

## **SPE WATER ELECTROLYSIS AND STEAM ELECTROLYSIS**

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### **Summary**

Both SPE and HTE are new methods of water electrolysis still under development. SPE is closer to actual use than HTE and there are some commercialized electrolyzers of this type, though still on a very small scale.

The very high efficiency of SPE is attractive for energy conversion use, but a large-scale plant has yet to be developed. The comparison of this type to alkaline electrolysis must be carefully made, taking both economy and efficiency into consideration.

HTE is in a far earlier stage of development. The use of a very high temperature heat source, of nearly 1000 °C, is unique to this type of electrolysis. Much of the energy

needed to electrolyze water can be provided with heat, which reduces consumption of electricity.

This system may be used in situations in which a heat source such as a high temperature gas-cooled nuclear reactor is available. It is too early to evaluate this system, since there is much to be developed and only basic experiments on components have been made.

## **1. SPE Water Electrolysis: Introduction**

Alkaline water electrolysis is a matured technology which has long history in industrial application. Though it is still being developed for better efficiency and economy, only a little room is left for the improvement.

On the other hand, new technologies of water electrolysis which are under development have more possibilities of improvement. These technologies are SPE (solid polymer electrolyte) water electrolysis and HTE (high temperature steam electrolysis).

Different from alkaline water electrolysis in which alkaline solution is used as electrolyte, solid electrolytes are used in these processes. Though both processes use solid for electrolyte, these two processes are quite different each other.

SPE system electrolyzes liquid water at similar temperature to alkaline, but HTE works at much higher temperature and electrolyzes water vapor (steam). Both of them are still under development at the time this paper is written and industrial scale plants are yet to be built.

Solid polymer water electrolysis is a new advanced method of water electrolysis, using proton ion exchange polymer film as electrolyte instead of alkaline solution. Fluorinated polymer having sulfonic acid group is used as solid polymer electrolyte (SPE).

This method enables high current density electrolysis with high energy efficiency of conversion and is expected to be the next generation water electrolysis method.

This system was first developed as a fuel cell, which is the reversed reaction of electrolysis. The fuel cell technology, originally developed for use in space, was applied to electrolysis by General Electric Co.

This system has been developed further by Japanese research institutes and private companies under the auspices of the Japanese government.

### **1.1 Principle of SPE Water Electrolysis**

Figure 1 shows the general idea of SPE water electrolysis. SPE film in the center works both as electrolyte and as the gas separating membrane.

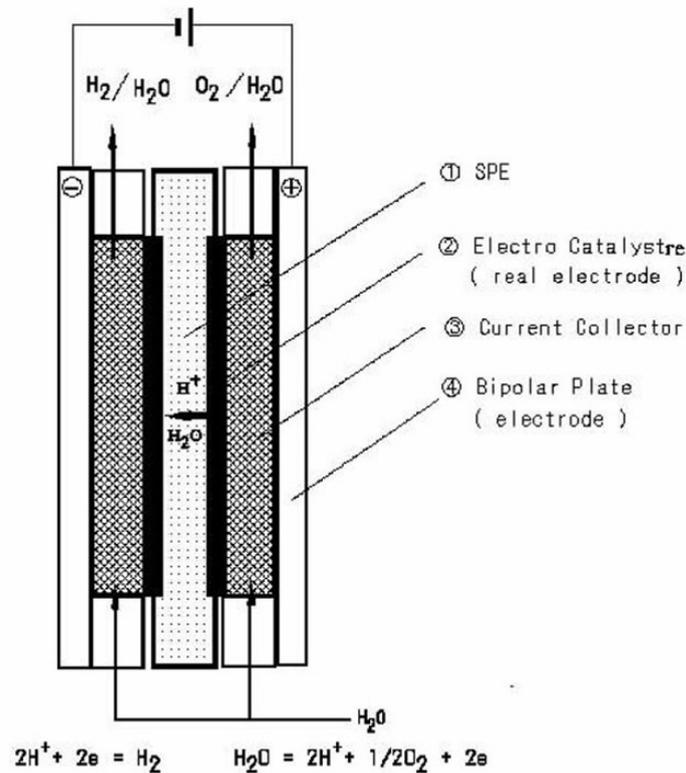


Figure 1. Principle of SPE water electrolysis.

The electrodes are directly attached onto the surface of SPE by means of plating or hot press to form a membrane–electrode composite. Since SPE is highly corrosive, noble metals such as platinum, iridium, or rhodium are used for electrodes with electrocatalysis activity.

