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Laboratory Water Distiller project

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LABORATORY WATER DISTILLER PROJECT

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Abstract

The goal of the water distiller project is to provide purified water to all hospitals and laboratories for daily use. As per WHO standards, purified water is a great necessity in these facilities for DNA sequencing, protein research, among others. Available water is not always clean because it is transported through pipes and can get into contact with organisms thereby causing the spread of waterborne diseases. Water distillation processes remove 99.9% of contaminants and water chemicals like fluorine and calcium to produce pure water. For every use, the distiller mechanism uses an electric current as the source of energy which is run into a heating element located in the contaminated water (in the boiler) through transferring heat, causing it to boil to steam. The evaporated water (steam) leaves behind 99.9% of the contaminants in the boiler producing mostly uncontaminated vapor. The steam created then enters into the condensing coil where heat transfer takes place and the result is purified water which is directed to the storage container. To construct the distiller unit, individual parts components are first developed in SolidWorks drawings and then assembled based on design calculations and dimensions. Purchased and manufactured parts are then assembled to a complete distiller unit. The system is designed to efficiently transmit heat to the water, heating it to steam thereby providing 1 pint of purified water per hour. All components of the unit are cost efficient making it affordable to everyone. The machine is easy to operate and requires minimal maintenance.

INTRODUCTION

Description

All laboratories require purified water for daily use. As per WHO requirement and standard, purified water is a necessity for hospitals and laboratories for PCR, DNA sequencing, protein research and chromatograph. Unfortunately, the water available in hospitals and laboratories is piped water that is transported through pipes and can get into contact with organisms from waste and sewerage outlets. This eventually attributes to widespread of waterborne diseases. Due to this unsafe water supplies, piped water poses health risks and considered unsafe for laboratories and hospitals use. Therefore, there is a need for alternative and effective solution to address this problem.

Motivation

This project was motivated by a device that would purify water of contaminants through distillation and provide quality affordable pure water.

Function statement

To provide distilled water from unknown water.

Requirements

- It should be easy to transport and operate.
- To provide a minimum of 1 pint of contaminants free water/ hour
- It should cost less than $450.00 to manufacture (Affordable)
- It should weigh less than 24 pounds

Research Application

To investigate the effectiveness of the distiller in providing quality pure water

Specific Objective

To determine the quality of lab water distiller in providing affordable, pure water as per WHO standards after distillation process. To assess the suitability of using Lab water distiller in purifying water by comparing distilled water and other water.

Research hypothesis

The distillation of unknown water using the distiller will shed light to the potential resource that lie in unknown water.

Success Criteria

With expectation to provide a minimum of one pint per hour, this device will have a unique condenser design to ensure the droplets of distilled water remains in contact with cooling coils for the longest time producing cold distilled water and pre heating the boiler to increase efficiency.

Scope of this effort

- Should buy individual components to assemble
- Design interface like carbon filter housing, carbon filter holder, and steam valve.

Bench mark

According World Health Organization, 9 million deaths annually attribute to waterborne diseases. 80% of this death are attributed by worldwide infectious diseases due to unsafe water supplies. Bottled water companies have provided the solution for this problem by producing pure bottled water. The truth is that this is not effective solution because bottled water is expensive, have chemicals risks and poses health risk making it unsafe for laboratories, hospital use. There are large distillers that can provide solution for this problem but smaller distillers like desk top distillers are most preferred to address this need effectively.

Success of this project

Success of this project will depend on the design and fabrication of desk top distiller with efficiency and effectiveness to meet the requirement of producing free pyrogen water at a minimum of one pint per hour.

DESIGN AND ANALYSIS

There is a need to develop a device that can heat unknown water in a distiller using heat energy. The process requires to design and manufacture an electrical heating element to provide enough thermal energy to heat water to steam.

ANALYSIS

First, determine the following:

- Required heat transfer energy, Q total
- Required power demand per hour
- Heater unit: conversion efficiency
- Heat loss of unit, outside surface temperature (safe touch)
- Surface temperature of the heater if there is no water
- Water storage unit, dimensions and load steam flow rate
- Cooler materials: heat transfer specifications
- Cooler materials: durability/corrosion
- Controller: heating load control
- Controller: heating cut off
- Material selection
- Benchmark process steps and time
- Inspection for quality and dimension

Required heat transfer energy, Q total

To determine the total energy required (Q total), let assume that

Q total = E1 + E2 where,

E1 = Energy required to reach boiling point

E2 = Energy required for vapor phase transformation

To get E1, E1 = M (Cp) (T2 – T1)   where,

M =   mass of water = 1kg

Cp = specific heat = 4.2kj/kg/k

T2 = boiling temperature = 100 degrees

T1 = surface temperature = 15 degrees (predicted)

E1 therefore is calculated as follows,

E1 = 1kg (4.2kj/kg/k) (100 – 15)

E1 = 357kj/kg

To get E2, E2 = M (hg – hf) where,

M = mass of water = 1kg

H_g = saturated vapor energy (From saturated water pressure Table A-5)

H_g = 2675kj/kg

H_f= saturated liquid energy (again from Table A-5) = 417.5 KJ/kg

E2 therefore is calculated as follows,

E2 = 1kg (2675kj/kg – 417.5kj/kg)

E2 = 2257kj/kg

Q total = E1 + E2

Q total = 357kj/kg+ 2257kj/kg = 2614kj/kg

Required power: demand per hour

With Q total = 2614 KJ /kg, determine maximum power required per hour for the unit. 2614kj/kg (1hr/3600sec) (1000j/1kj) = 726 joule /sec (W) approx. 726W on the higher side.

With 726W, can determine the maximum current draw required for,

V = 120V, then P = IV where P = 726W, V = 120V

I = P/V = 726/120 = 6.05amps…approx. 6amps

V = 240V, then I =P/V = 726/240 = 3.025 amps approximately 3amps

Therefore, the unit electrical requirement is as follows,

For 120V, will use 6 amps, but is rated 6.6A.

Power required = 726 Watts, but is rated 800 Watts

Determine heater unit: conversion efficiency

The heater unit is predicted to have a heat energy efficiency of 95%. This means it is able to utilize 95% of the incoming heat energy to heat water to steam. The rest of the heat is lost through the lateral surfaces of the unit.

To determine the amount of energy utilized to heat water to steam,

Predicted Q utilized = Energy input * efficiency

Energy input (Q total) = 2614 KJ/kg

Predicted efficiency = 95% = 0.95

Predicted Q utilized = (2614KJ/KG) (.95) = 2483.3 KJ/KG

Heat flow

With the heating element made of copper when temperature rise from 15 degrees to boiling temperature (100 degrees), the direction of the heat flow can be determined by:

Heat flow (Q) = (H)(A) (Boiling temperature – Room temperature)

Where, H = heat transfer coefficient

A = area of copper

h = Nu k/D where Nu = 3.66, d (diameter of copper) = 0.0254m

K = thermal conductivity of copper = 385.3 w/m/k

h = 3.66 (385.3w/m/k)/0.0254m = 29539 w/m/k

A = 3.14 (0.0127) (0.0127) = 0.001 m^2

Heat flow = 29539w/m^2/k(0.001m) (100 – 15) = 2510.8 w/m/k

Cooler materials: heat transfer specification

Once the steam enters the condenser, it travel through a long vapor path where heat transfer takes place ie cool air from the cooling fans causes the steam to condense.

The distillate is then re-routed to a take off pipe and collected into a reservoir. At this stage, volatile chemicals like chlorine, calcium are stacked at the top of the packing and are allowed to escape.

The condensing coil is made up of stainless steel and has a specially formed spiral innertube providing a long path for good heat transfer.

Condensing coil: heat transfer specification

The thermal conductivity of stainless steel (205) and and its has good machinability though copper is much recommended material for condensing coil because it transfer more heat than aluminium. One advantage of copper is that if there is leak, it can easily be fixed unlike aluminium. Some of its properties are:

- Good electrical conductivity
- Good thermal conductivity
- Corrosion resistance
- Easy to alloy
- Ductile
- Tough
- Easily joined
- Recyclable
- catalytic

Determine the heat loss of the unit outside surface temperature (safe touch)

The transfer of heat energy is always from the higher temperature medium to the lower medium, and its stops when the two medium reach the equilbrium temperature. With the efficiency of 95%, the heater unit is expected to lose approximately 5% of the heat through lateral surfaces of the unit.

The amount of heat loss to the surface is the same as the amount of heat gained by the surrounding surfaces.

To determine the predicted amount of heat lost to the outside surface:

Qin =2614kj/kg or 726W

Qout = (Energy input)(5%)

Qout = (2614kj/kg)(0.05) = 130.7kj/kg (Predicted)

To minimize amount of heat loss , the unit requires to be well insulated so that only a negligible amount of heat can pass through the surface.

Contoller: Heat cut-off

The distiller unit works on the principle of evaporation and condensation. An electric heating element (800 Watts) boils water in a stainless steel boiling chamber to 100 degrees which eventually turns to steam. When water boils to steam in the boiling chamber, a timed float switch automatically stops the cycle. This controls the minimum and maximum heat load in the boiling chamber because it shut off the element when it exceed. The controller also act as safety shut off switch which turns the unit off should it overheat. However, safety standard should observed when connecting float switch electrical wires.

DESIGN AND ANALYSIS

Design Description

The initial design comprises of a distiller unit sketch shown in the Appendix A-1. Individual parts components are developed in solid works and then assembled into a complete assembly drawing as shown in Appendix B.

Performance Predictions

The heater unit is predicted to have an efficiency of 95%. This means it is able to utilize 95% of the heat energy produced by the heating element.However, to minimize energy loss, insulation is done to conserve energy and improve the efficiency of the unit.

Description of Analyses

As shown in Appendix B, figure B-8 show a drawing of the steam valve in which steam pass to the condenser. Figure B-7 shows the drawing of a condenser and its surface area required for heat transfer to take place. Figure B-4 show a drawing of the filter holder where chemicals are filtered out to produce 99% pure water. Figure B-13, shows a drawing of a boiler in which water is heated to steam. Cool air from cooling fans causes the steam to condense. Figure B-15 shows a drawing of a boiling chamber liner which houses the main tank. Figure B-20 shows a complete working distiller unit.

Scope of Testing and Evaluation

The scope of the testing and evaluation on the lab water distiller must use at least 95% of the incoming heat energy.

Analyses

Design issue

- First design is the design of the heating element
- Second design is the design of the condensing coil

Calculated parameter

The appendix of the analyses shows the sketchs and calculations required to generate an effective lab water distiller unit. The calculations are meant to explain the above design issues.

As shown in Appendix A, figure A-1 show a sketch of the project (Lab water distiller). Figure A-2 shows a sketch of a copper wire and calculated surface area of the material required to construct the heating element. Figure A-3 show a complete sketch of a heating element. H-type shape provide two perforated ends where heat energy is emitted to the boiling chamber. Calculation is done assuming that Qtotal = E1 + E2. Figure A-4 shows a sketch of a condensing coil which is coiled to provide a long vapor path where heat transfer take place. Cool air from cooling fans causes the steam to condense. Figure A-5 shows a sketch of a boiling chamber with energy total input to the unit. Figure A-6 show a sketch an insulated boiling chamber to minimize energy loss.

Device: Parts, Shapes and Conformation

The distiller unit will be manufactured by the following parts.

Device: Parts (carbon filter holder, housing, steam valve)

Stainless steel sheet metal
Aluminum tube 3/8" O.D

Device Assembly

The device consists of the parts in the Parts, Shapes and Conformation above. Others remaining parts of the units are in the Appendix C parts list and are purchased, assembled and some are welded and joined.

Tolerances, Kinematics, Ergonomics

Tolerances

Tolerances for manufactured parts and other parts of the unit are as low as +/– 0.1. For joints and drilled holes would require accuracy at +/ - 0.1.

Kinematics

The unit is designed to be placed on countertops in the laboratories and in hospitals and it require no or minimal movement.

Ergonomics

The units require no movement and is easy to operate and therefore demands less skills to use it.

Technical Risks Analysis, Failure mode Analysis, Safety factors, Operational limits.

There are few possible risk in this device ; the unit can overheat and burn the user incase controller fails, safety switch off switch fails and when the operator use it beyond the recommended limits.

METHOD AND CONSTRUCTION SECTION

Methods

The laboratory water distiller project is designed and analyzed using resources and personel from Central washington University Mechanical Engineering Technology department. Some of the project's parts are designed and manufactured in the Mechanical Engineering Lab . Examples of those parts are carbon filter housing, housing holder and steam valve. Other parts of the distiller are purchased and assembled.

Distiller Construction Approach

To fabricate the water distiller that would function effectively, the following design considerations must be met:

Design Considerations

The unit is made of stainless steel because of the following properties

- Resistance to corrosion

- Durability
- Good thermal conductivity
- Good ductility
- Good machinability
- Resistant to chemical attack

The design of the distiller unit is largely art in that different components (parts) must be accommodated. Some of the technical requrements already met are:

- Strength
- Appearance
- Cost to manufacture
- Weight
- Durability, size and stiffness.

Distiller's Specifications

- Width: 13.75 inch (35cm)
- Depth: 9.875 inch (25 cm)
- Height: 15.75 inch (40 cm)
- Rated current draw : 6.6 Amps, 120 V
- Rated power demand: 800 Watts

Manufactured parts Construction

Carbon filter housing

Carbon filter is a proven option to remove impurities and organic chemicals that give objectionable odors or tastes to the water. Once the steam flows through the cooling tubes and condenses back to into pure water, the carbon filter (located upper part of the unit) removes all potentially harmful organism to make pure water. For this to work, the carbon filter is placed in a stainless steel filter housing designed to slide into the guides in the distiller and holds the carbon filter pack.

Design requirement

- Stainless steel sheet

Properties of stainless steel

-Good thermal conductivity

-Resistance to chemical attack

- Resistance to corrosion

Manufactured Parts Construction Methods

Carbon filter housing was constructed from stainless steel sheet based on design calculations, for example it will be 1.5inch length by 1inch width.

To construct it, a sheet of stainless steel is cut at a given dimensions and then bend the edges (¼ inch) where the guides holds the housing. All joints are welded to avoid leakages.

Manufacturing issues

There was a challenge when welding the joints because of lack of experience in welding, holes mismatch but assistance from welding team in the Welding and Casting Lab was provided.

Carbon Filter Holder and Steam Valve

To fabricate the carbon filter holder and steam valve to continuously produce distilled water, the following materials or components are required.

- Stainless steel sheet/plate
- Aluminum tube 3/8" O.D
- Screws
- Clips

Design requirements

Stainless steel sheet

Stainless sheet is used because of the following properties

- resistance to corrosion
- durability
- good thermal conductivity
- resistance to chemical attack

Stainless steel sheet - used to construct the main tank. The tank houses the boiling chamber and electrical heater. The tank capacity is 1.5 gallons and has upper part open end of the tank is slanted to make the condensate flow down to the collector under the influence of gravity.

Electrical heater: heater used in this system is rated as 800W. The decision was to buy the boiler which comprises of the main tank and electrical heater rather than fabricating one. It has all the properties of a standard distiller boiler.

Clips – Screw adjustable are used to ensure that all joints are tight enough to prevent leakages.

Other Parts

1. **Main tank** – It houses the boiling chamber and electric heater. It is constructed from stainless steel sheet based on the dimension obtained from the design calculations.

2. **Boiling Chamber liner**…is constructed from stainless steel sheets based on design calculations. It houses the main tank.

3. **Condensing coil**….is constructed from aluminum. The decision to order the aluminum coil was made after the copper design failed during construction.

MANUFACTURING ISSUES

Condensing coil… made of copper tubing, 3/8” * 10 ft long. Bending process used to make this coil. To do this, a soft annealed copper tubing was ordered and rolled around the pipe of diameter 5.28” at about 7 times. However, the bending process was challenging because you cannot roll the copper to the required dimension and rotate the pipe at the same time. A helper was needed to rotate the pipe while you roll the copper tube into equal spiral rings; to avoid damaging the copper surface. However, the copper tubing **broke into pieces** during bending process and have to order a complete aluminum condensing coil due to time factor.

Main tank – constructed using stainless steel sheet bent and welded based on the design calculations, 12” long by 10” wide by 14” high. Had to order the boiler with design specifications.

Electrical heater - the heater is **rated 800W**. The boiler consist of the heater, the chamber and was order as one part.

Distiller Design Testing

First in the design process, the size of the distiller unit, heating system, condensing system is calculated. The specifications of the rest of the remaining parts of the system are then determined.

Finally before construction, the system is designed in a 3D models of the parts (based on the information from suppliers) and their assembly.

Design Test

The following design requirements will be tested:

- Heating system must generate 800Watts power to heat water to steam.
- Condensing coil must be 10 feet long enough for good heat transfer.
- The system should weigh less than or 24 lb.

Test Method

Once the construction is complete, boiling tank will be filled with unclean water and plugged in to the power source. Water will be heated to steam which enters to condensing coil and eventually to the storage container. If one liter of pure water gets into the container within an hour, that would be considered as success of the project. If not, system adjustment has to be done to figure out the source of the test.

TEST 2

ENERGY COMSUPTION TEST

The purpose of the energy consumption test is to ensure that the distillation process runs effectively to meet requirements; provide 1 pint of water per hour. For excellent performance, the distiller unit requires simultaneous heat input and this test is performed to calculate how much energy is required to produce 1 pint of water per hour.

Predicted Value

The system is predicted to have efficiency of 95%.

Procedures

- Fill the boiler with 1kg of water and take surface temperature of water
- Record the temperature in the table and insert the boiler to its position
- Plug the power cord into electric source and then the Ammeter
- Plug the unit cord to the Ammeter and set the Kilowatts reading to zero. Turn on the power.
- Press the on/off and start cycle buttons to start the cycle. Put the timer on.
- Wait for 20 to 25 minutes for water to boil
- Take the temperature of the boiling water and record it in the table
- Put the storage container to its position and watch as pure water flow into the container.
- Stop the timer and the cycle after 60 minutes and measure the amount of pure water in the storage container. Record the Ammeter reading in Kilowatts/hour.

Results

Boiler water(kg)	Time (min)	Thermal Energy (kj/kg)	Electric Energy (kj/kg)	Pre. Effi. %	Calc. Eff. %	Pure Water (ML)	Pass/fail Or fair
1	60	2614	2808	95%	93%	590	fair

Efficiency = thermal energy/ Eletric energy (100%)

= 2614/2808 (100%) = 93.09 %

The test shows that the efficiency is almost close to predicted value and so is successful.

Design Test

The purpose of design testing is to ensure that the distiller function effectively to provide 1 pint of pure water per hour. The machine has been constructed based on the following design considerations.

- Made of Stainless steel material
- It should be easy to transport
- Easy to manufacture
- Weigh less than 24lbs

The above design constraints should therefore be tested as follows:

Stainless Steel material – Take a sample of material used in the construction of the distiller and determine material properties. If the material has good thermal conductivity, good durability, resistant to chemical attack, good machinability then be aware that the material is Stainless Steel material. If not, change the material order the right one.

Easy to transport - Lift the machine with your hands and move from one point to the other and determine how easy is it to transport.

Weigh less than 24lbs – Lift the machine and place it on a weight scale and take the scale reading. If the readings are greater than 24lbs, figure out how to address this problem.

Testing Schedule

The purpose of the testing schedule is to provide 1 pint of water per hour. The testing schedule is divided into test sections as shown in the Gant chart.

