**Version 2.6. with summary of open issues from 11th MAC meeting (28-02-2014)**

**Track change (TC) accepted of items agreed 11th MAC meeting. See version 2.5 for proposed TC.**

**New proposals for text added in track change mode. All solved issues not tracked anymore to make document readable.**

**Open issues**

* **to be discussed if generic size correction is needed by ACEA**
* **check and amend text on allowed measurement options (instantaneous from CVS, instantaneous undiluted according to GTR?, 6 bags, 4 bags only if it is shown to TA, that the brake to analyse and purge bags between phase 3 and 4 of the MAC test cycle does not influence the test results.**
* **Set up formula for mass flow for N1 vehicles (constant 230 kg or more sophisticated according to volume for passenger transport?). Without alternative suggestion from ACEA a simple generic value of 230 kg/h may be used for N1 vehicles.**
* **Text “roof pane should be excluded” (chapter 4.4.11) seemed to be accepted in meeting on 28.02.2014, since insolation sliding roof below this pane can be closed (or pane be opened), so the question marks there have been removed in this version: check if ok.**
* Check data for difference (8%) in cabin air mass flow between lab and reference instrument. TUG
* Bag values at all labs possible? ACEA.
* Check general lab standards and requirements for humidity sensors (TUG). Include a check of the humidity sensor, the check (not calibration) to be performed before the MAC test (TUG to provide text).
* How to deal with amount of recirc? Agreed on 28.02.2014: . “It is agreed to skip the fixed limitation but keep the demand, that in real operation the recirculating air amount has to be similar or larger than in the MAC test (at same t and RH)
* ACEA to provide text and criteria for the Annex to exclude the largest N1 from MAC testing.
* Requirement for maximum test to test variation.
	+ Statistical evaluation of BMW data to be done by **TNO**.
	+ Include current measurement from WLTP (OBD or current clamp) TUG

**Type XXX test: DETERMINATION OF THE ADDITIONAL CO2 EMISSIONS AND FUEL CONSUMPTION DUE TO THE OPERATION OF THE MOBILE AIR CONDITIONING (MAC) SYSTEM**

1. INTRODUCTION

This Annex describes the procedure for the measurement of the additional fuel consumption and CO2 emission due to the operation of the Mobile Air Conditioning (MAC) system in a light-duty vehicle.

The procedure consists of a physical test with the entire vehicle on a chassis dynamometer in an emission laboratory.

1. DEFINITIONS

*“AC”* means Air Conditioning system.

*“CAP”* means Cooling Capacity of the MAC system.

*“COP”* means Coefficient of Performance (CAP / MAC-compressor work).

*“CVS”* means Constant Volume Sampling (dilution system for emission measurements).

*“DPF”* means Diesel Particle Filter.

 *“FC”* means Fuel Consumption.

*“GSI”* means Gear Shift Indicator.

*“HVAC”* means Heating, Ventilating and Air Conditioning, consisting of the MAC and systems to control the heating of the vehicles cabin interior.

*“MACFC”* the additional Fuel Consumption due to the operation of the MAC in a light-duty vehicle as determined according to the MAC test procedure as described in this annex.

*“MACCO2”* the additional CO2 emission due to the operation of the MAC in a light-duty vehicle as determined according to the MAC test procedure as described in this annex.

*“MAC”* means Mobile Air Conditioning system and consists of all parts required to achieve active cooling and control of the temperature of a vehicles cabin interior and occupants and the drying of air to defog the windshields.

*“MAC test cycle”* means the vehicle speed cycle defined for MAC testing startingwith the preconditioning phase and including the 6 MAC test phases with FC measurement.

*“MAC test phase”* means a single time window of the MAC test cycle with specific FC measurement (total 6 MAC test phases per cycle exist: idling, 50 km/h and 100 km/h with MAC on and MAC off respectively, see Figure 51).

*“MAC test procedure”* means the entire procedure for determining the additional fuel consumption (MACFC) and CO2 emissions (MACCO2) due to the MAC system.

*“OBD”* means On-Board Diagnostics.

*“RH”* means Relative Humidity.

*“SOC” means State of Charge.*

*"TAA"* means Type Approval Authority.

1. GENERAL REQUIREMENTS
	1. The type XXX test shall be executed according to Annex 4a of UN ECE regulation 83 with exception of 3.1, 4.4, 4.5, 4.6, 6.1, 6.3, 6.4.6, items and paragraphs related to PM, PN or NOx measurement and shall be executed according the Type XXX test described in this annex.
	2. The type XXX test shall apply to all vehicles (M1 and N1) falling under the scope of this regulation which are fitted with MAC systems directly powered by the internal combustion engine.
	3. The type XXX test is not applicable to vehicles whose MAC systems are electrically powered.
	4. Self-declaration

The manufacturer shall declare the value of additional fuel consumption (MACFC) and CO2 emission (MACCO2). The physical tests can be done for vehicle families.

