Chapter 16

EMISSION TESTS AND MEASUREMENT OF FUEL CONSUMPTION FOR HYBRID ELECTRIC VEHICLES

1. INTRODUCTION

This chapter defines the specific provisions regarding type-approval of hybrid electric vehicles.

2. Categories of Hybrid Electric Vehicles

HEV's are categorized as below.

Vehicle charging	**Off Vehicle Charging (OVC) [1/]**		**Not Off Vehicle Charging (NOVC) [2/]**	
Operating mode switch	without	with	without	with
[1/] also known as "externally chargeable" [2/] also known as "not externally chargeable"				

3. **Type I test method for Externally Chargeable (OVC HEV) without an Operating Mode Switch**

Two tests shall be performed under the following conditions

(a) **Condition A**: test shall be carried out with a fully charged electrical energy / power storage device.

(b) **Condition B**: test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

(c) The profile of the state of charge (SOC) of the electrical energy/power storage device during different stages of the Type I test for condition A and B are given in Annex II**.**

3.1. Condition A

3.1.1. Discharge of Battery

The procedure shall start with the discharge of the electrical energy / power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.) :

a) at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up

b) or, if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine or for other reasons, the speed shall be reduced until the vehicle can run at a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between testing agency and manufacturer).

c) or with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

Conditioning of Vehicle

3.1.2

M and N Category fitted with Compression Ignition Engine

3.1.2.1

Vehicle shall be driven according to paragraph 3.1.4.2. for three consecutive Part II cycles of the modified Indian driving cycle defined in Table II of Annex IV B of CMVR 1989.

M and N Category fitted with Positive Ignition Engine

3.1.2.2

Vehicle shall be driven according to paragraph 3.1.4.2**.** for one Part One and two Part Two driving cycles of the modified Indian driving cycle defined in Table I and Table II of Annex IV B respectively of CMVR 1989.

L Category

3.1.2.3

Vehicle shall be driven according to paragraph 3.1.4.2 for three consecutive cycles of IDC defined in Annexure II of CMVR 1989.

Soak

3.1.3

3.1.3.1

After this preconditioning, and before testing, the vehicle shall be soaked as prescribed for IC engined vehicles as per MORTH/CMVR/TAP-115/116 and the electrical energy/power storage device is fully charged as a result of the charging prescribed in paragraph 3.1.3.2.

3.1.3.2

During soak, the electrical energy/power storage device shall be charged:

(a) with the on board charger if fitted, or

(b) with an external charger recommended by the manufacturer, using the normal overnight charging procedure (see 4.1.2. of Annexure I)

This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalization charges or the servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred

(c) For details of end of charge, see 4.1.3 of Annexure I.

Mass Emission Test

3.1.4

3.1.4.1 Mass emission test shall be carried out, as prescribed for corresponding IC engined vehicle

3.1.4.2 However, in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information) shall be followed. For these vehicles the gear shifting points prescribed in MORTH/CMVR/TAP-115/116 are not applied.

3.1.4.3 In the case of L category vehicle, the weight of traction battery shall be ignored for the purpose of calculating the reference mass and inertia mass.

Measurement of Energy

3.1.4.4

Within the 30 minutes after the conclusion of the cycle, of the v_1 test, the electrical energy/power storage device shall be charged according to paragraph 4.1.2 and 4.1.3 of Annexure I.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_1 [Wh] delivered from the mains.

The electric energy consumption for condition A is e_1 [Wh].

3.1.4.5 Number of tests to be carried and averaging shall be as prescribed in MORTH/CMVR/TAP-115/116 for IC engined vehicles.

Condition B

3.2

3.2.1 Conditioning of vehicle: shall be as per paragraph 3.1.2

3.2.2 Discharge of battery shall be as per paragraph 3.1.1

3.2.3 After this discharge of the battery and before testing, the vehicle shall be soaked as prescribed for IC engined vehicles as per

MORTH/CMVR/TAP-115/116.

Mass emission test shall be as per 3.1.4

3.2.4

Measurement of Energy

3.2.5

3.2.5.1 Within the 30 minutes after the conclusion of the cycle, of the v_1 test, the electrical energy/power storage device shall be charged according to paragraph 4.1.2 and 4.1.3 of Annexure I.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_2 [Wh] delivered from the mains.

