Commission Regulation (EU) 2017/2400 of 12 December 2017 implementing Regulation (EC) No 595/2009 of the European Parliament and of the Council as regards the determination of the CO2 emissions and fuel consumption of heavy-duty vehicles and amending Directive 2007/46/EC of the European Parliament and of the Council and Commission Regulation (EU) No 582/2011 (Text with EEA relevance)

ANNEX VIII

VERIFYING AIR DRAG DATA

3. Determination of air drag

The constant speed test procedure shall be applied to determine the air drag characteristics. During the constant speed test the main measurement signals driving torque, vehicle speed, air flow velocity and yaw angle shall be measured at two different constant vehicle speeds (low and high speed) under defined conditions on a test track. The measurement data recorded during the constant speed test shall be entered into the air drag pre-processing tool which determines product of drag coefficient by cross sectional area for zero crosswind conditions $C_d \cdot A_{cr}$ *(0)* as input for the simulation tool. The applicant for a certificate shall declare a value $C_d \cdot A_{declared}$ in a range from equal up to a maximum of + 0,2 m^2 higher than $C_d \cdot A_{cr}$ *(0)*. The value $C_d \cdot A_{declared}$ shall be the input for the simulation tool CO_2 simulation tool and the reference value for conformity of the certified CO_2 emissions and fuel consumption related properties testing.

Vehicles which are not measured by the constant speed test shall use the standard values for $C_d \cdot A_{declared}$ as described in Appendix 7 to this Annex. In this case no input data on air drag shall be provided. The allocation of standard values is done automatically by the simulation tool.

3.1. Test track requirements

3.1.1. The geometry of test track shall be either a:

i. Circuit track (drivable in one direction (*)):

with two measurement areas, one on each straight part, with maximum deviation of less than 20 degrees);

(*) At least for the misalignment correction of the mobile anemometer (see 3.6) the test track has to be driven in both directions

or

ii. Circuit or straight line track (drivable in both directions):

with one measurement area (or two with the above named maximum deviation); two options: alternating driving direction after each test section; or after a selectable set of test sections e.g. ten times driving direction 1 followed by ten times driving direction 2.

3.1.2. Measurement sections

On the test track measurement section(s) of a length of 250 m with a tolerance of ± 3 m shall be defined.

3.1.3. Measurement areas

A measurement area shall consist of at least one measurement section and a stabilisation section. The first measurement section of a measurement area shall be preceded by a stabilisation section to stabilise the speed and torque. The stabilisation section shall have a length of minimum 25 m. The test track layout shall enable that the vehicle enters the stabilisation section already with the intended maximum vehicle speed during the test.

Latitude and longitude of start and end point of each measurement section shall be determined with an accuracy of better or equal 0,15 m 95 % Circular Error Probable (DGPS accuracy).

3.1.4. Shape of the measurement sections

The measurement section and the stabilization section have to be a straight line.

3.1.5. Longitudinal slope of the measurement sections

The average longitudinal slope of each measurement and the stabilisation section shall not exceed ± 1 per cent. Slope variations on the measurement section shall not lead to velocity and torque variations above the thresholds specified in 3.10.1.1 items vii. and viii. of this Annex.

3.1.6. Track surface

The test track shall consist of asphalt or concrete. The measurement sections shall have one surface. Different measurement sections are allowed to have different surfaces.

3.1.7. Standstill area

There shall be a standstill area on the test track where the vehicle can be stopped to perform the zeroing and the drift check of the torque measurement system.

3.1.8. Distance to roadside obstacles and vertical clearance

There shall be no obstacles within 5 m distance to both sides of the vehicle. Safety barriers up to a height of 1 m with more than 2,5 m distance to the vehicle are permitted. Any bridges or similar constructions over the measurement sections are not allowed. The test track shall have enough vertical clearance to allow the anemometer installation on the vehicle as specified in 3.4.7 of this Annex.

3.1.9. Altitude profile

The manufacturer shall define whether the altitude correction shall be applied in the test evaluation. In case an altitude correction is applied, for each measurement section the altitude profile shall be made available. The data shall meet the following requirements:

i. The altitude profile shall be measured at a grid distance of lower or equal than 50 m in driving direction.

ii. For each grid point the longitude, the latitude and the altitude shall be measured at least at one point (‘altitude measurement point’) on each side of the centre line of the lane and then be processed to an average value for the grid point.

iii. The grid points as provided to the air drag pre-processing tool shall have a distance to the centre line of the measurement section of less than 1 m.

iv The positioning of the altitude measurement points to the centre line of the lane (perpendicular distance, number of points) shall be chosen in a way that the resulting altitude profile is representative for the gradient driven by the test vehicle.

v. The altitude profile shall have an accuracy of ± 1cm or better.

vi. The measurement data shall not be older than 10 years. A renewal of the surface in the measurement area requires a new altitude profile measurement.

