Kobe Steel Supplies
High Heat Transfer Titanium Sheet for Use in OTEC Demonstration Project in Okinawa

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AKIO OKAMOTO
Titanium Marketing & Technical Service Section
KOBE STEEL, LTD.
What has been improved?

Heat transfer coefficient \(( h )\)

for Ocean Thermal Energy Conversion

\[
Q = h \ A \ \Delta t
\]

- **\( Q \)**: heat exchange  \([\text{J/s}]\)
- **\( h \)**: heat transfer coefficient  \([\text{W/m}^2 \text{K}]\)
- **\( A \)**: heat transfer area  \([\text{m}^2]\)
- **\( \Delta t \)**: temperature difference  \([\text{K}]\)
Image of OTEC Plant

onshore type
by courtesy of Xenesys

floating type
by courtesy of Tokyo Univ.
High heat transfer titanium sheet used in heat exchangers for OTEC

Warm Seawater at Surface

⑤ Warm Seawater pump
① Evaporator

② Turbine

③ Condenser

④ Working fluid pump

Cold Seawater in Depth

⑥ Cold seawater pump

PHE using titanium plates for evaporator and condenser
Improved heat transfer reduces OTEC power generation costs

\[ Q = hA \Delta t \]

Image of OTEC plant (floating type)

by courtesy of Japan Marine United
Improved heat transfer reduces OTEC power generation costs

Initial cost for 10MW floating type OTEC plant
But mass productivity is indispensable

**Quantity of Titanium for OTEC**

<table>
<thead>
<tr>
<th>System of Power Generation</th>
<th>Quantity of Titanium / Power Generation Output (MT / MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal, Petroleum, LNG</td>
<td>0.08</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.18</td>
</tr>
<tr>
<td>OTEC</td>
<td>12.4 – 18</td>
</tr>
</tbody>
</table>
We chose transfer-printing technology in the rolling process.
One feature in common was hidden that was “cavity”:

for tubular

bended fin

“Y” fin

for sheet

minute dimple

Heat transfer enhancement (result of former studies)
“Cavity” made in rolling process increases heat transfer

Normal surface

Special surface

Special surface treated sheet
Grade : 1
Thickness : 0.4~0.6mm
“Cavity” made in rolling process increases heat transfer

Special surface
The effects are apparent

Normal surface

Special surface
(HEET™)
Proving the effectiveness of the heat exchanger in the OTEC demonstration plant

Overall heat transfer coefficient for heat flux
HEET™ @ the heat exchanger
in the OTEC demonstration plant

OTECL pilot plant on Kume Island

by courtesy of Okinawa prefectural office
Heat transfer improves at demonstration plant

Evaporator U-Value (Experimental Data / Approximate Formula)
Time-Series Data Aug, 2013: 10 Minutes Average

by courtesy of Xenesys
## Power generation efficiency improves

Economical effect  (10MW floating type off Okinawa main island)

<table>
<thead>
<tr>
<th></th>
<th>titanium</th>
<th>normal</th>
<th>HEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep sea water depth</td>
<td>m</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>Deep sea water temperature</td>
<td>oC</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Surface sea water temperature</td>
<td>oC</td>
<td>25.5</td>
<td></td>
</tr>
<tr>
<td>Generating-end output</td>
<td>kW</td>
<td>15036</td>
<td>14,809</td>
</tr>
<tr>
<td>Sending-end output</td>
<td>kW</td>
<td>10,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Deep sea water mass flow rate</td>
<td>t/h</td>
<td>165,979</td>
<td>152,354</td>
</tr>
<tr>
<td>Surface sea water mass flow rate</td>
<td>t/h</td>
<td>173,131</td>
<td>158,776</td>
</tr>
<tr>
<td>Evaporator U-Value</td>
<td>W/m²K</td>
<td>3265</td>
<td>4594</td>
</tr>
<tr>
<td>Electricity cost</td>
<td>yen/kWh</td>
<td>19.9</td>
<td>18.5</td>
</tr>
<tr>
<td><strong>Electricity cost cut ratio</strong></td>
<td>%</td>
<td>-</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Renewable energy symposium 2012 (NEDO)
Practical use aimed at 2015 - 2020

Okinawa District

- Okinawa main island
- Kume Island
- Miyako Island
- Ishigaki Island

Energy resource by OTEC [MW] | 2,797
---|---
Present power capacity [MW] | 1,905

(NEDO, 2011)

Temperature difference between surface and 1,000m depth

Potential site for OTEC in Okinawa
### Practical use aimed at 2015 – 2020

Road map for the practical use of OTEC (NEDO*)

<table>
<thead>
<tr>
<th>C.Y.</th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
<th>2050</th>
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</thead>
<tbody>
<tr>
<td>TWh / year</td>
<td>2.5</td>
<td>12.5</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>MW</td>
<td>510</td>
<td>2,550</td>
<td>8,150</td>
<td></td>
</tr>
</tbody>
</table>

*N ative Energy and Industrial Technology Development Organization*
Further development of HEET™
to make effective use of energy

National project by NEDO
R&D of core technology for 10MW OTEC  (Kobe Steel, Saga Univ.)

High heat transfer
- with higher strength
- for condenser

by courtesy of Okinawa prefectural office
Renewable energy for a sustainable society
Thank you for your kind attention!

by courtesy of Okinawa prefectural office