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(*पहला पुनरीक्षण*)

Draft Indian Standard

AUTOMOTIVE VEHICLES ─ EXHAUST EMISSIONS ─ GASEOUS POLLUTANTS FROM VEHICLES FITTED WITH COMPRESSION IGNITION ENGINES ─ METHOD OF MEASUREMENT

(First Revision)

ICS: 43.060.20; 19.060

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Automotive Primemovers, Transmission Systems and Internal Combustion Engine Sectional Committee, TED 2

FOREWORD

(Formal Clause to be added later)

The present day emphasis is on controlling of emissions from automobiles. This standard deals with the method of measurement of gaseous emissions from diesel engines. The method of measurement of black smoke emissions through the engine exhaust gases by means of standard smoke meter are dealt separately by IS 8118 ‘Smoke emission levels for diesel vehicles’ which prescribes the determination of smoke density in terms of light absorption coefficient in Bosch and Hartridge Units. However, for the approval of diesel engines for vehicular applications, in-factory measurement of CO, HC and NOx, a draft was considered necessary by the committee.

In this first revision following changes have been incorporated:

a) References, ICS No. have been updated; and

b) Other editorial changes have been done to bring the standard in the latest style and format of Indian Standards.

With the increasing emphasis on environment, the Government of India has already come out with legislation under Central Motor Vehicle Rules for the new vehicles fitted with compression ignition (diesel) engines to check and confirm that the gaseous pollutants in the exhaust of the vehicles are within the prescribed limits.

While preparing the standard considerable assistance has been taken from the following:

ECE R 49	Uniform provisions concerning the approval of diesel engines with regard to the emission of gaseous pollutants.
Annexure-V of Ranganathan Committee Report	Details of standards for emission of gaseous pollutants from diesel engine vehicles and test procedures effective from 01.04.1992. (Part V of Doc No. MOST/CMVR/TAP-115-116)

The composition of the Committee responsible for the formulation of this standard is given at Annex C **(Will be added later).**

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off it shall be done in accordance with IS 2: 2022 ‘Rules for rounding off numerical values (*Second Revision*)’

Draft Indian Standard

AUTOMOTIVE VEHICLES ─ EXHAUST EMISSIONS ─ GASEOUS POLLUTANTS FROM VEHICLES FITTED WITH COMPRESSION IGNITION ENGINES ─ METHOD OF MEASUREMENT

(First Revision)

1 SCOPE

This standard covers the test procedures for the measurement and determination of gaseous pollutants from vehicles fitted with compression ignition (diesel) engine and also the requirements of the component to be used for the tests.

2 REFERENCES

The following Indian Standards contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
14599: 1999	Automotive vehicles — Performance requirements of internal combustion engines — Method of test
14600: 1999	Automotive vehicles — Exhaust emissions — Gaseous pollutants from vehicles equipped with spark ignition engines — Method of measurement

3 TERMINOLOGY

For the purpose of this standard the following definitions shall apply.

3.1 Compression Ignition Engine ─ Means an internal combustion engine which operates on compression ignition principle (Diesel Engines).

3.2 Maximum Rated Speed ─ Means the maximum speed permitted by governor at full load, unless otherwise declared by the manufacturer.

3.3 Minimum Rated Speed ─ Means either the highest of the following three engine speeds:

a) 45 percent of maximum net power speed;
b) 1000 rev/min; and
c) minimum speed permitted by the idling control, or such lower speed as the manufacturer may request.

3.4 Percent Load ─ Means the fraction of the maximum available torque at an engine speed.

3.5 Intermediate Speed ─ Means the speed corresponding to the maximum torque value if such speed is within the range of 60 to 75 percent of rated speed; in other cases it means a speed equal to 60 percent of rated speed.

3.6 Net Power ─ Means the power obtained on a test bench at the end of the crankshaft or its equivalent (if power measurement can be carried out only on an engine with the gear box mounted, the efficiency of the gearbox shall be taken into account) at the corresponding engine speed with the auxiliaries listed in Table 1 of IS 14599 and determined under reference atmospheric conditions specified in it.

3.7 Unladen Mass ─ Means the mass of the vehicle in running order without crew, passengers or load, but with the fuel tank 90 percent full and the usual set of tools and spare wheel on board where applicable.

