SEAFDEC Training Department

Southeast Asian Fisheries Development Center

TD/RES/16 July 1987

REPORT OF REFRIGERATION SYSTEM INSTALLATION EXPERIMENTS

(This report mainly concerns the installation of a pre-cooling system on board small- and medium-sized vessels in Southeast Asia)

by

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Published by the Training Department, Southeast Asian Fisheries Development Center
P.O. Box 4, Phrapradaeng, Samutprakarn, Thailand.

Research Paper Series No.16

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PREFACE

As is well known in the ASEAN Region, the fishery resources in the coastal and offshore waters have a tendency to decline, with the increase of fishing intensity, though the actual situation of the coastal resources will vary for each country. On the other hand, the demand by both local and international markets for fish, both quantitatively and qualitatively, has been increasing, particularly the demand for high quality fish. It is therefore essential to maintain the high standard of freshness of the catch until it reaches the consumers.

There is a tendency to enlarge the size of fishing vessels in order to be able to increase the catch by going to distant fishing grounds where fish resources are less exploited. As the number of fishing days in a cruise will be expected to increase, it will be necessary to install sufficient refrigeration facilities to preserve the fish on board.

As the large-sized fishing vessels of 150-200 gross tons class have sufficient refrigeration facilities for preserving the fish on board, there would be no problem to maintain the freshness of fish until they reach the landing places.

As the small coastal fishing vessels of less than 10 gross tons have only one or one-half days of cruise, there would be few problems for preserving the freshness of fish by using the ice storage system.

However, the medium-sized fishing vessels of 10 to 40 gross tons, which are the major supply source of fish to the large fish markets in the region, do not have an adequate preserving facility to maintain the freshness of the fish on board.

In order to improve on the system for maintaining the freshness of the fish on board medium-sized Thai trawlers, I devised a plan during the last two years for introducing a type of refrigeration system, and in 1986 conducted the experiment to collect data by using the M.V.PLALUNG which belongs to the SEAFDEC Training Department.

Before explaining the idea of my experiment, its process and my evaluation at each step of the experiment for introducing a new type of refrigeration system, I would like to take this opportunity to express my sincere appreciation to Dr. Veravat Hongskul, Chief of the SEAFDEC Training Department, and to the Japan International Cooperation Agency for their kind assistance in allowing me to conduct the experiment.

I would also like to thank my counterparts in the Training Department for assisting me in conducting the experiment.

Chapter 1. Formulation of the experiment and the problems encountered.

1. Plan of the experiment.

1) Cooling method and target temperatures for preserving fish.

Currently, the majority of Thai trawlers use the ice storage method, without refrigeration equipment, for preserving the fish on board, but it is not sufficient to keep up the level of freshness of the catch.

Taking the above into consideration, it would be ideal to add the pre-cooling method using chilled or super-chilled sea water. The target temperatures of chilled water and super-chilled water range from +5°C to -1°C and from -2°C to -8°C respectively.

In order to preserve the freshness of the fish caught by Thai trawlers, it would be advisable to combine the following two cooling systems:

a. Pre-cooling the fish to the level of +2°C to -3°C with chilled or super-chilled sea water, and

b. After the chilling by pre-cooling, the fish are preserved in sufficient ice, on board, until they reach the fish markets.

As the temperature of natural sea water in the tropics is high, it is necessary to install a refrigeration set to cool down the sea water to the target level of chilled water (± 0°C) or super-chilled water (-8°C). Super-chilled water is obtained by adding salt to the cooling water, up to 10-15 per cent of its salinity.

The effectiveness of the pre-cooling method for preservation of the freshness of the fish caught is shown in the Annex Fig. 1 as one sample.

For this experiment I decided that the target temperature of cooling sea water should be at the level of ± 0°C to -1°C and the inner fish body temperature should be kept at the level of +2°C to +1°C. In the case of super-chilled water of -4°C to -8°C, the inner fish body temperature is expected to be at the level of -2°C to -3°C.

2) Method of installing the pre-cooling tanks and the location of the refrigeration equipment.

As the space for installing cooling tanks onboard fishing vessels of 20 gross tons is limited, the small fish holds must be converted into two pre-cooling tanks which will be used on at a time in rotation, when the vessels are a long time at sea. If the capacity of a cooling tank is one ton, about 0.6 tons of sea water can be kept in it.