A family thus is a group of vehicles covered by one MAC test procedure. The resulting FC-MACT value can be applied to more than one version of a vehicle type that certification is sought for. In the case that a manufacturer decides to cover different versions with one declared value, he shall demonstrate to TAA, that the chosen value is covering all versions. This may be accomplished by showing that relevant technical specifications for all versions give a MACFC no greater than the declared value.

Physical testing necessary for the self-declaration approach: a manufacturer shall perform the MAC test procedure for each vehicle family. The family will receive a FC-MACT value which represents the corrected and weighted test result from the chassis dynamometer testing but without correction for size and glazing. The manufacturer may choose to group all versions of a vehicle type under one FC-MACT value (family) given that he tested the version of the family with the highest FC-MACT and shows to the TAA based on all relevant technical specifications that the versions declared under the same value and not tested are expected to have lower FC-MACT. If a manufacturer desires to distinguish between versions of one type he may test any different versions to make smaller families.

Correction for cabin size and size and quality of glazing have to be applied to the declared MACFC and MACCO2 values based on the FC-MACT value of the vehicle family a model corresponds to. Applying these corrections does not require extra testing but have to be made by post-processing correction factors as described in 4.4.1.1.

* 1. MAC deactivation

The MACFC and MACCO2 from this procedure may be corrected.

20% of the MACFC and MACCO2 may be deducted from the MAC FC and MACCO2 result from the MAC test procedure if the manufacturer declares that the following conditions are always met:

The MAC is off when the vehicle is powered up after the vehicle has been parked for longer than 1 hour time at an ambient temperature of below 18ºC and below 75% RH. After powering up of the vehicle the MAC may only be activated by the user of the car.

10% of the MACFC and MAC CO2 may be deducted from the MACFC and MACCO2 result from the MAC test procedure and may be applied if the manufacturer declares that the following conditions are always met:

The MAC is off when the vehicle is powered up after the vehicle has been parked for longer than 1 hour time at an ambient temperature of below 15ºC and below 75% RH. After powering up of the vehicle the MAC may only be activated by the user of the car.

The ‘MAC deactivation’ shall be demonstrated at request of the type-approval authority and always meet the requirements above.

1. TECHNICAL REQUIREMENTS
	1. Test set-up
		1. Test cell
			1. Characteristics

The test bed and test cell shall fulfil the definitions given in Annex 4a appendix 1 of UN/ECE Regulation 83 as well as the specific requirements and definitions in this Annex.

* + - 1. Frontal air flow sensors positioning

The sensors used for monitoring the temperature and humidity of the test cell (ta and$ φ\_{a}$ respectively) shall be positioned either at the inlet of the fan providing the air flow to the vehicle or inside the test cell, in a position proven to be representative for the MAC intake air condition.

* + - 1. Target values for temperature and humidity of the test cell.

During the MAC test cycle the humidity and the temperature of the test cell shall meet the following requirements:

1. Average Humidity in the test cell:

φa=8,9 gwater/kgair ± 1 gwater/kgair

1. The instantaneous Humidity in the test cell during the sampling phases:

φi=8,9 gwater/kgair ± 1.5 gwater/kgair

1. The average temperature in the test cell:

 Ta = 25°C ± 2°C

1. The instantaneous temperature in the test cell during the sampling phases:

ti = 25°C ± 3°C

* + 1. Vehicle
			1. The test vehicle shall meet the requirements set out in UN/ECE Regulation 83.
			2. Vents outlet sensors position

The vents outlet temperatures shall be measured in the dashboard vents. One temperature sensor has to be located in front of the centre of each vent outlet. The distance of the temperature sensor from the vent outlet face shall not exceed 2 cm outside of the air vent and 5 cm inside the air vent.

* + - 1. Vehicle openings

Before the start of the test cycle, all openings of the vehicle must be closed, e.g. windows, doors, hood, roof, etc., with exception of the intake and outlet of the HVAC system.

* + 1. HVAC
			1. HVAC settings

The settings of the HVAC system have to be adjusted at the beginning of the preconditioning phase of the MAC test cycle. From second 1500 of the MAC test cycle on, no changes in the settings shall be made until the end of phase 3 of the MAC test cycle (i.e. when the MAC-on phases end).

Manual settings of the mass flow and target cabin head temperature will be typically necessary to reach the values defined in sections 4.1.3.3 and4.1.3.4.