Current collectors, which are made of porous material, are pressed to the composite to feed electricity to electrodes. Water is fed to the anodic side where water is split into oxygen gas and hydrogen ion.

The hydrogen ion moves through the polymer electrolyte membrane toward the cathode and gets an electron there to generate hydrogen gas. Both feed water and generated gas pass through porous current collectors. Outside the current collector are bipolar plates which separate one cell unit from the neighboring cell.

The total configuration of the SPE electrolyzer is similar to the filterpress alkaline water electrolyzer though a little simpler. The system needs a pure water circulation system and gas–liquid separators to remove evolved gas and to cool electrolysis cells.

The efficiency of electrolysis is calculated in the same way as for alkaline water electrolysis, dividing 1.48 V by cell voltage. High temperature improves efficiency also in this system.

Figure 2 shows an example of cell configuration and Figure 3 shows total flow sheet.

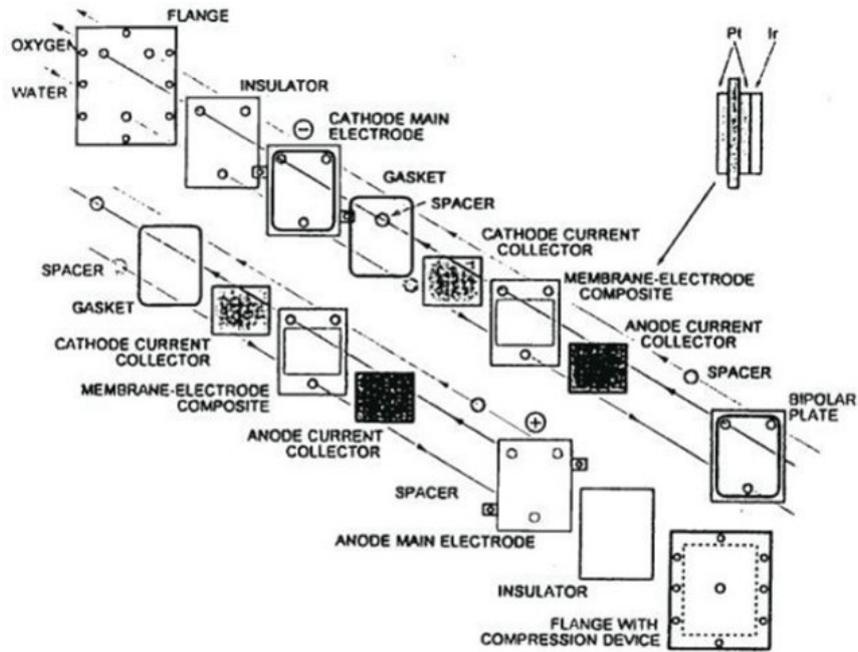
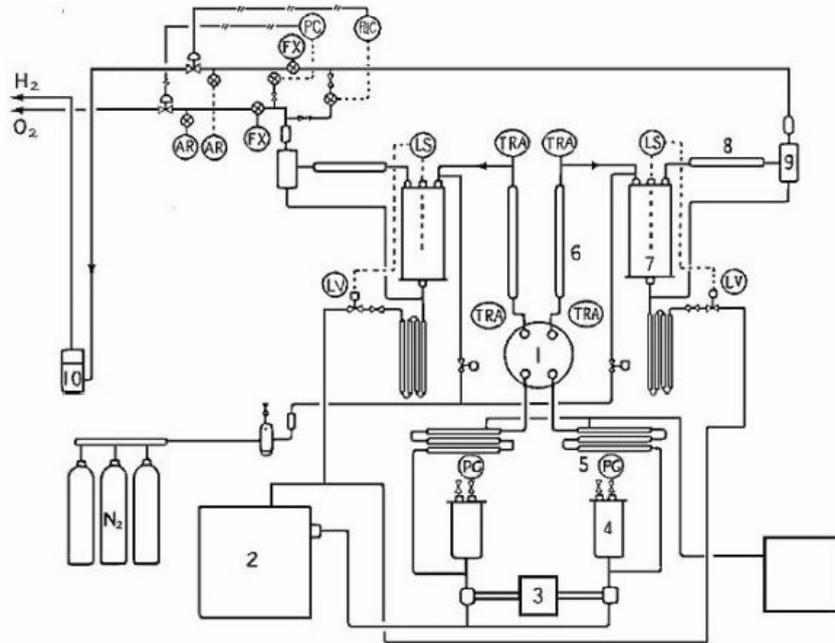


Figure 2. Exploded view of SPE electrolytic cell block.



