

CHAPTER III : TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF 4 GAS ANALYSER

1. PURPOSE

The introduction of stringent emission regulation for post year 2000 vehicles in India requires exhaust gas instrument capable of measuring gasoline vehicle exhaust emissions under idling conditions with high accuracy and lower detectable values of CO, HC emissions. The new generation vehicles require lambda measurement to ensure efficient working of closed loop electronic engine management system fitted with 3-way catalytic converter and lambda sensor. This document based on the ISO 3930:2000 (E) is prepared for such exhaust gas analysers.

2. SCOPE

This document specifies the metrological, technical requirements and tests for measuring instruments [hereafter termed “instrument(s)”, that serve to determine the volume fractions of certain components of the exhaust gases emanating from motor vehicles, and establishes the conditions with which such instruments must comply in order to meet any CMVR performance requirements.

It is applicable to instruments particularly to those used according to the procedure defined in CMVR TAP Document intended for the inspection and maintenance of vehicles having spark ignition engines. (both 2 and 4 stroke)

These instruments are used to determine the volume fraction of one or more of the following exhaust gas components:

- _ Carbon monoxide (CO)
- _ Carbon dioxide (CO₂)
- _ Hydrocarbons (HC, in terms of n-hexane) and
- _ Oxygen (O₂)

at the moisture level condition of the sample as analyzed .

This document covers instruments whose principle of detection is based on infrared absorption in gases for CO, CO₂ and HC. Oxygen is generally measured with a fuel cell. It is not intended, however, to exclude any other types of instruments that although based on other principles of detection meet the specified metrological and technical requirements and satisfy the associated tests.

Reference : This document is based on the ‘ISO 3930:2000(E) : Instruments for measuring vehicular exhaust gas emissions’.

3.0 TERMS AND DEFINITIONS

For the purposes of this documentation, the following terms and definitions shall apply.

3.1 Sampling probe

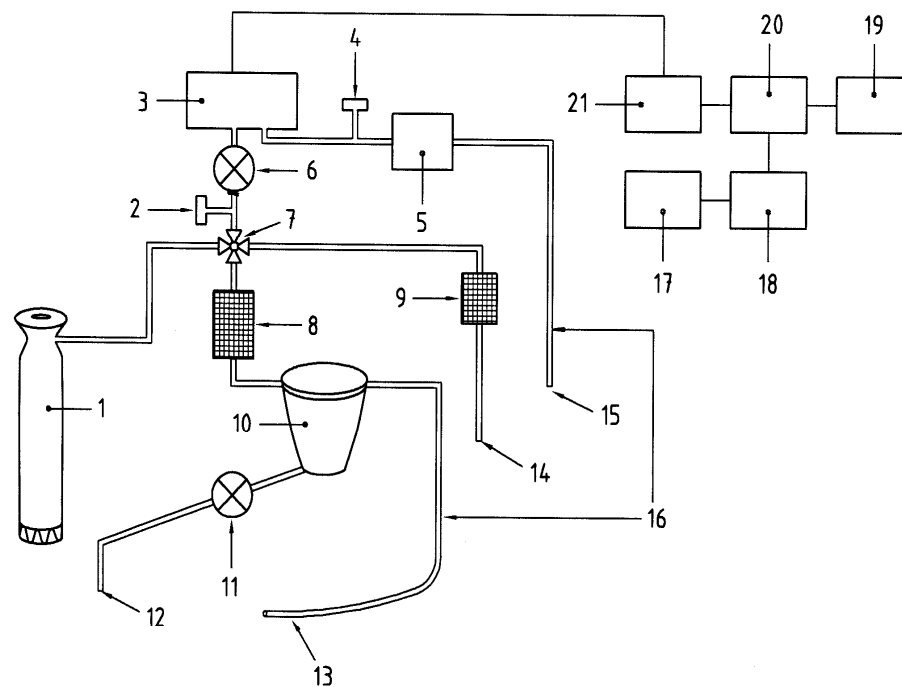
Tube that is introduced into the exhaust tail pipe of a vehicle to take gas samples,

- 3.2 **Water Separator**
- Water separator device that removes water to a level that prevents condensation within the gas handling system downstream from its location
- 3.3 **Filter unit**
- Device that removes particulate matter from the exhaust gas sample
- 3.4 **Gas Handling System**
- All instrument components from the sampling probe to the gas sample outlet, through which the exhaust gas sample is conveyed by the pump.
- 3.5 **Adjustment (of a measuring Instrument)**
- Operation of bringing a measuring instrument into a state of performance suitable for its use (VIM:1993,4.30)
- 3.6 **User adjustment (of a measuring Instrument)**
- Adjustment employing only the means at the disposal of the user. (VIM:1993, 4.31)
- 3.7 **Manual adjustment facility**
- Facility allowing the adjustment of the instrument by the user
- 3.8 **Semi-automatic adjustment facility**
- Facility allowing the user to initiate an adjustment of the instrument without having the possibility of influencing its magnitude whether the adjustment is automatically required or not.
- Note : For those Instruments that require the values of the calibration gas to be entered manually, the facility is considered to be semi-automatic.
- 3.9 **Automatic adjustment facility**
- Facility performing the adjustment of the instrument as programmed without the intervention of the user, to initiate the adjustment or its magnitude.
- 3.10 **Zero-setting facility**
- Facility to set the indication of the instrument to zero.
- 3.11 **Calibration gas adjustment facility**
- Facility to adjust the instrument to the value of a calibration gas.
- 3.12 **Internal adjustment facility**
- Facility to adjust the instrument to a designated value without the use of an external calibration gas.

- 3.13 Warm-up time
- Elapsed time between the instant powers is applied to an instrument and the instant at which the instrument is capable of complying with the metrological requirements.
- 3.14 Response time
- Time interval between the instant when the instrument is subjected to a specified abrupt change in gas mixture composition and the instant when the response reaches within specified limits of its final steady value.
- 3.15 Error (of indication)
- Indication of a measuring instrument minus a true value of the corresponding input quantity. (VIM:1993, 5.20)
- 3.16 Intrinsic error
- Error of a measuring instrument, determined under reference conditions. (VIM:1993, 5.24)
- 3.17 Absolute error of measurement
- Result of a measurement minus the conventional true value of the measurand.
- 3.18 Relative error
- Absolute error of measurement divided by the conventional true value of the measurand.
- 3.19 Fault
- Difference between the error of indication and the intrinsic error of the instrument.
- 3.20 Significant fault
- Fault, the magnitude of which is greater than the magnitude of the maximum permissible error on initial verification.
- NOTE : The following faults are considered not to be significant.
- a) Fault arising from simultaneous and mutually independent causes in the instrument itself or in its checking facilities
 - b) Faults implying the impossibility to perform any measurement
 - c) Transitory faults being momentary variations in the indication, which cannot be interpreted, recorded or transmitted as a measurement result and
 - d) Faults giving rise to variations in the measurement results that are so large as to be noticed by all users of the instruments.

- 3.21 Influence quantity
- Quantity that is not the measurand but which affects the result of the measurement. (VIM:1993, 2.7)
- 3.22 Rated operating conditions
- Conditions of use giving the ranges of the influence quantities for which the metrological characteristics of an instrument are intended to lie within the specified maximum permissible errors.
- 3.23 Influence factor
- Influence quantity having a value within the rated operating conditions of the instrument.
- 3.24 Disturbance
- Influence quantity having a value within the limits specified in this document but outside the rated operating conditions of the instrument.
- 3.25 Reference conditions
- Conditions of use prescribed for testing the performance of Instrument or for inter-comparison of results of measurements. (VIM:1993, 5.7)
- 3.26 Checking facility
- Facility that is incorporated in the instrument and that enables significant faults to be detected and acted upon.
- NOTE : “Acted upon” means any adequate response by the Instrument (luminous or acoustic signal, by blocking of process, etc.)
- 3.27 **Automatic checking facility**
- Checking facility operating without the intervention of the user.
- 3.27.1 **Permanent automatic checking facility (type P)**
- Automatic checking facility operating during each measurement cycle.
- 3.27.2 **Intermittent automatic checking facility (type I)**
- Automatic checking facility operating at certain time intervals or per fixed number of measurement cycles.
- 3.28 Test
- Series of operations intended to verify the compliance of the Equipment under test (EUT) with specified requirements.

