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**Safety evaluation test for stationary
polymer electrolyte fuel cell stack**

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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 of establishing a Japanese Industrial Standard from the Japan Electrical Manufacturers' Association (JEMA) with a draft of Industrial Standard based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

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Safety evaluation test for stationary polymer electrolyte fuel cell stack

1 Scope

This Japanese Industrial Standard specifies the safety evaluation test for the atmospheric pressure fuel cell stack of the stationary polymer electrolyte fuel cell stack (hereafter referred to as “PEFC”).

This Standard is not intended to be used as the completed design documentation or the instruction for use.

Any person, organization or business enterprise does not necessarily evade the observance responsibility for other related regulations even if it conforms to this Standard.

NOTE : For the fuel cell stack of external humidification type, the test may be performed by connecting the humidifier which the manufacturer offers.

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 8800 *Glossary of terms for fuel cell power system*

JIS Z 8703 *Standard atmospheric conditions for testing*

3 Terms and definitions

For the purposes of this Standard, the definitions given in **JIS C 8800** and the following definitions shall apply.

3.1 operating temperature

temperature representing the fuel cell stack in operation

3.2 operating pressure

pressure (gauge pressure) of a fuel gas and an oxidant gas in a fuel cell stack inlet

3.3 reactant gas dew point

dew point of a fuel gas and an oxidant gas in a fuel cell stack inlet

3.4 reference measurement condition

conditions of current, operating temperature, fuel utilization, oxidant utilization, test gas composition, operating pressure and reactant gas dew point of the fuel cell stack specified by the manufacturer in order to obtain the fuel cell stack performance as the reference performance

Here, the fuel utilization means the value obtained by dividing the hydrogen consumption rate calculated from a current value by the hydrogen flow rate in a supply fuel gas. In the same way, the oxidant utilization means the value obtained by dividing

the oxygen consumption rate calculated from a current value by the oxygen flow rate in a supply oxidant gas.

The basis for calculation shall be as given in clause 5.

3.5 reference voltage

fuel cell stack voltage in design specified by the manufacturer under the reference measurement condition

3.6 gas leakage reference value

amount of maximum permissible gas leakage in design specified by the manufacturer at the highest operating pressure

3.7 highest operating temperature

upper limit operating temperature in design specified by the manufacturer at which a fuel cell stack can operate continuously

3.8 lowest operating temperature

lower limit operating temperature in design specified by the manufacturer at which a fuel cell stack can operate continuously

3.9 highest operating pressure

upper limit operating pressure in design specified by the manufacturer at which a fuel cell stack can operate continuously

3.10 permissible operating pressure

upper limit operating pressure in design specified by the manufacturer at which a fuel cell stack can maintain functional characteristics without damage

3.11 permissible operation differential pressure

maximum pressure difference between the fuel electrode and the air electrode in design specified by the manufacturer at which a fuel cell stack can maintain functional characteristics without damage

3.12 maximum operating current

upper limit operating current in design specified by the manufacturer at which a fuel cell stack can operate continuously

3.13 permissible duration

operating duration in design specified by the manufacturer during which a fuel cell stack can operate in a state where the cooling function of a fuel cell stack stops at the maximum operating current

3.14 heat stability

state in which the temperature fluctuation width becomes 3 °C or less, or 1 % or under of operating temperature (absolute temperature) at intervals of 15 min

3.15 dangerous state

physical situation with the possibility of harm to a human body, damage to property and adverse effects on the environment

3.16 gas purge

protect operation which eliminates the gas such as a reactant gas and steam out of the target device of system at the time of stop or start

4 Test

4.1 Type of test

The type of test shall be as follows.

- a) Gas leakage test
- b) Permissible operating pressure test
- c) Pressure-proof test of cooling system
- d) Electric overload test
- e) Dielectric strength test
- f) Differential pressure test
- g) Fuel gas and oxidant gas shutoff test
- h) Short circuit test
- i) Cooling shortage/cooling inhibition test
- j) Freezing/melting cycle test

4.2 Test method

The test method shall be as follows.

