FINAL
DRAFT

TECHNICAL
REPORT

ISO/DTR 17326

ISO/TC **22**/SC **37**

Secretariat: **DIN**

Voting begins on:
2023-09-04

Voting terminates on:
2023-10-30

Fuel cell road vehicles — Cold start performances under sub-zero temperature — Vehicles fuelled with compressed hydrogen

Véhicules routiers à piles à combustible — Performances de démarrage à froid à des températures inférieures à zéro — Véhicules alimentés en hydrogène comprimé

Reference number
ISO/DTR 17326:2023(E)

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Published in Switzerland

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Foreword

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This document was prepared by Technical Committee ISO/TC 22 *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

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Fuel cell road vehicles — Cold start performances under sub-zero temperature — Vehicles fuelled with compressed hydrogen

1 Scope

This document describes the test methods for the cold start performances of fuel cell hybrid electric vehicles (FCHEV) under sub-zero temperature conditions.

This document applies to FCHEV as passenger cars and light duty trucks with a maximum authorized total mass of 3 500 kg (hereinafter referred to as vehicle) and fuelled with compressed hydrogen.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TR 8713, *Electrically propelled road vehicles — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 8713 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
ADT
applicable driving test
single driving test schedule which is specified for a relevant region

Note 1 to entry: Chassis dynamometer test schedules for a relevant region are the worldwide light-duty test cycle (WLTC) or the urban dynamometer driving schedule (UDDS).

[SOURCE: ISO 23274-2:2021, 3.1]

3.2
FCHEV
fuel cell hybrid electric vehicle
electrically propelled vehicle with a *rechargeable energy storage system (RESS)* (3.6) and a fuel cell system as power sources for vehicle propulsion

[SOURCE: ISO 23828:2022, 3.7]

3.3
fuel cell stack
assembly of two or more fuel cells, which are electrically connected

[SOURCE: ISO 6469-3:2021, 3.20]

3.4
fuel cell system
system typically containing the following subsystems: *fuel cell stack* (3.3), air processing system, fuel processing system, thermal management, water management, and their control system

[SOURCE: ISO 6469-3:2021, 3.21]

3.5
rated power of the fuel cell system
maximum continuous power output from the *fuel cell system* (3.4) as specified by the vehicle manufacturer

3.6
RESS
rechargeable energy storage system
rechargeable system that stores energy for delivery of electric energy for the electric drive

EXAMPLE Battery, capacitor, flywheel.

[SOURCE: ISO 6469-1:2019, 3.117]

3.7
RESS SOC
RESS state of charge
residual capacity of *rechargeable energy storage system (RESS)* (3.6) available to be discharged

[SOURCE: ISO/TR 11954:2023, 3.11]

4 Abbreviated terms

ECU electronic control unit

VIN vehicle identification number

5 Test instrumentation

The test instrumentation has the accuracy levels as given in Table 1, unless otherwise specified in the relevant regional ADT standard.

Table 1 — Accuracy of measured values[a]

Item	Unit	Accuracy
Time	s	±0,1 s
Distance	m	±0,1 %
Speed	km/h	±1 %
Mass	kg	±0,5 %
Temperature	°C	±1 °C

[a] If necessary, DC current and voltage accuracy are specified by the vehicle manufacturer.

6 Vehicle conditions

The vehicle conditions are the following:

— the outline structure and technical parameters of the vehicle is maintained by default;

— the viscosity of the lubricating oil for mechanical moving parts is based on the vehicle manufacturer's requirements;

— the corresponding coolant is selected for a variety of ambient temperatures according to the vehicle manufacturer's requirements;

— ISO 14687 and the equivalent regional standard apply to the test fuel.

7 Test temperature conditions

From the beginning of the soak to the end of the test, the test temperature is controlled within +2 K of the set temperature.

The test temperature is set in agreement with the vehicle manufacturer. It is preferable -7 °C, but not higher than 0 °C and not lower than -30 °C.

The air temperature is measured at the test chamber's cooling fan outlet at a minimum frequency of 0,1 Hz.

For the soak area, the sensor is at least 10 cm away from the wall of the soak area and shielded from direct air flow.

8 Test methods

8.1 General

The whole test process is given in Figure A.1.

8.2 Soak method under sub-zero temperature

The vehicle is soaked according to the following steps.

a) Before the start of the soak, it is possible to adjust the vehicle state and the rechargeable energy storage system (RESS) state of charge (SOC) in accordance with the vehicle manufacturer's requirements. The adjustment duration, t, the RESS SOC before and after the adjustment, and the fuel cell system state during the adjustment process are recorded.

b) If necessary, for the measurement of hydrogen consumption during cold start, the additional external tank is connected to the vehicle in accordance with the methods described in ISO 23828. The originally installed tank is shut off during the test.

c) Test chamber is set to reach the target temperature directly, or according to the temperature drop curve instructed by the vehicle manufacturer.

d) During the time when ambient temperature drops to the set temperature, a start and shutdown operation is possible in accordance with the vehicle manufacturer's specifications.

e) The time measurement is started after the test temperature reaches the set temperature. Note that the effective soaking time is not less than 12 h.

