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DESIGN AND FABRICATION OF DISTILLATION EQUIPMENT OF FRESH WATER FROM THE SEAWATER BY THE USE OF THE WASTE HEAT FROM DIESEL ENGINES

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ABSTRACT

Although freshwater distilled from poor seawater, the amount of impurities is very small, does not meet the needs of the human body but is very good for machinery (such as cooling for machinery , equipment used for boilers), it is less corrosive or deposits on the cooling surface. Distilled water is often used for crew activities (bathing, washing, ...). In order to ensure the health for crew members, in addition to fresh water systems, on board the ship is also equipped with drinking water systems (drinking water) to provide drinking water and cooking. If this amount of fresh water must be purchased from the port, it will be costly for the ship owner and especially not to be able to take advantage of the fresh water on the vessel when operating a long route or buying fresh water of poor quality. In order to overcome this problem, on the large vessels, the international route owners have all equipped fresh water distillation equipment to take advantage of waste heat from the main diesel engine. Fresh water is created according to the principle of evaporation and condensation of seawater at temperature and pressure. The capacity of freshwater distillation equipment is installed depending on the tonnage of the vessel and the number of crew members working on board or in other words the demand for fresh water on board. The paper presents a method for designing and manufacturing a freshwater distillation device for use on small vessels.

KEYWORDS

distillation, seawater, freshwater, design, and fabrication.

1. INTRODUCTION

Currently, sea and river transport is developing strongly, transporting goods by ships and river vessels have been contributing mainly to the transport of goods in the country and countries around the world. Diesel engines are the heart of a ship, a diesel propeller, and a rotary motion for the propeller [1]. During the working of diesel engines, the fuel burned in the combustion chamber forms a combustion gas with high temperature and pressure, expansion and mechanical work acting on the top of the piston, making the piston moves downward, the reciprocating motion of the piston is transformed into the rotation of the crankshaft thanks to the driving of the engine boundary arm, the crankshaft transmits the rotary motion for the propeller via clutch, gearbox [2,3]. The thermal energy generated during the combustion of the fuel is not completely turned into mechanical success but is partially lost due to losses such as the discharge of gas, heating the cylinder profile, cylinder cap, piston top and warm up the engine [4,5]. If the engine is not cooled at the right temperature, the engine parts will be destroyed by thermal stress [6,7]. To maintain the temperature of the engine parts at the right temperature one must cool the engine in fresh water, fresh water will receive heat from the details of the engine will heat up and be led out, this fresh water will be cooled by seawater to the right temperature and then returned to cooling the machine according to the next cycle [8,9].

To maintain the temperature of the engine parts at the right temperature one must cool the engine in fresh water, fresh water will receive heat from the details of the engine will heat up and be led out [10,11]. This fresh water will be cooled by seawater to the right temperature and then returned to cooling the machine according to the next cycle. Exhaust gas brings out a huge amount of heat, so to take advantage of this heat, people have made a freshwater distillation machine [12]. Use fresh water after cooling the diesel engine with high temperature to boil and evaporate seawater under low-pressure conditions, then use cooling seawater to condense the steam at the condenser into fresh water and brought fresh water to use [13,14]. People take advantage of the exhaust heat of diesel engine to boil the boiler, then take the steam from the boiler to produce high temperature and pressure to lead into the freshwater distiller, the steam with high temperature will do the task of boiling and evaporating seawater at the evaporation bulb is condensed into water at the condenser and fresh water is taken out for use [15,16].

The desalination of seawater to produce fresh water has become a reliable solution for the supply of water in the world and marine industry [17,18]. Based on the successful-practised results during many decades, the technical-economical feasibility may be considered as an obvious fact. However, the common processes aiming to distillate the seawater such as ED (electrodialysis), EDR (electrodialysis reversal), MED (multi-effect distillation), MSF (multi-stage flash), RO (reverse osmosis) have been known from the evaluation of expensive techniques that have been indicated to require the large amount of energy to produce and supply the fresh water [19]. The cost was thought to reduce to 0.50-0.80 $/m^3$ for the desalinated water and it might be even decreased to 0.20-0.35 $/m^3$ for brackish water [20]. These cost may be further decreased after applying some new methods to improve the process technologies, especially when alternative energy sources are applied [21]. Commonly, the technologies based on the automation and control process are very useful in the design. However, high-cost plants should avoid by keeping the process parameters within the specifications [22]. The desalinated water has always been of excellent quality, practically regardless of the influent quality. Moreover, the results on the analyses for the permeate process have also shown that potable water was able to be produced without the remineralisation [23]. Nonetheless, some problems like the silt density index (SDI) of the influent is too high, which may cause membrane fouling in RO; corrosion is another recurrent problem, mainly in MSF are thought to occur [24]. This advance should allow producing fresh water at a low cost and a minimal effect on the environment, thus the water production with a large scale is feasible and that regional economic development is not hindered by water scarcity. Therefore, it is worth mentioning that the distillation of fresh water should be low cost and low energy consumption resulting in the consideration of the use of waste heat from diesel engine for the distillation from seawater [25-29]. This paper points out the method for design and fabrication of a equipment for distilling the water.

