

# Performance Analysis of a Thin Tube Water Heater for Egerton University Using Comsol

Dr. Owino, George Omollo<sup>1</sup>, Isiah Otieno Onditi<sup>2</sup>,

Lecturer, Department of Industrial and Energy Engineering, Egerton University Kenya<sup>1</sup>

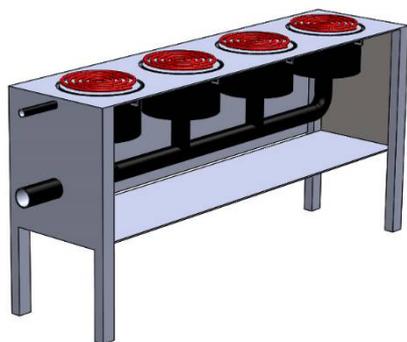
Technologist, Department of Industrial and Energy Engineering, Egerton University Kenya<sup>2</sup>

**ABSTRACT:**Water heaters and boilers are important equipment's due to their use in almost all process manufacturing industries and for domestic use as in environmental control systems for houses, hospitals, and schools or in other facility that require heat. This paper looks at performance of a thin shell helical water heater designed to boil 200 litres (55 gal) water for students at the University of Egerton in Kenya.

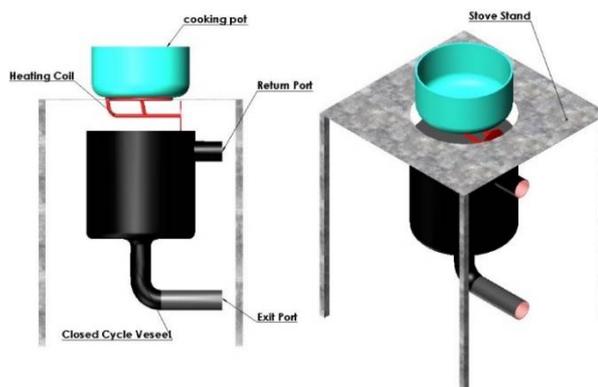
The source of heat channelled to the thin tube heat exchanger is from heat recovered from several electric coils. It is therefore important that the heater performance is optimal to ensure large volumes of water is boiled within the shortest time possible. Egerton university kitchen runs 24hrs for weeks with each kitchen having 6 stoves each having 4 electric cooking coils, radiated heat recovered from a set of 4 coils will be channelled to boil 200 litres of water

**KEYWORDS:**Heat Recovery, Radiation, Heat Exchanges, Electric Stove, Water heater, Comsol Multiphysics Software

## I. INTRODUCTION



(Fig 1. Four Kitchen Stove interconnected)



(Fig 2. Radiation Vessel Supply and Return Port)

Heat radiated by the electric coil is absorbed by four vessels placed under the stove the vessel supply and return port connected to the 55 gallon tank forming a closed loop cycle, the liquid inside the vessel gains heat and pressure becoming super-heated. Heat is therefore transmitted through the thin tubes in the large water gallon to the targeted water to be heated. Study results for the performance and optimization of this small vessel under the coil were presented in a previous paper

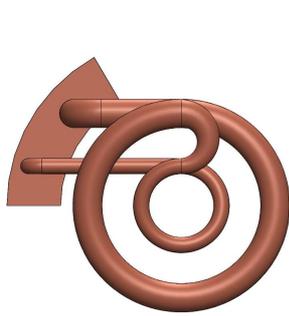
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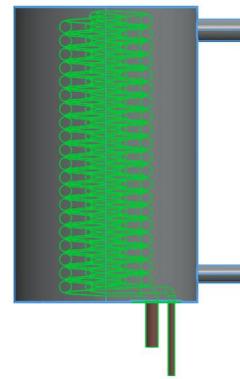
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## Experimental Setup

The thin tube 55 gallon water heater consist of two concentric copper coils the outside coil having a diameter of 50mm and the inside coil with a diameter of 25mm both coils are connected on one end with the other two ends connected to the supply and return ports of the vessel under the electric coil.



