

CIRCULAR 37/00-9-1

TEST PROCEDURES

ADR 37/00-EMISSION CONTROL FOR LIGHT 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.**

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1 SCOPE

This procedure covers the testing of vehicles fitted with petrol fuelled spark ignition engines to determine the amount of pollutants present in the emission from the exhaust and the level of evaporative hydrocarbons emitted from the fuel system. It 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 or witness tests for compliance with the ADR. This Circular may also be useful to vehicle manufacturers and testing organisations. However, the requirements as specified in the ADR always remain the primary reference.

All vehicles subject to this Design Rule are required to operate on unleaded fuel.

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 they demonstrate compliance with the ADR.

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 VEHICLES

All petrol fuelled spark ignition vehicles listed in the applicability section of ADR 37/00 shall comply.

The selection of vehicles for certification testing is provided in the Design Rule (Clause 37.4). Details of the Certification Fleet are provided to the Administrator by the manufacturer as part of the Summary of Evidence Report Selection of Test Fleet SF 37/00 (Section 8).

3 IDENTIFICATION OF TEST COMPONENTS

Vehicles subjected to test for certification purposes are normally built before production cars are available. The vehicles to be tested are representative of the design condition as reflected in 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 vehicle model the manufacturer may introduce changes to the vehicle which are likely to affect emission performance. These running changes should be shown on the test records to identify the build status of each vehicle tested.

4 NUMBER OF TEST VEHICLES

The number of vehicles tested to demonstrate compliance

will vary according to the provisions of Clause 37.4.3.5 and it is the responsibility of the manufacturer to ensure that a sufficient number of vehicles are tested to meet these requirements.

In certain cases vehicles are selected based upon features which are likely to produce the highest emissions of the vehicle models within the engine family. Consideration is given to such features as emission control system characteristics, fuel system type, engine power, engine torque, compression ratio, reference mass, transmission type and axle ratio when making test vehicle selection.

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 temperature can be maintained between 20 and 30 degrees Celsius for at least 12 hours prior to and during the test. Preferably the temperature should be maintained within ± 2 degrees Celsius of the set point. The laboratory air conditioning system may be equipped with humidity or pressure control or both.

5.2 Chassis Dynamometer

Chassis dynamometers shall be of the power absorption type utilising hydraulic, eddy current or DC absorption units with variable inertia capability. Installation of the dynamometer should be such that the vehicle is substantially level when being tested.

The dynamometer apparatus should include a means to read and/or record (on a strip chart recorder) the vehicle speed/time profile.

The power absorption unit must be adjustable for road load power conditions at 80 km/h steady speed and have $\pm 2.0\%$ accuracy and repeatability. (The dynamometer absorption unit shall be warmed up by running for 15 minutes at 50 km/h using either a non-test vehicle or as instructed by the dynamometer manufacturer before power settings are made).

Under transient conditions vehicle inertia must be reproducible on the vehicle test dynamometer. This is commonly accomplished through the use of flywheels, but may be achieved electrically, with the appropriate inertia loading (57 or 114 kg increments) for the weight of the vehicle.

The dynamometer equipment should be calibrated at least as often as indicated in Circular 0-12-3 See Annex A for Dynamometer Calibration Procedure.

The laboratory should maintain calibration records.

5.3 Constant Volume Sampler (CVS)

The principal component of the CVS is either a positive displacement pump (PDP type) or a critical flow venturi (CFV type). Schematic diagrams of these arrangements are shown in Annex B.

The dilution air filter system consists of a particulate filter, a charcoal filter and a second particulate filter which together remove airborne dust particles, stabilise hydrocarbons and trap charcoal particles. A flexible coupling to the tailpipe of the test vehicle brings the

undiluted exhaust gas to the mixing chamber. At the mixing chamber the undiluted exhaust gas is mixed with the dilution air into a homogeneous mixture.

The sampling system transfers the exhaust-gas mixture from the sampling duct to the sample bag at a constant flow rate during the test. Each sampling system consists of a glassfibre filter, a diaphragm pump, a flow control valve and a flow indicator. All surfaces in contact with the sample gas should be of stainless steel or other non reactive material such as Teflon.

A similar sampling system is used to collect dilution air from a point downstream of the dilution air filters and transfers the sample to a separate bag.

Evacuation and purge pumps are employed to remove excess sample from the bags and to purge the bags with clean air.

Sample bags should be constructed from a non reactive material. Acceptable materials are Mylar and Tedlar.

The CVS system should limit the static pressure variations at the tailpipe of the vehicle to within ± 1.2 kPa when measured during a dynamometer driving cycle with no connection to the tailpipe (Clauses 37.7.2.1.5.1 and 37.7.2.1.6.1). The flow capacity of the CVS should be large enough to eliminate condensation in the system (140 to 165 l/s is normally sufficient for most vehicles).

In the case of the PDP arrangement the gas mixture temperature, measured immediately upstream of the positive displacement pump shall be within ± 6 degrees Celsius of the designated operating temperature at the start of the test and shall be limited to a variation of ± 6 degrees Celsius during the entire test. For the CFV arrangement the temperature measuring system shall have an accuracy of ± 1 degree Celsius and a response time of 0.1 seconds to 62.5% of the temperature change. The PDP-CVS shall be calibrated at least every 500 hours of use after the stabilisation period or after major overhaul. Calibration procedures for both the PDP and CFV systems are shown in Annex C.

Any equipment used in the calibration of the CVS whether laminar flow element, venturi or orifice plate should be traceable to National Standards. The U.S. National Bureau of Standards is commonly used for this purpose.

An independent CVS system verification should be conducted at least on a weekly basis using procedures described in Annex D.

5.4 Gas Analysers

A typical sampling and analytical train is shown in Annex E together with a component description. Individual systems may vary considerably from that shown, but the analysers to monitor carbon monoxide, carbon dioxide, hydrocarbons and oxides of nitrogen must be included and use the analysis techniques shown in Annex E.

The analytical instruments should be calibrated in the manner described in Annex F 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 $\pm 2\%$ accuracy. Working gases,

often known as secondary standards which have been referenced to the NBS standards are normally used for routine calibrations. Calibration and other instrument check periods not less than those shown in Circular 0-12-3 shall be conducted and the records of these calibrations maintained by the laboratory.

Values should be compared with previous curves. Any significant change reflects some problem with the system. Before and after each test phase the analysers shall be zeroed and the gains set using a span gas having a concentration of the constituent being measured that will result in 75-95% of full scale deflection. 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 Sealed Housing for Evaporative Determination (SHED)

The test method provides for sealing the vehicle in an enclosure during test. Emissions are determined from the changes in the hydrocarbon concentrations in the enclosure. The method produces a single measurement of evaporative emissions during a soak regardless of the number of sources.

Interior surfaces must be impermeable to hydrocarbons. Any permeable surfaces must be covered with polyvinyl flouride sheet and one wall or door or ceiling should be of flexible material to provide a safety 'blow out'.

The temperature in the SHED shall be between 20 and 30 degrees Celsius throughout the test. A cooling/heating system may be necessary to control within this temperature range.

The SHED shall be equipped with at least two blower fans, one to mix the air in the enclosure during test to ensure homogeneity and the other to purge the enclosure following completion of the tests.

Two temperature sensors shall be located at the approximate vertical centreline of each side wall extending 100 mm ± 20 mm into the SHED at a height of 900 ± 200 mm. (Clause 37.6.1.5)

The enclosure shall be equipped with a Flame Ionisation Detector (FID) hydrocarbon analyser capable of measuring in the range of 10 - 3000 ppm carbon equivalent. A typical sample train is shown in Annex H. The sample should be withdrawn from the enclosure through a tube of 6.4 mm ID, terminating 50-300 mm inside the wall and located on the geometric centre of any wall or the ceiling but not the door.

An electric heating pad is needed to heat the tank fuel. The pad should cover 50% or more of the area wetted by the tank fuel although alternative methods may be necessary on vehicles of unusual fuel tank configurations. Heat must not be applied to the vapour in the tank above the liquid fuel. A variable voltage transformer or a programmable temperature controller may be used to regulate the heat from the electric heating pad. Fuel temperature must be monitored with a thermocouple mounted on the mid point of the tank test volume and the output recorded on a suitable potentiometric recorder within ± 0.5 degrees Celsius.

Calibration should be conducted at the period described in Circular 0-12-3 and the records of these calibrations maintained by the laboratory.

Values should be compared with previous results. Any significant change indicates a problem with the system.

5.6 Fuel Conditioning

Facilities must be provided to refill vehicle tanks with the specified test fuel such that, on completion of the fill, the temperature in the fuel tank is above 10 degrees Celsius and at or below 16 degrees Celsius. (Clause 37.6.4.2.5).

Independent of the arrangement used, fuel filling should not abnormally load the evaporative loss control system fitted to the vehicle.

5.7 Engine Cooling Fan

A fixed speed cooling fan with a nominal capacity of 150 m³/min must be provided for test vehicle cooling. In the case of rear engined vehicles (or in the case of unusual configurations where the above is impractical) other cooling fans may be used to provide sufficient air to maintain engine cooling (Clause 37.8.4.2).

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 Evaporative Emissions Test

6.1.1 General Requirements. Review programme to ensure that the vehicle to be tested conforms with the specification details.

It may be necessary to ensure that the test vehicle has stable background (non-fuel) emissions (Clause 37.6.1.6). These emissions have been found to be relatively small for vehicles more than 60 days old that are in good repair.

To determine the level of background emissions excessive accumulations of dirt and grease should be removed from the vehicle, the carburettor removed, the fuel lines and fuel pump purged with air and plugged together with all other exits from the engine and exhaust system which could supply a source of hydrocarbons.

The vehicle is then placed in the SHED and the hydrocarbon emissions level monitored for a period of 1 hour.

To determine the background emissions during the hot soak phase the carburettor is refitted and fed from an external fuel supply and the test vehicle operated over the prescribed driving cycle on the chassis dynamometer. After the driving test the carburettor is quickly removed and all external openings plugged. The test vehicle is then placed in the SHED and the emissions monitored for a period of 1 hour.

The 'Cold Car' and the 'Hot Car' background emissions are calculated using the procedures shown in Section 6.1.5.

6.1.2 Setting Up. Ascertain that the exhaust

system is completely free from leaks.

A thermocouple must be mounted in the fuel tank such that it records the temperature of the fuel near the geometric centre of the tank fuel liquid.

The vehicle should be inspected for liquid fuel and oil leaks while the engine is running and all leaks should be repaired.

NOTE. Solvents used in windscreen washers are a potential source of hydrocarbons and attention should be paid to leaks from this system.

A pressure test of the evaporative loss control system should be performed to ensure freedom from leaks. The pressure test should not purge or load the control system.

6.1.3 Vehicle Pre-Conditioning. The fuel tank shall be drained and filled to 40% of the nominal capacity of the fuel tank, with Standard Test Fuel (ADR 37/00 Appendix 2) whose temperature is less than 30 degrees Celsius.

Weigh the test vehicle to determine its Reference Mass and adjust for the additional fuel required to fill the fuel tank.

Within one hour of filling the tank the vehicle should be placed on the chassis dynamometer and operated over the simulated trip of 1372 seconds (Clause 37.6.3.5). Within 5 minutes of completion of the simulated trip the vehicle shall be driven off the dynamometer and parked in an area where the ambient temperature is between 20 and 30 degrees Celsius for a period of not less than 12 and not more than 36 hours.

The manufacturer may at his discretion conduct additional pre-conditioning to ensure system stability. Clause 37.6.3.3 provides the limitations applying to this additional pre-conditioning.

6.1.4 Test Sequence. The test is intended to simulate typical vehicle usage in a metropolitan area during summer months and consists of two phases: a diurnal breathing loss test and a hot soak loss test.

6.1.4.1 Diurnal Loss Test. The SHED purge and mixing blowers shall be switched on and the FID hydrocarbon analyser prepared in readiness for the test.

