

CHAPTER I : TECHNICAL SPECIFICATIONS AND TEST PROCEDURE FOR TYPE APPROVAL OF SMOKE METERS

2 SMOKE METER SPECIFICATIONS

1.1 Type of Tests

Smoke meter shall be suitable for conducting full load and free acceleration tests or only free acceleration test on different types of diesel vehicles as per Central Motor Vehicle Rules 115 (2) C and 115 (4). The smoke meter shall be labelled accordingly.

☒ *The smoke meter shall have probes of sufficient length (minimum 2 meter) to facilitate easy attachment to the tailpipe of vehicles. According to the test procedure for free acceleration tests, the ratio of cross sectional area of the probe to that of exhaust pipe shall not be less than 0.05. Considering the exhaust pipe diameter of 4 inch, the equipment shall be supplied with at least one probe of internal diameter not less than 2.25 cm.*

1.2 Display

The smoke meter shall indicate light absorption coefficient 'K' directly or in case of end of line full flow meter when it may not be possible to indicate light absorption coefficient directly, it shall be easily possible to calculate value of 'K' based on the display reading using either a formula or a suitable table. The instrument shall have peak hold facility to display/print the maximum smoke reading obtained during free acceleration test.

1.3 Oil temperature measurement system

1.4 The oil temperature measurement system shall have measurement range of at least 0 to 150° C. The oil temperature measurement shall have resolution of 1°C with accuracy of at least $\pm 3^\circ\text{C}$. Temperature probe arrangement shall be such that it can be used for all types of diesel vehicles with different oil dipstick lengths. The temperature probe shall have a sleeve for fixing in to the oil probe assembly.

1.5 Engine speed measurement system

The speed measurement shall be carried out with an easily attachable speed sensor. The speed measurement range 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

☒ 1.3 Printer

The instrument shall be provided with a printer. It shall print all the smoke readings and mean of the valid smoke readings in English along with measured oil temperature and maximum no load speed when tested for free-acceleration test. The printer shall also print the average value of the maximum no load speed determined during the flushing cycle. The printer shall print the date and time of the test. A software provision shall be made so that maximum of two print outs can be taken after each test.

A facility to print the reading along with date and time when calibrated using neutral density filter shall also be provided.

1.4 Heating

The condensation in the smoke chamber shall be avoided. If necessary, instrument shall have heating facility for the same.

1.5 Temperature & Pressure

The smoke meters used for full load test shall have the pressure and mean temperature indication of the smoke into the smoke chamber. Smoke reading shall be corrected for reference pressure of 100 kPa and reference temperature of 373 K and displayed.

1.6 Markings

The meter shall be fitted with a permanent and easily readable label giving its model number, serial number, name and address of the manufacturer, electrical power requirements, year and month of manufacture and operating voltage range, in English language.

1.7 Scale

The scale shall be zero to at least 6 m^{-1} for light absorption coefficient.

1.8 Resolution

The smoke meter shall have a resolution of at least 0.1 m^{-1} between the range 0 to 4 m^{-1} .

1.9 Calibration

The smoke meter shall have facility to adjust zero reading when the smoke meter is filled with clean air. Each smoke meter shall be supplied with a neutral density filter of known value to accuracy of $\pm 0.05 \text{ m}^{-1}$ light absorption coefficient (along with the calibration certificate) in the region of 1.5 to 2.5 m^{-1} . It shall be possible to calibrate the smoke meter easily in the field using this filter.

1.10 Linearity

The linearity of the smoke meter shall be within $\pm 0.1 \text{ m}^{-1}$.

1.11 Drift

The instrument zero drift and span drift with neutral density filter having value between 1.5 to 2.5 m^{-1} , shall not exceed $\pm 0.1 \text{ m}^{-1}$ for four hours after warming up.

1.12 Repeatability

The repeatability of the instrument shall not exceed $\pm 0.1 \text{ m}^{-1}$ during five successive calibration tests with the neutral density filter having value between 1.5 to 2.5 m^{-1} .

1.13 Light Source

The light source shall be an incandescent lamp with a colour temperature in the range 2800 to 3250 K or a green light emitting diode (LED) with a spectral peak between 550 and 570 nm. The smoke meter shall be supplied with spectral response characteristics of the light source received from a reputed organisation.

1.14 Light Detector

It shall be a photo cell or photo diode (with filter if necessary). Any other equivalent device can be used if the equivalence is established by the manufacturer. In the case of an incandescent light source, the detector shall have a peak spectral response in the range 550 to 570 nm and shall have gradual reduction in response to value less than 4 % of the peak response value below 430 nm and above 680 nm. The smoke meter shall be supplied with spectral response characteristics of the detector received from a reputed organisation.