(Fig 3. Concentric Copper Tubes with different Diameters)



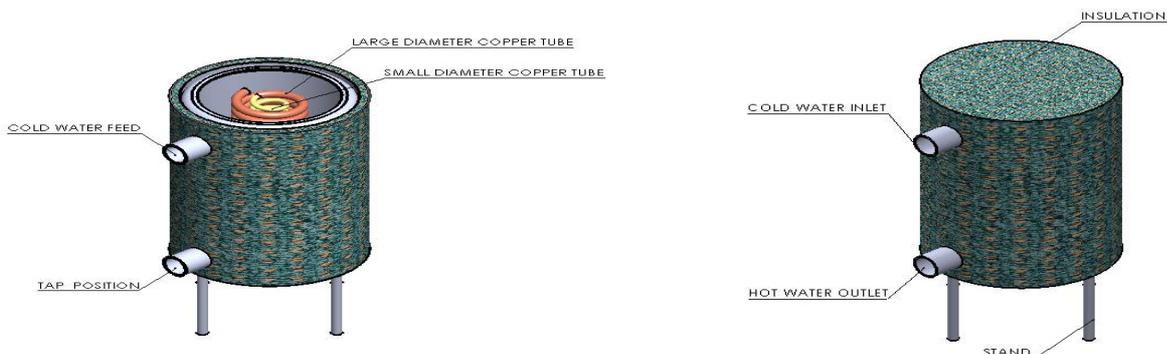
(Fig 4. 55 gallon tank with Concentric Copper Tubes)

The thin copper tubes protrude out the tank. The gap between the copper coil and the tank fills with cold clean water through one opening and the bottom opening as seen in figure 3 is fitted with a tap for withdrawing the water once it is hot.

The copper tubing and the vessel under the electric heater forms a closed loop however for increased efficiency the super-heated water with it needs to flow at low speed.

The solution to water flowing from the region of the coil to the copper tubing is by having the outer copper tubing with a wider diameter to the inside tube. Since they are connected to form a loop pressure build up in the system will experience slightly lower pressure in the wider region compared with the thin region of the tube before the whole system equalize. This pressure gradient causes a flow from high pressure region to the low pressure region.

It is however important to sustain the pressure gradient which is attained by inducing differential temperature within the line. The wider copper tubing has more surface area exposed to the water in the tank and therefore more heat is lost to the cold water. This causes this region to be cooler than the narrower section creating temperature gradient that drives more heat to move from the coil region to the tank



(Fig 5. Tank Insulation)

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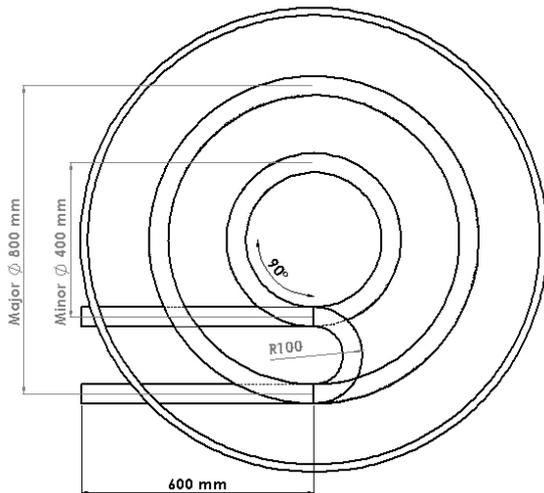
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The whole tank and the exposed pipes are insulated with glass wool to prevent heat loss to the atmosphere

## II. HELICAL COIL AND PARAMETERS

**Table 1 Control Parameters**

Item		Parameter		
Outer Diameter	50 mm	Fluid (Water)	Hot Water	Cold Water
Inner Diameter	48 mm	Mass Flow (kg/m)	0.1	Stationary
Outer Diameter	30 mm	Thermal Conductivity (W/m <sup>2</sup> Deg C)	383	16.2
Inner Diameter	28mm	Density (kg/m <sup>3</sup> )	997.5	961
Material	Copper	Initial Temperature °C	20~30	20~30
		Viscosity ( N-s/m <sup>2</sup> )	0.00082942	0.00028157



