Model : KTE-7000HS

HYDROGEN FUEL CELL GENERATION EXP. EQUIPMENT USAGE MANUAL

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1. Hydrogen fuel cell power generation experimental equipment

1-1. Introduction

This hydrogen fuel cell power generation experimental equipment generates extremely pure hydrogen by electrolyzing water through a pure chemical reaction without the addition of alkali. The pure hydrogen generated is highly efficient and has excellent performance in energy saving and environmental protection. The SPE electrode, which is the core of the product, is a highly active catalytic electrode formed by the integration of a synthetic catalyst with high electrolytic efficiency and an ion membrane, with the inter-electrode distance converging to almost 0. All other key parts are manufactured using top-grade engineering plastic molds with excellent quality. The design using a fully electronic control system ensures reliable quality, high degree of automation and improved output of pure hydrogen.

1) Principle of operation and technical process

When the power is turned on, electrolytic water is placed in the anode chamber of the electrolytic cell (electrical resistance exceeding 1 MΩ/cm, for which water is deionized and redistilled in the electronics and analytical industries), and the electrolytic water that satisfies the requirements is immediately decomposed at the anode. (2H2O=4H++2O-2)

The decomposed oxygen anions (O-2) immediately release electrons to form oxygen (O2), which are then released into the water tank from the anode chamber containing a small amount of water. The water can be recycled and the oxygen is released into the atmosphere through a small hole in the top cover of the water tank. Hydrogen protons, acting under the action of electric field through the SPE ion membrane in the form of aqua ions (H+·XH2O), reach the cathode to absorb electrons forming hydrogen, and are then released into the gas/water separator, which takes most of the water from the electrolytic cell to be removed from the cathode chamber.

Therefore, hydrogen with little water will follow the moisture absorption of the dryer with a purity of 99.997% or more. When the condensate in the gas/water separator accumulates to a certain amount, the float rises and is discharged from the bottom discharge port of the gas/water separator to the water tank for recirculation. After discharge, the float immediately returns to its original position, and the water level in the gas/water separator is thus kept constant.

2) Electrical Control

The overall electrical system mainly consists of four parts: the electrolytic power system, the main control unit, the auxiliary control unit, and the display panel.

When the power switch SW1 is pressed, the generator starts to operate. During the electrolysis process, when the air pressure reaches the preset value, the pressure transducer SEN starts to control the electrolysis current, which decreases with the increase in air pressure, thereby automatically enabling the output of hydrogen generated under a stable pressure to meet the consumption demand.

To ensure normal operation, the generator is equipped with two warning protection systems.

A. Overpressure warning

If the generator shakes violently during operation or some parts fail, the output pressure cannot be controlled and the pressure rises to 0.42 MPa, the generator will automatically cut off the electrolysis power supply and stop electrolysis with four beeps at intervals to recognize the overpressure protection. Then, the pressure warning light (red) on the front panel will light up and the hydrogen output will show 0.

The user should discharge the pressure and make sure the power connection is secure, and then restart the generator. If the above-mentioned phenomenon continues to occur, it should be considered a failure and reported to the manufacturer for maintenance.

B. Water level warning

If the water level in the water tank falls to the minimum limit during the operation of the generator or the water accumulation in the gas/water separator rises to the maximum limit due to long-term operation of the generator under 0 output pressure, the generator will emit a ‘beep’ sound approximately once every 6 seconds and stop electrolysis.

The user should turn off the generator to determine if there is a malfunction. If the water level in the water tank is normal and the output pressure of the generator is maintained at 0.02 MPa or higher, the warnings due to the two factors mentioned above are considered not to occur and the manufacturer should be notified for maintenance.

3) Technical parameter

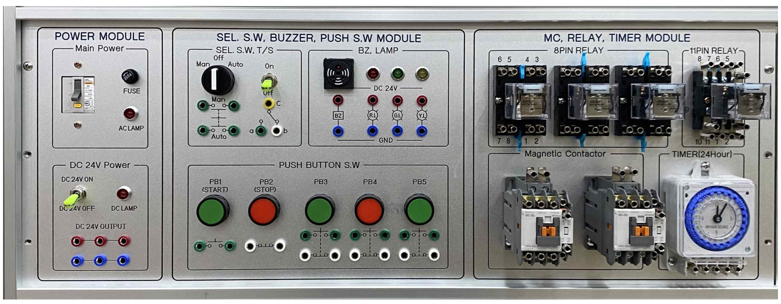
Name / Model Parameters	**HYDROGEN FUEL CELL GENERATION EXP. EQUIPMENT** (KTE-7000HS)
Output flow rate (ml/min)	0-1020
Output pressure (MPa)	0.02-0.32 (Output under stable pressure)
Hydrogen purity (%)	>99.999
Pressure value for overpressure protection (MPa)	0.42
Output voltage (V)	220-240V ~ 50-60 Hz
Input power (W)	<500

1-2. Configuration of experimental equipment

1) Control panel
2) Electrolyzer
3) Hydrogen dehumidification unit
4) Hydrogen fuel cell
5) Water tank
6) Gas/water separator
7) Load unit
8) List of main parts
9) Description of main parts

1-3. Function of each part

1) Control Panel



[Common Control Panel]

[Hydrogen control panel]

A. Control Panel Features

(1) It is configured to be controlled by turning the toggle switch on and off.

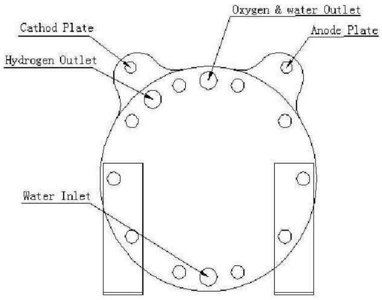
(2) The voltage, current and hydrogen generation amount of each part can be checked through the digital instrument.

(3) You can design and verify the hydrogen fuel cell circuit diagram using MC and relay.

2) Electrolytic cell

A. After being placed in the anode chamber of the electrolytic cell, the electrolytic water that meets the requirements (electrical resistance exceeding 1 MΩ/cm, for which water is deionized and redistilled in the electronics and analytical industries) is immediately decomposed at the anode. $(2H_2O = 4H^+ + 2O^{-2})$

The decomposed oxygen anions (O^{-2}) immediately release electrons to form oxygen (O_2), which are then released into the water tank from the anode chamber, which contains a small amount of water. The water can be recycled and the oxygen is released into the atmosphere through a small hole in the top cover of the water tank. Hydrogen protons, acting under the action of electric field through the SPE ion membrane in the form of aqua ions ($H^+ \cdot XH_2O$), reach the cathode to absorb electrons forming hydrogen, which are then released into the gas/water separator, which takes most of the water from the electrolytic cell to be removed from the cathode chamber.

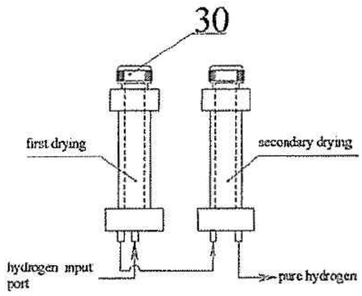


hydrogen outlet
water outlet
oxygen/water outlet
water inlet
anode plate
cathod plate

[Electrolytic cell parts names]

3) Hydrogen dehumidification unit

A. Hydrogen with little water is absorbed by the dryer with a purity of 99.997% or higher, and when the condensate in the gas/water separator accumulates to a certain amount, the float rises and is discharged from the bottom discharge port of the gas/water separator to the water tank for recirculation. After discharge, the float immediately returns to its original position, thereby maintaining the water level in the gas/water separator at a constant level, and the generated hydrogen is fed into the fuel cell.

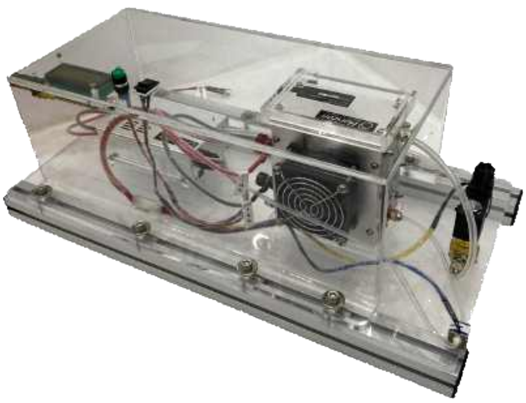


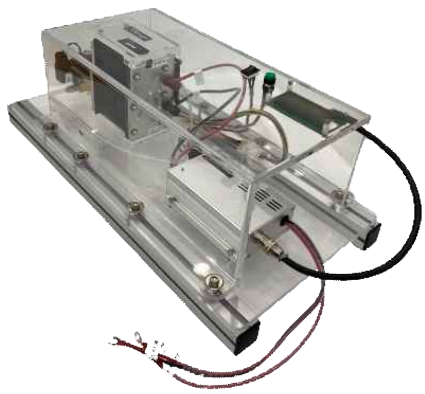
first drying
secondary drying
hydrogen input port
pure hydrogen

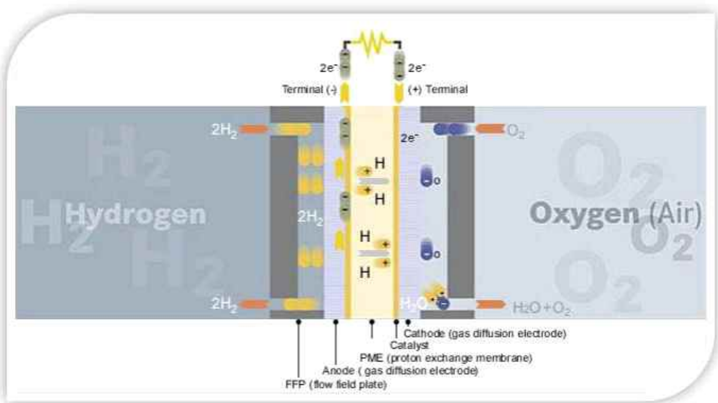
[Hydrogen Dehumidification unit parts names]

4) Hydrogen Fuel Cell

A. A fuel cell consists of a proton exchange membrane, a catalyst layer, a cathode (gas diffusion layer), an anode (gas diffusion layer), and a collector plate. The proton exchange membrane and the catalyst layer constitute the membrane electrode. The membrane electrode, the cathode, and the anode gas diffusion layer constitute the MEA. Finally, the MEA and two collector plates constitute a single cell.





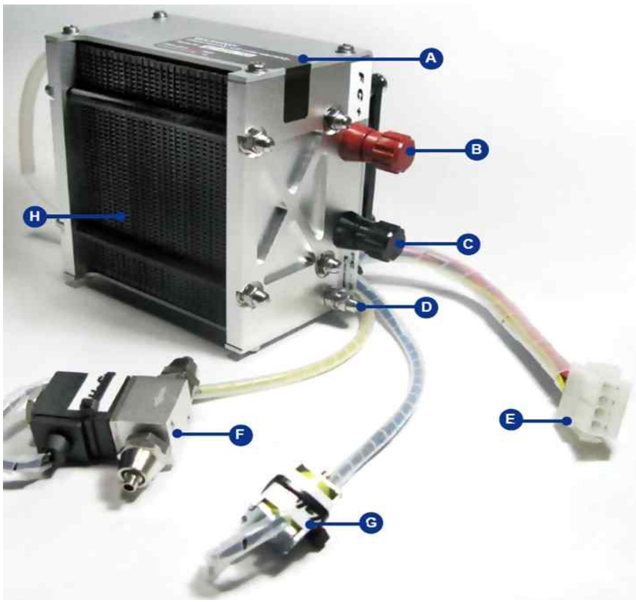


[Hydrogen Fuel Cell **Theorem]**

Gases (hydrogen and air) passing through the collector plates flow to both sides of the electrodes of the proton exchange membrane. Through this channel, hydrogen flows to the anode coated with a platinum catalyst, where it is separated into hydrogen protons and hydrogen ions. Free electrons flow into the external circuit, generating current, and protons move through the electrolyte membrane to the cathode. Oxygen in the air, electrons and protons in the external circuit react at the anode to produce pure water and release heat.

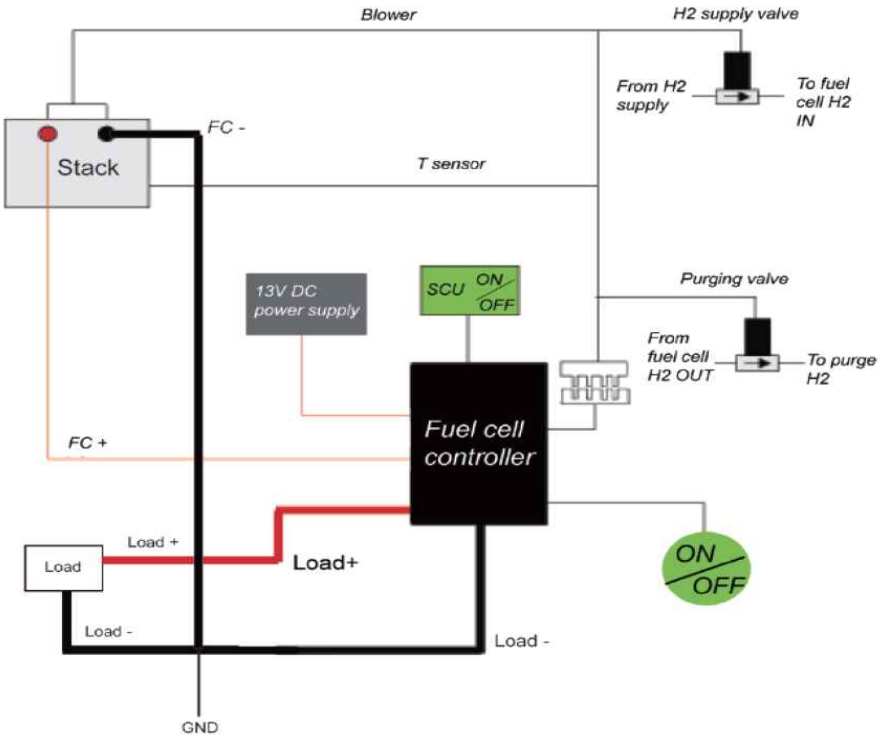
Provides the power required by the number of single cell fuel cell stacks formed by the junction. The rated voltage of hydrogen fuel cells is about 19.2 V, and the rated current is 2.6 A. Single cells form a series of fuel cell stacks to provide the required output voltage. Since the output current of a fuel cell is proportional to the effective area, fuel cell stacks can be geometrically joined to produce the required output voltage, current, and power.

