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The Study of the Heating Efficiency of the Coil-Type Electric Stove with Commonly Used Cooking Utensils in Boiling Water

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Abstract

A three separate three-factor fixed-effect model experimental design was used to study the heating efficiency of the electric stove in boiling water. Each experimental design used the three levels of water as reference. First level of water is 1000 ml, the second is 2000 ml, and the third is 3000 ml. The three factors were Factor A, Clay Enclosure; Factor B, Stove Setting and Factor C, Water Container. The three volumes of water were also considered to determine the effect on the efficiency of the electric stove.

At 95% confidence level, for 1000 ml of water, only Factors B and C were statistically significant but their interactions were not. For 2000 ml and 3000 ml of water, the three factors and the interactions between Factors B and C were statistically significant. The efficiency of the electric stove increases as the volume of water increases. The efficiency was higher when the stove setting was medium. The clay enclosure helped but not quite significantly in reduçing the bulk of heat transfer loss.

Introduction

One of the major consumers of energy is the electric stove. Most households use electric energy for cooking, boiling and other heating activities. An electric stove is a resistance heater that is used for the conversion of the electrical energy into heat energy. The conversion is al-

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most 100% efficient because losses are minimal unlike in the combustion of fuel where there is a considerable energy loss due to inefficient combustion and in the flue gas (Swenson, 1995).

With the current economic crises and high cost of living, consumers, especially housewives should consider new ways of cutting down expenses. Attention should be given on monthly electric bill. The bulk of the electrical energy consumption of an average household is due to cooking if electric stove is used. This study investigates the efficiency of an electric stove and intends to identify possible ways of reducing energy consumption without denying the comfort of cooking using an electric stove. It also investigates the reduction of heat loss by convection and radiation due to the enclosure of clay (knowing that clay is a good insulator) to the water containers thereby increasing the efficiency of the electric stove. In the experiment, the electric stove was used to boil water of different volumes. Water was used as a medium to determine the efficiency of the electric stove since it absorbs heat efficiently and the water temperature is almost the same at every point inside the container upon reaching boiling point. The properties of water are also well known. The study used only two settings, medium and high with a pot and a pan used as containers for water. The medium setting has a smaller heating area than the high setting.

The Experiment

Twenty-four runs in three replicates were performed at random in this experiment. In every test run, the initial temperature of water, the ambient air temperature, the mass of water, the type of water container and the setting of the electric stove were recorded. The start of the counting of the number of revolutions of the disk of the electric meter was started simultaneously with the switching on of the stove. When the temperature of water reached 100°C and just before the start of evaporation, the electric stove was shut off and the number of revolutions made was recorded. The number of revolutions would give the equivalent energy consumed during the test run. The efficiency of the stove was calculated as the heat energy absorbed by the water divided by the electrical energy consumed by the stove. The electric stove and the water container were allowed to cool back to their initial temperature before another test run was performed.

Results and Discussion

The Effect of Varying the Volume of Water

It is observed from Figure 1 that the mean efficiency of the electric stove increases as the volume of water increases. For 1000 ml of water, the mean efficiency is 16.25%; for 2000 ml of water, it is 20.60%, and 22.33% for 3000 ml of water.

