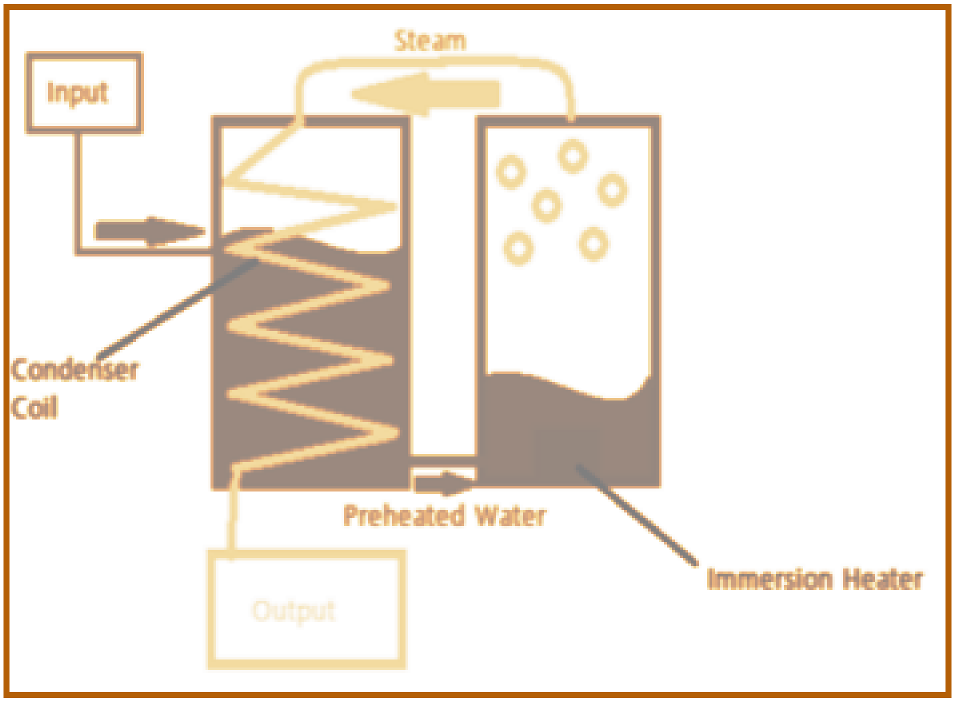
Universal Water Purification

Increasing efficiency

using a

Heat Exchanger & Waste Heat Recovery system



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March 19, 2016

INTRODUCTION - Rationale and Engineering Goal

Problem Clean water is not easy to find in many places and determining exactly what kinds of impurities are in the water can be even harder. Recently, bottled water had to be delivered for extended period to Flint, Michigan and Hoosick Falls, NY, due to the lead in the water. Additionally, Peritoneal Dialysis machines require sterile water to be physically delivered. Distillation is a sure way to get rid of all impurities in the water, but distillation consumes a lot of energy.

Proposed Design We propose adding a heat exchanger to a conventional boiler to distill water. The water surrounding the condensing coil should condense more steam and heat the surrounding water, allowing for waste heat recovery.

Engineering Goal Using waste heat recovery and a heat exchanger, this device should be able to produce distilled water more efficiently than currently available distillers.

PROPOSED DESIGN

Method Water heater boils water and produces steam that is forced through a condensing coil and condenses into clean water. The steam releases its latent heat when condensed and preheats the input water before it reaches the boiler.

HYPOTHESIS

Hypothesis A

A Heat Exchanger (water around the the condensing coil) should improve the efficiency of the water distiller.

Hypothesis B

Waste Heat Recovery (WHR) in addition to the Heat Exchanger (water around the condensing coil) should further improve the efficiency of the water distiller.

MATERIALS - Equipment & Technology

1. Stove or electric pressure cooker (1000W) for steam generation
2. Copper condenser coil used to condense steam into distilled water

3. PVC canister that houses the condenser coil surrounded by intake water and acts as the heat exchanger

PROCEDURE

1. Benefits of waste heat recovery -Waste heat recovery is a method of using heat released from other processes as a resource to improve efficiency. The energy savings comes from preheating the water to Tin.

2. Basic Energy Analysis

   Let l = latent heat of steam = 2257000 joules/kg
   cp = specific heat of water = 4187 joules/kg
   t = time = 30 minutes = 1800 seconds
   m = mass of water in the boiler = 2 kg
   s = steam produced (kg)
   Tin = Starting temperature in boiler (^oC)

Energy required to heat m kg at Tin to 100 C = m*cp*(100-Tin)

Energy required to convert s kg of water at 100 C to s kg of steam = s*l

Energy input from 1000 W heater over t seconds = 1000 x t

Therefore, $m \times cp \times (100 - T_{in}) + s \times l = 1000 \times t$

Solving $s = \dfrac{1500 \times t - m \times cp \times (100 - T_{in})}{l}$

Starting Temperature (Tin) in boiler Vs Steam Produced

T_{in} ^oC	20	60	80	90
s (kg)	0.50	0.65	0.72	0.76

2 kg boiler 30mins theoretical benefit is shown in the table; 52% increase in steam

TESTING PLAN

Test 1 Efficiency of Boiler
Test 2 Water Production Without Heat Exchanger (Control)
Test 3 Water Production With Heat Exchanger, Without Waste Heat Recovery
Test 4 Water Production With Heat Exchanger, With Waste Heat Recovery

RESULTS

Test 1	Trial 1	Trial 2	Percent Variation	Mean
Actual steam produced	0.500 kg	0.475	5%	0.4875
Theoretical steam produced	0.649 kg	0.649 kg	0	0.649
Boiler Efficiency	83.1%	78.2%	3%	80.65 %

Test 2 Actual water produced	0.075 kg
Theoretical water produced (100% steam condensed)	0.280 kg
Actual Efficiency	26.8%

Test 3 Water in Heat Exchanger at end of test	96.3ºC
Actual water produced	0.200 kg
Theoretical water produced (assuming all steam condensed, actual boiler efficiency used)	0.280 kg
Efficiency	71.4%

Test 4 Actual water produced	0.225 kg
Theoretical water produced (all condensed, actual boiler efficiency used)	0.280 kg
Efficiency	80.4%

The heat exchanger increases the efficiency from 26.8% to 71.4%. That is a 44.6% improvement in efficiency.

The Waste Heat Recovery (WHR) incrementally increases the efficiency from 71.4% to 80.4%. That is an 9% improvement in efficiency.

CONCLUSION

A heat exchanger can be used to more efficiently produce distilled water

The major benefit of using a heat exchanger is its ability to condense more steam. The benefit of waste heat recovery is minor in comparison.

After many tests we found that the water in the heat exchanger would easily reach 100^{o}C. A larger heat exchanger would solve this problem

Maintaining a water seal proved to be the most challenging part. Initially we set out to make our own boiler using a paint can and an immersion heater. We opted for an off the shelf boiler after having trouble sealing the container from pressurized steam.

Originally we hoped for a continuous process that would constantly be producing water where the preheated water would be continuously flowing into the boiler, but this proved very complicated as forcing water into a pressurized boiler takes immense force.

APPLICATIONS & FURTHER WORK

Applications

The device could be used in remote places with a common wood fired pressure cooker as well as the addition of a solar heater

This device could be used to provide medical grade water for dialysis machines which would save energy in the transport of distilled water.

Further Work

Automate the boiling and condensing batches using a microcontroller

Heat exchanger can be made more efficient with a continuous system where water is always flowing through the heat exchanger and into the boiler.

Using a small pump convection currents could be set up inside the heat exchanger to further increase its efficiently.