3.2.5.2 The electrical energy/power storage device of the vehicle shall be discharged in accordance with paragraph 3.1.1**.**

3.2.5.3 Within the 30 minutes after discharge, the electrical energy/power storage device shall be charged according to paragraph 4.1.2 and 4.1.3 of Annexure I.

The energy measurement equipment, placed between the mains socket and the vehicle charger, measures the charge energy e_3 [Wh] delivered from the mains.

3.2.5.4 The electric energy consumption e_4 [Wh] for condition B is:
$e_4 = e_2 - e_3$

Final Test Results

3.3.0

3.3.1 The final results of pollutants for deciding on compliance and for CO_2 shall be:

Mi = (De x M1i + Dav x M2i) / (De + Dav)

where

Mi = mass emission of the pollutant i in grams per kilometer

M1i = average mass emission of the pollutant i in grams per kilometre with a fully charged electrical energy/power storage device, determined as per paragraph 3.1.4

M2i = average mass emission of the pollutant i in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) determined as per paragraph 3.2.4

De = vehicle electric range, according to the procedure described in Annex I.

Dav = 25 km (average distance between two battery recharges)

3.3.2 **Fuel Consumption**

Reported fuel consumption shall be calculated by carbon balance method, as per procedure prescribed in MORTH/CMVR/TAP-115/116, except that the values of HC, CO and CO_2 for calculation of fuel consumption shall be based on figures arrived at, as per paragraph 3.3.1.

3.3.3 **Electric Energy Consumption**

3.3.3.1 The values of electric energy consumption shall be

$E_1 = e_1/D_{test1}$ [Wh/km] for condition A, and

$E_4 = e_4/D_{test2}$ [Wh/km] for condition B

with D_{test1} and D_{test2} are the actual driven distances in the tests performed under conditions A (3.1.4.) and B (3.2.4) respectively, and e_1 and e_4 determined in paragraphs 3.1.4.4. and 3.2.5.4 respectively.

3.3.3.2 The weighted values of electric energy consumption shall be calculated as below:

$E = (D_e * E_1 + D_{av} * E_4) / (D_e + D_{av})$

Where:

E = electric consumption Wh/km

E_1 = electric consumption Wh/km with a fully charged electrical energy/power storage device calculated as per 3.3.3.1**.**

E_4 = electric consumption Wh/km with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) 3.3.3.1.

D_e = vehicle electric range, according to the procedure described in Annex I.

D_{av} = 25 km (assumed average distance between two battery recharges)

3.4 If the tests are carried out only for measurement of CO_2, fuel consumption and electrical energy:

3.4.1 Only one test need be carried out and the conditions of paragraph 3.1.4.5 are not applicable.

3.4.2 The preconditioning as per paragraph 3.2.1 need to be carried out only on manufacturer's request.

If measurement of electric energy consumption is not part of the test, it is not necessary to carry out the measurement as per paragraphs 3.1.4.4 and 3.2.5.

4.0 Type I Test for Externally Chargeable (OVC HEV) with an Operating Mode Switch

4.1 The operating mode switch shall be positioned according the table below

Hybrid-modes / Battery State of charge	- Pure electric - Hybrid Switch in position	- Pure fuel consuming - Hybrid Switch in position	- Pure electric - Pure fuel consuming - Hybrid Switch in position	- Hybrid mode n [1/] - Hybrid mode m [1/] Switch in position
Condition A Fully charged	Hybrid	Hybrid	Hybrid	Most electric hybrid mode [2/]
Condition B Min. state of charge	Hybrid	Fuel consuming	Fuel consuming	Most fuel consuming mode [3/]

1/ For instance: sport, economic, urban, extra urban position

2/ Most electric hybrid mode:

The hybrid mode which can be proven to have the highest electricity consumption of all selectable hybrid modes when tested in accordance with Condition A of this chapter, to be established based on information/test reports provided by the manufacturer and in agreement with the testing agency.

3/ Most fuel consuming mode:

The hybrid mode which can be proven to have the highest fuel consumption of all selectable hybrid modes when tested in accordance with Condition B of this chapter, to be established based on information/test reports provided by the manufacturer and in agreement with the testing agency.

