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**Performance 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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Performance test for stationary polymer electrolyte fuel cell stack

1 Scope

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

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

condition 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

3.5 reference voltage

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

3.6 highest operating temperature

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

3.7 lowest operating temperature

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

3.8 maximum operating current

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

3.9 minimum operating current

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

3.10 fuel utilization

value obtained by dividing the hydrogen consumption rate calculated from the current value by the hydrogen flow rate in a supply fuel gas

3.11 oxidant utilization

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

4 Test

4.1 Type of test

The type of test shall be as follows.

- a) Current dependence test
- b) Temperature dependence test
- c) Fuel/oxidant utilization dependence test
- d) Fuel/oxidant gas dew point dependence test
- e) Carbon monoxide concentration in fuel gas dependence test
- f) Ammonia concentration in fuel gas dependence test
- g) Nitrogen dioxide concentration in oxidant gas dependence test
- h) Sulphur dioxide concentration in oxidant gas dependence test
- i) Ammonia concentration in oxidant gas dependence test
- j) Toluene concentration in oxidant gas dependence test

4.2 Test method

The test method shall be as follows.

- a) The test method for current dependence test shall be in accordance with Annex A.

- b) The test method for temperature dependence test shall be in accordance with Annex B.
- c) The test method for fuel/oxidant utilization dependence test shall be in accordance with Annex C.
- d) The test method for fuel/oxidant gas dew point dependence test shall be in accordance with Annex D.
- e) The test method for carbon monoxide concentration in fuel gas dependence test shall be in accordance with Annex E.
- f) The test method for ammonia concentration in fuel gas dependence test shall be in accordance with Annex F.
- g) The test method for nitrogen dioxide concentration in oxidant gas dependence test shall be in accordance with Annex G.
- h) The test method for sulphur dioxide concentration in oxidant gas dependence test shall be in accordance with Annex H.
- i) The test method for ammonia concentration in oxidant gas dependence test shall be in accordance with Annex J.
- j) The test method for toluene concentration in oxidant gas dependence test shall be in accordance with Annex K.

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).

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

- 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).

$$U_O = \frac{10\,000 Q_O}{21 F_{Air}} \dots\dots\dots (8)$$

- 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.

Annex A (normative)

Current dependence test method

Introduction

This Annex specifies the current dependence test method for the stationary polymer electrolyte fuel cell stack.

A.1 Test condition

a) **Measurement condition** The measurement condition of current dependence test shall be as given in table A.1. The measurement range shall be from no-load current to highest current.

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 fuel gas used as a test gas shall be hydrogen or a mixed gas of hydrogen and carbon dioxide etc. specified by the manufacturer.

For the mixed gas, the composition ratio shall be clearly specified. The oxidant gas used as a test gas shall be air or the simulant air of which the composition ratio of oxygen and nitrogen is 21:79.

e) **Measurement period of data** The maximum interval of measurement period of data shall be within 30 s.

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 current dependence test procedure shall be as given in figure A.2.

A.4 Measurement record

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

Table A.1 Measurement condition

Item	Content
Current condition	Measurement range
	From no-load current to highest current
Other conditions	Operating temperature
	Fuel utilization ^{a)}
	Oxidant utilization ^{a)}
	Fuel gas dew point
	Oxidant gas dew point
	Test gas composition
	Operating pressure
Note ^{a)} In the range in which measurement cannot be performed due to small flow rate, it shall be also possible to adopt the condition of fixed flow rate.	