- a) The test method for gas leakage test shall be in accordance with Annex A.
- b) The test method for permissible operating pressure test shall be in accordance with Annex B.
- c) The test method for pressure-proof test of cooling system shall be in accordance with Annex C.
- d) The test method for electric overload test shall be in accordance with Annex D.
- e) The test method for dielectric strength test shall be in accordance with Annex E.
- f) The test method for differential pressure test shall be in accordance with Annex F.
- g) The test method for fuel gas and oxidant gas shutoff test shall be in accordance with Annex G.
- h) The test method for short circuit test shall be in accordance with Annex H.
- i) The test method for cooling shortage/cooling inhibition test shall be in accordance with Annex J.

- j) The test method for freezing/melting cycle test shall be in accordance with Annex K.

4.3 Example of test procedure

The outline of the example of safety evaluation test procedure shall be as shown in figure 1.

5 Others

The highest operating pressure of the atmospheric pressure PEFC fuel cell stack covered by this Standard shall be under 100 kPa.

The basis for calculating the utilization from the supply gas flow rate and the current value shall be as follows.

- a) **Fuel utilization** The following relational expression shall be established by taking fuel utilization as U_F (%), current value as I (A), number of laminations as n (—), hydrogen consumption rate in a fuel cell stack calculated from a current value as Q_H (L/min), hydrogen flow rate supplied to a fuel cell stack as F_H (L/min) and fuel gas flow rate supplied to a fuel cell stack as F_F (L/min), provided that the hydrogen concentration in a fuel gas is taken as C_H (%).

The hydrogen consumption rate and the flow rate to be used here shall be values under the reference condition (standard condition) of 0 °C and 101.3 kPa.

The hydrogen consumption rate in a fuel cell stack shall be obtained according to the formula (1).

$$Q_H = \frac{nI}{2 \times 96\,500} \times 22.4 \times 60 \dots\dots\dots (1)$$

where, Q_H : hydrogen consumption rate in fuel cell stack (L/min)

n : number of laminations (—)

I : current value (A)

96 500 : faraday constant (C/mol)

22.4 : volume per 1 mol of gas under standard condition (L/mol)

60 : minute to second conversion (s/min)

The hydrogen flow rate supplied to a fuel cell stack shall be obtained according to the formula (2).

$$F_H = \frac{100 Q_H}{U_F} \dots\dots\dots (2)$$

where, F_H : hydrogen flow rate supplied to fuel cell stack (L/min)

U_F : fuel utilization (%)

Q_H : hydrogen consumption rate in fuel cell stack (L/min)

The fuel gas flow rate supplied to a fuel cell stack shall be obtained according to the formula (3).

$$F_F = \frac{100 F_H}{C_H} \dots\dots\dots (3)$$

where, F_F : fuel gas flow rate supplied to fuel cell stack (L/min)
 F_H : hydrogen flow rate supplied to fuel cell stack (L/min)
 C_H : hydrogen concentration in fuel gas (%)

Therefore, the fuel utilization shall be obtained according to the formula (4).

$$U_F = \frac{10\,000 Q_H}{C_H F_F} \dots\dots\dots (4)$$

where, U_F : fuel utilization (%)
 Q_H : hydrogen consumption rate in fuel cell stack (L/min)
 C_H : hydrogen concentration in fuel gas (%)
 F_F : fuel gas flow rate supplied to fuel cell stack (L/min)

- b) **Oxidant utilization** The following relational expression shall be established by taking oxidant utilization as U_O (%), current value as I (A), number of laminations as n (—), oxygen consumption rate in a fuel cell stack calculated from a current value as Q_O (L/min), oxygen flow rate supplied to a fuel cell stack as F_O (L/min) and oxidant gas flow rate supplied to a fuel cell stack as F_{Air} (L/min), provided that the oxygen concentration in an oxidant gas is taken as 21 % on the assumption that air is used.

The oxygen consumption rate and the flow rate to be used here shall be values under the standard condition.

