Electrolyser for CECE Process

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1. Introduction

A combined electrolysis catalytic exchange (CECE) facility employing a liquid phase catalytic exchange (LPCE) column for water detritiation is currently being studied at the tritium treatment laboratory in KAERI, which is also adopted for water detritiation in JET, ITER, and TLK (tritium laboratory karlsruhe). The CECE facility is needed for process performance studies, to support the design of the Water Detritiation System for the nuclear industry, such as nuclear reactor operations and a radioisotope production, and medical research. The design and commissioning of this demonstration scale facility to investigate the achievable tritium decontamination factor are ongoing.

A simple schematic of the CECE process is shown in Figure 1. The key elements of the facility are an electrolyser for conversion of tritiated water to gaseous hydrogen, and a LPCE column where this hydrogen is detritiated via isotopic exchange with liquid water [1, 2].

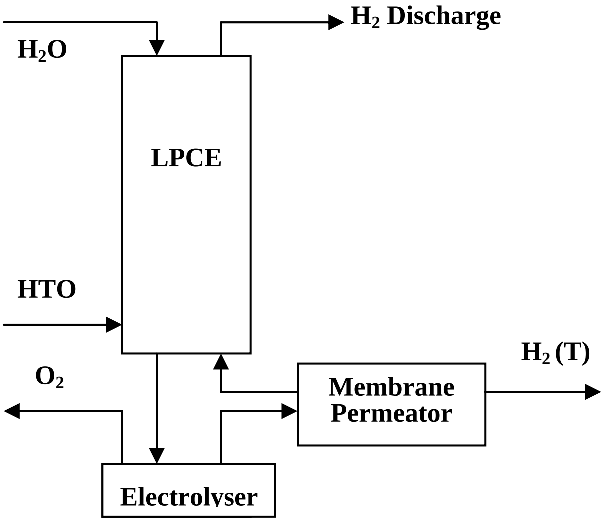

Figure1. Schematic flow of CECE Process

2. Electrolyser

2.1 electrolyser type

The electrolyser consisting of a cascade of electrolytic cells has the potential to be a major source of tritium leakage from the facility. Water electrolysers are divided broadly into two categories: a conventional electrolyser with alkali electrolyte and an electrolyser with a solid polymer electrolyte (SPE). The alkali electrolyte requires special attention to eliminate its poisoning effect on the catalysts in the LPCE column, the membrane permeator, and other hydrogen purification devices. The SPE-type, which does not need a liquid electrolyte and auxiliary devices to remove alkali from the gas streams, is more attractive, and the SPE type electrolyser can operate over a wide range of temperature, pressure and current density compared with the alkaline-type electrolyser.

In this research the SPE-type water electrolyser is adopted as the subject of invesigation. However, the SPE-type still requires an extensive and long-term testing programme to reach the level of confidence necessary for safe operation with tritium-contaminated water.

2.2 electrolysis cell

Electrolysis cell is composed of polymer electrolyte, gas diffusion layer, current collector, gas collector, and etc as shown in Figure 2. Polymer electrolyte used is cation exchange membrane, such as Nafion manufactured by Du Pont.

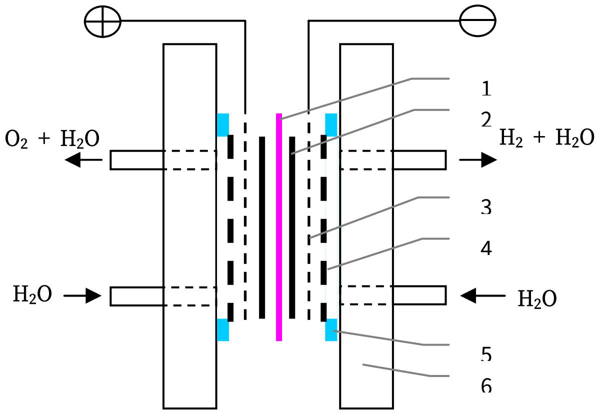

Figure 2. Cross-sectional view of the electrolysis cell (1. Polymer elctrolyte, 2.Gas diffusion layer, 3. Current Collector, 4. Gas Collector, 5. Seal adhesives, 6. Body)

Water is electrolyzed in accordance with the following equations.

Anode $2H_2O \rightarrow 4H^+ + O_2 + 4e$ (1)
Cathode $4H^+ + 4e \rightarrow 2H_2$ (2)

Oxygen is generated in the anode. Charge carriers are protons, which are generated at the anode and move through SPE. Protons recombine electrochemically with electorns to form the hydrogen in the cathode. Since SPE is a physical barrier separating the hydrogen from the oxygen, it is necessary that PEM must be free of defects and structually strong enough to prevent the two gases from intermixing [3].

3. Experiment

It is necessary to evaluate the performance of electrolysis cell. For the purpose, current-voltage characteristics, energy efficiency, and Faraday efficiency is considered in the SPE-type electrolyser.

3.1 Current-voltage characteristics

To split water into hydrogen and oxygen, the voltage applied to the electrolyser has to exceed a certain value, the ‘decomposition voltage’of the water. Below this valtage no splitting takes place. The theoretical decomposition voltage is 1.23V. For this, the voltage on the electrolyser is continually increased, recording each voltage and the corresponding current in a table. When a readily measurable current flows, the water started to split into hydrogen and oxygen.

3.2 Energy efficiency

The electrical power comsumption of the electrolyser is constant with hydrogen production. Energy efficiency, η_e, states the amount of input energy, $E_{electric}$, which is electric energy in the form of actually useful energy, $E_{hydrogen}$, which is chemical energy of hydrogen produced.

$$\eta_e = \frac{E_{hydrogen}}{E_{electric}} \qquad (3)$$

Generally, the energy efficiency of the SPE-type electrolyser is near 90%. The losses arise from the internal resistance of the electrolytic cell and the diffusion losses of the gases with in the cell.

3.3 Faraday efficiency

Faraday’s first law of electrolysis describes the relationship between the magnitude of the current flowing and the volume of gas produced. It follows from the fact that one atom of hydrogen produced has one electron that had previously contributed to the current flowing. The Faraday efficiency, η_f, of the electrolyzer is obtained from the ratio of the produced volume of gas, to that calculated for the electrical power.

$$\eta_f = \frac{E_{produced}}{E_{calculated}} \qquad (4)$$

The Faraday efficiency of the SPE-type electrolyser is around 90%. The deviation from theory (η_f=100%) arises from the fact that a proportion of the gases diffuses through the membrane and reacts in contact with the anode catalyst to reform water.

4. Conclusion

The CECE system is adopted for water detritiation. As an important element in the CECE system, the SPE-type electrolyser is considered. We studied the structure of electrolysis cell and performed basic experiment on the SPE-type electrolyser to support the design of the CECE System.

Acknowledgement

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