8.3 Cold start performance test under sub-zero temperature

The cold start performance test under sub-zero temperature is performed by the following steps. Data sampling is started as soon as the vehicle is started. Parameters (see Figure B.1), such as voltage of fuel cell stack, U_{FC}, current of fuel cell stack, I_{FC}, voltage of RESS, U_{RESS}, and current of RESS, I_{RESS}, are collected. This is possible using a measurement method specified by the vehicle manufacturer by using data from the ECU. Data sampling ends after the vehicle is completely shut down.

a) The vehicle is soaked in accordance with the information presented in 8.2.

b) After soaking, an external source of hydrogen is turned on (if necessary), then the vehicle is started in accordance with the starting procedure specified by the vehicle manufacturer.

c) After the action of starting the vehicle, the heating device, air conditioning, etc. can be switched on in accordance with the requirements specified by the vehicle manufacturer to consume the power.

d) Time t_1 from starting the vehicle to the vehicle powertrain being ready (e.g. “READY” or “OK” is displayed on the vehicle dashboard) is recorded.

e) Time t_2 from starting the vehicle to the output power of the fuel cell stack is not less than 1 kW (namely, cold start time under sub-zero temperature) is recorded. After the output power of fuel cell stack reaching 1 kW, the fuel cell stack can continuously operate for 10 min at not less than 1 kW or cumulatively operate for 10 min at not less than 1 kW within 20 min after reaching 1 kW. If necessary, total hydrogen consumption C_{H2} from starting the vehicle to t_2 is recorded.

f) The vehicle is shut down in accordance with the vehicle manufacturer's procedure and terminate the test.

g) After completing all the above steps, it is considered that the vehicle starts successfully at the set temperature. If the vehicle shuts down during the starting process, then the start fails and the test is restarted in accordance with the step a) to f).

8.4 Launch performance test under sub-zero temperature

8.4.1 Determining the dynamometer load coefficient

8.4.1.1 Vehicle road load and its reproduction on chassis dynamometer could be determined according to ISO 10521 series. The regenerative braking systems, which works even when the brake pedal is not depressed, is disable during the deceleration portion of coast-down testing on both the test track and dynamometer.

8.4.1.2 The dynamometer load coefficient is adjusted to simulate the operation conditions of the vehicle on real road in sub-zero temperature environment. The adjustment is based on the identified changing characteristics of road load under sub-zero temperature, it can also reduce the sliding time of the road load measured in accordance with 8.4.1.1 by a percentage specified by the vehicle manufacturer to obtain the load as the alternative road load.

8.4.2 Setting of vehicle's driving mode

If the vehicle’s driving mode recommended by the vehicle manufacturer can match the ADT curve, then the mode recommended by the vehicle manufacturer is adopted. If the vehicle’s driving mode recommended by the vehicle manufacturer fails to match to the ADT curve, then the mode with a maximum speed is selected.

8.4.3 Test method

The launch performance test under sub-zero temperature is performed according to the following steps. Data sampling is started as soon as the vehicle is started. Parameters, such as voltage of fuel cell stack U_{FC}, current of fuel cell stack I_{FC}, voltage of RESS U_{RESS}, and current of RESS I_{RESS} are collected. Data sampling ends after the vehicle is completely shut down.

a) The vehicle is soaked in accordance with the information presented in 8.2.

b) After soaking, an external source of hydrogen is turned on (if necessary), then the vehicle is started in accordance with the starting procedure specified by the vehicle manufacturer.

c) Time t_1 from starting the vehicle to the vehicle powertrain being ready (e.g. "READY" or "OK" is displayed on the vehicle dashboard) is recorded.

d) After the vehicle powertrain is ready, the driving mode is switched to the driveable mode and the vehicle is operated at fully depressed accelerator pedal until the output power of the fuel cell stack

is not less than 50 % of the rated power of the fuel cell system (P_{FCS}), and time t_3 is recorded. If necessary, total hydrogen consumption C_{H2} from starting the vehicle to t_3 is recorded.

e) The driveable mode is kept, the accelerator pedal is released, the brake pedal is pressed down slowly, and the vehicle is stopped within 1 min.

f) Within 3 min after the stop, the drive test is carried out in accordance with the information of the relevant regional ADT. One drive cycle is performed in the test.

g) The vehicle is shut down in accordance with the procedure specified by the vehicle manufacturer and terminate the test.

h) After completing all the above steps, it is considered that the vehicle launches successfully at the set temperature. If the condition of termination criteria in 8.4.5 is reached during the test process, then the test fails. In that case, the test is restarted in accordance with the steps a) to g).

8.4.4 Tolerance of drive cycle test

Tolerances of speed and time on the ADT cycle are based on the requirements of the relevant regional ADT procedure.

8.4.5 Test termination criteria

The test is terminated if one of the following conditions is met:

a) when an indicator to stop the vehicle is presented by the vehicle dashboard;

b) when the vehicle fails to conform to the tolerance specifications provided in 8.4.4 during the launch test under sub-zero temperature;

c) if the maximum vehicle speed declared by the vehicle manufacturer is less than the maximum speed of the ADT cycle, and the vehicle cannot reach the declared maximum vehicle speed.