3.8 Gross Vehicle Weight (GVW) ─ Means the technically permissible maximum weight declared by the vehicle manufacturer.

3.9 Gaseous Pollutants ─ Means carbon monoxide, hydrocarbons (assuming a ratio of CH 1.85) and oxides of nitrogen (expressed in nitrogen dioxide NO_2 equivalent).

3.10 Cold Start Device ─ Means a device which enriches the air-fuel mixture of the engine temporarily and thus to assist engine start-up.

3.11 Starting Aid ─ Means a device which assists the engine start-up without enrichment of the fuel mixture, for example, glow plug, change of injection timing, etc.

3.12 Vehicle Model ─ Means a category of power driven vehicle which do not differ in such essential respects of the vehicle characteristics which affect the vehicular emission and as listed in Annex B of IS 14599.

4 DESCRIPTION OF THE TEST

4.1 Measurement Principle

The test shall be carried out with the engine mounted on a test bench and connected to a dynamometer. The gaseous emissions from the exhaust of the engine include hydrocarbons, carbon monoxide and oxides of nitrogen. During a prescribed sequence of warmed up engine operating conditions the amounts of the above gases in the exhaust shall be examined continuously. The prescribed sequence of operations consist of a number of speed and power modes which span the typical operating range of diesel engines. During each mode the concentration of each pollutant, exhaust flow and power output shall be determined and the measured values weighted and used to calculate the grams of each pollutant emitted per kilowatt hour, as outlined in this standard.

4.2 Test Equipment

4.2.1 *Dynamometer and Engine Equipment*

The following equipment shall be used for emission tests of engines on engine dynamometers.

4.2.1.1 An engine dynamometer with adequate characteristics to perform the test cycle specified in **4.3.1**.

4.2.1.2 The accuracy of measuring instruments for speed, torque, fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and section flow resistance, air inlet temperature, atmospheric pressure, fuel temperature and humidity shall satisfy the method of measuring the power of the internal combustion engines of road vehicles specified in IS 14599.

4.2.1.3 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures for the duration of the prescribed engine tests.

4.2.1.4 A non-insulated and uncooled exhaust system extending at least 0.5 m past the point where the exhaust probe is located, and presenting an exhaust back pressure within ±650 Pa of the upper limit at the maximum rated power, as established by the engine manufacturer's sale and service literature for vehicle application.

4.2.1.5 An engine air inlet system presenting an air inlet restriction within ±300 Pa of the upper limit for the engine operating condition which results in maximum air flow, as established by the engine manufacturer for an air cleaner, for the engine being tested. When an engine is tested for exhaust emissions, the complete engine shall be tested with all standard accessories which might reasonably be expected to influence emissions to the atmosphere installed and functioning as listed in IS 14599.

4.2.2 *Exhaust Gas Sampling System*

4.2.2.1 The exhaust gas sampling system shall be designed to enable the measurement of the true mass emissions of the exhaust

4.2.2.2 The probe shall extract a true sample of the exhaust gases.

4.2.2.3 The system shall be free of gas leaks. The design and materials shall be such that the system does not influence the pollutant concentration in the exhaust gas.

4.2.2.4 The various valves used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

4.2.3 Analytical Equipment

4.2.3.1 Pollutant gases shall be analyzed with the following instruments:

a) *Carbon monoxide (CO) and carbon dioxide (CO_2) analysis* — The carbon monoxide and carbon dioxide analysers shall be of the non-dispersive infrared (NDIR) absorption type.

b) *Hydrocarbon (HC) analysis* — The hydrocarbon analyser shall be of the flame ionization type with the whole flame ionization detector (FID) system maintained at a temperature between 423 K and 473 K. It shall be calibrated with propane gas of equivalent to carbon atoms (C_1).

c) *Nitrogen oxide (NOx) analysis* — The nitrogen oxide analyzer shall be of the Chemiluminescent (CLA) type with an NOx-NO converter or heated Chemiluminescent (HCLA).

d) *Accuracy* — The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants:

Measurement errors shall not exceed ±3 percent disregarding the true value of the calibration gases.

For concentrations of less than 100 ppm the measurement error shall not exceed ±3 ppm. The ambient air sample shall be measured on the same analyser and range as the corresponding diluted exhaust sample.

e) Annex A describes the analytical systems recommended. Other systems of analysers which have proved to give equivalent results may be used.

f) Annex B outlines the method of measurement of efficiency of the NOx converter.

