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PERFORMANT INSTALLATION FOR PURIFICATION AND DESALINATION OF SEA-WATER FOR CRUISE SHIP

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ABSTRACT

The current paper presents a more efficient system that has been required to obtain higher quality feed water for cruise ship. The fresh water reserves must be completed with desalination water that comes from the ship's own desalination installation, wich must be carried on board of cruise ships. If salt and other substances in the sea water were eliminated, sufficient pure water for human consumption but also for other purposes would be produced. The salt water has generally been removed prior to injection into the boiler. After desalination, the particles such as iron and copper become greater problems. This particles determine corrosion of installation and must returning from the condensate system and depositing in the boiler. If iron is in a soluble form and not a particulate form, it can produce precipitates such as iron phosphates and iron silicates which are extremely adherent deposits. The resultant precipitate has a strong affinity for tube metal through surface attraction. Water flow and circulation of particles in installation, will provide a force to keep the particles in suspension and moving. To maintain the desalination installation in function for a long time, it is important to have the optimum concentration of the suspended particles which are continuously moving through the installation.

Keywords: desalination installation, corrosion particles, purification, desalination, cruise ship

1. ELEMENTS OF SEA-WATER PROCESSING

Fresh water on cruise ships board has always been an important element, being the factor that has determined the time a vessel will spend at sea. Production of drinking water on ship board is an absolutely necessary activity and it focuses on its quality, in terms of consumers' use. This water is used for drinking, cooking, bathing, but also as a cooling agent for modern Diesel engines.

Modern ships (Fig. 1), cruisers in particular, use over 260,000 liters of fresh water every day. Cruise ships convert sea water into drinking water through a process known as desalination. The processing of sea water means the use of an installation where processes of evaporation and condensation take place for a certain quantity of sea water, during which the temperature remains constant.

The important issue here is that the melting (also, freezing) point of water is used to mark the "0" on the Celsius scale and the evaporation (also, condensation) point of water is used to mark the "100" on the Celsius scale, of course, performed at one atmosphere of air pressure**.** The "0" on the Celsius scale corresponds to "32" on the Fahrenheit scale and "100" on the Celsius scale corresponds to "212" on the Fahrenheit scale**.** This means that pure water freezes at 32° F and boils at 212° F if the air pressure is one atmosphere [1]**.**

In most cases, impurities are largely eliminated by boiling so that, after condensation, the liquid is relatively pure.

Fig.1. Ocean cruise ship

These two processes take place with a phase change, which implies a high energy consumption and are considered to be already classic. Sea water does not have the same boiling point as fresh water, having a boiling point a few degrees higher.

When it reaches the boiling point of sea water, it moves in a vapor state at that temperature, and the steam is driven by a clean container, where it condenses. By condensation, pure water is obtained. Salt, but also other solids of sea water does not evaporate and therefore do not appear in the water. Other solids can be eliminated by using the reverse osmosis process [3].

Nowadays, most vessels are equipped with a generator of fresh water, also called an evaporator, which converts sea water into drinking water. The process by which fresh water is generated is known as the process of distillation. The boiling temperature can actually be reached; however**,** with great cooling, temperatures very close to evaporation process have been reached**.**

Experiments made in the laboratory have shown that when a gas is cooled down, its volume decreases**.** At constant pressure, the volume decrease for a gas is proportional to the temperature decrease.

In other words, the ratio $\Delta V/\Delta T$ remains constant**.** That means that if V (the gas volume) is plotted versus T (the gas temperature) while pressure is kept constant, the graph is a straight line like in Fig. 2 [2]**.**

