PROTOCOL FOR REAL-WORLD FUEL CONSUMPTION MEASUREMENTS

1 Introduction

The aim of this protocol is to set out the equipment and method to be employed whenever required for measuring average consumption under average customer conditions.

This protocol is valid for Europe

It is carried out in three stages:
- Selection and verification of the vehicle
- Road testing the vehicle and recording measurements
- Post-processing of measurement results

2 List of participants and their roles

OEM:
- Project leader:
  - Concurrent development of the methodology and test procedure
  - General organisation
  - List of vehicles to be tested
  - Internal communication within OEM and externally (NGO, certification organisation…)

- Measurement manager and technicians and workshop support
  - Verification and preparation of tests (workshop, fitting and calibrating PEMS « *Portable Emissions Measurement system* »,…),…)
  - Availability and reliability of test equipment
  - Testing the vehicles on the road and rolling road testing
  - Collection of measurement results, initial analysis (dynamics…)
  - …
- Calculations manager
  - Creation of the Excel spreadsheet
  - Composition of families, test standard conditions (mass, CD…)
  - Detailed analysis of the results, calculation of the consumption to be published
  - Consistency with customer surveys

NGO:
- Concurrent development of the methodology and test procedure
- Selection of vehicles to be tested
- Validation of results
- Internal communication within NGO and externally (OEM)
- …

Certification organisation:
- Rental of vehicles
- Tamper-proofing the vehicle (fitting, removing seals)
- Conducting audits
- Verification of results
- …

3 Input data required

- “Standard” and “loaded” tyre pressures
- Mass:
  - unladen weight of trim level tested
  - average mass of options statistically purchased by customers on this trim level
  - average number of occupants for the vehicle type tested split into adults (70 kg) and children (35 kg)
  - average mass of occupants for the model tested
  - average mass of luggage for the model tested
- Coast down (CD) or "rolling resistance"::
  - actual CD previously measured on a vehicle close to the test vehicle under test conditions (temperature, atmospheric pressure and mass on the day CD was tested)
  - actual CD of the model being tested under measurement conditions (temperature, atmospheric pressure, relative humidity) and vehicle characteristics (mass, aerodynamics, tyre rolling resistance) determined from the actual CD
  - CD for rolling road test with correction by calculation for the mass, weather conditions and the aerodynamic impact of the PEMS : 14°C, 100 kPa and reference mass (chapter 10.2) calculated from the measured CD.
- Route: a Route designed for “regulatory NOx RDE” with:
  - A mixture of Urban, Rural and Motorway (URM) evaluated topographically and not by speed bands (total distance about 100km)
  - An urban portion increased to be closer to the average customer behaviour
  - Altitude measurements

- Driving conditions for the model tested: normal distribution of customer usage statistics giving average speeds and accelerations for Urban, Rural and Motorway (or by speed band)

- Ambient temperature measured before testing (no test if the weather is too hot or too cold)

- Atmospheric temperature and pressure on the day of the test (mean value of data logged by the PEMS)

- Mass on the day of the test (as recorded in the test log)

- Aerodynamic impact of the PEMS on the model tested

- The Urban Rural Motorway mix achieved during the test is:
  - Urban = 22.8km (24.7% of the total distance)
  - Rural = 39.6km (42.9% of the total distance)
  - Motorway = 29.9km (32.4% of the total distance)

- The U R M mix of the 50 percentile customer of the model tested

- Statistical data for average customer driving of the model tested:
  - Mean distribution of individual journey distances
  - Average journey distance
  - Mean distribution of inter-journeys by class of duration
  - Percentage of journeys completed cold.

- Particle Filter:
  - Homologation data:
    - homologated particle filter K
    - distance between two homologated regenerations
  - Statistical usage data:
    - percentage of particle filter regeneration events by class of distance between regenerations [km]
    - weighted mean distance between regenerations in use.

For light commercial vehicles (LCVs):

- Maximum Authorised Mass (MAM)
- loading distribution (light load, loaded, exceptional)
- distribution of mean distance covered under each load
- and from this is deduced the mean loading mass

4 Equipment required

- MIDTRONICS or equivalent equipment
- New, charged battery (may be required)
- Numbered seals
- Towing hitch
- Workshop equipped with welding set (for exhaust system)
- Exhaust system gas-tightness tester
- New exhaust system rear part
- PEMS
- Standard gas for calibrating PEMS
- Weather station
- Scales
- Ballast for loading vehicle (may be required)
- Emissions rolling road test

5 Stage 1: selection and verification of the vehicle

5.1 Selection of the vehicle

Rental vehicles are used, rented by the certification organisation.