4.2 Two tests shall be performed one under Condition A and the other under Condition as defined in 3.0. The test procedures for Condition A and Condition B shall be same as those given in 3.1 and 3.2 respectively, except that the switching modes shall be as given in 4.1, 4.2.1 and 4.3.

4.2.1 However, if the pure electric range of the vehicle measured in accordance with Annex-I is higher than one full emission test cycle, on

the request of the manufacturer, the Type I test for condition A may not be carried out.

In such cases, the value of M1i shall be taken as zero for calculation of final results. (3.3.1 and 3.3.2).

In this case, engine preconditioning prescribed in paragraph 3.1.2 can be omitted at the request of manufacturer.

Discharge of Battery

4.3

4.3.1 In the case of OVC HEV's equipped with a pure electric mode, the procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 per cent ± 5 per cent of the maximum thirty minutes speed of the vehicle (determined according to clause 6.0 of AIS-041).

Stopping the discharge occurs when any of the following conditions happens, earliest :

- when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed; or
- when an indication to stop the vehicle is given to the driver by the standard onboard instrumentation, or
- after covering the distance of 100 km.

4.3.2 In case of HEV's not equipped with "pure electric" mode, the discharge procedure shall be as per 3.1.1.

Final test results shall be obtained using procedure given in 3.3.

4.4

5.0 Type I Tests for Not Externally Chargeable (NOT OVC HEV) without an Operating Mode Switch

5.1 These vehicles shall be tested according to MORTH/CMVR/ TAP-115/116

5.2 In the case of M and N category vehicles, for preconditioning, at least two consecutive complete driving cycles (one Part One and one Part Two) are carried out without soak.

In the case of L category vehicles, preconditioning as per 3.1.2.3 are carried out without soak.

5.3 The vehicle shall be driven according to driving cycles prescribed, taking into account requirements given in paragraph 3.1.4.2 in case of special gear shifting strategy.

5.4 Special requirements for measurement and correction of the test results

for CO_2 and fuel consumption are given in Annex III.

6.0 Type I Tests for Not Externally Chargeable (NOT OVC HEV) with an Operating Mode Switch

6.1 These vehicles shall be tested in Hybrid mode, according to MORTH/CMVR/TAP-115/116. If several hybrid modes are available, the test shall be carried out in the mode that is automatically set after turn on of the ignition key (normal mode). On the basis of information provided by the manufacturer, the testing agency will make sure that the limit values are met in all hybrid modes.

6.2 Preconditioning of vehicle shall be as per 5.2.

6.3 The vehicle shall be driven according to driving cycles prescribed, taking into account requirements given in paragraph 3.1.4.2 in case of special gear shifting strategy.

6.4 Special requirements for measurement and correction of the test results for CO_2 and fuel consumption are given in Annex III.

Type II Test Methods (Idling Emissions) for SI Engines

7.0

7.1 The vehicles shall be tested according to MoRTH/CMVR/TAP-115/116 with the fuel consuming engine running.

7.2 The manufacturer shall provide a “service mode” that makes execution of this test possible, However for HEV’s using constant speed engine for charging of batteries, above test shall be exempted.

7.3 If necessary, the special procedure provided for in paragraph 7.4. shall be used

7.4 It shall be possible to inspect the vehicle for roadworthiness test in order to determine its performance in relation to the data collected in accordance with the procedure prescribed in MORTH/CMVR/ TAP-115/116. If this inspection requires a special procedure, this shall be detailed in the service manual (or equivalent media). This special procedure shall not require the use of special equipment other than that provided with the vehicle

Type III Test Method: (Crank Case Emission)

8.0

8.1 In the case of M and N categories, the vehicles shall be tested according to conditions (1) and (2) of testing for crankcase emissions as mentioned in MoRTH/CMVR/TAP-115/116 with the fuel consuming engine running. The manufacturer shall provide a "service mode" that makes execution of this test possible.

