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Hybrid-electric road vehicles — Exhaust emissions and fuel consumption measurements — Non-externally chargeable vehicles

Véhicules routiers électriques hybrides — Mesurages des émissions à l'échappement et de la consomation de carburant — Véhicules non rechargeables par des moyens externes

Reference number
ISO 23274:2007(E)

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 23274 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electrically propelled road vehicles*.

Introduction

Hybrid-electric road vehicle (HEV) design has huge flexibility (in applied components or in operational manners). HEV can be roughly classified by following three characteristics (see also Table 1):

a) external charge capability: externally chargeable/non-externally chargeable;

b) rechargeable energy storage system (RESS): battery/capacitor;

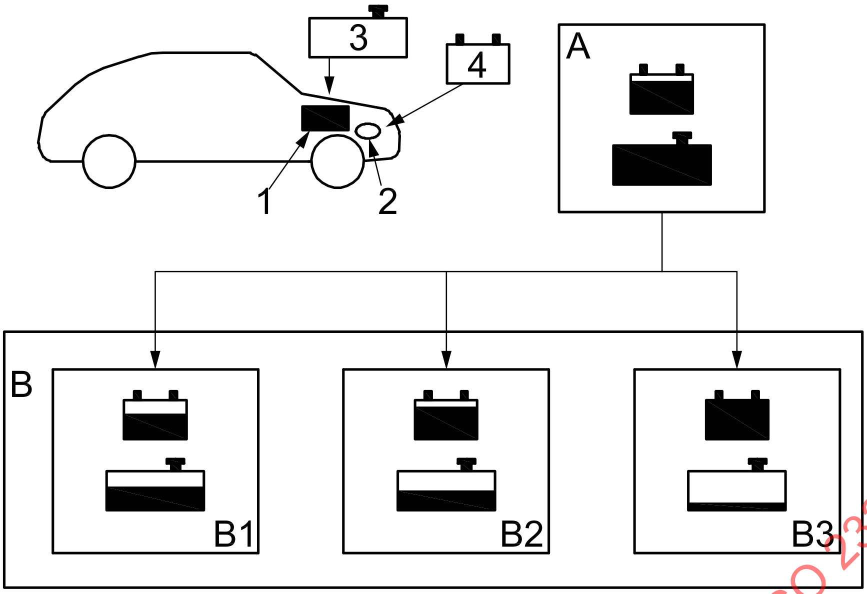
c) driver-selected operating modes: if HEV has no driver-selected operating mode, it has only HEV mode; if HEV has driver-selected operating mode, it has three possibilities [i.e. HEV mode, internal combustion engine vehicle (ICEV) mode and electric vehicle (EV) mode].

Table 1 — Classification of HEV

External charge	Operating mode
Externally chargeable	HEV operating mode
	ICEV operating mode
	EV operating mode
Non-externally chargeable	HEV operating mode
	ICEV operating mode
	EV operating mode

For hybrid-electric vehicles with internal combustion engines (ICE), exhaust emissions and fuel consumption measurements are principally the same as for ICEV. The measured exhaust emissions and fuel consumption, however, cannot be assumed to be the correct ones because the battery state of charge (SOC) of the RESS at the end of the test cycle is not necessarily the same as that at the beginning of the test cycle. In addition, it is not always possible for the SOC of the RESS at the end of test cycle to be equal to that at the beginning of test cycle (see Figure 1).

In this case illustrated in Figure 1, a correction needs to be introduced as described in this International Standard. The linear correction method, as described in Annex D, represents the current state of the art.



Key

1	combustion engine	A	condition before test
2	electric motor	B	condition after test
3	fuel tank	B1	case 1: driven partly by fuel, partly by battery
4	battery	B2	case 2: driven only by fuel
		B3	case 3: driven only by fuel, additional fuel used to charge battery

Figure 1 — Status of energy storage system before and after test

Hybrid-electric road vehicles — Exhaust emissions and fuel consumption measurements — Non-externally chargeable vehicles

1 Scope

This International Standard establishes a uniform chassis dynamometer test procedure for hybrid-electric road vehicles (HEV) with internal combustion engines (ICE) classified as passenger cars and light duty trucks, as defined in each regional annex. This International Standard proposes ways of correcting the measured emissions and fuel consumption of HEV, in order to obtain the correct values when the battery state of charge (SOC) of the rechargeable energy storage system (RESS) does not remain the same between the beginning and the end of test cycle.

This International Standard applies to HEV with ICE of which the nominal energy of the RESS is at least 2 % of the total energy consumption by the vehicle over the test cycle.

This International Standard applies to non-externally chargeable vehicles without an operating mode switch to draw propulsion energy from the following sources of energy:

— consumable fuel, and

— an energy storage battery/capacitor system that is rechargeable only by an on-board engine-generator/electric motor system.

Consumable fuels covered by this International Standard are limited to petroleum-based liquid fuels (e.g. gasoline and diesel fuel).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10521 (all parts), *Road vehicles — Road load*

3 Terms and definitions

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

3.1
battery state of charge
battery SOC
residual capacity of battery available to be discharged, normally expressed as a percentage of full charge

3.2
charge balance of battery
change of charge in battery during test period, normally expressed in Ah

3.3
driver selected operating mode
vehicle propulsion operating mode that the driver can select through on-board switches or other means

3.4
electric vehicle operating mode
EV operating mode
mode of a HEV in which only the RESS is used for vehicle propulsion and possibly auxiliary systems

3.5
energy balance of battery
charge balance of battery multiplied by the nominal voltage, normally expressed in Wh

NOTE This definition is an approximation of the actual energy balance used for practical purpose.

3.6
externally chargeable HEV
plug-in HEV
HEV with RESS that is intended to be recharged for normal operation from an external electric energy source

3.7
hybrid electric vehicle
HEV
vehicle using both a RESS and a fuelled power source for vehicle propulsion

NOTE ICE or fuel cell systems are typical types of fuelled propulsion power sources.

3.8
hybrid-electric vehicle operating mode
HEV operating mode
mode of a HEV with ICE in which both RESS and ICE are used simultaneously or sequentially for vehicle propulsion

NOTE The ICE may also charge the RESS during propulsion or standstill.

3.9
internal combustion engine vehicle operating mode
ICEV operating mode
mode of a HEV with ICE in which only the ICE is used for vehicle propulsion, and in which regenerative braking is excluded

3.10
non-externally chargeable HEV
non plug-in HEV
HEV with RESS that is not intended to be recharged for normal operation from an external electric energy source

NOTE The RESS may be externally charged for infrequent conditioning of the RESS, or other purposes unrelated to vehicle propulsion.

3.11
rechargeable energy storage system
RESS
system that stores energy for delivery of electric energy and which is rechargeable

EXAMPLES Batteries or capacitors.

3.12
regenerative braking
partial recovery of the energy normally dissipated in friction braking, which is returned as electric energy to a RESS

4 Test conditions and instrumentation

4.1 Test conditions

4.1.1 General

Adequate test site capabilities for safe venting and cooling of batteries, protection from exposure to high voltage, or any other necessary safety precaution shall be provided during testing. The conditions in 4.1.2, 4.1.3 and 4.1.4 shall also apply to all tests specified, unless specified differently in Annexes A, B or C.

4.1.2 Ambient temperature

Tests shall be conducted at ambient temperature of 25 ± 5 °C.

4.1.3 Vehicle conditions

4.1.3.1 Vehicle stabilization

Prior to testing, the test vehicle shall be stabilized, including accumulation of vehicle mileage either to a manufacturer-determined distance, or to above 3 000 km and less than 15 000 km.

4.1.3.2 Vehicle appendages

Vehicles shall be tested with normal appendages (mirrors, bumpers, etc.). Certain items on the dynamometer (e.g. hub caps) may be removed for safety, where necessary.

4.1.3.3 Vehicle test mass

The vehicle test mass shall be selected in accordance with Annexes A, B, or C.

4.1.3.4 Tyres

The tyres recommended by the vehicle manufacturer shall be used.

4.1.3.4.1 Tyre pressure

The vehicle tyres shall be inflated to the pressure specified by the vehicle manufacturer in accordance with the test chosen (track or chassis dynamometer) when the tyres are at ambient temperature.

4.1.3.4.2 Tyre conditioning

The tyres shall be conditioned as recommended by the vehicle manufacturer. See Annexes A, B or C for additional requirements for particular regions.

4.1.3.5 Lubricants

The vehicle lubricants normally specified by the manufacturer shall be used.