The oxygen consumption rate in a fuel cell stack shall be obtained according to the formula (5).

$$Q_O = \frac{nI}{4 \times 96\,500} \times 22.4 \times 60 \dots\dots\dots (5)$$

where, Q_O : oxygen consumption rate in fuel cell stack (L/min)
 n : number of laminations (—)
 I : current value (A)
96 500 : faraday constant (C/mol)
22.4 : volume per 1 mol of gas under standard condition (L/mol)
60 : minute to second conversion (s/min)

The oxygen flow rate supplied to a fuel cell stack shall be obtained according to the formula (6).

$$F_O = \frac{100 Q_O}{U_O} \dots\dots\dots (6)$$

where, F_O : oxygen flow rate supplied to fuel cell stack (L/min)
 Q_O : oxygen consumption rate in fuel cell stack (L/min)
 U_O : oxidant utilization (%)

The oxidant gas flow rate supplied to a fuel cell stack shall be obtained according to the formula (7).

$$F_{\text{Air}} = \frac{100 F_{\text{O}}}{21} \dots\dots\dots (7)$$

where, F_{Air} : oxidant gas flow rate supplied to fuel cell stack (L/min)
 F_{O} : oxygen flow rate supplied to fuel cell stack (L/min)
 21 : oxygen concentration in oxidant gas (%)

Therefore, the oxidant utilization shall be obtained according to the formula (8).

$$U_{\text{O}} = \frac{10\,000 Q_{\text{O}}}{21 F_{\text{Air}}} \dots\dots\dots (8)$$

where, U_{O} : oxidant utilization (%)
 Q_{O} : oxygen consumption rate in fuel cell stack (L/min)
 F_{Air} : oxidant gas flow rate supplied to fuel cell stack (L/min)
 21 : oxygen concentration in oxidant gas (%)

The flow rate measurement of a fuel gas and an oxidant gas shall be performed before humidification.

In the gas leakage test and the gas leakage check test, when helium gas is used as a test gas, it shall be converted into an equivalent amount of gas leakage in a fuel gas based on the formula (9).

(Conversion formula)

The measured value of the amount of gas leakage in a test gas shall be taken as L_{test} (L/min), an equivalent amount of gas leakage in a fuel gas as L_{F} (L/min), the specific gravity of a test gas as G_{test} (g/L), the specific gravity of a fuel gas as G_{F} (g/L), the viscosity of a test gas as μ_{test} (Pa·s) and the viscosity of a fuel gas as μ_{F} (Pa·s).

Equivalent amount of gas leakage in a fuel gas:

$$L_{\text{F}} = R \times L_{\text{test}} \dots\dots\dots (9)$$

where, R : use either of following numerical values, whichever is larger.
 $R = G_{\text{test}}/G_{\text{F}}$ or $R = \mu_{\text{test}}/\mu_{\text{F}}$

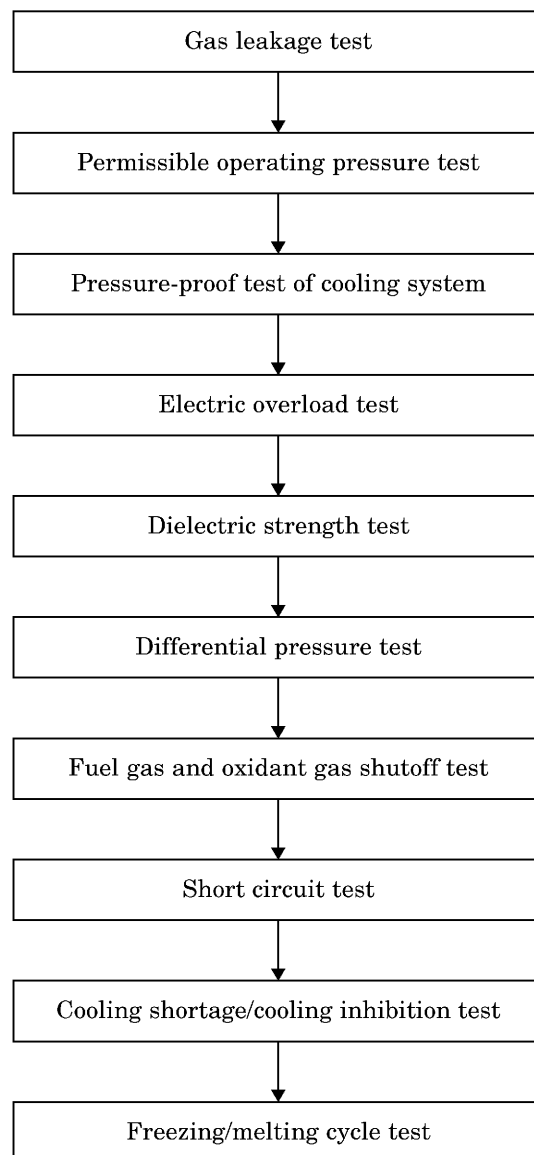


Figure 1 Example of safety evaluation test procedure

Annex A (normative)

Gas leakage test method

Introduction

This Annex specifies the gas leakage test method for the stationary polymer electrolyte fuel cell stack.