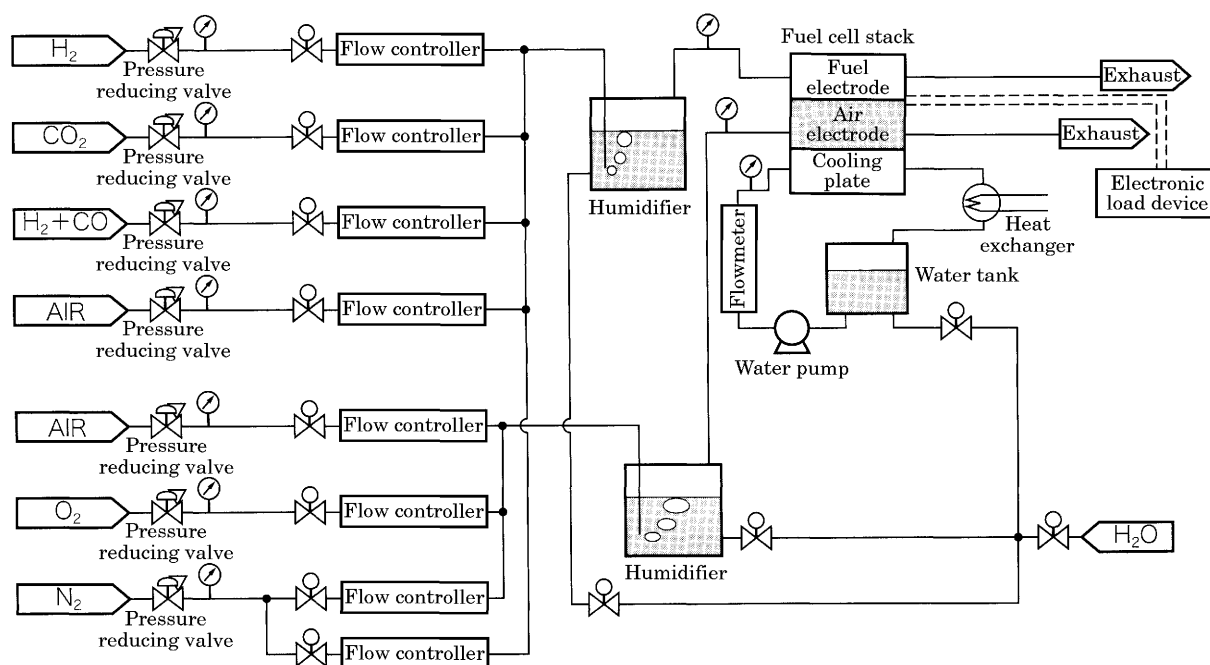
**Figure A.1 Configuration example of test apparatus**

Table A.2 Measurement item

Item		Unit	NOTE
Atmosphere	Environment (testing room) temperature	°C	
	Pressure	hPa	
	Environment (testing room) humidity	RH%	
Voltage	Fuel cell stack	V	
Current	Fuel cell stack	A	
Operating temperature		°C	Temperature at point used to know actual operating temperature of each fuel cell stack is available.
Operating pressure	Fuel gas	kPa	Fuel cell stack inlet
	Oxidant gas	kPa	Fuel cell stack inlet
Fuel gas flow rate	Hydrogen	L/min (NTP) ^{a)}	
	Carbon dioxide	L/min (NTP) ^{a)}	
	Carbon monoxide (concentration)	ppm	
	Air	%	Measured only for fuel cell stack designed with assumption of air introduction for fuel electrode. Volume ratio to fuel gas (100 %) except air
	Others	L/min (NTP) ^{a)}	
Oxidant gas flow rate	Air	L/min (NTP) ^{a)}	
	Oxygen	L/min (NTP) ^{a)}	
	Nitrogen	L/min (NTP) ^{a)}	
Reactant gas dew point	Fuel gas	°C	Fuel cell stack inlet
	Oxidant gas	°C	Fuel cell stack inlet
Others			Shall be measured when there are items required for performing this test.
Note ^{a)} NTP: normal pressure and temperature 0 °C, 1 atm			