3.2. Requirements for ambient conditions

3.2.1. The ambient conditions shall be measured with the equipment specified in 3.4.

3.2.2. The ambient temperature shall be in the range of 0 °C to 25 °C. This criterion is checked by the air drag pre-processing tool based on the signal for ambient temperature measured on the vehicle. This criterion only applies to the datasets

recorded in the low speed - high speed – low speed sequence and not to the misalignment test and the warm-up phases.

3.2.3. The ground temperature shall not exceed 40 °C. This criterion is checked by the air drag pre-processing tool based on the signal for ground temperature measured on the vehicle by an IR Sensor. This criterion only applies to the datasets recorded in the low speed - high speed – low speed sequence and not to the misalignment test and the warm-up phases.

3.2.4. The road surface shall be dry during the low speed – high speed - low speed sequence to provide comparable rolling resistance coefficients.

3.2.5. The wind conditions shall be within the following range:

i. Average wind speed: ≤ 5 m/s

ii. Gust wind speed (1s central moving average): ≤ 8 m/s

Items i. and ii. are applicable for the datasets recorded in the high speed test and the misalignment calibration test but not for the low speed tests.

iii. Average yaw angle (β):

≤ 3 degrees for datasets recorded in the high speed test

≤ 5 degrees for datasets recorded during misalignment calibration test

The validity of wind conditions is checked by the air drag pre-processing based on the signals recorded at the vehicle after application of the boundary layer correction. Measurement data collected under conditions exceeding the above named limits are automatically excluded from the calculation.

3.3. Installation of the vehicle

3.3.1. The vehicle chassis shall fit to the dimensions of the standard body or semi-trailer as defined in Appendix 5 of this Annex.

3.3.2. The vehicle height determined according to 3.5.3.1 item vii. shall be within the limits as specified in Appendix 4 to this Annex.

3.3.3. The minimal distance between cabin and the box or semi-trailer shall be in accordance with manufacturer requirements and body builder instructions of the manufacturer.

3.3.4. The cabin and the aero accessories (e.g. spoilers) shall be adapted to best fit to the defined standard body or semi-trailer.

3.3.5. The vehicle shall fulfil the legal requirements for a whole vehicle type approval. Equipment which is necessary to execute the constant speed test (e.g. overall vehicle height including anemometer is excluded from this provision).

3.3.6. The setup of the semi-trailer shall be as defined in Appendix 4 to this Annex.

3.3.7. The vehicle shall be equipped with tyres meeting the following demands:

i. Best or second best label for rolling resistance which is available at the moment the test is performed

ii. Maximum tread depth of 10 mm on the complete vehicle including trailer

iii. Tyres inflated to the highest allowable pressure of the tire manufacturer

3.3.8. The axle alignment shall be within the manufacturer specifications.

3.3.9. No active tyre pressure control systems are allowed to be used during the measurements of the low speed - high speed - low speed tests.

3.3.10. If the vehicle is equipped with an active aero device it has to be demonstrated to the approval authority that

i. The device is always activated and effective to reduce the air drag at vehicle speed over 60 km/h

ii. The device is installed and effective in a similar manner on all vehicles of the family.

If i. and ii. are not applicable the active aero device has to be fully deactivated during the constant speed test.

3.3.11. The vehicle shall not have any provisional features, modifications or devices that are aimed only to reduce the air drag value, e.g. sealed gaps. Modifications which aim to align the aerodynamic characteristics of the tested vehicle to the defined conditions for the parent vehicle (e.g. sealing of mounting-holes for sun-roofs) are allowed.

3.3.12. All different removable add on parts like sun visors, horns, additional head lights, signal lights or bull bars are not considered in the air drag for the CO_2 regulation. Any such removable add on parts shall be removed from the vehicle before the air drag measurement

3.3.13. The vehicle shall be measured without payload.

3.4. Measurement equipment

The calibration laboratory shall comply with the requirements of either ISO/TS 16949, ISO 9000 series or ISO/IEC 17025. All laboratory reference measurement equipment, used for calibration and/or verification, shall be traceable to national (international) standards.

3.4.1. Torque

3.4.1.1. The direct torque at all driven axles shall be measured with one of the following measurement systems:

a. Hub torque meter

b. Rim torque meter

c. Half shaft torque meter

3.4.1.2. The following system requirements shall be met by a single torque meter by calibration:

i. Non linearity: $< \pm 6$ Nm

ii. Repeatability: $< \pm 6$ Nm

iii. Crosstalk: $< \pm 1$ % FSO (only applicable for rim torque meters)

iv. Measurement rate: ≥ 20 Hz

where:

‘Non linearity’ means the maximum deviation between ideal and actual output signal characteristics in relation to the measurand in a specific measuring range.

'Repeatability' means closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement.

