# CIRCULAR 36/00-9-1

# TEST PROCEDURES

# ADR 36/00 - EXHAUST EMISSION CONTROL

# FOR HEAVY DUTY VEHICLES

# “A Guide for Inspectors”

**This Circular is relevant to the Third Edition of the**

**Australian Design Rules gazetted as**

**National Standards under the Motor Vehicle Standards Act 1989.**

# CONTENTS

## 1 SCOPE

This procedure when read in conjunction with other Circulars provides sufficient information without reference to other standards for testing of vehicles fitted with petrol fuelled spark ignition engines to determine the amount of pollutants present in the exhaust.

Vehicles manufactured to comply with the technical requirements of 2nd Edition ADRs 27A, 27B or 27C "Vehicle Emission Control" are deemed to meet the technical requirements of ADR 36/00. Vehicles which are required to comply with this rule shall also be required to comply with ADR 41/00 - Mandatory Operation on Unleaded Petrol.

The equipment, orders of accuracy and step by step actions described in this procedure are drawn from the standards and recommended practices quoted in the ADR and from accepted laboratory and testing practices. While conformance with this procedure is sufficient to demonstrate compliance with the ADR, other equipment, orders of accuracy and procedures may be used provided it can be shown that they demonstrate compliance with the ADR.

The exhaust emissions test is designed to determine hydrocarbon and carbon monoxide concentrations during a heavy vehicle driving pattern in a metropolitan area as simulated on an engine dynamometer.

This procedure is intended primarily as a guide for Officers of the Australian Department of Transport and Communications or Agents acting on behalf of the Administrator when they carry out audit inspections of Test Facilities or witness tests for compliance with the ADR. This and other Circulars dealing with Test Procedures for ADRs may also be useful to vehicle manufacturers and testing organisations.

Nothing in this Circular, however, absolves the manufacturers from complying with the requirements as specified in the ADR which always remains the primary reference.

## 2 SELECTION OF TEST ENGINES

The engines of all petrol fuelled spark ignition vehicles listed in the applicability section of ADR 36/00 shall comply.

The criteria for selection of engines for certification testing are provided in the Design Rule (Clause 36.3). Details of the Certification Test Engine Fleet are provided to the Administrator by the manufacturer as part of the Summary of Evidence Report (SF 36/00).

## 3 IDENTIFICATION OF TEST ENGINES

The engines tested shall be representative of the design condition as reflected in the production drawings and build specifications.

Emission critical components should be subjected to special inspection procedures to ensure conformity with production build tolerances which will have been established by test. These criteria apply especially to fuel metering and ignition system calibrations and records must be maintained for all certification vehicles.

Through the certification life of the engine the manufacturer may introduce changes to the engine which are likely to affect the emissions performance. These running changes should be shown on the test records to identify the build status of each engine tested.

## 4 NUMBER OF TEST ENGINES

The number of engines tested to demonstrate compliance will vary according to the provisions of Clause 36.3.4.5 and it is the responsibility of the manufacturer to ensure that a sufficient number of engines are tested to meet these requirements.

In certain cases engines are selected based upon features which are likely to produce the highest emissions of the engines within the engine family. Consideration is given to such features as emission control system, induction and ignition system characteristics, fuel system, rated power, rated torque and compression ratio.

## 5 EQUIPMENT

At least the following equipment should be installed in the laboratory.

### 5.1 Test Laboratory

A test laboratory with a controlled environment such that the air inlet temperature to the test engine can be maintained between 20 and 30 degrees Celsius during engine testing and an ambient temperature between 15 and 30 degrees Celsius during the engine soak period.

Preferably the temperature should be maintained within ±2 degrees Celsius of the set point throughout the test period. The laboratory may be equipped with humidity and pressure control or both.

### 5.2 Engine Dynamometer

The engine dynamometer shall be of the power absorption/motoring type having a control system capable of maintaining a constant speed of 2000 r/min ±100 r/min from full load to closed throttle for the engine being tested.

The dynamometer apparatus shall include a means to monitor and record (on a strip chart recorder) the engine speed during testing.

The dynamometer equipment should be calibrated at least as often as indicated below and directly after a major overhaul:-

| | |
|---|---|
| Load Cell Deadweight Check | Six Monthly |
| Speed measurement | Three Monthly |

The laboratory should maintain calibration records as described in Circular 0-12-3.

