Unit-V

Drive train components and vehicle testing

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❖Syllabus

Vehicle Testing - Road test, free acceleration test, coast down test, passer by noise test, road load data acquisition for vehicle.

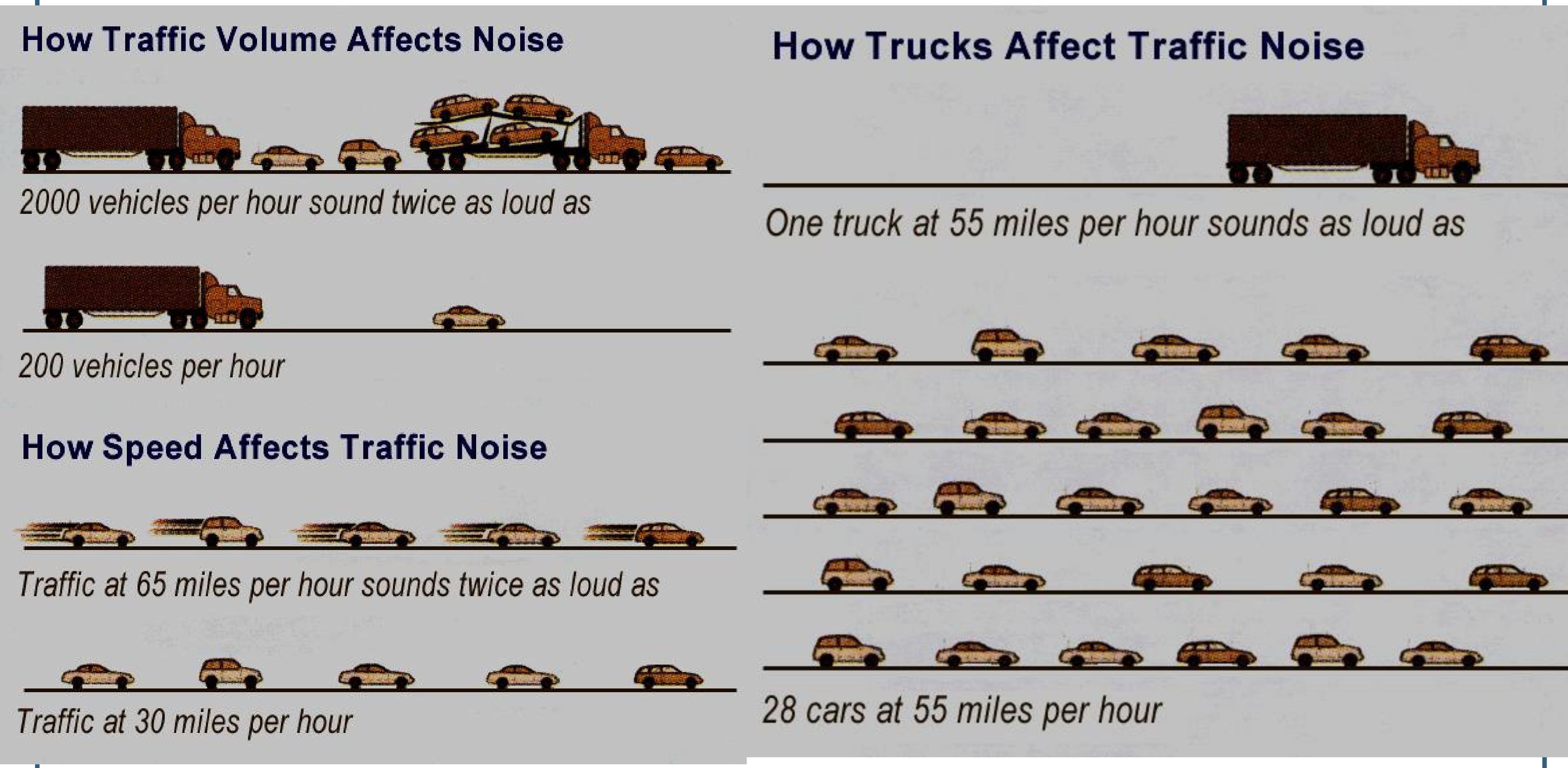
Test tracks: Proving ground testing, high speed track, pavement track, corrugated track, mud track, steering pad, gradient track, deep wading through shallow water

Laboratory testing : Testing on chassis dynamometer, transition testing (Euro III onwards), accelerated testing, virtual testing, evaporative emission testing, oil consumption testing, endurance test, high speed performance test.

Vehicle Testing:

- Automotive safety and governmental standards vary greatly around the world. Automotive testing and homologation is the process of certifying that these standards have been satisfied.
- Whether on a full vehicle or component level, the process of testing and subsequent reporting to the regulatory authorities that allow the vehicle to be sold in India
- The process is relentless, time-consuming, and subject to strict requirements.

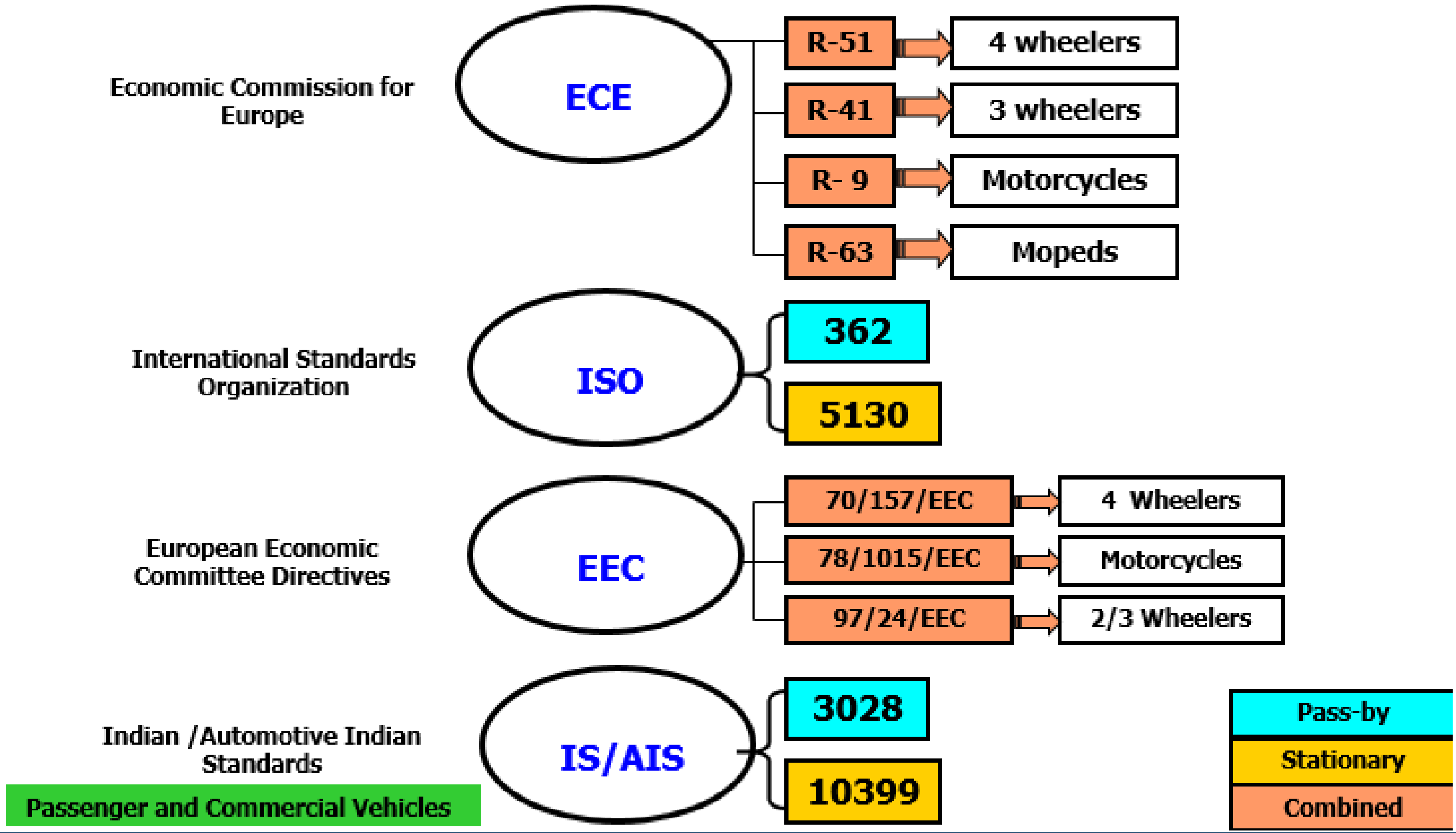
Automotive Noise:



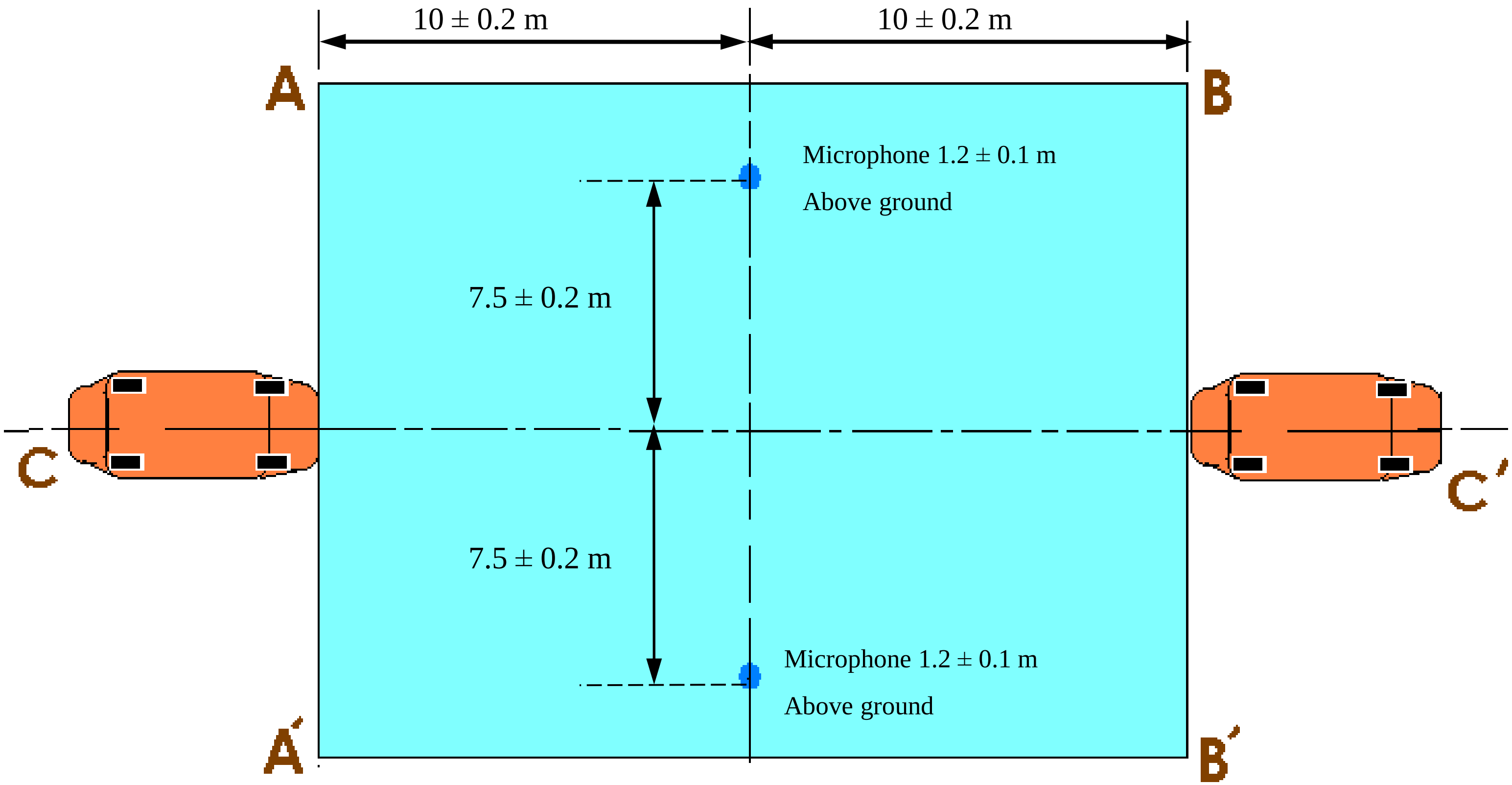
VEHICLE NOISE MEASUREMENT STANDARDS

1.	IS 3028:1998	# Noise Emissions - Pass-by
2.	IS 10399:1998	# Noise Emissions – Stationary
3.	Environment Protection Agency/ Subchapter G/ Part 204	# Transportation Equipment Noise Emission Controls
4.	ECE R –51,R-41,R-9,R-63	# Noise Emissions
5.	70/157/EEC, 78/1015/ EEC, 97/24/EEC	# Noise Emissions
6.	ISO 362:1998	# Noise Emissions - Pass-by
7.	ISO 5130:1998	# Noise Emissions – Stationary

AUTOMOBILE NOISE MEASUREMENT STANDARDS



Pass by Noise Test: Reference IS 3028 : 1998



❑ Preparation of the Vehicle:

1. The vehicle shall conform in all its parts, components and systems to the design and/or production series as applicable.
2. Prior to test, the vehicle shall be run-in as recommended by the manufacturer.
3. The vehicle's tyres shall be of the type normally fitted to such vehicles by the manufacturer. Tyres that have covered only 10 percent or less of their expected life shall be fitted on the vehicle.
4. The tyres shall be inflated to the appropriate pressure(s) for the load condition prescribed for the test as specified by the vehicle manufacturer.

5. Before the measurements are obtained, the engine shall be brought to its normal operating condition with regard to temperatures, settings, fuel, spark plugs, carburetor, etc.
6. If the vehicle is fitted with fan(s) having an automatic actuating mechanism, this system shall not be interfered during the measurements.
7. Prior to testing it shall be ensured that the vehicle is in running order as defined for the kerb weight condition, and with the test driver/rider. The kerb weight condition shall be the same as defined in IS 9211, IS 9726, IS 11422 as appropriate. In the case of two and three wheelers the combined weight of the rider and the test equipment used on the vehicle shall be within 80 * 10 kg. If necessary additional weights may be added to the vehicle to meet this requirement.

8. If the vehicle is designed to be attached with trailer or semi-frailer, they shall be uncoupled except in the case of vehicles where trailer or semi-trailer cannot be uncoupled.
9. Only the normal highway drive shall reengaged in vehicle with more than two drive wheels
10. In case of two wheelers fitted with a sidecar, the side car shall be detached.
11. The test shall be carried out on fully built vehicles where applicable including cabin and load body or on a drive away chassis on manufacturer’s request.

❑ Nature and Number of Measurements

- The maximum sound level expressed in A-weighted decibels [dB(A)] shall be measured as the vehicle is driven between lines *AA'* and ***BB'*** (Fig. 2). The measurement shall be invalid if an abnormal discrepancy between the peak value and the general sound level is recorded. At least two measurements shall be taken on each side of the vehicle. The measurements are considered valid if the difference between two consecutive measurements on the same side of the **vehicle** does not exceed **2** dB (A).

❑ Positioning of the Microphone

- The microphone shall be located at a distance of 7.5 ±0.2 m from the reference line CC' of the track and 1.2 ±0.1 m above the ground. Its axis of maximum sensitivity shall be horizontal and perpendicular to the path of the vehicle (line CC').

PASS BY NOISE MEASUREMENTS – Operation

- Vehicle shall be driven in a straight line over the acceleration section in such a way that median longitudinal plane of the vehicle is as close as possible to the line CC′.
- The vehicle approaches line AA′ with steady approach speed explained below and prescribed gear ratio. As front end of vehicle reaches AA′ , the accelerator control is operated as rapidly and smoothly until the rear of vehicle reaches the line BB′, the accelerator is released as early as possible.
- The maximum sound level measured in dB(A) for above operation constitutes the SPL reading for the vehicle.

