A Preliminary Experiment on Utilizing the Ocean Temperature Difference for Desalination

(I : Fixing the ship for Experiment in the Sea and Pumping up the Cold Sea Water)

by

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1. Introduction

On the investigation of the research project and other reasearch organizations,[1] it is found in Western Japan Sea that there are cold waters (about 2°C) in the shallow bottom, (up 200m —deep) as far the surface warm water of Tsushima current flows into this area, the highest temperature of the warm water in summer is 27°C.[2] So that the area with temperature difference can be found.

Fig. 1 shows an energy plant structure which is imagined by the research project, and Table 1 shows the strength of the structure. A actual measure in the Hawaiian area compared with that in the Shimane area of Japan Sea, it is found that the depth from 663m decrease to 200m, and the cost of construction from 1 decreases to 0.33.

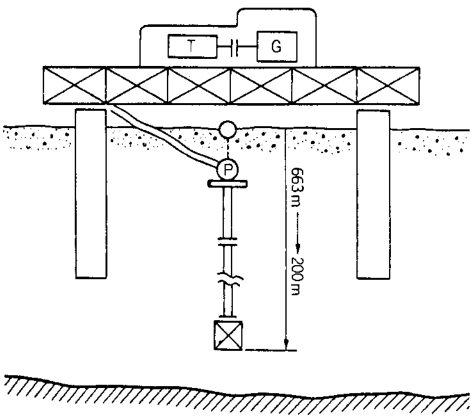

Fig. 1 The energy plant in the ocean.

Table 1 The strength of the structure

Intensity	200m	663m
Bridge	1	3.3
Column	1	10.
Fund (X100Million)	1	33.

It is meaning that this area being utilized for OTEC is suitable, and other researches of energy utilizing have been performing. The successtful preliminary experiment of the research will be reported here.

When the experiment was studying, various organizations have assisted and aided, further more the Kaiou Maru, with 512 gross-tons, which is a retired ship acquired from Japan Marine Defense Authority, this ship was equiped to be the Marine Energy Research Ship now.

And when the oceanic experiment was performing it was assisted and taught the skillness and the experience by the department of Fishery (Nagasaki University) for a long time.

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2. An investigation of the experimental area.

Fig. 2[3] (a) shows the variance of Kuroshio along the Japan Islands, (b) shows the distribution of temperature among the experiment area. Moreover, Fig. 3 shows a result of this investigation, (a) shows the seasonal variation of the current, (b) shows its vertical distribution of the temperature.[5] On these figure it is couspicuous that the temperature distribution in the Tsushima bank (Western Japan Sea) was different from the other place, it was a suitable place because of its big temperature difference between a shallow depth. That is the reason of why the temperature distribution shown in Japan Sea to be is that Japan Sea is formed by glacier which made the Tsushima area at the depth of 200m and across here the depth increased quickly to 5000m.