A set of refrigeration equipment, consisting of a compressor and its accessories, would be installed as near to the cooling tanks as possible. In the case of larger trawlers of the 25 to 40 gross tons class, the refrigeration set could be installed on board. As smaller trawlers of the 10 to 24 gross tons class do not have space for installing a refrigeration set, either in the fish hold or in the engine room, special consideration is required on where and how to install a refrigeration set of sufficient capacity for pre-cooling fish, in such small trawlers.

2. Installation of refrigeration set at a bulbous bow.

1) Basic consideration and many trials and errors.

It is unnecessary to consider the technical renovation of the refrigeration machinery itself as mechanically, it is highly developed and is reliable. The important issue is how to install the equipment in the small fishing vessels.

After long consideration of various alternatives, I decided to install the equipment in the bulbous bow of the vessel, (I will call it BB) and after many trails and errors I eventually decided the locations for installing the refrigeration equipment on the small vessels, as follows:

a. Small trawlers of 10-24 gross tons:

All the refrigeration equipment will be set inside the BB.

b. Medium-sized trawlers of 25-40 gross tons:

The main part such as the compressor, will be set beside the pre-cooling tank. All the other parts will be put in the BB.

c. All small and medium-sized trawlers of 10 to 40 gross tons:

The condenser and receiver, which are the largest and heaviest parts of the refrigeration set, will be palced in the rear part of the BB.

2) Supplemental problems relating to the BB.

In this experiment, as the BB is fixed on the outside of the bow of the fishing vessels currently operating, it must be carefully designed and fitted so as to be strong enough to withstand the pressure of the waves as well as allow the fishermen to carry out their fishing operations easily. This mechanical construction should be acceptable in each country for governmental rules and regulations relating to construction of fishing vessels.

It would be more practical and easier from the mechanical point of view, if the BB can be included into the construction of new fishing vessels.

The BB has two advantages. In general, the objective of the construction of a BB is to decrease the wave-making resistance (Rw) and to increase the length between perpendicular (Lpp) for safe and economical navigation. When the refrigeration equipment is installed inside the BB, the volume of the BB will be much larger than that of an ordinary one, and the frictional resistance (R_f) will be increased, therefore, we have to analyse the balance of the effect between R_f and Rw, based on the results of the experiment. However, since the primary objective of the BB in this experiment is to install the refrigeration equipment inside it, the analysis of the effects of R_f and Rw will be merely secondary in this testing.

For general evaluation of the effect of the BB, the total resistance (R_t) which will be the sum of R_f and Rw, will be examined. If the effect of the refrigeration system is high, this experiment can be said to be successful, although the total resistance value is slightly increased. If the increase of R_t is negative, the experiment will be evaluated to be doubly successful.

The buoyancy of the BB will be generally designed to be equivalent to or larger than the weight of the refrigeration set. The additional buoyancy will act as the restoring force of the hull's pitching in rough sea conditions.

Chapter 2. Process of the experiment, analysis and consideration of the results.

1. Staff who took part in the experiment:

   Mr. M. Yoshizawa, JICA Expert on Marine Engineering, designed, supervised the dockyard work and conducted the experiment

   Mr. Montien Paewsakul, Chief Engineer of M.V. PLATOO

   Mr. Cheevit Ploikaew, staff of the engineering section workshop

   Crew of the training vessels M.V. PLALUNG, M.V. PLATOO, and M.V. PAKNAM assisted in the experiment at sea

2. Particulars of the experimental vessel:

Name of vessel	:	M.V. PLALUNG (belonging to the SEAFDEC Training Department)
Gross tonnage	:	17.06
Net tonnage	:	13.64
Overall length	:	17.00 m
Breadth extreme	:	3.50 m
Depth	:	1.20 m
Cruise speed	:	8.00 knots
Engine	:	one type diesel
Horsepower	:	260 hp, 6 cylinder
Manufacturer	:	HINO (High speed)
Ship's body	:	Wood

3. Fundamental experiment on "condenser and receiver" outside the hull:

1) Place : mooring harbour of SEAFDEC;

2) Period : March 1985 to February 1986;

3) Data : Annex Table 1. and Fig. 2;

4) Budget : a. SEAFDEC provided the M.V. PLALUNG and allocated ฿ 28,000 in March 1985 and ฿ 82,000 in August 1985;

b. JICA provided special research budget equivalent to ฿ 144,000 in 1985.

