A Preliminary Experiment on Utilizing the Ocean Temperature Difference for Desalination

(II : Utilizing the Raising Temperature Cycle to Desalinate)

by

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1. Introduction

It is found that the biggest temperature difference below the Japan sea is about 25°C, utilizing such a lower temperature difference for desalination is very difficult, so that the research project used a chemical heat pump for overcoming this question. It is to say that utilizing the cold deep sea water and the surface sea water (27°C) will raise the temperature difference from 25°C to 50°C, then the difficulty is overcomed. The principle of the heat pump is that mixing LiBr with the solution will decrease the evaporation pressure of the mixture, the vapor coming from the same temperature of pure water will be injected by the mixture, and on this moment the condensed heat will be utilized to raise the water temperature.

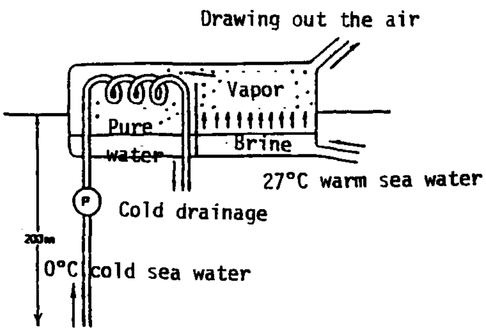

Fig. 1 The principle of utilizing the temperature difference to desalinate

2. Desalination of Sea water

The principle of utilizing the ocean temperature difference to desalinate is explained in Fig. 1. Pump the surface water (Summer, 27°C) to a closed tank, and drew out the air to make a vacuum. When the pressure decreases to 0.03 atm, the water becomes boiling. The produced steam is conducted to the other tank, and condenses with the cold sea water which is pumped up from the sea bottom, at last the distilled water is gained.

2. 1 The technique question in utilizing temperature differnce to desalt

The principle of the former was easy, but various questions will be coming while carrying out.

The first question is the technique of making a vacuum. Fig. 2 shows a relation between the temperature of sea water and its degree of vacuum, while in 1 atm evaporation pressure, the boiling temperature is 100°C, while at the top of Fuji-San (evaporation pressure is about 0.64 atm) the boiling point is 80°C, while in 0.03 atm (evaporation pres-

Received May 6, 1982
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sure is about 25000 m-high) which needs a super vacuum equipment, the boiling is 25℃, but there is no such a equipment. The technique of utilizing oceanic energy is just to say that it is a fight with the vacuum.

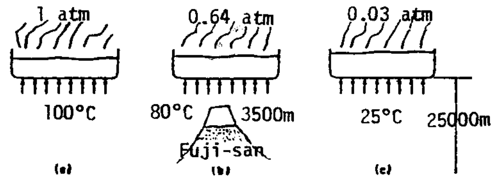


Fig. 2 The principle of making evaporation

The second question is the low efficiency of utilizing. Although the efficiency of utilizing the temperature difference of 25℃ to generate the electricity is estimated about0.01,utilizing the oceanic temperature difference energy between warm and cold water is meaningful. It is to say that the high efficiency 100% is more useful than getting the amount of water 100 times. Actually the metal of heat exchanger may be made of the high price metal which is erosion preventing, but economic problem is the most important condition. Utilizing the oceanic energy must have a huge heat exchanger.

On the present condition, the interest of the equipment fund is higher than that of burning oil, so how to let the equipment be cheap is the most important of all. Then it is eager to develop the metal with low price and high efficiency.

On ultilizing the oceanic energy, former questions stay. The research project has developed a special principle of the raising temperature cycle[1),2)] for solving it, and now the basic experiment has successfully been finished. This success is the most meaningful in carrying out, the detail is explained in the next chapter.

2. 2 Result

Fig. 3 shows the experiment equipment of desalination, and its character is shown in fig. 4.