For vehicles not yet on the market, the OEM supplies a pre-series vehicle. A confirmatory measurement will be carried out on a rental vehicle 6 months after production launch.

Ideal kilometre reading: between 3000 km and 20,000 km. A vehicle totalling 1000km is acceptable. If below 1000km, it should be run to reach 1000km minimum. A vehicle over 20,000km is acceptable.

In the case of a rental vehicle, the certification organisation:
- checks that the service log is up to date
- delivers the vehicle to the OEM
- watches over it until the seals are fitted
- attends the check-list
- fits the seals

5.2 Verification of the vehicle:

There is no preconditioning before the check
The vehicle must be at rest, doors closed, bonnet open, for at least an hour.
The points to be checked are: battery condition, oil level, tyre pressures
The checks are recorded by the OEM in a test log: see appendix 1

- Battery condition check:
  - battery charging must not be carried out before the test
  - check the condition of the battery using a MIDTRONICS or equivalent equipment
  - If the battery is not in good condition: charge it then run the vehicle for 30km minimum to bring it back to the regulation SOC (state of charge). Repeat the battery condition check.
  - If the battery is still not in good condition, change it for a new, charged battery then run the vehicle for 30km minimum to bring it back to the regulation SOC.

- Oil level check:
  - must be between the minimum and maximum levels, if so: do not alter it
  - if not the case: adjust to middle level

- Tyre check:
  - Check that the tyres are not worn down to the Tyre Wear Indicators
  - Check the tyre pressures
    - If 2 people + PEMS: “normal” pressures
    - If more than 2 people + PEMS: “loaded” pressures

  The tyre pressures are recorded in the Test log

- Fuel check
  The fuel left in the tank is not modified. If we need to fill the tank, we use ordinary fuel.

- The certification organisation fits seals to:
  - Bonnet
  - Diagnostic plug
  - Valve of each tyre
  - One nut on each wheel

  The certification organisation removes the seals after the road test, before the correlation rolling road test (access is required to the CAN - Controller Area Network - to obtain a speed signal as GPS is not operational on the rolling road)

- Workshop modifications before testing:
  - Fit the towing hitch
  - Modify the exhaust tail pipe and check gas-tightness of the exhaust system before fitting the PEMS
  - Fit the PEMS
  - Fit weather station and GPS (vehicle speed data are obtained from the 1Hz GPS signal, as the PEMS is not connected to the CAN)

- Calibration of the PEMS before testing.

- Vehicle mass:

The standard mass is calculated by: Standard mass = unladen weight of tested trim level + average mass of options statistically purchased by customers on this trim level + mass of occupants + mass of luggage

If the test vehicle is lighter than the standard mass: add ballast to bring the vehicle to standard mass
If the test vehicle is heavier than the standard mass: conduct the test in this condition, the consumption measured will be corrected to bring it in line with the standard mass (see “Post-processing of measurement results” stage)

6 Stage 2: Road testing the vehicle and recording measurements

6.1 The test log

The driver fills in the test log: see appendix 1

6.2 Driver:

- May be anyone with a driving licence, preferably not a trained driver, the aim being to drive as a customer would
- Driver identified by their name
- Two drivers minimum for every vehicle to be tested

6.3 *Weather conditions:*

- Limits beyond which the test is not conducted
  - Mean outside temperature during the test: $5° < T^{ext} < 30°$
  - Relative humidity < 95%
  - Wind and rain: … any orange or red alert from Météo France
- Starting temperature for the test: workshop temperature
  - This allows the PEMS to be kept warmed-up under shelter
  - Seasonality will have a lower impact on the average consumption (the measured fuel consumption will be lower in winter and higher in summer)
  - It allows smoothing of the results by coming nearer to standard conditions of 14°C and average usage

  Weather conditions are noted in the test log

6.4 *Driving instructions:*

- There are no specific driving instructions, but an attempt should be made to get as close as possible to the average speed and acceleration for the type of vehicle being tested (see chapter 8.3)
- All speed limits should be followed, and adjusted limits when it is raining
- Comfort equipment :
  - Where they are automatic, they should be set to “auto”
    - If automatic air conditioning is fitted: set the level to 21°C
    - Automatic head-lamp illumination
    - …
  - If manual air conditioning is fitted: set the level for the comfort of the occupants and record the setting in the test log
  - Heating: set the temperature as required, as a customer would
  - …

6.5 *Tests to be carried out:*

The following tests are carried out

- road test
- PEMS/rolling road correlation after road testing

6.5.1 *Road test:*

- Start with the engine cold (workshop temperature)
- Route : “regulatory NOx RDE” type driving
  - The Urban Rural Motorway (URM) mix is calculated topographically (total distance around 100 km)
- Whenever the route has to be modified (section closed for road-works……), the test remains valid but the U R M is recalculated

In order to validate a test series, there must be at least three tests that meet the dynamic criteria (see chapter 8.3), carried out by at least two different drivers. In order to achieve this, at least 5 tests should be planned for a series.