- 3.29 Lambda
- Dimensionless value representative of the burning efficiency of an engine in terms of the air/fuel ratio in the exhaust gases and determined with a referenced standardized formula.
- 3.30 Calibration gas
- Stable gas mixture of known concentration used for periodic calibration of the instruments and for various performance tests.
- 3.31 Modulus (of a number) absolute value
- Value of the number without regard to its sign.
- 3.32 **Hand-held instrument**
- Type of portable instrument that can be transported by one person with its standard accessories, and that rests on a suitable surface during use or mounted on a suitable trolley.
- 4.0 **DESCRIPTION OF THE INSTRUMENTS**
- 4.1 **Generally, the instruments shall provide a means for sampling and then measuring the exhaust gases emitted from the tail pipe of a motor vehicle. A pump shall be provided to transport the gas sample through a gas sample handling system. One or more detection devices may be used and incorporated in the gas handling system to analyze the sample and provide signals related to the volume fractions of gas components of interest, namely CO, CO₂, HC and O₂ . The detector signals are then electrically processed to display and record the results of a measurement in volumetric units of the gas components together with other important related information such as a lambda value calculation.**
- 4.2 Acceptable overall performance of the Instrument is dependent upon its various components for the associated characteristics.
- An example of an instrument using gas calibration for adjustment is shown in Fig 1.**



Key

- | | | |
|--|---------------------------------------|------------------------------------|
| 1 Calibration gas input (6.1.5) | 8 Filter gas (6.1.3) | 15 Gas output |
| 2 Differential pressure sensor (6.1.7) | 9 Charcoal filter (6.1.5) | 16 Gas handling system (6.1.8) |
| 3 CO, CO ₂ and HC analysis | 10 Water separator (6.1.4) | 17 Seals (6.3.8) |
| 4 Atmospheric pressure sensor | 11 Water pump | 18 Adjustment facilities (6.2) |
| 5 O ₂ analysis | 12 Water output | 19 Interfaces (6.1.9) |
| 6 Gas pump (6.1.6) | 13 Sampling probe (6.1.2) | 20 Indicating device (6.2 and 6.3) |
| 7 Electrovalve | 14 Gas input for zero-setting (6.1.5) | 21 Signal conversion |

Figure 1 — Diagrammatic illustration of an instrument for measuring vehicle exhaust emissions (references in parenthesis are to the relevant subclauses in the text)

4.3 **The major Instrument components are as follows:**

- a sampling probe introduced in the tail pipe of an operating motor vehicle to collect the exhaust gas sample
- a hose with associated tubing connected to the probe to provide a path for the gas sample to enter, pass through and exit the Instrument
- a pump to convey the gases through the Instrument
- a water separator to prevent water condensation from forming in the Instrument
- **a filter to remove particulate matter that could cause contamination of various sensitive parts of the Instrument**
- Ports downstream from the water separator and filter to introduce ambient air and calibration gas when required by the technology used. The calibration gas port should have a suitable provision for connection to the pressurized 10 / 47 litre gas cylinders by the means of 1/4" Teflon tube and compression tube fitting.
- Detection devices to analyze the gas sample into its components according to volume fractions
- a data system to process the signal and an indicating device to display the results of a measurement and
 - a control facility to initiate and check Instrument operations and a manual, semi-automatic, or automatic adjustment facility to set Instrument operating parameters within prescribed limits.

Either a built-in printer and/or an RS 232 serial interface through which the data can be transferred to a PC.

- 4.4 The instrument will be supplied with an exhaust extension pipe as a standard accessory. The extension pipe connection should be leak proof and should be universally adaptable to the exhaust pipe, where probe insertion of 300mm is not possible.

5.0 **METROLOGICAL REQUIREMENTS**

5.1 ***Indication of the measured result***

The volume fractions of the gas components shall be expressed as a percentage (% vol) for CO, CO₂ and O₂ and in parts per million (ppm vol) for HC. The permanent inscriptions for these units or electronic display shall be assigned unambiguously to the indication, for example “%vol CO”, “%vol CO₂”, “% vol O₂” and “ppm vol HC”

5.2 **Measuring range**

The minimum indicating ranges shall be as:

CO:	0-5 %vol
CO ₂ :	0-16 %vol
HC:	0-10000 ppm vol
O ₂ :	0-21 %vol

5.3 **Resolution of indication**

5.3.1 Digital indication

Digital figures shall be at least 5 mm high. The least significant figure of the display shall provide a resolution equal to or one order of magnitude higher than the values given below:

Minimum resolutions:

CO:	0.01 %vol
CO ₂ :	0.1 %vol
HC:	1 ppm vol
O ₂ :	0.02 %vol for measurand values ≤ 4 %vol

0.1 % vol for measurand values > 4 %vol

5.4 Maximum permissible errors

5.4.1 **Maximum permissible intrinsic errors**

Maximum permissible errors shall apply for an Instrument under the reference conditions.

CO:	Absolute: ± 0.06 %vol	Relative: ± 3 % whichever is greater
CO ₂ :	Absolute: ± 0.4 %vol	Relative: ± 4 % whichever is greater
HC:	Absolute: ± 12 ppm vol	Relative: ± 5 % whichever is greater
O ₂ :	Absolute: ± 0.1 %vol	Relative: ± 3 % whichever is greater

5.4.2 **Maximum permissible errors on initial verification**

Maximum permissible errors shall apply for an Instrument at initial verification under the Rated Operating conditions.

CO: Absolute: ± 0.06 %vol Relative: ± 5 % whichever is greater
CO₂: Absolute: ± 0.5 %vol Relative: ± 5 % whichever is greater
HC: Absolute: ± 12 ppm vol Relative: ± 5 % whichever is greater
O₂: Absolute: ± 0.1 %vol Relative: ± 5 % whichever is greater

5.4.3 Maximum permissible errors on subsequent verification

The maximum permissible errors on subsequent verification shall be equal to the errors on initial verification.

5.5 Influence quantities

5.5.1.1 Reference conditions

- a) Temperature: $25\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$
- b) Relative Humidity : $60\text{ \%} \pm 10\text{ \%}$
- c) Atmospheric Pressure : Stable ambient
- d) Mains voltage: $\pm 2\%$ Nominal voltage $\pm 1\%$, Nominal frequency
- e) Presence of influencing gas components: None except the measurands in N₂

NOTE : In case of Infrared technology, a relative humidity range from 30% to 60% is acceptable.

5.5.1.2 Rated Operation Conditions

- a) Temperature: 5°C to 45°C
- b) Relative Humidity : up to 90 %
- c) Atmospheric Pressure: :860 hPa to 1060 hPa
- d) Mains voltage variation : $-15\text{ \%}$ to $+10\text{ \%}$ of the nominal voltage, $\pm 2\text{ \%}$ of the nominal frequency.

If a battery is used to power the instrument, the limits of power supplied shall be within the instrument manufacturer's specifications. In case the battery power drops outside the limits, there should be an indication on the instrument and it should not be possible to make any measurement with the instrument. If a portable generator is used, its requirements shall comply with the specifications for the mains voltage.

5.5.3 Influence of gases other than the measurand (cross sensitivity)

The design of the instruments shall be such that measurements do not vary by more than half the modulus of the maximum permissible error on initial verification when gases other than the measurand are present in the following maximum volume fractions:

16 %vol CO₂

6 %vol CO

0.3 %vol NO

5 % vol. H₂

10 % vol O₂

5000 ppm vol HC (as n-hexane)

water vapor up to saturation.

However the presence of H₂ is not necessary for testing the O₂ channel and the presence of H₂ and O₂ is not necessary in case of Infrared technology.