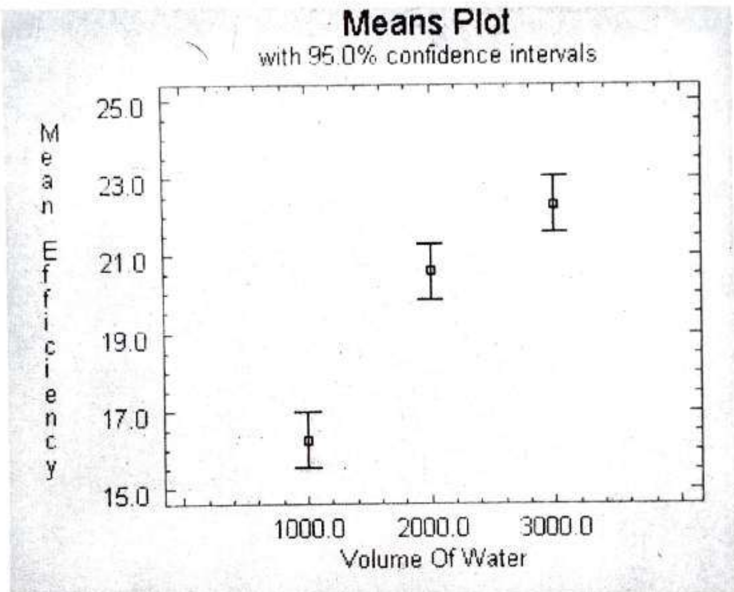

Figure 1. The Mean Efficiency vs. Volume of Water

The increase in efficiency with the increase in volume indicates a lesser percentage of heat loss although more heat is needed to reach boiling point when the volume of water is increased.

The input electrical energy in every test run was distributed as:

1) heat absorbed by water
2) heat losses

The heat absorbed by the water was considered as the useful energy and all the others were considered as heat losses. The heat losses were due to (a) heat absorbed by the water container, (b) energy loss as electrical energy is converted to heat energy, and (c) heat loss due to conduction, convection and radiation. The heat loss was measured as the difference between the energy input and the energy that was absorbed by water. The results indicate that the percentage of the heat losses decreases as the volume of water to be boiled is increased.

The Effect of the Clay Enclosure for 1000 ml of Water

It was found statistically that there was no significant difference for the clay enclosure at 5% level of significance for 1000 ml of water. Although there was a slight increase (figure 2) on the mean efficiency of the electric stove from 15.785% to 16.399%. The clay enclosure was not able to significantly trap the bulk of the heat losses due to convective heat transfer. It was because of the short time required to boil the water making the bulk of heat input went to the heating of the coil and the water container.

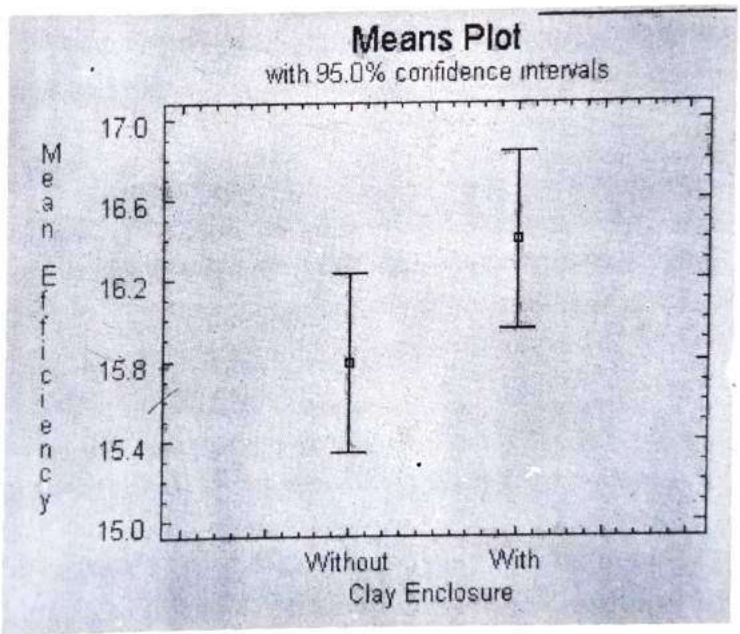

Figure 2. *The Mean Efficiency vs. Clay Enclosure*

The Effect of the Stove Setting for 1000 ml of Water

It was found statistically that there was a significant difference for the stove setting at 5% level of significance.

