MAC test pilot phase A

Assessment of test data and MAC test during pilot phase A
Round robin testing at pilot phase B

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MAC Pilot Test Phase contains two test phases:

**Phase A**
- Multi-lab Pilot test phase-A (improve procedure and cover open issues) ~ 11 labs
- Data review
- Procedure evaluation to draft final

**Phase B**
- Multi-lab Round Robin test phase-B with “golden vehicle” (reproducibility, sensitivity and repeatability) ~ 4 labs
- Data review
- Procedure evaluation to final procedure
- Write technical annex to regulation (incl. reviews)

WP100
- Programme definition, preparation
- Identify procedure improvement possibilities
- Prepare simple test elaboration tool
- Process comments from stakeholder meeting

WP210
- Multi-lab Pilot test phase-A (improve procedure and cover open issues) ~ 11 labs

WP310
- Data review
- Procedure evaluation to draft final

WP230
- Multi-lab Round Robin test phase-B with “golden vehicle” (reproducibility, sensitivity and repeatability) ~ 4 labs

WP310 WP400
- Data review
- Procedure evaluation to final procedure
- Write technical annex to regulation (incl. reviews)

Presentation of phase-A results and adjustment of phase-B on 11th June stakeholder meeting in Brussels

Current status

Stakeholder comments and learning points
Participation in pilot Phase-A

- 14 laboratories expressed interest to participate
- 8 laboratories submitted data
- 17 vehicles were tested
- 89 valid tests are available for analysis
Topics that have been addressed in pilot phase-A

- Sensitivity of the procedure for different:
  - Engine size and fuel types
  - Vehicle sizes and classes
  - MAC technologies (as far as possible)

- Sensitivity of the procedure for variations in:
  - Ambient temperature and humidity (test at low and high)
  - GSI versus fixed gear shift strategy
  - Soaking temperatures (between 20°C and 30°C)
  - Drive cycle at minimum and maximum speed (dyno power)
  - Blower on/off in MAC off phase of the test
  - Solar load simulation during the test
MAC test specifications

› Soaking on the day before measurement:
  › Preconditioning cycle: no (option: NEDC)
  › Duration: >8 h
  › Temperature: 25±2°C (sensitivity test: 20 - 30°C)

› Conditions during test:
  › Relative humidity: \( \varphi_a = 45\% \pm 5\% \) (sensitivity test: 40, 50%)
  › Temperature: \( T_a = 25°C \pm 2°C \) (sensitivity test: 20, 30°C)
  › Vent out. temperature: \( T_{vi} < 15°C \)
  › Air mass flow: \( m_a > 230 \text{ kg/h} \)
  › Gear shifting: MAC (sensitivity test: GSI)
  › Solar load simulation: no (sensitivity test: yes)
  › Speed: MAC (sensitivity test: +2 km/h, -2 km/h)
Data classification and nomenclature

› Vehicle types
  › small
  › sedan
  › estate
  › suv

› Engine size classes
  › small:  <1.2 l
  › mid:  1.2-1.8 l
  › high:  1.8-3.0 l
  › x-high:  >3.0 l

› Random vehicle naming
  › A, B, C…

› Random laboratory naming
  › 1-8

Note: In the following results confidence intervals correspond to max, min value if not otherwise stated (and only wherever more than 1 test repetition was available)
All labs were within MAC test specifications

Labs 1, 4, 5, 7 were the best performing labs in terms of temperature control (candidates for Phase B round robin testing)
Not all labs were within MAC test specifications

Lab 1 followed a wrong humidity target but with good control performance

Labs 1, 4, 5, 6 were the best performing labs in terms of humidity control (candidates for Phase B round robin testing)
## Correction methodologies (factors) applied

<table>
<thead>
<tr>
<th>Description</th>
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</tr>
</thead>
<tbody>
<tr>
<td>MAC FC uncorrected</td>
<td>MAC FC uncorrected (difference $\Delta FC_{MAC \text{on}} - FC_{MAC \text{off}}$)</td>
</tr>
<tr>
<td>(1) TA (Power, Tcell, RHcell)</td>
<td>The basic result proposed for Type-Approval. Corrected for power, for temperature and humidity in the test cell (according to polynomial equations in report) but not for vent outlet temperature.</td>
</tr>
<tr>
<td>(2) = (1) &amp; Tvent_average</td>
<td>As (1) but corrected also for measured vent outlet temperatures. For the correction factor the average of all vent outlet temperatures in the corresponding period is used.</td>
</tr>
<tr>
<td>(3) = (2) but with thermodynamic model</td>
<td>As (2), but correction for temperature and humidity in the test cell and for vent outlet temperature according to cooling capacity demand calculated by a thermodynamic model for the MAC.</td>
</tr>
<tr>
<td>(4) = (3) &amp; HVAC fan energy</td>
<td>As (3), but correction is not based only on cooling capacity demand but also on electric energy for the HVAC fan (this model was basis for the final polynomial equations used above)</td>
</tr>
<tr>
<td>(5) = (1) &amp; Tvent_max</td>
<td>As (2), but correction for vent outlet temperature is using the maximum of the vent outlet temperature to calculate the correction factor.</td>
</tr>
<tr>
<td>(6) = (1) &amp; Tcabin</td>
<td>As (2) but instead of the vent outlet temperature the correction is using the average cabin temperature in each period.</td>
</tr>
<tr>
<td>(7) = (1) &amp; glazing</td>
<td>As (1) but with correction for size and quality of glazing.</td>
</tr>
</tbody>
</table>
Different correction methods were tested besides the proposed correction for the MAC test (correction 1)
In general it was confirmed that higher temperature leads to higher fuel consumption due to higher intake air enthalpy (validated by measurements with similar humidity).