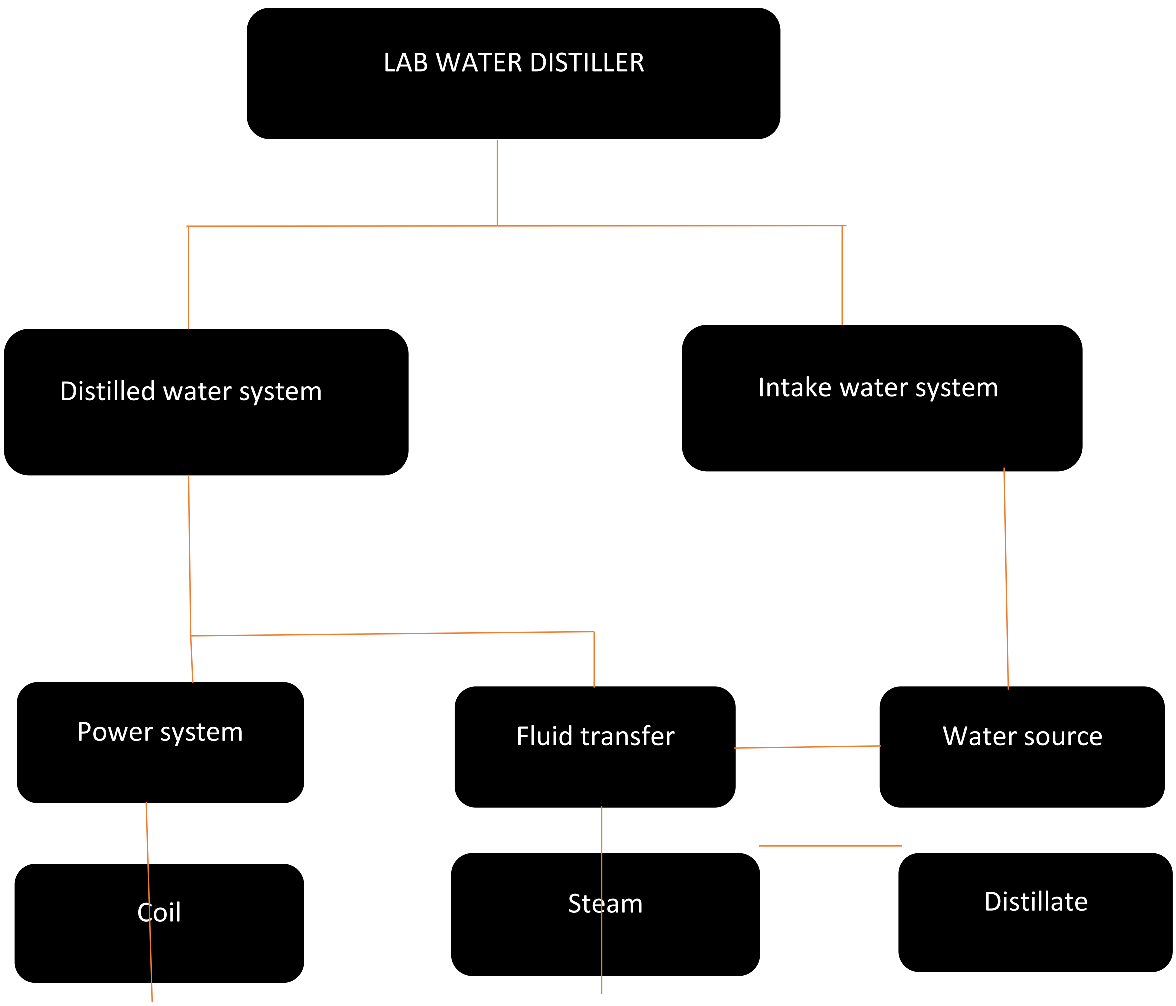
Test1 (Performance test): The allocated time for this test was approximately 3.5hours. This is because the test involved 3 trials with each trial taking approximately an hour. The remaining time was used to set up the test and data recording.

Test 2 (Energy Consumption test): The allocated time for this test was 1.5 hours. The test involved 1 trial taking approximately one hour and the remaining 30 minutes was used for set-up, electrical energy calculation and data recording.

Test 3 (Design testing) The allocated time for this test was 30 minutes. The test involved determining the weight of the unit, dimensions and data recording.

All the tests were conducted as scheduled in the Gant Chart.

A DRAWING TREE



Manufacturing issue

The manufacturing processes should strictly follow the lay down schedule. The purchase of materials was done on time to with out delay. Construction materials were delivered on time to carry out construction procedures with a uniform manufacturing layout because delivering each part at a time leads to different manufacturing layouts. The design process should started early to avoid redesigning.

Discussion of assembly, sub assemblies, parts, drawings

This project is an assembly of many different parts as shown in Appendix A and B. Figure B-1 shows a drawing of the heating element which is made of copper which is a good thermal conductor of heat. The heating element heats the water and brings it to a boiling point (100 degrees). At 100 degrees, water turns into steam and is channelled through a long vapor path in the condenser where heat transfer takes place. Figure B-2 shows a drawing of the condenser where the steam is cooled down into pure distilled water. The condenser is made of copper and has a long spiral coil to provide good surface area for efficient heat transfer. Figure B-3 shows a drawing of the cooling fan made of sheet metal and a motor to rotate the fan. As the steam leaves the boiler, it goes past a gas release vent and enters the condenser where cool air from cooling fan causes it to condense to pure water.

TESTING METHOD

Introduction

The purpose of this testing method of this project is to provide drinking water to laboratoties and hospitals free of pyrogens and organisms from sewerage outlets and chemical added as part of water treatment process. The device to be tested are the heating element, condensing coil and the cooling fan.

The testing process was in Senior project lab Hogue 211 in Mechanical Engineering Hogue Building. The tested device must be:

- Heating element must generate 1290kj/kg energy to heat water to steam.
- Condensing coil must be 20'', long enough for good heat transfer.

- All devices should weigh less than 4 lb.
- All devices should cost less than $200 to manufacture.
-

Method/approach

The heating element will be plugged into eletrical circuit with 4 amps

The heating element will be plugged into circuit wth 6.6 amps current,120V which use 6 amps while operating . It is then submerged into closed container with water which is expected to boil to 100 degrees. Once the water starts boiling the condensing coil is hooked unto the container where the steam is expected to pass through the spiral coil on its way to cool air from the cooling fan and enventually to the storage container..thereby providing pure water .

TEST PROCEDURES DESCRIPTION

Test procedures

Testing procedures was conducted in the Senior project Hogue 211 table.

- Place the manufactured heating element, condensing coil and the coiling fan on the testing table.
- Plug in the heating element unto the circuit with a current 6 amps for 120V
- Place testing container on the testing table
- Pour a litre of water into the container and place it on the testing table.
- Submerge the heating element and cover it with a lid. Covering it with a lid prevent the vapor from escaping to the surrounding surface.
- Connect the condensor coil inlet with testing cointainer outlet.
- Connect the storage container inlet with condenser outlet.
- Switch on the power and start heating the water in the testing container.
- Place the cooling fans underneath the condensing coil and switch it on after the water has boiled for 5 minutes.
- Upon reaching 100 degree, water turns to steam and so switch off the power when the container is ¼ full. Refill the water and repeat the process for an hour with a timer on for every process.
- Measure the volume of pure water distilled in the storage tank in an hour

Expected performance results

Although there is the possibility of energy loss through the container surfaces , the volume of water collected in an hour is expected to be over 1 pint. This shows that the test was succeful and indeed will be far much successful when 95% of the energy is used .However, saftey must be taken into consideration when testing the performance of the unit by not touching the hot surfaces like lid, boiling water, testing container surfaces as this may lead to burn. Wear protective clothing like gloves and saftey glasses.

Deliverables

Trial	Time (minutes)	Volume of Water used (L)	Inlet Temp.	Outlet Temp.	Qin W	Qout W
1	20	1	15	94	370	100
2	15	3/4	50	98	340	120
3	10	3/4	48	95	300	105
4	15	3/4	55	98	320	104

BUDGET/SCHEDULE/PROJECT MANAGEMENT

Initial Proposed budget

The budget for this project is estimated to be less than $500. It includes the parts, labor and transportation.

Appendix C shows an estimated budget as shown below.

Parts	Quantity	Source	Estimate	Actual	Total
120V	1		$ 15.00	$ 18.00	$18.00
240V	1		$ 18.00	$12.00	$12.00
Copper	10 ft		$ 18.00	$ 8.40	$8.40
B. tank	1		$ 20.00	$86.00	$86.00
P cord	1		$ 18.00	$26.70	$26.70
Connector	1		$15.00	$18.00	$18.00
switch	1		$15.00	$2.50	$2.50
Top cover	1		$5.00	$ 35.00	$35.00
Insulation	1		$4.00	$3.50	$3.50

Cooling F	1		$14.00	$86.00	$86.00
Fan motor	1		$7.50	$0.00	$0.00
Stand	1		$8.50	$0.00	$0.00
S. switch	1		$7.50	$3.50	$3.50
Carbon F	1pack		$5.89	$3.50	$3.50
Screw,fan	1 pack		$ 8.00	$4.50	$4.50
Guard fan	1		$12.99	$7.50	$7.50

Screws	10		$4.99	$2.50	$2.50
Hose Cl.	1		$5.98	$0.00	$0.00
Filter cu.	1		$21.00	$0.00	$0.00
Adapter	1		$14.00	$12.50	$12.50
T. cover	1		$15.00	$35.00	$12.50
Nut	10-24		$1.89	$2.50	$2.50
Nut	8-32		$2.00	$2.50	$2.50
Jar	1 gal.		$9.89	$8.50	$8.50
Assembly	1 door		$7.59	$16.00	$16.00
Fan blade	1		$3.99	$0.00	$0.00
			293.43		

Parts were orderd on time from different suppliers who ship them on time.

The estimated cost for the unit is $ 500 including the labor any other issue that may arise .

Labor estimate cost is $ 100 noting that a lot work was done by the owner.

To funding of the project came from individual contributions and Engineering department to ensure the success of the project.

PARTS, COST AND BUDGET (Refer Appendix D)

Part #		Quantity	Description	Estimated cost	Actual cost	Total cost
120V	240V					
		10ft	Copper wire	$9.50/ft	$8.40	$8.40
718B	718BV	1	Boiling tank	$ 20.00	$86.00	$86.00
7246		1	Power cord	$ 20.00	$26.70	$26.70
7275	7275	1	connector	$ 15.00	$18.00	$18.00
642	642	1	On/off switch	$ 15.00	$5.50	$5.50
45014	45014	1	Top cover	$ 5.00	$35.00	$35.00
45016	45016	1	insulation	$ 4.00	$3.50	$3.50
667	667	1	Fan box	$ 14.00	$12.00	$12.00
45517		1	Cooling Fan		$86.00	$86.00
		1	Condensing		$87.00	$87.00
643	643	1	Start switch	$ 7.50	$5.50	$5.50
45518	45518	1 pack	Carbon filter	$ 5.89	$3.50	$3.50
	9025	1	Screw, fan	$ 2.00	$4.50	$4.50
9342	9342	1	Guard, fan	$12.99	$7.50	$7.50
9029	9029	10	Screws, SM	$5.98	$2.50	$2.50
9204A	9204A	1	Adapter	$14.00	$12.50	$12.50
9070	9070	#10-24	Nut	$ 2.00	$2.50	$2.50
9003	9003	#8-32	Nut	$ 1.89	$4.50	$4.50
745	745	1 gallon	Jar, w/lid	$ 9.89	$8.50	$8.50
713A	713A	1 door	assembly	$ 7.59	$16.00	$16.00

Devices Parts

Lab water distiller (Heating element)

- 1 Copper tubing (low density) with magnesium oxide and nickel plating (10’’)
- 1 Wire connector
- 1 Power controller (k type thermocouple
- 1 Lead wire (4”)

SCHEDULE (Refer Appendix E)

The schedule is attached in the Appendix E. It is divided into plans per quarter. Some of the crucial activities in the project are developing and writing the proposal, material selection and analysis, assembling and testing of the device. The schedule depends on the work priority, time and availability of materials and parts. Figure E-1 shows the completed Gantt Chart.

Proposed Schedule

The majority of parts for this project was ordered from different suppliers from different stores even internet store. The parts were ordered early to enable the construction of the unit to begin early as shown in the schedule. However, it is expected that tools for construction and testing be provided by Mechanical Engineering department because they are not in the budget. Tasks allocation, sequence and estimate duration is highlighted in the Gantt Chart.

The project is estimated to take 90 days to complete depending on the availability of the material. The material/parts were purchased on time and shipped on time. This allowed the construction of the project to begin on time as scheduled.

Budget /Schedule

The proposed budget for this project is approximately $500. Due to several changes in design; like changing the position of water collection tank in the distiller unit has saved time, labor and cost to $480. Some parts have already been ordered through Amazon website and are expected to arrive without delay in order for the construction of the distiller unit to kick off.

Other parts like boiling chamber and the base are not yet ordered because has to match the electrical specifications and dimension of the part with calculation in the report but seeking help from the Lab Machinist on how to match the parts specification and process the order as fast as possible.

SENIOR PROJECT SCHEDULE

started on time ended on lat e
started on time ended on time
started late ended late
started early ended early

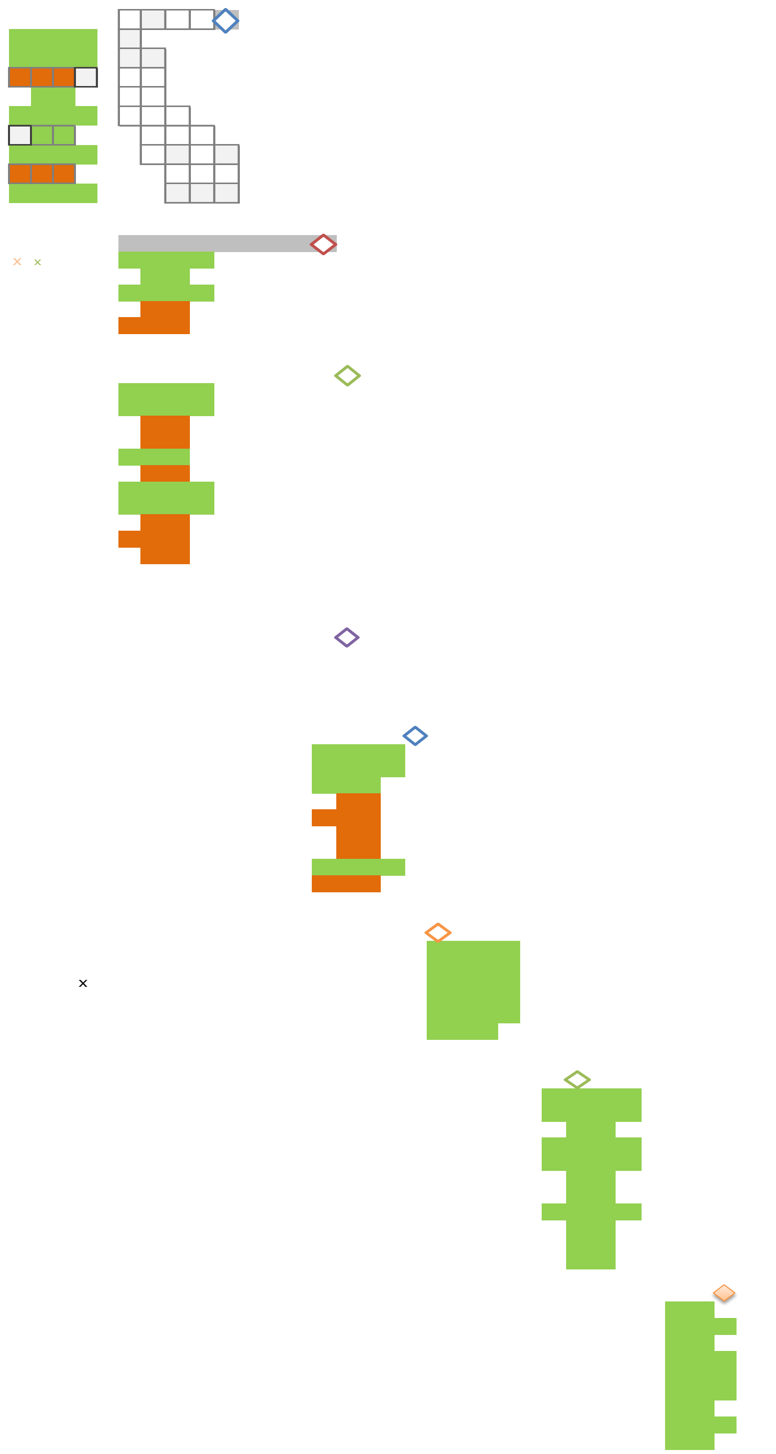
Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

LABORATORY WATER DISTILLER

DUNCAN NJUNGE **DUNCAN NJUNGE**

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	%Com
1	Proposal*			
1a	Outline	20	10	
1b	Intro	20	2	
1c	Methods	15	3	
1d	Analysis	10	2	
1e	Discussion	15	2	
1f	Parts and Budget	20	4	
1g	Drawings	30	8	
1h	Schedule	20	2	
1i	Summary & Appx	30	2	
	subtotal:	180	35	
2	Analyses			
2a	Heat Trans=>Geo	10	4	
2b	Heat transfer calc	15	4	
2c	Power Anal=>Geo	15	5	
2d	power Analsis calc	20	4	
2e	Tolerance => Geo	10	4	
	subtotal:	70	21	
3	Documentation			
3a	part1 h. element drawing	15	4	
3b	part2 arm drawing	10	2	
3c	Energy Calculation	30	20	
3d	part 3 coil drawing	25	20	
3e	Part 4 cooling fan drawing	15	10	
3f	Boiling tank drawing	20	10	
3g	Fan motor drawing	20	8	
3h	Boiling tank liner drawing	15	5	
3i	Wieding boiling tank liner	20	5	
3j	Fan blade drawing	10	2	
3k	update calculation	15	2	
3l	ANSIY14.5 Compl	20	8	
3m	Make Object Files	15	10	
	subtotal:	230	106	
4	Proposal Mods			
4a	Project Robot Schedule	10	4	
4b	Project Robot Part Inv.	15	6	
4c	Crit Des Review*	15	4	
	subtotal:	40		
7	Part Construction			
7a	Buy boiling tank, base	10	4	
7b	Make heating element	20	10	
7c	Make condensing coil	25	15	
7d	Weld boiling plate liner	20	15	
7e	Buy top cabinet	10	8	
7f	Buy assembly parts	15	6	
7g	Take Part Pictures	4	2	
7h	Update Website	r4t4r	2	
7i	connecting parts	10	2	
	subtotal:	114	64	
9	Device Construct			
9a	Assemble purchased parts	15	6	
9b	cut and size h. element	20	8	
9c	cut and size coil	10	6	
9d	cut and size the plate	25	15	
9e	Take Dev Pictures	5	3	
9f	Update Website	4	2	
	subtotal:	79	40	
10	Device Evaluation			
10a	List Parameters	15	4	
10b	Design Test&Scope	20	6	
10c	Obtain resources	20	8	
10d	test 1 report	10	4	
10e	Plan analyses	6	3	
10f	Instrument Robot	15	8	
10g	Test 2 report	15	6	
10h	Perform Evaluation	10	4	
10i	Take Testing Pics	10	4	
10h	Update Website	8	2	
	subtotal:	129	49	
11	495 Deliverables			
11a	short report	20	10	
11b	Presentation1 , outline	15	6	
11c	Write Report	50	10	
11d	Make Slide Outline	20	10	
11e	ppresentation2	25	15	
11f	Make CD Deliv. List	25	10	
11e	Write 495 CD parts	20	15	
11f	Update Website	15	3	
11g	Project CD*	30	18	
	subtotal:	220	97	
	Total Est. Hours=	1062	412	

S October November Dec January February March April May June



=Total Actual Hrs

Labor$ 100

Note: Deliverables*
Draft Proposal
Analyses Mod
Document Mods
Final Proposal
Part Construction
Device Construct
Device Evaluation
495 Deliverables

PROJECT MANAGEMENT

The project required 90 hours to complete, beginning January 4th of 2019 and ending its construction phase on March 11th 2019. The documentation of the project continued until June 1st 2019.

