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# Design and Fabrication of a Water Distiller

**[1]Oyawale F. A., [2]Odior, A.O., [1]Ismaila M. M**

[1]Department of Industrial and Production Engineering, University of Ibadan, Nigeria.
[2]Department of Production Engineering, University of Benin, Nigeria.

**Corresponding Author: A. O. Odior**

**Abstract**

*The objective of this project is to design and fabricate a low cost water distiller capable of producing water that is pure in all ramifications for domestic and commercial consumers. The critical components of the distiller are made of stainless steel. These parts include the tank, the lid/condenser and the distilled water collector. Selection of material used is based on both their physical and chemical properties. The tank has a square base and the opening end of the tank is slanted. This will make the condensate to trickle downward for collection at the end of the lid. The lid is continuously cooled by water at room temperature that runs from a tap. The distiller is able to produce 29.4 x $10^{-3}$ litres (29.4 ml) of distilled water in 10 minutes. Once the water is boiled, the heater can be switched off and continuous cooling of the condenser/lid could last 30 minutes. The volume of water produced is approximately 105.3ml. Distillation continues until the temperature drops to room temperature i.e. $25^0$C by which time, the volume of distilled water will drop since the production of steam will decrease due to the drop in temperature of water in the tank. The water distiller is designed and fabricated from locally sourced materials and this makes it cheap and affordable to the common man in our society.*

**Keywords:** water distiller, pure water, condenser, critical components, design, fabricate

## INTRODUCTION

Drinking water comes from several sources among which are surface water (lakes, rivers and reservoirs), groundwater (wells, borehole) and rain. Treatment of water depends on the source. Surface water is exposed to environmental elements like wildlife droppings, urban and agricultural run-off, and trash. Groundwater has historically been assumed safe without treatment because layers of soil act as natural filter, removing microbes and other particles as water seeps through. Groundwater is stored in underground reservoirs known as aquifers and is more protected from environmental elements than surface water as it is freed from air pollution, (Swann, 1998). Some groundwater systems such as surface well require the addition of disinfectant while deep well such as borehole requires little treatment. The traditional media used in cleaning toxins from water is carbon. Carbon or "charcoal" has a tremendous ability to adsorb (draw) impurities to itself, particularly organic chemicals such as pesticides and fertilizers as well as chlorine added by water treatment plants to kill bacteria and algae. Another method is reverse osmosis which forces pure water through a membrane with the pressure from the water line. Nearly all contaminants, including chemicals, dissolved solids, many of the minerals and most microbes are screened out.

A ceramic filter is a microscopic screening agent, made from a fine clay material. It removes any particles as small as 0.5 micron in size such as bacteria and parasites. The disadvantage however is that it cannot remove particles less than 0.5 micron. Ultraviolet systems (UV) expose water supplied to intense UV radiation, which kills pathogenic bacteria (cholera, typhoid, salmonella dysentery, etc). This is however, not effective against cysts. Chlorination is the most common method for the treatment of public water in towns and cities. Poisonous chlorine is added to water to prevent infectious illnesses from bacteria and toxic algae. Even though it is the most common method of water purification, drinking chlorinated water has been found to promote colon, liver and breast cancer (Montague, 1988). Bathing with hot chlorinated water is even more dangerous than drinking it because the skin absorbs chlorine like sponge, delivering 100 times chlorine than drinking directly into the bloodstream.

The foregoing underlines the need for a water purifier for both drinking and bathing to remove chlorine. Distillation produces the best quality water for transporting nutrients and for eliminating wastes from the body. Distilled water is pure water. It copies the nature's way of purifying. Water from oceans, seas, lakes and rivers is heated by the sun, evaporates,

