National Environment Protection Council
Proposed Diesel Emissions
National Environment Protection Measure
PREPARATORY WORK

IN-SERVICE EMISSIONS PERFORMANCE
PROJECT 2
PHASE 2: VEHICLE TESTING
AND SUPPLEMENTARY WORK

1. OBJECTIVES

1.1 To test a representative sample of diesel vehicles in use in urban Australia under an agreed composite urban emission drive cycle established in Phase 1 and determine their emission performance.

1.2 To evaluate and compare the suitability of five in-service emissions assessment procedures for the measurement of diesel vehicle emissions.

2. BACKGROUND

This project is one of a series of projects encompassing the preparatory work to be carried out prior to developing a Diesel Emissions National Environment Protection Measure (NEPM) for consideration by the National Environment Protection Council (NEPC).

The emissions of most interest in relation to diesel vehicles are oxides of nitrogen (NO_x) and fine particles, (also known as fine particulates). NO_x is a precursor to the formation of photochemical smog. There is also some evidence that NO_x can react with other pollutants to form particles. Nitrogen dioxide (NO_2), a large proportion of NO_x as well as being a precursor to photochemical smog formation, is also a pollutant in its own right.

Fine particles have been identified as the major health risk in vehicle emissions: the smaller the particle the greater the risk. Diesel particles are small enough to be inhaled deep into the lungs (< 2.5 microns in diameter) and have been recently classified by the California Air Resources Board as a toxic air contaminant. Whilst diesel vehicle emission standards in the Australian Design Rules have only recently included particles (by reference to standards applying in Europe, US and Japan), local vehicle standards have placed limits on emissions of visible smoke for some time.

Diesel engined vehicles offered for sale in Australia between 1976 and 1996 were required to be constructed in compliance with Australian Design Rule ADR30. Under this design rule vehicles were required to meet an exhaust smoke opacity standard. Little is known regarding the construction design standards for emissions performance that these vehicles were built to. Vehicles imported into Australia since 1996 must conform to ADR70 which requires specific emission performance for designated pollutants during testing on a defined certification test cycle.

Construction design standards for emission performance are important as a means for achieving improved fleet emission performance. It is recognised however, that certification emission performance as prescribed for ADR compliance does not provide a means of accurately estimating real world fleet emission performance under typical Australian driving conditions.

The need for real world emission data

The lack of heavy duty diesel dynamometer transient cycle testing facilities in Australia and the use of steady-state testing using engine dynamometer systems for certification testing overseas, has meant that correction factors to convert from g/bhp-hr or g/kW-hr to g/km have had to be used. This has made it difficult to use existing data to reliably establish what current diesel emissions are or to predict the actual (on the ground and in the air) outcomes of changing the way diesel emissions are currently controlled. Thus, there is a need to gather real-world emission data to compare against existing estimates to improve our information base. In this way, a more accurate picture of the actual impact of diesel emission control scenarios can be developed.

Given the uncertainty in establishing the construction design standards for many vehicles currently in service (pre 1996) and the limitations in using construction design standards for estimating real world emission performance, Project 2 aims to obtain a more accurate and representative measure of actual emissions from the Australian diesel vehicle fleet.

In-service vehicle emission testing

It is well known that a vehicle's emission performance can deteriorate as it ages. The level of deterioration is primarily impacted by natural wearing of components and the level of maintenance applied. Any in-service maintenance program designed to maintain original vehicle emission performance requires a reliable and easily used testing procedure.

Much research being undertaken overseas is targeted to develop practical and effective in-service inspection procedures. Testing is often based upon static or chassis dynamometer tests. Engine dynamometer testing has been proven to have no practical application as an in-service tool for identifying high emitting vehicles, or for component fault diagnosis.

At present there is no consistent approach to in-service diesel vehicle emission testing here or internationally. Many overseas authorities base diesel vehicle inspection/maintenance programs on the use of a free acceleration test, specified as the 'MOT' test in Europe and as the SAE J1667 test in the USA. It is generally conceded these tests have considerable shortcomings, and that a more scientific and real world test is required for effective in-service fault discrimination.

Project Goal and Outcomes

This project is being conducted in two phases.

Phase 1 (Drive Cycles) comprised three areas of investigation:

- development of representative Composite Urban Emission Drive Cycles for specified Australian Design Rules vehicle categories (MC, NA, NB, NC, NC(≥42.5t) and ME);
- investigation of the literature regarding short in-service emission tests for diesel powered vehicles; and
- identification of the vehicle components which impact on diesel vehicle emissions and possible non-invasive means to identify vehicles with faults in these components which lead to excessive emissions.

This phase is now complete.

Phase 2 (Vehicle Testing)
The goal of this phase of the project is to establish the emissions performance of the existing in-service diesel fleet using drive cycles based on real world driving patterns established in phase 1. The project also seeks to evaluate tests for their suitability to be used for in-service vehicle testing. The information obtained will assist in developing a sound technical basis for scoping the development of a NEPM.

This phase involves laboratory analysis of the emissions performance of a representative sample of diesel vehicles selected from the in-service diesel fleet under driving conditions represented by the urban emission drive cycles developed in Phase 1. This will allow the development of emission factors that can be used for local air-shed inventory calculations in Australia and improve the knowledge of the impact of the diesel fleet on ambient air quality. Phase 2 will also involve the evaluation of five in-service emission tests identified and two inspection procedures identified in Phase 1.

