# Clean Air Zone (CAZ) - CLEAN VEHICLE RETROFIT CERTIFICATION (CVRC)

# CHASSIS DYNAMOMETER TEST PROCEDURES FOR APPROVAL OF LOW EMISSION ADAPTATIONS

Test procedures for measuring pollutant and greenhouse gas emissions of conventionally-powered (pre-Euro VI/6 diesel) vehicles equipped with retrofitted low emission adaptation equipment (intended to meet or exceed Euro 6/VI in-service performance) on chassis dynamometers.

# Contents

## 1. Scope

This document provides an accurate and reproducible procedure for simulating the operation of vehicles powered by conventional (diesel) powertrains on dynamometers for the purpose of measuring emissions and to evaluate the efficacy of retrofitted equipment, as part of the Clean Vehicle Retrofit Accreditation Scheme (CVRAS).

It should be noted that the vehicles addressed in this recommended practice are expected to be powered by diesel engines certified to any one of the pre-Euro VI/6 standards.

This generic test procedure does not make specific provisions or recommendations for testing of individual vehicle types – requirements for each vehicle type, including test cycles, emissions limit values and use of auxiliary loads, air conditioning, heating systems, PTOs, etc, are contained within the relevant annexes.

The intention is to test the vehicle in its normal road-going condition and operating strategy as far as reasonably practical, within the constraints of the equipment and cycle. Potential exceptions to this include antilock brakes and traction control. Any aspect of vehicle operation which needs to be modified for the test shall be discussed with the test centre and recorded in the test report.

As well as measuring pollutant emissions performance to determine if the vehicle achieves Euro VI/6 equivalence, specifically for NOx and PM, the procedure requires the calculation of Tank-to-Wheel (TTW) Greenhouse Gas (GHG) emissions to determine if the retrofit system incurs unacceptable increases in such emissions.

Regulated emissions (HC, $NH_3$, CO, NO, $NO_2$, and PM) and GHG emissions ($CO_2$, $N_2O$ and $CH_4$) shall be sampled over the entire cycle and the results presented as g/km.

Vehicles too heavy or for any other reason not able to be tested on a chassis dynamometer shall instead be tested according to the (separate) track-based test protocols.

## 2. Test preparations

### Test site

The ambient temperature levels encountered by the test vehicle in the dynamometer laboratory shall be maintained at 18°C+/- 2°C throughout the test, unless otherwise stated.

Ambient temperatures must be recorded at the beginning and end of the test period.

Adequate test site capabilities for safe venting and cooling of batteries, containment of flywheels, protection from exposure to high voltage, or any other necessary safety precaution shall be provided during testing.

One or more speed tracking fans shall direct cooling air to the vehicle in an attempt to maintain the engine operating temperature as specified by the manufacturer during testing. These fans shall only be operating when the vehicle is in operation and shall be switched off for all key-off dwell periods. Fans for brake cooling can be utilized at all times. Additional fixed speed fans should be used if required and must be documented in the test report.

### Pre-test data collection

Prior to testing, detailed characteristics of the vehicle should be recorded, including details of the retrofitted equipment, as defined in Appendix 1.

For all tests, a fuel sample shall be taken for potential analysis at a later date. The vehicle will be tested using the fuel with which it arrives at the test facility. Fuels should meet the requirements of EN590 and any exceptions to this should be advised by the technology supplier for reporting purposes.

### Operation of the vehicle

If the vehicle is unable to be driven on the chassis dynamometer in its conventional operating mode then the reasons for this should be provided by the technology supplier in advance of the tests for reporting purposes. Any deviations from standard operation must be approved by the LowCVP prior to the issue of a CVRAS certificate (where appropriate).

### Condition of the Vehicle

Vehicle Stabilization -- Prior to testing, the vehicle shall be stabilized to a minimum distance of 3000km. This will be documented in the test report.

Tyres -- Manufacturer's recommended tyres shall be used and shall be the same size as would be used in service. This will be documented in the test report.

Tyre Pressure -- Tyre pressures should be set at the beginning of the test to manufacturer's recommended pressure. This will be documented in the test report.

Lubricants -- The vehicle lubricants normally specified by the manufacturer shall be used. This specification shall be supplied by the technology supplier in advance of the tests and recorded in the test report.

Gear Shifting – The vehicle shall be driven with appropriate accelerator pedal movement to achieve the time versus speed relationship prescribed by the drive cycle. Both smoothing of speed variations and excessive acceleration pedal perturbations are to be avoided and may cause invalidation of the test run. In the case of test vehicles equipped with manual transmissions, the transmission shall be shifted in accordance with procedures that are representative of shift patterns that may reasonably be expected to be followed by vehicles in use.

For these tests, it is not a requirement that test houses should follow precisely the exact gear change points and strategies specified by Type Approval legislation that use the same cycles (e.g. WLTP), though they may do so if they feel such an approach meets the requirements of the preceding paragraph.