The fuel tank(s) of the test vehicle shall be drained and filled with Standard Test Fuel to 40% of the nominal tank volume. The temperature of this fuel shall be between 10 and 16 degrees Celsius. With the fuel tank cap off the vehicle shall be pushed into the SHED.

Zero and span the FID analyser.

All vehicle windows and luggage compartment shall be opened, the fuel temperature thermocouple connected and the tank heating pad positioned.

The fuel temperature shall be monitored and the tank fuel heater used to raise the fuel temperature to the starting temperature of 14 to 16 degrees Centigrade. Once this temperature has been achieved the tank fuel cap shall be fitted, the purge

fan switched off and the SHED door closed.

When the fuel temperature reaches 15-17 degrees Celsius make initial reading on FID. Record SHED temperature and barometric pressure. Heat the tank fuel 13.3 ±0.5 degrees Celsius above this initial temperature at a constant rate over a period of 60 ±2 minutes. The enclosure interior air temperature shall be monitored and held between 20 and 30 degrees Celsius.

At the end of the 1 hour soak, record final enclosure hydrocarbon concentration and auxiliary information required to calculate emissions.

6.1.4.2 Running Test. Push test vehicle onto chassis dynamometer. Time between end of the diurnal soak and starting engine for the running phase shall not exceed 1 hour. The vehicle shall then be operated over the CVS-CH dynamometer schedule (See Section 6.2)

6.1.4.3 Hot Soak Test. Prior to completion of the running test purge the SHED and zero and span the hydrocarbon analyser.

Immediately after the dynamometer test, shut off the cooling fan but allow the engine to continue running at idle while the test equipment is disconnected from the vehicle. Drive the vehicle

off the dynamometer and coast or push the vehicle with the engine off into the SHED. Time from the completion of the dynamometer test until engine shutdown shall not exceed 5 minutes. Before the vehicle enters the SHED the purge blower shall be switched off. The vehicle windows and luggage compartment shall be opened and the SHED door closed within two minutes of engine shutdown.

Soak the vehicle in the enclosure for a period of 60 ±0.5 minutes from the time the door is closed. The enclosure interior air temperature shall be monitored and held between 20 and 30 degrees Celsius. Perform the necessary measurements as described in the diurnal soak phase.

6.1.5 Determination of Results. All original data used for determining results shall be retained either as part of the Test Facility's internal report or in a separate original data file. In any case the direct readings and the computation showing method of determining the results are to be given in the internal report.

The formula shown below shall be used to compute the results for both the diurnal loss test and the hot soak loss test and these two values are summated to provide the final result.

$$HC \text{ mass} = K V_n 10^{-4} \left(\frac{(HC_{conc_f} \times PP_f)}{(T_f)} - \frac{(HC_{conc_i} \times PP_i)}{(T_i)} \right)$$

Where:

HC mass	= hydrocarbon mass, grams
HCconc	= hydrocarbon concentration, as ppm carbon equivalent
V _n	= nett SHED volume (calculated internal volume of SHED in cubic metres, less 1.42 cubic metres.
PP	= corrected laboratory barometric pressure, kPa
T	= ambient temperature within the SHED, degrees Kelvin.
K	= Coefficient: Diurnal = 17.20 Hot soak = 17.04
subscript i	= indicates initial reading
subscript f	= indicates final reading

6.2 Exhaust Emissions Test

6.2.1 General Requirements. Where the vehicle is to be tested for exhaust emissions only the vehicle pre-conditioning procedures given in Section 6.1.3 shall be performed.

The dynamometer driving schedule (CVS-CH) consists of a cold start drive of 1372 seconds, a pause of 10 minutes with the engine shut off and a hot start drive of 505 seconds. The cold start drive is divided into two periods, the first terminating after 505 seconds representing the 'cold start' phase and the second consisting of the remainder of the 1372 seconds representing the 'transient'

phase.

6.2.2 Preparation for Test. The dynamometer inertia shall be set to the equivalent inertia loading for the vehicle being tested. If the equivalent inertia loading is not available on the dynamometer being used, the next higher inertia available shall be used. Refer Annex L.

The dynamometer road load shall be set using a non-test vehicle to the value provided in the Table given in Annex L or as determined by the vehicle manufacturer using the procedures given in Annex K. This operation may be part of the dynamometer warm up before testing.

Alternative methods may be used by the manufacturer to set the dynamometer road load power provided they are acceptable to the Administrator.

Where it is expected that more than 33 percent of the vehicle model under consideration will be produced with air conditioning, the road load absorber setting as determined by the above procedures shall be increased by 10 percent for testing all vehicles of that model.

Check that the driver's aid is capable of producing a permanent record of the driver's performance and ensure that the speeds indicated by the recorder correspond to the vehicle speed.

The driving tyres of the test vehicle may be inflated to 310 kPa to prevent tyre damage.

6.2.3 Test Sequence. Verify that the test vehicle has been stored in an area where the temperature was between 20 and 30 degrees Celsius for a period of not less than 12 hours and not more than 36 hours.

The vehicle shall be pushed onto the dynamometer without starting the engine.

The vehicle may be restrained by using chocks on the non driving wheels or a cable and winch to minimise rocking on the dynamometer rolls.

Open the vehicle engine cover compartment and squarely position the cooling fan 200 to 310 mm in front of the radiator grille.

Attach the flexible exhaust sample tube to the vehicle exhaust pipe ensuring that the connection is free from leaks.

Ensure that the CVS has been prepared in accordance with the provisions given in Section 5.3.

The engine shall be started according to the manufacturer's instructions and the driver may use more choke or more throttle to keep the engine running.

At commencement of engine cranking, simultaneously switch on the CVS counter or timer to commence bag sampling. As the engine starts the driver's aid shall be switched on.

If the engine fails to start after 10 seconds cranking a diagnosis shall be made of the reasons for the failure to start.

If stalling occurs during the driving cycle the engine shall be restarted immediately and the test continued. Reference should be made to Clause 37.8.6 for action to be taken when other abnormal conditions occur.

The transmission of the test vehicle shall be engaged 15 seconds after the engine has started. For manual transmission vehicles the transmission shall be shifted from first to second gear at 24 km/h, second to third at 40 km/h and third to fourth at 65 km/h unless otherwise specified by the manufacturer. Where the transmission ratio in first gear exceeds 5:1, this gear shall not be used. In the case of automatic transmission vehicles the test shall be run with the transmission in 'Drive'.

At the end of the deceleration which is scheduled to occur at 505 seconds the exhaust sample shall be switched to the 'stabilised' sample bag.

The exhaust sample shall be analysed not less than 20 minutes after collection.

The engine shall be switched off 2 seconds after the last deceleration.

Sample collection shall be terminated 5 seconds after the engine has been switched off. If the engine 'diesels' the 5 second period commences when dieseling stops and this fact shall be noted.

Immediately after the end of the sample collection

period the cooling fan shall be switched off, the engine compartment cover closed and the exhaust collection tube disconnected from the tail pipe.

After a period of between 9 and 11 minutes the cooling fan shall be switched on and the engine cover opened.

Upon starting the engine the driver's aid shall be switched on and the CVS counter or timer started simultaneously.

At the end of the deceleration period which is scheduled to occur after 505 seconds the exhaust sample shall be switched off.

6.2.4 Exhaust Gas Analysis. Power to the NDIR and CL analysers is normally left on when not in use but at least 2 hours should be allowed for warm up from cold. The FID requires at least 20 minutes warm up period.

Before and after the test the analysers shall be adjusted using known zero and span gases at the same flow rates and pressures used during analysis. The outputs from the analysers shall be recorded on a suitable recorder together with the actual concentrations of the span gases used.

Measure and record the HC, CO, CO₂ and NO_x concentrations of the dilution air and exhaust gas samples.

6.2.5 Other Observations. Measure and record the average dilute exhaust gas mixture temperature.

Record the number of revolutions of the PDP during each of the test phases.

Record the corrected barometric pressure during the emissions test.

Record the pressure depression below atmospheric at the inlet to the PDP.

Record the pressure differential across the PDP.

Record the relative humidity of the ambient air in the vicinity of the test vehicle.

Record the standard volume metered by the CFV during each of the test phases.

Record the idle speed, idle CO values and spark timing of the test vehicle.

Examine the trace from the driver's aid and ensure compliance with the tolerance shown in Annex M.

6.2.6 Determination of Results. All original data used for determining results shall be retained either as part of the Test Facility's internal report or in a separate original data file. In any case the direct readings and the computation of results are to be given in the internal report.

The formulae shown below shall be used to compute the results for the exhaust emissions test.

6.2.7 Calculation of Exhaust Emissions Result. The test result shall be calculated by use of one of the following equations 7.1(a) or 7.1(b). (These equation numbers are as used in ADR 37/00) (Clause 37.7.3)

ALTERNATIVE 1:

$$Y_{wm} = (0.43 Y_{ct} + Y_s + 0.57 Y_{ht}) / 12.07 \dots (\text{Equation 7.1(a)})$$

where:

Ywm = Weighted mass emissions for each emission. (i.e. HC, CO, NO_x, CO₂) in grams per kilometre.

Yct, Ys, Yht, = mass emission for each test phase in grams/phase.

Subscript ct = cold start drive 'transient' test phase.

Subscript s = cold start drive 'stabilised' test phase.

Subscript ht = hot start drive 'transient' test phase.

ALTERNATIVE 2:

Ywm = $0.43 ((Y_{ct} + Y_s)/(D_{ct} + D_s)) + 0.57 ((Y_{ht} + Y_s)/(D_{ht} + D_s))$ (Equation 7.1(b))

where, additionally to above designations,

Dct = measured driven distance in 'transient' phase of cold start test, in km;

Ds = measured driven distance in 'stabilised' phase of cold start test, in km;

Dht = measured driven distance in 'transient' phase of hot start test, in km.

The mass of each emission for each phase of the test is determined from the following:

- for hydrocarbons

HC mass = $V_{mix} \times \text{Density}_{HC} \times \frac{HC \text{ conc}}{10^6}$ (Equation 7.2)

- for carbon monoxide

CO mass = $V_{mix} \times \text{Density}_{CO} \times \frac{CO \text{ conc}}{10^6}$ (Equation 7.3)

- for oxides of nitrogen

NO_x mass = $V_{mix} \times \text{Density}_{NO_x} \times \frac{NO_x \text{ conc}}{10^6} \times KH$ (Equation 7.4)

- for carbon dioxide

CO₂ mass = $V_{mix} \times \text{Density}_{CO_2} \times \frac{CO_2 \text{ conc}}{10^2}$ (Equation 7.5)

PART A:

HC mass = hydrocarbons emission, calculated using Equation 7.2, grams/test phase

where

Density HC = density of exhaust hydrocarbons, assuming the average C:H ratio in the fuel is 1:1.85, at 293 degrees K and 101.3 kPa pressure
= 0.577 g/litre.

HC conc. = hydrocarbons concentration of the dilute exhaust emissions sample corrected for background, ppm carbon equivalent i.e. equivalent propane times 3.
= HCe-HCd (1-1/DF)(Equation 7.6)

and where:

HCe = hydrocarbons concentration of dilute exhaust emissions sample as measured, ppm carbon equivalent.

HCd = hydrocarbons concentration of the dilution air as measured, ppm carbon equivalent.

DF = Dilution Factor(Refer Equation 7.14)

PART B:

CO mass = carbon monoxide emission, calculated using Equation 7.3, grams/test phase.

where:

Density CO = density of carbon monoxide, at 293 degrees K and 101.3 kPa pressure = 1.164 g/litre.

CO conc. = carbon monoxide concentration of dilute exhaust sample corrected for background, water vapour and CO₂ extraction, ppm.
= COe - COd (1-1/DF)(Equation 7.7)

and where:

COe = carbon monoxide concentration in dilute exhaust emissions sample corrected for water vapour and CO₂ extraction, ppm.

