Improvement of Conventional Electric Heater to Reduce Energy Loss and Its Performance Test

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Abstract

With rapid growth of population and urbanization, the energy demand is increasing day by day. Electrical energy is an important component for developing economy. Only 40% of our population has access to electricity. Due to shortage in supply, it becomes important to conserve electricity. Although there is restriction to use electric heaters, still it is being used in small scale in halls, hostels, messes etc. Conventional electric heater losses heat by radiation through bottom and by conduction through the mortar. Heating is not very effective, if the air gap between the utensils' bottom and coil plate is not optimized. A comprehensive study has been conducted to improve the conventional electric heater to reduce energy loss. Heat loss through the bottom and mortar is reduced by putting thermal insulation and a reflective coating. Three test specimens have been used to carry out the test with an improved heater and a conventional heater. The results reveal that energy can be saved by 35%, 30% and 17% for boiling water, cooking rice and red lentil respectively. Also, aluminum sheet is used instead of white cement and thermal insulation to make the construction simpler and the performance test has been carried out. It is found that when glass wool with white cement is used, save energy is around 30% whereas the same is around 28% when only aluminum sheet is used. Thus, by providing thermal insulation and reflective coating the heat losses from an electric heater can be reduced significantly.

Keywords: Electric heater, Thermal Insulation, Reflective coating, Cooking time, Energy conservation.

1.0 Introduction

Modern world depending upon coal, oil and natural gas for a majority of its energy needs and the prediction that the world will need nearly double its energy resources within several decades; therefore, it is important to conserve energy. There are two kinds of energy sources on which we depend – renewable and nonrenewable. Renewable energy sources are those that are continuously replenished such as water, wind and solar. Non-renewable energy sources, on the other hand, like gas, coal, and oil cannot be replaced within a shorter duration [1]. Therefore, consumption of these sources needs to be controlled to ensure that the limited supply we have will be available to future generations.

Like the rest of the countries of the world, the demand for energy is increasing day by day in Bangladesh. Electricity is the major source of power for most of the country's economic activities.

According to PDB records, the demand of electricity varies between 5500 - 6000 MW daily but it goes up to a maximum of 6700 - 6800 MW during the peak summer [2]. The installed capacity is 8525 MW in 2013 but the highest generation was so far 6350 MW recorded on 04-08-2012. Only 40% of the population has access to electricity grid with a per capita consumption of 136 kW-hr per annum. Overall, the country's generation plants have been unable to meet the demand over the past decade [3, 4, 5]. Also, there are several areas like Khulna, Rajshahi, and Barisal where natural gas supply is not available. In those areas, liquefied petroleum gas (LPG) is most commonly used for cooking purposes. Besides, sometimes electric heaters are used. Although, PDB has banned the use of such electric heaters, still it is used for cooking purposes in small scale in hostels, halls, messes etc. But the people are not aware of the energy loss it causes.

The structure of a conventional electric heater is such that appreciable amount of heat is wasted during cooking. A greater portion of the bottom area of the heater is open to the atmosphere which causes heat loss by radiation. Again, through the inside wall of the heater which is mainly mortar, appreciable amount of heat is lost by conduction. Moreover, the height of the heater body is not to any standard and there is air gap in between utensil's bottom and the coil plate. This causes less heat to receive by the utensil as air acts as thermal insulator which ultimately is a loss of energy. Due to these losses, the heater is needed to keep on completing the cooking operation for a longer period and hence consumes more electrical energy. So, if this heat loss can be reduced, then electrical energy will be saved. The aim of this work is to conserve energy by means of improving the conventional electric heaters by reducing the energy loss and thus the cooking time.

It is obvious that thermal insulation can reduce heat losses in a conventional electric heater [6]. Among various thermal insulators, glass wool may be considered suitable because of its very low thermal conductivity and temperature resistance [7, 8]. Moreover, it is readily available and low cost comparing to other type of insulators. Again, heat loss through the mortar can be reduced by providing a reflective coating. Considering this a light-colored material (say white cement) is chosen as reflective material [9, 10]. On the other hand, the reflectivity of aluminum sheet is around 84% to 98% [11, 12]. Since it provides high reflectivity and use of it makes the construction easier, so it may also be chosen as alternative of white cement coating. In this work both materials have been used and tested.