The amount of recirculating air can be controlled by the vehicles MAC controller in automatic settings of the vehicles MAC system. The maximum allowed amount of recirculating air in the MAC test is limited by the amount the MAC also controls at minimum under the same ambient conditions as the test in the real world in automatic setting of the MAC system.

Manually controlled systems shall be set to fresh air mode.

For manually controlled systems it is not allowed to switch on the recirculation mode.

* + - 1. Air vent nozzle settings

All flaps of the vents in the front area of the cabin shall be set fully opened (i.e. 90° position relative to the sectional area of the vent). Vents at the dashboard have to be open, all other vents, such as for the rear seats or for the foot well, shall be closed and/or be deactivated by the MAC control panel. All open vents have to be included in the temperature measurement system as set out in section 4.1.2.2.

* + - 1. Target values for vent temperatures

The vent outlet air temperatures (TV1 to TVn) shall be measured according 4.1.2.2. The arithmetic mean value of each MAC test phase with MAC on (i.e. idling, 50 km/h and 100 km/h) of each vent outlet air temperature shall not exceed 15°C.

* + - 1. Target values for cabin mass flow

The standard settings of the mass flow of the air conditioning system shall be adjusted to achieve at least 230 kg/h. The methodology for measuring, adjusting and checking the air mass is set out in Appendix 1.

The standard setting shall be adapted to the size of the tested vehicle according to the following method:

[kg/h]

The cabin volume shall be calculated with:



L Wheelbase [m]

B Axle width [m]

H height of the vehicle [m]= The height of the vehicle is the total height minus ground clearance.

* + 1. Additional requirements
			1. Battery SOC (electric imbalance)

The test shall always be started at 100% SOC of the vehicles main battery, so connect a battery charger to the vehicle during the soak phase.

The test result must be corrected for differences in electric energy stored in the battery between the MAC on phase and the MAC off phase, see paragraph 4.3.3.9.

The vehicles main battery and the SOC starting conditions may be altered against serial conditions if necessary to reach the tolerances for the imbalance of electric energy flow described in 4.3.3.9.

* + - 1. Start stop systems

For vehicle types equipped with a system that automatically stalls the combustion engine when the vehicle is in standstill condition, generally known as Start/Stop systems, these systems shall be disabled during the entire MAC test cycle.

* + - 1. Additional requirements

In accordance with the self-declaration approach the manufacturer shall declare that, with exception of the MAC system, the MAC test shall be conducted with the vehicle, the control systems and accessories in the same state in the MAC on and in the MAC off phase. Systems which are needed for normal operation of the vehicle may be active but should be in the same state in both the MAC on and the MAC off test phase.

The manufacturer shall declare that during the MAC test, regeneration processes of the aftertreatment systems, non-continuous OBD activities influencing the fuel consumption and any other none continuously running process with influence on the engine work or on the engine combustion process did not occur.

Results should stay in an expected range. If this is not the case it should be carefully evaluated whether no system interfere with the test, e.g. regeneration of the DPF, or other storage devices, OBD emission events, start-stop system interference, …. .

For vehicles with particle filters measures may be taken to prevent a regeneration during the measurement phases with MAC on and MAC off. The particle filter may be regenerated by an external trigger in the preconditioning phase of the test between the start of the preconditioning and 1500 seconds before the end of the preconditioning phase.

The FC with MAC on must be higher than the FC with MAC off.

The manufacturer shall declare that the operation of the MAC and the amount of air recirculation during the MAC test are the same as during normal operation on the road. No sensors or control systems shall affect the normal MAC operation during the MAC test. This may be checked by the type approval authority by requesting a test according Annex XX – Appendix 12.3.

* + 1. Test fuel

The test fuel shall be conform to the specifications in XII of 692/2008/EC (latest amended by 195/2013/EC).

* 1. Quantities to be measured
		1. Mandatory quantities

Following quantities shall be measured and recorded at 1 Hz over the entire MAC test cycle.

1. Test cell temperature. Sensor position and tolerances for the measured quantities shall be those set out in section 4.1.1.2 and section 4.1.1.3.
2. The sensors shall meet the requirements of WLTP (REFERENCE to final WLTP Regulation) Test cell humidity [g/kg]. Sensor position and tolerances for the measured quantities shall be those set out in section 4.1.1.2 and section 4.1.1.3.

Sensors with an absolute humidity accuracy of < 0.2 g/kg at +20..30 °C (i.e. ±1% for a range between 35% to 55% RH) shall be used.

1. Vent outlet temperatures. Sensor position and target values for the measured quantities shall be those set out in section 4.1.2.2 and 4.1.3.3.

Sensors with an accuracy of ≤ ±0.3K+0.005\*T shall be used.

