HEAVY-DUTY TRUCK EMISSIONS AND FUEL CONSUMPTION
SIMULATING REAL-WORLD DRIVING
IN LABORATORY CONDITIONS

Nils-Olof Nylund & Kimmo Erkkilä
VTT Technical Research Centre of Finland
CONTENTS

- Research on heavy-duty vehicles
- Rationale for testing complete heavy-duty vehicles
- Development of test cycles
- Test results
  - fuel consumption
  - exhaust emissions
- Summary
RESEARCH INTEGRATE ON HEAVY-DUTY VEHICLES

- Finland, like many other countries is highly dependent on road transports
- Some 75% of the goods within the borders of Finland are transported on rubber wheels
- VTT initiated a three-year (2003-2005) multi-client research project to seek fuel savings for heavy-duty vehicles
  - 6 research institutes and some 20 sponsors from government, industry and transport companies cooperating

www.motiva.fi/raskaskalusto (in Finnish)
THE GOAL OF THE PROJECT
- in a 5-year perspective

- Vehicles & technology
  - 5-10 %
  - Permanent fuel savings

- Systems & operations

- Driver & information
EMISSION CERTIFICATION

- For light-duty vehicles, certification is done running complete vehicles
  - both emissions and fuel consumption are reported

- Both for the US and Europe, HD emission certification is done using stand-alone engines
  - the outcome is specific emission values (g/hph or g/kWh) for the engine itself tested over a certain duty cycle
  - the testing does not in any way reflect the properties of the vehicle itself (weight, aerodynamic drag, design of the driveline etc.)
  - no requirements to report fuel economy
WHY TEST COMPLETE HD VEHICLES?

- There is a clear need to generate emission and fuel consumption figures that take into account the properties of the complete vehicle:
  - generating truthful distance based emission and fuel consumption figures
  - effects of load and driving cycle
  - comparison of vehicles
  - chassis dyno testing also enables checking of in-use vehicles

- Within VTT’s research project, both the authorities and the transport companies are very interested in comparable (vehicle to vehicle) emission and fuel consumption figures for various HD vehicles
  - fuel economy is extremely important for the operators
DEVELOPMENT OF TEST METHODOLOGY

- Together with one of the biggest transport companies in Finland (Transpoint) VTT developed a methodology for chassis dynamometer measurement of heavy-duty trucks

- The key elements in the methodology are
  - transient type testing on dyno with 2,5 m diameter rollers
  - using truthful vehicle loading and speed profiles
  - also taking into account road gradient
  - determination of accurate rolling and drag resistance by conducting coast-down measurements

- The speed and road gradient profiles were recorded from actual routes served by Transpoint

- Varying speed and taking into account the road gradient creates highly transient loading
TEST METHODOLOGY – POWER VS. SPEED

Driving resistances against speed for different vehicle categories (fully loaded)

- 60t truck with full trailer
- 42t semi-trailer
- 26t truck
- 18t truck
- 2-axle citybus
- Large van
- Small van
TEST METHODOLOGY – CYCLE DEVELOPMENT

- **Freeway cycle** for a 60 t truck with full trailer
  - 420 hp truck + 4-axle trailer
  - total weight 49 050 kg
  - cruise control active

- **Highway cycle** for a 60 t truck with full trailer
  - 420 hp truck + 4-axle trailer
  - total weight 49 050 kg
  - driver controls speed

- **Delivery cycle** for a 26 t truck
  - 26 t truck, 420 hp
  - vehicle weight 21 700 kg
  - “normal” style of driving
TEST METHODOLOGY

Freeway cycle, original onroad data, 420 hp / 50 t
TEST METHODOLOGY

Highway cycle, original onroad data, 420 hp / 50 t

Delivery cycle, original onroad data, 420 hp / 50 t
TEST METHODOLOGY - ACCREDITATION

The Finnish Centre for Metrology and Accreditation granted accreditation for VTT's measurements in 2003

- Light-duty vehicle chassis dynamometer emission testing 70/220/EEC 91/441/EEC 98/69/EC
- Heavy-duty engine engine dynamometer emission testing 96/1999/EC
- Heavy-duty vehicle chassis dynamometer measurements VTT PRO
- General safety instructions
- Heavy-duty vehicle chassis dynamometer measurements Recommended Code of Practise SAE J2711

VTT PROCESSES
Kimmo Erkkilä

2005 DEER Conference
Aug 21 – 25, Chicago, Illinois, USA
SUBPROJECT TRUCK 2004:

Exhaust emissions and fuel consumption of Euro 3 certified trucks
TEST MATRIX 2004