Fig. 1: Pass-by Noise Measurement Set-up

PASS BY NOISE MEASUREMENTS – Operating Conditions

- **Approach Speed for Two & Three Wheelers:**

Sr. No.	Vehicle Type	Approach Speed (km/h)		Criteria
1	Two Wheelers (2W)	30 km/h		For all with maximum design speed of 45 km/h and engine capacity ≤ 50 cc
1.1	With manual shift gear box (2W & 3W)	Minimum of	50 km/h	---------
			Speed #	75% of engine rpm at max.power
			Speed #	75% of engine rpm permitted by governor
1.2	With Automatic Transmission			
	a) Without a manual selector or with fixed transmission ratio	Any of 30 /40 / 50 km/h		All these speeds should be less than 75 % max. design engine speed
	b) With manual X forward drive positions	Same as of 1.1		Speed is 60 km/h if kick down occurs at 50 km/h

Passenger and Commercial Vehicles

PASS BY NOISE MEASUREMENTS – Operating Conditions

- **Approach Speed for Four Wheelers**:

	Vehicle Type	Approach Speed (km/h)		Criteria	
1	Four Wheelers (4W) and multi-axle vehicles				
1.1	For vehicles	Minimum of	50 km/h	------	
			Speed #	75% of engine rpm at max.power for M1 and less than 225kW	
			Speed #	50% of engine rpm at max.power for non M1 and more than 225kW	
1.2	For vehicles with automatic transmission with more than 2 ratios	Either one of	60 km/h	To avoid change down of gear	
			50 km/h #	95% of full load throttle	
				S.I.	90% of full throttle
				C.I.	90%of the rack's full travel of pump
1.3	For vehicles with automatic transmission with no manual override		30 /40 /50 km/h	----	
			Speed #	75% of max road speed	

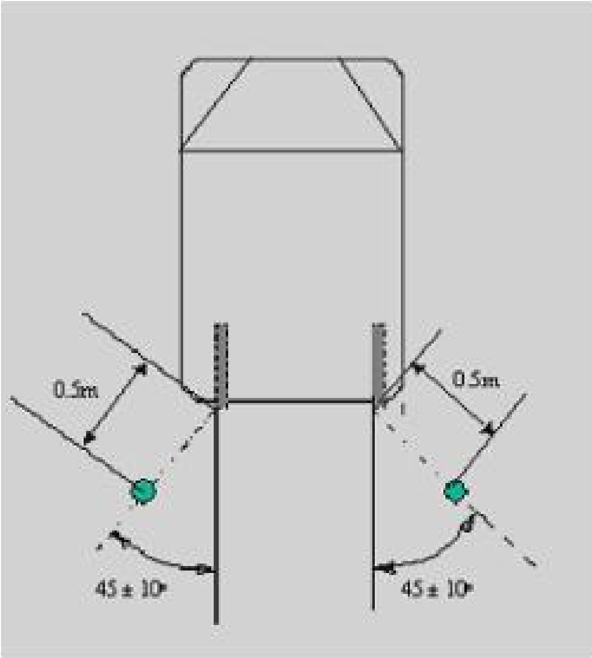
Passenger and Commercial Vehicles

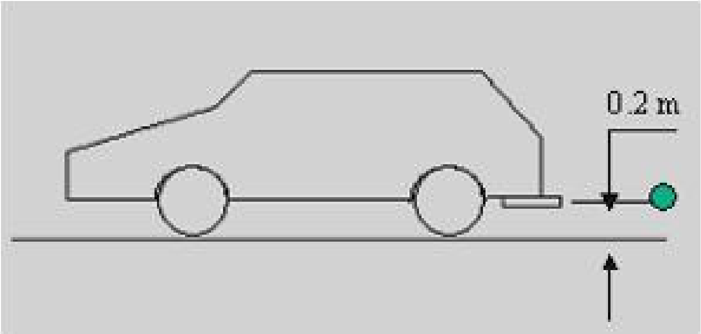
STATIONARY NOISE MEASUREMENTS

Fig. 2: Stationary Noise Measurement Set-up

	Class of Vehicles Category	Existing dB(A)
1	2 Wheelers	
	< 80 cc	75
	80 cc & 175 cc	77
	> 175 cc	80
2	3 Wheelers	
	< 175 cc	77
	> 175 cc	80
3	M1	74
4	M2/N1	
	GVW < 2 ton	76
	2 – 3.5 ton	77
5	M2/M3	
	< 150 kW	78
	>= 150 kW	80
6	N2/N3	
	< 75 kW	77
	75 – 150 kW	78
	> 150 kW	80

STATIONARY NOISE MEASUREMENTS – Microphone locations





Passenger and Commercial Vehicles

STATIONARY NOISE MEASUREMENTS –
Operating Conditions

- **Near Exhaust** : -

- Vehicle's Normal operating condition with no gear engaged

- Measure the SPL for accelerating the span starting from accelerating the engine by opening the throttle & keeping this open for short period & immediate release of accelerator pedal

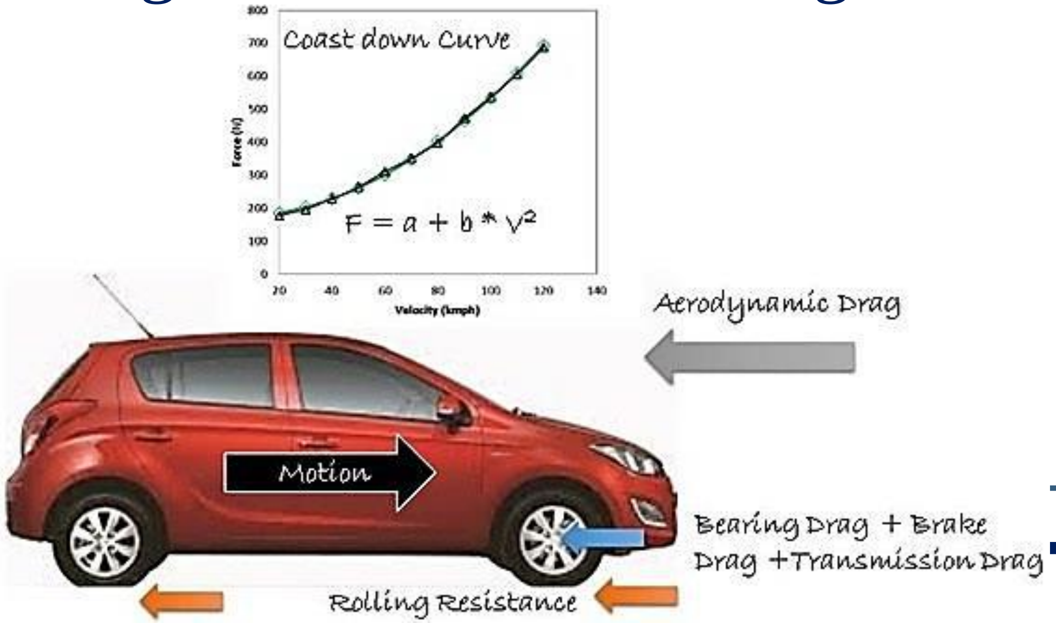
S_{test} =(1/2) S_{rated} if S_{rated} > 5000 rev/min only for 2W/3W

=(3/4) S_{rated} if S_{rated} < 5000 rev/min for all other vehicles

Passenger and Commercial Vehicles

Coast Down Test: Reference IS 14785:2000

- Coast down is nothing but a simple test performed on a perfectly flat road to calculate all the resistance offered to a running vehicle.
- When we drive on road there are lot of drag that tries to slow down the vehicle such as Aerodynamic drag, brake drag, bearing and transmission drag.



General

- Coast down test for a specific test speed (v) is basically to establish the road-load 'F' from the deceleration by measuring time elapsed from speed 'v + δv' to speed 'v - δv', when the transmission is in neutral. From the values of ***'F*** at different speeds, values of constants ***'a'*** and 'b ' in equation F = $\boldsymbol{a} + \boldsymbol{b}\boldsymbol{v}^2$ are determined by best curve fit method.
- In the case of two wheelers, the recommended height of rider shall be 1.7 f 0.05 m and the rider shall wear helmet and proper riding gear. He shall be seated upright on the seat provided for the rider, his feet upon the pedals or foot rests. This position shall, nevertheless, allow the rider at all times to have proper control of the vehicle during the test.

- While carrying out the test, the portion of the test track where the vehicle is decelerated from ‘v + δv’ to ‘v - δv’ shall be kept approximately same in both directions to reduce the effect of track variation. This shall be followed for each test speed
- For improving the consistency of the test results, it is preferable that :

  a) the test at all speeds is conducted by the same rider/ driver.

  b) the test at each speed shall be done continuously without intermediate stoppage.

Testing Procedure

- The test shall be conducted with load condition of weight required for-establishing the road-load.
- The test shall be conducted at least at 5 speeds. Difference between each test speed shall not be less than 10 km/h.
- The lowest speed at which test is done shall not be less than 20 km/h.
- However in case of vehicle with maximum speed attainable under the test load and track condition is not exceeding 60 km/h,
    1. The interval between test speeds (a) above may be reduced to the extent particularly needed, but not less than 5 km/h
    2. The lowest speed (b) above may be reduced to 10 km/h.
- The highest speed shall be more than or equal to speed at which road load equation is intended to be used. However, the highest test speed shall not be more than 80 percent of the maximum speed achievable by the vehicle under the test load and test track condition.

- The value of ‘δv’ shall not be less than 3km/h and not more than 5 km/h.
- Mount the instrumentation on the vehicle and make necessary connections. km/h and not more than 5 km/h.
- During the test, the windows and other ventilating passages shall be kept closed. They may be kept open to the minimum extent needed for installing the instruments.
- The vehicle shall be warmed up by running the vehicle for at least 15 km, at test speed prior to test. The test shall begin immediately after completion of warming up. Warming up shall be repeated before tests for each speed.
- The vehicle shall be driven along a straight line during the test.

- Attain a speed of about 5 to 10 km/h above ($v + \delta v$) and shift the transmission of vehicle in neutral. Measure time (t_1) up to 2 decimal places required for the speed to reduce from '$v + \delta v$' to '$v - \delta v$' in one direction. In case the vehicle has transmission without manual control, the test shall be done by towing/ pushing the vehicle to achieve required speed and releasing the towing/pushing arrangement. In case of electric vehicles, if the regenerative braking system can be electrically switched off, disconnecting the drive from the wheels may be done by switching off the same and the power supply to the motor. If it is not possible to do so, the motor should be decoupled before the test and the test shall be done by towing/ pushing the vehicle to achieve required speed and releasing the towing/pushing arrangement. The towing/ pushing shall be done in such a way that it does not affect the test.

- Repeat the test immediately in the opposite direction and note the time (t_1) as explained above. Take arithmetic average (r) of t_1 and t_2 from the value of t, calculate the deceleration force (F_{mean}) as:

$$F_{mean} = \frac{(\text{Test load}).(\delta v).(\beta)}{1.8 . t} \text{ Newton}$$

Where, Test load = weight of test vehicle, in kg,

β = (A factor to take into account the inertia of rotating parts), that is, 1 for 2 and 3 wheelers and 1.035 for other vehicles; and

t = time, in seconds.

- Repeat the tests sufficient number of times to enable to select the lowest 10 statistically consistent readings of F_{mean} at each speed. The reading shall be considered as statistically consistent when the statistical error (P) calculated as per formula given below is within 2 percent:

$$P = \frac{k \cdot s \cdot 100}{F_{av} \cdot \sqrt{10}} = 24.24 \times \frac{\sqrt{\Sigma (F_{mean} - F_{av})^2}}{F_{av}}$$

where

$k = 2.3$ for $n = 10$,

s = standard deviation $= \dfrac{\sqrt{\Sigma (F_{mean} - F_{av})^2}}{\sqrt{(10-1)}}$,

F_{mean} = average for force in both directions, and

F_{av} = average of 10 readings of 'F_{mean}'.

- Repeat the test for all the desired test speeds. Depending on consistent length of test track available, the tests may be carried out for more than one speed in the same run. In such cases, as the condition of 8.2.3 would not be satisfied, it shall be ensured that the variation of the track does not affect the test results.
- The road load is calculated as

$$F = \boldsymbol{a + bv^2}$$

where

F = road load, in Newton;

a and b = road load constants; and

V = test speed, in km/h.

❖ Free Acceleration Test: Reference- IS 8118:2008

❑ ***Measurement Procedure for Free Acceleration Test***

1. The test shall be carried out on an engine Installed on a test bench or on a vehicle.
2. The engine of the vehicle shall be warmed-up to attain oil temperature of 60 °C. The test shall be carried out as soon as this engine condition is reached.
3. The combustion chamber shall not have been cooled or fouled by a prolonged period of idling preceding the test.

4. The vehicle gear change control shall be set in the neutral position and the drive between engine and gearbox engaged. 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 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 opacimeter 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.

5. The operation described in 4 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 operation the sample probe shall not be inserted in to the vehicle exhaust system.

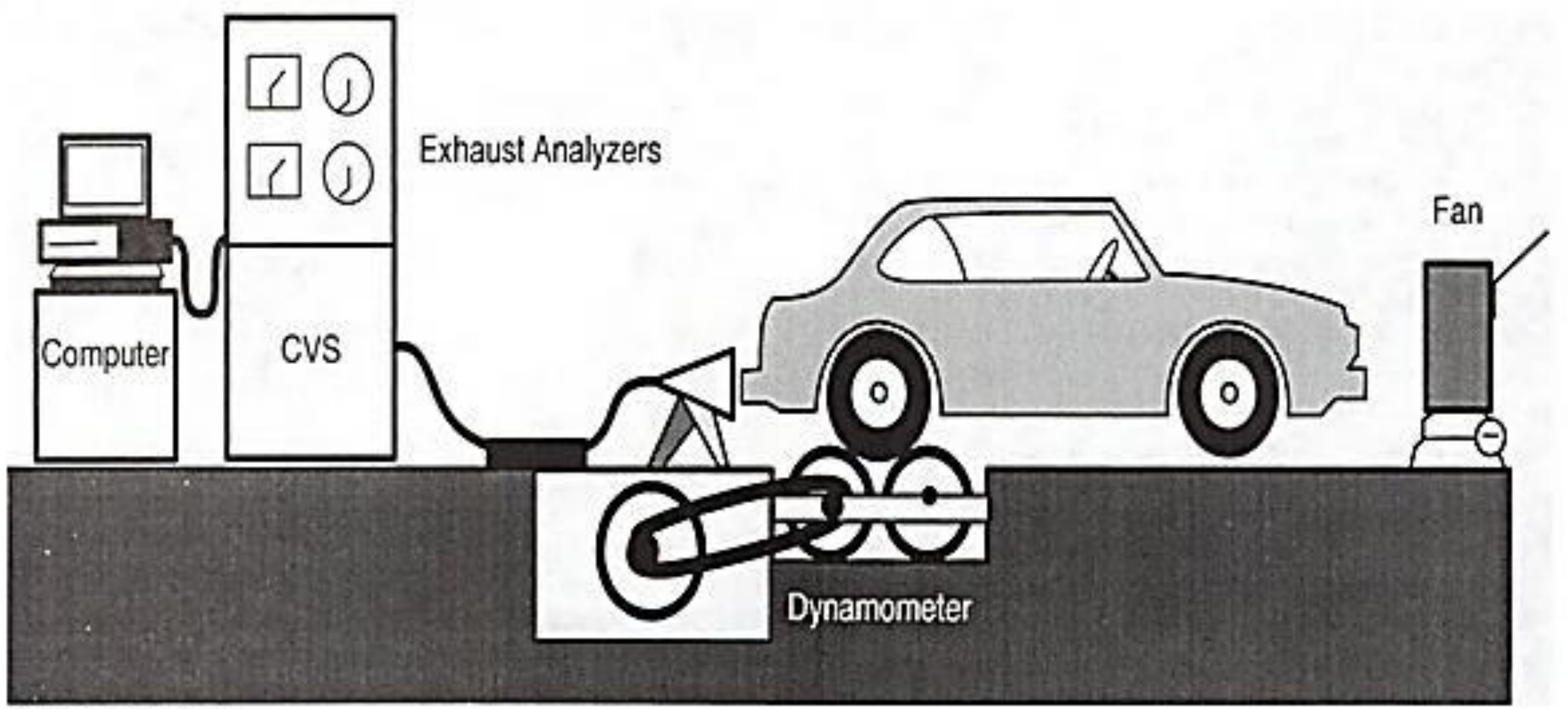
6. The free acceleration smoke test as per operation in 4 shall be carried out with sample probe inserted in to the vehicle exhaust system. The maximum no load rpm reached during this operation shall be within + 500 rpm in respect of 3 wheeler vehicles and + 300 rpm for all other categories of vehicles, of the average value obtained in the last four of the six flushing cycles in 5. 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. The vehicle should be considered meeting the requirement if the absorption coefficient thus recorded is less than the prescribed limits.

In case the valid readings are not obtained within the 10 free-accelerations, the testing shall be discontinued and the vehicle owner shall be advised to re-submit the vehicle after the same is repaired / serviced.

7. For the purpose of PUC certification if the smoke is not within limits as per table below, the testing shall be discontinued and the vehicle owner shall be advised to re-submit the vehicle after the same is repaired / serviced.

Method of Test	Maximum Smoke Density	
	Light absorption coefficient(1/m)	Hartridge units
Free acceleration test for turbo charged engine and naturally aspirated engine complying BSIII and below norms	2.45	65
Free acceleration test for turbo charged engine and naturally aspirated engine complying BSIV and above norms	1.62	50



Source: U.S. EPA 1995

❖ Road Load Data Acquisition

- Road load data measurement is used by many vehicles and OEM manufacturers in vehicle testing to optimise the design of each components and system. The data collection is done on the test track on the road, proving ground or on test rig. The data acquired is used to correlate test data result to simulation models and to develop and optimize better components.
- The measured data can be replayed on a test bed to simulate all loads in laboratory environment. All systems and components are tested under customer's specific test conditions using road load data inputs as well as duty cycle inputs correlated to real world conditions on a test rig. To optimize mechanical components, it is necessary to know the loads that the product withstands during its lifetime. Therefore precise measurement from a high number of sensors is required.

- Road load data is one of the best sources of fundamental information necessary for analysis of the design, reliability, and structural integrity of vehicle components. All elements of the measuring system must have high accuracy and resolution to ensure reproduction of the test conditions. This demand requires that you combine a durable, highly accurate wheel sensor with an electronics package that can record and process the data quickly and accurately.
- The sensors must be accurate, but most importantly, they must be robust and reliable to survive the shock, heat, humidity, and contamination associated with various measurement locations on the vehicle and the adverse conditions of the road profile

- The basic requirement for road load data (RLDA) measurement systems are:

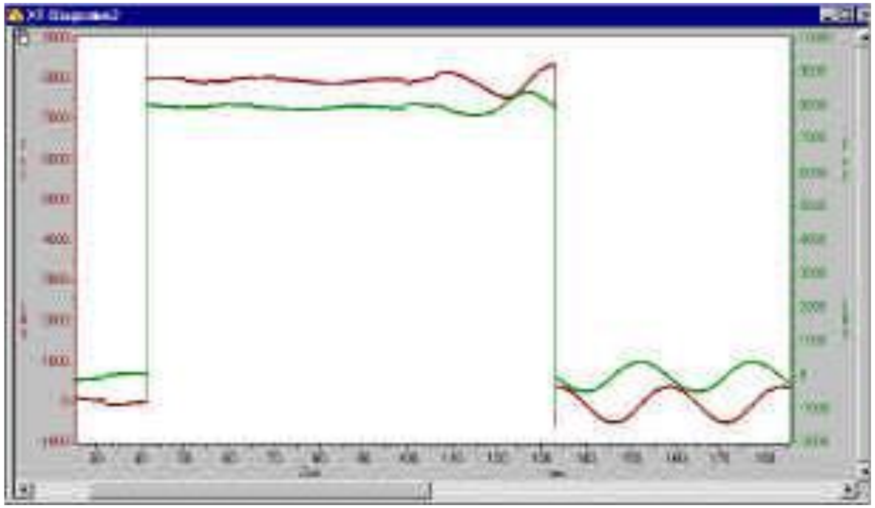
- Simultaneous and aliasing free recording with high channel count
- Connectivity for a broad range of sensors - including a flexible power supply
- Shunt calibration
- Amplifier and sensor balance
- Powerful online mathematical, statistical and filter conversion
- Trigger and alarm event
- Fast and efficient data visualization and processing
- Traceability, export, replay and share of data




❑ Data Acquisition Software

- The data acquisition software provides for on-line calibration and alignment during driving on a horizontal road under non-force conditions. It also provides for on-line supervising of the status of the wheel sensors with an on-line display and recording of any potential errors together with the data stream to disk.
- Potential errors can be identified as an angle deviation larger than a programmable amount, a mismatch of shunt cal values during calibration, or a large zero offset.
- All settings are stored in a protocol trace file and can be printed out later as corner loads, zero offsets, or shunt cal values.
- It provides for on-line calculation and recording of the resolved signals

- It has the capability of storing all signals or subsets of the channels like resolved signals only.
- Data is available for evaluation and analysis immediately after recording is finished; areas with potential errors during the test run can be easily identified.
- Data can be directly transformed into various software formats such as nCode's DAC-format or MTS' RPCIII format



Sensors required for Road-load measurements:

1. Accelerometers,
2. Pressure Sensors,
3. Force Sensors (Wheel Force Transducers),
4. Strain Sensors,
5. Load Cells, and
6. Signal Conditioners

Multi-Axis Wheel Force Transducers

- Multi-Axis Wheel Force Transducers are designed as rugged one piece sensors that mount between the vehicle hub and the wheel rim, delivering highly accurate road load data measurement and superior performance in a durable water resistant package. Possessing superior temperature compensation properties and integral overload stops, these sensors provide a high level of confidence in data acquired during aggressive road events, including heavy braking tests.