5) Evaluation of the results of the experiment.

The effectiveness of the refrigeration has been confirmed based on the fundamental experiment conducted under such conditions that a) a condenser and a receiver were fixed outside the hull in flowing water, and b) the other refrigeration set were on the deck with two pre-cooling tanks. With the success of the experiment, the BB system was proved.

4. Experiment of the BB system under sailing conditions:

1) Place : Chao Praya River in front of the SEAFDEC Training Department.

2) Period : a. March to August 1986; Design and preparation of budget.

b. August to September 1986; Attaching the BB onto the M.V. PLALUNG at the dockyard.

c. September to November 1986; Conducted the experiment.

3) Data obtained is shown in the Annex, Table 2, and Table 3. The photos, in Plate 1, Plate 2, Plate 3 and Plate 4.

4) Budget : a. SEAFDEC provided ฿ 80,000 in August 1986;

b. JICA provided a special research fund of ฿ 93,140 for conducting the experiment.

5. Analysis of the experiment and consideration of the BB.

Based on the theory of the ship's propulsion, "V and N curve" No. 1 and No. 2 of Fig. 3 were obtained from Table 3. I added one more estimate curve No. 3, to clarify the effectiveness of the BB.

Where:

V : Ship's speed in knots;

N : Revolutions of the main engine per minute (rpm);

Load : Power in x/4, X = 1, 2 and 4;

No.1 : the curve before setting the BB;

No.2 : the curve after setting the BB;

No.3 : the curve, estimated if a box for containing a refrigeration set is fitted to the outside of the hull, which may be positioned either at the middle of the hull, the bottom of the hull or outside at the stern of the hull.

In considering Fig. 3, my conclusions are:

1) Comparing the curve No. 2 to No. 1, the ship's speed increased by 7.2% at 2/4 power position, but the speed decreased by 6.4% (or R_t up), at 4/4 power position.

2) It is well known by specialists that the ship's speed will increase or decrease, depending on the design of the BB. The purpose of this experiment is not to secure the quantitative analysis by changing the position of BB as well as the velocity of the ship's speed, but to get a kind of qualitative analysis from a macroscopic view in order to compare the two curves of No. 1 and No. 2, or No. 2 and No. 3 and the behaviour of their approximation or their variation, as a whole.

3) From this point of view, I found the following:

a) Curves No. 1 and No. 2 were almost overlapping or were nearly the same value.

b) In comparing the curves No. 1 and No. 3, or No. 2 and No. 3 they were much further apart from each other, and curve No. 3 always had a much lower speed than the curves No. 1 and No. 2.

4) Finally I concluded that:

a) The BB has sufficient space in which to install a refrigeration set either partially or totally.

b) The BB's redeeming feature is that the vessel's speed was always nearly equal to that before fitting the BB, in spite of having the larger size of BB compared to larger vessels with smaller BB which aims at reducing wave resistance.

c) If the size of the BB is designed based on the theoretical calculation of naval architecture, it would result in the reduction of more fuel consumption at the most desirable speed for fishing.

6. Analysis and evaluation of the experiment.

The last step of conducting the experiment was on the effectiveness of the cooling system with the BB. The refrigeration equipment set inside the BB should be operated under both mooring and sailing conditions. I had the opportunity to conduct the cooling experiment of the BB under mooring conditions and the data obtained are shown in Annex Table 4 and Fig. 4.

The cooling sea water used in the experiment contained about 15 per cent of salinity by adding salt to sea water so that the lowest temperature of the cooling water should have been -8°C, but the actual lowest temperature of the cooling water obtained was -4°C. There were two reasons for such a difference, i.e., the condenser was kept in the BB under mooring conditions where the speed of the current was 0.2 to 0.5 knots at that time, and the insulation of the cooling tanks and the long pipe on deck were not sufficient to keep the low temperature in the cooling tank.

In other words, if this experiment was conducted under improved conditions and under normal sail speed, the lowest temperature of the cooling water would be around -8°C, and the experiment would have been successful.

7. General considerations and conclusions.

I have explained the experiment and my evaluations at each step and summarize as follows:

1) This experiment was designed and conducted in order to apply this pre-cooling system to Thai fishing vessels of 10 to 40 gross tons.

I strongly recommend the owners of fishing vessels of these sizes to install such a pre-cooling system in addition to the present ice-storage, in order to preserve the freshness of their catch which would fetch a higher price in the fish markets.