A: Hydrogen inlet connector
B: Vent
C: Hydrogen outlet connector
D: Silicone tube



A: Protective Label
B: Fuel Cell+ Connector
C: Fuel Cell- & Load Connector
D: Fuel Cell- & Load-Stick
E: Multi-Connector and Controller Connection
F: Hydrogen Supply Valve
G: Hydrogen Purge Valve
H: Fuel Cell Air Inlet Side

[Hydrogen Fuel Cell]



[Hydrogen Fuel Cell system configuration diagram]

B. Hydrogen Fuel Cell Technical Data

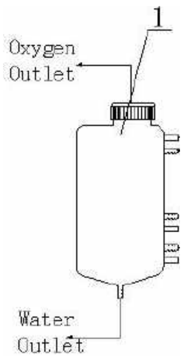
1. Fuel Cell Type : PEM
2. Built-in Cell : 24
3. Rated Power : 100W
4. Rated Performance : 14V, 7.2A
5. Output Voltage : 13V ~ 23V
6. Weight (including fan & case) : 0.95 kg (2.1 lb)
7. Dimensions : 104 x 135 x 90 mm (4.1 x 5.3 x 3.5 in)
8. Reactants : Hydrogen & Air
9. Rated H^2 Consumption : 1.4 L/min (83 in^3/min)
10. Hydrogen Pressure : 0.4 ~ 0.45 bar (5.8-6.5 psi)
11. Controller Weight : 362.4 g (0.8 lb)
12. Controller Dimensions : 88 x 133 x 40 mm (3.5 x 5.2 x 16 in)
13. Hydrogen supply valve voltage : 12V
14. Air exhaust valve voltage : 12V
15. Feed voltage : 4 ~ 12V
16. Ambient temperature : 5 ~ 35℃

17. Stack maximum temperature : 65℃
18. Hydrogen purity : 99.999% Dry H^2
19. Humidity : Automatic humidity control system
20. Cooling system : Built-in cooling fan
21. Start response : <30s (room temperature standard)
22. System efficiency : 40% @ 14V at maximum power

5) Water Tank

A. As a water tank for generating hydrogen, first fill it with deionized or redistilled water, and then wait for 5 minutes before starting. If used for a long time, microorganisms that affect the output of hydrogen and the useful life of the electrolyzer may multiply and become cloudy, so the water tank must be kept clean.

[Water Tank]



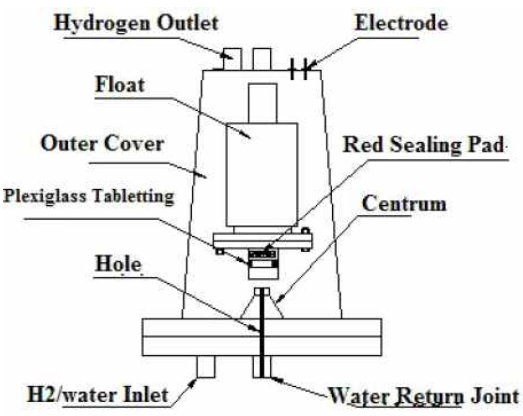
oxygen Outlet
water Outlet

[Water Tank Parts Names]

6) Gas/Water Separator

A. When the condensate in the gas/water separator accumulates to a certain amount, the float rises and is discharged from the bottom discharge port of the gas/water separator to the water tank for recirculation. After discharge, the float immediately returns to its original position, thereby maintaining the water level in the gas/water separator at a constant level.

[Gas/Water Separator]



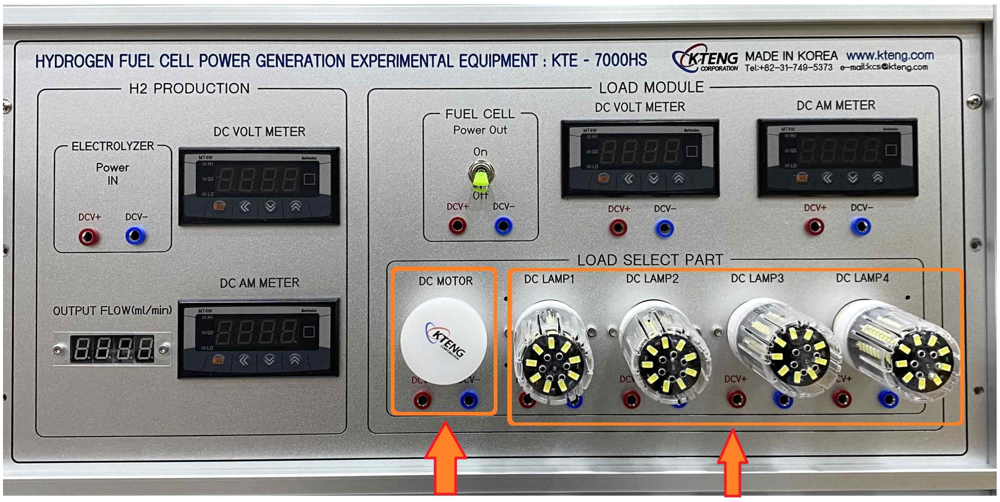
Hydrogen outlet
Electrode
Red Sealing Pad
Centrum
Water Return Joint
H2/Water Inlet
Hole
Plexiglass Tabletting
Outer cover
Float

[Gas/Water Separator Parts Names]

7) Load department

A. Electricity generated from hydrogen fuel cells can be used to drive DC motors.

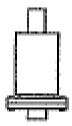
B. Each DC lamp can be lit using electricity generated from a hydrogen fuel cell.

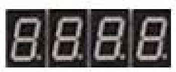


DC MOTOR 부하부 DC LAMP 부하부

[Load Select Part]

8) List and description of major parts

Nr.	Part name	shape	explanation
1	Water tank		As a water tank for generating hydrogen, first fill it with deionized or redistilled water, and then wait for 5 minutes before starting. This water is decomposed into oxygen and hydrogen through the electrolytic cell.
2	Condenser		Hydrogen and water coming out of the water outlet of the electrolyzer are condensed into the condenser until the water reaches a certain level.
3	Gas/water separator		When the condensate in the gas/water separator reaches a certain level, the float rises. The condensed water is discharged to the water tank and recycled due to the hydrogen pressure. After draining, the float returns to its original position. Repeatedly, the water level inside the gas/water separator is stabilized, so that hydrogen can be separated from water.
4	Pontoon		It moves up and down so that it can be discharged from the bottom discharge port of the gas/water separator to the water tank for recirculation, and after discharge, it returns to its original position, so that the water level remains constant.
5	Electrical Load Department		The DC voltage generated by the fuel cell is used to turn on the installed DC LED lamps, and the load on the fuel cell can be changed by adjusting the number of DC lamps.
6	Hydrogen/water Outlet		As a SUS pipe, it serves as a hydrogen transport pipe.

Nr.	Part name	shape	explanation
7	Electrolytic cell		The electrolytic water is immediately decomposed at the anode. ($2H_2O = 4H^+ + 2O^{-2}$) The decomposed oxygen acid anions (O^{-2}) immediately release electrons to form oxygen (O_2), which are then released into the water tank from the anode chamber with a little water. The water can be used cyclically, and the oxygen is released into the atmosphere from a small hole in the top cover of the water tank. Hydrogen protons under the action of electric field through the SPE ion membrane in the form of aqua ions ($H^+ \cdot XH_2O$) reach the cathode to absorb electrons to form hydrogen, and are then released into the gas/water separator, which takes most of the water from the electrolytic cell to be removed from the cathode chamber.
8	Oxygen/water Outlet		A hose made of silicone material used to recirculate and release oxygen and water.
9	Flow rate display Screen		You can check the output flow rate of hydrogen.
10	Fuse		It performs the role of a power cutoff.
11	Power Supply		This is a power supply device to maintain a voltage of 4V for the electrolytic production efficiency of the electrolytic cell.
12	Outlet Pressure Gauge		This device indicates the pressure of hydrogen.

Nr.	Part name	shape	explanation
13	Flow control Device		This is a hydrogen output flow control device.
14	4-way piece		This device connects each of the suspension pipes and can display the pressure gauge status of each section.
15	Dryer		The drying procedure is divided into two stages. Two drying cartridges using blue silica gel each are primary drying, and one drying cartridge using flesh-colored molecular sieve is secondary drying. It plays a role in separating high-purity hydrogen by absorbing moisture contained in gaseous hydrogen.
16	Exhaust Valve		After the device test, it is used to relieve the remaining pressure, and the nut on the vent valve in front of the hydrogen exhaust port should be loosened and discharged. After the pressure is relieved, the valve should be closed again to seal it.
17	Pressure Switch		When the pressure rises, the device automatically shuts off the electrolytic power supply and stops electrolysis to recognize overpressure protection.
18	Condensate Circulation Pipe		A silicone hose used to discharge the gas/water separator's bottom outlet into a recirculating water tank.
19	Transformer		A device used to increase or decrease alternating voltage. The transformer is located inside the control panel.
20	Power Socket		This is a power socket that inputs AC 220V.
21	Fuel Cell		It is a device that receives hydrogen and converts the chemical energy of the hydrogen into electrical energy to produce electricity.

2. Operation and practice

Experiment name	2-1. Experimenting with the performance of hydrogen fuel cells using electrolysis	Class time(hr)
		8
Object	① Learn the structure and operation method of the fuel cell system. ② Understand the principle of hydrogen generation through water electrolysis. ③ Analyze the components and design technology of the hydrogen fuel cell system, and the efficiency of each part.	

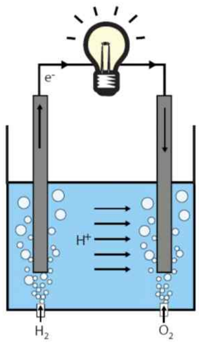
Experiment equipment	Tool & material	Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Driver	· #2× 6× 175mm	1
	· Nipper	· 150mm	1
	· Wire stripper	· 0.5~6㎟	1
	· Hook meter	· 300A 600V	1/Group

Control Circuit

1. Related Theory

(1) Theorem of Fuel Cell

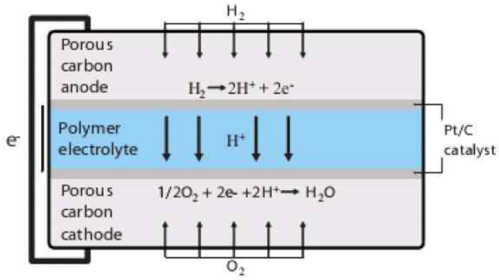
There are many different types of fuel cells, but basically, the main reaction takes place through an anode, a cathode, and an electrolyte between them. The fuel supplied to the anode is separated into ions and electrons by a catalyst, and the ions generated at this time move to the cathode along the electrolyte and combine with oxygen, etc., and the remaining electrons move between the electrodes through the wire and generate electric current.



[Theorem of Fuel Cell]

PEMFC is one of the most widely used types of hydrogen fuel cells in various fields due to its high energy density and relatively low operating temperature/pressure. It uses a thin special polymer electrolyte membrane as an electrolyte, through which protons generated at the oxidation electrode pass, and the movement of gases and electrons is suppressed. The chemical reaction that occurs in PEMFC can be expressed by the following equation, and depending on the type of hydrogen fuel cell, the reactions that occur at the oxidation and reduction electrodes may differ from the equation below, but the chemical reaction of the entire system is the same.

$$\begin{aligned}&\text{Anode:} && H_2 \rightarrow 2H^+ + 2e^- \\ &\text{Cathode:} && \frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O \\ \hline &\text{Overall:} && H_2 + \frac{1}{2}O_2 \rightarrow H_2O\end{aligned}$$



[Fuel cell reaction formula] [Schematic diagram of a fuel cell]

(2) Efficiency of fuel cells

The energy that can be obtained through the oxidation of fuel can be known through the reaction enthalpy ($\Delta\hat{h}^{o}_{rxn}$: enthalpy of reaction), which corresponds to the difference in enthalpy before and after the overall reaction, and this is generally calculated using the formation enthalpy ($\Delta\hat{h}^{o}_{f}$: formation enthalpy). However, since the energy corresponding to the reaction enthalpy cannot be fully utilized, the Gibbs free energy ($\Delta\hat{g}^{o}_{rxn}$: Gibbs free energy) is used as a measure of the available energy. In addition, the relationship between these energy terms and the voltage generated in an actual fuel cell can be compared and organized using the following equation.

$$W_{\text{elec}} = EQ = -\Delta g_{rxn}$$
$$Q = nF$$
$$\Delta\hat{g} = -nFE$$
$$E^0 = \frac{-\Delta\hat{g}^0_{\text{rxn}}}{nF}$$

(n = number of electrons transferred, F = Faraday’s constant)

The relationship between the reaction occurring in the fuel cell and conditions such as temperature, pressure, and concentration can be found through the Nernst equation below, and the reversible cell voltage can be calculated with this equation.

$$\begin{aligned}E &= E^0 - \frac{RT}{nF}\ln\frac{a_{H_2O}}{a_{H_2}a_{O_2}^{1/2}} \\ &= E^0 - \frac{RT}{2F}\ln\frac{1}{p_{H_2}p_{O_2}^{1/2}}\end{aligned}$$

The efficiency of an actual fuel cell can be expressed as the product of three efficiencies, as shown in the equation below. The first efficiency is the reversible thermodynamic efficiency using the enthalpy and Gibbs energy mentioned above, and the second efficiency is the efficiency related to the voltage drop that occurs within the fuel cell system. The last efficiency is the ratio of the fuel used that participated in the actual reaction, and is usually calculated using the stoichiometric factor.

$$\varepsilon_{real} = (\varepsilon_{thermo}) \times (\varepsilon_{voltage}) \times (\varepsilon_{fuel})$$
$$= \left(\frac{\Delta \hat{g}}{\Delta \hat{h}_{HHV}} \right) \times \left(\frac{V}{E} \right) \times \left(\frac{i / nF}{v_{fuel}} \right)$$

g: Gibbs free energy (kJ/mol)
h: reaction enthalpy (kJ/mol)
E: reversible cell voltage (V)
vfuel: hydrogen flow rate supplied to the fuel cell (mol/s)
n: number of electrons produced per molecule

The amount of a substance decomposed through electrolysis is quantified using Faraday's law. Faraday's law of electrolysis states that the mass being electrolyzed is proportional to the amount of charge applied and the chemical equivalent of the substance, and can be expressed by the following equation.

$$m = \left(\frac{Q}{F} \right) \left(\frac{M}{z} \right)$$

(M : molar mass, z : valency number of ions, F : Faraday's constant)

(3) Volumetric flow rate ratio of hydrogen and air under Stoichiometric conditions

Composition ratio of air

No.	ingredient	Volume ratio(%)
1	Nitrogen(N_2)	78.3
2	Oxygen(O_2)	20.99
3	Argon(Ar)	0.94
4	Carbon dioxide(CO_2)	0.03
5	Hydrogen(H_2)	0.01

The reaction formula for hydrogen and oxygen is $2H_2 + O_2 \rightarrow 2H_2O$.