- A wide variety of sizes are available for vehicles including passenger cars; light, medium- and heavy-duty trucks; commercial vehicles including tractor trailers, buses, agriculture, and earth-moving equipment; and military vehicles.
- Passenger car and light truck units use a custom hub adaptor to accommodate a wide range of vehicle sizes while maintaining vehicle geometry. Heavy truck units mount directly to the vehicle hub.
- All units can be fitted with either slip ring or telemetry signal transmission, and come equipped with on-board signal conditioning and calibration circuitry for each channel of data measurement, making their setup and use with the Transducer Interface Unit (TIU) quick and easy.

❖ **Test Tracks:**

1. Proving Ground

- A **proving ground** (US), **training area** (Australia, Ireland, UK) or **training centre** (Canada) is a military installation or reservation where weapons or other military technology are experimented with or are tested.
- There's a good chance that you drive (or at least ride in) a car every day.
- You may have a family that rides in that car with you. And chances are that you trust that car to keep you and your family safe.
- Even under unusual driving conditions -- weird weather, high speeds, bumpy roads, accidents -- you expect your car to respond well and protect you and your loved ones.
- After all, the manufacturer has advertised the car as having certain capabilities and being safe to drive.

- But how, exactly, does the manufacturer know that? How do the people who built your car know exactly what conditions it can stand up to?
- Did they drive it through all possible road conditions under all possible circumstances?
- Well, yes, they did. Before a car is put on the market, it has to be tested in extreme conditions to make sure that no manufacturing defects or design miscalculations will cause it to be unsafe or behave in unpredictable ways.
- Every now and then, of course, we hear of a car being recalled because of some unexpected defect, like sudden acceleration or exploding on impact, but these things are quite rare.
- Most cars behave exactly the way they're supposed to, at least the great majority of the time.

History:

- Until the 1920s, automotive testing was done in the same place as most automobile driving -- on city streets and country roads.
- But as the automobile became an increasingly important mode of transportation and the roads filled with cars, this ceased to be feasible.
- It was too dangerous to test cars in public places. Furthermore, auto manufacturers became wary of letting the public see their cars while they were still in the testing phase.
- Competitors might have a chance to steal trade secrets or journalists might get too close a look at future models.

- In 1924, General Motors opened the Milford Proving Grounds in what was then a fairly isolated portion of Michigan.
- It was the world's first dedicated automotive proving ground. The original site consisted of a gravel loop just under 4 miles (6.4 kilometers) in circumference, plus a straightaway.
- The entire facility was only 1,125 acres (4.6 square kilometers) in size and only a single employee worked at the proving grounds full time.
- In 1925 Ford opened its own proving ground in Dearborn, Mich., and the same year Packard built a proving ground in Shelby Township, Mich. By the mid-1920s, rural Michigan was a hotbed of automotive test tracks.

- A typical automotive proving ground looks like a combination of a military base and an amusement park.
- Proving grounds are used to provide a simulation of ‘worst case’ field events. The major problems with proving ground testing are that not all field events can be simulated, individual components and subassemblies cannot be tested and generally the cost of testing is very high.

Proving Ground (GM's Milford Proving Ground)

❖ High Speed Track:

- It is an oval shape circuit designed to meet performance need of lots of tests parameters as follows,

    1. Maximum Speed
    2. Lane Changes at high speed
    3. Braking at high speed
    4. Vehicle type approval tests
    5. Other R & D Activities

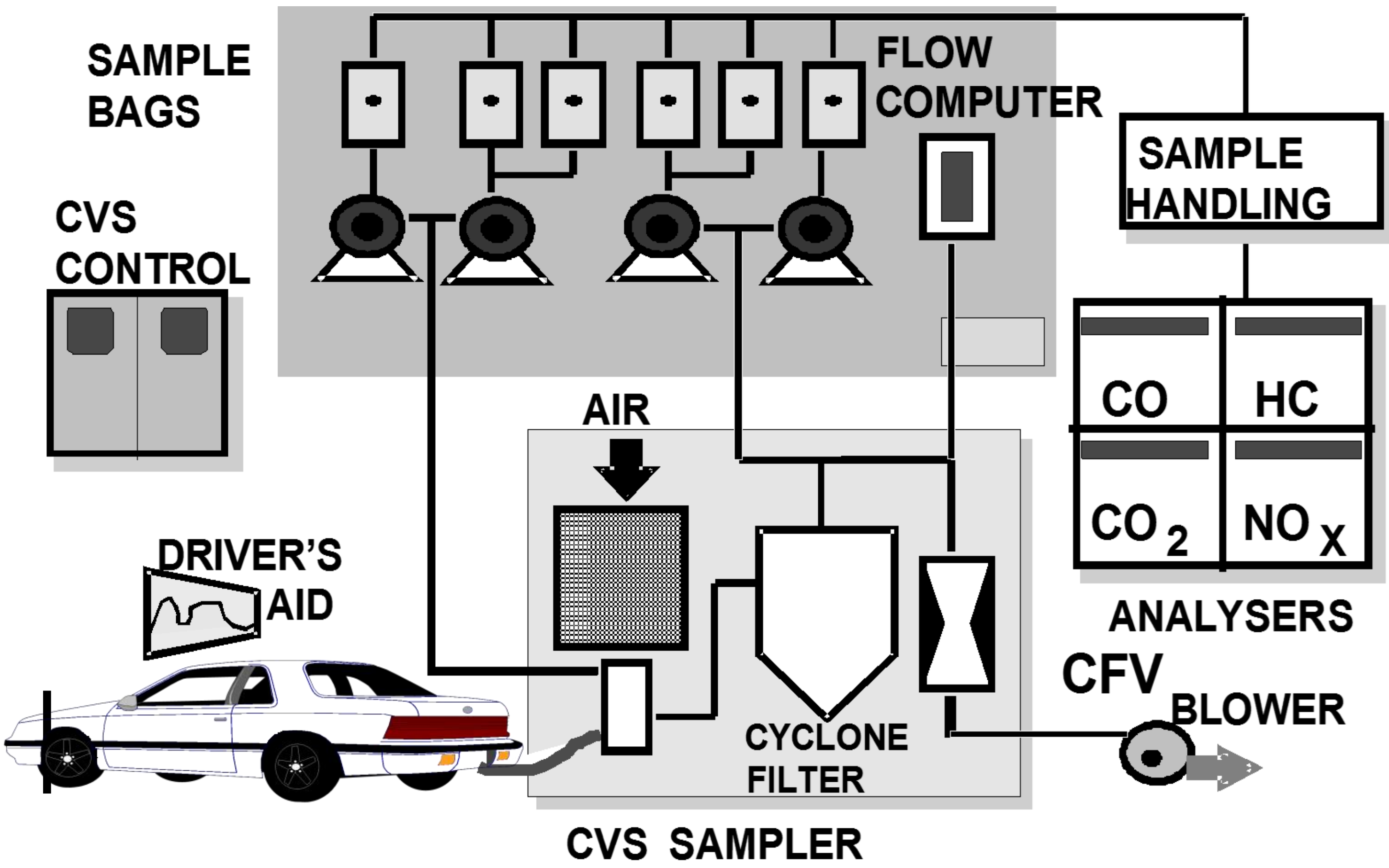
❖ Corrugated Test Track:

- Corrugated test track is mostly used for testing of following parameters
  - Suspension
  - Damping
  - Mountings
  - Components
  - Bodies and structures
  - Trailers
  - Accessories
- Corrugation has a specific height, and pitch and vary depending on the type of testing application.

❖ Chassis Dynamometer:

- A chassis dynamometer, sometimes referred to as a rolling road, measures power delivered to the surface of the "drive roller" by the drive wheels. The vehicle is often parked on the roller or rollers, which the car then turns, and the output measured thereby.
- Modern roller-type chassis dyno systems use the "Salvisberg roller", which improves traction and repeatability, as compared to the use of smooth or knurled drive rollers.
- Chassis dynamometers can be fixed or portable, and can do much more than display RPM, horsepower, and torque. With modern electronics and quick reacting, low inertia dyno systems, it is now possible to tune to best power and the smoothest runs in real time

- Motor vehicle emissions development and homologation dynamometer test systems often integrate emissions sampling, measurement, engine speed and load control, data acquisition, and safety monitoring into a complete test cell system.
- These test systems usually include complex emissions sampling equipment (such as constant volume samplers and raw exhaust gas sample preparation systems) and analyzers.
- These analyzers are much more sensitive and much faster than a typical portable exhaust gas analyzer.
- Response times of well under one second are common, and are required by many transient test cycles. In retail settings it is also common to tune the air-fuel ratio using a wideband oxygen sensor that is graphed along with the RPM.


SAMPLE
BAGS
FLOW
COMPUTER
SAMPLE
HANDLING
CVS
CONTROL
CO
HC
CO_2
NO_X
AIR
DRIVER'S
AID
ANALYSERS
CFV
BLOWER
CYCLONE
FILTER
CVS SAMPLER

- **Chassis dynamometer** is used for the following tests. It accurately simulates the vehicle in terms of inertia and road load force. With chassis dynamometers, it is possible to programme road load equation in the form:

$$F = a + bv^2 + m\, dv/dt$$

F = Tractive effort (N)

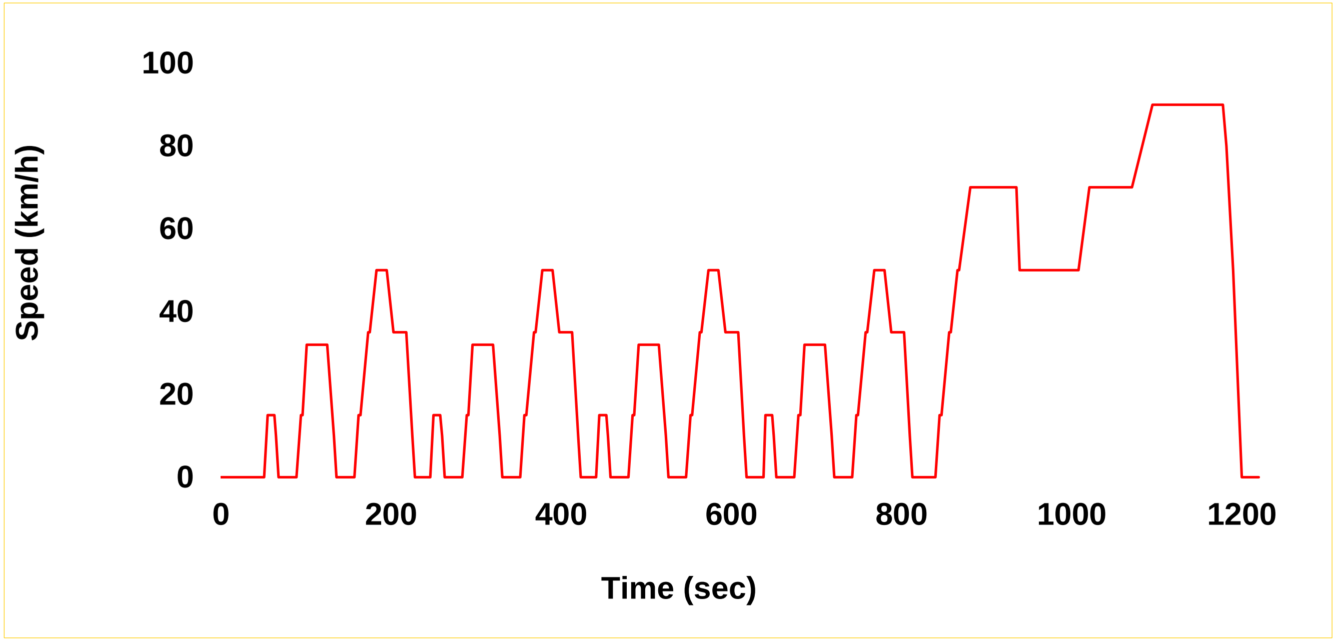
a= Rolling resistance coefficient (N)

b= Aerodynamic drag coefficient ($N/(km/hr)^2$)

m= Vehicle inertia (kg)

v= Vehicle speed (km/hr)

- The vehicles are driven according to the Indian driving cycle.



- The exhaust from test vehicle flows to the mass analyser which consists of CVS system, filters, cyclone separator, venturi, sample bags, sample analyser.

- The Exhaust flow varies according to the vehicle speed and hence to measure the exhaust volume, proportional air is added to the exhaust flow. Total volume of exhaust+ air is measured at the end of cycle which is required to calculate the mass of the constituents. Proportional sample will be collected in sample bags for analysis.
- Analysis of various constituents like CO, HC, Nox, CO2 are done on volumetric basis. CO & CO2 are measured with NDIR principle. Nox is measured with Chemilumienscent principle. HC is measured with FID principle.
- PM (for diesel vehicles) is measured by weighing filter paper on which it is collected.

$$M_i = V_{mix} \times Q_i \times K\,H \times C_{conc} \times 10\text{-}3 / Ds$$

Where,

M_i : Mass emission in g/km

V_{mix} : Vol. of diluted exhaust gas in m^3

Q i : Density of Pollutant, kg/m^3

K H : Humidity correction factor

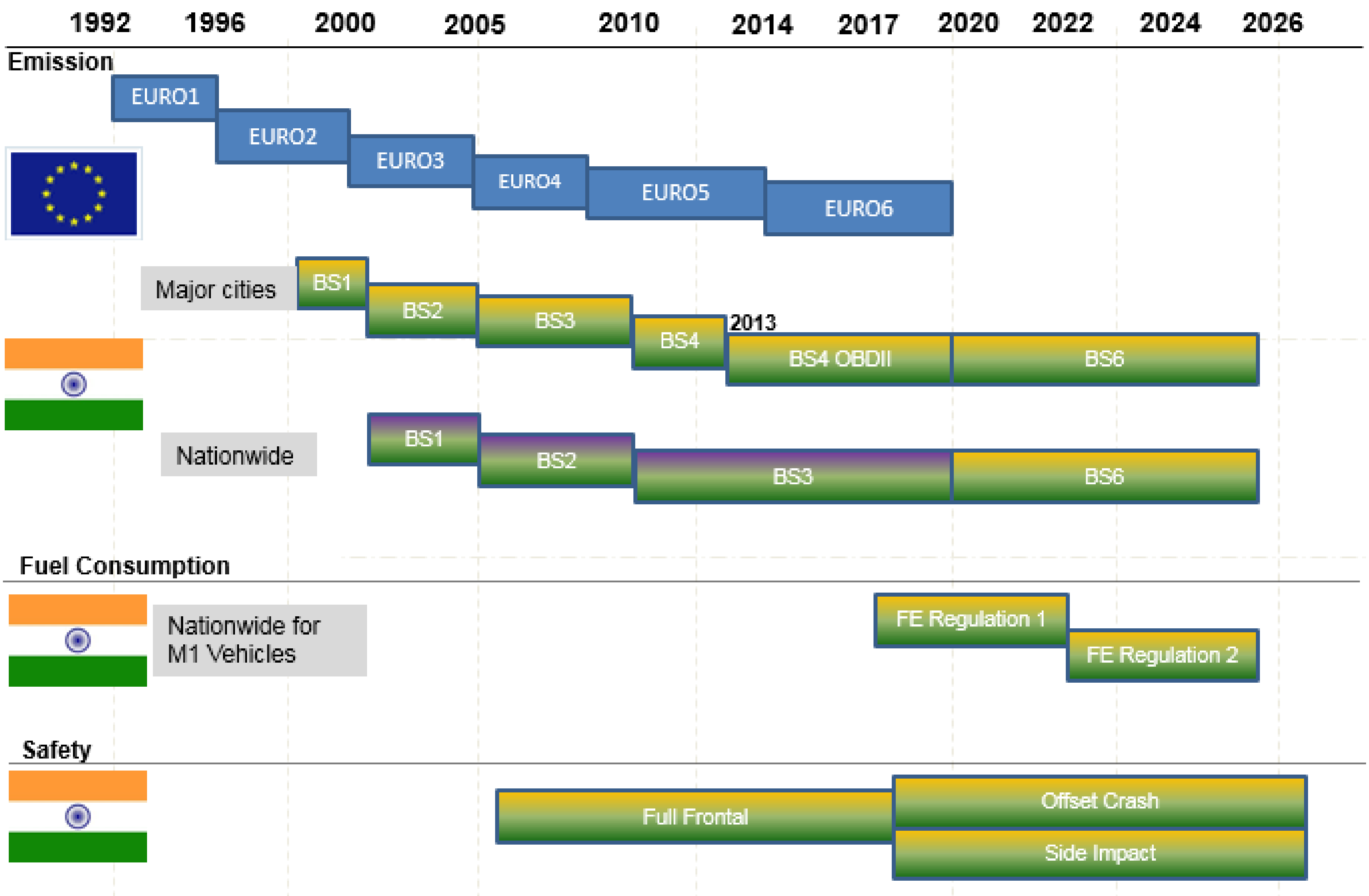
C_{conc} = Volumetric Concentration of the Constituent [C_{conc}=Ce- Cd (1-1/DF)]