The test shall be performed only on the fuel electrode side. However, it does not apply to the fuel cell accommodated in an airtight container. If it is impossible to use the whole fuel cell stack, one fuel cell stack with a typical number of cells of which the number of laminations is reduced may be used. In this case, the amount of gas leakage shall be calculated based on the ratio of the number of laminations.

A.1 Test condition

- a) **Measurement condition** The measurement condition of gas leakage test shall be as given in table A.1.
- b) **Testing room**
 - **Temperature** The temperature in testing room shall be “ordinary temperature” (standard temperature condition Class 15: $20\text{ °C} \pm 15\text{ °C}$) specified in table 1 of **JIS Z 8703**, and the temperature fluctuation during test shall be $\pm 5\text{ °C}$.
 - **Humidity** The humidity in testing room shall be “ordinary humidity” [standard humidity condition Class 20: $(65 \pm 20)\%$] specified in table 2 of **JIS Z 8703**.
- c) **Test apparatus** The configuration example of test apparatus shall be as given in figure A.1.
- d) **Test gas** The test gas shall be fuel gas or helium gas, and when the fuel gas is used, the composition ratio shall be specified.

A.2 Measurement item

The required measurement item shall be as given in table A.2.

A.3 Test procedure

The outline of the example of gas leakage test procedure shall be as given in figure A.2.

A.4 Measurement record

The example of the record form of gas leakage test shall be as given in table A.3.

A.5 Evaluation criteria

The amount of gas leakage shall be the gas leakage reference value or under.

Table A.1 Measurement condition

Item	Content
Test temperature	State without temperature change at lowest operating temperature or under
Test pressure	Highest operating pressure
Pressurization time	1 min
Test gas	Fuel gas or helium gas
Flow controller	Instrument whose error is 2 % or under of full scale shall be used