That is, hydrogen and oxygen react in a volume ratio of 2:1, and looking at the composition ratio of air, we can see that oxygen accounts for about 21%. The air supplied for the reaction of hydrogen and oxygen is from above, and since the ratio of oxygen and air is 21:100, we can see that the ratio of hydrogen:oxygen:air is 42:21:100. That is, the ratio of oxygen and air is 42:100, and the volume flow rate ratio is about 1:2.38.

(4) Gibbs function

Gibbs free energy is the thermodynamic energy that can be converted into work in a system that maintains constant temperature and pressure. Free energy is a function of enthalpy H, temperature T, and entropy S, and is defined as . It is a state function that can tell whether a reaction is spontaneous or involuntary regardless of the surroundings. Since internal energy is originally a quantity that is difficult to obtain an absolute value for, enthalpy (H) usually only considers the increase and decrease due to thermal change. While the amount of heat given and received by a material system while maintaining a constant volume is the same as the increase and decrease in internal energy, the amount of heat entering and leaving a material system while maintaining a constant pressure is equal to the increase and decrease in the enthalpy of the material system. An isothermal and isobaric reaction is spontaneous if the free energy change is less than 0, involuntary if it is greater than 0, and equilibrium if it is 0. In a system at a constant temperature and pressure, the change in Gibbs free energy (ΔG) is proportional to the total entropy change of the system and its surroundings. That is $\triangle G = \triangle H - T \triangle S$.

Spontaneous change involves an increase in total entropy (Second Law of Thermodynamics). Therefore, according to the Gibbs Function, spontaneous changes that occur at constant temperature and pressure result in a decrease in the Gibbs free energy of the system. Therefore, we can determine whether the system can undergo a spontaneous change through the change in Gibbs free energy of the system. Therefore, Gibbs free energy is useful for obtaining chemical equilibrium conditions under constant temperature and pressure conditions. The relationship between ΔG and spontaneity of a reaction is that, when temperature and pressure are constant, if ΔG is less than 0, the forward reaction is spontaneous, if it is 0, the reaction is at equilibrium, and if it is greater than 0, the forward reaction is non-spontaneous but the reverse reaction is spontaneous. In other words, we can determine whether the system can undergo a spontaneous change through the change in Gibbs free energy of the system, and therefore Gibbs free energy can be useful for obtaining chemical equilibrium conditions under constant temperature and pressure conditions.

In a fuel cell, in a reversible reaction that occurs at a constant temperature such as the ambient temperature, the work output of the fuel cell can be expressed as $W = -(\Sigma n_e \overline{g_e} - \Sigma n_i \overline{g_i}) = -\triangle G$ by the change in Gibbs Function.

(5) i-V and power density curves

The performance of a fuel cell can be known through its current and voltage characteristics, and since the voltage changes depending on the current used, the performance of the fuel cell is observed using a current-voltage curve. Also, since the larger the fuel cell size, the larger the current it can produce, the curve uses the current density (A/cm2), which is the size of the current per unit area, instead of the general current. The voltage when the current is 0 is called the open circuit voltage (OCV), and the power density (W/cm2) curve can be expressed by multiplying the current and voltage at each point on the current-voltage curve.

2. Experimental equipment

The experimental equipment consists of an electrolytic cell, hydrogen fuel cell, dehumidifier, DC lamp, water tank, control switch, and instrument panel.

Distilled pure water is stored in the water tank, and this water is decomposed into oxygen and hydrogen through the electrolytic cell. At this time, a voltage of 4 V is maintained for the production efficiency of electrolysis. The decomposed oxygen is released, and the hydrogen is sent to the fuel cell after removing the water mixed in through the dehumidifier. At this time, the flow rate of hydrogen can be measured through a flow meter, and this can be controlled using a valve. The electricity generated through the fuel cell is used to turn on the installed DC lamp, and the load of the fuel cell can be changed by controlling the number of DC lamps.

The instrument panel can check the voltage and current values related to electrolysis and fuel cell.

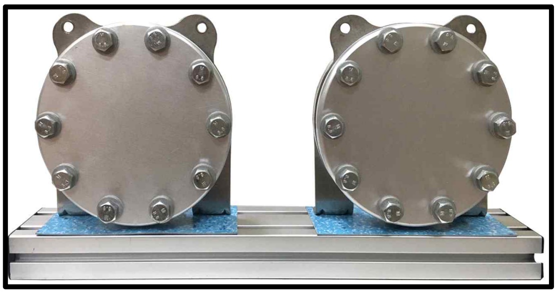
[Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment]

[Hydrogen Fuel Cell Control Panel]

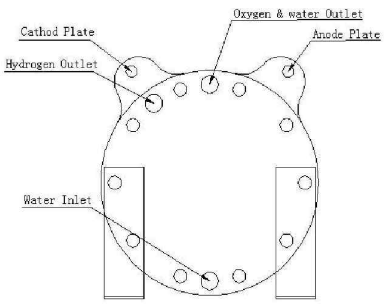
3. Description of Main Components

(1) Electrolytic Cell

After being placed in the anode chamber of the electrolytic cell, the electrolytic water that meets the requirements (electrical resistance exceeding 1 MΩ/cm, for which water is deionized and redistilled in the electronics and analytical industries) is immediately decomposed at the anode($2H_2O = 4H^+ + 2O^{-2}$). The decomposed oxygen anions (O^{-2}) immediately release electrons to form oxygen (O_2) and are then released into the water tank from the anode chamber with a little water. The water can be circulated, and the oxygen is released into the atmosphere from a small hole in the top cover of the water tank. Hydrogen protons under the action of electric field through the SPE ion membrane in the form of aqua ions ($H^+ \cdot XH_2O$) reach the cathode to absorb electrons to form hydrogen, and are then released into the gas/water separator, which takes most of the water from the electrolytic cell to be removed from the cathode chamber.



[Electrolytic Cell]



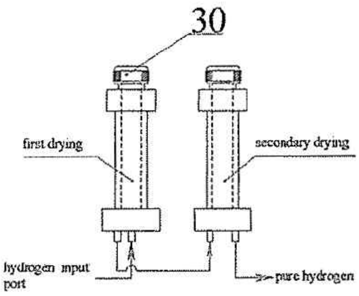
hydrogen outlet
water outlet
oxygen/water outlet
water inlet
anode plate
cathod plate

[Electrolytic Cell Parts Names]

(2) Hydrogen Dehumidification Unit

Hydrogen with little water is absorbed by the dryer with a purity of 99.997% or higher, and when the condensate in the gas/water separator accumulates to a certain amount, the float rises and is discharged from the bottom discharge port of the gas/water separator to the water tank for recirculation. After discharge, the float immediately returns to its original position, thereby maintaining the water level in the gas/water separator at a constant level, and the generated hydrogen is fed into the fuel cell.

[Hydrogen Dehumidification]

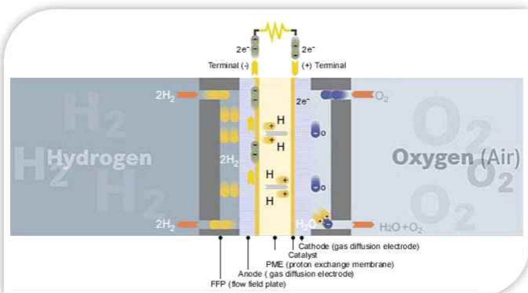


first drying
secondary drying
hydrogen input port
pure hydrogen

[Hydrogen Dehumidification Unit Parts Names]

(3) Hydrogen Fuel Cell

A fuel cell consists of a proton exchange membrane, a catalyst layer, a cathode (gas diffusion layer), an anode (gas diffusion layer), and a collector plate. The proton exchange membrane and the catalyst layer constitute the membrane electrode. The membrane electrode, the cathode, and the anode gas diffusion layer constitute the MEA. Finally, the MEA and two collector plates constitute a single cell.



[Hydrogen Fuel Cell Theorem]

Gases (hydrogen and air) passing through the collector plates flow to both sides of the electrodes of the proton exchange membrane. Through this channel, hydrogen flows to the anode coated with a platinum catalyst, where it is separated into hydrogen protons and hydrogen ions. Free electrons flow into the external circuit, generating current, and protons move through the electrolyte membrane to the cathode. Oxygen in the air, electrons and protons from the external circuit react at the anode to produce pure water and release heat.

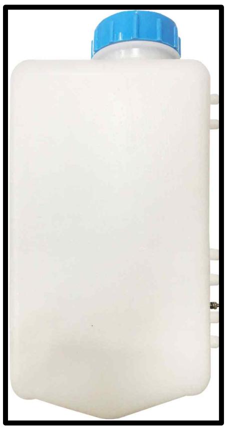
It provides the power required for the number of single-cell fuel cell stacks formed by the junction. The rated voltage of a hydrogen fuel cell is about 19.2 V, and the rated current is 2.6 A. A single cell forms a series of fuel cell stacks to provide the required output voltage. Since the output current of a fuel cell is proportional to the effective area, fuel cell stacks can be geometrically joined to produce the required output voltage, current, and power.

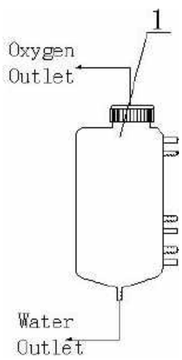
[Hydrogen Fuel Cell]

(4) Water Tank

As a water tank for generating hydrogen, first fill it with deionized or redistilled water and wait for 5 minutes before starting.

The water tank must be kept clean as long-term use can cause the water to become cloudy and harbor microorganisms that can affect the output of hydrogen and the useful life of the electrolyzer.





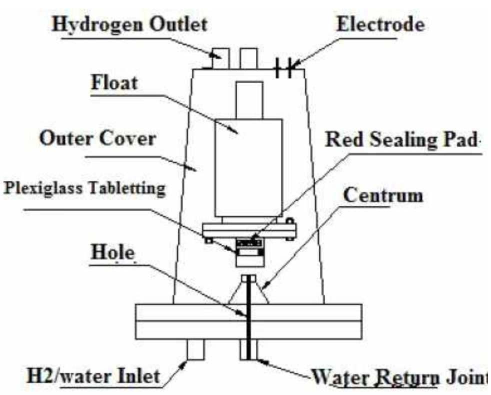
Oxygen Outlet
Water Outlet

[Water Tank] [Water Tank Parts Names]

(5) Gas/Water Separator

When the condensate in the gas/water separator accumulates to a certain amount, the float rises and is discharged from the bottom discharge port of the gas/water separator to the water tank for recirculation. After discharge, the float immediately returns to its original position, thereby maintaining the water level in the gas/water separator at a constant level.

[Gas/Water Separator]



Hydrogen outlet
Electrode
Red Sealing Pad
Centrum :
Water Return Joint
H2/Water Inlet
Hole
Plexiglass Tabletting
Outer cover
Float

[Name of each department of Gas/Water Separator]

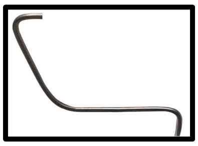
(6) Electrical Load Department

Each DC lamp can be lit using the power generated from the hydrogen fuel cell. The DC motor can be operated using the power generated from the hydrogen fuel cell.

[Electrical Load Department]

(7) Hydrogen/Water Outlet

As a SUS pipe, it serves as a hydrogen transport pipe.

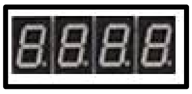


[Hydrogen/Water Outlet]

(8) Oxygen/Water Outlet

A hose made of silicone material used to recirculate and release oxygen and water.

(9) Flow Rate Display Screen



You can check the output flow rate of hydrogen.

(10) Power Supply

This is a power supply device to maintain a voltage of 4V for the electrolytic production efficiency of the electrolytic cell.

(11) 4-way Piece

Connects each sus pipe and can display the pressure gauge status of each part.