The calculation assumes the ratio of C:H in the fuel is 1:1.85.

COe = (1-0.01925 CO_{2e} - 0.000323Ra) COem(Equation 7.8)

COe = COem if instrument has no CO₂ or water vapour response).

COem = carbon monoxide concentration in dilute exhaust emissions sample as measured, ppm.

CO_{2e} = carbon dioxide concentration of dilute exhaust emissions sample, mole percent.

Ra = relative humidity of the ambient air, percent.

COd = carbon monoxide concentration of the dilution air corrected for water vapour extraction, ppm.

COd = (1-0.000323Ra) COdm(Equation 7.9)

(COd = COdm, if instrument has no water vapour response)

COdm = carbon monoxide concentration of the background air sample as measured, ppm.

DF = Dilution Factor(Refer Equation 7.14)

PART C:

NOx mass = oxides of nitrogen emission, calculated using Equation 7.4, grams/test phase.

where:

Density NOx = density of oxides of nitrogen in exhaust gas, assuming they are in the form of nitrogen dioxide, at 293 degrees K and 101.3 kPa pressure
= 1.913 litre.

NOx conc. = oxides of nitrogen concentration of the dilute exhaust emissions sample corrected for background, ppm.
= NOxe - NOxd (1-1/DF)(Equation 7.10)

and where:

NOxe = oxides of nitrogen concentration in the dilute exhaust emissions sample as measured, ppm.

DF = Dilute Factor(Refer Equation 7.14)

NOxd = oxides of nitrogen concentration of the dilution air as measured, ppm.

K_H = Humidity Correction Factor.

K_H =
$$\frac{1}{1-0.0329(H-10.71)}$$
(Equation 7.11)

where:

H = absolute humidity in grams of water per kilogram of dry air.

H =
$$\frac{6.211 \times Ra \times Pd}{P_B - (Pd \times Ra)}$$
(Equation 7.12)

Ra = Relative humidity of ambient air, percent.

Pd = Saturated vapour pressure, in kPa, at the ambient dry bulb temperature.

P_B = Corrected barometric pressure during or immediately prior to the test, in kPa.

PART D:

CO₂ mass = carbon dioxide emission, calculated using Equation 7.5, in grams/test phase.

where:

Density CO₂ = density of carbon dioxide, at 293 Kelvin and 101.3 kPa pressure.
= 1.830 litre.

CO₂ conc = carbon dioxide concentration of the dilute exhaust emissions sample corrected for background, in mole percent.

$$= \text{CO}_{2e} - \text{CO}_{2d} (1-1/\text{DF}) \dots(\text{Equation 7.13})$$

and where:

CO_{2e} = carbon dioxide concentration of the dilute exhaust emissions sample as measured, in mole percent.

CO_{2d} = carbon dioxide concentration of dilution air as measured, in mole percent.

DF = Dilution Factor

$$= \frac{13.4}{\text{CO}_{2e} + (\text{HC}_e + \text{CO}_e) 10^{-4}} \dots(\text{Equation 7.14})$$

PART E:

V_{mix} = Total dilute exhaust volume, in litres per test phase, corrected to standard conditions (293 Kelvin and 101.3 kPa).

(i) For a Positive Displacement Pump - Constant Volume Sampler Unit:

$$V_{\text{mix}} = \frac{V_o \times N \times (P_B - P_1)}{101.3} \times \frac{293}{T_p} \dots(\text{Equation 7.15})$$

where:

V_o = Volume of gas pumped by PDP, in litres per revolution. This volume is dependent upon the pressure differential across the PDP and the absolute inlet pressure.

N = Number of revolutions of the PDP during the test phase.

P_B = Corrected barometric pressure during or immediately prior to the test, in kPa.

P₁ = Pressure depression below atmospheric measured at the inlet to the PDP, in kPa.

T_p = Average temperature of the dilute exhaust entering the PDP during test while the samples for each phase are being collected, in degrees Kelvin.

(ii) For a Critical Flow Venturi - Constant Volume Sampler Unit:

V_{mix} is read directly from a calibrated instrument or is calculated:

$$V_{\text{mix}} = \frac{Q_m \times 293}{T_p} \times t \times \frac{P_2}{101.3} \dots(\text{Equation 7.16})$$

where:

Q_m = Flow rate, in litres per second at T_p, P₂.

P₂ = Average absolute pressure at inlet to CFV, in kPa.

t = Time, in seconds.

T_p = Average temperature of the dilute exhaust entering the CFV during test while the samples for each phase are being collected, in degrees Kelvin.

7 ANALYSIS OF RESULTS

All 'Certification' vehicle test results under the provisions of this Design Rule shall not exceed the following standards:
Fuel evaporative emissions,
hydrocarbons - 1.9 grams per test.

Exhaust emissions - (grams per kilometre)		
	MA vehicles	MB1, MC1, MD5 & NA1 vehicles -
Hydrocarbons	0.85	1.13
Carbon Monoxide	8.45	11.30
Oxides of Nitrogen	1.75	1.75

All vehicles when tested under the provisions of this Design Rule shall not exceed the following standards:
Fuel evaporative emissions, hydrocarbons - 2.0 grams per test.

Exhaust emissions - (grams per kilometre)		
	MA vehicles	MB1, MC1, MD5 & NA1 vehicles
Hydrocarbons	0.93	1.24
Carbon Monoxide	9.30	12.40
Oxides of Nitrogen	1.93	1.93

8 SUMMARY OF EVIDENCE REPORT

The Summary of Evidence Report SE 37/00 and Selection of Test Fleet SF 37/00 are the only documents to be sent to the Administrator for demonstration of compliance to ADR 37/00. 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 37/00 form for each relevant clause of the ADR.

9 PROCEDURE FOR DESIGNS WITH CERTIFICATION TO ALTERNATIVE STANDARDS

In determining whether compliance has been established the 'Administrator' may accept 'Approvals' issued with respect to other emissions standards equal to or more stringent than this Rule (Clause 37.9.1).

Tests conducted with unleaded fuels meeting overseas fuel specifications may be accepted, at the discretion of the 'Administrator' (Clause 37.9.2).

US EPA Approvals for MA Vehicle

Approval certificates issued under (USA) "Federal Environmental Protection Agency Regulations" for 1975 and later model year "light duty vehicles" shall be accepted as evidence of compliance with the 'Exhaust Emissions 37/00' requirements of this Rule, provided that 'Unleaded Petrol' of RON equivalent to an 'Appropriate Standard Test Fuel' was used as the test fuel, and the vehicle operates on 'Unleaded Petrol' having a RON of either 91-93 or 95-96. For 1981 and later model year vehicles an (USA) EPA approval certificate shall be accepted as evidence of compliance with the 'Fuel Evaporative Emissions' requirements of this Rule (Clause 37.9.3).

US EPA Approvals for Vehicles other than MA

Vehicles Approval certificates issued under (USA) "Federal Environment Protection Agency Regulations" for 1975 and later model year "light duty vehicles" or "light duty trucks" shall be accepted as evidence of compliance with the 'Exhaust Emissions 37/00, requirements of this Rule, provided that "Unleaded Petrol" of RON equivalent to an 'Appropriate Standard Test Fuel' was used as the test fuel and that the vehicle operates on 'Unleaded petrol' having a RON of either 91-93 or 95-96. For 1981 and later model year vehicles a (USA) EPA approval certificate shall be accepted as evidence of compliance with the 'Fuel Evaporative Emissions' requirements of the Rule (Clause 37.9.4).

10 REFERENCES

ADR References

ADR Definitions

ADR 37/00 - Emission Control for Light Vehicles

ADR 41/00 - Mandatory Operation on Unleaded Petrol

SAE Recommended Practice J1140 - Filler Pipes and Openings of Fuel Tanks

SAE Recommended Practice J285a - Gasoline Dispenser Nozzle Spouts

ASTM D86 - 82 - Distillation of Petroleum Products

ASTM D323 - 82 - Vapour Pressure of Petroleum Products (Reid Method)

ASTM D1319 - 84 - Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Absorption

ASTM D2699 - 1980 - Test Method for Knock Characteristics of Motor Fuels by the Research Method

ASTM D2700 - 1980 - Test Method for Knock Characteristics of Motor and Aviation Fuels, by Motor Method

ASTM D3237 - 79(1984) - Test Method for Lead in Gasoline, by Atomic Absorption Spectrometry

ASTM D2785 - 80 - Test for Trace Quantities of Total Sulphur (Wickbold and Beckman Combustion Apparatus)

ASTM D3231 - 67 or 83 - Test Method for Phosphorus in Gasoline

ASTM D2551 - 80 - Test Method for Vapour Pressure of Petroleum Products (Micro-Method)

ASTM D1266 - 80 - Sulphur in Petroleum Products (Lamp Method)

ASTM E29-67 - Recommended Practice for Indicating which Places of Figures are to be Considered Significant in Specified Limiting Values

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.

Other References

SAE Recommended Practice J1094a - Constant Volume Sampler System for Exhaust Emissions Measurement

SAE Recommended Practice J171 - Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars and Light Duty Trucks using the Enclosure Method.

ANNEX A

DYNAMOMETER CALIBRATION

The calibration shall consist of the manufacturer's recommended calibration procedure plus a determination of the dynamometer frictional power absorption at 80 km/h.

This Annex describes a suggested method for determining the road power absorbed by a chassis dynamometer for a single equivalent test inertia mass. Similar calibrations should be established for all equivalent test inertia masses used. Alternative methods of calibration may be used. The actual absorbed road power includes the dynamometer friction as well as the power absorbed by the power absorption unit. Where multiple rolls are used, the calculation of actual absorbed road power may neglect the inertia and friction of the rear or idle roll(s). The dynamometer is driven above the test speed range. The device used to drive the dynamometer is then disengaged from the dynamometer and the roll(s) is allowed to coast down. The kinetic energy of the system is dissipated by the dynamometer friction and absorption unit.

This procedure shall be followed:

1. Determine the speed of the drive roll if not already measured. A fifth wheel, revolution pickup or other suitable means may be used.
2. Place a vehicle on the dynamometer or use another method of driving the dynamometer. DC machines may motor the dynamometer.
3. Engage inertia flywheel for the most common equivalent test inertia mass for which the dynamometer is used.
4. Drive dynamometer up to 80 km/h.
5. Record indicated road power absorber setting.
6. Drive dynamometer up to 100 km/h.
7. Disengage the device used to drive the dynamometer.
8. Record the time for the dynamometer drive roll to coast down from 90 km/h to 70 km/h.
9. Adjust the power absorption unit to a different level.
10. Repeat steps 4 to 9 above sufficient times to cover the range of road power absorber settings used.
11. Calculate actual absorbed road power from:

$$RP_d = \frac{1/2 W(V_1^2 - V_2^2)}{1000t}$$

$$RP_d = 0.12354 \times \frac{W}{t}$$

where:

RP_d = Actual absorbed road power (kW)

W = Equivalent test inertia mass, (kg)

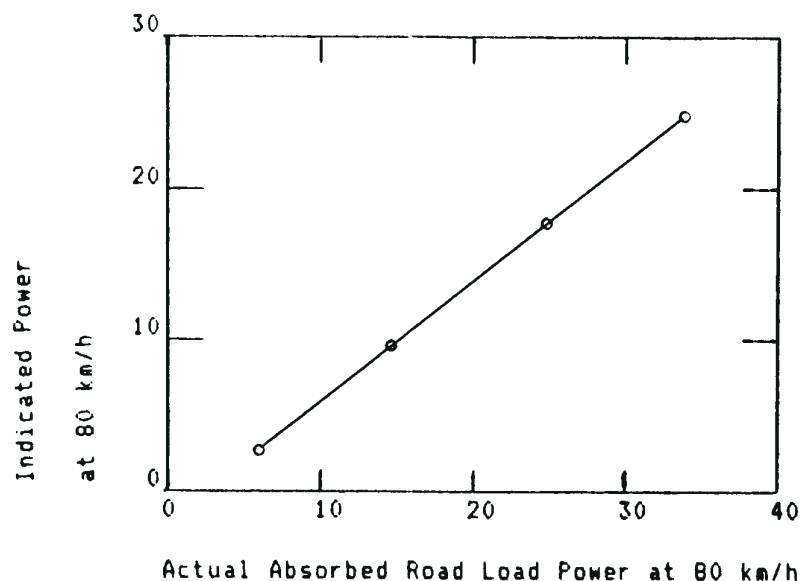
V₁ = Initial velocity in m/s (90 km/h = 25 m/s)

V₂ = Final velocity in m/s (70 km/h = 19.44 m/s)

t = Elapsed time in seconds for rolls to coast from 90 km/h to 70 km/h.