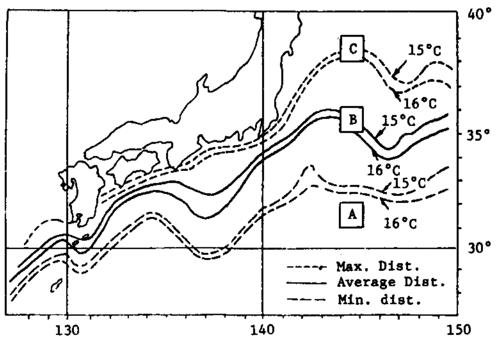


Fig. 2 (a) The seasonal variation of KUROSHIO

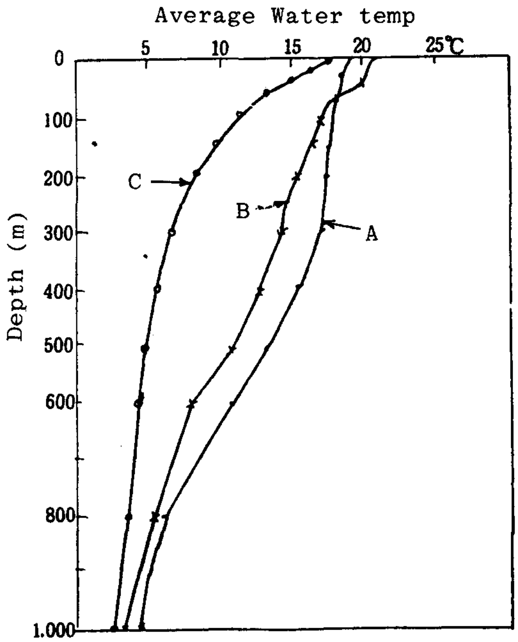


Fig. 2 (b) The temperature distribution of Pasific Ocean

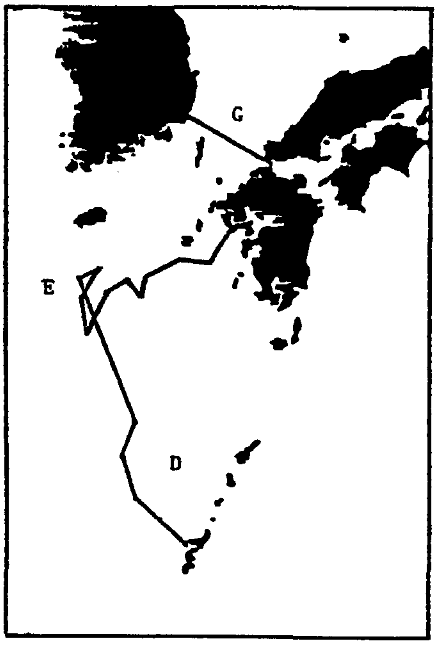


Fig. 3 (a) An investigation in Eastern China Sea and Tsushima

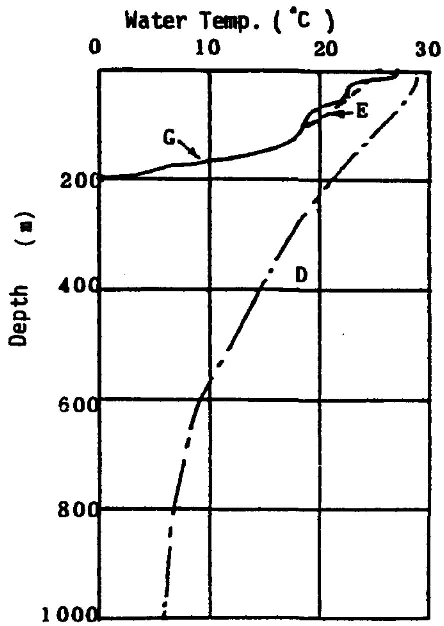


Fig. 3 (b) The comparison on the temperature distribution

