MARINE REFRIGERATION SYSTEM

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Abstract - This paper presents a design of marine refrigeration system applying absorption refrigeration that uses kerosene as fuel to supply heat to the generator. The coefficient of performance and the time to achieve certain values of evaporating temperatures are compared for the design of marine refrigeration system with and without waste heat return channel. The highest value of coefficient of performance and a faster rate of cooling are met with the application of waste heat return channel.

Keywords - Absorption Refrigeration, Waste Heat, Kerosene, Marine Refrigeration.

I. INTRODUCTION

Western Philippines is known to be one of the major fishing grounds of the Philippines from where the exportation on fisheries, livelihood, and other economic benefits depend on. There are several studies included in the Southeast Asian Fisheries Development Center (SEAFDEC) Collaborative Research Program which aimed for fishing gear technology, fishing ground survey, post-harvest technology and aquaculture in the said location, some of which are focused on oceanic squid jigging activities for a reason that giant squid can also be caught in the said location for exportation.

Based on Annex D of Philippine National Standard (PNS) for Fresh and frozen cephalopods (PNS BAFS 136:2014), Guidelines on Pre-Cooling/Chilling of Cephalopods, "Direct icing for squid and cuttlefish cannot be considered a suitable method of preservation and maintaining high quality. Although spoilage is retarded, the textural attributes and appearance is adversely affected such as tearing of the skin and bursting of ink sac, which causes extreme discoloration of the mantle and are the manifestations of poor quality". However, some fishermen are still using box with ice as a preservation method for their catch on the boat resulting to some of their catch being rejected for exportation. And in some other places, they are not able to use ice during fishing operations since there is lack of source of ice in their respective locations and some places don't have supply of electricity to make ice.If there is no ice and no electricity, having another way on how to maintain their catch in the required temperature to maintain its freshness is still available, and it is by means of refrigeration. One type of refrigeration system is the absorption refrigeration that doesn't need electricity to run the system.

Absorption refrigeration is known to be a heat-operated cycle because the heat is used to drive off the vapour from the high-pressure liquid [1]. The principal difference in the absorption and vapour compression cycles is the motivating force that circulates the refrigerant through the system and provides the necessary pressure differential between the vaporizing and condensing processes [2].The vapour compressor employed in the vapour-compression cycle is replaced by an absorber and generator in an absorption cycle. The energy input required by the vapour compression cycle is supplied by the mechanical work of the compressor, while the energy input in the absorption cycle is in the form of heat supplied directly to the generator. Commonly, low-pressure steam or hot water is the source of the heat supplied to the generator. But for smaller systems, the heat is usually supplied by the combustion of fuel such as natural gas, propane, or kerosene, directly in the generator.

A basic absorption refrigeration cycle consists of a refrigerant loop and a solution loop [3]. The solution loop consists of an absorber, generator, solution pump and a solution throttle valve. The absorbent with strong absorbability is used to absorb the refrigerant vapour from the evaporator which is in low temperature and low pressure. Then through this process, the absorbent becomes a weak solution and so being pumped to the generator to be heated, and the refrigerant with a lower boiling point is boiled. At this point, the high temperature and high pressure refrigerant vapour is separated from the absorbent going to the condenser. Once the refrigerant is being separated, the absorbent becomes a strong solution again and is sent back to the absorber through the throttle valve.

Coefficient of performance of an absorption cycle is not computed in the same way as a standard vapour compression cycle [4]. The heat energy necessary to drive an absorption cycle is at a much lower availability than the electrical energy necessary to power a work-driven cycle. Since absorption systems are heat driven rather than work driven, their practical

COP values tend to be around 1.0 or less.

The comparison of COPs of absorption refrigeration cycles that are used for refrigeration temperatures below 0°C showed that the highest and the lowest

COP were found as a function of the generator, condenser, absorber, and evaporating temperature [5].

