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**Testing methods for small polymer
electrolyte fuel cell power systems**

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by the Japan Electrical Manufacturers' Association (JEMA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

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Testing methods for small polymer electrolyte fuel cell power systems

1 Scope

This Japanese Industrial Standard specifies the testing methods for safety and performance for the stationary and portable small polymer electrolyte fuel cell power system (hereafter referred to as “fuel cell system”).

Following this Standard does not exempt any person, organization or business enterprise from the responsibilities to observe other related regulations.

This Standard is applied to the fuel cell system applicable to the following items.

- a) **Type of fuel cell** Polymer electrolyte fuel cell (abbreviation: PEFC)
- b) **Output** Rated transmission output, less than 10 kW
- c) **Output mode** Grid-connected operation, grid-independent operation or independent operation of dc output or ac output, 220 V or less
- d) **Raw fuel** Gaseous fuel (city gas, liquefied petroleum gas, etc.), liquid fuel (kerosene, etc.) or hydrogen
- e) **Operating pressure** Maximum allowable working pressure of the portion through which fuel gas passes, less than 0.1 MPa
- f) **System configuration** Stationary and portable dedicated power generation system or cogeneration system stored in a package (except a micro fuel cell)

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 1302 *Insulation resistance testers*

JIS C 8800 *Glossary of terms for fuel cell power system*

JIS C 8960 *Glossary of terms for photovoltaic power generation*

JIS C 8962 *Testing procedure of power conditioner for small photovoltaic power generating systems*

JIS C 60068-2-30 *Basic environmental testing procedures Part 2: Tests Test Db: Damp heat, cyclic (12 + 12-Hour cycle)*

JIS C 60068-2-38 *Basic environmental testing procedures Part 2: Tests Test Z/AD: Composite temperature/humidity cyclic test*

JIS K 2201 *Gasoline for industrial purpose*

JIS K 2202 *Motor gasoline*

JIS K 2203 *Kerosine*

- JIS K 2240 *Liquefied petroleum gases*
- JIS K 2279 *Crude petroleum and petroleum products—Determination and estimation of heat of combustion*
- JIS K 2301 *Fuel gases and natural gas—Methods for chemical analysis and testing*
- JIS S 2093 *Test methods of gas burning appliances for domestic use*
- JIS S 2109 *Gas burning water heaters for domestic use*
- JIS S 3031 *General rules for test methods of oil burning appliances*
- JIS Z 8703 *Standard atmospheric conditions for testing*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions in **JIS C 8800** and **JIS C 8960** and the following apply.

3.1 cold state

state in which energy is not supplied from the outside and a polymer electrolyte fuel cell power generation unit (hereafter referred to as “power generation unit”) stops near at ordinary temperature

3.2 storage state

state in which although energy is supplied from the outside, a power generation unit stops in order to protect the equipment in the system

3.3 transmission output

electric output of an output terminal which is taken out from a power generation unit to the outside except the auxiliary equipment power of the power generation unit

3.4 start-up time

in the case of a power generation unit not needing utility power to maintain the storage state, the time required for the power generation unit to start generating transmission output from a cold state

In the case of a power generation unit needing utility power to maintain the storage state, the time required for the power generation unit to start generating transmission output from a storage state.

3.5 stand-by state

a state of a power generation unit in which it is maintained at such a temperature that it can output power to the outside, can readily switch to the operation mode of transmission and start outputting electric power, but not currently outputting any electric power to the outside

3.6 load change

automatic change to an ordered value of the output electric power of a power generation unit together with a certain load change order

3.7 response time up to rated power generation

time from the moment when the output operation moving to rated power generation is started by the moment when rated power generation is achieved

3.8 stop time

time from the moment when a stop operation is started in rated power generation to the moment when a power generation unit reaches the cold state specified in specifications

3.9 output response time

time from the moment when the change of electric output or thermal output is ordered until each output establishes a stable state within the tolerance of its setting value

3.10 90 % output response time

time from the moment when the change of electric output or thermal output is ordered until this output reaches 90 % of the desired value

3.11 start-up electric power

maximum electric power of a power generation unit required during start-up time

3.12 thermal output

heat quantity of exhaust heat recovery which can be recovered from a power generation unit

3.13 package

container in which main devices constituting a power generation unit such as a fuel cell stack, a fuel reformer, a power conditioner, a control unit, auxiliary equipment are stored

The container in which a power conditioner and others are stored may be separated from the package of a power generation unit.

3.14 amount of make-up water

amount of water which a power generation unit needs at the time of rated power generation, which is expressed in an average flow rate per hour

3.15 hot-water storage unit

unit which stores heat recovered from a power generation unit as hot-water and supplies it to the outside as necessary

It consists of a hot-water storage tank, a heat exchanger, a hot-water supply system, etc. Furthermore, heat functions by using gaseous fuel, liquid fuel, electricity, etc. are added to it as necessary.

3.16 indoor type

equipment installed and used indoors

3.17 outdoor type

equipment installed and used outdoors

3.18 unvented type

type in which combustion air is taken from surroundings of equipment and exhaust gas is discharged to surroundings of equipment

There are both types of an indoor type and an outdoor type.