- |    |                      |   |                |   |                 |
|----|----------------------|---|----------------|---|-----------------|
| 1  | Electrolytic Cell    | 2 | Water Purifier | 3 | Water Feed Pump |
| 4  | Air Chamber          | 5 | Heater         | 6 | Gas Cooler      |
| 7  | Gas-Liquid Separator | 8 | Gas Cooler     | 9 | Mist Separator  |
| 10 | Water Seal           |   |                |   |                 |

Figure 3. Flow sheet of SPE water electrolysis plant.

## 1.2 Membrane–Electrode Composite

### 1.2.1 SPE Membrane

A thin film of perfluoroethylene polymer containing sulfonic acid group is used for the SPE membrane. Figure 4 shows the chemical structure of DuPont's Nafion, the most commonly used SPE material. A membrane made of thinner film and polymer with higher cation exchange capacity has less electric resistance, but usually inferior mechanical properties. It also has the problem of hydrogen gas permeation through the membrane, which reduces current efficiency of the cell. The optimum film, therefore, must be designed considering these trade-offs.

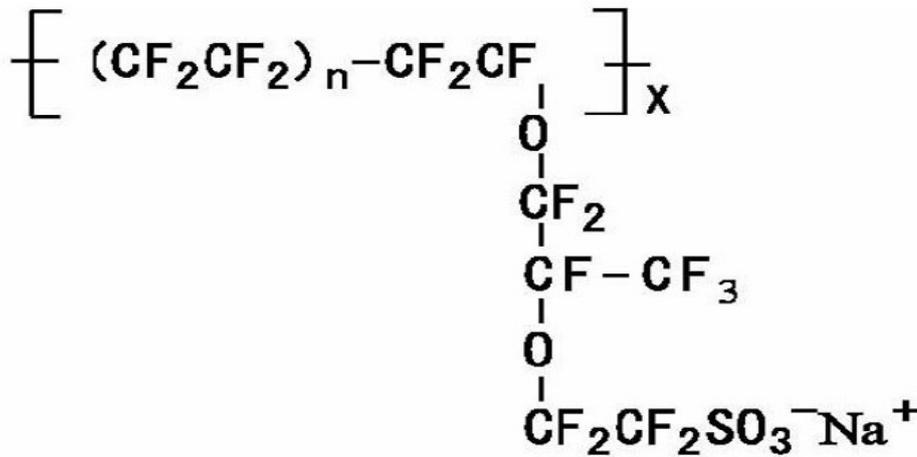


Figure 4. Chemical structure of solid polymer electrolyte.

### 1.2.2 Electrode Catalyst

Since SPE film is strongly acid, electrode materials must resist corrosion. It also has to be a good catalyst for electrochemical reaction. Usually, noble metals like platinum and its family are used for electrode materials.

Overpotential of electrolysis, hence energy efficiency, depends greatly on the catalytic activity of these materials. Platinum is the most popular cathode material and ruthenium oxide ( $\text{RuO}_2$ ) is also a good catalyst.

Selection of anode material depends on the method of making the composite. In the case of hot press, oxides of the platinum family like ruthenium oxide are used for the material and alloys of the platinum family such as platinum-iridium are used for the non-electroplating method.

Anodic overpotential occupies a big portion of total overpotential of the cell and it is influenced by the amount of catalyst. Therefore, at least  $2 \text{ mg cm}^{-2}$  of anode catalyst is required to reduce overpotential and ohmic resistance of the electrode.

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### **Biographical Sketch**

**Isao Abe**, born September 16, 1939, in Osaka, Japan, received his Bachelor of Engineering degree from the Department of Fuel Engineering, Faculty of Engineering, University of Tokyo (1963), and Master of Engineering from the Department of Reaction Chemistry of the same faculty, the same university (1966). He worked for Showa Denko K.K. as a chemical engineer (1966–1999), and was involved in development of the advanced alkaline water electrolyzer under the Sunshine Project of the Japanese government as the director of technical development (1974–1984); during that period, he worked as formal alternate representative of Japan to the IEA Task IV (water electrolysis) workshop. He has been editor-in-chief of *Journal of the Hydrogen Energy System Society of Japan* since 1998.

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