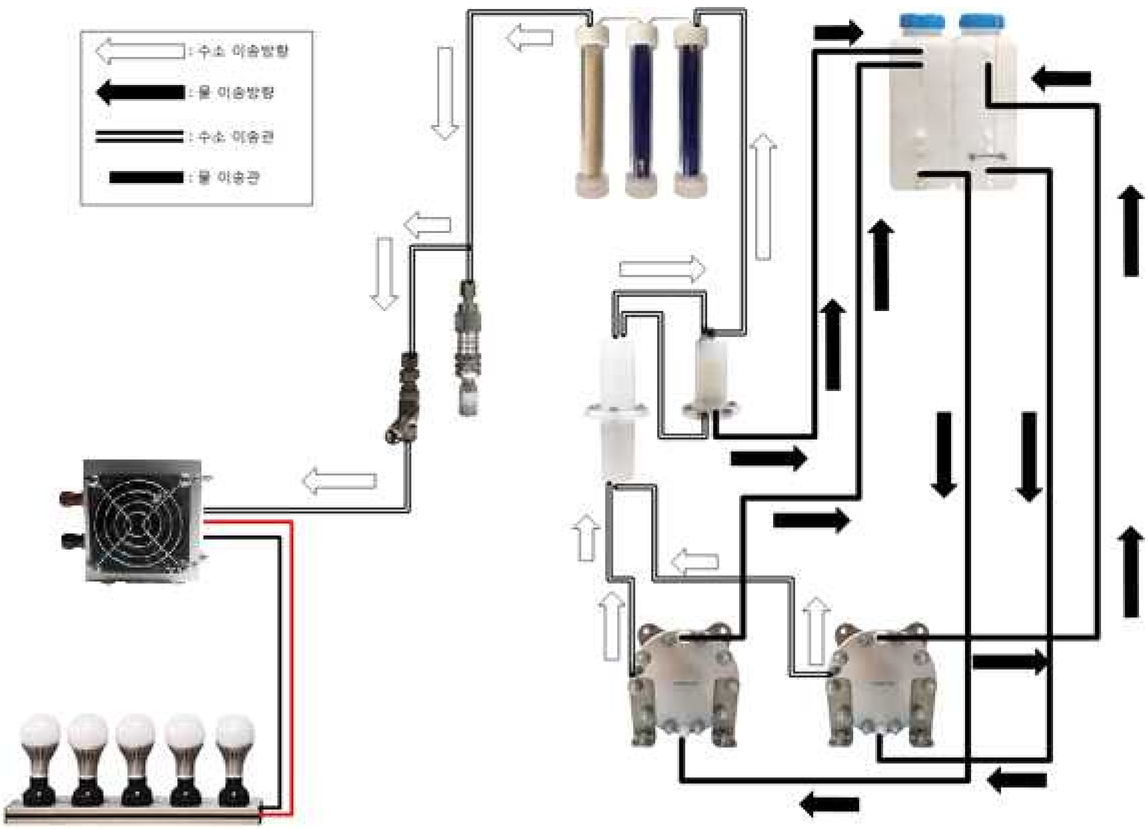
(12) Exhaust Valve

After the experimental device experiment, it is used to relieve the remaining pressure, and the nut on the vent valve in front of the hydrogen exhaust port must be loosened and discharged. After the pressure is relieved, the valve must be closed again to seal it.

(13) Condensate Circulation Pipe

A silicone hose used to discharge the gas/water separator's bottom outlet into a recirculating water tank.

4. Hydrogen Fuel Cell Transport Route



[Example diagram showing the transport path of water and hydrogen]

5. Experimental method

(1) Turn the circuit breaker switch on the Control Panel to ON.

(2) Fill the generator tank with distilled water.

(3) The hydrogen generator is operated using a switch.

(4) Once the hydrogen flow rate is secured, turn the hydrogen fuel cell switch ON.

(5) After the hydrogen generator and fuel cell are stabilized, the lamp is turned on using the load switch.

(6) When the system reaches normal state, the conditions such as voltage and current of the Control Panel are recorded.

(7) In the same way, the experiment is performed in the same way by changing the load through the number of lamps.

(8) Writing the experimental results

6. Writing the experimental results

(1) Using the values measured in the experiment, calculate and graph the following values.

A. Electrolysis efficiency

$$\eta_{elec} = \frac{m_{real}}{m_{theory}}$$

$$m_{theory} = \left(\frac{I}{F}\right)\left(\frac{M}{Z}\right)$$

m_{real} : Mass flow rate of hydrogen produced in the electrolyzer (g/s)

m_{theory} : Theoretical calculated maximum hydrogen mass flow rate (g/s)

F : faraday constant (C/mol)

B. Equivalence ratio and efficiency of hydrogen fuel cells (at full load)

$$\lambda = \frac{V_{fuel}}{i/nF}$$

v_{fuel} : Hydrogen flow rate supplied to the fuel cell (mol/s)

n : Number of electrons generated per molecule

$$\varepsilon_{real} = \left(\varepsilon_{thermo}\right)\times\left(\varepsilon_{voltage}\right)\times\left(\varepsilon_{fuel}\right)$$

$$= \left(\frac{\Delta\hat{g}}{\Delta\hat{h}_{HHV}}\right)\times\left(\frac{V}{E}\right)\times\left(\frac{i/nF}{v_{fuel}}\right)$$

g : Gibbs free energy (kJ/mol)

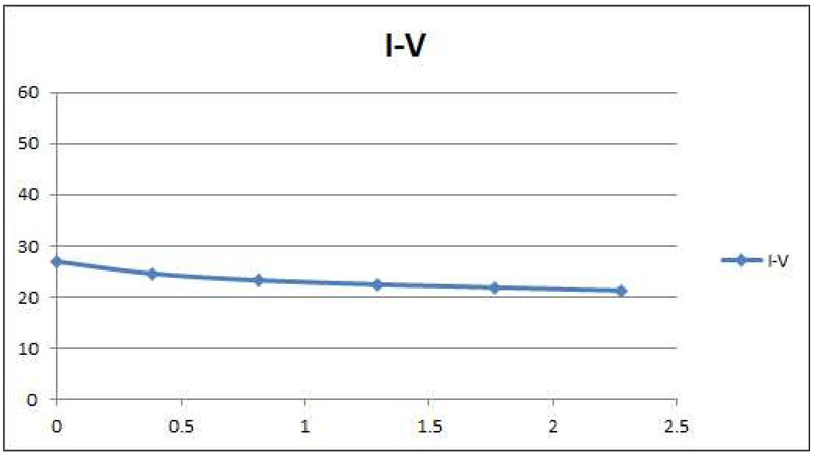
h : Reaction enthalpy (kJ/mol)

E : Reversible battery voltage (V)

v_{fuel} : Hydrogen flow rate supplied to the fuel cell (mol/s)

n : Number of electrons generated per molecule

C. i-V curve



Assignment Evaluation

Experimental equipment for hydrogen fuel cell power generation using electrolysis (KTE-7000HS)

・Requirements

1. Prepare and inspect experimental equipment and tools.
2. Configure and operate according to the experimental operation sequence.
3. Check whether Electrolyze performs electrolysis.
4. Measure the hydrogen fuel cell voltage, current, and flow rate values and explain the generation principle.
5. Analyze the performance and efficiency of the experimental equipment that occurs when the system is operated.

<table>
<tr><td rowspan="9">Evaluation</td><td colspan="2">Appraisal</td><td>Allot</td><td>Point</td><td colspan="4">Remark</td></tr>
<tr><td rowspan="4">Work Point (80)</td><td>Understanding each mechanism</td><td>20</td><td></td><td colspan="4" rowspan="6"></td></tr>
<tr><td>Understanding the entire circuit</td><td>20</td><td></td></tr>
<tr><td>Operation status</td><td>20</td><td></td></tr>
<tr><td>Voltage, current, and flow measurement</td><td>20</td><td></td></tr>
<tr><td rowspan="2">Task Point (10)</td><td>Work attitude and safety</td><td>5</td><td></td></tr>
<tr><td>Use and organize materials and tools</td><td>5</td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>Experiment Name</td><td colspan="2">2-2. Practice comparing performance according to load changes of hydrogen fuel cell using electrolysis</td><td>Class time(hr)
8</td></tr>
<tr><td>Object</td><td colspan="3">① Learn the structure and operation of a fuel cell system.
② You can understand the principle of hydrogen generation through water electrolysis.
③ You can analyze the components and design technology of hydrogen fuel cell systems and the efficiency of each part.</td></tr>
<tr><td>Experiment equipment</td><td>Tool & material</td><td>Spec of tools</td><td>Q`nty</td></tr>
<tr><td>• Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)</td><td>• Driver
• Nipper
• Wire stripper
• Hook meter</td><td>• #2× 6× 175㎜
• 150㎜
• 0.5~6㎟
• 300A 600V</td><td>1
1
1
1/Group</td></tr>
<tr><td colspan="4">Control Circuit</td></tr>
</table>

1. Related Theory

(1) Efficiency of fuel cells

The energy that can be obtained through the oxidation of fuel can be known through the reaction enthalpy ($\Delta\hat{h}^{o}_{rxn}$: enthalpy of reaction), which corresponds to the difference in enthalpy before and after the overall reaction. This is generally calculated using the formation enthalpy ($\Delta\hat{h}^{o}_{f}$: formation enthalpy). However, since the energy corresponding to the reaction enthalpy cannot be fully utilized, the Gibbs free energy ($\Delta\hat{g}^{o}_{rxn}$: Gibbs free energy) is used as a measure of the available energy. In addition, the relationship between these energy terms and the voltage generated in an actual fuel cell can be compared and organized using the following equation.

$$W_{elec} = EQ = -\Delta g_{rxn}$$

$$Q = nF$$

$$\Delta\hat{g} = -nFE$$

$$E^{0} = \frac{-\Delta\hat{g}^{0}_{rxn}}{nF}$$

(n = number of electrons transferred, F = Faraday’s constant)

The relationship between the reaction occurring in the fuel cell and conditions such as temperature, pressure, and concentration can be found through the Nernst equation below, and the reversible cell voltage can be calculated with this equation.

$$E = E^0 - \frac{RT}{nF}\ln\frac{a_{H_2O}}{a_{H_2}a_{O_2}^{1/2}}$$
$$= E^0 - \frac{RT}{2F}\ln\frac{1}{p_{H_2}p_{O_2}^{1/2}}$$

The efficiency of an actual fuel cell can be expressed as the product of three efficiencies, as shown in the equation below. The first efficiency is the reversible thermodynamic efficiency using the enthalpy and Gibbs energy mentioned above, and the second efficiency is the efficiency related to the voltage drop that occurs within the fuel cell system. The last efficiency is the ratio of the fuel used that participated in the actual reaction, and is usually calculated using the stoichiometric factor.

$$\varepsilon_{real} = \left(\varepsilon_{thermo}\right)\times\left(\varepsilon_{voltage}\right)\times\left(\varepsilon_{fuel}\right)$$
$$= \left(\frac{\Delta\hat{g}}{\Delta\hat{h}_{HHV}}\right)\times\left(\frac{V}{E}\right)\times\left(\frac{i/nF}{v_{fuel}}\right)$$

g : Gibbs free energy (kJ/mol)

h : Reaction enthalpy (kJ/mol)

E : Reversible battery voltage (V)

v_{fuel} : Hydrogen flow rate supplied to the fuel cell (mol/s)

n : Number of electrons generated per molecule

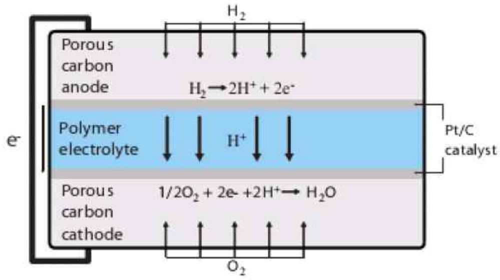
The amount of a substance decomposed through electrolysis is quantified using Faraday's law. Faraday's law of electrolysis states that the mass being electrolyzed is proportional to the amount of charge applied and the chemical equivalent of the substance, and can be expressed by the following equation.

$$m = \left(\frac{Q}{F}\right)\left(\frac{M}{z}\right)$$

(M : molar mass, z : valency number of ions, F : Faraday's constant)

$$\text{Anode:} \quad H_2 \rightarrow 2H^+ + 2e^-$$
$$\text{Cathode:} \quad \frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$$
$$\text{Overall:} \quad H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

[Fuel cell reaction formula]



[Schematic diagram of a fuel cell]

2. How to configure performance comparison according to load

(1) Fill the generator's water tank with enough distilled water.

(2) Turn the main switch on the Control Panel to ON.

(3) Turn the H2 production part Electrolyzer toggle switch ON.

(4) Once the hydrogen flow is secured, turn the Fuel Cell toggle switch ON.

(5) After the hydrogen generator and fuel cell are stabilized, the lamp is turned on using the load switch.

(6) When the system reaches normal state, the conditions such as voltage and current of the Control Panel are recorded.

(7) In the same way, the experiment is performed in the same way by changing the load through the number of lamps.

(8) Writing the experimental results

※ Caution ※

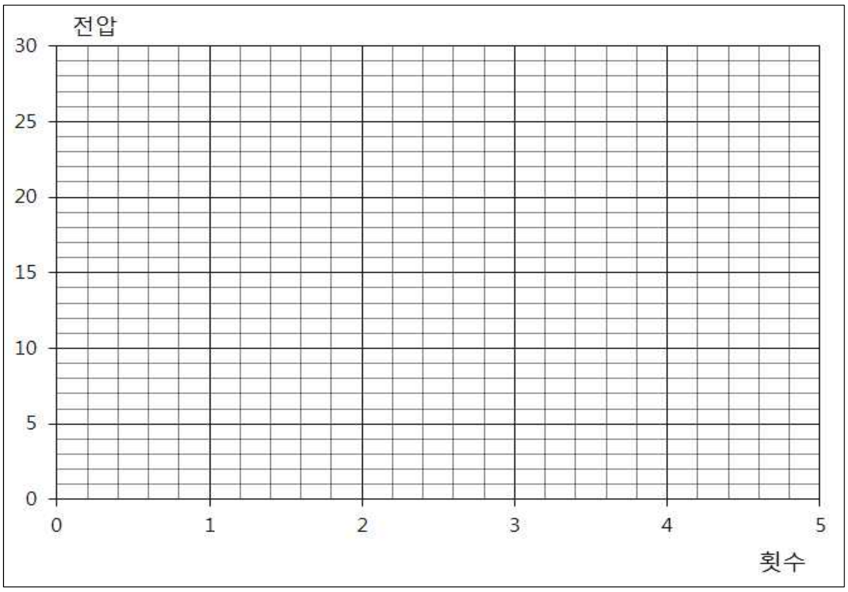
Be sure to use distilled water, as other liquids will permanently damage the Electrolyze membrane.