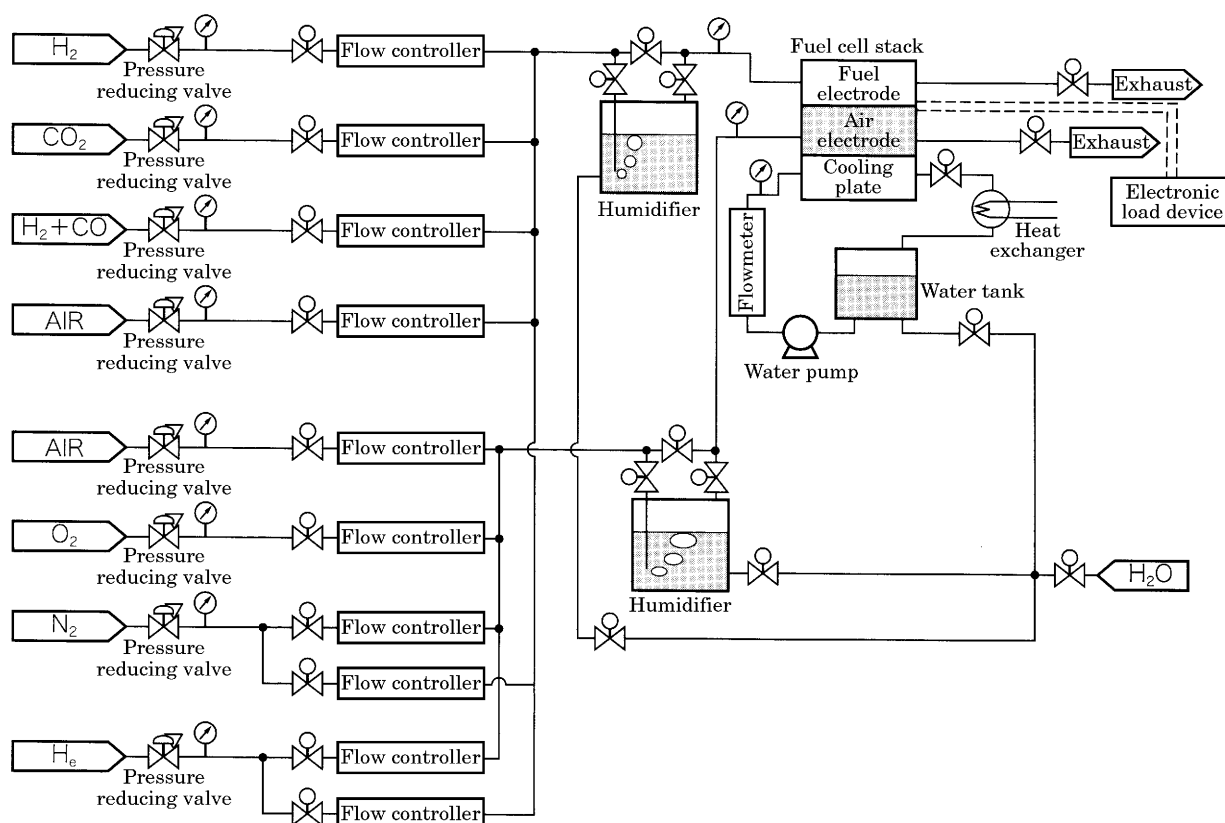


Figure A.1 Configuration example of test apparatus

Table A.2 Measurement item

Item		Unit	NOTE
Atmosphere	Environment (testing room) temperature	°C	
	Pressure	hPa	
	Environment (testing room) humidity	RH%	
Test temperature		°C	Fuel cell stack temperature at measurement when temperature becomes lowest operating temperature or under
Test pressure	Fuel electrode	kPa	
Pressurization time		min	
Amount of gas leakage (before conversion)		L/min (NTP) ^{a)}	Amount of gas leakage of test gas used before conversion (in evaluation, converted into an equivalent amount of gas leakage in fuel gas)
Note ^{a)} NTP: normal pressure and temperature 0 °C, 1 atm			