9.0 Type IV Test Method (Evaporative Emission)

9.1 In the case of petrol engined M and N categories, the vehicles shall be tested according to MoRTH/CMVR/TAP-115/116

9.2 Before starting the test procedure (MoRTH/CMVR/TAP-115/116), the vehicles shall be preconditioned as follows:

9.2.1 **For Externally Chargeable (OVC HEV) Vehicles**

9.2.1.1 **For Externally Chargeable (OVC HEV) Vehicles without an Operating Mode Switch:** The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle as per paragraph 3.1.1

9.2.1.2 **For Externally Chargeable (OVC HEV) Vehicles with an Operating Mode Switch with a "Pure Electric" mode:** The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position as per 4.3.1.

9.2.1.3 **For Externally Chargeable (OVC HEV) Vehicles with Operating mode switch but without an Operating Mode for a "Pure Electric" mode:** The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle as per paragraph 3.1.1.

9.2.2 **For Not Externally Chargeable (NOVC HEV) Vehicles**

9.2.2.1 **NOVC Vehicles without an Operating Mode Switch:** The procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak.

9.2.2.2 **NOVC Vehicles with an Operating Mode Switch:** The procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak, performed with the vehicle in "hybrid" mode. If several hybrid modes are available, the test shall be carried out in the mode which is automatically set after turn on of the ignition key (normal mode).

9.3 The preconditioning drive and the dynamometer test shall be carried out according to cycles and procedure given in MORTH/CMVR/ TAP-115/116.

9.3.1 In the case of externally chargeable (OVC) HEV: Under the same conditions, as specified by condition B of the Type I test (paragraphs 3.2 and 4.2)

9.3.2 In the case of not externally chargeable (NOVC) HEV:: Under the same conditions of Type I test as specified in 5.2 and 6.2.

10.0 Type V Test Methods (Durability)

In case the mileage accumulation for durability tests is opted by the vehicle manufacturer, vehicles shall be tested according to MoRTH/CMVR/TAP-115/116 with the following additional requirements.

10.1 For External Chargeable Vehicles (OVC)

10.1.1 It is allowed to charge the electrical energy/power storage device twice a day during mileage accumulation.

10.1.2 For External Chargeable vehicles (OVC) with an operating mode switch, mileage accumulation should be driven in the mode which is automatically set after turn on of the ignition key (normal mode). During the mileage accumulation a change into another hybrid mode is allowed if necessary in order to continue the mileage accumulation after agreement of the testing agency.

10.1.3 The measurements of emissions of pollutants shall be carried out under the same conditions as specified by condition B of the Type I test (paragraphs 3.2 and 4.2).

10.2 For Not Externally Chargeable (NOVC HEV) Vehicles

For not externally chargeable (NOVC HEV) vehicles with an operating mode switch, mileage accumulation shall be driven in the mode which is automatically set after turn on of the ignition key (normal mode). The measurements of emissions of pollutants shall be carried out in the same conditions as in the Type I test.(Refer 6.0 and 5.0).

11. ON BOARD DIAGNOSTICS (OBD) TEST METHODS

11.1. The vehicles shall be tested according to Chapter 13 & 14.

11.2. For OVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as specified for condition B of the Type I test.

11.3. For NOVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as in the Type I test.

12. For the measurement of Net Power AIS 041 as amended time to time is applicable.

Annexure I

METHOD OF MEASURING THE ELECTRIC RANGE OF VEHICLES POWERED BY A HYBRID ELECTRIC POWER TRAIN

1.0 The test method described hereafter permits to measure the electric range, expressed in km, of externally chargeable HEV's (OVC-HEV) as defined in paragraph 2 of Chapter 16.

Parameters, Units and Accuracy of Measurements

2.0 Parameters, units and accuracy of measurements shall be as given in Table -1:

Table 1
Parameters, Units and Accuracy of Measurements

Parameter	Unit	Accuracy	Resolution
Time	s	± 0.1 s	0.1 s
Distance	m	± 0.1 per cent	1 m
Temperature	°C	± 1°C	1°C
Speed	km/h	± 1 per cent	0.2 km/h
Mass	kg	± 0.5 per cent	1 kg

Test Conditions

3.0

Condition of the Vehicle

3.1

3.1.1. The vehicle tyres shall be inflated to the pressure specified by the vehicle manufacturer when the tyres are at the ambient temperature.