1. Battery current and voltage: Energy flow into the battery shall be measured as positive current, energy from the battery as negative value. The accuracy as well as the application of the current clamp for the measurement of the battery current shall be conform Annex 6 - Appendix 2, chapter 2.1 Current transducer of the WLTP-DTP 263 (Comment Hausberger: actual version 263rev2 which foresees following: The current transducer (i.e. a current sensor without data acquisition equipment) shall have a minimum accuracy of 0.5 per cent of the measured value (in A) or 0.1 per cent of full scale deflection. Also the position and frequency is defined there in a useful way).
2. The speed on the chassis dynamometer shall be recorded according to UN/ECE Regulation 83
3. Road load (power to the wheel) [kW] as calculated from the chassis dynamometer force and speed, see paragraph 4.3.3.6.
4. For measurement of the fuel consumption per MAC test phase following options are allowed:
(vii-1) The average fuel consumption [kg/h] per MAC test phase by bag measurement, using the carbon balance method.
(vii-2) The instantaneous fuel consumption [kg/h] determined by means of the carbon balance from the dilute emissions.
(vii-2) The average CO2 emission [kg/h] per MAC test phase by bag measurement.
(vii-2) The instantaneous CO2 emission [kg/h] determined by means of the carbon balance from the dilute emissions.
	* 1. Analysers

During the MAC test cycle, the exhaust gas analysers should have the same calibration (span, zero) during one test at MAC on and MAC off. Before each MAC test cycle one calibration shall be done.

The analysers specifications and all other requirements with regard to the checking and handling of the analysers shall be conform UN/ECE Regulation 83.

* 1. Test procedure
		1. Vehicle preparation, dynamometer calibration procedure and soak phase

The MAC test cycle is preceded by a soak phase. The preconditioning phase is established within the MAC test cycle for bringing all the relevant vehicle parts to a defined status as well as for providing time to properly set the MAC system.

The following soak and preconditioning procedure should be used before the MAC test starts.

1. Set the road load and the inertia of the roller test bed according to paragraph 6.2.1 of Annex 4a of ECE R83.
2. Set the tyre pressure according to paragraph 6.2.3 of annex 4a of ECE R83.
3. Soak phase. The temperature of the vehicle before test start shall be the stabilised temperature which would be reached by soaking the vehicle indoors between 20°C and 30°C. The vehicle shall be put at the test bed in the cell or in the close vicinity at given temperatures for at least 8 hours. The temperature of the room in which the vehicle is soaked should be measured and recorded according ECE R83.
4. Set the HVAC System:
	1. Automatic HVAC system: set the HVAC system of the vehicle to “automatic position”;
	2. Manual HVAC System: set the HVAC system of the vehicle to “outside air” (no recirculation);
5. Set the air distribution only to the dashboard vent outlet. Seal all the other vents;
6. Set the temperature setting such that the target air temperatures at vent outlet set out in section 4.1.3.3 will be achieved. The settings can be further tuned in the MAC preconditioning phase as described in section 4.3;
7. Set the blower so that the air flow target value set out in section 4.1.3.5 will be achieved;
8. Connect a battery charger to the vehicles main battery and charge until 100% battery SOC is reached before test start, as set out in section 4.1.4.
9. Start the test as set out in section 4.3.2
10. For a repetition of the MAC test cycle set out in section 4.3.2 with the same settings, no additional soak procedure is required if the vehicle is running in idle conditions between the repetitions and if the duration between the MAC test cycles is less than 20 minutes (this is the maximum time available for measurement finalisation and for purging the bags and calibration of the analysers). The preconditioning phase, described in section 4.3.2, is part of the MAC test cycle and is always mandatory.
	* 1. MAC test cycle

The MAC test cycle (Appendix 2 to this annex) for the type XXX test consists of a series of MAC test phases, as depicted also in Figure 51:

1. Preconditioning phase with MAC on;
2. Three steady state phases with MAC on;
3. A repetition of the three steady state phases with MAC off;

For driving the MAC test cycle a tolerance of ±1 km/h is allowed between the indicated speed and the theoretical speed, during steady speeds. Use of the cruise control is allowed. For the other parts of the MAC test cycle tolerance shall be those set out in Annex 4a of UN/ECE Regulation 83. Special requirements are set out for gear shifting in paragraph 4.3.2.3.

|  |
| --- |
|  |
| Figure 1. MAC test cycle with preconditioning phase and six MAC test phases. The preconditioning phase and the first three MAC test phases are with the MAC switched on and last three MAC test phases are with MAC switched off. |

The MAC and the blower shall be switched off when the vehicle reaches idling in second 3015 in the basic test procedure depicted in Figure 51.

