# Waste Heat Recovery Of Ship Engine: A review

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***Abstract*—This work presents absorption refrigeration cycles with water-Li-Br and ammonia-water working pairs for purpose of application on a ship. Absorption refrigeration systems were execute by using exhaust gases, jacket water, and scavenge air as energy sources. By using different waste heat sources different refrigerant temperatures were found and for the absorption cycle itself. In two different climate conditions the process data of exhaust gases and cooling water flows. A theoretical potential of saving of 70% of the electricity used in accommodation (AC use) compressor in ISO conditions and 61% in tropical conditions was recognized. Those estimates enable between 47 and 95 tons of annual fuel savings, respectively. Moreover, jacket water heat recovery with a water-Li-Br system has the potential to provide 2.2–4.0 times more cooling power than required during sea-time operations in ISO conditions, depending on the main engine load.**

***Index Terms*—Absorption, Waste Heat, Fuel Consumption, Thermodynamic.**

## I. Introduction

Marin time transport is a huge energy-consuming sector globally. Typically on board energy is produced using diesel engine combustion. This power is used for propulsion and to generate electricity that is needed on board. However, environmental and economic concerns have caused the maritime sector to explore alternative solutions in order to improve the efficiency of the energy usage system and to reduce their emissions and waste heat. The focus was to provide a better understanding of the options available for waste heat recovery in order to improve fuel economy and environmental compliance. At present, some effort has been devoted to the utilization of the vast amount of waste energy from diesel engines used aboard ships for refrigeration.

There are several types of refrigeration technology being used for marine applications, including compression refrigeration, absorption refrigeration, and injection refrigeration. Typically refrigeration is produced using vapour compression, which consumes considerably more electricity compared to an absorption refrigeration system. This electricity is produced at a rather low efficiency using diesel engine combustion.

An absorption refrigeration system is driven by thermal energy and needs little electricity, and it can utilize the waste heat of the engine and improve the energy conversion efficiency. Therefore, fuel can be saved considerably. The chilling process is necessary for different requirements in maritime transport. For example the AC, ice-making, and medical or food preservation all need refrigeration.

It presents an experimental study of a Lithium-Bromide absorption refrigeration system using the exhaust gas of an internal combustion engine as an energy source. Heat was recovered by an economizer in a flue gas flow, using a circulating hot water cycle. Hot water was used as a heat source for the generator after which it is used for hot water production to meet shipboard hot water demands. Both the condenser and the absorber were cooled with sea water. [1]

## II. Vapour Absorption Refrigeration System :-

**Fundamentals: -** The absorption refrigeration system is based on the physical phenomenon of the different boiling points of pure fluids and for a mixture of compounds. The difference in the equilibrium temperatures is used for the pumping effect in absorption refrigeration. When heat is conducted to a vacuum tank containing pure water, the water starts to evaporate. At the same time the solution tank (of water-Li-Br for example) is cooled below its boiling point.

Now the partial pressure of the solution vapour is lower than the pressure of the vapour in the pure water content tank. When these two tanks are combined with a pipe above the liquids, the water vapour flows into the solution using the partial pressure difference as kinetic energy. This pressure difference is the basis of absorption refrigerators and heat pumps. Lithium Bromide (Li Br) salt is hygroscopic and has the property to absorb water due to its chemical affinity. It is soluble in water. As the concentration of Li-Br increases, its affinity towards water also increases and vice versa. [2]

## III. Depending upon the source of heat, Vapour Absorption System may be of two types:-

1. **Direct Fired Vapour Absorption System** in which heat is supplied by combustion of fuel in a combustion chamber.
2. **Steam Fired Vapour Absorption System** in which heat is supplied by steam obtained from an external source.

**IV. Components of Vapour Absorption System:-** It has four basic components

1. **Evaporator** in which water boils and flash cools itself when maintained at high vacuum.
2. **Absorber** in which vaporised refrigerant (water) is absorbed by concentrated Li-Br solution which has great affinity for water.
3. **Generator** in which the Li-Br solution which has become dilute and has lost its capacity to absorb water vapour is reconcentrated using an external heat source.
4. **Condenser** in which the vapour released from the Li Br solution is condensed to form liquid refrigerant.[2]

