Pathways for a post-Euro 6 regulation for LDV

What is next?

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March 6th, 2018
Motor Vehicles Emissions group
Euro standard lags behind Tier 3 (US) and soon China 6

- Tier 3 and China 6:
  - Are fuel neutral with a unique set of limits for NO\textsubscript{x} and PN
  - Are technology neutral with a PN limit that includes gasoline indirect injection engines
  - Set lower NO\textsubscript{x} limit than the Euro 6 regulation

See also, ICCT: China's Stage 6 emission standard for new light-duty vehicles (final rule)
The importance of enforcement: NO\textsubscript{x} emissions from diesel cars in Europe have not decreased as expected

Diesel cars: Nitrogen oxide (NO\textsubscript{x}) emissions (in g/km)

Gasoline cars: Nitrogen oxide (NO\textsubscript{x}) emissions (in g/km)

Source: NO\textsubscript{x} emissions from remote-sensing across European cities, CONOX project (ICCT, IVL, BAFU)
NO$_x$ and primary NO$_2$ emissions are contributing to exceed the EU air quality standard for NO$_2$.

- Record of several exceedances of the EU air quality standard for NO$_2$
- Local NO$_2$ concentration matters
- The NO$_2$/NO$_x$ ratio increased with latest diesel technology

We cannot forecast the behavior of future technologies. But an **EU limit on primary NO$_2$ emissions** would set a maximum level and help reducing the local concentration for the most exposed populations.

*Source:* EEA Air quality in Europe – 2015 report
*Source:* “Have vehicle emissions of primary NO$_2$ peaked?” (D. Carslaw, et al.)
Emissions not directly accounted for in EU-LDV standard

Primary NO₂:
- Has a direct effect on local NO₂ concentration levels
- Share of NO₂ is observed to increase:
  - Highest SCR catalyst efficiency is achieved at NO₂/NOₓ ratios of ~50%
  - LNT’s store NOₓ as NO₂ and hence show best efficiency at high NO₂ concentrations
  - Both systems rely on catalytic coating to increase the engine-out NO₂/NOₓ ratio

NH₃:
- Is a precursor to ultra-fine particles
- EU HDV regulation limits emissions to 10 ppm
- Euro 6 vehicles show high NH₃ emissions:
  - Euro 6 TWC’s and operating strategies result in increased NH₃ emissions
  - LNT’s can produce NH₃ during regeneration and cold start
  - SCR catalysts require NH₃ for NOₓ reduction. High conversion efficiency demands can lead to overdosing or dosing at too low temperatures resulting in NH₃ slip

N₂O and CH₄:
- Have a strong global warming potential
- Tier-LEV (US) and China are setting limits or accounting for CO₂ equivalence
- N₂O is formed in oxidation catalysts (TWC, DOC, LNT) and SCR catalysts

See also, JRC’s study: Impact of cold temperature on Euro 6 passenger car emissions, 2018
In-service conformity and durability requirements are too limited compared to average age of the EU fleet.

- Average age of vehicles in EU is 10.7 years old, and more than 16 years old for some EU country (e.g. Poland)*

Emission standards are undermined if emission controls are allowed to rapidly deteriorate.

** Average of 12,000 km/year for the EU as a whole in 2015. Source: EEA
RDE not to exceed limits shall apply to representative city driving distance

Average city driving distance much shorter than RDE urban phase:

<table>
<thead>
<tr>
<th></th>
<th>Average RDE urban part&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Average city trip – Germany&lt;sup&gt;2)&lt;/sup&gt;</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>33 km</td>
<td>10 km</td>
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<tr>
<td></td>
<td>66 min</td>
<td>21 min</td>
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Emissions during representative city driving significantly higher than in RDE urban<sup>1)</sup>:

Source: <sup>1)</sup> ICCT RDE monitoring database  <sup>2)</sup> SrV2013 - Große SrV-Vergleichsstädte
Low temperature type approval test needed (Type 6)

Low temperature type approval test needed:
- High regulated and non-regulated emissions at -7°C reported*
- Can currently only be checked during RDE ISC testing

RDE at low ambient temperature cannot replace Type 6 test:
- RDE currently only limits NO\textsubscript{x} and PN emissions
- PEMS for non-regulated pollutants not available
- Time slots for low temperature ISC tests are small and unpredictable

*JRC*: “Higher emissions of THC, CO, NO\textsubscript{x}, SPN and NH\textsubscript{3} were observed when vehicles were tested at -7°C instead of 23°C…For that reason, (these) vehicular emissions should be addressed in the next revision of the EU legislation of light-duty vehicle emissions at cold temperature for all vehicle technologies”
Additional post-Euro 6 topics

- Covering additional pollutants: PN down to 10 nm, PAHs, aldehydes (e.g. HCHO)
- RDE: wider conditions for testing, higher contribution of the cold start, limits for CO and NO₂, tighter conformity factor, use of raw emissions for reporting
- Application neutral: e.g. emissions limit for M1 and all categories of N1 vehicles should converge
- Enhanced evaporative test (3-day diurnal test, leak test with E10 fuels) including Onboard refueling vapor recovery (ORVR)
- Include air-conditioning, head-lights, auxiliaries
- Implement next generation of on-board diagnostic (OBD) and develop emissions on-board monitoring (OBM)
- Improved oversight and enforcement of coast down provisions, defect reporting, fiscal penalties, customer compensation, and recall provisions
- Improved defeat-device guideline improvement (e.g. not for NOₓ only), prohibit “dirty” techniques (e.g. setting a maximum level of fuel enrichment for gasoline engines)
- Include provisions for non-exhaust emissions (from brakes, tires, heat burner, etc.)
Conclusion: post-Euro 6 pathways

- Post Euro 6 standard should be fuel, technology and application neutral
- The ISC and durability requirements should be aligned and extended to a realistic useful life of the vehicle (e.g. US Tier 3 and LEV III are 240 000 km - 15 years)
- Neither the WLTP Type 1 or RDE tests are representative of cold start emissions at low ambient temperature. The -7°C (Type 6) test is needed for all, including limits for every pollutants, while monitoring CO2
- Limit NO₂ and NH₃ emissions, a safeguard as technology shifts
- Account for the greenhouse effect of N₂O and CH₄ emissions (e.g. in CO₂ equivalent)

None of the Euro requirements matter if manufacturers can ignore them without significant repercussions
For more detail, please visit our ICCT website