The capacity of the refrigeration equipment should be minimum to reduce the installation cost.

Of course, it might be much better to have cooling pipe in all the fish holds and a larger capacity refrigeration equipment on board. The BB method suggested here would be one of the solutions which would enable fishermen to install larger refrigeration equipment inside the BB.

The advantage of the BB method is the easy installation of the refrigeration equipment outside the hull of the existing fishing vessels, and new vessels would not need to be constructed.

2) I had a chance to visit Malaysia recently to observe the cooling system of trawlers of the A, B and C classes. The Malaysian Government classified the trawlers, based on their gross tonnage, in order to demarcate the fishing areas for each class of trawlers.

It was explained to me that about 70 per cent of the trawlers of 7 to 50 gross tons in Malaysia have been equipped with refrigeration sets.

It is interesting to compare the cooling systems of the Thai and Malaysian trawlers. The current cooling system of trawlers in Thailand is solely ice storage without refrigeration equipment on board, and the freshness of the fish kept in ice storage is not sufficient to satisfy the market's requirement, while the cooling system used in Malaysia is the refrigeration system with cooling sea water but without the ice for storage.

I cannot explain well the reason for such a difference between Thai and Malaysian trawlers as I was in Malaysia for only a few days.

In the Malaysian system, if I dare to comment, there are also many problems to be overcome in order to preserve the freshness of fish on board, which I wrote about in my trip report to Malaysia in February 1987. For instance, if the fish were kept in the cooling water for a long time, the flesh would be saturated and its freshness would deteriorate.

I would like to make some suggestions which are applicable to both Thai and Malaysian trawlers for improving their systems for preserving the freshness of fish while on board. Additional energy to cool down the temperature of fish is required, larger refrigeration should be installed on board.

Thai trawlers should be equipped with a refrigeration set for pre-cooling, while Malaysian vessels should have either ice storage thanks on board to store the fish after being cooled, or larger refrigeration machinery equivalent to the ice storage.

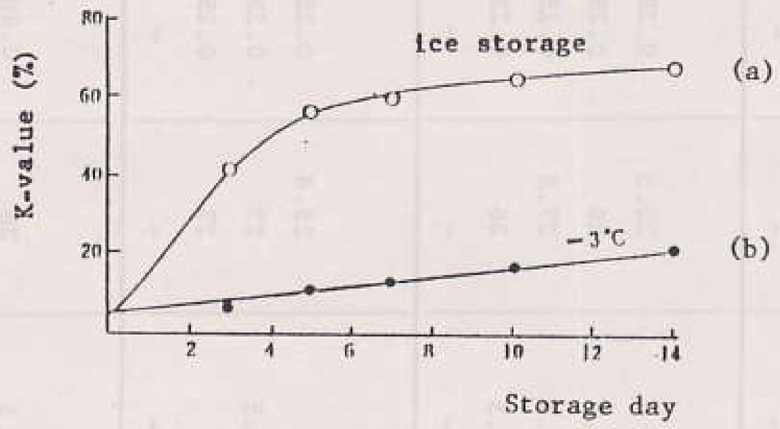


Fig. 1. An experimental data of "SEA BASS" "K-value-storage day" curve (by Dr. H. Uchiyama, 1974)