2.0 Fabrication

2.1 Fabrication of an insulated electric eeater by esing glass gool and ghite cement

At first a box is made using MS sheet, which provides the necessary structure to hold the glass wool insulation surrounding the electric heater base. Both the bottom and surrounding of the heater is insulated by glass wool. On inside wall of the base, a mixture of white cement, chalk powder and water is brushed so that the mixture acts as a reflective coating. Figure 1 illustrates the thermal insulation and reflective coating.

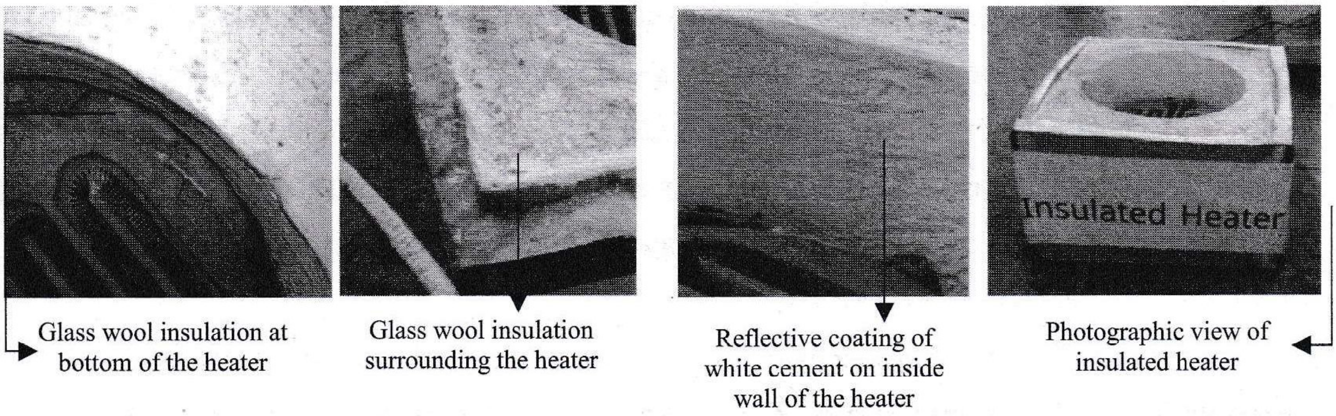

Fig. 1. Detail photographic view of Insulated Electric heater using glass wool, white cement.

2.1 Fabrication of an improved electric heater using aluminum sheet

A piece of aluminum sheet is bend and is placed inside the wall of an electric heater to form the coating as shown in Figure 2. Again, the open bottom area of the heater is covered by another piece of aluminum sheet as shown in figure. Using aluminum sheet instead of glass wool and white cement helps reducing the complexity of the previous construction.

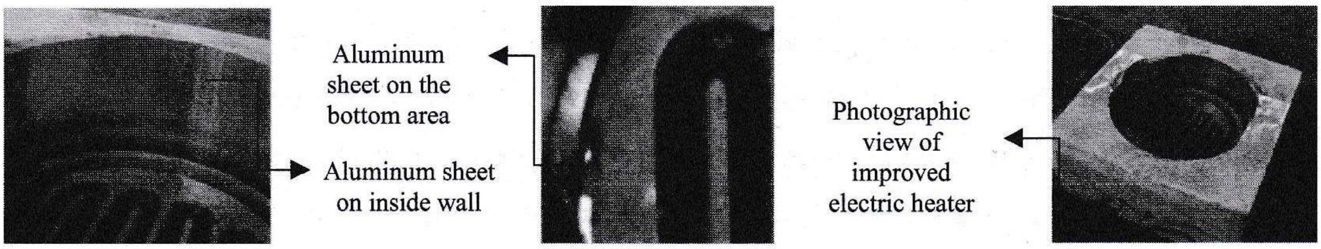

Fig. 2. Photographic view of an Improved electric heater using aluminum sheet and coated areas

3.0 Experimental setup

3.1 Test section for temperature profile along radial and vertical directions

To obtain the optimum height between the coil surface and the utensil, temperature profile for both insulated and bare electric heaters are determined along radial and vertical direction from coil plate surface to a height of 4.5 cm. For this, three thermocouples and three temperature recorders are used. A wooden frame is fabricated and used to hold the thermocouples along the radial direction and to move the thermocouples vertically easily at different heights. Along radial direction at 0 cm (centre of the coil plate), 5.75 cm and 11.5 cm, three thermocouples are placed to record the temperature. Again, along vertical direction, temperature is determined at six heights from coil plate to the utensils bottom surface. These set-ups are shown in Fig. 3 and Fig. 4.