* + - 1. Preconditioning phase

The settings of the MAC system set out in section 4.1.3.3 have to be adjusted before second 1500 after the test starts. After second 1500 no further adjustments shall be made.

* + - 1. Repetition of the MAC test cycle

The MAC test cycle shall be repeated at least 3 times. The analysers shall be calibrated before each test cycle.

A maximum variation between the additional fuel consumption from each test cycle is allowed where the standard deviation, or confidence interval or p (..or maximum and minimum, choose option) shall stay within XX% of the average of the MAC test cycles.

* + - 1. Gear shifting

For the steady state speeds of the MAC test cycle the gear shift rules are as follows:

1. The MAC test phases at 100km/h have to be driven in the highest gear
2. The MAC test phases at 50 km/h have to be driven in the “highest gear minus 2”, e.g. if top gear is 8th, drive in 6th gear.

Gear shifts for the whole MAC test cycle are given in Appendix 2 to this Annex. To follow these gear shift rules, a test vehicle with manual gear box is preferred. If an automatic gear box is used, manual gear selection shall be used when available, to avoid shifts during constant speed phases. Shifts during the steady speed phases are not allowed.

If the gear shifting rules lead to engine speeds outside the normal operation of the vehicle the manufacturer may request the TAA to use an alternative gear shifting algorithm according to the requirements of the World Light Duty Test Procedure (WLTP). REFERENCE to final WLTP Regulation.

Shifts during steady speeds are never allowed. The gear shifting points shall be the same for the MAC on test phases as for the MAC off test phases of the MAC test cycle.

* 1. Test evaluation
		1. Gaseous emissions sampling and analysis

The method used to measure the mass emissions of CO2, THC and CO with bags shall be this prescribed in Annex 4a and Appendix 2 and 3 of Annex 4a of UN/ECE Regulation 83.

Bags can be used several times during one test if the system is fast enough with analysing and purging of one sampled phase before a next test phase has to be sampled. No more than one phase may be sampled in one bag.

The bag emissions shall be determined as the average emissions in gram per hour, corrected for the dilution air, for each time window of the six MAC test phases of MAC on and MAC off.

The concentration of CO2, THC and CO in the dilution air can optionally be taken from one background bag reading for all phases of the MAC test cycle and shall be used to correct the measured concentrations of the diluted exhaust gas for the entire cycle. The Dilution Factor shall be calculated as set out in Appendix 2 of Annex 4a of UN/ECE Regulation 83.

* + 1. Gaseous emissions sampling and analysis using the continuous dilute method

Where the use of one bag per MAC test phase is not possible, the mass emissions may also be determined by means of the continuous sampling of the dilute exhaust gas from the dilution tunnel.

The conditions and requirements for the determination of the mass emissions from the dilute exhaust gas shall be conform WLTP REFERENCE to final WLTP Regulation. For the continuous dilute method, the average emission concentrations from the instantaneous emission signals shall be used over the MAC test phases in the calculation instead of the bag concentrations and shall be calculated over the same time windows as the bags need to be sampled. The average CO2, CO and HC concentrations shall be calculated from the integrated analyser readings, corrected for varying flow of the C.V.S. if necessary. Adding reference to WLTP.

* + 1. Gaseous emissions sampling and analysis using the method of sampling the undiluted exhaust gas.

Where the use of one bag per MAC test phase is not possible, the mass emissions may also be determined by means of sampling the undiluted exhaust gas. This method may be used if it can be demonstrated that the accuracy of the determination of the exhaust gas mass or volume flow is <2%.

* + 1. Calculation of the fuel consumption per MAC test phase

The fuel consumption of each MAC test phase in kg/h shall be calculated by means of the basic principles and constants for fuel composition from the carbon balance method according Annex XII of 692/2008/EC from the mass emissions of CO2, CO and THC for each time window of a MAC test phase.

* + 1. Time windows for calculation of the fuel consumption

The MAC test phases and corresponding time windows within the MAC test cycle for the calculation of the fuel consumption are shown in Appendix 2 to this annex.

* + 1. Correction for the fuel consumption

The additional fuel consumption due to the MAC is the weighted difference in fuel consumption between the MAC-on and the MAC-off phases in the test cycle of each of the speeds or idling. The evaluation of each of the phases is calculated by means of the following formula:

FCMACei=CCOPi x (FCi MAC on - (FCi MAC off + CPei) )

In this formula:

i = speed step i (0 km/h, 50 km/h, 100 km/h);

FCMACei = additional fuel consumption of the MAC system [kg/h] in MAC test phase i, including all correction factors for variability in chassis dyno braking power, in test cell temperature and in humidity; Correction for electric energy misbalance is considered later in 4.4.9.