(Where, DF is dilution factor and Cd is diluted exhaust concentration)

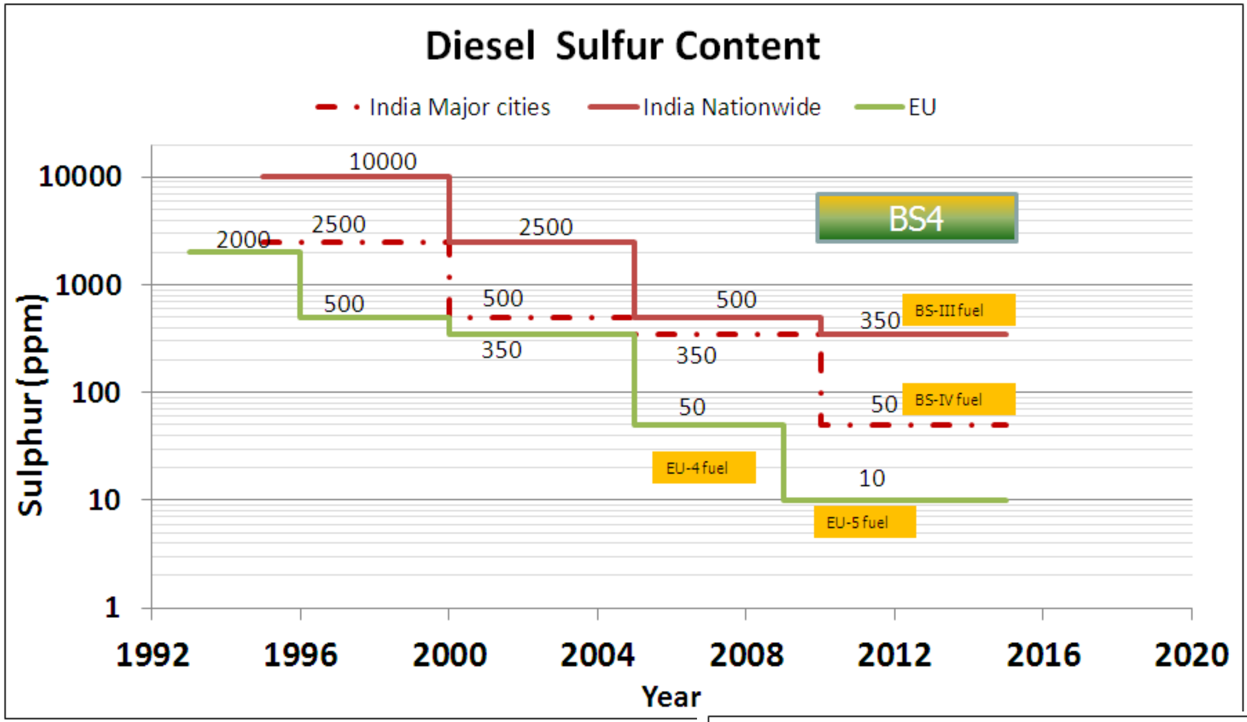
Parameter	FCL make 2-Wheeler	BEP make 3-wheeler	BEP make 4-wheeler	FCL make HCV
Type	DC Machine	AC Machine	AC Machine	DC Machine
Maximum power	5 kW absorption / motoring	50 kW absorption / motoring	149 kW absorption / motoring	155 kW absorption / motoring
Maximum Speed	100 km/h	200 km/h	200 km/h	100 km/h
Maximum tractive effort	250 N	2233 N	5844 N	14000 N
Vehicle inertia range	Up to 335 Kg.	100-450 kg for 2-Wheeler, 400- 1500 kg for 3-Wheeler	120-5443 kg Universal dyno for 2W, 3W & 4W	Up to 32000 Kg.
Roller diameter	610 mm	610 mm	1220 mm	2500 mm.
Width over rollers	--	1900 mm	2742 mm	2800 mm.
Space between the rollers	--	Single roller	Single roller	800 mm


HORIBA

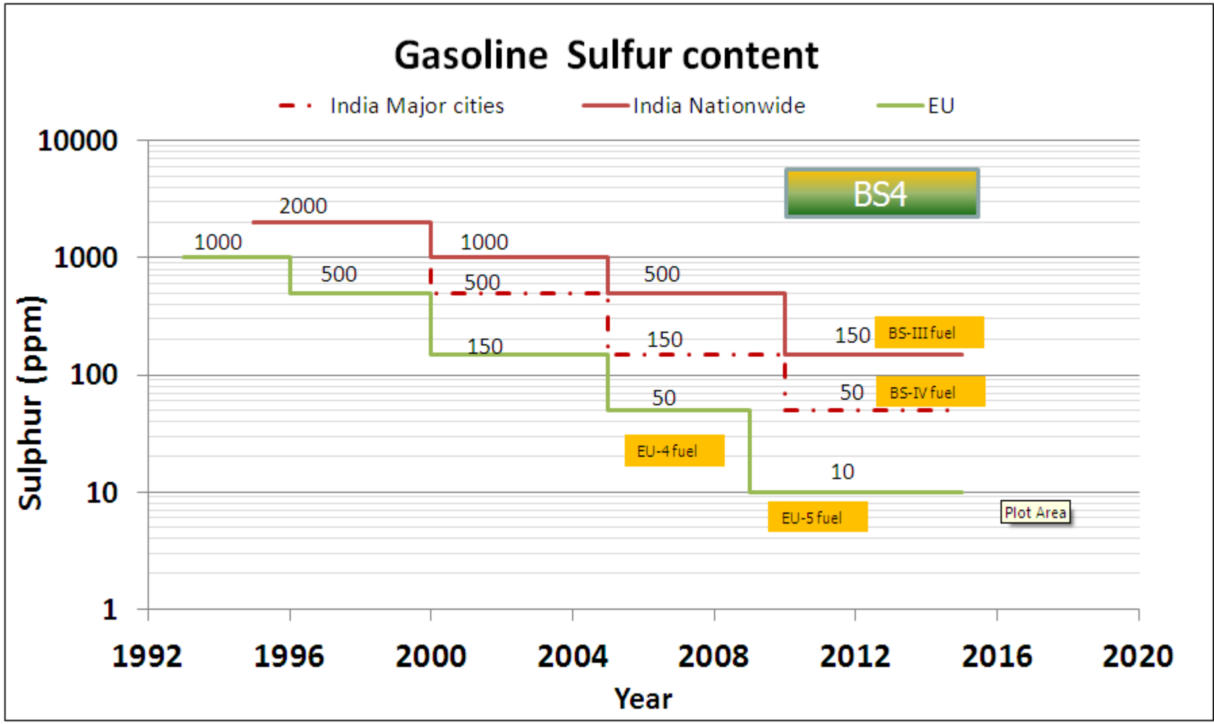
Emissions/Safety Regulations Progression in India



ri (Kd)



Diesel Sulfur Content
India Major cities
India Nationwide
EU
BS4
10000
2500
2000
500
350
50
10
BS-III fuel
BS-IV fuel
EU-4 fuel
EU-5 fuel
Sulphur (ppm)
1992 1996 2000 2004 2008 2012 2016 2020
Year



Gasoline Sulfur content
India Major cities
India Nationwide
EU
BS4
2000
1000
500
150
50
10
BS-III fuel
BS-IV fuel
EU-4 fuel
EU-5 fuel
Plot Area
Sulphur (ppm)
1992 1996 2000 2004 2008 2012 2016 2020
Year

❖ Vehicle Emission Tests

1. Type I Test (For Vehicles)- IS 14600 : 1999

- Test Setup for Type –I Mass Emission Test on Vehicles
- Driving Cycles for 2/3 Wheelers & 4-Wheelers
- Calculations for Mass Emission Test
- Emission Norms for Different Vehicle Categories

2. Type II Tests - IS 14600 : 1999

- Type II Tests for Gasoline and Diesel Vehicles (Idling Test)
- Emission Norms

3.Type III Test (Crankcase Emissions)

4. Type IV Test : IS 14555 : 1998

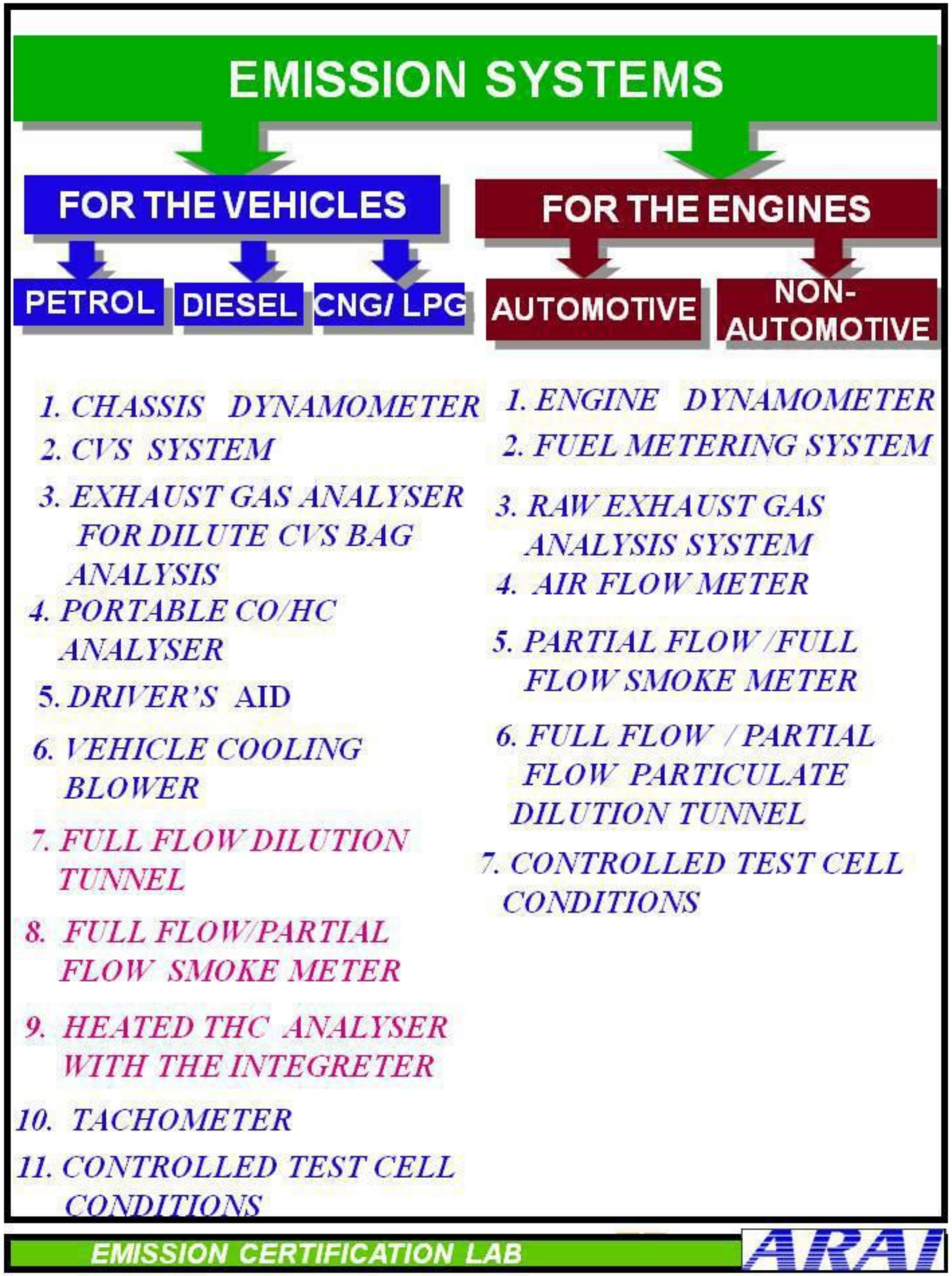
- Evaporative Emission Test – Necessity
- Indian Test Procedure Evaporative Emission - 1996
- BS-III Evaporative Emission Test Procedure

5. Type V Test (Durability Test)

- Type V Test : Comparison in India & Europe

6. Type VI Test

- Cold CO & HC emission Test for Europe

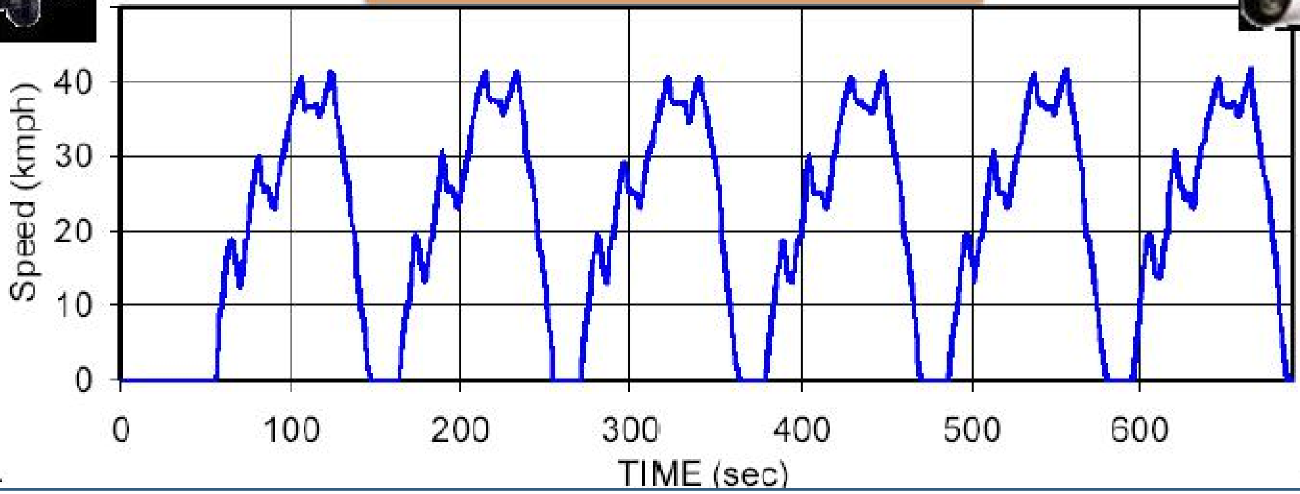

EMISSION SYSTEMS
FOR THE VEHICLES
FOR THE ENGINES
PETROL
DIESEL
CNG/ LPG
AUTOMOTIVE
NON-AUTOMOTIVE
1. CHASSIS DYNAMOMETER
2. CVS SYSTEM
3. EXHAUST GAS ANALYSER FOR DILUTE CVS BAG ANALYSIS
4. PORTABLE CO/HC ANALYSER
5. DRIVER'S AID
6. VEHICLE COOLING BLOWER
7. FULL FLOW DILUTION TUNNEL
8. FULL FLOW/PARTIAL FLOW SMOKE METER
9. HEATED THC ANALYSER WITH THE INTEGRETER
10. TACHOMETER
11. CONTROLLED TEST CELL CONDITIONS
1. ENGINE DYNAMOMETER
2. FUEL METERING SYSTEM
3. RAW EXHAUST GAS ANALYSIS SYSTEM
4. AIR FLOW METER
5. PARTIAL FLOW /FULL FLOW SMOKE METER
6. FULL FLOW / PARTIAL FLOW PARTICULATE DILUTION TUNNEL
7. CONTROLLED TEST CELL CONDITIONS
EMISSION CERTIFICATION LAB
ARAI

❖ Type-I Test

2 Wheeler & 3 Wheeler

Indian Driving Cycle is applicable	1991 norms	1996 norms	Bharat Stage -2	Bharat Stage -3
All Over India	Year 1991	Year 1996	April 2005	April 2010

Indian Driving Cycle



1. Test Procedure:

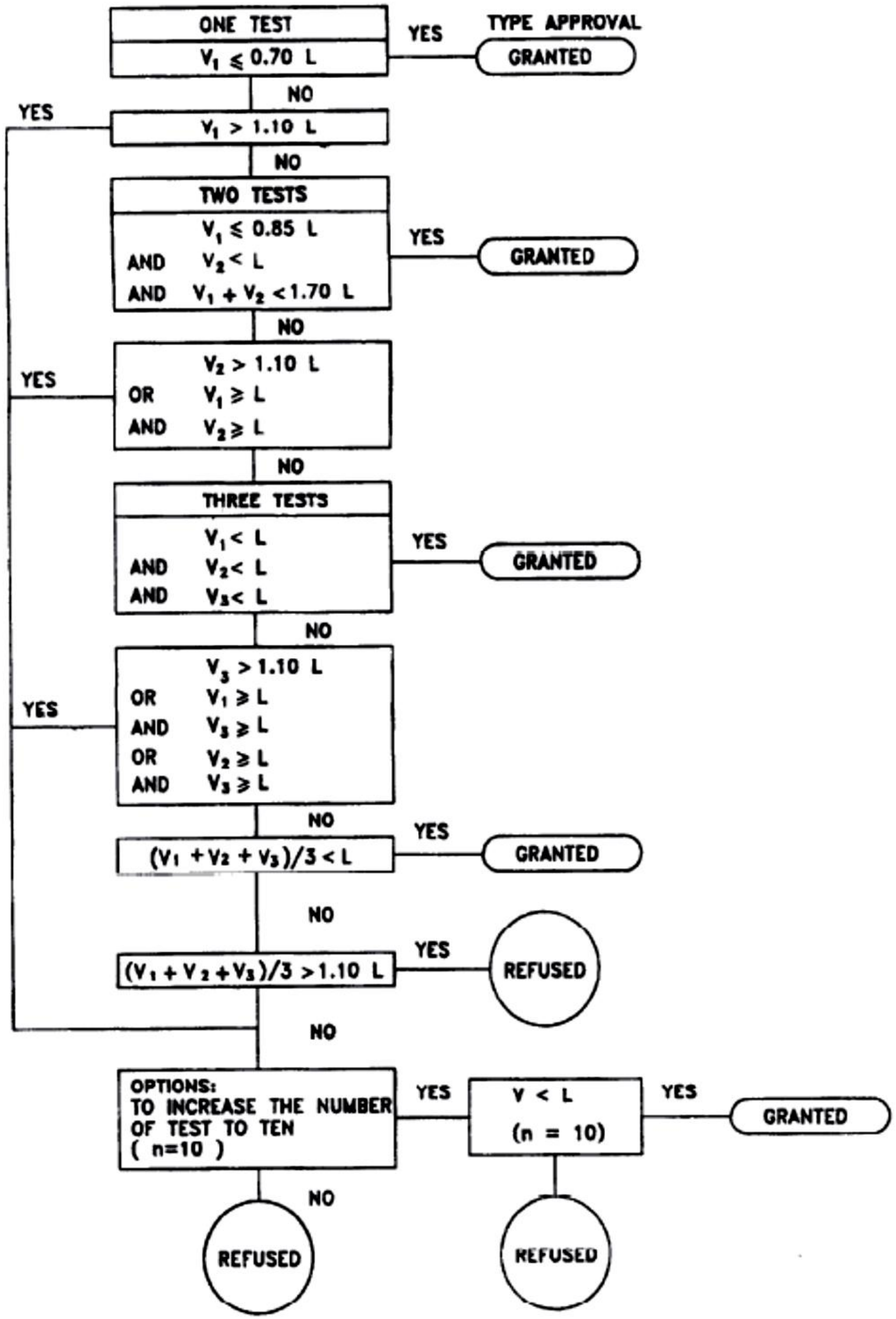
1.1 The vehicle shall be placed on a dynamometer bench equipped with a means of load and inertia simulation. A test lasting a total duration of 648 s and comprising six cycles as stipulated in **2** shall be carried out, without interruption. During the test, the exhaust gases shall be diluted with air and a proportional sample collected in one or more bags. The contents of the bags shall be analysed at the end of the test. The total volume of the diluted exhaust shall be measured.