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

The marine refrigeration system(MRS) in this research projectis an absorption refrigeration system that consists of generator, condenser, absorber and evaporator. Figure 1 shows the design of the system. The generator is supplied with heat from a kerosene burner on top of the kerosene tank. The waste heat return channel (WHRC) is designed to redirect the high temperature exhaust gas from the top of the stack of the generator going down to the burner. The coefficient of performance (COP) of the MRS with WHRC is determined and compared to that without WHRC. Different lengths of wick are applied for both designs. The time to achieve the evaporating temperatures required for the maintenance of the catch is also observed.

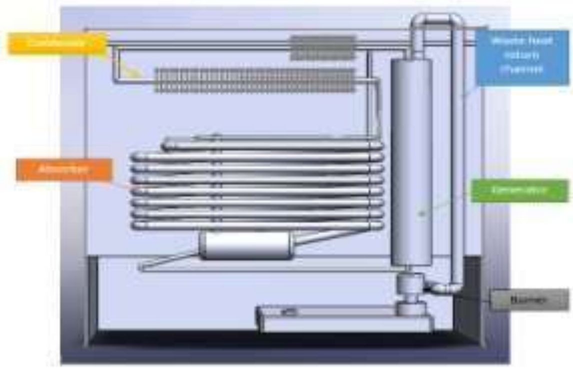

Fig.1. Design of MRS.

III. RESULTS AND DISCUSSION

3.1. Coefficient of Performance

Figure 2 shows the coefficient of performance of MRS at evaporating temperatures ranging from 0°C down to -10°Cfor both designs with WHRC and without WHRC at 0 cm length of wick.

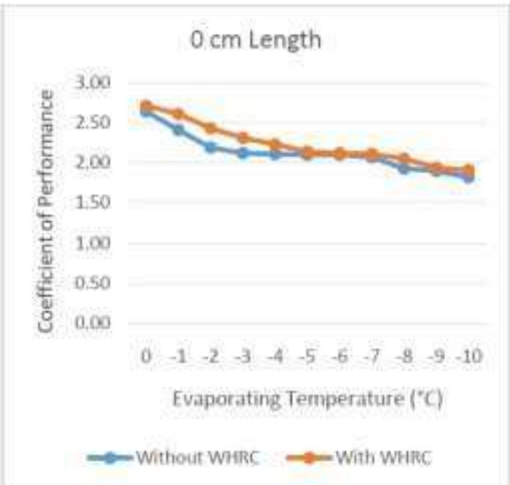

Fig.2. COP at 0 cm length of wick.

At 0°C, the COP of MRS without WHRC is around 2.64, while that with WHRC is 2.71.
As the temperature goes down, the values of COP are also declining. At -5°C, wherein this temperature can be used to maintain the refrigeration box at around 0°C to 4°C as the target temperature for the cephalopods, the COP is 2.10 for that without WHRCand 2.14 for that with WHRC.

At -10°C, where the refrigeration box can be maintained from -5°C to 0°C for fish, the COP for that without WHRC is 1.82 while that with WHRC is
1.91. By observation, the COP of the design withWHRC are higher than that of without WHRC.

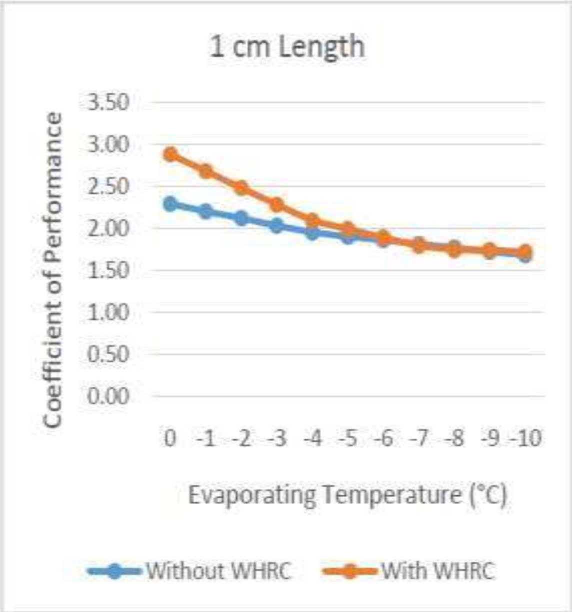

Fig.3. COP at 1 cm length of wick.