6.5.2 PEMS/rolling road correlation after road test

In order to determine the precision of the PEMS used and apply any PEMS/rolling road correlation coefficient required (see chapter 10.1), the vehicle is run on the rolling road with the PEMS, after the road test, according to the following sequence:

- Seals removed by the certification organisation (connection to the CAN)
- Vehicle maintained at 23°C for 12hours
- No regulatory preconditioning
- WLTP Cycle
- Test mass = standard mass
- Test CD = Actual CD of vehicle tested brought to standard conditions: 14°C, 100 kPa and standard mass (see chapter 10.2)
- WLTP manual gearbox gear shift pattern

7 Verification of the vehicle after testing

- Weighing the vehicle: after testing, all running mass is weighed: vehicle, driver, any passengers, PEMS. The mass is recorded on the Test log

- Calibration of the PEMS: post-test check

- Workshop modifications after test:
  - Removal of towing hitch
  - Restoration of condition of exhaust (fitting a new rear exhaust section if needed)

8 Admissibility of test

8.1 Particle filter regeneration

For diesel versions: a regeneration of the particle filter may occur during the test. To determine this, check the exhaust gas temperature measured by the PEMS. If a regeneration has occurred, a sharp rise in temperature relative to other tests will be evident.

If there has been a regeneration during the test: the test is rejected, if there has not: the test is accepted and the consumption measured is corrected upwards by the particle filter k (see chapter 10.5).

If the regeneration started mid-test, then sufficient time is deemed to have elapsed to complete the regeneration, and the following day's test will be free from regeneration.
If the regeneration started at the end of the test, sufficient time has not elapsed. In order to avoid the regeneration restarting the next day, the vehicle should be run in the evening to complete the regeneration, for around 20km.

8.2 PEMS measurement

The measurement uncertainty of a PEMS at very low flow-rates may cause recordings with negative flow-rates.
After the test, a check is made to see if any have occurred and their impact on the CO_2.

A test is admissible if the following two conditions are met:
- % of measurement points with negative CO_2: max = 3%
- Impact on CO_2: max 0.3%

8.3 Test dynamics

A test is considered admissible if the dynamics are close to the 50 percentile customer.

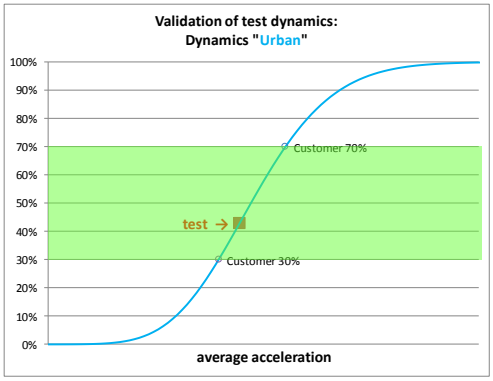
Dynamics are assessed on:
- Average speed
- Average acceleration

The 50% customer has :
- The average speed is the average of all the customers driving the same model
- The average acceleration is the average of all the customers driving the same model

The 0% customer has the lowest average accelerations for the same model
The 100% customer has the highest average accelerations for the same model

- For average speed:
  - the run is considered admissible if the average speed on Urban Rural Motorway (or for each speed segment) is within ± 3 km/h of customer usage statistics
  - extended conditions for Urban section, an average speed within ± 5 km/h is acceptable

- For average acceleration:
  - the run is considered admissible if the average positive acceleration on Urban Rural Motorway (or for each speed segment) is representative of 30 to 70 percentile customers
  - extended conditions for Motorway section, an average acceleration representative of 20 to 80 percentile customers is acceptable



9 Consumption calculations

- Coefficient for conversion of g/km of CO_2 to l/100km
  The fuel used is from the open market. It is necessary to have an analysis of the fuel composition to calculate the coefficient between CO2 and fuel
  - Diesel : is B7, the coefficient is 26.2
  - Petrol: is E10, the coefficient is 22.6

- HC and CO concentration?