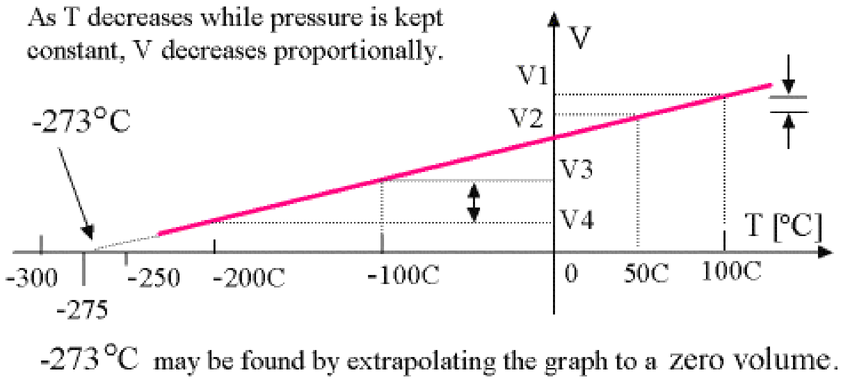


Fig. 2. The V- T variation in the desalination process

To increase the very low temperatures it is necessary to increase the hitting energy consumption. We have to extrapolate the graph to cross the temperature axis. This means that the gas is so cold that its electrons are not spinning around the nuclei and do not need any space for their vibration. The no need for space means Zero Volume. The temperature (-273 °C) is chosen to be the Zero on the Kelvin scale. This makes the zero on the Celsius scale to correspond to 273 on the Kelvin scale; therefore,

$$K = °C + 273$$

Parallel to the above discussion, if the temperatures on the graph are expressed in °F, extrapolation crosses the temperature axis at -460°F. That constitutes the basis for the "Rankin Scale." It can write:

$$R = °F + 460.$$

Heat is a form of energy that transfers due to a temperature difference.

Units of Heat: one calorie (1cal) is the amount of heat energy that can raise the temperature of one gram of pure water by 1 °C. 1 kcal is the amount of heat energy that can raise the temperature of 1kg of pure water by 1 °C. A non-Metric unit for heat energy is Btu (British thermal unit). 1 Btu is the amount of heat energy that can raise the temperature of 1 lb_m of pure water by 1 °F.

2. HEAT CALCULATION

When heat is given to a pure substance or taken from it, its temperature starts changing if a phase change does not start. During a phase change (solid to liquid, liquid to solid, liquid to vapor, or vapor to liquid), the temperature remains constant. We will look at the following two cases:

1) heat calculation for temperature change,
2) heat calculation for phase change.

2.1 Heat Calculation when only temperature changes (no phase change):

In this case the amount of heat given or taken is obviously proportional to mass (M) of the object, its specific heat (c), and the temperature change (ΔT).

The formula is therefore:

$$Q = Mc\Delta T$$

Thermal equilibrium requires that heat is absorbed by colder objects. $Q = Mc\Delta T$ must be applied to each side of the equation. Note that the final temperature of both water samples will be the same. We may either call this final temperature T_f or T_{eq}, the equilibrium temperature.

$$Mc\,[T_f - T_i]_{Al} = Mc[T_f - T_i]_{water}$$

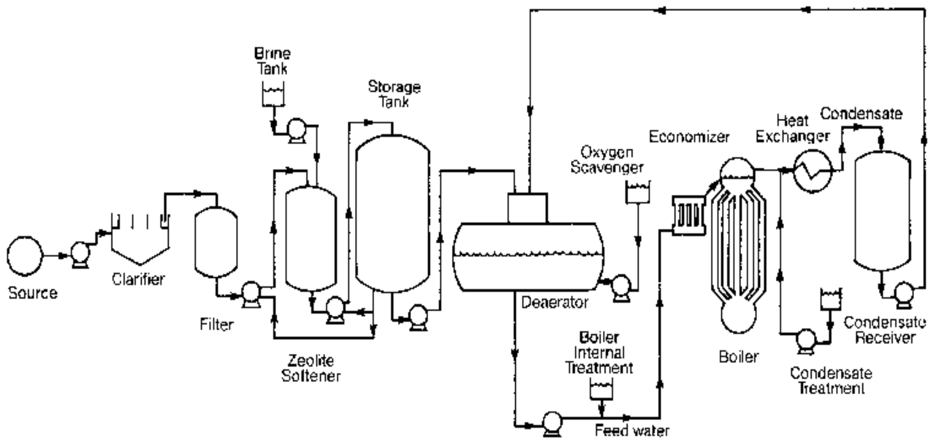
The generator of fresh water is provided with a heat exchanger and it is connected to the cooling system of the diesel engine. During this experiment, temperature will decrease between 4 and 13 °C depending on the amount of cooling water which has been used. The boiler house or steam generation installation applies a consequent treatment for sea water. Operating personnel can be reluctant to change treatment programs if the one currently in use is deemed successful. On the other hand, if a treatment program is linked to a boiler failure, change usually comes quickly [1].