5.6 Disturbances

Significant faults as defined in (Significant fault) shall not occur or shall be detected and acted upon by means of checking facilities for the following disturbances:

- a) Mechanical shock and vibrations
- b) Short time power reductions
- c) Bursts from the mains (transients)
- d) Electrostatic discharges
- e) Radiated radio frequency electromagnetic fields
- f) Mains frequency magnetic fields.

5.7 Response time

For measuring CO, CO₂ and HC, Instrument including the specified gas handling system shall indicate 95 % of the final value (as determined with calibration gases) within 15 s or less after changing from a gas with zero content. For measuring O₂ the instruments shall indicate a value differing less than 0.1 % vol. of the final value within 60 s after changing from air to oxygen-free calibration gas.

5.8 Warm-up time

After the warm-up time, the Instruments shall meet the metrological requirements as stated in this document. – Instruments shall have the means to prevent measurement and an indication of measured gas volume fractions during the warm-up time. Instruments shall have a warm-up time not exceeding 10 min.

5.9 Propane/hexane equivalency factor

The content of hydrocarbons shall be expressed in ppm vol *n*-hexane (C₆ H₁₄) equivalent. The adjustment may be carried out using propane (C₃ H₈). Therefore, a conversion factor referred to as “C₃ /C₆ Equivalence Factor”, or PEF, shall be permanently and conspicuously marked or easily displayed on each instrument. Alternatively, display of an array of conversion factors is allowed provided that the associated volume fractions are also displayed. The manufacturer shall provide the conversion factor(s) for each individual instrument to three significant figures. If the gas-sensitive element is replaced or repaired, the new conversion factor(s) shall be attached to the Instrument. For Instruments with one single conversion factor, the measuring values obtained when tested with *n*-hexane shall not differ by more than the applicable maximum permissible error from the curve established with propane. For instrument capable of displaying an array of conversion factors, the measuring values obtained when tested with *n*-hexane shall not differ by more than half the value of the applicable maximum permissible error from the curve established with propane.

NOTE: The value for this factor is usually between 0.490 and 0.540.

5.10 Lambda calculation

Instruments equipped with a lambda indication shall carry out the appropriate calculation for different fuel options such as petrol, CNG, LPG with a suitable formula for lambda values between 0.8 and 1.2, the maximum permissible error in the calculation with respect to the resolution and the application of the chosen formula shall not exceed 0.3 %. For this purpose, the conventional true value will be calculated according to the following formula:

$$\lambda = \frac{[\text{CO}_2] + \frac{[\text{CO}]}{2} + [\text{O}_2] + \left\{ \left(\frac{H_{cv}}{4} \times \frac{3,5}{3,5 + \frac{[\text{CO}]}{[\text{CO}_2]}} - \frac{O_{cv}}{2} \right) \times ([\text{CO}_2] + [\text{CO}]) \right\}}{\left(1 + \frac{H_{cv}}{4} - \frac{O_{cv}}{2} \right) \times \{ ([\text{CO}_2] + [\text{CO}]) + (K_1 \times [\text{HC}]) \}}$$

Where

[] is the concentration in %vol, for HC only in ppm vol

K₁ is the conversion factor for HC if expressed in ppm vol *n*-hexane (C₆H₁₄) equivalent. Its value in this formula is 6 x 10⁻⁴

H_{cv} is the atomic ratio of hydrogen to carbon in the fuel. The arbitrary value is 1.7261

O_{cv} is the atomic ratio of oxygen to carbon in the fuel. The arbitrary value is 0.0176

The lambda value shall be displayed digitally to four figures and shall be identified by an appropriate symbol or sign (e.g. lambda or λ) in any of the following format:

Lambda = x.xxx

OR

$\lambda = x.xxx$

For analysers not equipped with oxygen channel but capable of calculating A/F ratio (air to fuel) an A/F / Lambda indication shall be carried out using a suitable formula. The details of the formula will be provided.

For lambda values between 0.8 and 1.2, the maximum permissible error in the calculation with respect to the resolution and the application of the chosen formula shall not exceed 0.3 %. For this purpose, the conventional true value will be calculated according to the following formula.

Lambda = 1 / AF

$$A/F = 2.088 \times \frac{100 + 0.46 CO_2 - 0.060 CO - THC}{CO_2 + CO + THC}$$

Where CO, CO₂ are vol % and THC in Vol % C1.

5.11 ***Stability with time or drift***

When used in accordance with the manufacturer's operating instructions, the measurements made by the Instruments, under stable environmental conditions and after adjustment using a calibration gas or the internal adjustment facility, shall remain within the maximum permissible errors on initial verification for at least 4 h without the need for calibration gas or internal readjustments by the user.

If the Instruments are equipped with a means for drift compensation, such as automatic zero or automatic internal adjustment, then the action of such adjustments control shall not produce an indication/display that can be confused with a measurement of an external gas. It should not be possible to pass the gas sample and measure the same while the automatic adjustments are in process.

5.12 ***Repeatability***

For 20 consecutive measurements, using the same calibration gas mixture, carried out by the same person with the same Instrument within relatively short time interval the experimental standard deviation of the 20 results shall

not be greater than one third of the modulus of the “maximum permissible error on initial verification” taken from 5.4.2 for the relevant gas mixture.

5.13 Engine Speed Measurement System

The speed measurement range of the measurement system shall be minimum from 200 to 6000 rpm with the resolution of 10 rpm. The accuracy of speed measurement shall be ± 20 rpm or $\pm 2\%$ of the reading, whichever is greater and the rpm display shall be updated at least at 0.5 s time interval.”

6.0 TECHNICAL REQUIREMENTS

6.1 Construction

6.1.1 All components of the sample gas handling system shall be made of corrosion-resistant material in particular, the material of the sampling probe shall withstand the exhaust gas temperature. The materials used shall not influence the composition of the gas sample.

6.1.2 The sampling probe shall be so designed that it can be inserted at least 300 mm into the exhaust tail pipe of the vehicle and held in place by a retaining device regardless of the depth of insertion.

6.1.3 The sample gas handling system shall contain a filter with reusable or replaceable filter elements capable of removing dust, soot or like particles larger than 5 μm in diameter. It shall be possible to use the Instruments for a period of at least 15 minutes with exhaust gas from a specially adjusted test engine having an HC fraction concentration of approximately 6000 ppm. It shall be possible to observe the degree of a filter’s contamination without its removal, and it shall also be possible to replace, when necessary, this filter easily without special tools.

6.1.4 The sample gas handling system shall contain a water separator to prevent water condensation from forming in the measuring transducer. In the case of saturation of the separator, it shall empty automatically or manually. In any case the measurement operation shall be automatically stopped if there is a danger of water going inside the measuring transducer with water filled in the water separator.

6.1.5 In addition to the probe, Instruments equipped with an HC measurement channel shall have:

A port for drawing in ambient air or other gas without hydrocarbons to provide a reference for zero-setting of the measuring instrument. For this purpose, ambient air shall pass through a charcoal filter or equivalent system. Instruments without an HC channel may also be equipped with this additional port. Oxygen measuring cells cannot use ambient air for zero-setting. if zero-setting is required an oxygen-free gas should be used.

Another additional port shall be provided in the sample gas handling system for introducing calibration gas.

Both ports shall be located downstream of the water separator and filter unit in order to minimize potential contamination of the gases introduced.

A means shall be provided to maintain the same pressure within the detector during zero setting, gas calibration, and sampling.

6.1.6 The sampling pump conveying the exhaust gas shall be mounted so that its vibrations do not affect the measurements. It shall be possible to turn the pump on and off separately from the other instrument components by the user however, it shall not be possible to make a measurement when the pump is switched off. Instrument is required to purge and back-flush the sample gas handling system automatically with ambient air before the pump is switched off.

6.1.7 The instruments shall be equipped with a device that indicates when the gas flow rate decreases to a level that would cause the detection to exceed the response time and/or half the modulus of the maximum permissible error on initial verification and when that limit is reached, the device shall prevent measurements.