Vehicle Preparation & Preconditioning -- as a minimum, should include:

- The vehicle should be preconditioned using a complete run of the test cycle followed by the appropriate key-off dwell period

### Dynamometer Specifications

The evaluation of the emissions should be performed using a laboratory that incorporates a chassis dynamometer, a full-scale dilution tunnel, and laboratory-grade exhaust gas analyzers as described in ECE R83 (Light-duty vehicles) and ECE R49 (Heavy-duty engines). The chassis dynamometer should be capable of simulating the transient inertial load, aerodynamic drag and rolling resistance associated with normal operations of the vehicle. The transient inertial load should be simulated using appropriately sized flywheels and/or electronically controlled power absorbers. The aerodynamic drag and rolling resistance may be implemented by power absorbers with an appropriate computer control system. The drag and rolling resistance should be established as a function of vehicle

speed. The actual vehicle weight for the on-road coast down should be the same as the anticipated vehicle testing weight as simulated on the dynamometer. The vehicle should be mounted on the chassis dynamometer so that it can be driven through a test cycle. The driver should be provided with a visual display of the desired and actual vehicle speed to allow the driver to operate the vehicle on the prescribed cycle.

### Dynamometer Calibrations

The dynamometer laboratory should provide evidence of compliance with calibration procedures as recommended by the manufacturer.

### Inertial Load

Inertial load must be simulated correctly from a complete stop (e.g., total energy used to accelerate the vehicle plus road and aerodynamic losses should equal theoretical calculations and actual coast-downs).

### Road Load

Road load and wind losses should be simulated by an energy device such as a power absorber. Road load should be verified by comparison to previously tested vehicles having similar characteristics or by coast-down analysis on the track.

### Dynamometer Load Coefficient Determination

The dynamometer coefficients that simulate road-load forces shall be determined as specified in Directive ECE R83. The vehicles shall be weighted to the correct dynamometer test weight when the on road coast-downs are performed.

### Dynamometer Settings

The dynamometer's power absorption and inertia simulation shall be set as specified in ECE R83. It is preferable to ensure that the dynamometer system provides the appropriate retarding force at all speeds, rather than simply satisfying a coast-down time between two specified speeds. The remaining operating conditions of the vehicle should be set to the same operating mode during coast-downs on road and on the dynamometer (e.g., air conditioning, etc).

### Test Instrumentation

Equipment referenced in ECE R83 and ECE R49 (including exhaust emissions sampling and analytical systems) is required for emissions measurements, where appropriate. All instrumentation shall be traceable. to national standards.

The chassis test laboratory will be used to measure actual cycle distance during a test.

## 3. Test Procedure

### Vehicle Propulsion System Starting and Restarting

The vehicle's propulsion system – specifically, the unit that provides the primary motive energy, e.g., the internal combustion engine -- shall be started according to the manufacturer's recommended starting procedures in the owner's manual. The air conditioner and other auxiliary on-board equipment generally used during normal service shall be activated or disabled in accordance with the specific vehicle test requirements.

### Dynamometer Driving Procedure

The emission test sequence starts with a "hot" vehicle that can be utilized to warm the dynamometer to operating temperature and allow for vehicle rolling loss calibration.

### Dynamometer Warm-up

The test vehicle is used to warm the dynamometer and operated to allow for proper laboratory and vehicle loss calibrations.

### Practice and Warm Up Runs

The test vehicle will be operated through a preliminary run of the desired test cycle. During this preliminary cycle, the driver will become familiar with the vehicle operation, and the suitability of the selected operating range of gas analysers will be verified. Additional preliminary runs will be made, if necessary, to assure that the vehicle, driver, and laboratory instrumentation are performing satisfactorily.

### Emission Tests

During the actual emission tests the test facility shall measure all emission data from the moment the vehicle is started, excluding the actual start event.

If the vehicle has not been operated for more than 30 minutes then it shall be started and warmed to operating temperature utilizing the same test cycle that will be used for emission characterization, unless a different warm-up procedure is specified in the relevant detailed test conditions Annex. Once the vehicle is at operating temperature the test cycle shall then begin and emission measurements will be taken. At the end of the test cycle the vehicle shall be returned to the “key off” condition. Analysis will be carried out between test cycles

The number of tests runs performed must be sufficient to provide a minimum of three test runs with valid results. If the test sequence lapses in timing, another preliminary warm up run must be performed, after which the schedule can be resumed. Valid data gained prior to the breaking of the schedule may be preserved and reported. It is important to adhere to the time schedule and soak periods because engines and after-treatment devices are sensitive to operating temperature.

### Test Termination

The test shall terminate at the conclusion of the test run. However, sufficient idle time should be included at the end of a run, such that the analysers are not missing emissions that are still in the sampling train.

### Data Recording

The emissions from the vehicle exhaust will be ducted to a full-scale dilution tunnel where the gaseous emissions of carbon monoxide, oxides of nitrogen (both nitric oxide and nitrogen dioxide) and carbon dioxide will be analysed as an integrated bag sample. Emissions of hydrocarbons, methane and nitrous oxide shall be measured on a continuous basis at a frequency of 5 Hz or greater. It is recommended that emissions of carbon monoxide, oxides of nitrogen and carbon dioxide are also measured on a continuous basis, and that these levels be compared to the integrated bag measurements as a quality assurance check. Particulate matter will be measured gravimetrically using fluorocarbon-coated glass fibre filters by weighing the filters before and after testing. Filters will be conditioned to temperature and humidity conditions as specified by ECE R49

For each constituent, a background sample using the same sampling train as used during the actual testing must be measured before and after the emission test, and the background correction must be performed as specified by ECE R83. In cases where some speciality fuels are examined by the test procedure, it may prove necessary to sample for additional species, including alcohols, aldehydes, ketones, or organic toxics if it is suspected that the levels of these additional species might be significantly higher than is normally found for

diesel fuel. It is recommended that the tunnel inlet be filtered for PM with a HEPA filter to aid in lowering the detection limits.