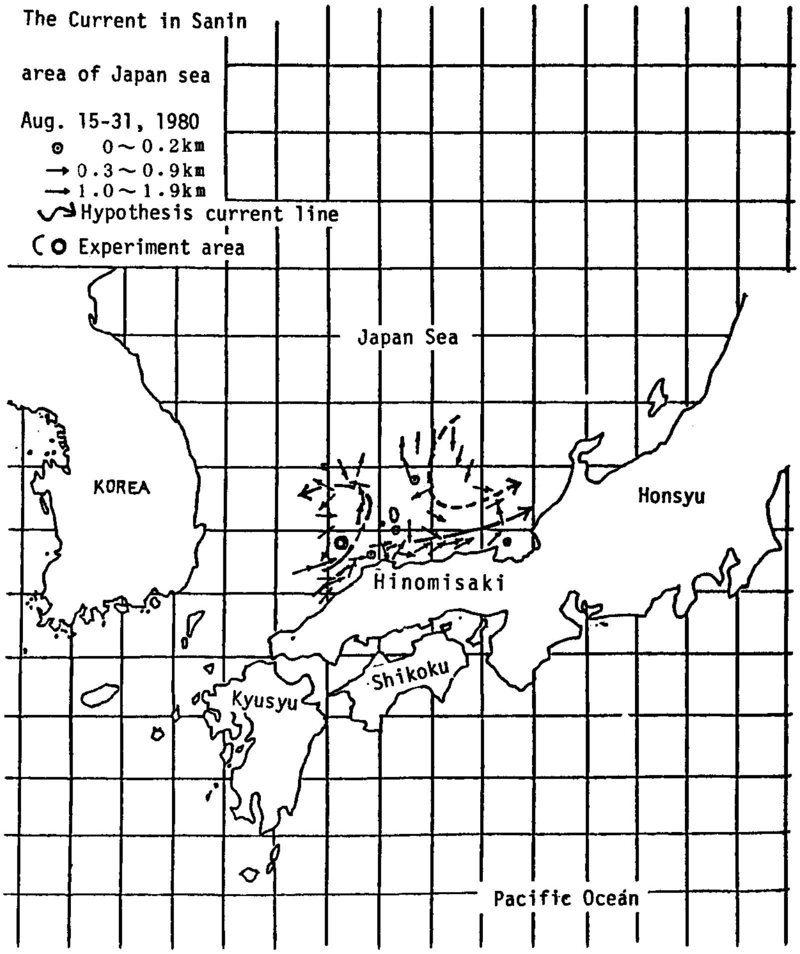


Fig. 4 The current on the experiment area

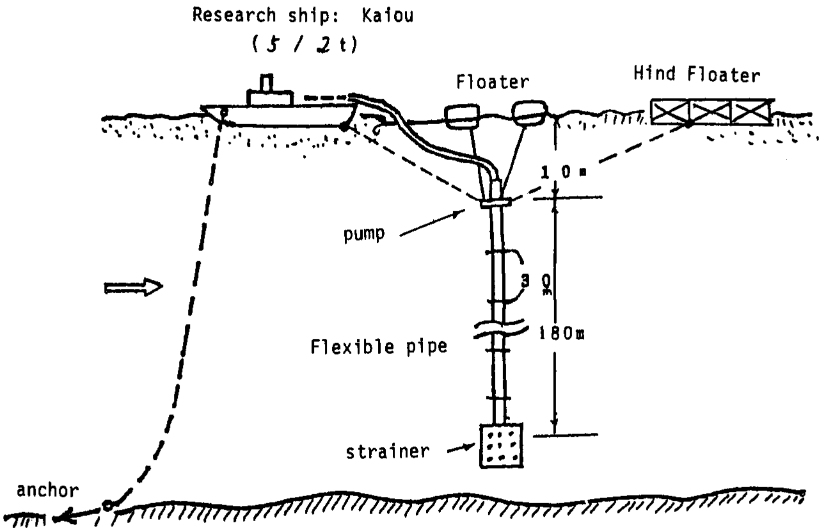


Fig. 5 The anchoring position of the research ship and pipe line for pumping up

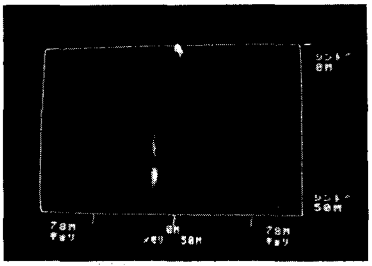


Fig. 6　The condition of hanging down the pipe line
(A photograph in Graphic Sonar)

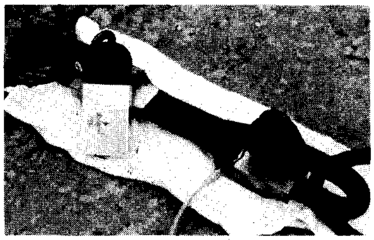


Fig. 8　The tension bar (for 5 tons)