'Crosstalk' means signal at the main output of a sensor (M_y), produced by a measurand (F_z) acting on the sensor, which is different from the measurand assigned to this output. Coordinate system assignment is defined according to ISO 4130.

'FSO' means full scale output of calibrated range.

The recorded torque data shall be corrected for the instrument error determined by the supplier.

3.4.2. Vehicle speed

The vehicle speed is determined by the air drag pre-processing tool based on the CAN-bus front axle signal which is calibrated based on either:

Option (a) : a reference speed calculated by a delta-time from two fixed opto-electronic barriers (see 3.4.4 of this Annex) and the known length(s) of the measurement section(s) or

Option (b) : a delta-time determined speed signal from the position signal of a DGPS and the known length(s) of the measurement section(s), derived by the DGPS coordinates

For the vehicle speed calibration the data recorded during the high speed test are used.

3.4.3. Reference signal for calculation of rotational speed of the wheels at the driven axle

For the calculation of rotational speed of the wheels at the driven axle the CAN engine speed signal together with the transmission ratios (gears for low speed test and high speed test, axle ratio) shall be made available. For the CAN engine speed signal it shall be demonstrated that the signal provided to the air drag pre-processing tool is identical to the signal to be used for in-service testing as set out in Annex I of Regulation (EU) No 582/2011.

For vehicles with torque converter which are not able to drive the low speed test with closed lockup clutch additionally the cardan shaft speed signal and the axle ratio or the average wheel speed signal for the driven axle shall be provided to the air drag pre-processing tool. It shall be demonstrated that the engine speed calculated from this additional signal is within 1 % range compared to the CAN engine speed. This shall be demonstrated for the average value over a measurement section driven at the lowest possible vehicle speed in the torque converter locked mode and at the applicable vehicle speed for the high speed test.

3.4.4. Opto-electronic barriers

The signal of the barriers shall be made available to the air drag pre-processing tool for triggering begin and end of the measurement section and the calibration of the vehicle speed signal. The measurement rate of the trigger signal shall be greater or equal to 100 Hz. Alternatively a DGPS system can be used.

3.4.5. (D)GPS system

Option a) for position measurement only: GPS

Required accuracy:

i. Position : < 3 m 95 % Circular Error Probable

ii. Update rate : ≥ 4 Hz

Option b) for vehicle speed calibration and position measurement: Differential GPS system (DGPS)

Required accuracy:

i. Position : 0,15 m 95 % Circular Error Probable
ii. Update rate : ≥ 100 Hz

3.4.6. Stationary weather station

Ambient pressure and humidity of the ambient air are determined from a stationary weather station. This meteorological instrumentation shall be positioned in a distance less than 2 000 m to one of the measurement areas, and shall be positioned at an altitude exceeding or equal that of the measurement areas.

Required accuracy:

i. Temperature : ± 1 °C
ii. Humidity : ± 5 % RH
iii. Pressure : ± 1 mbar
iv. Update rate : ≤ 6 minutes

3.4.7. Mobile anemometer

A mobile anemometer shall be used to measure air flow conditions, i.e. air flow velocity and yaw angle (β) between total air flow and vehicle longitudinal axis.

3.4.7.1. Accuracy requirements

The anemometer shall be calibrated in facility according to ISO 16622. The accuracy requirements according to Table 1 have to be fulfilled:

TABLE 1

Anemometer accuracy requirements

Air speed range[m/s]	**Accuracy air speed[m/s]**	**Accuracy yaw angle in yaw angle range of 180 ± 7 degrees[degrees]**
20 ± 1	± 0,7	± 1,0
27 ± 1	± 0,9	± 1,0
35 ± 1	± 1,2	± 1,0

3.4.7.2. Installation position

The mobile anemometer shall be installed on the vehicle in the prescribed position:

(i) X position:

truck: front face ± 0,3 m of the semi-trailer or box-body

(ii) Y position: plane of symmetry within a tolerance ± 0,1 m

(iii) Z position:

The installation height above the vehicle shall be one third of total vehicle height with in a tolerance of 0,0 m to + 0,2 m.

The instrumentation shall be done as exact as possible using geometrical/optical aids. Any remaining misalignment is subject to the misalignment calibration to be performed in accordance with 3.6 of this Annex.

3.4.7.3. The update rate of the anemometer shall be 4 Hz or higher.

3.4.8. Temperature transducer for ambient temperature on vehicle

The ambient air temperature shall be measured on the pole of the mobile anemometer. The installation height shall be maximum 600 mm below the mobile anemometer. The sensor shall be shielded to the sun.

Required accuracy: ± 1 °C

Update rate: ≥ 1 Hz

3.4.9. Proving ground temperature

The temperature of the proving ground shall be recorded on vehicle by means of a contactless IR sensor by wideband (8 to 14 μm). For tarmac and concrete an emissivity factor of 0,90 shall be used. The IR sensor shall be calibrated according to ASTM E2847.