Equipment Requirements for Phase 2

Dynamometer
The drive cycles developed in Phase 1 are transient in nature and will require the use of a dynamometer with either inertia rolls, or computer-controlled dynamic load inertia simulation. The chassis dynamometer system(s) proposed will have to be capable of testing a range of small passenger vehicles up to large buses and articulated trucks.

Detailed requirements are set out in Appendix 2, section 5.

Exhaust Gas Sampling and Analysis
Exhaust gas sampling and analysis requirements are set out in Appendix 2, section 5.

In-Service Maintenance
Equipment requirements for the in-service emission tests are set out in the test descriptions in Appendix 3.

Particulate sampling

The instruments to be used to cover the size range of particles are:

1. Scanning Mobility Particle Sizer (SMPS) for sub micron size particles; and
2. Aerodynamic Particle Sizer (APS) for particles above 1 micron.
3. Tapered Element Oscillating Microbalance for real-time particle mass measurements.
4. Laser light scattering photometer for real-time particle mass analyses evaluation

The two instruments are to be used in parallel during the drive cycle phase of vehicle testing. An agglomeration duct is to be fabricated to ensure particles have adequate time to agglomerate and form the size as they would during on-road driving under atmospheric conditions.

To perform this work, the consultant must have an in-depth knowledge of diesel vehicle exhaust emission testing, heavy-duty vehicle chassis dynamometers, diesel gaseous analysers and particulate measuring equipment suitable for transient drive cycle analysis. It is anticipated that prospective tenderers may need to form partnerships in order to achieve the necessary combination of skills required to meet the testing, analytical and equipment requirements of this project.

3. SCOPE

The project will focus on an 80-vehicle sample covering the range of vehicles in the current in-service fleet. Any correlation of the drive cycles with certification testing cycles is outside the scope of this project as are the correlation of the seven assessment procedures with certification tests.

The successful tenderer is required to conduct the following principal tasks:

3.1 Establishment of fleet emission performance

The successful tenderer will test the emission performance of a representative sample of 80 diesel engine vehicles (ADR vehicle categories MC, NA, NB, NC, NC (≥42.5t) and ME) from the Australian diesel fleet under the Composite Urban Emission Drive Cycle(s) (CUEDC) established in Phase 1 of this project. The details of the CUEDC are attached in electronic format (Excel) and are described in the Phase 1 report attached as Appendix 3. Vehicle selection conditions and vehicle sampling distributions are provided in Appendix 1.

For each vehicle, separate measurements of each nominated emission and fuel consumption will be made over the portion of the appropriate drive cycle that represents each of the four traffic flow conditions of the drive cycle. An appropriately weighted measurement collected over the entire drive cycle (all four traffic flow conditions) will also be provided for each of the nominated emissions and for fuel consumption. The measurements will be expressed in total grams per kilometre for emissions and litres per 100 kilometres for fuel consumption.

The nominated emissions to be measured are:

- oxides of nitrogen;
- particles;

- carbon monoxide
- carbon dioxide;
- oxygen;
- total hydrocarbons; and
- visible smoke.

During emission testing each vehicle will be subjected to an inertia load equal to one-half the vehicles cargo weight capacity. This capacity will be calculated as:

(Gross Vehicle Mass less vehicle Tare Weight) divided by 2.

The emission and inspection data is to be collected according to the inspection and test sequence specified in Appendix 2**.** The drive cycles may require modification depending on the initial experience with running them on the test dynamometer. Testing should be halted after the first six vehicles so that the results can be assessed by the project team and modifications to testing procedures considered. Each of the first six vehicles will undergo the CUEDC three times to enable evaluation of test procedure variance. The first six vehicles shall comprise one vehicle from each of the vehicle categories in Table 1 of Appendix 1

The makes, models, and vintages of vehicles to be tested will be in accordance with Appendix 1.

Should the CUEDCs prove to exceed the capabilities of available dynamometers or emission sampling and analysis equipment, the testing of vehicles on simplified CUEDCs will be considered (also attached in Appendix 3). For the purpose of this study:

- CUEDCs developed in Phase 1 will be referred to as complex CUEDCs; and
- adjusted CUEDCs developed in Phase 1 will be referred to as simplified CUEDCs.

3.2 Evaluation of in-service emission assessment procedures

The same vehicles tested in 3.1 will be subjected to analysis by each of the five in-service emission tests listed in Appendix 3. In addition each vehicle will be tested according to the 10 Second Smoke Rule and subjected to the 6 Point inspection (Appendix 2, section 3).

If a test procedure proves impractical or cannot provide useful information regarding the emission performance of a vehicle the contractor may, upon written approval from the project manager, cease evaluation of that procedure before completion of testing on all vehicles.

Evaluation of each in-service emission test will include evaluation of:

- test correlation to the results of CUEDC emissions for
  - (a) I&M smoke and CUEDC particulates;
  - (b) I&M NO_x and CUEDC NO_x;
  - (c) I&M THC and CUEDC THC;
  - (d) I&M particulates and CUEDC particulates; and
  - (e) I&M smoke and CUEDC smoke;

The correlations in (a) to (e) will be determined for each nominated ADR category, traffic flow condition, and the overall CUEDC cycles.

Tenders should indicate how an in-service maintenance measurements in the form of concentration (eg. Ppm) will be correlated with measurements measured in grams per kilometre for the CUEDCs.

