Test Procedure for Measuring Fuel Economy and Emissions of Trucks Equipped with Aftermarket Devices

1 SCOPE

This document sets out an accurate, reproducible and representative procedure for simulating the operations of trucks (> 3.5t gross weight) used for the carriage of freight, on a test track and for the purpose of measuring fuel economy and/or emissions changes associated with the fitment of aftermarket devices or systems. It is intended primarily for vehicles powered by conventional powertrains, but can be adapted for hybrid powertrains if necessary.

For the track-based testing of vehicles, the procedures use essentially standard industry practices. These involve having two nominally identical vehicles, with one remaining unmodified and used as a control, e.g. for changes in atmospheric conditions, and the other being the test vehicle run first, in baseline configuration, unmodified and then again, with the technology under evaluation being fitted/operational. This 'back-to-back' test method leads to four data sets for each test cycle:

i. Control vehicle – baseline
ii. Control vehicle – testing
iii. Test vehicle – baseline
iv. Test vehicle – testing

One of the wider objectives of the LowCVP scheme is to ensure any testing is affordable to as wide a part of the technology supplier community as possible. For this reason, testing is limited to two days, with the "baseline" tests on Day 1, and the "testing" tests on Day 2. Days 1 and 2 would not necessarily follow concurrently, depending, for example, on weather suitability and time needed to fit the technology.

Where the nature of the aftermarket technology being evaluated prohibits its easy removal, or to do so would leave the vehicle in such a condition as to be unrepresentative of normal freight operations, an appropriate comparator vehicle shall be selected and used in place of the Control vehicle, with as far as reasonably practicable, otherwise identical specifications to the Test vehicle (e.g. tyres, lubricants, engine power, transmission ratios etc.).

This test procedure does not make specific provisions for testing the effects of auxiliary loads such as cab air conditioning systems or loading compartment refrigeration units. All such loads will be turned off during the tests, unless they affect the normal operation of the vehicle.

The intention is to test the vehicle in its normal road-going condition and operating strategy as far as reasonably practicable, within the constraints of the equipment and duty cycles. 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.

The vehicles will be tested over a minimum of three duty cycles, simulating City Centre Delivery, Urban Delivery, Regional Delivery and Long Haul operations. The required cycle characteristics are defined in Appendix 1.

For the test vehicle, carbon dioxide (CO_2) and regulated emissions (Total Hydrocarbons, CO and NO_x) shall be sampled over the entire cycle and the results presented as g/km, using PEMS equipment attached to the tailpipe.

The Control vehicle shall, as a minimum, be equipped with a fuel-flow meter to accurately determine any changes in fuel economy performance between the baseline and testing days.

The following procedures should be considered as minimum requirements and guidance, rather than a very detailed test specification; test centres should make appropriate use of their wider expertise and capabilities to deliver additional data and/or analytical robustness where it is cost effective to do so. All testing should be carried out with the approval of the Low Carbon Vehicle Partnership via its technical advisory group. Additional testing may be necessary for some vehicles/technologies, e.g. via a chassis dynamometer to measure other emissions such as particulates or Nitrous Oxide, not currently measurable to an acceptable level of accuracy by PEMS.

2 VEHICLE PREPARATION

2.1 PRE-TEST INSPECTION

Upon arrival of the test/control vehicle at the test centre, a vehicle check and road test is to be conducted to assess the suitability of the vehicle for testing. This check will also include ensuring there are no faults being reported by the OBD system, fluid level checks and correct adjustment of tyre pressures (all to be set and maintained in accordance with manufacturer's recommendations for tested axle load), and may include a check that the vehicle has been maintained correctly. Suitability should also be assessed with regard to the "newness" of the vehicle; brand new or nearly new vehicles that may still be running in (i.e. their fuel economy and emissions performance may be subject to change even in otherwise identical ambient and other conditions) are unlikely to be considered suitable until such time as their performance has stabilized, normally after at least 3,000 km operation.

2.2 INSTRUMENTATION

The test and control vehicles shall be instrumented with the following equipment, all calibrated and otherwise maintained in accordance with their manufacturers' specifications:

- GPS equipment to record vehicle speed, position and elevation
- A fuel flow meter
- A data logger for CAN bus data, where available
- Thermocouples to record engine oil and coolant temperatures

In addition, the test vehicle shall also be instrumented with:

- Portable Emissions Measuring System (PEMS) to measure tailpipe emissions and fuel consumption via the carbon balance method, powered independently of the vehicle.