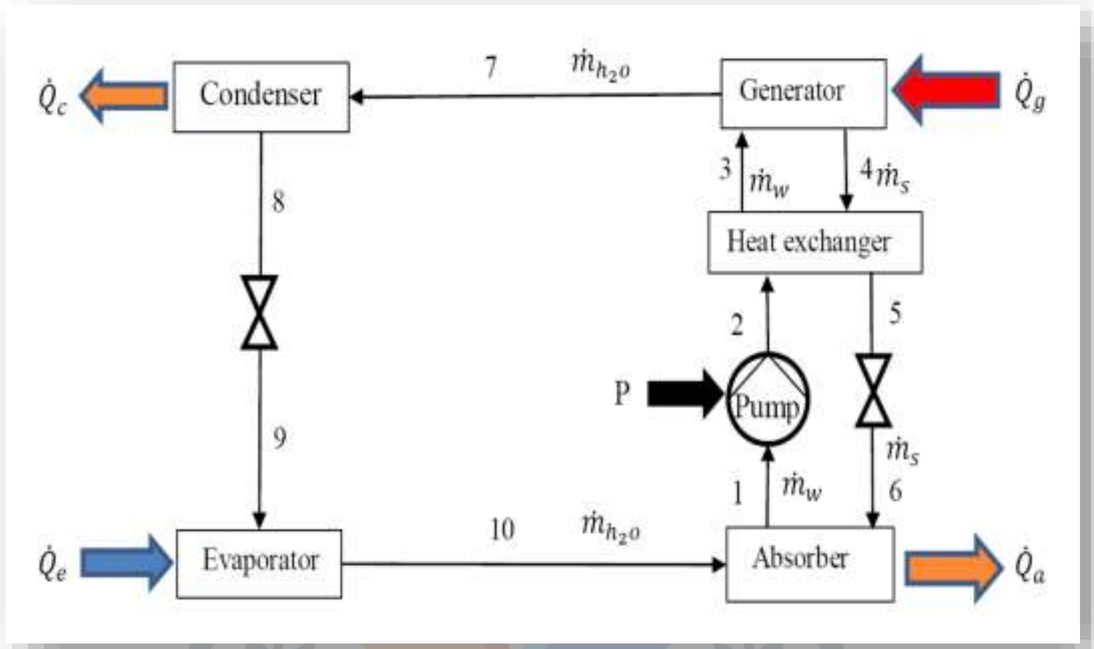



**Fig.1 A schematic of a single effect water Li-Br absorption refrigeration cycle.**

**V. Working Of Vapour Absorption System On Ship**

Figure shows the schematic diagram of the waste heat powered cooling system. The waste heat powered ABC cooling system has the same chilled water loop, air loop and control strategy design as the baseline cooling system. Instead of the vapour compression chiller, the H2O/Li-Br ABC is applied. The evaporator in the absorption cycle cools down the returned chilled water to the set temperature.

The condenser and absorber are cooled by parallel sea water flows. The absorption cycle is hot water powered, which means the hot water flowed through the generator and transfers heat to H2O/Li-Br solution. The hot water is obtained by pumping fresh water through the exhaust gas heat exchanger and absorbed heat from exhaust gas. The outlet hot water from the generator is used to meet shipboard hot water demands (residential, kitchen and clinic), then pumped back to the exhaust gas heat exchanger, to be heated up again.

A water to water HX is designed to provide hot water demands. One side is recirculated hot water from outlet of the generator in the absorption cycle. The other side is demanded hot water from residential, kitchen and clinic. The sanitary demands were simulated with standard TRNSYS type 1234a. This component treats water usage with a daily schedule.[3]