For the length of 1 cm, the values of COP are shown in Figure 3. At 0°C, the COPs are 2.29 and 2.88 for the design without WHRC and with WHRC, respectively. At -5°C, the COP for that without WHRC is 1.90 and for that with WHRC is 1.99. At -10°C, 1.68 is the COP for that without WHRC and
1.72 for that with WHRC. As the evaporating temperature goes down from 0°C to -5°C, the values of COP are also declining.

But from -6°C down to -10°C, the values of COP are still decreasing but with a little value. It is mostly maintained from 1.68 to 1.86 for that without WHRC and from 1.72 to 1.89 for that with WHRC. By observation, the COP of the MRS with WHRC is still higher than that without WHRC at 1 cm length of wick.

The COPs at 2 cm length of wick can be observed in Figure 4. At 0°C, the COP for the MRS without WHRC is 2.68, while that with WHRC is 2.77. At

-5°C, the COPs are 1.99 and 2.23 for the design without WHRC and with WHRC, respectively.

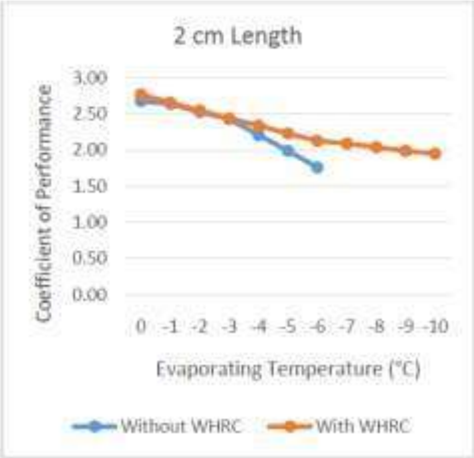

Fig.4. COP at 2 cm length of wick.

By observation, the COP of MRS without WHRC declined to 1.76 at -6°C and no more values available at evaporating temperatures lower than -6°C. This is due to the accumulation of carbon residue, see Figure 4, in the burner and at the stack just above the burner that causes either the fire to cease or redirecting the fire out of the generator which prevents the continuous supply of heat to the generator.

As a result, the evaporating temperature goes high and high until the heat is supplied again to the generator after cleaning the burner and the stack. As the experiment continues with 2 cm length without WHRC, the lowest evaporating temperature reached is -6°C before the carbon residue builds again in and out of the burner.

Fig.4. Carbon Residue.

As a result, the evaporating temperature goes high and high until the heat is supplied again to the generator after cleaning the burner and the stack. As the experiment continues with 2 cm length without WHRC, the lowest evaporating temperature reached is -6°C before the carbon residue builds again in and out of the burner.

On the other hand, MRS with WHRC reached -10°C with no accumulation of large carbon residue, and the COP is 1.95.

In the case of 3 cm length of wick, the design without WHRC cannot achieve 0°C due to faster accumulation of carbon residue. Only the design of MRS with WHRC was able to achieve the target temperatures from 0°C down to -10°C, see Figure 5.

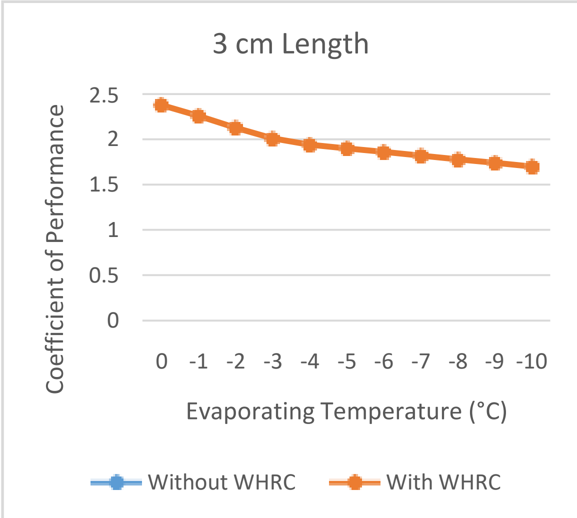

Fig.5. COP at 3 cm length of wick.

