

## Advantages of Plate-Type Heat Exchanger over Tube-Type Heat Exchanger for OTEC Power Plant

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### INTRODUCTION

A high-performance heat exchanger should be used in the evaporator and condenser of Ocean Thermal Energy Conversion (OTEC) since the utilizable temperature difference is small (about 20°C). It is generally said that the plate-type and the double-fluted tube-type heat exchangers are suitable for an OTEC power plant. In this paper, optimization carried out using a double-fluted tube-type heat exchanger, considering turbine configuration. Ammonia is used as the working fluid. The performance of an OTEC plant with a plate-type exchanger is compared with the performance of a plant with a double-fluted tube-type exchanger.

### OBJECTIVE FUNCTION

The objective function  $\gamma$  is defined by the following equation:

$$\gamma = \frac{\text{Total heat exchanger area}}{\text{Net power}} = \frac{A_r}{P_N} \quad (m^2 / kW) \quad (1)$$

The net power is obtained by subtracting the power of the warm seawater pump, the cold seawater pump and the working fluid pump from the gross power. The total heat transfer area is obtained by using heat transfer coefficients of the seawater and the working fluid side.

### FUNDAMENTAL EQUATION

The overall heat transfer area of the evaporator  $A_E$ , and the overall heat transfer area of the condenser  $A_C$  are given as follows:

$$A_E = Q_E / \{U_E(\Delta T_m)_E\} \quad (2)$$

$$A_C = Q_C / \{U_C(\Delta T_m)_C\} \quad (3)$$

where  $U_E$  and  $U_C$  are the overall heat transfer coefficients of the evaporator and condenser, respectively.  $Q_E$  and  $Q_C$  are the heat flow rate of the evaporator and the condenser, respectively.  $(\Delta T_m)_E$  and  $(\Delta T_m)_C$  are the logarithmic mean temperature differences of the evaporator and condenser, respectively. These overall heat transfer coefficients are calculated using the boiling heat transfer coefficient (Nakaoka and Uehara, 1988a; Rothfus and Neuman, 1977), the condensation heat transfer coefficient (Nakaoka and Uehara, 1988b), and the heat transfer coefficients of the seawater side (Nakaoka and Uehara, 1988b; Obana, 1974).

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The details of these equations are shown in Mitsumori et al. (1998).

If the variable parameters are given, the objective function can be rewritten as:

$$\gamma = f(T_E, T_C, V_{WS}, V_{CS}, Ns, Ds, h / D) \quad (4)$$

where  $T_E$  and  $T_C$  are evaporation and condensation temperatures, respectively.  $V_{WS}$  and  $V_{CS}$  are the velocity of warm seawater and cold seawater, respectively.  $Ns$  is the specific velocity and  $Ds$  is the specific diameter.  $h/D$  is the ration of blade height and diameter. In this paper the optimization of an OTEC power plant is calculated using Powell's method (Fletcher and Powell, 1963).

### RESULTS

Fig. 1 shows the heat transfer area at several warm seawater inlet temperatures.  $(A_E)_p$ ,  $(A_C)_p$  and  $(A_T)_p$  denote the heat transfer areas of evaporator, condenser and total, respectively, for the case of an OTEC system with the plate-type heat exchanger.  $(A_E)_t$ ,  $(A_C)_t$  and  $(A_T)_t$  denote the heat transfer areas of evaporator, condenser and total, respectively, for the case of an OTEC system with the tube-type heat exchanger. The heat transfer area decreases with the increase of the surface seawater temperature. The heat transfer area at 23°C is about twice as large as at 28°C. The heat transfer area for the case of the double-fluted tube-type exchanger is about 1.5 times as large as when using the plate-type one (Table 1).

Gross power	(MW)	100
Warm seawater inlet temp.	(°C)	23.0~28.0
Cold seawater inlet temp.	(°C)	4.0
Cold seawater pipe length	(m)	1000.0
Material of heat exchanger		titanium
Plate length	(m)	4.0
Plate width	(m)	1.5
Tube length	(m)	5.0
Tube diameter	(m)	0.0254

Table 1 Calculation conditions

Fig. 2 shows the overall heat transfer coefficient.  $(U_E)_p$  and  $(U_C)_p$  denote the overall heat transfer coefficients of evaporator and condenser, respectively, for the case of the plate-type heat exchanger.  $(U_E)_t$  and  $(U_C)_t$  denote the overall heat transfer coefficients of evaporator and condenser, respectively, for the case of the double-fluted tube-type exchanger. The performance of the plate-type exchanger is higher than that of the double-fluted tube-type one.

Fig. 3 shows the volume of the heat exchanger. In this paper, 4