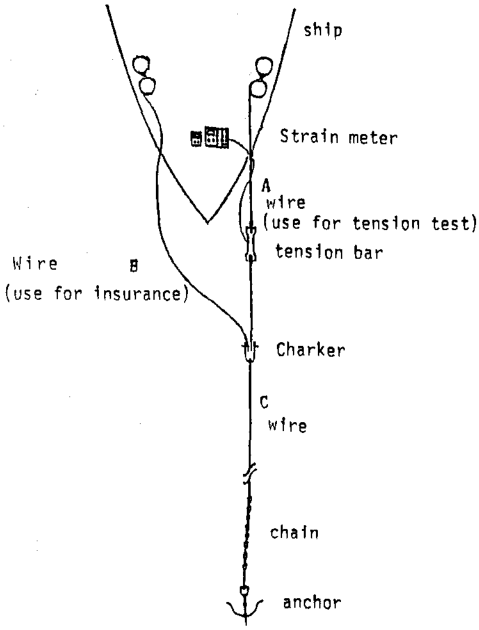


Fig. 7　The test of tension

Table 2　The data of force on the tension bar (July 27,1980).

TIME	ε_c	C	A	ε $\times 10^{-6}$	σ kg/cm^2	Force kg	Weather condition direc	Weather condition speed
19 : 10	100×10	100	54	51.4	107.9	357	N	3.0
19 : 30			50	47.6	100.0	325	N	4.0
20 : 00			40	38.1	80.0	252	N	4.0
20 : 30			55	52.4	110.0	365	N	4.0
21 : 30			72	68.6	144.1	492	N	3.5
22 : 30			85	81.0	170.1	590	NNE	3.5
23 : 00			80	76.2	160.0	551	NNE	3.5
23 : 30			70	66.7	140.1	476	E	3.5
00 : 00			80	76.2	160.0	551	E	3.5
00 : 30			75	71.4	150.0	515	E	2.0
		AVE	66.1	63.0	132.3	447		3.5

(備考)
ε_c……………A correcting constant.
C……………An indicate number for ε_c.
ε'……………An indicate number is arrenged by Ks.
ε……………The quantity of strain is arrenged by Ks.
Ks……………A gage rate. (=2.1)

$$\varepsilon = \varepsilon' \cdot \frac{2.0}{Ks} \qquad \varepsilon' = \varepsilon \cdot \frac{A}{C}$$

$\sigma = E \cdot \varepsilon$　　E : Yang rate of soft steel. (2.1* 10kg/cm^2)

In this basin the deep cold sea water moved seldom. Although the Tsushima warm water flows into the basin from west, but the Siberia cold water flows into this area northward, so a huge of cold sea water is conserved.

All of previous investigation reports indicate

Table 3 The result of harmonic analysis (*Unit Cm/Sec)

Component current	Time	July 21, 15:10 --23, 14:50		July 24, 00:00 --25, 06:00	July 25, 09:00 --26, 16:00	July 28, 11:20 --29, 09:20
Lumer semi-diurnal	EW NS	42.70 38.06	28.59 40.59	35.18 49.44	70.18 35.33	34.26 47.50
Solar semi-diurnal	EW NS	47.01 37.68	24.86 34.17	39.84 52.76	73.21 33.55	32.48 46.49
Constant stream	EW NS	21.13 30.11	20.58 29.08	9.08 24.91	3.62 8.89	11.19 −0.88
Depth (a)		3	10	10	10	10

that the exit of Tsushima area (=the westren Japan Sea) is the most suitable place for utilzing the oceanic temperature difference energy. The most important reason is that the surface layer in summer is about 27°C, and the 200m−deep cold sea water is nearly 2°C.

According to the result place at the depth of 200m−deep compares with the other place (Ex. Hawaiian area is 663m−deep), it is conspicuously profitable that (a) the producing fund of the energy plant will be decreased (about 1/33) (b) the power for pumping up the deep water will be small. (c) the temperature increasing in the pipe will be small.

3. Anchoring the research ship on the sea

Fig. 4 shows currents nearby the experiment place and shows that the experiment was performed in the Shimane area of Japan Sea from July, 1980 to August, 1980 (about 3 weeks).

Fig. 5 shows the anchoring method on the sea. At first an anchor is fixed at the head of the ship, then tighten some floaters at the tail (distance is about 70m), and the pipe line is tighten between these floaters. Just like the figure whenever the direction of the wind or the tidal current changes, the direction of all equipments follows that way slowly. The anchor is hanging a 25m−long chain at the bottom of the sea, and a 600m−long wire rope (25ϕ) joints with the research ship.