Required accuracy at calibration: Temperature: ± 2,5 °C

Update rate: ≥ 1 Hz

3.5. Constant speed test procedure

On each applicable combination of measurement section and driving direction the constant speed test procedure consisting of the low speed, high speed and low speed test sequence as specified below shall be performed in the same direction.

3.5.1. The average speed within a measurement section in the low speed test shall be a in the range of 10 to 15 km/h.

3.5.2. The average speed within a measurement section in the high speed test shall be in the following range:
maximum speed: 95 km/h;
minimum speed: 85 km/h or 3 km/h less than the maximum vehicle speed the vehicle can be operated at the test track, whichever value is lower.

3.5.3. The testing shall be performed strictly according to the sequence as specified in 3.5.3.1 to 3.5.3.9 of this Annex.

3.5.3.1. Preparation of vehicle and measurement systems

(i) Installation of torque meters on the driven axles of the test vehicle and check of installation and signal data according to the manufacturer specification.

(ii) Documentation of relevant general vehicle data for the official testing template in accordance with 3.7 of this Annex.

(iii) For the calculation of the acceleration correction by the air drag pre-processing tool the actual vehicle weight shall be determined before the test within a range of ± 500 kg.

(iv) Check of tyres for the maximum allowable inflation pressure and documentation of tyre pressure values.

(v) Preparation of opto-electronic barriers at the measurement section(s) or check of proper function of the DGPS system.

(vi) Installation of mobile anemometer on the vehicle and/or control of the installation, position and orientation. A misalignment calibration test has to be performed every time the anemometer has been mounted newly on the vehicle.

(vii) Check of vehicle setup regarding the maximum height and geometry, with running engine. The maximum height of the vehicle shall be determined by measuring at the four corners of the box/semi-trailer.

(viii) Adjustment the height of the semi-trailer to the target value and redo determination of maximum vehicle height if necessary.

(ix) Mirrors or optical systems, roof fairing or other aerodynamic devices shall be in their regular driving condition.

3.5.3.2. Warm-up phase

Drive the vehicle minimum 90 minutes at the target speed of the high speed test to warm-up the system. A repeated warm up (e.g. after a configuration change, an invalid test etc.) shall be at least as long as the standstill time. The warm-up phase can be used to perform the misalignment calibration test as specified in 3.6 of this Annex.

3.5.3.3. Zeroing of torque meters

The zeroing of the torque meters shall be performed as follows:

i. Bring the vehicle to a standstill

ii. Lift the instrumented wheels off the ground

iii. Perform the zeroing of the amplifier reading of the torque meters

The standstill phase shall not exceed 10 minutes.

3.5.3.4. Drive another warm-up phase of minimum 10 minutes at the target speed of the high speed test.

3.5.3.5. First low speed test

Perform the first measurement at low speed. It shall be ensured that:

i. the vehicle is driven through the measurement section along a straight line as straight as possible

ii. the average driving speed is in accordance with 3.5.1 of this Annex for the measurement section and the preceding stabilisation section

iii. the stability of the driving speed inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item vii. of this Annex

iv. the stability of the measured torque inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item viii. of this Annex

v. the beginning and the end of the measurement sections are clearly recognizable in the measurement data via a recorded trigger signal (opto-electronic barriers plus recorded GPS data) or via use of a DGPS system

vi. driving at the parts of the test track outside the measurement sections and the preceding stabilisation sections shall be performed without any delay. Any unnecessary manoeuvres shall be avoided during these phases (e.g. driving in sinuous lines)

vii. the maximum time for the low speed test shall not exceed 20 minutes in order to prevent cool down of the tires.

3.5.3.6. Drive another warm-up phase of minimum 5 minutes at the target speed of the high speed test.

3.5.3.7. High speed test

Perform the measurement at the high speed. It shall be ensured that:

i. the vehicle is driven through the measurement section along a straight line as straight as possible

ii. the average driving speed is in accordance with 3.5.2 of this Annex for the measurement section and the preceding stabilisation section

iii. the stability of the driving speed inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item vii. of this Annex

iv. the stability of the measured torque inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item viii. of this Annex

v. the beginning and the end of the measurement sections are clearly recognizable in the measurement data via a recorded trigger signal (opto-electronic barriers plus recorded GPS data) or via use of a DGPS system

vi. in the driving phases outside the measurement sections and the preceding stabilization sections any unnecessary manoeuvres shall be avoided (e.g. driving in sinuous lines, unnecessary accelerations or decelerations)

vii. the distance between the measured vehicle to another driven vehicle on the test track shall be at least 500 m.

viii. at least 10 valid passings per heading are recorded

The high speed test can be used to determine the misalignment of the anemometer if the provisions stated in 3.6 are fulfilled.

3.5.3.8. Second low speed test

Perform the second measurement at the low speed directly after the high speed test. Similar provisions as for the first low speed test shall be fulfilled.

