

## Module 4: Vehicle Emission Standards and Measurement

### Lecture16:Emission Test Procedures

#### Vehicle Emission Standards and Measurement

The Lecture Contains:

- EMISSION TEST PROCEDURES
  - Units of Emission Limits
- EMISSION TEST CYCLES
  - Driving Cycles for Light Duty Vehicles
  - Heavy Duty Vehicle Engines
  - Motorcycles

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#### EMISSION TEST PROCEDURES

The vehicle emission limits are specified based on a standard test procedure, which includes;

- A specified vehicle driving or engine operation schedule of varying speeds and loads which represents real life driving/usage pattern of the vehicles and engines. The test schedule of vehicle or engine operation is known as 'driving cycle'.
- Use of emission sampling systems and analyzers that operate on the working principles specified in the emission regulations.

The new production vehicles and engines are tested for compliance with the emission standards in a government approved laboratory.

The USA and particularly the state of California have led the world in developing vehicle emission test methods and in setting the vehicle emission limits. The test cycles used in the USA, Europe and Japan for emission measurement and certification of vehicles/engines for compliance with the standards differ and so also the numerical values of the emission limits. Therefore, direct comparison between standards in different countries is generally not possible.

#### Units of Emission Limits

Two types of emission limits are specified in the standards

- For the light and medium duty vehicles, passenger cars and, two and three wheelers are in terms of mass of pollutant emitted per unit distance travelled i.e., g/km ( g/mile in the USA , 1 g/km = 1.61 g/mile).
- For heavy duty vehicles and engines test is carried on the engine itself and the limits are specified in terms of mass of pollutant per unit of work done, i.e., g/kW-h or g/bhp-h (1 g/kW-h = 1.34 g/bhp-h) .

The test cycle and measurement procedures have been accordingly developed whether test is to be done on a vehicle or on the engine.

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## EMISSION TEST CYCLES

The US and European driving cycles used for emission measurement are presented below. Most of the other countries follow either the European or the US test methods except Japan which has its own driving cycles. In India European test methods are used except for the motorcycles and three wheelers.

## Driving Cycles for Light Duty Vehicles

The emission test driving cycles are composed of a cold start period, idling, moderate acceleration and deceleration, and cruise modes. The test cycle is given in terms of vehicle speed versus time. The light and medium duty vehicles are driven through the prescribed driving cycle on a chassis roller dynamometer. During operation the engine is required to develop road horse power that depends on the vehicle speed for a given vehicle. The road horsepower requirement versus speed data as provided by the vehicle manufacturer or determined by vehicle coast down test is stored into chassis dynamometer controller to simulate the real life road operation of the vehicle. The vehicle weight i.e. inertia needed during transient modes of the driving cycle is simulated by mechanically changing the rotating masses or electronically changing the inertia on the roller dynamometer. A typical emission test facility with a vehicle operating on chassis dynamometer is shown in Fig 4.1