### 5.3 Gas Analysers

A typical sampling and analytical train is shown in Annex A together with a component description. Individual systems may vary considerably from that shown, but the non-dispersive infrared analysers to measure hydrocarbons, carbon monoxide and carbon dioxide must be used. The detectors of the hydrocarbon analysers are sensitised with n-hexane and the ranges chosen for these instruments are normally 0 to 1000 ppm and 0 to 10000 ppm hexane equivalent.

Propane in air or nitrogen may be used instead of n-hexane for calibration purposes, hexane equivalent of propane is prescribed to be 0.52 (propane concentration x 0.52 = hexane equivalent concentration).

The analytical instruments should be calibrated using gases referenced in AS2719-1984 or to other National Standards. The U.S. National Bureau of Standards is commonly used for this purpose. The concentration of the standard gases should be known with at least ±2% accuracy. Working gases, often known as secondary standards which have been referenced to NBS Standards are normally used for routine calibrations.

Prior to their introduction into service and monthly thereafter the analysers should be calibrated as follows:-

(a) Follow the manufacturer's instructions for instrument start up and operation. Adjust the analysers to optimise performance.

(b) Zero the analysers with either zero-grade air or zero grade $N_2$. The allowable zero gas impurity concentrations should not exceed 10 ppm equivalent hydrocarbon response and 10 ppm carbon monoxide.

(c) Calibrate on each normally used operating range with gases blended with zero grade $N_2$ having nominal concentrations of approximately 15, 30, 45, 60, 75 and 90 percent of that range. Multi-mixes of carbon monoxide and carbon dioxide in nitrogen may be used. Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is 2 percent or less of the value at each data point, concentration values may be calculated by the use of a single calibration factor for that range. If the deviation exceeds 2 percent at any point, the best-fit non-linear equation which represents the data to within 2 percent of each test point shall be used to determine concentration.

Dynamic gas blending devices such as a Standard Gas Divider with an accuracy of better than 1 percent may be used.

(d) Compare values with previous curves. Any significant change may reflect some problem in the system.

(e) Check the response of the hydrocarbon analysers to 100 percent $CO_2$. If response is greater than 0.5 percent of full scale, filter cells or detector may be faulty.

(f) Check the response of the hydrocarbon analyser to nitrogen saturated with water at ambient temperature. If the low range analyser response exceeds 5 percent or the high range response exceeds 0.5 percent of full scale, the interference cells, interference filters or detector may be faulty.

Where the equipment is used infrequently calibration should be conducted prior to testing.

Before and after each test the analysers should be zeroed and the gains set using a span gas having a concentration of the constituent being measured that will result in a 75-95 percent of full scale deflection.

**5.4 Sampling System**

Exhaust gases shall be sampled continuously and passed through the Analysers undiluted to give a continuous trace of the exhaust emissions (Clause 36.8.3.1).

The sample probe shall take the exhaust sample downstream of any muffler or catalytic converter fitted (Clause 36.8.3.2).

The sample flow rates in the analytical train shall be used for calibration, zero, span and exhaust emissions (Clause 36.8.4.1).

The output from each analyser should be recorded on a suitable potentiometric recorder. In the case of equipment fitted with computerised data acquisition and reduction systems, the hard copy printout is suitable for record purposes.

**5.5 Engine Cooling System**

A radiator of a type fitted to a typical vehicle application for the engine under test shall be used to maintain the engine operating temperature. An auxiliary fixed speed cooling fan may be used to maintain cooling during sustained operation on the dynamometer (Clause 36.7.2.1).

**5.6 Engine Exhaust System**

The exhaust system of a type fitted to a typical vehicle application shall be used for the emissions test (Clause 36.7.2.2).

**5.7 Intake Manifold Depression**

A pressure transducer having a range capable of measuring the intake manifold pressure experienced over the drive cycle shall be used. The output from this transducer is usually recorded on the same potentiometric recorder as that used to measure engine speed.

The transducer should be calibrated before each test and the record of these calibrations should be maintained by the laboratory.