3.5.3.9. Drift check of torque meters

Directly after the finalisation of the second low speed test the drift check of the torque meters shall be performed in accordance to the following procedure:

1. Bring the vehicle to standstill

2. Lift the instrumented wheels off the ground

3. The drift of each torque meter calculated from the average of the minimum sequence of 10 seconds shall be less than 25 Nm.

Exceeding this limit leads to an invalid test.

3.6. Misalignment calibration test

The misalignment of the anemometer shall be determined by a misalignment calibration test on the test track.

3.6.1. At least 5 valid passings of a 250 ± 3 m straight section driven in each direction at high vehicle speed shall be performed.

3.6.2. The validity criteria for wind conditions as specified in section 3.2.5 of this Annex and the test track criteria as specified in section 3.1 of this Annex are applicable.

3.6.3. The data recorded during the misalignment calibration test shall be used by the air drag pre-processing tool to calculate the misalignment error and perform the according correction. The signals for wheel torques and engine speed are not used in the evaluation.

3.6.4. The misalignment calibration test can be performed independently from the constant speed test procedure. If the misalignment calibration test is performed separately it shall be executed as follows:

i. Prepare the opto-electronic barriers at the 250 m ± 3 m section, or check the proper function of the DGPS System.

ii. Check the vehicle setup regarding the height and geometry in accordance with 3.5.3.1 of this Annex. Adjust the height of the semi-trailer to the requirements as specified in appendix 4 to this Annex if necessary

iii. No prescriptions for warm-up are applicable

iv Perform the misalignment calibration test by at least 5 valid passings as described above.

3.6.5. A new misalignment test shall be performed in the following cases:

a. the anemometer has been dismounted from the vehicle

b. the anemometer has been moved

c. a different tractor or truck is used

d. the cab family has been changed

3.7. Testing Template

In addition to the recording of the modal measurement data, the testing shall be documented in a template which contains at least the following data:

i. General vehicle description (specifications see Appendix 2 - Information Document)

ii. Actual maximum vehicle height as determined according to 3.5.3.1 item vii.

iii. Start time and date of the test

iv. Vehicle mass within a range of ± 500 kg

v. Tyre pressures

vi. Filenames of measurement data

vii. Documentation of extraordinary events (with time and number of measurement sections), e.g.
- close passing of another vehicle
- manoeuvres to avoid accidents, driving errors
- technical errors
- measurement errors

3.8. Data processing

3.8.1. The recorded data shall be synchronised and aligned to 100 Hz temporal resolution, either by arithmetical average, nearest neighbour or linear interpolation.

3.8.2. All recorded data shall be checked for any errors. Measurement data shall be excluded from further consideration in the following cases:
- Datasets became invalid due to events during the measurement (see 3.7 item vii)
- Instrument saturation during the measurement sections (e.g. high wind gusts which might have led to anemometer signal saturation)
- Measurements in which the permitted limits for the torque meter drift were exceeded

3.8.3. For the evaluation of the constant speed tests the application of the latest available version of the air drag pre-processing tool shall be obligatory. Besides the above mentioned data processing, all evaluation steps including validity checks (with exception of the list as specified above) are performed by the air drag pre-processing tool.

3.9. Input data for Vehicle Energy Consumption calculation Tool Air Drag tool

The following tables show the requirements for the measurement data recording and the preparatory data processing for the input into the air drag pre-processing tool:

Table 2 for the vehicle data file
Table 3 for the ambient conditions file
Table 4 for the measurement section configuration file
Table 5 for the measurement data file
Table 6 for the altitude profile files (optional input data)

A detailed description of the requested data formats, the input files and the evaluation principles can be found in the technical documentation of the Vehicle Energy Consumption calculation Tool Air Drag tool. The data processing shall be applied as specified in section 3.8 of this Annex.

TABLE 2

Input data for the air drag pre-processing tool – vehicle data file

Input data	Unit	Remarks
Vehicle group code	[-]	1 - 17 for trucks
Vehicle configuration with trailer	[-]	if the vehicle was measured without trailer (input 'No') or with trailer i.e. as a truck/

a	Specification of transmission ratios with at least 3 digits after decimal separator
b	If the wheel speed signal is provided to the air drag pre-processing tool (option for vehicles with torque converters, see section 3.4.3 the axle ratio shall be set to '1.000'.
c	Input only required if value is lower than 88 km/h.

		trailer or tractor semitrailer combination (input 'Yes')
Vehicle test mass	[kg]	actual mass during measurements
Gross vehicle mass	[kg]	gross vehicle mass of the rigid or tractor (w/o trailer or semitrailer)
Axle ratio	[-]	axle transmission ratio[ab]
Gear ratio high speed	[-]	transmission ratio of gear engaged during high speed test[a]
Gear ratio low speed	[-]	transmission ratio of gear engaged during low speed test[a]
Anemometer height	[m]	height above ground of the measurement point of installed anemometer
Vehicle height	[m]	maximum vehicle height according to 3.5.3.1 item vii.
Gear box type	[-]	manual or automated transmission: 'MT_AMT' automatic transmission with torque converter: 'AT'
Vehicle maximum speed	[km/h]	maximum speed the vehicle can be practically operated at the test track[c]

a Specification of transmission ratios with at least 3 digits after decimal separator

b If the wheel speed signal is provided to the air drag pre-processing tool (option for vehicles with torque converters, see section 3.4.3 the axle ratio shall be set to '1.000'.

c Input only required if value is lower than 88 km/h.