3. A flow desalination installation

A boiler of desalination installation must be designed to absorb the maximum amount of heat released in the process of combustion. This heat is transferred to the boiler water through radiation, conduction and convection. The relative percentage of each is dependent upon the type of boiler, the designed heat transfer surface and the fuels [4].

A boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. In the boiler furnace, the fuel energy is converted into heat, and this heat is transferred to the salt water in the most efficient manner.

The boiler should also be designed to generate high quality steam in desalination installation. A flow desalination installation is presented in Fig. 3.



. Fig. 3 A flow desalination installation [1]

External treatment, as the term is applied to water prepared for use as boiler feed water, usually refers to the chemical and mechanical treatment of the water source. The goal is to improve the quality of this source prior to its use as boiler feed water, external to the operating boiler itself. Such external treatment normally includes: 1. Clarification of sea water; 2. Filtering; 3. Softening; 4. Dealkalization; 5. Demineralization; 6. Deaeration; 7. Heating.

4. VACUUM DESALINATION INSTALLATION

The use of vacuum is the original idea (fig.4) and it aimed at lowering the temperature at which the evaporation of sea-water occurs. This is why vacuum is produced in the evaporation enclosure. The Main Body of the generator of fresh water on the ship consists of a cylinder tank, with two compartments: one of them is in the condenser, and the other one is in the evaporator.

The sea water is entered into the system at the bottom of the evaporator chamber, then along an upward path. This sea water is pre-heated by means of a heater inoperable, so that when you arrive at the boiling temperature, it emerges from the top end in a state of water vapor. Water vapors are led by a vapor separator to condenser, then discharged on to the bottom, in a tank.

The situation is different in the compressor, when vapors penetrate indoors. The sea water found in boiling can then be compressed without affecting the boiling point of water.

