Working paper No. MACTP-**01-03**
(Geneva, 8 June 2010)

Mobile Air Conditioning (MAC)

Test procedure development

Progress update
08-06-2010

Contents

- Project overview
- Progress made so far
  - Identification of major influential parameters
  - Definition of test plan
  - Preliminary testing results

Project overview

Goal: To develop test conditions and procedures for MAC

- Main evaluation parameter: **impact on CO_2 / fuel consumption** and other regulated emissions
- Procedure should be clearly **discriminative** of different systems
- Target **accuracy** and **repeatability** need to be clearly established

Project overview

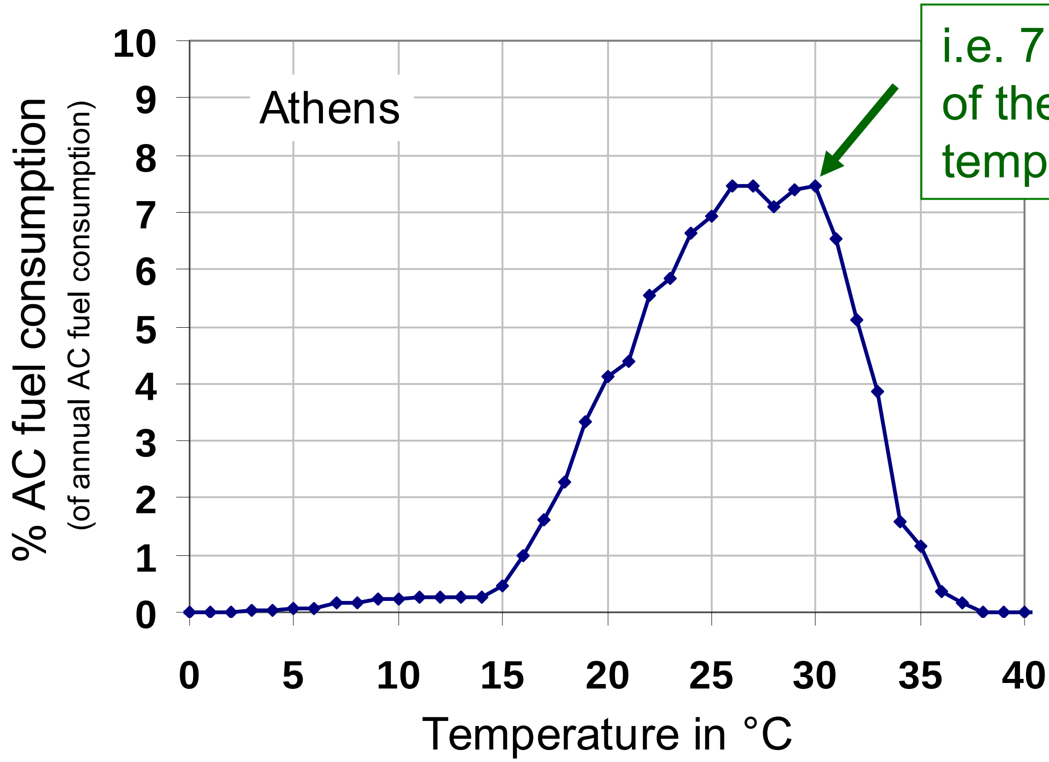
- Definition of a test procedure(s) for MAC performance at type approval
- Focus on physical testing but with options to include virtual testing later.
- Procedure should provide the possibility (partial) substitution by virtual testing in the future
  - Cost efficiency
  - Realistic representation of MAC efficiency
  - Use previous experience (ADAC 2007, TNO 2006)