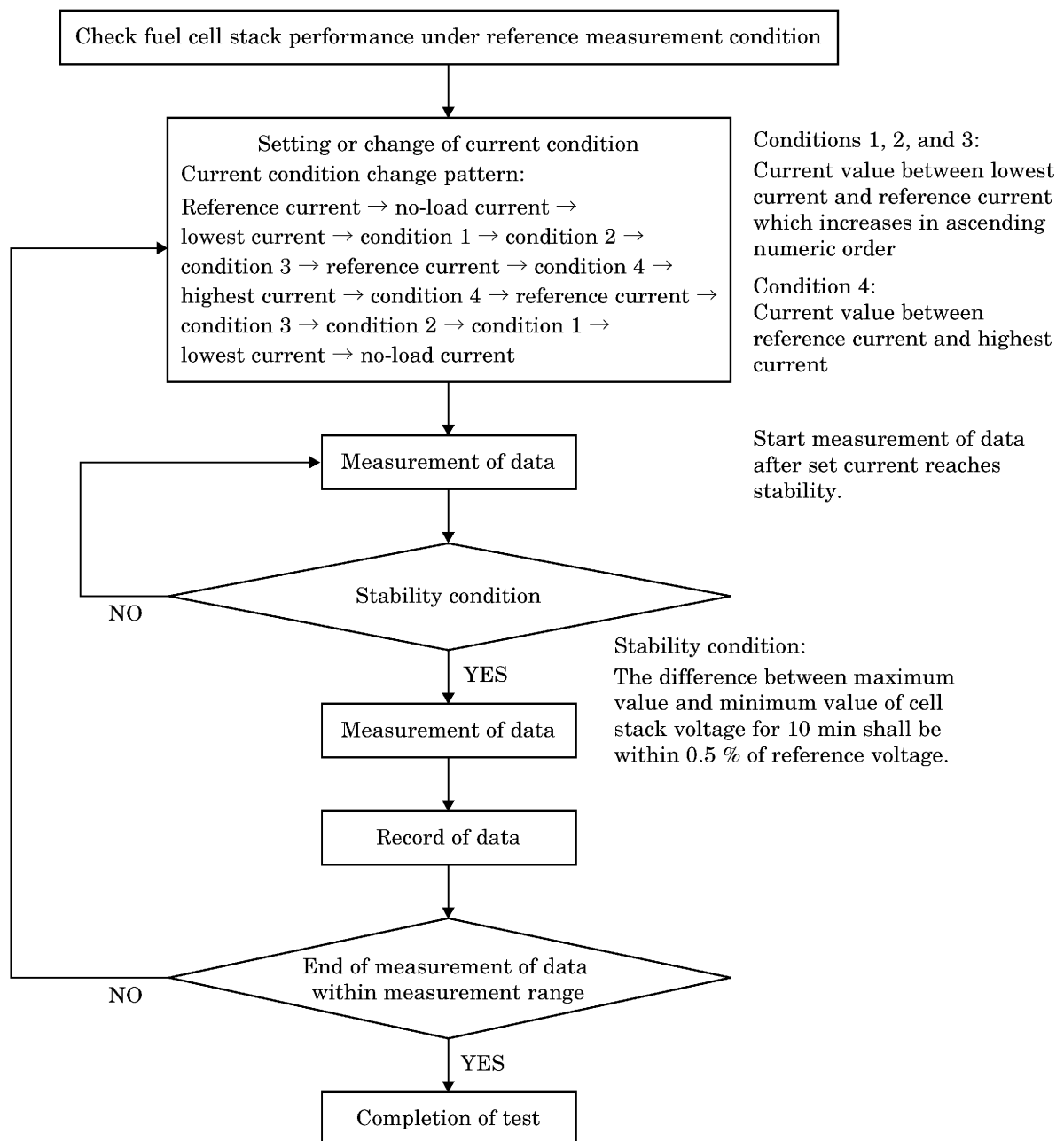


Figure A.2 Example of current dependence test procedure

Table A.3 Record form example for current dependence 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			
Voltmeter (manufacturer's name • product name • type • precision)							
Ammeter (manufacturer's name • product name • type • precision)							
Flowmeter (manufacturer's name • product name • type • precision)							

2 Measurement condition

Item		Unit	Value	NOTE
Current		A		
Operating temperature		°C		
Operating pressure	Fuel gas	kPa		
	Oxidant gas	kPa		
Fuel utilization		%		
Oxidant utilization		%		
Reactant gas dew point	Fuel gas	°C		
	Oxidant gas	°C		
Fuel gas composition	Hydrogen	%		
	Carbon dioxide	%		
	Carbon monoxide	ppm		Volume ratio to fuel gas (100 %)
	Air	%		Volume ratio to fuel gas (100 %) except air
	Others	%		
Oxidant gas composition	Air	%		
	Oxygen	%		
	Nitrogen	%		

3 Test result

Current (A)						
Fuel cell stack voltage (V)						

Annex B (normative)

Temperature dependence test method

Introduction

This Annex specifies the temperature dependence test method for the stationary polymer electrolyte fuel cell stack.

B.1 Test condition

- a) **Measurement condition** The measurement condition of temperature dependence test shall be as given in table B.1. The measurement range shall be from the lowest operating temperature to the highest operating temperature.
- b) **Testing room**
 - **Temperature** The temperature in testing room shall be “ordinary temperature” (standard temperature condition Class 15: $20\text{ }^{\circ}\text{C} \pm 15\text{ }^{\circ}\text{C}$) specified in table 1 of **JIS Z 8703**, and the temperature fluctuation during test shall be $\pm 5\text{ }^{\circ}\text{C}$.
 - **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** The fuel gas used as a test gas shall be hydrogen or a mixed gas of hydrogen and carbon dioxide etc. specified by the manufacturer.