Figure 4.1

View of a vehicle emission test and chassis dynamometer facility

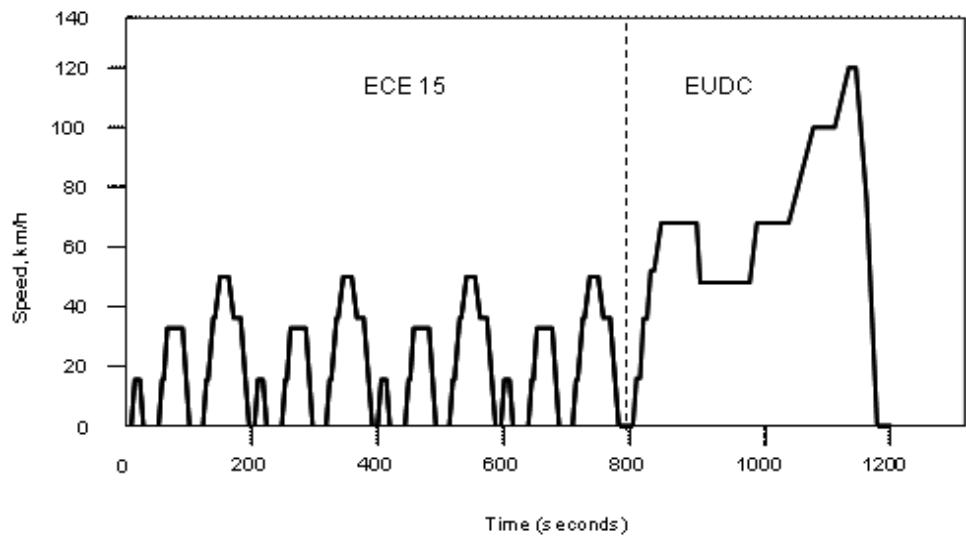
## European Test Driving Cycle

The driving cycles followed in Europe for light and medium duty vehicles is shown in Fig. 4.2. The European test cycle is composed of steady operation modes derived from the actual vehicle operation data on road. Although it consists of acceleration and deceleration modes but as all the modes represent averaged operating conditions, the cycle is often referred to as steady mode cycle. The European test cycle as given in Fig. 4.2 was implemented from Euro 1 emission standards in 1992. It

has two parts;

- (i) an urban driving cycle (ECE 15) and
- (ii) an extra-urban driving cycle (EUDC)

The break-up of different operating modes in the two parts of the cycle is also given in Figure 4.2.



	ECE-15 cycle	EUDC Cycle
Distance, km	4.052	6.955
Time, s	780	400
Average speed, km/h	19	62.5
Maximum speed, km/h	50	120
Acceleration, %time	21.16	-
Maximum Acceleration, m/s <sup>2</sup>	-	0.833
Deceleration, % time	13.8	-
Maximum Deceleration, m/s <sup>2</sup>	-	-1.389
Idle, % time	35.4	-
Steady speed, % time	29.3	-

Figure 4.2	European driving cycle for light and medium duty vehicles: ECE 15 cycle followed by extra urban driving cycle (EUDC).
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Prior to Euro 1 regulations, only the ECE 15 cycle was used. The low speed urban test cycle consists of repetition of 15 mode cycle four times without interruption for a total duration of 780 seconds. The total distance covered is 4.052 km at an average speed of 19 km/h. The high-speed test cycle called as Extra Urban Driving Cycle (EUDC) is carried out after the ECE-15 cycle. This high-speed cycle has maximum speed of 120 km/h. The EUDC part gives a higher contribution to NOx while the ECE-15 cycle has more contribution to CO and HC emissions.

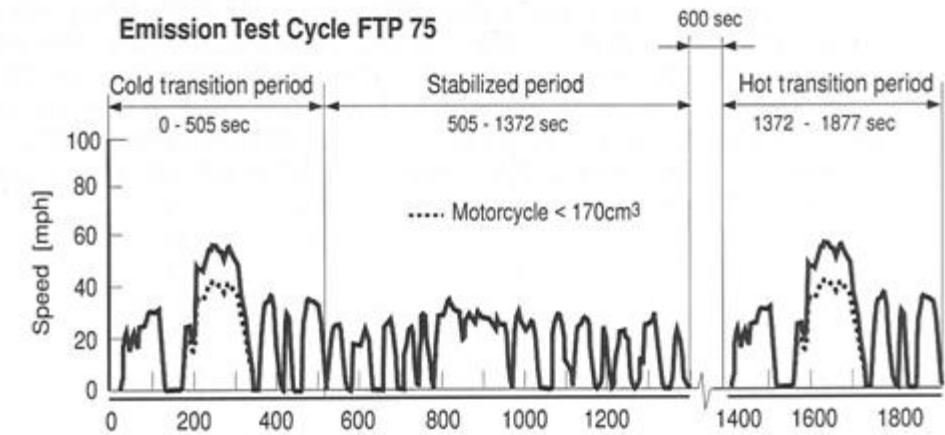
Emission measurement commences with the engine cold start at the beginning of the first ECE-15 mode cycle itself. The emissions are measured using CVS technique as explained later.