MAC test conditions

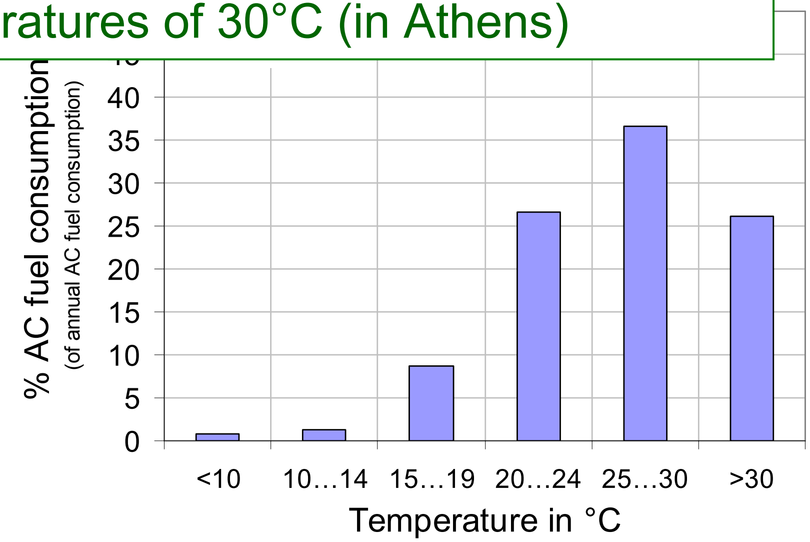
- Which are the most important ambient conditions concerning the real operation of the MAC system?
  - investigation of three „typical“ climates
    - hot: Athens
    - medium: Frankfurt
    - cold: Helsinki

MAC test conditions - weather, e.g. Athens

% AC fuel consumption of annual AC fuel consumption depending on ambient temperature



i.e. 7.5% of the annual fuel consumption of the ac system is caused at ambient temperatures of 30°C (in Athens)



=> proposal for test condition #1: 30°C/40%*

*average relative humidity at 30°C

Solar radiation 700 W/m²

TU Graz virtual vehicle LAT KTI TNO

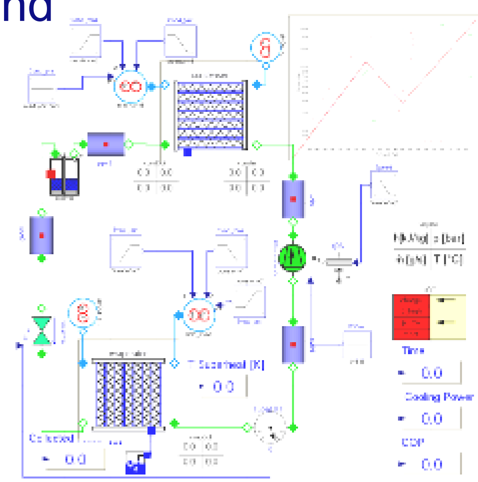
MAC test conditions - overview

- 15°C/75% (300 W/m²)
- 20°C/65% (500 W/m²)
- 30°C/40% (700 W/m²)

Based on assessment of annual weather data in Athens, Frankfurt, Helsinki.

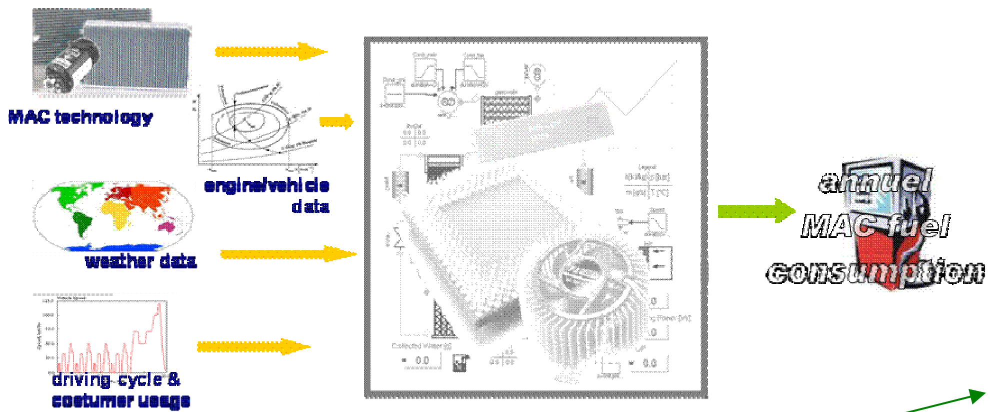
- <u>Remarks (results from simulation of refrigerant cycle):</u>
  - ±1 K at inlet temperature (≈ abient temperature) will result in a variation of ≈ ± 5% to 10% in cooling demand (greater impact at lower ambient temp.)
  - ±3 % at inlet humidity will result in a variation of ≈ ± 5% in cooling capacity

  -> important for control of climatic chamber!



