Vehicle Emissions Standards
A Key To Clean Air

Clean Fuels and Vehicles in Vietnam
12 – 14 May 2004
Hanoi

WHO Estimate of Premature Deaths Annually Due To Outdoor Air Pollution

Total: 793000
Rest of the World 39.6%
Asia 61.0%

World Motor Vehicle Population

Global Trends in the Total Vehicle Population (Excluding Motorcycles)
The Global Market For New Motorcycles and Mopeds

Source: Honda Facts & Figures

The Global Market For New Motorcycles and Mopeds

Total: 2,979,2139

Africa 0.4%
Asia 84.4%
Europe 7.9%
Latin America 3.5%
Middle East 0.4%
North America 3.1%
Oceania 0.3%

Evolution of California Auto Controls
(Implementation: 1963 – 1993)

Positive Crankcase Ventilation
Exhaust Standards
Oxidation Catalyst
Three Way Catalyst
On-Board Computer
Advanced Computer
Fuel Injection
O2 Sensor

Elements of a Comprehensive Vehicle Pollution Control Strategy

Clean Vehicle Technology
Appropriate Maintenance
Transportation & Land Use Planning
Clean Fuels
Evolution of ARB Auto Controls
Implementation: 1994 - 2010

- Low Emission Vehicle I
- Low Emission Vehicle II
- Cleaner Gasoline

Goal: Zero

Status of Lead Free Gasoline 2003

Dakar +2 Scheduled
For May 5-7 in Nairobi

The Three-way Catalytic Converter: A Familiar Technology Re-Engineered for High Performance in Close-coupled and Underfloor Applications

- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management

Light Duty Vehicle Emissions Standards

Can Only Be Used With Lead Free Fuel
Emission Standards for New Vehicles (light duty)

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Two Challenges:
- Eliminate The Yellow Colored Areas
- Narrow the Technology/Fuel Quality Gap in Blue Areas

Tons of Directly Emitted PM From Diesel Fuels Sulfur

Emissions Regulation for HDDV

Developing Countries Which Have Adopted US Or EU Standards For New Vehicles

Population

Vehilce Population

Adopted 65.0% Not Adopted 35.0%

Adopted 58.0% Not Adopted 42.0%

Adopted 71.0% Not Adopted 29.0%

USA PM (g/kWh) Europe PM (g/kWh)

Japan PM (g/kWh)
Diesel Particulate Filters

- Trapped PM Cell Plugs
- Exhaust (PM, CO, HC) Enter
- Ceramic Honeycomb Wall
- Exhaust (CO₂, H₂O) Out
- Issues to balance:
  - Sulfate formation
  - Regeneration and back pressure
  - Fuel Economy

Reductions:
- ~80 to 95% PM
- ~80-100% HC, CO
- ~80%+ toxins

Higher Sulfur Reduces Efficiency, Potential Durability, Fuel Economy

Close Linkage Between Vehicle Emissions Standards and Fuel Sulfur Levels

<table>
<thead>
<tr>
<th>Year</th>
<th>NOx</th>
<th>PM</th>
<th>Source</th>
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<tr>
<td>1998</td>
<td>4.0</td>
<td>0.10</td>
<td>EPA 98</td>
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<tr>
<td>1999</td>
<td>3.5</td>
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<td>EURO IV</td>
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<tr>
<td>2000</td>
<td>5.0</td>
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<td>EURO III</td>
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<td>2002</td>
<td>3.0</td>
<td>0.02</td>
<td>EURO IV</td>
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<tr>
<td>2003</td>
<td>2.0</td>
<td>0.01</td>
<td>DIESEL 15 ppm</td>
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Impact of Clean Vehicles and Fuels On Diesel Vehicle Emissions

Percent Reduction in Emissions

- NOx 2005
- PM10 2005
- NOx 2020
- PM10 2020

Source: Camarasa, BAQ 2003

Ultra Low Sulfur Diesel Fuel Is Spreading

- PPM
- US EPA 2000
- US EPA 2005
- EU 2000
- EU 2005
- South Korea 2006
- Thailad 2007
- Japan 2007
- Hong Kong 2007
- South Korea 2008
- Texas 2008

Impact of Clean Vehicles and Fuels On Diesel Vehicle Emissions
Worldwide Emission Regulations

<table>
<thead>
<tr>
<th>Nation</th>
<th>Engine Displacement</th>
<th>Engine Type</th>
<th>CO (g/km)</th>
<th>HC (g/km)</th>
<th>NOx (g/km)</th>
<th>Evap. (g/test)</th>
<th>Effective Year</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Taiwan</td>
<td>2-stroke 7.0 1.0 2.0</td>
<td>10,000 km</td>
<td>CO: 7.0</td>
<td>HC: 1.0</td>
<td>NOx: 2.0</td>
<td>Evap. 2.0</td>
<td>2004</td>
<td>ECE R40 Cold Start</td>
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<tr>
<td>China</td>
<td>2-stroke 1.2 1.5 0.3</td>
<td>20,000 km</td>
<td>CO: 1.5</td>
<td>HC: 1.5</td>
<td>NOx: 0.3</td>
<td>Evap. 1.5</td>
<td>2005</td>
<td>IDC Cold Start</td>
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<tr>
<td>India</td>
<td>2-stroke 1.0 1.0 0.15</td>
<td>30,000 km</td>
<td>CO: 1.0</td>
<td>HC: 1.0</td>
<td>NOx: 0.15</td>
<td>Evap. 1.0</td>
<td>2006</td>
<td>ECE R40 Cold Start</td>
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<tr>
<td>Europe</td>
<td>&gt; 150 c.c. 2.0 2.0 0.3</td>
<td>30,000 km</td>
<td>CO: 2.0</td>
<td>HC: 2.0</td>
<td>NOx: 0.3</td>
<td>Evap. 2.0</td>
<td>2006</td>
<td>ECE R40 Cold Start</td>
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</table>