3.1.2. The viscosity of the oils for the mechanical moving parts shall conform to the specifications of the vehicle manufacturer.

3.1.3. The lighting and light-signaling and auxiliary devices shall be off, except those required for testing and usual daytime operation of the vehicle.

3.1.4. All energy storage systems available for other than traction purposes (electric, hydraulic, pneumatic, etc.) shall be charged up to their maximum level specified by the manufacturer.

3.1.5. If the batteries are operated above the ambient temperature, the operator shall follow the procedure recommended by the vehicle manufacturer in order to keep the temperature of the battery in the

normal operating range.

The manufacturer's agent shall be in a position to attest that the thermal management system of the battery is neither disabled nor reduced.

3.1.6. The vehicle must have run at least 300 km during the seven days before the test with those batteries that are installed in the test vehicle. This condition can be waived on request of the vehicle manufacturer

3.2 **Climatic Conditions**

3.2.1 For testing performed outdoors, the ambient temperature shall be between 5 °C and 32 °C.

3.2.2 The indoors testing shall be performed at a temperature between 20 °C and 30 °C.

3.2.3 The test may be carried out at temperatures different from those specified above, at the request of manufacturer.

4.0 Operation Modes

The test method includes the following steps:

(a) Initial charge of the battery.

(b) Application of the cycle and measurement of the electric range. Between the steps, if the vehicle shall move, it is pushed to the following test area (without regenerative recharging).

4.1. **Initial Charge of the Battery**

Charging the battery consists of the following procedures:

Note: "Initial charge of the battery" applies to the first charge of the battery, at the reception of the vehicle. In case of several combined tests or measurements, carried out consecutively, the first charge carried out shall be an "initial charge of the battery" and the following may be done in accordance with the "normal overnight charge" procedure.

4.1.1. **Discharge of the Battery**

4.1.1.2. For externally chargeable hybrid electric vehicle (OVC HEV) without an operating mode switch:

4.1.1.2.1. The manufacturer shall provide the means for performing the measurement with the vehicle running in pure electric operating state.

4.1.1.2.2. The procedure for discharge of the electrical energy/power storage device of the vehicle is as per paragraph 3.1.1 of Chapter 16.

4.1.1.3. For externally chargeable hybrid electric vehicle (OVC HEV) with an operating mode switch.

4.1.1.3.1. If there is not a pure electric position, the manufacturer shall provide the means for performing the measurement with the vehicle running in pure electric operating state. The procedure for discharge of the electrical energy/power storage device of the vehicle is as per paragraph 3.1.1 of Chapter 16.

4.1.1.3.2. If there is a pure electric position, the procedure for discharge of the electrical energy/power storage device of the vehicle is as per paragraph 4.3.1 of Chapter 16.

4.1.2. **Application of a Normal Overnight Charge**

The electrical energy/power storage device shall be charged according to the normal overnight charge procedure given below.

4.1.2.1 Normal Overnight Charge Procedure

The charging is carried out:

(a) with the on board charger if fitted, or

(b) with an external charger recommended by the manufacturer using the charging pattern prescribed for normal charging;

(c) in an ambient temperature comprised between 20 ºC and 30 ºC.

Charging may be carried out at temperatures different from those specified above, at the request of manufacturer.

This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges. The manufacturer shall declare that during the test, a special charge procedure has not occurred.

4.1.3 End of Charge Criteria

The end of charge criteria corresponds to a charging time of 12 hours, except if a clear indication is given to the driver by the standard instrumentation that the electrical energy/power storage device is not yet fully charged.

In this case,

$$\text{The maximum time is} = \frac{3 \times \text{claimed battery capacity (Wh)}}{\text{Mains power supply (W)}}$$

4.2. Application of the Cycle and Measurement of the Range

4.2.1. The applicable test sequence as per the driving cycle used for mass emission testing is applied on a chassis dynamometer until the end of the test criteria is reached. Gear shifting pattern shall be as prescribed in paragraph 3.1.4.2 of Chapter 16.

4.2.2. The end of the test criteria is reached earliest:

4.2.2.1 When the vehicle is not able to meet the target curve up to 30 km/h,

4.2.2.2 or when an indication from the standard on-board instrumentation is given to the driver to stop the vehicle

4.2.2.3 or when the fuel consuming engine starts up.