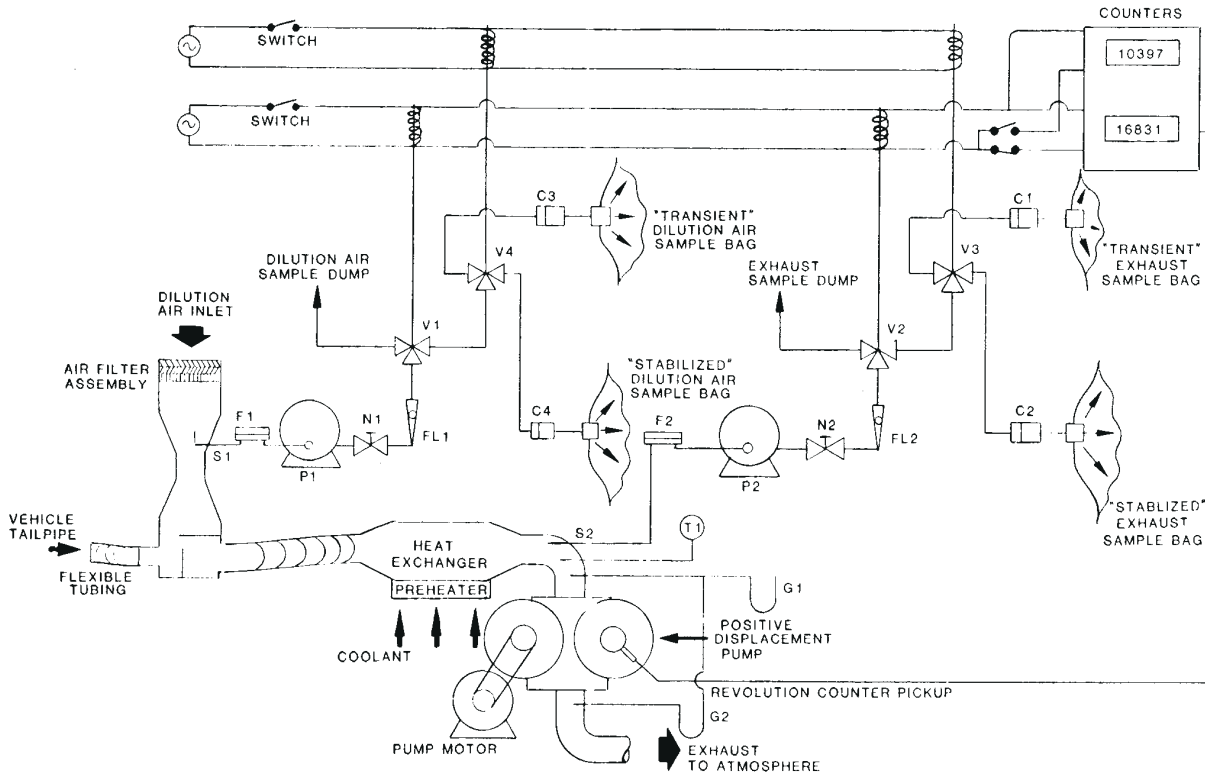
12. Plot indicated road power absorber setting at 80 km/h versus actual absorbed road power at 80 km/h.

13. The required dynamometer power absorber setting for the test is obtained by entering the figure from Annex K or L for road power absorber setting on the graph and reading off the indicated road power absorber setting for the dynamometer.

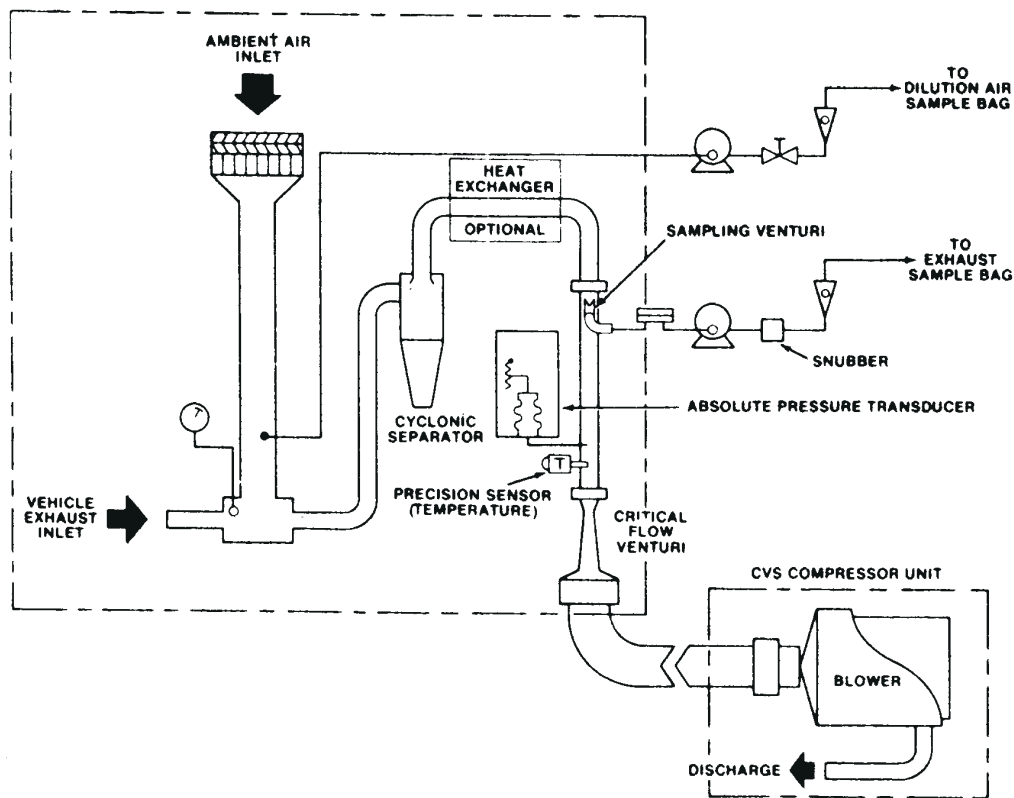


EXAMPLE OF A DYNAMOMETER CALIBRATION CURVE

ANNEX B



PDP-CVS SAMPLER UNIT



CFV-CVS SAMPLER UNIT

CONSTANT VOLUME SAMPLER SCHEMATICS

ANNEX C

CONSTANT VOLUME SAMPLER CALIBRATION

SECTION I - POSITIVE DISPLACEMENT PUMP

The following calibration procedure outlines the equipment, equipment configuration, and the various parameters which must be measured to establish the flow rate of the constant volume sampler pump. All the parameters related to the pump are simultaneously measured with the parameters related to a flowmeter which is connected in series with the pump. The calculated flow rate (litres/rev) at pump inlet absolute pressure and temperature) can be plotted versus a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump flow and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range should be performed.

This calculation procedure is based on the measurement of the absolute values of the pump and flowmeter parameters that relate the flow rate of each point. Three conditions must be maintained to assure the accuracy and integrity of the calibration curve. First, the pump pressures should be measured at taps on the pump rather than at the external piping on the pump inlet and outlet. Pressure taps that are mounted at the top and bottom centre of the pump drive headplate are exposed to the actual pump cavity pressures and therefore reflect the absolute pressure differentials. Secondly, temperature stability must be maintained during the calibration. The laminar flow element is sensitive to inlet temperature oscillations which cause the data points to be scattered. Gradual changes (± 1 degree C) in temperature are acceptable as long as they occur over a period of several minutes. Finally, there shall be no leakage in any connection between the flowmeter and the CVS pump.

During the CVS emissions test the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

After the calibration curve has been obtained, a verification test of the entire system can be performed by injecting a known mass of gas into the system and comparing the mass indicated by the system to the true mass injected. An indicated error does not necessarily mean that the calibration is wrong, since other factors can influence the accuracy of the system.

(A) EQUIPMENT

The following list of equipment will be needed to perform this calibration procedure. Figure 1 illustrates a typical equipment arrangement used for calibration. All of the equipment involved should conform to the range and accuracy as specified in Table 1.

Equipment List:

1. Flow Meter, Calibrated Laminar Flow Element, Subsonic Venturi or Orifice Plate
2. Micro-manometer
3. Thermometers
4. Timer
5. U-Tube or inclined manometer

6. A variable flow restrictor with appropriate piping to connect the PDP or CFV to the LFE.

After the system has been connected as shown in Figure 1, set the variable restrictor in the wide open position and run the CVS pump for 20 minutes to stabilise. Record the calibration data.

Reset the restrictor valve to a more restricted condition in an increment of pump inlet depression (about one kPa) that will yield a minimum of 6 data points for the total calibration.

Allow the system to stabilise for 3 minutes and repeat the data acquisition.

(B) DATA ANALYSIS - PDP SYSTEM

The data recorded during the calibration are to be used in the following calculations.

1. The air flow rate at each test point is calculated in standard litres per minute (Q_s) from the flowmeter data using the manufacturer's prescribed method.

2. The air flow rate is then converted to pump flow, V_o , in litres per revolution at absolute pump inlet temperature and pressure.

$$V_o = \frac{Q_s \times 101.3 \times T_p}{n \times P_p \times 293}$$

where:

Q_s = Air flow rate in standard litres per minute (standard conditions are 293 degrees K and 101.3 kPa.)

n = Pump speed in revolutions per minute.

T_p = PTI, Air temperature at PDP inlet, degrees K.

P_p = Absolute pump inlet pressure, kPa.

P_p = PB - PPI.

3. The correlation function at each test point is then calculated from the calibration data, as follows:

$$X_o = \frac{1}{n} \times \frac{(P_o - P_p)}{\partial (P_o)}$$

where:

$(P_o - P_p)$ = The pressure differential pump inlet to pump outlet, kPa.

P_o = Absolute pump outlet pressure, kPa.

P_o = PB + Ppo

Ppo = Pressure at PDP outlet, kPa.

4. A linear least-square fit is performed to generate the calibration equations which have the forms

$$V_o = D_o - M(X_o)$$

$$n = A - B(P_o)$$

where:

D_o , M , A and B are the slope and intercept constants describing the lines.

A PDP system having multiple speeds should be calibrated at each speed used. The calibration curves generated for the ranges will be approximately parallel and the intercept value (D_o) will increase as the pump flow range decreases.

If the calibration has been performed carefully, the calculated V_o values from the equation will be within $\pm 0.5\%$ of the measured value of V_o . Values of M will vary

from one pump to another, but values of Do for pumps of the same make, model, and range should agree within $\pm 3\%$ of each other. Particulate influx from use will cause the pump slip to decrease as reflected by lower values for M. Calibrations should be performed at 0, 50, 100, 200,

and 500 hours of pump operation to assure the stability of the pump slip rate. Thereafter it shall be recalibrated each 500 hours of pump operation or as system verification indicates necessary. Analysis of system verification data will also reflect pump slip stability.