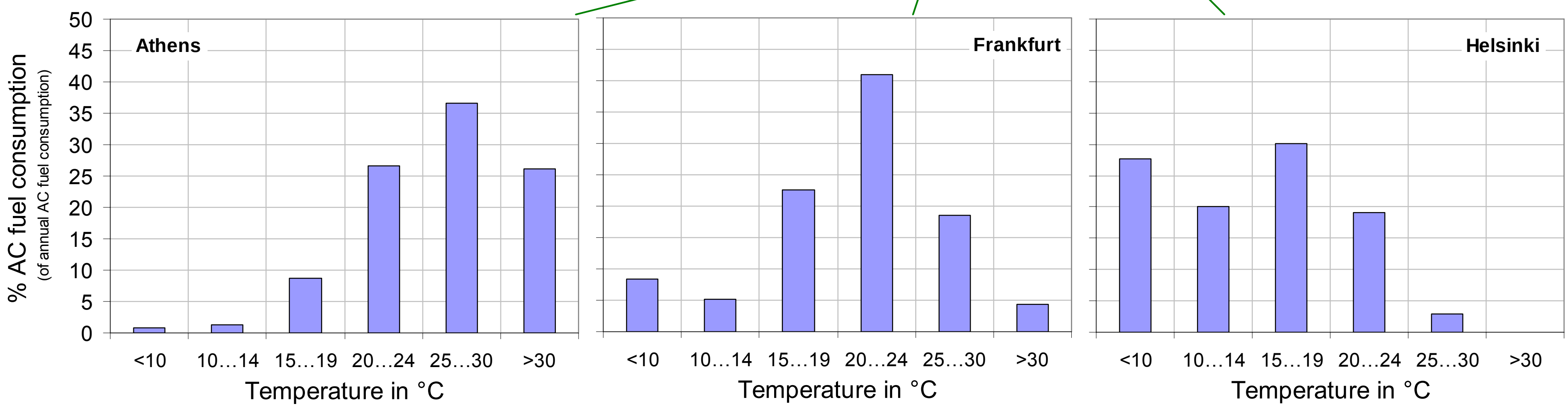
MAC test conditions - interior temperature

Condensing the results for the three evaluated cities



Findings:
T cabin < T ambient

From simulation work we suggest:
25°C and 40%? humidity in the test cell
21°C interior temperature
Sensitivity tests: 30°C/40%, 23°C/50%



Factors to be considered in test procedure

<u>Option for test procedure:</u>
Test vehicle on the chassis dynamometer with and without MAC.
Difference is the additional fuel consumption from the MAC system.