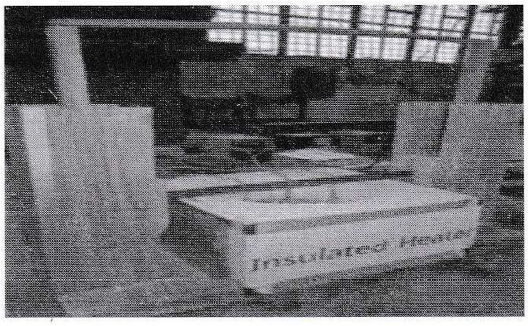

Fig. 3. Test section for temperature profile of insulated heater along radial and vertical direction

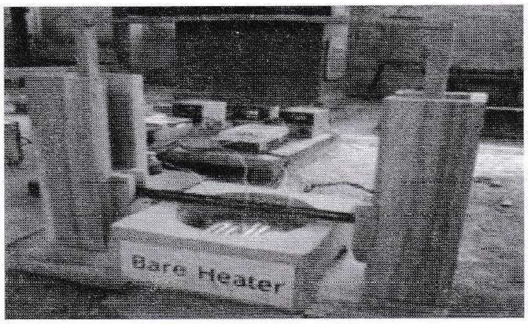

Fig. 4. Test section for temperature profile of bare heater along radial and vertical direction

3.2 Test section for performance tests

Three different specimens - Water, Minicate Rice and Red Lentil have been used for performance tests for both insulated heater and bare heater. In these tests, cooking time, initial water temperature, final water temperature and energy consumption have been measured for both the heaters with the help of stopwatch, thermocouple, temperature recorder and energy meter (as shown in Figure 5). Hence, the percent energy save is achieved. The variation in percent energy save with amount of cooking and hence maximum percentage of energy save is also determined.

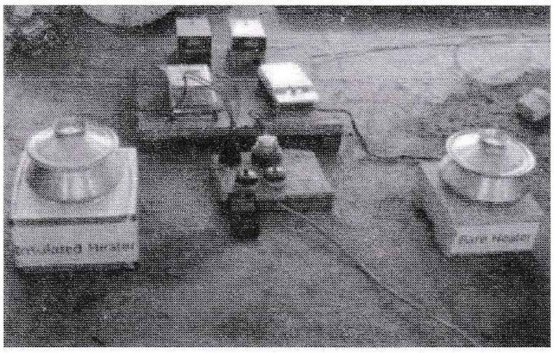

Fig. 5. Test section for performance tests using glass wool insulation and white cement

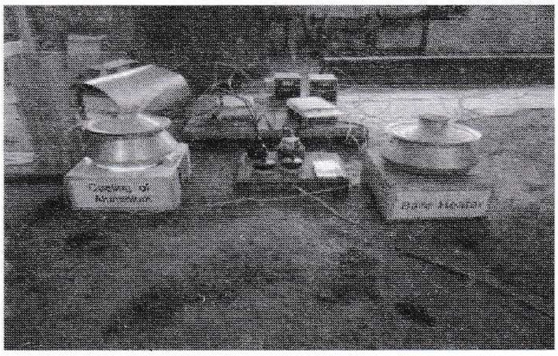

Fig. 6. Test section for performance tests using coating of aluminum sheet

3.3 Test section for Performance Tests using Aluminum Sheet

Instead of glass wool and white cement only reflective coating of aluminum sheet is used afterwards. Then the variation in percent energy save with amount of cooking and hence maximum percentage of energy save is determined. After that, the comparison between the improved insulated electric heater using glass wool and white cement and the improved heater using only aluminum sheet has been brought into picture. This set-up is represented in Fig. 6.

4.0 Results and discussions

4.1 Result for optimum height condition

The temperature profiles along radial direction at three different points are shown in Figure 7 for both the bare and insulated electric heaters. The three points are at 0 cm (centre of plate), 5.75 cm and 11.5 cm along the radial direction. It is evident from the figure that the temperature at various points inside an insulated heater is more than that of the bare heater at the same point. This is because heat loss has been recovered by providing thermal insulation.