4.2.4 Gases

4.2.4.1 The following pure gases shall be available when necessary, for calibration and operation:

Gas	Purity
Purified nitrogen	$\leq$ 1 ppm C, $\leq$ 1 ppm CO, $\leq$ 400 ppm CO_2, $\leq$ 0.5 ppm NO;
Purified synthetic air	$\leq$ 3 ppm C, $\leq$ 1 ppm CO, $\leq$ 400 ppm CO_2, $\leq$ 0.5 ppm NO; Oxygen content between 18 and 21 percent volume;
Purified oxygen	> 99.5 percent O_2 by volume
Purified hydrogen (and mixture containing hydrogen)	< 1ppm C, < 400 ppm CO_2.

4.2.4.2 *Calibration and span gases*

Gases having the following chemical compositions shall be available:

a) C_3H_8 and purified synthetic air **(***see* **4.2.4.1);**
b) CO and purified nitrogen; and
c) CO_2 and purified nitrogen.

NO and purified nitrogen (the amount of NO_2 contained in this calibration gas must not exceed 5 percent of the NO content).

4.2.4.3 The true concentration of a calibration gas shall be within ±2 percent of the stated figure.

4.2.4.4 The concentrations specified in **4.3.3** below may also be obtained by means of a gas divider, diluting with purified nitrogen or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined within ±2 percent.

4.3 Description of the Test

4.3.1 *Test Cycle*

The following 13-mode cycle shall be followed in dynamometer operation on the test engine:

Mode No.	Engine Speed	Percent Load
1	Idle	—
2	Intermediate	10
3		25
4		50
5		75
6		100
7	Idle	—
8	Rated	100
9		75
10		50
11		25
12		10
13	Idle	—

4.3.2 *Measurement of Exhaust Gas Flow*

For calculation of the emission it is necessary to know the exhaust flow, as given in **4.3.8** below. For determination of exhaust flow either of the following methods may be used.

4.3.2.1 Direct measurement of the exhaust flow by flow nozzle or equivalent metering system.

4.3.2.2 Measurement of the air flow and the fuel flow by suitable metering systems and calculation of the exhaust flow by the following equations:

$$G_{EXH} = G_{AIR} + G_{FUEL}$$

or

$$V'_{EXH} = V_{AIR} - 0.75\ G_{FUEL}$$

or

$$V''_{EXH} = V_{AIR} + 0.77\ G_{FUEL}$$

Where;

G_{EXH} — exhaust gas mass flow rate on wet basis in kg/h;

V'_{EXH} — exhaust gas volume on dry basis in m^3/h;

V''_{EXH} — exhaust gas volume on wet basis m^3/h;

G_{AIR} — intake air mass flow rate in kg /h;

V_{AIR} — intake air volume flow rate in m^3/h; and

G_{FUEL} — fuel mass flow rate in kg/h;

4.3.2.3 The accuracy of exhaust flow determination shall be ± 2.5 percent or better.

4.3.2.4 The concentration of carbon monoxide and nitric oxide are measured in the dry exhaust. For this reason, the CO and NOx emissions shall be calculated using the dry exhaust gas volume V_{EXH}. If the exhaust mass flow rate (G_{EXH}) is used in the calculation the CO and NOx concentrations shall be related to the wet exhaust. Calculation of the HC emission shall include G_{EXH} and V_{EXH} according to the measuring method used.

4.3.3 *Operating and Calibrating Procedure for Analysers and Sampling System*

The operating procedure for analysers shall follow the start-up and operating instructions of the instrument manufacturer. The following minimum requirements shall be included

4.3.3.1 *Establishment of calibration curve*

a) The analyser calibration curve shall be established by at least five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 90 percent of the full scale.

b) The calibration curve is calculated by the least square method. If the degree of the polynomial resulting from the curve is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

c) The calibration curve shall not differ by more than ±2 percent from the nominal value of calibration gas of each calibration point.

d) The different characteristic parameters of the analyser, particularly the scale, the sensitivity, the zero point and the date of carrying out the calibration shall be indicated on the calibration curve.

e) It can be shown to the satisfaction of the testing authority, that alternative technology, for example, computer, electronically controlled range switch, etc, can give equivalent accuracy, then these alternatives may be used.