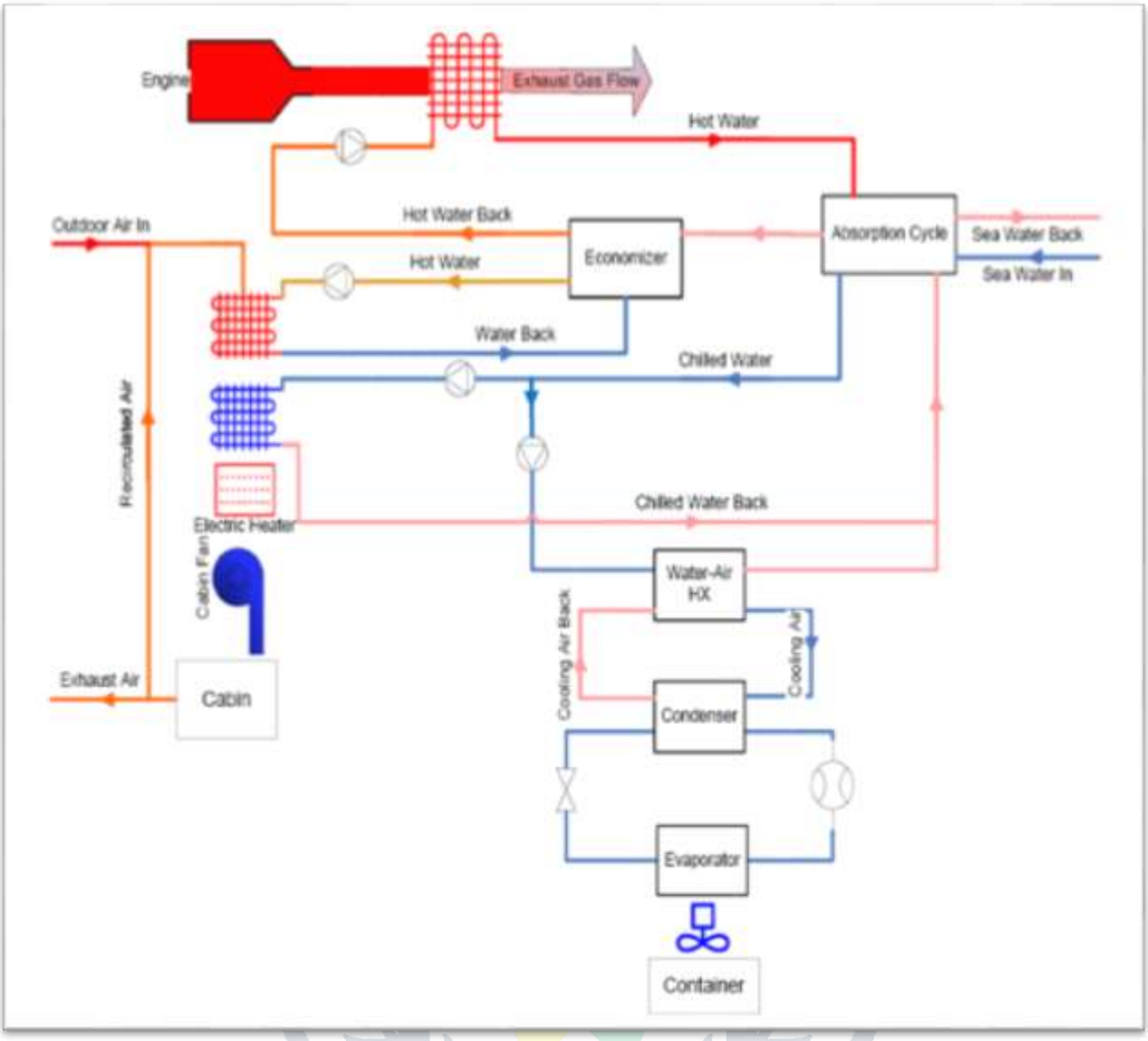
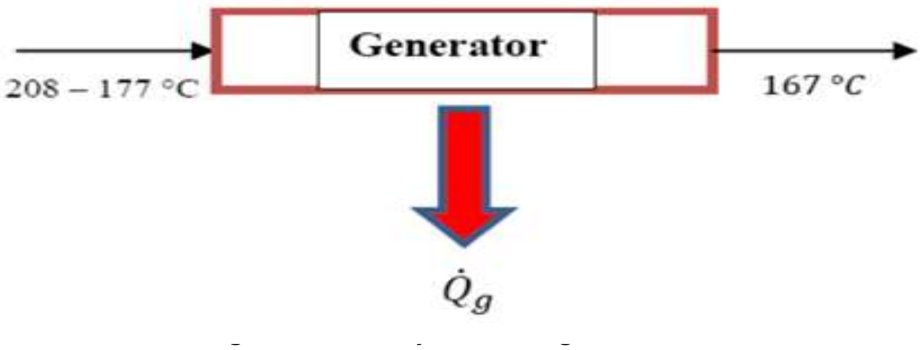



**Fig. 2. Schematic of the waste heat powered system**

**VI. Heat recovery from exhaust gases :-**

The temperature of the exhaust gases and mass flows varies during different engine operation conditions. This HT waste heat can be used as the input power for absorption refrigeration. The limitation in use is that the exhaust gases cannot be cooled under the temperature of 167°C.