The methods used to collect and analyse the gases shall be those specified. Other analysis methods may be approved if it is found that they yield equivalent results. The test shall be repeated three times. In case test is carried out for verification of compliance to statutory limits the condition stipulated in **1.4** shall apply.

1.2 For each of the pollutants, not more than one of the three results obtained may exceed by not more than 10 percent of the limit specified for that type of vehicle, provided the arithmetical mean of the three results rounded off to the second decimal place is not exceeding the specified limit. Where the specified limits are exceeded for more than one pollutant, it shall be immaterial whether this occurs in the same test or in different tests.

1.3 If one of the three results obtained of each of the pollutants exceeds by more than 10 percent the limit prescribed for that type of vehicle specified, the test may be continued as specified below. The number of tests specified in **1.1** may be increased to ten provided that the arithmetical mean ($\bar{x}$) of the three results falls between 100 and 110 percent of the limit (L). In this case, the decision, after testing, shall depend exclusively on the average results obtained from all 10 tests (rounded off to the second decimal place), with respect to the limits.

1.4 The number of tests specified in **1.1** shall be reduced in the conditions hereinafter specified, where V_1 *is* the result of the first test and V_2 the result of the second test for each of the pollutants. Only one test shall be carried out if V_1 readings of any of the pollutants is less than or equal to 0.70 L ($V_1 \leq 0.70$ L). Only two tests shall be carried out if the levels of the pollutants are $V_1 \leq 0.85$ L, and if, at the same time, one of these values is $V_1 > 0.70$ L. In addition, the *Vz* readings of the pollutants shall satisfy the requirement that $(V_1 + V_2) \leq 1.70$ L and $V_2 \leq$ L.


ONE TEST
V1 ≤ 0.70 L
YES
TYPE APPROVAL
GRANTED
NO
YES
V1 > 1.10 L
NO
TWO TESTS
V1 ≤ 0.85 L
AND V2 < L
AND V1 + V2 < 1.70 L
YES
GRANTED
NO
V2 > 1.10 L
OR V1 ≥ L
AND V2 ≥ L
YES
NO
THREE TESTS
V1 < L
AND V2 < L
AND V3 < L
YES
GRANTED
NO
V3 > 1.10 L
OR V1 ≥ L
AND V3 ≥ L
OR V2 ≥ L
AND V3 ≥ L
YES
NO
(V1 + V2 + V3)/3 < L
YES
GRANTED
NO
(V1 + V2 + V3)/3 > 1.10 L
YES
REFUSED
NO
OPTIONS:
TO INCREASE THE NUMBER
OF TEST TO TEN
(n=10)
YES
V < L
(n = 10)
YES
GRANTED
NO
REFUSED
REFUSED

2. Operating Cycle on the Chassis Dynamometer

2.1 Description of the cycle

- The operating cycle on the chassis dynamometer shall be as notified by the statutory authorities. The details of IDC are indicated in Tables 1 and 2 and shown in Fig. 2. In case the testing is carried out for any other driving cycle the details shall be given in the test report. Preliminary testing cycles should be carried out if necessary to determine how best to actuate the accelerator and brake controls so as to achieve a cycle approximately to the theoretical cycle within the specified limits.

Table 1 Operating Cycle on the Chassis Dynamometer
(*Clause* 4.2.2.1)

Sl No.	Operation	Acceleration (m/s^2)	Speed (km/h)	Duration of each Operation(s)	Cumulative Time (s)
i)	Idling	—	—	16	16
ii)	Acceleration	0.65	0-14	6	22
iii)	Acceleration	0.56	14-22	4	26
iv)	Deceleration	–0.63	22-13	4	30
v)	Steady speed	—	13	2	32
vi)	Acceleration	0.56	13-23	5	37
vii)	Acceleration	0.44	23-31	5	42
viii)	Deceleration	–0.56	31-25	3	45
ix)	Steady speed	—	25	4	49
x)	Deceleration	–0.56	25-21	2	51
xi)	Acceleration	0.45	21-34	8	59
xii)	Acceleration	0.32	34-42	7	66
xiii)	Deceleration	–0.46	42-37	3	69
xiv)	Steady speed	—	37	7	76
xv)	Deceleration	–0.42	37-34	2	78
xvi)	Acceleration	0.32	34-42	7	85
xvii)	Deceleration	–0.46	42-27	9	94
xviii)	Deceleration	–0.52	27-14	7	101
xix)	Deceleration	–0.56	14-00	7	108

Table 2 Break Down of the Operating Cyc Used for Type I Test
(*Clause* 4.2.2.1)

Sl No.	Operations	Time(s)	Percentage
i)	Idling	16	14.81
ii)	Steady speed periods	13	12.04
iii)	Accelerations	42	38.89
iv)	Decelerations	37	34.26
		108	100.00

NOTES

1. Average speed during test is 21.93 km/h.
2. Theoretical distance covered per cycle is 0.658 km.
3. Equivalent distance for the test (6 cycles) is 3.948 km.

2.2 Usage of the gear-box

The usage of the gear-box shall be as specified by the manufacturer. However, in the absence of any such instructions, the following points shall be taken into account.

2.3 Manual change gear-box

- During each phase at constant speed, the rotating speed of the engine shall be, if possible, between 50 and 90 percent of the speed corresponding to the maximum power of the engine. When this speed can be reached in two or more gears, the vehicle shall be tested with the higher gear engaged. During acceleration, the vehicle shall be tested in whichever gear is appropriate to the acceleration imposed by the cycle. A higher gear shall be engaged at the latest when the rotating speed is equal to 110 percent of the speed corresponding to the maximum power of the engine. During deceleration, a lower gear shall be engaged before the engine starts to idle roughly, at the latest when the engine revolutions are equal to 30 percent of the speed corresponding to the maximum power of the engine. No change down to first gear shall be effected during deceleration. Vehicles equipped with an overdrive which the driver can actuate shall be tested with the overdrive disengaged.

2.4 When it is not possible to adhere to the cycle, the operating cycle shall be modified for gear change points, allowing two seconds time interval at constant speed for each gear change keeping the total time constant. The operating cycle with recommended gear positions is shown in Fig. 3.

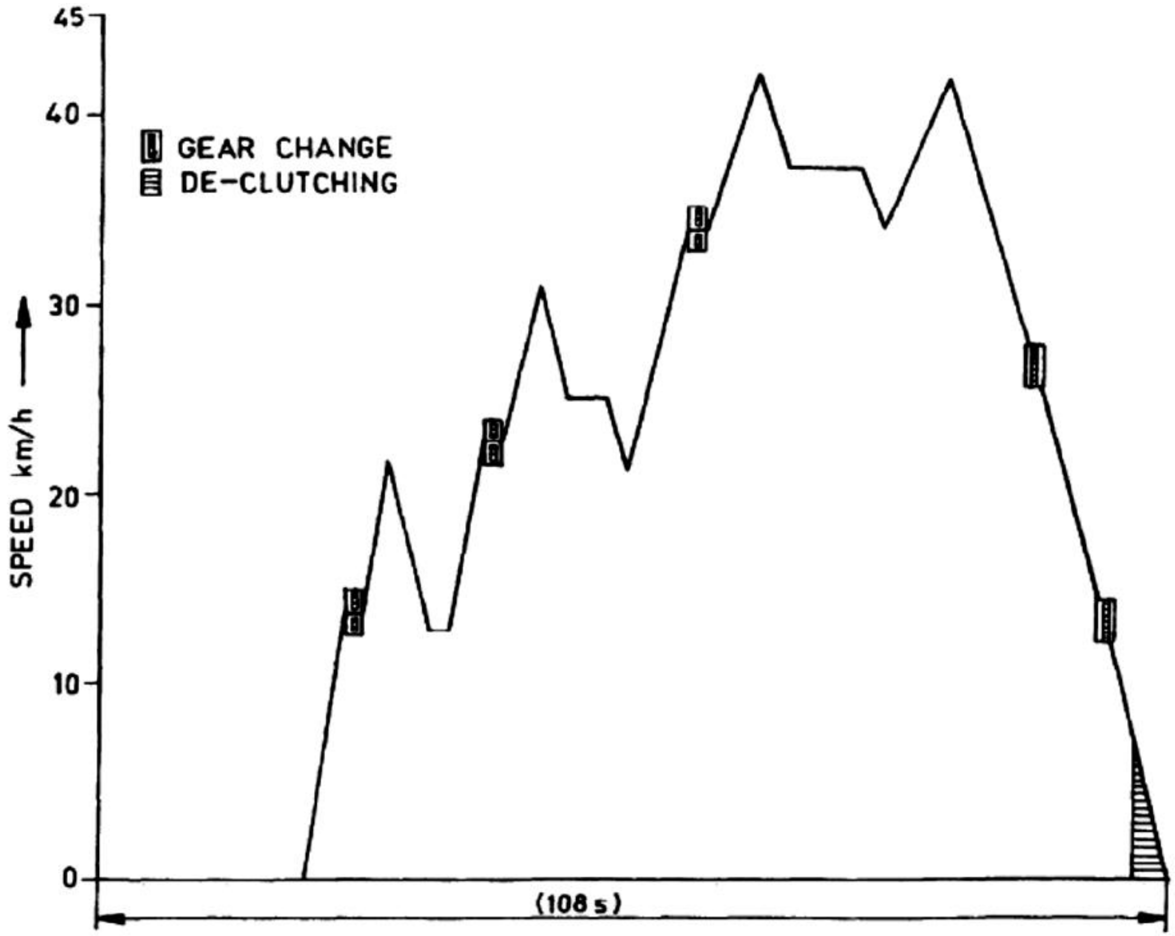


FIG. 3 OPERATING CYCLE WITH RECOMMENDED GEAR POSITION

2.5 Automatic gear-box

- Vehicles equipped with automatic shift gear-boxes shall be tested with the highest gear (drive) engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order.

3. Tolerances

3.1 A tolerance of +l km/h shall be allowed between the indicated speed and the theoretical speed during acceleration, during steady speed and during deceleration, when the vehicle's brakes are used. If the vehicle decelerates more rapidly without the use of the brakes, then the timing of the theoretical cycle shall be restored by constant speed or idling period merging into the following operation. Speed tolerances greater than those recommended shall be accepted, during phase changes provided that the tolerances never exceed 0.5 s on any one occasion.

3.2 Time tolerances of + 0.5 s shall be allowed. The above tolerances shall apply equally at the beginning and at the end of each gear changing period.

3.3 The speed and time tolerances shall be combined as shown in Fig. 2.

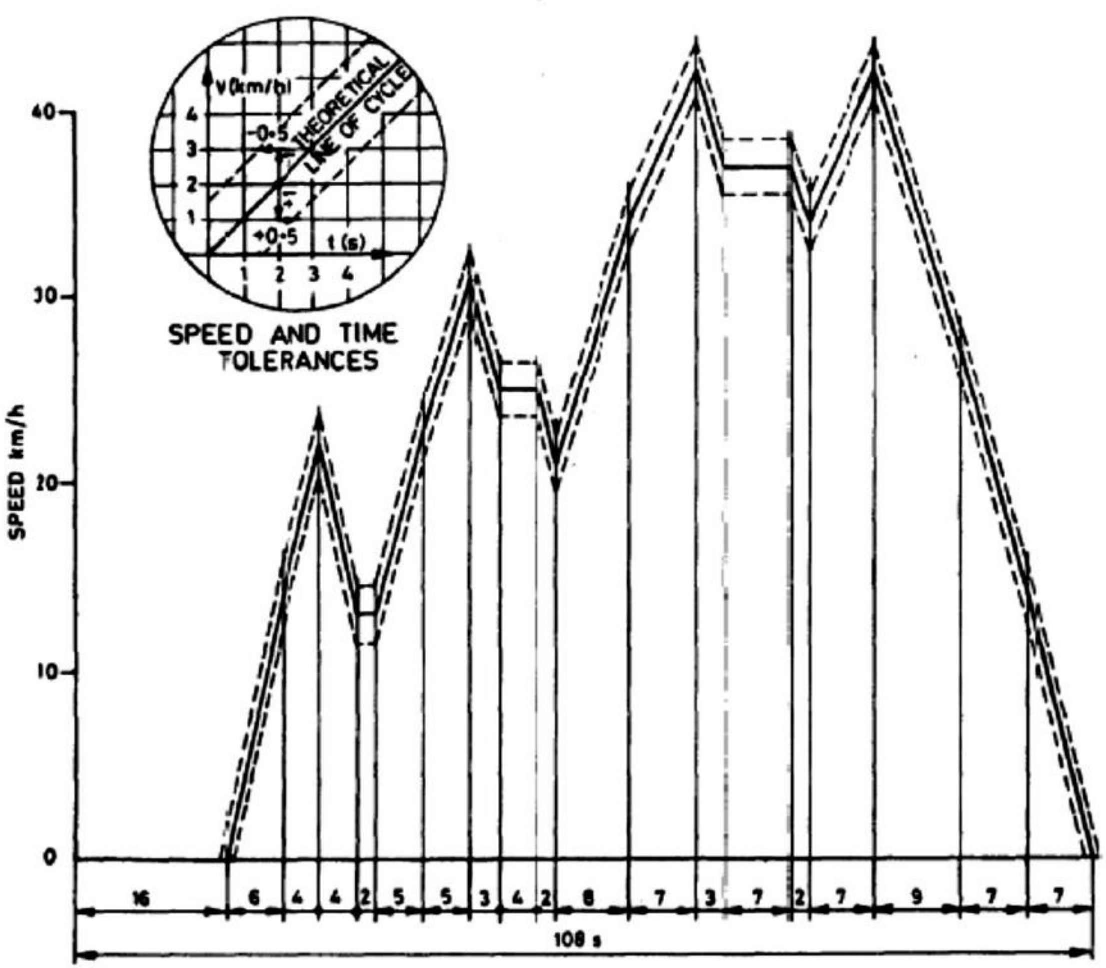
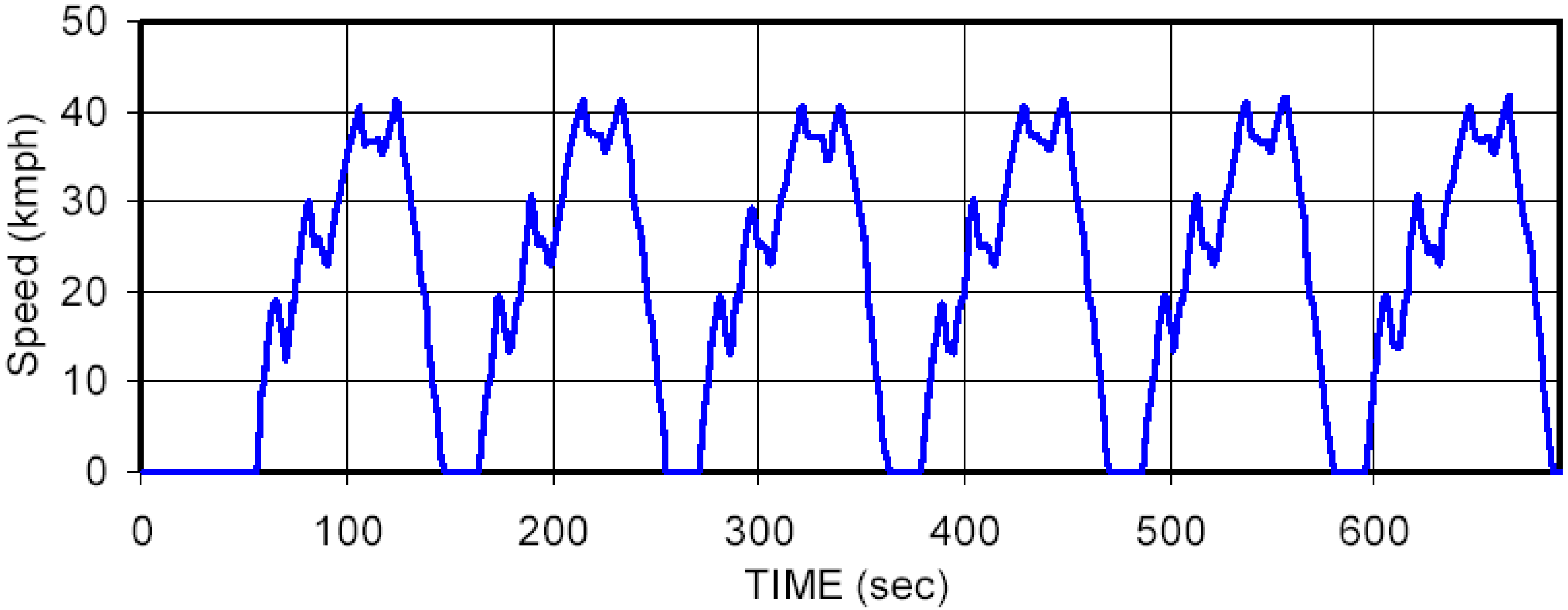


