Design and development of a prototype thermal power plant for recycling of sea water by distillation process

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Abstract. Water scarcity is nothing but the insufficient of fresh paper resources to meet the daily life of human activity. However the water scarcity is cause by growing population and change in weather pattern due to global warming. Many countries across the world will face the water scarcity in this century. As per the NITI Aayoga report release in June 2019. India has 4% of world fresh water and also has the 17% of world population. This research conclude that India will faces the worst ever water scarcity in history. In India, more than 90% of fresh water available in the ground is used for agriculture purpose and remaining is used as a drinking water. The most important crops grown in India are rice, wheat and sugarcane. These crops also consume more amount of water. For example, rice is the major crops exported in India which consume about 3500 liters of water for producing a kilogram of grains. So the aim of this paper is used to convert the saline water to drinking water by sending the saline water into the boiler which has inlayer of stainless steel to avoid the scale formation in the boiler surface and heated to the temperature of about 700c to produce the super-heated steam of fresh water and this steam is passed to the steam turbine to produce the electric power.

1. INTRODUCTION

Even though world is surrounded by 75% of water, among this only 3% of water is available as fresh water out of this 1.2% can be used as a drinking water, rest of the fresh water is locked in glaciers forms. This leads to scarcity of fresh water in the ecosystem. The process of removing dissolved salts and minerals from saline water (such as sea water) is known as Desalination of sea water. The main aim of the desalination process is to produce fresh water for drinking, irrigation and industrial usage. The three principle methods of desalination are carried out with the help of thermal, electrical, and pressure [10]. Electrical desalination is the process of separating the salt form sea water by creating the small electrical field. In this process, due to the applied electrical field, anions such as chloride, sulfate, etc. will move toward the anode and cations such as calcium, sodium, magnesium, potassium, etc. will move towards cathode. Pressure desalination is done by using high pressure pump which pushes the salt water at high pressure against the semipermeable membrane to deposit the salt on this membrane. In this process, 95% to 99% of fresh water will comes out of the semipermeable membrane due to high pressure.

Nowadays nano porous graphene is also used as a semipermeable membrane [3]. The porous size of this membrane is 20μm [12]. Thermal desalination process involves the converting of sea water into vapor by using thermal energy. Thermal desalination process uses heat energy to evaporate water and condense it again [7]. There is another thermal process to remove the salt by using the CO\textsubscript{2} coming out from the combustion engine. This CO\textsubscript{2} and salt in sea water will react and settle down and the fresh water will be obtained. In this paper we use thermal desalination process for recycling of sea water.

The distilled water does not taste well. So, some of the mineral are to be add in distilled water such as calcium, magnesium, potassium, sodium, zinc and iron. So, this will result in hard water and a little better taste for drinking.

2. METHODOLOGY
2.1 Analysis of sea water

Seawater is a mixture of 96.5% of water, 2.5% of salts and small amount of other substance including dissolved organic and inorganic material and a few percentage atmosphere gases. The basic ions available in sea water are chloride, sodium, sulfate, magnesium, calcium and potassium respectively. These ions make up about 99% of all seawater. The boiling point of water is 100°C at one atmosphere pressure (at a sea water) if you have added 58 grams of salt just to raise the boiling point of one liter of water by one half of a degree Celsius (0.5°C). When human drink sea water, the cell will take both the water and the salt. This will increase the concentration of the salt in the body this lead to the kidney disorders and finally to kidney failure. To avoid this we must drink the equal amount of other liquids to lower the concentration of the salt [9].

2.2 Structure and working of the boiler

When we send the saline water into the boiler. Usually the sea water will contain a larger amount of salts and other dissolved minerals. This will corrode the surface of the boiler. So, the boiler will lose its strength [8]. The boiler for this experiment is made up of three layers. First, the inner layer which should be corrosion resistance. So, the inner layer should be made up of either stainless steel or aluminum [4]. In this experiment, we cannot use the aluminum material inside the boiler because it will lose its strength when it reaches 600°C. So, stainless steel [4] is used in the inner surface. Then the middle layer which should conduct the heat to the saline water through the stainless steel without any loses. So we are using the copper pipes in the helical structure. Here the flue gases will go into the pipes at the bottom end of the boiler at the temperature of 700°C. Then the flue gases will go around the stainless steel and transfer the heat to the water. The flue gases will comes out through the top opening of the copper pipes in the boiler. The flue gases which come out of the boiler will be around 300 to 450 °C. The outer surface which should not transfer the heat to an atmosphere. So, here alumina Ceramic pipe is used to avoid the dissipation of heat to the surround.