According to the temperature difference (27℃) in this research,the estimation of water production

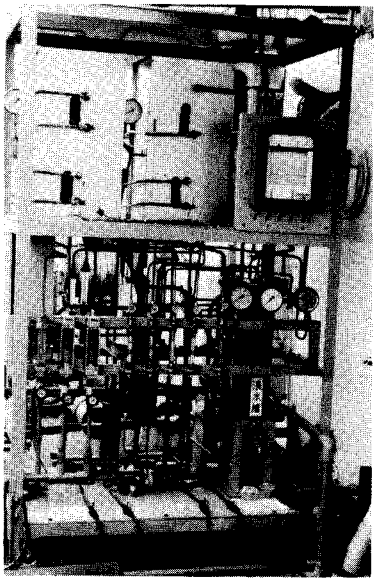


Fig. 3 The experiment equipment of desalination

was 2.2 ℓ/hr, but the experiment on the sea is found that the water production at 25℃ difference is 2.3ℓ/hr. The data of experiment is larger than that of pridict estmation. In the experiment the cold sea water about 200 ℓ/hr was used. Moreover, the amount of the warm sea water 400 ℓ/hr being used is double of the cold sea water. Then it is easy to estimate the sea water needed in 100 times of pure water producing. Only a part of the cold water pumped up was used for desalination (about 200 ℓ/hr), a part of that was used for testing the pumping up ability of pipe line (35m^3/hr) and for storing in the pump (about 35m^3/hr), all the other was pulled back to the sea.

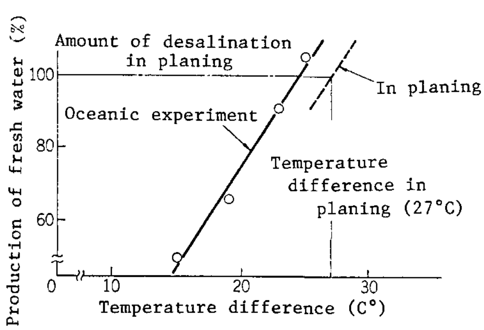


Fig. 4 The character of utilizing the oceanic temperature difference for desalination

3. Raising Temperature Cycle

There are two difficulties in utilizing the oceanic energy of temperature difference, as described in former. Then demanding for making a super vacuum and utilizing principle limited by Carnot's low efficiency for low temperature difference will be the fatal trouble. The research project developed the raising temperature cycle intending to solve both of these difficulties.

3. 1 Principle of chemical raising temperature

Chemical raising temperature is effective to utilize the low temperature difference, and utilizes cold sea water (0°C) to raise surface warm water temperature from 25°C to 50°C.

Fig. 5 shows 4 closed tanks (A,B,C,D), there is hot medium (mixture of LiBr and H_2O) in A,B, but pure water in C,D.Raising temperature is marching in B, the evaporation pressure of mixture B is low, so the produced steam is ingested in B. Then the steam of C moves to dilute the mixture of B. At this moment the concentrating heat and the diluting heat joined togather to raise the temperature in the high concentration mixture of B. In A it is a complete reversed reaction of B. The diluted mixture of B is concentrated in A, so that the condensation in D is very important.

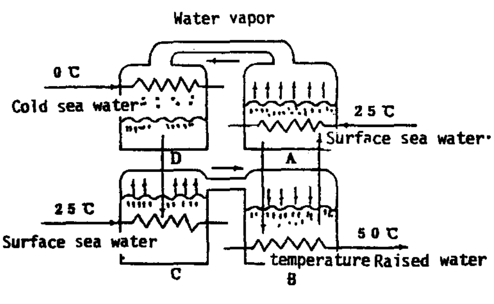


Fig. 5 The principle of chenical Raising Temperature Cycle

The most important point of chemical raising temperature is that discharging heat from mechanical reaction (compression and expansion) changes to chemical reaction (action among moleculars).

3. 2 Comparison between the raising temperature cycle and raising pressure cycle

Fig. 6 shows these eycles. Fig. 7 shows the relation between the temperature heating and the evaporation pressure producing. When the temperature is heating to 100°C, the steam produce 1 atm evaporation pressure, and the steam can be used for generating electricity by pushing turbine. But when the temperature is not high enough, the steam turbine is not moved. Therefore as showing in fig. 6, the raising pressure cycle has been used before. It used some kind of chemicals to make the pressure raising and to move the steam turbine.