Tasks Estimate Duration Summary

1. Ordering – 10 hours
2. Fabrication – 15 hours
3. Assembly – 15 hours
4. Testing – 20 hours
5. Analysis – 20 hours
6. Final process – 10 hours

Physical Resources

To succeed in this project, different machines in the Machine lab and casting laboratory in Mechanical Engineering Building were used, like drill holes, weld parts, join parts, cut sheets of metals were used in the construction of the unit. Tools like measuring tools, cutting tools, pliers and other required tool are not budgeted for and so had to use Mechanical Engineering Department's tools.

Software Resources

Computers from computer lab in Hogue Mechanical Engineering building were used to make any required drawing or to document project data/ information. Personal laptops were used to get any required information as well as updating data.

Financial Resources

To finance this project, personal contribution was required as well as resources available in Mechanical Engineering Department. Donation, grants, ideas and project parts were welcomed for anyone who would be willing support this project.

DISCUSSION

Design Evolution /Performance Creep

The lab distiller unit is designed that it should well weigh less than 20lbs and dimensions to be height 12”, width 9.5”, and depth 10”. This designed is expected to work to avoid redesigning. The unit was test and test data documented so that adjustment can be done to enhance excellent performance.

Project Risk Analysis

There are a number of risks that are anticipated during the construction process. First is time. Parts and material were ordered on time from different suppliers but there were delay in shipping them which led to time wastage. Lack of expertise in processes like welding, electric wiring knowhow led to delays and prolong the time scheduled to complete construction phase. If the planned design fails, this led to redesigning which means that the analysis will also be changed.

Successful

The success of this project depends on the vast engineering knowledge in heat transfer, material science, SolidWorks and AutoCAD, mechanical design, basic electricity, project management and planning. These skills led to design and fabrication of the distiller with efficiency and effectiveness to meet the requirement of producing free pyrogen water at a minimum of one pint per hour.

Project Documentation

The project information was documented in the engineering note book so that anybody can have access on the development of the project. Any changes done on the project like design change, parts change, process change was done also in the note book because it acts like a point of reference and the project owner manual in case of any question.

The next phase would be method and construction which will kick off on January 4th, 2019.

Manufacturing issues

The construction of the distiller unit is in progress although challenges like holes mismatch, receiving wrong part, parts high cost has been experienced.

To resolve holes mismatch problem, had to re- check the design holes dimensions

and also seek help from the Machine Lab Team. The issue of wrong part (Cooling fan box) has to be resolved by communicating with suppliers and making arrangement on how to receive the ordered part. The cost of some of the parts like boiling chamber is too high noting that one of the goal of this project is to create a system that is highly affordable. This means that the unit should be easy to manufacture. The current manufacturing method seems to be inefficient for large scale production because purchased parts like boiling tank costs $ 230. To resolve this problem, the cost reduction would be to buy a used functioning - boiling tank at $80 which lower the cost of the unit by 60% and make it affordable to the users.

Design testing issues/modification

Laboratory water distiller has been constructed based on the following design considerations:

- Boiling tank rated 800W to heat to steam
- Condensing coil 5 feet long and finned to provide good surface area for heat transfer.
- Well insulated to prevent heat loss to the surrounding surfaces
- Weigh less than 24lbs
- Easy to transport from one location to the other

Therefore, while performing design testing, the following details should be considered for testing:

- Is the boiler heating water to steam?
- Is the evaporated water condensed and separated from the contaminants?
- Is there any leak in the system?
- Is the setup simple and straight forward?
- Is the system structurally sound enough to be transported?
- Effects of available insulation in different parts of the system

The above design test considerations has been done on the unit and passed except the issue of insulation. The system is expected to use 95% of thermal energy to heat water to steam but uses 85% meaning that there is heat loss to the surrounding surface. Insulation materials should be replaced to address this problem.

CONCLUSION

The main reason for this project is to put vast engineering knowledge and skills gained from Mechanical Engineering Course into application of solving problems. Lab water distiller project is therefore undertaken to provide free pyrogen water (pure water) free from organisms from sewerage outlets and chemicals like calcium and fluorine that is added as part of water treatment process.

To address this problem, there is a need to design and manufacture electrical heating element to provide enough thermal energy to heat water to steam.

Analysis

- Determine required heat transfer energy, Q total
- Determine required power demand per hour
- Determine heater unit: conversion efficiency
- Determine heat loss of unit, outside temperature (safe touch)
- Cooler materials: heat transfer specifications
- Material selection
- Controller: heating cut off

The above analysis contributes to the success of the project by calculating the energy required to heat water to steam. With known energy, power demand per hour and current required in the circuit are determined. Heater unit efficiency and unit heat loss is calculated and determined. Cooler materials heat transfer specifications, materials selection and controller heat cut off are determined.

The project predicted design is expected to be successful so that the construction of the unit can be successful. The unit is also expected to function effectively and any challenge that may arise will be addressed. However, health and safety concerns will be observed when undertaking this project.

The design of the distiller unit has eventually succeeded although numerous challenges have emerged resulting to design change. Some of the design calculations has been adjusted to fit the new design calculations which have led to a successfully construct a working distiller unit. Major adjusted areas that have led to success of this project are:

- Heat transfer energy, Q, total now have maximum 800W from 400Watts
- The Water reservoir was underneath the unit but now have designed a place for water container
- Material selected - Stainless stain AISI 1035 and AISI 304.

ACKNOWLEDGEMENTS

A lot of appreciation and a word of thanks goes to Engineering Faculty, advisors:

Dr. Craig Johnson, Professor Charles Pringles, Dr. Choi and the entire Mechanical Engineering Department in CWU.

A word of thanks goes also to Machine Lab Team, Electrical Team, Welding and Casting Team.

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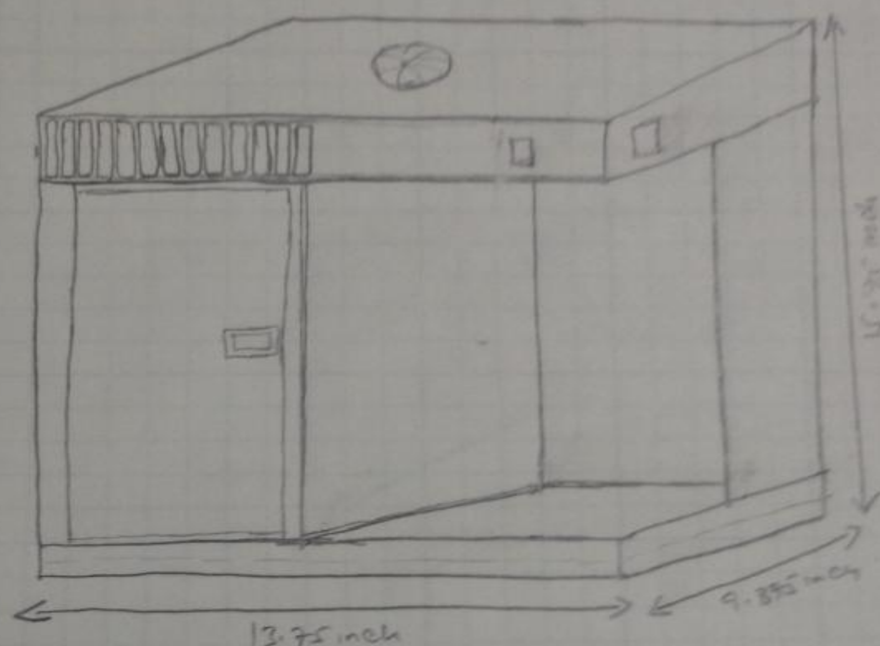
APPENDIX A

INITIAL IDEA : DISTILLER UNIT SKETCH



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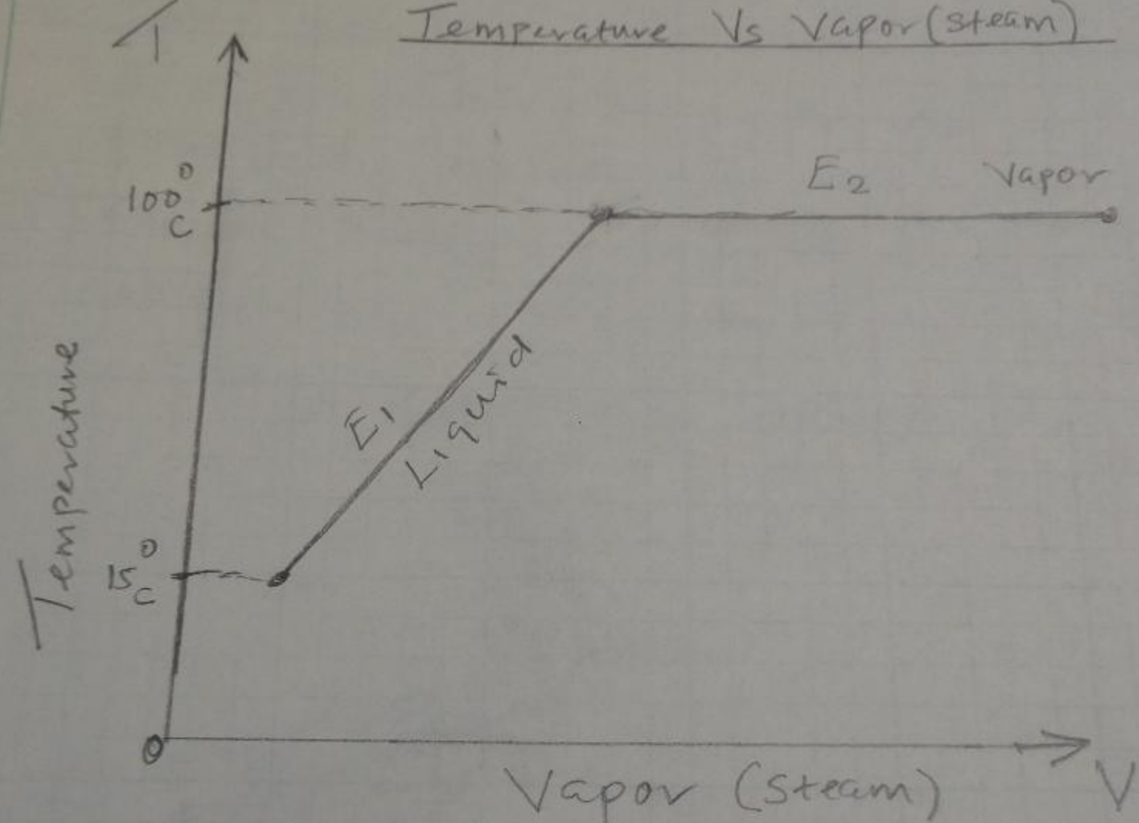
ENERGY REQUIRED TO TRANSFORM WATER TO STEAM (GRAPH)

Temperature Vs Vapor (steam)



$Q_{total} = E_1 + E_2$ where;

E_1 = Energy to reach boiling point

E_2 = Energy required for Vapor phase transformation [Liquid to vapor]

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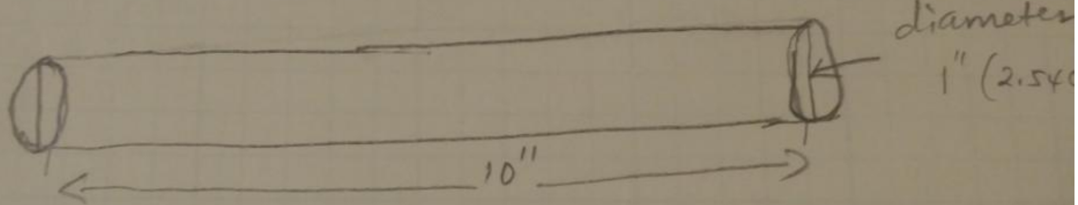
A sketch of copper wire

Area calculation.

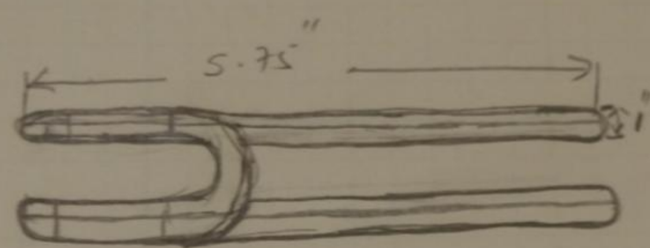


$A = \pi r^2 = 3.14(0.0127)^2 = 0.0005 m^2$

Figure A-2

DUNCAN NJUNGE | Senior project

A sketch of heating element



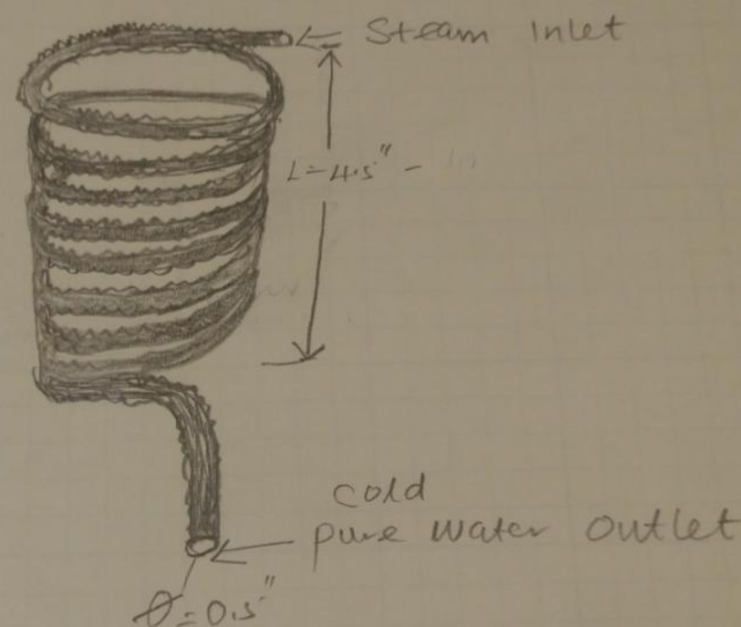
- Copper made heating element.

Figure A-3

DUNCAN NJUNGE | Senior project

Geometry of Condensing Coil.

A Sketch of Condensing coil.

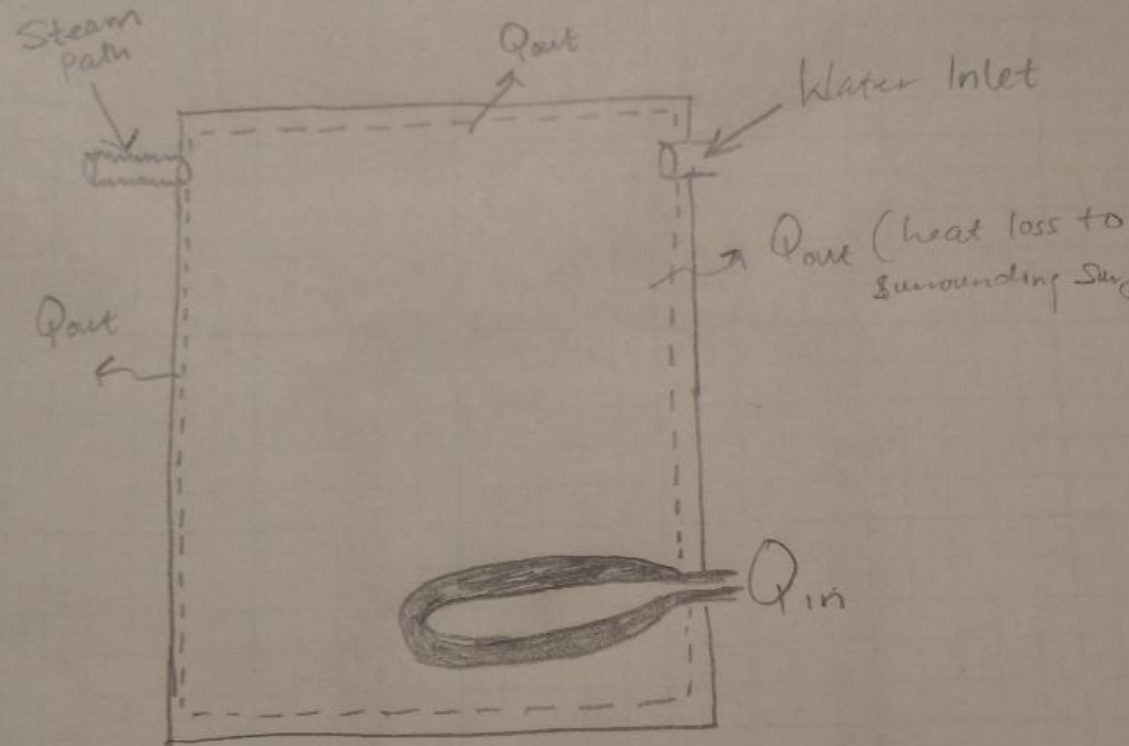


- The condensing coil provide a long vapo
path where heat transfer takes place.
cool air from cooling fans causes th
steam to condense.

Figure A-4

DUNCAN NJUNGE | Senior Project

Heater Unit boiling Chamber



$Q_{out} = Q_{in} \rightarrow 5\%$

$Q_{out} = 1290 kJ/kg (0.05) = 64.5 kJ/kg$

$Q_{out} = 64.5 kJ/kg \rightarrow$ Energy lost to the surrounding surface.