For the mixed gas, the composition ratio shall be clearly specified. The oxidant gas used as a test gas shall be air or the simulant air of which the composition ratio of oxygen and nitrogen is 21:79.
- e) **Measurement period of data** The maximum interval of measurement period of data shall be within 30 s.

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 temperature dependence test procedure shall be as given in figure B.2.

B.4 Measurement record

The example of the record form of temperature dependence test shall be as given in table B.3.

Table B.1 Measurement condition

Item	Content
Temperature condition	Measurement range From lowest operating temperature to highest operating temperature
Other conditions	Current Constant under reference measurement condition
	Fuel utilization Constant under reference measurement condition
	Oxidant utilization Constant under reference measurement condition
	Test gas composition Constant under reference measurement condition
	Operating pressure Constant under reference measurement condition
	Fuel gas dew point Constant under reference measurement condition
	Oxidant gas dew point Constant under reference measurement condition

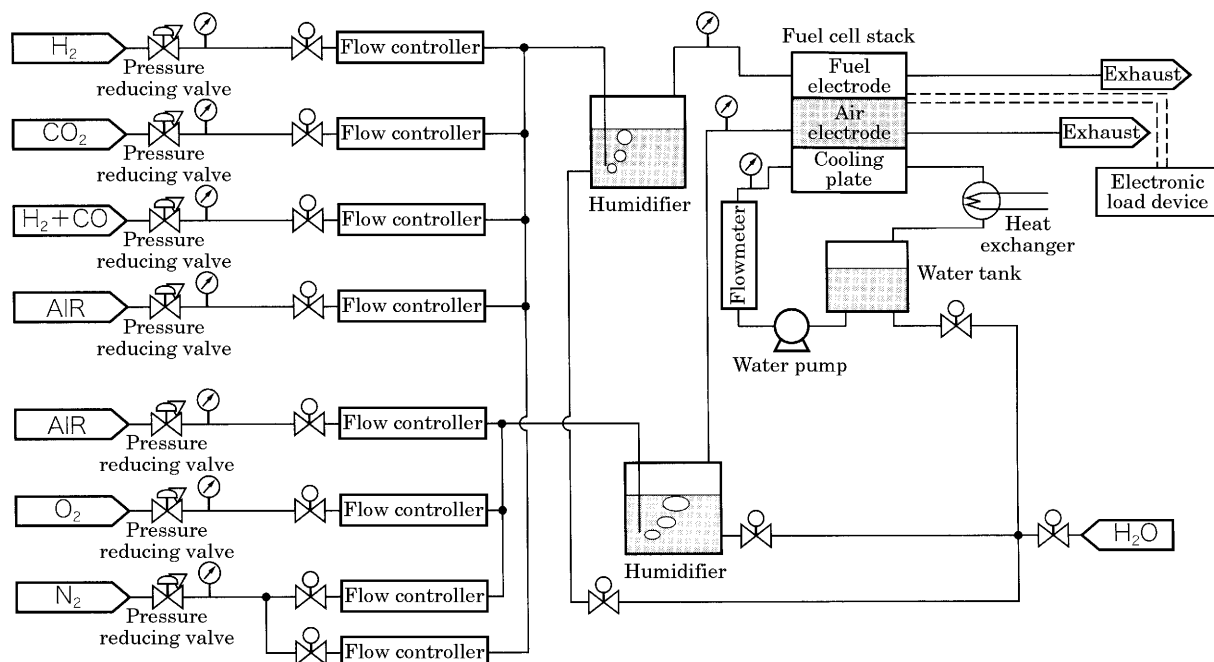


Figure B.1 Configuration example of test apparatus

Table B.2 Measurement item

Item		Unit	NOTE
Atmosphere	Environment (testing room) temperature	°C	
	Pressure	hPa	
	Environment (testing room) humidity	RH%	
Voltage	Fuel cell stack	V	
Current	Fuel cell stack	A	
Operating temperature		°C	Temperature at point used to know actual operating temperature of each fuel cell stack is available.
Operating pressure	Fuel gas	kPa	Fuel cell stack inlet
	Oxidant gas	kPa	Fuel cell stack inlet
Fuel gas flow rate	Hydrogen	L/min (NTP)	
	Carbon dioxide	L/min (NTP)	
	Carbon monoxide (concentration)	ppm	
	Air	%	Measured only for fuel cell stack designed with assumption of air introduction for fuel electrode. Volume ratio to fuel gas (100 %) except air
	Others	L/min (NTP)	
Oxidant gas flow rate	Air	L/min (NTP)	
	Oxygen	L/min (NTP)	
	Nitrogen	L/min (NTP)	
Reactant gas dew point	Fuel gas	°C	Fuel cell stack inlet
	Oxidant gas	°C	Fuel cell stack inlet
Others			Shall be measured when there are items required for performing this test.

