Results from Federal Emissions Tests on Alternative Fuel Vehicles and their Implications for the Environment and Public Health

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Test Program

- Statistically-designed study (light duty; transit buses)
- Federal fleet (light-duty), local transit agencies (transit buses), commercial entities (other heavy vehicles)
- Multiple testing labs
- Multiple makes/models of vehicles
- Vehicles from multiple sites throughout U.S.
- EPA test procedures (light-duty); other procedures (heavy vehicles)
- In-use emissions
- Tests repeated at various mileage levels
- Target fuels: Ethanol, Methanol, Compressed Natural Gas
- Most extensive study of its kind
Situation

• The U.S. Department of Energy (DOE) is heavily promoting development and deployment of alternative fuels and alternative fuel vehicles (AFVs) to:
  - Reduce dependence on imported oil
  - Improve air quality

• On behalf of DOE, the National Renewable Energy Lab (NREL) has undertaken an extensive evaluation of AFVs, including emissions performance.

• This presentation summarizes the emissions results and public health implications of this study
Public Health Considerations

- Automotive emissions are suspected to contribute to and/or cause a number of human health disorders.
- Human studies are not yet conclusive; results of animal studies are more compelling.
- AFV’s are expected to exhibit lower levels of exhaust emissions relative to conventionally-fueled vehicles.
- The DOE policy has the potential to substantially alter air quality and positively impact other public health scenarios.
Hypothesis

• If AFVs have improved overall emissions profiles,

• Then emissions-induced risk of disease and health disorders should be commensurately reduced,

• Particularly in communities having larger concentrations of such vehicles.

• Lower risk should translate to:
  - Reduced costs of medical care
  - Reduced insurance premiums
  - Generally more favorable business climate
### EPA Standards: (Tier 1; g/mi)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Carbon Monoxide</th>
<th>Oxides of Nitrogen</th>
<th>Hydrocarbons*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedans</td>
<td>3.4</td>
<td>0.4</td>
<td>0.25</td>
</tr>
<tr>
<td>Vans</td>
<td>5</td>
<td>1.1</td>
<td>0.39</td>
</tr>
<tr>
<td>Transit Buses</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*For gasoline and CNG, non-methane hydrocarbons; for ethanol and methanol, organic matter non-methane hydrocarbon equivalents
## Vehicles in Program

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>Conventional</th>
<th>Alternative Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dodge Spirit</td>
<td>70</td>
<td>71</td>
</tr>
<tr>
<td>Chevy Lumina</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Ford Econoline Van</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Dodge B250 Van</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>Transit Buses (DDC Engines)</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Transit Buses (Cummins Engines)</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>Line Haul Trucks</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Snow Plows</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Garbage Packers</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>184</strong></td>
<td><strong>199</strong></td>
</tr>
</tbody>
</table>
Findings

Sedans and Light-Duty Vans

• Most AFVs have uniformly lower exhaust emissions, with the levels of CO, NO\textsubscript{x}, and HC well below EPA standards

• For toxic constituents, AFVs have:
  - Lower aromatics
  - Mixed results for aldehydes (as expected), depending on the fuel

• For ozone-forming potential, AFVs have generally lower levels

Transit Buses

• AFVs have lower PM and NO\textsubscript{x}, but results for other constituents are mixed

Heavy-Duty Vehicles

• AFVs have lower PM
Experimental Results
Toxics and Ozone Precursors: Sedans and Light-Duty Service Vans (19 AFVs; 12 Controls)
Benzene (C₆H₆)

Vehicle Type

Mean mg/mi

Gasoline

Alternative

Ford Econoline Vans

Chevy Luminas

Dodge Spirits

Dodge B250 Vans

Ethanol Flex-Fuel

Methanol Flex-Fuel

CNG Dedicated
1,3-Butadiene

- Ethanol Flex-Fuel
- CNG Dedicated
- Methanol Flex-Fuel

Vehicle Type:
- Ford Econoline Vans
- Dodge Spirits
- Chevy Luminas
- Dodge B250 Vans

Mean mg/mi vs. Vehicle Type

Gasoline
Alternative
Acetaldehyde (CH₃CHO)