condenses and falls as rain. However rainwater is not pure because it contains dust, smoke and many other impurities. Distillation eliminates ALL contaminants - bacteria, viruses, lead, radon, chlorine and hundreds of other pollutants. We often asked about distilled water because distillation removes all contaminants, whether acid or alkaline the $P^H$ will always move closer to 7, which is neutral. The greatest damage done by inorganic minerals, waxy cholesterol and salt is to the small arteries and other blood vessels of the brain (75% water). Hardening of the arteries and calcification of blood vessels starts on the day you start taking inorganic chemicals and minerals from the tap water into your bodies (Harwood and Moody, 1989).
Distilled water is made pure by first boiling the water to the point of vaporization, so that all of the impurities are left behind. Then, the water vapour is condensed and the process results in water that is in its purest form. Distillation is the single most effective method of water purification, (Montague, 1988). Tap water invariably contains a variety of poisons such as chlorine, chloramines, asbestos, pesticides, fluoride, copper, mercury and lead. The best way to remove these contaminants is by distillation (Kennedy, 2001). Chlorine being a highly reactive chemical is a good disinfectant even in parts – per- million concentrations. Between 1974 and 2007, at least eighteen studies have appeared in the literature linking carcinogens in drinking water to human cancer. The average water intake among men in the study was 2 litres per person per day 1.4 litres of it from tap water. Women drank, on average 1.7 litres of water per day, 1.35 litres of it from tap water. The study revealed that those who drank 8 cups of chlorinated tap water for 40 to 59 years had a 40% greater risk of bladder cancer than those who drank less tap water or who drank non-chlorinated water. People who drank the most tap water for 60 years had 80% greater risk of bladder cancer.

According to Montague, (1988), Dr. Harris, a Scientist then working for Environmental Defence Fund (a traditional Environmental group) and many other scientists have said for a long time that we should consider changing our method of disinfecting drinking water. Europeans do not chlorinate their water, because they do not like the taste it gives to the water; instead, they bubble Ozone ($0_3$) through their water, which kills germs but does not affect the taste. It also does not create cancer-causing trihalomethanes. The following results were obtained from the study ((Montague, 1988)::

(i) Chlorinating our drinking water solves some problems but creates others. We should switch to ozone treatment and abandon chlorine.

(ii) This study gives powerful new evidence that chlorinated chemicals cause human cancer - their industrial use should be reduced

Experts had suggested many ways of purifying water. One of the new ways is to bubble Ozone into the water. Distillation provides us with the purest water obtainable because pure means distilled since distillation copies nature's way i.e. evaporation, condensation and precipitation. As the water is heated to boiling, killing bacteria and converting it to steam, contaminants and impurities are left behind. As the steam cools, it condenses into pure drinking water. Water hardness is the underlying cause of many, if not all, of the diseases resulting from poisons in the intestinal walls which get into the lymphatic system, which delivers all of its products to the blood, which in turn, distributes to all parts of the body. This is the cause of much human disease, (Kenneth, 1987).

**Desalination of Sea Water**

Desalination is a process that removes dissolved minerals from seawater, brackish water, or treated wastewater. A number of technologies have been developed for desalination including reverse osmosis (RO), distillation, electro dialysis, and vacuum freezing. Of the more than 7500 desalination plants in operation worldwide, 60 percent are located in the Middle East with the world's largest plant in Saudi Arabia. In contrast, 12 percent of the world's capacity is produced in the Americas, with most of the plants located in the Caribbean and Florida in the United States.

**DISTILLATION PROCESS**

Distillation is a method of separating mixtures based on differences in their volatilities in a boiling liquid mixture. Distillation is a unit operation, or a physical separation process, and not a chemical reaction. It is used to separate crude oil into more fractions for specific uses such as transport, power generation and heating. Water is distilled to remove impurities, such as salt from seawater. Air is distilled to separate its components, such as notably oxygen, nitrogen, and argon for industrial use (Harwood and Moody, 1989).
In distillation process, feed water is heated and then evaporated to separate out dissolved minerals. The most common method of distillation include multistage flash (MSF), multiple effect distillation (MED), and vapour compression (VC). In MSF, the feed water is heated and the pressure is lowered, so the water "flashes" into steam. This process constitutes one stage of a number of stages in series, each of which is at lower pressure. In MED, the feed water passes through a number of evaporators in series. Vapour from one series is subsequently used to evaporate water in the next series.

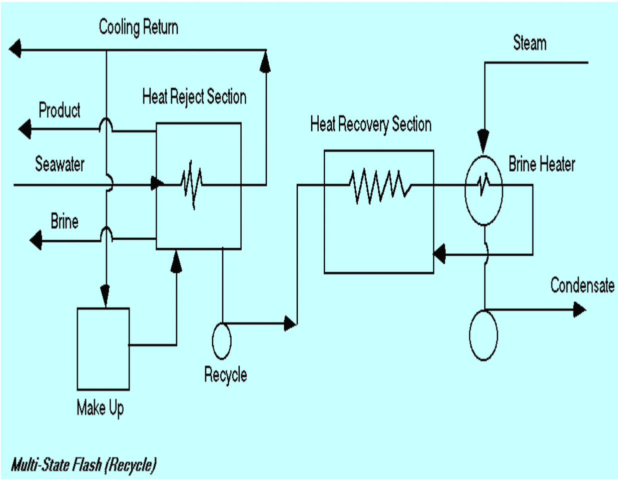


Figure 1: Distillation Process (Harwood and Moody, 1989)