8.5 Requirements of data acquisition

The data sampling frequency is not less than 10 Hz.

Alternatively, when the voltage and current of the fuel cell stack cannot be measured directly due to the vehicle structure, the voltage and current data of ECU can be used, or the output voltage and current of the DC/DC converter after the fuel cell stack can be measured.

9 Test data processing

According to the vehicle manufacturer's requirements, if necessary, the total output energy of the fuel cell stack and RESS in the cold start test under sub-zero temperature in 8.3 is calculated in accordance with Annex B.

According to the vehicle manufacturer's requirements, if necessary, the total output energy of the fuel cell stack and RESS in the launch test under sub-zero temperature in 8.4 is calculated in accordance with Annex B.

10 Test records

The test results are recorded in accordance with Annex C (Tables C.1 and C.2).

Annex A
(informative)

Test process

A.1 Test process

The test process is shown in Figure A.1.

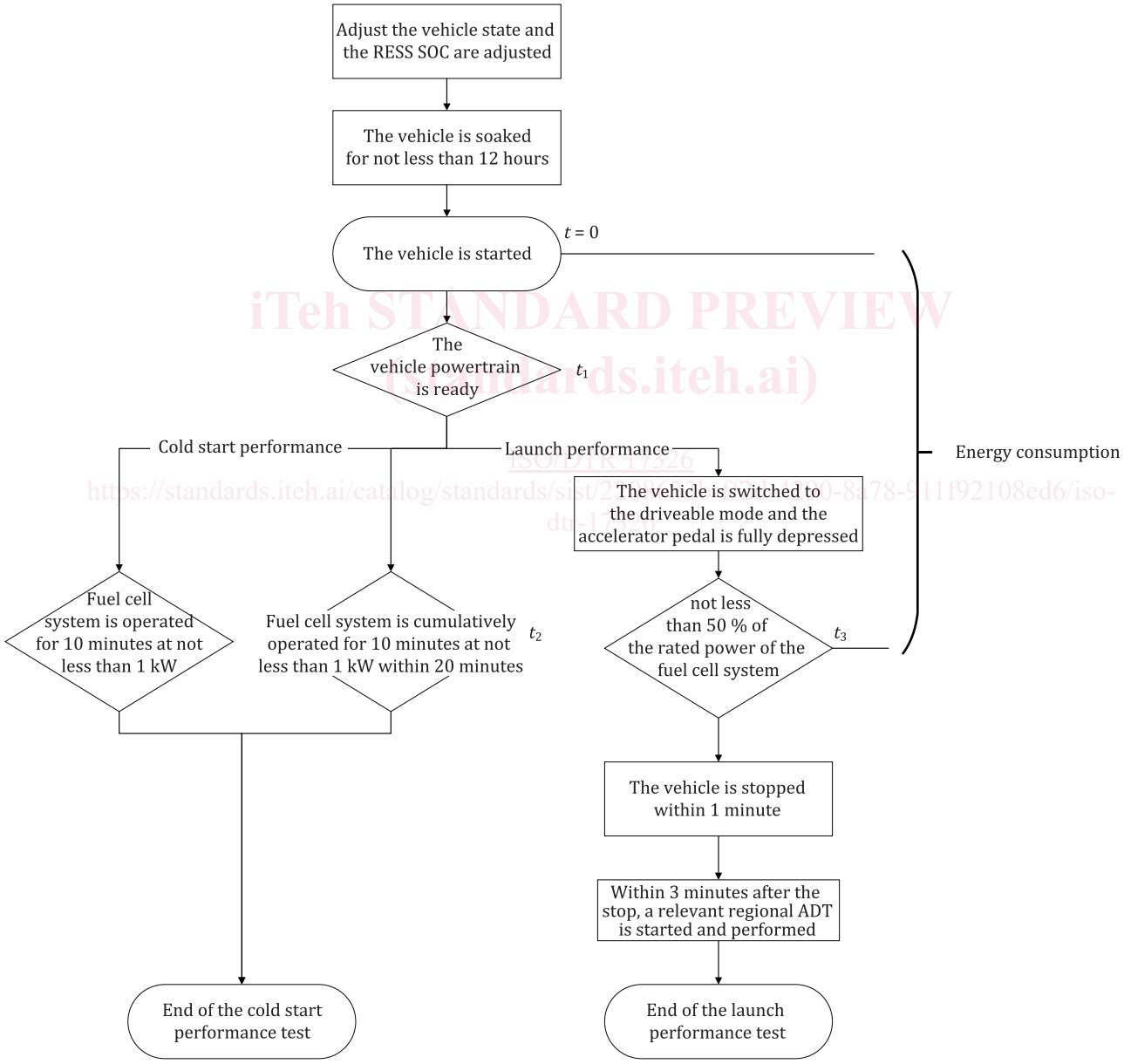

Figure A.1 — The diagram of test process