**5.8 Other Test Equipment**

Routine calibration of all other laboratory equipment used in the laboratory (eg. Thermometers, barometers, pressure gauges etc) should be carried out in accordance with Circular 0-12-3.

## 6 PROCEDURE

**6.1 General Requirements**

Review the programme to ensure that the engine to be tested conforms with the specification details.

**6.2 Setting Up**

The engine shall be fitted with an inlet manifold pressure transducer of a type described in Section 5.7.

The engine shall be fitted with all accessories which might reasonably be expected to affect emissions, although the evaporative emission controls need not be connected during the service accumulation period. Provided normal operating conditions are maintained in the engine induction system the fuel tank and vapour line may be disconnected during the emission test.

The engine shall be mounted on an engine dynamometer having a power absorption capacity at least equal to the rated power of the engine at 2000 r/min. The cooling system shall conform to the requirements of Section 5.5 and the exhaust system to the requirements of Section 5.6.

**6.3 Service Accumulation**

Emission tests are conducted at zero hours and after 125 service hours. The service accumulation shall consist of a cycle whose time shall not exceed one hour where the

operating conditions shall approximate the percentage times and modes of operation specified in the emission test cycle. (See Annex B). Average engine speed shall be between 1600 and 1700 r/min although for a period not exceeding 0.5 percent of the cycle time the engine shall be run at speeds in excess of 3200 r/min. This latter condition does not apply to governed engines where the governed speed shall be used for the high speed running where it is less than 3200 r/min, neither shall the rated speed of non-governed engines be exceeded.

Once started, the service accumulation of 125 hours shall run continuously. Full details and reasons for any discontinuation of an engine test shall be recorded.

Any maintenance conducted during service accumulation shall be limited to the extent and intervals recommended by the manufacturer. Unless otherwise approved, for this purpose one hour of dynamometer operation is deemed to be equivalent to 50 km. One adjustment of idle speed is allowed prior to the 125 hour test point.

Unscheduled maintenance may be conducted but full details and reasons shall be recorded (Clause 36.4.8).

Fuel used during service accumulation may be either Standard Reference Fuel as defined in Clause 36.6 (see Annex C) or commercial grade petrol.

**6.4 Exhaust Emission Test**

**6.4.1 Preconditioning.** The engine shall be preconditioned by operation over either one or more service accumulation cycles or the emission test cycle given in Annex B until the engine has reached normal operating conditions.

A soak period not less than 1 hour, but not exceeding two hours at an ambient temperature between 15 and 30 degrees Celsius with the engine switched off shall follow the preconditioning.

**6.4.2 Test Sequence**. Unless otherwise approved the fuel to be used for the emissions test shall conform to the specifications given in Annex C.

Connect the sample probe to the exhaust system such that the sample is collected downstream of the exhaust silencer system and catalytic converter.

Connect the manifold pressure sensor, engine speed indicator and air inlet temperature indicator to the potentiometric recorder.

Calibrate the exhaust emission analyser assembly recording the span and zero traces.

If used, start the engine cooling system.

The engine shall be started and run at the manufacturer's recommended idle speed for a period of 5 minutes.

Start the recorder to monitor the engine speed, manifold pressure and air inlet temperature.

The engine shall be operated over the emissions test cycle four times, the first two constituting the warm up cycles and the last two the hot cycles.

The idle modes may be run at the beginning and end of the test only to eliminate the need to change speed between cycles. One idle mode preceding the first cycle and one following the fourth is sufficient. Where this option is exercised the idle emissions from the first cycle shall be used for calculation of the first and second cycles and the final idle emissions shall be used for calculation of the third and fourth cycle emissions.

During the emissions test the air inlet temperature shall be between 20 and 30 degrees Celsius.

Where the manifold pressure cannot be reached during the full load mode, the engine shall be operated at wide open throttle during that mode.

If the specified manifold pressure cannot be reached during the part throttle deceleration mode, the engine shall be operated at closed throttle during that mode.

In certain cases the engine may be operated at engine speeds other than the 2000 r/min specified. Dependent upon its application, the engine may be tested at a representative speed which shall not be less than 1800 r/min and not exceed 3000 r/min.

Engine speed deviations not exceeding 200 r/min from the constant operating speed are allowed during the first 4 seconds of each mode.