## MATERIALS

To fabricate a water-distiller that will continuously produce distil water, the following materials or components are needed:

- Stainless steel plate
- Electric heater
- Clips
- Steel pipe
- Plastic tubing or hose
- Regulator

## DESIGN CONSIDERATIONS

### Stainless Steel Plate

Stainless steel plate is used because of the following properties

(a) resistance to corrosion
(b) durability
(c) good thermal conductivity
(d) resistance to chemical attack.

Stainless steel plate is used to construct the main tank and the lid; which also functions as the condenser. The tank houses the electric heater. On the top of the tank is the lid or condenser made of stainless steel and collectors that collect condensed (distilled) water before flowing out into a container for collection. The tank capacity is 5 litres (i.e. five cubic decimetres or 5 $dm^3$). The upper part or open end of the tank is slanted to make the condensate flow down to the collector under the influence of gravity. At the other side of the lid, water to be distilled is used to cool the condensate before flowing into the tank via a water flow regulator (See plate 1).

### The Tank

The tank has a base area of $400cm^2$ (20cm x 20cm). The end wall, with the hole, has a height of 23cm while the opposite wall has a height of 17.7cm. The sidewalls are trapezoidal with 23cm and 17.2cm being the highest and the lowest point respectively. Although the tank can accommodate a total volume of $7080cm^3$ (7.08 litres), the regulator will stop supplying water once the desired level is reached. This is possible because the flow rate of the pipe has been altered in such a way that the volume of water being collected (distilled water) is nearly equal to the volume of water entering the tank.

### The lid/Condenser

The lid or condenser is made of stainless steel plate. The function of the lid is to prevent the content (water) of the system from evaporating. It also acts as the condenser. Water to be distilled coming from the main tank flows through the surface of the lid conducting heat away from the lid and help in forming condensate below the surface (other side). The condensate trickles down and is collected by the collector. One end of the collector is opened and the other end is closed.

The work of the water flow regulator is to maintain constancy in the level of water in the tank by replacing the volume of steam leaving the tank. Excess water used in the cooling of the lid flows out through another outlet pipe at the other end of the condenser.

**Electric Heater** the electric heater used in this system is rated 2790W; the decision was to buy an electric heater rather than fabricating one. It has all the properties of a standard heater.

### Steel Pipe

The external diameter of the pipe is 7mm while the internal diameter is 6mm. This smaller diameter pipe is chosen because the flow rate of water is vital in controlling how much volume of water is flowing into and out of the system. The pipe is welded on two sides of the lid. Also on one side of the tank, where water pass through to the tank. The most important property of the pipe is the size, i.e. the diameter of the hole.

### Clips

Screw adjustable clips are used to ensure that the hose and the pipe joints are tight enough to prevent leakages. The joints are located at four different boundaries:

(i) the tank and regulator boundary
(ii) the regulator and condenser/lid boundary
(iii) the lid/condenser and waste boundary
(iv) the tank, regulator and lid/condenser boundary

### Plastic Tubing/Hose

The plastic hose was used because of the need to clean spirogyra (a green slippery aquatic plant) off the hose that thrives in such environment. This could block the pipe and cause system failure