where,

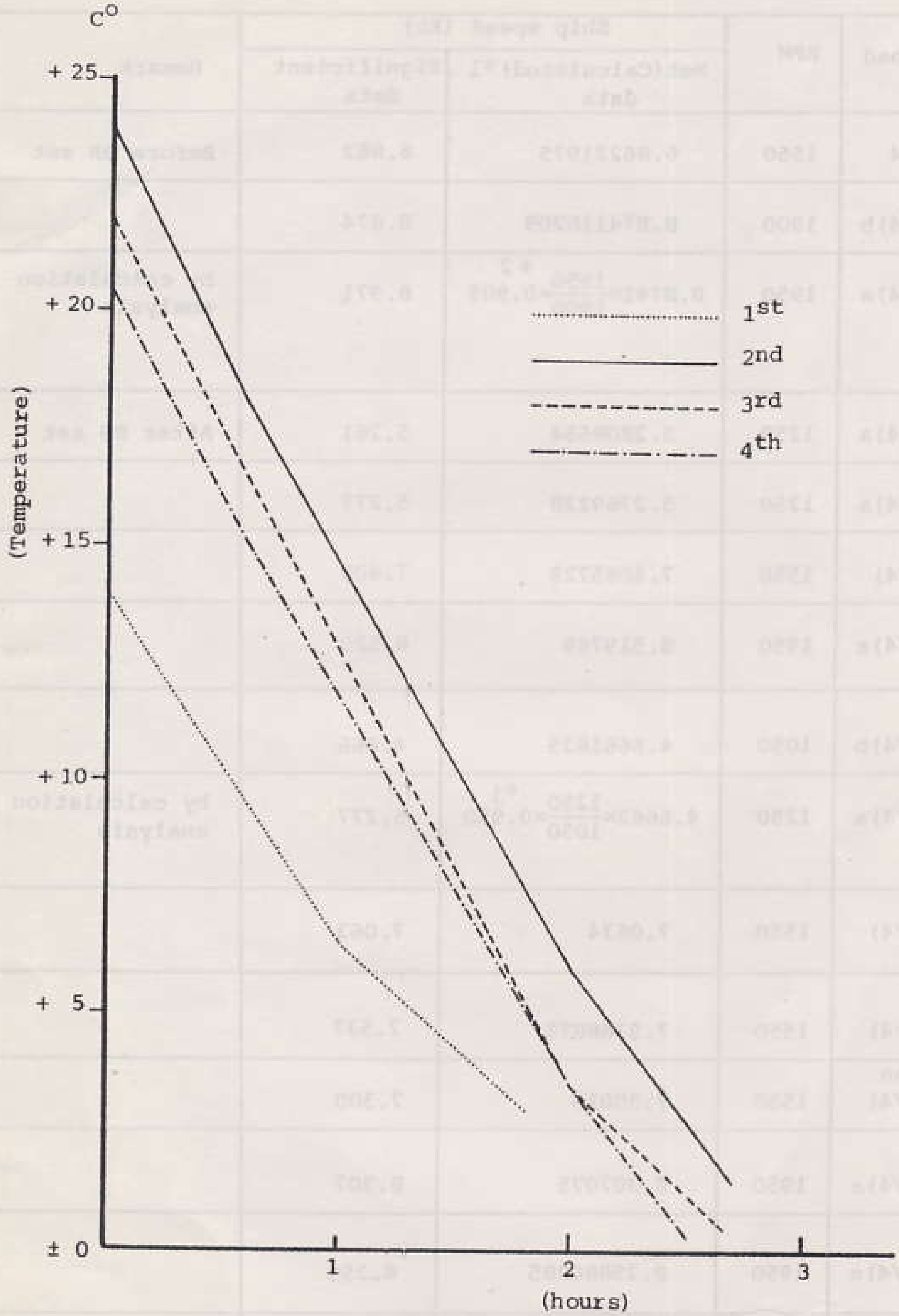
(a) is the case of ice storage only;

(b) is the case of ice storage after pre-cooling with $-3^{o}C$ fresh water.

Table 1 Fundamental experiment on condensor and receiver at outside hull

Date / Time	Cooling water Temp. °C	Amp. of compressor	High pressure kg/cm²	Low pressure kg/cm²	Sea water temp. °C	Air temp. °C	Water current knots	Remarks
25-01-86								1st
08:00	14	40	15	4.2	25.3	22	0.39	
10:00	6.5	35	13.8	3.2	25.3	22	0.28	
10:45*	3.5	-	-	-	-	-	-	
25-01-86								2nd
11:45	24	37	15.7	4.5	26	23.5	0.29	
12:45	14	37	15	4	26.4	26	0.28	
13:45	6	35	14	3	26.4	27.5	0.15	
14:20	1.8	34	14	1.5	26.5	26	0.23	
14:30*	1.5	-	-	-	-	-	-	
28-1-86								3rd
10:45	22	37	18.6	4	25	25.8	0.25	
11:45	12	39	15	4	25.5	27	0.23	
12:45	3.5	37	14.6	3.2	26	27	0.25	
13:25*	0.5	-	-	-	-	-	-	
4-2-86								4th
10:35	20.7	35	13.6	3.7	26.5	28	0.60	
11:35	11.4	34	15.2	4	27	28	0.30	
12:35	3.5	34	14.5	3.4	27.3	27.5	0.36	
13:10*	0.3	-	-	-	-	-	-	

Note: * The compressor was stopped when the over heat device circuit had done



Note: LOAD 1 KL of Sea water

Compressor: 5 HP 220V, 50 HZ.