FIG. 2 OPERATING CYCLE WITH SPEED AND TIME TOLERANCES

IDC (6 cycles)



	Time sec	Distance km	Avg. Speed km/h	Max. Speed km/h	Max. accel. m/s2	Max Decel m/s3	Idle time ratio %	Accel. Time ratio %	Decel time ratio %	Cruise time ratio %
IDC (6 Cycles)	648	3.948	21.93	42	0.65	0.63	14.81	38.89	34.26	12.04

❖ IDC for 4 Wheelers

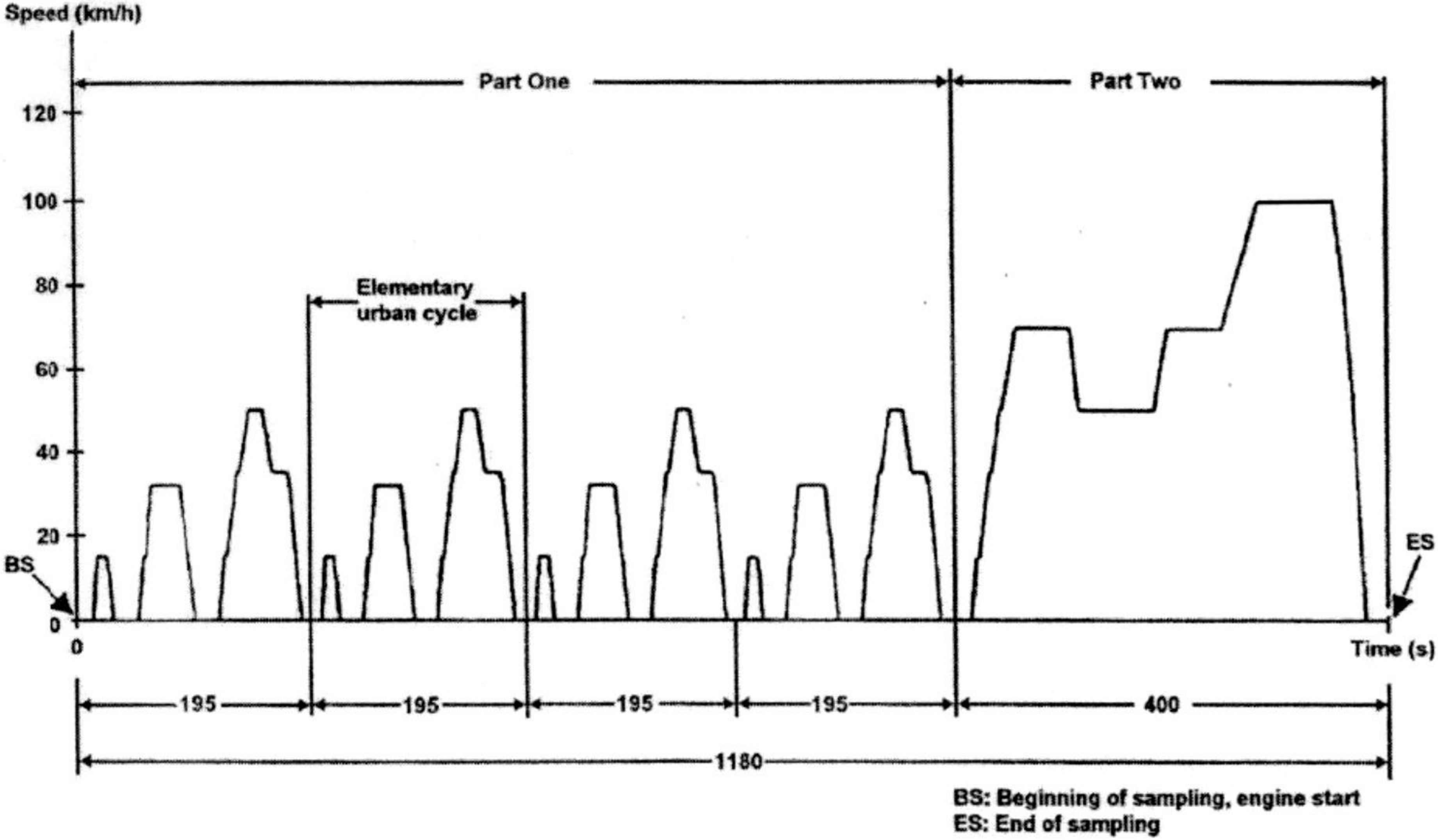


Table IV : Modified Indian Driving Cycle for the Year 2000

Operating Cycle on the Chassis Dynamometer (Part One)

No of Operation	Operation	Phase	Acceleration (m/s^2)	Speed (km/h)	Duration of each Operation (s)	Duration of each Phase (s)	Cumulative (s)	Gear to be used in case of manual gearbox
1	Idling	1			11	11	11	6s PM + 5 s K_1(*)
2	Acceleration	2	1.04	0-15	4	4	15	1
3	Steady speed	3		15	9	8	23	1
4	Deceleration		-0.69	15-10	2		25	1
5	Deceleration, Clutch disengaged	4	-0.92	10-0	3	5	28	K_1(*)
6	Idling	5			21	21	49	16 s PM + 5 s K_1(*)
7	Acceleration		0.83	0-15	5		54	1
8	Gear change	6			2	12	56	
9	Acceleration		0.94	15-32	5		61	2
10	Steady speed	7		32	24	24	85	2
11	Deceleration		-0.75	32-10	8		93	2
12	Deceleration, Clutch disengaged	8	-0.92	10-0	3	11	96	K_2(*)
13	Idling	9			21	21	117	6 s PM + 5 s K_1(*)
14	Acceleration		1.04	0-15	5		122	1
15	Gear change				2		124	
16	Acceleration	10	0.62	15-35	9		133	2
17	Gear change				2	26	135	
18	Acceleration		0.52	35-50	8		143	3
19	Steady speed	11		50	12	12	155	3
20	Deceleration	12	-0.52	50-35	8	8	163	3
21	Steady speed	13		35	13	13	176	3
22	Gear change				2		178	
23	Deceleration	14	-0.86	32-10	7		185	2
24	Deceleration Clutch disengaged		-0.92	10-0	3	12	188	K_2(*)
25	Idling	15			7	7	195	7s PM(*)

(*) PM = gearbox in neutral, clutch engaged

K_1, K_2 = first or second gear engaged, clutch disengaged.

Table V : Modified Indian Driving Cycle for the Year 2000
Extra-urban cycle (Part Two) for the type I Test

No of Operation	Operation	Phase	Acceleration	Speed (km/h)	Duration of each Operation (s)	Duration of each Phase (s)	Cumulative (s)	Gear to be used in case of a manual gearbox
1	Idling	1			20	20	20	K_1(*)
2	Acceleration	2	0.83	0-15	5	41	25	1
3	Gear change				2		27	--
4	Acceleration		0.62	15-35	9		36	2
5	Gear change				2		38	--
6	Acceleration		0.52	35-50	8		46	3
7	Gear change				2		48	--
8	Acceleration		0.43	50-70	13		61	4
9	Steady speed	3		70	50	50	111	5
10	Deceleration	4	-0.69	70-50	8	8	119	4 s.5 + 4 s.4
11	Steady speed	5		50	69	69	188	4
12	Acceleration	6	0.43	50-70	13	13	201	4
13	Steady speed	7		70	50	50	251	5
14	Acceleration	8	0.24	70-90	24	24	275	5
15	Steady speed	9		90	83	83	358	5
16	Deceleration	10	-0.69	90-80	4	22	362	5
17	Deceleration		-1.04	80-50	8		370	5
18	Deceleration		-1.39	50-00	10		380	K_5(*)
19	Idle	11			20	20	400	PM (*)

(*) PM = gearbox in neutral, clutch engaged
K_1,K_2 = first or second gear engaged, clutch disengaged

Emission standards for hevy-duty engines

Stage	Year	Test	CO	HC	CH_4	NOx	PM	PN	NH_3
			g/kWh					kWh^{-1}	ppm
	1992	ECE R49	17.3	2.7		-	-		
	1996	ECE R49	11.2	2.4		14.4	-		
India 2000	2000	ECE R49	4.5	1.1		8.0	0.36[a]		
BS II	2005†	ECE R49	4.0	1.1		7.0	0.15		
BS III	2010†	ESC	2.1	0.66		5.0	0.10		
		ETC	5.45	0.78		5.0	0.16		
BS IV	2010‡	ESC	1.5	0.46		3.5	0.02		
		ETC	4.0	0.55		3.5	0.03		
BS V	n/a [b]	ESC	1.5	0.46		2.0	0.02		
		ETC	4.0	0.55	1.1[d]	2.0	0.03		
BS VI	2020[c]	WHSC (CI)	1.5	0.13		0.40	0.01	8.0×10^{11}	10
		WHTC (CI)	4.0	0.16		0.46	0.01	6.0×10^{11}[e]	10
		WHTC (PI)	4.0	0.16[f]	0.50	0.46	0.01	6.0×10^{11}[e]	10

† earlier introduction in selected regions, see India: Table 1

‡ only in selected regions, see India: Table 1

[a] 0.612 for engines below 85 kW

[b] Initially proposed in 2015.11 [3297][3298] but removed from a 2016.02 proposal [3349]

[c] Proposed schedule and limits

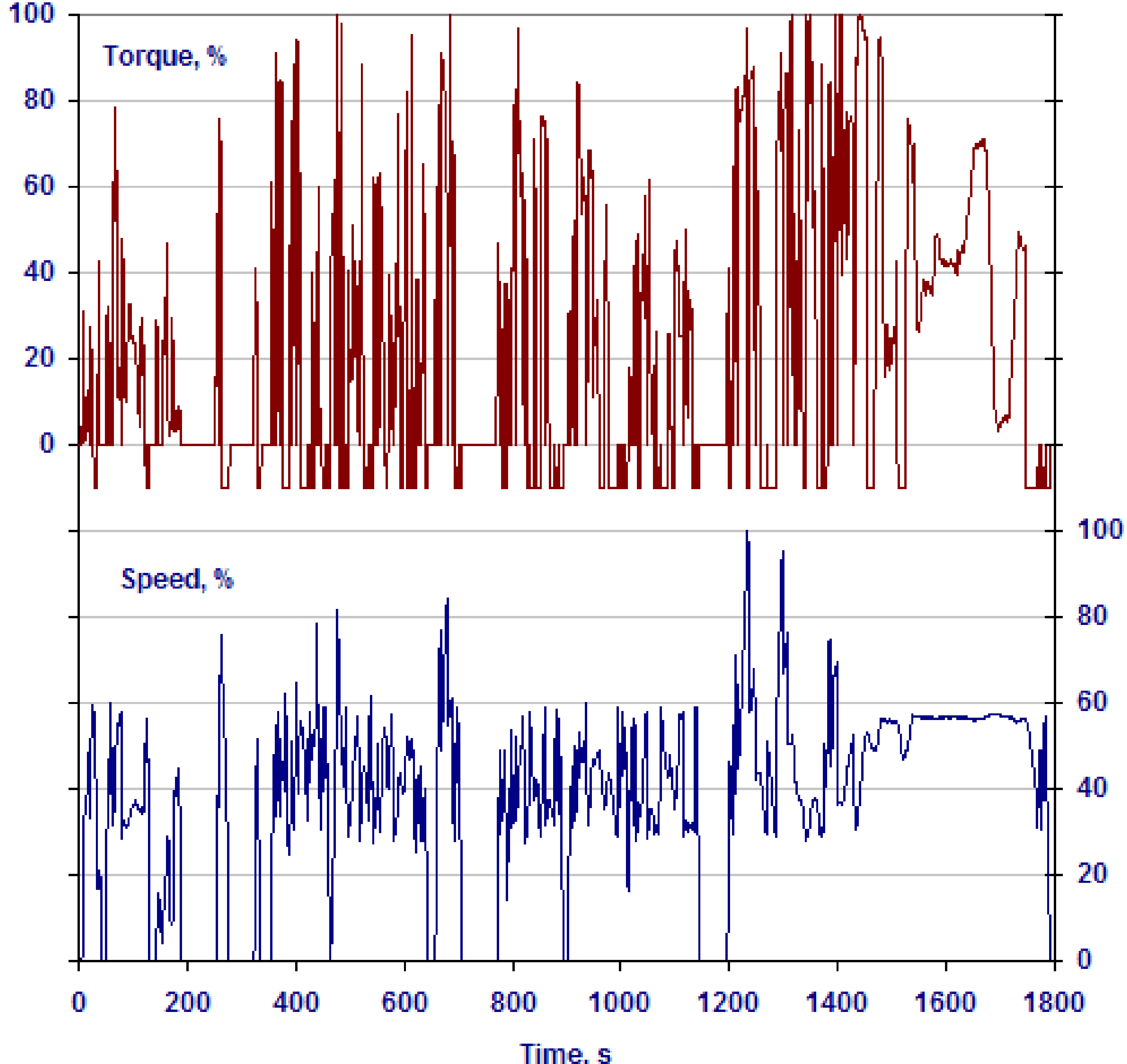
[d] For CNG engines only

[e] Applicable from April 1, 2025 for new models and April 1, 2026 for existing models

[f] NMHC

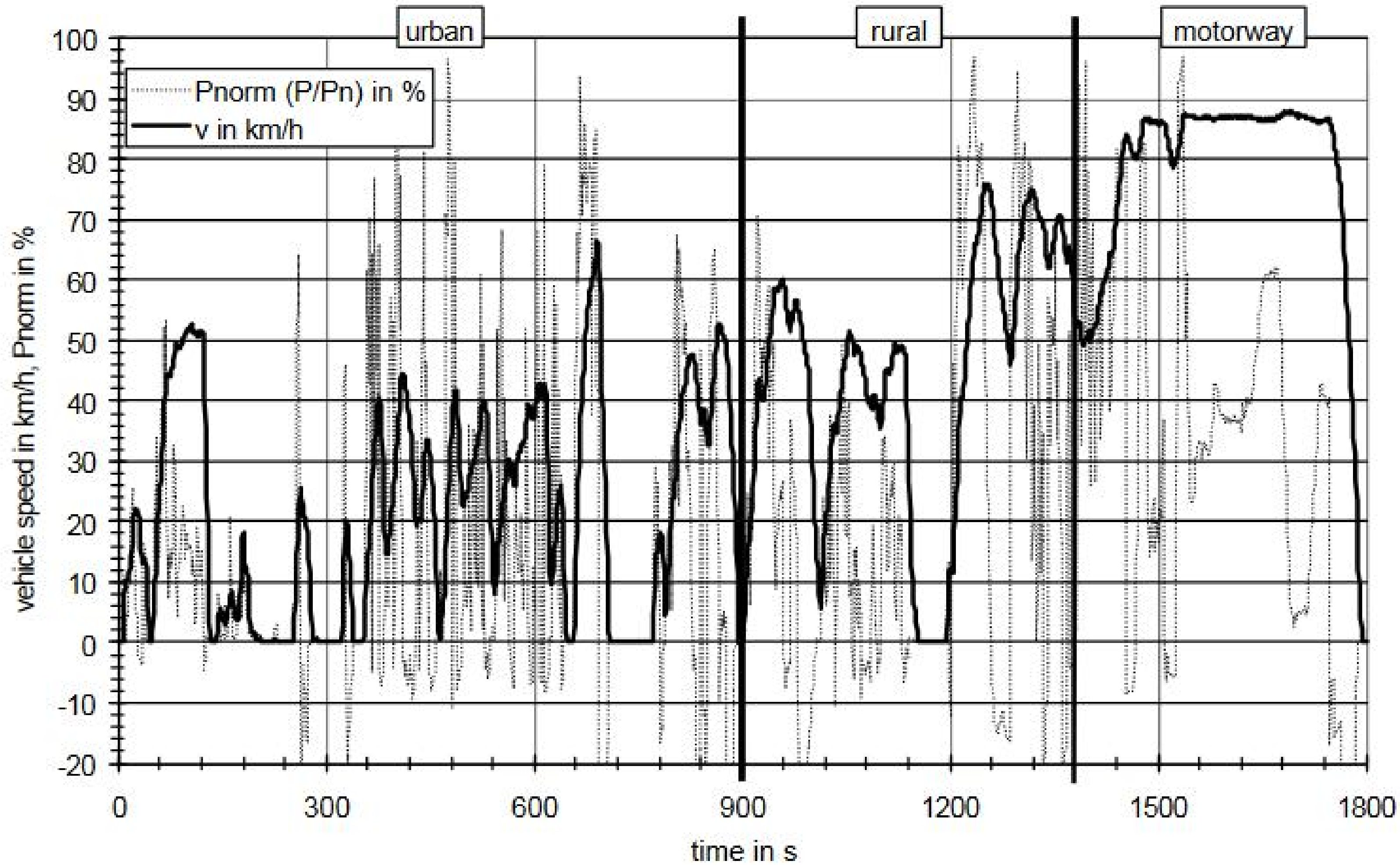
- **Transient Cycles:**
- **World Harmonized Transient Cycle (WHTC)**