1.15 Response Time

1.15.1 Physical Response Time

This is due to physical phenomena in the smoke chamber and is the time taken from the start of the gas entering the chamber to complete filling of the smoke chamber. It shall not exceed 0.4 seconds.

1.15.2 Electrical Response time

The response time of electrical measuring circuit, being the time necessary for the indicating dial to reach 90 % of full scale deflection on insertion of a screen fully obscuring the photoelectric cell, shall be maximum 1.1 second.

The damping of the electrical measuring circuit shall be such that the initial overswing beyond the final steady reading after any momentary variation in input (eg. calibration screen) does not exceed 0.1 m^{-1} with neutral density filter having value between 1.5 to 2.5 m^{-1} .

1.16 Soiling of Light Source and Receiver

The smoke meter shall be capable of being used for a period sufficient to take measurements without soiling of the light source and receiver. This is considered satisfactory if the overall drift of the instrument is less than 0.2 m^{-1} for over 1

hour when used on diesel engine/vehicle producing smoke of light absorption coefficient between 2 to 4 m⁻¹.

1.17 Warm Up Time

Unless otherwise indicated on the meter, the smoke meter shall be stabilised for operation within half an hour after power 'ON'.

1.18 Environmental Conditions

The smoke meter shall withstand following environmental conditions :

Supply voltage variation of 230 V $\pm$ 10%. The instruments powered by battery shall have the battery condition indication and shall withstand indicated voltage variation.

1.1.8.2 Temperature range of 278 K to 323 K.

1.1.8.3 The meter shall withstand the vibrations encountered in the normal garage environment. The test agency may decide suitable method to test this. The recommended levels as per IS 9000 Part-VIII 1981, are

Frequency : 5 to 9 Hz Amplitude $\pm$ 3 mm
 9 to 150 Hz Amplitude $\pm$ 1 g

Duration : 1 hour

Sweep rate : 1 octave per minute

1.18.4 Drop test

The meter shall withstand drop test of 2 falls on each edge from a height of 50 mm. Any other electric or electronic components, which are carried by operator during operation(e.g Remote Control Unit) shall withstand a drop test of 2 falls from a height of 0.5 meter.

1.19 Electromagnetic Isolation

The smoke meter is required to be capable of providing unaffected operation in electromagnetic radiation or conductive interference produced by vehicle ignition systems and building electrical systems.

1.20 Correlation to Reference Smoke Meter

The meter shall be correctable for the full load and free acceleration tests or only free acceleration test depending on intended use of the smoke meter with the reference standard meter meeting ECE regulation 24 requirements.

For the time being, Hartridge Mark-3 smoke meter will be used as a reference standard meter. This may be reviewed after a suitable time.

1.21 Documentation

When the smoke meter is submitted for testing, the smoke meter shall be accompanied with following information in English :

- a) All technical specifications of the smoke meter
- b) a description of the general principle of measurement
- c) a list of essential components with their characteristics
- d) a description of the essential components with drawings and diagrams that are necessary for testing and maintenance
- e) general information on the software required for a microprocessor equipped measuring instrument
- f) the operating instructions that shall be provided to the user
- g) details of how calculations are performed
- h) a fully documented calibration procedure and a set of calibration filters
- i) a photograph of the instrument.

☒ j) *The operating manual supplied with every smoke meter shall include the description of the test procedure described in Part-II of the document MOST/CMVR/TAP-115/116 (Details of Standards and Test Procedures for Smoke Levels by Free-acceleration for In-service vehicles fitted with Naturally Aspirated Diesel Engines).*

2.0 SMOKE METER TEST PROCEDURE

Physical Check

It shall consist of checking -

- 1) Suitability and label on the instrument for the intended use.
- 2) Identification of the instrument consisting of model, serial number, name and address of the manufacturer, electrical power requirement, year and month of manufacture and operating voltage range specified in English language.
- 3) Scale, resolution, display.
- 4) Peak hold facility.
- 5) Heating facility.
- 6) Calibration facility.
- 7) Printout specifications.
- 8) Oil temperature sensor probe
- 9) Engine speed sensor clamp / attachment.
- 10) Documentation.
- 11) Checking of probe

2.2 Linearity

1) Smoke measurement :

The linearity of smoke measurement shall be checked at minimum 4 points (5 points to include a full scale point, In case meter full scale corresponds to the total light cut-off) including the zero point. This will be checked by three different neutral density filters of known value within $\pm 0.05\text{m}^{-1}$ in the specified range given below, supplied by the smoke meter manufacturer or his representative along with Calibration Certificate from a reputed organisation. The neutral density filter shall have flat response (preferably within $\pm 2\%$ tolerance in absolute value) between the wavelength range 430 to 680 nm and the response at spot frequency between 550 to 570 nm as recommended by the manufacturer will be considered for linearity test. The test agency may decide to test the accuracy of the filter prior to the test.

one filter having $K \leq 1\text{ m}^{-1}$

one filter having K between 1.5 and 2.5 m^{-1}

one filter having $K \geq 3\text{ m}^{-1}$.