3. 1 Anchor tension

Fig. 7 shows the equipment of tension measurement on the ship. From the same figure, it can be seen that wire B and wire C on the ship head are connected for the common anchoring. The tension was test between A and C with a tension bar (Fig. 8) at the wire A, but B is not in use. Such a structure like Fig. 7 can insure that when the tension bar on A is broken, then the tension between B and C will be safety.

On the Table 2 the data of the factual tension was combined with the direction and the speed of wind. At this moment the direction of the current is NNE, the average speed of the current is 0.15m/s. From Table 2 a result can be shown, the vertical wire is 300kg downward vertically, and the value of tension is 250kg～590kg (400kg for average). The weight of anchor wire is 1.5kg/m, the water depth on this condition is 200m, and the vertical wire will be about 300kg.

3. 2 The experiment value of tidal current and its harmonic analysis

There are two automatic tidal meters of similar type on the ship. One of them is recording under the surface current of 3m−deep, the other is nearby the cold water pump under 10m−deep.

3. 2. 1 Observation time interval

Experiment observation on the tidal current was beginning on July 21, 1980 (about 1 week). But as we know, some other date was uncontinuenous.

The observation list is shown that:

1) July 21, 15:00～July 21, 14:50
2) July 23, 17:00～July 25, 14:20
3) July 27, 12:50～July 28, 10:00
4) July 28, 11:20～July 29, 09:00

The observation on the present time interval had expressed about 2 or 3 date obtained.

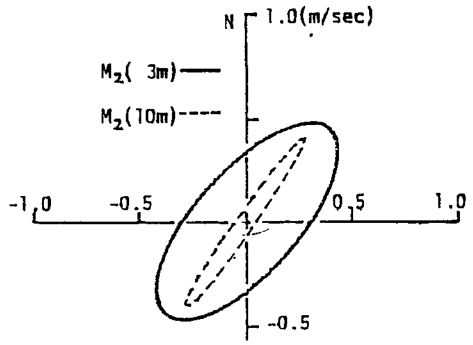
3. 2. 2 The result of observation and its harmonic analysis

Fig. 4 shows the tidal current which was examined by JMDA (Japan Marine Defance Authority). The location of the experimental place was in this area, moreover they were companying with us in a friendly way for a long time.

The harmonic analysis of tide in the research project was shown in Table 3, and tidal current circle was shown in Fig. 9, its vector was shown in Fig. 10.

In Fig. 9 the surface current and 10m−deep current flow to the same direction, but the value of surface current is almost bigger than that of 10m −deep current in North-South component.

Fig. 4 was an observation data examined by



•Fig. 9 The round tidal current

JMDA, Fig. 9 and 10 were their result data examined by the research project. Specially the research project modified a numerical simulation of the fluid in the experimental place, and it was found that these three information did not agree. It is a remaining question in future.

3. 3 Observation with Graphic Sonar

When the research project carry on the oceanic experiment, conditions of the pipe line and various equipments must be know, so the Graphic Sonar must be a useful equipment.

Fig. 11 (a) shows a sonar receptor which used in the experiment, (b) shows that the equipment is working. Moreover, Fig. 12 shows the surrounding of the research ship and another ship is a sonar ship which is needed. The sonar was developed in the experiment and its ability was increased.

The photographs of Fig. 6 and Fig. 13 are shown by this equipment. Fig. 6 shows the pipe line, and Fig. 13 shows the experiment of anchor.

4. Pumping up the cold sea water

In Fig. 5 the backward of the research ship hung a pipe line which pumped up the cold sea water. On the Shimane area the experiment carryed on, and several voyages to the offshore of Nagasaki and the Eastern China Sea were taken for preliminary experiment. The discription has