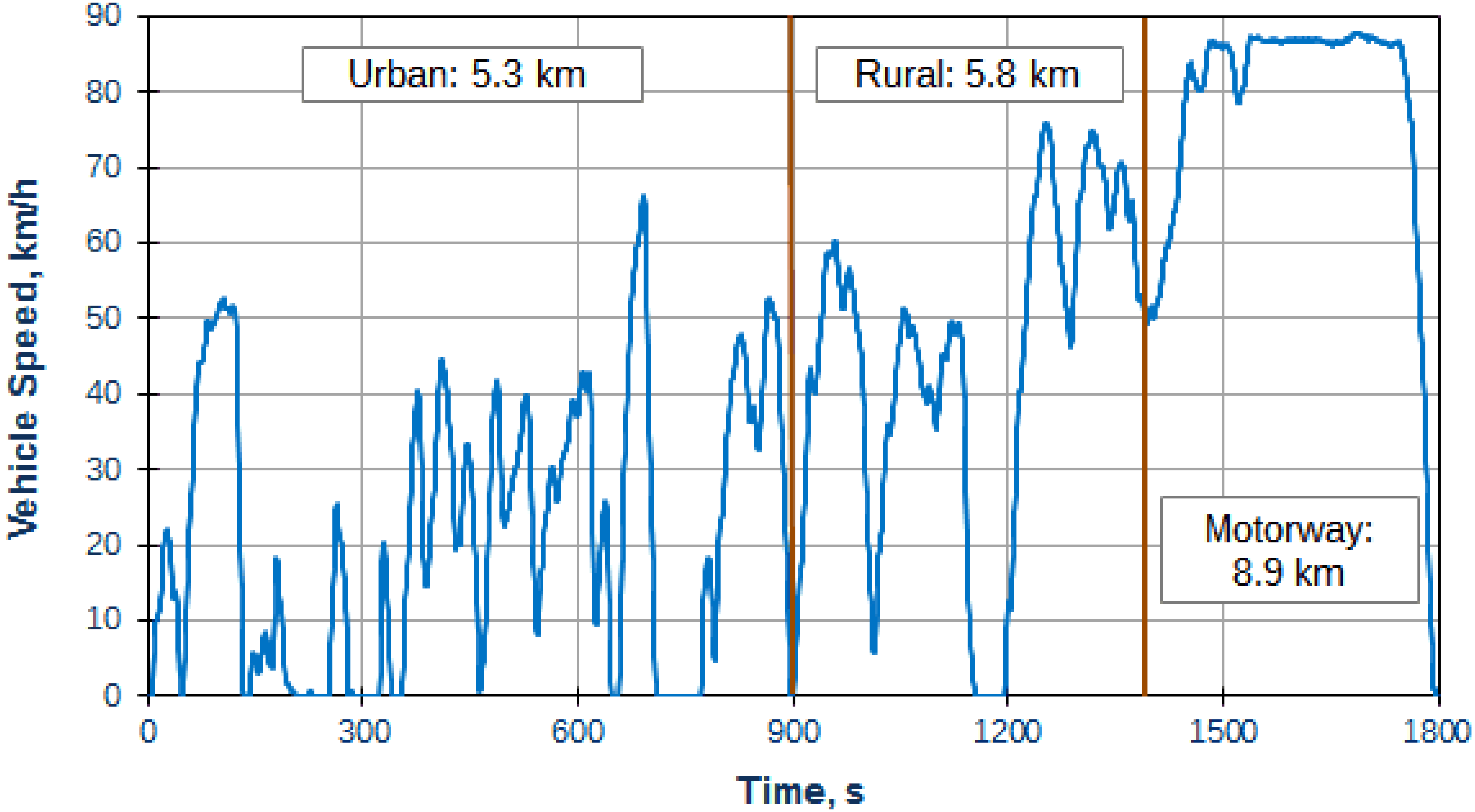
- The WHTC test is a transient engine dynamometer schedule defined by the global technical regulation (GTR) No. 4 developed by the UN ECE GRPE (The working party on pollution and energy) group. The GTR is covering a world-wide harmonized heavy-duty certification (WHDC) procedure for engine exhaust emissions. The regulation is based on the world-wide pattern of real heavy commercial vehicle use.
- Two representative test cycles, a transient test cycle (WHTC) with both cold and hot start requirements and a hot start steady-state test cycle (WHSC), have been created covering typical driving conditions in the EU, USA, Japan and India. WHTC testing requirements were adopted for the first time by the Euro VI emission regulation for heavy-duty engines.
- The WHTC is a transient test of 1800 s duration, with several motoring segments. Normalized engine speed and torque values over the WHTC cycle are schematically shown in Figure 1.



Torque, %
Speed, %
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400
1600
1800
Time, s

❖ World Harmonized Transient Vehicle Cycle (WTVC)




Urban: 5.3 km
Rural: 5.8 km
Motorway: 8.9 km
Vehicle Speed, km/h
Time, s
0
10
20
30
40
50
60
70
80
90
0
300
600
900
1200
1500
1800

- The World Harmonized Vehicle Cycle (WHVC) is a chassis dynamometer test developed based on the same set of data used for the development of the World Harmonized Transient Cycle (WHTC). While the WHVC chassis dynamometer test is not identical to the WHTC engine test, the WHVC results have been occasionally used to compare the respective vehicle and engine emission levels for research purposes.
- The duration of the WHVC test is 1800 s. The test includes three segments, representing urban, rural and motorway driving.
  - The first 900 seconds represent urban driving with an average speed of 21.3 km/h and a maximum speed of 66.2 km/h. This segment includes frequent starts, stops and idling.
  - The following 481 seconds represent rural driving with an average speed of 43.6 km/h and a maximum speed of 75.9 km/h.
  - The last 419 seconds are defined as highway driving with average speed of 76.7 km/h and a maximum speed of 87.8 km/h.

❖ Non Road Transient Cycles(NRTC)

- The NRTC test is a transient driving cycle for mobile nonroad diesel engines developed by the US EPA in cooperation with the authorities in the European Union (EU). The test is used internationally for emission certification/type approval of nonroad engines. NRTC testing is required by a number of emission standards for nonroad engines, including the EU Stage III/IV regulation, the US EPA Tier 4 rule and Japanese 2011/13 regulations.
- The cycle is an engine dynamometer transient driving schedule of total duration of 1238 seconds. The normalized engine speed and torque during the NRTC test are shown in the following chart.

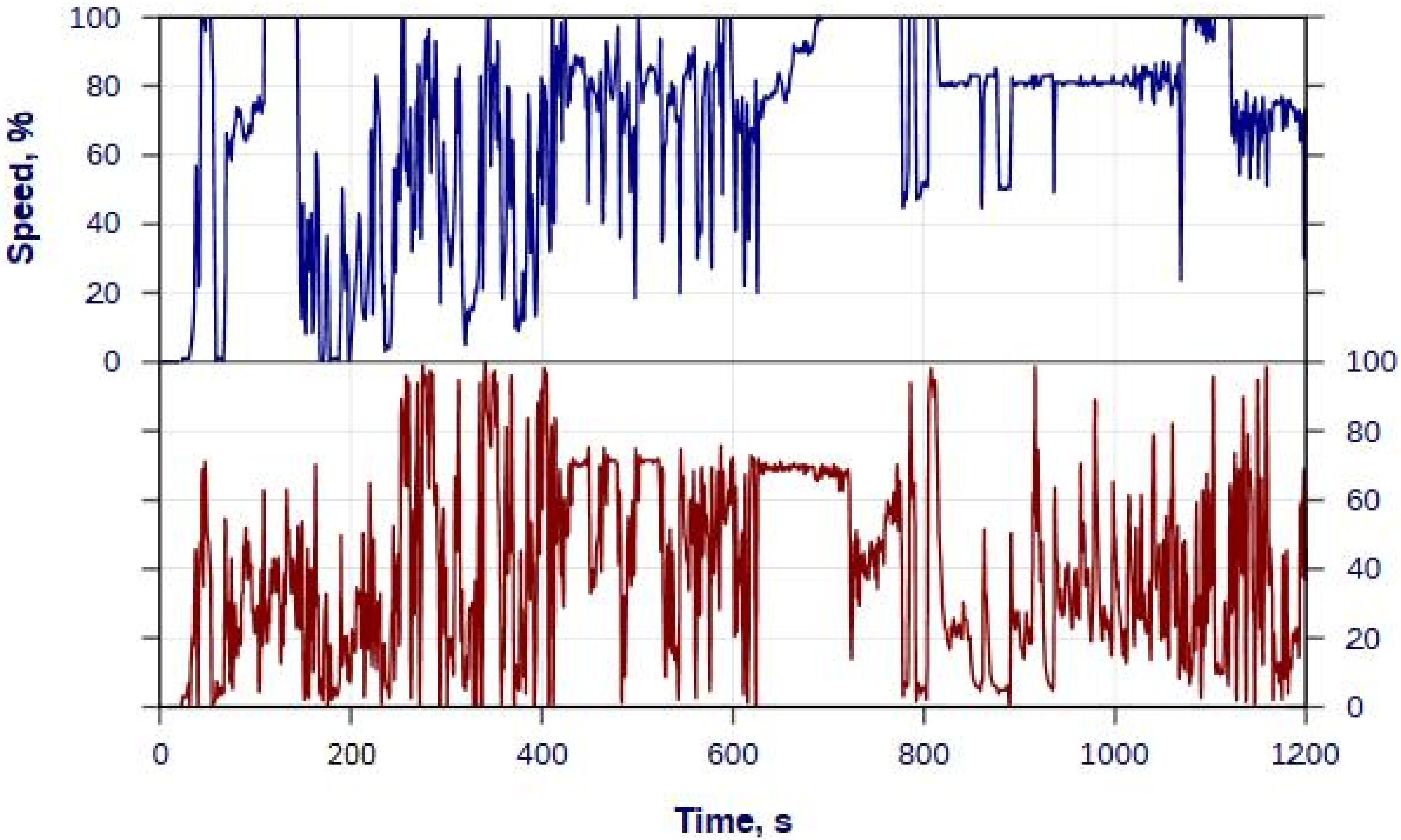


Figure 1. Normalized Speed and Torque over NRTC Cycle

❖ European Transient Cycle

- The ETC test cycle has been introduced, together with the ESC (European Stationary Cycle), for emission certification of heavy-duty diesel engines in Europe starting in the year 2000 *(Directive 1999/96/EC of December 13, 1999)*. The ESC and ETC cycles replace the earlier R-49 test.
- The ETC cycle (once also referred to as FIGE transient cycle) has been developed by the former FIGE Institute, Aachen, Germany, based on real road cycle measurements of heavy duty vehicles *(FIGE Report 104 05 316, January 1994)*. The final ETC cycle is a shortened and slightly modified version of the original FIGE proposal.

- Different driving conditions are represented by three parts of the ETC cycle, including urban, rural and motorway driving. The duration of the entire cycle is 1800s. The duration of each part is 600s.
  - Part one represents city driving with a maximum speed of 50 km/h, frequent starts, stops, and idling.
  - Part two is rural driving starting with a steep acceleration segment. The average speed is about 72 km/h
  - Part three is motorway driving with average speed of about 88 km/h.
- FIGE Institute developed the cycle in two variants: as a chassis and an engine dynamometer test. Vehicle speed vs time over the duration of the cycle is shown in Figure 1. For the purpose of engine certification/type approval, the ETC cycle is performed on an engine dynamometer. The pertinent engine speed and torque curves are shown in Figure 2 and Figure 3.

