TECHNICAL REPORT

# ISO/TR 11954

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# Fuel cell road vehicles — Maximum speed measurement

*Véhicules routiers à pile à combustible — Mesure de la vitesse maximale*

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# Foreword

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ISO/TR 11954 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electrically propelled road vehicles*.

# Introduction

Fuel cell vehicles (FCV) include the following types:

— pure fuel cell vehicles (PFCV), in which the fuel cell system is the only on-board energy source for propulsion and auxiliary systems,

— fuel cell hybrid electric vehicles (FCHEV), in which the fuel cell system is integrated with an on-board rechargeable energy storage system (RESS) for electric energy supply to propulsion and auxiliary systems.

FCHEV design options include the following:

a) externally chargeable or non-externally chargeable;

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

c) driver-selected operating modes: if FCHEV has no driver-selected operating mode, it has only an FCHEV mode.

Table 1 shows the classification of FCHEV.

**Table 1 — FCHEV classification**

| | **Chargeability** | **Operating mode** |
|---|---|---|
| **FCHEV** | externally chargeable | FCHEV mode |
| | | EV mode |
| | **non-externally chargeable** | **FCHEV mode** |
| | | EV mode |

This Technical Report is applicable to PFCV and to non-externally chargeable FCHEV with FCHEV mode only (see shaded boxes in Table 1).

# Fuel cell road vehicles — Maximum speed measurement

## 1 Scope

This Technical Report describes test procedures for measuring the maximum road speed of fuel cell passenger cars and light duty trucks which use compressed hydrogen and which are not externally chargeable, in accordance with national or regional standards or legal requirements.

## 2 Terms and definitions

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

**2.1**
**rechargeable energy storage system**
**RESS**
system that stores energy for delivery of electric energy and that is rechargeable

EXAMPLE Batteries, capacitors.

**2.2**
**RESS state of charge**
**RESS SOC**
residual capacity of RESS available to be discharged

NOTE RESS state of charge is normally expressed as a percentage of full charge.

**2.3**
**fuel cell hybrid electric vehicle operation mode**
**FCHEV operation mode**
mode of an FCHEV in which both RESS and fuel cell system are used sequentially or simultaneously for vehicle propulsion

NOTE The fuel cell system can also charge the RESS during propulsion or standstill.

**2.4**
**maximum speed**
highest average speed that the vehicle can maintain throughout a specified test

**2.5**
**test mass**
mass of a vehicle prepared for a defined test procedure

# 3 Parameters, units and accuracy of measurements

Table 2 shows parameters and their units and accuracy.

**Table 2 — Parameters, units and accuracy of measurements**

| Parameter | Unit | Accuracy |
|---|---|---|
| Time | s | ± 0,1 s |
| Distance | m | ± 0,1 % |
| Air temperature | °C or K | ± 1 °C or ± 1 °K |
| Air pressure | kPa | ± 1 kPa |
| Speed | km/h | ± 1 % or ± 0,1 km/h whichever is greater |
| Mass | kg | ± 0,5 % |

# 4 Descriptions

## 4.1 General

The maximum speed of the vehicle should be measured in accordance with the descriptions in this clause.

## 4.2 Preparation of the vehicle

The configuration of the vehicle and its attitude should be as determined by the manufacturer. In addition, the vehicle should be clean, the windows and air entries should be closed and only the accessories necessary for the operation of the vehicle for the purposes of the test should be in use. The viscosity of the oils for the mechanical moving parts and the tyre pressures (for operation under full load at maximum speed) should conform to the specifications of the vehicle manufacturer.

The running in of the transmission and tyres should be carried out in accordance with the manufacturer's instructions.

The fuel used should be the commercial grade for the type of vehicle tested or, in the event of a dispute, one of those prescribed in ISO/TS 14687-2.

## 4.3 Track characteristics

### 4.3.1 General

The measurements should be taken on a straight track (see 4.3.2) and/or a loop track (see 4.3.3). The surface of the track should be hard, smooth, clean and dry, and should give good adhesion.

### 4.3.2 Measurement on straight track

#### 4.3.2.1 Lengths

The length, $L$, in metres, should be selected in relation to the precision of the apparatus and the method used for measuring the time, $t$, of the run, in seconds, so that the actual speed can be determined to within ± 1 %. The length of the measuring zone should be at least 1 000 m. The length actually used for the measurement should be recorded in the test report.

#### 4.3.2.2 Stabilizing zone

The stabilizing zone should be of the same nature as the measuring zone, approximately straight and of sufficient length for the vehicle to have stabilized at its maximum speed by the time the vehicle reaches the measuring zone.

#### 4.3.2.3 Slopes

##### 4.3.2.3.1 Longitudinal

In the stabilizing and the measuring zones, the longitudinal slope should not exceed 0,5 %.

##### 4.3.2.3.2 Transverse

Transverse slope should not exceed 3 % in the measuring zone.

#### 4.3.2.4 Section of loop track

A section of loop track may be regarded as “straight” if

— the descriptions of 4.3.1 to 4.3.2.3.1 are satisfied, and

— the centrifugal inertia reaction is less than 20 % of the initial mass of the vehicle and is compensated by the transverse slope of the track.

### 4.3.3 Measurement on loop track

#### 4.3.3.1 Lengths

The length of the loop should be not less than 2 000 m. To calculate the maximum speed, the length of run should be the distance actually covered by the vehicle.

The loop track should be a convex curve and may vary from a perfect circle to straight sections linked by approximately circular sections. The radius of curves should be not less than 200 m. The effects of centrifugal force should be compensated by the transverse profile of the curves in such a way that the vehicle holds a normal line without any action on the steering wheel.

