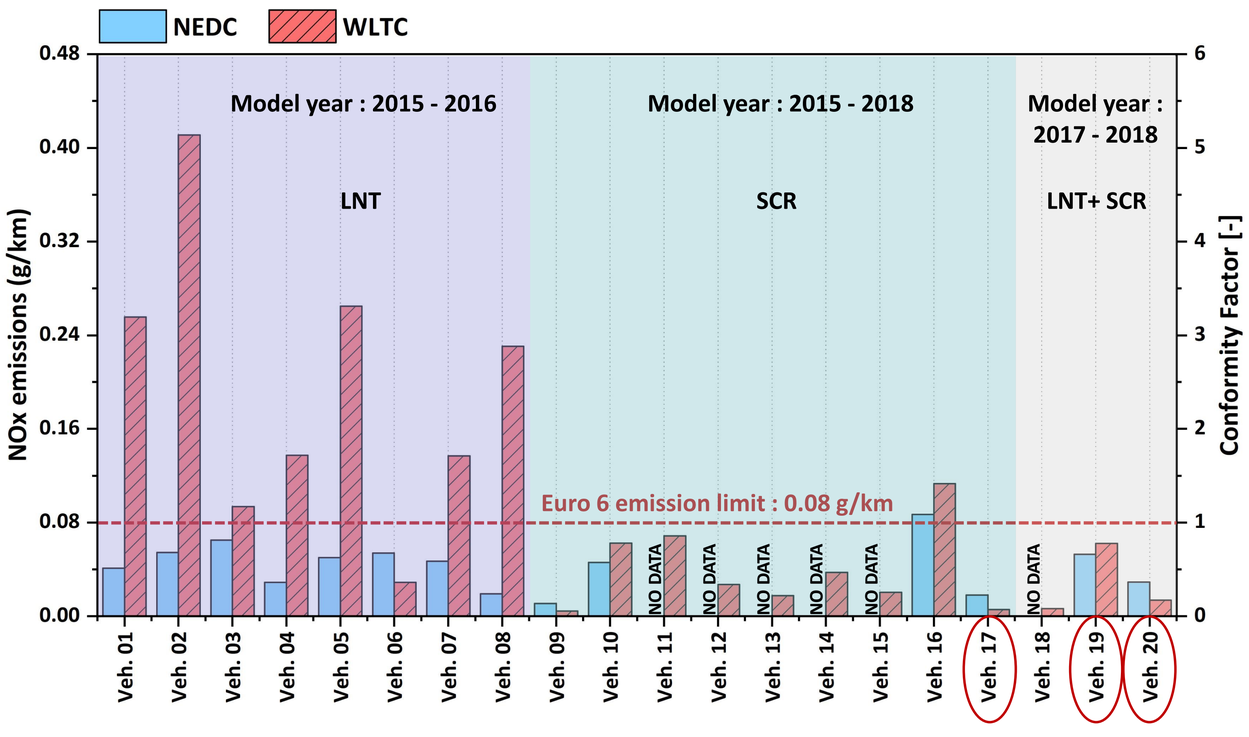
## Test equipment



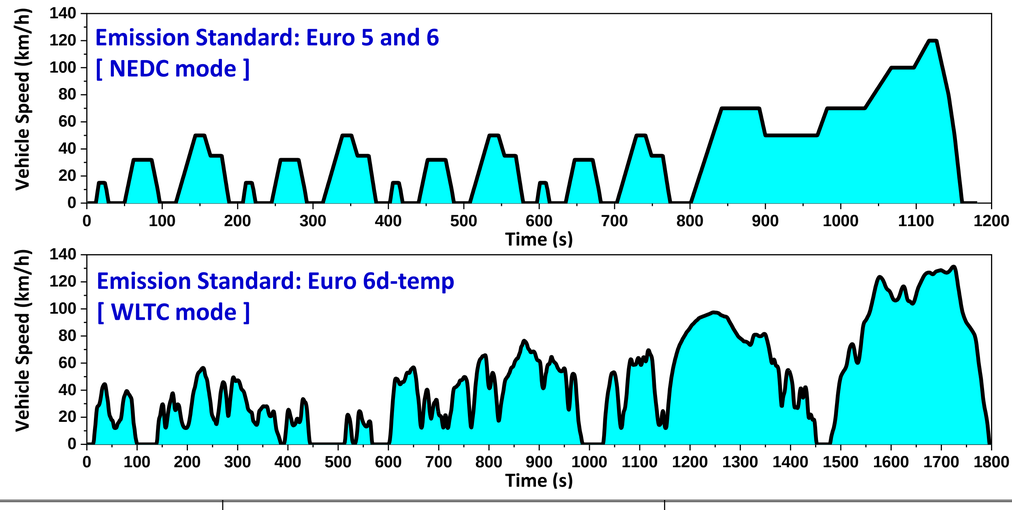

1. SEMTECH – GAS : Gas Analyzer System
2. SEMTECH – SCS : Sample Conditioning System
3. SEMTECH – EFM4 : Exhaust Flow Meter

| | Principle | Range |
|---|---|---|
| CO | Heated NDIR (Non-Dispersive Infrared Detection) | 0 ~ 8 vol. % |
| $CO_2$ | | 0 ~ 18 vol. % |
| NO, NOx | NDUV (Non-Dispersive Ultra Detection) | 0 ~ 3,000 ppm |
| Exhaust flow | Pitot flow meter | 0 ~ 670 kg/h |