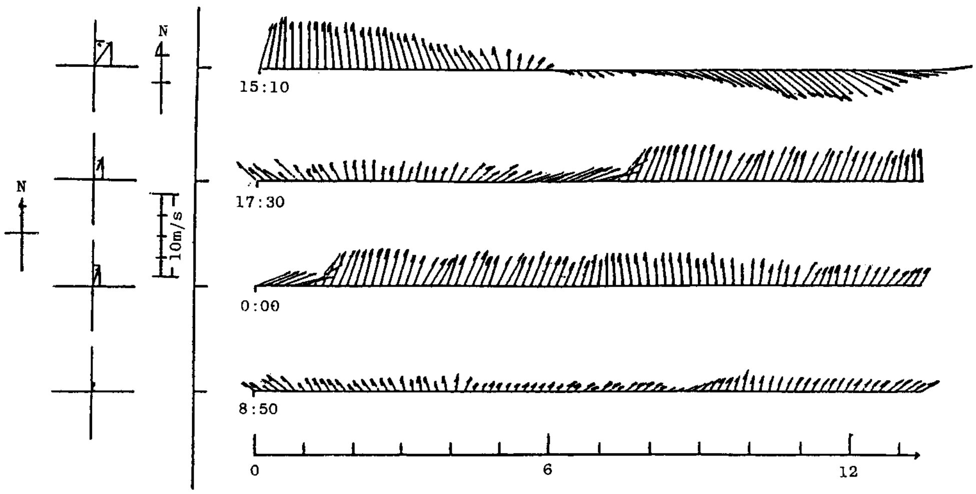


Fig. 10 The vectors of the tidal current

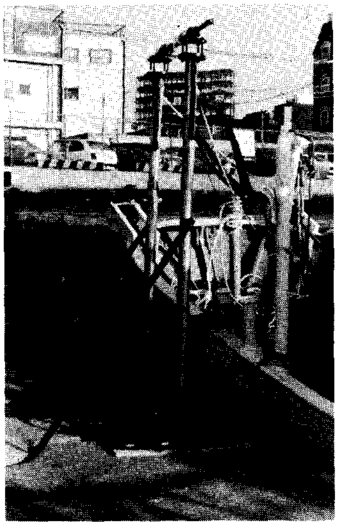


Fig. 11 (a) The acceptor of the Graphic Sonar

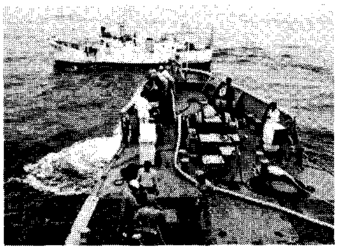


Fig. 12 The photograph of the surrounding of the research ship

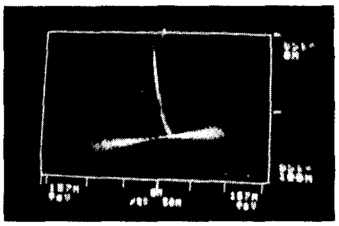


Fig. 13 The condition of the anchor of the research ship

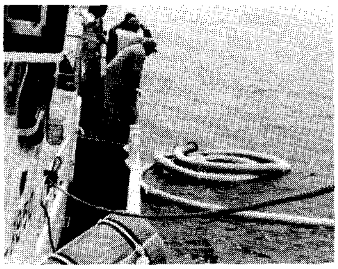


Fig. 14 Drowing down the research ship

Fig. 11 (b) The photograph of the Graphic Sonar

been omitted here.

4. 1 Upward and downward the pipe line

The pipe line for pumping-up was made from the salting flexible pipe. Fig. 14 shows the condition of throwing into the sea. At the beginning filled the air to the pipe, the pipe was floating on the ocean surface, then it dropped slowly.

Fig. 15 shows the sight of the cold water pump hung about 10m−deep under the sea surface. Preventing the cavitation is the reason why the pump was hung there. Fig. 15 shows the last stage of the pipe line being thrown in. Under the pipe line there is a strainer with double covers, if compared with the landing container, its surface area is about 300 times of that. See Fig. 16.

Fig. 17 shows the rewound eqipment of the pipe line. Fig. 18 shows the sight of the pipe winding, but it is rewound by the equipment in Fig. 17, its wire rope is rewound in a winch drum.

Each section of the pipe is 30m−long, its connector is shown in Fig. 19. The total weight of the pipe line for pumping-up the cold sea water is about 1 ton only, the pipe is not straightly connecting in the structure.