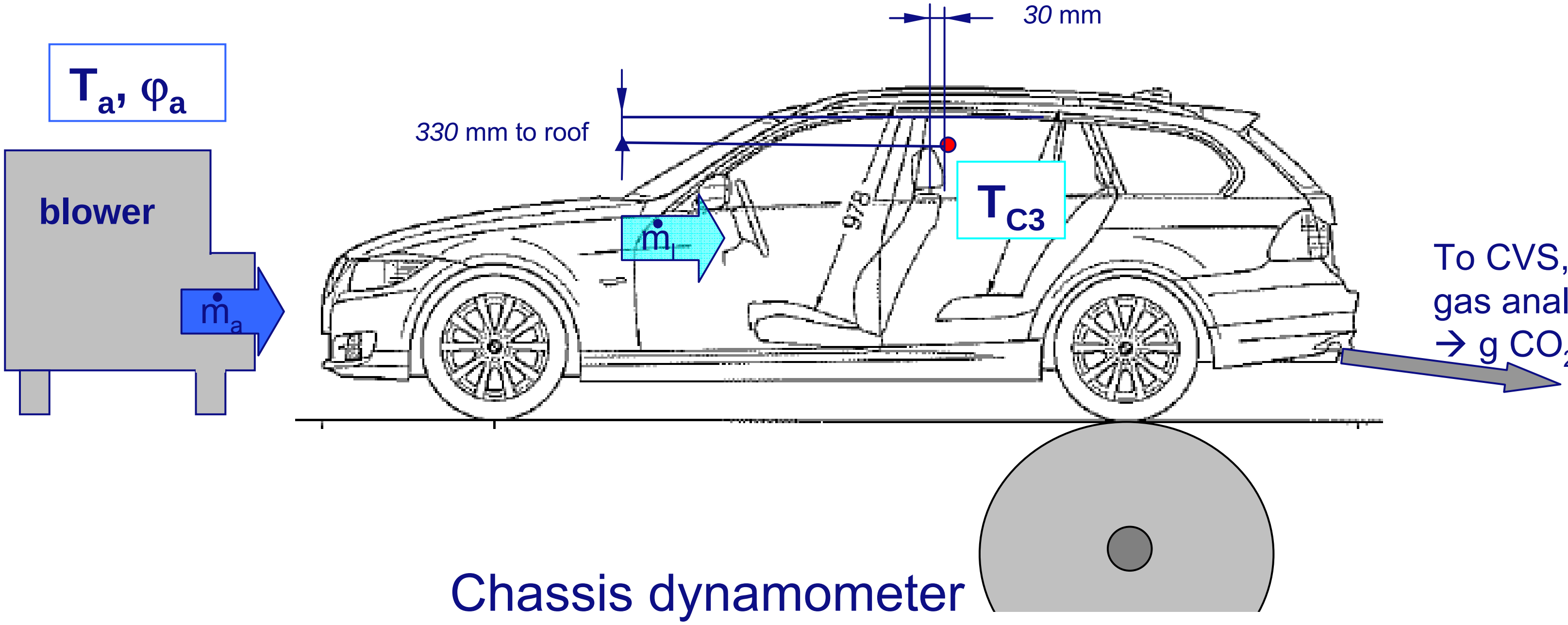
Define following settings:

1. Test cycle („easy to drive” for repeatable results at small fuel consumption effects)
2. Ambient temperature and humidity
3. Interior temperature to be reached with MAC
4. Simulation of heat from sun radiation (with heater in vehicle or via 3.)
5. Settings of the MAC system
6. Evaluation method for test results