- the sensitivity of the test to reflect changes in emission performance by vehicles tested on the CUEDCs;
- suitability for use across the range of vehicles tested;
- ease of use;
- time and resource requirements for testing by ADR vehicle category;
- suitability for use in a large scale in-service vehicle testing program (cost, equipment, training, etc); and
- correlation with vehicle 6 Point inspection and the 10 second smoke rule.

Emissions to be measured during evaluation of the in-service emission tests are as follows:

I & M Test	Smoke	NOx	THC	Particulates
J1667	✓			
D550	✓	✓	✓	✓*
2-Speed	✓			
Lug-Down	✓			
DT80	✓	✓	✓	✓*

* Tenderers are requested to advise on the feasibility of measuring particles during the operation of the in-service emissions tests.

Tenderers who can provide measurements of additional emissions at no extra cost should indicate so when tendering.

The methodology for the measuring of any emissions other than those specified in the test procedures, must not compromise the evaluation of the I&M Test when conducted according to its specifications.

3.3 Sourcing vehicles and fuel

In undertaking the test program in 3.1 and 3.2 above, the successful tenderer will also be responsible for managing and meeting all costs associated with:

- sourcing (including pick up and return) the test vehicles selected from Appendix 1;
- providing a single batch of commercial diesel fuel of sufficient quantity to cover all vehicle tests, together with a certificate of analysis of the batch which, as a minimum, identifies its density and cetane index, sulfur content, polyaromatics and distillation point (^{o}C) (T90 and T95). Fuel specifications must lie between the following parameters: cetane number 42 – 56, total Sulfur 0.08 – 0.12 %; and
- returning the test vehicles to the owner/supplier in a condition no worse than provided.

3.4 Measurement of particulate size and particulate mass

Particulate size and particulate mass emission data is to be collected from the 80 vehicles described in 3.1 using a scanning mobility particle sizer (SMPS) for sub-micron particles and an aerodynamic particle sizer (APS) for particles above 1µm in size.

An agglomeration duct is to be fabricated from which the instruments will draw a sample. The duct is to receive a sample from the dilution tunnel of known mass flow. The mass flow controller of the dilution tunnel is to provide all supplementary instruments with second-by-second flow rates for conversion of raw data to a mass flow basis.

Table 1: Format of Particulate Size Data

VEHICLE ID:									
	gm/kg of fuel			**gm/km**			**gm/k Wh**		
Road Mode	≤PM1.0 µm	≤PM2.5 µm	≤PM10 µm	≤PM1.0 µm	≤PM2.5 µm	≤PM10 µm	≤PM1.0 µm	≤PM2.5 µm	≤PM10 µm
Congested									
Arterial									
Minor									
Freeway									

The raw data generated by the instruments is to be converted to units that can be applied for inventory purposes. This is to be performed by using the known mass flow rate, the amount of fuel used calculated by carbon balance and the known amount of energy (integrating power over time) absorbed by the retarder during each of the road flow modes.

3.5 Measurement of particulate mass by TEOM

A Tapered Element Oscillating Microbalance (TEOM) will be used to measure real-time emissions of particles from the 80 vehicles described in 3.1. Measurements will be summarised over periods of acceleration, cruise, idle and deceleration for each road flow condition for each ADR complex drive cycle. A result in grams/km for each operating conditions is to be reported by obtaining the mass flow rate from the dilution tunnel mass flow controller. From this a percentage (%) contribution from each vehicle operating condition is to be provided and used to assess the importance of each condition in terms of contribution to total pollutant emitted.

Results from the TEOM for each ADR category are to be presented in a format as outlined in Table 2

Table 2: TEOM – modal analysis data

VEHICLE ID					
Road Mode	**Acceleration** grams/km and % contribution	**Cruise** grams/km and % contribution	**Idle** grams and % contribution	**Deceleration** grams/km and % contribution	**Total grams/km at 100%**
Congested					
Arterial					
Minor					
Freeway					

3.6 Measurement of particulate mass by laser light scattering

The laser light scattering equipment (ie Dust Trak) is to be used during all of the dynamometer based short tests and across the drive cycle tests on the 80 vehicles described in 3.1 to provide a comparison between the short tests and the drive cycle tests. The data from the Dust Trak is to be compared with data generated from the TEOM instrument.

During both the short test and drive cycle phases of this project the data is to be converted to a result in mg/km. During the short test phase a result is also to be given in total grams/test. Smoke opacity is also to be logged during the short test and the values are to be compared with the mass result. All data logged is to be made available for further analysis.

An analysis will be made of the feasibility of using laser light scattering devices for measuring particle emissions in in-service maintenance emission testing programs.

The data generated by the light scattering device is to be reported as shown in Table 3.

Table 3: Particulate mass during short test evaluation

VEHICLE ID						
Drive Cycle Pmass	**10s Smoke** Ringleman estimate	**Short test** 1 Pmass mg/s opacity %	**Short test** 2 Pmass mg/s opacity %	**Short test** 3 Pmass mg/s opacity %	**Short test** 4 Pmass mg/s opacity %	**Short test** 5 Pmass mg/s opacity %

4. OUTPUT

The successful tenderer is required to provide the following:

4.1 A report detailing vehicle emissions performance (as described in 3.1, 3.4, 3.5 and 3.6) under each road flow condition for the appropriate CUEDC test cycle for each test vehicle for each nominated pollutant. Emission performance will be reported in g/km, except for visible smoke.

This report will include a critical analysis of the results by ADR vehicle categories, odometer reading, vehicle/engine age and other variables agreed with the Project Manager. The consultant will provide a statistical analysis of the test results.