3. Summary and calculation of results

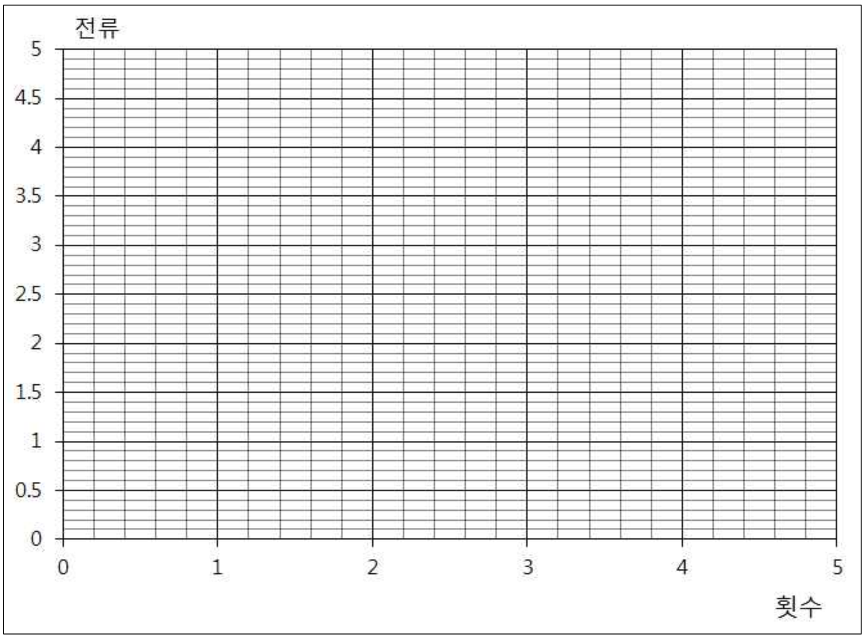
1. experiment

Experimental Results		
Electrical Load (LED)	Fuel cell voltage(V)	Fuel cell current(I)
1		
2		
3		
4		
5		

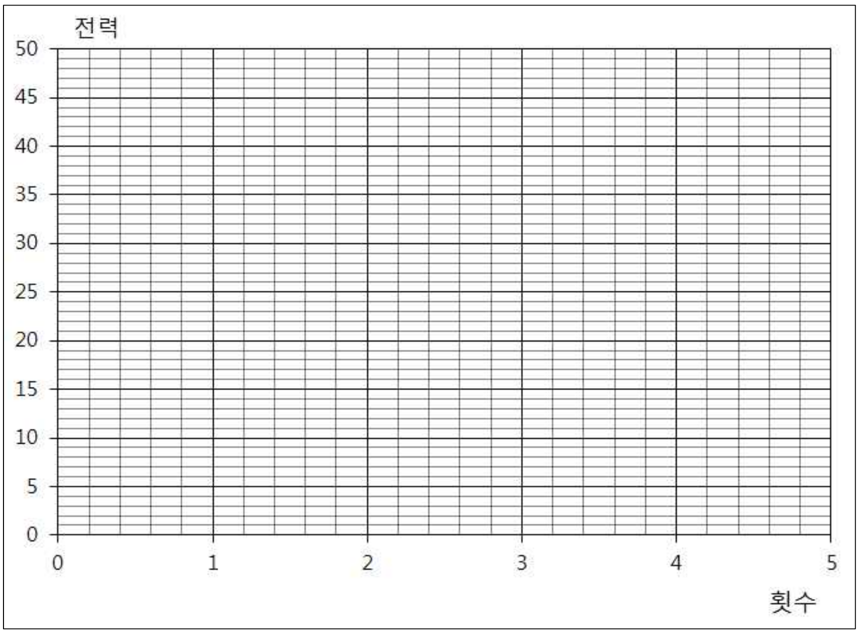
(1) Fuel cell voltage (V) Curve drawing



(2) Fuel cell current (I) Curve drawing



(3) Electrical Energy (W) Curve drawing



Assignment Evaluation

Experimental equipment for hydrogen fuel cell power generation using electrolysis (KTE-7000HS)

・Requirements

1. Prepare and inspect experimental equipment and tools.
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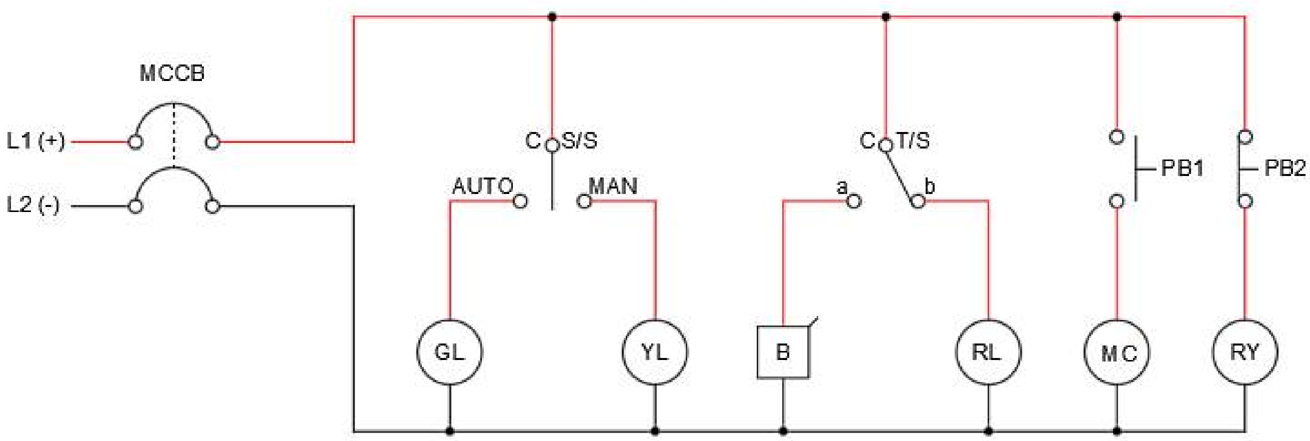
</table>

Chapter. 2 Basic Practice of Hydrogen Fuel Cell Power Generation Equipment Sequence Control

Experiment name	1. Basic circuit configuration driving practice using a switch	Class time(hr)
		2
Object	① Understand the principles of pushbutton switches and be able to wire the operating circuit. ② Understand the principles of toggle switches and be able to wire the driving circuit. ③ Understand the principles of selector switches and be able to wire driving circuits.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red · Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

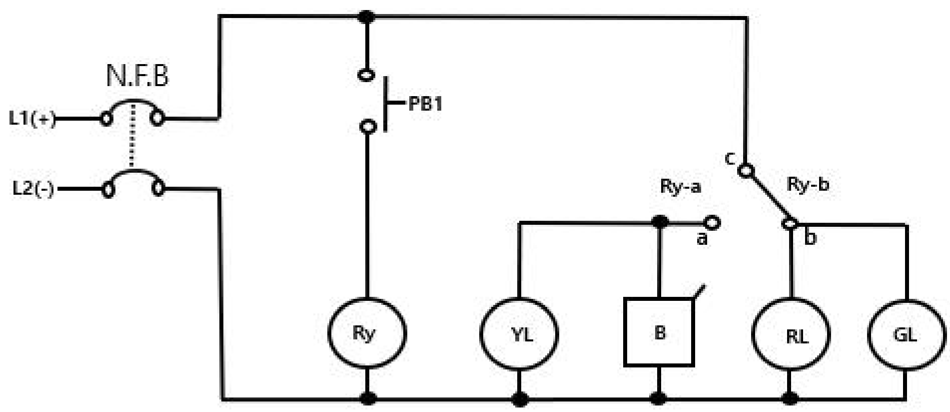
Control Circuit



A. When S/S is set to AUTO, the GL lamp lights up.
   When S/S is set to MAN, the YL lamp lights up and the GL lamp goes out.
B. When TS is set to b, the RL lamp lights up.
   When TS is set to a, the buzzer sounds.
C. When the a-contact push button PB1 is pressed, MC is energized.
   When the hand is released from PB1, MC is deenergized.
D. When the b-contact push button PB2 is pressed, RY is energized.
   When the hand is released from PB2, RY is deenergized.

Experiment name	2. Practice configuring a "c" contact circuit using a relay (RY)			Class time(hr) 2
Object	① You can understand the structure and operating principles of relays (Ry). ② The load of the refrigeration unit can be operated by utilizing the contacts of the relay (Ry). ③ The operation of the "c" contact driving circuit can be explained.			
Experiment equipment	Tool & material	Spec of tools		Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red · Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝		20 20

Control Circuit

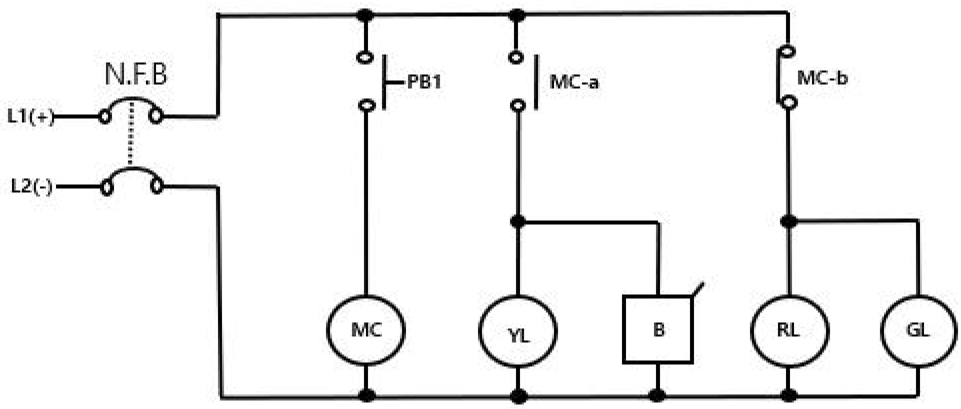


A. When the MCCB switch is turned on, the RY-b contact is closed, so RL and GL turn on, and the RY-a contact is open, so YL and the buzzer turn off. (PB1 is open)
B. When PB1 is pressed, the relay coil is energized and the RY-a contact is closed, so YL and the buzzer turn ON and RL and GL turn OFF.
C. Arbeit contact is an acronym for "working contact point" and is denoted by the initials "a".
D. Break contact is an acronym for 'open contact point' and is denoted by the initial letter "b".

<table>
<tr><td>Experiment name</td><td colspan="2">3. Practice of configuring “a” and “b” contact circuits using a magnetic contactor (MC)</td><td>Class time(hr)
2</td></tr>
<tr><td>Object</td><td colspan="3">① You can understand the structure and operating principles of the electromagnetic contactor (MC).
② The load of the refrigeration unit can be operated by utilizing the “a” and “b” contacts of the magnetic contactor (MC).
③ The operation of the “a” and “b” contact circuits using a magnetic contactor (MC) can be explained.</td></tr>
</table>

Experiment equipment	Tool & material	Spec of tools	Q`nty
• Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	• Banana Jack Red • Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit

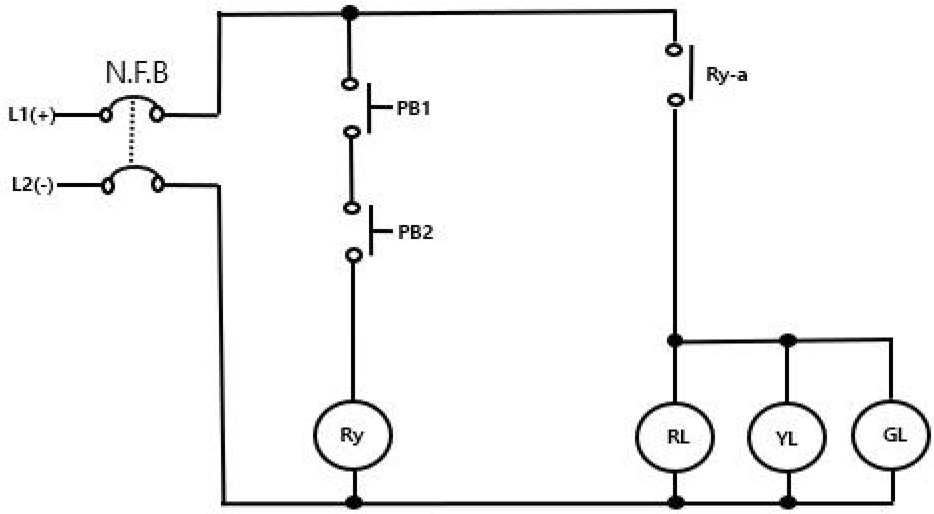


A. When the MCCB switch is turned on, the MC-b contact closes, RL and GL light up, and the MC-a contact opens, YL goes out and the buzzer turns off. (The PB switch is open.)
B. When the PB1 switch is pressed, the electronic coil MC is now excited, the MC-a contact closes, so YL lights up and the buzzer turns on, and the MC-b contact opens, so RL and GL turn off.
C. Arbeit contact is an acronym for "working contact point" and is denoted by the initials “a”.
D. Break contact is an acronym for "open contact point" and is denoted by the initial letter “b”.

