Japan’s Automotive Emissions Regulations and Emissions Control Technologies for 2005 and Later

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Japan Automobile Manufacturers Association, Inc.
1. Current Status of Air Pollution

2. Automotive Emissions Regulations

3. Automotive Emissions Control Technologies
## Attainment Rate of Environmental Quality Standard in 2006

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>All Regions</th>
<th>Nox, PM Law Measures Regions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NO2</strong></td>
<td>100%</td>
<td>90.7%</td>
</tr>
<tr>
<td><strong>SPM</strong></td>
<td>93.0%</td>
<td>92.8%</td>
</tr>
<tr>
<td><strong>Oxidant</strong></td>
<td>0.1%</td>
<td>3.7%</td>
</tr>
<tr>
<td><strong>SO2</strong></td>
<td>99.8%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>CO</strong></td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
1. Current Status of Air Pollution

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Emissions Regulations for Gasoline Passenger Cars in Japan

1965 = 100

1975-78 regulations

2005 New long-term regulations

2000 New short-term regulations

HC
NOx
CO

1966 1975 1978

65 70 75 80 85 90 95 00 05 10
Exhaust Emissions Standards for Passenger Cars

- Diesel New Long-term Standard
- Diesel Post New Long-term Standard
- Gasoline New Long-term Standard
- Gasoline 3
- Gasoline 4

Graph showing emissions standards for NOx, CO, PM, and HC.
Emissions Standards for Heavy–duty Diesel Vehicles

- Long-term regulations (starting 1997)
- New short-term regulations (starting 2003)
- New long-term regulations (starting 2005)
- Post New long-term regulations (starting 2009)
- Ultra-low PM vehicle certification standards

PM (g/kWh) vs. NOx (g/kW/h) chart.
Low Emission Vehicle Certification System

10-15 Mode

Combined Mode

[2000 Regulations]

[2005 Regulations]
Introduction of Certified Low Emission Passenger Cars in Japan

3.9 million low emission vehicles (3 *, 4 *) shipped in 2006, 90% or more of all passenger cars
Future Automotive Emissions Regulations in Japan

<table>
<thead>
<tr>
<th>2010 Fuel Efficiency Standard (10•15mode')</th>
<th>NOx Challenge Target?</th>
</tr>
</thead>
<tbody>
<tr>
<td>JC08 cold/hot</td>
<td></td>
</tr>
<tr>
<td>JE05 mode</td>
<td></td>
</tr>
<tr>
<td>New Long-term Reg.</td>
<td></td>
</tr>
<tr>
<td>JC08 mode(Cold)</td>
<td></td>
</tr>
<tr>
<td>High-level OBD</td>
<td></td>
</tr>
<tr>
<td>JC08 mode(hot)</td>
<td></td>
</tr>
<tr>
<td>2015 Fuel Efficiency Standard</td>
<td></td>
</tr>
<tr>
<td>2015 Fuel efficiency standard</td>
<td></td>
</tr>
</tbody>
</table>

Gasoline vehicle

Passenger car
Light- and Medium-truck

Diesel vehicle

Passenger car
Light- and Medium-truck

Heavy-duty vehicle

2010 Fuel Efficiency Standard (10•15mode')
New Emission Test Mode (JC08 Mode) for Vehicles with GVW of 3,500kg or less

10·15 Mode

- Distance: 4.165km
- Ave. speed: 22.7km
- Max. speed: 70km/h

JC08 Mode

- Distance: 8.159km
- Ave. speed: 24.4km/h
- Max. speed: 81.5km/h

In order to accurately assess the performance of exhaust emissions in real world.
New Emission Test Mode (JE05 Mode) for Vehicles with GVW of over 3,500kg

Representative Running Mode As the Basis of Test Mode

Distance: 13.9km, Ave. speed: 27.3km/h, Max. speed: 87.6km/h

Actual Max. Torque Curve Measured Data

Vehicle Specification Data

Simulation

Conversion to Engine RPM and Torque

Engine Operation on Engine Dynamometer
Worldwide Harmonization of Emission Test Procedure