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US FTP-75 Cycle

The US test procedure known as Federal Test Procedure -75 (FTP-75) is a transient cycle consisting of a typical actual driving trace for the light duty vehicles. It consists of four phases as shown on Fig 4.3.:

- Cold transition phase of 505 seconds with a weighting factor of 0.43
- Stabilized phase of 867 seconds with a weighting factor of 1.0
- Hot soak phase of 10 minutes
- Hot transition phase; repeat of first phase of 505 seconds with a weighting factor of 0.57



Cycle Details:			
Length	11.09 miles (17.85 km)	Max. Speed :	56.7 mph (91.2 km/h)
Time	1372 s + (600 s stop) + 505 s The first 505 s are repeated after a 10 minute stop (hot soak)	Idle :	17.3 %
Av. Speed	21.3 mph (34.3 km/h)	Steady speed :	20.5%
		Deceleration :	26.5%

Figure 4.3 US FTP-75 emission test cycle for light duty vehicles; the driving cycle for motor cycles is shown by dotted line.

The total vehicle driving schedule is of 31 minutes. In addition, after operation for 1372 seconds engine is switched off in hot condition to allow hot soaking period of 10 minutes. The total distance covered is 11.09 miles. The vehicle is preconditioned before test by soaking it for 12 hours at a temperature between 20 to 30° C. The test begins with cold start. FTP-75 procedure was the first to use CVS (Constant Volume Sampling) method for measurement of the mass of the pollutants emitted per km or mile travelled.. The sample of diluted exhaust gas with air from CVS system

is collected in three separate bags, one each for the three phases of vehicle operation. The concentration of pollutant in each bag and total volume of diluted exhaust gases for each test phase is determined to calculate the mass of pollutants emitted.. Weighting factors corresponding to each phase are used to give mass emission values for the total cycle.

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#### Heavy Duty Vehicle Engines

##### European Test Procedure

The first European test procedure for heavy duty vehicles, R-49 used 13-mode test having five different load points each at the rated and peak torque speeds and three idling speed points one in the beginning one in the middle and the third at the end. Each mode had a different weighing factor. A new test procedure has been adopted from the year 2000 along with implementation of Euro 3 standards. It consists of two separate tests each of about 30 minutes duration as below;

- (i) 13-mode steady state cycle (ESC) with a dynamic load response (ELR) smoke test
- (ii) A transient test cycle (ETC)

The steady state cycle (ESC) is used to prevent abnormally high emissions if an engine is made to operate at extreme conditions where emission controls may not be very effective. On the other hand, the transient cycle (ETC) represents the actual operating conditions and is better suited for the engines operating on alternative fuels or employing aftertreatment devices. For certification to Euro 3 standards, the conventional diesel engines are tested by the ESC only. However, the diesel engines with advanced emission control systems such as after-treatment devices and the SI engines such as natural gas engines are tested by both the procedures. From the Euro 4 standards implemented in year 2005, all heavy-duty engines are tested by both the ESC and ETC test procedures.

##### ESC and ELR Tests

The ESC and ELR test procedures are shown in Figs 4.4 and 4.5. Weighting factors for the ESC test for each mode are also shown on Fig. 4.4.

The test is carried out at three engine speeds and idle. The test speeds are determined as shown on Fig 4.4. At each of the three speeds, emissions are measured at 25%, 50%, 75% and 100 % loads. To ensure that there are no abnormal operating conditions which could result in abnormally high emissions, testing agency is authorized to select three more modes as indicated. The dynamic load response (ELR) test is carried out for smoke emissions. The engine is accelerated from 10% load to full load at maximum possible acceleration. In this way engine runs through the entire fuel/air ratios defined by the engine fuel management system. Thus, smoke emission from the diesel engines is measured for the entire range of fuel delivery i.e. fuel-air ratios. Peak smoke emissions are compared with the permissible limits as specified in the standards.