At 0°C, the COP of MRS with WHRC is 2.38. At -5°C, the COP is 1.90. At -10°C, the COP is 1.70.

For 4 cm length of wick, both designs, either with or without WHRC, cannot achieve 0°C due to the accumulation of carbon residue.

Comparison of values of COP per length of wick for MRS without WHRC is shown in Figure 6. The values of COP at 0 cm length is higher than that of 1 cm length. The COP at 2 cm is higher than 0 cm and 1 cm from 0°C down to -4°C but is not able to reach evaporating temperatures lower than -6°C.

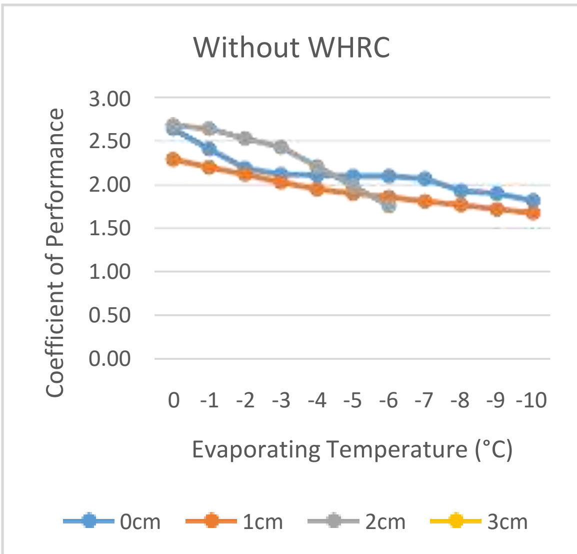

Fig.6. COP at different lengths of wick for MRC without WHRC.

The COPs per length of wick for MRS with WHRC is shown in Figure 7. The highest COP at 0°C and -1°C is reached at 1 cm length. From -2°C down to -5°C is reached at 2 cm length. The COP at 0 cm and 2 cm length are almost the same from -6°C down to -10°C ranging from 1.91 to 2.13. From -5°C to 0°C, the highest COP is reached at 2 cm length.

3.2. Time

Time to achieve evaporating temperatures from 0°C down to -10°C from the initial temperature of 24°C is determined for each length of wick for both MRS with or without WHRC.

Figure 8 shows the time to achieve up to -10°C for the system without WHRC. At 0 cm length, 0°C is achieved between 4 to 5 hours of continuous supply of heat in the generator. -5°C is achieved between 6 to 7 hours, and -10°C is achieved after 11 hours.

For 1 cm length, 0°C is met between 3 to 4 hours of continuous burning. -5°C is met between 5 to 6 hours, and -10°C is met between 7 to 8 hours.

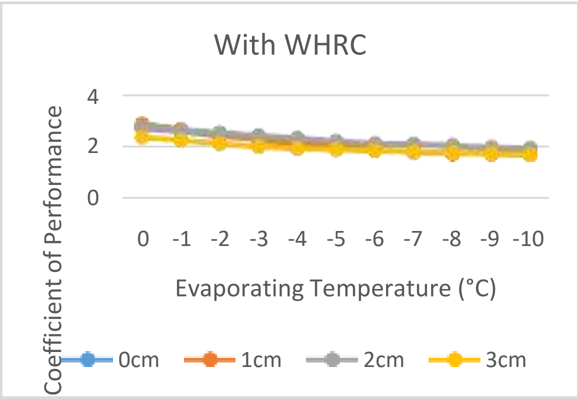

Fig.7. COP at different lengths of wick for MRC with WHRC.