No conclusion for temperature can be driven since humidity was also altered during the temperature tests.

In general the basic correction (1) brings all measurements at a more close average value but is not reducing the variability of extreme measurements.
Test 1, normal blower speed vs. high blower speed: confirmed higher MAC fuel consumption of second case due to higher energy flow (blue arrow)

Test 2, normal MAC test (blower off during MAC off phase) vs. MAC test with blower left on during MAC off phase too: no measurable effect on fuel consumption (green arrow)

Test 3, MAC off during both phases: phase 1 showed slightly higher fuel consumption (would a steady state conditioning phase be necessary between MAC on and MAC off phases?)
Higher soaking temperature had no effect on vehicle G tests

Vehicle D was affected but mainly only due to large relative humidity difference between the two tests
Test 1: The same car tested at two different labs resulted in significantly different MAC FC.

Test 2: Two methods of measuring fuel consumption at the same lab resulted in the same MAC FC. Performing bag analysis with a difference of 20 min between MAC on and MAC off phase resulted in the same MAC FC with performing the MAC test with no pause between phases.
In general, the variability of measurements is not affected by corrections (same confidence intervals before and after correction)

At measurements with low RH correction increases MAC FC and at measurement with high RH decrease MAC FC as expected

Highest MAC FCs are observed for cars with high volume (SUV, large sedan) and high engine capacities
Mass flow measurement

1) Connect auxiliary blower to cabin. Vary mass flow, record pressure difference. Draw diagram:

2) Vary HVAC setting, record pressure difference. Read corresponding mass flow from diagram from step 1.
Validation necessary!?  

Possible influences:  
• Dynamic pressure at HVAC intake increases with blower speed  
• Under pressure builds up at rear end where flaps for exhaust air from cabin are usually located  
→ Same electric power at HVAC fan gives different (higher) mass flows with increasing wind speed  
→ HVAC controller may compensate electric power to achieve stable mass flow  

→ Perform mass flow measurements at 0km/h, at 50km/h and at 100km/h. Use setting where > 230 kg/h are achieved at all wind speeds?
Validation of effect from solar load

Tests performed with solar lamps on chassis dynamometer. 500W as total solar load transmitted to cabin leads to heat entrance into cabin of ~750W (correct glazing quality used in evaluation sheet?)

Simulation with 750 W additional heat entrance with evaluation tool sub model for the “generic vehicle” gives similar results as measured.

→ Correction factor for glazing quality (FTTS) should be in realistic orders of magnitude

Comment: setting of vent outlet >230 kg/h and <15°C corresponds already to settings under solar radiation (measurements for thermal comfort by Daimler)

→ FTTS corrects against “average glazing with solar load”, not against “no solar load”
Alternative calculation of P-factor

**Original** (Correction for different braking power at chassis with MAC on/off)

\[ FC_{MAC_i} = 3.6 \times C_{COP_i} \times (FC_{i \text{ Measured} - AC \text{ on}} - C_{Pe_i} \times FC_{i \text{ Measured} - AC \text{ off}}) \]

\[ C_{Pe_i} = \frac{P_{BAC\text{ On Speed }_i}}{P_{BAC\text{ Off Speed }_i}} \]

Assumes constant specific fuel consumption at small changes in power

**Alternative**: consider change in efficiency
Alternative calculation of P-factor

Profile of a diesel engine map at 1200 rpm

Generic equation:
may need more engine maps as basis
should also be normalised to rated power

Target

\[
FC_{(\text{Target } Pe)} = FC_{\text{measured}} + (Pe_{\text{Target}} - Pe_{\text{measured}}) \times \frac{\text{Diff } FC}{\text{Diff } kW}
\]
Effect of alternative calculation of P-factor

Difference between fuel consumption at measured P_wheels and at target P_wheels is corrected with much higher engine efficiency:

• Diff-FC/kW ~ 170 g/kWh at 50km/h and 200 g/kWh at 100km/h
• be [g/kWh] ~ >300 g/kWh at 50km/h and >230 g/kWh at 100 km/h

→ Smaller influence of deviations of P_wheels between MAC-on and MAC-off

Method has some uncertainties:

Diff-FC /kW is not known from specific engine. Rough estimation from difference in fuel consumption and braking power between 100km/h and 50 km/h is possible but differences in engine speeds influence results and these differences are vehicle model dependent.