3.19 vented type

type in which combustion air is taken indoors and exhaust gas is discharged outdoors

It is applied only in the case of an indoor type. Although there are a natural exhaust type and a forced exhaust type, only the forced exhaust type is applied in this Standard.

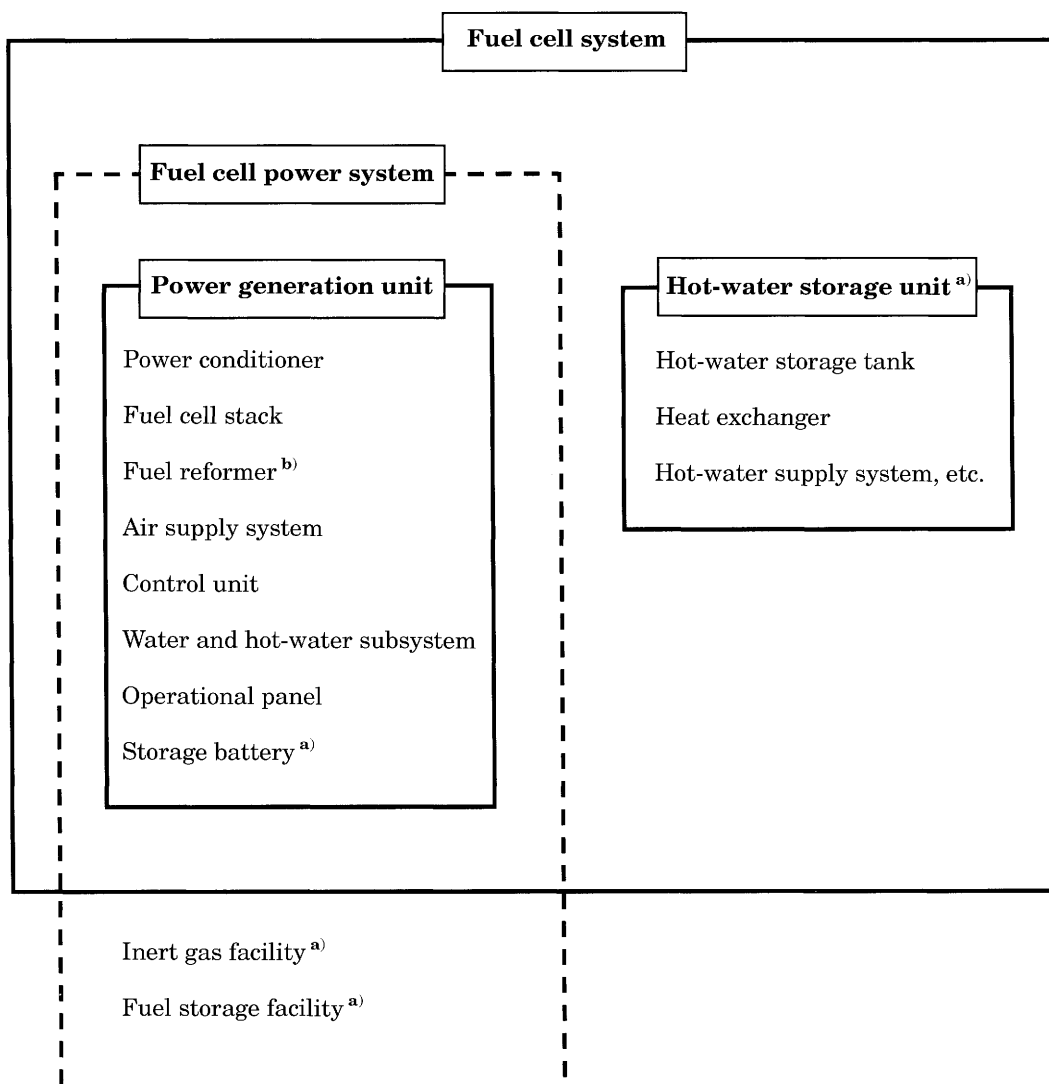
3.20 direct vent type

type in which a supply and exhaust tube is passed outdoors through the wall which has contact with the outside air, combustion air is taken outdoors and exhaust gas is discharged outdoors

It is applied only in the case of an indoor type. Although there are a natural supply and exhaust type and a forced supply and exhaust type, only the forced supply and exhaust type is applied in this Standard.

4 Configuration and scope

The basic configuration of the fuel cell system in the scope of this Standard shall be as shown in figure 1.



NOTE : Installation location of device, etc. is not limited to that in one package.

Notes ^{a)} Equipment or unit installed as necessary.

^{b)} It is not used when raw fuel is hydrogen.

Figure 1 Basic construction of fuel cell system

5 Conditions on test

5.1 Test condition

The test condition shall be as follows.

- a) **Condition of testing laboratory** The condition of a testing laboratory shall be as given in table 1 unless otherwise specified. However, in the case of test items the result of which is not likely to be affected by this condition, the conformance to table 1 is not necessary.