4.2 A report evaluating the comparative performance (as described in 3.2) of the five in-service tests and recommendations on their suitability for use in the testing of in-service vehicles.

5. MILESTONES

The Commencement date for the Project is upon signing of the contract by all parties. The Date of Completion is within four weeks of receiving comments, from the Client's Representative, on the draft Final Report.

Milestone achievement of Outputs 4.1 and 4.2 (for 80 vehicles) will be reported together and are due as follows:

1st detailed Report	Within 6 weeks of project Commencement (preliminary data and analysis for six vehicles)
2nd detailed Report	*Within 14 weeks of project Commencement (preliminary data and analysis for additional 30 vehicles)
3rd detailed Report	*Within 24 weeks of project Commencement (preliminary data and analysis for additional 44 vehicles)
draft Final Report	*Within 28 weeks of project Commencement (covering Output 4.1 and Output 4.2)
Final Report	*Within one month of receiving comments on the draft Final Report from the Project Manager

* Assuming a one week deferral of continuation of testing after the first six vehicles, as directed by the Project Manager.

Note: The types of vehicles to be tested in fulfilment of the first milestone report will be determined by the project manager and will be representative of all vehicle categories to be tested.

6. REPORTING

6.1 Progress reports

The successful tenderer will provide progress reports lodged fortnightly with the Project Manager in writing (typed) by letter, fax or e-mail. The initial progress report is to be presented to the Project Manager one calendar fortnight from project commencement.

Each progress report must include a clear statement of whether or not the project is running on time and a brief summary of progress since the previous progress report.

The contractor may be required to report to meetings of the Project Team.

6.2 Project report

The Final Project Report must meet the Project Manager's requirements in terms of style and format. All reports must be supplied to the NEPC Service Corporation in a printed form and in an electronic format fully compatible with Microsoft Word 97 and Microsoft Excel 97, and in a comprehensive format suitable for electronic publishing. All raw and derived data, associated formulae, and analyses shall be provided in an electronic form which readily enables further analysis by a third party.

6.3 Output Review

A working group has been established to oversee the project design and implementation. The working group will review the progress reports and provide direction and recommendations to the Project Manager as required during the course of the project. The working group will also review all outputs including draft and final reports and may submit output findings and reports to outside experts for additional review.

6.4 Data

All data gathered under this project will be provided to the project manager in a format compatible with MS Excel 97, MS Access, or as agreed to in writing.

7. PROJECT MANAGEMENT

The NEPC Service Corporation Project Manager is Mr Marc Thompson.

Project proposals must specify a person from the tenderer's organisation who will be responsible for the project. The nominated person will be required to report to the Project Manager and / or the Project Technical Committee on the progress of the project in accordance with section 6.1 and on any difficulties envisaged which might affect the project outcome or timetable. The successful tenderer will notify the Project Manager of any proposed alteration to the personnel assigned to the completion of this project, prior to any such alteration.

8. SUBMISSION OF TENDERS

8.1 Tender Requirements

Tenders must be submitted in writing as specified in section 11 and must include at least the following:

- a demonstrated understanding of the Project Brief and an appreciation of the scope of the task;
- the name and position within the organisation of the person nominated to be responsible for the project and percentage of their working time to be devoted to the project;
- state the details of the qualifications and experience, including recent relevant projects, of all persons who would work on the project, the percentage of their working time committed to the completion of this project and an indication of the role they would undertake, including details of any sub-contracting arrangements;
- a proposed methodology for the project, in sufficient detail to establish that the tenderer understands the issues and requirements of the project, thus ensuring successful outcomes;
- details of the test facility equipment and instrumentation to be used, including dynamometer(s) and emissions analysis equipment (which includes gaseous, particulate and smoke measurement equipment);
- location and accessibility of the test facility;
- the insurance arrangements for personnel and test vehicles;

- the total cost of the project, including outline estimates of costs other than fees (including cost to source vehicles, to provide “basic” emissions data set, to provide extra emissions data, and to supply fuel);
- the proposed dates for beginning and completing the project and a suggested schedule of output delivery and milestones, including identification of any constraints perceived by the tenderer;
- an estimate of the total test fuel requirements for the study (based on 80 test vehicles distributed across GVM categories in accordance with Appendix 1) and how this fuel will be sourced;
- a demonstrated capacity to drain and refuel vehicle fuel tanks for all sizes of vehicles, and to safely handle and store diesel fuel in accordance with the requirements of AS1940;
- proposed approach for sourcing vehicles including methods for picking up and returning vehicles;
- suggested approach for entering data in Microsoft Excel and / or Access;
- proposed method of data logging including type and frequency of data collection;
- a proposal for progress payments through the course of the project;
- details of quality assurance and best practice principles applied by the tenderer; and
- any other information the tenderer considers would facilitate evaluation of the tender or establish their suitability to undertake the project.