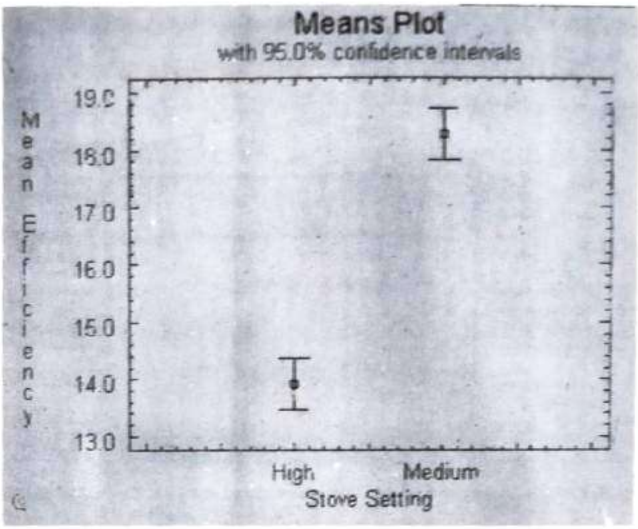

Figure 3. *The Mean Efficiency vs. Stove Setting*

Figure 3 shows that the mean efficiency of the electric stove with medium setting was higher and is equal to 18.265% compared to 13.918% for the high setting. Although they required the same amount of heat for boiling, more heat losses occurred when using the high setting. This was due to a larger heat transfer area for convection heat transfer between the heating coil and the surrounding air (see Figures 8 & 9).