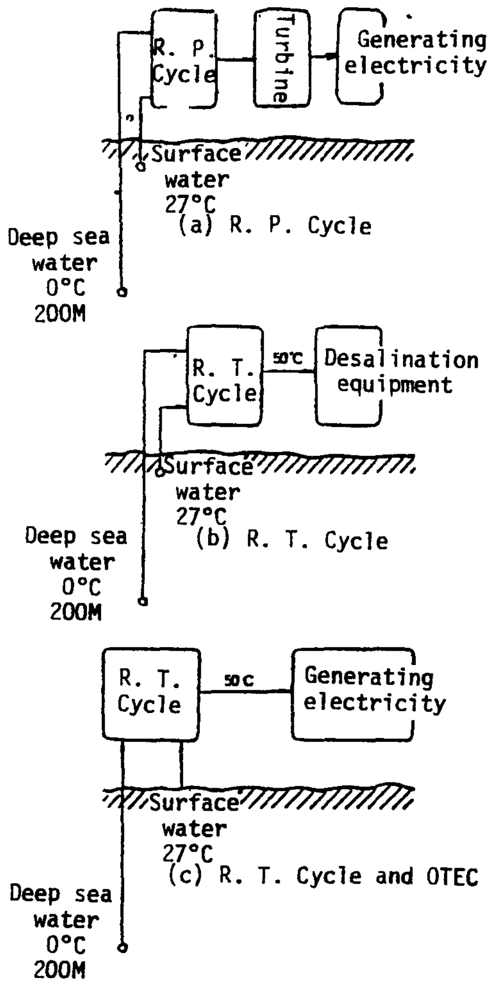


Fig. 6 The Raising Pressure Cycle and the Raising Temperature Cycle

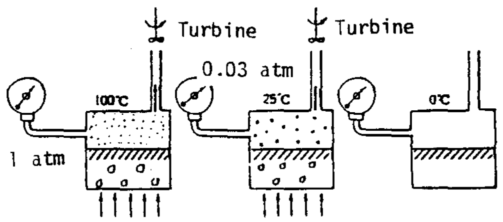


Fig. 7 The temperature heating and the evaporation pressure producing

The research has developed a raising temperature cycle that adding the same chemicals raises the temperature by means of the different concentration of mixture. The raising temperature cycle for utilizing the oceanic energy is convenient, and the circumstance of description will be described in the next.

3. 3 The experiment data of C. O. P in the part of raising temperature cycle

The equipment in Fig. 3 was one of the experiment of the research project. The detail is to show in other report[1),3)], but here the structure will be roughly reported. The pressure and the temperature are shown in Fig. 8. Moreover, Fig. 9 shows the heat balance of raising temperature part, Fig. 10 shows the structure and the heat balance of desalination part, Fig. 12 shows the temperature difference and heat change in every part. These figures show that when the temperature difference is more than 15℃ the heat conduction will increase linearly, but the temperature difference is less than 15℃, it cannot act. It is to say that there are 4 heat exchangers in the raising temperature part, these heat exchangers have a nearly 15℃ of heat conduction loss. Therefore, if there is no much temperature difference, there is no good heat conduction carried out.

Fig. 13 shows a relation between temperature difference and C. O. P. From this figure the temperature difference (about 15～32℃) will get a constant nearly C. O. P.=0.48. This estimation is the same as the principle of heat pump which shows in Fig. 5, C. O. P.=0.5.

3. 4 The C. O. P of desalination equipment

The heat balance of desalination equipment is shown in Fig. 10, from this experiment there is a result which is shown in Table 1. It is significant that the C. O. P is nearly 1, and the heat conducting to the desalination equipment will show a roughly efficiency for desalting. When desalting in the raising temperature cycle, we can intellectually say that there is no question in the part of desalination.

4. The benifit of utilizing the raising cycle to solve the OTEC

This research project is developing the raising temperature cycle to solve the economic question for utilizing the energy of oceanic temperature difference, and it is carryed out by the developed principle of the cycle and the preliminary experiment.