4.1.3.6 Gear shifting

If the vehicle is fitted with a manually shifted gear box, gear shifting positions correspond to the test procedure mentioned in Annexes A, B and C. However, the shift positions may have been selected and determined previously in accordance with the vehicle characteristics.

4.1.3.7 Regenerative braking

If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all dynamometer testing.

If the vehicle is tested on a single-roll dynamometer and is equipped with systems such as an antilock braking system (ABS) or a traction control system (TCS), these systems may inadvertently interpret the non-movement of the set of wheels that are off the dynamometer as a malfunctioning system. If so, modifications to the these systems shall be made to achieve normal operation of the remaining vehicle systems, including the regenerative braking system.

4.1.3.8 RESS stabilization

The RESS shall be stabilized with the vehicle as defined in 4.1.3.1, or by equivalent conditioning.

4.1.4 Chassis dynamometer conditions

4.1.4.1 General

HEV should generally be tested on a single-roll chassis dynamometer. HEV with four-wheel drive shall be tested by modifying the drive train of the vehicle. When the vehicle is modified, the details shall be explained in the test report.

Double roll dynamometer testing may be performed when a modification for single roll dynamometer testing is not possible for a specific four-wheel driven HEV.

4.1.4.2 Dynamometer calibration

The dynamometer shall be calibrated in accordance with the specifications indicated in the service manual provided by the dynamometer manufacturers.

4.1.4.3 Dynamometer warm-up

The dynamometer shall be warmed up sufficiently prior to testing.

4.1.4.4 Determining the dynamometer load coefficient

The determination of vehicle road load and the reproduction on a chassis dynamometer shall conform to ISO 10521. Vehicles equipped with regenerative braking systems that are activated at least in part when the brake pedal is not depressed shall have regenerative braking disabled during the deceleration portion of coast-down testing on both the test track and dynamometer.

4.2 Test instrumentation

Test instrumentation shall have accuracy levels as shown in Table 2, unless specified differently in Annexes A, B, or C.

Table 2 — Accuracy of measurement test instrumentation

Item	Unit	Accuracy
Time	s	± 0,1 s
Distance	m	± 0,1 %
Temperature	°C	± 1 °C
Speed	km/h	± 1 %
Mass	kg	± 0,5 %
Quantity of electricity	Ah	± 0,5 %
Capacitor voltage	V	± 0,5 % of nominal voltage
Rotating speed	r/min	± 0,5 % of maximum rotating speed

5 Exhaust emissions and fuel consumption tests

5.1 General

The appropriate procedure for a particular region shall be selected from Annexes A, B and C, for Japan, Europe and North America respectively. Details and common procedures for each test mode are described below.

5.2 Test procedure for HEV operating mode

5.2.1 Vehicle preconditioning

Vehicle preconditioning shall be carried out in accordance with the corresponding annex of regional test procedure, if necessary.

If necessary, the RESS SOC may be pre-adjusted by charging or discharging, to obtain suitable energy difference in RESS between the beginning and the end of test.

5.2.2 Vehicle soak

The vehicle shall be soaked in accordance with the appropriate regional procedure in Annexes A, B or C.

5.2.3 Vehicle movement to the test room

The vehicle shall be moved into test room by pushing or towing (never by driving). The test vehicle shall be set on the chassis dynamometer after the chassis dynamometer has warmed up just before the test. The vehicle shall be kept in a cold condition after soak.

5.2.4 Measurement over scheduled driving test

One cycle of the scheduled driving test shall be conducted. Driving distance, energy difference in RESS, consumed fuel and exhaust emissions shall be measured. The conditions of the vehicle during the scheduled driving test shall follow the appropriate regional test procedure in Annexes A, B or C.

5.3 Correction of the test results

5.3.1 General

Correct fuel consumption and exhaust emission shall be obtained from measured exhaust emissions and energy difference of RESS, through the procedure described below. Measurement shall follow the appropriate regional test method shown in Annexes A, B or C.

5.3.2 Allowable limit for RESS energy change

The allowable limit for RESS energy change is defined as follows:

$$|\Delta E_{\mathrm{RESS}}| \leqslant 0{,}01 \times E_{\mathrm{CF}} \qquad (1)$$

where

ΔE_{RESS} is the energy change in RESS over the test cycle;

E_{CF} is the energy of consumed fuel over the test cycle.

Energy change in RESS and maximum allowable energy change in RESS are specified in Annex E.

5.3.3 Correction procedure by correction coefficient

The vehicle manufacturer shall deliver the correction coefficient to calculate the fuel consumption and the exhaust emission at $\Delta E_{\mathrm{RESS}} = 0$. The correction coefficient can be obtained in accordance with Annex D. When the measured value is independent of ΔE_{RESS}, a correction is not required.

6 Calculations and expressions

Resultant exhaust emission and fuel consumption in each scheduled driving test shall be calculated individually in accordance with each regional requirement in Annexes A, B or C.

The basic result shall be calculated and expressed as follows.

$$\text{Exhaust emission (g/km)} = \frac{\text{(weighed mass emission, in grams)}}{\text{(driven distance, in km)}} \qquad (2)$$

$$\text{Fuel consumption (l/km)} = \frac{\text{(measured fuel, in litres)}}{\text{(driven distance, in km)}} \qquad (3)$$

To adapt regional regulation and rules, details in calculating procedure are specified in Annexes A, B and C.

Annex A
(informative)

Test procedure in Japan

A.1 General principles

A.1.1 General comments on regional information

This annex contains regional information, which supplements the provisions of this International Standard.

A.1.2 General considerations

This annex describes the typical procedures and related conditions used in Japan to measure the exhaust emissions and fuel consumption of the passenger cars and light duty trucks, as defined in Japanese regulations.

A.2 Accuracy of measurement

A.2.1 The accuracy of determining of road load shall conform to ISO 10521.

A.2.2 The repeatable test result of calibration gas in exhaust emission sampling and analytical systems shall be kept within ± 1 %.

A.2.3 The accuracy of constant volume sampling (CVS) equipment shall be kept within ± 2 %.

A.3 Driving procedure

A.3.1 General

The gear manipulation in each operational condition, specified in Tables A.1 and A.2, shall be performed smoothly and quickly, in accordance with A.3.2 to A.3.4.

A.3.2 Motor vehicles with manual transmission

A.3.2.1 The idling operation refers to a condition in which the accelerator pedal is not depressed, with the transmission gear in neutral.

A.3.2.2 The transmission gear shall be shifted to the low gear positions (or other gear in instances where the “low” gear position should read otherwise in Tables A.1 and A.2) 5 s before the idling operation mode is switched to the acceleration mode.

A.3.2.3 For deceleration, the clutch shall be disengaged at a speed of 10 km/h during the deceleration from 20 km/h to 0 km/h; at a speed of 20 km/h during the deceleration from 40 km/h to 0 km/h (as specified in Tables A.1 and A.2). In the same way, the clutch shall be disengaged at a speed of 30 km/h during the deceleration from 70 km/h to 0 km/h (as specified in Table A.2).

A.3.2.4 In A.3.2.3 above, if the engine speed is under the engine idling speed, the clutch shall be disengaged.

A.3.2.5 In the case of vehicles with a 6-speed transmission that cannot be driven properly by operating the shift schedule specified in Table A.2, the driving may be carried out in accordance with the 5-speed transmission shift schedule.

A.3.2.6 If the speed of the engine of the test vehicle exceeds the speed at which the engine delivers its maximum output during the operation of the test vehicle, the gear position that is one step higher than the original gear may be used. In this case, the vehicle speed at which the gearshift takes place shall be the vehicle speed corresponding to the engine speed at which the engine delivers its maximum output.

A.3.3 Motor vehicle with automatic transmission

The selector position shall remain in drive position. No further manipulation shall be made.

A.3.4 Motor vehicle with other transmission

The gear changes shall be made considering the running characteristics of the tested motor vehicle with other transmission than those in A.3.1 and A.3.2.

A.4 Vehicle test mass

The test vehicle shall have a mass obtained when two persons (assuming that the mass of a person is 55 kg) or mass of 110 kg are loaded on the test vehicle under the “unloaded state” [specified in Item (3) of Paragraph 1 of Article 1 of the Safety Regulations for Road Vehicles (Ministry of Transportation Ordinance No. 67 of 1951)].

A.5 Tyre conditioning

Tyres shall be conditioned as recommended by the vehicle manufacturer, have accumulated a minimum of 100 km (62 miles) and have at least 50 % of the original usable tread depth remaining.

A.6 Dynamometer inertia setting

The equivalent inertia mass set for the chassis dynamometer shall be the standard value of equivalent inertia mass corresponding to the vehicle test mass as specified in Table A.3.