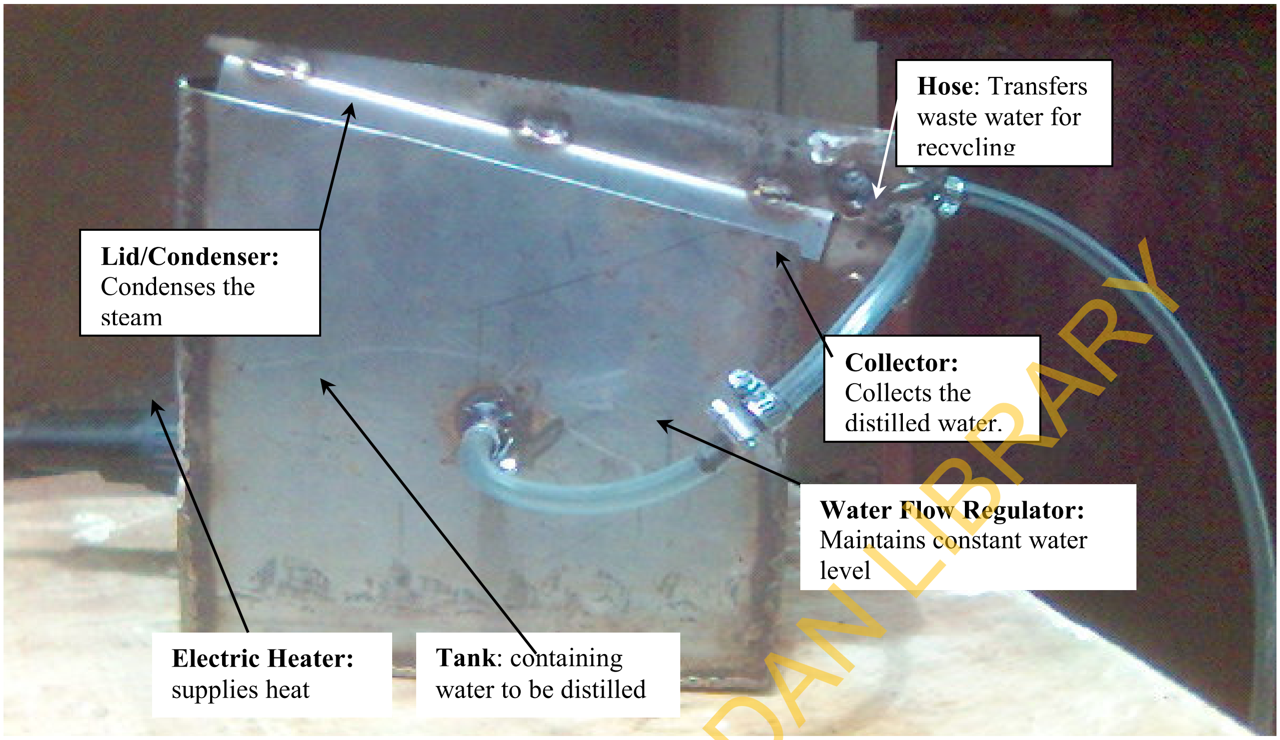


Plate 1: The water distiller showing the different components assembled

**ANALYSIS OF THE SYSTEM**

The heater is rated 2790 Watts. This means that it can supply 2790 Joules of heat per second. The capacity of the tank is five cubic decimetres i.e. 5 litres in S.I. Unit,

$5dm^3 = 5 \times 10^{-3}\ m^3$

From the relation

Mass = Volume x Density

Since the density of water is 1000 $kg/m^3$ the mass of water in the tank is

Mass = $5 \times 10^{-3} m^3 \times 1000\ kg/m^3 = 5\ kg$

The heater boils the water in 8 minutes leading to the production of steam. Water from a container is allowed to run through the surface of the lid. This will cause the steam to condense by losing heat. The condensed steam, due to the loss of temperature, becomes heavier and trickles down to the collector where it is collected. The principle used here is based on the fact that the higher the temperature of fluid, the lighter it becomes and the lower the temperature the denser it is. Since the water running at the outer surface of the lid has a lower temperature, it conducts heat from the condensate making the condensate heavier and move down to the collector due to the force of gravity. This distiller can produce $2.94 \times 10^{-5}$ cubic meter ($29.4 \times 10^{-3}$ liters) of distilled water in 10 minutes, the graph obtained from plotting the volume of distilled water produced against time will be parabolic with the base corresponding to the largest volume of distilled water that can be obtained at a certain period. Once the water is boiled, the heater is switched off and the cooling process starts. Since the relationship between time and the volume of distilled water produced is parabolic and not linear, mere multiplication of values such as; in 10 minutes, 29.4ml of water is produced; therefore in 1 hour which =60 minutes x 29.4ml i.e. 176.4ml will be produced. This is not the case because the volume of distilled water produced will increase and later decrease due to drop in the volume of steam produced as a result of switching of the heater.