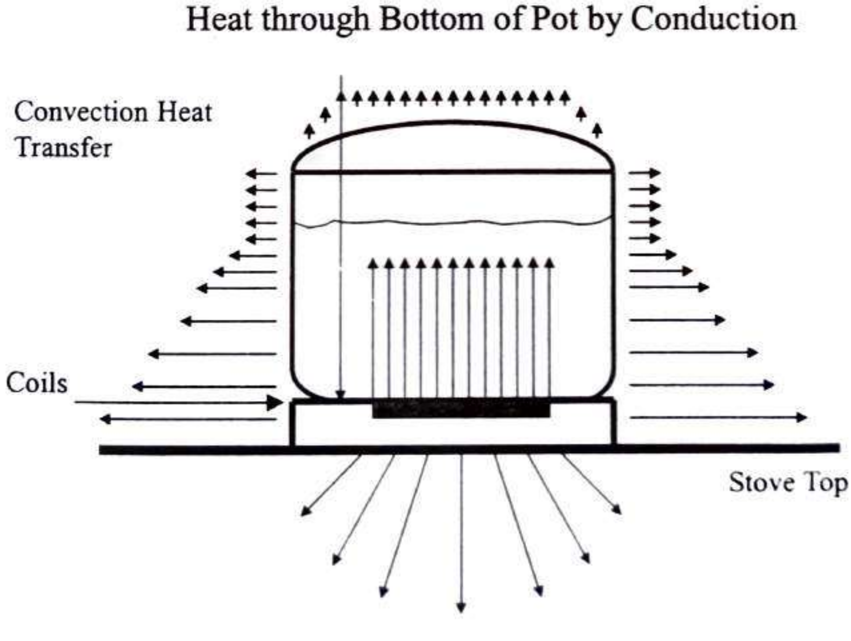

Figure 4. *Pot on Stove with Medium Setting*

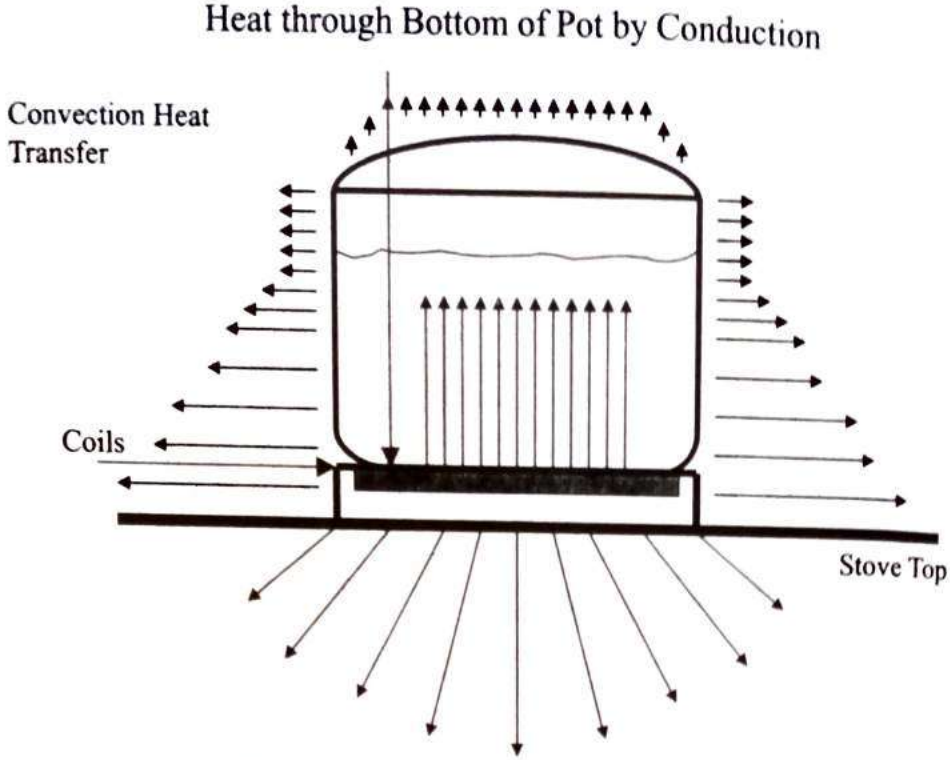

Figure 5. Pot on Stove with High Setting

Comparison on the Efficiency between Water Containers for 1000 ml of Water

It was found statistically that there was a significant difference for the water containers at 5% level of significance.

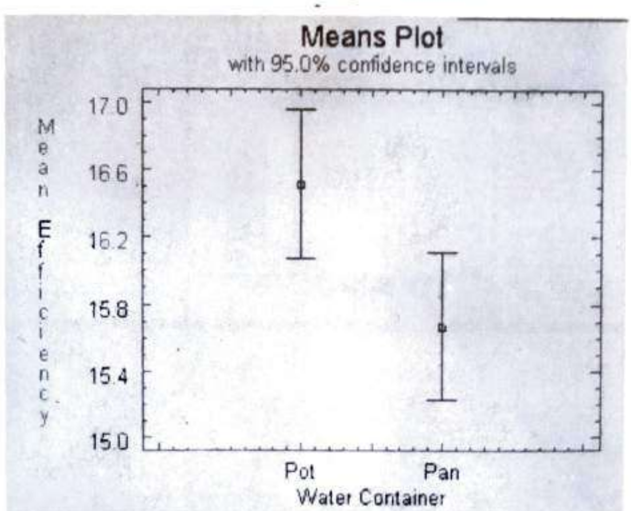

Figure 6. *The Mean Efficiency vs. Water Container*

Figure 6 shows that the mean efficiency for the pot is higher compared to the pan. It was because the pan has a bigger volume of material to be heated and the heating coil has a larger heat transfer area for convection with the surrounding air (see Figure 7).