FCiMAC-on = average fuel consumption measured at MAC test phase i in the MAC test phases with AC on [kg/h];

FCiMAC-off = average fuel consumption measured at MAC test phase i in the MAC test phases with AC off [kg/h];

CPei = correction value taking into account variability of the braking power of the chassis dynamometer due to speed variations;

CCOPi = correction factor taking into account variability of the cooling capacity demand (CAP) which occurs due to the variability from the temperature in the cabin and in the test cell as well as from the humidity in the test cell;

* + 1. Correction for the braking power

The correction factor CPei is based on a generic change in fuel flow of “factor\_Willans” in the unit [kg/kWh]. Thus the correction factor is calculated by means of the following formula:



In this formula:

 = average braking power of the rollers in [kW] in speed step i with MAC-on (0 km/h, 50 km/h, 100 km/h);

factor\_Willans Generic Willans factor depending on the engine technology and fuel used. The factor is defined in the ECE/Trans/WP.29/GRPE/2013/13 in Annex 6, Appendix 2. Cases not listed there shall use a factorWillans-Wheel of 0.25.

Table 1: **Willans factors (update with final WLTP regulation, transform then also l/kWh into kg/kWh).** (The factors in the table refer to engine power, since we need power at the wheel, we should divide the values by 0.95 to take transmission efficiency into account. This was added to the equation above)

|  |  |  | *Naturally aspirated* | *Supercharged* |
| --- | --- | --- | --- | --- |
| Positive ignition | Gasoline (E0) | l/kWh | 0.264 | 0.28 |
| gCO2/kWh | 630 | 668 |
| Gasoline (E5) | l/kWh | 0.268 | 0.284 |
| gCO2/kWh | 628 | 666 |
| CNG (G20) | m³/kWh | 0.259 | 0.275 |
| gCO2/kWh | 465 | 493 |
| LPG | l/kWh | 0.342 | 0.363 |
| gCO2/kWh | 557 | 591 |
| E85 | l/kWh | 0.367 | 0.389 |
| gCO2/kWh | 608 | 645 |
| Compression ignition | Diesel (B0) | l/kWh | 0.22 | 0.22 |
| gCO2/kWh | 581 | 581 |
| Diesel (B5) | l/kWh | 0.22 | 0.22 |
| gCO2/kWh | 581 | 581 |

 = average braking power of the rollers in [kW] in speed step i with MAC-off (0 km/h, 50 km/h, 100 km/h);

The braking power of the rollers PB should be calculated from the measured braking force F and the measured speed of the rollers *v* (PB = v ∙ F). Alternatively the power can be calculated according to the driving resistance polynomial used in the set up for the tested vehicle: PB = v ∙ (R0 + R1 ∙ v + R2 ∙ v2 + mass \* a). The average power is the average of the recorded instantaneous data for the entire evaluation phase of speed step i.

* + 1. Correction for humidity and temperatures

The correction factor CCOPi is calculated by means of the following formula:



In this formula:

 = correction factor for variation of test cell temperature Ta with TV and RH being exactly at the target values;

 = correction factor for variation of test cell humidity RH with TV and Ta being exactly at the target values;

The correction factors for the possible variability in the boundary conditions shall be computed by means of the following polynomial functions:

 with Ta in [°C]

 with RH as [%]

When the humidity is measured as absolute humidity X, the correction based on RH (CCOPi\_RH) has to be replaced by the correction based on X



 with X as [gWater/kgair]

* + 1. Correction for electric energy imbalance

The method for battery imbalance will be defined based on the findings in the mini-Round Robin. Options are: 1) alternator constant voltage by diagnosis mode, 2) use small battery during test or 3)limit imbalance (current clamp). It is suggested to define a maximum value for imbalance (i.e. 3.) The choice for a method to stay below this maximum value should be open to the manufacturer.. 4) measure and correct for alternator currant and voltage.

To limit the uncertainty of the test result, the maximum electrical imbalance shall be 20Wh as absolute value of the difference of the average electrical power in each corresponding MAC-on and MAC-off phase.

* for*

*;*

*;*

**

* [W] Average electric power from or to the battery over the measurement time for a test phase i*

The eventual imbalance of electric energy produced by the alternator and/or stored in the battery is corrected by the difference of the average electric power measured as flow into the battery with a generic additional fuel consumption per kW engine power of called “factorWillans” (see Table 1) and with a generic efficiency of the alternator of 67%:

**

*With  [kW]*

* + 1. Weighting of emissions

The results for the Fuel consumption of the MAC in kg/h per phase of the MAC test cycle shall be weighted according to the following shares:

1. Idling = 15%
2. 50 km/h = 65%
3. 100 km/h = 20%

The total, corrected, additional fuel consumption due to the operation of the MAC is the weighted average of the corrected, additional fuel consumption in the three phases:

FCMAC-T [kg/h] = 0,15 x FCMACi-idle + 0,65 x FCMACi-50km/h + 0,20 x FCMACi-100km/h

* + 1. Correction for the cabin size and quality of glazing.