4.3.3.2 *Verification of calibration*

a) The calibration procedure shall be carried out as often as necessary and in any case within one month preceding the type approval emission test and once in six months for verifying conformity of production

b) The verification shall be carried out using standard gases. The same gas flow rates shall be used as when sampling exhaust.

c) A minimum of two hours shall be allowed for warming up the analyzers.

d) The NDIR analyser shall be tuned, where appropriate, and the flame combustion of the FID analyser optimised.

e) Using purified dry air (or nitrogen), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser. Using appropriate calibrating gases mentioned in **3.2.4** above, the analysers shall be reset.

f) The zero setting shall be rechecked and the procedure outlined in (d) and (e) above shall be repeated, if necessary.

g) The calibration curves of the analysers shall be verified by checking at least at five calibration points, spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be at least equal to 90 percent of the full scale. It shall meet the requirement of (c) above.

h) If it does not meet, the system shall be checked, fault, if any, corrected and a new calibration curve shall be obtained.

4.3.3.3 *Pretest checks*

a) A minimum of two hours shall be allowed for warming up the infrared NDIR analyser, but it is preferable that power be left on continuously in the analysers. The chopper motors may be turned off when not in use.

b) Each normally used operating range shall be checked prior to each analysis.

c) Using purified dry air (or nitrogen), the CO and NOx analysers shall be set at zero; dry air shall be purified for the HC analyser.

d) Span gas having a concentration of the constituent that gives a 75-95 percent full-scale deflection shall be introduced and the gain set to match the calibration curve. The same flow rate shall be used for calibration, span and exhaust sampling to avoid correction for sample cell pressure.

e) The nominal value of the span calibration gas used shall remain within ±2 percent of the calibration curve.

f) If it does not, but it remains within ±5 percent of the calibration curve, the system parameters such as gain of the amplifier, turning of NDIR analysers, optimization of FID analysers, etc, may be adjusted to bring within ±2 percent.

g) If the system does not meet the requirement of (e) and (f) above, the system shall be checked, fault, if any, corrected and a new calibration curve shall be obtained.

h) Zero shall be checked and the procedures outlined in (c) and (d) above shall be repeated, if required.

4.3.4 *System Leak Test*

A system leakage test shall be performed. The probe shall he disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilization period all flow meters and pressure gauges shall read zero. If not, the sampling line(s) shall be checked and the fault corrected.

4.3.5 Fuel

The fuel shall be the reference fuel specified in IS 14599.

4.3.6 *Atmospheric Factor*

4.3.6.1 This factor is obtained by applying the formula:

Naturally aspirated and Mechanically supercharged engines.

$$F = (99/P_s) \times (T/298)^{0.7}$$

Turbo charged engines without charge air cooling or charge cooling by air/air cooler:

$$F = (99/P_s)^{0.7} \times (T/298)^{1.2}$$

Turbo charged engines with charge air cooling by engine coolant:

$$F = (99/P_s)^{0.7} \times (T/298)^{0.7}$$

Where

$P_s =$ the total dry atmospheric pressure in kPa, that is, the total barometric pressure minus water vapour pressure; and

T = the absolute temperature in kelvin (K) of the laboratory.

4.3.6.2 For a test to be recognized as valid, the parameter F shall be between 0.98 and 1.12.

4.3.7 *Test Run*

During each mode of the test cycle, the specified speed shall be held to within ±50 rpm and the specified torque shall be held to within ±2 percent of the maximum torque at the test speed. The fuel temperature at the injection pump inlet shall be 311±5 K. The governor and fuel system shall be adjusted as established by the manufacturer's sales and service literature. The following steps shall be taken for each test.

4.3.7.1 Instrumentation and sample probes shall be installed as required.

4.3.7.2 The cooling system shall be started.

4.3.7.3 The engine shall be started and warmed up until all temperatures and pressures have reached equilibrium.

4.3.7.4 The torque curve at full load shall be determined by experimentation to calculate the torque values for the specified test modes.