2. FRESH WATER DISTILLATION EQUIPMENT OF SOME MANUFACTURERS

Currently there are a number of manufacturers in the world that have researched and manufactured freshwater distillation equipment from seawater in low pressure environment to apply on sea-going ships, most notably The product is produced by Atlas and Alfalaval. The following will give an overview of the structural principles and working principles of freshwater distillation equipment of the two manufacturers just mentioned.

a. Fresh water distillation equipment of Atlas

Atlas is a Danish producer of freshwater distilleries specialized in the production of freshwater distillers installed on board ships. Atlas' fresh water distillers can produce freshwater output from 1.5 m3/24h to 1,000 m3/24h. Atlas freshwater distillation equipment includes: evaporation bulb; condenser gourd; moisture filter parts; piping systems, valves and pumps to bring water in and out of the equipment; ejector pump for creating vacuum in the device and other control, adjustment, protection and alarm devices. The condenser and evaporation bulb of the device are made from copper alloy tubes. Figure 1 shows the diagram of installation of Atlas' fresh water distillers in the main engine engine freshwater cooling system.

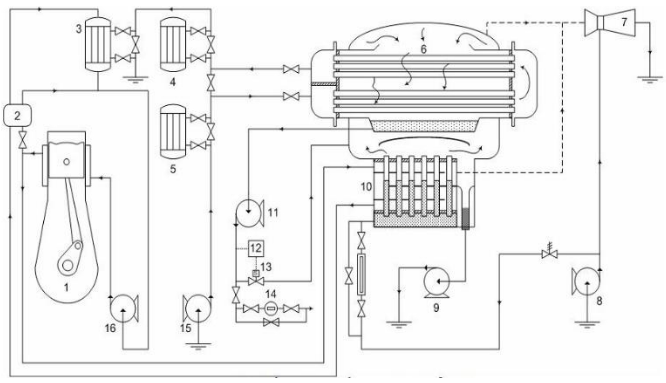

Figure 1: Principle diagram of Atlas fresh water distillation equipment

Table 1: The name of equipments

Parts	Name of equipment	Parts	Name of equipment
1	Main engine M.E	2	Temperature regulating valve
3	Fresh- water cooler for M.E	4	Lubricating oil cooler for M.E
5	Charging air for M.E	6	Condenser
7	Ejector pump	8	Sea water pump
9	Condensed salt pump	10	Evaporator
11	Condensed fresh-water pump	12	Salt concentration sensor
13	Electromagnetic valve	14	Flowmeter
15	Sea water pump	16	Fresh water circulation pump for M.E

Fresh water cooling the main engine after exiting the main machine is pumped into evaporation bulb (10). Here, fresh water will go outside the heat pipe to the sea water inside the tube. The water receives heat, boils and evaporates into the condenser (6). At the condenser, the steam that encapsulates the outside of the tube releases heat to the sea water inside the tube so it cools and condenses into fresh water. Condensed fresh water is pumped (11) pumped into storage tanks. The salt concentration sensor in the condensate (12) will send the solenoid valve open (13) to return condensate back to the evaporation if the salt concentration in the water is higher than the allowed value. Conversely, if the concentration of salt in the condensate is within the permitted limit, the sensor (12) sends a signal to close the solenoid valve (13) to return water to the fresh water tank on the ship. The seawater will be pumped (15) into the condenser (6), cooling the steam then continue to be evaporated (10) to evaporate. This design makes use of the heat that seawater receives from steam at the condenser (6), increasing the efficiency of the device. The Ejector pump (7) is responsible for creating vacuum for the device. The substance used for pumping is sea water due to pumping sea water (8). The pump (8), besides the task of supplying sea water for pumping (7), is also responsible for supplying sea water to the evaporation bulb (10) to evaporate into fresh water.

b. Fresh water distillation equipment of Alfalaval

Atlas is a Danish producer of freshwater distilleries specialized in the production of freshwater distillers installed on board ships. Atlas' fresh water distillers can produce freshwater output from 1.5 m3/24h to 1,000 m3/24h. Atlas freshwater distillation equipment includes: evaporation bulb; condenser gourd; moisture filter parts; piping systems, valves and pumps to bring water in and out of the equipment; ejector pump for creating vacuum in the device and other control, adjustment, protection and alarm devices. The condenser and evaporation bulb of the device are made from copper alloy tubes. Figure 1 shows the diagram of installation of Atlas' fresh water distillers in the main engine engine freshwater cooling system.