Comment Hausberger: I can not find the correction for cabin size here. Is it foreseen to have such an option?

Comment Vermeulen: It was at the time families were considered. Now we have the self-declaration approach this isn’t necessary anymore. Cabin size is taken into account with determination of air mass flow.

**🡪 needs to be discussed if generic size correction is needed by ACEA**

The specific heat entrance into the vehicle cabin in W/m² due to the sun radiation shall be extrapolated from Table 17 as function of the TTS value for the glazing quality and as function of the inclination angle of the windscreen or glass panes.

The extrapolated heat entrance into the cabin due to sun radiation is then used to compute the correction factor for the MAC fuel consumption from the physical MAC test to consider effects of glazing size, quality and mounting angles. Independently of the family concept demonstrated by the manufacturer to the Type approval authority as described in 3.4, the correction factor FTTS to consider the glazing effects shall be computed based on the glazing data for each model. The model specific correction factor FTTS can be applied to the FCMAC\_T value from physical MAC test on a wider family definition[[1]](#footnote-2).

The inclination angle for the windscreen or glass pane shall be determined according ECE-R43 paragraph 2.15. For glass panes on the sides of the vehicle the same method shall be used, with exception of the determination of the vertical pane through the longitudinal axis of the vehicle. Instead, the vertical pane shall be taken through the centre of gravity of the glass pane and perpendicular to the glass pane in the centre of gravity. For each windscreen or glass pane the specific heat entrance shall be calculated separately. The roof pane shall be excluded from the calculation. The TTS value shall be calculated according to ISO 13837 for each pane from its glazing data (Tds, Rds for 0° inclination angle from the sun radiation on the glass and heat transfer rates for parking).

Table 2: look up table for the specific heat entrance qsi in [W/m²] into the vehicle cabin due to sun radiation as function of the TTS value of the glazing quality and of the inclination angle.



The total heat entrance **QS** from all panes in W is then:



 With i index for pane number

qSi specific heat entrance for pane i in [W/m²] according to Table 17.

 Ai sectional area of pane i in [m²]

The influence of the heat entrance from sun radiation on the cooling capacity demand of the vehicle is taken into consideration by a correction factor on the MAC fuel consumption measured in the MAC test on the chassis dynamometer:



The FTTs depictures the relative change of the additional fuel consumption from the MAC system due to heat entrance from sun radiation against the basic MAC step test. The relative change is normalized against an estate car with average glazing quality and a plane area of 2.24m². This does mean that a QS of 530W leads to no correction of the test result (FTTS = 1.0) while for example a QS of 1000W leads to +18% (FTTS = 1.18). This normalisation of the correction factor to an average estate takes into account, that the defined MAC mass flow in the MAC test (>230 kg/h) is representing the settings of an average car under average climate conditions, i.e. includes an average effect of sun radiation already.

The final corrected test result for the MAC fuel consumption in [kg/h] is:

 

* + 1. Calculation of fuel consumption

For the calculation of the fuel consumption MACFC in l/100km the fuel densities are taken from XII of 692/2008/EC (latest amended by 195/2013/EC).

MACFC [l/h]= FCMAC [kg/h] / fuel density [kg/m3] x 1000

MACFC [l100km] = MACFC [l/h] / weighted average vehicle speed [km/h] x 100

With:

Weighted average vehicle speed [km/h] = 0,65 x average speed [km/h] (at MAC test phase 50km/h) + 0,2 x average speed [km/h] (at MAC test phase 100km/h).

**Annex XX – Appendix 1**

**Determination of the HVAC mass flow**

1. Objective

This appendix describes the Interior Pressure method for measuring the HVAC mass flow.

1. Method
	1. Pressure drop calibration for a known mass flow

The inlet air flow in the cabin is tightly closed, the outside air intake needs to be sealed, and a defined air flow can be brought into the passenger compartment (e.g. over a rear seat window) by an auxiliary blower unit. The air mass flow is measured in a duct section of the auxiliary blower inlet or at the feeding pipe to the cabin;

The accuracy of the mass flow measurement needs to be defined. First guess is that it shall be less than +/-2%, since it directly influences the test result. The possible accuracy needs to be checked at the mini-RR. A calibration of the mass flow measurement system needs to be made at least every 12 month.