8.2 Criteria for Selection

The selection of the successful contractor will be based on the following:

- value for money of the proposed method;
- demonstrated understanding of the project requirements;
- demonstrated capacity to source the range of vehicles meeting the requirements of Appendix 1 for testing;
- ability to complete the project within the identified time frame using the methodology proposed;
- ability to interpret the results in a scientifically rigorous manner and to present the findings by oral presentations and written reports;
- capacity to successfully undertake emissions testing of vehicles including collection and measurement of vehicle exhaust emissions (carbon monoxide, carbon dioxide, total hydrocarbons, oxides of nitrogen, particulate matter and smoke);
- access to chassis dynamometer test facilities suitable for testing light and heavy vehicles on the test drive cycle proposed (access and equipment capability to be demonstrated to the satisfaction of the Project Manager and may be demonstrated by proof of ownership of suitable facilities or letter of agreement to use a third party’s facilities);
- access to emissions analysis equipment suitable for the collection and analysis of exhaust emissions from vehicles with diesel engines on a chassis dynamometer;

- access to storage and handling facilities suitable for the conduct of the proposed testing, including fuel storage and handling of drum stock test fuels as well as storage handling and disposal of used diesel fuel;
- knowledge and experience in data collation and analysis in the road vehicle, transport and emissions fields;
- quality control procedures and specifications of the equipment/measuring system to be used; and
- possession of a comprehensive insurance policy to cover the operation of test vehicles while they are under the tenderers control, including the pick-up, delivery and return tasks;

9. PROJECT BUDGET

The contract will be awarded on a fixed fee basis.

10. FURTHER INFORMATION

Clarification of any issues relating to this project prior to the awarding of the contract may be obtained by contacting Mr Thompson.

SELECTION OF VEHICLES FOR TESTING

VEHICLE SELECTION CONDITIONS

The general aim of this project is to test a selection of diesel engine vehicles which are representative of the Australian fleet. Table 1 in Appendix 1 has been prepared in an attempt to address this aim, and indicates the number of vehicles of particular makes, vintages and types which are to be selected for testing, based on a sample of 80 vehicles. The contractor is required to select test vehicles in accordance with the Table.

In addition to meeting the specific requirements of Table 1, the contractor is expected to test as wide a variety of make, model and engine capacities within each cell[1] as possible. The contractor is required to comply with the conditions below, in addition to the requirements specified in the Table.

Should difficulties occur during the course of the project which seriously affect the contractor's capacity to meet the requirements of Table 1, or the following conditions, the contractor must obtain written agreement from the Project Manager to vary the requirements.

Conditions

- No more than one vehicle make shall be tested in each cell in the table, except where the number of makes is less than the number of vehicles required to be tested.
- A range of engine powers/capacities should be tested within each cell.
- The contractor shall contact vehicle manufacturers / suppliers to determine the original standards to which the test vehicle was built. This is likely to be easier with US and European sourced vehicles than with Japanese makes. Many US and European makes will have been certified to domestic standards which are more stringent than the minimum requirements specified in the relevant ADRs.
- In the articulated truck and route bus groups complying with ADR70/00, a mixture of Euro 1 / US 91 and Euro 2 / US 94 vehicles should be tested.

[1] A reference to a "cell" in the table means the cell containing the vehicle makes associated with the number of test vehicles.

Table 1 – Number of Vehicles to be Tested in Each Category (80 vehicle sample)

Vehicle Category* & GVM/GCM [tonnes]	**No of Vehicles to be Tested [by ADR &Year of Manufacture]**			
	Pre ADR70/00[1]		*ADR70/00 Compliant*[2]	***80 Vehicles***
	1980-89	*1990-95*	*1996-99*	*Total*
Passenger Car & Off Road Vehicle	**3**	**5**	**5**	**13**
Makes acceptable for testing ➨	Toyota Ford Nissan/Datsun Mitsubishi Holden Mazda	Toyota Ford Nissan Mitsubishi Holden Mazda	Toyota Ford Nissan Mitsubishi Holden Mazda	
Light Commercial <3.5 t GVM	**5**	**8**	**6**	**19**
Makes acceptable for testing ➨	Isuzu Ford Toyota International Mitsubishi	Isuzu Ford Toyota Mitsubishi	Isuzu Toyota Mitsubishi	
Rigid Truck ≥ 3.5-12 t GVM	**3**	**8**	**6**	**17**
Makes acceptable for testing ➨	International Isuzu Mitsubishi Toyota/Hino Ford Mercedes-Benz Volvo	International Isuzu Mitsubishi Toyota/Hino Ford Mercedes-Benz Nissan-UD Volvo	International Isuzu Mitsubishi Toyota/Hino Mercedes-Benz Nissan-UD Volvo	
Rigid Truck ≥ 12 t < 25 t GVM	**2**	**7**	**5**	**14**
Makes acceptable for testing ➨	International Isuzu Mitsubishi Toyota/Hino Ford Mercedes-Benz Volvo	International Isuzu Mitsubishi Toyota/Hino Ford Mercedes-Benz Nissan-UD Volvo	International Isuzu Mitsubishi Toyota/Hino Mercedes-Benz Nissan-UD Volvo	
Articulated Truck ≥ 42.5t **GCM**	**2**	**3**	**5**	**10**
Makes acceptable for testing ➨	International Kenworth Mack Volvo Ford	International Kenworth Mack Volvo Ford	International Kenworth Mack Volvo Ford Scania	
Route Bus ≥ 12t GVM	**3**		**4**	**7**
Makes acceptable for testing ➨	MAN Mercedes-Benz Scania Volvo		MAN Mercedes-Benz Scania Volvo	

[1] ADR70/00 was phased in over 1995-6, so 1995-6 vehicles will be mixture of pre and post ADR70/00 vehicles. Any 1995 vehicles sourced in this group must not be certified to ADR70/00.

[2] ADR70/00 was phased in over 1995-6, so 1995-6 vehicles will be mixture of pre and post ADR70/00 vehicles. Any 1996 vehicles sourced in this group must be certified to ADR70/00.