Fuel consumed shall typically be determined by carbon balance from the gas analysers, and the actual distance travelled by the dynamometer roll surface shall be used to provide the distance travelled during the driving cycles. Alternative methods for fuel consumption, such as direct mass measurement of the fuel tank, shall be considered if they are sufficiently accurate. This would require that the mass measurement system has an accuracy of greater than 1% of the fuel amount consumed during the test cycle.

### Deviations from Standard Procedure

It is permissible to deviate from the prescribed procedure in cases where it can clearly be shown that this would result in a more realistic simulation of real-world vehicle operation.

Any deviations from the standard test procedure must be recorded in the test report and approved by the LowCVP prior to the issue of a CVRAS certificate (where appropriate).

## 4. Test validation

The value of the mass emission rates for each species will be averaged over the test distance (i.e. reported in g/km). There will be a minimum of three valid runs for each type of drive cycle. For a group of three tests to be valid the 'total GHG emissions' from each test, must lie within a 5% range (max <= 1.05 x min). Any obvious error in the data should be identified and removed from the dataset; however, a minimum of three successful runs should be used in reporting the data.

At the end of each run, the total distance travelled by the vehicle over the test run will be noted from the dynamometer distance measurements. Adherence of the driver to the test cycle target speeds will be noted, and a regression will be performed to compare actual speeds with target speeds on a second-by-second basis. Target speed (x) and actual speed (y) should be charted in 1Hz increments and a trend line inserted with a zero intercept. If the resulting trend line has a slope that varies from unity by more than 10% or an $R^2$ of less than 0.8 the test run should be considered an invalid representation of that test cycle. The actual distance travelled by the dynamometer roller(s) should be used for the test cycle distance value.

If at any point during the test, vehicle propulsion is not possible or the driver is warned by the vehicle to discontinue driving then the test is considered invalid.

## 5. Reporting

The final test report shall include all measured parameters including vehicle configuration, vehicle statistics, test cycle, measured parameters and calculated test results.

The following information will be included in the report:

Technology name, vehicle to which fitted and technology supplier’s name and address.

Name of Technical Service carrying out the test, test cycles used and date(s) tested.

Essential vehicle and technology characteristics.

Name and organization of test witness(es).

Exhaust Emissions and Fuel Economy - The exhaust emissions and fuel economy of the vehicle shall be measured during each test. The measurements shall be reported in grams per kilometre and litres per 100 kilometres, respectively. NOx shall be calculated with the NO mass factored up to $NO_2$ equivalence.

Emissions results will be presented in the following format:

| Test Number | CO (g/km) | HC (g/km) | $NH_3$ (g/km) | NO (g/km) | $NO_2$ (g/km) | NOx (g/km) | PM (g/km) | PN (/km) | $CO_2$ (g/km) | $CH_4$ (g/km) | $N_2O$ (g/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| Average | | | | | | | | | | | |

Actual Distance Travelled - The actual distance that the dynamometer roll surface travelled shall be measured during each test phase. The total emissions and distance covered across the whole test cycle (all phases) shall be used to calculate the averages.

Tank-to Wheel emissions - Values for TTW GHG emissions will be presented for $CO_2$, $N_2O$ and $CH_4$ in the form of $CO_2e$. GWP values of 25 for methane and 298 for nitrous oxide shall be used. The average total GHG emissions (gCO2e/km) shall be divided by the $CO_2$ only figure to calculate the GHG increase factor.

Other consumables – if for correct operation, the retrofit equipment consumes any other reagents (e.g. AdBlue), where it is possible, the amounts consumed shall also be measured and recorded in the test report.

## Annex 1. Detailed test conditions; Buses

### Vehicle Loading

Buses shall be tested at kerb weight plus driver weight (75kg) and either:

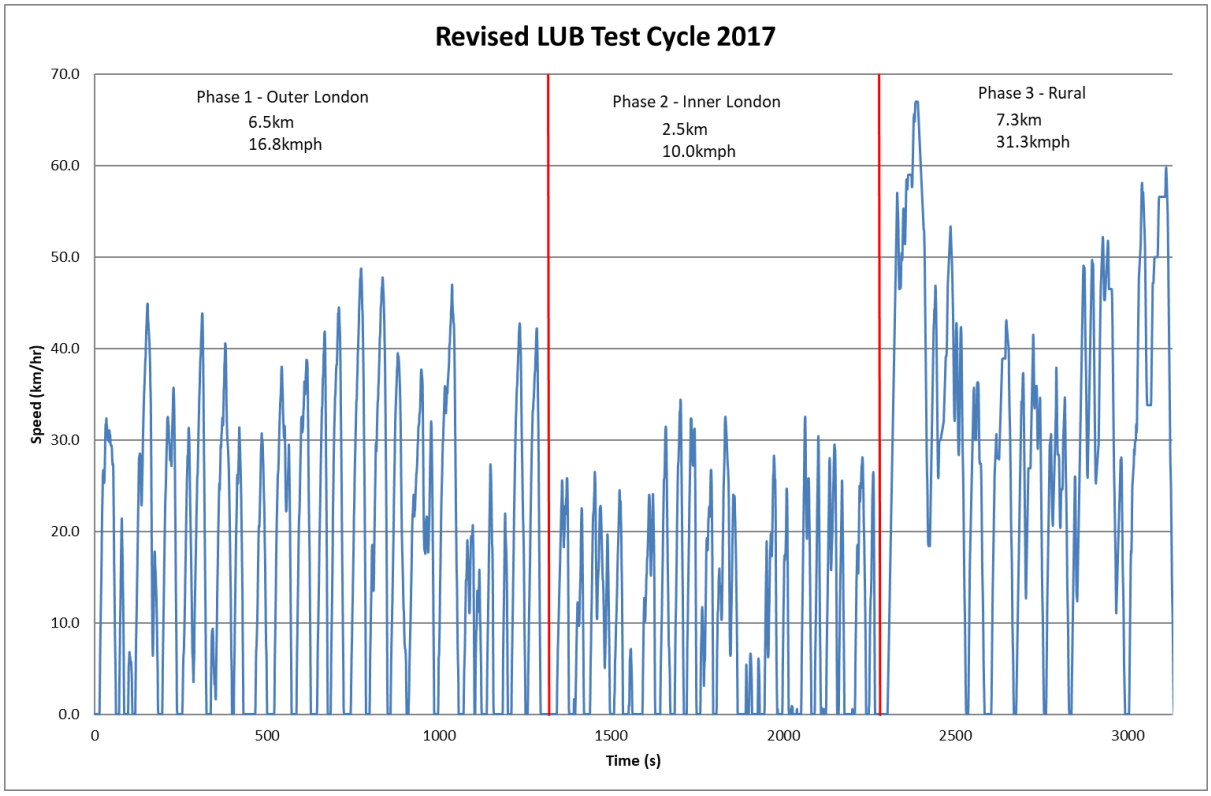
a) One quarter of the specified total passenger load using a weight of 68 kg per passenger, or
b) One half of the specified seated passenger load using a weight of 68 kg per passenger, whichever is judged by the technical service (and agreed by LowCVP) to be the worst case for effective performance of the retrofit system.