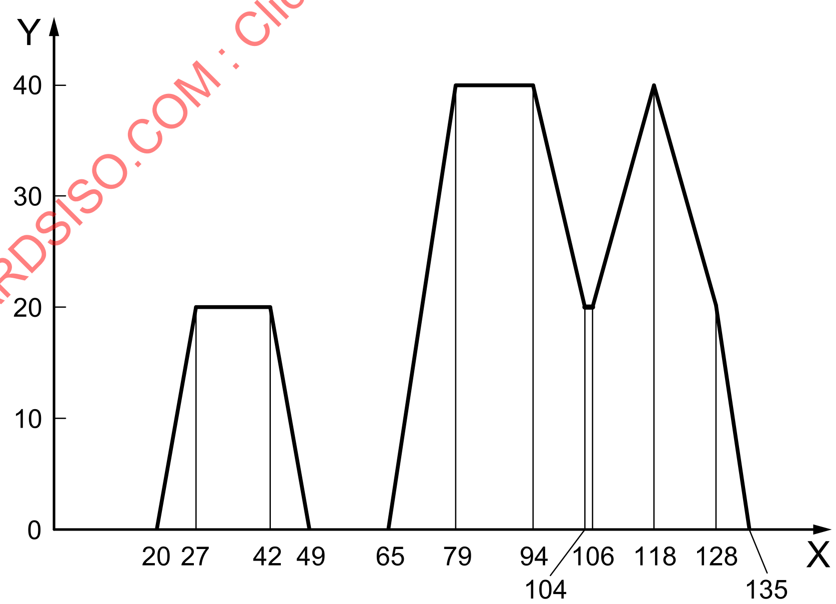
However, if the specified equivalent inertia mass is not available on the chassis dynamometer being used, the equivalent inertia mass within + 10 % of the specified standard value may be used.

Table A.1 — Operation conditions, vehicle speed, acceleration/deceleration of 10-mode operation

Mode no.	Operation conditions	Vehicle speed km/h	Duration of operation time s	Cumulative time s	Standard gear positions [a] 3-speed transmission	 (3+OD[b])-speed transmission	 4-speed transmission	 5-speed transmission	Acceleration or deceleration (m/s^2)
1	Idling		20	20	—	—	—	—	—
2	Acceleration	0–20	7	27	(0–20) Low	(0–20) Low	(0–15) Low (15–20) 2nd	(0–15) Low (15–20) 2nd	0,78
3	Constant speed	20	15	42	2nd	2nd	2nd	2nd	—
4	Deceleration	20–0	7	49	2nd	2nd	2nd	2nd	0,78
5	Idling		16	65	—	—	—	—	—
6	Acceleration	0–40	14	79	(0–20) Low (20–40) 2nd	(0–20) Low (20–40) 2nd	(0–15) Low (15–30) 2nd (30–40) 3rd	(0–15) Low (15–30) 2nd (30–40) 3rd	0,78
7	Constant speed	40	15	94	Top	3rd	Top	4th	—
8	Deceleration	40–20	10	104	Top	3rd	Top	4th	0,59
9	Constant speed	20	2	106	Top–2nd	3rd–2nd	Top–3rd	4th–3rd	—
10	Acceleration	20–40	12	118	2nd	2nd	3rd	3rd	0,49
11	Deceleration	40–20	10	128	Top	3rd	Top	4th	0,59
		20–0	7	135	Top	3rd	Top	4th	0,78

[a] Figures in brackets () represent vehicle speeds for the respective gear positions.

[b] Overdrive.



Key

X time, s

Y velocity, km/h

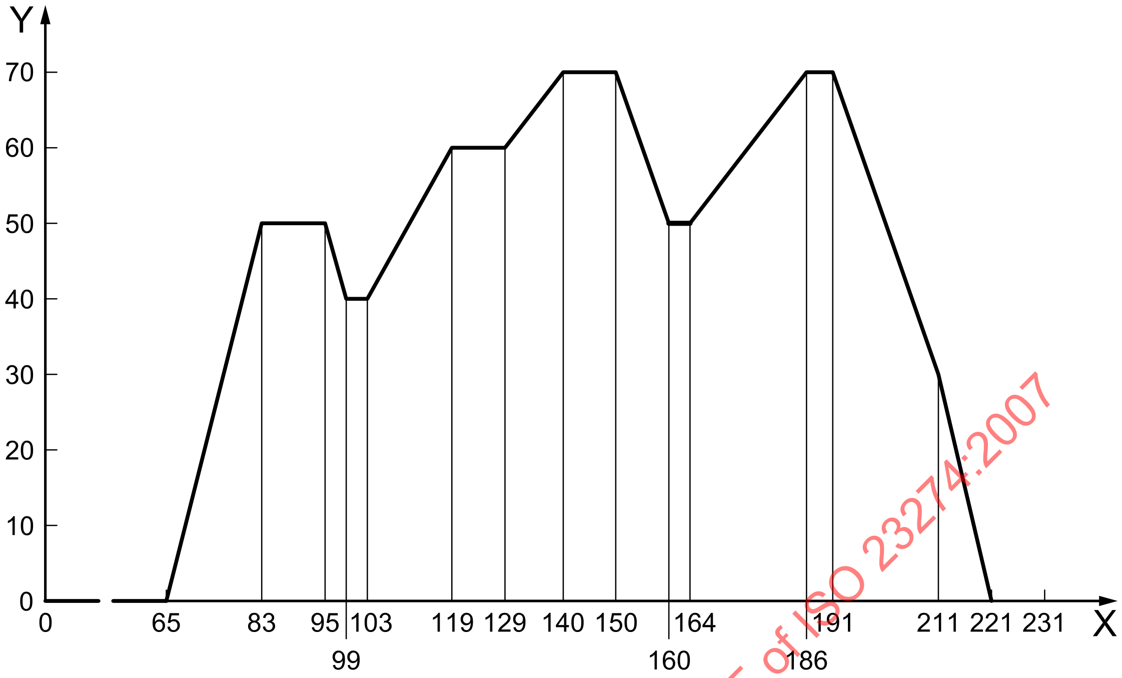
Figure A.1 — 10-mode operation, vehicle speed versus time

Table A.2 — Operation conditions, vehicle speed, acceleration/deceleration of 15-mode operation

Mode no.	Operation conditions	Vehicle speed km/h	Duration of operation time s	Cumulative time s	Standard gear positions [a] 3-speed transmission	(3+OD[b])-speed transmission	4-speed transmission	5-speed transmission	6-speed transmission	Acceleration or deceleration m/s²
1	Idling		65	65	—		—	—	—	—
2	Acceleration	0–50	18	83	(0–20) Low (20–40) 2nd (40–50) Top	(0–20) Low (20–40) 2nd (40–50) 3rd	(0–15) Low (15–35) 2nd (35–50) 3rd	(0–15) Low (15–35) 2nd (35–50) 3rd	(0–15) Low (15–35) 2nd (35–50) 3rd	0,78
3	Constant speed	50	12	95	Top	3rd	Top	4th	4th	—
4	Deceleration	50–40	4	99	Top	3rd	Top	4th	4th	0,69
5	Constant speed	40	4	103	Top	3rd	3rd	3rd	3rd	—
6	Acceleration	40–60	16	119	Top	3rd	3rd	3rd	(40–50)3rd (50–60)4th	0,39
7	Constant speed	60	10	129	Top	3rd	Top	4th	5th	—
8	Acceleration	60–70	11	140	Top	3rd	Top	4th	5th	0,29
9	Constant speed	70	10	150	Top	OD	Top	Top	Top	—
10	Deceleration	70–50	10	160	Top	OD	Top	Top	Top	0,59
11	Constant speed	50	4	164	Top	3rd	Top	4th	5th	—
12	Acceleration	50–70	22	186	Top	3rd	Top	4th	5th	0,29
13	Constant speed	70	5	191	Top	OD	Top	Top	Top	—
14	Deceleration	70–30	20	211	Top	OD	Top	Top	Top	0,59
		30–0	10	221	—	—	—	—	—	0,88
15	Idling		10	231	—	—	—	—	—	—

[a] Figures in brackets () represent vehicle speeds for the respective gear positions.

[b] Overdrive.