Table 1 Condition of testing laboratory

Item	Condition
Temperature of testing laboratory ^{a)}	The temperature of a testing laboratory shall be the “ordinary temperature” (standard temperature state class 15: 20 °C ± 15 °C) specified in table 1 of JIS Z 8703 , and the temperature fluctuation during test shall be ± 5 K.
Humidity of testing laboratory	The humidity of a testing laboratory shall be the “ordinary humidity” [standard humidity state class 20: (65 ± 20) %] specified in table 2 of JIS Z 8703 .
Indoor atmosphere	The indoor atmosphere shall not contain more than 0.2 % of carbon dioxide or more than 0.002 % of carbon monoxide. Furthermore, there shall not be any air flow which affects combustion.
Note ^{a)} The measurement of temperature of a testing laboratory shall normally be performed at a distance of about 1 m away from the equipment by fixing the temperature measurement part to almost the same height as that of the top surface of the equipment (when this height exceeds 1.5 m from the floor surface, the fixation height shall be 1.5 m from the floor surface), and at the four positions, i.e. in front and behind, to the left and to the right of the equipment. The arithmetic mean of thus obtained four measurements shall be taken as the room temperature. Care needs to be taken that the temperature measurement part is not directly affected by the combustion gas, radiant heat, etc. from the equipment.	

- b) **Installation condition and usage state of equipment** The installation condition and usage state of the equipment shall be as specified by the manufacturer (the state described in an operation manual, etc.) unless otherwise specified. However, this need not be observed in the case of test items the result of which is not likely to be affected by this condition.
- c) **Condition of power supply** The condition of a power supply for a test, etc. shall be as follows unless otherwise specified. However, this need not be observed in the case of test items the result of which is not likely to be affected by this condition.
- 1) **Equipment using household power supply** For the equipment using a household power supply, the test shall be performed by applying rated voltage with rated frequency.
 - 2) **Equipment using dry battery and storage battery** For the equipment using a dry battery and a storage battery, the test shall be performed by using the dry battery and the storage battery specified in an operation manual, etc.

5.2 Test fuel

5.2.1 Gaseous fuel

The type of gaseous fuel shall be a liquefied petroleum gas, a city gas and other gaseous fuels.

- a) **Type and quality of liquefied petroleum gas** The type and quality of a liquefied petroleum gas shall be as given in table 1 of **JIS K 2240**.

- b) **Type and quality of city gas** The type and quality of a city gas shall be as given in attached table 4 of **JIS S 2093**.
- c) **Type and quality of other gaseous fuels** The type and quality of gaseous fuels other than a liquefied petroleum gas and a city gas shall be as specified by the manufacturer.
- d) **Test gas**
- 1) **In the case of propane-powered equipment** The test gas containing propane (C_3H_8) of not less than 95 % in volume ratio (hereafter referred to as “propane”) shall be used.
 - 2) **In the case of butane-powered equipment** The test gas containing n-butane (C_4H_{10}) and i-butane (C_4H_{10}) in total of not less than 95 % in volume ratio (hereafter referred to as “butane”) shall be used.
 - 3) **In the case of city gas-powered equipment** The test gas having the same gas group name as the applicable gas group name marked on the name plate of the equipment shall be used (see attached table 4 of **JIS S 2093**).
- e) **Method for indication of condition of test gas** The condition of a test gas shall be indicated by the type of a test gas and the pressure of a test gas, and shall be as given in table 2 in the case of the propane-powered equipment and the butane-powered equipment and as given in table 3 (see attached table 4 of **JIS S 2093**) in the case of the city gas-powered equipment.

In addition, the condition of the test gas shall be indicated using the expression “symbol of type of test gas—symbol of pressure of test gas”.

Table 2 In the case of propane-powered equipment and butane-powered equipment

a) Type of test gas

Symbol	Type of test gas
P	Propane
B	Butane
S	Mixed gas of propane and butane

b) Pressure of test gas

Unit: kPa

Symbol	Pressure of test gas
1 (Maximum pressure)	3.3
2 (Standard pressure)	2.8
3 (Minimum pressure)	2.0

Table 3 In the case of city gas powered equipment

a) Type of test gas

Symbol	Type of test gas
0	Gas in the range of gas group
1	Gas in which incomplete combustion easily occurs
2	Gas in which back fire easily occurs
3	Gas which is easy to blow out
S	Any gas of 0, 1, 2 and 3.

b) Pressure of test gas

Unit: kPa

Symbol	Gas group to be applied		
	13A, 12A	6A	L1(6B, 6C, 7C) L2(5A, 5B, 5AN) L3(4A, 4B, 4C) 5C
1 (Maximum pressure)	2.5	2.2	2.0
2 (Standard pressure)	2.0	1.5	1.0
3 (Minimum pressure)	1.0	0.7	0.5

- f) **Condition of test gas** The condition of a test gas shall be as follows unless otherwise specified. However, this need not be observed in the case of test items the result of which is not likely to be affected by this condition.

1) In the case of propane-powered equipment

- 1.1) When the fuel gas supply pressure is in the pressure range given in table 2, the condition of the test gas shall be taken as P-2.
- 1.2) When the fuel gas supply pressure is outside the pressure range given in table 2, the condition of the test gas shall be taken as the intermediate value of maximum pressure and minimum pressure.