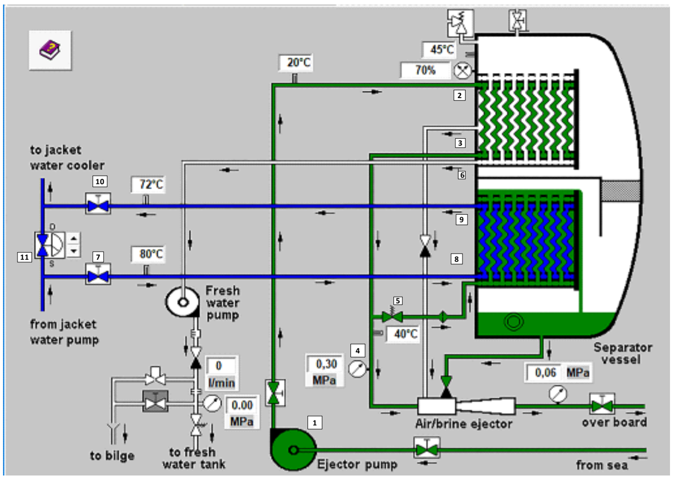

Figure 2: Principle diagram of Alfalaval fresh water distillation equipment

Fresh water after cooling the high temperature main machine is pumped and pushed along the lines (7), to (8) into the evaporation bulb after giving heat to the sea to make the sea boil and evaporate, fresh water goes away Follow the path (9) to (10), then produce fresh water. Temperature regulator (11) is responsible for regulating fresh water temperature after exchanging heat for seawater and out of evaporation. High-pumped (1) seawater is led to a condenser in line (2) into the condenser, at the condenser of seawater receiving heat from the steam to condense water then a part of sea water is extracted into the poll evaporate here where seawater receives heat from high temperature freshwater (after cooling the main machine) to exit. boiling water and evaporate at evaporation bulb, then vapor to evaporate and condense into water is pumped out of fresh water by the road (6). Air/brine pump is responsible for sucking out saline water and creating vacuum at evaporation.

3. DESIGN AND FABRICATION FOR FRESH WATER DISTILLATION MACHINE

a. Condenser

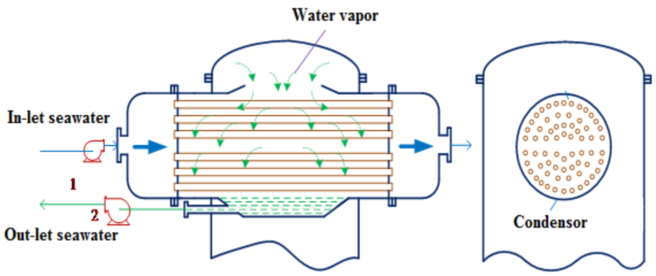

Figure 3: Structue of condenser

The condenser is expected to be designed in the form of a tube bundle. Round cylindrical shell is made by welding method from steel plate divided into 3 parts: condenser body and two condenser caps. The two condenser caps are coupled to the body through bolts, the middle of the lid and the condenser body are sealed with a heat-resistant cushion. The heat exchanger tubes are made of copper alloy (brass) and assembled on 2 sieves in the form of concentric circles. A fixed sieve is fixed to the condenser shell, the other sieve can be moved to allow the heat exchange tubes to expand freely when the temperature in the bulb stops changing. The journey number (pass) of seawater cooled through the condenser is 2.