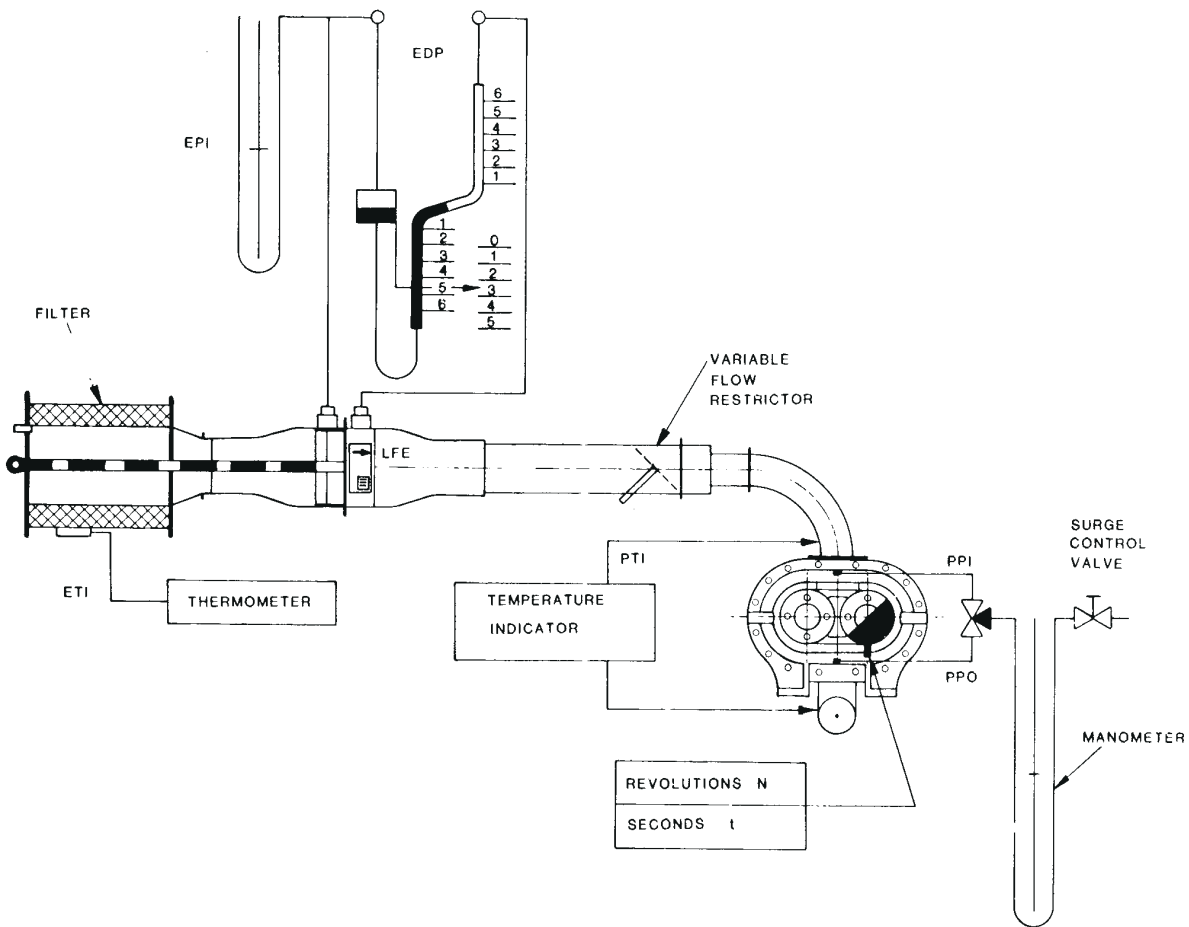


Figure 1.
PDP-CVS CALIBRATION CONFIGURATION

5. Alternative methods of calibration may be used, if approved.

NOTE: The fluid level in the manometer tube should stabilise before the reading is made and the elapsed time for revolution counting should be greater than 120 seconds.

ANNEX C

SECTION II

CRITICAL FLOW VENTURI

The general comments made at the beginning of Section I of this Annex and the equipment detailed there, also apply, as and where appropriate, to calibration of a CFV-CVS unit.

(C) DATA ANALYSIS - CFV-CVS SYSTEM

(i) Calibration of the Critical Flow Venturi (CFV) is based upon the flow equation for a critical venturi. Gas flow is a function of inlet pressure and temperature.

$$Q_s = \frac{K_v P}{\sqrt{T}}$$

where:

Q_s = Flow in litres/min.

K_v = Calibration coefficient.

P = Absolute pressure, kPa.

T = Absolute temperature, degrees K.

The calibration procedure described below establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow.

(ii) The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

(iii) Measurements necessary for flow calibrations are as follows:

(Refer to Table 1 for measurement tolerances).

(a) Set up equipment as shown in Figure 2 and check for leaks. Any leaks between the flow measuring device and the critical flow venturi will seriously affect the accuracy of the calibration.

(b) Set the variable flow restrictor to the open position, start the blower and allow the system to stabilise. Record data from all instruments.

(c) Vary the flow restrictor and make at least 8 readings

across the critical flow range of the venturi.

(iv) Data analysis. The data recorded during the calibration are to be used in the following calculations:

(a) The air flow rate, Q_s , at each test point is calculated from the flow meter data using the manufacturer's prescribed method.

(b) Calculate values of the calibration coefficient for each test point:

$$K_v = \frac{Q_s \times \sqrt{T_v}}{P_v}$$

where:

Q_s = Flow rate in standard litres/minute; (standard conditions are 293 degrees K and 101.3 kPa).

T_v = Temperature at venturi inlet, degrees K.

P_v = Pressure at venturi inlet, kPa.

$P_v = P_B - PP_I$.

PP_I = Venturi inlet pressure depression, kPa.

(c) Plot K_v , as a function of venturi inlet depression. For sonic flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases (is no longer constant). (Refer Figure 3).

(d) For a minimum of 8 points in the critical region calculate an average K_v and the standard deviation.

(e) If the standard deviation exceeds 0.3 percent of the average K_v , take corrective action.

(v) Alternative methods of calibration may be used, if approved.

ANNEX C

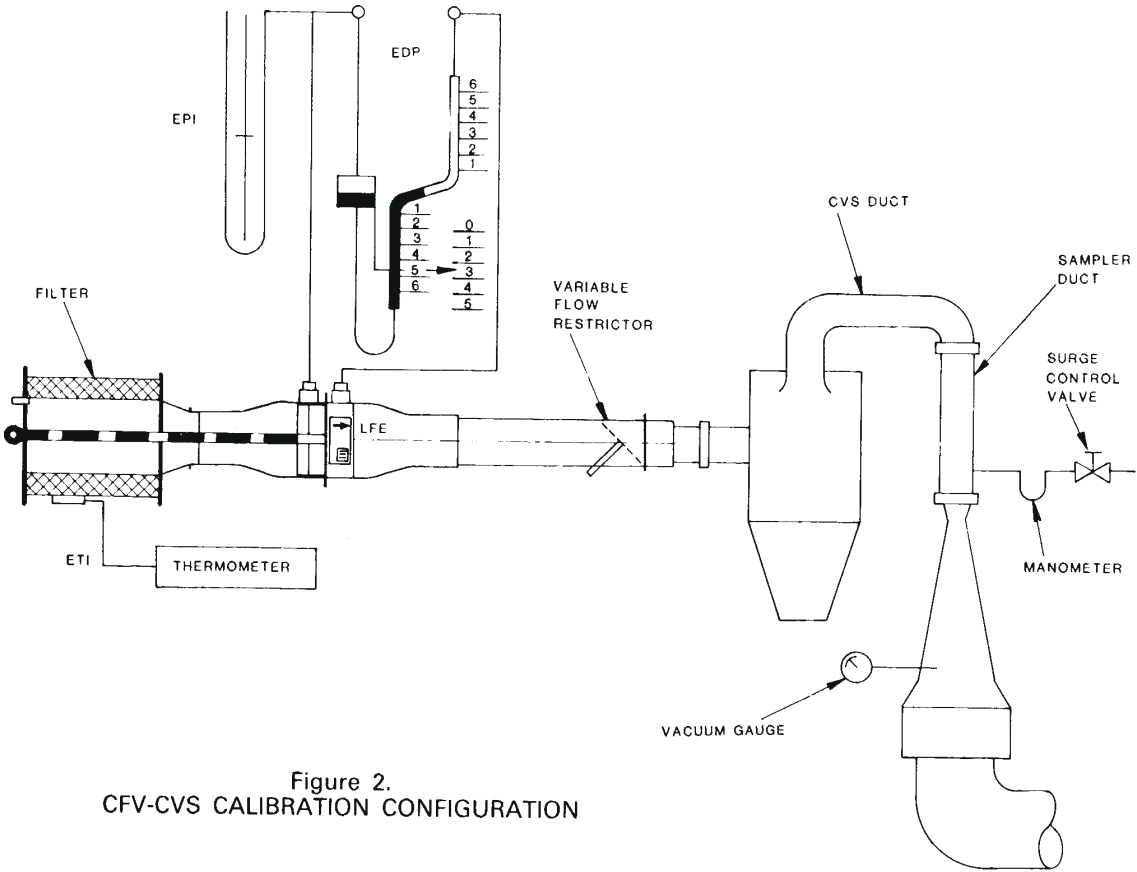


Figure 2.
CFV-CVS CALIBRATION CONFIGURATION

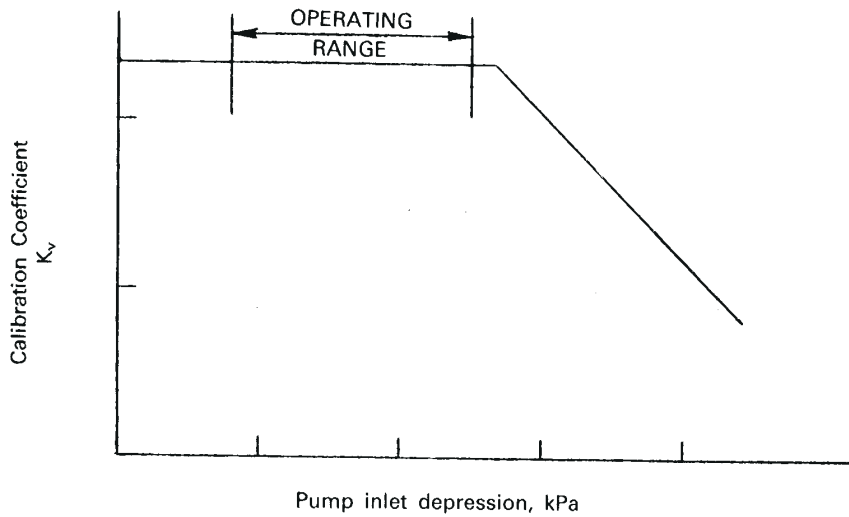


Figure 3
SONIC FLOW CHOKING IN CFV SYSTEM

ANNEX C

TABLE 1

**CALIBRATION DATA MEASUREMENT - FOR A
CONSTANT VOLUME SAMPLER (CVS) OF:**

- (i) Positive Displacement Pump (PDP) Type; or
(ii) Critical Flow Venturi (CFV) Type

PARAMETER	SYMBOL	TOLERANCE	INSTRUMENT
Atmospheric pressure	P _B	±30 Pa	Barometer
Ambient Temperature	T _A	±0.3°C	Thermometer
Air Temp. in to LFE	E _{TI}	±0.15°C	Thermometer
Pressure depression upstream of LFE	E _{PI}	±10 Pa	Manometer
Pressure differential across LFE	E _{DP}	± 0.1 Pa	Manometer
Air Temperature at:			
PDP inlet; or	P _{TI}	±0.3°C	Thermometer
CFV inlet	T _V	±0.3°C	Thermometer
Pressure depression at:			
PDP inlet; or CFV inlet	P _{PI}	± 10 Pa	Manometer
Pressure at PDP outlet	P _{PO}	±10 Pa	Manometer
Air temperature at PDP outlet (optional)	P _{TO}	±0.3°C	Thermometer
PDP revolutions during test phase	N	± one	Revolution counter
Elapsed time for test phase	t	±0.1 seconds	Stopwatch or equivalent
Air Flow (litres/minute)	Q _s	± 0.5 %	Laminar flow element or Sub-sonic Venturi flowmeter

ANNEX D

CONSTANT VOLUME SAMPLER VERIFICATION

(A) CVS SYSTEM VERIFICATION

One of the following methods shall be used to verify that the CVS and analytical instruments can accurately measure a mass of gas injected into the system.