  Experience has shown that the carbon content in HC and CO is negligible for petrol and diesel vehicles.

10 Post-processing of measurement results

Post-processing is carried out in the following chronological order:
- Correction for PEMS/rolling road correlation
- Correction for weather conditions, vehicle mass and aerodynamic drag of the PEMS
- Correction for U, R, M mix
- Weighting for the cold phase
- Accounting for particle filter regeneration

10.1 Correction for PEMS/rolling road correlation

- The correlation factor is calculated for the global WLTP cycle and for the four phases of the WLTP cycle (Low, Mid, High, Extra High) from the CO2 measurements of the PEMS and the rolling road by the formula :

$$\frac{\text{CO2 PEMS} - \text{CO2 rolling road}}{\text{CO2 rolling road}}$$

- If the correlation is outside the range of ± 10 % overall and by phase (*): the test is rejected

- If the correlation is within the range of ± 10 % overall and by phase (*): the test is accepted:
  - if the correlation by phase < ± 3 % : there is no correction
  - if ± 3 % < correlation by phase: the measurement by phase is corrected bringing it to 0%

- Special case for low cylinder-capacity petrol engines (≤ 1.2 l):
  - if the correlation is within the range of ± 10 % overall and by phase (*): idle phases are not excluded
  - if the correlation is outside the range of ± 10 % overall and by phase (*): idle phases are excluded
    - if the correlation comes within the range of ± 10 % overall and by phase (*): the correlation is applied
    - if the correlation remains outside the range of ± 10 % overall and by phase (*): all is discarded and we start again with another PEMS

(*) range extended to 12% on the Low for petrol engines

10.2 Correction for weather conditions, mass and drag of the PEMS

Using the WLTP formula, the impact of outside temperature, atmospheric pressure, vehicle mass and aerodynamic impact of the PEMS on the resistance of the vehicle are corrected by calculation to bring the consumption measured to the following conditions: 14°C, 100 kPa, standard test mass.

PEMS drag: a drag coefficient is applied in the WLTP formula used to correct for weather conditions and mass by adding: ½ ρ SCx V^2 to the calculation for coast-down on the day of the test with:

- the SCx value which is the impact on the model tested
- a value of ρ dependent on the conditions on the day of the test (**) according to the following formula

$$\rho(\varphi,\vartheta,p) = \frac{1}{287,06(\vartheta+273,15)}\left(p - 230,617\cdot\varphi\cdot\exp\left[\frac{17,5043\cdot\vartheta}{241,2\,°\mathrm{C}+\vartheta}\right]\right)$$

With

- φ Relative humidity
- ϑ Temperature in °C
- p Pressure in Pa

(**) under standard conditions of 14° and 100kPa, the value of ρ is 1,214

Using the WLTP formula below, calculations are made for:

- The CD on the day of the test
- The CD under standard conditions

WLTP Formula

$F^* = (f0 - K1 + f_1 v) \times \left(1 + K_0(T - 20)\right) + K_2 f_2 v^2$ + ½ ρ SCx V^2

F^* is the corrected road load, N;

f_0 is the constant term, N;

f_1 is the coefficient of the first order term, N·(h/km);

f_2 is the coefficient of the second order term, N·(h/km)^2;

K_0 is the correction factor for rolling resistance; $K_0 = 8.6 \times 10^{-3}$

K_1 is the test mass correction: $K_1 = f_0 \times \left(1 - \frac{M_{test\ veh}}{M_{veh\ coast\ down}}\right)$

$M_{test\ veh}$ is mass of the test vehicle kg;

$M_{veh\ coast\ down}$ is the mass of vehicle for the measure of the coast down kg.

K_2 is the correction factor for air resistance: $K_2 = \frac{T}{293} \times \frac{100}{P}$

T is the mean atmospheric temperature, Kelvin (K)

P is the mean atmospheric pressure, kPa

T is the mean atmospheric temperature, °C;

v is vehicle velocity, km/h;

- Energy is calculated for all runs (total energy for CD + acceleration + slope):
  - On the day of the test
  - Under standard conditions

- Energy is calculated for urban, rural and motorway:
  - On the day of the test
  - Under standard conditions

- Three CO2 graphs are prepared = f(energy) for urban, rural and motorway for a 1km window with a 20m pitch, from which the three U, R, M slopes are obtained

- The U slope is applied to the U energy difference, the R slope to the R energy difference and the M slope to the M energy difference, the % consumption corrections to be applied to the U, R, M consumptions is deduced.