DATA TO BE COLLECTED ON THE VEHICLE AND FROM TESTING

1. INSPECTION AND TEST SEQUENCE

The pre-test inspection and testing program shall be conducted in the following sequence:

1. Inspect vehicle and prepare, as required, in accordance with Appendix 2, section 2:
   If suitable for testing, complete report on pre-test inspection and proceed to step 2 below.
   If unsafe or otherwise unsuitable for testing, complete report on pre-test inspection and return vehicle to supplier as soon as possible, with a copy of the report.
2. Conduct the 6-point Inspection detailed in this Appendix 2, section 3.
3. Drain the vehicle fuel tank(s)[1] and store the fuel in suitable 200 L drums.
4. Refuel the vehicle with sufficient quantity of the specified test fuel to ensure the vehicle preconditioning and all the tests specified below can be completed without the need for refuelling.
5. Place vehicle on dynamometer and secure to ensure safe operation.
6. Precondition the vehicle by running at a low-moderate speed for a sufficient period to ensure normal engine operating temperature is reached. During this preconditioning period, run standard calibration checks on the emissions sampling and analysis equipment.
7. Connect the vehicle to the emissions sampling and analysis equipment.
8. Conduct the complex or simplified drive cycle specified in Appendix 3[2] and record the emissions results.
9. Leave vehicle on the dynamometer, and conduct the following short tests from Appendix 3[3] and record the emission results:
   - SAE J1667
   - D550
   - Full Load 2-Speed
   - Lug Down
   - Full Load Acceleration with 80km / hr Cruise
10. Disconnect emissions sampling and analysis equipment and remove vehicle from dynamometer.

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1 To minimise the time required for this task, vehicle owners/suppliers should be encouraged to provide vehicles with a minimum quantity of fuel in the fuel tank.

2 Which of the complex or simplified test is to be conducted, will be determined in the contract negotiations.

3 The order of these tests may be varied in consultation with the Project Manager prior to commencement of testing, however the agreed order must be maintained for all vehicles.

11. Drive the vehicle to a predetermined section of road and conduct the 10 Second Smoke Rule test specified in Appendix 2, section 4, and record the result.
12. Testing completed.
13. Top up the fuel tank with the waste fuel (provided it is of satisfactory quality), or if this is not sufficient, top up with fuel from a normal commercial outlet.
14. Return vehicle to supplier in accordance with contract requirements.

2. PRE-TEST INSPECTION

The attached check list shall be completed before testing is commenced. Record the details requested, or circle the correct option, as appropriate.

Apart from any adjustments to enable safe operation of the vehicle during the test, the person undertaking the pre-test inspection shall not undertake any work to alter the "as delivered" condition of the vehicle, as this would defeat the objective of assessing real world emissions.

ITEM	***INSERT ANSWER or SELECT CORRECT OPTION***
Vehicle Details	
Rego Number	
Vehicle Make	
Vehicle Model	
Vehicle Type	*Prime mover / Cab chassis rigid truck / Other rigid truck / Minibus / Route service bus / Other bus / 4WD passenger car derivative*
Engine Make	
Engine Model	
Compliance Plate Date	........../............../............
VIN	
GVM	................kg
Tare Weight	................kg
Vehicle ADR Category	
Odometer reading	.........................km (or km since last engine rebuild)
Engine displacement	L
No of cylinders	*4 / 6 / 8 / 12*
Turbocharged	*Yes / No*
Intercooler	*Yes / No*
Fuel system	*Direct injection / Indirect Injection*
Air conditioning	*Yes / No*
General Vehicle / Engine Checks	
Engine oil	Level - *ok/low*
Trans. fluid	Level - *ok/low*
Radiator	Water level - *ok/low*
Battery	Water level - *ok/low* Charge - *ok/low*
Tyres	Condition – *Suitable for testing?*

Engine Settings Checks

Idle Speed	Manufacturer's Spec................rpm
Electronic Engine Management System	*Operation & type / NA*
Drive line	Operation & Condition *Safe for test / unsafe*
Brakes	*Safe for test / unsafe*
Exhaust system	Security - *secure/loose* Leakage - *not leaking/leaking*
Safety Issues	Is the vehicle in a satisfactory condition for testing - *yes/no.*

3. 6 POINT INSPECTION

Item to be Checked	Record Response
Air filter condition ?	clean; moderate; needs replacing
Fuel pump condition Seal intact ? Tampering suspected?	 Yes; no Yes; no
Any missing engine parts ?	Yes; no
Any blue smoke from engine breather & exhaust pipe at idle ?	Yes; no
Turbocharger oil leaks?	Yes; no
Intercooler and compressed air inlet pump hoses condition ?	intact; leaking

4. 10 SECOND SMOKE RULE

The following procedure is to be used in assessing the smoke emissions from on-road use (compliance with the 10-second smoke rule).

<u>Equipment</u>:
Test vehicle plus chase vehicle
Stopwatch
2-way radio
Tape-recorder
Diesel fuel used is to be the same as that used in laboratory testing

<u>Procedure</u>:
The test vehicle should be loaded to a weight agreed upon with the Project Manager.
The test vehicle must be checked for roadworthiness before the test is undertaken.

The vehicle must be at proper operating temperature prior to the test.

A minimum of two staff are needed – one in the chase car and one in the test vehicle. If possible, the test vehicle driver should not change throughout the test series. In all cases, the test driver must be suitably qualified and hold the requisite licences.

An observer and/or data logging may be used to log the rpm, speed and gear selection of the test vehicle.