The maximum permitted transition time between any two modes is 20 seconds.

Upon completion of the test, the sample line shall be purged with nitrogen and the hydrocarbon hang-up shall drop to less than 5% of full scale in 10 seconds and 3% of full scale in 3 minutes for the test to be considered valid. However, where excessive hang-up does occur the Test Facility may exercise the option to use the results obtained for certification purposes.

Span and zero the analysers following the hang-up test. A drift of more than ±2% in the calibration of any one of the analysers will invalidate the test (Clause 36.9.4).

**6.4.3 Determination of Results.** Ensure the engine was operated according to the specified cycle timing, engine speed and manifold pressures.

Locate the last 3 seconds of modes 1 to 8 and integrate the chart readings for HC, CO and $CO_2$.

Integrate the complete HC, CO and $CO_2$ traces for mode 9.

Convert the chart readings to measured concentrations using the calibration curves for each instrument.

Correct the observed HC and CO concentrations for each mode using the dilution correction factor shown below:

$$a = \frac{14.5}{\%CO2 + (0.5)\ \%\ CO + (1.8 \times 6)\ \%HC}$$

Where the engine is fitted with a device which shuts off the fuel through the slow running system during deceleration the correction factor determined for the idle mode shall be used for the closed throttle mode.

Determine composite hydrocarbons and carbon monoxide concentrations for the first and second cycles as:

b = Summation of (emission x weighting factor)
Note: See Annex B for weighting factors for each mode. Where the summation extends over the 9 modes of the dynamometer cycle average the results of these two cycles. (Clause 36.11.1.2).
Determine composite hydrocarbons and carbon monoxide concentrations for the third and fourth cycles as:
c = Summation of (emission x weighting factor)
Where the summation extends over the 9 modes of the dynamometer cycle average the results of these two cycles.
Combine the results of b and c above as follows:
d = 0.35 x b + 0.65 x c (Clause 36.11.1.4).

## 7 ANALYSIS OF RESULTS

All engines tested under the provisions of this Design Rule, after 125 hours of service accumulation, shall not exceed the following emissions standards:-

| | |
|---|---|
| Hydrocarbons | 180 ppm hexane equivalent |
| Carbon Monoxide | 1.00 percent |

## 8 SUMMARY OF EVIDENCE REPORT

The Summary of Evidence Report SF 36/00 Selection of Test Fleet and SE 36/00 are the only document to be sent to the Administrator for demonstration of compliance with ADR 36/00. The original test report identification number, the location of the test report, the test facility identification number and the determined results are to be recorded in the appropriate place in the SE 36/00 form for each clause of the ADR.

## 9 PROCEDURE FOR DESIGNS WITH CERTIFICATION TO ALTERNATIVE STANDARDS

**9.1** The '*Administrator*' may accept, at his discretion, vehicles meeting the requirements of any standards equal to or more stringent than this Rule.

**9.2** In determining whether compliance has been established, the 'Administrator' shall accept any appropriate approvals issued by:

- the State of California (USA) Air Resources Board for 1972 or later model year engines; or
- the Environmental Protection Agency (USA) with regard to "Federal Regulation for Control of Air Pollution", for 1974 or later model year engines,
- provided that the test was conducted with fuel recognised in the Federal Regulations as 'Unleaded Petrol'.

**9.3** The technical requirements of the ADR 37/00 for "Emission Control for Light Vehicles" shall be deemed to be equivalent to the technical requirements of this Rule.

**9.4** The technical requirements of 2nd Edition ADRs 27A, 27B or 27C "Vehicle Emission Control", as at 30th June 1988, shall be deemed to be equivalent to the technical requirements of this Rule.

In these cases, the relevant parts of SE 36/00 shall be completed.