10.3 Correction of Urban Rural Motorway mix

Using the U R M consumptions measured with the PEMS, the mix achieved during the test and the 50 percentile customer mix of the model tested, we can work out the consumption for the 50 percentile customer mix

10.4 Weighting for the cold phase

The consumption road-test is around 100km but the average customer journey is shorter. The measurements include one cold start but the cold phase over-consumption is understated, and must be increased (weighted) to be representative of real-world usage.

To do this, we have to answer the following two questions:

- Question 1: when does the engine warm up, and how much is the over-consumption to warm it up?
- Question 2: how should statistical client data be used to weight this over-consumption?

- **For question 1**

The vehicle is run cold, followed immediately by the same run repeated hot.
The engine is hot when the instantaneous consumption during the cold run is the same as the consumption on the hot run.
The parameter to be considered is the rolling energy.
The cumulative difference in consumption cold/hot is calculated expressed in g of CO2 as a function of forward movement energy of the vehicle expressed in MJ calculated in steps of 2kJ.
Once this difference is constant, the engine is hot.
We therefore know how much dynamic energy was required to warm up the engine, what distance this corresponds to and over what time.
So we can calculate the penalty due to a cold start in l/100km over this distance.

- **For question 2:**

We use the statistical running data for the average customer of the model tested:

- Mean distribution of individual journey lengths
- Mean journey distance
- Mean distribution of inter-journey by class of duration
- Percentage of journeys run cold.

The weighting (over-consumption to be added to the measurements despite the cold start already included in the measurements) is thus:

$$RDE\ cold\ penalty\left(\frac{l}{100km}\right) \times cold\ \ RDE\ distance(km) \times Percentage\ of\ journeys\ run\ cold \times \left(\frac{1}{\frac{Mean\ journey}{istance\ (km)}} - \frac{1}{RDE\ journey\ distance\ (km)}\right)$$

This measurement is carried out once only for each engine and it is then considered that the energy to warm up an engine is independent of the vehicle. An add-on is made in the Excel spreadsheet

10.5 Accounting for particle filter regeneration

The homologated particle filter K is known, as is the homologated distance between two regenerations.

The statistical customer usage data give the percentage of occurrence of particle filter regenerations by class of inter-regeneration distance [km]. From this we can deduce the weighted mean distance between two regenerations in use.

We then deduce the percentage consumption to be added to the measured consumption to take account of the fact that the customer will experience a particle filter regeneration from time to time.

When a vehicle initiates regeneration every 3 tests or more frequently it is considered to be in continuous regeneration. In this case, regeneration is included in the consumption result and the KFAP penalty is not added.

10.6 Validation of the fuel consumption value

The final fuel consumption value determined by the average of the valid test runs is compared to values from customer surveys and other internal and external data. The value from the trip computer is also compared to check coherence of test results. In no circulstances can the measured fuel consumption be modified follwing these comparisons.

11 Application to LCVs

All of the above is valid for passenger cars. This chapter is specific to LCVs for which the protocol has to be adapted.

The adaptation concerns:
- Masses
- Urban Rural Motorway mix
- Cold phase weighting
- Particle filter regeneration
- Dynamic conditions

11.1 Masses

The average number of passengers is known.
The Maximum Authorised Mass (MAM), which is OEM information, is known.

We can work out the Maximum Laden Mass (MLM): MLM = MAM – mass of passengers

We know the loading distribution:
- Light load = xx% of MLM
- Loaded = xx% of MLM
- Exceptional load = xx% of MLM

We know the mean distribution in kilometres by load, from which we get the mean loading mass.

Standard mass = unladen weight of tested trim level + average mass of options statistically purchased by customers on this trim level + mass of passengers + loading mass.

11.2 Urban Rural Motorway mix

We know the URM of the LCV tested.

11.3 Weighting of the cold phase

We know the average journey and inter-journey time of the LCV tested.
From which we get the weighting to be added to the measured consumption.

11.4 Particle filter regeneration

Take the same value as for passenger cars.

11.5 Dynamic conditions

We know the customer usage statistics in terms of average speed and average acceleration for the LCV tested.

12 Adaptation to dynamic vehicles

(e.g.: Peugeot 308 GTi)

The masses, the town/road/motorway mix and the weighting of the cold phase are all the same as for classic vehicles.

Only the speed and acceleration need to be adapted as they are specific to dynamic vehicles. We have customer usage statistics for average speed and average acceleration for this type of vehicle.