METHOD 1

A critical flow orifice (CFO) may be used for injecting a measured amount of propane or CO into the sampling system, and for constant flow metering, using the instrument manufacturers' procedures for operating the equipment.

METHOD 2

- (i) Obtain a small cylinder that has been charged with propane or carbon monoxide gas.
- (ii) Determine a reference cylinder mass to the nearest 0.01 gram.
- (iii) Operate the CVS in the normal manner and release a known quantity of propane or carbon monoxide into the system during the sampling period.
- (iv) The calculations are performed in the normal way except, in the case of propane, the density of propane (0.611 g/litre/carbon atom) is used in place of the density of exhaust hydrocarbons. In the case of carbon monoxide, the density of 1.164 g/litre is used.
- (v) The gravimetric mass is subtracted from the CVS measured mass and then divided by the gravimetric mass to determine the percent accuracy of the system.
- (vi) The cause for any discrepancy greater than ± 2 percent should be found and corrected.

(B) ERROR DETECTION

The following list of parametric errors may assist the operator in locating the cause of large errors.

TYPE 1 Positive Error. (Indication is higher than true value)

(i) Calculated V_o is greater than actual V_o :

- (a) Original calibration in error.
- (ii) Pump inlet temperature recorder is reading low. A 3.5 degrees C discrepancy will give a one percent error.
- (iii) Pump inlet pressure indicator is reading high. A one kPa high reading will give a one percent error.
- (iv) Background concentration reading is too low. Check analyser zero. Check leakage at floor inlet.
- (v) Analyser is reading high. Check span.
- (vi) Barometer reading is in error (too high). Barometric pressure reading should be gravity and temperature corrected.
- (vii) Revolution counter is reading high. Check pump speed and counters.
- (viii) Mixture is stratified causing the sample to be higher than the average concentration in the mixture.

TYPE 2 Negative Error. (Indication is lower than true value)

(i) Calculated V_o is less than actual V_o :

- (a) Original calibration in error.
- (b) Pump clearances decreased due to influx of some surface adherent material. Recalibration may be needed.
- (ii) Pump inlet temperature recorder is reading high.
- (iii) Pump inlet pressure indicator is reading low.
- (iv) Background concentration reading is too high.
- (v) Analyser is reading low.
- (vi) Barometer reading is in error (too low).
- (vii) Revolution counter is reading low.
- (viii) There is a leak into the sampling system. Pressure check the lines and fittings on the intake side of sample transfer pumps on both the CVS and analyser console.

ANNEX E
SAMPLING AND ANALYSIS TRAIN

SCHEMATIC DIAGRAM OF TYPICAL SETUP

Component Description. - The following components are suggested for the CVS bag sampling and analytical systems for the analysis of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), carbon dioxide (CO₂), and oxygen (O₂).

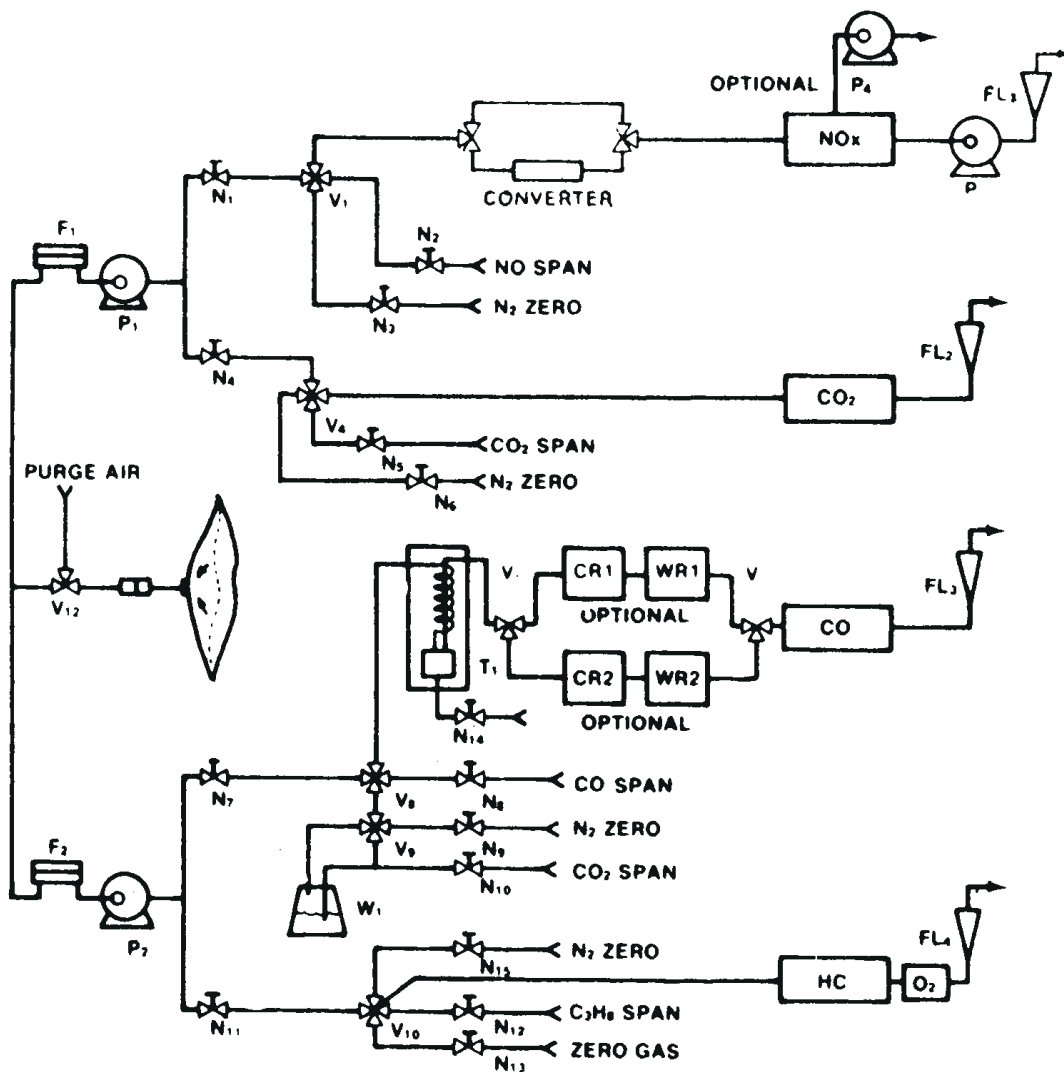
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NDIR analysers for measurement of CO and CO₂ with cells of appropriate length for concentration ranges being measured.

Chemiluminescent (CL) NO analyser equipped with a bypass and NO₂ and NO converter for the measurement of NO_x

FID for measurement of HC.

O
x
y
g
e



BAG SAMPLING AND ANALYSIS TRAIN

Valve V12 are used to direct the sample or purge air to the

analysers.

Valves V1, V4, V8 (optional) V9, and V10 are used to direct the sample, zero gas, or span gas streams to the analysers.

Filters, F1 and F2 are for removing particulate materials from the sample prior to analysis. A glass fiber filter of at least 7 cm diameter is suitable.

ANNEX E

Pumps P1 and P2 to move the sample through the system. Pumps should have stainless steel or aluminium chambers with diaphragms and valves made from or covered with an inert material, such as Teflon. Free air capacity should be approximately 1.1 m³/h).

Pumps P3 for bypass flow of chemiluminescent analyser and vacuum pump P4 (optional depending upon the design of chemiluminescent analyser) for evacuation of the chemiluminescent reactor chamber.

Needle valves, N1, N4, N7, and N11 to regulate sample gas flow to the analysers.

Needle valves N2, N5, N3, and N12 to regulate span gas flow to the analysers.

Optional **valve V9** used to direct CO₂ span gas through the water bubbler for checking the performance of drier and absorber system or to check the H₂O and CO₂ interference rejection characteristics of the CO analyser.

Needle valve N20 is used to regulate CO₂ flow.

Needle valves N3, N6, N9, and N15 to regulate zero gas flow to the analysers.

Flow meters FL1, FL2, FL3, and FL4 to indicate span gas, zero gas, and sample flow to the analysers.

Water trap T1, if necessary, to partially remove water and a valve N14 to allow the trap to be drained.

Optional sample conditioning columns CR1 and CR2 containing ascarite to remove CO₂ from the CO analysis stream, and WR1 and WR2 containing indicating CaSO₄ or indicating silica gel to remove the remainder of the water. Equivalent drying techniques such as diffusion driers may be used.

Optional valves V6 and V7 to permit switching from exhausted absorbing columns to fresh columns.

Optional water bubbler W1 to allow saturation of CO₂ span gas to check the efficiency of the absorbing columns in the CO system.

ANNEX F

CALIBRATION OF EMISSION ANALYSIS EQUIPMENT

(Alternative approved methods which yield equivalent results may be used)

SECTION I. Hydrocarbons Analyser Calibration

The flame ionisation detector (FID) hydrocarbons analyser shall receive the following initial and periodic calibration:

(a) Initial and periodic optimisation of detector response. Prior to its introduction into service and at least annually thereafter the FID hydrocarbons analyser shall be adjusted for optimum hydrocarbons response.

(1) Follow the manufacturer's instructions for instrument start up and basic operating adjustment using the appropriate fuel and zero-grade air (Refer Clause 37.1), or equivalent high purity oxygen.

(2) Optimise on the most common operating range. Introduce into the analyser, a propane in air mixture with a propane concentration equal to approximately 90 per cent of scale.

(3) Select an operating fuel flow-rate that will give near maximum response and least variation in response with minor fuel flow-rate variations.

(4) To determine the optimum air flow-rate, use the fuel flow-rate setting determined above and vary air flow.

(5) After the optimum flow-rates have been determined, they are recorded for future reference.

(b) Initial and periodic calibration. Prior to its introduction into service and monthly thereafter the FID hydrocarbons analyser shall be calibrated on all normally used instrument ranges, using the same flow-rate used when analysing samples, and as determined from (a) above.

(1) Adjust analyser to optimise performance.

(2) Zero the analyser with zero-grade air.

(3) Calibrate on each normally used operating range with propane in air calibration gases having nominal concentrations of 15, 30, 45, 60, 75 and 90 per cent of that range. For each range calibrated, if the deviation from a least-squares best-fit straight line is 2 per cent or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds 2% at any point, the best-fit non-linear equation which represents the data to within 2% of each test point shall be used to determine concentration.