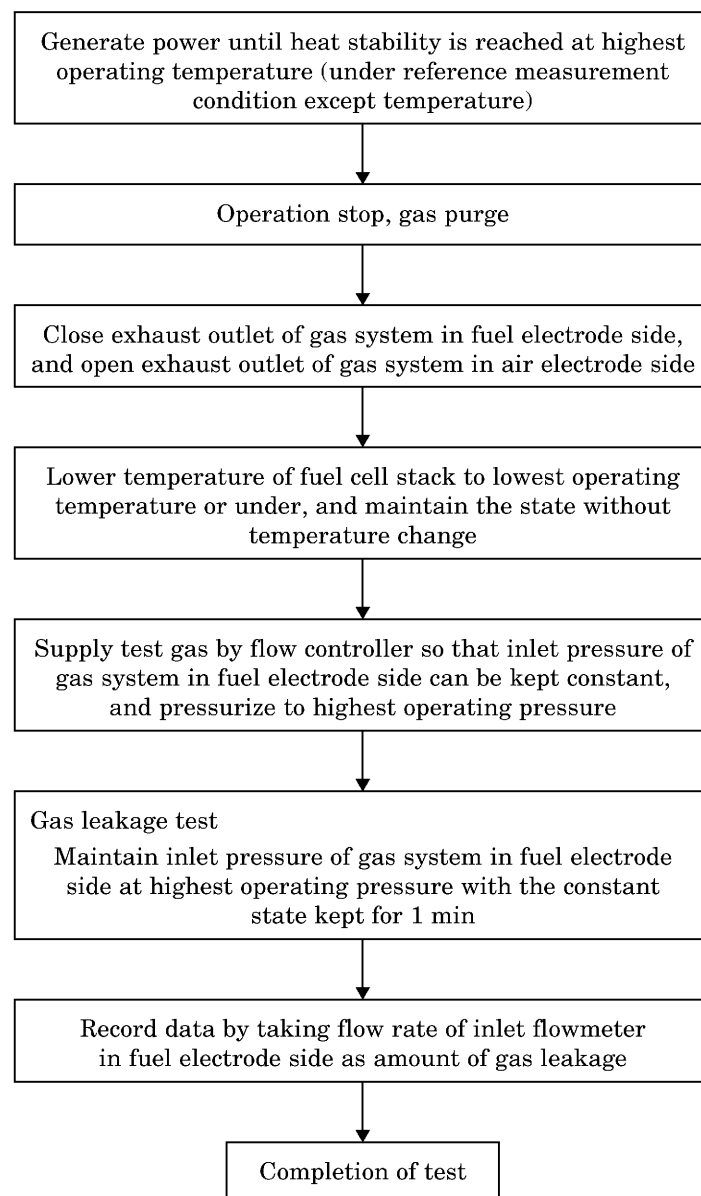


Figure A.2 Example of test procedure

Table A.3 Record form example for gas leakage test of stationary polymer electrolyte fuel cell stack

1 Basic matter

Test date and time	Year	Month	Day	:	to	:	
Temperature in testing room			°C	Humidity in testing room			RH%
Atmospheric pressure			hPa	Measurer			
Flowmeter (manufacturer's name • product name • type • maximum flow rate • precision)							

2 Measurement condition

Item		Unit	Value	NOTE
Test gas	Fuel electrode			Type or composition ratio of test gas shall be described.
	Air electrode			
Test temperature		°C		
Test pressure	Fuel electrode	kPa		
Pressurization time		min		
Gas leakage reference value (fuel gas equivalence)		L/min (NTP)		In evaluation, converted into an equivalent amount of gas leakage in fuel gas.

3 Test result

Item	Unit	Value	NOTE
Amount of gas leakage (fuel gas equivalence)	L/min (NTP)		In evaluation, converted into an equivalent amount of gas leakage in fuel gas.

Annex B (normative)

Permissible operating pressure test method

Introduction

This Annex specifies the permissible operating pressure test method for the stationary polymer electrolyte fuel cell stack.

B.1 Test condition

- a) **Measurement condition** The measurement condition of permissible operating pressure test shall be as given in table B.1.
- b) **Testing room**
 - **Temperature** The temperature in testing room shall be “ordinary temperature” (standard temperature condition Class 15: $20\text{ °C} \pm 15\text{ °C}$) specified in table 1 of **JIS Z 8703**, and the temperature fluctuation during test shall be $\pm 5\text{ °C}$.
 - **Humidity** The humidity in testing room shall be “ordinary humidity” [standard humidity condition Class 20: $(65 \pm 20)\%$] specified in table 2 of **JIS Z 8703**.
- c) **Test apparatus** The configuration example of test apparatus shall be as given in figure B.1.
- d) **Test gas** Any type of gas may be used at pressurization; however, the measurement conditions such as test gas, test system shall be set and clearly specified.

The test gas used when the gas leakage check test is performed shall be fuel gas or helium gas, and when fuel gas is used, the composition ratio shall be clearly specified.

B.2 Measurement item

The required measurement item shall be as given in table B.2.

B.3 Test procedure

The outline of the example of permissible operating pressure test procedure shall be as given in figure B.2.

B.4 Measurement record

The example of the record form of permissible operating pressure test shall be as given in table B.3.

B.5 Evaluation criteria

The fuel cell stack shall be free from fracture, breakage, permanent deformation or other physical damage. Furthermore, the amount of gas leakage by the gas leakage check test shall be the gas leakage reference value or under.