Experiment name	4. AND circuit configuration and practice	Class time(hr)
		2
Object	① You can understand and wire AND circuits.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
• Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	• Banana Jack Red	1.5㎟ * 60㎝	20
	• Banana Jack Black	1.5㎟ * 60㎝	20

Control Circuit



A. Power input

B. Press PB1 - RL, YL, GL OFF

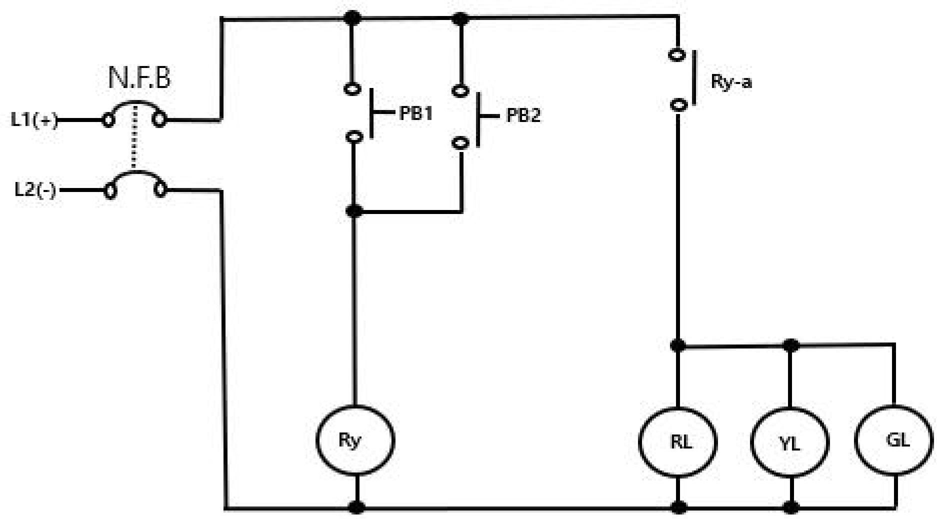
C. Press PB2 - RL, YL, GL OFF

D. When pressing PB1 and PB2 together - RL, YL, GL ON

Experiment name	5. OR Circuit Configuration and Practice	Class time(hr)
		2
Object	① You can understand and wire OR circuits.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
• Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	• Banana Jack Red	1.5㎟ * 60㎝	20
	• Banana Jack Black	1.5㎟ * 60㎝	20

Control Circuit

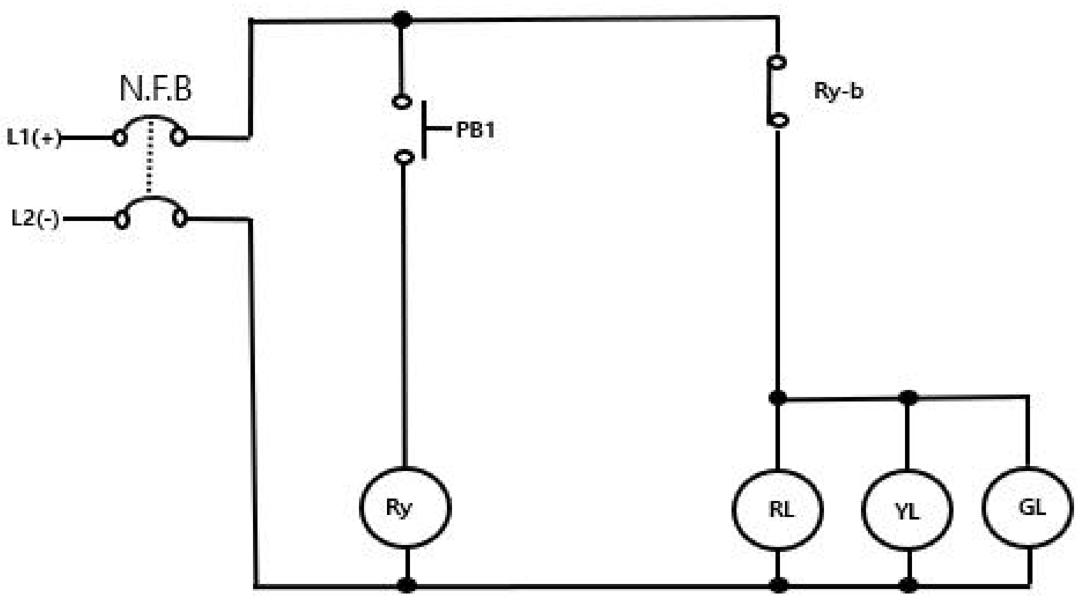


A. Power input
B. Press PB1 - RL, YL, GL ON
C. Press PB2 - RL, YL, GL ON
D. When pressing PB1 and PB2 together - RL, YL, GL ON

Experiment name	6. NOT circuit configuration and practice	Class time(hr)
		2
Object	① You can understand and wire NOT circuits.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
・Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	・Banana Jack Red ・Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



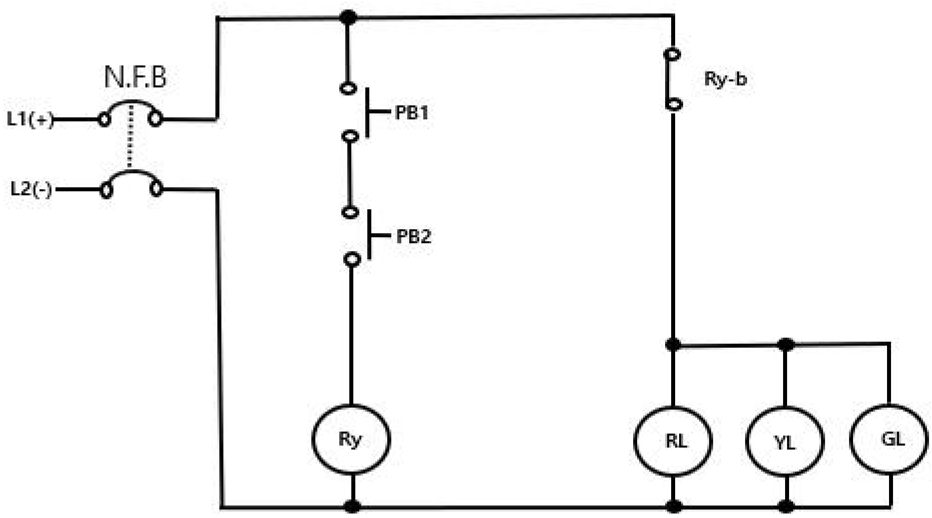
A. Power input - RL, YL, GL ON

B. Press PB1 - RL, YL, GL OFF

Experiment name	7. NAND circuit configuration and practice	Class time(hr)
		2
Object	① You can understand and wire NAND circuits.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
• Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	• Banana Jack Red • Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

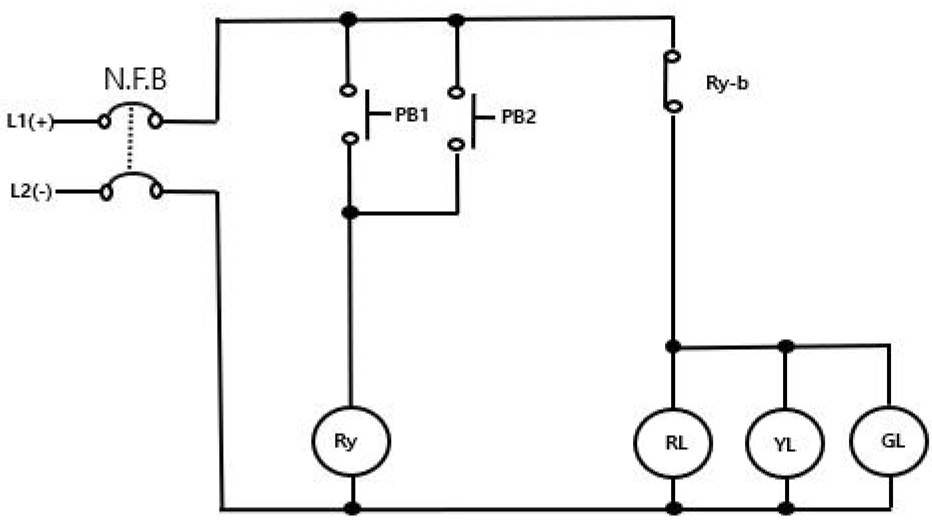
Control Circuit



A. Power input - RL, YL, GL ON
B. Press PB1 - RL, YL, GL ON
C. Press PB2 - RL, YL, GL ON
D. When pressing PB1 and PB2 together - RL, YL, GL OFF

Experiment name	8. NOR circuit configuration and practice			Class time(hr)
				2
Object	① You can understand and wire NOR circuits.			
Experiment equipment	Tool & material		Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red · Banana Jack Black		1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



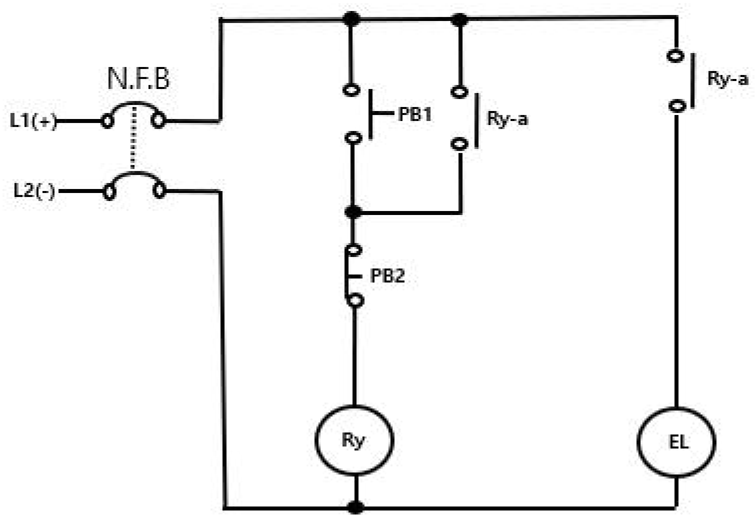
A. Power input - RL, YL, GL ON
B. Press PB1 - RL, YL, GL OFF
C. Press PB2 - RL, YL, GL OFF
D. When pressing PB1 and PB2 together - RL, YL, GL OFF

Chapter. 3 Basic circuit configuration and operation of hydrogen fuel cell power generation equipment

Experiment name	1. Operating the electrolyzer with a self-sustaining circuit with priority for stopping 1	Class time(hr)
Object	① Understand the operating principle of the stop-priority self-sustaining circuit and be able to operate the electrolyzer by configuring the circuit. ② Explain the process of operating and stopping the electrolyzer by the stop-priority self-sustaining circuit by looking at the circuit diagram.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red · Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



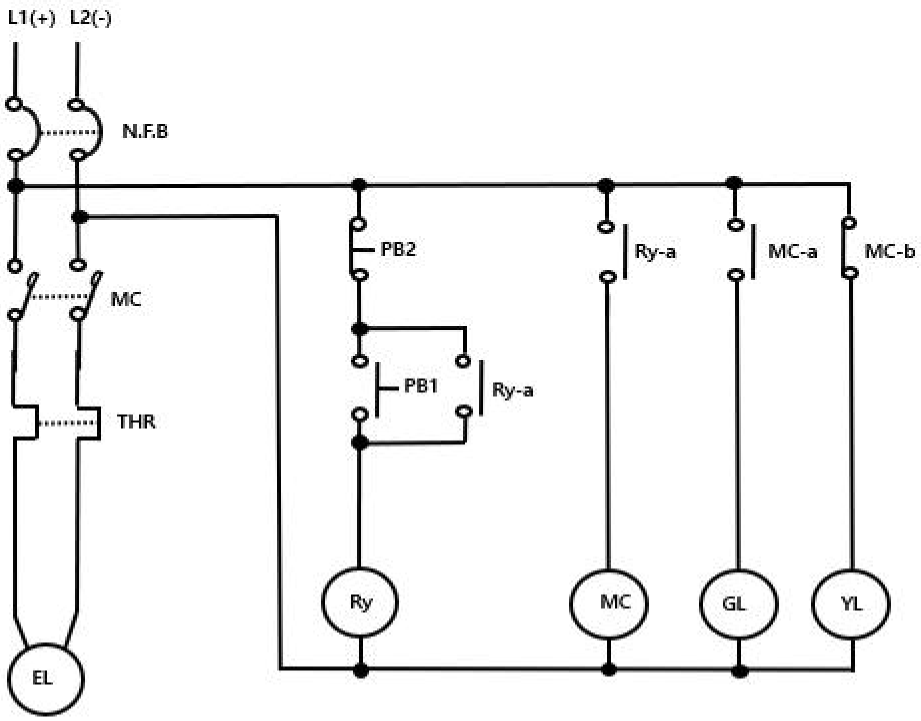
L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
Ry: Relay coil
Ry-a : Relay"a"contact

EL(Electrolyzer): Electrolyzer
PB1 : Push button switch"a"contact
PB2 : Push button switch"b"contact

Experiment name	1. Operating the electrolyzer with a self-sustaining circuit with priority for stopping 2	Class time(hr)
Object	① Understand the operating principle of the stop-priority self-sustaining circuit and be able to operate the electrolyzer by configuring the circuit. ② Explain the process of operating and stopping the electrolyzer by the stop-priority self-sustaining circuit by looking at the circuit diagram.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
• Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	• Banana Jack Red • Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



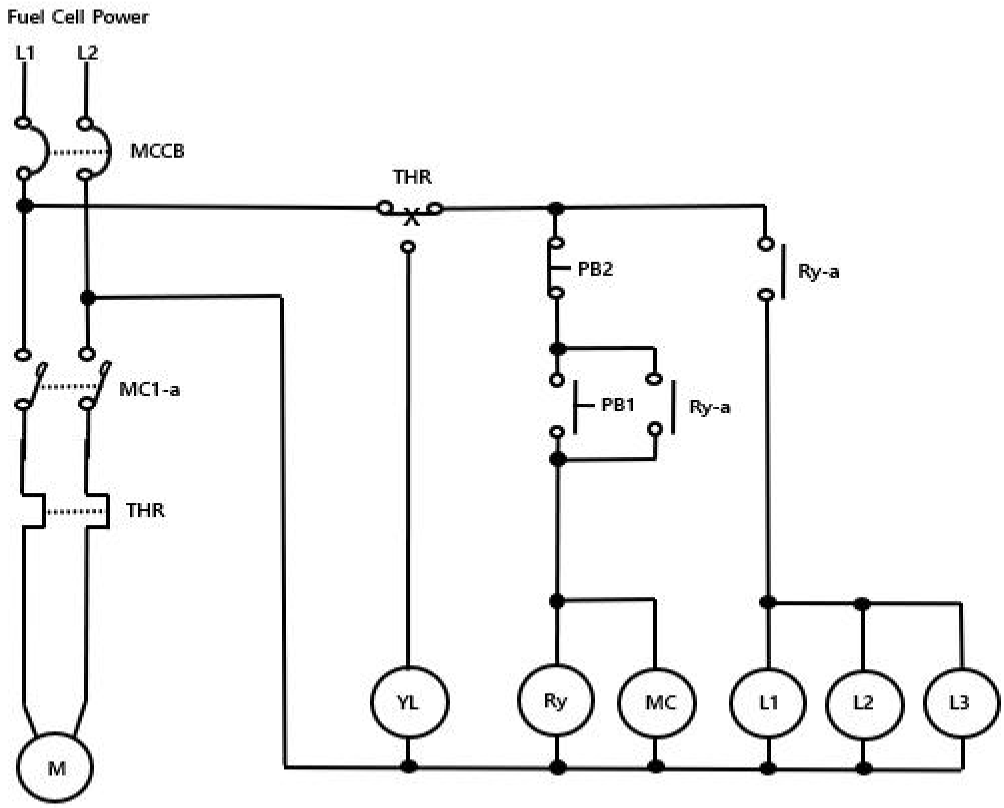
L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
Ry: Relay coil
Ry-a : Relay“a”contact

MC : Magnetic contactor coil
M : Motor
L1,L2,L3 : Lamp
PB1,PB2 : Push button switch

Experiment name	3. Configuring a load driving circuit using a fuel cell 1	Class time(hr)
Object	① Understand the operating principle of the self-sustaining circuit and be able to drive a motor and lamp load by configuring the circuit. ② Explain the process of driving and stopping a motor and load by a self-sustaining circuit by looking at the circuit diagram.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red · Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