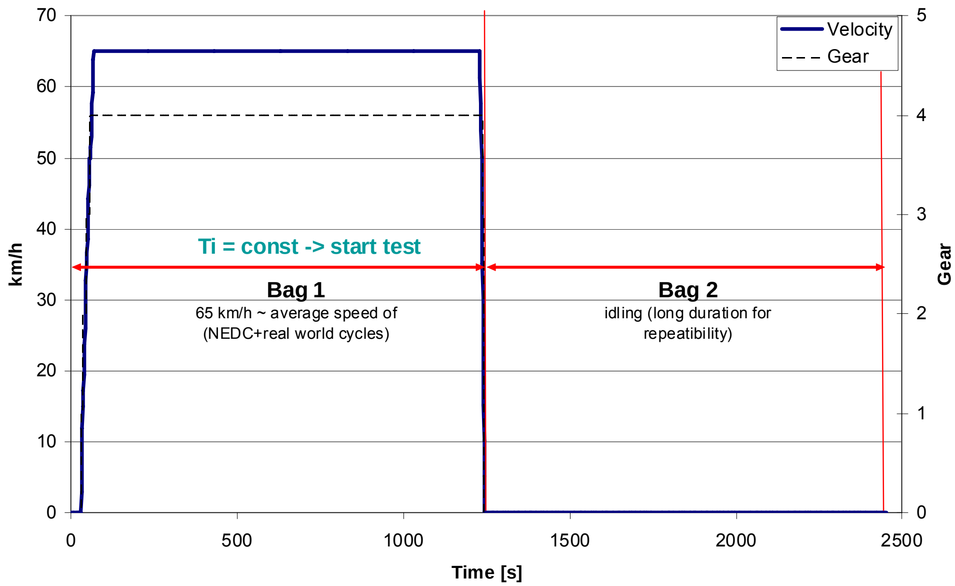
Working hypothesis for test procedure

Test programme on the chassis dynamometer for evaluation of:
* different test cycles
* different boundary conditions (T_a, φ_a, $\dot{m}_a$),
* settings of MAC (T_i, mass flow $\dot{m}_l$, recirculating air by blower settings)
* evaluation methods

Tests at TUG, KTI and LAT for reproducibility and repeatability

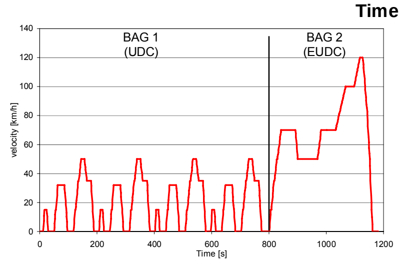


Test cycles



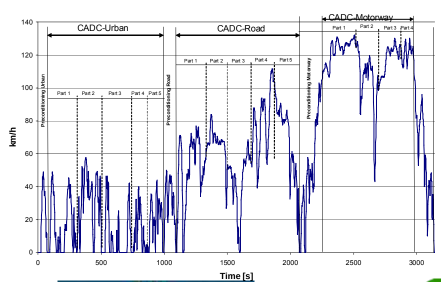
MAC-2-Step cycle

For for „quick“ basic tests, preferred



NEDC

Option for „not steady state test“



CADC

Measurement of additional fuel consumption from MAC in „real world“ cycle (not planned for type approval)

Soaking / preconditioning

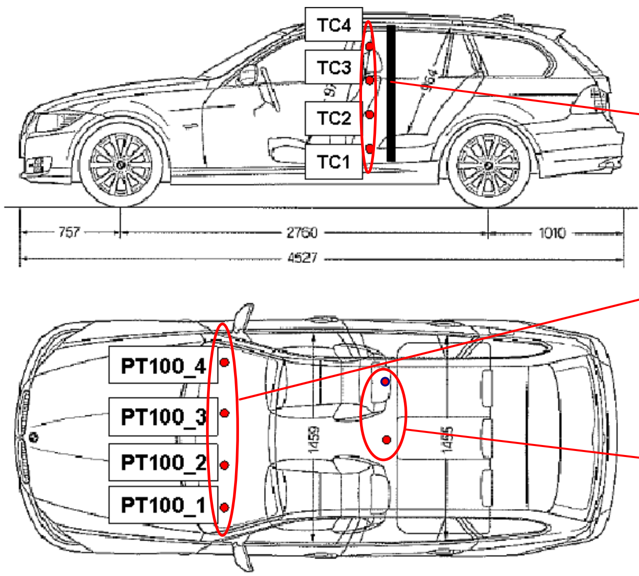
- Vehicle soaking:
  - Vehicle soaked at 25 °C for ~6 hours
  - Similar to emission testing pre-test soaking
  - Attainable at all type approval facilities

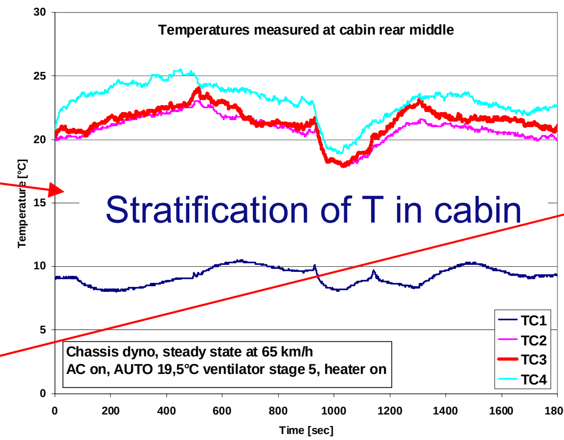
- Preconditioning phase:
  - Start drive cycle @ 65 km/h
  - Switch on MAC at desired setting*
  - Start measurement once desired interior temperature is attained and stable