4.3.7.5 The emission analysers shall be set at zero and spanned.

4.3.7.6 The test sequence as given in **4.3.1** above shall be started. The engine shall be operated for six minutes in each mode, completing engine speed and load changes in the first minute. The responses of the analysers shall be recorded on a strip chart recorder for the full six minutes with exhaust gas flowing through the analysers at least during the last three minutes, the engine speed and load, intake air temperature and vacuum exhaust back pressure, fuel flow and air or exhaust flow shall be recorded during the last five minutes of each mode, with the speed and load requirements being met during the last minute of each mode.

4.3.7.7 Any additional data required for calculation shall be read and recorded.

4.3.7.8 The zero and span settings of the emission analysers shall be checked and reset, as required, at least at the end of the test. The test shall be considered satisfactory if the adjustment necessary after the test does not exceed the accuracy of the analysers specified in **4.2.3.**

4.3.8 *Chart Reading*

During the last 60 seconds of each mode the average chart reading for HC, CO and NOx shall be determined. The concentration of HC, CO and NOx during each mode shall be determined from the average chart readings and the corresponding calibration data. However, a different type of recording can be used if it ensures an equivalent data acquisition.

4.4 Calculations

4.4.1 The final reported test results shall be derived through the following steps.

4.4.1.1 The exhaust gas mass flow rate G_{EXH}, or V'_{EXH} and V''_{EXH} shall be determined as given in **4.2** above for each mode.

4.4.1.2 When applying G_{EXH}, the measured carbon monoxide and nitric oxide concentration shall be converted to a wet basis according to **4.5.**

4.4.1.3 The NOx concentration shall be corrected according to **4.6.**

4.4.1.4 The pollutant mass flow for each mode shall he calculated as follows:

$$NOx_{mass} = 0.001587 \times (NOx_{conc}) \times (G_{EXH})$$

$$CO_{mass} = 0.000\ 966 \times (CO_{conc}) \times (G_{EXH})$$
$$HC_{mass} = 0.000\ 478 \times (HC_{conc}) \times (G_{EXH})$$

OR

$$NOx_{conc} = 0.002\ 05 \times (NOx_{conc}) \times (V'_{EXH})$$
$$CO_{mass} = 0.00125 \times (CO_{conc}) \times (V'_{EXH})$$
$$HC_{mass} = 0.000618 \times (HC_{conc}) \times (V''_{EXH})$$

4.4.2 The emissions shall be calculated in the following way:

$$NOx = (NOx_{mass} \times WF) / (P \times WF)$$

$$CO = (CO_{mass} \times WF) / (P \times WF)$$

$$HC = (HC_{mass} \times WF) / (P \times WF)$$

Where;

P — net power output uncorrected, kW;
CO — carbon monoxide emission, g/kWh;
HC — hydrocarbon emission, g/kWh;
NOx — emission of oxides of nitrogen, g/kWh;
Conc — concentration (ppm by volume), ppm:
Mass — pollutant mass flow, g/h; and
WF — weighing factor.

The weighing factors used in the above calculation are according to the following table:

Mode No.	*WF*
1	0.25/3
2	0.08
3	0.08
4	0.08
5	0.08
6	0.25
7	0.25/3
8	0.10
9	0.02
10	0.02

11	0.02
12	0.02
13	0.25/3

4.5 Conversion of CO and NOx Concentration to a wet basis. The CO and NOx exhaust gas concentration as measured in this procedure are on a dry basis. To convert the measured values to the concentrations, present in the exhaust (wet basis), the following relationship may be employed:

$$\text{ppm (wet basis)} = \text{ppm (dry basis)} \times [1 — (1.85 \times G_{FUEL}/G_{AIR})]$$

where

G_{FUEL} =the fuel flow, kg/s; and
G_{AIR} = the air flow, kg/s.

4.6 Correction Factor for Nitric Oxide for Humidity

The values of the nitric oxides shall be multiplied by the following humidity correction factor:

$$1/[1+ A \text{ x } (7m — 75) + 1.8 \times B \times (T\text{-}302)]$$
$$A = 0.044 \text{ x } (G_{FUEL} / G_{AIR}) — 0.0038$$
$$B = 0.005\,3 — 0.116 \text{ x } (G_{FUEL}/G_{AIR})$$

Where

m — humidity of the inlet air in grams of water per kilogram of dry air;

T — temperature of the air in Kelvin; and

G_{FUEL}/G_{AIR} — fuel air ratio (dry air basis)

ANNEX A

[*Clause* 4.2.3.1(e)]

ANALYSIS SYSTEM

A-1 SCOPE

A-1.1 This Annex describes the analysis system mentioned in **4.2.3.1**(e).