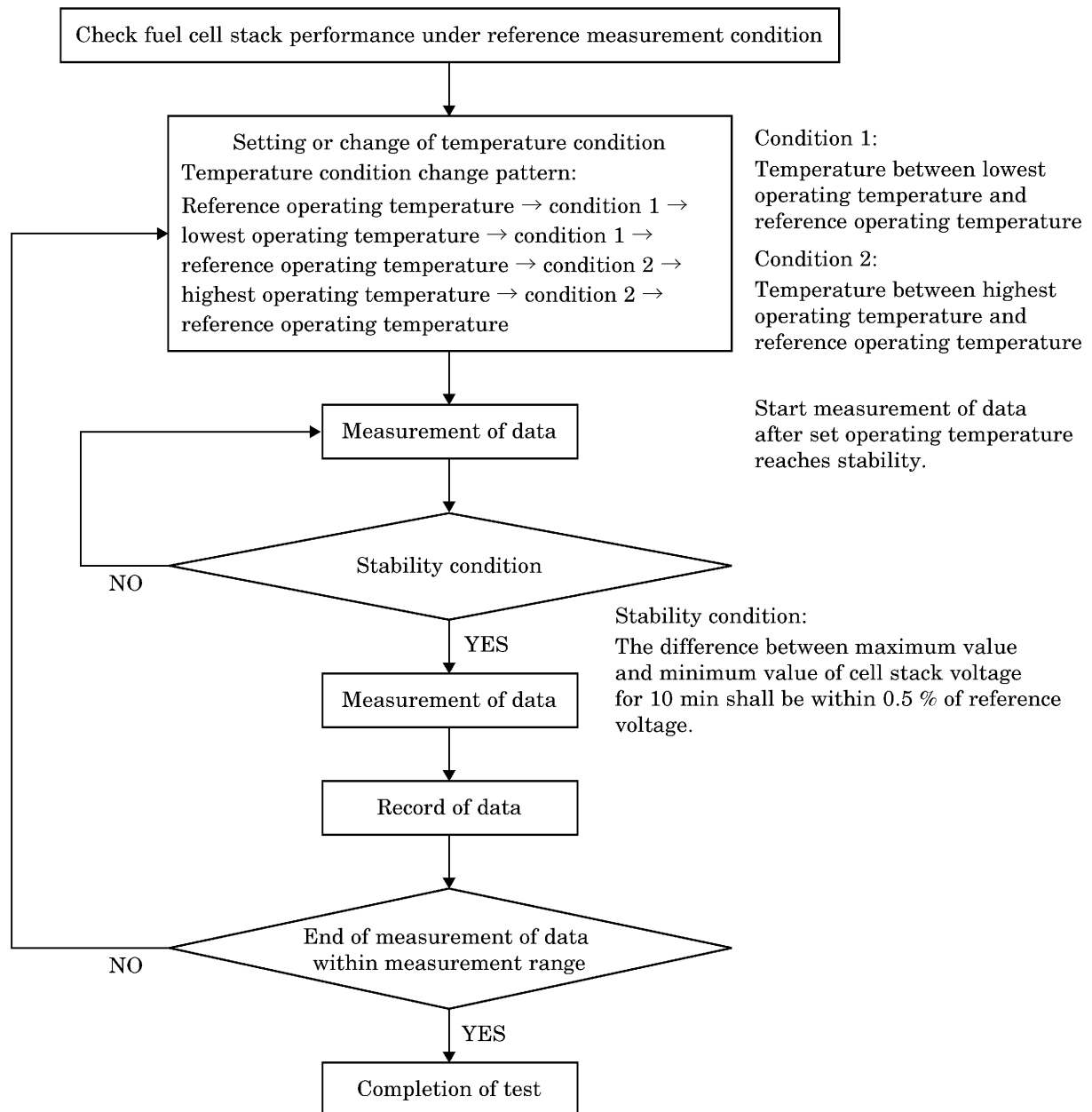


Figure B.2 Example of temperature dependence test procedure