Key

X time, s

Y velocity, km/h

Figure A.2 — 15-mode operation, vehicle speed versus time

Table A.3 — Standard value of equivalent inertia mass versus test vehicle mass

Test vehicle mass kg	**Standard value of equivalent inertia mass** kg
to 562	500
563 to 687	625
688 to 812	750
813 to 937	875
938 to 1 125	1 000
1 126 to 1375	1 250
1 376 to 1 625	1 500
1 626 to 1 875	1 750
1 876 to 2 125	2 000
2 126 to 2 375	2 250
2 376 to 2 625	2 500
2 626 to 2 875	2 750
2 876 to 3 250	3 000
Continues in increments of 500 kg	Continues in increments of 500 kg

A.7 Test procedure

A.7.1 Preconditioning the vehicle for PCT-HEV

The test vehicle shall be placed on the chassis dynamometer and warmed up for about 20 min continuously with a constant speed of 60 ± 2 km/h. The vehicle shall then further be warmed up with 15-mode operation, shown in Table A.2.

A.7.2 Operating cycle

After the preconditioning, the operating cycle shall start with the idling operation for 24 s, then the 10-mode operation, shown in Table A.1, shall be repeated three times consecutively, and the 15 mode operation, shown in Table A.2, shall be performed once.

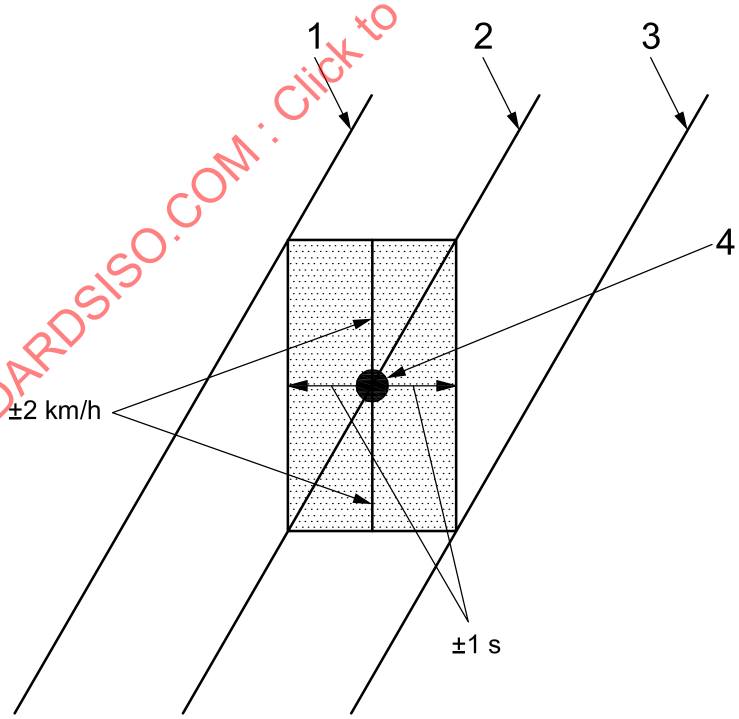
Sampling the exhaust gases shall begin before or at the initiation of the idling operation for 24 s, and end on conclusion of the final idling period in the 15-mode operation.

A.7.3 Tolerance of vehicle speed and time

With regard to the tolerable ranges of the vehicle speed and time, the test vehicle shall be operated within a range of ± 2 km/h of the specified speed and within a range of ± 1 s of the specified time, throughout all the operations specified in Tables A.1 and A.2. The ranges of tolerable are shown in the area marked in Figure A.3.

If the time of the testing deviates from the tolerance, but the deviation time is less than 1 s at the time of gear shift and transition of operation mode, the test result is acceptable.

For those motor vehicles that cannot reach the acceleration specified in Tables A.1 and A.2 with full opening of the throttle valve, the aforesaid requirement cannot apply and the acceleration value obtained from fully-opened throttle valve shall be used.



Key
1 upper tolerance line
2 reference mode
3 lower tolerance line
4 reference point

Figure A.3 — Tolerance of vehicle speed and time in 10-15 driving mode

A.8 Calculation

A.8.1 Exhaust emissions

A.8.1.1 Sampling

The entire exhaust gas emitted from the tail pipe of the test vehicle shall be brought into the CVS system and the necessary amount of emissions shall be sampled in a bag for the analysis (approximately 50 l to 100 l).

Moreover, for vehicles with a diesel engine, the exhaust gas for HC analysis shall be sampled at the place where the exhaust gas and the dilution air are mixed sufficiently and uniformly. For the CVS system with a heat exchanger, the gas sample shall be collected from the upstream side of the heat exchanger.

A.8.1.2 Analysing

The sampled gas shall be examined using the analyzers specified in Table A.4 for the respective exhaust emission components specified in the same table. Each emission mass shall be calculated using the formulas given in A.8.1.3.

Table A.4 — Analyser of exhaust emission components

Exhaust emission components	Analyzer
CO, CO_2	Nondispersive infrared analyzer (NDIR)
HC (gasoline engine vehicle)	Hydrogen flame ionization detector (FID)
HC (diesel engine vehicle)	Heating type hydrogen flame ionization detector (HFID)
NO_X	Chemiluminescence detector (CLD)

A.8.1.3 Calculation method of emission mass of each component

A.8.1.3.1 General

The CO emission mass, m_{CO}, in g/km, is calculated as follows:

$$m_{CO} = V_{mix} \times \rho_{CO} \times k_{CO} \times 10^{-6} \quad \text{(A.1)}$$

where

V_{mix} is the diluted exhaust gas volume per km running under standard conditions, in l/km;

ρ_{CO} is the density of the emission, in g/l;

k_{CO} is the concentration of the emission, in ppm.

The HC emission mass, m_{HC}, in g/km, is calculated as follows:

$$m_{HC} = V_{mix} \times \rho_{HC} \times k_{HC} \times 10^{-6} \quad \text{(A.2)}$$

where

ρ_{HC} is the density of the emission, in g/l;

k_{HC} is the concentration of the emission, in ppm.

The NO_X emission mass, m_{NOX}, in g/km, is calculated as follows:

$$m_{NOX} = V_{mix} \times \rho_{NOX} \times k_{NOX} \times K_h \times 10^{-6} \quad (A.3)$$

where

ρ_{NOX} is the density of the emission, in g/l;

k_{NOX} is the concentration of the emission, in ppm;

K_h is the humidity correction coefficient.

The CO_2 emission mass, m_{CO2}, in g/km, is calculated as follows:

$$m_{CO2} = V_{mix} \times \rho_{CO2} \times k_{CO2} \times 10^{-2} \quad (A.4)$$

where

ρ_{CO2} is the density of the emission, in g/l;

k_{CO2} is the concentration of the emission, in ppm.

A.8.1.3.2 CO density, ρ_{CO}

The CO density, ρ_{CO}, is the CO mass, in g/l, at the standard condition, 1,17 g/l.

A.8.1.3.3 CO concentration, k_{CO}

The CO concentration, k_{CO}, in ppm, corresponds to the CO concentration of diluted exhaust gas minus the CO concentration in dilution air, calculated as follows:

$$k_{CO} = k_{CO,e} - k_{CO,d}\left(1 - \frac{1}{D_f}\right) \quad (A.5)$$

where

$k_{CO,e}$ is the CO concentration of diluted exhaust gas, in ppm;

$k_{CO,d}$ is the CO concentration in dilution air, in ppm;

D_f is the dilution rate (recommended to be W 8 by water condensation in CVS system, etc.)

NOTE D_f is calculated using the formulae given in A.8.1.3.9.

A.8.1.3.4 HC density, ρ_{HC}

The HC density, ρ_{HC}; is the density of HC in exhaust sample gas.

This refers to HC mass, in g/l, under standard conditions, as calculated below:

$$\rho_{HC} = \frac{1{,}008 \times R_{HC,ex} + 12{,}01}{22{,}4} \times \frac{273}{293} \quad (A.6)$$

where

$R_{HC,ex}$ is the carbon to hydrogen atom ratio of HC in exhaust gas, as follows:

— gasoline: 1,85;

— diesel: 1,90.

A.8.1.3.5 HC concentration, k_{HC}

The HC concentration, k_{HC}, in ppm, corresponds to the HC concentration of diluted exhaust gas minus the HC concentration in dilution air, expressed by equivalent carbon concentration, in ppmC, as calculated below. It corresponds to three times of propane gas.

$$k_{HC} = k_{HC,e} - k_{HC,d}\left(1 - \frac{1}{D_f}\right) \quad (A.7)$$

where

$k_{HC,e}$ is the HC concentration of diluted exhaust gas, in ppmC;

$k_{HC,d}$ is the HC concentration in dilution air, in ppmC.

