Ocean Thermal Energy Conversion and Titanium Plate Heat Exchanger

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Five Issues In 21\textsuperscript{st} Century

\textbf{Background}

Human beings’ civilization progressed greatly in the 20th century.

Today at the beginning of the 21st century, however, we are confronting new problems.
Five Issues in 21st Century

- Population Issue
- Energy Issue
- Food Issue
- Water Issue
- Environment Issue
By considering future economic growth and environmental problem, it is obvious that we must develop alternative energy resources to oil, gas, coal and uranium.

One of the solutions of the problems is

Ocean Thermal Energy Conversion (OTEC) System.
Integrated OTEC

Integrated OTEC System

New Technology to Produce Energy, Water, Mineral and Food Without Emissions of CO₂
Principle of OTEC Technology
There is a temperature difference of between 10 and 30 degrees Celsius in the Ocean.

Power generation by OTEC is to utilize the temperature difference between warm and cold seawaters.
The principle is fundamentally the same mechanism used in thermal and nuclear power generation.

One major characteristic of OTEC is the use of a working fluid such as ammonia, with a low boiling point.
# OTEC Characteristics

<table>
<thead>
<tr>
<th>System of Power Generation</th>
<th>Kg-CO₂/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.916</td>
</tr>
<tr>
<td>Petroleum</td>
<td>0.756</td>
</tr>
<tr>
<td>LNG</td>
<td>0.563</td>
</tr>
<tr>
<td>Hydro</td>
<td>0.017</td>
</tr>
<tr>
<td>Solar Cell</td>
<td>0.153</td>
</tr>
<tr>
<td>OTEC(2.5MW)</td>
<td>0.119</td>
</tr>
<tr>
<td>OTEC(100MW)</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Ocean thermal energy is a natural and renewable. It is a clean energy which does not pollute the natural environment. Emission of carbon dioxide by OTEC is exceedingly low.
History of OTEC Development
Subject of OTEC

Small temperature difference
The temperature difference (10-20 degrees Celsius) between turbine inlet and outlet in OTEC is fairly smaller than that (120-550 degrees Celsius) in thermal and nuclear power generation.

Low thermal efficiency
Because of the small temperature difference, the thermal efficiency of OTEC cycle is smaller than that in the thermal and nuclear power generation.

Subject of OTEC
The subject is to enhance the thermal efficiency and to reduce the sea water flow rate and surface area of evaporators and condensers.
For Thermal Efficiency

We carried out the research of OTEC.

And get the solutions.
Principle of Uehara Cycle

Uehara Cycle invented in 1994 by Dr. Uehara and Dr. Ikegami (Saga University) is the most efficient cycle for OTEC.
Plate Heat Exchanger (PHE)

PHE can improve heat transfer efficiency.

Shell & tube heat exchanger

Plate heat exchanger
Plate Material for OTEC PHE

Thermal resource is sea water.

Vapor pressure in plate channels is more than 0.9MPa.

Plates are manufactured by Press forming.

Titanium with High strength and Press formability
Suitable combination of chemical composition, cold rolling process, and heat treatment have been studied.

An advanced manufacturing process enables production of high-strength titanium sheet applicable to plate heat exchanger.
New Xenesys XP- PHE for OTEC

New XP-PHE

- Plate pattern : XP-Plate
- Two phase OTEC duties
- All welded construction
- Very high heat transfer rate
- Very low pressure drop
- Very high design pressure
- High strength titanium
Features of New Xenesys XP-PHE

- XP-Plate is extremely efficient with extremely low pressure drop, which makes OTEC feasible.

- Titanium XP-Plate can stand high design pressure thanks to the high strength property and the plate geometry.

- Large flow rate can be handled both on seawater and working fluid sides with low pressure drop.

- PHE can be designed for countercurrent, cocurrent or cross flow.
- PHE can be installed vertically or horizontally.
- Plate can be pressed in different sizes.
- No leakage of working fluid due to all welded construction
Future on OTEC
OTEC is not unfeasible any longer.
Image of OTEC Plant

- Cool Green House for Fruits and/or Vegetables
- Deep Ocean Water/Fresh Water Tanks
- Local Area Chilling Service (Air Cooling for Hotels and/or Offices)
- OTEC Plant Barge
- Port for Ocean Mineral Water Exporting
- Deep Ocean Water Aquaculture
There are almost 100 countries suitable for OTEC.

Potential Area of OTEC

Suitable Area for OTEC and Temperature Difference Between Surface and 1000m Depth

There are almost 100 countries suitable for OTEC.
# Quantity of Titanium for OTEC

<table>
<thead>
<tr>
<th>Power Generation Output</th>
<th>Quantity of Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>10MW</td>
<td>124mt - 180mt</td>
</tr>
<tr>
<td>100MW</td>
<td>1240mt - 1800mt</td>
</tr>
</tbody>
</table>

There is a possibility to generate **1 billion MW** by OTEC in the whole world.

**Indispensable Material to OTEC**
Towards Large OTEC Plants

Saga University Japan

established Institute of Ocean Energy, Saga University (IOES) for study on integrated hybrid OTEC system in 2002.


New Energy and Industrial Technology Development Organization (NEDO) Japan

has started a study of 3MW power generation using waste heat discharged from an oil refinery plant.

Titanium manufactures in Japan

are planning to organize a national project team establishing a new process of refining titanium by support of Ministry of Economy, Trade and Industry.
Conclusions

We firmly believe that Ocean Thermal Energy Conversion (OTEC) is one of the most reliable means to give a solution to the problems that humanity face.

We are working to install the integrated hybrid OTEC plants in many countries.
END