6.1.8 The sample gas handling system shall be airtight to such an extent that the influence of dilution with ambient air on the measuring results shall not be more than:

_ for CO, CO₂ and HC: half the modulus of the “maximum permissible error on initial verification”

_ for O₂: 0.1 %vol.

A leakage test system / device along with procedure with sufficient accuracy to detect this specific maximum leakage shall be provided in the manufacturer’s operating instructions.

Instruments shall not be able to make a measurement if this value is exceeded.

6.1.9 The Instrument shall be equipped with an RS 232 interface permitting coupling to any peripheral devices or instruments. An interface shall not allow the metrological functions of the instruments or their measurement data to be inadmissibly influenced by the peripheral devices, by other interconnected instruments, or by disturbances acting on the interface. Functions that are performed or initiated via an interface shall meet the relevant requirements and conditions of the Clause “Technical requirements”.

If the Instrument are connected to a data printer then the data transmission from the Instrument to the printer shall be designed so that the results cannot be falsified. It shall not be possible to measure and or print out a document or test report or test certificate for legal purposes, if the

Instrument checking facility(ies) detect(s) a significant fault or a malfunction Instrument.

6.2 *Adjustment facilities*

6.2.1 The Instrument shall have an adjustment facility that provides operations for zero-setting, gas calibration (if applicable), and internal adjustment.

6.2.2 The facility shall be automatic for zero-setting and internal adjustment.

6.2.3 The internal adjustment shall neither influence the adjusted zero nor the linearity of the response of the Instruments and these shall be coupled to any adjustment made with a calibration gas. A method for coupling shall be provided such that each time a gas calibration is conducted, the gas value and the internal adjustment value are adjusted and the indication equals the calibration gas value.

6.2.4 Instrument shall be provided with a means to observe negative indications near zero for certain tests.

6.3 *Security of operation*

6.3.1 The instruments shall be designed and manufactured such that when exposed to any of the disturbances listed in 5.6

Significant faults do not occur or are detected and acted upon by means of a checking facility. If this is achieved by the use of automatic self-checking facilities, then it shall be possible to check the correct functioning of such facilities.

6.3.2 The Instruments with an HC-channel shall be equipped with a checking facility for detecting HC gas residues. This facility serves to ascertain that before a measurement is made the value indicated is less than 20 ppm vol *n*-hexane for an ambient air sample taken through the probe.

6.3.3 Instrument shall not be able to make a measurement if the HC residue value exceeds 20 ppm vol *n*-hexane. If the measuring instrument are provided with the measuring cycle, this requirement shall be fulfilled at the beginning of each measuring cycle otherwise the manufacturer shall indicate what constitutes the beginning of the measurement.

6.3.4 Instruments with an O₂-channel shall be equipped with a device for automatically recognizing any malfunctioning of the sensor due to aging or a break in the connecting line.

6.3.5 Instrument shall be controlled by an automatic self-checking facility that shall operate in such a way that before a measurement can be indicated or printed, all internal adjustments, calibration gas adjustments, and all other checking facility parameters shall be confirmed for proper values or status (i.e. within limits). The Semi or Automatic checking facility for the Instrument, as a minimum requirement shall cover following:

Warm-up check: Permanent Automatic

Low flow and Leak check: Always on POWER ON

Gas calibration check : once in a day

HC residue check : Always on POWER ON and before each measurement.

6.3.6 Instruments and peripheral devices like PC equipped with an automatic adjustment facility or a semi-automatic adjustment facility shall not be able to make a measurement until correct adjustments have been completed.

6.3.7 Instruments and peripheral devices like PC equipped with a semi-automatic adjustment facility shall not be able to make a measurement when an adjustment is required.

6.3.8 A means for warning of a required adjustment may be provided for both automatic and semi-automatic adjustment facilities.

6.3.9 Effective sealing devices shall be provided on all parts of the Instrument that cannot be materially protected in another way against operations liable to affect the accuracy or the integrity of the instruments. This applies in particular to:

- _ adjustment means
- _ peripheral hardware
- software integrity
- _ disposable oxygen fuel cell.

6.3.10 For instruments without a pressure-compensating device, daily calibration is required. The operating instructions shall contain this requirement.

6.3.11 A battery-operated instrument shall either continue to function correctly or not indicate any values whenever the voltage is below the manufacturer's specified value.

7.0 ***INSCRIPTIONS AND OPERATING INSTRUCTIONS***

7.1 ***Inscriptions***

7.1.1 The instruments shall have a permanent and easily readable label or labels giving the following information:

- a) Manufacturer's trade mark/corporate name
- b) Year of manufacture
- c) CMVR type approval designation
- d) Type approval certificate number & model number
- e) Serial number of the instrument and of the measuring transducer
- f) Minimum and nominal flow rate

- g) Nominal mains voltage, frequency and power required
- h) Gas components and respective maximum measured value
- i) Type description and model of the oxygen fuel cell.

7.1.2 Furthermore, the value of the propane/hexane equivalency factor for each Instrument shall be marked permanently on the front panel of the Instrument or shall be displayable on the indicating device. In the case where more than one single propane/ hexane equivalency factor is available, these factors shall be displayed with the associated concentrations.

7.2 *Operating instructions*

7.2.1 The manufacturer shall provide written operating instructions for each instrument in the English language.

7.2.2 The operating instructions shall include:

- a) The time intervals and the procedures for adjustment and maintenance that shall be followed to comply with the maximum permissible errors
- b) A description of the leakage test procedure
- c) An instruction for the user to conduct an HC-residue check prior to each HC measurement, including a description of the HC-residue check procedure
- d) The maximum and minimum storage temperatures
- e) A specification of the voltage and frequency required of any portable generator consistent with 5.5.2, taking into account varying load conditions typical of those encountered at the location of use
- f) A statement of the rated operating conditions
- g) In case a lambda value is calculated, a description of the applied formula and
- h) An instruction for the replacement of the oxygen fuel cell.
- i) The description of the possible errors along with test data if the instrument is used for the temperature up to 50 °C and frequency variations of 48 to 52 Hz.

8.0 METROLOGICAL CONTROLS

8.1 *Type approval*

8.1.1 Documentation

The documentation for an Instrument supplied by the manufacturer when applying for type approval shall include:

- a) A description of its general principle of measurement
- b) A list of its essential components with their characteristics
- c) A description of its essential components with drawings and diagrams that is necessary for testing and maintenance
- d) The general information on the software required for a microprocessor equipped measuring Instrument
- e) For Lambda calculation or A/F calculation or as included, a description of the applied formula with the values of the parameters and physical constants incorporated and evidence showing that the requirement of 5.10 is met shall be indicated in operating manual.
- f) The operating instructions that shall be provided to the user.

Along with an application for type approval, the manufacturer shall provide any data or other information that may support the assertion that the design and construction of the Instrument complies the requirements.

8.1.2 General requirements

Type approval shall be carried out on at least one and normally not more than three units, which represent the definitive pattern. The evaluation shall consist of the tests specified here under:

8.1.3 Inspection and tests

The inspection and testing of Instrument is intended to verify compliance with the requirements of Clauses 4.3, 5, 6 & 7.

As a rule, tests should be carried out on the complete Instrument or along with its connected peripheral devices like PC if these devices need to be compulsorily used for operating the instruments. However, if these devices are used only for printing / data acquisition purposes, the tests will be carried out on the instruments. The peripheral devices will not be subjected to all the environmental conditions but will be verified by the test agencies for the proper operation. If the size or configuration of the Instrument do not render it suitably to being tested as a unit, or, if only a particular component or device of the Instrument is concerned, a test may be carried out on the component or device separately. Such tests may only be performed if a simulated measurement set-up can be achieved that reflects the rated operating conditions of the component or device.

The contents of gas mixtures used during type approval shall conform to those specified in annex. A (normative) (generally a measurand gas in N₂). For initial verification, subsequent verification and routine testing, the use of more realistic gas mixtures containing CO, CO₂ and HC in N₂ when applicable, should be considered.