In the case of gasoline engine vehicles, the diluted exhaust gas in the bag shall be calculated using an FID analyzer. In the case of diesel engine vehicles, the diluted exhaust gas taken from an exclusive sample line shall be calculated using an HFID analyzer and the following formula:

$$k_{HC,e} = \frac{\int_0^{t_e} C_{HC,dt}}{t_e - 0} \quad (A.8)$$

where

$\int_0^{t_e} C_{HC,dt}$ is the cumulative value of the HFID analyzer record during the test (t_e –0), in ppmC.

A.8.1.3.6 NO_X density, ρ_{NOX}

The NO_X density, ρ_{NOX}, is the NO_X mass in g/l at the standard condition, 1,91 g/l.

A.8.1.3.7 NO_X concentration, k_{NOX}

The NO_X concentration, k_{NOX}, in ppm, corresponds to the NO_X concentration of diluted exhaust gas minus the NO_X concentration in dilution air, calculated as follows:

$$k_{NOX} = k_{NOX,e} - k_{NOX,d}\left(1 - \frac{1}{D_f}\right) \quad (A.9)$$

where

$k_{NOX,e}$ is the NO_X concentration of diluted exhaust gas, in ppm;

$k_{NOX,d}$ is the NO_X concentration in dilution air, in ppm;

D_f is the dilution rate (recommended to be $\geqslant$ 8 by water condensation in CVS system, etc.)

NOTE D_f is calculated using the formulae given in A.8.1.3.9.

A.8.1.3.8 CO_2 density, ρ_{CO2}

The CO_2 density, ρ_{CO2}, is the CO_2 mass in g/l at the standard condition, 1,83 g/l.

A.8.1.3.9 CO_2 concentration, k_{CO2}

The CO_2 concentration, k_{CO2}, in %, corresponds to the CO_2 concentration percentage of diluted exhaust gas minus the CO_2 concentration percentage in dilution air, calculated as follows:

$$k_{CO2} = k_{CO2,e} - k_{CO2,d}\left(1 - \frac{1}{D_f}\right) \quad \text{(A.10)}$$

where

$k_{CO2,e}$ is the percentage of CO_2 concentration of diluted exhaust gas, in %;

$k_{CO2,d}$ is the percentage of CO_2 concentration of dilution air, in %;

D_f is the dilution rate (recommended to be W 8 by water condensation in CVS system, etc.), calculated as follows:

— in the case of gasoline engine vehicles:

$$D_f = \frac{13{,}4}{k_{CO2,e} + (k_{HC,e} + k_{CO,e}) \times 10^{-4}} \quad \text{(A.11)}$$

— in the case of diesel engine vehicles:

$$D_f = \frac{13{,}3}{k_{CO2,e} + (k_{HC,e} + k_{CO,e}) \times 10^{-4}} \quad \text{(A.12)}$$

A.8.1.3.10 Diluted exhaust gas volume, V_{mix}

V_{mix} is the diluted exhaust gas volume per km running under standard conditions, in l/km, calculated using either method a) or method b) below.

a) In the case of positive displacement pump (PDP) type CVS systems:

$$V_{mix} = K_1 \times V_e \times N \times \frac{P_P}{T_P} \times \frac{1}{L} \quad \text{(A.13)}$$

$$K_1 = \frac{293}{101{,}3} = 2{,}892 \quad \text{(A.14)}$$

where

K_1 corresponds to the atmospheric absolute temperature, in degrees Kelvin (K), divided by the atmospheric pressure under standard conditions, in K/kPa;

V_e is the total volume, in l, of diluted exhaust gas pumped by the positive displacement pump per revolution (l/revolution); this value varies according to the pressure difference before and after the positive displacement pump;

N is the total number of revolutions of the positive displacement pump during the diluted exhaust gas sampling;

P_P is the absolute pressure, in kPa, of diluted exhaust gas at the positive displacement pump inlet; the amount is derived as atmospheric pressure minus pressure depression of mixture gas entering the positive displacement pump;

T_P is the average temperature, in degrees Kelvin (K), of diluted exhaust gas at the positive displacement pump inlet;

L is the running distance, in km; in the case of 10 to 15 mode operation, L = 4,165 km.

b) In the case of critical flow venturi (CFV) type CVS systems:

$$V_{mix} = V_S \times \frac{1}{L} \tag{A.15}$$

where

V_S is the diluted exhaust gas volume, in litres per test, under standard conditions, calculated as follows:

$$V_S = K_2 \int_0^{t_e} \frac{P_V(t)}{\sqrt{T_V(t)}} dt \tag{A.16}$$

where

K_2 is the venturi calibration coefficient, calculated as follows:

$$K_2 = Q_{cal} \times \frac{\sqrt{T_0}}{P_0} \tag{A.17}$$

where

Q_{cal} is the gas flow, in l/s, under standard conditions (a value that is converted from measured flow using a laminar flow meter etc.), calculated as follows:

$$Q_{cal} = K_1 \times Q_c \frac{P_c}{T_c} \tag{A.18}$$

$$K_1 = \frac{293}{101,3} = 2,892 \tag{A.19}$$

where

K_1 corresponds to the atmospheric temperature, in K/kPa, under standard conditions;

Q_c is the measured gas flow, in l/s;

T_c is the measured atmospheric temperature, in degrees Kelvin (K);

P_c is the measured atmospheric pressure, in kPa;

T_0 is the temperature at the venturi inlet, in degrees Kelvin (K);

P_0 is the pressure at the venturi inlet, in kPa;

t_e is the cumulative time per test, in s (in principle, t_e is actual cumulative time; however, if the time is required, that time is t_e, e.g. in the case of 10 to 15 mode operation, t_e = 660 s);

$P_V(t)$ is the pressure, in kPa, of diluted exhaust gas at the venturi inlet;

$T_V(t)$ is the temperature, in degrees Kelvin (K), of diluted exhaust gas at the venturi inlet;

t is the time, in s;

L is the running distance, in km; in the case of 10 to 15 mode operation, L = 4,165 km.

A.8.2 Fuel consumption, F_e

Fuel consumption, F_e, in km/l, shall be calculated using the carbon balance method by means of the formula below, using the mass of exhaust gas derived in D.2.1.4.2.

In the case of gasoline engine vehicles:

$$F_e = \frac{649}{0,429 \times m_{CO} + 0,866 \times m_{HC} + 0,273 \times m_{CO2}} \quad \text{(A.20)}$$

and in the case of diesel engine vehicles:

$$F_e = \frac{718}{0,429 \times m_{CO} + 0,862 \times m_{HC} + 0,273 \times m_{CO2}} \quad \text{(A.21)}$$

where

m_{CO} is the CO emission mass, in g/km;

m_{HC} is the HC emission mass, in g/km;

m_{CO2} is the CO_2 emission mass, in g/km.

Annex B
(informative)

Test procedure in Europe

B.1 General principles

B.1.1 General comments on regional information

This annex contains regional information, which supplements the provisions of this International Standard.

B.1.2 General considerations

The test procedure specified in this annex is based on UNECE Regulation No. 101, as amended to be applied to hybrid electric vehicles, and on UNECE Regulation No. 83. In UNECE Regulation No. 101, Annex 8, Clause 5, HEV, non-externally chargeable vehicles with HEV mode only are dealt with, but the measurements shall be done as for ICE vehicles, as specified in UNECE Regulation No. 101, Annex 6, with reference to UNECE Regulation No. 83, Annex 4.[1)]

The measurements of the exhaust emissions (CO, NO_X, HC particulates) and of CO_2 emission and fuel consumption are performed by applying the Type I test in UNECE Regulation No. 83. According to the energy change of the RESS during the test, the values measured are corrected using a correction factor as provided by the vehicle manufacturer.

The description given in the following clauses contain only the essentials to understand the procedure. For further details, see the relevant clauses of the two UNECE Regulations, to which reference is made in the text.

B.2 Rationale

Based on the legal requirements in Europe, this annex specifies the measurement procedures for the determination of the exhaust and the carbon dioxide emission and the fuel consumption of HEV non-externally chargeable and with HEV mode only of categories M1 and N1 with a maximum permissible total mass of 3 500 kg (in accordance with ISO 1176). As fuels for the ICE only, gasoline and diesel fuel are considered.

B.3 Test equipment

B.3.1 Chassis

Features, accuracy, load and inertia setting, calibration and other steps to prepare the chassis dynamometer to be used are specified in UNECE Regulation No. 83, Annex 4, 4.1, 5.1 and 5.2, and in UNECE Regulation

1) The following documents of both Regulations have been considered in this annex:

— UNECE Regulation No. 101: Trans/WP.29/GRPE/2004/2, 30 October 2003 (as amended not yet in force)

— UNECE Regulation No. 83: E/ECE/324 Rev.1/Add.82/Rev.2 E/ECE/Trans/505, 30 October 2001(in force)

Upon further amendments of UNECE Regulation No. 101 and UNECE Regulation No. 83, this International Standard, especially this annex, will need to be reviewed.