Table 2: Selected parameters for condenser calculation

Parameter	Values
Freshwater production required	$G_{n.ng}$ = 2.5 t/24h
The temperature of the sea water to cool the condenser	t_{nb1} = 25°C
The temperature of the sea water out of the condenser	t_{nb2} = 35°C
Pipe made of brass with diameter	d_2/d_1 = 14/12 mm/mm
Thermal conductivity coefficient of pipe	λ = 104.5 W/m.K
Number of journeys of seawater inside the tube	2
Saturated steam stops outside the tube at vacuum pressure	Pck = 0.1 bar
The amount of heat loss to the environment	Q_{loss} = 2%

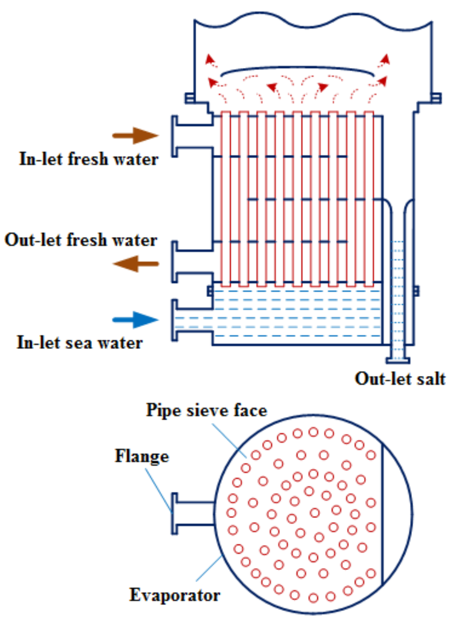

Figure 4: Structue of evaporator

The evaporator has a round cylinder, including a shell made of welded steel plates and heat exchangers made of brass. The tubes in the volatile bulb are arranged on the sieve in concentric circles. The evaporation is responsible for generating steam to provide condenser condenser into fresh water. Seawater is pumped into seawater into the lower chamber of the evaporator and enters heat exchangers. Temperatures of about 80°C are pumped with fresh water into the evaporator from the top to give heat to boil seawater inside the tube, then discharge out through the exhaust valve below. To enhance the heat exchange ability, we use 3 partitions to change the direction of movement and speed up the movement of fresh water.

Table 3: Selected parameters for evaporator calculation

Parameters	Values
The temperature of in-let fresh water	t_{nn1} = 80°C
The temperature of out-let fresh water	t_{nn2} = 70°C
Pipe made of brass with diameter	d_2/d_1 = 18/16 mm/mm
The flow rate of fresh water through the narrowest section of the device	ω = 1m/s
Thermal conductivity coefficient of pipe	λ = 104.5 W/m.K
Number of journeys of seawater inside the tube	4
Seawater evaporates inside the tube at vacuum pressure	Pck = 0.1 bar
The amount of heat loss to the environment	Q_{loss} = 2%

The steam generation process in the evaporation bulb is shown on the is of water-vapor graph (see Figure 2.9) as follows: At pressure p = 0.1 bar, the fresh water in the sea water inside the heat pipe of high temperature fresh water outside the tube to increase the temperature from the initial temperature $t_1^{nb} = 25^0C$ to boiling temperature $t_s = 45{,}84^0C$, the state of the water changes From point A to point B, the enthalpy of seawater increases from $i_1^{nb} = 100{,}8\ kJ/kg$ to $i_2^{nb} = 191{,}9\ kJ/kg$. Fresh water outside the tube continues to provide heat to the seawater inside the tube, but this time only the water containing particles in the moisture-saturated fraction inside the heat-receiving tube to change the phase from the liquid phase to the dry saturated phase, the temperature during the evaporation does not change, the state of the vapor changes from point B to point C, the enthalpy of water vapor changes from $i' = i_2^{nb} = 191{,}9\ kJ/kg$ to $i'' = 2584\ kJ/kg$. Thus, we can see that the boiling surface in the evaporation bulb to boil water ($\Delta i_{ds} = 191{,}9 - 100{,}8 = 91{,}9\ kJ/kg$) is much smaller. evaporation surface ($\Delta i_{bh} = 2584 - 191{,}9 = 2392{,}1\ kJ/kg$), so when calculating the average logarithmic temperature (Δt) we can skip the process of boiling water in the tube only interested in the evaporation process, ie the liquid contained in the saturated moisture vapor receives the child t to transition into dry saturated steam in boiling t_s conditions unchanged (isothermal heat receiving).