Note It is not intended that the instrument or its components should be dismantled for a test.

- 8.1.3.1 An Instrument shall be given a visual inspection to obtain a general appraisal of its design and construction.
- 8.1.3.2 An Instrument shall be tested according to clause 9 to determine its correct functioning.
- 8.1.3.3 The manufacturer's written operating instructions for an Instrument shall be checked to ensure that correct procedures are clearly indicated, especially those specified in 7.2.

8.2 Initial verification

8.2.1 General requirements

A new Instrument shall undergo initial verification only after type approval. The verification shall be carried out using suitable testing means and certified calibration gases.

8.2.2 Inspection and tests

- 8.2.2.1 Initial verification of an Instrument includes a visual inspection to determine conformance with the approved type approval. NOTE: Procedures should be provided for initial verification. An example of such a procedure is given in Annexure-C (Informative).
- 8.2.2.2 After adjusting an Instrument according to the routine adjustment procedure described in the manufacturer's operating instructions, tests to determine its errors shall be carried out under rated operating conditions at several values over the measuring range. The tests shall be performed using gas mixtures of at least three different volume fractions within the nominal ranges of the measurands as listed below:

Gas Concentrations Nominal range

CO : 0.5 %vol to 5 %vol

CO₂ : 4 %vol to 16 %vol

HC : 100 ppm vol to 10000 ppm vol as *n*-hexane

For all classes Oxygen channel should be tested for zero reading and span reading using a calibration gas without oxygen (only CO and/or CO₂ and/or HC in N₂) and a calibration gas containing 20.9 %vol O₂ .

The calibration gases shall be introduced at the sample probe inlet at ambient pressure (to within 750 Pa). The errors observed shall be within the limits of the maximum permissible error of 5.4.2 on initial verification for each measurement.

8.3 Subsequent verification

Clear and unambiguous Instructions about requirements and intervals for subsequent verification and advice about routine testing shall be provided in the Operating manuals and all other related documents for e.g. Service Manual, etc.

Note : Examples of procedures for subsequent verification for routing testing are given in Annexes D & E (Informative) respectively.

Note 2 –The user should be informed that measurements of volume fractions below the lower limits specified during initial verification will result in large relative errors, even though the absolute errors may remain within acceptable limits. The user should be promptly informed of current applicable lower limit values. These large relative errors should be carefully considered before using such low volume fractions to evaluate vehicle emission performance.

9.0 PERFORMANCE TESTS FOR APPROVAL

Prior to the type approval tests and as specified in the manufacturer's operating instruction manual provided (under 8.1.1.F), to be supplied with each Instrument, the instrument shall be adjusted with calibration gases according to these instructions provided. The calibration gases shall be supplied at the sample probe inlet at ambient pressure (to within 750 Pa).

9.1 Check of the calibration curve

This test shall be carried out according to Clause A.2, under reference conditions. During this test, the errors shall not exceed the maximum permissible intrinsic error of 5.4.1 for any measurement.

9.2 Stability with time or drift

This test shall be carried out according to Clause A.3, under reference conditions. During this test, the requirements of 5.11 shall be met.

9.3 Repeatability

This test shall be carried out according to Clause A.4 under reference conditions. During this test, the requirements of 5.12 shall be met.

9.4 Effect of influence quantities

As a rule, only one influence quantity shall be varied during a test while all others are kept at their reference values.

9.4.1 Environmental conditions and electrical supply

The indications of the Instruments shall remain within the maximum permissible error on initial verification during the following tests covering the rated operating conditions specified in 5.5.2 except for power supply variations that shall not cause a variation of indication larger than half the modulus of the maximum permissible error on initial verification.

- a. Dry heat : See Clause A.5
- b. Cold : See Clause A.6
- c. Damp heat, steady state : See Clause A.7
- d. Atmospheric pressure : See Clause A.8
- e. Power supply variation : See Clause A.9

9.4.2 Influence of gas components other than the measurand (cross sensitivity).

This test shall be carried out under reference conditions except for 5.5.1E

During this test, the requirements of 5.5.3 shall be met where the absolute value of the variation of the indication found shall not exceed half the modulus of the maximum permissible error on initial verification.

9.5 Disturbances

Significant faults shall not occur, or shall be detected by means of checking facilities during the following tests when carried out to verify the requirements of 5.6 for the instruments under rated operating conditions (as specified in 5.5.2)

- a) Mechanical shock and vibrations (See Point A.11)
- b) Short time power reductions (See Point A.12)
- c) Bursts from the mains (transients) (See point A.13)
- d) Electrostatic discharges (See point A.14)
- e) Radiated radio frequency electromagnetic fields (See Point A.15)
- f) Mains frequency magnetic fields. (See Point A.16)

9.6 Other important technical and metrological requirements

The Instrument shall be tested for conformity to the following Requirements:

- a) Warm up time according to 5.8 : See Clause A.17
- b) Response time according to 5.7 : See Clause A.18
- c) Low flow according to 6.1.7 : See Clause A.19
- d) Leakage according to 6.1.8 : See Clause A.20
- e) HC residue according to 6.3.2 : See Clause A.21
- f) Filter unit according to 6.1.3 : See Clause A.22
- g) Water separator according to 6.1.4 : See Clause A.23

h) Propane / Hexane equivalency factor according to 5.9 : See Clause A.24

i) Engine Speed Measurement System: See Clause A.25

9.7 Source of power for Pattern Evaluation

The appropriate source of power for field use of Instruments shall be specified in the manufacturer's operating instructions. If a source of power is specified in addition to the mains, for example a battery or Portable generator, then the Instrument shall undergo type approval tests with each source of power with which it is intended to operate.

Each specified test in Annexure – A (normative / mandatory) shall be started and completed without changing or recharging the power source.

ANNEXURE – A (NORMATIVE / MANDATORY)

**DESCRIPTION OF PERFORMANCE TESTS FOR
TYPE APPROVAL**

A.1 General

The HC volume fractions specified for these tests are expressed in terms of N-hexane, however, propane may be used as the HC component of the calibration gas as required for each performance test except the one specified in Clause A.24 (See Clause 1 and 5.9).

A.2 Calibration Curve

The errors of the Instruments shall be determined separately for each measurand and for at least three values within their measuring range using the recommended volume fractions.

The measurements shall be performed successively.

	1st	2nd	3rd
CO	0.5 % vol	1 % vol	3.5 % vol and/or 5% vol
CO ₂	6 % vol	10 % vol	14 % vol
HC	1000 ppm vol	5000 ppm vol	7000 ppm vol
O ₂	0.5 % vol	10 % vol	20.9 %vol.

The measurements shall be performed successively.

A.3 Stability with Time or Drift

This test shall be conducted for a period of 4 h following the warm-up time. Measurements shall be performed at least every half-hour using the following Gas Mixtures.

CO: 0.5 %vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5 %vol

A.4

Repeatability

The test procedure specified in 5.12 shall be carried out with the recommended volume fractions.

Measurand Volume fraction of measurand

CO: 0.5 %vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5 %vol

A.5

Dry Heat Test:

A.5.1

This test consists of exposure of the Instruments to a temperature of 45 °C under “free air” conditions for 2 h (the time duration specified begins after the Instrument has reached temperature stability). During the test, the rate of change in temperature shall not exceed 1 °C/min during heating up and cooling down, and the relative humidity in the testing atmosphere shall not exceed 50%.

A.5.2

The following calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test one measurement shall be performed every half-hour using the two mixtures composed of the recommended volume fractions.

	1st mixture	2nd mixture
CO	0.5 % vol	3.5 % vol
CO ₂	14 % vol	14 % vol
HC	1000 ppm vol	5000 ppm vol
O ₂	0.5 % vol	0.5 % vol

The tests will be repeated at 50° C also and the results of the test will be noted. These tests results will be provided in the manual for the information of the user.