A-1.2 Two analytical systems are specified based on the use of FID analyser for the measurement of hydrocarbons, and NDIR analyser for the measurement of CO and the alternative choice of CLA and equivalent analysers for the measurement of NOx.

A-2 SYSTEM 1

A schematic diagram of the analytical and sampling system using the chemiluminescent analyser for measuring NOx is shown in Fig. 1.

SP — Stainless steel sample probe, to obtain samples from the exhaust system. A closed end, multihold static probe extending at least 80 percent across the exhaust pipe is recommended. The exhaust gas temperature at the probe shall be not less than 343 K.

HSL — Heated sampling line, temperature shall be kept between 423 K and 473 K, the line shall be made in stainless steel or FIFE.

F_1 — Heated pre-filter, if used; temperature shall be the same as HSL.

T_1 — Temperature readout of sample stream entering oven compartment.

V_1 — Suitable valving for selecting sample, span gas or air gas flow to the system. The valve shall be in the oven compartment or heated to the temperature of the sampling line.

V_2 ,V_3 — Needle valves to regulate calibration gas and zero gas.

F_3 — Filter to remove particulates. A 70 mm diameter glass fibre type filter disc is suitable. The filter shall be readily accessible and changed daily or more frequently, as needed.

P_1 — Heated sample pump.

G_1 — Pressure gauge to measure pressure in sample line.

V_4 — Pressure regulator valve to control pressure in sample line and flow detector.

FID — Heated flame ionization detector for hydrocarbons. Temperature of oven shall be kept between 423 K and 473 K.

FL_1 — Flow meter to measure sample by-pass flow

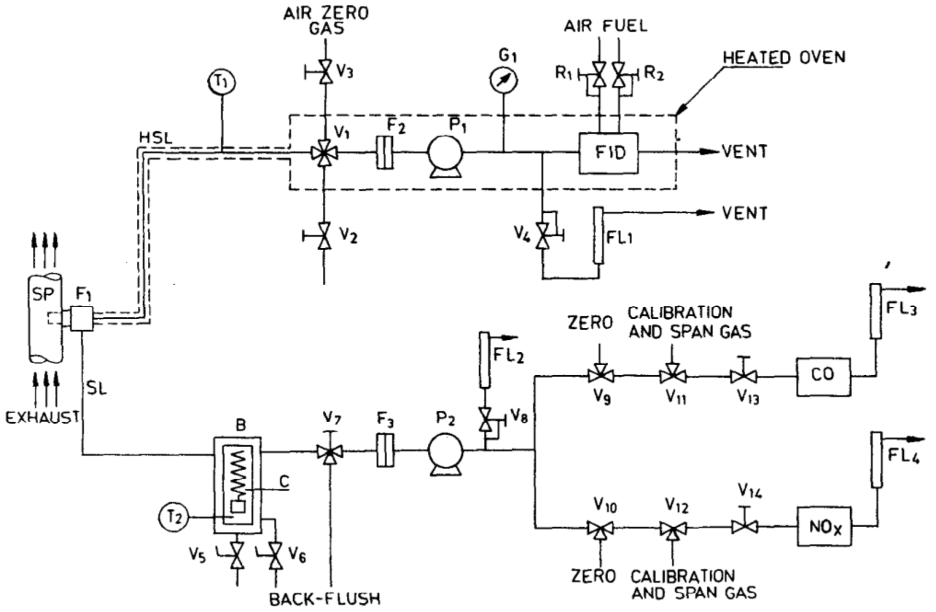

Fig.1 Flow Diagram of Exhaust Gas Analysis System for CO, NOx, HC (NOx analysis by CLA)

R_1, R_2 — Pressure regulators for air and fuel.

SL — Sample line, the line shall be made in PTFE or in stainless steel. it may be heated or unheated.

B — Bath to cool and condense water from exhaust sample. The bath shall be maintained at a temperature of 273 to 277 K by ice or refrigeration.

C — Cooling coil and trap to condense and collect water vapour. A coiled 2.5 to 3mm stainless steel line attached to '2.5mm diameter, 150mm length trap would be typical.