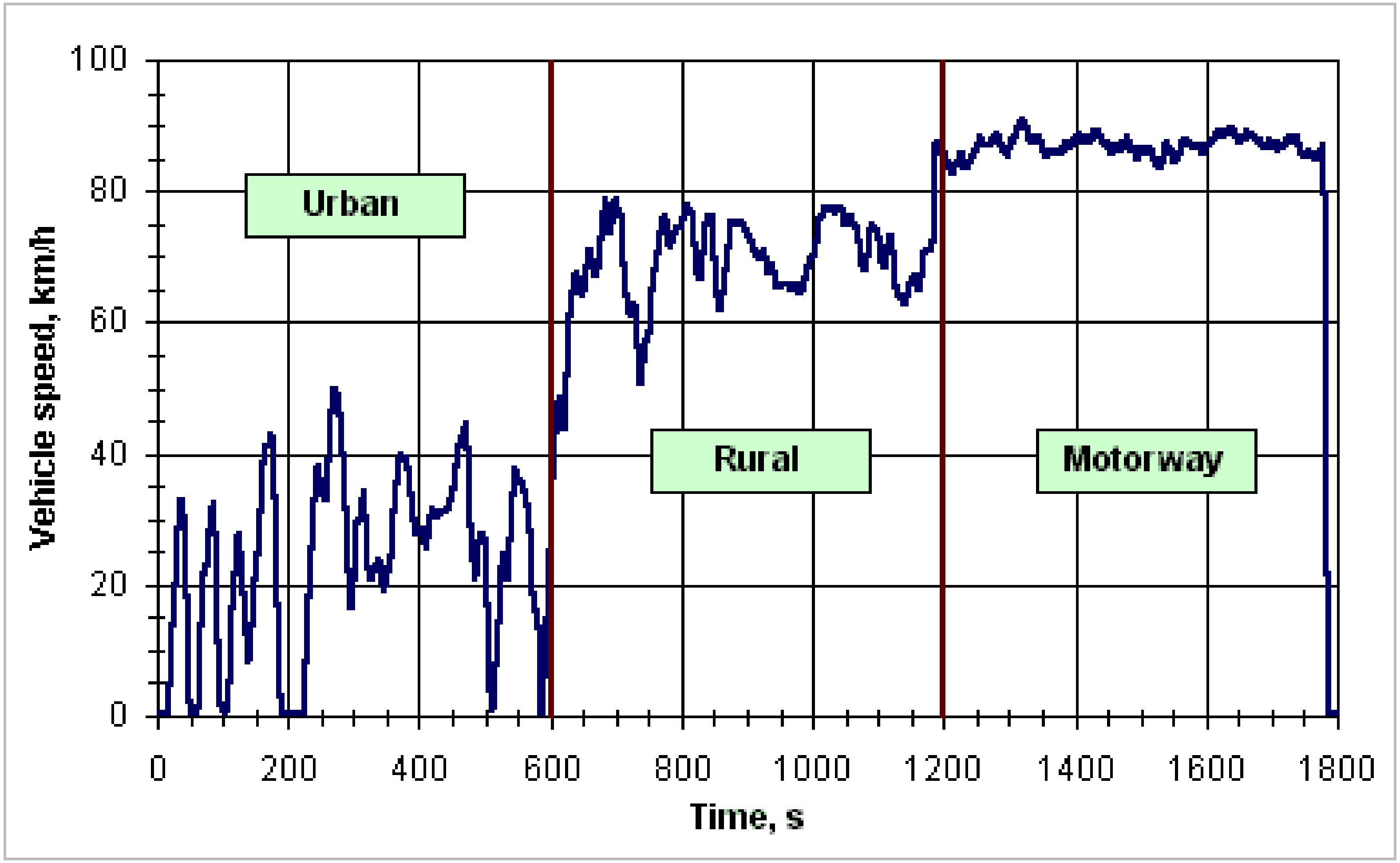


Fig.1 ETC for Vehicle

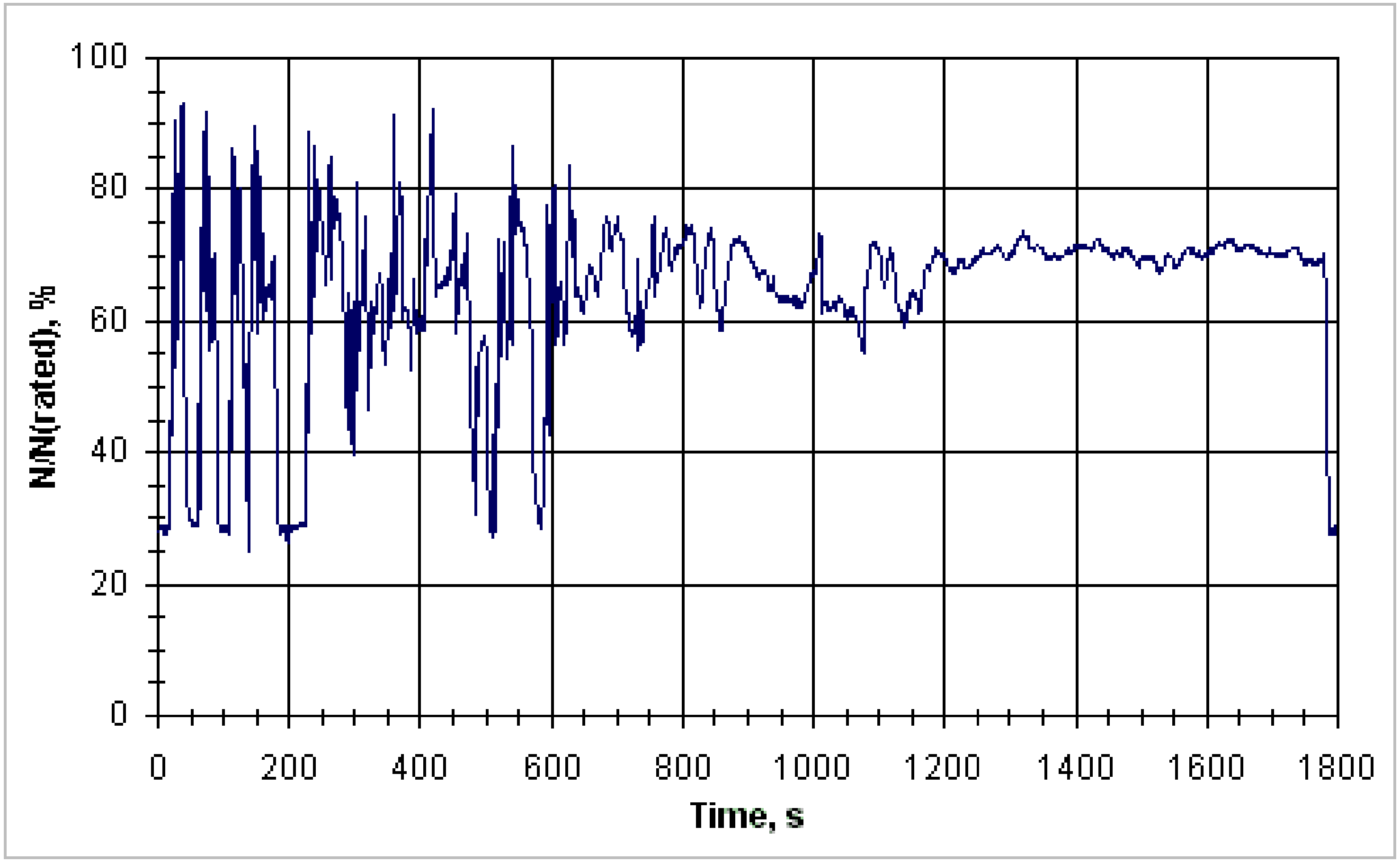


Fig.2 ETC Transient Cycle—Engine Speed

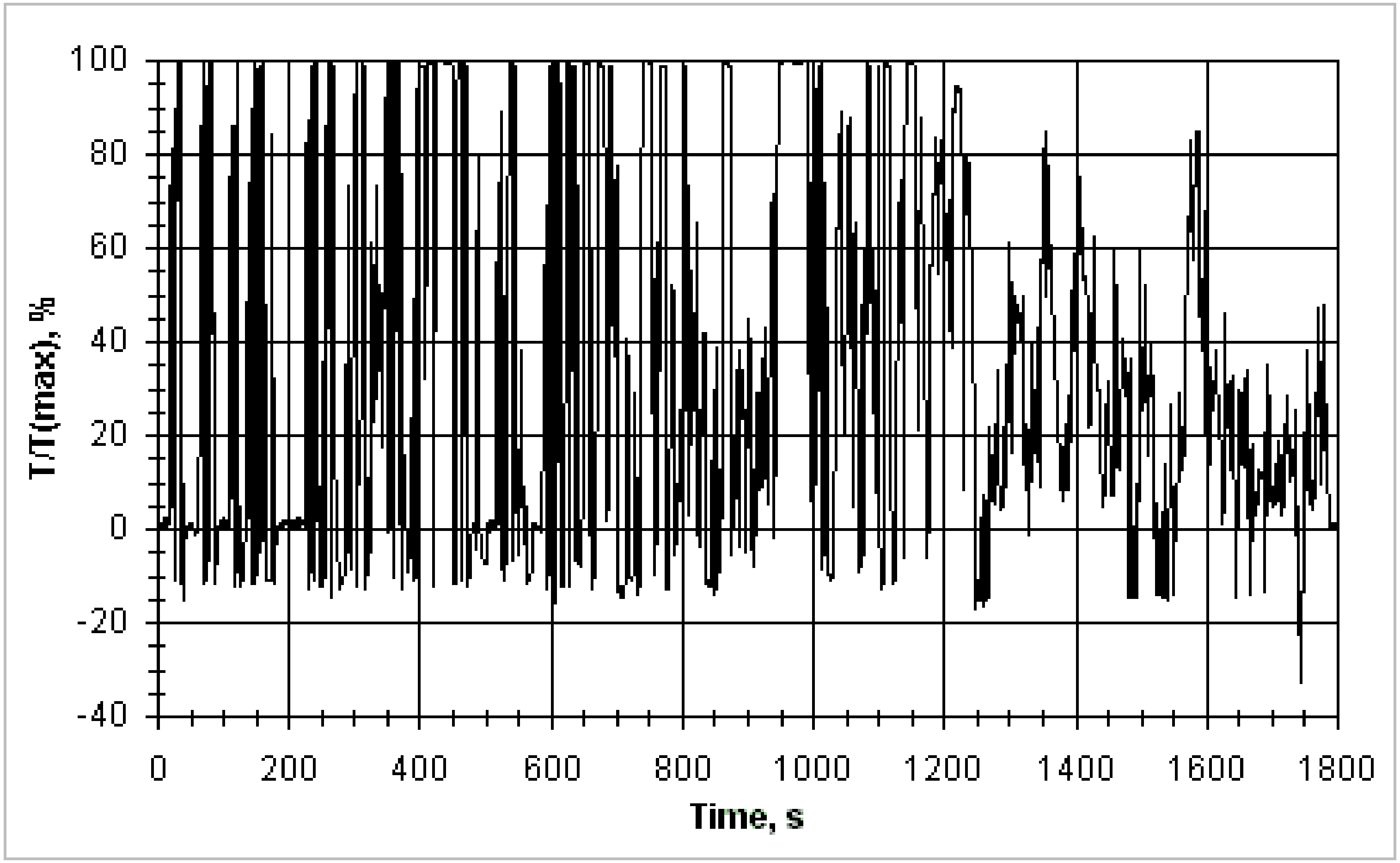


Fig. 3 ETC Transient Cycle—Engine Torque

Parameter	WHTC	ETC	NRTC*
Total Cycle Duration (sec)	1800	1800	1238
Average % Speed	37.08	50.83	67.67
Average % Load	30.75	44.70	39.32
% of Idling	17.06	6.72	4.52
% of Time engine is operated at Speed > 70%	2.33	3.06	62.20
% of Time engine is operated at Load > 70%	33.44	42.94	16.24
% of time engine is operated at Speed and Load > 70%	1.67	2.00	13.09
% of Motoring time	22.30	18.00	0.00

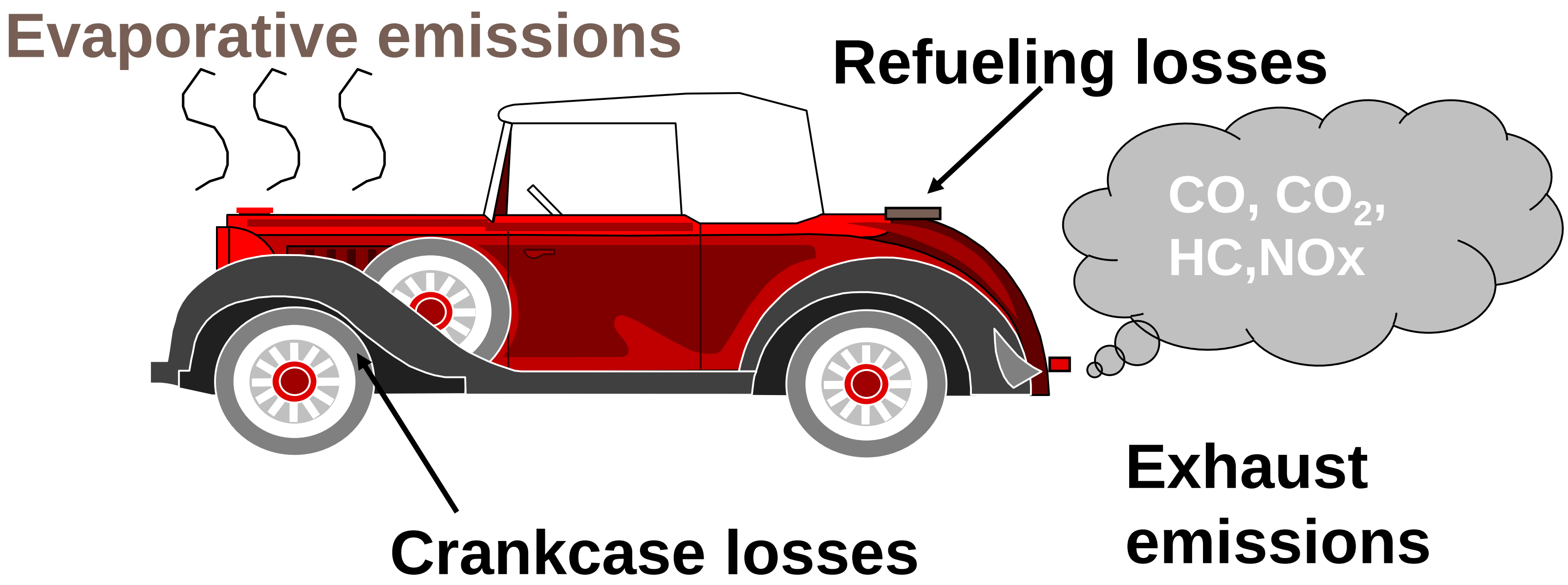
❖ Evaporative Emissions Testing:

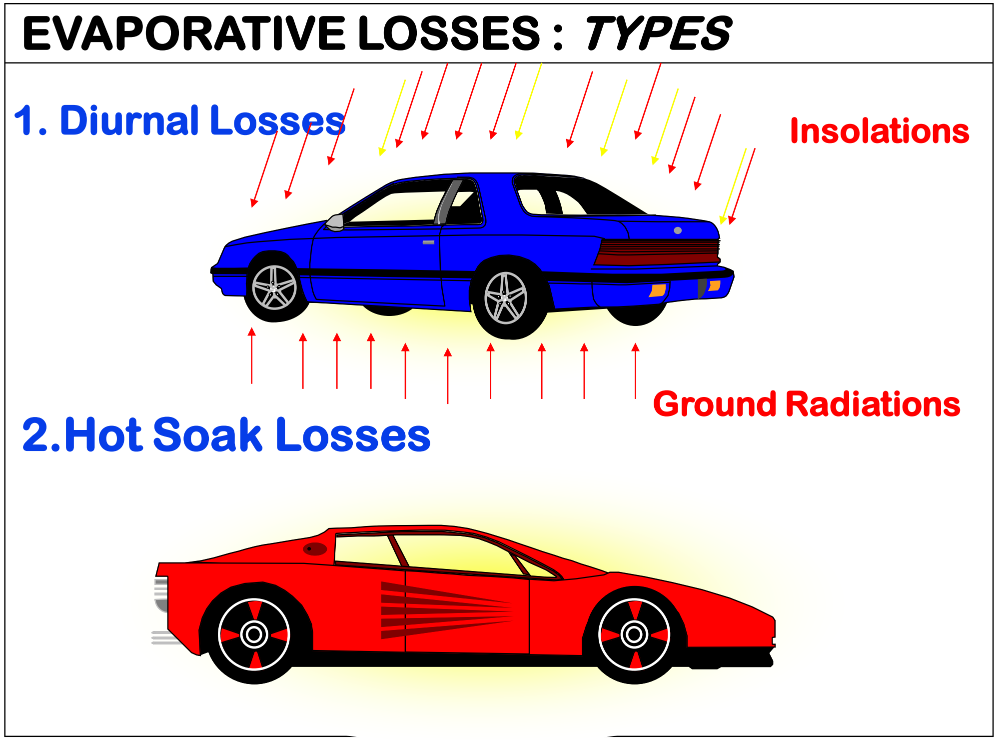
- **Reference IS 14555 : 1998**

- Approximately 20% of all Hydrocarbon emissions from the automobile originates from evaporative sources.
- Legislation was passed, prohibiting venting of gas tank fumes into the atmosphere
- Sources of Evaporative Emission
  1) Fuel Tank Vent
  2) Carburetor Vent
  3) Others

SOURCES OF AUTOMOBILE EMISSIONS

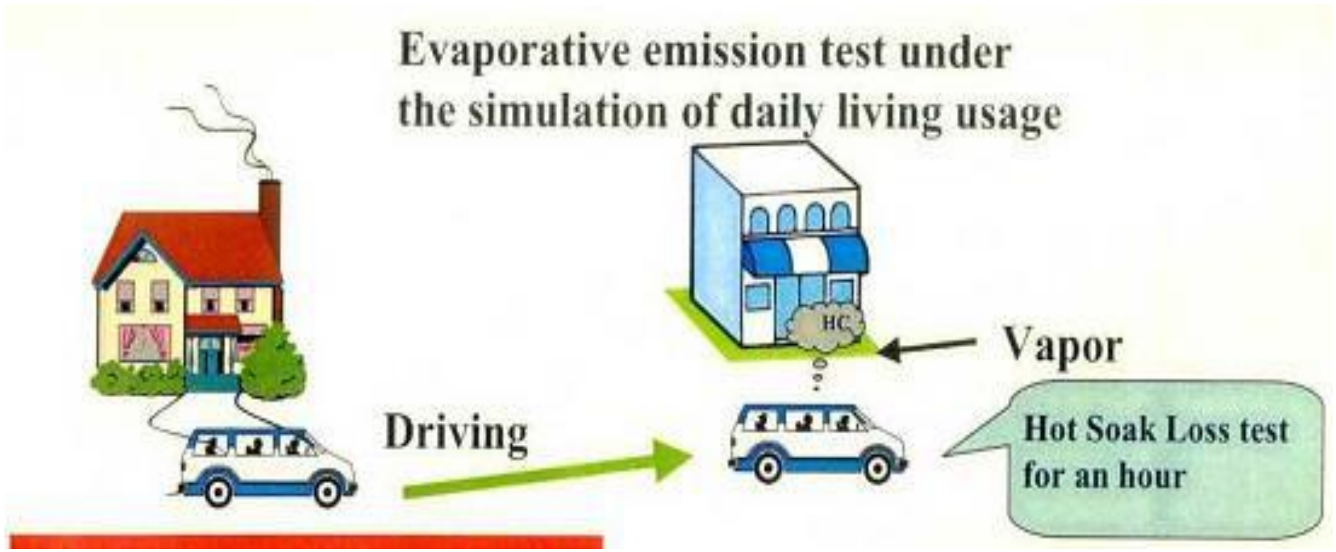
- Hot Soak Loss
- Diurnal Loss
- Running Loss





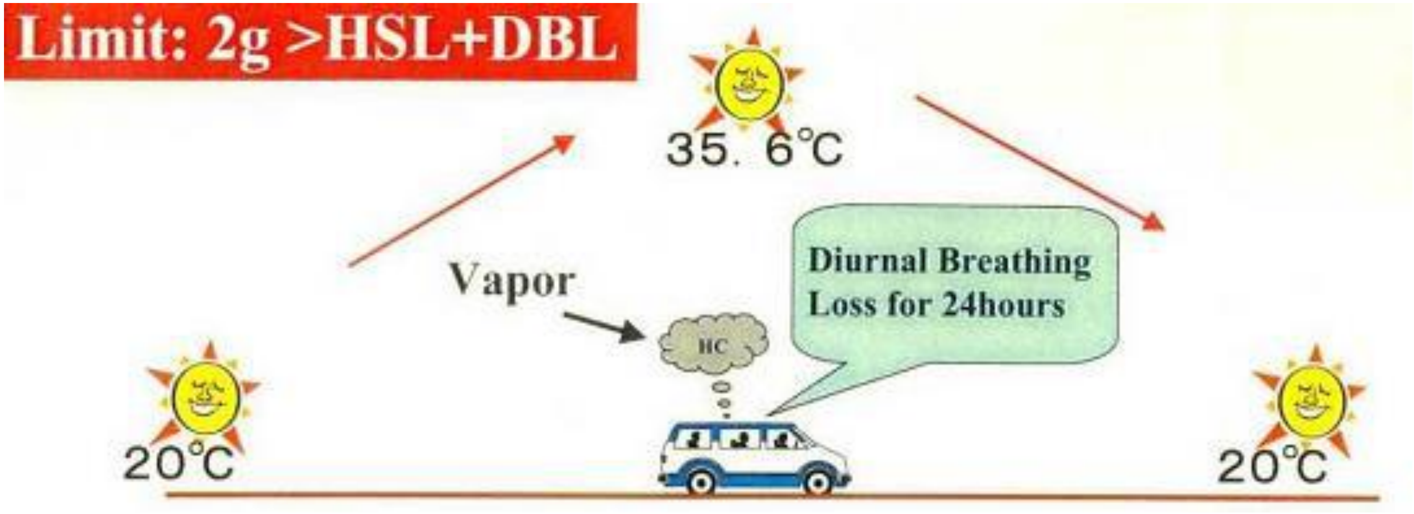
Total Evaporative emissions = Diurnal Losses+ Hot Soak Losses

❑ Hot Soak Losses



- Occurs when fully warmed up vehicle is kept stationary with engine stopped. These are contributed from carburetor bowl & fuel tank.

❑ Diurnal Losses



- Occurs when vehicle is stationary with engine switched off. These are mainly contributed from fuel tank

Evaporative System:

- The evaporative system, sometimes abbreviated as EVAP, consists of
  - fuel cap
  - fuel tank
  - carbon canister
  - canister purge valve
  - interconnecting lines and hoses.

❖ TEST PROCEDURE

- **Test Preparation**

1.1 Prior to test the following shall be ensured:

a) The exhaust system of the vehicle shall not exhibit any leaks.

b) The vehicle shall be steam cleaned.

c) The **fuel tank (s) of the vehicle shall be equipped** with a temperature sensor to enable the temperature to be measured at the mid point of the fuel in the fuel tank when filled to 40 percent of its capacity.

d) Additional fittings, adapters of devices shall be fitted to allow complete draining of the fuel tank

1.2 The test (schematic) schedule is described in Annex C.

1.3 The vehicle shall be taken into the test area where the ambient temperature is between 20 and 30°C.

1.4 The canister of the vehicle shall be purged for 30 minutes by driving the vehicle at 60 km/h at the dynamometer setting as per total inertia of the rotating masses to be obtained proportional to the reference weight. Alternatively the canister may be purged by passing air (at ambient temperature and humidity) through it at a flow rate which shall be identical to the actual air flow through the canister when operating the vehicle at 60 km/h. The canister shall be subsequently loaded with two diurnal emission tests.

1.5 The fuel tank(s) shall be emptied using the fuel tank drain(s) provided for this purpose. This shall be done so as not to abnormally purge nor abnormally load the evaporative control devices fitted to the vehicle. [Removal of the fuel cap(s) is normally considered sufficient to achieve this purpose].

1.6 The fuel tank(s) shall be filled with specified test fuel at a temperature between 10°C and 14°C to 40 ±2 percent of its (their) normal fuel capacity. The vehicles fuel cap(s) shall not be replaced at this point.

1.7 In the case of vehicles fitted with more than one fuel tank, all the tanks shall be heated in the same way, as described below. The temperatures of the tanks shall be identical to within ± 1.5°C.

1.8 The fuel may be initially heated to the starting temperature of 16 ± 1°C.

1.9 As soon as the fuel reaches the temperature of 14°C, the fuel tanks(s) shall be sealed. When the temperature of the fuel tank reaches 16 ± 1°C, a linear heat build of 14 ± 0.5°C over a period of 60 ± 2 minutes begins. The temperature of the fuel during the heating shall conform to the function below to within ± l.5°C

$$T_f = T_o + \frac{7}{30}(t)$$

where

T_f = required temperature (°C),

T_o = initial temperature of tank (°C), and

t = time from start to the tank heat build in minutes.

1.10 After a period of not more than one hour, the operations of fuel draining and filling shall begin according to 1.5 to 1.8.

1.11 Within two hours of the end of the first diurnal heating period the second diurnal heating operation shall begin as specified in 1.9 and be completed with the recording of the temperature rise and elapsed time of the heat build.

1.12 Within one hour of the end of the second diurnal heat build the vehicle is placed on a chassis dynamometer and driven six Indian Driving Cycle and a drive for a duration of 10 minutes at a speed of 60 km/ h on a chassis dynamometer. Samples of the exhaust emissions shall not be collected during this operation.

1.13 Within five minutes of completing the preconditioning operation specified in 1.12, the engine bonnet shall be completely closed and the vehicle shall be driven off the chassis dynamometer and parked in the soak area. The vehicle shall be parked for a min.10h and maximum of 36h.Theengine oil and coolant temperatures shall have reached the temperature of the soak area to within ± 2°C at the end of this period.