2) In the case of butane-powered equipment

- 2.1) When the fuel gas supply pressure is in the pressure range given in table 2, the condition of the test gas shall be taken as B-2.
- 2.2) When the fuel gas supply pressure is outside the pressure range given in table 2, the condition of the test gas shall be taken as the intermediate value of maximum pressure and minimum pressure.

3) In the case of city gas-powered equipment

- 3.1) When the fuel gas supply pressure is in the pressure range given in table 3, the condition of the test gas shall be taken as 0-2.
- 3.2) When the fuel gas supply pressure is outside the pressure range given in table 3, the condition of the test gas shall be taken as the intermediate value of maximum pressure and minimum pressure.

5.2.2 Liquid fuel

The type of a liquid fuel shall be a gasoline fuel, a kerosene fuel and other liquid fuels.

- a) **Type and quality of gasoline fuel** The type and quality of a gasoline fuel shall be an industrial gasoline and an automotive gasoline.

Type and quality of industrial gasoline shall be as given in table 1 and table 2 of **JIS K 2201**.

Type and quality of automotive gasoline shall be as given in table 1 of **JIS K 2202**.

- b) **Type and quality of kerosene fuel** The type and quality of kerosene fuel shall be as given in table 1 and table 2 of **JIS K 2203**.

- c) **Type and quality of other liquid fuels** The type and quality of liquid fuels other than gasoline fuel and kerosene fuel shall be as specified by the manufacturer.

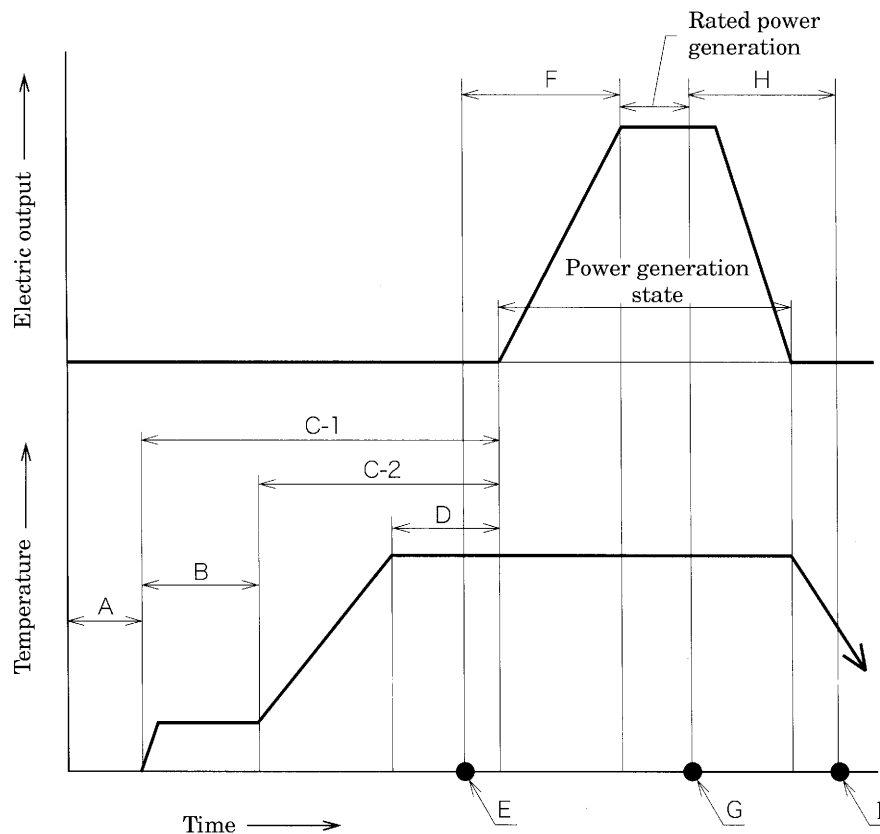
5.3 Measuring instrument for testing and test apparatus

The measuring instrument for testing and test apparatus to be used shall be as follows.

- a) **Equipment using gaseous fuel** The measuring instrument for testing and test apparatus to be used shall be as given in attached table 5 and attached table 6 of **JIS S 2093**, or those equivalent to these.
- b) **Equipment using liquid fuel** The measuring instrument for testing and test apparatus to be used shall be as given in attached table 1 of **JIS S 3031** or those equivalent to these.

5.4 Operation process of power generation unit

The representative operation process is shown in figure 2. Figure 2 illustrates a series of operational states of a power generation unit in chronological order, starting from the cold state, then start-up, power generation, and finally the stop. The definitions of terms to describe each operational state are also given.



NOTE : The symbols in the chart shall be as follows.