The kerb weight of the vehicle shall be determined prior to test by the technical service carrying out the test.

### Test cycle

Buses shall be tested using the 2017 revised LowCVP UK Bus (LUB Revised) cycle, consisting of an outer-London phase followed by an inner-London phase and ending with a rural phase, as shown in the figure below. A number of simulated bus stop events are also included (not shown in figure).

To warm the vehicle up prior to testing, only the Outer-London phase shall be used.




### Auxillary Loads

All set to off.

## Emissions limits applying to buses

| Exhaust emission parameter | | Maximum permitted limit | Reduction performance |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 500mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 100mg/km | |
| Particulate matter (PM) | PM | 10mg/km | |
| Number of particles (PN) | PN | $6 \times 10^{11}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 5% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Annex 2. Detailed test conditions; Coaches

### Vehicle Loading

Coaches shall be tested at kerb weight plus driver weight (75kg) and either:

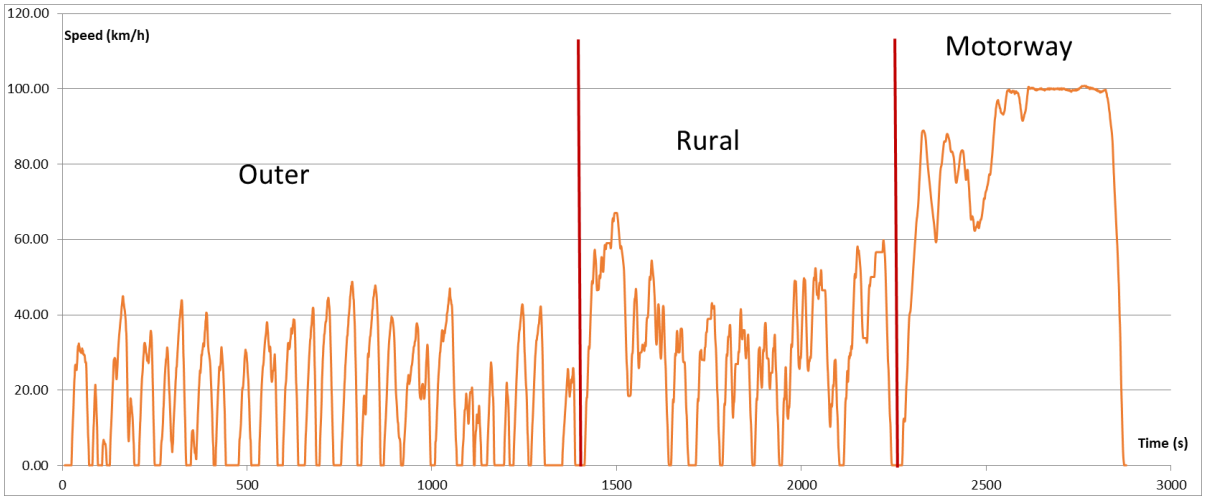
a) 100% of the specified total passenger load using a weight of 68 kg per passenger, or
b) 50% of the specified maximum payload capacity, whichever is judged by the technical service (and agreed by LowCVP) to be the worst case for effective performance of the retrofit system.

The kerb weight of the vehicle shall be determined prior to test by the technical service carrying out the test.

### Test cycle

Coaches shall be tested using the 2017 LowCVP UK Coach (LUC) cycle, consisting of an outer-city phase followed by a rural phase and ending with a dual-carriageway/motorway phase, as shown in the figure below.

To warm the vehicle up prior to testing, only the Outer phase shall be used.




### Auxillary Loads

All set to off.