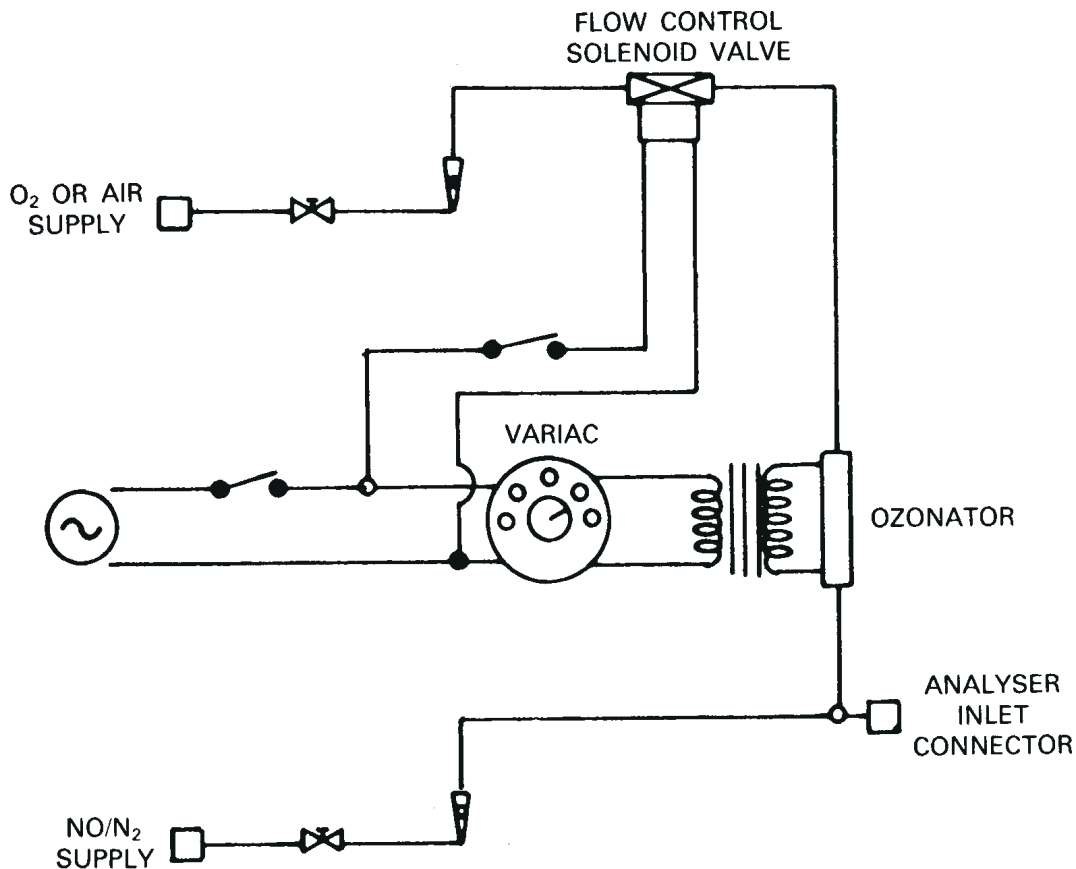


Figure 1
NO_x CONVERTER EFFICIENCY DETECTOR

SECTION II. Carbon Monoxide Analyser Calibration

The non-dispersive infrared (NDIR) carbon monoxide (CO) analyser shall receive the following initial and periodic calibration:

(a) Initial and periodic interference check. Prior to its introduction into service and annually thereafter the NDIR CO analyser shall be checked for response to water-vapour and carbon dioxide (CO₂).

(1) Follow the manufacturer's instructions for the instrument startup and operation. Adjust the analyser to optimise performance on the most sensitive range to be used.

(2) Zero the analyser with either zero-grade air or zero-grade nitrogen (N₂). (Refer Definitions Clause 37.1).

(3) Bubble a mixture of 3% CO₂ in N₂ through water at room temperature (20-30 degrees C) and record analyser response.

(4) An analyser response, as measured on the most sensitive CO range, of more than one percent of full scale for ranges above 300 ppm full scale or of more than 3 ppm on ranges below 300 ppm full scale will require corrective action. (Use of sample conditioning columns is

one form of corrective action which may be taken. One form of sample conditioning column consists of anhydrous calcium sulphate or indicating silica gel to remove water-vapour and containing ascarite to remove CO₂ from the CO sample stream.)

(b) Initial and periodic calibration. Prior to its introduction into service and monthly thereafter the NDIR CO analyser shall be calibrated.

(1) Adjust the analyser to optimise performance.

(2) Zero the analyser with either zero-grade air or zero-grade N₂.

(3) Calibrate on each normally used operating range with CO in N₂ calibration gases having nominal concentrations of 15, 30, 45, 60, 75 and 90 percent of that range. 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 use of a single calibration factor for that range. If the deviation exceeds 2% at any point, the best-fit non-linear equation which represents the data to within 2% of each test point shall be used to determine concentration.

SECTION III. Oxides of Nitrogen Analyser Calibration.

The chemiluminescent (CL) oxides of nitrogen (NO_x) analyser shall receive the following initial and periodic calibration:

(a) Prior to its introduction into service and weekly thereafter the CL NO_x analyser shall be checked for nitrogen dioxide (NO₂) to nitric oxide (NO) converter efficiency. Figure 1 is a reference for the following steps:

(1) Follow the manufacturer's instructions for instrument startup and operation. Adjust the analyser to optimise performance.

(2) Zero the analyser with zero-grade air or zero-grade N₂.

(3) Connect the outlet of the NO_x generator to the sample inlet of the NO_x analyser which has been set to the most common operating range.

(4) Introduce into the NO_x generator-analyser system an NO in N₂ mixture with an NO concentration equal to approximately 80 percent of the most common operating range. The NO₂ content of the gas mixture shall be less than 5 percent of the NO concentration.

(5) With the analyser in the NO mode, record the concentration of NO indicated by the analyser.

(6) Turn on the NO_x generator O₂ (or air) supply and adjust the O₂ (or air) flow-rate so that the NO indicated by the analyser is about 10 percent less than indicated in step (5). Record the concentration of NO in this NO + O₂ mixture.

(7) Switch the NO_x generator to the generation mode and adjust the generation rate so that the NO measured on the analyser is 20 percent of that measured in step (5). There must be at least 10 percent unreacted NO at this point. Record the concentration of residual NO.

(8) Switch the analyser to the NO_x mode and measure total NO_x. Record this value.

(9) Switch off the NO_x generation but maintain gas flow through the system. The analyser will indicate the NO_x in the NO + O₂ mixture. Record this value.

(10) Turn off the NO_x generator O₂ (or air) supply. The analyser will now indicate the NO_x in the original NO in N₂ mixture. This value should be no more than 5 percent above the value indicated in step (4).

(11) Calculate the efficiency of the NO_x converted by substituting the concentrations obtained into the following equation:

$$\text{Converter efficiency} = (1 + (a-b)/(c-d)) \times 100 \text{ percent}$$

where:

a = concentration obtained in step (8).

b = concentration obtained in step (9).

c = concentration obtained in step (6).

d = concentration obtained in step (7).

If converter efficiency is not greater than 90 percent corrective action will be required.

(b) Initial and periodic calibration. Prior to its introduction into service and monthly thereafter the CL NO_x analyser shall be calibrated on all normally used instrument ranges. Use the same flow-rate as when analysing samples. Proceed as follows:

(1) Adjust analyser to optimise performance.

(2) Zero the analyser with zero-grade air or zero-grade N₂.

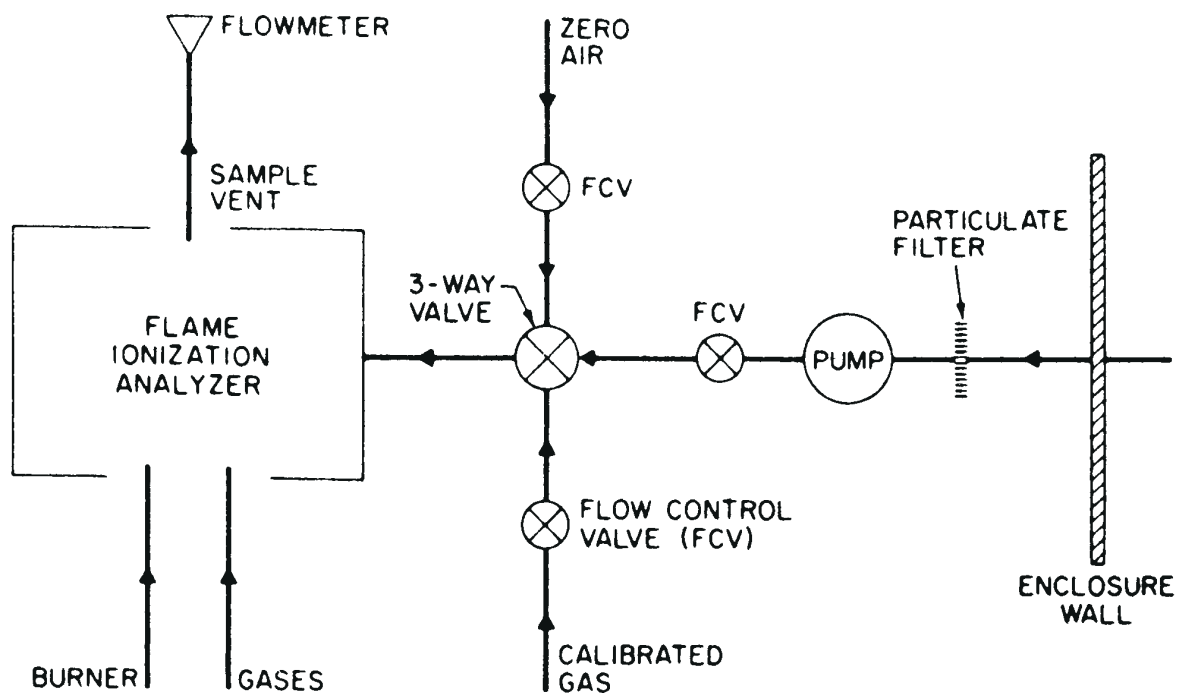
(3) Calibrate on each normally used operating range with NO in N₂ calibration gases having nominal concentrations of 15, 30, 45, 60, 75 and 90 percent of that range. For each range calibrated, if the deviation from a least-squares best-fit straight line is 2 percent or less of the value at each data point, concentration values may be calculated by 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.

SECTION IV. Carbon Dioxide Analyser Calibration.

Prior to its introduction into service and monthly thereafter the NDIR carbon dioxide (CO₂) analyser shall be calibrated:

(a) Follow the manufacturer's instructions for instrument startup and operation. Adjust the analyser to optimise

of 15, 30, 45, 60, 75 and 90 percent of that range. 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 use of a single calibration factor for that range. If the



Sample Train for Sealed Housing for Evaporative Determination.

performance.

(b) Zero the analyser with either zero-grade air or zero-grade N₂.

(c) Calibrate on each normally used operating range with CO₂ in N₂ calibration gases with nominal concentrations

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.

ANNEX G**CALIBRATION GASES**

SECTION I. Analyser Gases (refer Definitions Clause 37.1)

(a) Gases for the CO and CO₂ analyser shall be single blends of CO and CO₂ respectively using N₂ as the diluent.

(b) Gases for the HC analyser shall be single blends of propane using air as the diluent.

(c) Gases for the NO_x analyser shall be single blends of NO named as NO_x with a maximum NO₂ concentration of 5 percent of the nominal value using N₂ as the diluent.

(d) HC analyser fuel:

(1) The fuel shall contain less than one ppm equivalent carbon response;

(2) for exhaust emission measurement, fuel for the HC analyser shall be a blend of 40 ±2 percent by volume hydrogen with the balance being helium;

(3) for fuel evaporative emission measurement, fuel for the HC analyser shall be a blend of 40 ±2 percent by volume hydrogen with the balance being helium.

(e) for allowable zero grade gas (air or N₂) impurity concentration. (Refer to Definitions Clause 37.1).

(f) The use of proportioning and precision blending devices to obtain the required analyser gas concentration is allowable provided their accuracy has been established.

SECTION II. Calibration Gases

Calibration gases should be known to be within ±2 percent of the true values. They should have traceability to a recognised National Standard or to SAA Traceable Reference Material.

ANNEX H

ANNEX J

SEALED HOUSING FOR EVAPORATIVE DETERMINATION

CALIBRATIONS

(Alternative approved methods which yield equivalent results may be used)

The calibration of the SHED consists of three parts: Initial and periodic determination of SHED background emissions; initial determination of SHED internal volume; and periodic hydrocarbons retention check and calibration.

SECTION I. Initial and periodic determination of SHED background emissions.

Prior to its introduction into service, annually thereafter, and after any repair which can affect the SHED background emissions, the SHED shall be checked to determine that it does not contain materials which will themselves emit hydrocarbons. Proceed as follows:

(a) Zero and span (calibrate if required) the hydrocarbons analyser.