No. 83, Annex 4, Appendixes 2 and 3. The adjustment of the inertia simulators to the vehicle's translatory inertias shall be in accordance with Table B.1 (as specified in UNECE Regulation No. 83, Annex 4, 5.1).

Table B.1 — Equivalent inertia of dynamometer related to the reference mass of the vehicle

Reference mass of the vehicle m_{ref} kg	Equivalent inertia I kg
$m_{ref} \leqslant 480$	455
$480 < m_{ref} \leqslant 540$	510
$540 < m_{ref} \leqslant 595$	570
$595 < m_{ref} \leqslant 650$	625
$650 < m_{ref} \leqslant 710$	680
$710 < m_{ref} \leqslant 765$	740
$765 < m_{ref} \leqslant 850$	800
$850 < m_{ref} \leqslant 965$	910
$965 < m_{ref} \leqslant 1\,080$	1 020
$1\,080 < m_{ref} \leqslant 1\,190$	1 130
$1\,190 < m_{ref} \leqslant 1\,305$	1 250
$1\,305 < m_{ref} \leqslant 1\,420$	1 360
$1\,420 < m_{ref} \leqslant 1\,530$	1 470
$1\,530 < m_{ref} \leqslant 1\,640$	1 590
$1\,640 < m_{ref} \leqslant 1\,760$	1 700
$1\,760 < m_{ref} \leqslant 1\,870$	1 810
$1\,870 < m_{ref} \leqslant 1\,980$	1 930
$1\,980 < m_{ref} \leqslant 2\,100$	2 040
$2\,100 < m_{ref} \leqslant 2\,210$	2 150
$2\,210 < m_{ref} \leqslant 2\,380$	2 270
$2\,380 < m_{ref} \leqslant 2\,610$	2 270
$2\,610 < m_{ref}$	2 270

B.3.2 Exhaust gas sampling system

The system that shall be used is the constant volume sampler (CVS) system. Details of the system, as well as for calibration and accuracy, are given in UNECE Regulation No. 83, Annex 4, 4.2 and 4.4, and in UNECE Regulation No. 83, Annex 4, Appendix 5.

B.3.3 Analytical equipment

Emitted gases shall be analysed with the following instruments:

— non dispersive infra-red (NDIR) absorption type analysers for CO and CO_2 determination;

— for HC determination flame ionisation (FID) type analysers for spark ignition engines and heated flame ionisation (HFID) type analysers for compression ignition engines;

— chemical luminescent (CLA) or non dispersive ultraviolet resonance absorption (NDUVR) analysers for NO_X determination.

Particulates shall be gravimetrically determined from the particulates collected with two series mounted filters.

Details on applying, calibration and accuracy requirements are specified in UNECE Regulation No. 83, Annex 4, 4.3 and 4.5 (for gases used for calibration), and in UNECE Regulation No. 83, Annex 4, Appendix 6.

B.4 Test vehicle

B.4.1 General

The test vehicle shall be in running order, as determined by the manufacturer, with all the equipment, as provided as standard.

B.4.2 Test mass

The mass of the vehicle under test (referred to as "reference mass" in UNECE Regulation No. 83, 2.2) shall be the "unloaded mass" plus a uniform figure of 100 kg. The "unloaded mass" (see UNECE Regulation No. 83, 2.2.1) is the mass of the vehicle in running order, without load and persons, but with the fuel tank 90 % full.

B.4.3 Tyres

The tests shall be performed with all tyres in respect to their width provided as standard by the vehicle manufacturer. Alternatively, the prescription of UNECE Regulation No. 83, Annex 4, Appendix 3, 4.1.2 may be applied, i.e. only the widest of the standard widths or the widest minus one (in the case of more than three standard widths) shall be chosen.

The tyre pressure shall be in accordance with the vehicle manufacturer's specification, but may be increased by up to 50 % when the test is done on a two roller dynamometer (see UNECE Regulation No. 83, Annex 4, 5.3.2)

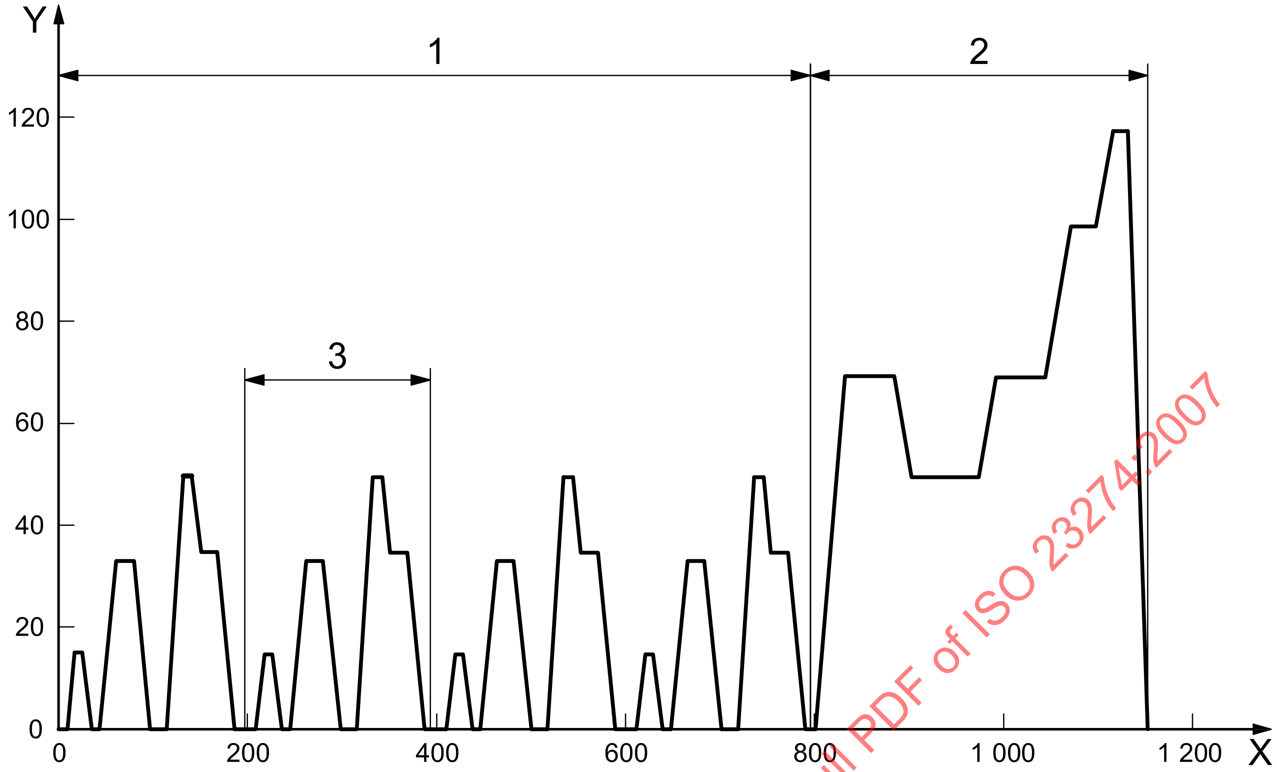
B.4.4 Test fuels

Details on the test fuels (called "reference fuels" in UNECE Regulation No. 83) are given in UNECE Regulation No. 83, Annexes 10 and 10a.

B.4.5 Test cycle

The test cycle specified for the Type I test (verifying exhaust emissions, see also B.5.2) is described in detail in UNECE Regulation No. 83, Annex 4, Appendix 1, including allowable tolerances.

The test cycle is made up of one Part One (urban) cycle consisting of four elementary urban cycles, and one Part Two (extra urban) cycle, as roughly illustrated in Figure B.1 and described in Table B.2.



Key

X time, s

Y velocity, km/h

1 Part One (urban) cycle

2 Part Two (extra urban) cycle

3 elementary urban cycle

Figure B.1 — Test cycle

Table B.2 — General information on test cycle

Characteristic	Urban cycle	Extra urban cycle
Average speed	19 km/h	62.6 km/h
Max. speed	50 km/h	120 km/h
Effective running time	4 times 195 s = 780 s (13 min)	400 s (6 min, 40 s)
Theoretical distance	4 times 1,013 km = 4,052 km	6,955 km

B.5 Test procedure

B.5.1 Preconditioning of vehicle

Besides the vehicle stabilization over at least 3 000 km (see 4.1.3.1), UNECE Regulation No. 101, Annex 8, 5.2, requires two consecutive full test cycles (see B.4) as preconditioning. At the manufacturer's request, one Part One and two Part Two cycles may be applied for positive ignition engines.