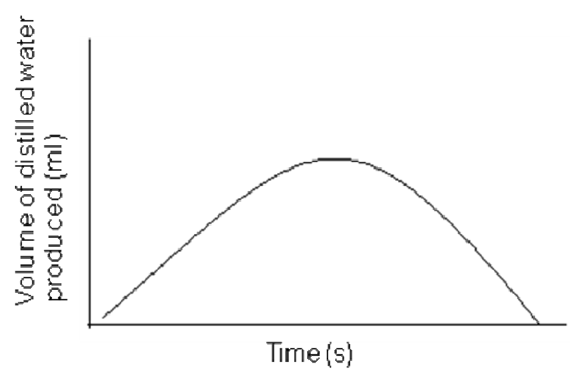


Fig 2: The Behavior of the Distiller When the Heater is on

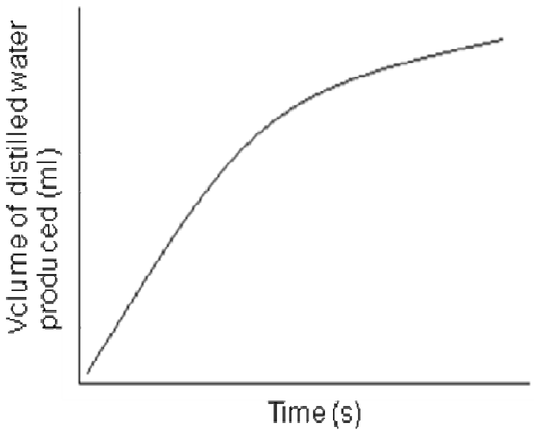


Fig 3: The Volume of the Distilled Water with Time During Heating

If the heater is left on (as shown in fig 2), the volume of the steam produced will increase and hence the volume of distilled water produced will increase.
As long as water is being supplied into the system, the regulator will ensure that the level of water in the tank is maintained preventing the heater from burning and the process from stopping.

**Efficiency of the System**

The efficiency of the system is calculated as follows:
The heater supply heat for 10 minutes, then the quantity of heat supply $Q_s$: is

$Q_s = Pt$

Where P is the Power rating of the heater i.e. 2790W and t is the time it takes to boil the water i.e. 10 minutes (10 x 60 seconds)

$Q_s = 2790 \times 10 \times 60$
$= 1656\,000$ Joules
$= 1656$ Kilo Joules

Heat gained by the water in raising its temperature from $25^0$C (room temperature) to $100^0$C is $Q_w = mc(T_2 - T_1)$

Where

m = mass of water in the tank = 5 kg
c = specific heat capacity of water = 4200 J/Kg k(Appendix II)
$T_2$ = final temperature of water = $100^0$C
$T_1$ = Initial temperature of water = $25^0$C

$Q_w = 5 \times 4200 \times (100 - 25)$
$= 5 \times 4200 \times 75$
$= 1575000$ Joules
$= 1575$ Kilo Joules

The efficiency of the system; E is

$$E = \frac{\text{work output}}{\text{Work input}} \times 100\%$$

$$= \frac{\text{heat gained by water}}{\text{Heat supplied by heater}} \times 100\%$$

$$= \frac{1575\text{ Kj}}{1656\text{Kj}} \times 100\%$$

$= 0.951 \times 100\%$
$= 95\%$

Heat lost is (1656 – 1575) kJ = 81 Kj
The efficiency can be slightly increased by lagging the system.

**The factors that affect the efficiency of the system are:**

(1) The quantity of heat supplied. If there are many source of heat, such as increasing the number of heaters, the water will boil faster and produces steam quicker.
(2) Minimize the loss of loss of heat. By lagging the system with felt or any other good insulator, loss of heat will be minimized but can never be eliminated.
(3) The rate at which the lid is being cooled. If we continue to cool the lid/condenser with water, more steam will condense by losing heat to the water-cooling it.
**(4)** The temperature of the water being used to cool the lid. The lower the temperature of the cooling agent (water in this case), the faster the rate of forming the condensate and the larger the volume of distilled water produces.

## CONCLUSION AND RECOMENDATION

The water distiller was designed and fabricated using locally sourced materials and this makes it cheaper than imported ones thereby making it affordable to numerous consumers in our society.
Distilled water removes poisonous substances and inorganic mineral matter from the human body and this process will be impeded if the water you drink is already contaminated. Experts including those who oppose continuous drinking of distilled water agreed that it detoxifies the human body system. Therefore distilled water is always recommended for drinking. The volume of distilled water produced per hour can be increased tremendously by increasing the volume of the tank, increasing the surface area of the condenser/lid, increasing the number of heaters, using a set of thermostat to automatically switched on and off the heaters at the required temperature, use of a water pump to feed the tank and the use of a refrigerating unit to cool water meant for cooling the condenser since the lower the temperature of the cooling agent, the faster the cooling rate and the larger the volume of distilled water produced .

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