2) Engine speed measurement:

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 $\pm 3\text{ rpm}$.

3) Oil temperature measurement:

The linearity of oil temperature measurement shall be checked at minimum 4 points, uniformly distributed over the full-scale range. The linearity shall be

checked using temperature measurement system, preferably oil bath, with the accuracy of at least $\pm 0.5^{\circ}\text{C}$.

2.3 Drift

Both zero drift and span drift shall be checked for four hours with readings taken at every half an hour interval. Span drift shall be tested using neutral density filter having light absorption coefficient in the range 1.5 to 2.5 m^{-1} .

2.4 Repeatability

Repeatability shall be checked five times with the neutral density filter having light absorption coefficient in the range 1.5 to 2.5 m^{-1} .

2.5 Light Source

Check that with voltage variation specified in clause 1.18.1, the colour temperature of the light source is between 2800 to 3250 K or verify that a green light emitting diode (LED) is used by checking the spectral peak between 550 and 570 nm .

2.6 Light Detector

Check that the combined receiver and filter characteristics have a maximum response in the range 550 to 570 nm , and less than 4% of that maximum response below 430 nm and above 680 nm , or verify that a green LED is used in conjunction with a photodiode; since the wavelength is set by the green light emitting diode (LED). It is not necessary to check the photodiode when used with a green light emitting diode (LED).

2.7 Response Time

2.7.1 Physical Response Time

Smoke meter manufacturer or its representative shall provide sufficient data and sample calculations to verify the physical response time. Test agencies will calculate the same at minimum and maximum flow conditions based on this data.

2.7.2 Electrical Response Time

Smoke meter manufacturer or representative shall provide the sufficient supporting documents to meet the specifications. Damping of the electrical measuring circuit shall be checked by inserting the neutral density filter having value between 2.5 m^{-1} .

2.8 Soiling of Light Source and Receiver

After calibration, the meter will be continuously used for 1 hour on an

engine/vehicle producing smoke of light absorption coefficient between 2 to 4 m⁻¹. The zero reading after the test shall be checked and compared. The difference shall not be more than 0.2 m⁻¹.

2.9 Environmental Testing

2.9.1 Voltage Variation

Smoke meter zero and span (with a neutral density filter having value between 1.5 and 2.5 m⁻¹) reading shall be checked at 230 V ± 10 % value. In case of the instruments powered by battery, voltage shall be varied within the indicated voltage range. The difference in the reading shall be less than 0.1 m⁻¹.

2.9.2 Temperature

The smoke meter shall be maintained at 278 K and 323 K temperature. Span reading with neutral density filter having value between 1.5 to 2.5 m⁻¹ at both these temperatures shall be within 0.1 m⁻¹ from the reading obtained at the room temperature of 303 ± 2 K.

2.9.3 Vibration

The smoke meter shall be checked for the vibrations as per clause 1.18.3 preferably with electrical power 'ON' condition. A span measurement with neutral density filter having value between 1.5 to 2.5 m⁻¹, shall be taken before and after the test and the difference in the reading shall be within 0.1 m⁻¹. In case the electrical power of the instrument is switched 'OFF', the readings shall be taken after warming up and initial calibration of the instrument.

2.9.4 Drop Test

Part-I : The meter components (except those which are wall mounted) shall be positioned in their normal orientation of use on a rigid surface. They shall be tilted on one bottom edge and then allowed to fall freely on to the test surface. All covers shall be fitted properly. They shall be subjected to two falls on each edge from a height of 50 mm, measured from the elevated edge of the unit to the test surface.

A span measurement with neutral density filter having value between 1.5 to 2.5 m⁻¹, shall be taken before and after the test and the difference in the reading shall be within 0.1 m⁻¹. As the electrical power of the instrument is switched 'OFF', the readings shall be taken after warming up and initial calibration of the instrument.

Part-II : This part applies only to those parts of the meter which contain electrical or electronic components and which are carried by the operator during normal use, for example any part which attaches to the vehicle exhaust or a remote control unit etc.

The test consists of subjecting the relevant component to two falls from a height of 0.5 m onto a smooth hard rigid surface of either concrete or steel. A span measurement with neutral density filter having value between 1.5 to 2.5 m^{-1} , shall be taken before and after the test and the difference in the reading shall be within 0.1 m^{-1} . As the electrical power of the instrument is switched 'OFF', the readings shall be taken after warming up and initial calibration of the instrument.

