To investigate the surface properties for increasing efficiency of solar water heater

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Abstract. Energy crisis is becoming a major problem in Pakistan. Renewable energy sources are used to overcome this crisis. This research is about to increase the efficiency of fin type solar water heater by modification of its surface properties. During this research work, solar water heater module is fabricated and the modification of surfaces by using bare surface, external surface coated with high conductivity paint and lead electroplating is studied and the efficiency of solar heater is observed. The temperature profile and the heat transferred is studied and it was found that paint coated surface is more efficient than bare surface, further surface electroplated with lead is more efficient than painted surface for the same ambient conditions. The average increase in the heat absorption for lead plated and paint coated surface was observed 28.57% and 10.79 % respectively.

1. Introduction
There is a major problem of energy crisis which is faced by all over the world. In order to control this energy crisis problem many researches are performed using renewable energy sources like using solar energy instead of electrical and fuel energy. Because solar energy is free of cost and environmentally friendly. In this perspective different solar water heaters are designed to use solar energy for heating of water, which is used for domestic and industrial purposes.

Solar water heater largely depends on transmittance, absorption and conduction of solar and the conductivity of the working fluid [1]. The design parameters such as plate efficiency factors have been analyzed by Hottle and Whiller, in1958 [2]. Thermal performance of collector is also dependent on the optical efficiency of glass cover, design and thermal properties of absorber plate. The maximum energy conversion of absorber plate using selective coatings to reduce radioactive losses has been analyzed by many researchers in 1979 [3-5]. Shariah et al. in 1999 studied the effect of thermal conductivity of the absorber plate on the performance of solar collectors through the transient simulation system (TRNSYS). They confirmed that the characteristic factors like fin efficiency, collector efficiency and heat removal are strongly dependent on the thermal conductivity of absorber plate [6]. Storage tank is a main component in solar water heater for achieving maximum efficiency, there should be minimum energy losses from the storage tank. For this purpose Colle, et al. in 2001, worked on proper insulation using various materials and various thicknesses [7]. Results showed that the heat removal efficiency of thermosyphon solar water heater is highly dependent on thermal stratification. Further experimental studies have been carried out by Chang in 2004 [8]. He evaluated

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the heat removal efficiency during the system application phase. The overall performance rating of a thermosyphon solar heater considering the thermal performance of the system during the energy collecting phase and the system cooling loss during the cooling face has been analyzed experimentally by Chang, et al. in 2004 ‘[9]’. Heat transfer, friction factor coefficient of plain, microfin and twisted tape insert tube has been analyzed by A-Fahed, et al. in 1999 [10]. The collector efficiency is also accessible to increase the transfer area by adding fins [11]. Researchers have been made for special coatings on collector tube which behaves as a selective surface with low diffusivity constant for solar radiation [12]. Solomon, et al. in 2006, have developed a model of a flat plate solar collection system [13]. Yousef and Adnan in 2008, have investigated the effect of mass flow rate, flow channel depth and collector length on the system thermal performance and pressure drop through the collector with and without porous medium [14].

In the recent research, we observed the effect of different surface properties to improve heat transfer coefficient and the heat transfer rate. Heat transfer rate is evaluated for each modified surface.

2. Material and method

2.1. Experimental setup
The experiments were conducted on a lab scale fabricated solar water heater. The figure 1. shows the schematic diagram of solar water heater.

![Figure 1(a). Solar water heater](image1)

![Figure 1(b). Solar water heater](image2)
2.2. Experimental procedure
Solar water heater consists of a storage tank and collector tube. Storage tank has a capacity of 5 litres. The collector tube is fabricated from copper tube of having a diameter of 0.75 in and length 75 cm with fins on both sides. To avoid the heat transfer from the collector tube towards the surroundings, it is fixed in a glass tube. Three thermocouples were used to find the temperature of storage tank at three different locations named T₁, T₂ and T₃.

Now for the bared copper tube, starting from a temperature of 28°C, the temperature of three thermocouples is noted at a time interval of 10 minutes. Then the copper tube is covered with a black paint and again the readings are noted at the same time interval. Finally the lead electroplating is applied on the copper tube and the same procedure is repeated for the same time interval.

3. Results and discussions
Different experiments are carried out to find surface properties of solar water heater by different techniques.

3.1. Heat flux of solar water heater with bared copper tube
Figure 2. shows the effect of heat flux for simple copper tube surface. The time interval is 10 minutes. We observed that with the passage of time the temperature within the storage tank increases which in turn increase the heat flux. The reason of this increase is that when the light falls on the collector surface, it is transferred to the water by convective mode of heat transfer. With the passage of time the temperature within the tank increases showing the absorption power of collectors.

3.2. Heat flux of solar water heater with copper tube coated with black paint
Figure 3. shows the effect of heat flux for collector tube (copper tube) coated with black paint. The time interval is 10 minutes. We observed that with the passage of time the temperature within the storage tank increases which in turn increase the heat flux. Here the increase in heat flux is greater than the previous case where we used bared copper tube; the reason for it is that the surface coated with black paint is more absorptive for light. So the convective heat transfer rate increases due to black paint on the collector surface.
3.3. Heat flux of solar water heater with copper tube electroplated with lead

Figure 4. shows the effect of electroplating on collector tube of solar water heater. In this case the collector tube is electroplated with lead. We used the lead nitrate salt and a strip of lead is used for providing lead ions at a constant rate. The current is passed and lead is coated on the copper tube (collector tube). Then the same procedure is repeated and the different readings are recorded at time interval of 10 minutes. We observed that the temperature increased within the storage tank very rapidly as compared to other two cases. This shows a rapid increase of heat flux for electroplated collector tube.

3.4. Comparison of time Vs heat flux for different cases

Figure 5. shows the comparison of time vs. heat flux for different surfaces. It is proved that heat flux for copper tube coated with paint is greater than bare surface. Further the heat flux for the copper tube electroplated with lead is greater than bared copper tube as well as surface coated with paint. Table 1. shows the maximum percentage increase and average percentage increase for different cases.
Figure 5. Comparison of time vs. heat flux for different cases

Table 1. Percentage increase for different surfaces.

| Solar heater Type                  | Maximum percentage increase in heat flux | Average percentage increase |
|-----------------------------------|------------------------------------------|-----------------------------|
| Surface coated with black paint   | 29.03%                                   | 10.79%                      |
| Surface electroplated with lead   | 77.33%                                   | 28.57%                      |

4. Conclusions
From this research, we conclude that the solar absorption in solar heater can be increased by mainly its surface modification. The electroplated surface is more efficient as compared to the surface coating with high conductive black paint. The average increase in the heat absorption for lead plated and coated surface was observed 28.57% and 10.79% respectively.

Nomenclature

| Symbol | Definition                  |
|--------|----------------------------|
| $T_1$  | First thermometer reading  |
| $T_2$  | Second thermometer reading |
| $T_3$  | Third thermometer reading  |
| $Q$    | Rate of Heat Transfer (kW) |
| $q^*$  | Heat Flux (kW)             |
| $A$    | Area (m²)                  |
| $°C$   | Degree Centigrade          |
| $C_p$  | Specific Heat (kJ/kg.K)    |
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