Generic Diff-FC/kW is not accurately valid for all engines→ analyse data from phase A

Suggestions:

Test both options, maybe adapt generic Diff-FC/kW with more measured engine maps
Select option which gives better repeatability from data gained in pilot phase A
Restrict allowed deviation of velocity (depends on pilot phase results, +/- 1 km/h shall be possible at constant speed?)
Power correction factor

More different engines shall be analysed to improve correction function.

**Option 1)** analyse “Diff FC [g/h] / kW-Diff” for 100 second intervals with AC-off.

Typical differences in braking power are 0.001 to 0.05 kW within one constant speed in one test

Below measurement accuracy → No trends visible:

**Option 2)** analyse “Diff FC [g/h] / kW-Diff” between 50km/h and 100km/h with AC-off.

Problems:

• Different engine speeds influence efficiency

• Differences in braking power much higher than at one constant speed.

→ Only to validate magnitude of “Diff FC [g/h] / kW-Diff”.

E.g. analysis of 2 gasoline cars from MAC tests
Further assessment was performed by comparing a normal test phase with MAX off vs. test phase with MAC off of the same vehicle deliberately deviating speed to higher and lower levels compared to nominal (next slide)

No final decision possible with cars analysed yet
Target of assessment:
study the effect of power deviation and power correction factor on FC without the effect of MAC FC variation.

Two alternative power correction factor methodologies were applied for MAC OFF phases run at max and min speed to be compared to normal speed.

Comparison: mixed results, probably due to the fact that the alternative methodology has taken into account the change in energy efficiency of a specific diesel engine → check also other cars tested in phase A in detail.
Most data regard sedan, medium engine capacity vehicles

Variations of test cell conditions mainly due to conditions control restrictions

Settings results in most cases to cabin temperature between 15-20°C

Most data regard sedan, medium engine capacity vehicles

→ no conclusion on $T_{\text{cabin}} - T_{\text{vent}}$ correlation with vehicle size, engine size
Conclusions of phase A so far

- Application of MAC test procedure in phase A was successful and showed no needs for changing the basic set up
- Soak at 20° to 30° seems to be sufficient, no temperature control necessary
- Method to determine HVAC mass flow seems not to be sufficiently validated
- Preconditioning time of 1895 seconds seems to be sufficient. Extend to e.g. 2000 seconds to be on safer side?
- Tolerances for T and RH were not met at all labs. Broader tolerances are however not suggested due to influence on reproducibility.
- Tolerances for vehicle speed may be reduced to improve accuracy
- It is suggested to switch off AC and HVAC blower in 2nd phase of MAC test
- Proposed correction (1) is simple and equivalent to more advanced corrections in terms of variability reduction
Conclusions of phase A so far

- Correction factor affect positively measurement where conditions were severely violated (e.g. relative humidity) but do not completely correct these deviations

- *One test showed no blower effect on MAC off FC*

- Alternative power correction methodology needs further refinement
Open topics to be discussed and finalized

- Influence of SOC of battery not analyzed yet. Eventually a separate correction factor can be applied if SOC shows to be important (further data processing from phase A, no need to change test procedure for phase B but measure current from/to battery)

- Data from phase A will be further analyzed if further optimization of correction functions for T, X and braking power is possible (no need to change test procedure)

- Number of repetitions for Type-Approval (suggested = 3)

- Allow bag measurements (suggested = yes)

- Allow bags analysis after MAC on phase, empty bags and then MAC off phase

- Steady state phase between MAC on and MAC off phase (needs to be decided today, since it would change test procedure for phase B!)

- Different vehicle sizes in relation to HVAC mass flow setting

- Shall we prepare a questionnaire to clarify open issues? (suggested = yes)
Outlook of activities

› Stakeholder meeting on 11th of June
› Fine tuning of the procedure
› Round Robin testing (July – October)
› Procedure finalization
› Develop technical annex to regulation
# Time Schedule of the Pilot Test Phase

- **Project started 16 August 2011**

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</tbody>
</table>

**Current status**
Pilot Phase-B, round robin testing

- Target:
  - test the same vehicle
  - at 4 different laboratories
  - over the basic MAC test procedure

- Test requirements:
  - at least 3 repetitions of the MAC test
  - two days of testing
  - all labs using the same dyno settings

- Witness testing
  - A golden engineer will be present during testing

- Selection of participating labs
  - It is proposed that the 4 labs with the best test cell conditions capability participate in the round robin

Labs to be discussed:
JRC
BMW
Volvo
Daimler
Others
(TUG?)
Who takes care of mass flow settings?
Pilot Phase-B, round robin testing

- Logistics
  - car will be transported to test labs (not driven)
  - each partner receives the car at own expenses
  - each lab keeps the car for 1 week (receive on Monday, release on Friday)

- Test vehicle (golden vehicle)
  - expected be provided by one partner
  - ability to record as many on-board sensor data as possible
  - known blower flow rate and configurable to settings required by MAC test
  - Perform mass flow measurement as suggested in test procedure at different settings of wind speed fan in test cell. Measure pressure difference cabin vs. test cell also during MAC test together with blower current (any additional ideas how to further validate mass flow?)
  - additional time necessary in first lab

- Time schedule
  - tests to be performed within the period July 2012 - September 2012
Thank you for your attention