- A: Cold state (ordinary temperature, no input of energy)
- B: Storage state
- C: Start-up time
 - C-1: For the device which does not need utility power in order to maintain a storage state, measure from a cold state.
 - C-2: For the device which needs utility power, etc. in order to maintain a storage state, measure from a storage state.
- D: Stand-by state
- E: Start of rising operation of power generation output
- F: Response time up to rated power generation
- G: Start of stop operation
- H: Stop time
- I: Completion of stop operation (stop completion condition specified in specifications)
- C to H: Operating condition (from start of start-up operation to completion of stop operation)

Figure 2 Operation process chart of power generation unit

6 Fuel consumption test

This test shall be applied to a power generation unit. The block diagram of the power generation unit shall be as shown in figure 3.

6.1 Gaseous fuel consumption test

The gaseous fuel consumption test shall be as follows.

- a) **State of equipment** The equipment shall be under rated power generation and in a state in which 30 min or more have elapsed from the generation of electric power at the rating. Furthermore, preparation shall be performed so that each measurement item shown in figure 2 can be measured as follows.
- 1) **Fuel consumption volume to be measured** Install a volume flow meter for fuel (hereafter referred to as “fuel flow meter”) at the location nearest to the power generation unit and measure the fuel consumption volume to be measured in the power generation unit by using integrating flow.
 - 2) **Fuel temperature** Connect a thermometer to the location nearest to the fuel flow meter or the power generation unit, and measure the fuel temperature.
 - 3) **Fuel pressure** For the gaseous fuel-powered equipment, connect a differential pressure gauge (water column gauge, etc.) to the location nearest to the fuel flow meter and measure the gauge pressure of fuel.
 - 4) **Atmospheric pressure** Install an absolute pressure gauge at the location nearest to the power generation unit and the location not affected by exhaust, ventilation, etc. of the power generation unit, and measure the atmospheric pressure around the power generation unit.
- b) **Condition of test** The condition of test shall be as specified in clause 5.
- c) **Test method** After starting up the equipment, move to the rated power generation, and start the measurement with the equipment in the state in which 30 min or more have elapsed from the generation of electric power at the rating. The duration of measurement shall be 3 h or longer. However, when fuel is intermittently supplied, perform the data collection for a period of either 20 times the fuel supply interval or 3 h, whichever is longer. Measure the fuel consumption volume to be measured (F_1), and calculate the fuel consumption at a temperature of 15 °C and at an atmospheric pressure of 101.3 kPa according to the formulae (1) to (4). For the fuel temperature, fuel pressure and atmospheric pressure, use the average during the measurement time, respectively, for calculation.

Hot press correction of fuel consumption volume

$$F = \frac{F_1}{1\,000} \times \frac{288.2}{273.2 + T_1} \times \frac{P_1 + P_2}{101.3} \dots\dots\dots (1)$$

where, F : fuel consumption volume after hot press correction (m³)

F_1 : fuel consumption volume to be measured (L)

T_1 : average of fuel temperature (°C)

P_1 : average of fuel pressure (kPa)

P_2 : average of atmospheric pressure (kPa)

Fuel heating value per unit volume

$$C = \sum Q_a \times \frac{V_a}{100} \dots\dots\dots (2)$$

where, C : fuel heating value per unit volume (kWh/m³)

Q_a : heating value of each component at a temperature of 15 °C and at an atmospheric pressure of 101.3 kPa (kWh/m³)

V_a : volume percentage of each component (%)

Integrated fuel consumption

$$I = F \times C \quad \text{..... (3)}$$

where, I : integrated fuel consumption (kWh)

F : fuel consumption volume after hot press correction (m³)

C : fuel heating value per unit volume (kWh/m³)

Fuel consumption per unit time

$$I_s = \frac{I}{t} \quad \text{..... (4)}$$

where, I_s : fuel consumption per unit time (kW)

I : integrated fuel consumption (kWh)

t : measurement time (h)

Generally fuel consumption and heating value shall be based on lower heating value (LHV). However, in the case of indication in higher heating value (HHV), the measurement shall be performed based on higher heating value (HHV).

Atmospheric pressure P_2

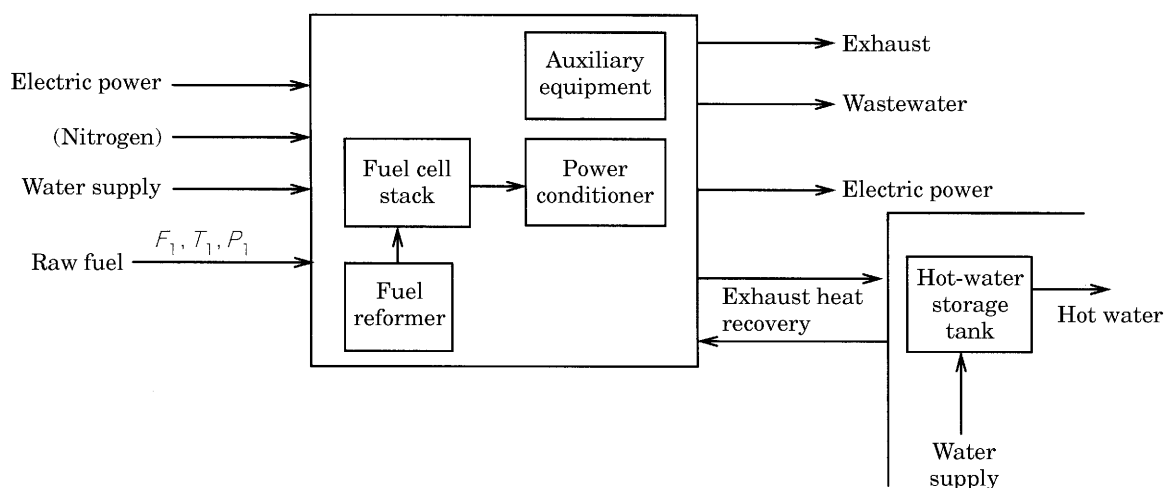


Figure 3 Power generation unit block diagram

d) **Record of results** An example of the test result table is shown in table 4.

