

SPECIFICATIONS FOR DIESEL RETROFIT DEVICES FOR OVER 4 TONNES VEHICLES

Each retrofit device manufacturer shall be responsible for demonstrating the performance (baseline tests) of their products in laboratory tests (transient and steady-state) conducted on an engine dynamometer or on a chassis dynamometer. Further, in-use, in-field performance of the retrofit device shall be verified on a minimum of ten (10) randomly selected retrofit device-equipped vehicles. While the in-laboratory tests (referred to as in-lab tests in this document) will be conducted at the beginning of the program, in-field tests will be conducted each year, up to the full duration of the retrofit device's warranty period. If in-field tested vehicles fail to comply with the regulation, the certificate will be withdrawn and the manufacturer of the device can no longer deliver devices on the market. Manufacturers can choose to certify their devices for use with 350 PPM sulfur fuel, 5000 PPM sulfur fuel or both depending upon which vehicles they would like to retrofit with their device.

Performance Specifications

Any retrofit device tested with 350-ppm (wt%) sulfur fuel must achieve an initial total particulate matter (TPM) reduction (on a brake specific mass- basis, or distance specific mass basis, depending upon the type of test being conducted) of no less than 35%, and during or after the full durability demonstration no less than 25%. The test fuel for all tests should never contain less than 325 PPM sulfur.

Any retrofit device tested with 5000-ppm (wt%) sulfur fuel must achieve at least an initial TPM reduction of 25% (on a brake specific mass- basis, or distance specific mass basis, depending upon the type of test being conducted), and during or after the full durability demonstration no less than 25%. The test fuel for all tests should never contain less than 4000 PPM sulfur.

The retrofit device shall not result in an increase in exhaust backpressure of more than 1” (25 mm) Hg. The limitation on the allowable backpressure shall be applicable not only in the laboratory testing phase (engine or chassis dynamometer tests) of the program, but also during the complete warranty period of the retrofit device. Furthermore, the back pressure should if possible not exceed the upper limit given by the engine manufacturer.

There should be no increase in CO, THC or other harmful emissions when testing with the device compared to testing without the device. Measuring NO_x and NO using a single heated chemiluminescent analyzer and calculating the difference between the measured values of NO_x and NO emissions should determine NO₂ emission changes with and without the retrofit device. The coefficient of variation (COV) for NO_x and NO shall not exceed 8%.

Certification Test Requirements

The tests for verification of emission performance of devices should be carried out at a laboratory approved and recognized by the authority in Hong Kong. The Hong Kong EPD has delegated this approval authority to the DREP. Preferably the tests should be carried out at an independent third party laboratory either accredited according to EN 45 001 or certified according to ISO 9 000/ISO 14 000. Examples of qualified laboratories can be found on the EU/EPA web sites including TUV, VCR, MTC, Millbrook, etc <http://www.listec.lu/>, <http://www.epa.gov/otaq/consumer/lablist.pdf> or the lab list issued by the California Air Resources Board as per attached. (See attached file: labs.doc)

Hong Kong EPD and DREP does not endorse, rate or certify individual vehicle emission test laboratories. It is the responsibility of the individual supplier to evaluate a laboratory's current test capabilities and quality.

Device suppliers shall provide evidence to DREP to their satisfaction that the emission lab meets the requirement referred. Although the above lists are updated regularly, other labs may exist that can perform emission testing.

The specification of the laboratory equipment is listed in CFR Title 40 Part 86 subpart I, N and also in the relevant sections of CCR - California Code of Regulation via the link: <http://www.arb.ca.gov/msprog/onroadhd/onroadhd.htm>., or EU directive of 98/69/EC or 91/542/EC.

Any device manufacturer, who is in doubt, may as soon as possible write to the authority to seek advice on the acceptance of a lab before conducting testing. The device manufacturer has to demonstrate to the authority that testing can be conducted in accordance with the test procedures referenced in the above specification. The laboratory also needs to show that its testing equipment meets the specifications of the CCR/CFR, etc. The decision of the authority will be final.

A report with analysis on the test fuel used during the certification testing (including total sulfur, aromatics, Cetane number, viscosity, API gravity, initial boiling point, T₁₀ and T₉₀ points on the distillation curve) shall be provided with the final report.

All engine and chassis dynamometer tests, with and without the retrofit device shall be conducted at an exhaust backpressure that will not exceed the engine manufacturer's maximum specifications and no tests with device shall increase back pressure more than 1" (25 mm) Hg. In the test report the backpressure during the tests should be reported.

In order to obtain a certificate for a device, an application for approval must be submitted to the authority in Hong Kong. The content to be contained in the application will be explained in a separate document (Guidelines for the applicant). In the document, the manufacturer of the device must submit instructions for the installation on vehicles and information regarding working temperature of the device and other important information.