2.10 Electromagnetic Isolation

This test shall be conducted in the vicinity of minimum five number of SI engine vehicles operating within approximate distance of 3 to 5 metres from the equipment. The vehicles shall not be fitted with ignition suppression devices. A span measurement with neutral density filter having the value between 1.5 to 2.5 m^{-1} shall not vary by more than 0.1 m^{-1} after switching on the SI engine vehicles.

2.11 Correlation Tests

2.11.1 Full Load Test

The smoke meter under test and reference smoke meter shall be installed on an engine or a vehicle and full load test will be carried out. If it is not possible to install both the meters simultaneously, the testing will be carried out at first with reference smoke meter and subsequently with the meter under testing. The test shall be repeated to measure smoke of different 'K' values (minimum five points) approximately evenly spaced over the range 0 to 4 m^{-1} . If required the air system or the fuel system of the engine shall be adjusted to get smoke of different 'K' values. The difference in the reading shall be within percentage specified in the table below.

Mean value of test in K (m^{-1})	% Difference allowed
≤ 1 $>1, \leq 2$ $>2, \leq 3$ >3	5 } or 0.1 m^{-1} whichever 7.5 } is higher 10 12.5

2.11.2 Free Acceleration Test

The test shall be carried out on at least five different diesel vehicles/engines as below :

- a) one engine used for car/jeep application
- b) four different engines used for LCV/HCV application

The correlation tests shall be performed using either engines or complete vehicles. If the test is carried out on an engine mounted on test bench, the engine shall be decoupled from the dynamometer. If the test is carried out on a vehicle, the gear change control shall be set in the neutral position and the drive between engine and gearbox engaged. Test engines shall be warmed up to attain oil temperature of minimum 60°C. The test shall be carried out only after this engine condition is reached.

The free acceleration test shall be conducted as below: With the engine idling, the accelerator control shall be operated quickly, but not violently, so as to obtain maximum delivery from the injection pump. This position shall be maintained until maximum engine speed is reached and the speed governor comes into action. As soon as this speed is reached the accelerator shall be released until the engine resumes its idling speed and the smoke meter reverts to the corresponding conditions. Typically the maximum time for acceleration shall be 5s and for the stabilization at maximum no load speed shall be 2s. The time duration between the two free accelerations shall be between 5-20s.

The operation described above shall be repeated not less than six times in order to clear the exhaust system and to allow for any necessary adjustments of the apparatus. During this flushing cycle operation the sample probe shall not be inserted in to the vehicle exhaust system.

The operation described above shall then be carried out with sample probe inserted in to the vehicle exhaust system. The maximum no load rpm reached during this operation shall be within ± 500 rpm in respect of 3 wheeler vehicles and ± 300 rpm for all other categories of vehicles, of the average value obtained in the last four of the six flushing cycles above. If for any reason the speed is not within the specified tolerance band the particular smoke reading shall be considered as invalid and shall be discarded. The above operation shall be repeated till the peak smoke values recorded in four successive accelerations are valid and are situated within a bandwidth of 25 % of the arithmetic mean (in m^{-1} unit) of these values or within a bandwidth of 0.25 K, whichever is higher and do not form a decreasing sequence. The absorption coefficient to be recorded shall be the arithmetic mean of these four valid readings.

Zero drift shall be checked after the test and if drift is greater than 0.2 m^{-1} this test shall be taken as invalid and repeated.

If the drift is 0.2 m^{-1} or less and positive, it shall be subtracted from the mean of

the last valid reading.

A sequence of four free acceleration tests as per the procedure above shall be conducted with smoke meters as given below :

Test 1 With reference smoke meter.

Test 2 Subject meter installed on its own in the vehicle tailpipe and calibrated according to manufacturer's instructions using a neutral density filter.

Test 3 As per Test 2.

Test 4 As per Test 1.

Based on the mean of valid four readings in each test :

a) A test sequence is valid only if 'K' value of Test does not vary from Test 1 by more than 0.3 m^{-1} .

b) The percentage difference between the mean of the test 1 and 4 and the mean of test 2 and 3, for five vehicles, shall be less than figures given in the table below

Mean value of test 1 & 4 K (m^{-1})	% Difference allowed	
	(3 vehicles)	(2 vehicles)
≤ 1	5	10
$>1 \leq 2$	7.5	15
$>2, \leq 3$	10	20
>3	12.5	25

c) The result of Test 2 and 3 must lie within $\pm 10\%$ of the mean of the two tests.

d) In case correlation test does not meet the tolerances specified above in only one of the vehicles/engines, additional two correlation tests each consisting of five tests as mentioned above shall be carried out on different vehicles / engines (vehicles/engines other than used in the first series of correlation tests). The meter can be considered satisfactory if it meets these additional correlation tests.