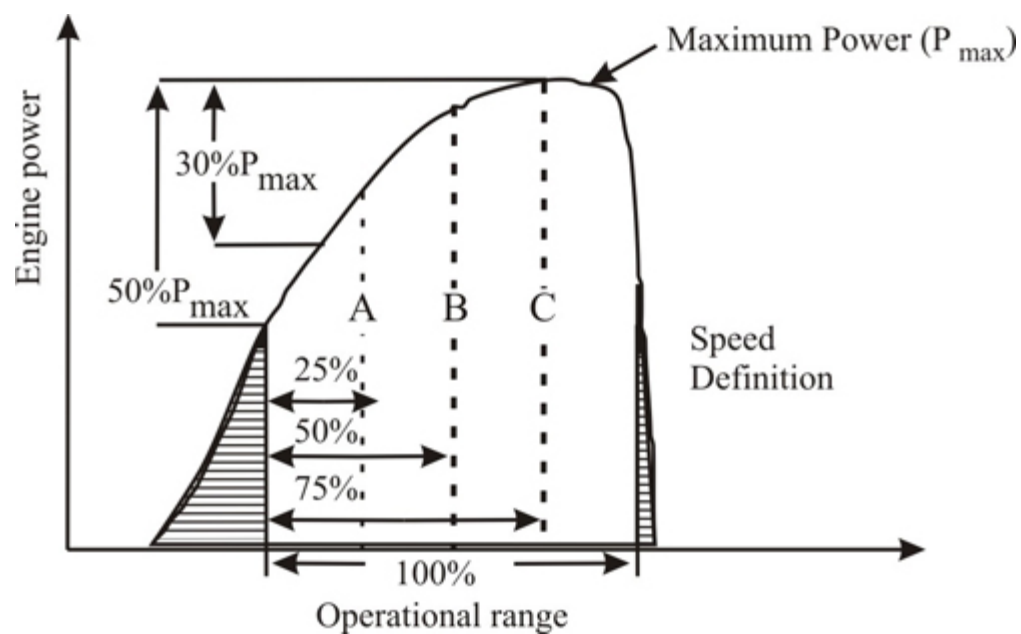
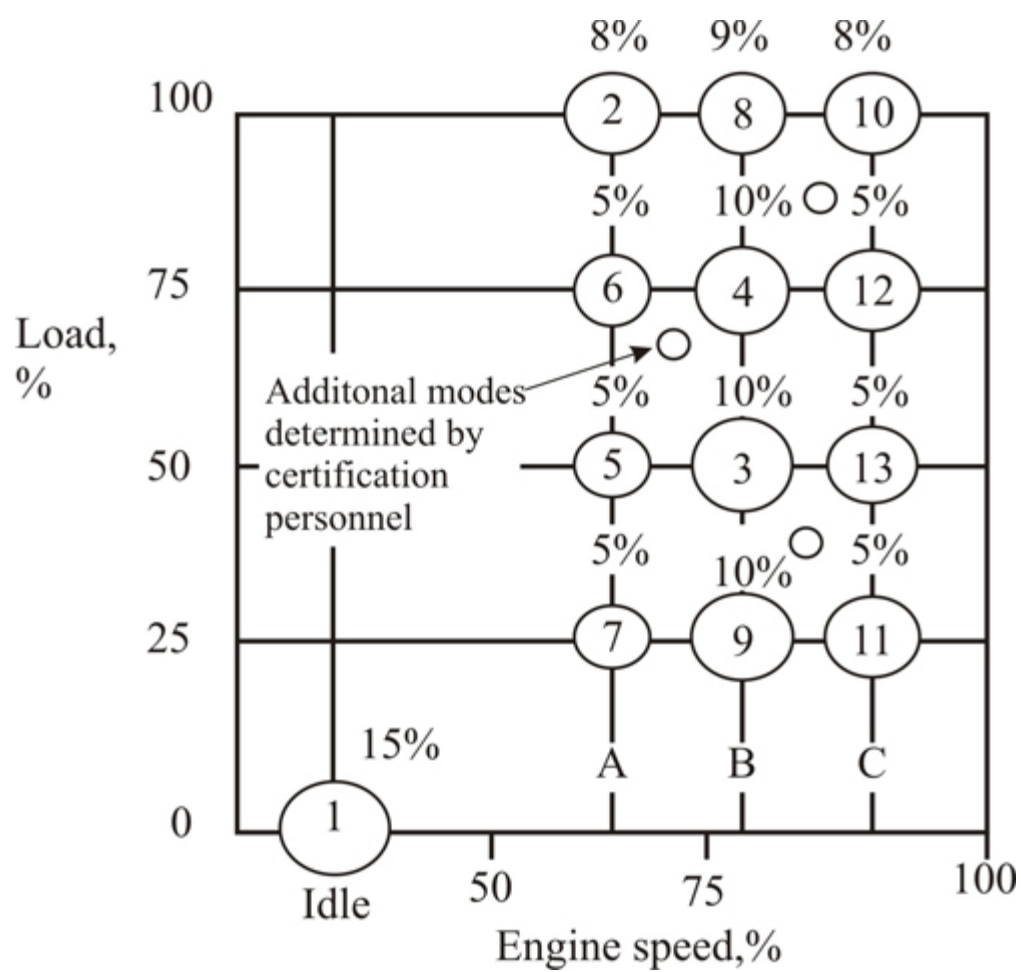


Figure 4.4 European ESC heavy-duty exhaust emission procedure -13 mode cycle.