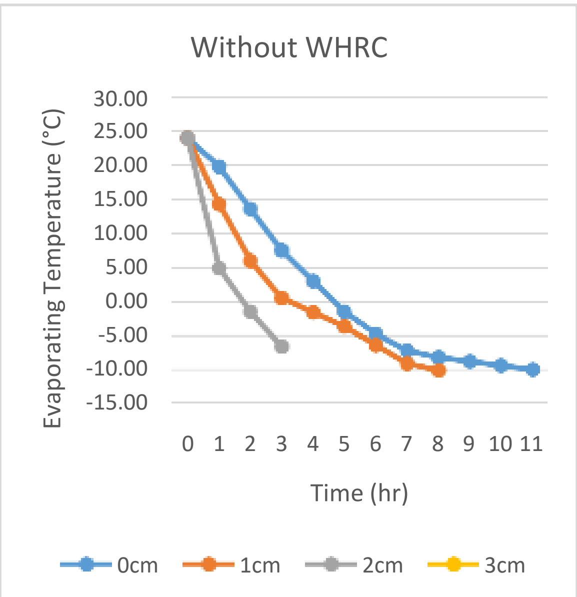

Fig.8. Time to achieve -10°C for each length of wick for MRS without WHRC.

0°C at 2 cm length is achieved between 1 to 2 hours. This is the fastest time to achieve 0°C compared to 0 cm and 1 cm length. Also, -5°C is achieved between 2 to 3 hours being the fastest time to reach this evaporating temperature compared to that of 0 cm and 1 cm length. But -10°C is not reached for 2 cm length.

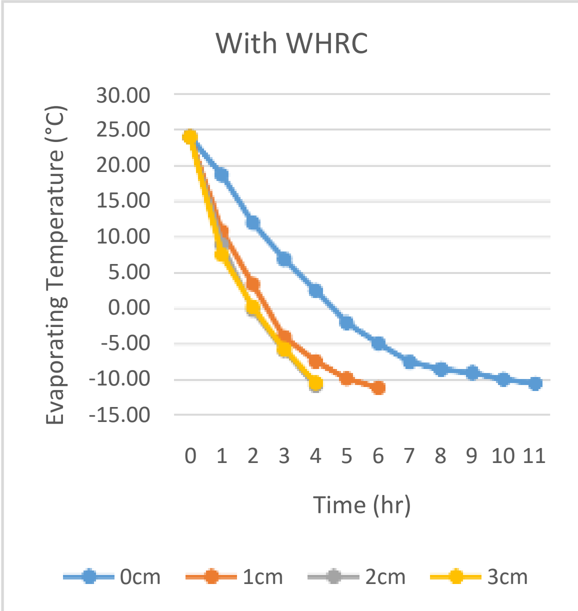

Fig.9. Time to achieve -10°C for each length of wick for MRS with WHRC.

Time to achieve evaporating temperatures up to-10°C for the system with WHRC is shown in Figure 9. For 0 cm length, 0°C is reached between 4 to 5 hours of continuous burning of kerosene on the generator. -5°C evaporating temperature is achieved between 6 to 7 hours, and -10°C is met between 10 to 11 hours. It is almost the same rate with the MRS without WHRC at 0 cm length of wick.

For 1 cm length, 0°C is reached between 2 to 3 hours, -5°C is achieved between 3 to 4 hours, and -10°C is met between 5 to 6 hours. This shows a faster rate than that of without WHRC.

For 2 cm length of wick, 0°C is met between 1 to 2 hours, -5°C is achieved between 2 to 3 hours, and -10°C is reached between 3 to 4 hours.

For 3 cm length, 0°C and -5°C is achieved between 2 to 3 hours, and -10°C is achieved between 3 to 4 hours which is comparable with the rate of cooling at 2 cm length.

IV. CONCLUSION

The performance of the MRS with and without WHRC were presented in this paper. It is evident that the COPs at different lengths of wick for MRS with WHRC are higher than that of without WHRC. The time to achieve the target evaporating temperatures are comparable for both designs. At some point, the MRS with WHRC has a faster rate of cooling than that of without WHRC. It is also shown that it is hard to continue burning kerosene without WHRC due to the accumulation of carbon residue in and out of the burner. Therefore, it is recommended to use the design of MRS with WHRC for continuous operation of the refrigeration system.

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