### Emissions limits applying to coaches

| Exhaust emission parameter | | Maximum permitted limit | Reduction performance |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 500mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 100mg/km | |
| Particulate matter (PM) | PM | 25mg/km | |
| Number of particles (PN) | PN | 1 x $10^{12}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 5% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Annex 3. Detailed test conditions; HGVs ($N_2$ & $N_3$)

### Vehicle Loading

Trucks shall be tested at kerb weight plus driver weight (75kg) and either:

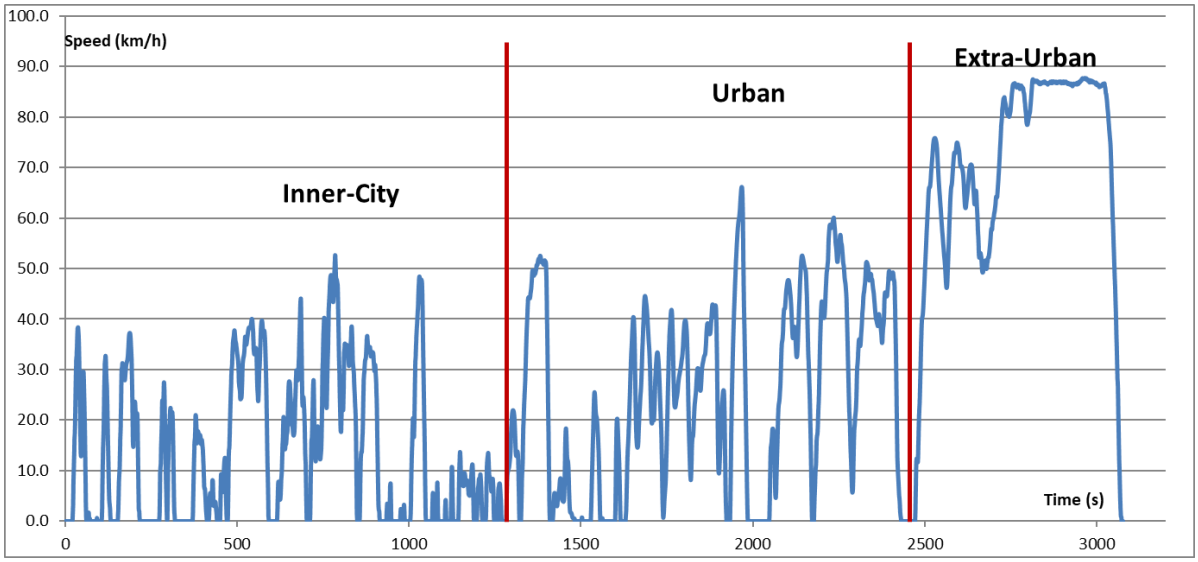
a) 50-60% of the specified maximum payload capacity, or, in cases where this is not technically possible;
b) Loading up to a vehicle weight equivalent to at least 90% of the specified maximum load of the dynamometer

The kerb weight of the vehicle shall be determined prior to test by the technical service carrying out the test.

### Test cycle

HGVs shall be tested using the 2017 LowCVP UK HGV cycle (a combination of a shortened version of the TfL AM Peak and WHVC cycles), consisting of an inner-city phase followed by urban and ending with an extra-urban phase, as shown in the figure below.

To warm the vehicle up prior to testing, only the Urban and Inner-City phases shall be used, and in that order.




### Auxillary Loads

The following vehicle ancillaries will be used:

All ancillaries on including;

a. All exterior sidelights and dipped beams on.
b. Interior heating on maximum (if not automatically controlled) or set to 22°C if automatically controlled).

## Emissions limits applying to HGVs type approval category $N_2$

| Exhaust emission parameter | | Maximum permitted limit | Reduction performance |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 500mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 100mg/km | |
| Particulate matter (PM) | PM | 10mg/km | |
| Number of particles (PN) | PN | $6 \times 10^{11}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 5% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Emissions limits applying to HGVs type approval category $N_3$

| Exhaust emission parameter | | Maximum permitted limit | Reduction performance |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 500mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 100mg/km | |
| Particulate matter (PM) | PM | 10mg/km | |
| Number of particles (PN) | PN | $6 \times 10^{11}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 5% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Annex 4. Detailed test conditions; Vans ($N_1$)

### Vehicle Loading

Vans shall be tested at kerb weight plus driver weight (75kg) and 50-60% of the specified maximum payload capacity.

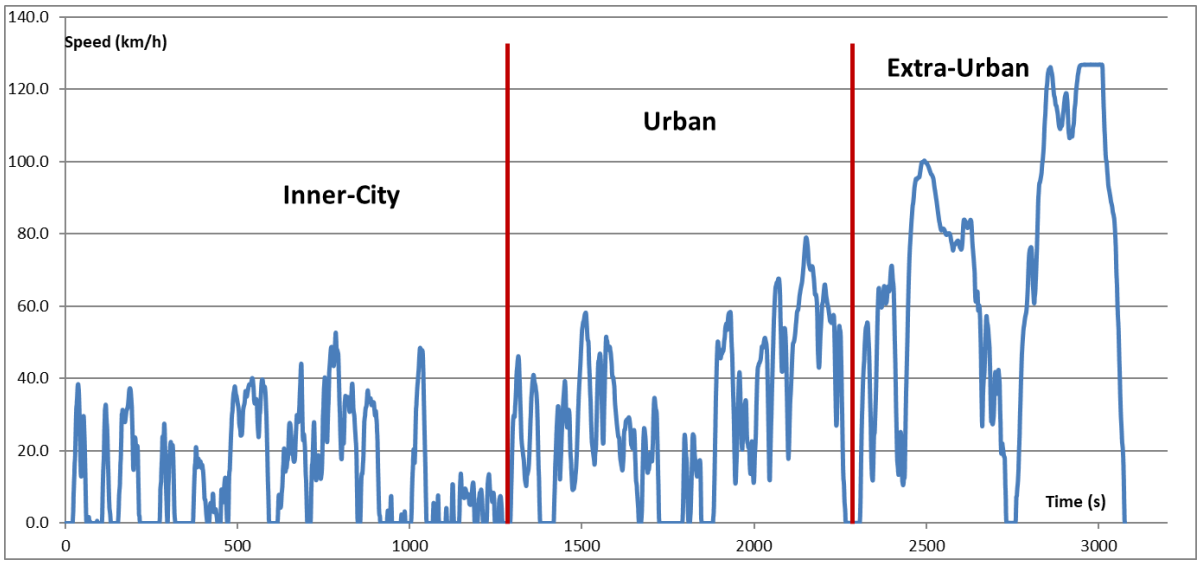
The kerb weight of the vehicle shall be determined prior to test by the technical service carrying out the test.

