Commercial Transportation - Clean Choices for the 21st Century
The Role of Advanced Diesel Technology

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Outline

- Introduction
- Commercial Mobility
- The story of the diesel engine
- Successes in diesel development to date
- Challenges for the future
- Green diesel - “the brilliance of common sense”
- Alternative fuels - issues and challenges
- Conclusions
Commercial Mobility

- Backbone of economic development
  - Flexible and efficient transportation of materials, products, goods, people, etc., on land, railroads and water
  - Modern agriculture
  - Construction industry
  - Forestry, mining

- The engine of choice is the “diesel”
The Story of the Diesel Engine

Dr. Rudolph Diesel
German Inventor
The Story Continues

- before 1914
  - Ship propulsion; stationary applications

- 1914-1918
  - Higher speed diesels; transportation

- by 1930
  - Trucks, buses, railroad engines

- 1939-1945
  - Airplanes (high supercharging), esp. Germany

- after 1945
  - Dominant in heavy road transport (esp. Europe)
  - Scaled down to agricultural and industrial applications
The Story Continues

- **by 1935**
  - Diesel engines in taxicabs (in Europe)

- **1975-1990**
  - US and Japan expand the diesel in transport after the 70’s
  - Light/high speed diesels (NA, TC) evolving
  - In 1990 18% of cars in Europe were diesels!

- **After 1980**
  - Diesels subjected to emission regulations in US, then in Europe and Japan
Undisputed “King of the Road” in Heavy and Medium Transport

Significant in-roads in passenger cars!
- France  60% of new cars
  40% of car population
- Austria /Germany  30% (aprox.)
- Europe  36%(today); 50%(by 2006)

Topic of heated debates!
Diesel Engine Benefits

- Fuel Efficiency and Greenhouse Gas Emissions
  - Most efficient powerplant
  - Very Low CO\textsubscript{2} emissions; No CO emissions

- Energy Use
  - About 30\% of crude oil energy is in diesel fuels

- Durability and Reliability
  - Unsurpassed by other machines

- Safe Fuel Handling
  - Fuel is not flammable
Diesel Engine Challenges

- **Technical**
  - Emission profile (NOx and Particulates)
  - Emission control more difficult than in gasoline engines
  - NOx/Particulate Trade-off

- **Societal**
  - Benchmarked against Gasoline Engine
  - Regulatory Environment
  - Public Perception
  - Unrealistic assessment of alternatives
Progress In Reducing HD Truck PM Emissions

<table>
<thead>
<tr>
<th>Model Year</th>
<th>Particulates (g/bhp-hr)</th>
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<tbody>
<tr>
<td>Unregulated 1988</td>
<td>1.0</td>
</tr>
<tr>
<td>Base 1991</td>
<td>0.6</td>
</tr>
<tr>
<td>1994</td>
<td>0.4</td>
</tr>
<tr>
<td>Urban Bus 1996</td>
<td>0.2</td>
</tr>
<tr>
<td>2007</td>
<td>0.0</td>
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</tbody>
</table>

The chart shows a significant reduction in particulate emissions from HD trucks over the years, with a baseline reduction of 40% and further reductions of 75%, 90%, 95%, and 99% in subsequent years.
Progress In Reducing HD Truck NOx Emissions

Industry Reductions

- 1974: BASE 15 NOx
- 1990: 6 NOx (60% reduction)
- 1991: 5 NOx (67% reduction)
- 1998: 4 NOx (73% reduction)
- 2004: 2 NOx (87% reduction)
- 2007: 0.2 NOx (99% reduction)


NOx (g/bhp-hr)
Diesel Progress to Date

- Significant reduction of emission levels (80-95%) while preserving and enhancing all other diesel attributes.

- “Technology trail” of success was mainly basic engine development:
  - Direct injection, high pressure injection
  - Turbocharging, air management
  - Electronic control of injection
  - Advanced combustion chambers
  - etc.
Challenges Ahead - 2004!