Figure A-5

DUNCAN NJUNGE | Senior Project

TO Minimize heat loss the boiling chamber should be Insulated

INSULATED BOILING CHAMBER

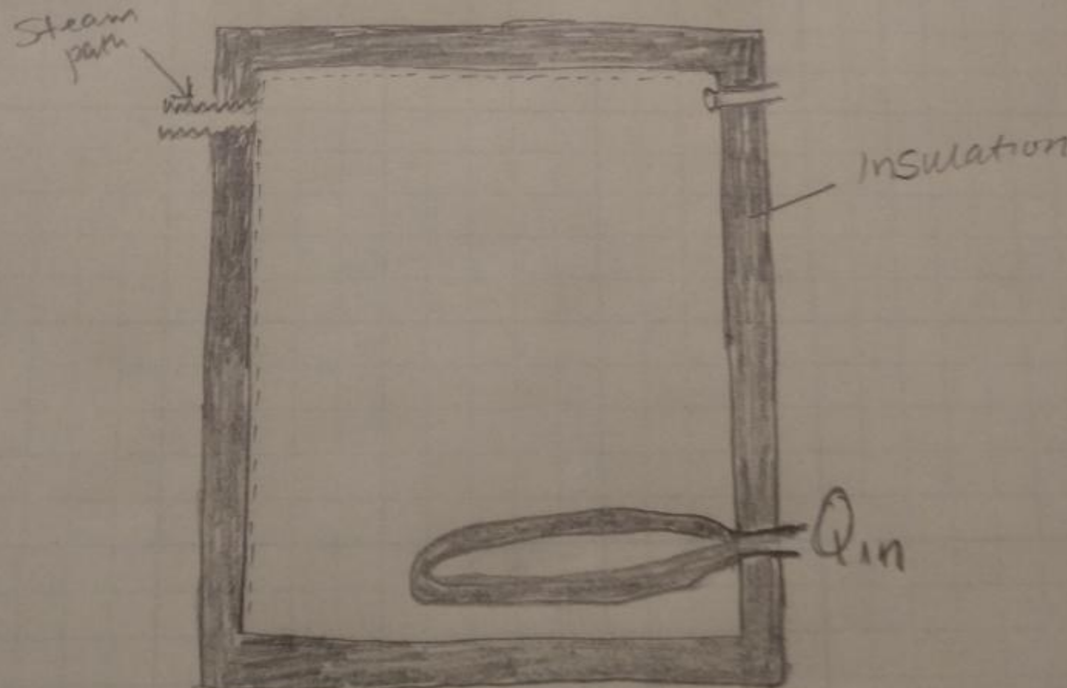
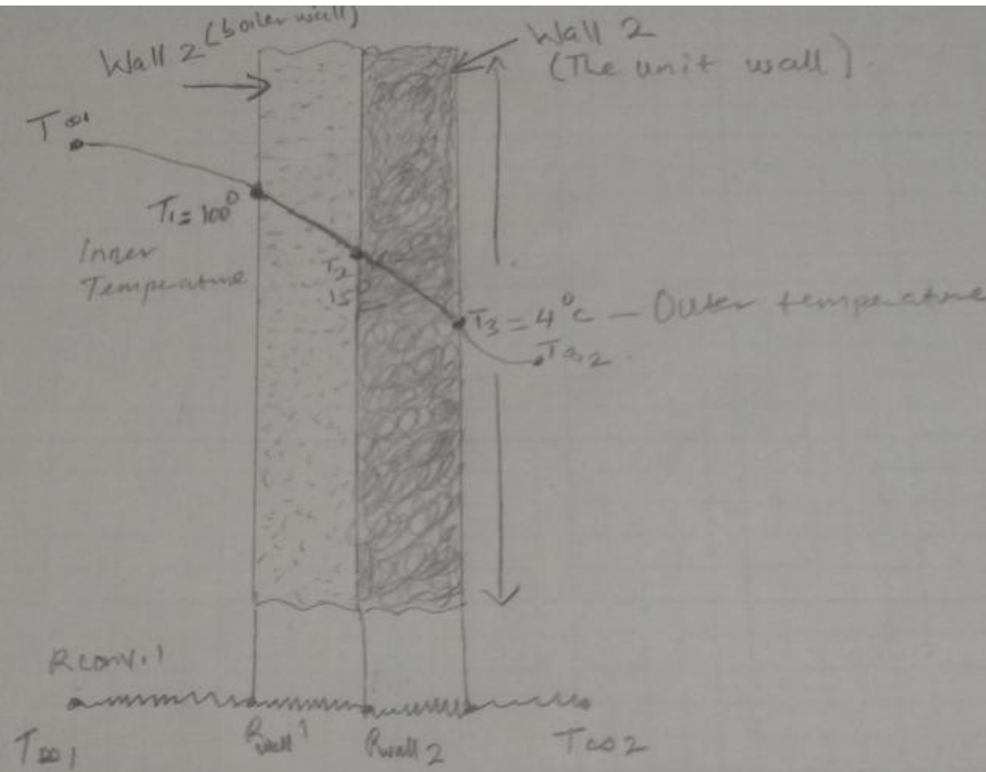


Figure A-6



$h = 0.3\,m$ $L = 0.127\,m$ thickness $= 0.0762\,m$

Steady Heat transfer through the wall

$A = (0.3\,m)(0.0762\,m) = 0.0229\,m^2$

$K = 0.9\,W/m \cdot K$

$$Q = KA\,\frac{T_1 - T_2}{L}$$

$$Q = (0.9\,W/m \cdot K)(0.0229\,m^2)\,\frac{(100 - 15)^0 c}{0.3\,m} =$$

$$Q = \underline{5.8395\,W}$$

Figure A-7

Rate of Heat Loss (Boiler insulation).

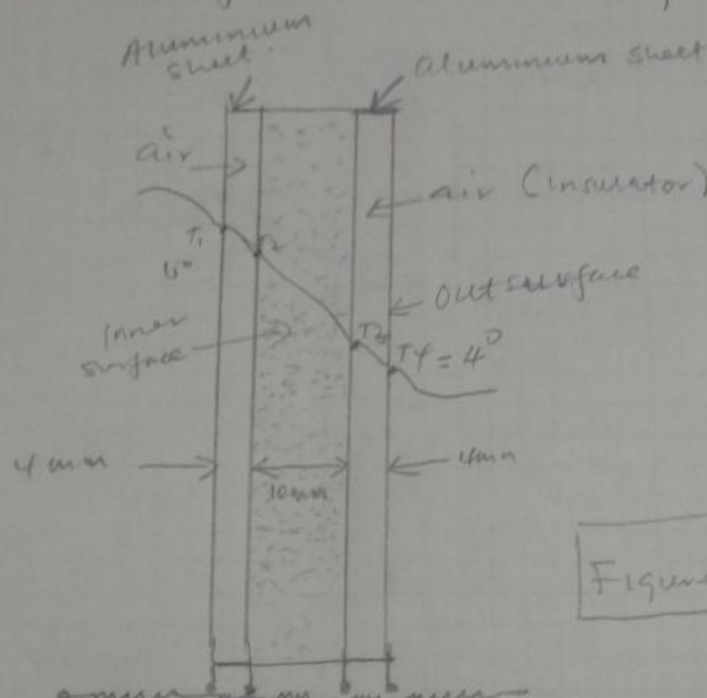


Figure A-8

$T_{\infty 1}$ R_i R_1 R_2 R_3 R_o $T_{\infty 2}$

$h = 0.3m$, $L = 0.127m$, $t = 0.0762m$, Alu. $K = 237\ W/m \cdot K$

$A = 0.127 \times 0.0762 m = 0.0097 m^2$

$$R_1 = R_{conv,1} = \frac{1}{h_1 A} = \frac{1}{(237\ w/m^2 \cdot k)(0.0097 m^2)}$$

$$R_1 = 0.437\ C/W$$

$$R_1 = R_3 = 0.437\ C/W$$

$K_{air} = 0.026\ W/m \cdot K$

$$R_2 = R_{air} = \frac{L}{K_2 A} = \frac{0.3m}{(0.026)(0.0097m^2)} = 128^\circ C/W$$

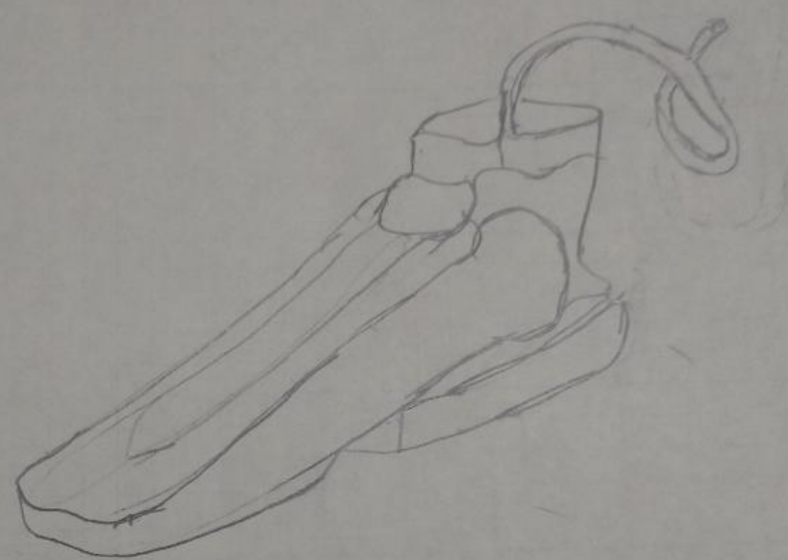
$$R_o = 0.0324\ ^\circ C/W$$

$$R_{total} = R_{conv,1} + R_{alum} + R_{air} + R_{conv,2}$$

$$R_{total} = 0.437 + 0.437 + 128 + 0.0324 = 128.9064\ ^\circ C/W$$

$$Q = \frac{T_{\infty 2} - T_{\infty 4}}{R_{total}} = \frac{(100 - 4)}{128.9} = 0.744\ W$$

SAFETY FLOAT switch



The above safety switch, switch off when the water reaches boiling point thereby prevent the boiler from over heating.

Figure A_9

Heat transfer in Condensing coil.

Geometry of coil fin

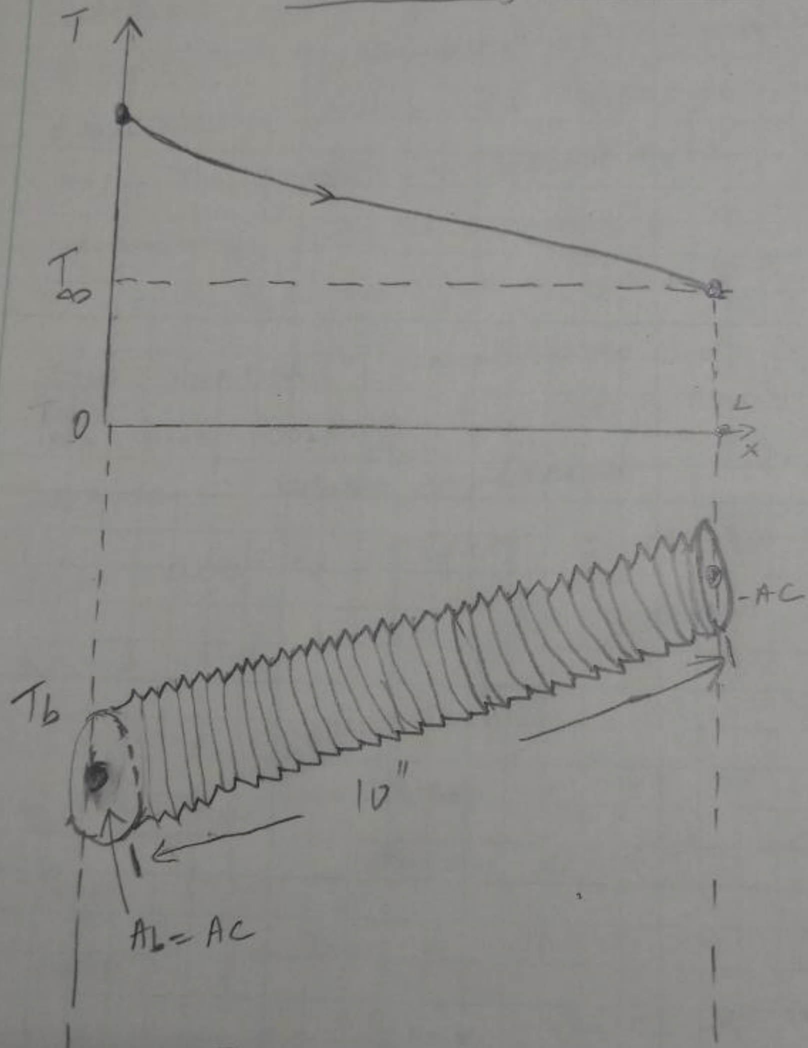


Figure A-10

APPENDIX MET 489B

CALCULATIONS BELOW

(1)

Calculations

Required heat transfer energy Q total

Given:

Mass of water = 0.568 kg — Temp(T_2) = 100°C

Specific heat = 4.2 kJ/kg/K — Temp.(room) = 15°C

Find: Q total

Assumption: $E_1 + E_2 = Q_{total}$

Solution:

$Q_{total} = E_1 + E_2$

$\therefore E_1 = m(c_p)(T_2 - T_1)$

$E_1 = 0.568\,kg\,(4.2\,kJ/kg/K)(100°C - 15°C)$

$E_1 = 202.776\,kJ/kg.$

$\therefore E_2 = m(h_g - h_f)$

h_g = saturated vapor en[...]

$h_g = 2675\,kJ/kg$

$E_2 = 0.568\,kg\,(2675\,kJ/kg - 417.5\,kJ/kg)$

$E_2 = 1282\,kJ/kg$

h_f = saturated liquid e[...]

$h_f = 417.5\,kJ/kg$

$\therefore Q_{total} = E_1 + E_2$

$Q_{total} = 202.776\,kJ/kg + 1282\,kJ/kg$

$Q_{total} = \boxed{1484\,kJ/kg}$

(3) Required power: demand per hour

$Q_{total} = 1484\ kJ/kg$

Given

$Q_{total} = 1484.766\ kJ/kg$

Find: power.

Solution

$$1484.766\ kJ/kg \left(\frac{1\ hr}{3600\ sec}\right)\left(\frac{1000\ J}{1\ kJ}\right) = 412\ Joules/se$$

power = 412 Joules/sec or Watts

power = 412 Watts

(5) **Heat Flow (Boiling Chamber)**

Given

Diameter of copper = 0.0254 M

K = thermal conductivity of copper.

Find

Heat flow

$h = \frac{Nu\,K}{D}$

Nu = 3.66
d = 0.0254 m
K = 401 w/m/K

$h = \frac{3.66\,(401\ w/m/K)}{0.0254\ m} = 57782\ w/m\,K$

$A = 3.14\,(0.0127)(0.0127) = 0.001\ m^2$

Heatflow = (H)(A)(Boiling temp − Room temp)

H = heat transfer coeff
Boiling temp = 100°c
surface temp = 15°c

Heat flow = 57782 w/m/K (0.001)(100−15) = 4911.

Heat flow = 4911 w/m/K

Heat transfer (Condensing coil fin)

Given:

$\dot{Q}_{total}$ in the fin = 1409.8 kJ/kg

P = 10 psia → 100°C — ambient air condition.

15°C → surface temperature.

L (of fin) = 20 mm   50 W/m²/K → heat transfer coefficient

Fin temp = 4°C K = 240 W/m²/K

Find: heat transfer rate of the fin.

$$ML = \sqrt{\frac{4h}{KD}}\,L = \sqrt{\frac{4(50\ W/m^2 \cdot K)}{240\ W/m \cdot K)\,0.05\ m}}\ 0.02 = 0.2582$$

$$A_{fin} = 2.106 \times 10^{-4}\ m^2$$

$$\eta_{fin} = \frac{3}{2mL} = 5.8095\left(\frac{0.3443}{0.3443}\right) = 5.8095$$

$$\text{Efficiency of the fin} = 5.3095\left(\frac{0.1716}{1.0330}\right) = 0.9632$$

$$Q_{fin} = \eta_{fin}\, h A_{fin} (T_b - T_\infty)$$

$$= 0.9632(50\ W\ m^2 K)(2.106 \times 10^{-4})(100 - 25)$$

$$3621 \times 10^{-4} = 0.362\ W$$

$$\boxed{Q_{fin} = 0.362\ W}$$

③ Determine current draw:

Given

Power = 412 Watts,

$V = 120V$ $\quad V = 240V$

find:

current, I

Solution:

$V = 120V$, $P = 412$ Watts

$$I = \frac{P}{V} = \frac{412}{120} = 3.4 \simeq 4 \text{ amps}$$

for $V = 240$, $P = 412$ Watts

$$I = \frac{P}{V} = \frac{412}{240} = 1.7 \text{amp} \simeq \underline{2 \text{ amps}}$$

Fuse circuit, 120V → **4 Amps**

Fuse circuit, 240V → **2 Amps**

(7)

Rate of heat loss (Boiler Insulation)

Given

$h = 0.3\,m$, $L = 0.127\,m$, $t = 0.0762\,m$

$k = 237\,W/m \cdot K$, $A = 0.0097\,m^2$

Find

- Total resistance
- Boiler wall heat loss

Solution:

$$R_1 = R_{conv,1} = \frac{1}{h_1 A} = \frac{1}{(237\,W/m^2 K)(0.0097\,m^2)}$$

$$R_1 = 0.437\ C/W$$

$$R_1 = R_3 = 0.437\ C/W$$

$$R_2 = R_{air} = \frac{L}{k_2 A} = \frac{0.3\,m}{(0.026)(0.0097\,m^2)} = 128\,^\circ C/W$$

$$k_{air} = 0.026\ W/m \cdot K$$

$$R_0 = 0.0324\,^\circ C/W$$

$$R_{total} = R_{conv,1} + R_{Alum} + R_{air} + R_{conv,2}$$

$$R_{total} = 0.437 + 0.437 + 128 + 0.0314 = \boxed{128.905}$$

$$Q = \frac{T_{\infty 2} - T_{\infty 1}}{R_{total}} = \frac{100 - 4}{128.9} = \boxed{0.744\,W}$$

(8) Determine heater unit: conversion efficiency

Given

Q_{total} → 1484.66 kJ/kg → 412 Watts.

Assumptions → Efficiency → 95%

Find:

$Q_{utilized}$

Solution

$$Q_{utilized} = \text{Energy Input} \, (\text{efficiency})$$

$$Q_{total} = 1484.766 \text{ kJ/kg} = 412 \text{ Watts}$$

$$\text{Efficiency} = 95\% \rightarrow 0.95$$

$$Q_{utilized} = (412)(0.95) = 391.4 \text{ Watts}$$

$$\boxed{Q_{utilized} = 391.4 \text{ Watts}}$$

(6)

Heat Loss

Given.

Q_{total} 1484 kJ/kg → 412 watts

Find: Heat Loss

Solution

$Q_{total} = 1484$ kJ/kg → 412 watts

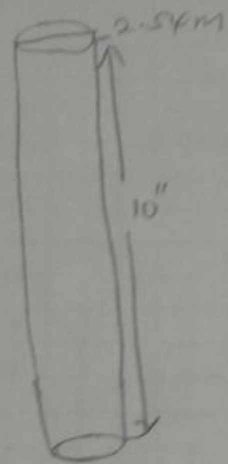
$Q_{out} = (\text{Energy Input})(5\%)$

$Q_{out} = (1484 \text{ kJ/kg})(0.05) = 74.2$ kJ/k

$$Q_{out} = 74.2 \text{ kJ/kg}$$

(7)

A Surface Area of Copper wire



Given:

Height = 10"

Ø = 2.54 m

Find: Surface Area.

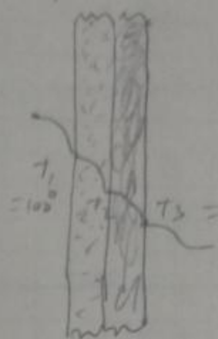
solution.