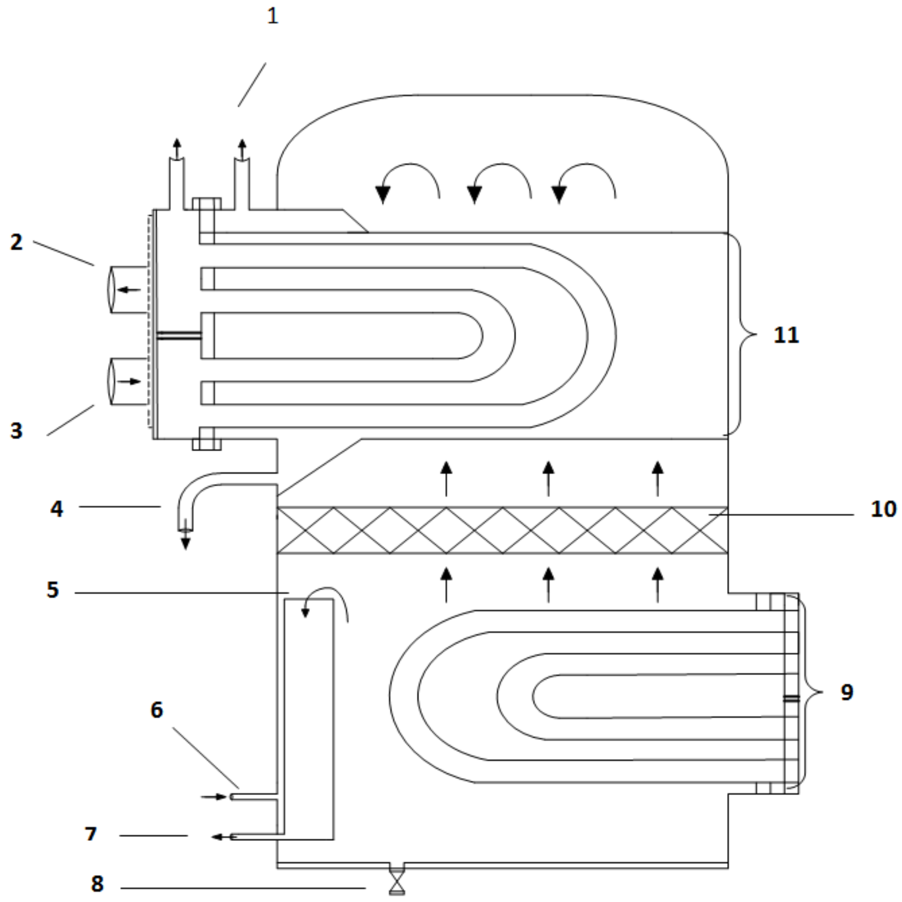


Fig .4. Vacuum desalination installation.
1- vacuum system; 2 - water exit; 3 - water entrance; 4 - the exit of distilled water to the main tank; 5 - overloading; 6 - sea water entrance; 7 - exit for residual salt; 8 - drain tap; 9 - heating zone; 10 - filtering; 11 - the condensation of vapors zone

The installation is equipped with a breather pipe to lower area called vapor separator. This sunroof ensures that the pressure of the vapor separator reaches a pressure similar to that of the atmosphere.

Although the breather pipe opens at the bottom of the plant, the steam will not be able to flow. Any excess of steam that the capacitor can not retain will be able to pass through the vents, which acts as a safety system. This the breather pipe also used to drain the coolant gross which collects at the top of the desalination installation. The temperature available is approximately 70 °C but, at this temperature the evaporation of sea-water is not possible. The evaporation of sea-water takes place at 100 °C, at atmospheric pressure.

In order to produce fresh water at 70 °C, vacuum is created inside the evaporation room, where the evaporation takes place, followed by a reduction of the atmospheric pressure. As a result, the cooling of sea-water, after having been subject to evaporation process, can be carried out also at lower temperatures.

Spring-loaded nozzles located at the top of the unit spray the water into a steam atmosphere that heats it. Simply stated, the steam heats the water and, at the elevated temperature, the solubility of oxygen is extremely low and most of the dissolved gases are removed from the system by venting. The spray will reduce the dissolved oxygen content to 20-50 ppb, while the scrubber or trays further reduce the oxygen content to approximately 7 ppb or less [1].

5. EXPERIMENTS AND MEASUREMENTS

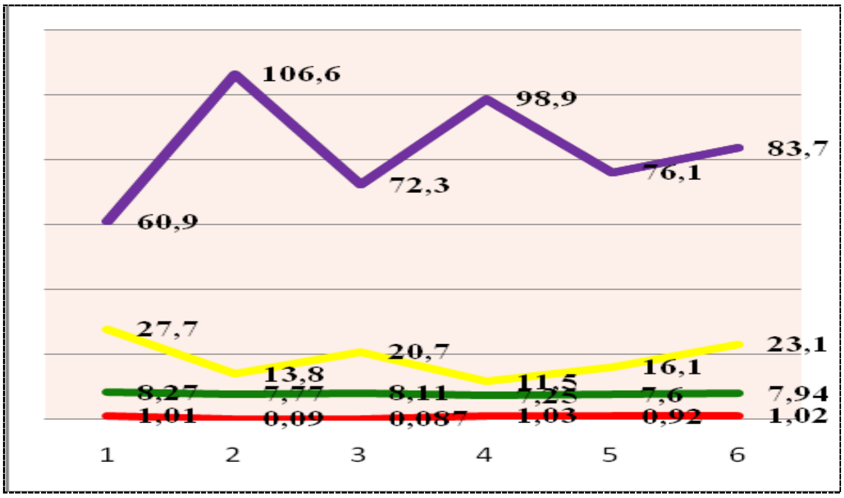
During experiment operation, which was made in laboratory, we analyzed six samples of sea water. Firstly, we determined the quantity of NaCl in 250ml of sea water, pH of sea water, Mg, Ca, Fl, the dissolved oxygen and the hardness degrees of each sample like in Table 1.