Because of utilizing the effective raising temperature cycle in kow temperature difference, there is a distinct comparison of numerical data. Pretendingly it is raising the surface water temperature from 25℃ to 50℃ with the cold sea water of 0℃, according to the following investigation.

4. 1 The benifit of ultilzing the raising temperature cycle for desalination

Fig. 6 shows a cambination equipment of the raising temperature part and the desalination part. There are two benefits produced from such a equipment.

i] Technique of extacting vacuum will be easy.

ii] The power for removing gas in the unactive gas will be decreased.

4. 2 Utilizing the combination equipment of the raising temperature cycle for OTEC.

When the raising pressure cycle of Fig. 6 (a) can be generating power, the effect in the turbine of the cycle will be estimated that:

Principle of Carnot's effect (25℃) $=\frac{25}{273+25}=$ 0.08

But in the same figure (c) when raising temperature difference to 50℃ the effect in turbine of OTEC will

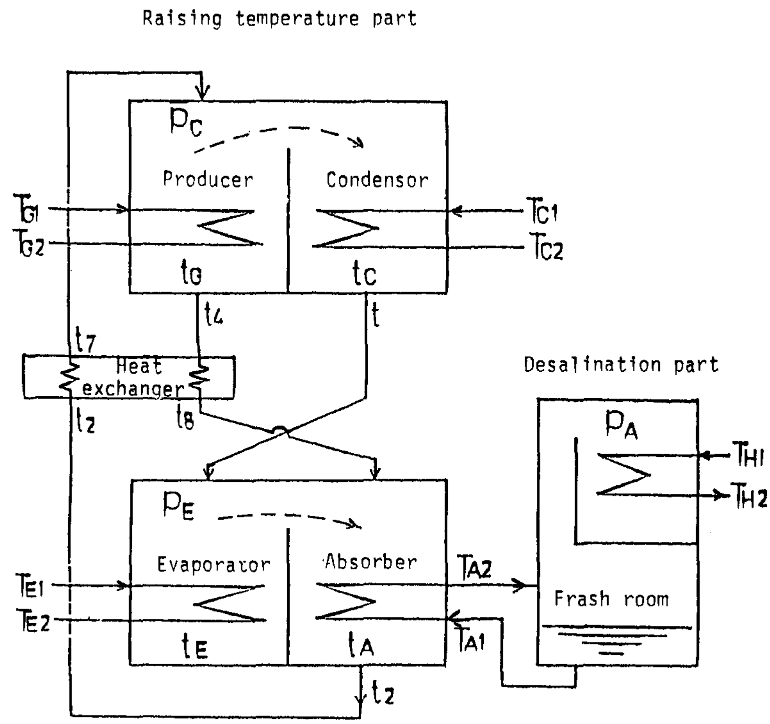


Fig. 8 The temperature and pressure in each part of the desalinature equipment

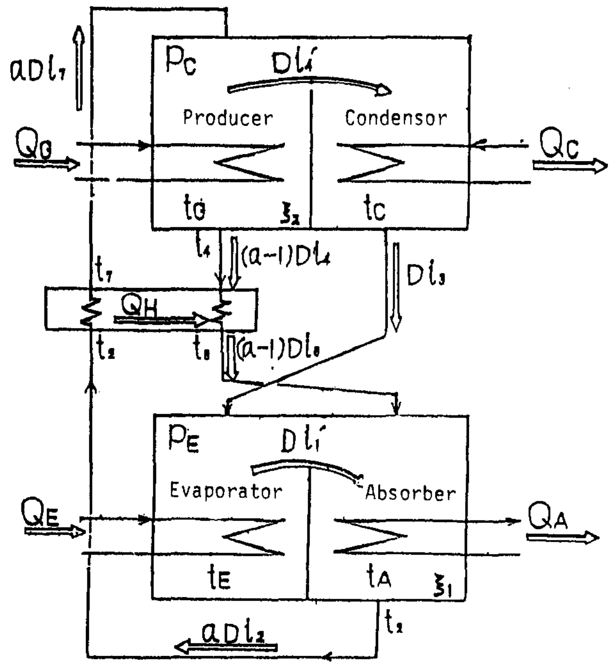


Fig. 9 The heat balance of the raising temperature cycle

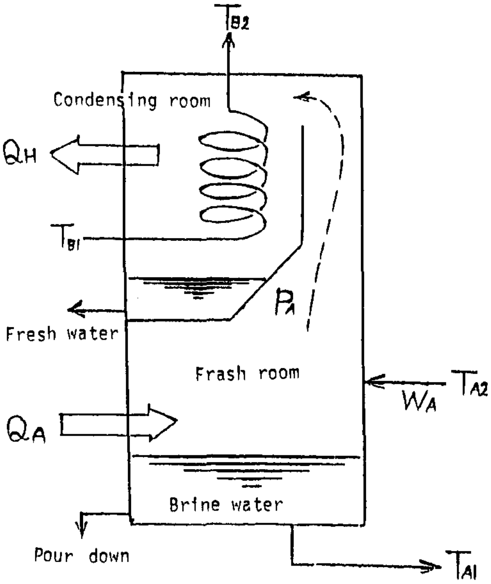


Fig. 10 The structure of the desalting part

Table 1 The C. O. P of the desalination

Q_A kcal/h	Q_H kcal/h	Production kg/h	$\frac{Q_H}{Q_A}$
1184	1170	2.00	0.988
680	676	1.17	0.994
561	558	0.97	0.995
250	240	0.41	0.960
255	250	0.48	0.980

be easily seen that:

Principle of Carnot's effect (50°C) $=\frac{50}{273+50}=0.16$

From these equations, we can easily know the effect of turbine will increase about 2 times, but in the condition of (c), this estimation is not reasonable, because it does not combine the raising temperature cycle and the turbine to compare with (a).

Based on this reason the effect of the raising temperature part (chemical heat pump) is simply discussed here. Both of the heat engine and the heat pump must be distinguished, because the efficient of them are not the same in quality.

Comparing with Fig. 6 (a) and (c), raising the temperature to 50°C in (c), the turbine efficient may be raised twice. And if the efficient of the raising temperaure part is larger than 0.5, the combining efficient of (c) is good, but if it is smaller than 0.5, (c) is bad. It is precisely to say when utilizing the temperature difference about 25°C the combining efficient is decided by the efficient of heat pump being larger than 0.5 or smaller than 0.5. Owing to this meaning, the capacity of the raising temperature part would influence the whole project.

Synthetically utilizing the temperature difference about 25°C to generating the electric power, the C. O. P of the raising temperature part is larger