Fig. 2 Experiment on Chiller Type.

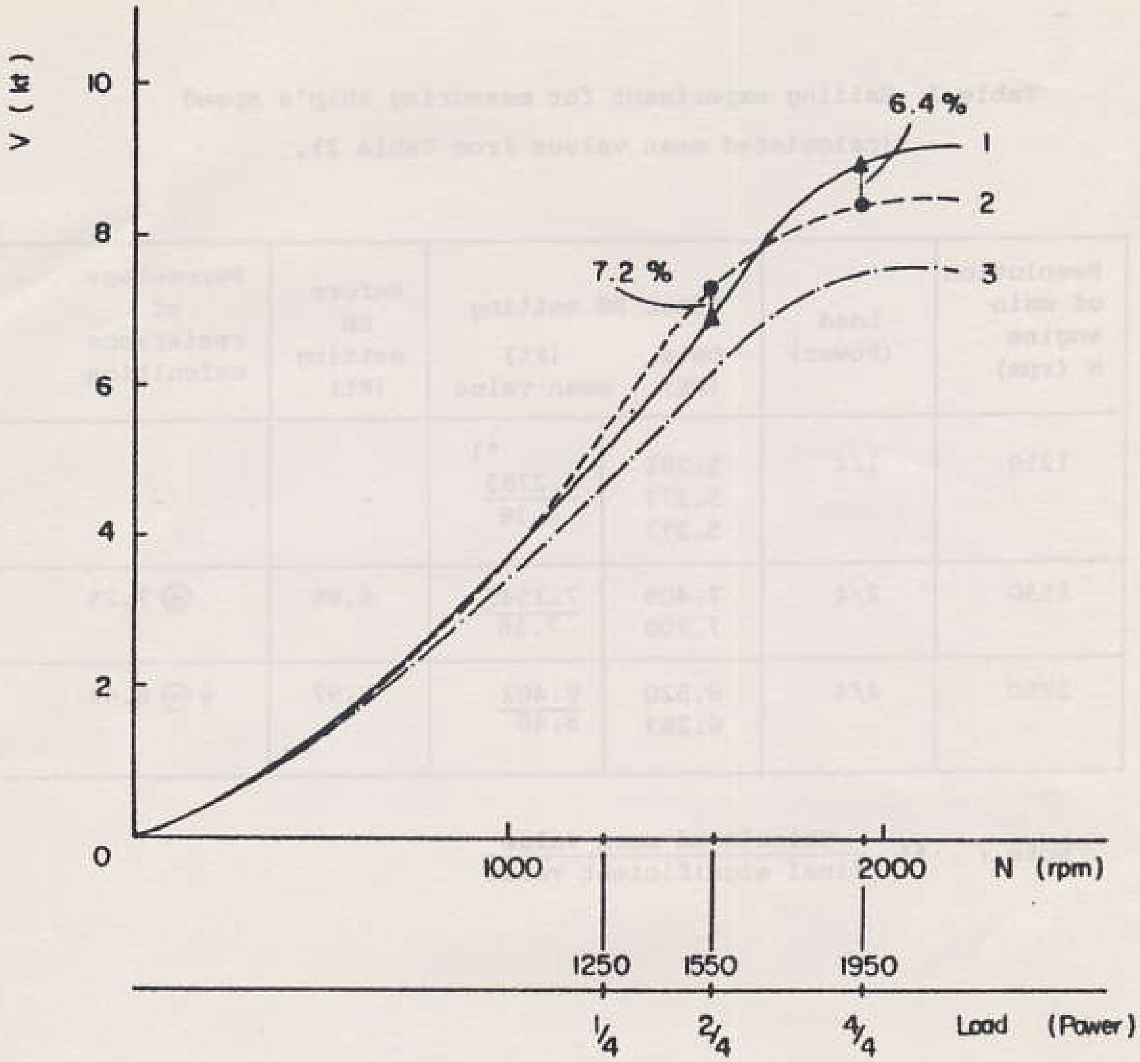
Table 2 Sailing experiment for measuring ship speed.