Table 4 Measurement record table of fuel consumption test/gaseous fuel consumption test

Name of fuel cell power system _____	Measurement date _____ year _____ month _____ day _____ (day of week) _____
Rated output (at sending end) _____ kW	Measurement location _____
Type of raw fuel _____	Weather _____
Fuel heating value _____ kWh/m ³	Ambient temperature _____ °C
Flow meter _____	Relative humidity _____ RH%
Type _____	Atmospheric pressure _____ hPa
Product number _____	
Manufacturer _____	Measured by: _____

Measurement records

Test number	Time h:min	Fuel consumption volume to be measured F_1 L	Fuel temperature T_1 °C	Fuel pressure P_1 kPa	Atmospheric pressure P_2 kPa	Fuel consumption volume after hot press correction F m ³	Integrated fuel consumption I kWh	Fuel consumption per unit time I_s kW	NOTE

6.2 Liquid fuel consumption test

The liquid fuel consumption test shall be as follows.

- State of equipment** The equipment shall be under rated power generation and in a state in which 30 min or more have elapsed from the generation of electric power at the rating.
- Test condition** The test condition shall be as specified in clause 5.
- Test method** After starting up the equipment, move to the rated power generation, and start the measurement with the equipment in the state in which 30 min or more have elapsed from the generation of electric power at the rating. The duration of measurement shall be 3 h or more. However, when fuel is intermittently supplied, perform the data collection for a period of either 20 times the fuel supply interval or 3 h, whichever is longer. Measure the mass of the oil tank or the equipment including the oil tank at the time of test start and at the time of test end, and calculate the fuel consumption according to the formulae (5) and (6).

Integrated fuel consumption

$$I = (A - B) \times \frac{H}{3.6} \dots\dots\dots (5)$$

where, I : integrated fuel consumption (kWh)
 A : mass at the time of test start (kg)
 B : mass at the time of test end (kg)
 H : fuel heating value (MJ/kg)

Fuel consumption per unit time

$$I_s = \frac{I}{t} \dots\dots\dots (6)$$

where, I_s : fuel consumption per unit time (kW)
 I : integrated fuel consumption (kWh)
 t : measurement time (h)

Generally, the fuel consumption and heating value shall be based on lower heating value (LHV). However, in the case of indication in higher heating value (HHV), the measurement shall be performed based on higher heating value (HHV).

If necessary, the fuel heating value H shall be obtained as specified in **JIS K 2279**.

d) **Record of results** An example of the test result table is given in table 5.

Table 5 Measurement record table of fuel consumption test/liquid fuel consumption test

Name of fuel cell power system _____	Measurement date _____ year _____ month _____ day _____ (day of week)
Rated output (at sending end) _____ kW	Measurement location _____
Type of raw fuel _____	Weather _____
Fuel heating value _____ MJ/kg	Ambient temperature _____ °C
Flow meter _____	Relative humidity _____ RH%
Type _____	Atmospheric pressure _____ hPa
Product number _____	
Manufacturer _____	Measured by: _____

Measurement records

Test number	Time h:min	Mass at the time of test start A kg	Mass at the time of test end B kg	Integrated fuel consumption I kWh	Fuel consumption per unit time I_s kW	NOTE

7 Airtightness test

This test shall be applied to the power generation unit.

- a) **State of equipment** This test shall be performed in a state in which a power generation unit is stopped and the temperature of a reforming system and a fuel cell stack has fallen to approximately $20\text{ }^{\circ}\text{C} \pm 15\text{ }^{\circ}\text{C}$.
- b) **Test condition** The test condition shall be as specified in clause 5.
- c) **Test method**
 - 1) Measure the amount of leakage by connecting a precision gas flow meter to the inlet part with the shut-off valve closed in the passage up to the fuel inlet shut-off valve and by applying a pressure of 4.2 kPa with air or nitrogen from the inlet side. Alternatively, connect a pressure gauge, shut off introduction of air or nitrogen after pressure has become stabilized at 4.2 kPa and measure the pressure drop. Furthermore, for a booster or subsequent ones, measure the amount of leakage while applying the pressure of 1.1 times the maximum allowable working pressure with air or nitrogen.
 - 2) For the part which contains gas, after passing gas, confirm that there is no external leakage from each part with a bubble solution, a detector, etc.
 - 3) For the power generation unit using a liquid fuel, apply the maximum pressure in a steady state to the passage up to the fuel inlet shut-off valve and the pressure of 1.1 times the maximum allowable working pressure to the pressure-resistant section with air or nitrogen, and confirm that there is no leakage with a bubble solution, etc.
- d) **Record of results** An example of the test result table is given in table 6.