A schematic view of the process is demonstrated in Figure 2. The generator is placed in the flue gas flow and it is assumed that the temperature inside the generator does not heat up over the optimal temperature.[1]



## VII. Heat recovery from jacket water :-

Main engine jacket cooling water is relatively HT (85°C) water and, therefore, it could be used as an energy source for the absorption refrigeration. The generator could be placed before the HT water cooler, as presented in Figure 12 where a schematic view of the generator heating and main engine cooling process by jacket water are shown. An HT water cooler is used as an auxiliary cooler when the generator cannot use all the available energy to cool the water cycle for the ME operating conditions. To simplify the case, the energy consumption of the fresh water generator is not taken into account.

The operating temperatures of the HT water cycle are 85°C and 70°C (the return and supply water of the ME). In this case the generator temperature was set to 65°C to ensure a 5°C temperature difference in the heat exchanger. Lower generator temperatures do not improve the system performance and much higher temperatures cannot be reached.[1]

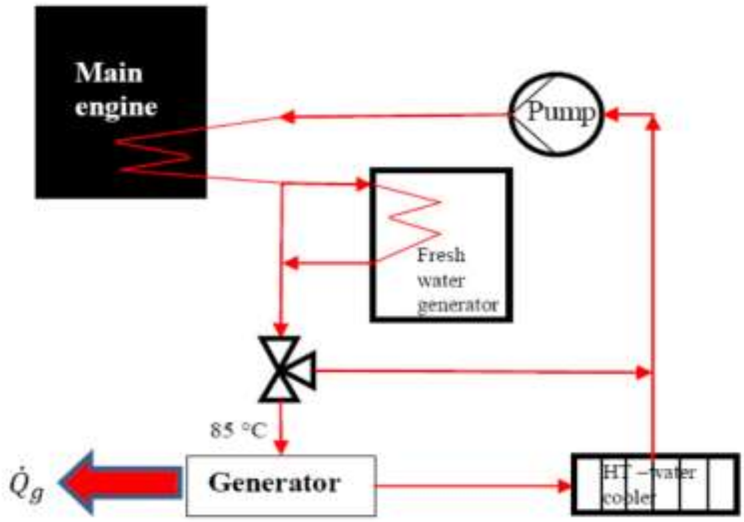



**Fig.4 Heat recovery in jacket water.**

## VIII. Benefits of Waste Heat Recovery :-

- **Direct Benefits:** Waste heat recovery has a direct effect on the efficiency of the process. This reflected by reduction in the utility consumption & costs, and process cost.

- **Indirect Benefits:**

  a) **Reduction in pollution**:A number of toxic combustible wastes such as carbon monoxide gas, sour gas, carbon black off gases, oil sludge, Acrylonitrile and other plastic chemicals etc, releasing to atmosphere if/when burnt in the incinerators serves dual purpose i.e. recovers heat and reduces the environmental pollution levels.

  b) **Reduction in equipment sizes**:Recovery of waste heat reduces the fuel consumption, which helps to reduction in the flue gas produced. This results in reduction in equipment size of flue gas handling equipment such as fans, stacks, ducts, burners, etc.

  c) **Reduction in energy consumption**: Additional benefits by Reduction in equipment sizes gives reduction in energy consumption like electricity for fans, pumps etc.

## IX. Conclusion :-

State-of-art literature study fundamentals of absorption refrigeration, presentation of thermodynamic of water-lithium-bromide working is made in order to study the energy production possibilities from waste heat recovery for cooling power production in bulk carrier ship. The water-lithium-bromide working pair using exhaust gases or jacket water as energy sources is the best absorption chiller solution in ISO conditions for energy saving purpose on ships. Ammonia-water working fluid is more suitable for below freezing point cooling requirements. Both solutions offer more cooling power then is required (while the ME is on) in the case ship, but the water –lithium-bromide working pair is more efficient. This means that 70% of the cooling energy required can be produce by absorption refrigeration. Moreover, this percentage value could be higher if the exhaust gases of auxiliary engines could be utilized when the ME is not being operated. This option was not studied

This study shows that there is a possibility to save 70% of compression electricity by using an absorption refrigeration solution in exhaust gases or in jacket water in ISO condition if all of the technical difficulties can be overcome it means that approximately 46.8 tons of fuel could be saved every year. Cooling possibilities we are also studied in tropical conditions. The water-lithium-bromide absorption refrigeration system in exhaust gases seems to be the best solution for air conditioning cooling purpose in tropical condition. It has the potential to cover 61% of the cooling energy of needs in the case of ship. In tropical condition that means approximately 95.0 tons of fuel saving every year.

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