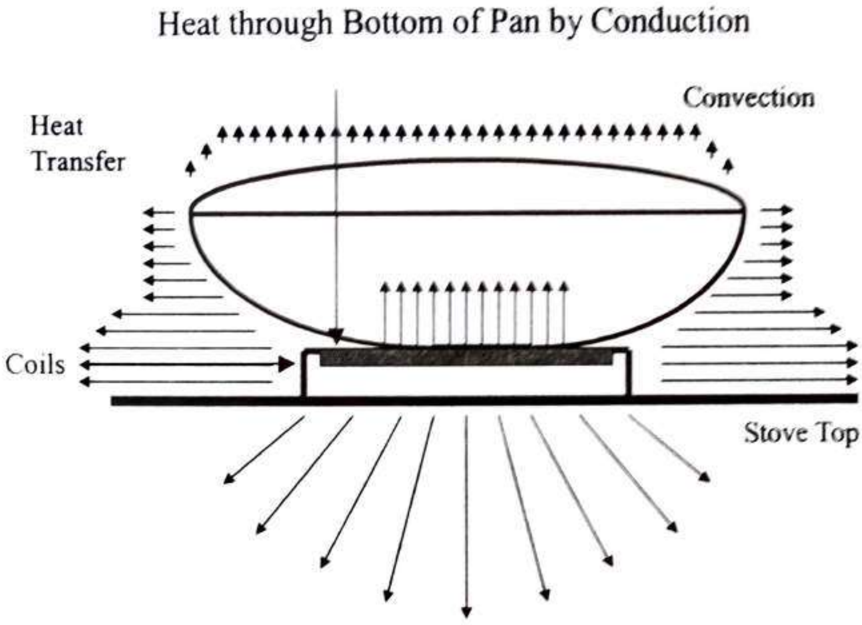

Figure 7. Pan on Stove with High Setting

The Effect of the Clay Enclosure for 2000 and 3000 ml of Water

It was found statistically that there was a significant difference for the clay enclosure at 5% level of significance unlike in the case of 1000 ml of water. The clay enclosure was able to reduce significantly the heat loss due to convection (see Figures 8 and 9). It was because of the longer time required to boil 2000 and 3000 ml than 1000 ml of water. The mean efficiency of the electric stove increases as the water container was enclosed with clay.