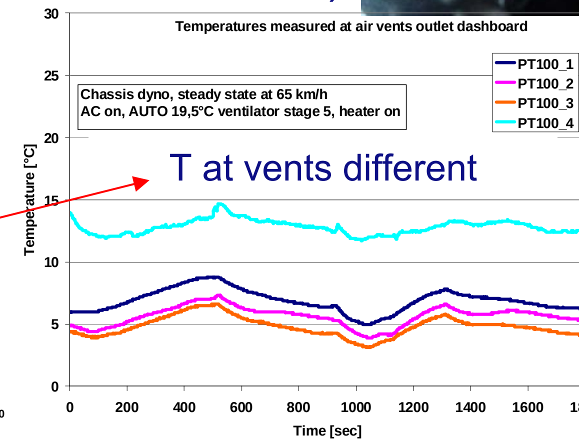
*settings to attain desired interior temperature need to be determined (either by trial-and-error or by manufacturer specification) and validated before start of the official test.

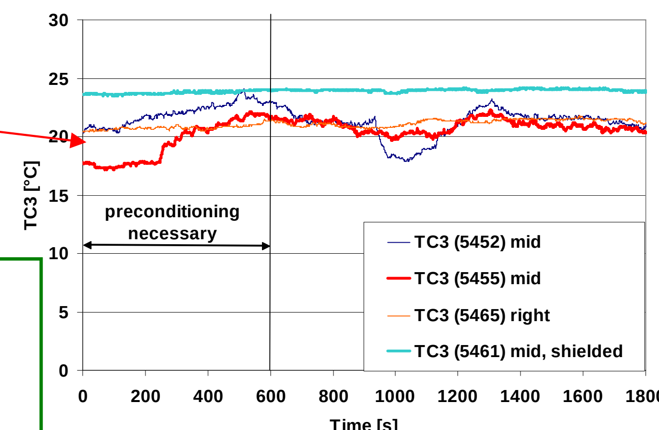
Selection of the interior temperature
(measurement point and settings)

Different measurement points in the vehicle and different sensor options
Position “TC3” seems to be best option (representative for head/shoulder)









Findings:
*Radiation from vehicle interior makes preconditioning necessary (>600s)
*T at vents outlet different and depending on MAC-comfort strategy of the model → not recommended as reference
*TC3 mid, not shielded best option?

Real world measurements in the project

Main task: evaluation, if test procedure is representative?
(due to very different climate conditions within Europe meeting exactly the "average" European MAC usage seems not to be the main goal. Covering the main influences for COP is more important)

M-1.1) Parameterization and validation of the simulation of the sun radiation
-> Park vehicles outside in sun (**LAT, JRC**)