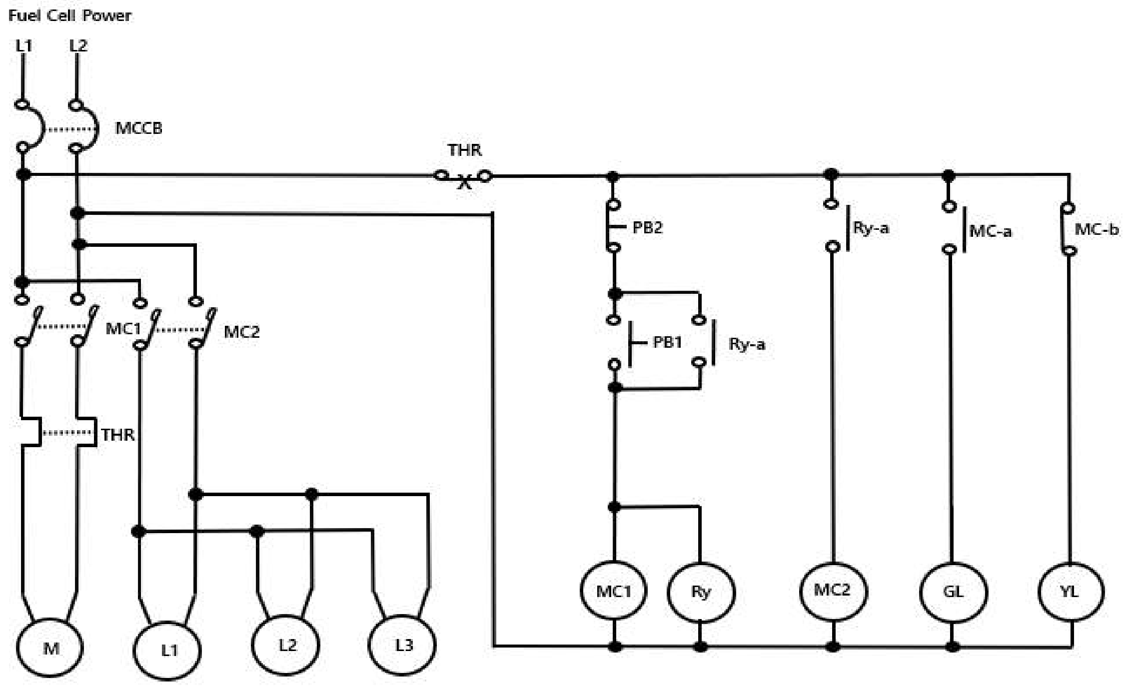
L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
Ry: Relay coil
Ry-a : Relay"a"contact

MC : Magnetic contactor coil
M : Motor
L1,L2,L3 : Lamp
PB1,PB2 : Push button switch

Experiment name	4. Configuring a load driving circuit using a fuel cell 2	Class time(hr)
Object	① Understand the operating principle of the self-sustaining circuit and be able to drive a motor and lamp load by configuring the circuit. ② Explain the process of driving and stopping a motor and load by a self-sustaining circuit by looking at the circuit diagram.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red · Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



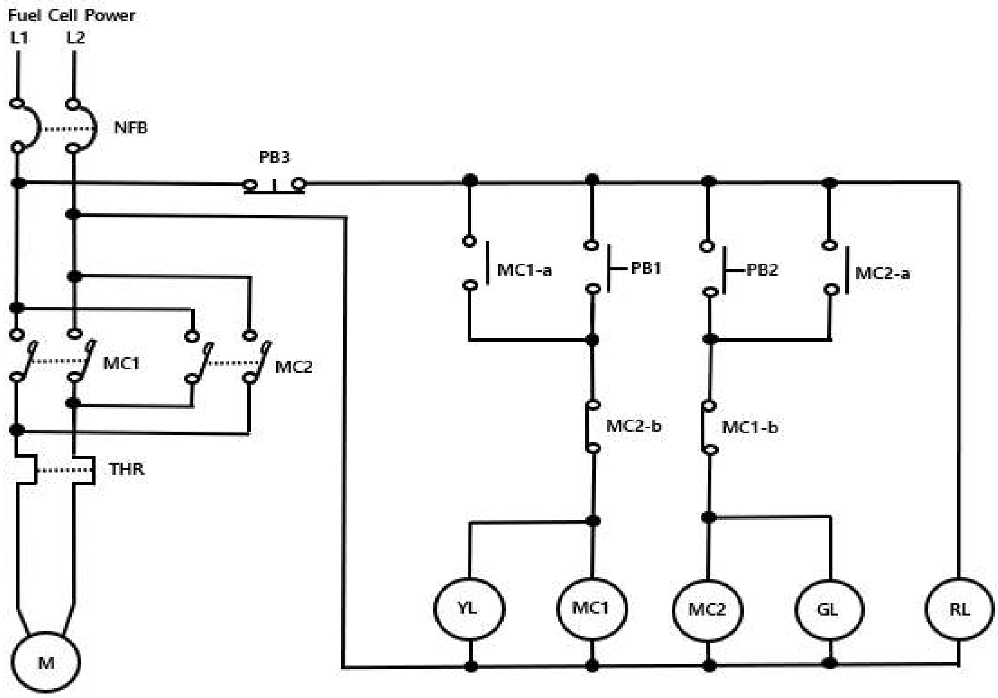
L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
Ry: Relay coil
Ry-a : Relay“a”contact

MC : Magnetic contactor coil
M : Motor
L1,L2,L3 : Lamp
PB1,PB2 : Push button switch

Experiment name	5. Configuring a load driving circuit using a fuel cell 3	Class time(hr)
Object	① Understand the operating principle of the interlock circuit and configure the circuit to drive the motor forward and reverse. ② Explain the process of driving the motor forward and reverse and stopping it by looking at the circuit diagram.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
・Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	・Banana Jack Red ・Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
M : Motor

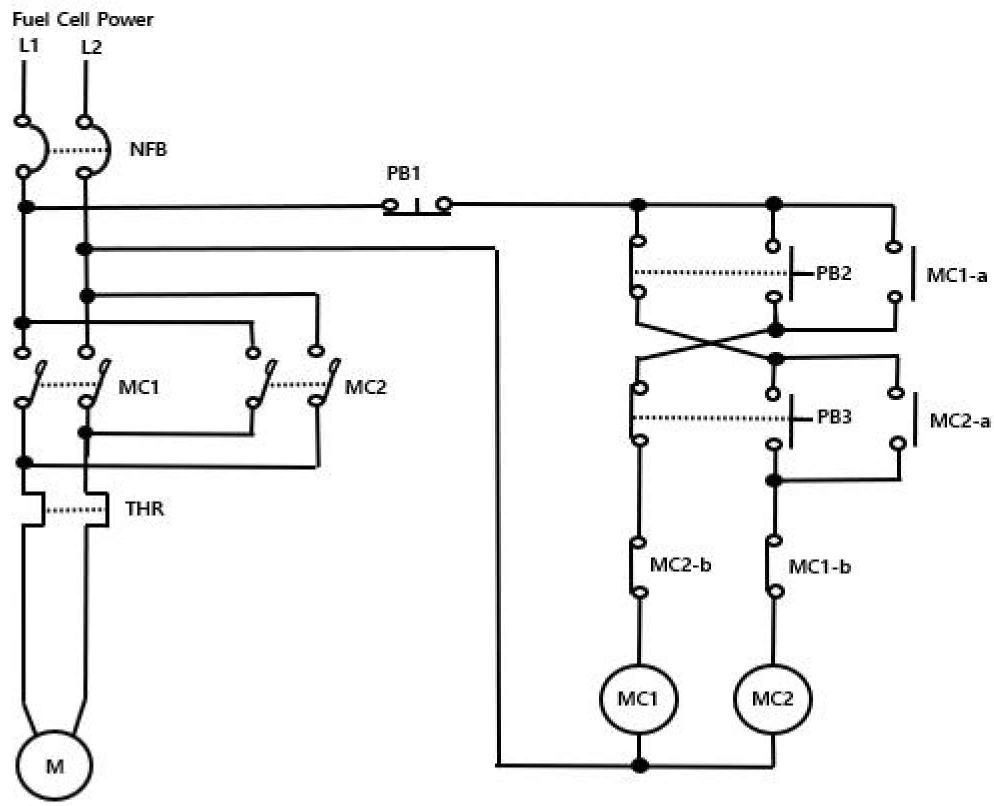
MC : Magnetic contactor coil
L1,L2,L3 : Lamp
PB1,PB2,PB3 : Push button switch

Chapter. 4 Hydrogen fuel cell power generation equipment application circuit configuration operation

Experiment name	1. Practice of driving a motor in forward and reverse directions using an interlock circuit 1	Class time(hr)
		4
Object	① Understand the principles of interlock circuits and be able to wire the driving circuit. ② Understand the principles of motor forward and reverse operation and be able to wire the driving circuit.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red	1.5㎟ * 60㎝	20
	· Banana Jack Black	1.5㎟ * 60㎝	20

Control Circuit



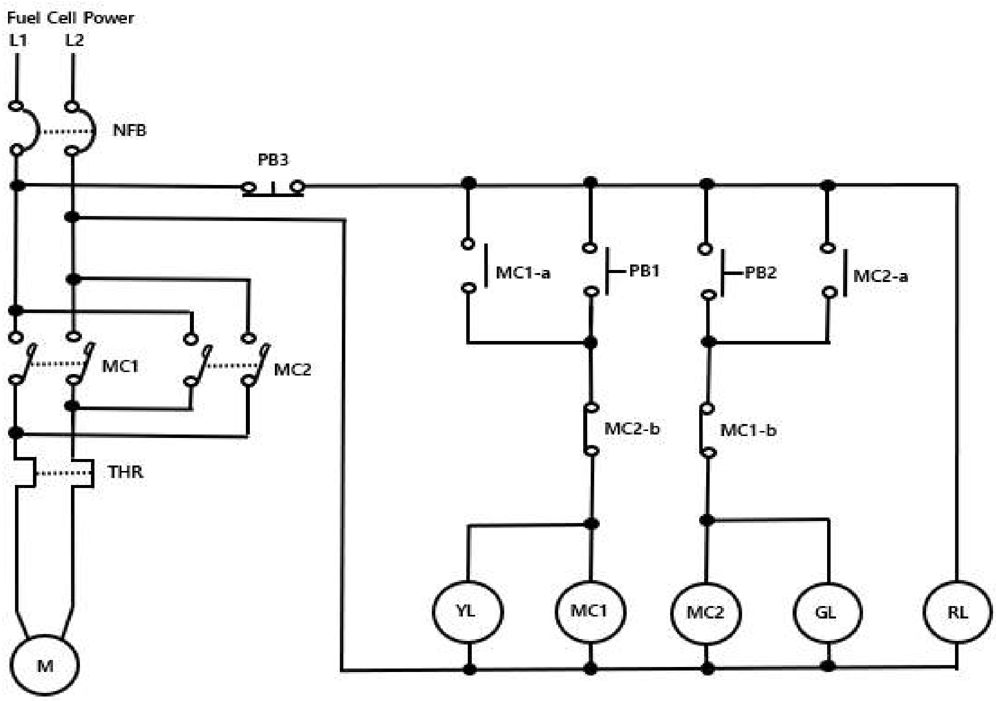
L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
M : Forward and reverse DC motor

MC : Magnetic contactor coil
PB1,PB2,PB3 : Push button switch

Experiment name	2. Practice of driving a motor in forward and reverse directions using an interlock circuit 2	Class time(hr)
		4
Object	① Understand the principles of interlock circuits and be able to wire the driving circuit. ② Understand the principles of motor forward and reverse operation and be able to wire the driving circuit.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
• Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	• Banana Jack Red • Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit

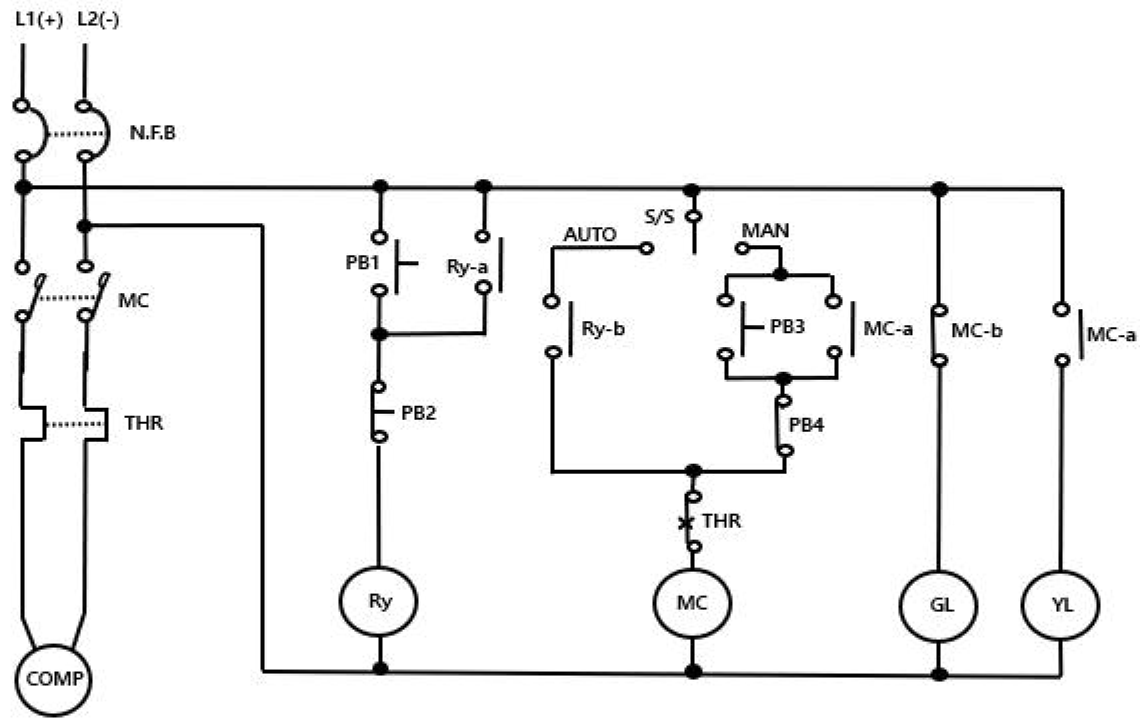


L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
M : Motor
Ry : Relay
MC : Magnetic contactor coil
PB : Push button switch
YL, GL, RL : Lamp