TABLE 3

Input data for the air drag pre-processing tool – ambient conditions file

Signal	**Column identifier in input file**	**Unit**	**Measurement rate**	**Remarks**
Time	<t>	[s] since day start (first day)	—	—
Ambient temperature	<t_amb_stat>	[°C]	At least 1 averaged value per 6 minutes	Stationary weather station
Ambient pressure	<p_amb_stat>	[mbar]		Stationary weather station

Relative air humidity	<rh_stat>	[%]		Stationary weather station

TABLE 4

Input data for Vehicle Energy Consumption calculation Tool Air Drag – measurement section configuration file

Input data	Unit	Remarks
Trigger signal used	[-]	1 = trigger signal used; 0 = no trigger signal used
Measurement section ID	[-]	user defined ID number
Driving direction ID	[-]	user defined ID number
Heading	[°]	heading of the measurement section
Length of the measurement section	[m]	—
Latitude start point of section	decimal degrees or decimal minutes	standard GPS, unit decimal degrees: minimum 5 digits after decimal separator
Longitude start point of section		standard GPS, unit decimal minutes: minimum 3 digits after decimal separator
Latitude end point of section		DGPS, unit decimal degrees: minimum 7 digits after decimal separator
Longitude end point of section		DGPS, unit decimal minutes: minimum 5 digits after decimal separator
Path and/or filename of altitude file	[-]	only required for the constant speed tests (not the misalignment test) and if the altitude correction is enabled.

TABLE 5

Input data for the air drag pre-processing tool – measurement data file

Signal	Column identifier in input file	Unit	Measurement rate	Remarks
Time	<t>	[s] since day start (of first day)	100 Hz	rate fixed to 100 Hz; time signal used for correlation with weather data

				and for check of frequency
(D)GPS latitude	<lat>	decimal degrees or decimal minutes	GPS: ≥ 4 Hz DGPS: ≥ 100 Hz	standard GPS, unit decimal degrees: minimum 5 digits after decimal separator
(D)GPS longitude	<long>			standard GPS, unit decimal minutes: minimum 3 digits after decimal separator DGPS, unit decimal degrees: minimum 7 digits after decimal separator DGPS, unit decimal minutes: minimum 5 digits after decimal separator
(D)GPS heading	<hdg>	[°]	≥ 4Hz	
DGPS velocity	<v_veh_GPS>	[km/h]	≥ 20 Hz	
Vehicle velocity	<v_veh_CAN>	[km/h]	≥ 20 Hz	raw CAN bus front axle signal
Air speed	<v_air>	[m/s]	≥ 4 Hz	raw data (instrument reading)
Inflow angle (beta)	<beta>	[°]	≥ 4 Hz	raw data (instrument reading); ‘180°’ refers to air flow from front
Engine speed or cardan speed	<n_eng> or <n_card>	[rpm]	≥ 20 Hz	cardan speed for vehicles with torque converter not locked during low speed test
Torque meter (left wheel)	<tq_l>	[Nm]	≥ 20 Hz	—

Torque meter (right wheel)	<tq_r>	[Nm]	≥ 20 Hz	
Ambient temperature on vehicle	<t_amb_veh>	[°C]	≥ 1 Hz	
Trigger signal	<trigger>	[-]	100 Hz	optional signal; required if measurement sections are identified by opto electronic barriers (option 'trigger_used=1')
Proving ground temperature	<t_ground>	[°C]	≥ 1 Hz	
Validity	<valid>	[-]	—	optional signal (1=valid; 0=invalid);

TABLE 6

Input data for the air drag pre-processing tool – altitude profile file

Input data	Unit	Remarks
Latitude	decimal degrees or decimal minutes	unit decimal degrees: minimum 7 digits after decimal separator
Longitude		unit decimal minutes: minimum 5 digits after decimal separator
Altitude	[m]	minimum 2 digits after decimal separator

3.10. Validity criteria

This sections sets out the criteria to obtain valid results in the air drag pre-processing tool.