The following sections provide directions on how each of the in-lab baseline tests and in-field tests shall be conducted:

Engine Dynamometer Testing

1. The retrofit device used in engine dynamometer tests shall be “broken-in” per retrofit device manufacturer’s specifications. For example, an oxidation catalytic converter shall be de-greened for at least 10 hours per established industry standards. The manufacturer of the device must explain in the application document how the de-greening/ageing should be carried out.
2. The retrofit device manufacturer shall propose tests of a combination of vehicle/engine and device that is representative of those in operation in Hong Kong. The engine must be a pre-Euro I engine, that is, an engine designed to meet emission limits more lenient than Euro I standards. In order to reduce the test burden for the manufacturer, the authority together with the manufacturer could decide to test a “worst-case” scenario. The authority in Hong Kong should accept the tested combination prior to the testing.
3. Brake-specific emissions of TPM, CO, THC (total hydrocarbons), NO_x, NO, NO₂ (by difference between NO_x and NO), CO₂, and soluble organic fraction (SOF), shall be measured using an exhaust dilution tunnel (full or double) in combination with a constant volume sampler (CVS). Engine testing must be carried out using the US FTP or the European Transient Cycle¹, and at least two steady state modes (Modes 2 and 3 of the European Stationary Cycle, ESC). Calibrations and routine checks of all analyzers, dynamometer, sensors, and CVS shall be performed following requirements in respectively US regulation or EU directive.. Emissions analysis shall also be performed according to regulations or directives, respectively.
4. All tests, as described below, shall be conducted first without the retrofit device, and then with the retrofit device installed on the vehicle. Retrofit devices shall be installed in accordance with instructions included in the application formats.
5. Before the test starts, the engine should be preconditioned appropriately. It is essential that the engine be preconditioned in the same way before each test. Temperature measurements before and after the DOC could serve as one indicator for equal conditioning. The engine (without the retrofit device) shall be operated over the transient cycle selected (see above) and brake-specific emissions shall be determined. At least two consecutive back-to-back transient test hot starts shall be conducted and results shall be reported as an average of the two test runs. At their own option, device suppliers can carry out additional tests if they so choose with the overall average considered as a result. Each hot start transient cycle shall be followed by a twenty (20) minute soak.
6. Following the last soak of the transient test series (and prior to installing the retrofit device on the engines), the manufacturer shall conduct steady state tests (Modes 2 and 3) of the ESC procedure on the engine. Exhaust

backpressure shall be set at a value that is within the engine manufacturer's specifications.

7. During steady-state tests, the engines shall be operated for a total of 10 minutes at each mode. The engine shall be allowed to stabilize during the first five minutes, and emissions data shall be collected during the remaining 5 minutes. Gaseous emissions data for THC, NO_x, NO and NO₂ (by difference between NO_x and NO) shall be collected continuously for at least two minutes. Both NO_x and NO data shall be collected, using one heated chemiluminescent analyzer, during this 5-minute period.
8. The brake-specific emissions data that will be reported should be an average of a minimum of two steady state tests for each of the two modes. At their own option, device suppliers can carry out additional tests if they so choose with the overall average considered as a result. The coefficient of variation (COV) for NO₂ shall not exceed 8%.
9. Install the retrofit device on the engine and repeat steps 5,6,7 and 8.
10. A fuel analysis report showing the test fuel sulfur content should be supplied with the certification application.
11. Exhaust temperatures (immediately upstream of the retrofit device as well as downstream) and exhaust backpressures shall be continuously recorded and reported. The exhaust backpressures should be similar in all of the tests (respectively with and without the retrofit device) on the vehicle. Under no circumstance shall the backpressure exceed the engine manufacturers' specifications with more than 1" (25 mm) Hg. during the tests.

Chassis Dynamometer Testing

12. The retrofit device that will be installed on the test vehicle (for chassis dynamometer testing) shall be identical in all important respects with the device that was employed in the engine dynamometer tests.
13. The retrofit device should be "broken-in" following retrofit device manufacturer's specifications. For example, a catalytic converter should be "de-greened" per manufacturer's specifications as indicated in the application documents.
14. All test vehicles (trucks, transit buses, etc.) should be powered by engines that are representative of those in operation in Hong Kong. The vehicle must be equipped with a pre Euro 1 engine, i.e., an engine designed to meet emissions limits more lenient than Euro 1.
15. Chassis dynamometer-based testing shall be performed using good engineering practices.
16. Vehicles shall be tested at the following inertial test weights:
 - a. Trucks: For trucks with GVWR less than or equal to 60,000 lbs., the test weight shall be 70% of the GVWR. For trucks with GVWR greater than 60,000 lbs., the test weight should be set at a maximum of 42,000 lbs.