Table 6 Measurement record table of airtightness test

Name of fuel cell power system _____	Measurement date _____ year month day (day of week)
	Measurement location _____
Type of raw fuel _____	Weather _____
Temperature of reforming system _____ °C	Ambient temperature _____ °C
Temperature of cell stack _____ °C	Relative humidity _____ RH%
	Atmospheric pressure _____ hPa
	Measured by: _____

Measurement records

Test number	Time h:min	Measurement Existence of leakage (passage up to fuel inlet shut-off valve)	Measurement Existence of leakage (booster or subsequent ones)	NOTE Test method

8 Ignition test and combustion test

These tests shall be applied to the power generation unit.

8.1 Ignition test

The ignition test shall be as follows.

- a) **State of equipment** The test shall be performed with the equipment in the installation state and the usage state under the conditions on test.
- b) **Test condition** The test condition shall be as specified in clause 5, except that, for the power supply condition, the power supply voltage shall be 90 % of the rated voltage with the rated frequency.
- c) **Test method** Perform the ignition operation repeatedly in accordance with the ignition method specified by the manufacturer, and confirm the number of times of ignition and that the explosive ignition does not occur. For the first ignition, start up in a cold state, confirm ignition and stop operation. For the second and subsequent ignitions, perform this test successively. The number of times of ignition test shall be three or more.

The confirmation of ignition shall be performed by the combustion detection means, the method specified by the manufacturer, etc.

- d) **Record of results** An example of the test result table is given in table 7.

Table 7 Measurement record table of ignition test and combustion test/ignition test

Name of fuel cell power system _____	Measurement date _____ year _____ month _____ day _____ (day of week) _____
	Measurement location _____
Type of raw fuel _____	Weather _____
Power supply voltage _____ V	Ambient temperature _____ °C
	Relative humidity _____ RH%
	Atmospheric pressure _____ hPa
	Measured by: _____

Measurement records

Test number	Time h:min	Number of times of ignition operation	Number of times of ignitions	Number of times of explosive ignition	NOTE

8.2 Combustion test

The combustion test shall be as follows.

- a) **State of equipment** The test shall be performed with the equipment in the installation state and the usage state under the conditions on test. Start up the equipment in a cold state, and after a lapse of 30 min or more from the attainment of the rated output (the operating condition by the maximum fuel consumption), perform the output change [from rated output to minimum output (under the operating condition by the minimum fuel consumption)] prior to the stop operation which is to be further performed.
- b) **Test condition** The test condition shall be as specified in clause 5.
- c) **Test method**
 - 1) **Confirmation of ignition** Start up the equipment from the cold state. Confirm the combustion state by the combustion detection means installed in the furnace (targeted for all the burners) from the start of start-up until the attainment of the state in which the furnace temperature has become stabilized after the completion of the off-gas switching.
 - 2) **Confirmation of combustion and operating condition** After a lapse of 30 min or more from the attainment of the rated output from the state in which the furnace temperature has become stabilized after the off-gas switching is completed, perform the output change up to the minimum output, and confirm the combustion state by the combustion detection means installed in the furnace.
 - 3) **Confirmation at the time of stop** Perform the stop operation from the power generation state, and confirm that fire extinction is ensured by the combustion detection means, etc.
 - 4) **CO concentration in theoretical dry combustion gas (volume fraction %)** In the case of a gaseous fuel, the conditions of test gas shall be 1-1 or B-1 given in table 2 or table 3 of **JIS S 2093**, and the combustion gas shall be sampled over the whole surface of the combustion gas exhaust part of the equipment as uniformly as possible either until 15 min after burner ignition or until before off-gas switching, whichever is earlier, and the CO concentration and O₂ or CO₂ concentration in the dry combustion gas shall be measured and calculated according to the formulae (7) and (8).

In addition, when the test is performed, the adjustment of combustion air-fuel ratio, etc. may be performed.

$$CO = CO_a \times \frac{O_{2t}}{O_{2t} - O_{2a}} \dots\dots\dots (7)$$

or

$$CO = CO_a \times \frac{CO_{2max}}{CO_{2a} - CO_{2t}} \dots\dots\dots (8)$$

where, CO : CO concentration in theoretical dry combustion gas (volume fraction %)

CO_a : measured value of CO concentration in dry combustion gas (volume fraction %)

- O_{2t} : measured value of O_2 concentration in atmosphere of air supply opening (dry state) (volume fraction %) (in the case of fresh air, $O_{2t} = 21$ %)
- O_{2a} : measured value of O_2 concentration in dry combustion gas (volume fraction %)
- CO_{2max} : CO_2 concentration in theoretical dry combustion gas (volume fraction %)
- CO_{2a} : measured value of CO_2 concentration in dry combustion gas (volume fraction %)
- CO_{2t} : measured value of CO_2 concentration in atmosphere of air supply opening (dry state) (volume fraction %)

- 5) **Confirmation of back fire** Confirm by using the combustion detection means, etc. installed in the furnace (targeted for all the burners) that in the state of **a**), such a state as a flame burning inside a burner is not caused and that fire extinction does not occur by back fire.