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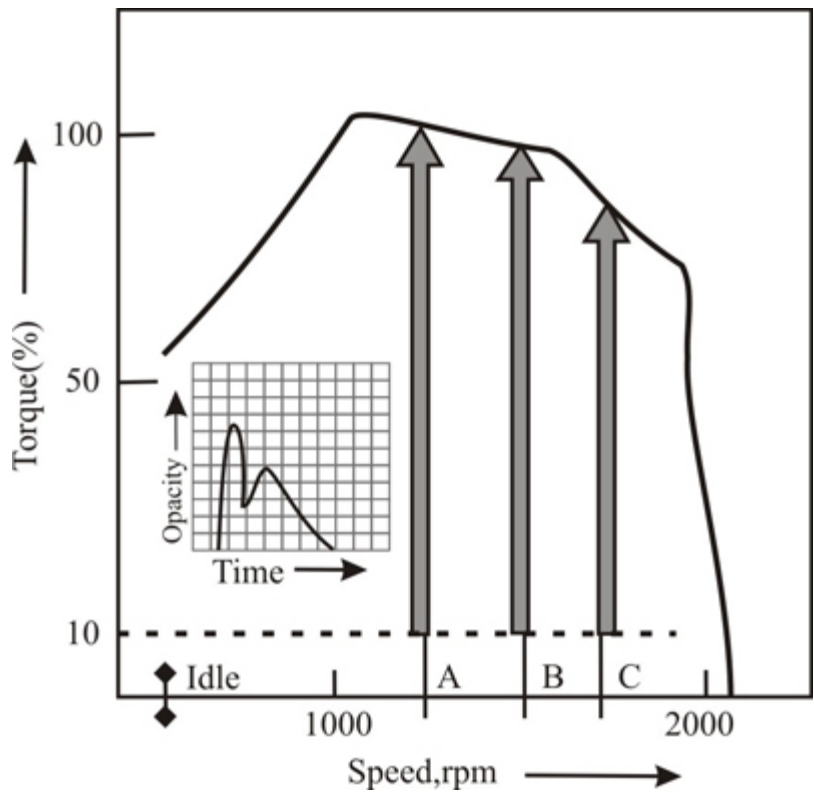


Figure 4.5 European ELR dynamic response test for smoke emissions.