(advanced for Oct. 2002)

- Additional stringencies
  - Compliance ranges widened
  - NTE limits (flatter emission maps)
- Technology may include use of EGR and continued enhancements of basic engine
Challenges Ahead - 2007!

- Emission Reductions of about 90% of NOx and PM Required!!!
- Technology Trail of basic engine development hits a dead end!
Challenges Ahead - 2007!

- System approach
  - Engine-Exhaust aftertreatment- Fuel
- Advanced engine design and function
- Leverages the development of diesel catalytic systems for NOx and PM control
- Requires "sulfurless" diesel fuel
Challenges Ahead - 2007!

- Sulfur effect
  - Sulfate Generation (increases PM)
  - Catalyst inhibition
  - Catalyst Poisoning
Challenges Ahead- 2007!

- EPA Ruling will assure ultra-low sulfur (ULS) diesel fuel for on-highway applications by June 2006 (max. 15 ppm).

- ULS fuel is already available today in some markets to support early demonstrations of clean diesels!
Enter Advanced Diesel!
Industry Moving Ahead!

• Diesel Engine Industry and Catalytic Systems Companies working intensively to develop the technology for 2007!

• Early Introductions!

• International’s approach:

  Green Diesel Technology™
Why Green Diesel Technology™

- Demonstrate that alternative-fuel emission levels can be achieved by advanced diesel technology
- Demonstrate the emissions reductions that can be achieved with ultra-low sulfur fuel (technology enabler)
- Provide an answer to public health concerns associated with particulate matter and toxic hydrocarbons
- GDT certified in 50 states (03/12/2001)
Advanced Diesel Cleaner than CNG!  
2002 Results by CARB

- **Application** - urban bus
- **Contenders** - CNG engine
  - diesel engine w/ ultra low sulfur and DPF
- **Sponsor** - California ARB
- **Results**
  - Mutagenicity of exhaust higher for the CNG engine!
  - In 8 out of 11 pollutant criteria the diesel had lower emissions than the CNG engine!

- Several studies in the industry support similar conclusions!
Diesel Toxicity Issue
Alternative Fuels for Diesel Engines

- Compressed Natural Gas (CNG)
- Liquefied Natural Gas (LNG)
- Biodiesel
- Dimethylether (DME)
- Syntethic Diesel (FT fuel/GTL fuel)
- Alcohols (methanol, ethanol)
- Blends (diesel/water, diesel/alcohol)
Alternative Fuels for Diesel Engines

Driving forces
- Emissions (before)
- Domestic resources
- Long term potential when crude oil is depleted

Challenges
- Availability, Infrastructure
- Technology maturity
- Cost
- Fuel Quality
- Emissions?
Other Technologies in the Works for Future Commercial Transportation

- **Short-Medium Term (5-10 years)**
  - Hybrid (diesel/electric) powertrain
    - excellent “well-to-wheel” greenhouse gas potential!

- **Long Term (15 + years)**
  - Fuel cell technology (hydrogen based)
    - best “well-to-wheel” greenhouse gas potential only when renewable energy is used to generate hydrogen!
Conclusions

- Environmental and energy considerations will continue to drive the development of Diesel Technology.
- Hybrid Diesel Technology may extend the applications of diesel engines in the future (passenger cars as well as urban trucks).
- As long as crude oil is available the advanced diesel technology will be hard to beat!

but…
Conclusions (cont’d)

• Emerging technologies may evolve and their progress may bring about competition to the diesel

• Fuel cells may come into vehicular applications, but will likely appear first as auxiliary power units in heavy trucks
Conclusions (cont’d)

• Light Duty Diesel Technology is leading in progress

• Its achievements will be applicable to Heavy Duty Engines
Conclusions (cont’d)

• Despite its venerable age, the Diesel Engine is evolving!
• The “Diesel Paradigm” has shifted!
• We are witnessing the “Greening” of Diesel Technology!
“by 2007, the diesel technology will be as clean or cleaner than any other alternative fuel technology!”

Carroll Browner
(former EPA Administrator)
And in his wildest dreams, Mr. Rudolf Diesel could not have imagined that!