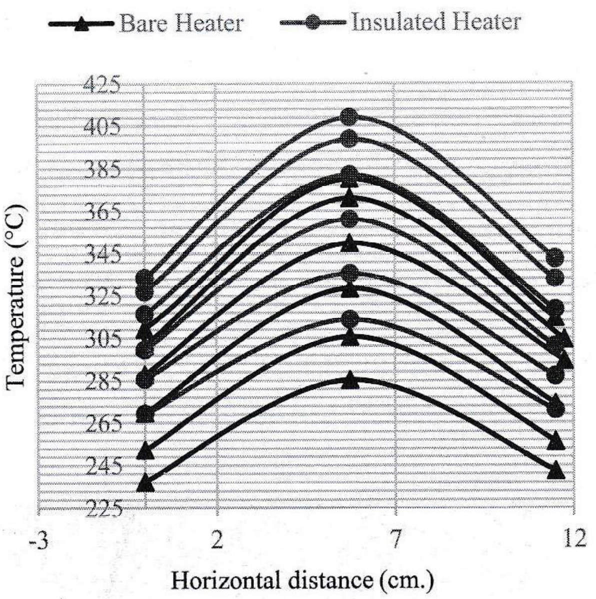

Fig. 7. Temperature Profile along Radial Direction for both Bare and Insulated Heater.

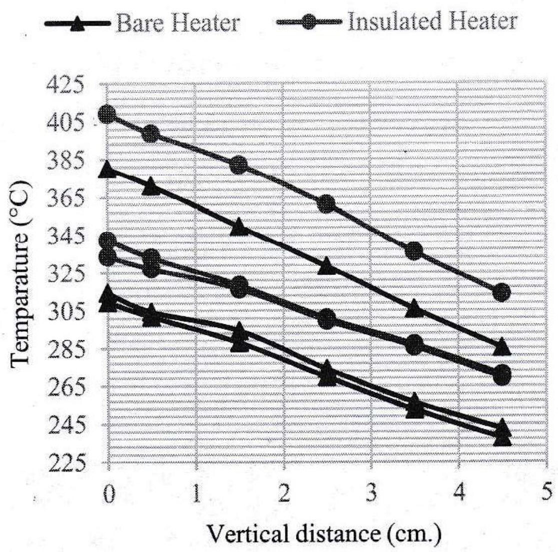

Fig. 8. Temperature Profile along Vertical Height for both Bare and Insulated Heater.

Fig. 7 also represents that temperature at the mid-point is always higher than that at the sides. This might be because of coil density is more at the middle. Figure 8 shows the temperature distribution along the height from the coil plate to the utensils' bottom. At points closer to the coil plate, the temperature is significantly more than that at distances points. This is due to the air gap. As thermal conductivity of atmospheric air is low as 0.024 W/m.K, it acts as an insulator in between utensils and coil plate. Observing these temperature profiles, it can be concluded that, if an electric heater is insulated and coated then heat energy and electrical energy can be saved. Also, if the distance between utensils' bottom surface and coil plate is reduced, then the utensils will receive more heat because the air gap will be minimized appreciably. So, cooking time will be less and energy will be saved. But care should be taken so that the utensils' bottom must not touch the coil surface to avoid accident.

4.2 Result for performance tests of insulated electric heater

With the three test specimens - Water, Minicate Rice and Red Lentil the performance tests have been carried with bare and insulated heaters as described earlier for several days. In each case, the percentage energy save has been calculated from the observed information during each cooking.

Table 1: Results for energy save (%) by Insulated heater in boiling 800 ml water.

Obs. No.	Energy consumed with Insulated heater (kWhr)	Energy consumed with Bare heater (kWhr)	Energy Save (%)
14.07.2013 (Sunday)			
1.	0.23	0.33	30.30
2.	0.24	0.29	17.24
3.	0.23	0.35	34.30
15.07.2013 (Monday)			
1.	0.23	0.41	43.90
2.	0.24	0.38	36.84
3.	0.26	0.41	36.59
16.07.2013 (Tuesday)			
1.	0.25	0.39	35.89
2.	0.25	0.37	32.43
3.	0.23	0.27	15.00

Table 2: Results for energy save (%) by Insulated heater in cooking 60 gm rice along with 500 ml water.

