3. Definition

3.3XX

Fuel cell vehicle means a vehicle which has an electric drive train powered by fuel cell system that generates electric power electro-chemically using hydrogen.

Reference

- **GTR13**

C.1

Hydrogen-fuelled fuel cell vehicles (HFCVs) have an electric drive-train powered by a fuel cell that generates electric power electrochemically using hydrogen.

3.24. "Fuel cell system" is a system containing the fuel cell stack(s), air processing system, fuel flow control system, exhaust system, thermal management system and water management system.

3.28. "Hydrogen-fuelled vehicle" indicates any motor vehicle that uses compressed gaseous or liquefied hydrogen as a fuel to propel the vehicle, including fuel cell and internal combustion engine vehicles. Hydrogen fuel for passenger vehicles is specified in ISO 14687-2 and SAE J2719.

- **GRPE/VPSD** Informal document No. **VPSD-02-04-Rev.1**

Vehicle Propulsion System Definitions version 22.05.2013

9.3. "Fuel Cell Vehicle (FCV)" means a vehicle with a powertrain containing exclusively fuel cell(s) and electric machine(s) as energy converter.

[9.4. "Fuel Cell Hybrid Electric Vehicle (FCHEV)" means a FCV with a powertrain containing one or more fuel storage system(s) and one or more REESS.]

- **ECE R101**

2.21. "Hydrogen fuel cell vehicle" means a vehicle powered by a fuel cell that converts chemical energy from hydrogen into electric energy, for propulsion of the vehicle."

コメント [g1]: We do not agree with "at least one", this is too vague. If a vehicle would be equipped with a fuel cell to power an ancillary device but would use a combustion engine to propel the vehicle this would else be classified as a FCV

コメント [g2]: Proposal by Serge Dubuc

削除: a

削除: t least one

コメント [DL3]: Proposal by Serge Dubuc

削除: at least one

削除: motor

コメント [dl4]: 04.04.13
Mr Albus; to check with WLTP GTR if this 2nd definition is needed. Most likely it is needed

削除: e

Draft of Annex 3 Reference fuels

6. Compressed hydrogen gas for fuel cell vehicle

Table A3/XX

Hydrogen (Type I, Grade D)

Characteristics	*Units*	*Limits*	
		Minimum	*Maximum*
Hydrogen fuel index [a]	% mole	99,97	
Total non-hydrogen gases	µmol/mol		300
Maximum concentration of individual contaminants			
Water (H_2O)	µmol/mol		5
Total hydrocarbons[b] (Methane basis)	µmol/mol		2
Oxygen (O_2)	µmol/mol		5
Helium (He)	µmol/mol		300
Total Nitrogen (N_2) and Argon (Ar)[b]	µmol/mol		100
Carbon dioxide (CO_2)	µmol/mol		2
Carbon monoxide (CO)	µmol/mol		0,2
Total sulfur compounds[c] (H_2S basis)	µmol/mol		0,004
Formaldehyde (HCHO)	µmol/mol		0,01
Formic acid (HCOOH)	µmol/mol		0,2
Ammonia (NH_3)	µmol/mol		0,1
Total halogenated compounds[d] (Halogenate ion basis)	µmol/mol		0,05
Maximum particulates concentration	mg/kg		1

For the constituents that are additive, such as total hydrocarbons and total sulfur compounds, the sum of the constituents are to be less than or equal to the acceptable limit.

[a] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[b] Total hydrocarbons include oxygenated organic species. Total hydrocarbons shall be measured on a carbon basis (µmolC/mol). Total hydrocarbons may exceed 2 µmol/mol due only to the presence of methane, in which case the summation of methane, nitrogen and argon shall not exceed 100 µmol/mol.

[c] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[d] Total halogenated compounds include, for example, hydrogen bromide (HBr), hydrogen chloride (HCl), chlorine (Cl_2), and organic halides (R-X).

Reference

- **Gtr No.13**

3.28. "*Hydrogen-fuelled vehicle*" indicates any motor vehicle that uses compressed gaseous or liquefied hydrogen as a fuel to propel the vehicle, including fuel cell and internal combustion engine vehicles. Hydrogen fuel for passenger vehicles is specified in ISO 14687-2 and SAE J2719.

- **ISO 14687-2 (2012)**

Table 1 — Directory of limiting characteristics

Characteristics (assay)	Type I, Type II
	Grade D
Hydrogen fuel index (minimum mole fraction)[a]	99,97 %
Total non-hydrogen gases	300 µmol/mol
Maximum concentration of individual contaminants	
Water (H_2O)	5 µmol/mol
Total hydrocarbons[b] (Methane basis)	2 µmol/mol
Oxygen (O_2)	5 µmol/mol
Helium (He)	300 µmol/mol
Total Nitrogen (N_2) and Argon (Ar)[b]	100 µmol/mol
Carbon dioxide (CO_2)	2 µmol/mol
Carbon monoxide (CO)	0,2 µmol/mol
Total sulfur compounds[c] (H_2S basis)	0,004 µmol/mol
Formaldehyde (HCHO)	0,01 µmol/mol
Formic acid (HCOOH)	0,2 µmol/mol
Ammonia (NH_3)	0,1 µmol/mol
Total halogenated compounds[d] (Halogenate ion basis)	0,05 µmol/mol
Maximum particulates concentration	1 mg/kg

For the constituents that are additive, such as total hydrocarbons and total sulfur compounds, the sum of the constituents are to be less than or equal to the acceptable limit.

[a] The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.

[b] Total hydrocarbons include oxygenated organic species. Total hydrocarbons shall be measured on a carbon basis (µmolC/mol). Total hydrocarbons may exceed 2 µmol/mol due only to the presence of methane, in which case the summation of methane, nitrogen and argon shall not exceed 100 µmol/mol.

[c] As a minimum, total sulphur compounds include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.

[d] Total halogenated compounds include, for example, hydrogen bromide (HBr), hydrogen chloride (HCl), chlorine (Cl2), and organic halides (R-X).

- WLTP Annex 3 (Phase 1a)

3.	Liquid fuels for positive ignition engines
4.	Gaseous fuels for positive ignition engines
4.1.	LPG (A and B)
	Table A3/8
4.2.	NG/biomethane
4.2.1.	"G20""High Gas" (nominal 100 % Methane)
	Table A3/9
4.2.2.	"K-Gas" (nominal 88 % Methane)
	Table A3/10
4.2.3.	"G25""Low Gas" (nominal 86 % Methane)
	Table A3/11
4.2.4.	"J-Gas" (nominal 85 % Methane)
	Table A3/12
5.	Liquid fuels for compression ignition engines

Draft of Annex 7

Calculations

1. General requirements

1.1. Calculations related specifically to hybrid and pure electric vehicles and compressed hydrogen fuel cell vehicle are described in Annex 8.

1.2. The calculations described in this annex shall be used for vehicles using combustion engines.

1.3.. The final test results shall be rounded in one step to the number of places to the right of the decimal point indicated by the applicable emission standard plus one additional significant figure. Intermediate steps in the calculations shall not be rounded.

1.4. The NO_x correction factor, KH, shall be rounded to 2 decimal places.

1.5. The dilution factor, DF, shall be rounded to 2 decimal places.

1.6. For information not related to standards, good engineering judgement shall be used.

Annex 8

Pure and hybrid electric vehicles and Compressed hydrogen fuel cell vehicle

1. General requirements

In the case of testing NOVC-HEV, ~~and~~ OVC-HEV and fuel cell vehicle(FCV), Appendix 2a or 2b to this annex replaces Appendix 2 to Annex 6.

1.1. Energy balance

The energy balance shall be the sum of the ΔE_{REESS} of all rechargeable electric energy storage systems (REESS), i.e. the sum of the RCB values multiplied by the respective nominal V_{REESS} for each REESS.

1.2. Electric energy consumption and range testing

Parameters, units and accuracy of measurements shall be as in Table A8/1.

Table A8/1

Parameters, units and accuracy of measurements

Parameter	*Units*	*Accuracy*	*Resolution*
Electrical energy [(1)]	Wh	±1 per cent	0.001 Wh[(2)]
Electrical current	A	±0.3 per cent FSD or ±1 per cent of reading [(3,4)]	0.01 A

(1) Equipment: static meter for active energy.