## Test results of Chassis dynamometer

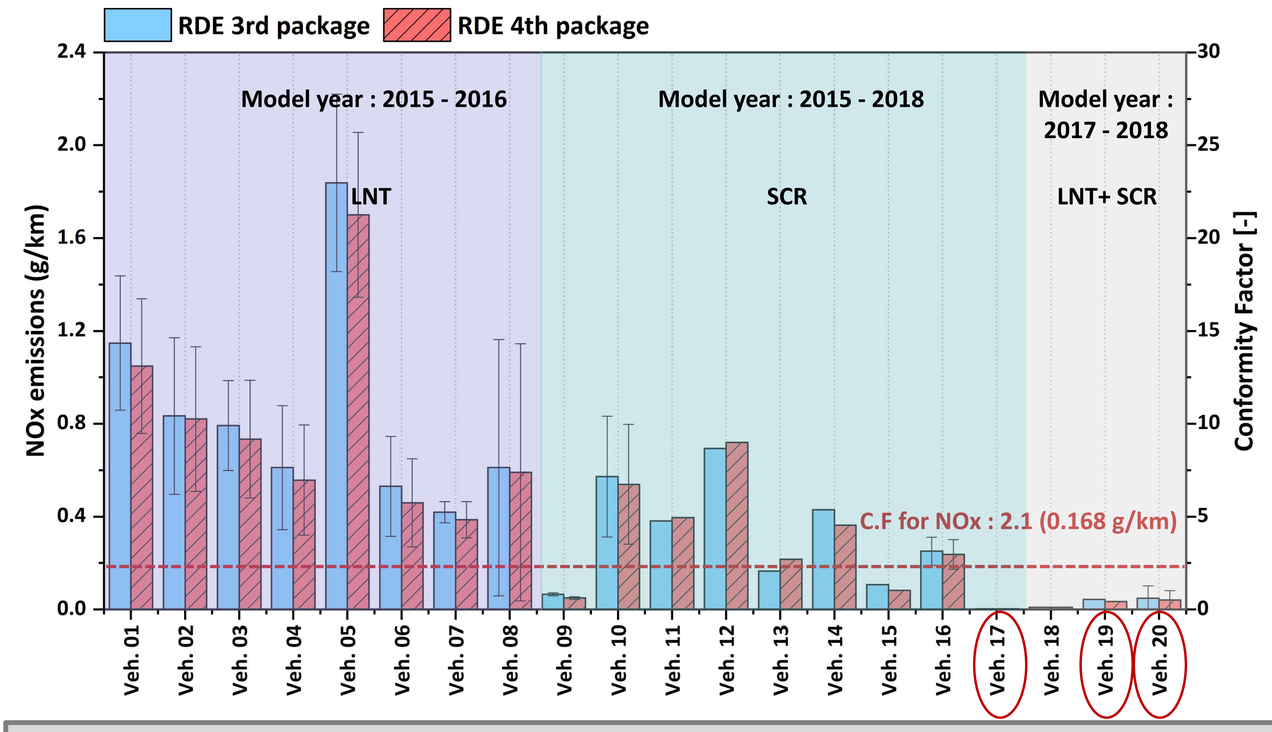



## Chassis dynamometer test cycles

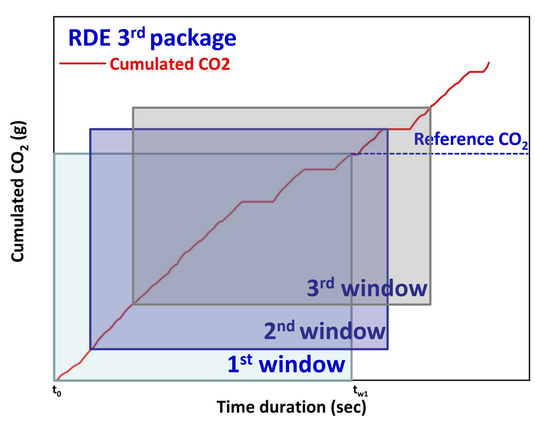


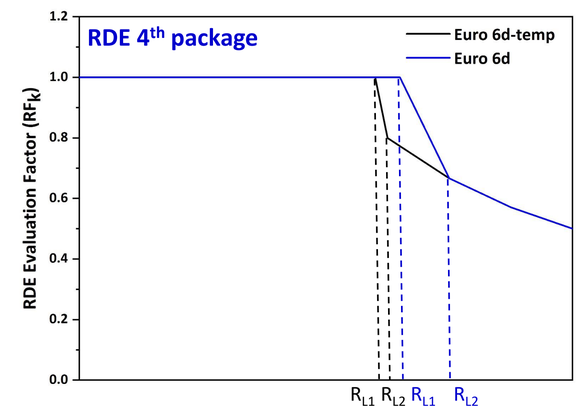

| | NEDC | WLTC |
|---|---|---|
| Time [sec] | 1,180 | 1,800 |
| Distance [km] | 11 | 23.25 |
| Idle Time [%] | 25 | 13 |
| Speed [km/h] | Avg. 23, Max. 120 | Avg. 46.5, Max. 131 |

## Test results of RDE route




## Comparison of Data methods (RDE 3rd package and 4th package)




[ Euro 6d-temp ]
$R_{L1}$=1.20
$R_{L2}$=1.25

[ Euro 6d ]
$R_{L1}$=1.30
$R_{L2}$=1.50

$$NOx_{win} = \frac{Nox_{win}(g/window)}{mileage_{win}(km/window)}$$

$$CO_{2win} = \frac{CO_{2win}(g/window)}{mileage_{win}(km/window)}$$

$$M_{RDE,k} = m_{RDE,k}.R_k \text{ (k=t=total, k=u=urban)}$$

$$r_k = \frac{m_{CO_2,RDE,k}}{m_{CO_2,WLTP,k}}$$

| | |
|---|---|
| $r_k \le R_{L1}$ | $R_k = 1$ |
| $R_{L1} < r_k \le R_{L2}$ | $R_k = a_1 r_k + b_1$, $a_1 = \frac{R_{L2}-1}{[RL_2(R_{L1}-RL_2)]}$, $b_1 = 1 - a_1 R_{L1}$ |
| $R_{L2} < r_k$ | $R_k = 1 / r_k$ |

## Summary

- High performance by combination of LNT, SCR with urea injection(Veh.18 – 20) and Almost, test vehicles with SCR system(Veh.09 – 17) were satisfied with Euro 6 emission limit. This suggests that an SCR system using urea injection strategy is essential to meet the strengthening emission regulations.
- The evaluation methods between RDE 3rd package and RDE 4th package have error within 10% in vehicle equipped with LNT system(Veh. 01 - 08). But, both vehicles equipped with LNT, SCR and vehicles equipped with SCR system have error within 30%. Because the SCR uses urea as the reductant to reduce Nox on a catalyst.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※ Acknowledgments
This research was supported by Korea Evaluation Institute of Industrial Technology(20002762) in 2019