Date (1986)	Load	RPM	Ship speed (Kt) Net (Calculated) *1 data	Significient data	Remark
20 Sep.	2/4	1550	6.86221975	6.862	Before BB set
"	(4/4)b	1900	8.874116209	8.874	
"	(4/4)a	1950	$8.8741 \times \frac{1950}{1900} \times 0.985$ *2	8.971	by calculation analysis
29 Oct.	(1/4)a	1250	5.2808554	5.281	After BB set
30 Oct.	(1/4)a	1250	5.2769228	5.277	
30 Oct.	(2/4)	1550	7.4085729	7.409	
29 Oct.	(4/4)a	1950	8.519769	8.520	
10 Nov.	PM (1/4)b	1050	4.6661625	4.666	
"	(1/4)a	1250	$4.6662 \times \frac{1250}{1050} \times 0.950$ *3	5.277	by calculation analysis
"	AM (2/4)	1550	7.0634	7.063	
"	PM (2/4)	1550	7.5368875	7.537	
"	mean (2/4)	1550	7.30015	7.300	
"	AM (4/4)a	1950	8.307075	8.307	
"	PM (4/4)a	1950	8.25880285	8.259	
"	mean (4/4)a	1950	8.282939	8.283	

Note: *1 Calculated by "mean of means" method.

*2 Slip down ratio estimation.

*3 Estimated ratio.



Note: 1 Curve before setting the BB;
2 Curve after setting the BB;
3 Curve estimated, with other box; which a compressor is set inside.

Fig. 3. "V-N curves" from Table 3.

Table 3 Sailing experiment for measuring ship's speed (calculated mean values from Table 2).

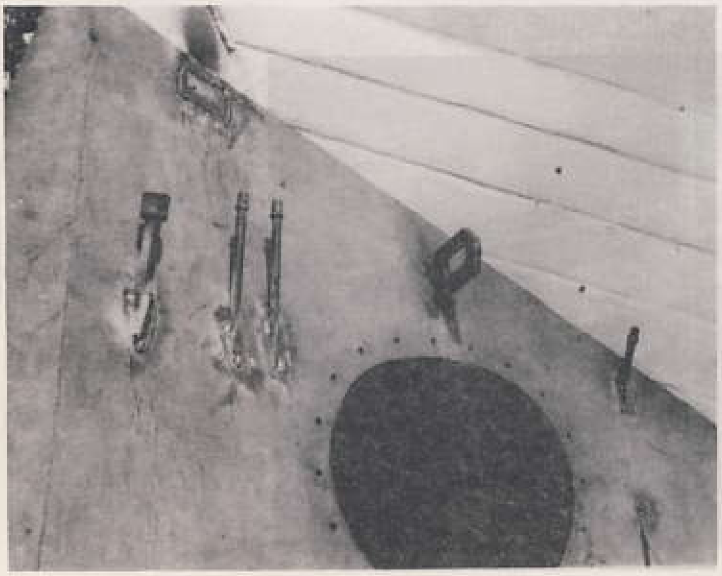
Revolution of main engine N (rpm)	Load (Power)	After BB setting Data (Kt)	(Kt) mean value	Before BB setting (Kt)	Percentage of resistance calcultion
1250	1/4	5.281 5.277 5.277	*1 5.2783 5.28	-	-
1550	2/4	7.409 7.300	7.3545 7.36	6.86	⊕ 7.2%
1950	4/4	8.520 8.283	8.402 8.40	8.97	≑ ⊖ 6.4%

Note : *1 $\frac{\text{Calculated mean value}}{\text{final significient value}}$

(1)

During Installation
of "Bulbous Bow Tank".

(2)
"BB Tank" body
with condenser
coils (one side
two, total four).



(3)

Compressor is inside
of the Tank, and
refrigerant pipes
have already set.

Plate 1

(1)

Before Installation of "BB"

(2)

(3)

After Installation of "B.B"

Plate 2

(1)

Running Test
without
"Bubbous Bow Tank"

(2)

(3)

Plate 3

(1)

Running Test

$\frac{1}{4}$ Load

(2)

$\frac{2}{4}$ Load

(3)

$\frac{4}{4}$ Load

Plate 4

Table 4 Temperature measuring test of Pre-cooling tank on board M.V. PLALUNG.