(2) AC watt-hour meter, Class 1 according to IEC 62053-21 or equivalent.

(3) Whichever is greater.

(4) Current integration frequency 10 Hz or more.

1.3. Emission and fuel consumption testing

Parameters, units and accuracy of measurements shall be the same as those required for conventional combustion engine-powered vehicles as found of Annex 5 (test equipment and calibrations).

1.4. Measurement units and presentation of results

The accuracy of measurement units and the presentation of the results shall follow the indications given in Table A8/2.

Table A8/2

Accuracy of measurement units and presentation of the results

Parameter	*Units*	*Communication of test result*
AER, AERcity	km	Rounded to nearest whole number
EAER	km	Rounded to nearest whole number
R_{CDA}	km	Rounded to nearest whole number
R_{CDC}	km	Rounded to nearest whole number
Distance	km	Rounded to nearest whole number; for calculation purposes: 0.1 km
Electric energy consumption	Wh/km	Rounded to nearest whole number
NEC	Wh	Rounded to first decimal place
NEC ratio	per cent	Rounded to first decimal place
E_{AC} recharge E	Wh	Rounded to nearest whole number
FC correction factor	l/100 km/(Wh/km) or kg/100km/(Wh/km) in the case of FCV	Rounded to 4 significant digits
CO_2 correction factor	g/km/(Wh/km)	Rounded to 4 significant digits
Utility factor		Rounded to 3 decimal places

1.5. Type 1 test cycles to be driven according to Table A8/3.

1.5.1. All OVC-HEVs, NOVC-HEVs ~~and~~ , PEVs and FCVs with and without driver-selectable operating modes shall be classified as Class 3 vehicles.

1.5.1.1. OVC-HEV and PEV

1.5.1.1.1. WLTC test

1.5.1.1.1.1. Class 3a vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-1}$), a high phase ($High_{3-1}$) and an extra high phase ($Extra\ High_3$).

1.5.1.1.1.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-2}$), a high phase ($High_{3-2}$) and an extra high phase ($Extra\ High_3$).

1.5.1.1.1.3. At the option of the Contracting Party, the $Extra\ High_3$ phase may be excluded.

1.5.1.1.2. WLTC city test

1.5.1.1.2.1. Class 3a vehicles shall drive a cycle consisting of a low phase (Low_3) and a medium phase ($Medium_{3-1}$)

1.5.1.1.2.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low_3) and a medium phase ($Medium_{3-2}$)

1.5.1.2. NOVC-HEV and FCV

1.5.1.2.1. WLTC test

1.5.1.2.1.1. Class 3a vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-1}$), a high phase ($High_{3-1}$) and an extra high phase (Extra $High_3$).

1.5.1.2.1.2. Class 3b vehicles shall drive a cycle consisting of a low phase (Low_3), a medium phase ($Medium_{3-2}$), a high phase ($High_{3-2}$) and an extra high phase (Extra $High_3$).

1.5.1.2.1.3. At the option of the Contracting Party, the Extra $High_3$ phase may be excluded.

Table A8/3

Test matrix

		WLTP		*WLTP city*
		Criteria Emissions, FC, CO_2, AER, EAER, R_{CDC}, R_{CDA}, E_{AC}	*Criteria Emissions, FC, CO_2*	*AERcity, E_{AC}city*
		Charge-depleting	*Charge-sustaining*	*Charge-depleting*
OVC-HEV	Class 3a	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra$High_3$)	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra$High_3$)	Low_3 + $Medium_{3-1}$
	Class 3b	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra$High_3$)	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra$High_3$)	Low_3 + $Medium_{3-2}$
NOVC-HEV	Class 3a	--	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra$High_3$)	--
	Class 3b	--	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra$High_3$)	--
PEV	Class 3a	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra$High_3$)	--	Low_3 + $Medium_{3-1}$
	Class 3b	Low_3 + $Medium_{3-2}$ + $High_{3-2}$ + (Extra$High_3$)	--	Low_3 + $Medium_{3-2}$
FCV	Class 3a	--	Low_3 + $Medium_{3-1}$ + $High_{3-1}$ + (Extra$High_3$)	--
	Class 3b	--	Low_3 + $Medium_{3-2}$	--

				WLTP	*WLTP city*
			Criteria Emissions, FC, CO_2, AER, EAER, R_{CDC}, R_{CDA}, E_{AC}	*Criteria Emissions, FC, CO_2*	*AERcity, E_{AC}city*
			Charge-depleting	*Charge-sustaining*	*Charge-depleting*
				+ $High_{3-2}$ + ($ExtraHigh_3$)	

1.6. OVC-HEVs. NOVC-HEVs ~~and~~ , PEVs and FCVs with manual transmissions shall be driven according to the manufacturer's instructions, as incorporated in the manufacturer's handbook of production vehicles and indicated by a technical gear shift instrument.

2. ~~REESS~~ Preparation of REESS and fuel cell system

2.1. REESS Preparation

For all OVC-HEVs, NOVC-HEVs, ~~and~~ PEVs and FCVs with and without driver-selectable operating modes, the following shall apply:

(a) Without prejudice to the requirements of paragraph 1.2.3.3. of Annex 6, the vehicles tested to this annex must have been driven at least 300 km with those batteries installed in the test vehicle;

(b) If the batteries are operated above the ambient temperature, the operator shall follow the procedure recommended by the car manufacturer in order to keep the temperature of the REESS in its normal operating range. The manufacturer's agent shall be in a position to demonstrate that the thermal management system of the REESS is neither disabled nor reduced.

2.2. Fuel cell system preparation

For fuel cell vehicles with and without driver-selectable operating modes, without prejudice to the requirements of paragraph 1.2.3.3. of Annex 6, the vehicles tested to this annex must have been driven at least 300 km with those fuel cell system installed in the test vehicle;

3. Test procedure

3.1. General requirements

3.1.1. For all OVC-HEVs, NOVC-HEVs, ~~and~~ PEVs and FCVs with and without driver-selectable operating modes, the following shall apply where applicable:

3.1.1.1. Vehicles shall be conditioned, soaked and tested according to the test procedures applicable to vehicles powered solely by a combustion engine described in Annex 6 to this gtr unless modified by this annex. Measurement methods of fuel consumption for FCVs are described in appendix X of this annex.

3.1.1.2. If the vehicles cannot follow the speed trace, the acceleration control shall be fully activated until the required speed trace is reached again. Power to mass calculations and classification methods shall not apply to these vehicle types.

3.1.1.3. The vehicle shall be started by the means provided for normal use to the driver.

3.1.1.4. Exhaust emission sampling and electricity measuring shall begin for each test cycle before or at the initiation of the vehicle start up procedure and end on conclusion of each test cycle.

3.1.1.5. Emissions compounds shall be sampled and analysed for each individual WLTC phase when the combustion engine starts consuming fuel.

3.1.2. Forced cooling as per paragraph 1.2.7.2. of Annex 6 shall apply only for the charge-sustaining test and for the testing of NOVC-HEVs.

3.2. OVC-HEV, with and without driver-selectable operating modes

3.2.1. Vehicles shall be tested under charge-depleting (CD) and charge-sustaining (CS) conditions according to the cycles described in paragraph 1.5.1.1.1. of this annex.

3.2.2. Vehicles may be tested according to four possible test sequences:

3.2.2.1. Option 1: charge-depleting test with a subsequent charge-sustaining test (CD + CS test).

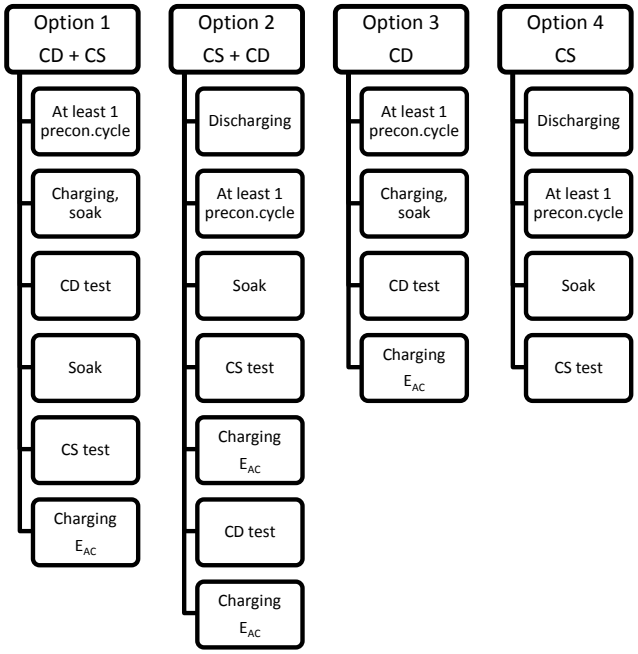
3.2.2.2. Option 2: charge-sustaining test with a subsequent charge-depleting test (CS + CD test).