- b. Buses: Test weights for buses shall be equal to the curb weight + half of the total passenger load + one driver. Weight of each passenger and driver shall be considered to be 150 lbs.
17. Vehicles shall be exercised over the US EPA Urban Dynamometer Driving Schedule (UDDS), and a steady state operation at 45 mph using test weights listed in Item 14 above.
18. Distance-specific emissions (for example, grams/mile) shall be determined using an exhaust dilution tunnel (full or double) in combination with a CVS system. Distance-specific emissions measurements shall be made with and without the retrofit device on the vehicle. During the transient test cycle the emissions should be measured and reported. Pollutants to be measured are shown below. During the steady speed testing continuous measurements of TPM, CO, THC (total hydrocarbons), NO_x, NO, NO₂ (by difference between NO_x and NO), CO₂, and soluble organic fraction (SOF), shall be reported. Calibrations and routine checks of all analyzers, dynamometer, sensors, and CVS shall be performed in accordance with prescribed regulation and following accepted industry procedures. Emissions analysis shall also be performed in accordance with prescribed regulation and following accepted industry procedures. Exhaust temperatures (immediately upstream of the retrofit device as well as downstream) and exhaust backpressures shall be continuously recorded and reported. The exhaust backpressures should be similar in all of the tests (respectively with and without the retrofit device) on the vehicle. Under no circumstance shall the backpressure exceed the engine manufacturers' specifications with more than 1" (25 mm) Hg during the tests.
19. Results from only hot-starts shall be reported.
20. The following sequence of tests shall be followed:
 - a. Once the vehicle (without the catalytic converter) is mounted on the chassis dynamometer, it shall undergo a warm-up cycle (one UDDS) prior to logging any data. The vehicle shall then be exercised through two continuous back-to-back UDDS runs (called a set), followed by a 20-minute soak. Immediately after the 20-minute soak, another set of two continuous back-to-back UDDS runs shall be repeated. Continuous data collected during each back-to-back double UDDS shall be integrated. Distance-specific mass emissions from a minimum of two sets shall be averaged and reported as the final distance-specific mass emissions data for the vehicle.
 - b. The last UDDS shall be followed by a 20-minute soak.
 - c. Following the soak period, the vehicle shall be operated at 45 mph for 10 minutes at the inertial test weights employed in Item 18a, and specified in Item 14. The vehicle should be allowed to stabilize during the first five minutes, and gaseous emissions data should be collected/analyzed in the remaining last five minutes. Continuous data should be recorded for at least two

continuous minutes. Gaseous emissions data shall include CO, THC, NO_x, NO₂, and CO₂. Both NO_x and NO data shall be collected using the same heated chemiluminescent analyzer during the last 5 minutes of the steady state operation. The NO_x and NO data should be recorded continuously for at least two minutes. The NO₂ results should have a coefficient of variation of less than 8%.

21. Repeat steps a, b, and c in Item 20 with the retrofit device on the vehicle. During chassis dynamometer testing the exhaust backpressure shall be equal to the setting used in Item 18, and shall not exceed the engine manufacturer's specifications.
22. A fuel analysis report showing the test fuel sulfur content should be supplied with the certification application.

Durability Demonstration Requirements

The device must be tested on a vehicle equipped with a pre-Euro I engine for a minimum of 500 hours and must achieve the performance criteria stated above at the beginning and end of the test. This must be verified by the test procedures spelled out above using the same device used for the durability demonstration. During the mileage accumulation, if carried out on the road, the driver should make note of the fuel quality used, specially regarding the content of sulfur. A specific log book should be established and on request constitute one part of the application documents.

In-Use Verification Testing

Random Screening Tests

In-use, in-field performance of the retrofit devices shall be verified on a minimum of ten (10) randomly selected retrofit device-equipped vehicles. In-field tests shall be conducted every year within the warranty period of the retrofits.

1. In-use verification testing shall be conducted on a vehicle using ports at the inlet and outlet ends of the retrofit device. All operational components of the retrofit device shall be contained within these two ports.
2. A randomly selected vehicle shall be parked with its parking brakes set. The vehicle shall be kept in neutral gear, and operated at the engine's governed speed. The engine shall be allowed to stabilize for six minutes and emissions data shall be collected for at least one minute after the stabilization period. With engine operating at the governed speed, CO₂ and total hydrocarbons (THC) and/or CO¹ emissions data shall be logged at a minimum rate of 1 Hz for at least one minute after the stabilization period. CO₂ and total hydrocarbons (THC) and/or CO

¹ At the discretion of the authority, either THC or CO will be used for in use verification. Suppliers are requested to recommend one or the other if they have a preference and the reasons why they believe it is the most appropriate for their device.