$A = \pi r^2 = 3.14 (0.0127)^2 = 0.001m^2$

$A = 0.001 m^2$

Given

h = 0.3m, L_1 = 0.127, thickness = 0.0762m



Find:

Q_{LOSS}

SOLUTION

$$Area = (0.3m)(0.0702m) = 0.0228m^2$$

$K = 0.9\ W/m.K$

$T_1 = 100°c$

$T_2 = 15°c$

$L = 0.3m$

$$Q_{loss} = KA\frac{T_1 - T_2}{L}$$

$$Q_{loss} = \frac{(0.9\ W/m/K)(0.0229m^2)(100° - 15°)}{0.3m}$$

$$\boxed{Q_{Loss} = 5.8395\ W}$$

APPENDIX B

DISTILLER UNIT SOLIDWORKS DRAWINGS

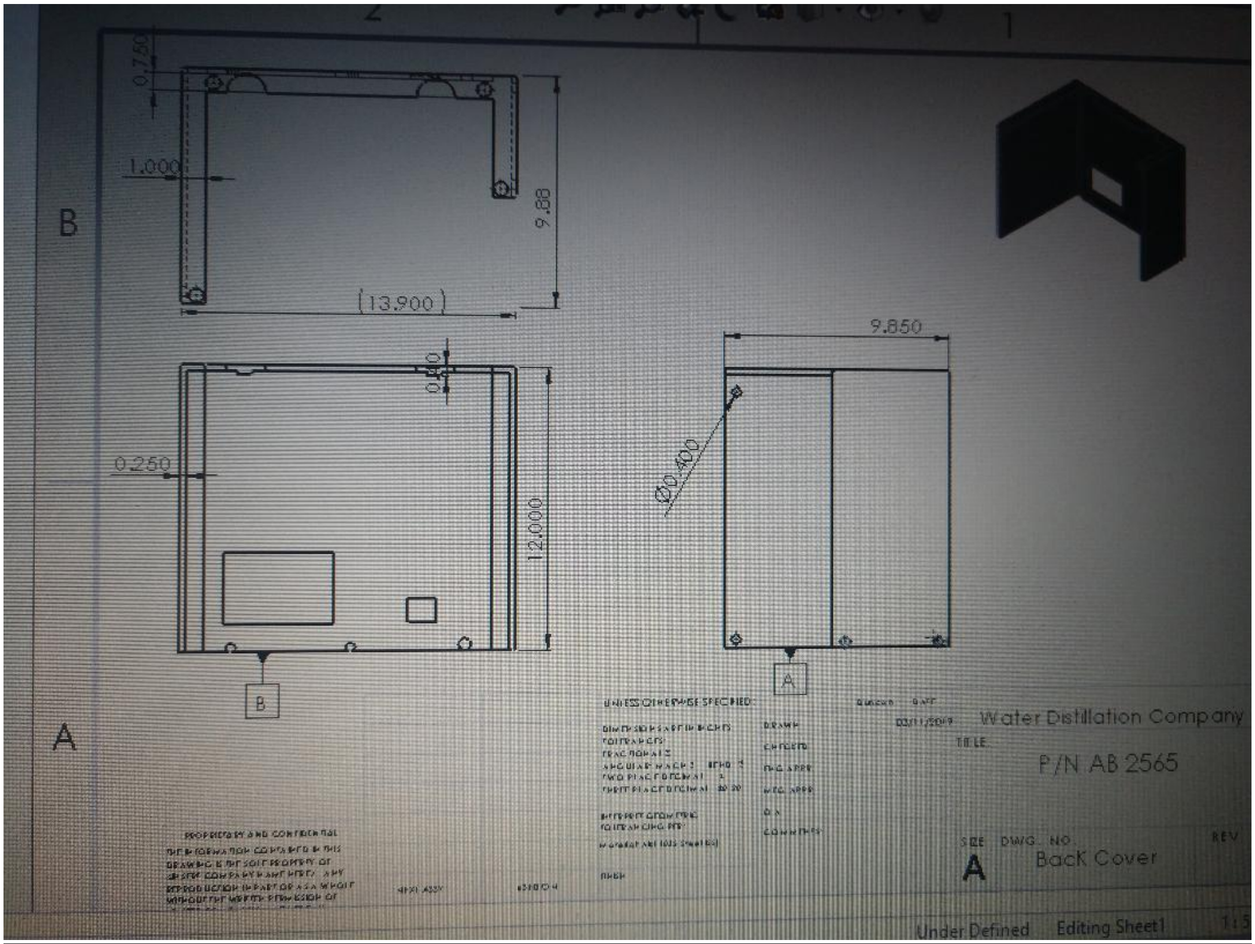


Figure 2 – B Back cover

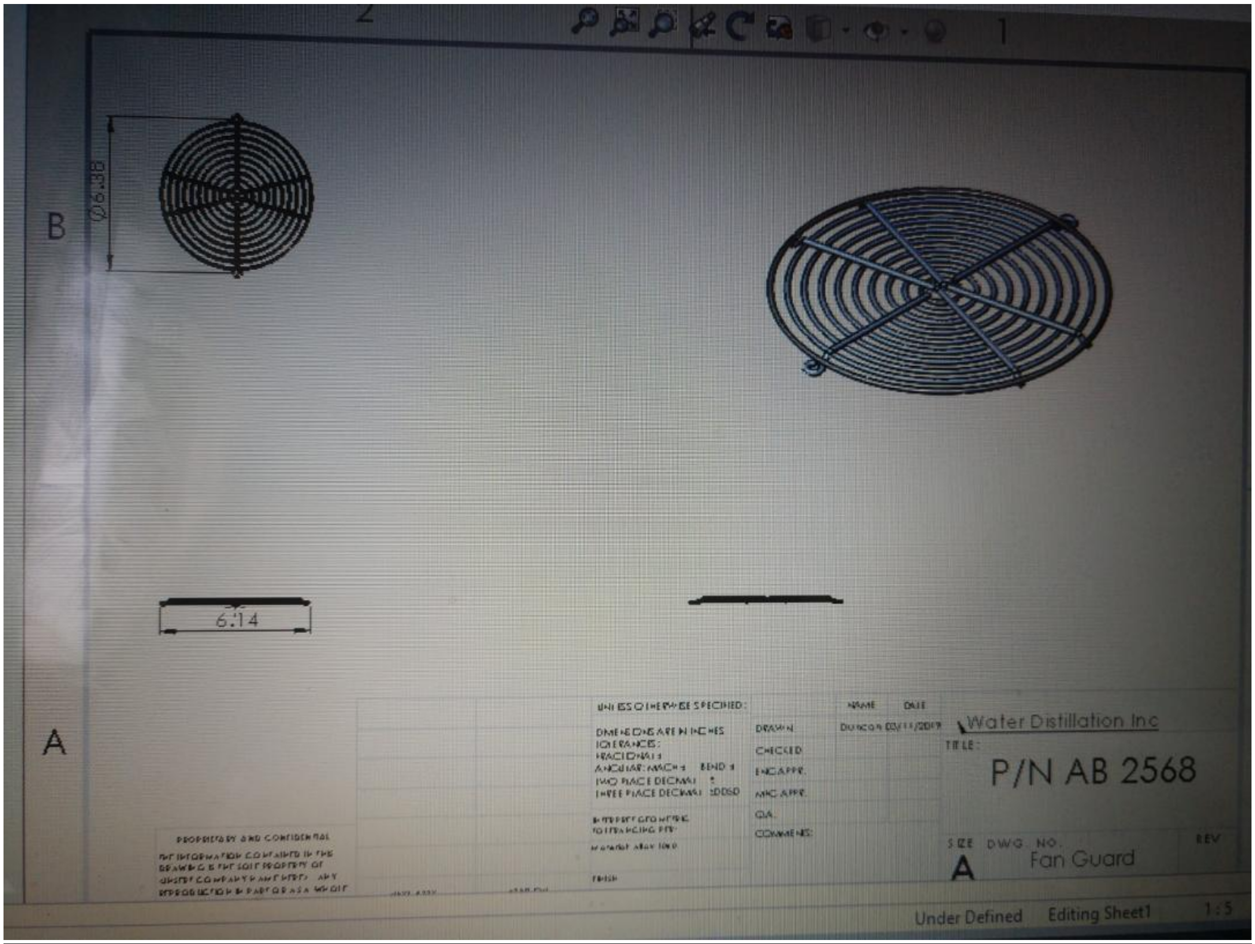


Figure 3-B Fan Guard

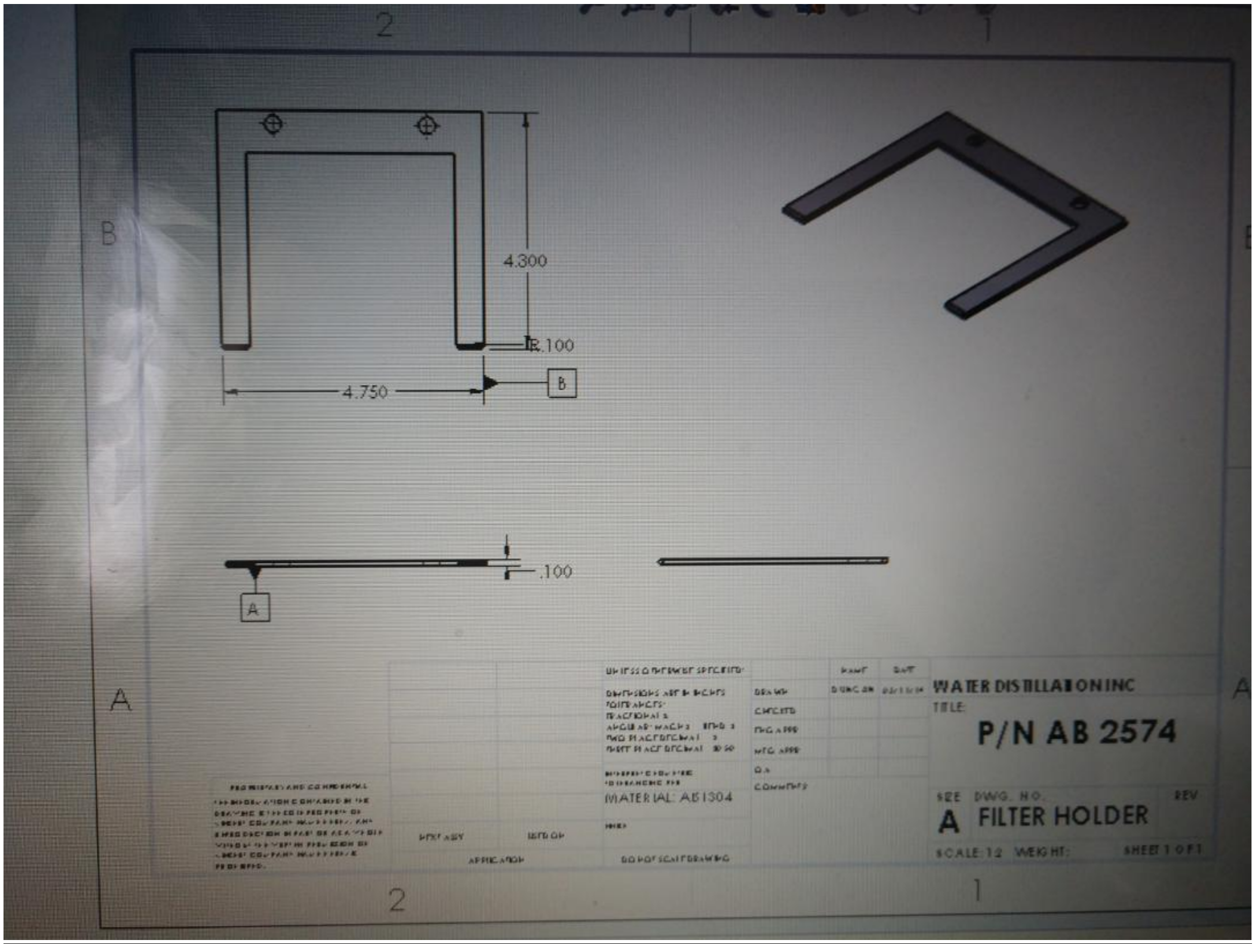


Figure4-B Filter holder

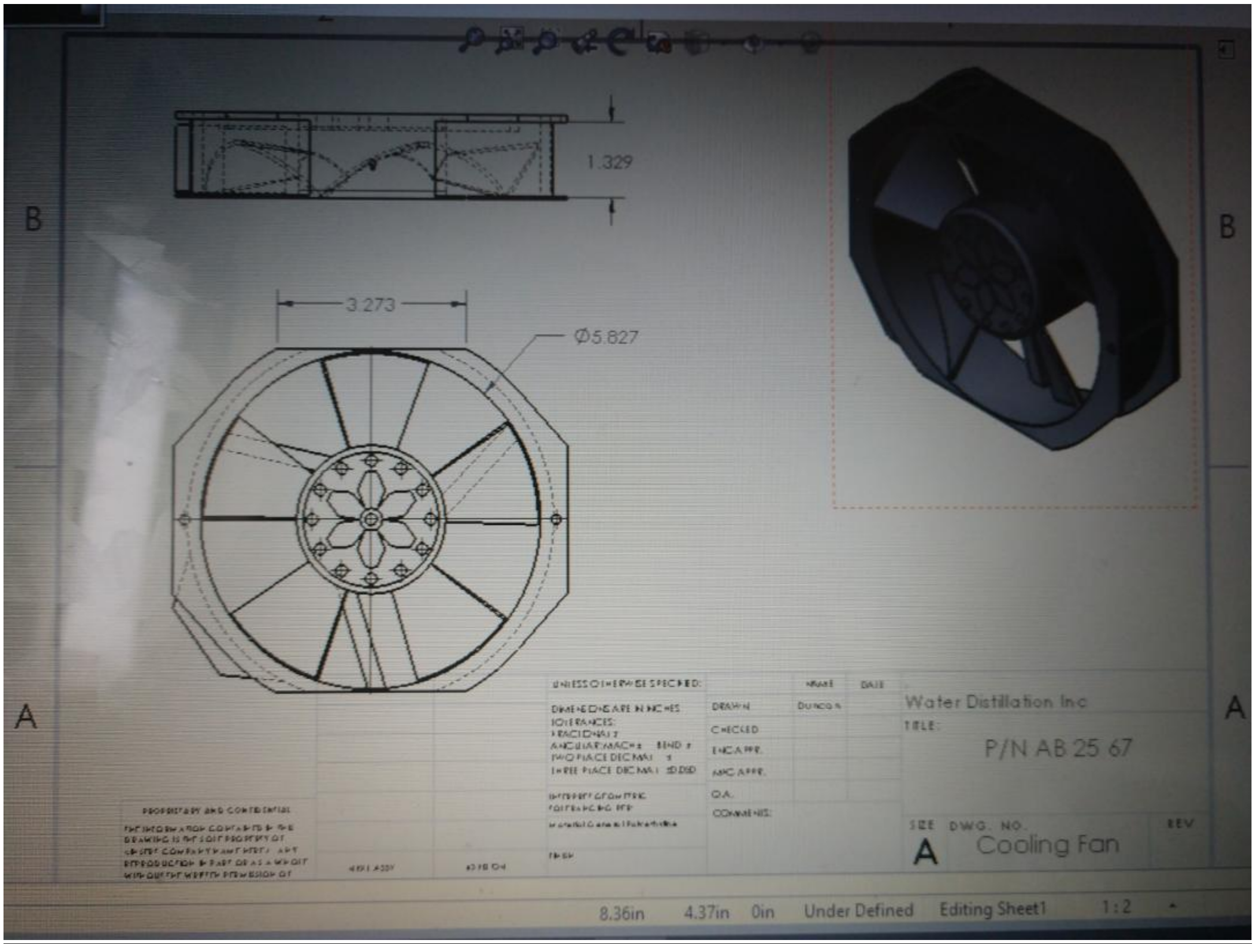


Figure5-B Cooling Fan

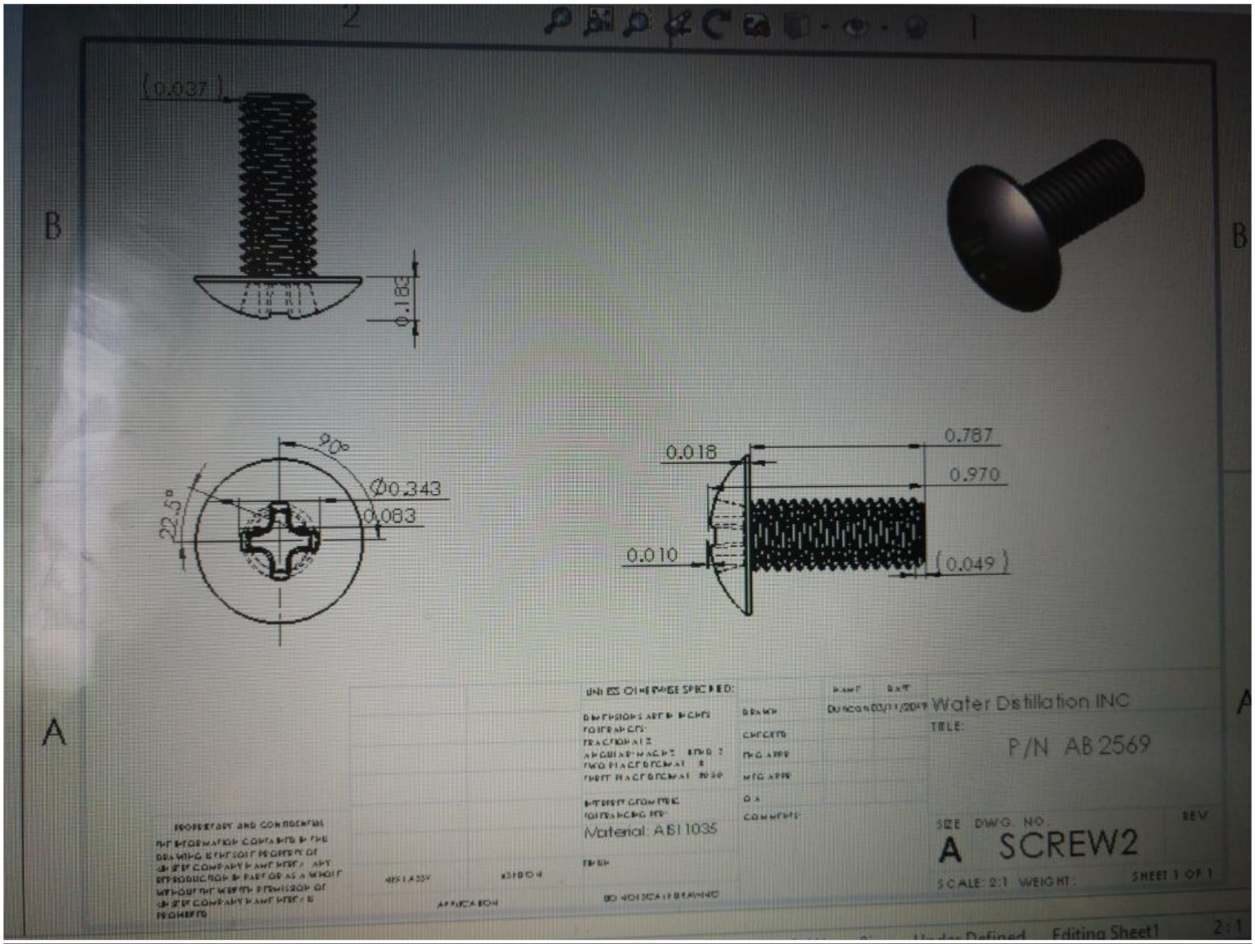


Figure 6-B Screw

Figure 7-B Condensing coil

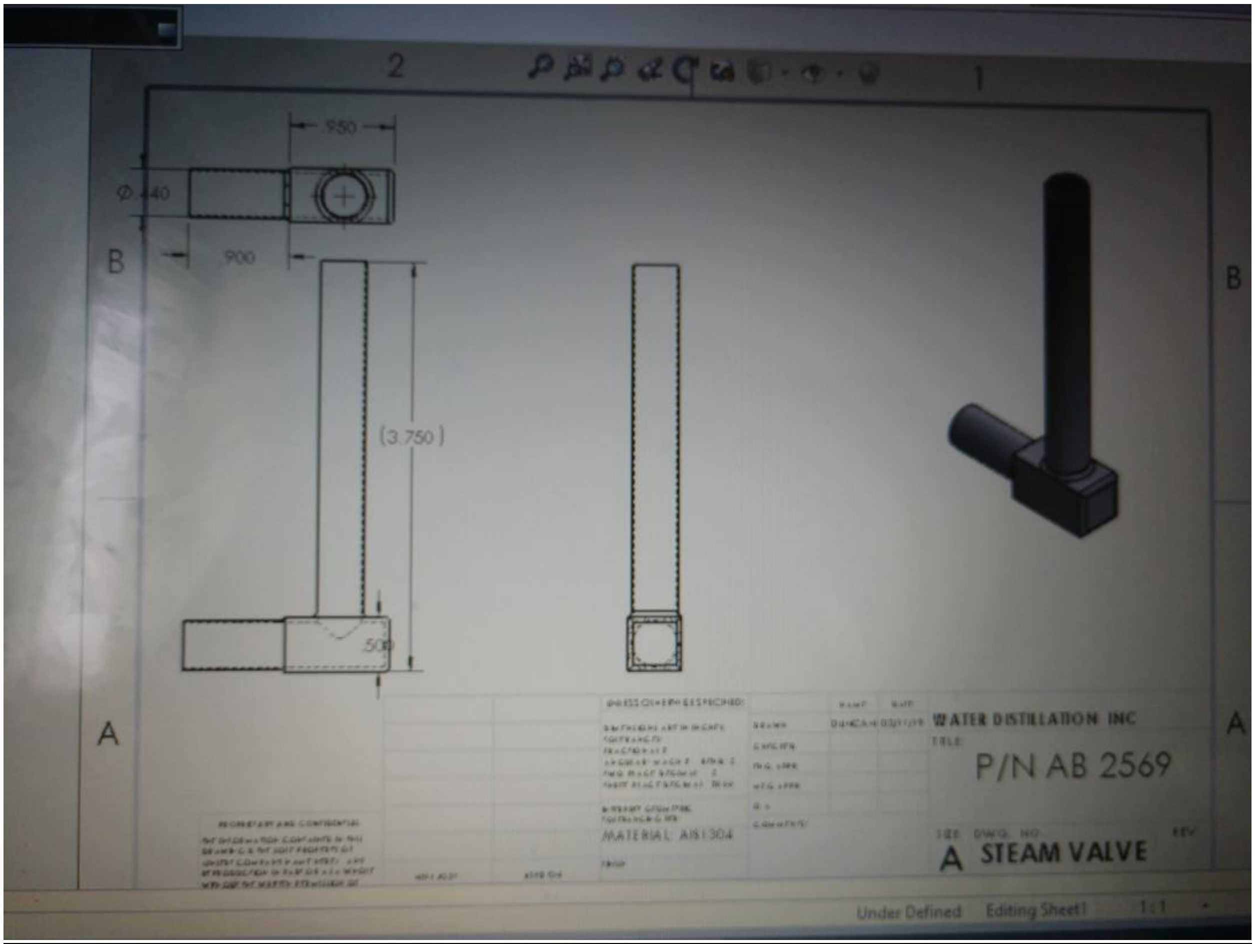


Figure 8 -B Steam Valve

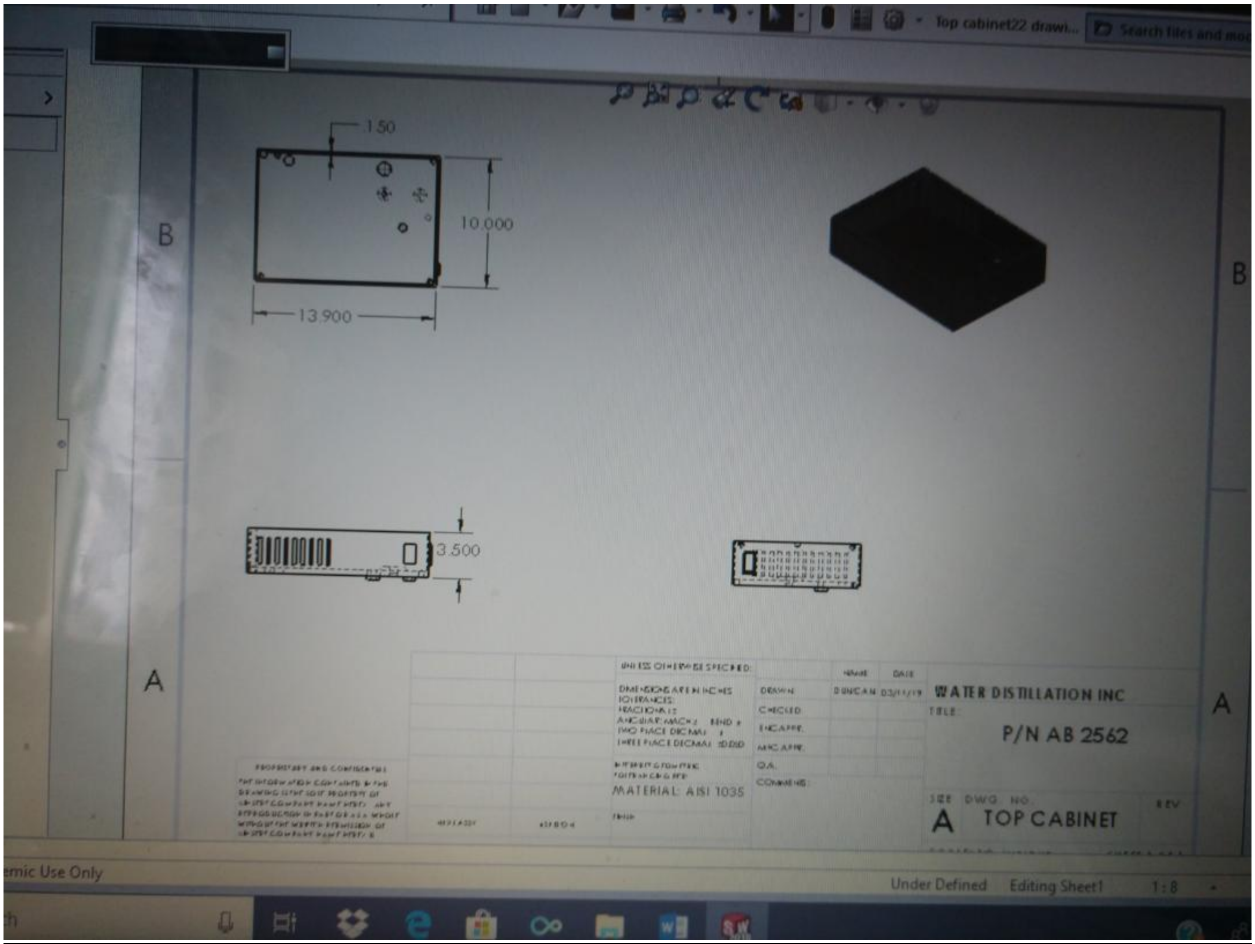


Figure 9 -B   Top Cabinet

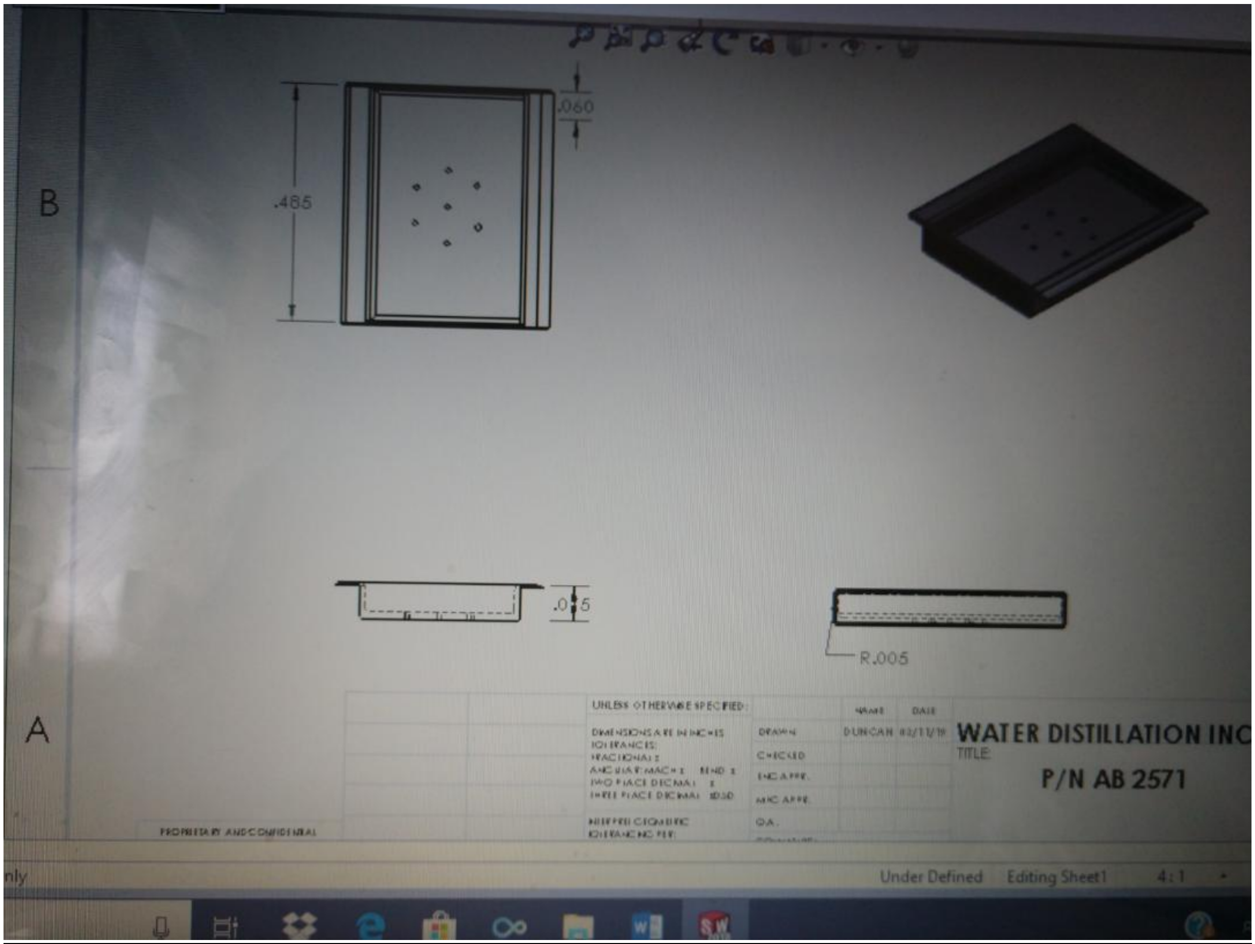


Figure 10 -B Carbon Filter Housing

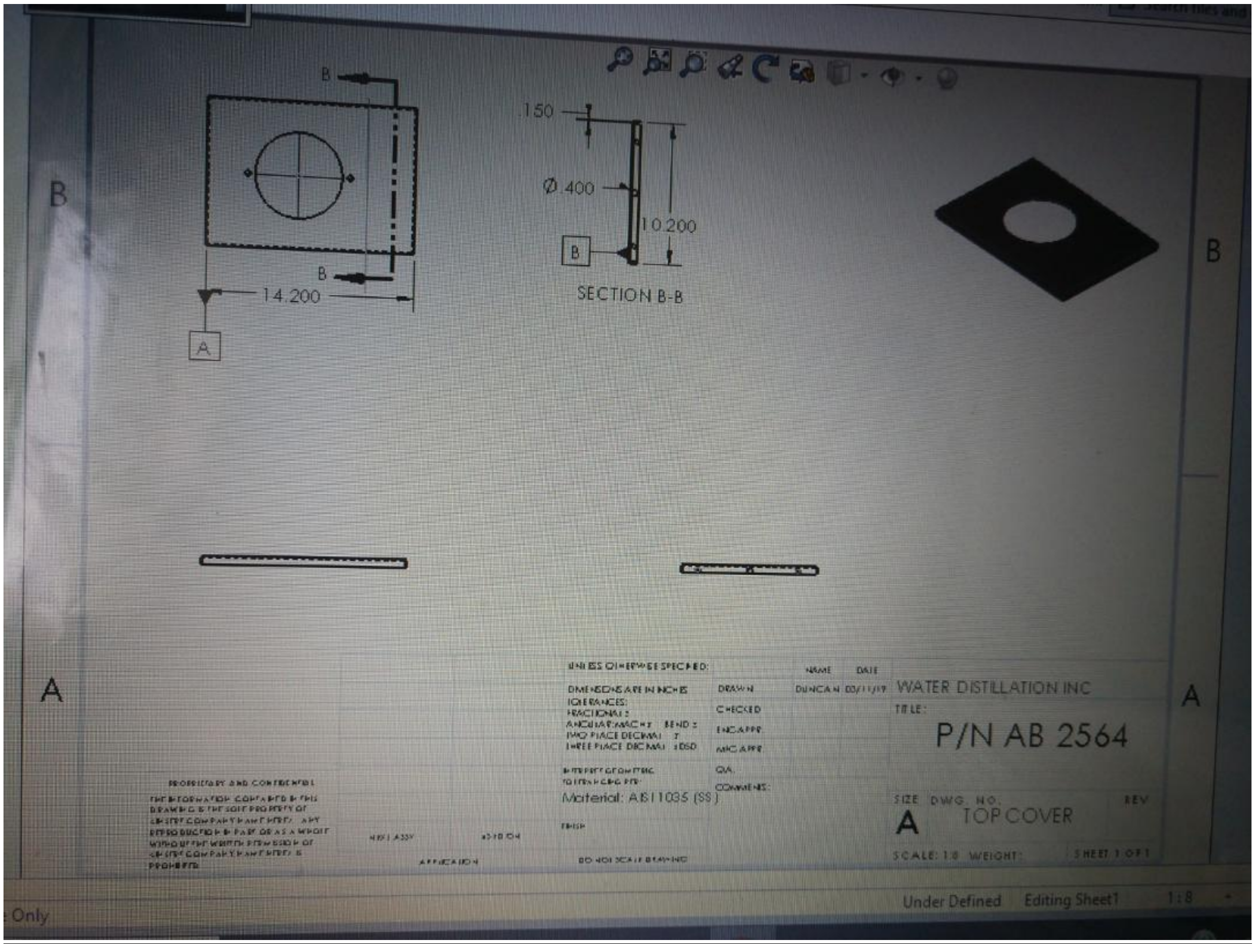


Figure 11 -B Top Cover

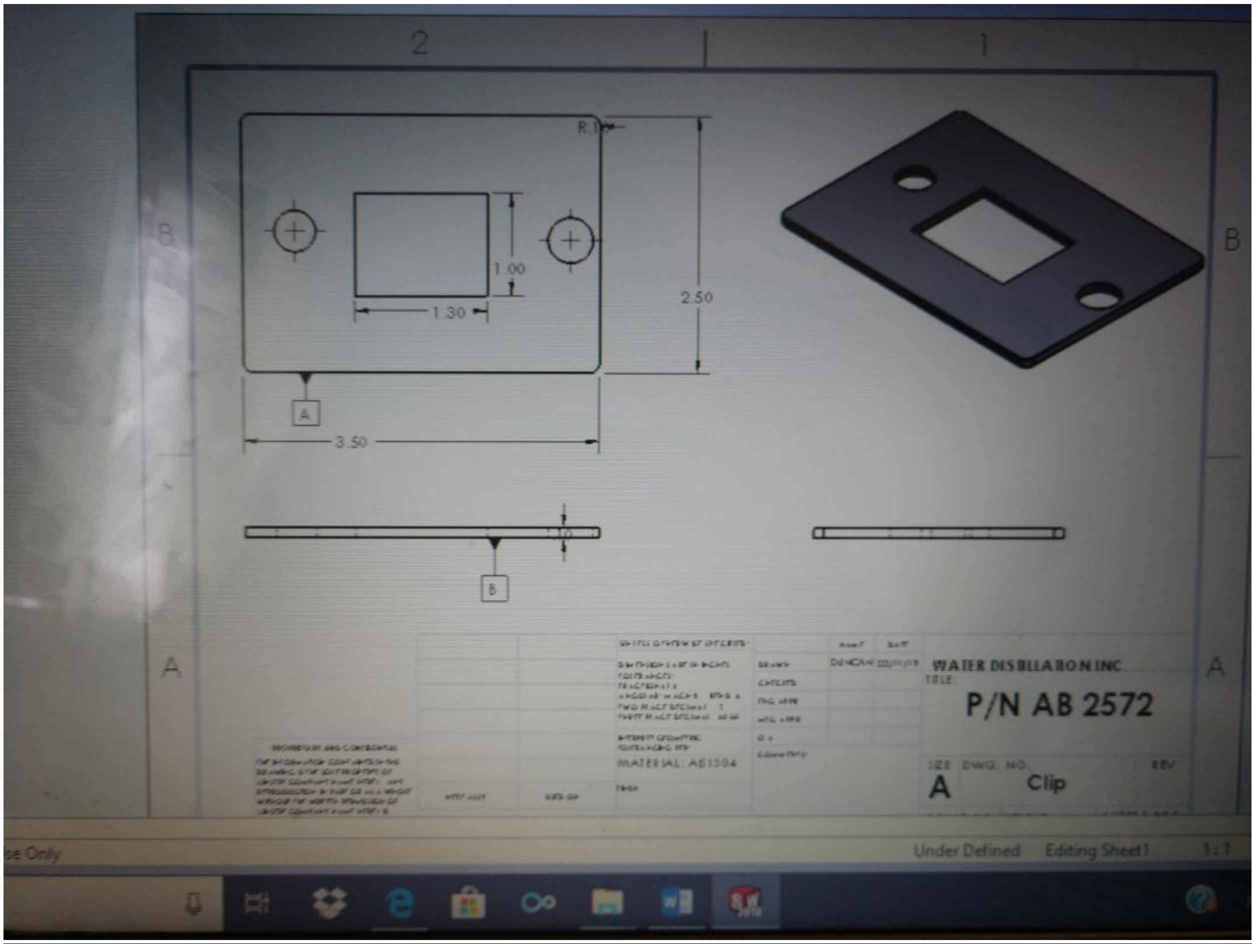


Figure 12-B Clip

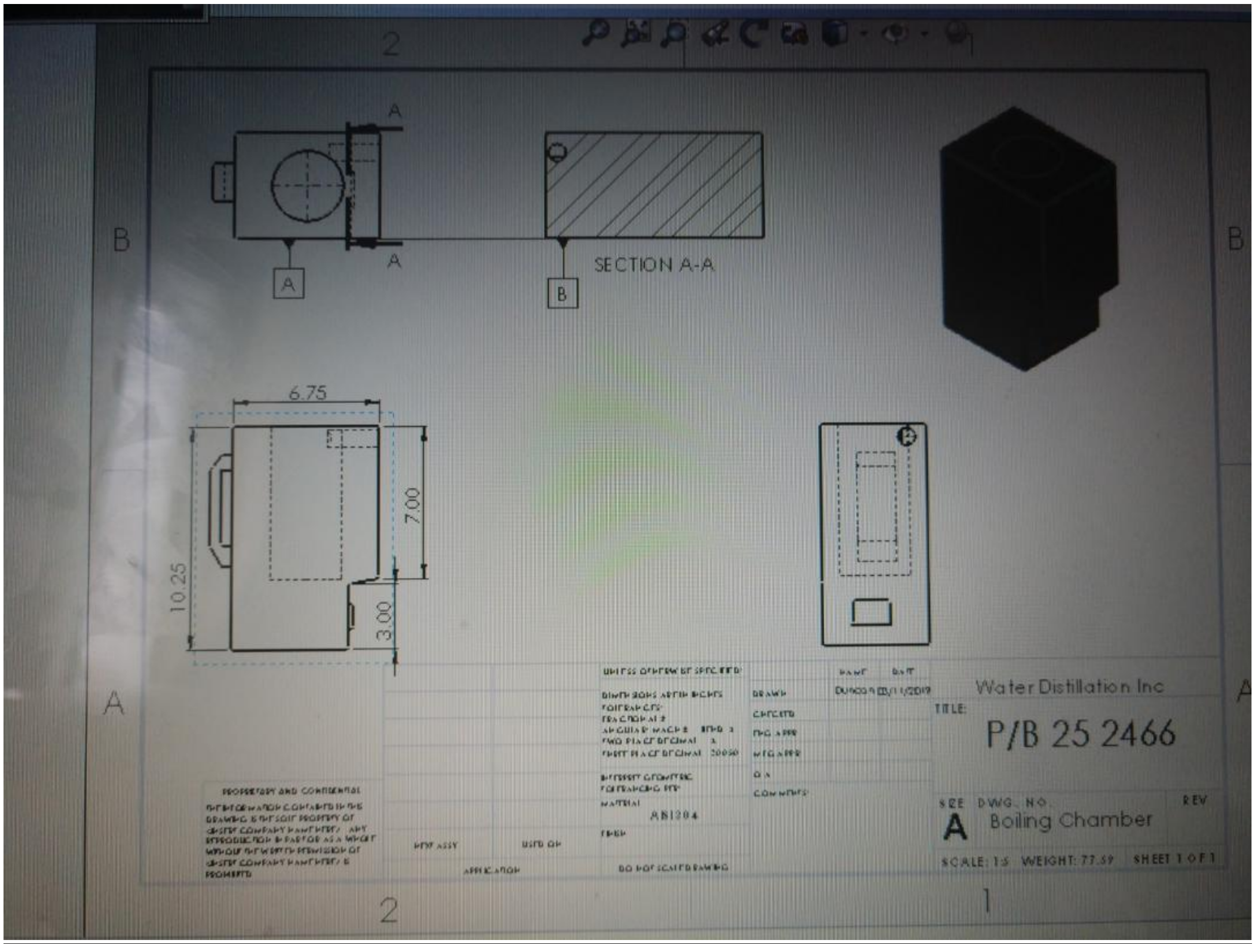


Figure 13-B   Boiling Chamber

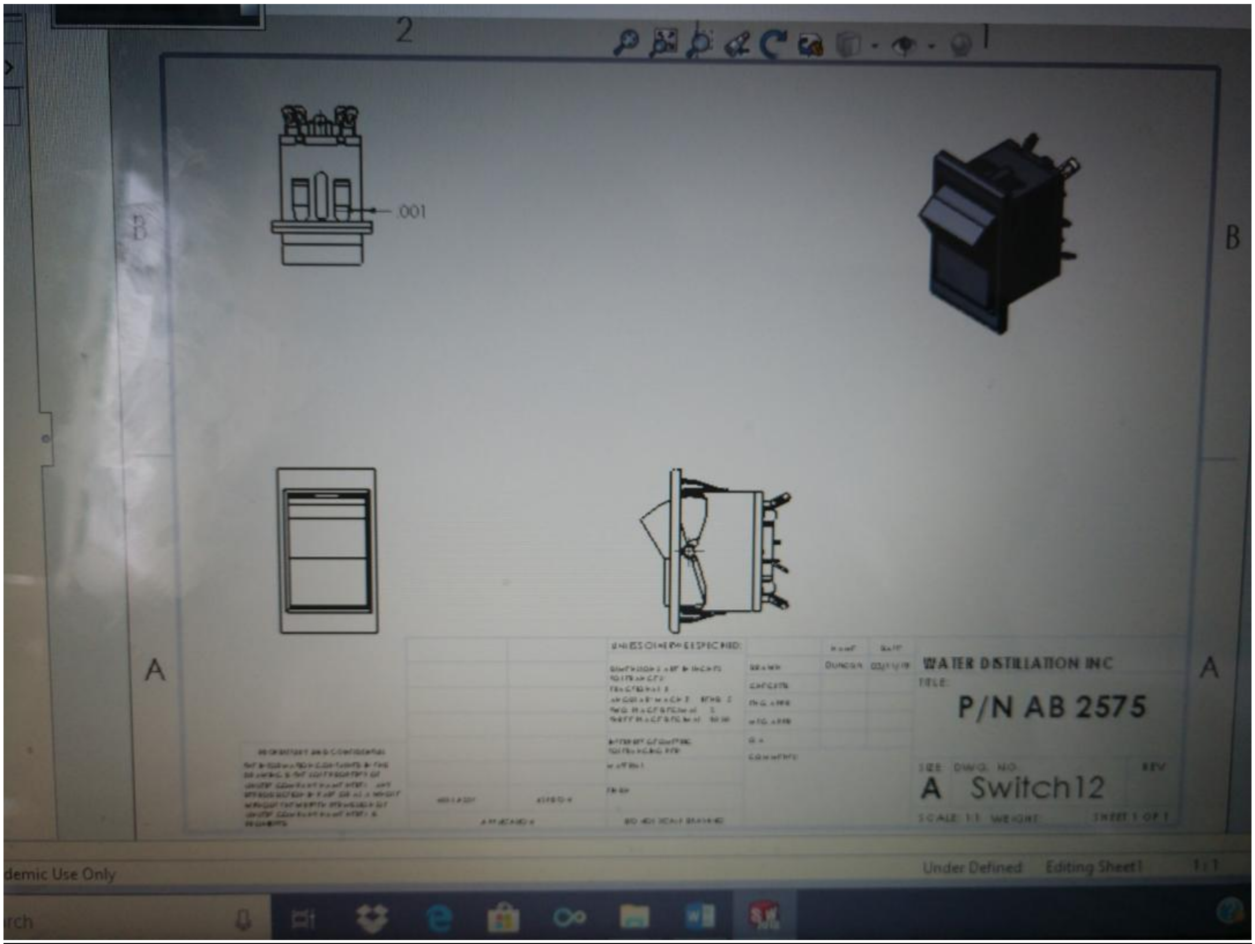


Figure 14-B Switch

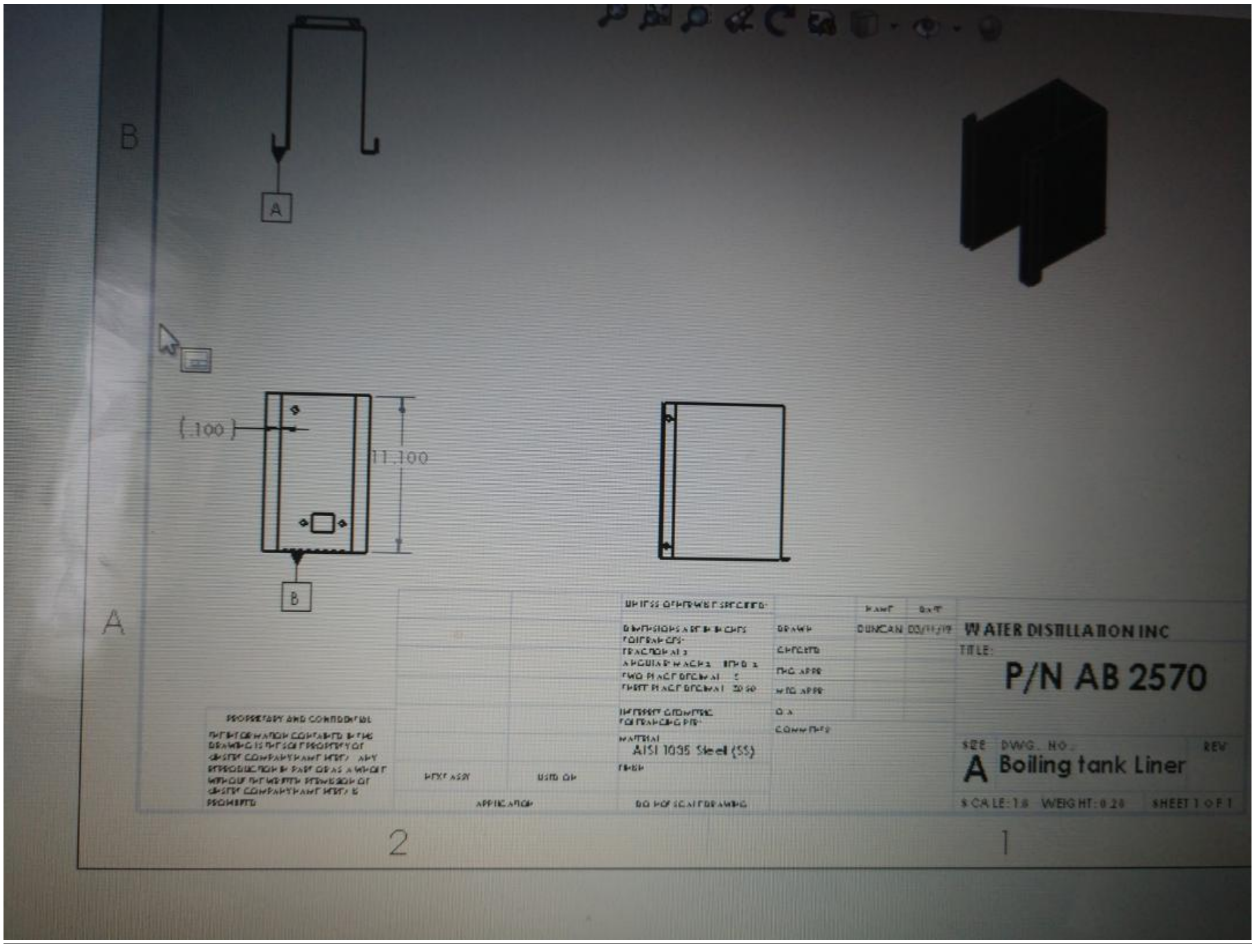


Figure 15-B Boiling Tank Liner

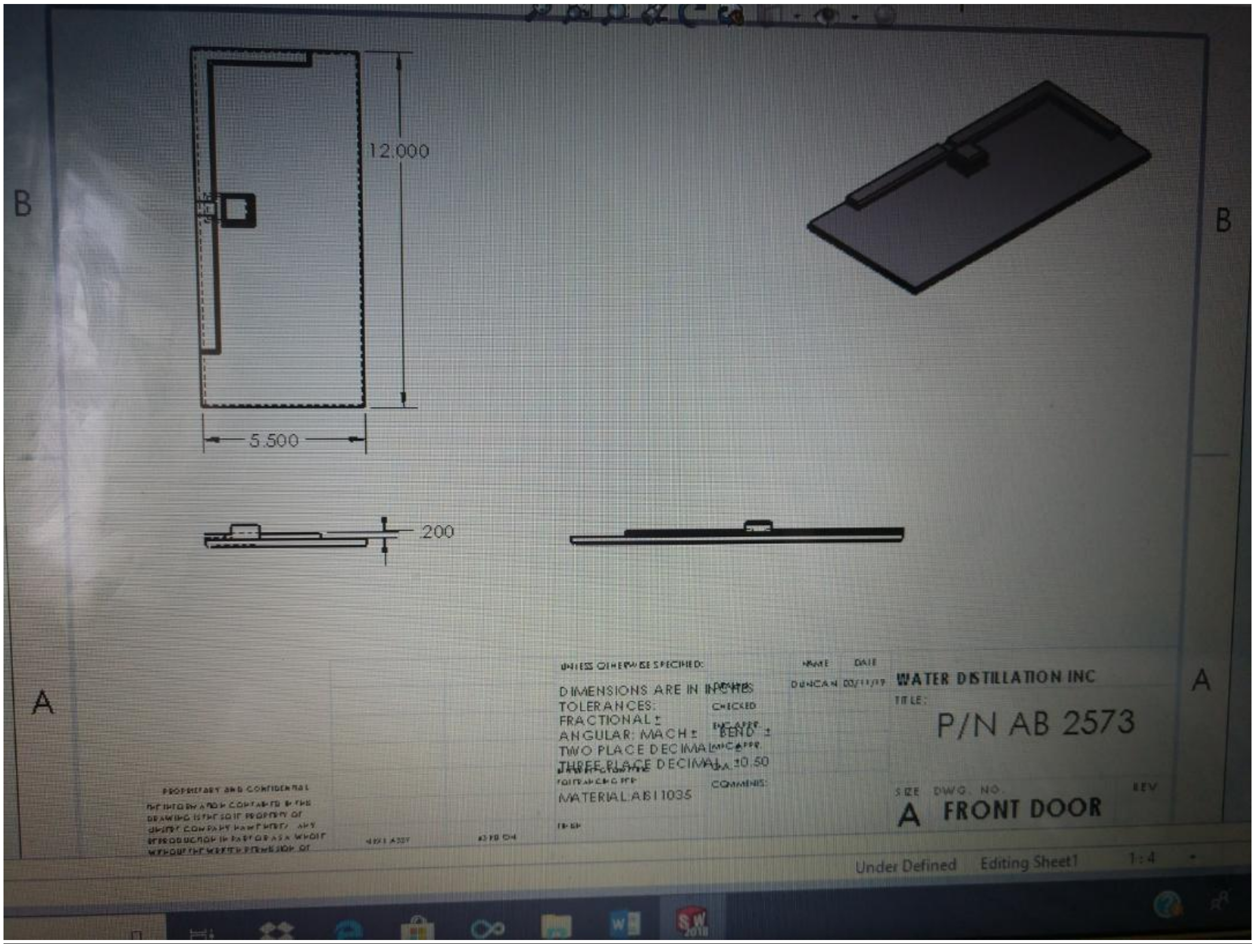


Figure 16 – B FRONT DOOR

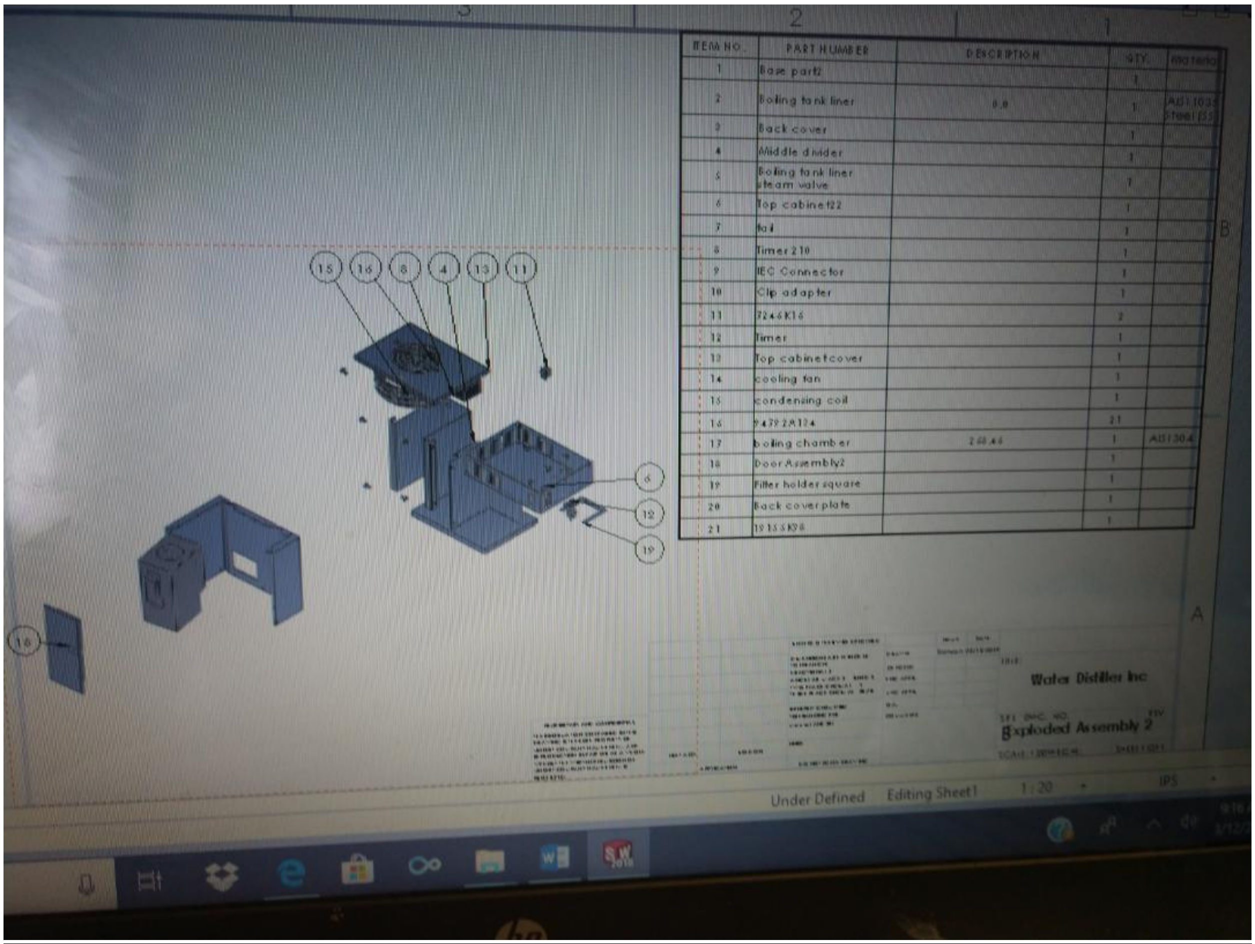


Figure 17 -B Exploded Assembly

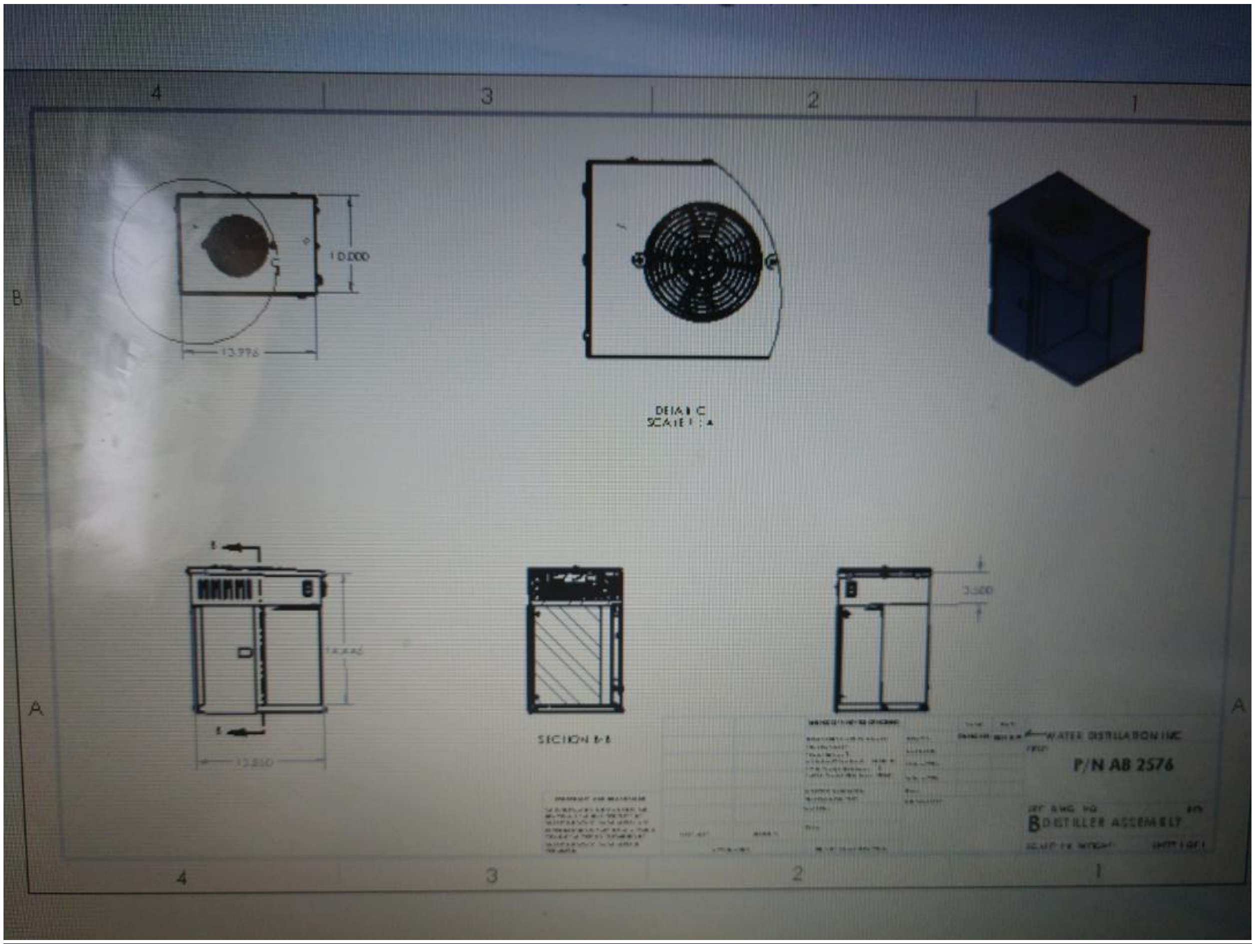
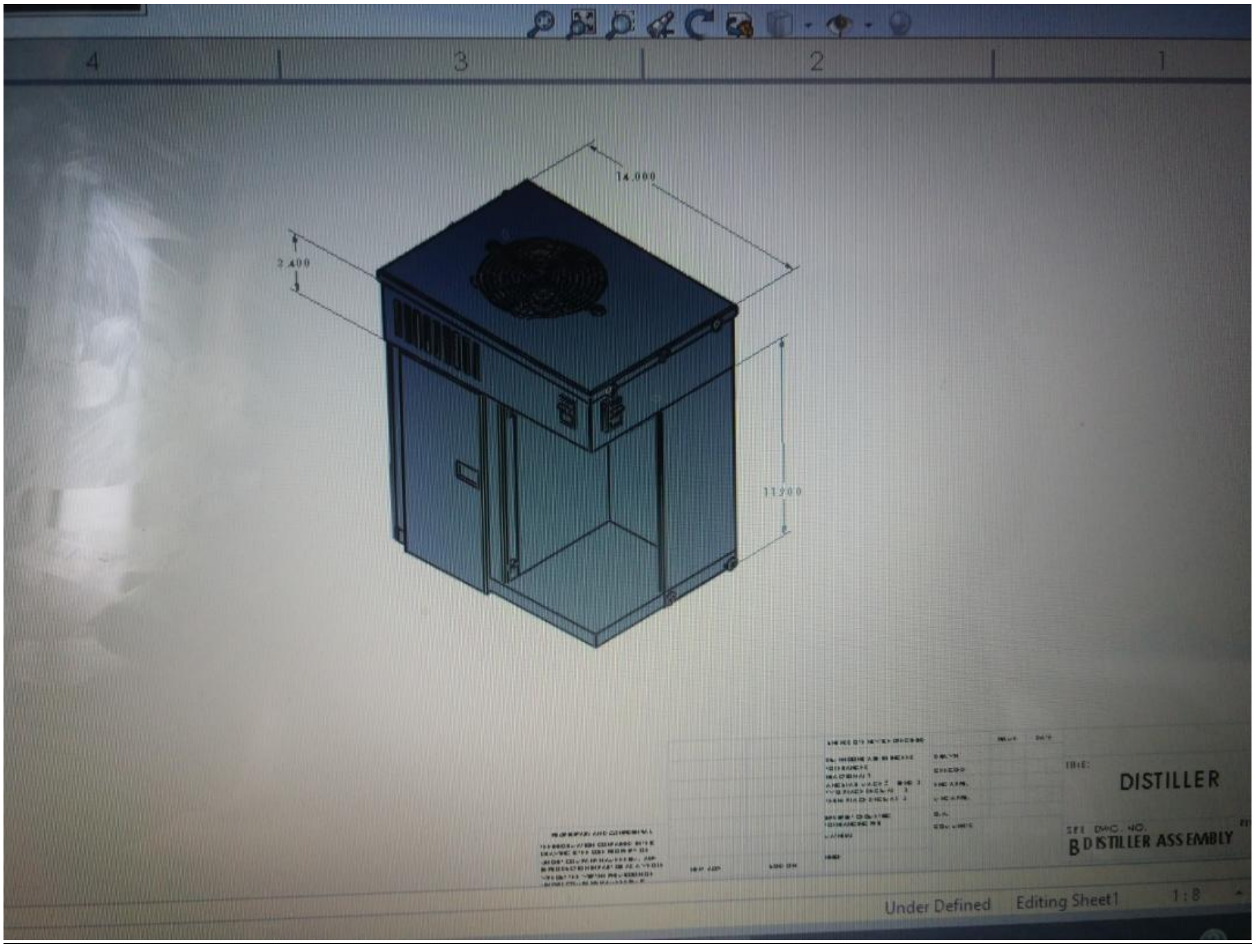


Figure 18-B Assembly



<u>**Figure 19-B   Distiller Unit Assembly**</u>

Figure 20 – B **A Working Completed Distiller Unit**

APPENDIX C
PART LIST

Parts	quantity	Source	Est. cost	Actual cost	Total cost
120 V Connector	1		$15.00		
Copper	10 ft		$18.00		
power cord	1		$18.00		
Boiler	1		$20.00		
Connector	1		$15.00		
Switches	1		$30.00		
Top cover	1		$25.00		
Back cover	1		$15.00		
Top cabinet	1		$16		
Timer	1		$25		
Liner	1		$31.00		
Adapter	1		$14.00		

Storage container	**1**		**$5.00**		
Door	**1**		**$23.00**		
Screws	**8-32**		**$3.50**		
Nut	**12**		**$2.50**		
Electrical wires	**10**		**$40.00**		
Divider	**1**		**$25.00**		
		TOTAL	**$400**		

APPENDIX D
BUDGET

The purpose of the budget section was to ensure that enough finances are available to meet the requirement of providing 1 pint of free contaminants water per hour.

The proposed budget was estimated to be $400 including cost all parts, labor, tax and shipping. The total below shows the actual budget total in detail.

Parts	quantity	Source	Est. cost	Actual cost	Total cost
120V Conn.	1	www.mcmaster-carr	$15.00	$18.00	$18.00
Copper	10 ft	www.amazon.com	$18.00	$15.50	$18.00
power cord	1	www.amazon.com	$18.00	$27.50	$27.50
Boiler	1	www.amazon.com	$20.00	$100.50	$100.50
connector	1	www.fastenal.com	$15.00	$20.00	$20.00
Switches	1	www.mcmastor-carr	$30.00	$33.00	$33.00
Top cover	1	www.purewater.com	$16.00	$13.00	$13.00
Back cover	1	www.purewater.com	$15.00	$37.00	$37.00
Top cabinet	1	www.purewater.com	$16.00	$13.00	$13.00

Timer	1	www.amazon.com	$25.00	$38.50	$38.50
Liner	1	www.purewater.com	$31.00	$32.00	$32.00
Adapter	1	www.mcmaster-carr	$14.00	$21.00	$21.00
Storage container	1	www.purewater.com	$5.00	$2.50	$2.50
Door	1	www.purewater.com	$5.00	$2.50	$2.50
Screws	8-32	www.mcmaster-carr	$3.50	$4.50	$4.50
Nut	12	www.fastenal.com	$2.50	$2.50	$2.50
Fan	1	www.mcmaster-carr	$40.00	$91.50	$91.50
Electrical wires	10	www.mcmaster-carr	$40.00	$19.00	$19.00
Divider	1	www.purewater.com	$25.00	$19.00	$19.00
		TOTAL COST	$400	$450.00	$450.00

APPENDIX E

SCHEDULE

The schedule is attached in the Appendix E. It is divided into plans per quarter. Some of the crucial activities in the project are developing and writing the proposal, material selection and analysis, assembling and testing of the device. The schedule depends on the work priority, time and availability of materials and parts. Figure E-1 shows the completed Gantt Chart.