The adjusted pressure difference to the ambient is determined as a function of the air mass flow through the passenger compartment. The static pressure in the cabin shall be measured at the same conditions of the air mass flow measurements;

The curve on the left picture in Figure 3 shall be depicted for several mass flow and pressure difference measurements.

* 1. Mass flow calculation from pressure drop measurement

After the process described in section 2.1 is complete, the air measuring section is closed, the vehicle inlet nozzles are opened again and ventilation is operated;

For any blower setting, the equilibrium between the blower characteristic curve (mass flow versus pressure gain) and the pressure differential between the cabin inlet and outlet is reached;

The measurement shall be done for the wind blower speeds applied in the MAC test, i.e. at idling, 50 km/h, 100 km/h and for MAC on and MAC-off condition.

The mass flow may be determined over the idle test phase only if it can be demonstrated to the TAA on request of the TAA that the mass flow determined by this method is higher in in any other steady operating speed.

For the MAC test a HVAC setting has to be selected, in which the mass flow is equal or higher than defined in 4.1.3.4 at all wind blower speeds tested, i.e. where the pressure drop exceeds the pressure drop from 2.1 achieved at the same wind blower speed.

Additional air exchange through the body occurs under static conditions and is expected to be negligible.

|  |  |
| --- | --- |
|  |  |
| Figure 3 and Figure 4: measured pressure loss curve including outlet vents of car (example for B-Class size vehicle at 0 km/h in left picture) and Ventilation operation points (example in right picture). |
|  |

* 1. Mass flow check at recirculation mode

If the MAC system is using recirculating air in the MAC test at the temperature and humidity conditions defined in 4.1.1.3, following tests need to be performed to ensure that the HVAC mass flow is also under these conditions above the mass flow defined in 4.1.3.4:

Measure the vent outlet velocity (ci) at each vent as additional measurands in the test described in 2.2 of this annex in all tests (i.e. 0, 50, 100 km/h with MAC-on and with MAC-off) without air recirculation.

Repeat the test with recirculating air conditions. The vent outlet velocity (ci-r) has to be measured in these tests also.

Calculate the mass flow with recirculating air according to the gas equation:



With  HVAC mass flow with recirculating air

 Ci average velocity over the vent outlets measured without recirculation air in vehicle speed i (0, 50, 100 km/h) in [m/s]

 Ci-r average velocity over the vent outlets measured with recirculation air in vehicle speed i (0, 50, 100 km/h)

 Ti average temperature at vent outlets measured without recirculation air in vehicle speed i (0, 50, 100 km/h)

 Ti-r average temperature at vent outlets measured with recirculation air in vehicle speed i (0, 50, 100 km/h)

 pi average pressure difference from cabin to test cell at vent outlets measured without recirculation air in vehicle speed i (0, 50, 100 km/h)

 pi-r average pressure difference from cabin to test cell measured with recirculation air in vehicle speed i (0, 50, 100 km/h)

If pressure and temperature are not measured in this test Ti and Ti-r can be both set to 298K and pi and p1-r can both be set to 1bar.

It must be ensured, that in all conditions the mass flow is above the minimum mass flow for the car according to 4.1.3.4.

In addition it must be ensured that in the MAC-off phase under all conditions (idle / 50km/h / 100 km/h) the vent outlet air mass flow is equal or lower than in the MAC-on phase.

The type approval authority can request a basic validation of the share of recirculating air which occurred during the MAC test on the chassis dynamometer.

The basic validation foresees an independent testing under idling conditions where the vehicle is not mounted on a chassis dyno to ensure that no specific chassis dynamometer mode is active.

The test procedure is:

The car is directly after a normal driving on the road parked in a room which allows a similar conditioning of temperature and humidity as defined for the MAC test soak (chapter4.3.1).

After vehicle soak the vehicle is started and hold in normal idling conditions.

The settings of the air conditioning system are selected as for the MAC test.

The differential pressure between vehicle and test room is measured as described in chapter 2 of Annex XX – Appendix 1.

The differential pressure measured under these conditions must not differ by more than 10% or 3Pa whatever the higher tolerance is.

On demand of the type approval authority also the controller logics of the recirculation air settings have to be demonstrated and proved by the CAN signal for the flap position controlling the recirculation air share also under non idling conditions.

**Annex XX – Appendix 2 MAC test cycle**





1. To reduce the physical test burden, a manufacturer can choose to group several models into one MAC Test family where all of them have to be below the family FCMAC\_T value. The Product of FCMAC-T x F TTS gives the total FC MAC [kg/h] and MACFC [l/h] values. These again can be grouped to the final MAC families where each vehicle in the family has to have a MACFC value below the declared value. [↑](#footnote-ref-2)