13 The "family" concept

To define a vehicle type in terms of its consumption, 6 items of information must be known:
- Model
- Body type
- Trim levels
- Engine
- Gearbox
- Type of tyre

A family of vehicles is defined by the following invariable pieces of information:
- Model
- Engine
- Gearbox type

The concept of vehicle families allows us, based on measurements carried out according to the test protocol, to estimate fuel consumption for a vehicle of the same model, with the same engine and gearbox type, but with a different body type and/or trim level and/or a different tyre type from the vehicle being measured. We can then use the calculation rules to estimate differences in consumption based on technical differences.

The possible variables are:

- Body type: the concept of family means that by measuring a saloon car, we can estimate the fuel consumption of the estate version.
- Trim levels: the concept of family means that by measuring a given trim level we can estimate the consumption of other trim levels.
- Type of tyre: the concept of family means that by measuring one tyre we can estimate the consumption with other tyres.
- Aerodynamics: the concept of family means that by measuring one aerodynamic we can estimate consumption with other levels of aerodynamics.
- Transmission length: the concept of family means that by measuring one transmission length we can estimate consumption with other transmission lengths (with the same gearbox type)

* The notion of transmission length is explained as follows:

- It is said that the gearbox is long, when a motor is running "slowly" at a given speed (eg 2000 rpm at 90 km / h)
- It is said that the gearbox is short, when a motor runs faster at the same speed (eg 2500 rpm at 90 km / h)

14 Online simulator

The online simulator allows customers, once they have answered a few simple questions, to estimate their fuel consumption based on the following four usage characteristics:

- number of passengers and vehicle load
- number of daily journeys and average journey distance
- types of route
- driving style

The online simulator also allows for weather conditions and the percentage of journeys where the engine starts from cold.

The online simulator can give a good estimate of the customer's consumption starting from the benchmark consumption of the same model, which has been established using the protocol.

The online simulator will only work for vehicle families that have been tested in accordance with the protocol.

14.1 Number of passengers and vehicle load

The benchmark consumption takes account of the average load of the vehicle configured. To get the load based on the customers' estimated usage, we need to add or subtract a certain mass from the average load.

There is no need to specify the vehicle, engine or fuel type (petrol or diesel).

We establish the town/road/motorway mix by taking an average mix which applies to all vehicles.

The impact of a 100 kg load on town, road and motorway fuel consumption is known.

Factoring in the number of passengers and luggage and the load frequency according to the table below:

	Jamais	Occasionnellement	Souvent
Conducteur seul	◉	○	○
Conducteur avec 1 ou2 passagers	○	○	◉
Conducteur avec 3 passagers ou plus	○	○	◉
Bagages (supérieur à 30kg)	○	◉	○

The mass to add or subtract for a customer's estimated usage is based on the customer's different possible responses.

Number of persons on board and luggage weight:
- Case 1: driver only
- Case 2: driver with 1 or 2 passengers→ we assume 1.5 passengers
- Case 3: driver with 3 or more passengers→we assume 3.5 passengers
- Case 4: luggage
    - Anything less than 30 kg of luggage is ignored
    - If luggage weighs more than 30 kg, we assume a weight of 40 kg

Frequency:
- Never→ means 0% of the time
- Occasionally→means 25% of the time
- Often→means 75% of the time

14.2 Journeys

The benchmark consumption factors in average journey distance and the percentage of journeys with a cold start by the average customer for the vehicle configured.

To adapt the cold phase weighting to the customer's estimated use, we have to add or subtract a consumption factor from the benchmark.

To do this, we need to know the average distance of a customer's journey and the number of journeys per driving day.

One journey = 1 engine start and 1 engine stop:
e.g.: a customer leaves for work, then returns from work and stops off at a shop before continuing home. This is 3 journeys: journey 1 = home-work; journey 2 = work to shop; journey 3 = shop-home.
Using the same example: journey 1 home-work = 15 km; journey 2 work-shop = 13 km; journey 3 = shop to home = 2 km. Average journey distance = 10 km

For the percentage of journeys with cold starts, we assume that:
- 100% of journeys start from cold if the customer says "1-2" journeys per driving day"
- 33% (1/3) of journeys start from cold if the customer says "3-4 journeys per driving day"
- 20% of journeys start from cold if the customer says "5-9" journeys per driving day"
- 10% of journeys start from cold if the customer says "more than 10 journeys per driving day"

14.3 Routes

The benchmark consumption incorporates the town/road/motorway mix of the average customer based on the segment and fuel of the vehicle configured.