Proposed Schedule

The majority of parts for this project will be ordered from different suppliers from different stores even internet store. The parts will be ordered early to enable the construction of the unit to begin early as shown in the schedule. However, the tools for construction and testing provided by Mechanical Engineering department because they are not in the budget. Tasks allocation, sequence and estimate duration is highlighted in the Gantt Chart.

The project was estimated to take 90 days to complete depending on the availability of the material. The material/parts was purchased on time and was shipped on time. This allowed the construction of the project to begin on time as scheduled

started on time ended on lat e
started on time ended on time
started late ended late
started early ended early

SENIOR PROJECT SCHEDULE

Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

LABORATORY WATER DISTILLER

DUNCAN NJUNGE **DUNCAN NJUNGE**

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	%Com
1	Proposal*			
1a	Outline	20	10	
1b	Intro	20	2	
1c	Methods	15	3	
1d	Analysis	10	2	
1e	Discussion	15	2	
1f	Parts and Budget	20	4	
1g	Drawings	30	8	
1h	Schedule	20	2	
1i	Summary & Appx	30	2	
	subtotal:	180	35	
2	Analyses			
2a	Heat Trans=>Geo	10	4	
2b	Heat transfer calc	15	4	
2c	Power Anal=>Geo	15	5	
2d	power Analsis calc	20	4	
2e	Tolerance => Geo	10	4	
	subtotal:	70	21	
3	Documentation			
3a	part1 h. element drawing	15	4	
3b	part2 arm drawing	10	2	
3c	Energy Calculation	30	20	
3d	part 3 coil drawing	25	20	
3e	Part 4 cooling fan drawing	15	10	
3f	Boiling tank drawing	20	10	
3g	Fan motor drawing	20	8	
3h	Boiling tank liner drawing	15	5	
3i	Wieding boiling tank liner	20	5	
3j	Fan blade drawing	10	2	
3k	update calculation	15	2	
3l	ANSIY14.5 Compl	20	8	
3m	Make Object Files	15	10	
	subtotal:	230	106	
4	Proposal Mods			
4a	Project Robot Schedule	10	4	
4b	Project Robot Part Inv.	15	6	
4c	Crit Des Review*	15	4	
	subtotal:	40		
7	Part Construction			
7a	Buy boiling tank, base	10	4	
7b	Make heating element	20	10	
7c	Make condensing coil	25	15	
7d	Weld boiling plate liner	20	15	
7e	Buy top cabinet	10	8	
7f	Buy assembly parts	15	6	
7g	Take Part Pictures	4	2	
7h	Update Website	r4t4r	2	
7i	connecting parts	10	2	
	subtotal:	114	64	
9	Device Construct			
9a	Assemble purchased parts	15	6	
9b	cut and size h. element	20	8	
9c	cut and size coil	10	6	
9d	cut and size the plate	25	15	
9e	Take Dev Pictures	5	3	
9f	Update Website	4	2	
	subtotal:	79	40	
10	Device Evaluation			
10a	List Parameters	15	4	
10b	Design Test&Scope	20	6	
10c	Obtain resources	20	8	
10d	test 1 report	10	4	
10e	Plan analyses	6	3	
10f	Instrument Robot	15	8	
10g	Test 2 report	15	6	
10h	Perform Evaluation	10	4	
10i	Take Testing Pics	10	4	
10h	Update Website	8	2	
	subtotal:	129	49	
11	495 Deliverables			
11a	short report	20	10	
11b	Presentation1 , outline	15	6	
11c	Write Report	50	10	
11d	Make Slide Outline	20	10	
11e	ppresentation2	25	15	
11f	Make CD Deliv. List	25	10	
11e	Write 495 CD parts	20	15	
11f	Update Website	15	3	
11g	Project CD*	30	18	
	subtotal:	220	97	
	Total Est. Hours=	1062	412	
Labor$		100		

Months: S | October | November | Dec | January | February | March | April | May | June

=Total Actual Hrs

Note: Deliverables*
- Draft Proposal
- Analyses Mod
- Document Mods
- Final Proposal
- Part Construction
- Device Construct
- Device Evaluation
- 495 Deliverables

APPENDIX F
Expertise and Resources

Physical Resources

The machines, equipment, tools in the machine shop and casting laboratory in Mechanical Engineering Building was used to drill holes, weld parts, join parts, cut sheets of metals used in the construction of the unit. Tools like measuring tools, cutting tools, pliers and other required tool were not budgeted for and so had to use Mechanical Engineering Department's tools.

Software Resources