Obs. No.	Energy consumed with Insulated heater (kWhr)	Energy consumed with Bare heater (kWhr)	Energy saves (%)
18.08.2013 (Sunday)			
1.	0.31	0.45	31.11
2.	0.32	0.47	32.00
3.	0.31	0.44	29.55
19.08.2013 (Monday)			
1.	0.33	0.44	25.00
2.	0.32	0.43	25.58
3.	0.32	0.44	27.27
20.08.2013 (Tuesday)			
1.	0.30	0.43	30.23
2.	0.33	0.45	26.70
3.	0.32	0.45	28.90

In case of water, it is observed that the insulated heater performs better compared to the bare heater for raising the temperature of water to its boiling point. For each observation, 800 ml water has been used as sample. By determining the energy consumption by both heaters, the percent energy save has been calculated.

The insulated heater has reduced heat losses, saved cooking time and for this appreciable amount of energy has been saved. Hence, from Table 1, it is observed that maximum energy save is 43.9% while the minimum save is 15%. From Table 1, it can be concluded that around 35% energy is saved in boiling 800 ml water.

Similarly, performance tests have also been conducted for cooking 60 gm Minicate rice along with 500 ml water. From Table 2, it is seen that maximum save is 32% and minimum save is 25% by using glass wool insulation with white cement coating. It can be concluded that around 27% to 30% energy have been saved in cooking 60 gm Minicate rice along with 500 ml water.

Again, for cooking 50 gm red lentil along with 375 ml water, from Table 3, it is seen that maximum energy has been saved 23.08% and minimum 16%. It can be concluded that around 17% energy has been saved by the insulated heater in this case.

Table 3: Results for energy save (%) by insulated heater in cooking 50 gm red lentil along with 375 ml water.

Obs. No.	Energy consumed with Insulated heater (kWhr)	Energy Consumed with Bare Heater (kWhr)	Energy Save %
18.08.2013 (Sunday)			
1.	0.21	0.25	16.00
2.	0.18	0.23	21.74
3.	0.20	0.26	23.08
19.08.2013 (Monday)			
1.	0.22	0.27	18.52
2.	0.20	0.24	16.67
3.	0.21	0.25	16.00
20.08.2013 (Tuesday)			
1.	0.21	0.25	16.00
2.	0.20	0.24	16.67
3.	0.23	0.28	17.86

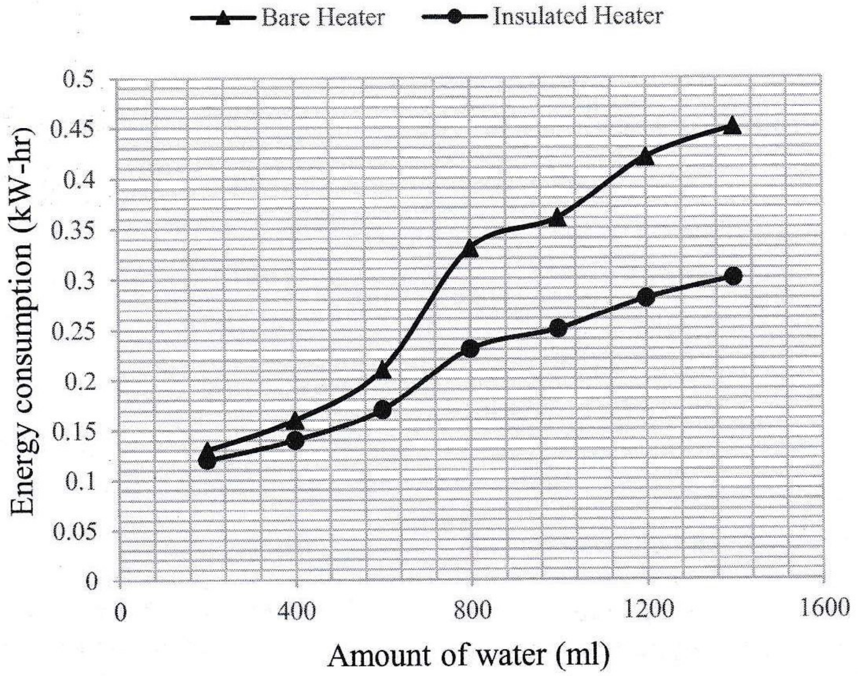

Fig. 9. Energy consumption (kW-hr) with varying amount of boiling water (ml).