Then the vehicle shall be slowed down to 5 km/h by releasing the accelerator pedal, without touching the brake pedal and then stopped by braking.

4.2.2.4 At a speed over speeds specified in paragraph 4.2.2.1 when the vehicle does not reach the required acceleration or speed of the test cycle, the accelerator pedal shall remain fully depressed until the reference curve has been reached again.

4.2.2.5 To respect human needs, up to three interruptions are permitted between test sequences, of no more than 15 minutes in total.

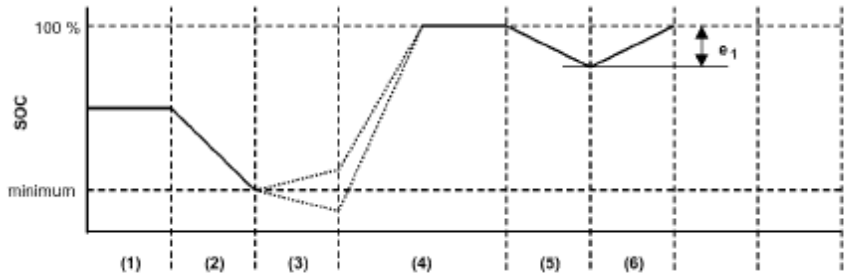
4.2.2.6 At the end, the measure D_e of the covered distance in km is the electric range of the hybrid electric vehicle. It shall be rounded to the nearest whole number as per IS 2.

Annexure II

ELECTRICAL ENERGY/POWER STORAGE DEVICE STATE OF CHARGE (SOC) PROFILE FOR OVC-HEV'S.

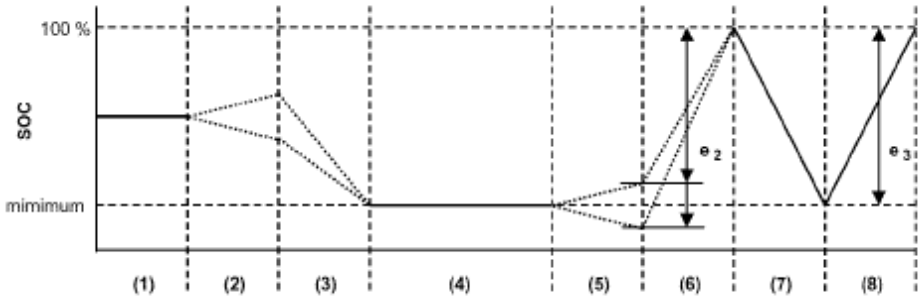
The SOC profiles for OVC-HEV's tested under conditions A and B are:

Condition A:



(1) initial state of charge of the electrical energy/power storage device
(2) discharge according to paragraph 3.1.1 or 4.3 of Chapter 16
(3) vehicle conditioning according to paragraph 3.1.2 of Chapter 16
(4) charge during soak according to paragraph 3.1.3.2 of Chapter 16
(5) test according to paragraph 3.1.4 of Chapter 16
(6) charging (3.1.4.4 of Chapter 16)

Condition B:



(1) initial state of charge
(2) vehicle conditioning according to paragraph 3.2.1 of Chapter 16
(3) discharge according to paragraph 3.2.2 of Chapter 16
(4) soak according to paragraph 3.2.3 of Chapter 16
(5) test according to paragraph 3.2.4 of Chapter 16
(6) charging according to paragraph 3.2.5.1 of Chapter 16
(7) discharging according to paragraph 3.2.5.2 of Chapter 16.
(8) charging according to paragraph 3.2.5.3 of Chapter 16.

ANNEX III

SPECIAL REQUIREMENTS FOR MEASUREMENT AND CORRECTION OF THE TEST RESULTS FOR CO_2 AND FUEL CONSUMPTION FOR NOT EXTERNALLY CHARGEABLE (NOVC) HEV'S.

1 In the case of M and N category vehicles, emissions of carbon dioxide (CO_2) and fuel consumption shall be determined separately for the Part One (urban driving) and the Part Two (extra-urban driving) of the specified driving cycle.