NOTE In UNECE Regulation No. 83, Annex 4, 5.3.1, three consecutive extra urban cycles are specified for the particulate determination of compression ignition engines.

B.5.2 Conditioning of the vehicle

After preconditioning in accordance with B.5.1, the vehicles shall be kept in a room with a relative constant temperature between 20 °C and 30 °C for at least 6 h, until the engine oil and coolant temperatures are within ± 2 °C of the room temperature. (For details, see UNECE Regulation No. 83, Annex 4, 5.3.)

B.5.3 Performance of the test

B.5.3.1 General

One complete test cycle shall be run in accordance with B.4.5, with the test equipment as in B.3 and the test vehicle as in B.4, after the preconditioning and conditioning as in B.5.1 and B.5.2, and the requirements below shall be met during the test. General descriptions of the test, including the number of tests, are given in UNECE Regulation No. 83, 5.3.

B.5.3.2 Special conditions

The temperature shall be between 20 °C and 30 °C and the absolute humidity between 5,5 g H_2O/kg and 12,2 g H_2O/kg dry air. (For details, see UNECE Regulation No. 83, Annex 4, 6.1.1.)

For details on air blown over the vehicle under test, see UNECE Regulation No. 83, Annex 4, 6.1.3.

B.5.3.3 Performing the different steps of the test cycle

The test shall be performed in accordance with the prescriptions of the vehicle manufacturer, starting with the activation of the propulsion system and followed by the procedure to meet the allowed tolerances of the test cycle.

NOTE The detailed prescriptions for the Type I test in UNECE Regulation No. 83, Annex 4, might not be applicable in many cases to HEV non-externally chargeable and with HEV mode only, e.g. if the vehicle starts driving only using the electric propulsion motor and switches to the ICE at a certain speed.

B.5.3.4 Sampling and analysis

As for ICE vehicles, the CO_2 emission and the fuel consumption shall be determined separately for the urban and the extra urban cycles (see UNECE Regulation No. 101, Annex 5, 5.1.1). Therefore, sampling and analysis shall be performed separately, although this is not required for the determination of the exhaust emissions (CO, HC, NO_X and particulates), in accordance with UNECE Regulation No. 83.

Details on sampling and analysis are given in UNECE Regulation No. 83, Annex 4, 7.1 and 7.2.

B.6 Calculation of the exhaust emission and fuel consumption

B.6.1 Exhaust gas, CO_2 and particulate emission

The mass and volume calculation of the emitted pollutants and their correction to standard conditions (273,2 K and 101,33 kPa) and the determination of the no-humidity-correction-factor for NO_X shall be performed in accordance with UNECE Regulation No. 83, Annex 4, Clause 8, and UNECE Regulation No. 83, Annex 4, Appendix 8.

The results shall be expressed in g/km

B.6.2 Fuel consumption

The calculation of the fuel consumption shall be done as specified in UNECE Regulation No. 101, Annex 6, 1.4. If the fuels used differ from the reference fuels to which the formulae refer, correction factors may be applied (see also UNECE Regulation No. 101, Annex 6, 1.4).

The result shall be expressed in l/100 km.

B.6.3 Correction procedure in relation to the energy change in the RESS during the test

If the energy content of the RESS during the test has been changed (due to participating in the propulsion of the vehicle, or to being charged during regenerative braking or by energy from the ICE), a correction of the results obtained in B.6.1 (in relation to CO_2 emission) and B.6.2 is necessary.

However, in accordance with UNECE Regulation No. 101, Annex 8, 5.3.2, a correction is unnecessary, if

— it can be proved that there is no relation between the energy change of the RESS and the consumption, or

— the energy content of the RESS has increased during the test, or

— a decrease of the energy content of the RESS is smaller than 1 % of the total energy consumption during the test (over one test cycle).

UNECE Regulation No. 101, Annex 8, Appendix 2, explains how the energy change can be determined.

The correction shall be done using correction factors (for CO_2 emission and for fuel consumption) provided by the vehicle manufacturer.

For the determination of the correction factors (for the urban and extra urban test cycle separately) and the correction procedures, 5.3.3 provides the necessary prescriptions.

Annex C
(informative)

Test procedure in North America

C.1 General principles

C.1.1 General comments on regional information

This annex contains regional information, which supplements the provisions of this International Standard.

C.1.2 General considerations

This annex describes the test procedure recommended for use in the United States and other countries that embrace the use of SAE (Society of Automotive Engineers) methods, for measuring exhaust emissions and fuel economy of hybrid-electric vehicles. Specifically, SAE J1711:1999, is the governing document, and citations throughout this annex refer to this issue.[2)]

C.2 Rationale

This annex specifies the uniform chassis dynamometer test procedures for hybrid-electric vehicles (HEV) that are designed to be driven on public roads. Instructions are given for measuring and calculating the exhaust emissions and fuel economy of HEV driven on the urban dynamometer driving schedule (UDDS) and the highway fuel economy driving schedule (HFEDS), as well as exhaust emissions determined from the US06 driving schedule (US06) and the SC03 driving schedule (SC03). Other methods may be used provided other corresponding factors are appropriately modified. Selection of the emission constituents to be measured is dependent upon the objectives of the tester. This annex deals only with HEV that use gasoline or diesel as the consumable fuel, and which have a rechargeable energy storage system (RESS) consisting of batteries that can be recharged only by an on-vehicle device, whereas SAE J1711 covers a broader scope of HEV types.

C.3 Test general information

C.3.1 Driving schedules

The four driving schedules, two for determining exhaust emissions and fuel economy, and two for determining only exhaust emissions, are generally as defined in the Code of Federal Regulations, specifically CFR Title 40. SAE J1711:1999, 3.5, delineates specific references to CFR Title 40 for these schedules and related speed tolerances.

2) SAE J1711 was developed by a task force established by the Light Duty Vehicle Performance and Economy Measurement Standards Committee of SAE. The task force included experts from vehicle manufacturers, national laboratories, and various interested parties. Representatives from the US Environmental Protection Agency and the California Air Resources Board participated informally. The document was released as a Recommended Practice to recognize that it is an early attempt to standardize HEV testing and, as such, as HEV technology and associated testing technology evolve, significant refinements to the document may occur.

C.3.2 Battery state of charge

When the partial-charge test method is used (see C.4), SAE J1711:1999, 3.7, specifies that the change in the RESS stored electrical energy over the test cycle be limited to ± 1 % of the total fuel energy consumed over the same cycle, as expressed by the equation presented below.

$$\frac{\Delta E_e}{E_f} \leqslant 1\% \quad \text{(C.1)}$$

where

ΔE_e is the change in the RESS stored electrical energy

E_f is the total fuel energy

For the case of an HEV equipped with a battery RESS, the following general equations are used for electrical and fuel energy respectively, when calculating the maximum and minimum allowed final battery state of charge (SOC) using the detailed equations found in SAE J1711:1999, 3.7.1.

$$\Delta E_e = \left(A_{h,final} - A_{h,initial}\right) \times V_{system} \quad \text{(C.2)}$$

$$E_f = j_{NHV} \times m_{fuel} \quad \text{(C.3)}$$

where

$A_{h,final}$ is the stored battery ampere-hours for the stated condition at the end;

$A_{h,initial}$ is the stored battery ampere-hours for the stated condition at the start;

V_{system} is the battery d.c. nominal system voltage;

j_{NHV} is the net heating value (per consumable fuel analysis), in J/kg;

m_{fuel} is the total mass of fuel consumed over test phase, in kg.

C.4 Test requirements

C.4.1 Vehicle condition

C.4.1.1 General

Prior to initiation of testing and during the testing, the overall condition and configuration of the vehicle shall be as delineated in the paragraphs that follow SAE J1711:1999, 4.1.1, all of which are represented below.

C.4.1.2 Vehicle stabilisation

Prior to testing, the test vehicle shall be stabilized as specified in CFR Title 40, Part 86.098-26, which includes vehicle mileage accumulation either to a manufacturer-determined distance or to 4 000 miles, over the durability driving schedule (defined in CFR Title 40, Part 86, Appendix IV).

C.4.1.3 Vehicle appendages

Vehicles shall be tested with normal appendages (mirrors, bumpers, etc.). Certain items (e.g. hub caps) may be removed where necessary for safety on the dynamometer.