Vehicle Type

Mean mg/mi

Gasoline

Alternative

Ford Econoline Vans

Chevy Luminas

Dodge Spirits

Dodge B250 Vans

Ethanol Flex-Fuel

CNG Dedicated

Methanol Flex-Fuel
Regulated Emissions:
Sedans and Light-Duty Service Vans (146 AFVs; 148 Controls)
Carbon Monoxide (CO)

Vehicle Type

- Gasoline
- Alternatives: Ethanol Flex-Fuel, Methanol Flex-Fuel, CNG Dedicated

Mean g/mi

- 5.0
- 4.5
- 4.0
- 3.5
- 3.0
- 2.5
- 2.0
- 1.5
- 1.0
- 0.5
- 0.0

Vehicle Models:
- Ford Econoline Vans
- Chevy Luminas
- Dodge Spirits
- Dodge B250 Vans

Graph shows emissions levels for different vehicles and fuel types.
Oxides of Nitrogen (NOx)

Mean g/mi

Vehicle Type

Gasoline

Alternative

Ford Econoline Vans
Chevy Luminas
Dodge Spirits
Dodge B250 Vans

Methanol Flex-Fuel
CNG Dedicated
Ethanol Flex-Fuel
Hydrocarbons* 

Mean g/mi

Vehicle Type

Gasoline

Alternative

Ford Econoline Vans
Chevy Luminas
Dodge Spirits
Dodge B250 Vans

Methanol Flex-Fuel
Ethanol Flex-Fuel
Methanol Flex-Fuel
CNG Dedicated

(*CNG = Non-Methane Hydrocarbons; Ethanol & Methonal = Organic Matter Non-Methane Hydrocarbons)
Regulated Emissions:

Transit Buses (41 AFVs; 31 Controls)
Carbon Monoxide (CO)

Mean g/mi

Vehicle Type

Diesel

Alternative

Detroit Diesel

Methanol (all buses before catalyst replacement)

Ethanol (all buses before catalyst replacement)

Detroit Diesel (2 buses after catalyst replacement)

CNG

Detroit Diesel

Cummins Engines

Ethanol (all buses before catalyst replacement)
Oxides of Nitrogen (NO$_x$)

Vehicle Type

Mean g/mi

Detroit Diesel

Ethanol

CNG

Methanol

Detroit Diesel

Cummins Engines
Some engines were equipped with faulty catalysts which adversely affected emissions of hydrocarbons.
Particulate Matter:

Heavy-Duty Engines (in buses and trucks)
Particulate Matter (PM): Transit Buses
(41 AFVs, 31 Controls)

Mean g/mi

Vehicle Type

Diesel
Alternative

Detroit Diesel
Cummins Engines

Ethanol
Methanol
CNG
Particulate Matter (PM): Heavy-Duty Trucks
(12 AFVS, 5 Controls)

Mean g/mi

Vehicle Type

Diesel
Alternative

Snow Plows
Line Haul Trucks
Garbage Packers

Ethanol
CNG
Heavy-Duty Emissions

• Engine certification data indicates alternative fuels have the potential to reduce regulated emissions.

• In-use emissions testing technology is developing.

• Certification standards focus on reducing PM, without affecting NO$_x$.

• Alternative fuel engine technology is developing; careful ongoing maintenance and repair is important to emissions performance.

• Early results indicate substantial reductions in PM; levels of other emissions constituents not yet as low as desired.

• R&D efforts are continuing.
Conclusions and Implications

• Original equipment AFVs have improved overall emissions profiles relative to conventionally-fueled vehicles (regulated exhaust emissions, toxic emissions, particulate matter, ozone forming potential)

• These findings corroborate results from other studies, but carry more weight because of the extensiveness of the testing program.

• In addition, medical investigations indicate that automotive emissions associated with alternative fuels are generally less toxic than those associated with gasoline and diesel.

• So far, reductions in emissions constituents attributable to alternative fuels are most wide-ranging for sedans and other light-duty vehicles, but heavy-duty vehicles are showing great promise.

• This result is important because of the sheer numbers of these types of vehicles on the road.

• Extensive deployment of original equipment AFVs would enable communities to realize improvements in public health and associated economic benefits.

• Work is continuing to quantifiably establish these links.
Suggested Reading


Bibliography