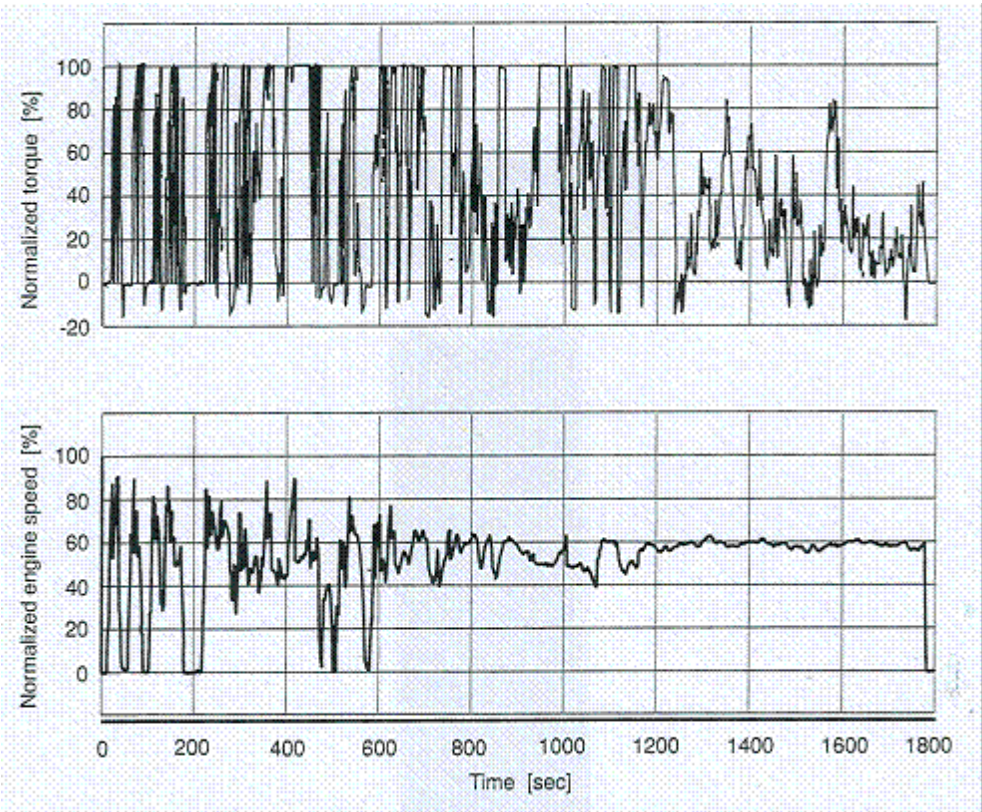


Figure 4.6

**European heavy-duty exhaust emissions transient test cycle (ETC).**

The vehicle speed –time and normalized torque -time curves for the ETC are shown in Fig. 4.6. The cycle was derived from the data collected on different road types i.e., highway, urban and rural roads, under varying traffic density, road gradients and distance between stopping points. The data were collected for different types of vehicles such as trucks, buses and city buses. The normalized figures are integrated in three sub-cycles of

10 minutes each. For establishing limits, emissions from the three sub- parts of the cycle may be measured separately and later combined using weighting factors.

### US Heavy Duty Test Procedure

In the USA until 1984, a steady state test cycle consisting of 13 different engine speed and load combinations was used for measurement of gaseous exhaust emissions from the heavy-duty vehicle engines. Emissions were measured under engine idling, and at rated and maximum torque engine speeds as in European R-49 cycle but at different engine loads and the engine operating modes had different weighting factors than the European test procedure. From 1985, a transient mode test replaced the 13-mode test. This test cycle was developed from the driving pattern data measured in New York and Los Angeles. The cycle represents driving pattern only for the city operation. It contains the traffic characteristics of congested urban, uncongested urban and city expressway driving. The US transient cycle test is run over a full range of load and speed conditions with equal weighing factor to each operation point of the cycle. The total test consists of three phases, cold start cycle, hot soak and hot start cycle; each phase of 20 minutes duration. Data on engine speed, load and gaseous emissions are monitored once per second. Computer controlled engine test bed and data acquisition are used. The emission results are integrated over the test cycle. The weighting factors for the cold start and hot start cycles are 1/7 and 6/7, respectively.