3.2.2.3. Option 3: charge-depleting test with no subsequent charge-sustaining test (CD test).

3.2.2.4. Option 4: charge-sustaining test with no subsequent charge-depleting test (CS test).

Figure A8/1

Possible test sequences in case of OVC-HEV testing



3.2.3. The driver selectable operating mode switch shall be set according to the test conditions.

3.2.4. Charge-depleting (CD) test with no subsequent charge-sustaining (CS) test (option 3)

3.2.4.1. Preconditioning

The vehicle shall be prepared according to the procedures in Appendix 4, paragraph 2.2. of this annex.

3.2.4.2. Test conditions

3.2.4.2.1. The test shall be carried out with a fully charged REESS according the charging requirements as described in 2.2.5. of Appendix 4 to this annex.

3.2.4.2.2. Operation mode selection

3.2.4.2.2.1. The charge-depleting test shall be performed by using the most electric energy consuming mode that best matches the driving cycle. If the vehicle cannot follow the trace, other installed propulsion systems shall be used to allow the vehicle to best follow the cycle.

3.2.4.2.2.2. Dedicated driver-selectable modes such as "mountain mode" or "maintenance mode" which are not intended for normal daily operation but only for special limited purposes shall not be considered for charge-depleting condition testing.

3.2.4.3. Type 1 test procedure

3.2.4.3.1. The charge-depleting test procedure shall consist of a number of consecutive cycles, each followed by a maximum of 30 minute soak period until charge-sustaining operation is achieved.

3.2.4.3.2. During soaking between individual WLTCs, the key switch shall be in the "off" position, and the REESS shall not be recharged from an external electric energy source. The RCB instrumentation shall not be turned off between test cycle phases. In the case of ampere-hour meter measurement, the integration shall remain active throughout the entire test until the test is concluded.

Restarting after soak, the vehicle shall be operated in the required driver-selectable operation mode.

3.2.4.3.3. In deviation from paragraph 5.3.1. of Annex 5 and without prejudice to paragraph 5.3.1.3., analysers may be calibrated and zero checked before and after the charge-depleting test.

3.2.4.4. End of the charge-depleting test

The end of the charge-depleting test is considered to have been reached at the end of WLTC n (defined as the transition cycle) when the break-off criteria during cycle n + 1 is reached for the first time.

3.2.4.4.1. For vehicles without charge-sustaining capability on the complete WLTC, end of test is reached by an indication on a standard on-board instrument panel to stop the vehicle, or when the vehicle deviates from the prescribed driving tolerance for four seconds or more. The acceleration controller shall be deactivated. The vehicle shall be braked to a standstill within sixty seconds.

3.2.4.5. Break-off criteria

3.2.4.5.1. The break-off criteria for the charge-depleting test is reached when the relative net energy change, NEC, as shown in the equation below is less than 4 per cent.

$$\text{NEC}\ (\%) = \left(\frac{\text{RCB} \times \text{nominal REESS voltage}}{\text{cycle energy demand, test vehicle}} \times 100\right) < 4\ \%$$

where:

NEC is the net energy change, per cent;

RCB is the REESS charge balance, Ah;

nominal REESS voltage is the voltage of an electrochemical system according to DIN EN 60050-482.

3.2.4.6. REESS charging and measuring electric energy consumption

The vehicle shall be connected to the mains within 120 minutes after the conclusion of the charge-depleting Type 1 test. The energy measurement equipment, placed before the vehicle charger, shall measure the charge energy, E_{AC}, delivered from the mains, as well as its duration. Electric energy measurement can be stopped when the state of charge after the CD test is at least equal to the state of charge measured before the CD test. The state of charge can be determined by on-board or external instruments.

3.2.4.7. Each individual full WLTC within the charge-depleting test shall fulfil the applicable exhaust emission limits according to paragraph 1.1.1.2. of Annex 6.

3.2.5. CS test with no subsequent CD test (option 4)

3.2.5.1. Preconditioning

The vehicle shall be prepared according to the procedures in paragraph 2.1. of Appendix 4 to this annex.

3.2.5.2. Test conditions

3.2.5.2.1. Tests shall be carried out with the vehicle operated in charge-sustaining operation condition in which the energy stored in the REESS may fluctuate but, on average, is maintained at a charging neutral balance level while the vehicle is driven.

3.2.5.2.2. For vehicles equipped with a driver-selectable operating mode, the charge-sustaining test shall be performed in the charging balance neutral hybrid mode that best matches the target curve.

3.2.5.2.3. The profile of the state of charge of the REESS during different stages of the Type 1 test in CD and CS mode respectively is given in Appendices 1a and 1b to this annex.

3.2.5.2.4. Upon request of the manufacturer and with approval of the responsible authority, the manufacturer may set the start state of charge of the traction REESS for the charge-sustaining test.

3.2.5.3. Type 1 test procedure

3.2.5.3.1. If required by paragraph 4.2.1.3. of this annex, CO_2, emissions and fuel consumption results shall be corrected according to the RCB correction as described in Appendix 2a of this annex.

3.2.5.3.2. The charge-sustaining test shall fulfil the applicable exhaust emission limits according to paragraph 1.1.1.2. of Annex 6.

3.2.6. CD test with a subsequent CS test (option 1)

3.2.6.1. The procedures for the CD test from paragraph 3.2.4.1. up to and including paragraph 3.2.4.5. of this annex shall be followed.

3.2.6.2. Subsequently, the procedures for the CS test from paragraph 3.2.5.1. up to and including paragraph 3.2.5.3. (except paragraph 3.2.5.2.5.) in this annex shall be followed.

3.2.6.3. REESS charging and measuring electric energy consumption

The vehicle shall be connected to the mains within 120 minutes after the conclusion of the charge-sustaining Type 1 test. The energy measurement equipment, placed before the vehicle

charger, shall measure the charge energy, E, delivered from the mains, as well as its duration. Electric energy measurement may be stopped when the state of charge after the CS test is at least equal to the state of charge measured before the CD test. The state of charge shall be determined by on-board or external instruments.

3.2.7. CS test with a subsequent CD test (option 2)

3.2.7.1. The procedures for the CS test from paragraph 3.2.5.1. to paragraph 3.2.5.3. and paragraph 3.2.6.3. in this annex shall be followed.

3.2.7.2. Subsequently, the procedures for the CD test from paragraph 3.2.4.3. to paragraph 3.2.4.7. of this annex shall be followed.

3.2.8. Cycle energy demand

3.2.8.1. Cycle energy demand of the test vehicle shall be calculated according to paragraph 5 of Annex 7.

3.2.9. Electric range determination

3.2.9.1. The charge-depleting test procedure as described in paragraph 3.2.4. of this annex shall apply to electric range measurements.

3.2.9.2. All-electric range (AER, AERcity)

3.2.9.2.1. The total distance travelled over the test cycles from the beginning of the charge-depleting test to the point in time during the test when the combustion engine starts to consume fuel shall be measured.

3.2.9.2.2. At the option of the Contracting Party, the determination of AERcity may be excluded.

3.2.9.3. Equivalent all-electric range (EAER)

3.2.9.3.1. The range shall be calculated according to paragraph 4.4.1.2. below.

3.2.9.4. Charge-depleting cycle range (R_{CDC})

3.2.9.4.1. The distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criteria shall be measured. This shall include the

distance travelled during the transition cycle where the vehicle operates in both depleting and sustaining modes. If the charge-depleting test possesses a transition range, the R_{CDC} shall include those transition cycles or cycles.

3.2.9.5. Actual charge-depleting range (R_{CDA})

3.2.9.5.1. The range shall be calculated according to paragraph 4.4.1.4. below.

3.3. NOVC-HEV with and without driver-selectable operating modes

3.3.1. Vehicles shall be tested under charge-sustaining (CS) conditions according to the cycles described in paragraph 1.5.1.2.1. of this annex.

3.3.2. Vehicle and REESS Conditioning

3.3.2.1. Alternatively, at the request of the manufacturer, the level of the state of charge of the traction REESS for the charge-sustaining test may be set according to manufacturer's recommendation in order to achieve a charge balance neutral charge-sustaining test.

3.3.3. Type 1 Test

3.3.3.1. If required by paragraph 4.2.2. of this annex, CO_2 emissions and fuel consumption results shall be corrected according to the RCB correction described in Appendix 2a to this annex.

3.4. PEV, with and without driver-selectable operating mode

3.4.1. Vehicles shall be tested under charge-depleting (CD) conditions according to the cycles described in paragraph 1.5.1.1. of this annex.

3.4.2. The total distance travelled over the test cycles from the beginning of the charge-depleting test until the break-off criteria is reached shall be recorded.

3.4.3. Breaks for the driver and/or operator shall be permitted only between test cycles as described in Table A8/4.

Table A8/4

Breaks for the driver and/or test operator

Distance driven (km)	*Maximum total break time (min)*
Up to 100	10
Up to 150	20
Up to 200	30
Up to 300	60
More than 300	Shall be based on the manufacturer's recommendation

Note: During a break, the propulsion system switch shall be in the "OFF" position.

3.4.4. Testing

3.4.4.1. If the vehicle is equipped with a driver-selectable operating mode, the charge-depleting test shall be performed in the highest electric energy consumption mode that best matches the speed trace.

3.4.4.2. The measurement of all-electric range AER and electric energy consumption shall be performed during the same test.

3.4.4.3. All-electric range test

3.4.4.3.1. The test method shall include the following steps:

(a) Initial charging of the traction REESS;

(b) Driving consecutive WLTCs until the break-off criteria is reached and measuring AER;

(c) Recharging the traction REESS and measuring electric energy consumption.

3.4.4.3.1.1. The all-electric range test shall be carried out with a fully charged traction REESS according to the charging requirements as described in paragraph 3. of Appendix 4 to this annex.

3.4.4.3.1.2. WLTCs shall be driven and the all-electric range (AER) distance shall be measured.

3.4.4.3.1.3. The end of the test occurs when the break-off criteria is reached.

The break-off criteria shall have been reached when the vehicle deviates from the prescribed driving tolerance for four seconds

or more. The acceleration controller shall be deactivated. The vehicle shall be braked to a standstill within sixty seconds.

3.4.4.3.1.4. The vehicle shall be connected to the mains within 120 minutes after the conclusion of the all-electric range AER determination. The energy measurement equipment, placed before the vehicle charger, shall measure the charge energy, E_{AC}, delivered from the mains, as well as its duration. Electric energy measurement may be stopped when the state of charge after the range test is at least equal to the state of charge measured before the range test. The state of charge shall be determined by on-board or external instruments.

3.4.4.4. All-electric range city (AERcity) test

3.4.4.4.1. The test method includes the following steps:

(a) Initial charging of the traction REESS;

(b) Driving consecutive WLTC city cycles until the break-off criteria is reached and measuring AERcity;

(c) Recharging the traction REESS and measuring electric energy

3.4.4.4.1.1. The initial charging procedure of the traction REESS shall start with a normal charging and the end of charge criteria shall be as defined in paragraph 3.4.4.3.1.5. above and in Appendix 4 of this annex.

3.4.4.4.1.2. City cycles shall be driven and the all-electric range city (AERcity) distance shall be measured.

3.4.4.4.1.3. The end of the test occurs when the break-off criteria is reached according to paragraph 3.4.4.3.1.3. above.

3.5 FCVs with and without driver-selectable operating modes

3.5.1. Vehicles shall be tested under charge-sustaining (CS) conditions according to the cycles described in paragraph 1.5.1.2.1. of this annex.

3.5.2. Vehicle and REESS Conditioning

3.5.2.1. Alternatively, at the request of the manufacturer, the level of the state of charge of the traction REESS for the charge-sustaining test may be set according to manufacturer's

recommendation in order to achieve a charge balance neutral charge-sustaining test.

3.5.3. Type 1 Test

3.5.3.1. If required by paragraph 4.2.3 of this annex, fuel consumption results shall be corrected according to the RCB correction described in Appendix 2b to this annex.

4. Calculations

4.1. Emission compound calculations

Exhaust gases shall be analysed according to Annex 6. All equations shall apply to WLTC tests.

4.1.1. OVC-HEV with and without operating mode switch

4.1.1.1. Charge-depleting mode emissions

The level of the emission compounds at charge-depleting, $M_{i,CD}$, shall be calculated as follows:

$$M_{i,CD} = \frac{\sum_{j=1}^{k}(UF_j * M_{i,CD,j})}{\sum_{j=1}^{k} UF_j}$$

where:

$M_{i,CD,j}$ is the mass of the emissions compound measured during the j^{th} phase, g/km;

i is the emissions compound;

UF_j is the fractional utility factor of the j^{th} phase;

j is the index number of the phases up to the end of the transition cycle n:

k is the number of phases driven until the end of transition cycle n.

4.1.1.2. Charge-sustaining mode emissions

4.1.1.2.1. The charging balance correction (RCB) calculation is not required for the determination of emissions compounds.

4.1.1.3. Weighted emissions compounds

The weighted emissions compounds $M_{i,weighted}$, from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

$$M_{i,weighted} = \sum_{j=1}^{k}(UF_j * M_{i,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * M_{i,CS}$$

where:

$M_{i,weighted}$ is the utility factor-weighted exhaust emissions of each measured emission compound, g/km;

i is the emissions compound;

UF_j is the fractional utility factor of the j^{th} phase;

$M_{i,CD,j}$ are the compound mass emissions measured during the j^{th} charge-depleting phase, g/km;

$M_{i,CS}$ are the compound mass emissions for the charge-sustaining test according to 3.2.5., g/km;

j is the index number of the phases up to the end of the transition cycle n;

k is the number of phases driven until the end of transition cycle n.

4.1.2. NOVC-HEV with and without driver-selectable operating modes

4.1.2.1. Exhaust emissions shall be calculated as required for conventional vehicles according to Annex 7.

4.1.2.2. The charging balance correction (RCB) calculation is not required for the determination of emissions compounds.

4.2. CO_2 and fuel consumption calculations

Exhaust gases shall be analysed according to Annex 6.

4.2.1. OVC-HEV with and without an operating mode switch

All equations shall apply to the WLTC tests.

4.2.1.1. Weighted charge-depleting CO_2 Emissions

The CO_2 values at charge-depleting, $CO_{2,CD}$, shall be calculated as follows:

$$CO_{2,CD} = \sum_{j=1}^{k}(UF_j * CO_{2,CD,j}) / \sum_{j=1}^{k} UF_j$$

where:

$CO_{2,CD}$ is the utility factor-adjusted mass of CO_2 emissions during charge-depleting mode, g/km;

$CO_{2,CD,j}$ are the CO_2 emissions measured during the j^{th} charge-depleting phase, g/km;

UF_j the driving cycle and phase-specific utility factor according to Appendix 5 to this annex;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.2.1.2. Weighted charge-depleting fuel consumption

The fuel consumption values, FC_{CD}, at charge-depleting shall be calculated as follows:

$$FC_{CD} = \sum_{j=1}^{k}(UF_j * FC_{CD,j}) / \sum_{j=1}^{k} UF_j$$

where:

FC_{CD} is the utility factor-adjusted fuel consumption charge-depleting mode, l/100 km;

$FC_{CD,j}$ is the fuel consumption measured during the j^{th} charge-depletion phase, l/100 km;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this annex;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.2.1.3. Charge-sustaining fuel consumption and CO_2 emissions

4.2.1.3.1. Test result correction as a function of REESS charging balance

The corrected values $CO_{2,CS,corrected}$ and $FC_{CS,corrected}$ shall correspond to a zero charging balance (RCB = 0), and shall be determined according to Appendix 2a to this annex.

4.2.1.3.2. The electricity balance, measured using the procedure specified in Appendix 3 to this annex, is used as a measure of the difference in the vehicle REESS's energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined for the WLTC driven.

4.2.1.3.3. The test results shall be the uncorrected measured values of $CO_{2,CS}$ and FC_{CS} in case any of the following applies:

(a) The manufacturer can prove that there is no relation between the energy balance and CO_2 emissions/fuel consumption;

(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging,

(c) ΔE_{REESS} as calculated from the test result corresponds to REESS discharging. ΔE_{REESS}, expressed as a percentage of the energy content of the fuel consumed over the cycle, is calculated in the equation below:

$$\Delta E_{REESS} = \frac{\text{~~0.0036 ×~~ RCB} \times U_{REESS}}{E_{Fuel}} \times 100$$

where:

ΔE_{REESS} is the change in the REESS energy content, per cent;

U_{REESS} is the nominal REESS voltage, V;

RCB is REESS charging balance over the whole cycle, Ah;

E_{Fuel} is the energy content of the consumed fuel, Wh. (Lower heating value)

ΔE_{REESS} is lower than the RCB correction criteria, according to the equation below and Table A8/5:

$\Delta E_{REESS} \leq$ RCB correction criteria

Table A8/5

RCB correction criteria

Cycle	*WLTC (Low + Medium + High)*	*WLTC (Low + Medium + High + Extra High)*
RCB correction criteria (%)	1	0.5

4.2.1.4. Weighted CO_2 emissions

The weighted CO_2 emissions from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

$$CO_{2,weighted} = \sum_{j=1}^{k}(UF_j * CO_{2,CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * CO_{2,CS}$$

where:

$CO_{2,weighted}$ are the utility factor-weighted CO_2 emissions, g/km;

UF_j is the fractional utility factor of the j^{th} phase;

$CO_{2,CD,j}$ are the CO_2 emissions measured during the j^{th} charge-depleting phase, g/km;

$CO_{2,CS}$ are the CO_2 emissions for the charge-sustaining test according to paragraph 4.2.1.3. above, g/km;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.2.1.5. Weighted fuel consumption

The weighted fuel consumption from the charge-depleting and charge-sustaining test results shall be calculated using the equation below:

$$FC_{weighted} = \sum_{j=1}^{k}(UF_j * FC_{CD,j}) + (1 - \sum_{j=1}^{k} UF_j) * FC_{CS}$$

where:

$FC_{weighted}$ is the utility factor-weighted fuel consumption, l/100 km;

UF_j is the fractional utility factor of the j^{th} phase;

$FC_{CD,j}$ is the fuel consumption measured during the j^{th} charge-depleting phase, l/100 km;

FC_{CS} is the fuel consumption measured during the charge-sustaining test according to paragraph 4.2.1.3. above, l/100 km;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.2.2. NOVC-HEV with and without driver-selectable operating modes

4.2.2.1. Exhaust gases shall be analysed according to Annex 6.

4.2.2.2. Charge-sustaining fuel consumption and CO_2 emissions shall be calculated according to paragraph 4.2.1.3. of this annex.

4.2.2.3. Test result correction as a function of REESS charging balance

The corrected values $CO_{2,CS,corrected}$ and $FC_{CS,corrected}$ shall correspond to a zero energy balance ($RCB = 0$), and shall be determined according to Appendix 2a to this annex.

4.2.2.3.1. The electricity balance, measured using the procedure specified in Appendix 3 to this annex, is used as a measure of the difference in the vehicle REESS's energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined for the WLTC driven.

4.2.2.3.2. The test results shall be the uncorrected measured values of $CO_{2,CS}$ and FC_{CS} in case any of the following applies:

(a) The manufacturer can prove that there is no relation between the energy balance and fuel consumption;

(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging;

(c) ΔE_{REESS} as calculated from the test result corresponds to REESS discharging. ΔE_{REESS}, expressed as a percentage of the energy content of the fuel consumed over the cycle, is calculated in the equation below:

$$\Delta E_{REESS} = \frac{0.0036 \times \sum_{i=1}^{z}(RCB_i \times U_{REESSi})}{E_{fuel}} \times 100$$

where:

U_{REESSi} is the nominal REESS voltage for i^{th} REESS, V;

RCB_i is the charging balance over the whole cycle for the i^{th} REESS, Ah;

E_{fuel} is the energy content of the consumed fuel, MJ. (Lower heating value)

i index of REESS

z number of installed REESS

ΔE_{REESS} is smaller than the RCB correction criteria, according to the following equation and Table A8/6 :

$\Delta E_{REESS} \leq$ RCB correction criteria

Table A8/6

RCB correction criteria

Cycle	*WLTC (Low + Medium + High)*	*WLTC (Low + Medium + High + Extra High)*
RCB correction criteria (%)	1	0.5

4.2.2.3.3. Where RCB corrections of CO_2 and fuel consumption measurement values are required, the procedure described in Appendix 2a to this annex shall be used.

4.2.3. Fuel cell vehicles with and without driver-selectable operating modes

4.2.3.1. Fuel consumption shall be measured according to Appendix X of this annex.

4.2.3.2. Charge-sustaining fuel consumption shall be calculated according to paragraph 4.2.1.3. of this annex.

4.2.3.3. Test result correction as a function of REESS charging balance

The corrected values $FC_{CS,corrected}$ shall correspond to a zero energy balance (RCB = 0), and shall be determined according to Appendix 2b to this annex.

4.2.3.3.1. The electricity balance, measured using the procedure specified in Appendix 3 to this annex, is used as a measure of the difference in the vehicle REESS's energy content at the end of the cycle compared to the beginning of the cycle. The electricity balance is to be determined for the WLTC driven.

4.2.3.3.2. The test results shall be the uncorrected measured values of FC_{CS} in case any of the following applies:

(a) The manufacturer can prove that there is no relation between the energy balance and fuel consumption;

(b) ΔE_{REESS} as calculated from the test result corresponds to REESS charging;

(c) ΔE_{REESS} as calculated from the test result corresponds to REESS discharging. ΔE_{REESS}, expressed as a percentage of the energy content of the fuel consumed over the cycle, is calculated in the equation below:

$$\Delta E_{REESS} = \frac{0.0036 \times \sum_{i=1}^{z}(RCB_i \times U_{REESSi})}{E_{fuel}} \times 100$$

where:

U_{REESSi} is the nominal REESS voltage for i^{th} REESS, V;

RCB_i is the charging balance over the whole cycle for the i^{th} REESS, Ah;

E_{fuel} is the energy content of the consumed fuel, MJ. (Lower heating value)

i index of REESS

z number of installed REESS

ΔE_{REESS} is smaller than the RCB correction criteria, according to the following equation and Table A8/X :

$\Delta E_{REESS} \leq$ RCB correction criteria

Table A8/X

RCB correction criteria

Cycle	*WLTC (Low + Medium + High)*	*WLTC (Low + Medium + High + Extra High)*
RCB correction criteria (%)	1	0.5

4.2.3.3.3. Where RCB corrections of fuel consumption measurement values are required, the procedure described in Appendix 2b to this annex shall be used.

4.3. Electric energy consumption calculations

4.3.1. OVC-HEV

4.3.1.1. Utility factor-weighted total AC electric energy consumption including charging losses shall be calculated using the following equations:

$$EC_{weighted} = \sum_{j=1}^{k} (UF_j * EC_{CD,j})$$

$$EC_{CD,j} = \frac{RCB_j}{D_j * \sum_{j=1}^{k} RCB_j} * E_{AC}$$

where:

$EC_{weighted}$ is the utility factor-weighted total energy consumption, Wh/km;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this annex;

$EC_{CD,j}$ is the calculated fraction of E_{AC} used in the j^{th} phase during the charge-depleting test, Wh/km;

RCB_j is the measured charge balance of the traction REESS of the j^{th} phase during the charge-depleting test, Ah;

D_j is the distance driven in the j^{th} phase during the charge-depleting test, km;

E_{AC} is the measured recharged electric energy from the mains, Wh;

j is the index number of each phase up to the end of transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.3.1.2. Electric energy consumption including charging losses

4.3.1.2.1. Recharged electric energy E in Wh and charging time measurements shall be recorded.

4.3.1.2.2. Electric energy consumption EC is defined by the equation:

$EC = E_{AC}/EAER$

where:

EC is the electric energy consumption, Wh/km;

E_{AC} is the recharged electric energy from the mains, Wh;

EAER is the equivalent all-electric range according to paragraph 4.4.1.3. below, km.