- emissions shall be measured from the ports that are located both upstream and downstream of the retrofit device. A minimum of two separate back-to-back data sets (one minute long) shall be collected for CO₂ and THC and/or CO. The final results shall be an average of at least two sets of data. A manufacturer has the option of running more than two tests but all results must be included in the average. If leaks are detected, they must be repaired and the tests repeated on that vehicle with the tests on the leaking system discarded.
3. A heated flame ionization detector (HFID), calibrated on propane, shall be used for measurement of total hydrocarbon emission concentrations. Sample lines and the HFID shall be heated, insulated and maintained at 191±5C for the entire duration of the test. CO₂ and CO concentration measurements shall be conducted with a non-dispersive infrared detector (NDIR). Industry accepted standards for HFID and NDIR analyzers for warm-up, stabilization, calibrations, and data acquisition and analysis shall be followed.
 4. The average HC or CO emissions reduction comparing tests with the retrofit device to those without the device of all vehicles tested must be at least 70% of the THC or CO reductions achieved during the steady state tests carried out as part of the engine and chassis dynamometer tests. If the device achieves at 70% reduction on average, the device is deemed to have passed the test. If the device achieves less than 70% THC or CO reduction, the manufacturer can carry out as many additional tests on randomly selected vehicles as he chooses up to a maximum of 10 additional tests but at the end of the testing the device must achieve 70% reduction on average or it is deemed to have failed.
 5. If a device fails, the manufacturer is responsible for carrying out a complete diagnosis of the reasons for the failure and designing a fix to correct the problem. The fix must be approved by the Hong Kong EPD and when approved must be offered at the manufacturers cost to all vehicles which were originally retrofitted.
 6. Any individual vehicle which when tested fails to achieve the 70% reduction specified must be repaired by the retrofit device manufacturer unless the manufacturer can demonstrate that the failure was due to improper maintenance or use of the vehicle.
 7. Exhaust temperatures (immediately upstream of the retrofit device) and exhaust backpressures shall be continuously recorded and reported. The exhaust backpressures should be similar in all of the tests (with and without the retrofit device) on the vehicle. Under no circumstance shall the backpressure exceed the engine manufacturers' specifications during the tests.

Installation Requirements

The device must be installed using good engineering practice. Further it must be identical in all important respects with the approved device. Catalyst manufacturer must supply catalysts to the same formulation as that of the unit certified. Manufacturer will maintain production records of all products produced by lot for the purposes of traceability as outlined in ISO 9002 procedures. This should include labeling the device or part in a manner that allows it to be traced back to the production batch. Catalyst manufacturers will be permitted to upgrade the catalyst formulation by demonstrating proof to the Hong Kong

EPD that it meets or exceeds the original performance.

Other Conditions

Catalytic Devices

If the device is a catalytic converter, it must be degreased for a minimum of 10 hours using industry-accepted procedures.

No Unreasonable Risk

The manufacturer of the device must submit a statement as part of the certification application to the effect that the manufacturer knows of “no unreasonable risk to health, welfare or safety” which could occur as a result of the installation of his device.

Noise

The manufacturer of the device must submit a statement as part of the certification application to the effect that the device will not result in any increase in noise.

Principle of Operation

The certification application must contain a detailed description of the principle of operation of the device that demonstrates that the device would achieve the actual emissions reduction indicated. Devices for which the explanation is not readily apparent may be required to carry out additional tests at suppliers cost to further demonstrate that the device will actually achieve the emissions reductions intended.

Inlet Openings

The device must provide two openings at the inlet position for measuring the back pressure by data logger, concentrations of exhaust emissions by gas analyzers and smoke opacity by smoke meter. Hence, both openings should have diameter no less than 20 mm. Moreover, one of the two openings should with an angle about 135° face to the inlet gas direction. The device must also provide one port at the outlet end to allow measurement of exhaust gas concentrations by gas analyzers. Removable metal plugs should seal the openings.

Modifications

The device must be designed for retrofitting diesel vehicles without any engine modifications or engine setting changes such as timing adjustment.

Back Pressure

After the device installation, the exhaust backpressure at rated power must not exceed the

maximum specified by the engine manufacturer.

Warranty

The manufacturer must provide mechanical warranty of the device for not less than 250,000 km or the device's life period not less than five years. Furthermore, the manufacturer must provide emissions defect warranty of the device for not less than 160,000 km when the device is properly installed and maintained in accordance with original equipment manufacturer's instructions for proper maintenance and use.

Maintenance

The device must be maintenance free over its full useful life, requiring no addition of additives or chemicals beyond those installed with the device.

¹ The reduction could be based not only on the US Federal Test Procedure (FTP) heavy-duty transient cycle but also on the European Transient Cycle (ETC) test cycle