## 10 REFERENCES

**ADR Reference**

ADR Definitions
ADR 36/00 Exhaust Emission Control for Heavy Duty Vehicles
ADR 41/00 - Mandatory Operation on Unleaded Petrol
ASTM D 2699-80 - Test Method for Knock Characteristics of Motor Fuels by the Research Method
ASTM D 2700-80 - Test Method for Knock Characteristics of Motor and Aviation Fuels by the Motor Method
ASTM D 3237-79 (1984) - Test Method for Lead in Gasoline, by Atomic Absorption Spectrometry
ASTM D 3231-67 or -83 - Test Method for Phosphorus in Gasoline
ASTM D 1266-80 - Sulphur in Petroleum Products (Lamp Method)
ASTM D 2785-80 - Test Method for Trace Quantities of Total Sulphur (Wickbold and Beckman Combustion Apparatus)
ASTM D 86-67 or -82 - Distillation of Petroleum Products
ASTM D 1319-84 - Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Absorption
ASTM D 323-82 - Vapour Pressure of Petroleum Products (Reid Method)
ASTM D 2551-80 - Test Method for Vapour Pressure of Petroleum Products (Micro-Method)
AS 2719 -1984 - Traceable Reference Gases - For Analysis of Emission Gases of Internal Combustion Engines and Motor Vehicles - Preparation, Analysis and Certification

**Circulars**

Circular 0-12-2 - General Requirements for Test Facilities
Circular 0-12-3 - General Requirements for Calibration of Test Equipment and Instrumentation
Circular 36-1-1 - General Information Relating to Compliance with ADR 36
Circular 36.2.1 - Recommended Application Procedures for Approval by the Administrator of Compliance with ADR 36
Circular 36-3 - Interpretations
Circular 36-4 Standard Submission Forms for Demonstrating Compliance with ADR 36

**Other References**

U.S. Federal Register - Part 85.

AS 2719 - 1984 - Traceable Reference Gases - For analysis of emission gases of internal combustion engines and motor vehicles - Preparation, analysis and certification.

# ANNEX A

Component description

The following components shall be used in sampling and analytical systems.

(1) Flowmeters FL1, FL2, FL3 and FL4 indicate sample flow rate through analysers.

(2) Low range hydrocarbon analyser.

(3) Carbon monoxide analyser.

(4) Carbon dioxide analyser.

(5) High range hydrocarbon analyser.

(6) Pressure gauges P1, P2, P3 and P4 indicate the analyser sample pressure.

(7) Needle valves N1, N2, N3 and N4 regulate sample flow rate to analysers.

(8) Needle valves N5, N6, N7, N8, N9 and N10 regulate the flow rates of N2 and normalising gases to the analysers.

(9) Ball valves V1, V2 and V3 for directing either sample or calibration gases to the analysers.

(10) Needle valves N11, N12 and N13 regulate the sample flow rate through the bypass network.

(11) Flowmeters FL5, FL6 and FL7 indicate the flow rate through the bypass system.

(12) Pumps P1, P2 and P3 for pulling the sample from the source.

(13) Filters F1, F2 and F3 remove contaminants from sample prior to analysis.

(14) Ball valves V4, V5 and V6 for directing sample to the analyser or directing air in the reverse direction as a backflush.

(15) Toggle valves V8, V9, V10 and V11 for draining condensate traps and refrigerated bath.

(16) Traps T1, T2 and T3 for condensating water vapour and cooling exhaust gas sample.

(17) Ball valve V7 for directing air to low hydrocarbon analyser during purge conditions.

(18) Needle valve N14 for regulating air flow to low hydrocarbon analyser during purge conditions.

(19) Thermometer for indicating bath temperature.

(20) Refrigerated water bath for condensating water vapour and cooling exhaust sample.