4.3 Variation in energy save (%) with cooking-time in case of insulated electric heater

It has been seen that with the change in amount of cooking i.e. cooking time, the percentage in energy save also changes. In Figure 9, these results are shown graphically. It is evident from the figure, that when amount of water is less, the difference in energy consumption with bare and insulated heater is less. With the increase in amount of cooking i.e. amount of water (ml), this difference increases. As a result, when the amount of cooking is less, save in energy (%) is also less; when the amount increases, percent energy save also increases. This is due to the fact that when cooking amount is less, then less cooking time is needed. As a result, heat entrapment inside the insulated electric heater is less for small period and hence save in energy (%) is not so significant. But when amount of cooking increases, the time period also increases. As a result, heat entrapment occurs inside the heater for longer time and hence significant portion of energy is saved.

4.4 Variation in energy save (%) with cooking-time in case of coating of aluminum sheet

As aluminum sheet is appreciably reflective, this has been chosen and applied instead of thermal insulation and white cement coating. This reduced the complexity of construction. With various amount of cooking, the variation in energy save (%) in this case is also observed is illustrated in Figure 10. It shows the energy consumption with both heaters at various amount of boiling water (ml).

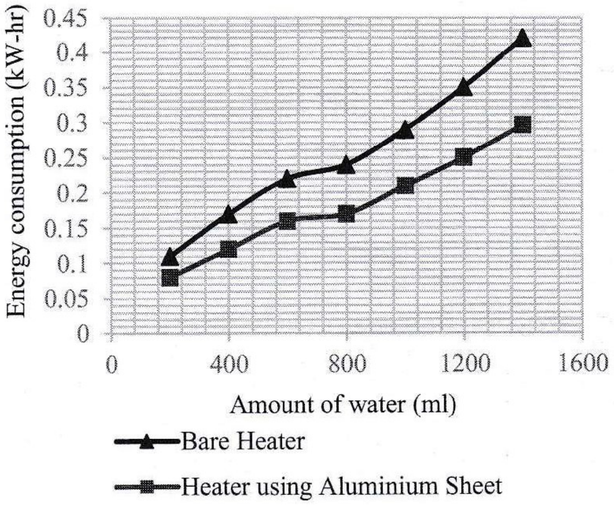

Fig. 10. Energy consumption with varying amount of boiling water (ml) when aluminum sheet is used.

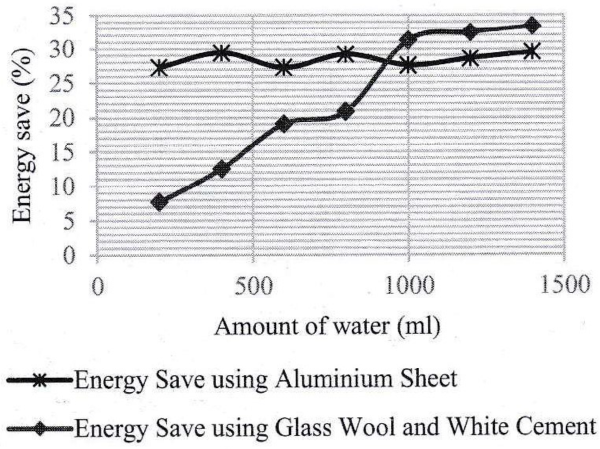

Fig. 11. Comparison in Energy save (%) between aluminum sheet coating and glass wool insulation with white cement coating.

Figure 10 reveals that when aluminum sheet is used as reflective surface on both bottom and inside wall of an electric heater, then the difference between energy consumption with the improved heater and bare heater almost remains same though the amount of cooing material. As a result, percent energy save remains almost same in all cases.

4.5 Comparison of energy save with aluminum sheet vs thermal insulation with white cement coating

Fig.11 illustrates that when heat lost has been recovered by using thermal insulation of glass wool with white cement coating, save in energy (%) has varied from 7.69% to 33.33% for various amount of cooking i.e. amount of boiling water (ml). But when only aluminum sheet has been used, save in energy has varied from 27.27% to 29.52% for same amounts of cooking. So, the application of aluminum sheet provides more stable output than application of glass wool with white cement. Moreover, it makes the fabrication simpler than before.

5. Conclusions

The following conclusions may be drawn from this study:

- Around 30% save in energy is possible if thermal insulation of glass wool with reflective coating of white cement is used.
- If reflective coating of simply aluminum sheet is used, around 28% energy is saved.
- Anyone can use either one of this to reduce energy loss in a heater.

- If around 30% energy loss could be recovered every day in each kitchen in those areas where electric heaters are used for cooking purpose then life will change drastically.

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