Prior to the test, the engine speed at maximum torque is assessed as per the SAE J1349 or by other methods accepted by the Project Manager.

A bitumen test strip (may be a public road or private test track) is chosen with a grade of greater than 3-5% for at least 0.5 kilometre in length. A flat piece of road with at least an 80 km/hr limit and 3 kilometres in length is also needed for higher speed checking.

Incline Smoke Test

The truck is driven up the sloped test strip at a speed and in a gear that allows the engine to operate between 40% and 80% of the engine speed at maximum power (ESMP), which is approximately equal to the maximum torque output. The driver should ensure that the vehicle is accelerating in the one gear in this engine speed band for more than 10 seconds. Data logging may be used as an additional check.

The observer in the chase vehicle is in two-way contact with the test vehicle and carries out the normal 10 second smoke rule observation whilst the test vehicle is climbing the incline. The chase vehicle driver must be positioned so that they have an uninterrupted view of the end of the test vehicle's exhaust pipe throughout the test. If other vehicles obstruct the test vehicle's path or the exhaust smoke is limited for some reason (eg. traffic congestion) then the test should be abandoned and repeated until a suitable observation is obtained.

The chase vehicle observer notes the following:

- the details of the vehicle (including the make, model, engine size and configuration, type of exhaust (horizontal or vertical), odometer reading, GVM, load carried);
- the location, date and time of the observation;
- the weather conditions (temperature, cloud cover, wind speed);
- the duration of any continuous smoke emitted (seconds) and an estimate of the length and/or height of the plume;
- the distance travelled during the test;
- a description of the intensity of the smoke as per the following:

Category	Intensity	Comments
1	Light	Approx. equiv. to Ringelmann Scale 2 (40% black)
2	Medium	Approx. equiv. to Ringelmann Scale 3 (60% black)
3	Dark	Approx. equiv. to Ringelmann Scale 4 (80% black)
4	Very Dark	Approx. equiv. to Ringelmann Scale 5 (100% black)

Other descriptions or methodologies may be used after discussion and approval by the project team.

The driver/observer in the test vehicle notes the following:

- the details of the vehicle (including the make, model, engine size and configuration, type of exhaust (horizontal or vertical), odometer reading, GVM, load carried);
- the location, date and start and stop time of the test;
- the weather conditions (temperature, cloud cover, wind speed);
- the duration of the test (stop watch);
- the odometer reading at the start and finish of the test;
- the engine speed range (rpm), the speed range (km/hr) and gear engaged during the test.

High Speed Test

The truck is driven along a flat piece of road at approximately 80 km/hr and in a gear that allows the engine to operate at between 40% and 80% of the engine speed at maximum power (ESMP), which is approximately equal to the maximum torque output. The driver should ensure that the vehicle is maintained in the one gear in this engine band for the duration of the test run. Data logging may be used as an additional check.

The observer in the chase vehicle is in two-way contact with the test vehicle and carries out the normal 10 second smoke rule observation whilst the test vehicle is being driven at this higher speed. The chase vehicle driver must be positioned so that they have an uninterrupted view of the end of the test vehicle's exhaust pipe throughout the test. If other vehicles obstruct the test vehicle's path or the exhaust smoke is limited for some reason (eg. traffic congestion) then the test should be abandoned and repeated until a suitable observation is obtained.

The chase vehicle observer notes the following:

- the details of the vehicle (including the make, model, engine size and configuration, type of exhaust (horizontal or vertical), odometer reading, GVM and load carried);
- the location, date and time of the observation;
- the weather conditions (temperature, cloud cover, wind speed);
- the duration of any continuous smoke emitted (seconds) and an estimate of the length and/or height of the plume;
- the distance travelled during the test;
- a description of the intensity of the smoke:

Category	Intensity	Comments
1	Light	Approx. equiv. to Ringelmann Scale 2 (40% black)
2	Medium	Approx. equiv. to Ringelmann Scale 3 (60% black)
3	Dark	Approx. equiv. to Ringelmann Scale 4 (80% black)
4	Very Dark	Approx. equiv. to Ringelmann Scale 5 (100% black)

Other descriptions or methodologies may be used after discussion and approval by the project team.

The driver/observer in the test vehicle notes the following:

- the details of the vehicle (including the make, model, engine size and configuration, type of exhaust (horizontal or vertical), odometer reading, GVM and load carried);
- the location, date and start and stop time of the test;
- the weather conditions (temperature, cloud cover, wind speed);
- the duration of the test (stop watch);
- the odometer reading at the start and finish of the test;
- the engine speed range (rpm), the speed range (km/hr) and gear engaged during the test.

Source: NSW EPA, 13 April 1999

5. VEHICLE TESTING EQUIPMENT REQUIREMENTS

Dynamometer

In order that each of the drive cycles can be performed, the dynamometer system should be capable of changing the load during each drive cycle so that the vehicle may simulate real world operation by accelerating, decelerating, braking and cruising under the load appropriate for its inertia.

It is recognised that testing of heavy vehicles (ie. those with a test weight greater than 4.5 tonnes) on a transient cycle will impose significant demands on a dynamometer.

For vehicles with a test weight up to 4.5 tonnes the dynamometer shall have a power absorption unit for simulation of road load power and flywheels or other means of simulating inertia weight as specified in the US EPA Code of Federal Regulations (40 CFR Part 86) Section 86.129. Other recognised standard(s) may be used if it applies similar principles of operation and calibration.