### Test cycle

Vans shall be tested using the 2017 LowCVP UK Van cycle (a combination of a shortened version of the TfL AM Peak and WLTC cycles), consisting of an inner-city phase followed by urban and ending with an extra-urban phase, as shown in the figure below.

To warm the vehicle up prior to testing, only the Urban and Inner-City phases shall be used, and in that order.

Vehicles unable to attain the high speeds of the extra-urban phase shall instead be allowed to deviate from the target speeds that are above the maximum capability of the vehicle. In these circumstances the driver should drive as closely to the target speeds as is possible, and cover the same overall cycle distance as if the cycle had been driven at the correct speeds throughout.




### Auxillary Loads

The following vehicle ancillaries will be used:

All ancillaries on including;

a. All exterior sidelights and dipped beams on
b. Interior heating on maximum (if not automatically controlled) or set to 22°C if automatically controlled).

## Emissions limits applying to vans (type approval category $N_1$)

| Exhaust emission parameter | | Maximum permitted limit | Reduction performance |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 250mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 100mg/km | |
| Particulate matter (PM) | PM | 10mg/km | |
| Number of particles (PN) | PN | $6 \times 10^{11}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 3% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Annex 5. Detailed test conditions; Taxis (Black Cabs) ($M_1$, GVW over 2t)

There are two potential test cycles for Taxis (Black Cabs), the PCO-CENEX London Taxi Drive Cycle or the WLTC. TfL Taxi & PH will require specific further evaluation **however Taxi CVRAS will accept TfL Taxi & PH (PCO) approvals**.

### PCO-CENEX London Taxi Drive Cycle

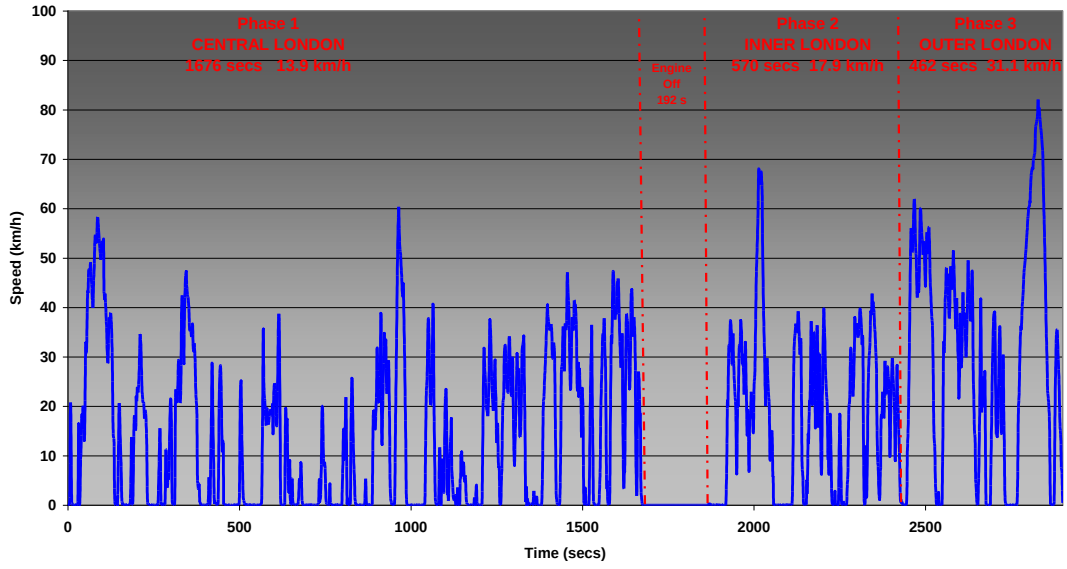
#### Vehicle Loading

Dynamometer inertia shall be set to kerb weight (no driver, full fluids) plus 150kg to represent a driver and single passenger. The inertia will be set to within 10kg of defined vehicle mass with no maximum defined.

#### Test cycle

Tests shall be conducted to the general procedures outlined in European Union Directive 70/220/EC, as amended by the latest version, with the following exceptions:
The test is a 'hot-start' drive cycle which requires a warm-up period of 15 minutes. The vehicle shall be driven at 50km/h for 5 minutes followed by 5 minutes at 40 km/h and 5 minutes at 30km/h.
Following this warm-up the vehicle shall be allowed to idle for a maximum of 30 seconds before starting the first phase of the drive cycle.
The Drive cycle to be followed is the PCO-CENEX London Taxi Cycle.
No exhaust emissions shall be measured during the 'key-off' stage between phases 1 and 2 of the drive cycle. The "cranking" at the start of Phase 2 shall be sampled.
Automatic transmissions shall be set in "Drive" for the complete driven cycle.
Phase 3 emission results shall be weighted by 0.65 to correct for increased Ph3 cycle time, unless emissions when commuting are required.