C.4.1.4 Vehicle test weight

The vehicle shall be tested at the weight as specified in CFR Title 40, Part 86, which includes definitions for loaded vehicle weight [curb weight plus 136,1 kg (300 lb)] and adjusted loaded vehicle weight (curb weight plus one-half vehicle payload).

C.4.1.5 Tyres

The manufacturer's recommended tyres shall be used. For dynamometer testing, tyre pressures should be set at the beginning of the test at the pressure used to establish the dynamometer road-load coefficients (see C.4.3) and shall not exceed levels necessary for safe operation. Tyres shall be conditioned as recommended by the vehicle manufacturer, have accumulated a minimum of 100 km (62 miles) and have at least 50 % of the original usable tread depth remaining.

C.4.1.6 Lubricants

The vehicle lubricants normally specified by the manufacturer shall be used.

C.4.1.7 Gear shifting

During testing, the vehicle's transmission shall be operated as specified in CFR Title 40, Part 86.128, which includes the requirement to follow the in-use shifting patterns for manual-transmission vehicles.

C.4.1.8 Regenerative braking

If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all dynamometer testing. An accurate way to account for the effect of regenerative braking is to test the vehicle on a four-wheel drive electric dynamometer. If the vehicle is tested on a two-wheel dynamometer, and is equipped with systems, e.g. an antilock braking system (ABS) or a traction control system (TCS), these systems may inadvertently interpret the non-movement of the set of wheels that are off the dynamometer as a malfunctioning system. If so, modifications to these systems shall be made to achieve normal operation of the remaining vehicle systems, including the regenerative braking system.

C.4.1.9 Vehicle preparation

The vehicle shall be prepared for testing as specified in CFR Title 40, Part 86-131-00, which includes provisions for the installation of fittings for draining fuel and a throttle position sensing signal to control dynamometer dynamic inertia weight adjustments, when applicable.

C.4.2 Rechargeable energy storage system (RESS) condition

The battery 100 % state of charge condition shall be established using the vehicle manufacturer’s recommended charging procedure and equipment. The battery RESS stabilization shall follow the prescription in SAE J1711:1999, 4.1.2.1. RESS state of charge considerations are given in SAE J1711:1999, 4.1.2.2 and 4.1.2.3. RESS failure is discussed in SAE J1711:1999, 4.1.2.5. At the conclusion of the vehicle test, the energy storage capability of the RESS may be verified against the vehicle manufacturer’s rating using a current discharge method or a method supplied by the manufacturer.

C.4.3 Dynamometer condition

All factors concerning the dynamometer, specifically its capability requirements, configuration, calibration, warm-up and settings, are presented in the sub-paragraphs to SAE J1711:1999, 4.1.3, which give reference to the applicable requirements as contained in CFR Title 40, Part 86. The determination of the dynamometer load coefficients shall be as specified in SAE J2263 and SAE J2264, with provisions specified in SAE J1711 for vehicles equipped with regenerative braking systems that are actuated only by the brake pedal, as well as for vehicles equipped with regenerative braking systems that are activated at least in part when the brake pedal is not depressed.

C.4.4 Instrumentation

As presented in SAE J1711:1999, 4.2, the equipment referenced in CFR Title 40, Part 86.106 (including exhaust emissions sampling and analysis systems) is required for emissions measurements, where applicable. All instrumentation shall be NIST (National Institute of Standards and Technology) traceable. Instrument accuracy shall be as specified in CFR Title 40, Part 86, as applicable. The accuracy of instruments for coast down measurements shall be as specified in SAE J2263 and SAE J2264, as applicable.

C.5 Types of tests

As indicated in SAE J1711:1999, 4.3, there are two basic kinds of exhaust emissions and fuel economy tests detailed in that document. One kind of test begins with a partially charged RESS (a "partial-charge test", PCT), and the other kind of test begins with a fully charged RESS (a "full charge test", FCT). There are variations of these tests depending on which mode of operation is being tested and which driving schedule is being used. The PCT has a variation for HEV operating modes and another variation for conventional vehicle operating modes. The FCT has a variation for HEV operating modes and another variation for electric vehicle operating modes. The following four tests are described in greater detail in SAE J1711:1999, 4.3.1 to 4.3.4:

— partial charge test for HEV operating modes (PCT–HEV);

— full charge test for HEV operating modes (FCT–HEV);

— partial charge test for conventional vehicle operating modes (PCT–CV);

— full charge test for electric vehicle operating modes (FCT–EV).

C.6 Testing the vehicle

The exhaust emissions and fuel economy tests that are required for an HEV depend upon its classification. For the purposes of this annex, only the HEV with a battery RESS and classified as "not off-vehicle-charge capable" is considered (see test matrix in Table C.1).

Table C.1 — Test matrix for HEV "not off-vehicle-charge capable"

Driver-selected operating modes	Required test procedures
1. HEV operating modes	Perform each driving schedule procedure of the PCT-HEV (see SAE J1711:1999, 4.3.1) in each HEV operating mode.
2. CV operating modes	Perform each driving schedule procedure of the PCT-CV (see SAE J1711:1999, 4.3.3) in each CV operating mode.
3. EV operating modes	Do not perform any tests in EV operating modes.

The PCT-HEV test measures the exhaust emissions and fuel economy of the HEV over driving cycles in the HEV operating mode, whereas the PCT-CV test only records measurements for the HEV being operated in the CV operating mode.

C.7 Calculation of exhaust emission and fuel consumption

A series of exhaust emissions and fuel economy calculations is necessary to account for cold start and hot start test phases, off-vehicle-charge equivalent fuel economy (when applicable), the effect of the driver's charging habits and the usage of driver-selected operating modes. The driving schedules available for developing exhaust emissions data are:

— UDDS (urban dynamometer driving schedule), which represents vehicle city driving;

— HFEDS (highway fuel economy driving schedule), which represents vehicle highway driving;

— US06, which represents vehicles driving at high speeds and accelerations;

— SC03, which represents vehicle operation with air conditioning.

UDDS exhaust emission calculation methods (as derived from CFR Title 40, Part 86, Appendix 1) are detailed in SAE J1711:1999, 5.1.

HFEDS exhaust calculations (CFR Title 40, Part 600, Appendix 1) are detailed in SAE J1711:1999, 5.2.

US06 exhaust emissions calculations (CFR Title 40, Part 86, Appendix 1) are found in SAE J1711:1999, 5.3.

SC03 exhaust emissions (CFR Title 40, Part 86) are detailed in SAE J1711:1999, 5.4.

UDDS fuel economy calculations are in SAE J1711:1999, 5.5, and HFEDS fuel economy calculations are in SAE J1711:1999, 5.6.

The slides in SAE J1711:1999, Appendix C, provide additional information on calculations, including assumptions used and graphical representations.

Annex D
(normative)

Linear correction method using a correction coefficient

D.1 Scope

This annex describes the calculation procedure to determine the exhaust emission and fuel consumption at $\Delta E_{RESS} = 0$, using the values of exhaust emission measured in accordance with the procedure established for ICEV.

D.2 Linear regression method

D.2.1 Method for correcting the exhaust emission and fuel consumption

D.2.1.1 General

The measurement of all exhaust gas components and the fuel consumption by the carbon balance method, correction for the carbon compound (CO, HC and CO_2) of exhaust gas shall be made with the following procedure.

D.2.1.2 Data acquisition for correction coefficient

The exhaust gas test of the mode concerned shall be repeated several times to determine the exhaust emission correction coefficient defined in D.2.1.4.1. The battery charging level and charge balance should be in the normal range specified by the vehicle manufacture. However, if it can be confirmed that the battery charging level and charge balance exert no influence on the exhaust emission amount in the normal range specified by the vehicle manufacturer due to the charge balance of battery, no correction shall be made.

An example of the procedure to obtain the correction coefficient is described in Annex F.

D.2.1.3 Records

The charging level and the charge balance of the battery at the time of the exhaust gas sampling of the CVS system are measured from time to time. In the event that the battery charging level and charge balance above exceed the ranges determined by the vehicle manufacturer, re-examination shall be conducted.

D.2.1.4 Corrections

D.2.1.4.1 Exhaust emission correction coefficient, K_{Ew}

The exhaust emission correction coefficient, K_{Ew}, in g/km Ah or g/test Ah, for all exhaust emission components of CO, HC, NO_X and CO_2 for each mode and fuel consumption test shall be calculated individually, using the following formula:

$$K_{Ew} = \frac{n \times \sum C_i E_{Wi} - \sum C_i \times \sum E_{Wi}}{n \times \sum C_i^2 - (\sum C_i)^2} \qquad \text{(E.1)}$$