Time	Brine water temperature (°C)	Room temperature (°C)	Compressor temperature	Compressor ampere	High pressure (kg/cm^2)	Low pressure (Kg/cm^2)
13.15	27	44	79	39	17	4.5
14.15	18	44	86	41	17	4.5
15.15	8	43	82	39	15	3.5
16.15	2	45	92	39	13	2.8
17.15	-0	50	110	39	13	1.4
18.15	-2	58	118	40	11	0.6
19.15	-3	46	93	70	11	0.8
20.15	-4	42	84	72	12	2.0
21.15	-4	42	104	45	10.8	0.8
23.15	-4	44	99	40	12	1.0
24.15	-4	43	98	41	11	1.0

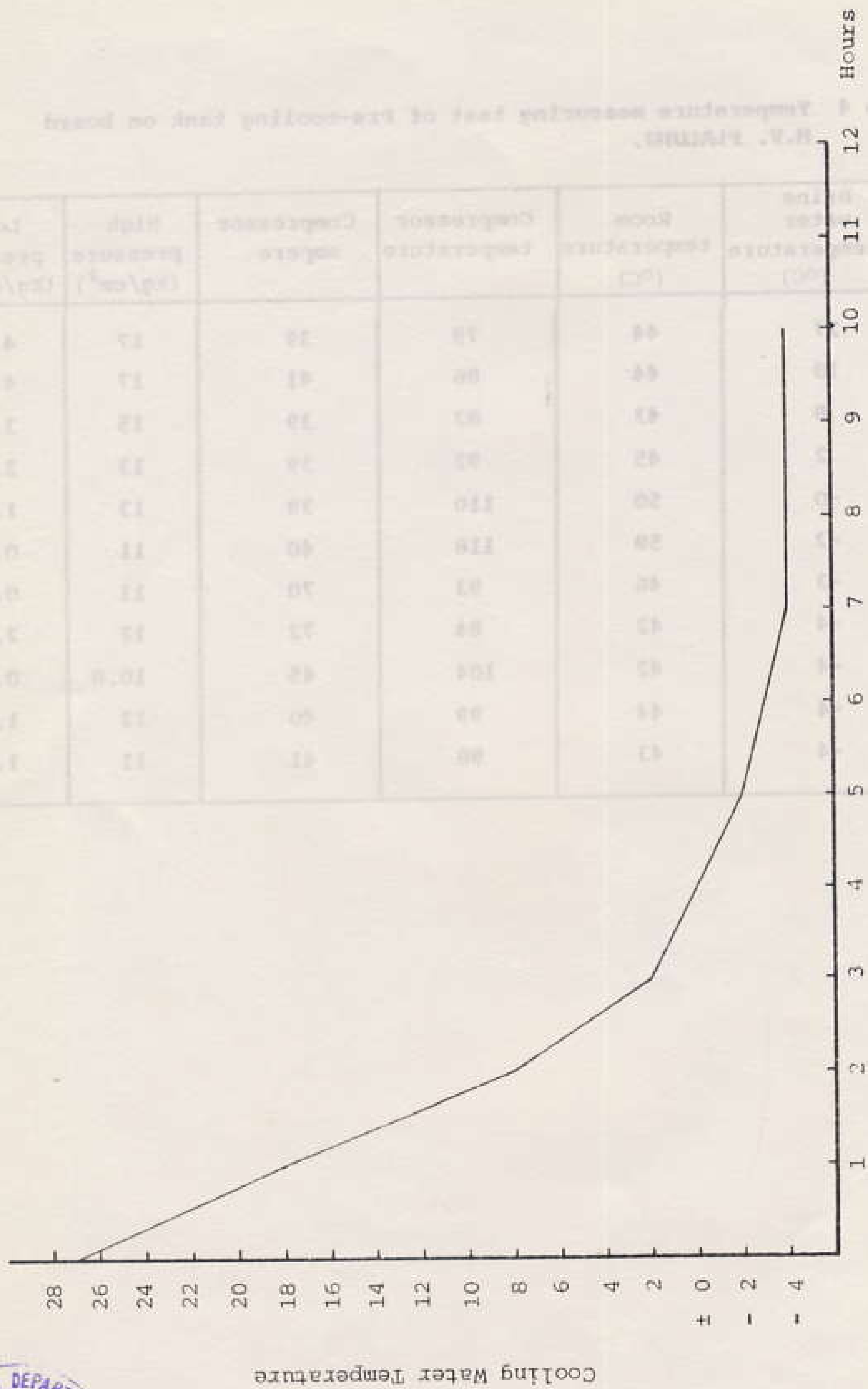


Fig. 4 Cooling Water Temperature at Mooring Condition