#### 4.3.3.2 Correction factor for loop track

A correction factor determined experimentally by the procedure given in UNECE R 68, Annex 3, or by national or regional standards, or legal requirements, may be applied for loop track. This correction factor should be subject to confirmation by the administrative service at the time of approval by the technical service responsible for the tests. The factor may in no case entail a correction exceeding 5 %. However, for vehicles equipped with a speed regulator, the factor should not be applied if the regulator is in operation during the test.

## 4.4 Atmospheric conditions

### 4.4.1 Air density

The air density at the time of the test, calculated by Equation (1), should not vary by more than 7,5 % from the air density in the reference conditions.

The air density in test conditions, $d_r$, should be calculated as follows:

$$d_r = d_0 \times \frac{H_T}{H_0} \times \frac{T_0}{T_T} \quad (1)$$

where

$d_0$ is the air density in reference conditions;

$H_T$ is the pressure during the test;

$T_T$ is the absolute temperature during the test, in kelvins;

$H_0$ is the pressure at reference conditions [$H_0 = 100$ kPa];

$T_0$ is the temperature at reference conditions [$T_0 = 293$ K (20 °C)].

In addition, the atmospheric pressure during the tests should be at least 91 kPa and temperature should be at least 278 K (5 °C).

### 4.4.2 Wind

The average wind speed measured at a height of 1 m above the ground should be less than 3 m/s. Gusts should be less than 5 m/s.

### 4.4.3 Relative humidity

The relative humidity should be less than 95 % and the track should be dry.

## 4.5 Test method

### 4.5.1 Warming up

Immediately before the test, the parts of the vehicle that might affect the measurement should be in the stable temperature conditions specified by the manufacturer.

During measurement, the gear ratio used should be that in which the vehicle is able to reach its maximum steady speed. The accelerator should be fully depressed.

### 4.5.2 RESS state of charge preconditioning

RESS SOC should be conditioned in accordance with the vehicle manufacturer's procedure.

### 4.5.3 Test procedures for maximum speed measurement on a straight track

#### 4.5.3.1 Standard test procedure (Two direction test)

In order to reduce the influence of factors such as road slope and wind direction/speed, the test should be executed in both directions of the test track in direct sequence, taking care to use the same stretch of the track.

The time, $t_i$, taken to cover the measured length, $L$, should be recorded. It should be checked that the speed does not vary by more than 2 % at any moment during the run.

This procedure should be carried out at least three times in each direction. The variation between the extreme values of the six "$t_i$" values recorded should not exceed 3 %.

Time, $t$, expressed in seconds, should be determined by Equation (2):

$$t = \frac{1}{6}\sum_{1}^{6} t_i \tag{2}$$

and the test speed, $V$, expressed in kilometres per hour, should be determined by Equation (3):

$$V = \frac{3{,}6L}{t} \tag{3}$$

#### 4.5.3.2 Single direction test

Testing in one direction only should be permissible if, in view of the characteristics of the circuit, it is not possible for the vehicle to reach its maximum speed in both directions.

In this case, the characteristics of the track should be as set out in 4.3.1 and 4.3.2. In addition:

— the variation in altitude should not exceed 1 m between any two points;

— the run should be repeated five times in immediate succession;

— the axial wind component speed should not exceed 2 m/s.

The maximum speed, $V_i$, should be determined by the correction formula in Equation (4), taking into account wind speed:

$$V_i = V_\mathrm{r} \pm \left(V_v \times f\right) \tag{4}$$

where

$V_\mathrm{r}$ is the maximum speed measured for each run ($V_\mathrm{r} = 3{,}6L/t$);

$v$ is the axial wind component, in metres per second;

$V_v$ is the axial wind component, in kilometres per hour ($V_v = 3{,}6v$);

$f$ is the correction factor ($f = 0{,}6$).

NOTE See UNECE R 68 for further details about the correction factor.

If the axial wind component is in the opposite direction to the vehicle:

$$V_i = V_\mathrm{r} + \left(V_v \times f\right)$$

If there is a following wind:

$$V_i = V_\mathrm{r} - \left(V_v \times f\right)$$

If the extreme values of $V_i$ are discarded, the maximum speed, $V$, is calculated by Equation (5):

$$V = \frac{1}{3}\sum_1^3 V_i \tag{5}$$

#### 4.5.4 Determination of the maximum speed on loop track

The time, $t_i$, required for a complete circuit should be recorded. At least three measurements should be made with the vehicle following a path corresponding approximately to that taken at the test speed, i.e. not requiring any correction of course by action on the steering wheel. The difference between the extreme values measured should not exceed 3 %.

The mean time, $\overline{t}$ , should be determined by Equation (6):

$$\overline{t} = \frac{1}{3}\sum_1^3 t_i \tag{6}$$

The apparent maximum speed, $V_\mathrm{a}$, expressed in kilometres per hour, should be determined by the Equation (7):

$$V_\mathrm{a} = \frac{3{,}6L}{t} \tag{7}$$

where

$L$ is the length of the path actually covered on the loop track, in metres;

$t$ is the time, in seconds.

In order to calculate the maximum speed, $V$, the apparent maximum speed, $V_\mathrm{a}$, should then be corrected by an experimentally determined factor specific to the loop track used, as shown in Equation (8), taking into account in particular the effects of centrifugal force in the curves and the consequent changes in the attitude of the vehicle:

$$V = V_\mathrm{a} \times k \tag{8}$$

where $k$ is the correction factor determined in accordance with UNECE R 68, Annex 3, or with national or regional standards, or legal requirements, and $1{,}00 \leqslant k \leqslant 1{,}05$.

# Bibliography

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