To calculate consumption based on the customer's estimated usage, we apply town/road/motorway consumptions for the vehicle measured according to the protocol and the mix declared by the customer.

This requires that the customer estimates their total annual average distance driven in town, on the open road and on motorways and then estimates their percentage of town, road and motorway driving.

e.g.: a customer drives 10,000 km annually, of which 2,000 km in town, 3,000 km on the open road, and 5,000 km on motorways. The distance percentages are, respectively, 20%, 30% and 50%.

14.4 Driving

The benchmark consumption factors in a driving style that is close to the average customer's in terms of average speed in town/road/motorway driving and average accelerations in town/road/motorway driving.

To adapt consumption to the dynamic conditions of the customer's own use, we need to introduce a corrective factor by adding or subtracting a certain amount of consumption from this starting value.

To do this, we need to know the average speed of the customer compared to other drivers and their driving style.

Beaucoup moins vite que les autres véhicules	Moins vite que les autres véhicules	Comme les autres véhicules	Plus vite que les autres véhicules	Beaucoup plus vite que les autres véhicules
○ 1	○ 2	◉ 3	○ 4	○ 5

Conduite très calme, pas de dépassement	Conduite calme, peu de dépassements	Conduite mesurée , dépassements opportuns	Conduite dynamique, dépassements fréquents	Conduite très dynamique, dépassements très fréquents
○ 1	○ 2	◉ 3	○ 4	○ 5

We break this down by vehicle segment and fuel (petrol or diesel) and factor in the town/road/motorway mix.

There are 5 different categories of customer:
- The "much slower" customer: they drive at a speed well below that of other vehicles and have a very calm driving style, without overtaking. A heavy correction is applied to this group which reduces consumption compared to the benchmark
- The "slower" customer: they drive at a speed below that of other vehicles and have a calm driving style, only overtaking occasionally. A correction is applied to this group which reduces consumption compared to the benchmark
- The "average" customer: they drive at the same speed as other vehicles, have a measured driving style and overtake when the opportunity presents itself. No correction is applied to this group as they mimic the behaviour of the protocol's benchmark customer
- The "faster" customer: they drive faster than other vehicles, have a dynamic driving style and overtake frequently. A correction is applied to this group which increases consumption compared to the benchmark
- The "much faster" customer: they drive much faster than other vehicles, have a highly dynamic driving style and overtake very frequently. A heavy correction is applied to this group which increases consumption compared to the benchmark

14.5 Weather conditions

Benchmark consumption factors in the weather conditions encountered by the average customer for the vehicle configured.

Weather conditions can affect a vehicle's consumption caused by using air-conditioning, heating and electrical accessories and by their effect on the vehicle's running resistance.

To adapt consumption to weather conditions for the client's estimated usage, we have to allow for extra consumption compared to the benchmark.

The country where the vehicle will be driven is thus an important factor.

This factor is automatically fed in by the website where the customer logs in and runs their simulation.

Country weather conditions are grouped into three categories:
- Cold climate, represented by Helsinki
- Temperate climate, represented by Paris
- Hot climate, represented by Seville

The benchmark consumption is for a temperate country

For air-conditioning, we apply:
- a "hot country" penalty
- no correction for "temperate" and "cold" countries

This penalty is based on
- measurements of variations in fuel consumption based on temperature difference
- the difference in average monthly high temperature between Seville and Paris

For heating and electrical accessories (heated seats, heated rear window, etc.), we apply:
- a "cold country" penalty

- no correction for "temperate" and "hot" countries

This penalty is based on a benchmark average total annual electricity usage which includes the usage of heating and electrical accessories and is adapted for the vehicle's body type.

For running resistance of the vehicle, we apply:
- a "cold country" penalty based on the difference between the annual average temperature in Helsinki and the benchmark temperature of 14°C
- a "hot country" penalty based on the difference between the annual average temperature in Seville and the benchmark temperature of 14°C
- no correction for "temperate countries"

15 Monitoring

Application of the protocol is subject to monitoring by the certification organisation who have permanent access to data made available on the OEM's server.

The certification organisation carries out a six-monthly assessment covering the correct application of the protocol including the organisational and technical arrangements from selection and preparation of the vehicle and test instruments (including calibration), conducting the test and the post-processing. This ensures that actual testing is carried out in accordance with the initially established protocol.

Monitoring may be either pre-arranged or unexpected.