2.3 Process

- The saline water is pumped into the tank which is kept for storage purpose.
- The water that is to be cleaned is sent into the boiler from the tank.
- Coal is used as a fuel in most of the thermal power plant or in small prototype model they use the direct sunlight this will used a large area to absorb the heat energy to boil the water [11].
- Due to insufficient coal in India, we have to go for an alternative method.
- In most of the furnaces only 50% of fuel is used for melting the metal scraps.
- The remaining 50% of heat will come out through the furnaces in the form of flue gases.
- These flues gases coming out from the furnaces are allowed to flow into the insulated pipes i.e. alumina ceramic till it reaches the boiler.
- This flue gases will goes around the helical shape copper pipes. When heat transfer is into the sea water, the superheated steam of fresh water is produced. Concentration of salt in the remaining saline water will increase.
- For example, if we take 100 liters of sea water. 80% to 85% of sea water is converted into superheated stream and remaining sea water which will have high concentration of salt content so it will comes out of the boiler through valve present at the bottom of the boiler
- The flue gas temperature is reduced, then these gases are let out through the copper pipe from the boiler.
- Here the superheated steam is produced due to heat transfer from the flue gases through copper pipes.
- Then the superheated steam coming out from the boiler is passed through the turbine at high pressure and temperature to produce the electric power.
- The steam from the turbine is again passed on to the tank by indirect contact for the regenerative purpose [6].
- The regenerative concept is used to reduce the temperature of the steam (approx. 70 °c). This is done to condense the steam.
- This liquid is then stored into fresh water tank.
- This water can be used for various general purposes and industrial use.

\[\text{Figure 1: Layout diagram}\]

\[\text{Figure 2: Dimension of the boiler}\]

\[\text{Figure 3: Side wall of the boiler}\]

2.4 Dimension of the Boiler
Table: 1 Dimension of the boiler

| Boiler Parts                                              | Dimension (mm)          |
|----------------------------------------------------------|-------------------------|
| Length of the boiler                                     | 5100 mm                 |
| Diameter of the boiler                                   | 1360 mm                 |
| Inner layer of the boiler (i.e. stainless steel)         | Inner diameter =1200 mm |
|                                                          | Outer diameter = 1220 mm|
| Middle layer of the boiler (i.e. copper)                 | Inner diameter = 1220 mm|
|                                                          | Outer diameter =1340 mm |
| Outer layer of the boiler (i.e. alumina ceramic)         | Inner diameter=1340 mm  |
|                                                          | Outer diameter=1360 mm  |
| Volume capacity of the boiler                            | 2.261x1010mm = 2.261x10^4 liters |
| Copper pipe diameter through the flue gas Enter          | 60 mm                   |
| Pitch of the helical copper pipes                         | 60 mm                   |
| Length of the inlet and outlet pipes Of the water and stream respectively | 750 mm                 |
| Inlet diameter of the pipe in boiler                      | 280 mm                  |
| Outlet diameter of the pipes in the boiler                | 280 mm                  |
| Diameter of the valve in the boiler                       | 280 mm                  |

3. RESULTS AND DISCUSSION

From this we analysis that when we pass 22500 liters of water into the boiler we generate 18000 to 19000 liters of fresh water is transform into a super heated steam and remaining 45000 to 35000 liters of water with high concentration of salt will comes out of the boiler through the valve and this saline water is sent to the near by salt bed for producing the salt. We have to send the salt water at the high velocity to avoid the deposition of the salt in the pipe.

With this developed model of the boiler, the temperature of the flue gases and water is monitored and controlled. Sending the flue gases at a temperature of 700°C through the copper pipes. Once it reaches the middle of the pipes, it will loses its thermal energy and reduce to the temperature of 450°C. When it comes out of the boiler the temperature will be reduced to 300°C. By this time, the water will transforms its state into super heated steam at the temperature of 180°C and it will comes out of the boiler at the high velocity to run the stream turbines.
Table: 2 Amount of fresh water and saline water produced per volume capacity of the boiler

| Type of Water                                                                 | Amount of water (liters) |
|-------------------------------------------------------------------------------|--------------------------|
| Amount of water sent into the boiler for distillation process                | 22500 liters             |
| Amount of water converted into super heated steam by flue gas               | 18000 to 19000 Liters    |
| Amount of saline water comes out through valve at the bottom of the boiler  | 4500 to 3500 liters      |

Table: 3 Temperature of flue gas and water at various part of the boiler

| Temperature at various part of the boiler                                      | Temperature (in °c) |
|-------------------------------------------------------------------------------|---------------------|
| Flue gas temperature at the inlet of the copper pipes                         | 700°C               |
| Flue gas temperature at the middle of the copper pipes                         | 450°C               |
| Flue gas temperature at the exit of the copper pipes                          | 300°C               |
| Water temperature at the inlet of the boiler                                  | 50°C to 70°C (due to regeneration heating) |
| Super heated steam temperature at the exit of the boiler                      | 180°C               |

4. CONCLUSION

From this we conclude that, this method we can able to produce not only the fresh water and also some amount of electric power by stream turbine. The thermal energy required to boil the water is relatively low by using regenerative method. By this regenerative process \(^6\), the saline water is heated to 70°C temperature by super-heated steam. The superheated steam is condensed to 50°C to obtain the fresh water, and this fresh water can be used for drinking, irrigation and industrial usage purposes. It is not a continuous process because when we pass 100 liters of saline water only 80% - 85% of fresh super-heated steam is produced and this amount super-heated steam is fully converted into fresh water. The remaining water will comes out through valve which will have high concentration amount of salt.

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