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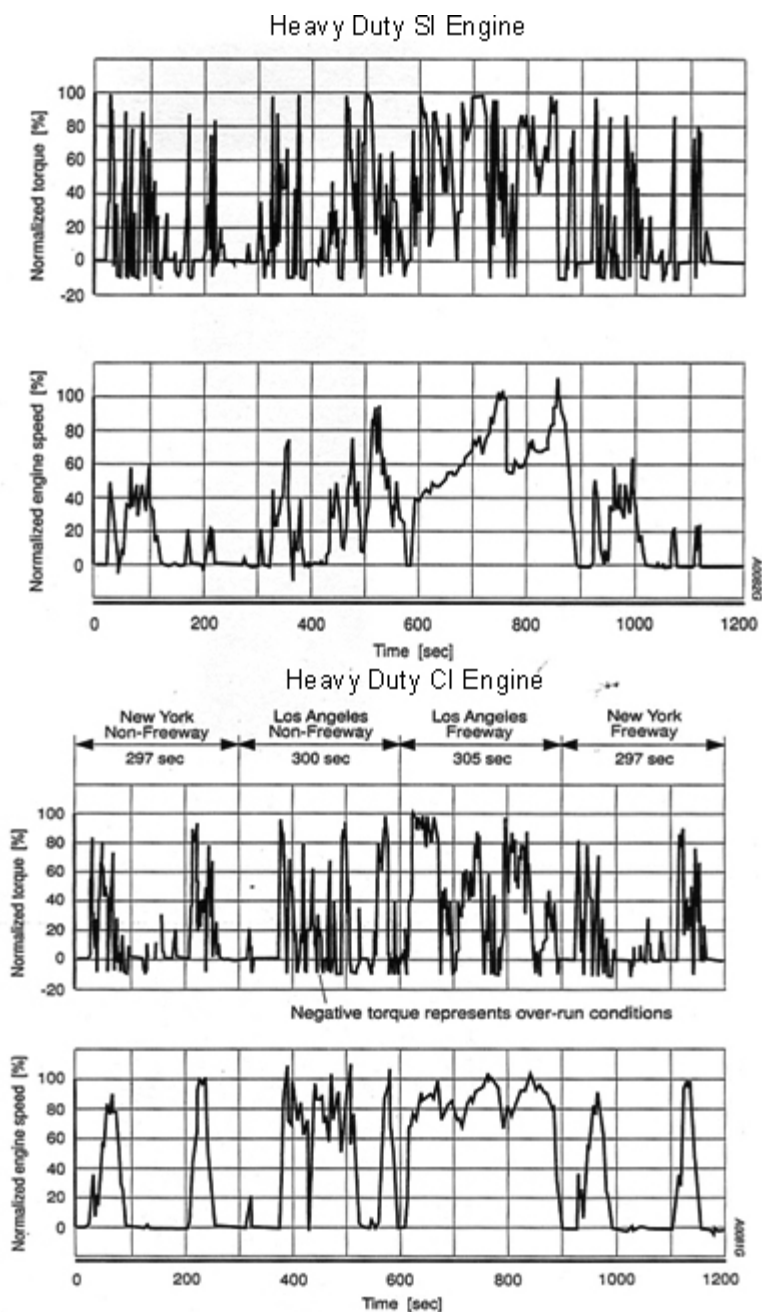


Figure 4.6

US Heavy Duty Emission Test Transient cycle

## Motor cycles

US test cycle for motorcycles has already been shown on Fig. 4.3. In Europe and India, different test cycles have been and are being followed. However, there is an attempt to harmonize the test cycle all over the world and a world motorcycle emission test cycle (WMTC) as shown in Fig 4.7 has been developed. European Union countries have now defined emission test limits as an alternative to the European test cycle, ECE-40. More and more countries are expected to adopt WMTC.

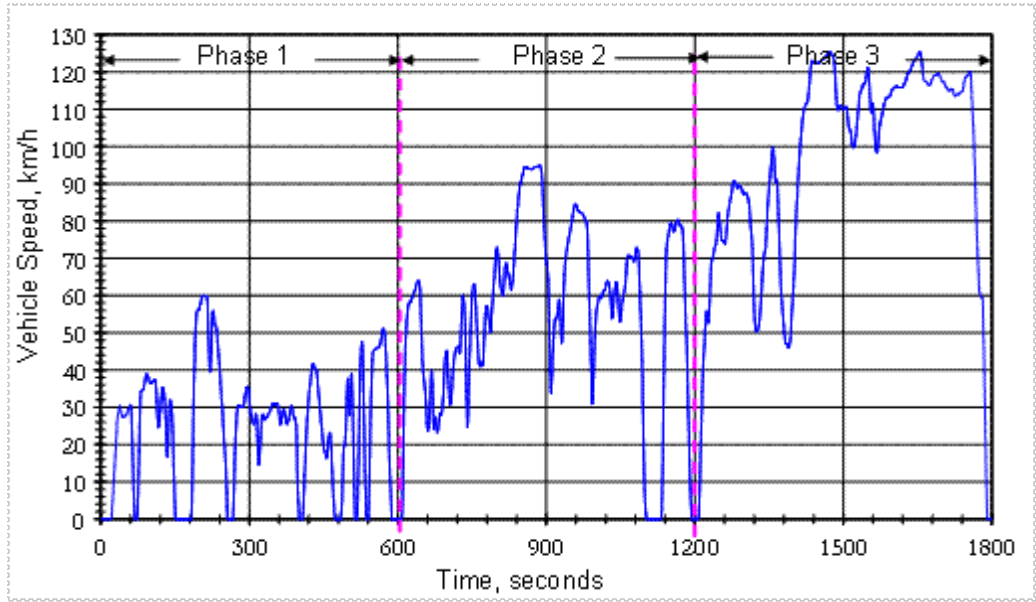


Figure 4.7

World motorcycle emission test cycle (WMTC).