Table B.1 Measurement condition

Item	Content
Test temperature	Normal test condition Condition of either highest operating temperature or lowest operating temperature, whichever is severer When normal test condition is not obtained Ambient temperature
Test pressure	Normal test condition Pressure of 1.3 times or more the permissible operating pressure At this time when permissible operating pressure of a fuel electrode and an air electrode is the same, both electrodes may be connected mutually. When normal test condition is not obtained Pressure of 1.5 times or more the permissible operating pressure At this time when permissible operating pressure of a fuel electrode and an air electrode is the same, both electrodes may be connected mutually.
Pressurization time	1 min or more
Test gas of gas leakage check test	Fuel gas or helium gas
Flow controller	Instrument whose error is 2 % or under of full scale shall be used

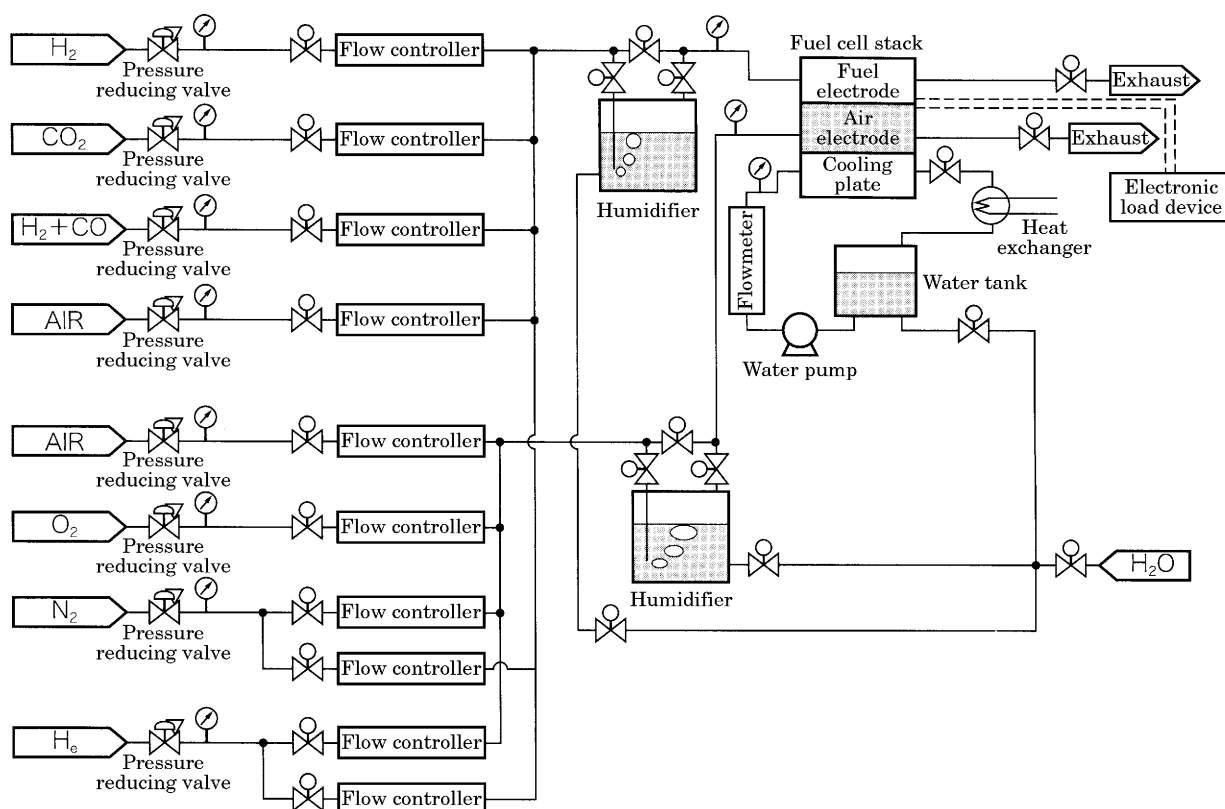


Figure B.1 Configuration example of test apparatus

Table B.2 Measurement item

Permissible operating pressure test

Item		Unit	NOTE
Atmosphere	Environment (testing room) temperature	°C	
	Pressure	hPa	
	Environment (testing room) humidity	RH%	
Test temperature		°C	Fuel cell stack temperature at pressurization
Test pressure	Fuel electrode	kPa	
	Air electrode	kPa	
Pressurization time		min	
Appearance check			

Gas leakage check test

Item		Unit	NOTE
Atmosphere	Environment (testing room) temperature	°C	
	Pressure	hPa	
	Environment (testing room) humidity	RH%	
Test temperature		°C	Fuel cell stack temperature at measurement when temperature becomes lowest operating temperature or under
Test pressure	Fuel electrode	kPa	
Pressurization time		min	
Amount of gas leakage (before conversion)		L/min (NTP)	Amount of gas leakage of test gas used before conversion (in evaluation, converted into an equivalent amount of gas leakage in fuel gas)