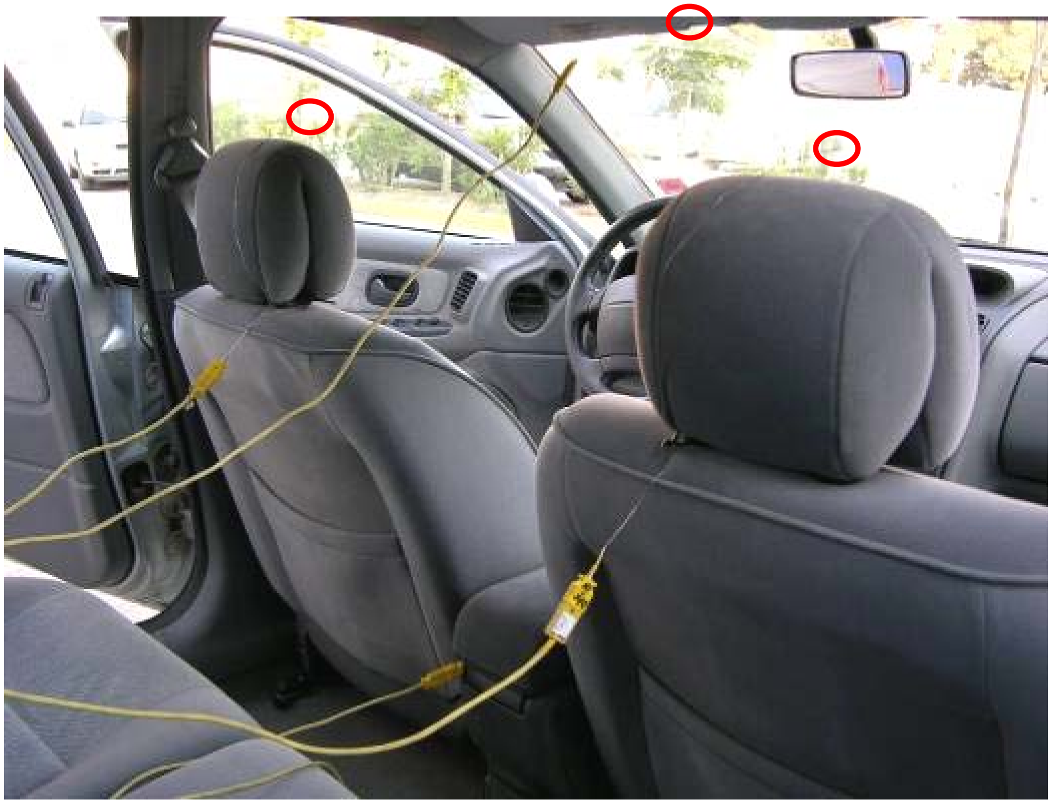
M-1.2) Influence of MAC in real world driving
-> Measure real world cycles on the chassis dyno. Measure with PEMS after vehicles parked outside in sun (**JRC, optional**) chasing of 2 similar vehicles, one MAC off, the other MAC on.

Real world measurements in the project

Ambient in-vehicle measurements (vehicle conditioned and then left parked under direct sunlight)

Measured quantities:

- Solar power density [W/m²] (top of the vehicle roof)
- Middle, front mirror [ºC]
- Head, driver [ºC]
- Head, front passenger [ºC]
- Floor, front passenger [ºC]
- Middle, by the gear lever [ºC]
- Head, middle back pass. [ºC]
- Trunk [ºC]



Solar Load

options to include effect into test procedure

Options (results from conference with Saint-Gobain Sekurit):

1) Calculate heat transmission by simplified approach:

- Measurement of direct solar transmittance (ISO 13837) of complete glazing, depending on average sun declination on each glass
- Calculating the total transmittance for complete glazing

2) Calculation of the thermal transfer:

- Calculating inner and outer surface temperatures for glazing & car body parts
- Calculating heat exchange by sun radiation, convection, conduction and emission

3) Detailed simulation with Open Source Tool (such as Energy+ for buildings)

Option 1) may be the best approach for type approval. Option 2) and 3) may be considered if in future a shift towards virtual testing is desired.

Repeatability

Influencing factors:

1. Variability in vehicle speed → variability of engine power demand
2. Variability in temperatures and humidity during the tests → influence on cooling demand and COP

↓

1) Correct for variation of vehicle speed with measured braking forces of the rollers
2) Correct for variations of Ta, φa, TC3 with simulated cooling demand
3) Define a sufficient preconditioning phase (if too long, DPF regeneration may happen during test phase)

Development of correction factors and procedures is in progress

Main open topics

- How can different settings of chassis dyno and of MAC be corrected. Can manufacturers make data for m_{air} t_2,.. for different blower positions available for the actual study to test methods?
  → discussion with ACEA (meeting in Graz on 03.05.2010, collection of options ongoing)
  → evaluation of different testing options to be finalized
- How can influence of sun radiation be depictured (in a simple way)?
  → discussion of options with Saint-Gobain Sekurit ongoing
- Which vehicle velocities (or rpm for MAC) shall be used in the tests?

Thank you

Thank you for your kind attention.