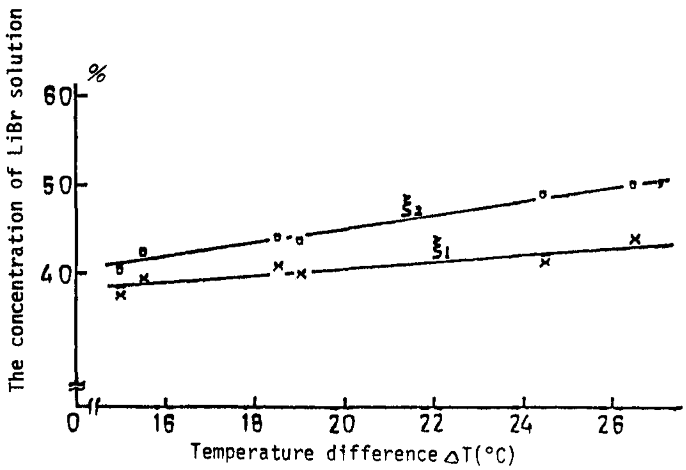


Fig. 11 The temperature difference and the concentration of LiBr liquid

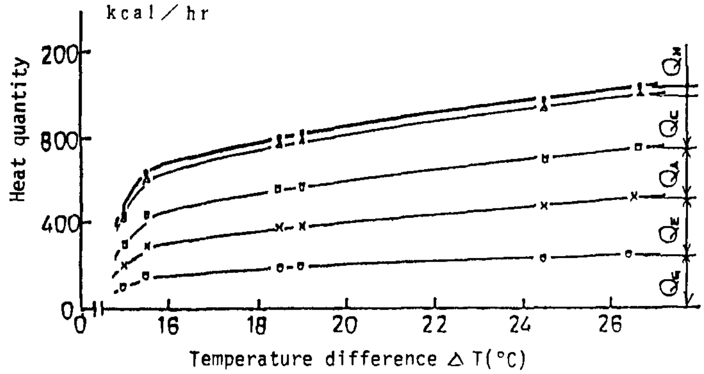


Fig. 12 The temperature difference and the heat

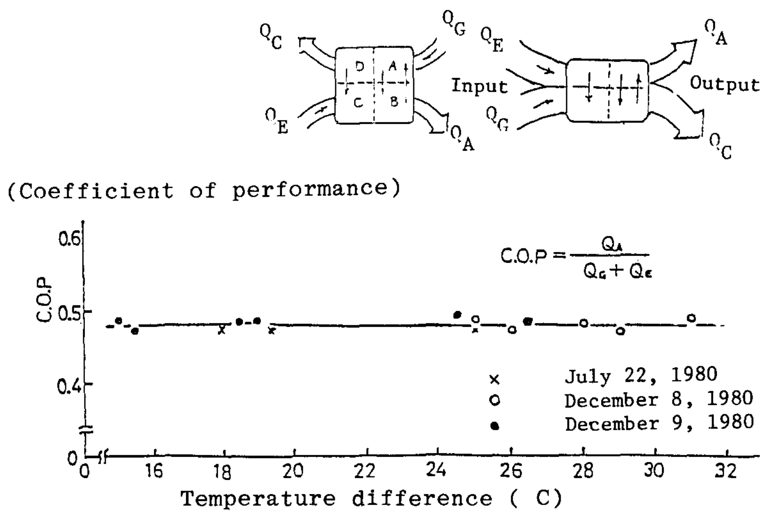


Fig. 13 The temperature difference and the C. O. P.

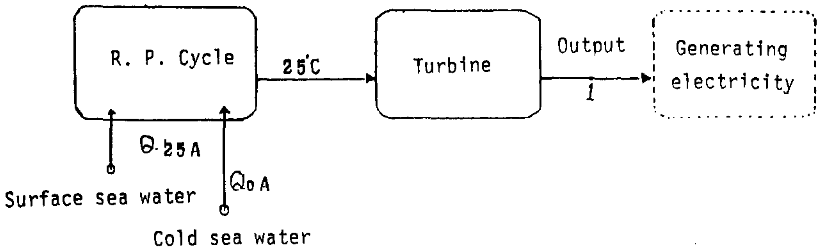
than 0.5, then this method is more economical and beneficial than the preceding method.

4. 3 The C. O. P of the chemcal Raising Temperature Cycle

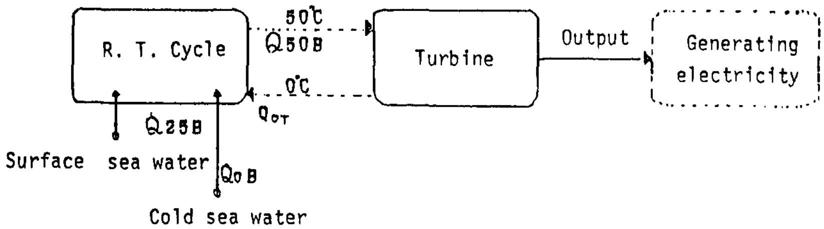
From now on, it is to be discussed about a result of the coefficient of performance (Abbrev: C. O. P) which is calculated by using the warm sea water and the cold sea water to raise the temperature difference from 25°C to 50°C in hypothesis. Fig. 13 shows an experiment result of the C. O. P. A calculation is using the common method for estimation, and the ratio of the input heat energy which is taking from high heat resources, and the heat energy of the raised temperature. (The atmosphere and the sea water are low heat resources, so it will be considered of utilizing the heat drainage.)

