Advanced Conventional Fuels and Vehicles

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Technical Coordinator
Fuels quality and Emissions
ADVANCED CONVENTIONAL FUELS AND VEHICLES

- Progress in EU fuel specifications
- Recent CONCAWE data on exhaust emissions with advanced vehicles and fuels
  - Gasoline
  - LD Diesel
  - HD Diesel
- Conclusions/Outlook
## MAJOR PROGRESS IN EU FUELS QUALITY

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Gasoline Unleaded 95/85</strong></td>
<td><strong>EN228</strong></td>
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<tr>
<td>Sulphur ppm m/m max</td>
<td>1000</td>
<td>500</td>
<td>150</td>
<td>50/10</td>
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<tr>
<td>Benzene % v/v max</td>
<td>5</td>
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<tr>
<td>Aromatics % v/v max</td>
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<td>Olefins % v/v max</td>
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<td>18</td>
<td></td>
<td></td>
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<tr>
<td>Oxygen % m/m max</td>
<td>2.5&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td></td>
<td>2.7</td>
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<tr>
<td>RVP (summer) kPa max</td>
<td>up to 80</td>
<td></td>
<td>60&lt;sup&gt;(2)&lt;/sup&gt;</td>
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<td>E100 % v/v min</td>
<td>40(s)/43(w)</td>
<td></td>
<td>46</td>
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<tr>
<td>FBP °C max</td>
<td>215</td>
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<td></td>
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<td>210</td>
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<tbody>
<tr>
<td><strong>Diesel (standard grade)</strong></td>
<td><strong>EN590</strong></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CI min</td>
<td>46</td>
<td></td>
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<tr>
<td>CN min</td>
<td>49</td>
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<tr>
<td>Sulphur ppm m/m max</td>
<td>2000</td>
<td>500</td>
<td>350</td>
<td>50/10</td>
<td>10&lt;sup&gt;(3)&lt;/sup&gt;</td>
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<tr>
<td>Density kg/m³ min</td>
<td>820</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>max</td>
<td>860</td>
<td></td>
<td></td>
<td></td>
<td>845</td>
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<tr>
<td>T95 deg C max</td>
<td>370</td>
<td>360</td>
<td>11</td>
<td></td>
<td></td>
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<tr>
<td>PAH % m/m max</td>
<td></td>
<td></td>
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<tr>
<td>Lubricity µm @ 60°C max</td>
<td></td>
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<td></td>
<td></td>
<td>460</td>
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</table>

<sup>(1)</sup> Up to 3.7% at Member State discretion. Individual limits apply to specific compounds

<sup>(2)</sup> 70 kPa max allowed in Member States with arctic or severe winter conditions

<sup>(3)</sup> End date for full introduction of 10 mg/kg S max diesel remains subject to further review

> Enables introduction of wide range of advanced engine / after-treatment systems to achieve low emissions
## EU MOST ADVANCED ON FUELS QUALITY

<table>
<thead>
<tr>
<th></th>
<th>CLE(1)</th>
<th>EU '09</th>
<th>US Fed '06</th>
<th>Japan '04</th>
<th>China</th>
<th>India</th>
<th>Brazil</th>
<th>RSA</th>
<th>NZ</th>
<th>WB '05 (4)</th>
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<tr>
<td><strong>GASOLINE</strong></td>
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<tr>
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<td>ppm m/m max</td>
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<td>30</td>
<td>50</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>500</td>
<td>400</td>
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<tr>
<td>Benzene</td>
<td>% v/v max</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2.5</td>
<td>5</td>
<td>1.5</td>
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<td>5</td>
<td>2.5</td>
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<tr>
<td>Aromatics</td>
<td>% v/v max</td>
<td>35</td>
<td>(5)</td>
<td>_</td>
<td>40</td>
<td>45</td>
<td></td>
<td></td>
<td>26-48</td>
<td>45</td>
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<tr>
<td>Olefins</td>
<td>% v/v max</td>
<td>18</td>
<td>(5)</td>
<td>_</td>
<td>35</td>
<td>_</td>
<td></td>
<td></td>
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<tr>
<td>Oxygen</td>
<td>% m/m max</td>
<td>2.7</td>
<td>2&lt;x&lt;2.7</td>
<td>7 (2)</td>
<td>2.7</td>
<td>2.5</td>
<td></td>
<td></td>
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<td>0.1</td>
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<tr>
<td>CI</td>
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<td>46</td>
<td>40</td>
<td></td>
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</tr>
<tr>
<td>CN</td>
<td>min</td>
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<td>45</td>
<td>42</td>
<td>45</td>
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<tr>
<td>Sulphur</td>
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<td>15</td>
<td>50</td>
<td>10000</td>
<td>2500</td>
<td>2000</td>
<td>3000</td>
<td>3000</td>
<td>2000</td>
</tr>
<tr>
<td>Density</td>
<td>kg/m³ min</td>
<td>820</td>
<td>_</td>
<td>_</td>
<td>820</td>
<td>820</td>
<td>800</td>
<td>820</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>max</td>
<td>845</td>
<td>_</td>
<td>_</td>
<td>870</td>
<td>870</td>
<td>_</td>
<td>_</td>
<td>860</td>
<td></td>
</tr>
<tr>
<td>PAH</td>
<td>% m/m max</td>
<td>11</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a</td>
<td>n.a</td>
<td></td>
</tr>
</tbody>
</table>