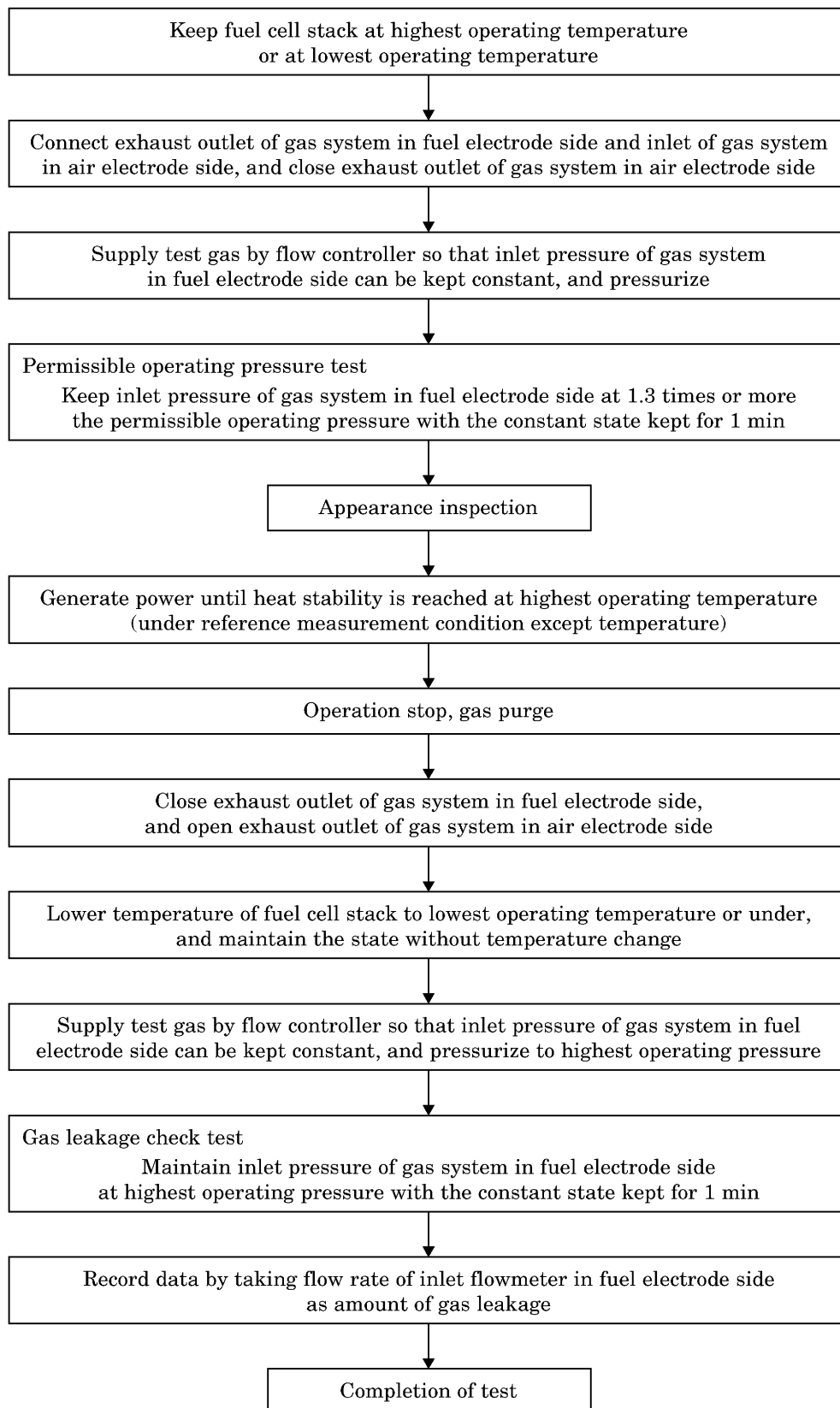


Figure B.2 Example of test procedure
(when test is performed simultaneously under normal test condition
by connecting fuel electrode and air electrode)