Appendix 1: test log

orgnisation logo	Test Log **EMISSIONS MEASUREMENTS USING PEMS EQUIPMENT DURING ROAD TEST**	Version 0 Date applicable: xx/xx/2016 Document manager: xxx	Page 1/1

Requirements :

- The driver must be authorised to drive the test vehicle
- For any external person, the contract between the OEM and the employee's own company must stipulate the authorisation to drive test vehicles
- The vehicle must be fitted with W (trade) plates and the driver must have authorisation to drive under W (trade) plates (valid for 1 day)
- The driver is in possession of the document referring to authorisation to conduct testing on the open road with a PEMS device.
- The Code de la Route (Highway Code) must be diligently followed during testing.

Identification of signatory
The signatory agrees to complete accurately all fields of the log.
Name/ Forename: Signature:

Identification of occupants
Name / Forename of driver:
Name / Forename of passengers:

Test identification
Date & Time:
Name of test:
Data stored under reference xxx:

Soaking of vehicle before road test
☐ Inside a building
☐ Outside
Soaking time since engine was last started (in h):

Vehicle identification
VIN:
Vehicle registration:
W (trade) plate:

Commercial description
Silhouette:
Engine:
Gearbox:

Internal description
Silhouette:
Engine:
Gearbox:

Tyres
Commercial description:
Dimensions :
☐ Normal load (<=2 passengers)
☐ Loaded (>2 passengers)
Pressure applied, cold (bar): Front: Rear:

Vehicle weight
☐ All occupants on board during weighing
☐ PEMS fitted during weighing
Fuel level in tank (to nearest 1/8th):
Weight of ballast added to approach target mass:
Target mass in kg: Measured, in kg:

Identification of measurement equipment (PEMS)

Serial number SCS		Serial number EFM	
Serial number GAS		Pitot tube diameter(EFM)	
Reference of calibration gas bottme		Serial number Cab module	
Calibration gas value CO2 (%)		Serial number GPS	
Calibration gas value CO (%)		Serial number Probe	
Calibration gas value NO (ppm)		Host software version of PEMS	
Calibration gas value NO2 (ppm)		SENSOR Tech-CT LDV software version	
For petrol engines, damper fitted (yes/no)			

Preparation of mesurement equipment
☐ PEMS heating phase completed.
☐ Set up a new recording using the pre-defined test name.
☐ Calibration of flowmeter and analysers according to manufacturer's reccommendations.
☐ Configuration of PEMS for petrol/diesel according to vehicle being tested has been checked.
☐ Concentration of content of calibration bottles in accordance with values entered into the PEMS for calibration phase has been checked.
☐ Restart recording in Sample mode, (with the engine stopped). Start engine and conduct test, pause recording at the end of the road test.
☐ Conduct check of PEMS analysers (Calibration mode), stop recording.

Temperature (start of test)
Soaking building:
Outside:

Traffic density

	Light	Heavy	Jams	Comments (diversions, disturbances,...)
Urban	☐	☐	☐	
Rural	☐	☐	☐	
Motorway	☐	☐	☐	

Weather conditions

	None	Intermittent	Continuous slow	Continuous fast	Comments
Urban	☐	☐	☐	☐	
Rural	☐	☐	☐	☐	
Motorway	☐	☐	☐	☐	

Rain intensity to be determined according to windscreen wiper speed

Wind
☐ No wind
☐ Light
☐ Strong
☐ Very strong (in theory, prohibits testing)

Road conditions

	Dry	Damp	Wet	Comments
Urban	☐	☐	☐	
Rural	☐	☐	☐	
Motorway	☐	☐	☐	

Vehicle parameters

Air-con / heating
☐ Vehicle fitted with automatic climate control (temperature regulation)
☐ Vehicle fitted with manual air-conditioning
☐ If regulated air-con: "A/C" and "Auto" set to 21°C
☐ If manual air-con: set to ensure passenger comfort

Demisting
☐ A windscreen demisting cycle was carried out during the test

Steering column stalks
☐ Automatic windscreen wiping activated
☐ Automatic headlamp illumination activated

Gear ratios
Enter the mode active during the test (for example Sport mode):

Stop & Start
☐ Vehicle fitted with a Stop & Start system
☐ Stop & Start active during road test
Stop & Start activation time, recorded at end of test (in s):

On-board computer
☐ Trip counter reset at start of test
Fuel consumption measured at end of test (l/100km):

General route data

Distance covered
Kilometres at start:
Kilometres at return:
Distance covered:

Time
Start time:
Return time: