

#### 5.4. Determination of hydrogen emissions

5.4.1. This test shall be carried out on all vehicles equipped with open type traction batteries.

5.4.2. The test shall be conducted following the method described in Annex 7 to the present Regulation. The hydrogen sampling and analysis shall be the ones prescribed. Other analysis methods can be approved if it is proven that they give equivalent results.

5.4.3. During a normal charge procedure in the conditions given in Annex 7, hydrogen emissions shall be below 125 g during 5 h, or below  $25 \times t_2$  g during  $t_2$  (in h).

5.4.4. During a charge carried out by an ~~on-board~~ charger presenting a failure (conditions given in Annex 7), hydrogen emissions shall be below 42 g. Furthermore the on-board charger shall limit this possible failure to 30 minutes.

5.4.5. All the operations linked to the REESS charging are controlled automatically, included the stop for charging.

5.4.6. It shall not be possible to take a manual control of the charging phases.

5.4.7. Normal operations of connection and disconnection to the mains or power cuts shall not affect the control system of the charging phases.

5.4.8. Important charging failures shall be permanently ~~indicated signaled to the driver~~. An important failure is a failure that can lead to a ~~disfunctioning malfunctioning~~ of the ~~on-board~~ charger during charging later on.

5.4.9. The manufacturer has to indicate in the owner's manual, the conformity of the vehicle to these requirements.

5.4.10. The approval granted to a vehicle type relative to hydrogen emissions can be extended to different vehicle types belonging to the same family, in accordance with the definition of the family given in Annex 7, Appendix 2.

## 6. PART II: REQUIREMENTS OF A RECHARGEABLE ENERGY STORAGE SYSTEM (REESS) WITH REGARD TO ITS SAFETY

### 6.11 Emission

Possible emission of gases caused by the energy conversion process shall be considered.

6.11.1 Open type traction batteries shall meet the requirements of paragraph 5.4 of this regulation according to hydrogen emissions.

Systems with a closed chemical process are considered as emission-free under normal operation (e.g. Li-ion).

The closed chemical process shall to be described by the manufacturer.

Other technologies shall be evaluated by the manufacturer and the Technical Service according possible emissions under normal operation.

#### 6.11.2. Acceptance criteria

For hydrogen emissions see paragraph 5.4 of this regulation.

Systems with closed chemical process are emission-free and no verification is necessary.]

### Annex 7

#### DETERMINATION OF HYDROGEN EMISSIONS DURING THE CHARGE PROCEDURES OF THE TRACTION BATTERY

##### 1. INTRODUCTION

This annex describes the procedure for the determination of hydrogen emissions during the charge procedures of the REESS of all road vehicles, according to paragraph 5.4. and of components or separate technical units, according to paragraph 6.11. of this Regulation.

##### 2. DESCRIPTION OF TEST

The hydrogen emission test (Figure 7.1) is conducted in order to determine hydrogen emissions during the charge procedures of the REESS with ~~the on-board~~ charger. The test consists in the following steps:

- (a) vehicle/REESS preparation,
- (b) discharge of the REESS,
- (c) determination of hydrogen emissions during a normal charge,
- (d) determination of hydrogen emissions during a charge carried out with the ~~on-board~~ charger failure.

##### 3. TESTS

###### 3.1. Vehicle based test

3.1.1 The vehicle shall be in good mechanical condition and have been driven at 300 km during seven days before the test. The vehicle shall be equipped with the REESS subject to the test of hydrogen emissions, over this period.

3.1.2. If the REESS is used at a temperature above the ambient temperature, the operator shall follow the manufacturer's procedure in order to keep the REESS temperature in normal functioning range.

The manufacturer's representative shall be able to certify that the temperature conditioning system of the REESS is neither damaged nor presenting a capacity defect.

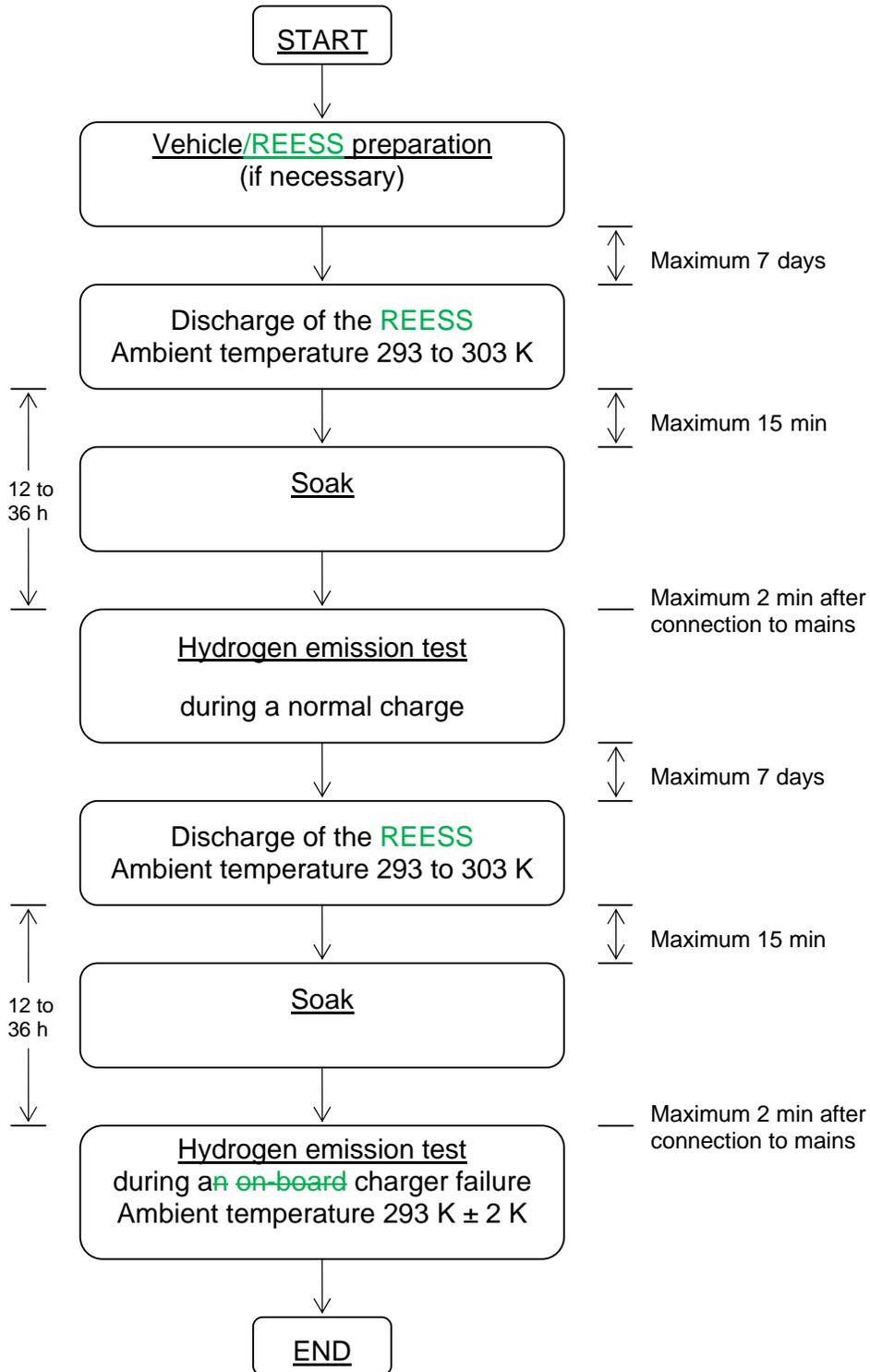
3.2. Component based test

3.2.1 The REESS shall be in good mechanical condition and have been subject to minimum of 5 standard cycles.

3.2.2. If the REESS is used at a temperature above the ambient temperature, the operator shall follow the manufacturer's procedure in order to keep the REESS temperature in normal functioning range.

The manufacturer's representative shall be able to certify that the temperature conditioning system of the REESS is neither damaged nor presenting a capacity defect.

Figure 7.1  
 Determination of hydrogen emissions during  
 the charge procedures of the REESS



#### 4. TEST EQUIPMENT FOR HYDROGEN EMISSION TEST

##### 4.1. Chassis dynamometer

The chassis dynamometer shall meet the requirements of the 06 series of amendments to Regulation No. 83.

##### 4.2. Hydrogen emission measurement enclosure

The hydrogen emission measurement enclosure shall be a gas-tight measuring chamber able to contain the vehicle/REESS under test. The vehicle/REESS shall be accessible from all sides and the enclosure when sealed shall be gas-tight in accordance with appendix 1 to this annex. The inner surface of the enclosure shall be impermeable and non-reactive to hydrogen. The temperature conditioning system shall be capable of controlling the internal enclosure air temperature to follow the prescribed temperature throughout the test, with an average tolerance of  $\pm 2$  K over the duration of the test.

To accommodate the volume changes due to enclosure hydrogen emissions, either a variable-volume or another test equipment may be used. The variable-volume enclosure expands and contracts in response to the hydrogen emissions in the enclosure. Two potential means of accommodating the internal volume changes are movable panels, or a bellows design, in which impermeable bags inside the enclosure expand and contract in response to internal pressure changes by exchanging air from outside the enclosure. Any design for volume accommodation shall maintain the integrity of the enclosure as specified in Appendix 1 to this annex.

Any method of volume accommodation shall limit the differential between the enclosure internal pressure and the barometric pressure to a maximum value of  $\pm 5$  hPa.

The enclosure shall be capable of latching to a fixed volume. A variable volume enclosure shall be capable of accommodating a change from its "nominal volume" (see Annex 7, Appendix 1, paragraph 2.1.1.), taking into account hydrogen emissions during testing.

##### 4.3. Analytical systems

###### 4.3.1. Hydrogen analyser

4.3.1.1. The atmosphere within the chamber is monitored using a hydrogen analyser (electrochemical detector type) or a chromatograph with thermal conductivity detection. Sample gas shall be drawn from the mid-point of one side-wall or roof of the chamber and any bypass flow shall be returned to the enclosure, preferably to a point immediately downstream of the mixing fan.

4.3.1.2. The hydrogen analyser shall have a response time to 90 per cent of final reading of less than 10 seconds. Its stability shall be better than 2 per cent of full scale at zero and at 80 per cent  $\pm 20$  per cent of full scale, over a 15-minute period for all operational ranges.

4.3.1.3. The repeatability of the analyser expressed as one standard deviation shall be better than 1 per cent of full scale, at zero and at 80 per cent  $\pm 20$  per cent of full scale on all ranges used.

4.3.1.4. The operational ranges of the analyser shall be chosen to give best resolution over the measurement, calibration and leak checking procedures.

#### 4.3.2. Hydrogen analyser data recording system

The hydrogen analyser shall be fitted with a device to record electrical signal output, at a frequency of at least once per minute. The recording system shall have operating characteristics at least equivalent to the signal being recorded and shall provide a permanent record of results. The recording shall show a clear indication of the beginning and end of the normal charge test and charging failure operation.

#### 4.4. Temperature recording

4.4.1. The temperature in the chamber is recorded at two points by temperature sensors, which are connected so as to show a mean value. The measuring points are extended approximately 0.1 m into the enclosure from the vertical centre line of each side-wall at a height of  $0.9 \pm 0.2$  m.

4.4.2. The temperatures of the battery **subsystems** are recorded by means of the sensors.

4.4.3. Temperatures shall, throughout the hydrogen emission measurements, be recorded at a frequency of at least once per minute.

4.4.4. The accuracy of the temperature recording system shall be within  $\pm 1.0$  K and the temperature shall be capable of being resolved to  $\pm 0.1$  K.

4.4.5. The recording or data processing system shall be capable of resolving time to  $\pm 15$  seconds.

#### 4.5. Pressure recording

4.5.1. The difference  $\Delta p$  between barometric pressure within the test area and the enclosure internal pressure shall, throughout the hydrogen emission measurements, be recorded at a frequency of at least once per minute.

4.5.2. The accuracy of the pressure recording system shall be within  $\pm 2$  hPa and the pressure shall be capable of being resolved to  $\pm 0.2$  hPa.

4.5.3. The recording or data processing system shall be capable of resolving time to  $\pm 15$  seconds.

#### 4.6. Voltage and current intensity recording

4.6.1. The on-board charger voltage and current intensity (battery) shall, throughout the hydrogen emission measurements, be recorded at a frequency of at least once per minute.

4.6.2. The accuracy of the voltage recording system shall be within  $\pm 1$  V and the voltage shall be capable of being resolved to  $\pm 0.1$  V.

4.6.3. The accuracy of the current intensity recording system shall be within  $\pm 0.5$  A and the current intensity shall be capable of being resolved to  $\pm 0.05$  A.

4.6.4. The recording or data processing system shall be capable of resolving time to  $\pm 15$  seconds.

#### 4.7. Fans

The chamber shall be equipped with one or more fans or blowers with a possible flow of 0.1 to 0.5 m<sup>3</sup>/second in order to thoroughly mix the atmosphere in the enclosure. It shall be possible to reach a homogeneous temperature and hydrogen concentration in the chamber during measurements. The vehicle in the enclosure shall not be subjected to a direct stream of air from the fans or blowers.

#### 4.8. Gases

4.8.1. The following pure gases shall be available for calibration and operation:

(a) purified synthetic air (purity <1 ppm C1 equivalent; <1 ppm CO; <400 ppm CO<sub>2</sub>; <0.1 ppm NO ); oxygen content between 18 and 21 per cent by volume,

(b) hydrogen ( H<sub>2</sub> ), 99.5 per cent minimum purity.

4.8.2. Calibration and span gases shall contain mixtures of hydrogen (H<sub>2</sub>) and purified synthetic air. The real concentrations of a calibration gas shall be within ± 2 per cent of the nominal values. The accuracy of the diluted gases obtained when using a gas divider shall be within ± 2 per cent of the nominal value. The concentrations specified in appendix 1 may also be obtained by a gas divider using synthetic air as the dilution gas.

### 5. TEST PROCEDURE

The test consists in the five following steps:

- (a) vehicle/REESS preparation,
- (b) discharge of the REESS,
- (c) determination of hydrogen emissions during a normal charge,
- (d) discharge of the traction battery,
- (e) determination of hydrogen emissions during a charge carried out with the ~~on-board~~ charger failure.

If the vehicle/REESS has to be moved between two steps, it shall be pushed to the following test area.

#### 5.1 Vehicle based test

##### 5.1.1. Vehicle preparation

The ageing of REESS shall be checked, proving that the vehicle has performed at least 300 km during seven days before the test. During this period, the vehicle shall be equipped with the REESS submitted to the hydrogen emission test. If this cannot be demonstrated then the following procedure will be applied.

##### 5.1.1.1. Discharges and initial charges of the REESS

The procedure starts with the discharge of the REESS of the vehicle while driving on the test track or on a chassis dynamometer at a steady speed of 70 per cent  $\pm$  5 per cent of the maximum speed of the vehicle during 30 minutes.

Discharging is stopped:

- (a) when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed, or
- (b) when an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or
- (c) after having covered the distance of 100 km.

#### 5. 1.1.2. Initial charge of the REESS

The charge is carried out:

- (a) with the on-board charger,
- (b) in an ambient temperature between 293 K and 303 K.

The procedure excludes all types of external chargers.

The end of REESS charge criteria corresponds to an automatic stop given by the ~~on-board~~ charger.

This procedure includes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges.

5. 1.1.3. Procedure from paragraphs 5.1.1. ~~to and~~ 5.1.2. shall be repeated two times.

#### 5. 1.2. Discharge of the REESS

The REESS is discharged while driving on the test track or on a chassis dynamometer at a steady speed of 70 per cent  $\pm$  5 per cent from the maximum thirty minutes speed of the vehicle.

Stopping the discharge occurs:

- (a) when an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or
- (b) when the maximum speed of the vehicle is lower than 20 km/h.

#### 5. 1.3. Soak

Within fifteen minutes of completing the REESS discharge operation specified in paragraph 5. 1.2., the vehicle is parked in the soak area. The vehicle is parked for a minimum of 12 hours and a maximum of 36 hours, between the end of the REESS discharge and the start of the hydrogen emission test during a normal charge. For this period, the vehicle shall be soaked at  $293\text{ K} \pm 2\text{ K}$ .

#### 5. 1.4. Hydrogen emission test during a normal charge

5. 1.4.1. Before the completion of the soak period, the measuring chamber shall be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) shall also be turned on at this time.
5. 1.4.2. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.
5. 1.4.3. At the end of the soak, the test vehicle, with the engine shut off and the test vehicle windows and luggage compartment opened shall be moved into the measuring chamber.
5. 1.4.4. The vehicle shall be connected to the mains. The REESS is charged according to normal charge procedure as specified in paragraph 5.4.7 below.
5. 1.4.5. The enclosure doors are closed and sealed gas-tight within two minutes from electrical interlock of the normal charge step.
5. 1.4.6. The start of a normal charge for hydrogen emission test period begins when the chamber is sealed. The hydrogen concentration, temperature and barometric pressure are measured to give the initial readings  $C_{H2i}$ ,  $T_i$  and  $P_i$  for the normal charge test.

These figures are used in the hydrogen emission calculation (paragraph 6.). The ambient enclosure temperature  $T$  shall not be less than 291 K and no more than 295 K during the normal charge period.

#### 5. 1.4.7. Procedure of normal charge

The normal charge is carried out with the on-board charger and consists of the following steps:

- (a) charging at constant power during  $t_1$ ;
- (b) over-charging at constant current during  $t_2$ . Over-charging intensity is specified by manufacturer and corresponds to the one used during equalisation charging.

The end of REESS charge criteria corresponds to an automatic stop given by the on-board charger to a charging time of  $t_1 + t_2$ . This charging time will be limited to  $t_1 + 5$  h, even if a clear indication is given to the driver by the standard instrumentation that the battery is not yet fully charged.

5. 1.4.8. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.
5. 1.4.9. The end of the emission sampling period occurs  $t_1 + t_2$  or  $t_1 + 5$  h after the beginning of the initial sampling, as specified in paragraph 5.4.6. The different times elapsed are recorded. The hydrogen concentration, temperature and barometric pressure are measured to give the final readings  $C_{H2f}$ ,  $T_f$  and  $P_f$  for the normal charge test, used for the calculation in paragraph 6.

#### 5. 1.5. Hydrogen emission test with the charger failure

5. 1.5.1. Within seven days maximum after having completed the prior test, the procedure starts with the discharge of the REESS of the vehicle according to paragraph 5.2.
5. 1.5.2. The steps of the procedure in paragraph 5.3 shall be repeated.

5. 1.5.3. Before the completion of the soak period, the measuring chamber shall be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) shall also be turned on at this time.

5. 1.5.4. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.

5. 1.5.5. At the end of the soak, the test vehicle, with the engine shut off and the test vehicle windows and luggage compartment opened shall be moved into the measuring chamber.

5. 1.5.6. The vehicle shall be connected to the mains. The REESS is charged according to failure charge procedure as specified in paragraph 5.5.9. below.

5. 1.5.7. The enclosure doors are closed and sealed gas-tight within two minutes from electrical interlock of the failure charge step.

5.1.5.8. The start of a failure charge for hydrogen emission test period begins when the chamber is sealed. The hydrogen concentration, temperature and barometric pressure are measured to give the initial readings  $C_{H_2i}$ ,  $T_i$  and  $P_i$  for the failure charge test.

These figures are used in the hydrogen emission calculation (paragraph 6). The ambient enclosure temperature  $T$  shall not be less than 291 K and no more than 295 K during the charging failure period.

5.1.5.9. Procedure of charging failure

The charging failure is carried out with the ~~on-board~~ suitable charger and consists of the following steps:

- (a) charging at constant power during  $t'_1$ ;
- (b) charging at maximum current as recommended by the manufacturer during 30 minutes. During this phase, the ~~on-board~~ charger ~~is blocked at~~ shall supply maximum current as recommended by the manufacturer.

5.1.5.10. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.

5.1.5.11. The end of test period occurs  $t'_1 + 30$  minutes after the beginning of the initial sampling, as specified in paragraph 5.5.8. The times elapsed are recorded. The hydrogen concentration, temperature and barometric pressure are measured to give the final readings  $C_{H_2f}$ ,  $T_f$  and  $P_f$  for the charging failure test, used for the calculation in paragraph 6.

## 5.2. Component based test

### 5.2.1. RESS preparation

The ageing of REESS shall be checked, proving that the REESS has performed at least 5 standard cycles. ~~During this period, the vehicle shall be equipped with the REESS submitted to the hydrogen emission test. If this cannot be demonstrated then the following procedure will be applied.~~

#### ~~5.2.1.1. Discharges and initial charges of the REESS~~

~~———— The procedure starts with the discharge of the REESS of the vehicle while driving on the test track or on a chassis dynamometer at a steady speed of 70 per cent  $\pm$  5 per cent of the maximum speed of the vehicle during 30 minutes.~~

~~———— Discharging is stopped:~~

- ~~(a) — when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed, or~~
- ~~(b) — when an indication to stop the vehicle is given to the driver by the standard on board instrumentation, or~~
- ~~(c) — after having covered the distance of 100 km.~~

#### 5.1.2. Initial charge of the REESS

~~———— The charge is carried out:~~

- ~~(a) — with the on board charger,~~
- ~~(b) — in an ambient temperature between 293 K and 303 K.~~

~~The procedure excludes all types of external chargers.~~

~~The end of REESS charge criteria corresponds to an automatic stop given by the on board charger.~~

~~This procedure includes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges.~~

~~5.1.3. — Procedure from paragraphs 5.1.1. to and 5.1.2. shall be repeated two times.~~

#### 5.2.2. Discharge of the REESS

The REESS is discharged at 70 per cent  $\pm$  5 per cent of the nominal power of the system.

Stopping the discharge occurs:

- (a) when minimum SOC as specified by the manufacturer is reached.

#### 5.2.3. Soak

Within fifteen minutes of completing the REESS discharge operation specified in paragraph 5.2.2., the REESS is stored in the soak area. For a minimum of 12 hours and a maximum of 36 hours, between the end of the REESS discharge and the start of the hydrogen emission test during a normal charge. For this period, the REESS shall be soaked at 293 K  $\pm$  2 K.

#### 5.2.4. Hydrogen emission test during a normal charge

5.2.4.1. Before the completion of the soak period, the measuring chamber shall be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) shall also be turned on at this time.

5. 2.4.2. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.
5. 2.4.3. At the end of the soak the REESS shall be moved into the measuring chamber.
5. 2.4.4. The REESS is charged according to normal charge procedure as specified in paragraph 5.2.4.7 below.
5. 2.4.5. The REESS enclosure are closed and sealed gas-tight within two minutes from electrical interlock of the normal charge step.
5. 2.4.6. The start of a normal charge for hydrogen emission test period begins when the chamber is sealed. The hydrogen concentration, temperature and barometric pressure are measured to give the initial readings  $C_{H2i}$ ,  $T_i$  and  $P_i$  for the normal charge test.

These figures are used in the hydrogen emission calculation (paragraph 6.). The ambient enclosure temperature  $T$  shall not be less than 291 K and no more than 295 K during the normal charge period.

#### 5. 2.4.7. Procedure of normal charge

The normal charge is carried out with the suitable charger and consists of the following steps:

- (a) charging at constant power during  $t_1$ ;
- (b) over-charging at constant current during  $t_2$ . Over-charging intensity is specified by manufacturer and corresponds to the one used during equalisation charging.

The end of REESS charge criteria corresponds to an automatic stop given by the charger to a charging time of  $t_1 + t_2$ . This charging time will be limited to  $t_1 + 5$  h, even if a clear indication is given by a suitable instrumentation that the REESS is not yet fully charged.

5. 2.4.8. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.
5. 2.4.9. The end of the emission sampling period occurs  $t_1 + t_2$  or  $t_1 + 5$  h after the beginning of the initial sampling, as specified in paragraph 5.4.6. The different times elapsed are recorded. The hydrogen concentration, temperature and barometric pressure are measured to give the final readings  $C_{H2f}$ ,  $T_f$  and  $P_f$  for the normal charge test, used for the calculation in paragraph 6.

#### 5. 2.5. Hydrogen emission test with the charger failure

5. 2.5.1. Within seven days maximum after having completed the prior test, the procedure starts with the discharge of the REESS of the vehicle according to paragraph 5.2.
5. 2.5.2. The steps of the procedure in paragraph 5.3 shall be repeated.
5. 2.5.3. Before the completion of the soak period, the measuring chamber shall be purged for several minutes until a stable hydrogen background is obtained. The enclosure mixing fan(s) shall also be turned on at this time.

5. 2.5.4. The hydrogen analyser shall be zeroed and spanned immediately prior to the test.
5. 2.5.5. At the end of the soak the REESS shall be moved into the measuring chamber.
5. 2.5.6. The REESS is charged according to failure charge procedure as specified in paragraph 5.2.5.9. below.
5. 2.5.7. The REESS enclosure shall be closed and sealed gas-tight within two minutes from electrical interlock of the failure charge step.
5. 2.5.8. The start of a failure charge for hydrogen emission test period begins when the chamber is sealed. The hydrogen concentration, temperature and barometric pressure are measured to give the initial readings  $C_{H2i}$ ,  $T_i$  and  $P_i$  for the failure charge test.

These figures are used in the hydrogen emission calculation (paragraph 6). The ambient enclosure temperature  $T$  shall not be less than 291 K and no more than 295 K during the charging failure period.

#### 5. 2.5.9. Procedure of charging failure

The charging failure is carried out with the suitable charger and consists of the following steps:

- (a) charging at constant power during  $t'_1$ ;
- (b) charging at maximum current as recommended by the manufacturer during 30 minutes. During this phase, the charger shall supply maximum current as recommended by the manufacturer.

5. 2.5.10. The hydrogen analyser shall be zeroed and spanned immediately before the end of the test.

5. 2.5.11. The end of test period occurs  $t'_1 + 30$  minutes after the beginning of the initial sampling, as specified in paragraph 5.5.8. The times elapsed are recorded. The hydrogen concentration, temperature and barometric pressure are measured to give the final readings  $C_{H2f}$ ,  $T_f$  and  $P_f$  for the charging failure test, used for the calculation in paragraph 6.

## 6. CALCULATION

The hydrogen emission tests described in paragraph 5 allow the calculation of the hydrogen emissions from the normal charge and charging failure phases. Hydrogen emissions from each of these phases are calculated using the initial and final hydrogen concentrations, temperatures and pressures in the enclosure, together with the net enclosure volume.

The formula below is used:

$$M_{H2} = k \times V \times 10^{-4} \times \left( \frac{\left(1 + \frac{V_{out}}{V}\right) \times C_{H2f} \times P_f}{T_f} - \frac{C_{H2i} \times P_i}{T_i} \right)$$

where:

$M_{H_2}$  = hydrogen mass, in grams

$C_{H_2}$  = measured hydrogen concentration in the enclosure, in ppm volume

$V$  = net enclosure volume in cubic metres ( $m^3$ ) corrected for the volume of the vehicle, with the windows and the luggage compartment open. If the volume of the vehicle is not determined a volume of  $1.42 m^3$  is subtracted.

$V_{out}$  = compensation volume in  $m^3$ , at the test temperature and pressure

$T$  = ambient chamber temperature, in K

$P$  = absolute enclosure pressure, in kPa

$k$  = 2.42

where:  $i$  is the initial reading  
 $f$  is the final reading

#### 6.1. Results of test

The hydrogen mass emissions for the REESS are:

$M_N$  = hydrogen mass emission for normal charge test, in grams

$M_D$  = hydrogen mass emission for charging failure test, in grams

Annex 7 - Appendix 1CALIBRATION OF EQUIPMENT  
FOR HYDROGEN EMISSION TESTING

## 1. CALIBRATION FREQUENCY AND METHODS

All equipment shall be calibrated before its initial use and then calibrated as often as necessary and in any case in the month before type approval testing. The calibration methods to be used are described in this appendix.

## 2. CALIBRATION OF THE ENCLOSURE

## 2.1. Initial determination of enclosure internal volume

2.1.1. Before its initial use, the internal volume of the chamber shall be determined as follows. The internal dimensions of the chamber are carefully measured, taking into account any irregularities such as bracing struts. The internal volume of the chamber is determined from these measurements.

The enclosure shall be latched to a fixed volume when the enclosure is held at an ambient temperature of 293 K. This nominal volume shall be repeatable within  $\pm 0.5$  per cent of the reported value.

2.1.2. The net internal volume is determined by subtracting  $1.42 \text{ m}^3$  from the internal volume of the chamber. Alternatively the volume of the test vehicle with the luggage compartment and windows open or REESS may be used instead of the  $1.42 \text{ m}^3$ .

2.1.3. The chamber shall be checked as in paragraph 2.3. If the hydrogen mass does not agree with the injected mass to within  $\pm 2$  per cent then corrective action is required.

## 2.2. Determination of chamber background emissions

This operation determines that the chamber does not contain any materials that emit significant amounts of hydrogen. The check shall be carried out at the enclosure's introduction to service, after any operations in the enclosure which may affect background emissions and at a frequency of at least once per year.

2.2.1. Variable-volume enclosure may be operated in either latched or unlatched volume configuration, as described in paragraph 2.1.1. Ambient temperature shall be maintained at  $293 \text{ K} \pm 2 \text{ K}$ , throughout the 4-hour period mentioned below.

2.2.2. The enclosure may be sealed and the mixing fan operated for a period of up to 12 hours before the four-hour background-sampling period begins.

2.2.3. The analyser (if required) shall be calibrated, then zeroed and spanned.

2.2.4. The enclosure shall be purged until a stable hydrogen reading is obtained, and the mixing fan turned on if not already on.

2.2.5. The chamber is then sealed and the background hydrogen concentration, temperature and barometric pressure are measured. These are the initial readings  $C_{H2i}$ ,  $T_i$  and  $P_i$  used in the enclosure background calculation.

2.2.6. The enclosure is allowed to stand undisturbed with the mixing fan on for a period of four hours.

2.2.7. At the end of this time the same analyser is used to measure the hydrogen concentration in the chamber. The temperature and the barometric pressure are also measured. These are the final readings  $C_{H2f}$ ,  $T_f$  and  $P_f$ .

2.2.8. The change in mass of hydrogen in the enclosure shall be calculated over the time of the test in accordance with paragraph 2.4 and shall not exceed 0.5 g.

### 2.3. Calibration and hydrogen retention test of the chamber

The calibration and hydrogen retention test in the chamber provides a check on the calculated volume (paragraph 2.1) and also measures any leak rate. The enclosure leak rate shall be determined at the enclosure's introduction to service, after any operations in the enclosure which may affect the integrity of the enclosure, and at least monthly thereafter. If six consecutive monthly retention checks are successfully completed without corrective action, the enclosure leak rate may be determined quarterly thereafter as long as no corrective action is required.

2.3.1. The enclosure shall be purged until a stable hydrogen concentration is reached. The mixing fan is turned on, if not already switched on. The hydrogen analyser is zeroed, calibrated if required, and spanned.

2.3.2. The enclosure shall be latched to the nominal volume position.

2.3.3. The ambient temperature control system is then turned on (if not already on) and adjusted for an initial temperature of 293 K.

2.3.4. When the enclosure temperature stabilizes at  $293\text{ K} \pm 2\text{ K}$ , the enclosure is sealed and the background concentration, temperature and barometric pressure measured. These are the initial readings  $C_{H2i}$ ,  $T_i$  and  $P_i$  used in the enclosure calibration.

2.3.5. The enclosure shall be unlatched from the nominal volume.

2.3.6. A quantity of approximately 100 g of hydrogen is injected into the enclosure. This mass of hydrogen shall be measured to an accuracy of  $\pm 2$  per cent of the measured value.

2.3.7. The contents of the chamber shall be allowed to mix for five minutes and then the hydrogen concentration, temperature and barometric pressure are measured. These are the final readings  $C_{H2f}$ ,  $T_f$  and  $P_f$  for the calibration of the enclosure as well as the initial readings  $C_{H2i}$ ,  $T_i$  and  $P_i$  for the retention check.

2.3.8. On the basis of the readings taken in paragraphs 2.3.4 and 2.3.7 and the formula in paragraph 2.4, the mass of hydrogen in the enclosure is calculated. This shall be within  $\pm 2$  per cent of the mass of hydrogen measured in paragraph 2.3.6.

2.3.9. The contents of the chamber shall be allowed to mix for a minimum of 10 hours. At the completion of the period, the final hydrogen concentration, temperature and barometric pressure are measured and recorded. These are the final readings  $C_{H2f}$ ,  $T_f$  and  $P_f$  for the hydrogen retention check.

2.3.10. Using the formula in paragraph 2.4, the hydrogen mass is then calculated from the readings taken in paragraphs 2.3.7 and 2.3.9. This mass may not differ by more than 5 per cent from the hydrogen mass given by paragraph 2.3.8.

#### 2.4. Calculation

The calculation of net hydrogen mass change within the enclosure is used to determine the chamber's hydrocarbon background and leak rate. Initial and final readings of hydrogen concentration, temperature and barometric pressure are used in the following formula to calculate the mass change.

$$M_{H2} = k \times V \times 10^{-4} \times \left( \frac{\left(1 + \frac{V_{out}}{V}\right) \times C_{H2f} \times P_f}{T_f} - \frac{C_{H2i} \times P_i}{T_i} \right)$$

where:

$M_{H2}$  = hydrogen mass, in grams

$C_{H2}$  = measured hydrogen concentration into the enclosure, in ppm volume

$V$  = enclosure volume in cubic metres ( $m^3$ ) as measured in paragraph 2.1.1.

$V_{out}$  = compensation volume in  $m^3$ , at the test temperature and pressure

$T$  = ambient chamber temperature, in K

$P$  = absolute enclosure pressure, in kPa

$k$  = 2.42

where: i is the initial reading

f is the final reading

### 3. CALIBRATION OF THE HYDROGEN ANALYSER

The analyser should be calibrated using hydrogen in air and purified synthetic air. See paragraph 4.8.2. of annex 7.

Each of the normally used operating ranges are calibrated by the following procedure:

3.1. Establish the calibration curve by at least five calibration points spaced as evenly as possible over the operating range. The nominal concentration of the calibration gas with the highest concentrations to be at least 80 per cent of the full scale.

3.2. Calculate the calibration curve by the method of least squares. If the resulting polynomial degree is greater than 3, then the number of calibration points shall be at least the number of the polynomial degree plus 2.

3.3. The calibration curve shall not differ by more than 2 per cent from the nominal value of each calibration gas.

3.4. Using the coefficients of the polynomial derived from paragraph 3.2. above, a table of analyser readings against true concentrations shall be drawn by steps no greater than 1 per cent of full scale. This is to be carried out for each analyser range calibrated.

This table shall also contain other relevant data such as:

(a) date of calibration;

(b) span and zero potentiometer readings (where applicable);

(c) nominal scale;

(d) reference data of each calibration gas used;

(e) real and indicated value of each calibration gas used together with the percentage differences;

(f) calibration pressure of analyser.

3.5. Alternative methods (e.g. computer, electronically controlled range switch) can be used if it is proven to the technical service that these methods give equivalent accuracy.

Annex 7 - Appendix 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE/REESS FAMILY

1. PARAMETERS DEFINING THE FAMILY RELATIVE TO HYDROGEN EMISSIONS

The family may be defined by basic design parameters which shall be common to vehicles/REESS within the family. In some cases there may be interaction of parameters. These effects shall also be taken into consideration to ensure that only vehicles/REESS with similar hydrogen emission characteristics are included within the family.

2. To this end, those vehicle/REESS types whose parameters described below are identical are considered to belong to the same hydrogen emissions.

**REESS:**

- (a) trade name or mark of the REESS
- (b) indication of all types of electro-chemical couples used
- (c) number of REESS cells
- (d) number of REESS subsystems
- (e) nominal voltage of the REESS (V)
- (f) REESS energy (kWh)
- (g) gas combination rate (in per cent)
- (h) type(s) of ventilation for REESS subsystem
- (i) type of cooling system (if any)

**Charger, if subsystem of the REESS:**

- (a) make and type of different charger parts
- (b) output nominal power (kW)
- (c) maximum voltage of charge (V)
- (d) maximum intensity of charge (A)
- (e) make and type of control unit (if any)

- (f) diagram of operating, controls and safety
- (g) characteristics of charge periods