Test Results

2

2.1 The test results (fuel consumption C [l/100 km] and CO_2-emission M [g/km]) of the test are corrected in function of the energy balance ΔE_{batt} of the vehicle's battery. The corrected values (C_0 [l/100 km] and M_0 [g/km]) should correspond to a zero energy balance ($\Delta E_{batt} = 0$), and are calculated using a correction coefficient determined by the manufacturer as defined below. In case of other storage systems than an electric battery, ΔE_{batt} is representing $\Delta E_{storage}$, the energy balance of the electric energy storage device.

2.2 The electricity balance Q [Ah], measured using the procedure specified in Clause 6.0, is used as a measure of the difference in the vehicle battery's energy content at the end of the cycle compared to the beginning of the cycle. In the case of M and N category vehicles, the electricity balance is to be determined separately for the Part One cycle and the Part Two cycle.

2.3 Under the conditions below, it is allowed to take the uncorrected measured values C and M as the test results:

a) in case the manufacturer can prove that there is no relation between the energy balance and fuel consumption,

b) in case that ΔE_{batt} always corresponds to a battery charging,

c) in case that ΔE_{batt} always corresponds to a battery decharging and ΔE_{batt} is within 1 per cent of the energy content of the consumed fuel (consumed fuel meaning the total fuel consumption over one cycle):

Energy content of the consumed fuel can be calculated from the following equation :

Total Fuel Energy = $NHV_{fuel} * m_{fuel}$

Where,

NHV_{fuel} = Net heating value of consumable fuel in J/kg

mf_{uel} = Total mass of fuel consumed over one test cycle

The change in battery energy content ΔE_{batt} can be calculated from the

measured electricity balance Q as follows:

$$\Delta E_{batt} = \Delta SOC(\%) \cdot E_{TEbatt} \cong 0.0036 \cdot |\Delta Ah| \cdot V_{batt} = 0.0036 \cdot Q \cdot V_{batt} \quad (MJ)$$

with E_{TEbatt} [MJ] the total energy storage capacity of the battery and V_{batt} [V] the nominal battery voltage.

3 **Fuel Consumption Correction Coefficient (K_{fuel}) Defined by the Manufacturer**

3.1 The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements performed by the manufacturer. This set should contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$.

3.2 If the latter condition can not be realised on the driving cycle (Part One or Part Two of modified Indian Driving Cycle in the case of M and N category or IDC in the case of L category as applicable) used in this test, then it is up to the testing agency to judge the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{batt} = 0$

The fuel consumption correction coefficient (K_{fuel}) is defined as

$$K_{fuel} = (n \cdot \Sigma Q_i C_i - \Sigma Q_i \cdot \Sigma C_i) / (n \cdot \Sigma Q_i^2 - (\Sigma Q_i)^2) \qquad (l/100\ km/Ah)$$

where:

C_i **:** fuel consumption measured during i-th manufacturer's test (l/100 km)

Q_i **:** electricity balance measured during i-th manufacturer's test (Ah)

n **:** number of data

The fuel consumption correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the fuel consumption correction coefficient is to be judged by the testing agency.

3.3 In the case of M and N category, separate fuel consumption correction coefficients shall be determined for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively

4 Fuel consumption at zero battery energy balance (C_0)

4.1 The fuel consumption C_0 at $\Delta E_{batt} = 0$ is determined by the following equation

$C_0 = C - K_{fuel} * Q$ (l/100 km)
where:

C **:** fuel consumption measured during test (l/100 km)

Q **:** electricity balance measured during test (Ah)

4.2 In the case of M and N category, fuel consumption at zero battery energy balance shall be determined separately for the fuel consumption values measured over the Part One cycle and the Part Two cycle respectively

5.0 CO_2-emission correction coefficient (K_{CO2}) defined by the manufacturer

5.1 The CO_2-emission correction coefficient (K_{CO2}) shall be determined as follows from a set of n measurements performed by the manufacturer. This set should contain at least one measurement with $Q_i < 0$ and at least one with $Q_j > 0$. If the latter condition can not be realised on the driving cycle (Part One or Part Two in the case of M and N category or IDC as applicable) used in this test, then it is up to the testing agency to judge the statistical significance of the extrapolation necessary to determine the CO_2- emission value at $\Delta E_{batt} = 0$.