Computers from computer lab in Hogue Mechanical Engineering building was used to make required drawings and to document project data/ information. Personal laptop was also used to get all required information as well as updating data.

Financial Resources

To finance this project, individual contribution was required as well as resources available in Mechanical Engineering Department. Donation, grants, ideas from well wishers and Engineering department were welcome.

Expertise

The Engineering department instructors were available to guide from report writing, construction phase and testing of the project. Machine lab team, electrical lab team, casting and welding team played a great role in the success of this project. A lot of appreciation goes to this teams that helped in shaping my idea into a reality. Thank you!

APPENDIX G
Testing Data

Test 1. Performance test Data

Trial	Time (Min.)	Water Temp.	Steam Temp.	Pure Water (ML)	Q out W	Q in W	Pass	Fail
1	59	21.25	98.45	600	726	780	pass	
2	57	22.7	97.7	580	726	780	pass	
3	58	22.87	97.6	590	726	780	pass	

Test 2: Energy Consumption Test

Boiler water	Time (min)	Thermal Energy (KJ/kg)	Electric Energy KJ/kg	Water Pro. (ml)	Pre. Eff. %	Calc. Eff. %	Pass /fair	Fail
1	60	2614	2808	590	95	93.09	fair	

APPENDIX H

EVALUATION SHEET

Reports/Sheet

The test results data Sheets

Test 1. Performance **test result**

Trial	Time (Min.)	Water Temp.	Steam Temp.	Pure water V.(ml)	Q (out) (W)	Q (in)	Pass	Fail
1	59	21.25	98.45	600	726	780	pass	
2	57	22.7	97.7	580	726	780	pass	
3	58	22.87	97.6	590	726	780	pass	

Test 2. Energy consumption test data

Water In boiler (kg)	Time (min)	Thermal Energy KJ/KG Calc.	Electric Energy KJ/KG	Water Prod. (ml)	Pre. Eff. %	Calc. Eff. %	Pass fair	Fail
1	60	2614	2808	590	95	93.09	fair	

APPENDIX I

TESTING REPORT

The purpose of testing method on distiller unit is to provide pure water to laboratories and hospitals free of pyrogens and organisms from sewerage outlets and chemicals added as part of water treatment process. The tests performed are performance test, energy consumption test and some of the details tested are:

- Is system efficiency 95% as predicted?
- Is 1pint of pure water produced within an hour?
- Is the evaporated water condensed and separated from the contaminants?
- Is it easy to transport?
- Are there any leaks in the system?

The testing process will take approximately an hour and data recorded on a data table. This allows data comparison in order to obtain accurate results.

Tasks allocation, sequence and estimate duration is highlighted in the Gant chart.

Method/Approach

The testing process required resources like floor space, a table, water source, electric outlet, pure water storage container, ammeter, thermometer and senior project room.

Test procedures overview

- Take the distiller to the senior project room and set it on the table

- Fill the boiler with tap water and take the surface temperature of the water with thermometer. Record the readings in the data table.
- Insert the boiler to it position (inside the unit) and plug the machine power outlet to the power source. Press power on/off button to power the machine and then start cycle button to begin the cycle process.

Operational limit – with the energy of 2614kj/kg (726W), can determine the maximum current draw required for;

V=120V, I= P/V, = 726W/120V = 6.05 A

The unit is rated to operate at 800W and maximum current draw being 6.6A.

Precision and accuracy – three trials have been done on test 1 and data compared to obtain accurate results.

Analysis – Results outcome for both tests shows that the unit has met the requirement of providing 1 pint in an hour. However, efficiency results value is very close to predicted value of 95%.

Presentation – Results data is presented in form of data sheet for c

Test procedures

First test was performance test (test 1), test 2 (energy consumption test) and were both conducted in senior project room.