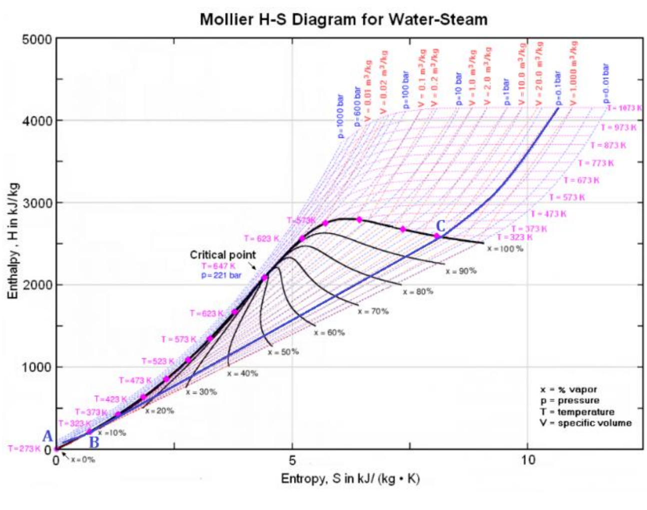

Figure 5: i-s graph of water - steam

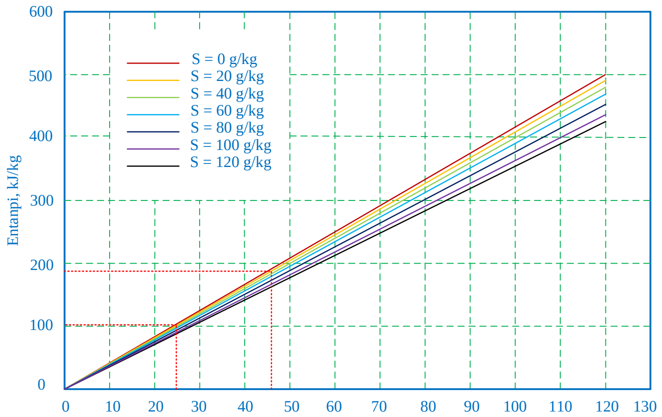

Figure 6: The change of enthalpy seawater according to temperature and salinity

Initially, the water in the tube at the single-phase liquid receives heat from the pipe wall to raise the temperature from the initial temperature to boiling temperature, when the water starts to boil, the flow begins to appear bubbly flow, at which time the water in the pipe continues to receive heat from the pipe wall to evaporate under constant temperature (receive isothermal heat). According to the flow, the water continues to receive heat from the wall to evaporate, in the upper part of the flow heat exchanger tube is an annular flow with a water towel ring in direct contact with the pipe wall, still inside is steam. The fluid flow continues to move upwards and receives heat from the pipe wall, at which time the liquid phase in the water-vapor mixture continues to receive heat to evaporate until evaporated, causing the upper part of the tube to exchange heat. only one single-phase vapour.

Figure 7: Fresh water distillation machine after fabrication

In the process of steam flow from the evaporation bulb to the condenser, heat loss will occur due to the steam mass transferring heat to the device shell so there will be a certain amount of steam condensed into boiling and falling back in elected to evaporate before reaching the condenser. Besides, an amount of steam evaporating will be sucked out by vacuum pump. Thus, in order to ensure sufficient steam required to enter the condenser to produce the required freshwater output, the steam flow generated in the evaporation must be greater than the steam flow into the condenser. For tube distillation equipment, the steam flow generated by the evaporation bulb must be 1.5 times higher than the steam flow into the condenser.

The boiling process inside the heat exchange tubes of the evaporation bulb is boiling. Under the effect of the temperature of boiled fresh water outside the tube, the seawater inside the tube will boil in the appearance of air bubbles on the surface of the heat exchange at the foaming centers, then the bubbles continue to receive. Heat, the seawater around the bubble will evaporate into the air bubbles to make it grow and float to the surface of the water film. For tube distillation equipment, to produce 1 kg of condensate per unit of time, the evaporation volume of seawater with a flow of 2.5 kg of seawater must be supplied to a single unit time. Thus, to generate $G_{n.ng} = 0{,}029\ kg/s$, the seawater flow need to be supplied to the evaporation bulb is $G_{BBH}^{nb} = 2{,}5.G_{n.ng} = 2{,}5 \times 0{,}029 = 0{,}0725\ kg/s$.

4. CONCLUSION

For people living in the sea, islands, remote areas, fresh water must be transported over a very long distance, so transportation costs are very high. Especially the coastal areas and islands of sea water are extremely abundant, so the creation of freshwater distillers is necessary to create fresh water for human life. Based on the basic principle of Atlas freshwater distillation machine and using the method of statistical collection of extraction parameters and the method of average temperature difference logarithms, the thesis has calculated heat and successfully fabricated tissue. fresh water distillation machine. The model of fresh water distillation machine after successful production has been operating well, stable, the results of actual exploitation are close to the theoretical calculation parameters.

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