But on a condition of utlizing the temperature difference of ocean, a huge amount of the surface warm sea water will be used, then, as usually, the C. O. P. of the warm sea water is defined on pumping up the cold sea water from the sea bottom, so the cold sea water will be considered actually:

$$\text{C. O. P of warm water} = \frac{Q_A}{Q_G + Q_E} = 0.48$$



(a) The raising pressure cycle
(Abbrev: R. P. Cycle)



(b) The raising temperature cycle
(Abbrev: R. T. Cycle)

Fig. 14 The conparision of the character between these two cycle

Table 2 The comparison of water using between these twe cycle

	Surface sea water	Cold sea water	Total
R. P. Cycle	Q 25 A (1)	Q 0 A (1)	2
R. T. Cycle	Q 25 B (1.04)	Q 0 B (0.25)	1.56

Fig. 8 The temperature and pressure in each part of the desalinature equipment

Fig. 9 The heat balance of the raising temperature cycle

C. O. P of cold water $=\frac{Q_A}{Q_C}=0.96$

The combination experiment of raising temperature and OTEC has not carryed out yet, but it is hypothetical here. Fig. 14(a) shows utilizing the temperature difference of 25°C to move the turbine, (b) shows raising the temperature difference until 50°C to move the turbine. Both of them push the same turbine and compare each other. However, on that condition the turbine is hypthetically moved by the effect of Carnot's theorem.

Condition (a) : the maximun expect value of Carnot's efficiency is that $\frac{25}{273+25}=0.085$

Condition (b) : the C. O. P. of raising temperature products the C. O. P. of 50°C Carnot's efficiency

warm sea water: C. O. P.$=0.48$

$$0.48 \, x \frac{50}{273+50}=0.077$$

cold sea water: C. O. P $=0.96$

$$0.96 \, x \frac{50}{273+50}=0.154$$

Factually, the C. O. P. of cold sea water in both of (a) and (b) is nearly the same, so it is very easy to know that the raising temperature cycle is benefitable.

Next, these two cycle must use the amount of water which is shown in Table 9. When the turbine effect is twice that :

0.50B = 1/2 Q 25A. The necessary heat (necessary water) of the two cycle can be estimated in the same table. It is shown that the necessary water in raising temperature cycle is small and this result would decrease the volum of heat exchanger. When the cold sea water decrease to 1/2 of the proceding, we can say that it is a big merit.

4.4 The advancement of the raising temperature cycle

In the research project utilizing the low temperature difference in OTEC, the most difficult question is the low efficiency of turbine, therefore, the raising temperature part is set in front of the turbine for promoting the studying. Putting the raising temperature part before the turbine is necessary in quality because there is no heat engine which is not controled by the Carnot's theoretical effect.

Now the simple experiment of chemical heat pump has been developed, the C. O. P. of heat pump part has been gained. Moreover, the character of pumping-up is promoted.

Because the raising temperature eqipment using here may not use chemical heat pump only, the jet raising temperature equipment must be thought about, therefore the other research must be promoted. The jet raising temperature cycle is a equipment for pure liquid, which applies the Bernoullis theorem escaped from the Carnot's theorem.

Now the C. O. P. of chemical heat pump is 0.48, it has been developed and estimated by so many studies, the reason may be explained by following:

25℃ temperature difference of heat pump

theoretical C. O. P. $=\frac{273+25}{25}=11.92$

Now it is 0.48, although it can not be developed to reach the theoretical date, the factual date of C. O. P. in mechanical heat pump is up to 4～5, so the data will be expectively developed. Even that 0.48 is better than the present cycle. If it can be developed form this, the temperature difference energy resource will be developed.

5. Summary:

The best place of utilizing the oceanic temperature difference energy in Japan Sea had been found Shimane area (Westen Japan Sea) by the research project. It can be experimented in utlizing the temperature difference to desalt there.

a) The success in utilizing the temperature difference to desalt.

b) The data of pumping up the cold sea water has gained.

c) The preliminary experiment in utilizing the chemical heat pump to raise the temperature difference has succeeded, and its usage is significant.

At last, this research project thanks various circles having given the assistant and the encouragement. And the whole members of the project thanks the help sincerity.

Moreover, it is sincerely thanks all sectors to render high supports to this research project with aids of funds, data and equipments.

6. References

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