5.2 The CO_2-emission correction coefficient (K_{CO2}) is defined as:

$$K_{CO2} = (n \cdot \Sigma Q_i M_i - \Sigma Q_i \cdot \Sigma M_i) / (n \cdot \Sigma Q_i^2 - (\Sigma Q_i)^2) \qquad (g/km/Ah)$$

where

M_i **:** CO_2-emission measured during i-th manufacturer's test (g/km)

Q_i **:** electricity balance during i-th manufacturer's test (Ah)

n **:** number of data

The CO_2-emission correction coefficient shall be rounded to four significant figures (e.g. 0.xxxx or xx.xx). The statistical significance of the CO_2-emission correction coefficient is to be judged by the testing agency.

5.3 In the case of M and N category, separate CO_2-emission correction coefficients shall be determined for the CO_2 emission values measured over the Part One cycle and the Part Two cycle respectively.

5.4 CO_2-emission at zero battery energy balance (M_0).

5.5 The CO_2-emission M_0 at $\Delta E_{batt} = 0$ is determined by the following equation:

$M_0 = M - K_{CO2} * Q$ (g/km)

where:

C **:** CO_2 emission measured during test (g/km)

Q **:** electricity balance measured during test (Ah)

5.6 In the case of M and N category, CO_2 - emission at zero battery energy balance shall be determined separately for the CO_2 - emission values measured over the Part One cycle and the Part Two cycle respectively

6.0 Electricity Balance

6.1 General

6.1.1. The purpose of this paragraph is to define the method and required instrumentation for measuring the electricity balance of Not externally chargeable Hybrid Electric Vehicles (NOVC HEVs). Measurement of the electricity balance is necessary to correct the measured fuel consumption and CO_2-emissions for the change in battery energy content occurring during the Type I test, using the method defined in paragraphs 4 and 5.

6.1.2. The method described in this paragraph shall be used by the manufacturer for the measurements that are performed to determine the correction factors K_{fuel} and K_{CO2}, as defined in paragraphs 3.2 and 5.2 The testing agency shall check whether these measurements have been performed in accordance with the procedure described in this annex.

6.1.3. The method described in this paragraph shall be used by the testing agency for the measurement of the electricity balance Q, as defined in paragraphs 4.1 and 5.5.

6.2 Measurement Equipment and Instrumentation

6.2.1 During the Type I tests as described in paragraphs 5.0. and 5.0 of Chapter 16, the battery current shall be measured using a current transducer of the clamp-on type or the closed type. The current transducer (i.e. the current sensor without data acquisition equipment) shall have a minimum accuracy of 0.5 per cent of the measured value or 0.1 per cent of the maximum value of the scale. OEM diagnostic testers are not to be used for the purpose of this test.

6.2.1.1 The current transducer shall be fitted on one of the wires directly

connected to the battery. In order to easily measure battery current using external measuring equipment, manufacturers should preferably integrate appropriate, safe and accessible connection points in the vehicle. If that is not feasible, the manufacturer is obliged to support the testing agency by providing the means to connect a current transducer to the wires connected to the battery in the above described manner.

6.2.1.2 The output of the current transducer shall be sampled with a minimum sample frequency of 5 Hz. The measured current shall be integrated over time, yielding the measured value of Q, expressed in Ampere hours (Ah).

6.2.1.3 The temperature at the location of the sensor shall be measured and sampled with the same sample frequency as the current, so that this value can be used for possible compensation of the drift of current transducers and, if applicable, the voltage transducer used to convert the output of the current transducer. Measurement of temperature can be skipped if accuracy of current measurement is guaranteed through the test term.

6.2.2. A list of the instrumentation (manufacturer, model no., serial no.) used by the manufacturer for determining the correction factors K_{fuel} and K_{CO2} (as defined in paragraphs 3.2 and 5.2) and the last calibration dates of the instruments (where applicable) should be provided to the testing agency.

6.3 Measurement Procedure

6.3.1. Measurement of the battery current shall start at the same time as the test starts . and shall end immediately after the vehicle has driven the complete driving cycle.

6.3.2. In the case of M and N category, separate values of Q shall be logged over the Part One and Part Two of the cycle.