The first testing process was conducted on 11th April 2019 (Tuesday) at 10.00 am and took approximately an hour for every trail. For accurate results, three trials (trial 1, trial 2, trial3) were conducted and so total time for all trials was 3 hours.

Procedures

- Take the distiller unit to the senior project room and set it on the table.
- Fill the boiler with tap water and take the surface temperature of water by thermometer. Record the readings in the data table.
- Insert the boiler to its position (inside the unit) and plug the machine power outlet to the power source. Press power on/off button to power the machine and then start cycle button to begin the process.
- Once the water starts to boil, take the temperature of the boiled water using thermometer and record it on the data sheet.
- As the water continues to boil, steam is created which enters into the condensing coil where heat transfer takes place: cool air from the cooling fan causes the steam to condense to pure water (distillate). The distillate is then rerouted through carbon filter outlet where chemicals like fluorine, calcium are filtered leaving 99.9% pure water.
- Observe whether there is any water flowing in the storage container.

Risk, Safety Evaluation

The testing process involve hot surfaces which pose a burn hazard and so care must be taken to avoid being burnt. Caution signs has been put in place on hot surfaces to prevent burn incident to the users. The machine has a safety shut off switch which turns off the unit should it overheat.

Discussion

The tests are considered successful when the distiller machine produce 1 pint of water per hour as required and has efficiency of 95% as predicted.

Deliverables

With input thermal energy of 2614kj/kg, long finned condensing coil and well insulated walls, the machine successfully produces 1 pint of water per hour.

Total energy required to heat water to steam

Q total = E1 +E2   E1 = Energy required to reach boiling point

E1= M (cp) (T2-T1)

= 1kg (4.2kj/kg/k) (100 – 15) = 357kj/kg

E2 = M (hg – hf)   E2 = energy for vapor phase transformation

= 1kg (2675kj/kg – 418kj/kg) = 2257kj/kg

Q total = 2257kj/kg + 357 KJ/kg = 2614kj/kg

Measured energy (ammeter) = 2808kj/kg (1hr/3600sec) (1000kj/kg) = 780 joules/sec or 780W

To calculate efficiency, efficiency = thermal energy/ electrical energy

= 2614kj/kg/2808kj/kg (100%) = 93.09%

Success criteria

With production of 600ml pure water in an hour, efficiency of 93.09%, no leak in the system the conducted tests are considered successful.

Reports

The test results data forms

Test 1. Performance test result

Trial	Time (Min.)	Water Temp.	Steam Temp.	Pure water V.(ml)	Q (out) (W)	Q (in)	Pass	Fail
1	**59**	**21.25**	**98.45**	**600**	**726**	**780**	**pass**	
2	**57**	**22.7**	**97.7**	**580**	**726**	**780**	**pass**	
3	**58**	**22.87**	**97.6**	**590**	**726**	**780**	**pass**	

Other test results are shown in testing data in Appendix G.

APPENDIX J

JOB HAZARD ANALYSIS
{Insert description of work task here}

Prepared by: Duncan Njunge	Reviewed by: Approved by:

Location of Task:	Electronic/electrical lab
Required Equipment / Training for Task:	Be trained on how to handle electric current wires when constructing heating and cooling elements for Lab water distiller project.
Reference Materials as appropriate:	Reference materials will be posted in the website and hard copy will be provided during construction.

Personal Protective Equipment (PPE) Required
(Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)

Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☒	☐	☒	☐	☐	☐	☐

Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.

PICTURES (if applicable)	TASK DESCRIPTION	HAZARDS	CONTROLS
	Constructing distiller's heating element	**Burn the user**	**- Put insulation Put automatic switch to avoid overheating**