A.6

Cold Test

A.6.1

This test consists of exposure of the Instruments to a temperature of 5 °C under “free air” conditions for 2 h (the time duration specified begins after the Instruments have reached temperature stability). During the heating up or cooling down of the Instrument, the rate of change in temperature shall not exceed 1 °C/min.

The following calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test one measurement shall be performed every half-hour using two mixtures composed of the recommended volume fractions.

	1st mixture	2nd mixture
CO	0.5 % vol	3.5 % vol
CO ₂	14 % vol	14 % vol
HC	1000 ppm vol	5000 ppm vol
O ₂	0.5 % vol	0.5 % vol

A.7 Damp Heat, Steady State test:

A.7.1 This test consists of exposure of the Instruments to a constant temperature of 30 °C and a constant relative humidity of 85 % for two days. The exposure shall be such that water does not condense on the Instruments. The temperature is deemed to be steady when the difference between the extreme temperatures does not exceed 5 °C, and the rate of change does not exceed 5 °C/h.

A.7.2 The following calibration gas shall be supplied to the probe at ambient pressure (to within 750 Pa). During the test, one measurement shall be performed every day using two mixtures composed of the recommended volume fractions.

	1st mixture	2nd mixture
CO	0.5 % vol	3.5 % vol
CO ₂	14 % vol	14 % vol
HC	1000 ppm vol	5000 ppm vol
O ₂	0.5 % vol	0.5 % vol

A.8 Atmospheric Pressure test

A.8.1 The test consists of measurements under the extreme pressures of the rated operating conditions or extreme pressures outside these limits when specified by the manufacturer. The extreme values shall be reached gradually from stable ambient pressure conditions and shall then be kept stable during 30 min before starting the measurements as specified in 8.2.

- A.8.2** Test gases shall be supplied at the probe at ambient test pressure (to within 750 Pa). At least two measurements shall be performed at each extreme pressure value using two mixtures composed of the recommended volume fractions.

The errors observed shall be within the limits of the maximum permissible errors as specified in Table 4 on initial verification for each measurement.

NOTE: If an automatic or semi-automatic adjustment is part of the pressure compensation process, care must be taken to ensure that the measurements at both extreme pressure values are performed after such adjustment has been carried out.

	1st mixture	2nd mixture
CO	0.5 % vol	3.5 % vol
CO ₂	14 % vol	14 % vol
HC	1000 ppm vol	5000 ppm vol
O ₂	0.5 % vol	0.5 % vol

- A.9.** Power Supply Variation Test:

- A.9.1** **The A.C. power supply test consists of exposure of the Instruments to extreme values of the nominal power supply voltage and nominal frequency for a period long enough to perform the required measurement under following variation conditions.**

Voltage: Nominal Voltage (230V), +10% ~ -15%

Frequency: Nominal Frequency (50 Hz), ± 1 Hz.

The AC power supply test will be repeated with frequency of 50 Hz ± 2 Hz also and the results of the test will be noted. These tests results will be provided in the manual for the information of the user.

- A.9.2** The D.C. Power Supply test consists of exposure of the Instruments to the specified power supply conditions for a period long enough to perform the required measurement. The upper tolerance limit shall be as specified by the manufacturer. The lower tolerance limit shall be the lowest voltage at which the Instrument provides measurement results.

- A.9.3** While the Instruments are exposed separately to each type of mains variation as indicated in A.9.1 or A.9.2 above the measurements shall be performed using following volume fractions of Gas Mixtures.

CO: 0.5 % vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5 %vol

The AC power supply test will be repeated at 50° C also and the results of the test will be noted. These tests results will be provided in the manual for the information of the user.

A.10 Influence of gas components other than the measurands (cross sensitivity)

A.10.1 The cross sensitivity shall be determined by the following two tests.

A.10.1.1 Test with N₂ alone:

- a) Supply the Instrument with N₂ alone.
- b) Supply the Instrument successively with each influencing gas alone in N₂ at its maximum value as specified in 5.5.3.
- c) Compare the “zero” responses of the Instruments determined in a) and b) for each measurand. The difference of indications shall meet the requirement specified in 5.5.3 for “ZERO” .

A.10.1.2 Test with all measurands in N₂ :

- a) Supply the Instrument with a measurand in N₂ alone. Repeat the operation for the other measurands.
- b) Supply the Instrument with all measurands together in N₂ .
- c) For each measurand, the difference between the errors of the Instruments determined in a) and the error determined in b) shall meet the requirements specified in 5.5.3.

A.10.2 For above test and for Instruments that detect with infra red absorption and for O₂ channel, the following volume fractions of gas mixture is required

For the measurands in N₂ :

- _ 3.5 %vol CO
- _ 14 % vol CO₂
- _ 1000 ppm vol HC and
- _ water up to saturation.

Referring to 5.5.3, if the presence of O₂ and H₂ is necessary, two different gas mixtures shall be used to avoid explosive risk. The recommended volume fractions for the measurands in N₂ are the following.

Mixture A : 3.5 % vol CO

14 % vol CO₂

1000 ppm HC

10 % O₂

Mixture B : 3.5 % vol CO

14 % vol CO₂

5000 ppm HC

5 % H₂

A.11 Mechanical shock and Vibrations Test:

A.11.1 For mechanical shock testing, the tested Instrument shall be placed in its normal position of use on a rigid surface. It shall be tilted on one bottom edge and then allowed to fall freely onto the test surface.

The following conditions shall be applied:

_ Height of fall: 25 mm

_ **Number of falls: 1 on each bottom edge.**

See IEC 60068-2-31.

A.11.2 Vibration test should be conducted as per IS 9000 Part VIII 1981. Analyser may be subjected to vibration in normal mounting axis for 5 to 9 Hz $\pm$ 3 mm displacement and 9 to 150 Hz $\pm$ 1 g acceleration amplitude, preferably with electrical power 'ON' condition. This test should be repeated for other two axes also. However, during the test the instrument shall be mounted in its normal position only.

A.11.3 Before and after the test, measurements shall be performed using Following volume fractions of gas mixture.

CO: 0.5 %vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5 %vol

A.12 Short Time Power Reductions Test:

- A.12.1** A test generator suitable for reducing the amplitude of the A.C. mains voltage is used. It shall be adjusted before being connected to the Instruments. The mains voltage interruptions and reductions shall be repeated 10 times with an interval of at least 10 s between successive disturbances. 100 % reductions shall be effectuated for duration of 10 ms 50 % reductions shall be effectuated for duration of 20 ms.
- A.12.2** During the test, measurements shall be performed using the following volume fractions of gas mixture:
- CO: 0.5 %vol
- CO₂: 14 %vol
- HC: 1000 ppm vol
- O₂: 0.5 %vol
- A.13** Bursts from the mains (transients):
- A.13.1** The test consists of exposure of the Instruments to bursts of voltage spikes of 1 kV and having a double exponential waveform. Each spike shall have a rise time of 5 ns and a half amplitude duration of 50 ns. The burst length shall be 15 ms, the burst period (repetition time interval) shall be 300 ms. Repetition frequency of the impulses and peak values of the output voltage on 50 Ω load: 5 kHz ± 1 kHz. The transient generator shall have an output impedance of 50 Ω and shall be adjusted before connecting the Instrument. At least 10 positive and 10 negative bursts randomly phased shall be applied. Insertion of blocking filters in the cables to the Instrument may be necessary to prevent the burst energy being dissipated in the mains.
- A.13.2** During the test, measurements shall be performed using the following volume fractions of gas mixture.
- CO : 0.5 %vol
- CO₂: 14 %vol
- HC: 1000 ppm vol
- O₂: 0.5 %vol
- A.14** Electrostatic discharges test:
- A.14.1** A capacitor of 150 pF shall be charged by a suitable DC voltage source of 6 kV in contact mode and 8 kV in air mode. Then it shall be discharged through the Instrument by connecting one terminal to the Instrument's ground chassis and the other through a 330 Ω resistance to the Instrument's surfaces that are normally accessible to the user. At least 10 successive discharges shall be applied with a time interval between discharges of at least 10 s. An Instrument not equipped with a grounding terminal shall be placed on a grounded plane surface that projects beyond the Instrument by at

least 0.1 m on all sides. The associated grounded connection to the capacitor shall be as short as possible.