The following equations governs the analysis of helical coil heat exchanger

Length of coil needed

$$L = N \times \sqrt{((2\pi R)^2 + P^2)} \dots\dots\dots 1$$

The fluid volume in the coil

$$V_c = \left(\frac{\pi}{4}\right) [d_o^2] L \dots\dots\dots 2$$

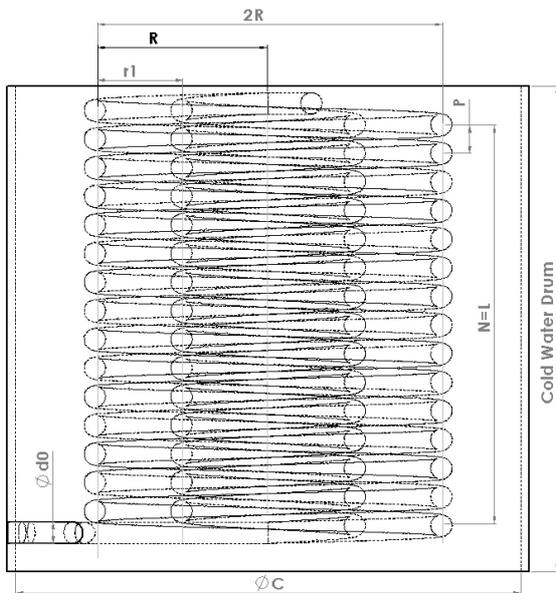
The fluid volume in the annulus

$$V_a = \left(\frac{\pi}{4}\right) (C^2) p N \dots\dots\dots 3$$

The shell side equivalent of shell tube  $D_e$

$$D_e = 4V_a / \pi d_o L \dots\dots\dots 4$$

The heat transfer coefficient of the fluid flowing inside the coil  $h_{i_o}$  can be determined



$$h_{io} = h_{ic} \left( \frac{D}{d_o} \right) \dots\dots\dots 5$$

The area required for heat transfer is determined by

$$A = Q/U\Delta t_c \dots\dots\dots 6$$

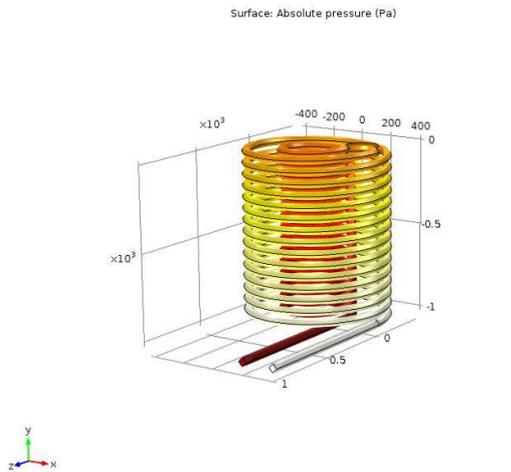
Number of turns of coil. Since  $A = \pi d_o L$  where L is expressed in terms of N the number of turns needed can be calculated by equation 7 below

$$N = A/(\pi d_o \left( \frac{L}{N} \right)) \dots\dots\dots 7$$

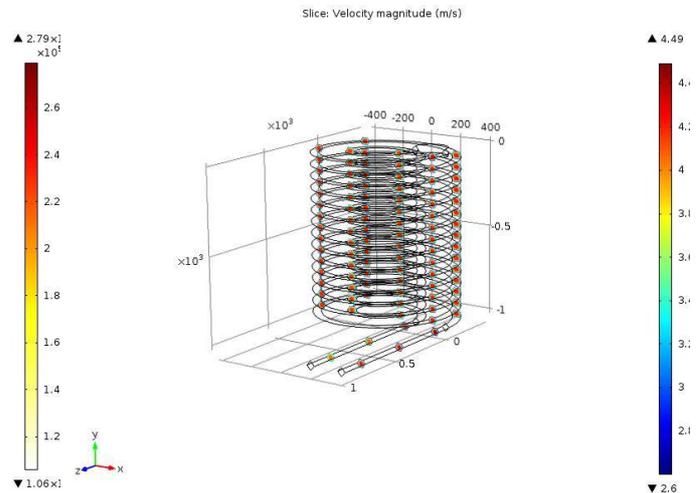
The figure 7 give the experimental set up of the system two concentric copper coils are placed inside a steel tank with insulation on the outside.