4.3.1.3. Charge-depleting AC electric energy consumption, EC_{CD}, including charging losses

$$EC_{CD} = \frac{EC_{weighted}}{\sum_{j=1}^{k} UF_j}$$

where:

$EC_{weighted}$ is the electric energy consumption, Wh/km;

EC_{CD} is the recharged electric energy from the grid including charging losses, Wh;

UF_j is the driving cycle and phase-specific utility factor according to Appendix 5 to this annex;

j is the index number of each phase up to the end of transition cycle n;

k is the number of phases driven up to the end of transition cycle n.

4.3.2. Pure electric vehicle (PEV)

4.3.2.1. Recharged electric energy E in Wh and charging time measurements shall be recorded.

4.3.2.2. The electric energy consumption EC including charging losses is defined by the equation:

$EC = E_{AC}/AER$

where:

EC is the electric energy consumption, Wh/km;

E_{AC} is the recharged electric energy from the mains, Wh;

AER is the all-electric range as defined in paragraph 4.4.2.1. of this annex.

4.4. Electric Range

4.4.1. OVC-HEV

4.4.1.1. All-electric range, AER, and all-electric range city, AERcity

The distance driven over consecutive test cycles according to paragraph 1.5.1.1. using only the REESS until the combustion engine starts consuming fuel for the first time shall be measured and be rounded to the nearest whole number.

4.4.1.2. Equivalent all-electric range, EAER

4.4.1.2.1. EAER shall be calculated as follows:

$$EAER = \left(\frac{CO_{2,CS} - CO_{2,CDavg}}{CO_{2,CS}}\right) * R_{CDC}$$

where:

$$CO_{2,CD,avg} = \frac{\sum_{j=1}^{k} CO_{2,CD,j}}{\sum_{j=1}^{k} D_j}$$

and:

EAER is the equivalent all-electric range EAER, km;

$CO_{2,CS}$ are the CO_2 emissions during the charge-sustaining test, g/km;

$CO_{2,CD,j}$ are the CO_2 emissions in the j^{th} phase during the charge-depleting test, g;

D_j is the distance driven in the j^{th} phase during the charge-depleting test, km;

R_{CDC} is the charge-depleting cycle range, km;

j is the index number of each phase up to the end of the transition cycle n;

k is the number of phases driven up to the end of the transition cyclen.

4.4.1.3. Charge-depleting cycle range (R_{CDC})

The distance from the beginning of the charge-depleting test to the end of the last cycle prior to the cycle or cycles satisfying the break-off criteria shall be measured. This shall include the distance travelled during the transition cycle where the vehicle operates in both depleting and sustaining modes. If the charge-depleting test possesses a transition range, the R_{cdc} shall include those transition cycles or cycles.

4.4.1.4. Actual charge-depleting cycle range (R_{CDA})

$$R_{CDA} = \sum_{j=1}^{n-1} D_{j,cycle} + \left(\frac{CO_{2,CS} - CO_{2,n,cycle}}{CO_{2,CS} - CO_{2,CD,average,n-1}}\right) \times D_n$$

where:

R_{CDA} is the actual charge-depleting range, km;

$CO_{2,CS}$ are the CO_2 emissions during the charge-sustaining test, g/km;

$CO_{2,n,cycle}$ are the CO_2 emissions over the n^{th} drive cycle in charge-depleting operating condition, g/km;

$CO_{2,CD,average,n-1}$ are the average CO_2 emissions in charge-depleting operating condition until the n-1^{th} drive cycle, g/km;

$D_{j,cycle}$ is the test distance travelled during j^{th} drive cycle, km;

D_n is the test distance travelled during the n^{th} drive cycle in charge-depleting operating condition, km;

j is the index number of each whole cycle up to the end of the transition cycle n;

n is the number of whole cycles driven including the transition cycle n.

4.4.2. PEV

4.4.2.1. All-electric range, AER

The distance driven over consecutive WLTCs until the break-off criterion is reached shall be measured and be rounded to the nearest whole number according to paragraph 3.4.2.4.1.3. above.

4.4.2.2. All-electric city range, AERcity

The distance driven over consecutive WLTC city cycles until the break-off criteria is reached shall be measured and be rounded to the nearest whole number.

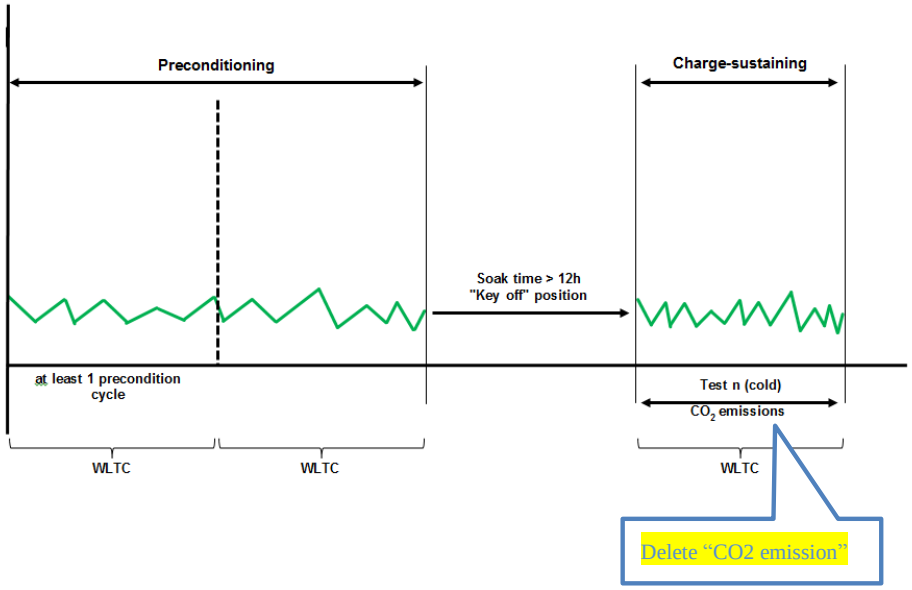
[RESERVED : Combined approach]

Annex 8 - Appendix 1b

RCB profile, OVC-HEV ~~and~~ , NOVC-HEV and FCV charge-sustaining test

1. RCB profile OVC-HEV, charge-sustaining test (Figure A8.App1b/1)

- Figure A8.App1b/1
- **OVC-HEV, charge-sustaining test**



Annex 8 - Appendix 2a

REESS charge balance (RCB) correction of NOVC-HEV and OVC-HEV

1. This appendix describes the test procedure for RCB compensation of CO_2 and fuel consumption measurement results when testing NOVC-HEV and OVC-HEV.

1.1. Separate CO_2 emission and fuel consumption correction coefficients shall be calculated separately for each phase of the WLTC and corrected to zero over each WLTC phase.

2. The fuel consumption correction coefficients (K_{fuel}) shall be defined as follows and might be supplied by the manufacturer :

2.1. The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with $E_{REESSi} \leq 0$ and at least one with $E_{REESSi} > 0$ over the complete test cycle.

If the latter condition cannot be realised on the driving cycle used in this test, the responsible authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{REESS} = 0$.

2.1.1. The fuel consumption correction coefficients (K_{fuel}) for the individual phases as well as for the complete test cycle are defined as:

$$K_{fuel} = \frac{(n \times \sum E_{REESS} \times FC_i - \sum E_{REESSi} \times \sum FC_i)}{n \times \sum E_{REESSi}^2 - (\sum E_{REESSi})^2}$$

where:

K_{fuel} are the fuel consumption correction coefficients, l/100 km/Wh/km;

FC_i are the fuel consumptions measured during the i^{th} test, l/100 km;

E_{REESSi} are the electricity balances measured during the i^{th} test, Wh/km;

n is the number of measurements.