3.10.1. Validity criteria for the constant speed test

3.10.1.1. The air drag pre-processing tool accepts datasets as recorded during the constant speed test in case the following validity criteria are met:

i. the average vehicle speed is inside the criteria as defined in 3.5.2

ii. the ambient temperature is inside the range as described in 3.2.2. This criterion is checked by the air drag pre-processing tool based on the ambient temperature measured on the vehicle.

iii. the proving ground temperature is in the range as described in 3.2.3

iv. valid average wind speed conditions according to point 3.2.5 item i

v. valid gust wind speed conditions according to point 3.2.5 item ii

vi. valid average yaw angle conditions according to point 3.2.5 item iii

vii. stability criteria for vehicle speed met:

Low speed test:

$$(v_{lms,avrg} - 0{,}5\,km/h) \leq v_{lm,avrg} \leq (v_{lms,avrg} + 0{,}5\,km/h)$$

where:

$v_{lms,avrg}$	=	average of vehicle speed per measurement section [km/h]
$v_{lm,avrg}$	=	central moving average of vehicle speed with X_{ms} seconds time base [km/h]
X_{ms}	=	time needed to drive 25 m distance at actual vehicle speed [s]

High speed test:

$$(v_{hms,avrg} - 0{,}3\,km/h) \leq v_{hm,avrg} \leq (v_{hms,avrg} + 0{,}3\,km/h)$$

where:

$v_{hms,avrg}$	=	average of vehicle speed per measurement section [km/h]
$v_{hm,avrg}$	=	1 s central moving average of vehicle speed [km/h]

viii. stability criteria for vehicle torque met:

Low speed test:

$$(T_{lms,avrg} - T_{grd}) \times 0{,}7 \leq (T_{lm,avrg} - T_{grd}) \leq (T_{lms,avrg} - T_{grd}) \times 1{,}3$$

$$T_{grd} = F_{grd,avrg} \times r_{dyn,avrg}$$

where:

$T_{lms,avrg}$	=	average of T_{sum} per measurement section
T_{grd}	=	average torque from gradient force
$F_{grd,avrg}$	=	average gradient force over measurement section
$r_{dyn,avrg}$	=	average effective rolling radius over measurement section (formula see item ix.) [m]
T_{sum}	=	T_L+T_R; sum of corrected torque values left and right wheel [Nm]
$T_{lm,avrg}$	=	central moving average of T_{sum} with X_{ms} seconds time base
X_{ms}	=	time needed to drive 25 m distance at actual vehicle speed [s]

High speed test

$$(T_{hms,avrg} - T_{grd}) \times 0{,}8 \leq (T_{hm,avrg} - T_{grd}) \leq (T_{hms,avrg} - T_{grd}) \times 1{,}2$$

where:

$T_{hms,avrg}$	=	average of T_{sum} per measurement section [Nm]

T_{grd}	=	average torque from gradient force (see Low speed test) [Nm]
T_{sum}	=	T_L+T_R; sum of corrected torque values left and right wheel [Nm]
$T_{hm,avrg}$	=	1 s central moving average of T_{sum} [Nm]

ix. valid heading of the vehicle passing a measurement section (< 10° deviation from target heading applicable for low speed test, high speed test and misalignment test)

x. driven distance inside measurement section calculated from the calibrated vehicle speed does not differ from target distance by more than 3 meters (applicable for low speed test and high speed test)

xi. plausibility check for engine speed or cardan speed whichever is applicable passed:

Engine speed check for high speed test:

$$\frac{30\times i_{gear}\times i_{axle}\times\frac{\left(v_{hms,avrg}-0{,}3\right)}{3{,}6}}{r_{dyn,ref,HS}\times\pi}\times(1-2\,\%)\leq n_{eng,1s}\leq\frac{30\times i_{gear}\times i_{axle}\times\frac{\left(v_{hms,avrg}+0{,}3\right)}{3{,}6}}{r_{dyn,ref,HS}\times\pi}\times(1+2\,\%)$$

$$r_{dyn,avrg}=\frac{30\times i_{gear}\times i_{axle}\times\frac{v_{hms,avrg}}{3{,}6}}{n_{eng,avrg}\times\pi}$$

$$r_{dyn,ref,HS}=\frac{1}{n}\sum_{j=1}^{n}r_{dyn,avrg,j}$$

where:

i_{gear}	=	transmission ratio of the gear selected in high speed test [-]
i_{axle}	=	axle transmission ratio [-]
$v_{hms,avrg}$	=	average vehicle speed (high speed measurement section) [km/h]
$n_{eng,1s}$	=	1 s central moving average of engine speed (high speed measurement section) [rpm]
$r_{dyn,avrg}$	=	average effective rolling radius for a single high speed measurement section [m]
$r_{dyn,ref,HS}$	=	reference effective rolling radius calculated from all valid high speed measurement sections (number = n) [m]