The feed and the return pipes exit the tank from below. The tank is mounted at a higher point than the stove to have positive pressure impinging in the vessel below the coils

**III. SIMULATION RESULTS AND DISCUSSIONS**



(Fig 8. Orthographic View of the Pressure Profile)



(Fig 9. Orthographic View of the Velocity Profile)

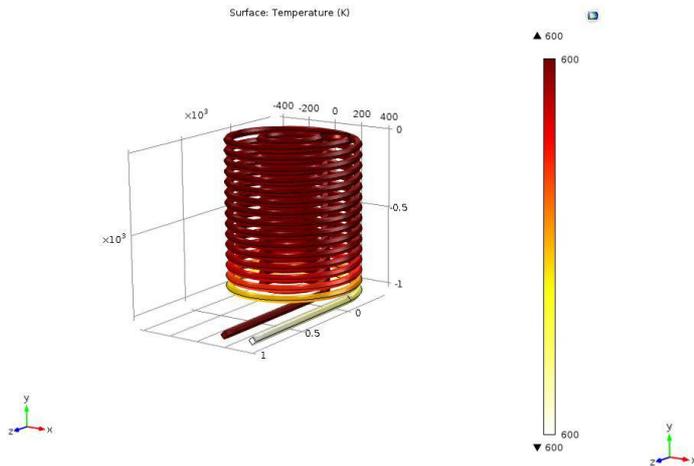
Figure 8 represents the absolute pressure simulation results of the copper coil, maximum pressure is  $2.79 \times 10^5$  pascals just slightly above ambient giving a positive flow in the coil and exits the coil at a reduced pressure of  $1.2 \times 10^5$  pascals the difference is associated with frictional pipe losses

Figure 9 on the other hand give the velocity results of the simulation the sectional slice displays velocity reduction from the centre towards the internal wall depicting a convective velocity profile due to frictional losses justifying pressure reduction as seen in figure 8 above.

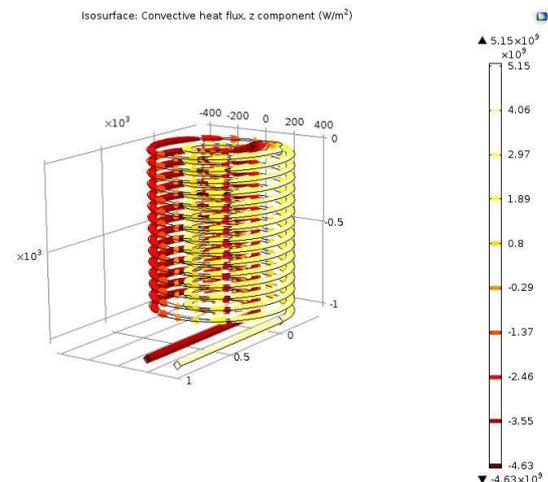
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(Fig 10.Orthographic View of the Temperature Profile)



(Fig 11. Orthographic View of the Convective Heat Flux)

The orthographic temperature distribution profile in figure 10 further indicate reduced temperature towards the return proving heat is lost to the coil water media surrounding it, high temperature are attained in the pipe as the loop is closed resulting to super-heated water caused by pressure build up.

It is important to determine the heat flux in the tube the temperature gradient existing between the coil and the cold water media define the efficiency, figure 11 shows high heat flux of about  $5.15 \times 10^9 \text{ W/m}^2$  on the feed side and reduces gradually as heat is lost to the water to reach  $4.63 \times 10^9 \text{ W/m}^2$  around the return.

## IV. INTERPRETATIONS OF SIMULATION RESULTS

The results featured in figure 10 and 11 indicate that heat is gained by the cold water and therefore we can conclude that radiative heat can successfully be trapped and put to use us in this case to boil water. Large volume of water can be heated having that most electric stoves at Egerton University work for 24 hrs through the month.

## V. CONCLUSION

Students and the kitchen can enjoy using hot water in the morning at no extra cost. If the system is installed in all the four kitchen within the university, the total volume of water boiled divided by the volume taken by each student can reduce the cost of heating water using an induction heater by up to 20% in the morning and another 8% after every 3hrs

## VI. ACKNOWLEDGEMENT

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