A.14.2 In the contact discharge mode, to be carried out on conductive surfaces, the electrode shall be in contact with the Instrument and the discharge shall be actuated by the discharge switch of the generator. In the air discharge mode, on insulating surfaces, the electrode is approached to the Instrument and the discharge occurs by spark.

A.14.3 During the test, measurements shall be performed using the following volume fractions of gas measurand.

CO: 0.5 %vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5 %vol

A.15 Radiated, radio frequency, electromagnetic fields test

A.15.1 Instruments shall be exposed to electromagnetic field strength as follows:

_ Frequency range: 26 MHz to 1000 MHz

_ Field strength: 10 V/m

_ Modulation: 80 % AM, 1 kHz sine wave.

A.15.2 The field strength may be generated in the following ways:

- a) A strip line for low frequencies for small instruments from DC to 150 MHz
- b) A TEM cell (Transverse Electromagnetic Mode cell) for higher frequencies, up to 1 GHz
- c) A biconical antenna (26 MHz to 300 MHz)
- d) A log periodic antenna (100 MHz to 1000 MHz).

The specified field strength shall be established prior to the actual testing (without the Instruments in the field). When the test is carried out in a shielded enclosure to comply with international laws prohibiting interference to radio communications care needs to be taken to handle reflections from walls. Anechoic shielding may be necessary.

A.15.3 During the test, measurements shall be performed using the following volume fractions of gas mixture.

CO: 0.5 %vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5 %vol

See IEC 61000-4-3.

NOTE : The attention of the experts is drawn to the fact that IEC 61000-4-3 refers to the frequency range from 80 MHz to 1000 MHz.

The lower frequencies are covered by IEC 61000-4-6.

A.16 Mains Frequency Magnetic Fields Test:

The Instrument tested shall be exposed in all directions to a magnetic field of 30 A/m at mains frequency. During the test, measurements shall be performed using the following volume fractions of gas measurand.

CO: 0.5 %vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5%vol

A.17 Warm-up time:

A.17.1 At reference conditions and at 5 °C, the warm-up time test to verify compliance with 5.8 shall consist of the following steps:

- a) Stabilize the Instrument at each temperature
- b) Let the Instrument warm up
- c) Immediately after either the manufacturer's prescribed warm-up period has elapsed or an automatic warm-up lockout has been deactivated, perform a volume fraction measurement (with any necessary internal adjustment being performed prior to this measurement)
- d) At time intervals of 2 min, 5 min and 15 min after warm-up, perform a measurement with the same calibration gas as above.

The difference between any of the measured values above shall not exceed the modulus maximum permissible error on initial verification.

NOTE: At reference conditions, the warm-up time test may be included with the drift test.

A.18 Response time

A.18.1 A measurement shall be taken to determine the time required for an Instrument to respond to a calibration gas after sampling ambient air supplied at the probe. A means shall be employed for instantly changing from sampling ambient air to sampling calibration gas through the sample gas inlet probe. The gases shall be supplied at the probe inlet at ambient pressure (to within 750 Pa). The response time shall not exceed the appropriate values specified in 5.7.

A.18.2 The following recommended volume fractions shall be used.

CO : 0.5 %

CO₂ : 14 %

HC : 1000 ppm

O₂ : 0.5 %

A.19 Low flow

A.19.1 A measurement shall be performed with a calibration gas that is initially supplied to the gas handling system at a gas flow rate greater than the minimum required by the tested Instrument. During the measurement, the gas flow rate shall be reduced until the low flow indicator responds according to requirements of 6.1.7.

A.19.2 The following recommended volume fractions shall be used.

CO: 0.5 %vol

CO₂: 14 %vol

HC: 1000 ppm vol

O₂: 0.5 %vol

A.20 Leakage

A.20.1 When following gas mixture is used, the adjustment of the leakage and the test shall be performed successively for each component.

A.20.2 An adjustable leak shall be introduced artificially into the gas handling system near the pump where a leak of an appropriate orifice size will have the greatest effect on the measurement. With this artificial leak closed, a calibration gas shall be supplied at the probe at ambient pressure (to within 750 Pa).

A.20.3 While sampling the calibration gas, record the indication, then adjust the leakage rate so that the indication of the calibration gas differs from the value indicated previously (without the leak) by an amount equal to the requirement of 6.1.8.

Without disturbing the artificial leak, remove the calibration gas supplied at the probe, and conduct the leakage test procedure as described in the manufacturer's operating instructions.

NOTE: Since the leakage test is performed by introducing air in to the system, the calibration gas supplied at the probe should have a volume content of O₂ close to 0 %.

A.20.4 The following volume fractions shall be used.

CO : 0.5 % vol

CO₂ : 14 % vol

HC : 1000 ppm vol

O₂ : 0 % vol.

A.21 HC residue

A.21.1 The exhaust of a specially adjusted test engine shall be sampled for at least 5 min by an Instrument in thermal equilibrium at 5 °C. The exhaust gas shall contain at least 5 % CO and 3000 ppm HC. Immediately after the sampling, conduct an HC residue check as described by the manufacturer's operating instructions. Repeat this operation as many times as necessary to obtain an HC residue that complies with the requirement of 6.3.2.

A.21.2 Then following calibration gases shall be supplied at the probe at ambient pressure (to within 750 Pa) to check compliance with the maximum permissible error on initial verification.

CO: 3.5 %vol

HC: 5000 ppm vol

A.22 Filter unit

A.22.1 At reference conditions, the Instrument shall be exposed to exhaust gases from a specially adjusted test engine for a period of at least 15 min. The exhaust gas shall contain at least 5 % CO and 6000 ppm HC. Immediately after the sampling, conduct an HC residue check as described by the manufacturer's operating instructions. Repeat this operation as many times as necessary to obtain an HC residue that complies with requirements of 6.3.2. The Instrument shall be checked immediately with a calibration gas that shall be supplied to the gas handling system at ambient pressure (to within 750 Pa). The Instrument shall comply with the requirements for the maximum permissible error on initial verification and for the response time.

A.22.2 The test shall be carried out using the following gas mixture:

CO: 3.5 %vol

CO₂ : 14 %vol

HC: 1000 ppm vol

O₂ : 0.5 %vol

A.23 Water separator

A.23.1 The water separator shall be subjected to the following two tests.

a) High temperature test:

_ Stabilize the Instrument at 45 °C, and

_ Expose the Instrument to water saturated N₂ at 45 °C, or water saturated ambient air at 45 °C, supplied to the gas handling system for 30 min.

b) Low temperature test:

_ stabilize the Instrument at a low ambient temperature within the rated operating conditions, and

_ expose the Instrument to exhaust gases from any car attached to the probe for 30 min.

A.23.2 After each test, the Instrument shall be checked immediately with the following gas mixture:

CO: 3.5 %vol

CO₂: 14 %vol

HC: 5000 ppm vol

O₂: 0.5 %vol

It shall comply with the requirements of the maximum permissible error on initial verification and with the response time requirements of 5.7, before and after the test.

A.24 Propane/hexane equivalency factor

A.24.1 The test procedure is as follows:

a) Make a measurement for each of the following recommended volume fractions of propane calibration gas: 2000 ppm vol and 10000 ppm vol

b) Calculate the absolute error of the Instruments for each of these two volume fractions of propane calibration gas.

To this end, the true value is determined as follows:

$$I_{\text{true}} = C \times \text{PEF}$$

Where, C is the true value of the volume concentration of propane, and

PEF is the value of the propane/hexane equivalency factor given by the Manufacturer

- c) Make a measurement for each of the following recommended fractions of hexane calibration gas: 1000 ppm vol and 5000 ppm vol
- d) Calculate the absolute error of the Instrument for each of these two volume fractions of hexane
- f) For each of the two volume fractions, calculate the difference between the error obtained with propane and that obtained with hexane.