Environment
- Better Air Quality
- Lower GHG

Government
- Easy-to-understand rulemaking
- Easy-to-evaluate each country policy

Manufacturer
- Improvement of R&D Efficiency
- Promotion of Advanced Technologies

Consumer
- EFV will be available more cheaper
- Greater freedom in selection of vehicles

UN/ECE/WP.29

Motorcycle
- WMTC
- GTR

Heavy-duty Vehicle
- WHDC
- GTR

Light-duty Vehicle
- WLTP
1. Current Status of Air Pollution

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3. Automotive Emissions Control Technologies
Emissions Regulations and Main Control Technologies in Japan

(Gasoline passenger car)

- Engine improvements
  - Oxidation catalyst
  - 3-way catalyst (O₂ sensor)
  - Microprocessor engine control

- Catalyst improvements
  - NOx storage-reduction catalyst
  - Air-fuel ratio sensor
  - VVTi

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  - NOx storage-reduction catalyst
  - Air-fuel ratio sensor
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  - Microprocessor engine control

- Catalyst improvements
  - NOx storage-reduction catalyst
  - Air-fuel ratio sensor
  - VVTi
## Emissions Control Technologies (Gasoline vehicles)

<table>
<thead>
<tr>
<th>Reduction Technology</th>
<th>NOx</th>
<th>HC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cold emission</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Move catalyst forward</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Cascade catalyst</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>HC adsorption system</td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>Supercharging</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Double-wall exhaust manifold</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>VVT</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Better control of transient A/F</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Reduce crevice volume</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Improve catalyst</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Strengthen swirl</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Increase catalyst size and carrier volume</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>Hot emission</strong></td>
<td></td>
<td></td>
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<tr>
<td>Improve NOx catalyst</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Electronically controlled EGR</td>
<td>○</td>
<td></td>
</tr>
</tbody>
</table>

(Note: ○ indicates technology is effective for that emission type)
Future Technologies to Reduce Emissions from Gasoline Vehicles

Points: Improve combustion, Warm up faster, Activate catalyst faster, Restrain deterioration, Improve control

- Develop engine control
  - Develop control technology
    - Increase control precision for A/F ratio, ignition timing
    - Improve OBD detection performance
  - Develop control parts
  - Develop sensors

- Use thermal energy
  - Heat cylinder head, port
  - Heat intake air etc.

- Develop exhaust system parts
  - Reduce heat capacity
  - Secondary air
  - Control exhaust temperature

- Improve engine combustion

- Develop valve mechanism

- Improve catalyst performance
  - Improve catalyst Low-temperature activation
  - Good heat resistance
  - Adsorption purification catalyst
  - New catalysts
# Diesel Emissions Control Technologies

<table>
<thead>
<tr>
<th>Year</th>
<th>'74</th>
<th>'77</th>
<th>'79</th>
<th>'83</th>
<th>'89</th>
<th>'94</th>
<th>'98</th>
<th>'03</th>
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<tbody>
<tr>
<td><strong>Emissions Regulations</strong></td>
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<tr>
<td>Retarded injection timing</td>
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<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Improved injection nozzle</td>
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<td>●</td>
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<td>●</td>
<td>●</td>
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<td>●</td>
<td>●</td>
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<tr>
<td>Higher injection pressure</td>
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<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>CR, UI</td>
<td>●</td>
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<tr>
<td>Variable injection rate</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<td>●</td>
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<tr>
<td>Multi-injection (common rail, etc.)</td>
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<td>●</td>
<td>●</td>
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<tr>
<td>Improved combustion chamber</td>
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<td>●</td>
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<td>●</td>
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<td>●</td>
<td>●</td>
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<tr>
<td><strong>Fuel Injection system</strong></td>
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<tr>
<td>Supercharger with intercooler</td>
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<td>●</td>
<td>●</td>
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<tr>
<td>Inertial supercharging, Supercharger with W/G, etc.</td>
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<tr>
<td>Variable nozzle turbocharging</td>
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<td>Variable swirl</td>
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<td><strong>EGR system</strong></td>
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<td>Internal EGR</td>
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<tr>
<td>External hot EGR</td>
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<tr>
<td>Cooled EGR</td>
<td>●</td>
<td>●</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td><strong>PM reduction</strong></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Oxidation catalyst</td>
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<td></td>
<td>●</td>
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<td>DPF</td>
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<td></td>
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<td>●</td>
<td>●</td>
</tr>
<tr>
<td><strong>NOx reduction</strong></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NO x catalyst</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>
Diesel Emission Control Technologies for New Long-term Regulation (1)