The fuel consumption correction coefficient shall be rounded to four significant figures. The statistical significance of the fuel consumption correction coefficient is to be evaluated by the responsible authority.

2.2. The fuel consumption correction coefficient shall be determined for the fuel consumption values measured over WLTC. This coefficient can be applied for each individual WLTC phase correction.

2.2.1. Without prejudice to the requirements of paragraph 2.1 of this appendix, at the manufacturer's request, separate fuel consumption correction coefficients for each individual WLTC phase may be developed.

2.3. Fuel consumption at zero REESS energy balance (FC_0)

2.3.1. The fuel consumption FC_0 at $\Delta E_{REESS} = 0$ shall be determined by the following equation:

$$FC_0 = FC - K_{fuel} \times \Delta E_{REESS}$$

where:

FC_0 is the fuel consumption at ΔE_{REESS} = 0, l/100 km ;

FC is the fuel consumption measured during the test, l/100 km;

ΔE_{REESS} is the electricity balance measured during test, Wh/km.

2.3.2. Fuel consumption at zero REESS energy balance shall be calculated separately for each phase of the WLTC and corrected to zero over each WLTC phase.

2.3.3. Fuel consumption at zero REESS energy balance shall also be calculated for the complete WLTC and corrected to zero.

3. CO_2 emission correction coefficient (K_{CO_2}) shall be defined as follows and may be supplied by the manufacturer

3.1. The CO_2 emission correction coefficient (K_{CO_2}) shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement

with $E_{REESSi} \leq 0$ and at least one with $E_{REESSi} > 0$ over the complete test cycle.

If the latter condition cannot be realised on the driving cycle used in this test, the responsible authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{REESS} = 0$.

3.1.1. The CO_2 emission correction coefficient (K_{CO_2}) is defined as:

$$K_{CO_2} = \frac{(n \times \sum E_{REESS} \times M_i - \sum E_{REESSi} \times \sum M_i)}{n \times \sum E_{REESSi}^2 - (\sum E_{REESSi})^2}$$

where:

K_{CO_2} are the CO_2 emissions correction coefficient, g/km/Wh/km;

M_i are the CO_2 emissions measured during the i^{th} test, g/km;

E_{REESSi} is the electricity balance during the i^{th} test, Wh/km;

n is the number of measurements.

3.1.2. The CO_2 emission correction coefficient shall be rounded to four significant figures. The statistical significance of the CO_2 emission correction coefficient is to be judged by the responsible authority.

3.1.3. The CO_2 emission correction coefficient shall be determined for the CO_2 emission values measured over the WLTC. This coefficient may be applied for each individual WLTC phase correction.

3.1.3.1 Without prejudice to the requirements of paragraph 2.1 of this appendix, at the manufacturer's request, separate CO_2 emission correction coefficients for each individual WLTC phase may be developed.

3.1.4. CO_2 emissions at zero REESS energy balance shall be also calculated for complete WLTC and corrected to zero.

3.2. CO_2 emission at zero REESS energy balance (M_0)

3.2.1. The CO_2 emission M_0 at $\Delta E_{REESS} = 0$ shall be determined by the following equation:

$$M_0 = M - K_{CO_2} \times \Delta E_{REESSi}$$

where:

M_0 are the CO_2 emissions at zero REESS energy balance, g/km;

K_{CO_2} are the CO_2 emissions correction coefficient, g/km/Wh/km;

ΔE_{REESSi} is the electricity balance measured during test, Wh/km.

Annex 8 - Appendix 2b

REESS charge balance (RCB) correction of FCV

1. This appendix describes the test procedure for RCB compensation of fuel consumption measurement results.

1.1. Fuel consumption correction coefficients shall be calculated separately for each phase of the WLTC and corrected to zero over each WLTC phase.

2. The fuel consumption correction coefficients (K_{fuel}) shall be defined as follows and might be supplied by the manufacturer :

2.1. The fuel consumption correction coefficient (K_{fuel}) shall be determined from a set of n measurements performed by the manufacturer. This set shall contain at least one measurement with $E_{REESSi} \leq 0$ and at least one with $E_{REESSi} > 0$ over the complete test cycle.

If the latter condition cannot be realised on the driving cycle used in this test, the responsible authority shall evaluate the statistical significance of the extrapolation necessary to determine the fuel consumption value at $\Delta E_{REESS} = 0$.

2.1.1. The fuel consumption correction coefficients (K_{fuel}) for the individual phases as well as for the complete test cycle are defined as:

$$K_{fuel} = \frac{(n \times \sum E_{REESS} \times FC_i - \sum E_{REESSi} \times \sum FC_i)}{n \times \sum E_{REESSi}^2 - (\sum E_{REESSi})^2}$$

where:

K_{fuel} are the fuel consumption correction coefficients, kg/100km/Wh/km;

FC_i are the fuel consumptions measured during the i^{th} test, kg/100km;

E_{REESSi} are the electricity balances measured during the i^{th} test, Wh/km;

n is the number of measurements.

The fuel consumption correction coefficient shall be rounded to four significant figures. The statistical significance of the fuel

consumption correction coefficient is to be evaluated by the responsible authority.

2.2. The fuel consumption correction coefficient shall be determined for the fuel consumption values measured over WLTC. This coefficient can be applied for each individual WLTC phase correction.

2.2.1. Without prejudice to the requirements of paragraph 2.1 of this appendix, at the manufacturer's request, separate fuel consumption correction coefficients for each individual WLTC phase may be developed.

2.3. Fuel consumption at zero REESS energy balance (FC_0)

2.3.1. The fuel consumption FC_0 at $\Delta E_{REESS} = 0$ shall be determined by the following equation:

$$FC_0 = FC - K_{fuel} \times \Delta E_{REESS}$$

where:

FC_0 is the fuel consumption at $\Delta E_{REESS} = 0$, kg/100km;

FC is the fuel consumption measured during the test, kg/100km;

ΔE_{REESS} is the electricity balance measured during test, Wh/km.

2.3.2. Fuel consumption at zero REESS energy balance shall be calculated separately for each phase of the WLTC and corrected to zero over each WLTC phase.

2.3.3. Fuel consumption at zero REESS energy balance shall also be calculated for the complete WLTC and corrected to zero.

Annex 8 - Appendix 3

Measuring the electricity balance of batteries for NOVC-HEV, ~~and~~ OVC-HEV and FCV ~~batteries~~

1. Introduction

1.1. This appendix defines the method and required instrumentation to measure the electricity balance of OVC-HEVs, ~~and~~ NOVC-HEVs and FCVs.

2. Measurement equipment and instrumentation

2.1. During the tests described in paragraph 3. of this annex, the REESS current can be measured using a current transducer of the clamp-on or closed type. The current transducer (i.e. a current sensor without data acquisition equipment) shall have a minimum accuracy specified in paragraph 2.1.1. of Appendix 2 to Annex 6.

2.1.1. Alternatively to 2.1 above, the RCB determination method described in Annex 6, Appendix 2, paragraph 2.2. shall be applicable for all vehicle REESSs.

2.1.2. The current transducer shall be fitted on one of the cables directly connected to the REESS. In order to easily measure REESS 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 responsible authority by providing the means to connect a current transducer to the wires connected to the REESS in the above described manner.

2.1.3. 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 RCB, expressed in ampere-hours (Ah).

2.2. A list of the instrumentation (manufacturer, model no., serial no.) used by the manufacturer to determine:

(a) When the minimum state of charge of the REESS has been reached during the test procedure defined in paragraph 3. of this annex;

(b) The correction factors K_{fuel} and K_{CO_2} (as defined in Appendix 2a or 2b to this annex);

(c) The last calibration dates of the instruments (where applicable) shall be provided to the responsible technical authority.

3. Measurement procedure

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

3.2. The RCB values of each phase shall be recorded.

Annex 8 - Appendix X

Fuel consumption measurement of Compressed hydrogen fuel cell vehicle

1. General

1.1. Preparation of test vehicle

Vehicles shall be conditioned and soaked according to the test procedures described in Annex 6 to this gtr unless modified by this annex.