The PEMS equipment shall installed, maintained and calibrated in accordance with the instructions issued by its manufacturer and, as far as is reasonably practicable, in accordance with Appendix 1 to Annex II of EC Regulation 582/2011/EC (*test procedure for vehicle emissions testing with portable emissions measurement system*).

2.3 PRE-TEST AND POST-TEST PROCEDURES

2.3.1 Loading

The vehicles shall be safely and securely loaded to the required test weight. If a separate comparator vehicle is being used, it shall be loaded as closely as possible with the same payload weight as the test vehicle. The truck bodies or trailers used shall be appropriate to the vehicle's intended service and consistent between the control and test configurations (e.g. semitrailers of similar or identical dimensions, construction and axle configurations).

2.3.2 Shake-down

Confirm correct operation of all fitted equipment and rectify any issues arising.

2.3.3 Cycle development and driver familiarization

The duty cycles may need to be developed and modified slightly, e.g. to suit the vehicles' power and transmission system capabilities and/or to match test site conditions, and their conformance with the requirements (Appendix 1) confirmed.

Suitably trained drivers and other test personnel should carry out some practice runs to familiarize themselves with the vehicle, cycles and equipment operation.

2.3.4 Conditioning

The vehicles and equipment shall be suitably conditioned to achieve a stable, warmed up condition immediately prior to the commencement of testing.

As part of this conditioning, the 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 operability of the instrumentation and other test equipment will be verified. Additional preliminary runs will be made, if necessary, to assure that the vehicle, driver, and instrumentation are performing satisfactorily.

2.3.5 Weather conditions

The ambient baseline and testing conditions should, as far as possible, be similar, and avoid extremes of temperature (below 0ºC or above 30ºC), precipitation (e.g. snow or heavy rain) and wind speeds. Ambient temperature, pressure, wind speed and direction shall be recorded immediately before and after each test run.

2.3.6 Fuel

A fuel sample shall be taken, before or after the tests, for potential analysis at a later date. The vehicles will be tested with fuel(s) available commercially within the locality of the test centre and complying with relevant standards.

3 TEST PROCEDURE

3.1 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. Only equipment necessary to the primary propulsion of the vehicle during normal service shall be operated. The air conditioner and other auxiliary on-board equipment not required during normal service shall be disabled during testing, if possible. Where auxiliary loads cannot be disabled, all reasonable steps should be taken to ensure their operation (energy consumption) is likely to be similar between test and baseline conditions.

3.2 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. Once the vehicle is at operating temperature it shall be turned off and will be restarted within 30 minutes. 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. Data will be collected in such a way that it is analyzable for each test run, ideally at 1Hz frequency or higher.

The number of tests runs performed must be sufficient to provide a minimum of three test runs with valid results for each duty cycle. 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.

3.3 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 analyzers are not missing emissions that are still in the sampling train.

3.4 DATA RECORDING

Fuel consumed shall typically be determined by carbon balance from the gas analyzers, and the actual distance travelled by the vehicle during the test run. 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. This method would be required for vehicles consuming hydrogen fuel. Mass measurement is preferred to volumetric measurement.

In the case where the vehicle is to be tested and operated on multiple fuels with different GHG pathways (e.g. diesel and natural gas or bio-diesel and fossil diesel) it is essential that the individual flows of each fuel can be resolved to an accuracy of 1% or better, either by measuring the flow of each fuel separately, or by introducing them at a fixed ratio into the engine.

3.5 Deviations from Standard Procedure

There may be certain circumstances when 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 representative vehicle operation. For example, where technology exists to enable the internal combustion engine to be switched off when stationary, the City Centre, Urban Delivery and Regional Delivery cycles may be modified to include a series of simulated stops. In this case the stops are defined as all periods where the vehicle remains stationary for 15 seconds or more.