Heat through Bottom of Pot by Conduction

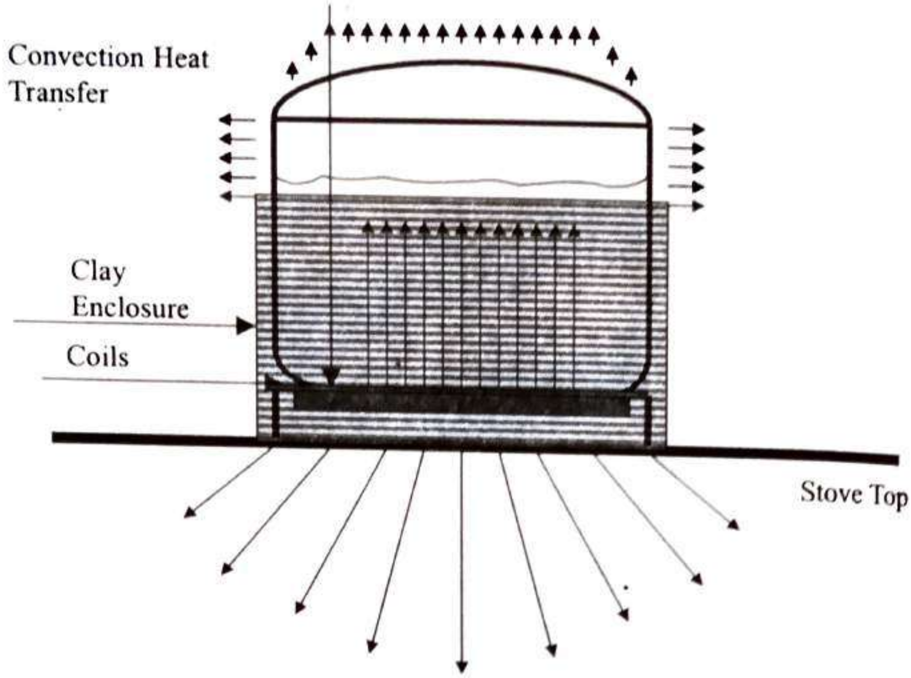

Figure 8. *Pot on Stove with Clay Enclosure*

Heat through Bottom of Pan by Conduction

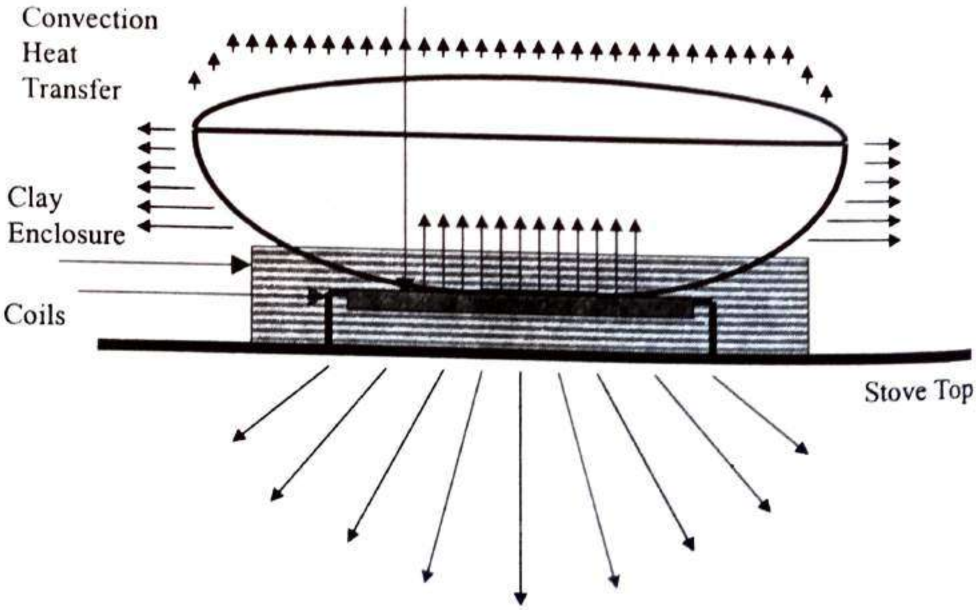

Figure 9. *Pan on Stove with Clay Enclosure*

The Effect of the Stove Setting for 2000 and 3000 ml of Water

It was found statistically that there was a significant difference for the stove setting at 5% level of significance for 2000 and 3000 ml of water.

The efficiency of the electric stove with medium setting was higher for the high setting. Although the medium and high setting required the same amount of heat for boiling, more heat losses occurred when using the high setting. This was due to a larger heat transfer area for convection heat transfer between the coil and the surrounding air (see also Figures 8 & 9).

Comparison on the Efficiency between Water Containers for 2000 and 3000 ml of Water

It was found statistically that there was a significant difference for the water containers at 5% level of significance.

The mean efficiency of the pot was higher than the pan. It was because the pan has a bigger volume of material to be heated and the heating coil has a larger heat transfer area for convection with the surrounding air.

Interactions

It was found statistically that there was a significant interaction between medium and high setting by water container at 5% level of significance.

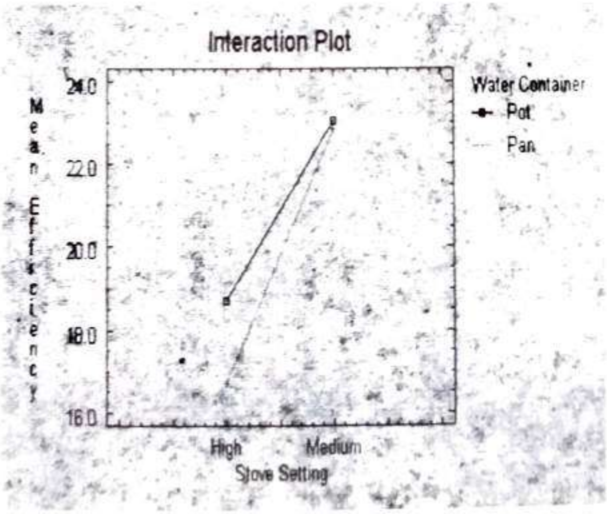

Figure 10. *Mean Efficiency vs. Interaction of Factors B & C*

Figure 10 shows that there was almost no difference on the mean efficiency between water containers using the medium setting of the electric stove. It was because in the medium setting, the convective heat transfer areas that would tend to increase the heat losses between the water containers did not differ much. While for the high setting, the mean efficiency for the pot was higher since the convective heat transfer area for the pan was larger compared with the pot.

Conclusions

The result of this study drew the following conclusions:

1. The mean efficiency of the electric stove increases as the volume of water increases.
2. The presence of the clay enclosure is only statistically significant for 2000 ml and 3000 ml of water.
3. The medium setting of the electric stove gave a higher efficiency than the high setting.
4. The mean efficiency difference between the pot and the pan is statistically significant.
5. The bulk heat loss on the average is 80%.

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