- d) **Record of results** An example of the test result table is given in table 8.

Table 8 Measurement record table of ignition and combustion test/combustion test

Name of fuel cell power system _____	Measurement date _____ year _____ month _____ day _____ (day of week) _____
	Measurement time _____ to _____
	Measurement location _____
Type of raw fuel _____	Weather _____
Power supply voltage _____ V	Ambient temperature _____ °C
	Relative humidity _____ RH%
	Atmospheric pressure _____ hPa
	Measured by: _____

Measurement records

Test number	CO concentration in dry combustion gas CO_a volume fraction %	O_2 concentration in dry combustion gas O_{2a} volume fraction %	CO_2 concentration in dry combustion gas CO_{2a} volume fraction %	CO_2 concentration in atmosphere of air supply opening CO_{2t} volume fraction %	O_2 concentration in atmosphere of air supply opening O_{2t} volume fraction %	CO concentration in theoretical dry combustion gas CO volume fraction %	NOTE

9 Wind proof test

9.1 Ignition test

This test shall be applied to the supply and exhaust tube part of the outdoor installation type equipment and indoor direct vent type equipment of a power generation unit.

- a) **State of equipment** Install the equipment in the test apparatus shown in figure 4 for the outdoor installation type equipment and that in figure 5 for the indoor direct vent type equipment, or any other apparatus equivalent to these.
- b) **Test condition** The test condition shall be as specified in clause 5, except that the “air current” shall be in accordance with this test method and for the power supply condition, the power supply voltage shall be 90 % of the rated voltage with rated frequency.
- c) **Test method** Send the wind at 5 m/s in two directions shown in figure 4 for the outdoor installation type equipment and in each direction of (A) and (B) shown in figure 5 for the indoor direct vent type equipment, repeat the ignition operation in accordance with the ignition method given in an operation manual, etc., and confirm the number of times of ignition and that the explosive ignition does not occur. For the first ignition, start up in a cold state, confirm ignition and stop operation. For the second and subsequent ignitions, perform this test successively. The number of times of ignition test shall be three or more.

The confirmation of ignition shall be performed by the combustion detection means, the method specified by the manufacturer, etc.

- d) **Record of results** An example of the test result table is given in table 9.

Table 9 Measurement record table of wind proof test/ignition test

Name of fuel cell power system _____	Measurement date _____ year month day (day of week)
	Measurement location _____
Type of raw fuel _____	Weather _____
Power supply voltage _____ V	Ambient temperature _____ °C
Wind blowing direction _____	Relative humidity _____ RH%
	Atmospheric pressure _____ hPa
	Measured by: _____

Measurement records

Test number	Time h : min	Number of times of ignition operation	Number of times of ignition	Number of times of explosive ignition	NOTE

9.2 Combustion test

9.2.1 Outdoor installation type and indoor direct vent type equipment

This test shall be applied to the supply and exhaust tube part of the outdoor installation type equipment and indoor direct vent type equipment of a power generation unit.

- a) **State of equipment** Install the equipment in the test apparatus shown in figure 4 for the outdoor installation type equipment and in figure 5 for the indoor direct vent type equipment or those apparatus equivalent to these. Start up the equipment in a cold state and perform this test until 30 min or more have elapsed from the attainment of the rated output (under the operating condition by the maximum fuel consumption).
- b) **Test condition** The test condition shall be as specified in clause 5, except that the “air current” is in accordance with this test method.
- c) **Test method**
 - 1) **Confirmation of ignition** Start up the equipment from the cold state, and with the wind being sent at 5 m/s in two directions shown in figure 4 for the outdoor installation type equipment and in each direction of (A) and (B) shown in figure 5 for the indoor direct vent type equipment, confirm, by the combustion detection means, etc. installed in the furnace (targeted for all the burners), that combustion is in a state of stability until 30 min or more have elapsed from the time when the load attains the rated output (under the operating condition by the maximum fuel consumption) from the start of start-up.
 - 2) **Confirmation of combustion and operating condition** Confirm that fire is extinguished and combustion is in a state of stability without back fire by the combustion detection means, etc. installed in the furnace in each of the states in which the wind is sent at 2.5 m/s for 3 min and the wind is sent at 15 m/s for 1 min in two directions shown in figure 4 for the outdoor installation type equipment and in each direction of (A) and (B) shown in figure 5 for the indoor direct vent type equipment at the stage in which 30 min or more have elapsed after making the equipment attain the rated output in 1).

In addition, for the direct vent type equipment of indoor installation type, perform this confirmation also in a state in which the wind is sent at 2.5 m/s for 3 min in each direction of (C) and (D) in figure 5.
 - 3) **Confirmation of start-up/operating condition** Confirm that an alarm or an abnormal stop and emergency stop do not occur during all the tests in 1) and 2).