T_2 — Temperature readout of bath temperature.

V_5 ,V_6 —Toggle valves to drain condensate traps bath.

V_7 — Three-way valve.

F_3 — Filter for removing particular contaminants from sample prior to analysis A glass fibre type of at least 70mm diameter is suitable.

P_2 — Sample pump.

V_8 — Pressure regulator to control sample flow.

V_9 ,V_{10} — Three-way ball valve or solenoid valves to

V_{11},V_{12} — direct sample, zero gas or calibrating gasstreams to the analyzers.

V_{13},V_{14} — Needle valves to regulate flows to the analysers.

CO — ND1R analyser for carbon monoxide.

NOx — CLA analyser for nitric oxides.

FL_2, FL_3, FL_4 — By-pass flowmeters.

A-3 SYSTEM 2

A schematic diagram of the analytical and sampling system using the NDIR analyser for measuring NO is shown in Fig 7.

Where,

SP — Stainless steel sample probe, to obtain samples from the exhaust system. A closed end, multi-hole static probe extending at least 80 percent across the exhaust pipe is recommended; the temperature at the probe shall be at least 373 K. The probe shall be located in the exhaust line at a distance of 1–5 m from the exhaust manifold outlets flange or the outlet of the turbocharger.

HSL — Heated sampling line, temperature shall be kept between 423 K and 473 K., the line shall be made in stainless steel or PTFE.

F_1 — Heated pre-filter, if used; temperature shall be the same as the HSL.

T_1 — Temperature readout of sample stream entering oven compartment.

V_1 — Suitable valving for selecting sample, span gas or air zero gas flow to the system. The valve shall be in the oven compartment or heated to the temperature of the sampling line.

V_2, V_3 — Needle valves to regulate calibration gas and zero gas.

F — Filter to remove particulates. A 70mm diameter glass fibre type filter disc is suitable. The filter shall be readily accessible and changed daily or more frequently, as needed.

P_1 — Heated sample pump.

G_1 — Pressure gauge to measure pressure in sample line.

V_4 — Pressure regulator valve to control pressure in sample line and flow to detector.

FID — Heated flame ionization detector for hydrocarbons. Temperature of oven shall be kept between 423 K and 473 K.

FL_1 — Flowmeter to measure sample by-pass flow.

R_1, R_2 — Pressure regulators for air and fuel.

SL — Sample line. The line shall be made in PTFE or in stainless steel.

B — Bath to cool and condense water from exhaust sample. The bath shall be maintained at a temperature of 273 to 277 K by ice or refrigeration.

C — Cooling coil and trap to condense and collect water vapour. A coiled 2.5 – 3 mm Stainless Steel line attached to 2.5 mm diameter, 150 mm length trap would he typical.

T — Temperature readout of bath temperature.

V_5, V_6 — Toggle valves to drain condensation trap and bath.

V_7 — Three-way valve.

F_3 — Filter for removing particulate contaminates from sample prior to analysis. A. glass fibre type of at least 70 mm diameter is suitable.

P_2 — Sample pump.

V_8 — Pressure regulator to control sample flow.

V_9 — Ball or solenoid valve to direct sample, zero gas or calibrating gas streams to the analysers.

V_{10} , V_{11} — Three – way valve to by – pas drier.

D — Drier to remove moisture in the sample stream/ If a drier is used before NOx analyser it shall have minimum effect on NOx concentration.

V_{12} — Needle valve to regulate flow to the analysers.

G_2 — Gauge to indicate inlet pressure to the analysers.

CO — NDIR analyers for carbon monoxide.

NOx — NDIR analyers for nitric oxides.

FL_2, FL_3 — By-Pass flowmeter.