The pipe line rewinding equipment was marvalous, it rewound the pipe 200m just only for 30 min. According to the experience of the research project, the rewinding work must be quickly over while the Typhoon is comming.

4. 2 The power for pumping-up and the pressure loss in the pipe line.

The sight of pumping up the cold sea water is shown in Fig. 20.

The maximum amount of pumping up is 35m/hr, and the pressure loss in the pipe line is 0.06m, but the net loss is 0.13hp and the consumption power is 0.22hp.

When the maximum amount of pumping-up is $35m^3/hr$ in the ocean, the pipe line has a volume $60m^3/hr$. Oceanic experiment was based on the preliminary experiment of laboratory.

Table 4 is a comparison of pressure loss in maximum amount of $60m^3/hr$, the coefficient of friction loss is shown in Table 5, the loss coefficient of the connector between the strainer and the pipe line is shown in Table 6. The Fig. 21 and

Fig. 15 The pomp under the sea

Fig. 17 The equipment of rewinding pipe line

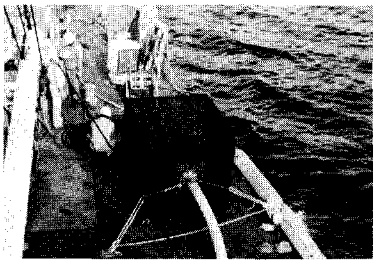


Fig. 16 The strainer

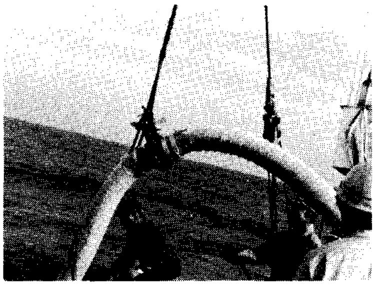


Fig. 18 The pipe line being rewound

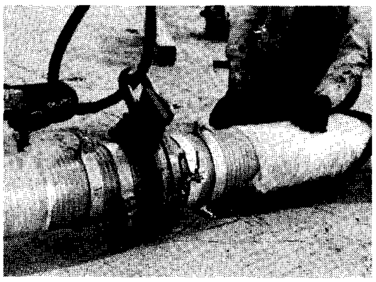


Fig. 19 The connecter of pipes

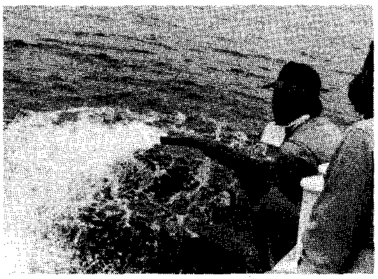


Fig. 20 The condition of pumping up the cold water

Table 5 The coefficient of friction loss in pipe line

No	Qm³/min	Vm/s	$\lambda \times 10^{-2}$	$Re \times 10^5$
1	1.575	1.447	1.057	1.68
2	1.491	1.369	1.980	1.59
3	1.383	1.270	2.013	1.48
4	1.262	1.159	2.072	1.35
5	1.110	1.019	2.296	1.19

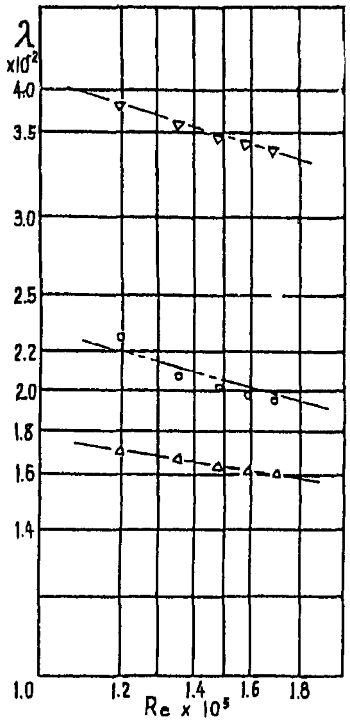


Fig. 21 The loss coefficient of pipe line

Table 6 The coefficient of friction loss in the connector of the strainer and pipe

	ave.	$Re \times 10^5$
ζ_1	0.2573	1.19～1.68
ζ_2	0.4957	1.39～1.63
ζ_3	1.2678	0.73～1.21