A.24.2 The difference between the errors shall not exceed (according to the case --- see 5.9) the applicable maximum permissible intrinsic error or half of the applicable maximum permissible intrinsic error.

NOTE: It is assumed that the error of the Instruments are constant both near 100 ppm vol and near 1000 ppm vol.

CAUTIONARY NOTE : Because of its low vapour pressure, Hexane can condense at ordinary temperatures of shipment, storage and use. Such condensation would invalidate the certified gas mixture concentration. Therefore, extreme care shall be taken at all times during shipment, storage and use to ensure that Hexane cylinders are maintained sufficiently above the condensation temperature for the specified gas volume fraction at the cylinder pressure.

A.25 Engine Speed Measurement System

The linearity of engine speed measurement shall be checked at minimum 4 points, which shall include at least one point, which is more than 80% of the required full scale range. The linearity shall be checked using engine speed measurement system with the accuracy of at least ± 3 rpm.

ANNEXURE – B

DESIGNATION OF CALIBRATION GASES AND

THEIR COMPOSITION

B.1 General requirements

B.1.1 The calibration gases shall be supplied either in gas cylinders or by dynamic blending.

a) Each gas cylinder shall be identified with the following information included as a mark, label and/or certificate):

- _ Supplier of the gas cylinder and serial number
- _ Composition of the gas mixture
- _ Temperature limits for use and storage
- _ Date of analysis and expiration date
- _ Testing authority and
- _ The marking “calibration gas mixture”.

b) Blended gases shall meet the requirements of ISO 6145 and 7395 or of B.1.2 and B.2.

B.1.2 The composition of calibration gases used for Type approval and verification shall be certified as complying with the requirements of B.2 by a competent authority and as being traceable to national, regional or international standards.

B.1.3 Calibration gases for all purposes except type approval and verification shall be certified by the supplier of the gases and shall be traceable to the appropriate standards.

B.1.4 The material of gas cylinders shall be inert to the gases contained therein.

B.1.5 The appropriate safety regulations shall be followed in the handling of the gases.

B.2 Specifications and uncertainties of composition of the gas mixtures:

B.2.1 The unit for the quantity of gases contained or delivered shall be either in molar or volume fractions. (See 5.1)

B.2.2 The blend / preparation tolerances of the calibration gas mixtures shall not exceed 15 % of the volume fraction of each component.

B.2.3 For gas mixtures the uncertainty/analytical accuracy in the composition shall be 1 % or less of the volume fraction of each measurand except for HC of 1000 ppm and below, where the uncertainty shall be 2 % or less for gas calibration and tests such as calibration curve, propane/hexane equivalency factor. For the remaining tests, the uncertainty/analytical accuracy of the gas mixtures may be 2% of the volume fraction of each measurand. The composition of each component not subject to measurement shall have an uncertainty of 5% or less.

The specified uncertainty values are values relative to the Standards referred to in B.1.2.

B.3 ***Preparation of gases in special cases***

B.3.1 Propane shall be used for calibration gas mixtures requiring HC therefore the propane/hexane equivalency factor shall be taken into account.

B.3.2 **Volume fractions of O₂, H₂, NO, and water vapor shall be blended with the other gases as required during the tests. The volume fraction of water vapor required should not be supplied in high-pressure gas cylinders because of instability and corrosion effects, and mixtures of O₂ shall only be blended with N₂.**

B.3.3 Ambient air shall be drawn through a charcoal filter or equivalent system when it is used to set zero for instruments measuring HC.

ANNEXURE - C (INFORMATIVE)

PROCEDURE FOR INITIAL VERIFICATION

The initial verification of the Instruments may include the following tests.

- a) Check the power supply voltage and frequency at the location of use to determine compliance with the specifications on the measuring Instrument's label.
- b) Check the activation of the warm-up lockout Instruments by attempting to make a measurement within 1 min of initial power-on of the Instruments.
- c) After the Instruments have warmed up, perform the calibration curve check as described in 8.2.2.2.
- d) Check the air-tightness of the system by performing a leak check as described in the manufacturer's operating instructions.
- e) Check for HC residues with the procedure described in the manufacturer's operating instructions.
- f) Check for the activation of the low gas flow device (and also for the low flow lockout) by restricting the gas flow supplied to the probe while sampling ambient air.
- g) Check the response time of the CO channel.

ANNEXURE - D (INFORMATIVE)

PROCEDURE FOR SUBSEQUENT VERIFICATION

Subsequent verification of an Instrument at the same location may include the following tests.

- a) For short-term subsequent verification, perform all tests included in the initial verification except for the power check and the warm-up check.
- b) **For short-term subsequent verification, perform the calibration curve check using the number of gas mixtures required for initial verification unless the responsible legal authority specifies fewer mixtures**
- c) For long-term subsequent verification, perform all tests included in the initial verification.
- d) When the Instruments have been moved to a new location (e.g. change in business address as defined by the responsible legal authority), or have undergone repairs other than replacement of components as defined in Step E of Annex-E or in the manufacturer's operating instructions, perform all tests included in the initial verification.

ANNEXURE – E (INFORMATIVE)

PROCEDURE FOR ROUTINE TESTING

A routine test of the Instruments should consist of at least the following.

- a) **Perform an internal adjustment check within 1 hour after performing each vehicle test.**
- b) Check for HC residues before testing each vehicle.
- c) Check the Instrument's gas calibration and internal adjustment with a calibration gas at intervals specified by the responsible legal authority or recommended in the manufacturer's operating instruction manual.
- d) Perform a leak check at least once a day. Repair any leaks and conduct a successful leak check before testing any vehicle.
- e) Conduct a leak check after each disassembly of the gas handling system (e.g. a probe or filter element replacement). Repair any subsequent leaks and conduct a successful leak check before testing any vehicle.

ANNEXURE-F (NORMATIVE / MANDATORY)

LAMBDA CALCULATION

F.1 Introduction : The value of lambda is determinant for the burning efficiency of an engine. The value depends on the composition of the fuel, the air that is used for the combustion and on the combustion products as found in the exhaust gases.

A basic formula, taking into account:

_ Components of the fuel: carbon, hydrogen, oxygen and water content

_ Water content of the air

_ **Components of the exhaust gases: carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxide has been developed by J. Brett Schneider.**

A simplified formula derived from the basic formula and based on the assumption that the water content of fuel and air and the NOx content in the exhaust gases are negligible, allows the computation of lambda when certain components of the exhaust are measured.

F.2 Simplified Lambda formula : **For lambda calculation, based upon measurements of CO, CO₂, HC and O₂ the following formula is standardised.**

$$\lambda = \frac{[\text{CO}_2] + \frac{[\text{CO}]}{2} + [\text{O}_2] + \left\{ \left(\frac{H_{cv}}{4} \times \frac{3,5}{3,5 + \frac{[\text{CO}]}{[\text{CO}_2]}} - \frac{O_{cv}}{2} \right) \times ([\text{CO}_2] + [\text{CO}]) \right\}}{\left(1 + \frac{H_{cv}}{4} - \frac{O_{cv}}{2} \right) \times ([\text{CO}_2] + [\text{CO}]) + (K_1 \times [\text{HC}])}$$

Where

[] is the concentration in %vol, for HC only in ppm vol

K₁ is the conversion factor for HC if expressed in ppm vol n-hexane (C₆H₁₄) equivalent. Its value in this formula is 6 x 10⁻⁴

H_{cv} is the atomic ratio of hydrogen to carbon in the fuel. The arbitrary value is 1.7261

O_{cv} is the atomic ratio of oxygen to carbon in the fuel. The arbitrary value is 0.0176

NOTE : The simplified lambda calculation is only valid for measurements on cars with negligible NO_x concentrations in the exhaust gas.

F.3 Other Formulae : Other formulae may also be applied. As specified in 7.2.2 the operating instructions shall include the applied model.