(b) Purge the SHED until a stable background hydrocarbons reading is obtained.

(c) Turn on the mixing fan.

(d) Seal SHED and measure background hydrocarbons concentration, temperature, and barometric pressure. These are the initial readings CHC_i , T_i and PBi for the SHED background determination.

(e) Allow the SHED to stand undisturbed without sampling for four hours.

(f) Measure the hydrocarbons concentration on the same analyser. This is the final concentration, CHC_f . Also measure final temperature and barometric pressure.

(g) Calculate the mass change of hydrocarbons in the SHED according to the equations in Section IV of this Annex. The SHED background emissions shall not be greater than 0.4 grams for the 4 hours.

SECTION II. Initial determination of SHED internal volume.

Prior to its introduction into service the SHED internal volume shall be determined by the following procedure:

(a) Carefully measure the internal length, width and height of the SHED, accounting for irregularities (such as braces) and calculate the internal volume.

(b) Perform a SHED calibration check according to steps (a) to (g) of Section III of this Annex.

(c) If the calculated mass does not agree within 2 percent of the injected propane mass, then corrective action is required.

SECTION III. Hydrocarbons retention check and calibration.

The hydrocarbons retention check provides a check upon the calculated volume and also measures the leak rate. Prior to its introduction into service and at least yearly thereafter the SHED leak rate shall be determined as follows:

(a) Zero and span (calibrate if required) the hydrocarbons analyser.

(b) Purge the SHED until a stable background hydrocarbons reading is obtained.

(c) Turn on the mixing fan.

(d) Seal SHED and measure background hydrocarbons concentration, temperature and barometric pressure. These are the initial readings CHC_i , T_i and PBi for the SHED calibration.

(e) Inject into the SHED a known quantity of propane. (4 grams is a convenient quantity). The propane may be measured by volume flow or by mass measurement. The method used to measure the propane shall have an accuracy and precision of $\pm 0.5\%$ of the measured value.

(f) After a minimum of 5 minutes of mixing, analyse the SHED atmosphere for hydrocarbons content, also record temperature and pressure. These measurements are the final readings for the SHED calibration as well as the initial readings for the hydrocarbons leak rate check.

(g) To verify the SHED calibration, calculate the mass of propane using the measurements taken in steps (d) and (f), and the equation in Section IV of this Annex. This quantity must be within $\pm 2\%$ of that measured in step (e) above.

(h) Allow the SHED to remain sealed for a minimum of 4 hours without sampling and with the mixing fan operating. After 4 hours analyse the SHED atmosphere for hydrocarbons content; record temperature and barometric pressure. This is the final reading for the hydrocarbons leak rate check.

(i) Calculate the hydrocarbons mass change, using the equation in Section IV of this Annex and the readings taken in step (h). It must not differ by more than 4% of that measured in step (e).

SECTION IV. Calculations

A calculation of hydrocarbons mass change is used to determine SHED background emissions and hydrocarbons leak rate. It is also used to check the SHED volume measurements. The mass change is calculated from the initial and final readings of hydrocarbons concentration, temperature ;and pressure according to the following equation:

$$M_{HC} = kV 10^{-4} \left(\frac{\pm CHC_f P_{Bf}}{E T_f} - \frac{CHC_i P_{Bi}}{T_i} \right)$$

where:

M_{HC} = Hydrocarbons mass change, in grams.

CHC = Hydrocarbons concentration, as ppm carbon equivalent.

NOTE: Hydrocarbons concentration is stated in ppm carbon equivalent, i.e. ppm propane times 3.

V = SHED volume, in cubic metres, as measured in Section II(a) of this Annex.

P_B = Corrected laboratory barometric pressure, in kPa.

T = SHED ambient temperature, in degrees K.

k = 17.60

Subscript i = Indicates initial reading.

Subscript f = Indicates final reading.

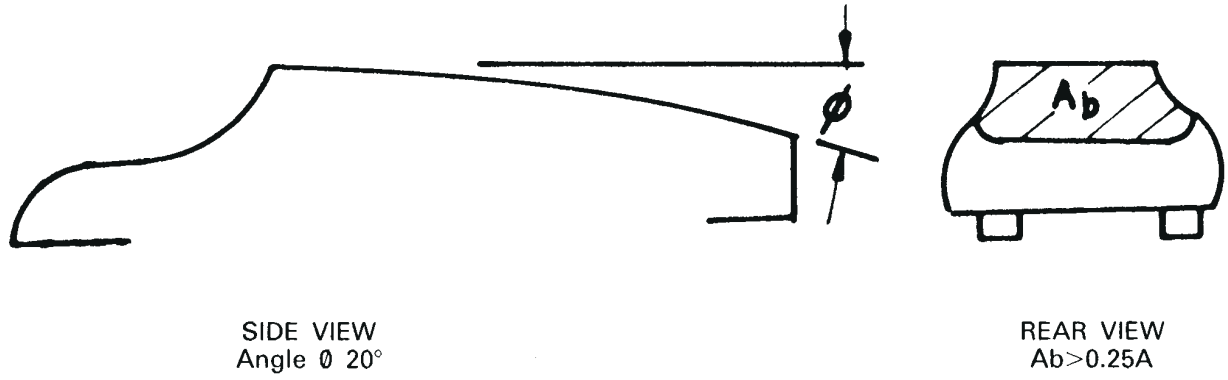


FIGURE 1

ANNEX K

DYNAMOMETER POWER ABSORPTION SETTING BY CALCULATION

The dynamometer road power absorber setting (RPAS) for a vehicle on a twin-roll dynamometer may be calculated using the following equation:

$$RPAS = aA + P + tw \quad \dots(\text{Equation 8.1})$$

where:

RPAS = the dynamometer road power absorber setting at 80 km/h, in kW.

a = 4.63 for “fastback-shaped” vehicles (see below).

= 5.38 for all other vehicles.

A vehicle is considered to have a “fastback shape” if the rearward projection of that portion of the rear surface (A_b) which slopes at an angle of less than 20 degrees from the horizontal is at least 25 percent as large as the vehicle reference frontal area. In addition, this surface must be smooth, continuous, and free from any local transitions greater than four degrees. An example of a ‘fastback shape’ is presented in Figure 1.

and where:

A = the vehicle’s reference frontal area defined as: “the area of the orthogonal projection of the vehicle (including tyres and suspension components, but excluding vehicle ‘protuberances’) onto a plane perpendicular to both the

longitudinal plane of the vehicle and the surface upon which the vehicle is positioned”;

Measurement of A shall be computed using a method approved in advance, and rounded to the nearest 0.01 square metres, using the “rounding off” method of ASTM E29-67.

P =the protuberance power correction factor, from Table 1 in kW.

The ‘protuberance frontal area’ (defined in a manner analogous to the definition of the vehicle reference frontal area, i.e. the total area of the orthogonal projections of the vehicle mirrors, hood ornaments, roof rack, and other protuberances onto a plane(s) perpendicular to both the longitudinal plane of the vehicle and the surface upon which the vehicle is positioned).

A ‘protuberance’ is defined as any fixture attached to the vehicle protruding more than 25 mm from the vehicle surface and having a projected area greater than 0.001 square metres, with the area calculated by a method approved in advance.

ANNEX K

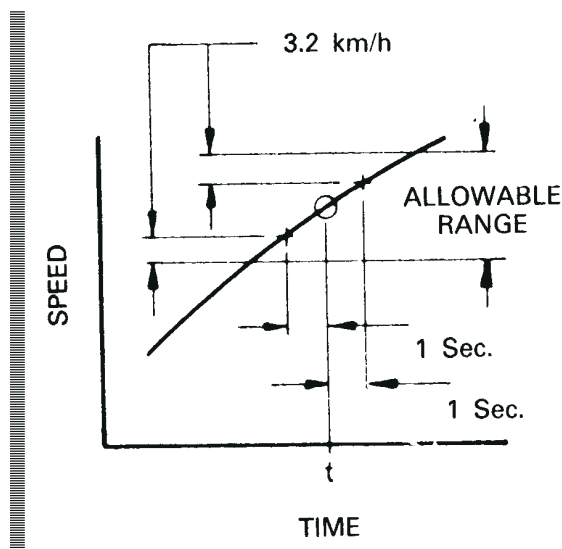


Figure 1

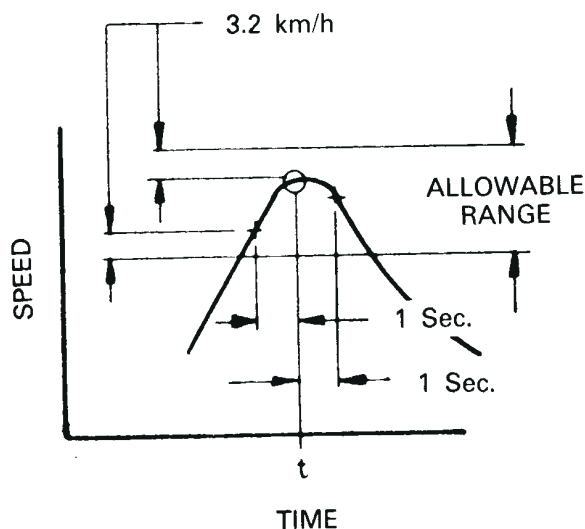


Figure 2

ACCEPTABLE SPEED TOLERANCES FOR DRIVE CYCLE

Figures 1 and 2 show the range of acceptable speed tolerances for typical points. Figure 1 is typical of portions of the speed curve which are increasing or decreasing throughout the 2 second time interval. Figure 2 is typical of portions of the speed curve which includes a maximum or minimum value.

TABLE 1

PROTUBERANCE FRONTAL AREA Ap (square metres)	PROTUBERANCE POWER CORRECTION FACTOR P (kilowatts)
Ap . @03	0.00
0.03 <Ap <.06	0.32
0.06 <Ap <.09	0.56
0.09 <Ap . <12	0.81
0.12 <Ap . <15	1.05
0.15 <Ap <.18	1.29
0.18 <Ap <.21	1.53
0.21 <Ap <.24	1.78
0.24 <Ap <.27	2.02
Ap . 27	2.26

Included in the total "protuberance frontal area" shall be all fixtures which occur as standard equipment. The area of any optional equipment shall also be included if it is expected that more than 33 percent of the vehicle engine family sold will be equipped with this option.

and where:

t = 0.0 for vehicles equipped with radial ply tyres.
 = 3×10^{-4} for all other vehicles.

w = vehicle equivalent test inertia mass (kg) from the Table given in Annex L.

ANNEX L

ROAD POWER ABSORBER SETTING v EQUIVALENT TEST INERTIA MASS

Reference Mass	Equivalent test Inertia Mass	Road Power Absorber Setting at 80 km/h
kg	kg	kW
Up to 481	454	4.4
482 to 538	510	4.6
539 to 595	567	4.8
596 to 652	624	5.0
653 to 708	680	5.3
709 to 765	737	5.5
766 to 822	794	5.7
823 to 878	850	6.0
879 to 935	907	6.2
936 to 992	964	6.4
993 to 1048	1021	6.6
1049 to 1105	1077	6.8
1106 to 1162	1134	7.0
1163 to 1219	1191	7.2
1220 to 1275	1247	7.4
1276 to 1332	1304	7.6
1333 to 1389	1361	7.7
1390 to 1445	1417	7.9
1446 to 1502	1474	8.0
1503 to 1559	1531	8.2
1560 to 1615	1588	8.4
1616 to 1672	1644	8.5
1673 to 1729	1701	8.6
1730 to 1786	1758	8.8
1787 to 1871	1814	9.0
Below this point, increment steps are 114 kg.		
1872 to 1984	1928	9.2
1985 to 209	2041	9.5
2098 to 2211	2155	9.7
2212 to 232	2268	10.0
2325 to 2438	2381	10.2
2439 to 2608	2495	10.4
above 2608	2722	10.7

ANNEX M