Worldwide Emission Regulations

<table>
<thead>
<tr>
<th>Nation</th>
<th>Engine Displacement</th>
<th>Engine Type</th>
<th>CO (g/km)</th>
<th>HC (g/km)</th>
<th>NOx (g/km)</th>
<th>Effort (Years)</th>
<th>Remarks</th>
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<tr>
<td>Japan</td>
<td>2-stroke 7.0 1.0 2.0</td>
<td>10,000 km</td>
<td>CO: 7.0</td>
<td>HC: 1.0</td>
<td>NOx: 2.0</td>
<td>Evap. 2.0</td>
<td>2004</td>
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<tr>
<td>Europe</td>
<td>&gt; 150 c.c. 2.0 2.0 0.3</td>
<td>30,000 km</td>
<td>CO: 2.0</td>
<td>HC: 2.0</td>
<td>NOx: 0.3</td>
<td>Evap. 2.0</td>
<td>2006</td>
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Annual Costs | Annual Benefits | Net Annual Benefits

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<td>70</td>
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Costs and Benefits of Low Sulfur Diesel Fuel (<15 PPM) and Very Stringent Heavy Duty Engine Standards in the US
Establishment of Testing Capability and Regulation Drafting

Passenger Car 1st Stage
- ECE 15
- HC, CO, NOx
- α GVW

Motorcycle 1st Stage
- ECE 40
- NC+NOx 8.8 g/km
- CO 5.5 g/km

Passenger Car 2nd Stage
- FTP75-83US STD
- CO 2.11 g/km
- HC 0.255 g/km
- NOx 0.62 g/km
- 5yrs 80,000 km Warranty

Publish New Vehicle Emission Testing Results

Motorcycle 2nd Stage
- ECE 40
- HC+NOx 3.0 g/km
- 6,000 km Warranty

In-use Vehicle Testing Development

Diesel Vehicle US Transient

Motorcycle 3rd Stage
- ECE 40
- HC+NOx 2.0 g/km
- CO 3.5 g/km
- 15,000 km Warranty

Passenger Car 3rd Stage
- FTP75-94US STD
- CO 2.11 g/km
- HC 0.255 g/km
- NOx 0.62 g/km
- 5yrs 80,000 km Warranty

Electric Scooter 2% Mandate

Motorcycle 4th Stage

Passenger Car 4th Stage

Taiwan Motorcycle Emission Regulation Milestones

1st & 2nd Stage-norms

2nd, 3rd & 4th Stage-norms

Cost and Emission Analysis

Cost (US$)

Electric
- EMS Closed-loop
  - D.F. < 1.1 No adjustment Req’d
  - D.F. 1.1~1.3 Manual Adjustment Req’d

EMS Open-loop
- D.F. > 1.3 Manual Adjustment Req’d

Carburetor 2nd Air Catalyst
- EMS Closed-loop

Carburetor 4-stroke

CO (g/km)

(HC (g/km))

Taiwan Motorcycle Emission Reduction

5yrs 80,000 km Warranty

1990
1992
1993
1998
1994
1995
2000
2004
Dealing With Existing Vehicles

- Ultra low sulfur diesel with a catalyzed diesel particulate filter offers the following benefits:
  - >90 - 98% PM reduction
  - >70 - 90% CO reduction
  - > 90% HC reduction
  - >90% air toxics & ozone precursor reduction
  - 0 – 5% NOx reduction

Durability & Reliability

Dealing With Existing Vehicles

Average Grocery Truck Emissions, CSHVR(1&2)

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CARB Fuel w/o DPF

Durability & Reliability

Conclusions

- Technologies Exist Today Which Would Allow Tight Control of New Vehicle Emissions
- These Technologies Are Spreading Throughout The Region and The World
- Clean Vehicle Technology Requires Clean Fuels
- Good I/M Program Can Help Maximize The Benefits of Any Vehicle Pollution Control Program
Vietnam Road Map

- Light Duty Gasoline Vehicle – Euro 2
- Light Duty Diesel Vehicle – Euro 1
- Heavy Duty Diesel Engines – Euro 1
- HDDE – Euro 2
- Fuel Sulfur
  - Gasoline 500 PPM
  - Diesel 500 PPM

- 2006/2007
- 2006/2007 (Why Not Euro 2?)
- 2006/2007 (Why Not Euro 2?)
- 2009 (Why Wait?)
  - 2005 in Discussion
  - 2004 In Discussion