For heavier vehicles (ie. those over 4.5 tonnes), the potential tenderer will need to specify in detail the equipment and proposed strategy to be followed to test these vehicles if different to that used for the lighter vehicles. This description should include:

- the location, physical description and specifications of the dynamometer system to be used (including any associated exhaust gas/particulate sampling system);
- the international standards to which this system is designed, maintained and operated;
- the means of simulation of road load power and inertia for the test vehicles; and
- the calibration procedures to be followed throughout the study (the dynamometer and associated sampling system).

In all cases, the dynamometer system should be capable of:

- stable control throughout the cycle being driven and sensitive to light and heavy-duty vehicles;
- testing 4WDs and bogy axle heavy-duty vehicles;
- testing vehicles throughout the ADR weight categories; and
- being calibrated using coast-down procedures to confirm parasitic losses and road-load curves.

The dynamometer must have appropriate software to control the load/speed relationship and a ‘drivers aid’ to display the appropriate driving trace for assisting a driver in maintaining the correct drive cycle acceleration, deceleration and idle conditions. The ‘drivers aid’ should provide the total number of errors occurring during the drive cycle.

Exhaust Gas Sampling and Analysis

The exhaust sample handling and analysis system should demonstrate compliance with the following Sub-parts of US EPA 40 CFR Part 86:

- Sub-part B - Emission Regulations for 1977 and Later Model Year New Light-Duty Vehicles and New Light-Duty Trucks; Test Procedures.
- Sub-part N - Emission Regulations for New Otto-Cycle and Diesel Heavy-Duty Engines; Gaseous and Particulate Exhaust Test Procedures.

Equivalent standards published by an internationally recognised organisation such as UN-ECE or SAE may also be followed. Any deviations from these standards should be justified by good engineering practice and highlighted in the tender proposals.

The mass of particulate in the exhaust should be determined gravimetrically via filtration. The particulate sampling system requires dilution of the exhaust in either of one or two steps to a temperature never greater than 51.7°C (125°F) at the primary sample filter. A backup filter provides a confirmation of sufficient filtering efficiency. Sampling and analysis of total particulate matter should be performed using a single or double dilution tunnel method in conjunction with a CVS as described in the US EPA standards.

Analysis for total hydrocarbons (THC) should be performed directly from the diluted sample stream within the primary dilution tunnel. The THC analytical system requires a heated flame ionisation detector (HFID) and heated sample system designed to maintain the sample temperature at 191°C +/- 6°C to avoid loss of high molecular weight hydrocarbons. A continuously integrated system is required for total hydrocarbon analysis for transient emission testing in order to calculate mass emission rates.

The NO_x analytical system requires a continuously integrated measurement of diluted NO_x. This requires a sampling system that is heated and insulated over its entire length to prevent water condensation, to a minimum temperature 55°C. Unless compensation for varying flow is made, a constant flow system must be used to ensure a representative sample.

The CO and CO_2 analytical system can be measured using either a bag sample/analysis system or a direct sample/analysis system with integration, in a similar manner to which THC and NO_x are measured.

Further requirements are listed below:

- Analysers should conform to the requirements of the US EPA Code of Federal Regulations (40 CFR Part 86) Section 86.111 "Exhaust Gas Analytical System" or an equivalent standard published by an internationally recognised organisation such as UN-ECE or SAE. Use of workshop grade analysers is unacceptable unless being used specifically to demonstrate a comparative ‘low cost’ analysis.
- Temperatures within the sample path for all analytes should be maintained at appropriate temperatures to avoid water condensation or loss of analyte. Any particulate or water filtration system should also be designed to ensure no loss of analyte.
- The operation of the system shall demonstrate a rigorous calibration and instrument optimisation regime. For instance the instruments should be calibrated and maintained in accordance with the principles of CFR 86.1316, 86.1320 to 86.1324 and 86.1326. All calibration gases should be supplied with analysis certificates from a laboratory accredited by NATA or an equivalent recognised organisation. The analysers should always be operated using the highest measuring ranges to achieve optimum sensitivity and accuracy.

In addition, the test vehicles will have a variety of exhaust types (straight, bent, vertical, horizontal, with/without raincaps, etc) and a range of exhaust pipe diameters. The successful tenderer will need to have the capacity to effectively connect exhaust sampling lines to this variety of exhaust outlets.

DRIVE CYCLES AND IN-SERVICE MAINTENANCE PROCEDURES FOR LABARATORY TESTING

Appendix 3 consists of:

1. Preparatory Work, Project 2: In-service Emissions Performance, Phase 1: Drive Cycles – Final Report, February 1999, Volumes 1 & 2; and
2. One 3 ½ inch floppy disk.

Complex and Simplified Drive Cycles

A detailed description of the complex and simplified drive cycles are provided in an excel file on floppy disk.

Discussion of drive cycles provided in Preparatory Work, Project 2: In-service Emissions Performance, Phase 1: Drive Cycles – Final Report, February 1999, Volumes 1 & 2.

In-service Emissions Assessment Procedures to be Evaluated

Details of the in-service emissions assessment procedures are provided in Volume 2 as listed below:

- SAE J1667 — Attachment 2
- D550 — Attachment 3
- Full Load 2 speed (ADR30) — Attachment 4
- Lug Down (State of Colorado Regulation 12) — Attachment 5
- DT80 Full Acceleration 80km / hr Cruise Test — Attachment 6

The test procedure for the 10 Second Smoke Rule is detailed in Appendix 2, section 4 of this brief.