1.2. Fuel consumption shall be measured using a) gravimetric method or b) pressure method.

a) Gravimetric method

Fuel consumption is calculated by measuring the mass of the fuel tank before and after the test. Gravimetric method shall be performed in accordance with paragraph 2.

b) Pressure method

Fuel consumption is determined by measuring the pressure and temperature of gas in the fuel tank before and after the test. A tank with known internal volume that allows measurement of gas pressure and temperature shall be used for the test. Pressure method shall be performed in accordance with paragraph 3.

2. Gravimetric method

2.1. Equipment and Setting

2.1.1. An example of instrumentation is shown in Figure A8/X1. Additional tank(s) are used to measure the fuel consumption. The additional tank(s) shall be connected to the vehicle fuel line between the original fuel tank and the fuel cell system.

2.1.2. For preconditioning, the originally installed tank or an external source of hydrogen shall be used as shown in Figure A8/X1.

2.1.3. The refuelling pressure shall be adjusted to the manufacturer's recommended value.

2.1.4. The gas supply pressures in an external fuel supply line and fuel line(s) downstream regulator(s) of additional tank(s) shall be maintained equal, so that input or output of gas is eliminated when the lines are switched.

If input or output of gas effect on fuel consumption, influence of the change of pressure shall be corrected by calculation of input or output of gas with monitored pressure, temperature and inner volume of relevant lines.

2.1.5. Precision balance

2.1.5.1. The precision balance used for fuel consumption measurement shall meet the specification of Table A8/X1 below.

Table A8/X1

Analytical balance verification criteria

Measurement system	*Resolution (Readability)*	*Precision *1 (Repeatability)*
Precision Balance	0.1 g max	2 per cent max

*1) per cent of fuel consumption(RCB=0) during the test , in mass, standard deviation

2.1.5.2. The precision balance shall be calibrated in accordance with the specifications provided by the balance manufacturer or at least as often as described in Table A8/X2.

Table A8/X2

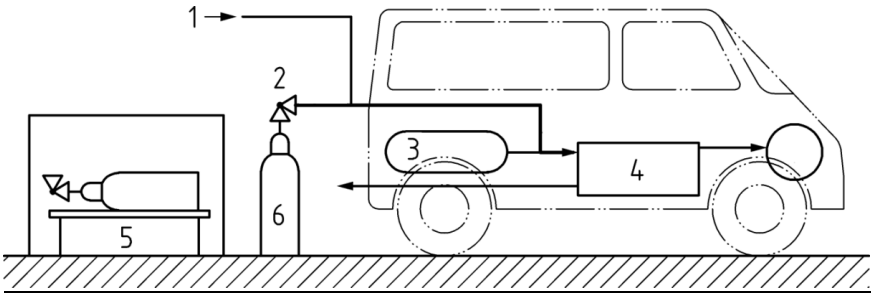
Instrument calibration intervals

Instrument checks	*Interval*
Precision (Repeatability)	Yearly and at major maintenance

2.1.5.3. Appropriate means for reducing the effects of vibration and convection, such as a damping table, wind barrier, shall be provided.

Figure A8/X1

Example of instrumentation



Key:

1 external fuel supply for preconditioning

2 pressure regulator

3 original tank

4 fuel cell system

5 precision balance

6 additional tank(s) for fuel consumption measurement

2.2. Test procedure

a) Measure the mass of the additional tank before the test.

Connect the additional tank to the vehicle fuel line as described in Figure A8/X1.

b) Conduct the test by fuelling from the additional tank.

c) Remove the additional tank from the line and measure the mass after the test.

d) Calculate the fuel consumption (FC), expressed in kg/100km, from the measured mass before and after the test, using the following equation:

$$FC = \frac{g_1 - g_2}{d} \times 100$$

Where

FC is the fuel consumption measured during the test, kg/100km

g_1 is the mass of the tank, in kg, at the start of the test;

g_1 is the mass of the tank, in kg, at the start of the test;

g_2 is the mass of the tank, in kg, at the end of the test.

d is the distance corresponding to the test , km

3. Pressure method

3.1. Equipment and Setting

3.1.1. An example of instrumentation is shown in Figure A8/X2. Additional tank(s) are used to measure the fuel consumption. The additional tank(s) shall be connected to the vehicle fuel line between the original tank and the fuel cell system. Prior to the test, the additional tank shall be soaked at least for 1 hour, after the outer surface temperature of the tank becomes the ambient temperature ± 3K of the room where the tank is placed during the test.

3.1.2. For preconditioning, the originally installed tank or an external source of hydrogen fuel shall be used as shown in Figure A8/X2.

3.1.3. The refuelling pressure of the additional tank shall be adjusted according to the manufacturer's recommended value.

3.1.4. The gas supply pressures in an external fuel supply line and fuel line(s) downstream regulator(s) of additional tank(s) shall be maintained equal, so that input or output of gas is eliminated when the lines are switched.

If input or output of gas effect on fuel consumption, influence of the change of pressure shall be corrected.

3.1.5. The following items are given as requirements for the additional tank.

- The internal volume of the tank (including volume of line upstream of the pressure regulator) shall be measured.
- Additional tank(s) shall be metal tank(s).
- A pressure gauge shall be installed upstream of a regulator of the additional tank(s)
- A temperature gauge shall be installed inside or on the outer surface of additional tank(s).

3.1.6. Measurement accuracy and calibration

Accuracy of the pressure gauge and the temperature gauge for the additional tank shall be at least ±15kPa and ±0.3K respectively.

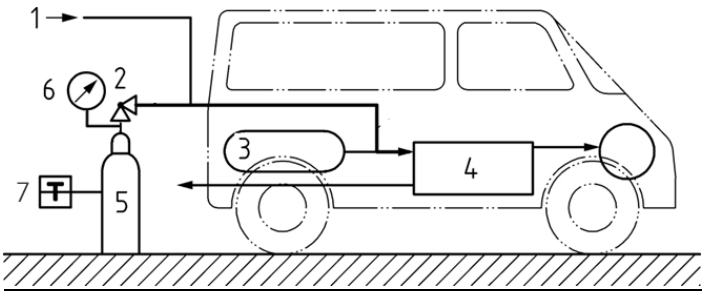
Each instrument for fuel consumption measurement shall be calibrated as specified by the instrument manufacturer or at least as often as described in Table A8/X3.

TableA8/X3 Instrument calibration intervals

Instrument checks	*Interval*	*Criteria*
Pressure gauge	Yearly	±15kPa
Temperature gauge	Yearly	±0.3K

Figure A8/X2

Example of instrumentation



Key

1 external fuel supply for preconditioning (if necessary)

2 pressure regulator

3 original tank

4 fuel cell system

5 additional tank(s) for fuel consumption measurement.

6 pressure gauge for additional tank(s)

7 temperature gauge for additional tank(s)

Table A8/X1

Example of hydrogen tank for pressure method

Item	Specification
Internal volume (measured)	40,872 l
Material	Cr-Mo steel
Maximum refuelling pressure	14,7 MPa
Tank diameter (outside)x tank length	Ø 232×1170mm
Mass	Approx. 42 kg

3.2. Test procedure

a) At the start of the test, the pressure and the temperature of the additional tank shall be measured by gauges described in 3.1.5.

b) Conduct the test by fuelling from the additional tank.

c) At the end of the test, the pressure and the temperature of the tank shall be measured after soaking at least for 1 hour.

d) Hydrogen fuel consumption (FC), expressed in kg/100km, is calculated by the measured pressure and temperature before and after the test using following equations:

$$FC = 0.02425 \times \frac{V}{d} \times \left(\frac{P_1}{z_1 \times T_1} - \frac{P_2}{z_2 \times T_2} \right)$$

Where

d is the distance corresponding to the test , km

p_1 is pressure in the additional tank before the test , Pa

p_2 is pressure in the additional tank after the test , Pa;

T_1 is temperature of the additional tank before the test , K.

T_2 is temperature of the additional tank after the test , K.

Z_1 is compressibility factor of the gaseous fuel at p_1 and T_1

Z_2 is compressibility factor of the gaseous fuel at p_2 and T_2

V is inner volume of the additional tank, m^3