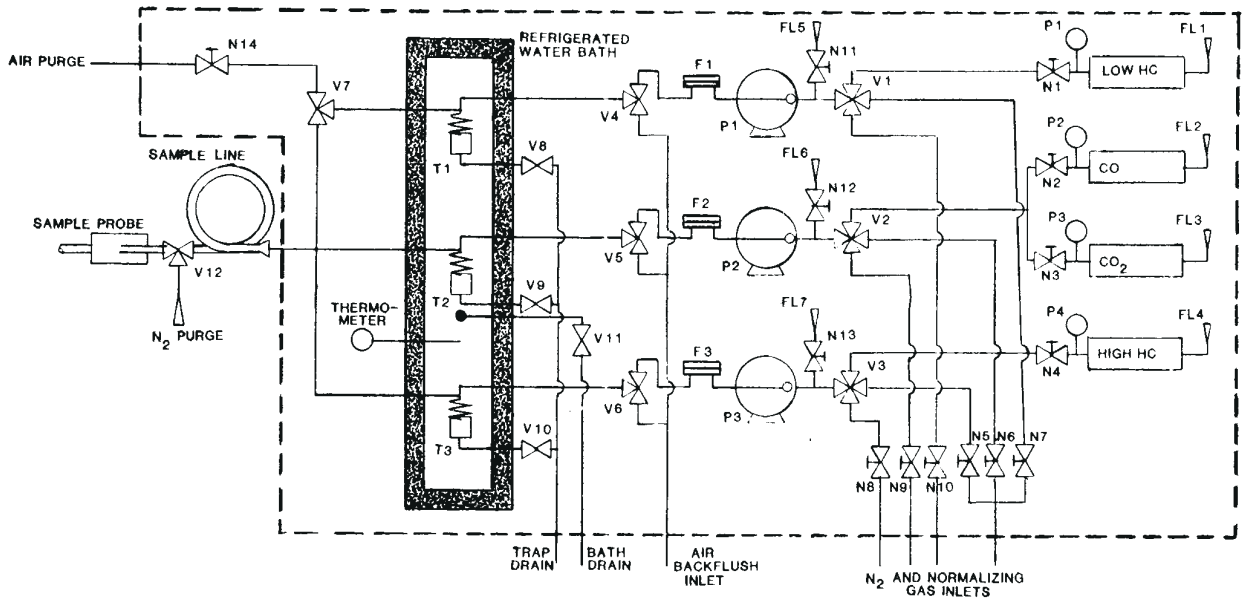
(21) Sample line from exhaust to analysis system.

(22) Sample probe to extract exhaust gas sample downstream of the muffler.

(23) Ball valve V12 for directing N2 to hydrocarbon analysers.

Stringent methods to reduce hangup should be employed e.g. minimum sample pipe lengths, elimination of condensate collection in sample lines, cleanliness etc.

## ANNEX B




SAMPLING AND ANALYTICAL SYSTEM FOR MEASURING EXHAUST EMISSIONS - ADR 36/00

**DYNAMOMETER OPERATION CYCLE (CLAUSE 36.7.1.1)**

| Seq. No. | Mode | Manifold Pressure below atmospheric (kPa) | Time in mode - (seconds) | Cumulative Time - (sec) | Weighting Factors |
|---|---|---|---|---|---|
| 1. | Idle | | 70 | 70 | 0.036 |
| 2. | Cruise | 54 | 23 | 93 | 0.089 |
| 3. | Part Throttle Acceleration | 34 | 44 | 137 | 0.257 |
| 4. | Cruise | 54 | 23 | 160 | 0.089 |
| 5. | Part Throttle Deceleration | 64 | 17 | 177 | 0.047 |
| 6. | Cruise | 54 | 23 | 200 | 0.089 |
| 7. | Full Load | 10 | 34 | 234 | 0.283 |
| 8. | Cruise | 54 | 23 | 257 | 0.089 |
| 9. | Closed Throttle | | 43 | 300 | 0.021 |

## ANNEX C

**TEST FUEL SPECIFICATIONS (CLAUSE 36.6)**

| PROPERTY | TEST METHOD ASTM | SPECIFICATION |
|---|---|---|
| Octane Number, Research | D 2699-80 | 91 min, 93 max |
| Octane Number, Motor | D 2700-80 | 82 min |
| Lead (organic), gram/litre | D 3237-79 (1984) | 0.013 max |
| Phosphorus, gram/litre | | 0.0013 max |
| Sulphur, percent by mass | D 1266-80 or D 2785-80 | 0.10 max |
| Distillation Range (degreesC) | D 86-67 or -82 | |
| Initial Boiling Point | ..... | 24-35 |
| 10 percent point | | 49-57 |
| 50 percent point | ..... | 93-110 |
| 90 percent point | | 149-163 |
| End Point | ..... | 213 maximum |
| Hydrocarbon Composition | D 1319-84 | |
| Olefins, percent | | 10 maximum |
| Aromatics, percent | | 35 maximum |
| Saturates | | Remainder |
| Reid Vapour Pressure (kPa) | D 323-82 or D 2551-80 | 55.0-63.4 (8.0-9.2 psi) |