**PCO-CENEX LONDON TAXI DRIVE CYCLE**




#### Auxillary Loads

The following vehicle ancillaries will be used:

- Ancillaries shall be switched off with the exception of the Taxi Meter and DRL (daytime running lights), where fitted

### Limits applying to Taxis (Black Cabs) over PCO-Cenex London Taxi Drive Cycle

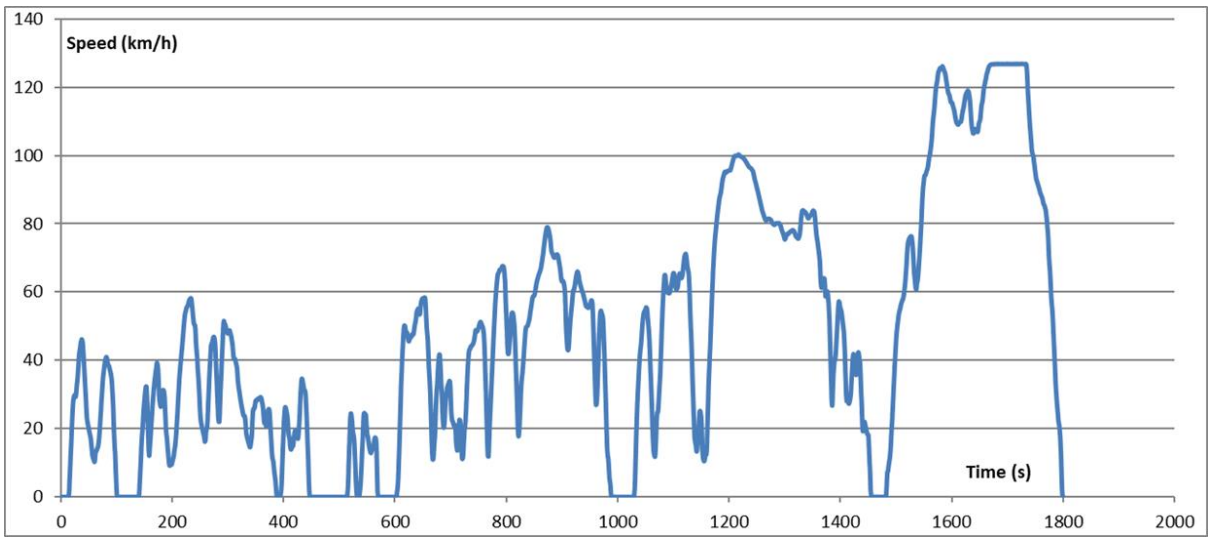
| Exhaust emission parameter | | Maximum permitted limit | Reduction performance |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 250mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 100mg/km | |
| Particulate matter (PM) | PM | 10mg/km | |
| Number of particles (PN) | PN | 6 x $10^{11}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 3% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Worldwide Harmonized Light Vehicles Test Cycle (WLTC -Cold Start)

### Vehicle Loading

Vehicle to be tested in accordance with Global technical regulation on Worldwide harmonized Light vehicles Test Procedures (WLTP, ECE/Trans/180/Add.15) and tested at kerb weight (unladen weight) with allowance fordriver and full fluids but no allowance for single passenger (according to ECE Regulation 83) . A WLTC Class 3a test is specified with cycle modifications allowed to accommodate drivability problems for vehicles with power to mass ratios close to the borderlines or with maximum speeds limited to values below the maximum speed required by the cycle.

### Test cycle



## Auxillary Loads

The following vehicle ancillaries will be used:

All ancillaries on including;

c. All exterior sidelights and dipped beams on
d. Interior heating on maximum (if not automatically controlled) or set to 22°C if automatically controlled).

## Limits applying to Taxis (Black Cabs) over Worldwide Harmonised Light Vehicles Test Cycle

| **Exhaust emission parameter** | | **Maximum permitted limit** | **Reduction performance** |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 125mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 100mg/km | |
| Particulate matter (PM) | PM | 10mg/km | |
| Number of particles (PN) | PN | $6 \times 10^{11}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 3% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Annex 6. Detailed test conditions; Refuse Collection Vehicles (RCVs)