Urea selective reduction catalyst (SCR) + High-pressure fuel injection unit + Cooled EGR
Diesel Emission Control Technologies for New Long-term Regulation (2)

DPF + High-pressure fuel injection unit + Cooled EGR
Corresponding technologies for post new long term regulation (JP 2009)

- Engine modification
  - High pressure injection
  - Cooled EGR
  - Combustion improvement

- After Treatment System (ATS)
  - DPF / NOx catalyst (SCR, NOx trap)
  - Exhaust temperature / Oxygen concentration

- Sophisticated control for engine and ATS
Technology for diesel emission reduction in Japan

Long term regulation
EGR
High pressure injection
NOx catalyst
DieSEL NOx Catalyst (SCR)

Diesel Particulate Filter (DPF)

PM [g/kWh]

NOx [g/kWh]

New short term regulation
DPF
PM volun
New long term regulation
Long term
Future Diesel Emission Control Technology

(1) DPF + NOx storage-reduction catalyst system

- Common rail high-pressure injection unit
- EGR valve
- Intake air throttle
- EGR cooler
- HC oxidation catalyst
- Intercooler
- Intake air
- NOx catalyst + DPF
- Exhaust

Chart:
- 1998 HDV
- 2003 HDV
- 2005 HDV

Current

(1) EM
(2) De-NOx Cat.
(3) DPF

PM (g/kWh)

NOx (g/kWh)
(2) Urea SCR System

- Intake air throttle
- EGR valve
- Intercooler
- EGR cooler
- Ultra-high pressure fuel injection
- Electronically controlled turbo
- DPF
- Ultra-high pressure injection controller
- Exhaust
- Ammonia oxidation catalyst
- High-performance selective reduction catalyst
- Urea-water injection controller
- Urea-water tank

Graph showing PM (g/kWh) vs. NOx (g/kWh) for 1998 HDV, 2003 HDV, and 2005 HDV. Current Ultra-high pressure injection is also shown.
# ATS characteristics for post new long term regulation

<table>
<thead>
<tr>
<th>Main Components</th>
<th>DPF+LNT</th>
<th>DPF+SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PM reduction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM filter</td>
<td>Ceramic Filter</td>
<td>-</td>
</tr>
<tr>
<td>Active regeneration device</td>
<td>CRS, etc</td>
<td>-</td>
</tr>
<tr>
<td><strong>NOx reduction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOx catalyst</td>
<td>LNT</td>
<td>SCR</td>
</tr>
<tr>
<td>reductant</td>
<td>Fuel (diesel)</td>
<td>Urea</td>
</tr>
<tr>
<td>Reductant additive device</td>
<td>Fuel additive</td>
<td>Urea additive</td>
</tr>
<tr>
<td>Reductant tank</td>
<td>No need</td>
<td>Urea tank</td>
</tr>
<tr>
<td><strong>Remarks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influence on economical efficiency (ex. Fuel economy)</td>
<td>Fuel economy degradation owing to back pressure increase and fuel additive</td>
<td>Fuel economy degradation owing to back pressure increase</td>
</tr>
<tr>
<td>Cost</td>
<td>Costly metal in catalyst</td>
<td>New components regarding urea system (tank, anti-icing system, etc)</td>
</tr>
<tr>
<td>Installation, Weight</td>
<td>Large size ATS</td>
<td>Large size ATS</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>No need</td>
<td>Need *</td>
</tr>
</tbody>
</table>

*Infrastructure at gas station, etc needed for light and medium duty vehicle*
Thank you for your attention!