Table 1

Samples	Quantity of NaCl in 250ml of sea water(g)	water pH	Mg mg/L	Ca mg/L	Fl mg/L	Disolved oxigen O_2, mg/L	Water hardness degrees [°d]
1	4.018	7.64	27.7	60.9	1.01	8.27	6º
2	4.063	8.25	13.8	106.6	0.09	7.77	4º
3	4.022	7.62	20.7	72.3	0.08	8.11	5º
4	4.025	8.15	11.5	98.9	1.03	7.25	6º
5	4.048	7.87	16.1	76.1	0.92	7.60	4º
6	4.053	8.10	23.1	83.7	1.02	7.94	5º

After the salt extraction from salt water, the hardness is measured. The hardness is expressed in degrees of hardness [ºd]. The soft hardness of salt water, after desalination is between 4º- 6º. The hardness of sea water, after measurement was 18º-22º.

Quantity (Mg/)l



sample

Fig. 5. The concentration of disolved ions in sea water:
$Ca^{2+ (magenta)}$, $Mg^{2+(yellow)}$, $Fl^{-1(red)}$, quantity of disolved oxigen(green).

The ions concentration in the sea water samples (fig.5) increases like: $Ca^{2+}>Mg^{2+}>Fl^{-1}$. The maximum limits of values from the fig.5 are coresponding to SR ISO 6058/2008 (water quality).

For optimum oxygen removal, the water in the storage section must be heated to within 5 º F of the temperature of the steam at saturation conditions.

The temperature of the water in the storage section should be at least 2 ºF for each 1psig of the steam supply, up to 30 psig.

Experiment: Minimum water temperature
At 3 psig steam
2ºF x 3= 6ºF
At 6 psig steam, 2ºF x 6 = 12ºF
Minimum water temperature
10 psig steam
2ºF x 10 = 20ºF
Minimum water temperature
12 psig steam
2ºF x 12= 24ºF
Minimum water temperature
14 psig steam
2ºF x 14 = 28ºF
Minimum water temperature
Saturation temperature = 227 ºF
212ºF + 10ºF = 222ºF
If the saturation temperature = 240ºF
212 ºF + 20 ºF = 232 ºF.

When the optimization was installed, good deaerating and heater operation is the most important because oxygen pitting is the most common cause of economizer tube failure. This vital part of the boiler must be protected with an oxygen scavenger, usually catalyzed sodium sulfite [1].

In order to insure complete corrosion protection of the economizer, it is common practice to maintain a sulfite residual of 5.5-10 ppm in the feed water and, if necessary, feed sufficient caustic soda or neutralizing amine to increase the feed water pH to between 8.2 and 9.1. Below 800 psi, the excess sulfite (up to 200 ppm) in the boiler will not be harmful. To maintain blow down rates, the conductivity can then be raised to compensate for the extra solids due to the presence of the higher level of sulfite in the boiler water. This added consideration (in protecting the economizer) is aimed at preventing a pitting failure.

Make the application of an oxygen scavenger, such as catalyzed sulfite, a standard recommendation in all of your boiler treatment [2].

CONCLUSIONS AND DISCUSSIONS

Inside of desalination installation the preparation of feed water for boiler injection has been optimized through the removal of undesirable salts and contaminants. In addition, the removal of oxygen and other non condensable gases has been completed through chemical and mechanical deaeration.

Establishing consistent feed water quality on cruise ships board is extremely important in designing the internal boiler water treatment program.

Boiler deposits result from hard salts, metallic oxides, silica and a number of other feed water contaminants that can enter the system. The amount of contamination that passes into the boiler with the fresh water must be controlled.

Minimizing the adverse impact of these contaminants is the role of the boiler water treatment program.

Even the best controlled systems occasionally have upsets that cause excessive amounts of contamination to pass into the boiler.

To obtain the pure water at the cruise ship board, the following must be accomplished:

1. Water must be submitted to an adequate antibacterial treatment;

2. The control of the leakage from an ion exchange system because various leakage may appear into the condensate section of desalination installation;

4. To diminish the corrosion products that are returning to the boiler because of the damage of the filtering system of the desalination installation.

5. Use of titanium has the effect of getting water as pure as intended to ensure retention of salt evaporation, condensation and separation;

6. Reducing fuel consumption by using the original solution proposed has the effect of producing fewer emissions of greenhouse gases in the atmosphere, such as CO2, NOx, SOx.

For an efficiently sea water desalination, it is important to do for the first time a strict water treatment and then the desalination of sea water.

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