### Vehicle Loading

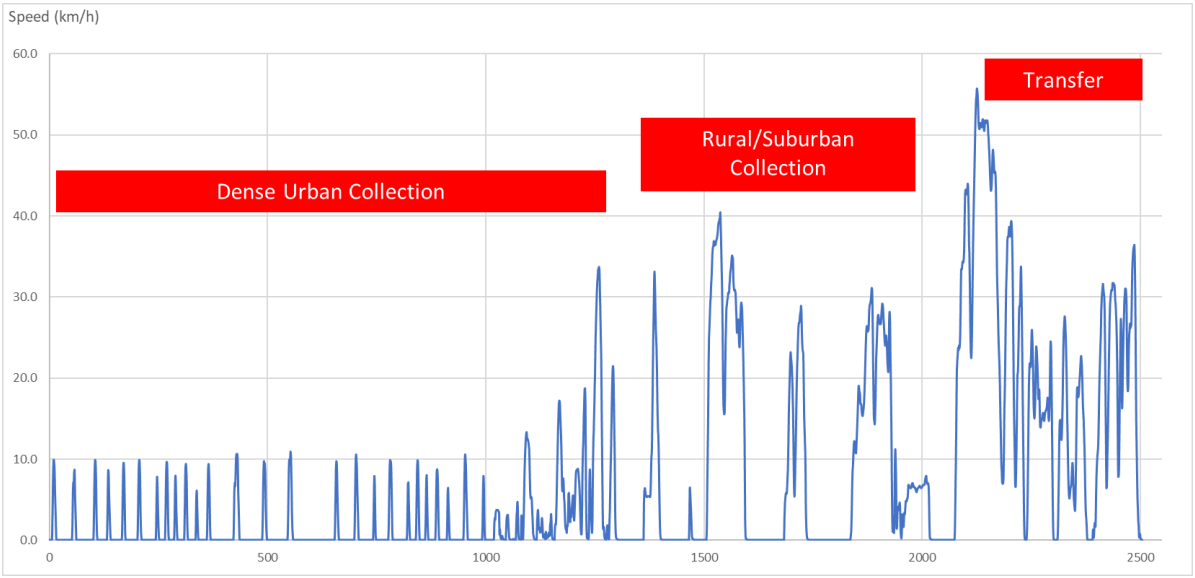
RCVs shall be tested at kerb weight plus driver weight (75kg) and either:

a) 50-60% of the specified maximum payload capacity, or, in cases where this is not technically possible;
b) Loading up to a vehicle weight equivalent to at least 90% of the specified maximum load of the dynamometer

The kerb weight of the vehicle shall be determined prior to test by the technical service carrying out the test.

### Test cycle

RCVs shall be tested according to the Transport for London LoCity refuse collection vehicle test cycle. This consists of a Dense Urban Collection phase, a Rural/Suburban Collection phase and a Transfer phase, as shown in the figure below.




Note: Test cycle supplied courtesy of Transport for London LoCity progamme.

The Transfer phase shall be used to warm the vehicle up prior to testing.

Dynamometer testing shall be performed at an ambient temperature of 10°C+/- 2°C throughout the test.

### Auxillary Loads

The waste collection hopper shall be filled with 850kg of rubber pellets to simulate typical UK domestic waste streams.

A mass of 25kg shall be attached to each bin lift arm. During the tests the bin-lift mechanisms shall be operated as follows:

- A minimum of 50 bin lifts during stops in the Dense Urban phase
- A minimum of 20 bin lifts during stops in the Rural/Suburban phase

The compactor mechanism, if not automatically deployed, shall be activated once for every 4 bin lifts.

The following other vehicle ancillaries will be used:

- All exterior sidelights and dipped beams on
- Interior heating on maximum (if not automatically controlled) or set to 20°C if automatically controlled).

## Limits applying to Refuse Collection Vehicles

| **Exhaust emission parameter** | | **Maximum permitted limit** | **Reduction performance** |
|---|---|---|---|
| **Primary emissions** | | | |
| Mixed oxides of nitrogen | NOx | 1500mg/km | >80% |
| Nitrogen dioxide | $NO_2$ | 250mg/km | |
| Particulate matter (PM) | PM | 10mg/km | |
| Number of particles (PN) | PN | $6 \times 10^{11}$/km | |
| **Secondary emissions** | | | |
| Nitrous oxide/methane | $N_2O/CH_4$ (as $CO_2e$) | < 5% of $CO_2$ | |
| Carbon dioxide | $CO_2$ | < 1% increase | |
| Ammonia | $NH_3$ | 10ppm average<br>25ppm peak | |
| **In service** | | | |
| Mixed oxides of nitrogen | NOx | | > 80%<br>daily average |

## Annex 7. Secondary emissions

Secondary exhaust emissions as specified must also be controlled from the vehicle fitted with the low emissions adaptation.

### Nitrous oxide and methane ($N_2O$ and $CH_4$) as $CO_2$ equivalent ($CO_2e$)

The following equation is used to calculate $CO_2e$:

$$CO_2\ e = (298 * N_2O) + (25 * CH_4)$$

where $CO_2e$ is defined as carbon dioxide equivalence and are the 100-year time horizon Global Warming Potential (GWP) values, as derived from greenhouse gas emissions studies conducted by Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report 2007 (IPCC AR4). This is consistent with reporting under the United Nations Framework Convention on Climate Change (UNFCCC) under which the UK GHG inventory is currently reported. Although the IPCC has issued a more recent assessment (IPCC AR5) with values of 265 for $N_2O$ and 28 for $CH_4$, these have not been officially accepted for use under UNFCCC reporting.

Carbon dioxide equivalence levels must be calculated from $N_2O$ and $CH_4$ emissions recorded during tests of the vehicle fitted with the low emissions adaptation. The value of $CO_2e$ calculated using equation above must not constitute more than 5% of the total carbon dioxide emissions recorded during the vehicle tests.

### Carbon dioxide ($CO_2$)

The fitting of the low emission adaptation to the test vehicle must not adversely affect the level of tailpipe $CO_2$ emissions by more than 1% (within test repeatability).

### Ammonia ($NH_3$)

Ammonia tailpipe emissions of the vehicle fitted with the low emissions adaptation are limited to a mean concentration of 10 parts per million (ppm) and a peak value of 25 ppm during the testing.