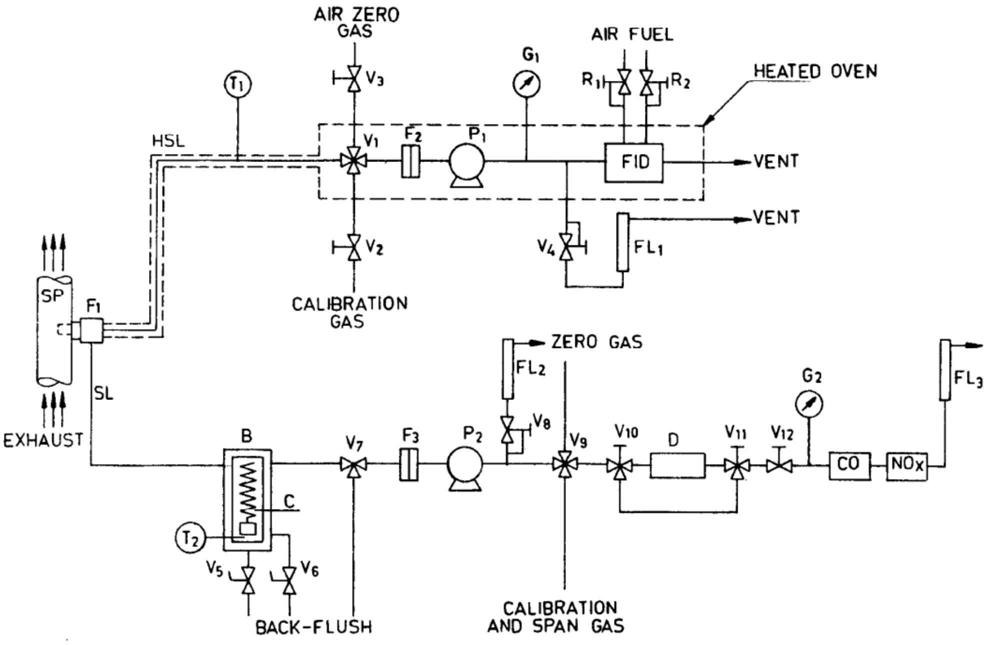

Fig. 2 Flow Diagram of Exhaust Gas Analysis System for CO_2, NO_X, HC (NOx Analysis by NDIR)

ANNEX B

[*Clause* 4.2.3.1(f)]

MEASUREMENT OF EFFCIENCY

B-1 SCOPE

B-1.1 This Annex describes the efficiency test of the NOx converter mentioned in **4.2.3.1 (f)**. Using the test set up as shown at the end of this Annex and the procedure below, the efficiency of converters can be tested by means of an ozonator.

B-1.2 Calibrate the *CLA* in the most common operation range complying with manufacturer's recommendations using zero and span gas (the NO content of which shall amount to about 80 percent of the operating range and the NO_2 concentration of the gas mixture to less the 5 percent of the NO concentration.) The NOx analyser shall be in the NO mode so that the span gas does not pass through the converter. Record the indicated concentration.

B-1.3 Via a *T* fitting, oxygen shall be added continuously to the gas flow until the concentration indicated is about 10 percent less than the indicated calibration concentration given in **B-1.2**. Record the indicated concertation (c). The ozonator is kept deactivated throughout the process.

B-1.4 The ozonator is now activated to generate enough ozonc to bring the NO concentration down to 20 percent (minimum 10 present) of the calibration concentration given in **B-1.2**. Record the indicated concentration *(d)*.

B-1.5 The NO analyser is then switched to the NOx mode which that the gas mixture (consisting of NO_2 O_2 and N_2) now through the converter. Record the indicated concentration (a).

B-1.6 The ozonator is now deactivated. The mixture of gases described in **B-1.3** passes through the converter into the detector. Record the indicated concentration *(b).*

B-1.7 With the ozontor deactivated, the flow of oxygen or synthetic air is also shut off. The NO_2 reading of the analyser shall then be no more than 5 percent above the value given in **B-1.2**.

B-2 CALCULATION

B-2.1 Calculation of the efficiency of the NOx converter:

$$\text{Efficiency (Percent)} = \left\{1 + \frac{a-b}{c-d}\right\} \times 100$$

B-2.2 The efficiency of the converter shall be tested prior to each calibration of the NOx analyser. The efficiency of the converter shall not less than 95 percent.

NOTE — If the analyser operating range is above the highest range that the NOx generator can operate to give a reeducation from 80 to 20 percent, then the highest range the NOx generator operates on shall be used.

ANNEX C

(*Foreword*)

COMMITTEE COMPOSITION

AUTOMOTIVE PRIMEMOVERS, TRANSMISSION SYSTEMS AND INTERNAL COMBUSTION ENGINE SECTIONAL COMMITTEE, TED 02

Will be added later