Engine speed check for low speed test:

$$\frac{30\times i_{gear}\times i_{axle}\times\frac{\left(v_{lms,avrg}-0{,}5\right)}{3{,}6}}{r_{dyn,ref,LS1/LS2}\times\pi}\times(1-2\,\%)\leq n_{eng,float}\leq\frac{30\times i_{gear}\times i_{axle}\times\frac{\left(v_{lms,avrg}+0{,}5\right)}{3{,}6}}{r_{dyn,ref,LS1/LS2}\times\pi}\times(1+2\,\%)$$

$$r_{dyn,avrg}=\frac{30\times i_{gear}\times i_{axle}\times\frac{v_{lms,avrg}}{3{,}6}}{n_{eng,avrg}\times\pi}$$

$$r_{dyn,ref,LS1/LS2}=\frac{1}{n}\sum_{j=1}^{n}r_{dyn,avrg,j}$$

where:

i_{gear}	=	transmission ratio of the gear selected in low speed test [-]
i_{axle}	=	axle transmission ratio [-]
$v_{lms,avrg}$	=	average vehicle speed (low speed measurement section) [km/h]

$n_{eng,float}$	=	central moving average of engine speed with X_{ms} seconds time base (low speed measurement section) [rpm]
X_{ms}	=	time needed to drive 25 meter distance at low speed [s]
$r_{dyn,avrg}$	=	average effective rolling radius for a single low speed measurement section [m]
$r_{dyn,ref,LS1/LS2}$	=	reference effective rolling radius calculated from all valid measurement sections for low speed test 1 or low speed test 2 (number = n) [m]

The plausibility check for cardan speed is performed in an analogue way with $n_{eng,1s}$ replaced by $n_{card,1s}$ (1 s central moving average of cardan speed in the high speed measurement section) and $n_{eng,float}$ replaced by $n_{card,float}$ (moving average of cardan speed with X_{ms} seconds time base in the low speed measurement section) and i_{gear} set to a value of 1.

xii. the particular part of the measurement data was not marked as 'invalid' in the air drag pre-processing tool input file.

3.10.1.2. The air drag pre-processing tool excludes single datasets from the evaluation in the case of unequal number of datasets for a particular combination of measurement section and driving direction for the first and the second low speed test. In this case the first datasets from the low speed run with the higher number of datasets are excluded.

3.10.1.3. The air drag pre-processing tool excludes single combinations of measurement sections and driving directions from the evaluation if:

i. no valid dataset is available from low speed test 1 or/and low speed test 2

ii. less than two valid datasets from the high speed test are available

3.10.1.4. The air drag pre-processing tool considers the complete constant speed test invalid in the following cases:

i. test track requirements as described in 3.1.1 not met

ii. less than 10 datasets per heading available (high speed test)

iii. less than 5 valid datasets per heading available (misalignment calibration test)

iv. the rolling resistance coefficients (RRC) for the first and the second low speed test differ more than 0,40 kg/t. This criterion is checked for each combination of measurement section and driving direction separately.

3.10.2. Validity criteria for the misalignment test

3.10.2.1. The air drag pre-processing tool accepts datasets as recorded during the misalignment test in case the following validity criteria are met:

i. the average vehicle speed is inside the criteria as defined in 3.5.2 for the high speed test

ii. valid average wind speed conditions according to point 3.2.5 item i

iii. valid gust wind speed conditions according to point 3.2.5 item ii

iv. valid average yaw angle conditions according to point 3.2.5 item iii

v. stability criteria for vehicle speed met:

$$(v_{hms,avrg} - 1\,km/h) \leq v_{hm,avrg} \leq (v_{hms,avrg} + 1\,km/h)$$

where:

$v_{hms,avrg}$	=	average of vehicle speed per measurement section [km/h]
$v_{hm,avrg}$	=	1 s central moving average of vehicle speed [km/h]

3.10.2.2. The air drag pre-processing tool considers the data from a single measurement section invalid in the following cases:

i. the average vehicle speeds from all valid datasets from each driving directions differ by more than 2 km/h.

ii. less than 5 datasets per heading available

3.10.2.3. The air drag pre-processing tool considers the complete misalignment test invalid in case no valid result for a single measurement section is available.

3.11. Declaration of air drag value

Base value for the declaration of the air drag value is the final result for $C_d \cdot A_{cr}\,(0)$ as calculated by the air drag pre-processing tool. The applicant for a certificate shall declare a value $C_d \cdot A_{declared}$ in a range from equal up to a maximum of + 0,2 m^2 higher than $C_d \cdot A_{cr}\,(0)$. This tolerance shall take into account uncertainties in the selection of the parent vehicles as the worst case for all testable members of the family. The value $C_d \cdot A_{declared}$ shall be the input for the simulation tool and the reference value for conformity of the certified CO_2 emissions and fuel consumption related properties testing.

More families with different declared values $C_d \cdot A_{declared}$ can be created based on a single measured $C_d \cdot A_{cr}\,(0)$ as long as the family provisions according to point 4 of Appendix 5 are fulfilled.