◆ The measurements were done running dynamic load cycles including simulation of road gradient (three cycles: freeway, highway and delivery)

◆ Measurements were conducted in four weight classes:
  - 18 t delivery trucks: 0, 1/3, 2/3 and 1/1 load (four load levels)
  - 26 t delivery trucks: 0, 1/2 and 1/1 (three load levels)
  - 42 t semi-trailers: 0, 1/2 and 1/1 (three load levels)
  - 60 t trucks with full trailers: 0, 1/2 and 1/1 (three load levels)

◆ Vehicles of different makes were tested in parallel:
  - 18 t: three brands
  - 26/60 t: four brands
  - 42 t: three brands

◆ 13 different vehicles were measured, and the number of combinations (vehicle/load/cycle) was 63
  - including repetitive tests, more than 130 tests were done
INFLUENCE OF VEHICLE MASS

Fuel consumption on highway cycle

Vehicle weight kg

Fuel consumption l/100km

- 42t semi-trailers
- 60t trucks with full trailers
- 60t trucks with full trailers (with smaller engines)
INFLUENCE OF LOAD

Fuel consumption per ton-kilometres on highway cycle

- 42t semi-trailers
- 60t trucks with full trailers
- 60t trucks with full trailers (with smaller engines)

Fuel consumption l/ton-kilometres
Pay load kg
## FUEL CONSUMPTION BY VEHICLE MAKE

Fuel consumption on highway and freeway cycles.
Semi-trailers (max. 42t), three brands.

### Fuel consumption l/100 km

<table>
<thead>
<tr>
<th>Condition</th>
<th>Brand A/42</th>
<th>Brand B/42</th>
<th>Brand C/42</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-load</td>
<td>15-20</td>
<td>20-25</td>
<td>17-30</td>
</tr>
<tr>
<td>1/2 load</td>
<td>17-22</td>
<td>22-28</td>
<td>19-32</td>
</tr>
<tr>
<td>2/2-load</td>
<td>19-24</td>
<td>24-30</td>
<td>21-28</td>
</tr>
</tbody>
</table>

**Highway**
- **max diff. 4%**

**Freeway**
- **max diff. 5%**

**max diff.**
- 14%
- 7%
- 4%
- 15%
- 8%
- 5%
FUEL CONSUMPTION BY VEHICLE MAKE

Fuel consumption on highway and freeway cycles.
Trucks with full trailers (max. 60t), four brands.

<table>
<thead>
<tr>
<th>Load Condition</th>
<th>Highway</th>
<th>Freeway</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-load</td>
<td>max diff. 8%</td>
<td>max diff. 9%</td>
</tr>
<tr>
<td>1/2 load</td>
<td>max diff. 9%</td>
<td>max diff. 9%</td>
</tr>
<tr>
<td>2/2-load</td>
<td>max diff. 6%</td>
<td>max diff. 9%</td>
</tr>
</tbody>
</table>

- A/60
- B/60
- C/60
- D/60
EMISSIONS (g/kWh at the driving wheels)
SUMMARY..

- VTT has now got measurement methods which make vehicle to vehicle comparisons, for emissions and fuel consumption, possible

- The methodology is based on transient-type chassis dynamometer measurements simulating realistic speed profiles, vehicle loads and also road gradient

- In 2004, a matrix of 13 new heavy-duty trucks in prime condition were measured for emissions and fuel consumption
..SUMMARY..

- Fuel consumption is primarily dependent on vehicle mass:
  - for delivery-type service fuel consumption is 25 – 42 l/100 km
  - for highway and freeway-type driving the fuel consumption of 42 t and 60 t vehicle combinations is 22 – 53 l/100 km depending on the weight of the combination

- The minimum specific fuel consumption was 0.04 l/ton-km over the delivery cycle and 0.015 l/ton-km over the highway cycle
  - transient-type driving increases fuel consumption significantly

- The variations in fuel consumption between vehicles within the same weight class are surprisingly big
  - the variation from vehicle to vehicle within the same category is 0 – 16 %
..SUMMARY

- The variations in exhaust emissions (NOx, PM) are even bigger
  - for 42 and 60 t vehicles on highway NOx varies by a factor of some 2.5 and PM by a factor of some 4
  - the differences in emissions are so big that the influence of load and even vehicle category is obscured
  - some manufacturers have succeeded in combining low emissions and low fuel consumption

- So far the vehicle makes have not been published
  - there is, however, an increasing demand for vehicle specific figures to guide vehicle procurements

- Euro 4 vehicles with either EGR + DPF or SCR will be introduced in Europe starting 2005
  - this might increase differences in both emissions and fuel economy in real-life service