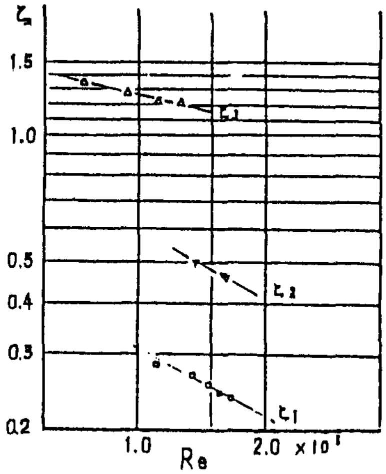


Fig. 22 The loss coefficient of connect part between pipes

Table 4 The comparision of pressure loss

water temperature		λ	ζ_1	ζ_2	$Re(\times 10^5)$	H(m)
0°C	:	0.030	0.35	1.35	0.848	2.00
2°C	:	0.025	0.32	1.30	0.903	1.69
20°C	:	0.020	0.25	1.25	1.520	1.21

viscosity v is that:
$\nu_1 = 1.792 \times 10^{-6}$, $\nu_2 = 1.683 \times 10^{-6}$, $\nu_{20} = 1.004 \times 10^{-6}$

Fig. 22 show the Table 5 and Table 6. The detail of discription is shown in other report.

4. 3 Increasing the water temperature in the pipe line

The distribution of depth and temperature at the experiment place was shown in Table 7 and Fig.

Table 7 The depth and the temperatur distribution in Hinomisaki by Nagasaki Maru

Hinomisaki July 21, 1980 19.95 mile--109.5°		Hinomisaki July 24, 1980 21.9 mile--329.0°	
Depth *m*	Temperature	Depth *m*	Temperature
0	22.76	0	22.98
50	17.59	50	17.34
100	15.42	100	15.26
110	14.74	110	14.84
120	13.29	120	4.52
130	9.68	130	13.28
140	7.30	140	10.59
150	5.96	150	7.33
160	5.45	160	6.03
170	4.25	170	5.34
172	2.33	180	5.06
		190	4.41
		200	3.51
		210	2.09

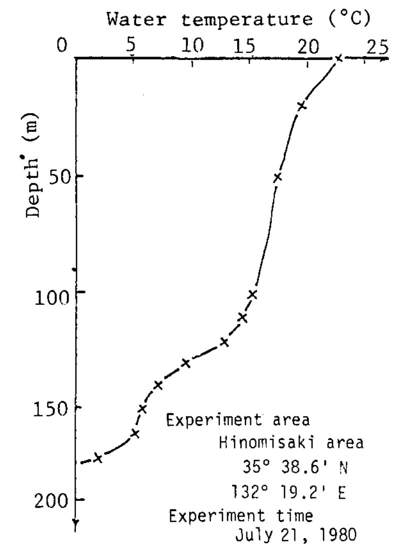


Fig. 23 The temperature distribution of the experiment area

23.

The cold deep sea water (about 2.1°C) in the experiment area is 3.2°C at the exit of the pipe line in summer. At the pipe line there is an increasing value about 1.1°C. For examing the temperature of sea water it is an experince that it is easy to test precisely on the surface of sea water, but there are so many questions in testing under the sea water.[3] On the testing of sea water temperature the experiment developed the diode senser, but it must be hung on a long lead line, the resistant of lead line was influenced by the temperature of sea water, too. The complement circuit is difficult to control and the lead line in the flowing tide directly influence the precision of the vertical distance. So the result of temperature testing remains a question of precision, it will be developed next time.

5. Summary:

a) Result of investigation in this area, Japan Islands of the Western Japan Sea, is a extremely beneficial place for utilizing temperature difference energy. It is the reason that there is a big temperature difference for a shallow depth.

b) It has got the anchoring data on the sea by the research ship.

6. Reference

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