Any deviations from the standard test procedure must be recorded in the test report and approved by the scheme administrators prior to testing. In assessing the appropriateness of any proposed deviations from the prescribed procedure, the test house shall be guided by the scheme administrators, and all such deviations can only be authorized by them. The supplier of the technology to be evaluated shall have an advisory role only.

4 TEST VALIDATION

The value of the mass emission rates for each emission species (chemical compound) will be averaged over the test distance (i.e. reported in g/km or mg/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 (average ± 2.5%). Total GHG emissions shall be calculated on a CO_2 equivalence basis using standard values for 100-year Global Warming Potential.

Any obvious error in the data should be identified and removed from the dataset, as should any runs where the vehicle performed automatic maintenance procedures such as charging of the particulate filter; 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 GPS equipment. Adherence of the driver to the test cycle target distance and average speed will be assessed, and must all lie within a target ± 1% range to be considered valid. Other cycle parameters must all meet the requirements set out in Appendix 1 in each test run.

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 cycles, measured parameters and calculated test results.

The following information will be included in the report:

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 (g/km) and litres per 100 kilometre (l/100km), respectively.

Actual Distance Travelled - The actual distance that the vehicle travelled shall be measured during each test phase.

Tank-to Wheel emissions - Values for TTW emissions will be presented for CO, HC, NO, NO_2 and CO_2 and, where relevant and possible, CH_4.

Appendix 1 – Duty cycle characteristics

The European Commission has been developing a methodology to measure, monitor and report fuel consumption and CO_2 emissions from Heavy Duty Vehicles (HDVs). The method is based on CO_2 simulation using a computer model named VECTO (Vehicle Energy Consumption calculation TOol). VECTO uses measured vehicle component performance as input data. These data and the vehicle manufacturer's process for generating CO_2 figures using VECTO will be type approved.

VECTO uses a range of simulated duty cycles for trucks, bus, municipal and construction vehicles. Of particular relevance are its Long Haul, Regional Delivery and Urban Delivery cycles. These cycles define particular journey profiles, on the basis of a pre-set distance, over defined terrain (up and down gradients), with target speeds defined for each section of the journey. The tool combines information about the route (i.e. vehicle speed and gradient) with a wide range of vehicle and engine parameters to calculate what it believes will be the fuel consumption for that vehicle, at various loading conditions, over the course of that journey.

The requirements defined here are based on those cycle metrics that the available evidence suggests correlate most strongly with vehicle fuel consumption and CO_2 emissions. The use of such metrics is thus designed to ensure that any track-based cycles used are likely to be broadly representative of the VECTO cycles, for example, and to ensure test cycles at different test facilities can be shown to be equivalent, at least in terms of their likely resultant fuel consumption (l/100 km) and emissions (g/km) for a given vehicle.

In addition, and to better evaluate the performance of technologies likely to be fitted to vehicles used in heavily congested city delivery operations, a fourth cycle (City Centre Delivery) has been developed by LowCVP. There is no direct equivalent to this cycle in the current version of VECTO.

Required Cycle Characteristics

Parameter	Long Haul	Regional Delivery	Urban Delivery	City Centre Delivery
Distance (km)	> 20	> 7.5	> 7.5	> 4.0
Average speed (km/h)	> 65	50 – 60	30 – 45	15 – 25
Stops/km	< 0.2	0.2 – 0.7	0.8 – 1.2	> 1.2
Aerodynamic speed (km/h)	75 – 85	65 - 75	50 – 60	20 – 30
Characteristic acceleration (m/s^2)	0.07 – 0.09	0.09 – 0.13	0.12 – 0.25	0.12 – 0.25
Kinetic Intensity (per km)	0.14 – 0.18	0.20 – 0.36	0.70 – 1.10	2.50 – 3.10

Definitions:

Distance: Total travelled from start to end of test run.

Average speed: Total distance / time taken to complete cycle (excluding time spent stationary at start and end of test run).

Stops/km:	Number of periods of at least 1 second spent stationary during the cycle (including at start and end) / Distance.
Aerodynamic speed:	The square root of the ratio of the overall average cubic speed to the average speed.
Characteristic acceleration:	The positive part of the specific kinetic and potential energy per distance associated with moving a vehicle over the duty cycle.
Kinetic Intensity:	The ratio of the Characteristic acceleration to the square of the Aerodynamic speed.