(1): CLE Current Legislation Enacted
(2): MTBE
(3): Gasohol specs
(4): World Bank recommendations
(5): US Fed: 'must meet requirements of complex model'
RECENT CONCAWE WORK ON EMISSIONS FROM ADVANCED ENGINES/VEHICLES

- Auto-Oil programmes were supported by EPEFE programme
  - Carried out 10 years ago on Euro 1-2 vehicles and engines

- To update knowledge, CONCAWE has continued to test new engines & vehicles as they enter/approach the market
  - Gasoline
  - LD Diesel
  - HD Diesel
  - Wide range of fuel qualities
RECENT GASOLINE EMISSIONS WORK

- Fuel effects on emissions evaluated with 4 advanced gasoline vehicles
  - 2 Euro-3 cars (A & C) and 2 Euro-4 cars (B & D)
    - Stoichiometric DI (Car A)
    - Advanced MPI (Car B)
    - 2 lean burn DIs (Cars C & D)
  - Fuel matrices: sulphur, aromatics, olefins, volatility and FBP

- Fuel effects were evaluated over a wide range of aromatics and olefins content, volatility and FBP, using a rigorous test protocol with multiple tests on each fuel/vehicle combination

- All 4 vehicles delivered very low NOx, HC and CO emissions
  - Only one Euro-3 car (C) exceeded Euro-4 limits on one emission (HC)

Reference: CONCAWE report 2/04
GASOLINE EFFECTS ON REGULATED EMISSIONS

EFFECT OF AROMATICS

Euro-4 limits (g/km): CO 1.0, HC 0.10, NOx 0.08

- Effects of reducing aromatics were small:
  - Conflicting trends on NOx emissions
  - Increased HC emissions in the DI cars but decreased in the MPI car
  - No significant effects on CO
GASOLINE EFFECTS ON REGULATED EMISSIONS
EFFECT OF OLEFINS

Reducing olefins content gave no significant benefits on NOx, HC or CO emissions in any of the cars.

Euro-4 limits (g/km): CO 1.0, HC 0.10, NOx 0.08
GASOLINE EFFECTS ON REGULATED EMISSIONS

EFFECT OF VOLATILITY (E70)

Euro-4 limits (g/km): CO 1.0, HC 0.10, NOx 0.08

➢ Effects of reducing volatility were small:
  ✗ No consistent effect on NOx emissions
  ✗ Increased HC emissions in all cars
  ✗ Decreased CO emissions in 2 cars
GASOLINE EFFECTS ON REGULATED EMISSIONS
EFFECT OF FBP

 euro-4 limits (g/km): CO 1.0, HC 0.10, NOx 0.08

- Effects of reducing FBP were small:
  - Trend to decrease HC emissions but increase CO and NOx
  - Not all effects significant
DIESEL EMISSIONS

Recent work included evaluation of a wide range of diesel fuel qualities in advanced LD vehicles and HD engines
- In connection with the DG TREN Particulates Consortium
- Advanced LD vehicles with and without DPF
- Advanced HD engines: Euro-3, prototype Euro-4 and Euro-5

Wide range of fuels
- D2 EN 590 Diesel: 280 ppm S
- D3 EN 590 Diesel: 38 ppm S
- D4 EN 590 Diesel: 8 ppm S
- D5 Swedish Class 1 Diesel
- D6 Pre-2000 Diesel
- D7 D4 + 5% RME
- D8 Fischer-Tropsch Diesel
**Advanced Conventional Fuels and Vehicles**

**Harts World Fuels Conference, Brussels, 11 May 2004**

**Neville Thompson, CONCAWE**

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**DIESEL PARTICULATE FILTERS: DRASTIC PM EMISSION REDUCTIONS**

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### LD Vehicle PM emissions – NEDC

<table>
<thead>
<tr>
<th>Fuel Code</th>
<th>Car A: without DPF</th>
<th>Car B: with DPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>0.02</td>
<td>0.01</td>
<td>0.005</td>
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</table>

- DPFs with low sulphur fuels deliver very low PM emissions
- No benefit from further changes to diesel fuel specifications

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SULPHUR REDUCTION REDUCES NANO-PARTICLES

LD Vehicles, SMPS data N<30 nm and N>30 nm @ 120 km/h

➢ Low sulphur fuels with advanced after-treatment systems capable of delivering very low emissions
CONCLUSIONS / OUTLOOK

- Major efforts are underway to introduce sulphur-free fuels (10 mg/kg max S)

- EU 2005 specification sulphur-free fuels meet the needs of all advanced vehicle technologies that can be expected in the 2010 time-frame
  - Advanced gasoline engines
    - Direct Injection, Variable Valve Actuation, Downsizing…
  - Improved diesel engines
    - Multiple high pressure injections, Exhaust gas recirculation…
  - Advanced after-treatment
    - Improved TWC, PM traps, lean NOx converters…
  - Hybrids

- Very low emissions can be achieved by such advanced vehicle technologies in combination with sulphur-free fuels
  - Changes to other fuel properties offer little or no additional Air Quality benefit, would increase CO₂ emissions and add to security of supply concerns, especially for diesel, where meeting the future demand is already a challenge

- Novel combustion systems e.g. HCCI, CAI need more study