Experiment name	3. AUTO/MAN operation using selector switch	Class time(hr)
		4
Object	① Understand the selector switch and be able to wire the driving circuit. ② Understand the AUTO and MAN driving circuits and be able to wire the driving circuit.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
・Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	・Banana Jack Red	1.5㎟ * 60㎝	20
	・Banana Jack Black	1.5㎟ * 60㎝	20

Control Circuit



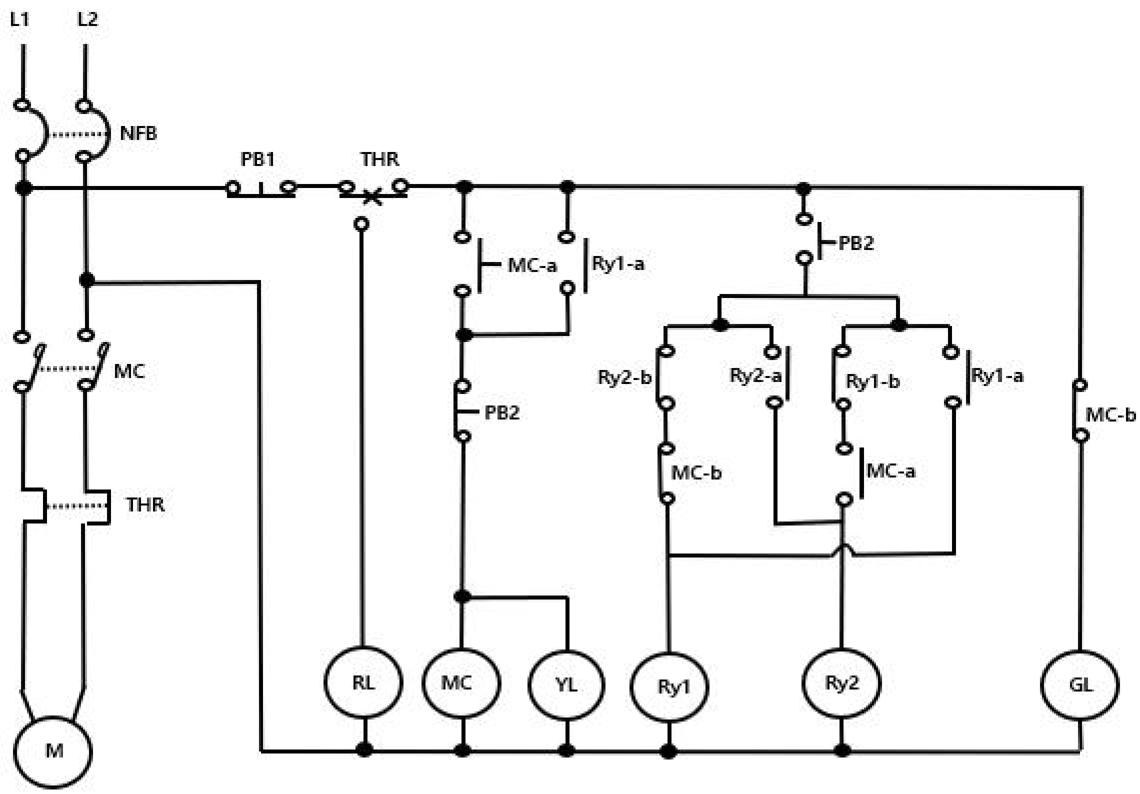
L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
THR : Thermal relay
Ry : 8 pin Relay
M : Motor

MC : Magnetic contactor coil
PB : Push button switch
S/S : Selector Switch
GL, YL : Lamp

Experiment name	4. Circuit configuration and practice of motor ON/OFF application using A contact push button	Class time(hr) 4
Object	① You can wire an operating circuit that can turn a load ON and OFF by configuring a circuit using an 8-pin relay with one A contact push button.	

Experiment equipment	Tool & material	Spec of tools	Q`nty
· Electrolysis Hydrogen Fuel Cell Power Generation Experimental Equipment (KTE-7000HS)	· Banana Jack Red · Banana Jack Black	1.5㎟ * 60㎝ 1.5㎟ * 60㎝	20 20

Control Circuit



L1, L2 : Line Voltage
MCCB : Molded Case Circuit Breaker
THR : Thermal relay
Ry : 8 pin Relay
M : Motor

MC : Magnetic contactor coil
PB : Push button switch
S/S : Selector Switch
GL, YL : Lamp

Chapter. 5 Precautions when using the equipment

1. Use the generator after fully understanding the user manual requirements.
2. Operation of hydrogen generators in confined spaces is prohibited.
   (1) The maximum output flow rate of this equipment is 1000 ml/min, which is required by customers who use hydrogen gas within 2/3 of the maximum output flow rate.
   (2) If long-term operation (more than 10 hours) is required, it is recommended to use an output flow rate within 1/2 of the maximum flow rate. The hydrogen output flow rate can be adjusted with the "flow control" valve.
3. Requirements for the operating environment and conditions of the generator
   (1) temperature : 4℃-40℃
   (2) humidity : 85%
   (3) sources of electricity : 220v-240v~50~60Hz or 99-121v~50-60Hz
   (4) For operational convenience, the front board facing the operator should be placed horizontally near the hydrogen application instrument.
   (5) There should be no vibration or shock.
   (6) There should be no direct sunlight or sources of ignition.
   (7) There should be no large dust, conductive particles, acids, alkalis and other corrosive gases.
   (8) There must be good ventilation.
   (9) The power connection must be good.
4. The generator's water tank must first be filled with deionized or redistributed water, and then waited for 5 minutes before starting.
5. Hydrogen treatment method that occurs when the set pressure is reached without pressure rise requirements and hydrogen application equipment connection
   (1) The generator does not operate when the output pressure is 0 and the minimum operating pressure is 0.02 MPa.
   (2) If the pressure build-up is delayed after start-up, internal water build-up may occur in the gas/water separator, causing the water level to reach the maximum warning limit, which will cause electrolysis to stop without normal discharge.
   (3) When the hydrogen output reaches the maximum value, the operating time for the

output pressure to indicate 0 should not exceed 10 minutes. (The generator has a brass pipeline connecting the two-stage dryer and the hydrogen output flow direction, so some internal resistance will be generated after the generator is delivered, and the internal resistance can reach the required minimum pressure limit.)

(4) Long-term operation of the generator without connecting the hydrogen application equipment after startup and reaching the set pressure may cause damage to key components of the electrolyzer.

6. The hydrogen generator pressure must be discharged to zero after the receiver is stopped.

   (1) Pressure must be released by loosening the nut on the vent valve in front of the hydrogen exhaust port on the back plate.

   (2) After the pressure has been relieved, the valve must be resealed.

7. Water quality requirements

   (1) The electrical resistance of the water (deionized water or distilled water) during electrolysis must be at least 1 MΩ/cm, as solid ions in unsuitable water may form precipitates that block the pores of the electrode, causing the electrode to be discarded.

   (2) Users should keep this in mind and assume responsibility for any incorrect driving.

8. Water tank level requirements

   (1) The water level should be at least 2/3 of the water tank capacity (the water tank capacity is 3.2 L).

   (2) When adding water to the water tank, do so slowly and carefully to prevent water from entering the generator, which could damage the electrical components, and to prevent water from flowing out of the nylon drain tube underneath where the O-ring seals the generator housing.

9. Water change and water tank cleaning requirements

   (1) The water tank must be kept clean.

   (2) Even if the water is suitable at first, over time it can become cloudy and harbor microorganisms, which can affect the output of hydrogen and the useful life of the electrolyzer.

   (3) The water tank should be emptied through the drain pipe every 2-3 months and

washed several times until the discharged water is clear and free of foreign substances (fill the tank with a small amount of new water and shake it gently several times).

(4) The water tank's drain pipe is located on the back of the generator and is detachable.

(5) The small hole on the top cover of the water tank is used as an oxygen release port, so it must not be blocked, and the top cover of the tank must not be changed arbitrarily.

10. When transporting the generator, do not store water in the water tank to prevent water from leaking out and damaging the electrical components.
11. There must be no shortage of water in the electrolytic cell.
12. Desiccant Replacement Requirements and Methods

* Hydrogen generators feature lower internal resistance, higher electrolytic efficiency and extremely low consumption for converting electrical energy into heat energy, so the useful life of the desiccant (silica gel or molecular sieve) is the longest of all hydrogen generators on the market so far.

* If the phenomenon contrary to the abovementioned occurs or the desiccant color changes significantly, it is likely that the generator is operating at full capacity for a long time, resulting in a large output. If the desiccant color changes rapidly despite correcting the improper operation, notify the manufacturer for maintenance.

(1) Introduction to Desiccant Replacement

1) The dryer, located inside the right side plate (looking back at the front board on the right side facing the front board), has a desiccant view port. The drying process is divided into two stages. Two desiccant cartridges using blue silica gel each are primary drying, and one desiccant cartridge using flesh-colored molecular sieves is secondary drying.
2) The top caps covering the three drying cartridges protrude outside the top cover of the generator and are arranged in a single row for replacing the cartridges in the same manner.

(2) Desiccant Replacement Requirements

1) To prevent high-pressure hydrogen leaks and personal injury, the desiccant must not be replaced while the generator is in operation.
2) Before replacing the desiccant, the generator must be stopped and the pressure relieved by unscrewing the top cap of the purifier before opening it.
3) The desiccant (discolored silica gel or molecular sieve) should be replaced in

time because it loses its effect after absorbing water to the saturation state. If the height of the discolored silica gel is more than half the height of the view port, the silica gel should be replaced. Otherwise, the water content in the hydrogen, which affects the purity of the generated hydrogen, will be above the standard. If the primary drying silica gel is replaced in time, the secondary drying molecular sieve may be replaced once every six months or once a year.

4) After replacing the desiccant, the generator should be stopped for several minutes to allow the air in the desiccant cartridge to evacuate. Use hydrogen only when the purity of the generated hydrogen reaches the standard.

(3) How to replace the desiccant

1) Turn off the generator, release the pressure, and then unscrew the top cap covering the primary drying cartridge clockwise. The top cap must remain in the generator in a clean state, and the sealing ring inside the cap must not be discarded. The spring attached to the top cap must not be removed or contaminated.

2) With clean fingers, pick up the top cap of the inner cartridge containing the desiccant, then unscrew the top cap of the inner cartridge clockwise to empty the desiccant. Wash the cartridge with distilled water and blow or air dry the cartridge. Refill the cartridge with new or regenerated desiccant, screw the top cap, and put the cartridge back in its original position. During the procedure, keep the following two points in mind:

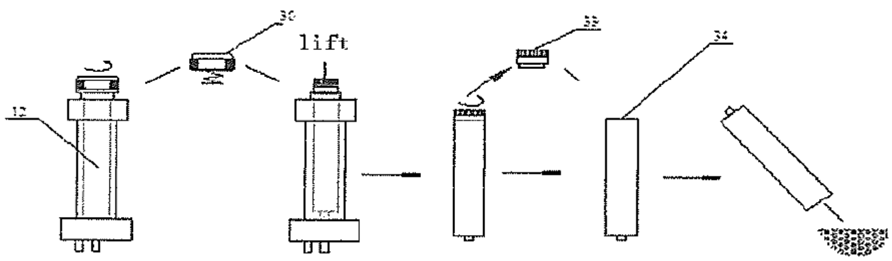
① The protruding head on the bottom of the inner cartridge must be placed into the hole in the bottom part of the outer cartridge.

② The O-ring inside the protruding head on the bottom of the inner cartridge must not be lost. If damaged, the attached accessory must be replaced with a new one.

- The reason these two things are important is to ensure that the hydrogen can pass through the dryer along the required drying path to ensure hydrogen purity.

3) The method for replacing the secondary desiccant is the same as the method for replacing the primary desiccant.

4) Finally, screw the top cover of the dryer to seal it.



Schematic diagram for replacing the desiccant

5) Desiccant regeneration

① Silica gel should not harden at a temperature of 120 to 140°C until it completely turns blue.

② Molecular sieves must not harden at a temperature of 120 to 140°C for 2 hours.

③ Once the aforementioned desiccant has dried and the temperature has dropped below 50°C, it should be packaged for use. Too high a temperature can cause damage to the container or the operator's skin.

13. The generator must be stopped before repairs are made. To avoid electric shock, do not disassemble the generator housing or other parts while the generator is in operation.
14. Before replacing the cartridge fuse, the generator must be stopped by disconnecting the power cord from the power source. The cartridge fuse model used in the 1000 is F8AL250V, and care must be taken when using the cartridge fuse to avoid fire.
15. Caution

1) This experimental equipment uses single-phase AC220V main power.

2) The equipment operation sequence is to turn on the N.F.B and turn the toggle switch On, assuming that the power cord is plugged in.

3) After the hydrogen generator stabilizes, turn on the load lamp.

4) Before using this equipment, please be sure to read the manual or instructions carefully.

5) If a malfunction occurs due to disassembly or modified use of the equipment, repair costs may be charged even if the equipment is within the free A/S period.

6) If you have any questions about equipment malfunctions or usage methods, please contact us and we will be happy to assist you.

Chapter. 5 Breakdowns and Solutions

1. When power is not applied

(1) If power is not supplied even when the N.F.B is turned on, check whether the power cord on the back of the N.F.B is installed into an outlet or power input.

2. When there is a problem with other parts

(1) If any of the other parts are malfunctioning or not working properly, please contact us for A/S and we will process it promptly.

3. General information

(1) Before using this equipment, please be sure to read the manual or instructions carefully.

(2) If a malfunction occurs due to disassembly or modified use of the equipment, repair costs may be charged even if the equipment is within the free A/S period.

(3) If you have any questions about equipment malfunctions or usage methods, please contact us and we will be happy to assist you.

Renewable Energy / Refrigeration & Air-conditioning & Welding
Automation controls(PLC) / Robot controls / Electric & Electronics(LED lighting)

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