CONCEPT OF HEAT EXCHANGER INSIDE ROOF OF BUILDINGS: AN APPROACH TO SAVE WASTED ENERGY

Sandeep Tripathi

Department of Aeronautical Engineering, Feroze Gandhi Institute of Engg. and Tech., Raebareli, Uttar Pradesh, (India)

ABSTRACT

To decrease the expenditure of non - renewable resources we have to approach towards a renewable energy system which utilizes the energy wasted by us. To utilize the solar energy accumulated during the daytime, this concept is introduced. This implementation of Heat Exchanger will provide an added advantage to the other conventional solar radiation collectors. These heat exchangers will be in the form of metallic pipes embedded inside the roof during its construction. They will be distributed in a regular pattern such that we get maximum rate of heat transfer. The proposed work is concerned with the procedures for the setup of this system and to analyze its performance. In the technical section heat transfer rates are calculated which determine the temperature upto which water will be heated in this system. Many previous researchers have proposed equivalent concept but most of them have done experiments on a particular portion of the roof by using metal reinforced concrete collectors. This renewable energy system will expand and apply their concept to the entire roof.

Keywords: Heat Exchanger, Metallic Pipes, Renewable Energy System, Roof, Water.

I. INTRODUCTION

With recent advancements in science and technology, we have got better ways to utilize solar energy. Devices like solar panel, solar cooker, solar water heater etc. have proved that we can save most of the non-renewable sources of energy by using a renewable energy system. My paper deals with the concept of heat exchangers inside the roof of buildings. These heat exchangers are basically metallic pipes which will be used for solar water heating. At noon , the temperature of upper surface of the roof is around 55°C, which can be used to heat water upto that temperature and can save LPG's or coal required for the same purpose. The heat exchangers we use are a kind of solar water heater where the metallic pipes are spread through the roof in a regular manner. This raises the temperature of water which flows in the pipe. The main aim is to save those resources which are non-renewable and apply a renewable energy system for a particular purpose. For example, we mostly use LPGs to boil water for household purposes which could be saved and energy which goes waste can be utilized in an optimized way. In this research the objective is to explain how to use this system, advantages and applications of this system. The technical analysis is performed considering some assumptions and includes the heat transfer method and whole description of material, dimensions of roof and pipe, and temperature details at any particular phase.

II. THEORY AND PROCEDURE

This analysis involves all three processes of heat flow which are conduction, convection and radiation. All aspects of heat flow contribute in saving the wasted energy. The result is determined by finding the final temperature of water at the outlet. This temperature also determines how much this system is economically stable.

It will be done in four stages:

- Above the roof
- Through the roof
- Between roof and pipe
- Between pipe and water

The sectional view of roof with pipes is given in Fig 1. The inlet and outlet of pipe is shown along with cross section of roof. The inside pattern is the proposed design of pipe to act as heat exchanger. More number of curves in the pipe will increase its surface area and more heat transfer will take place.

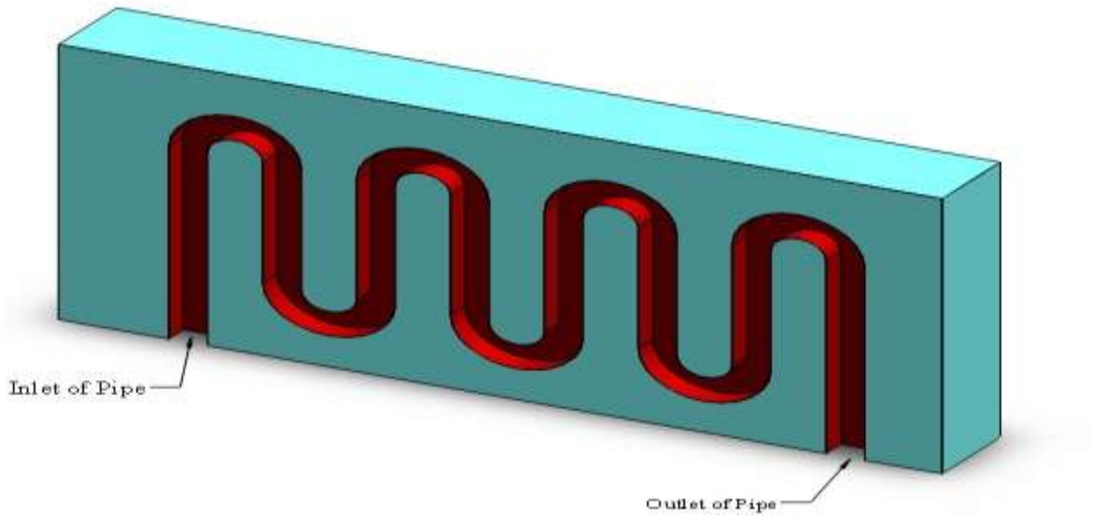

Fig 1. Sectional view of roof with pipe

Each stage is studied separately with some assumptions:

- The flow of heat is unidirectional.
- Steady state heat flow.
- No other internal heat generated source.
- No external equipment is used.
- Constant temperature all over the roof.

The study of stages of heat flow is given below:

2.1 Above the Roof

This is part of the system which is under direct exposure to sun. The phenomenon of heat flow over the surface of roof is only due to solar radiation. Since there is atmosphere between sun and roof so temperature of upper surface can’t be determined directly. This temperature will be determined by considering a suitable atmospheric model. In this section we will determine the rate of heat flow Q which will lead the analysis to further stages.

2.2 Through the Roof

This phase considers conduction as the phenomenon of heat flow. If $T1$ and $T2$ are temperatures of upper and inner surface then by using Fourier's Heat conduction equation, $T2$ is calculated.

$$Q = \frac{k \times A \times (T1 - T2)}{t1} \quad (1)$$

where Q is rate of heat flow in watts, k is thermal conductivity of concrete in watts per meter per °C and $t1$ is thickness of upper slab over the pipe.

2.3 Between Roof and Pipe

Since the pipe is fully covered with concrete all around so we can neglect air resistance caused due to voids. It can be assumed that temperature of lower surface of roof will be approximately equal to temperature of upper surface of pipe.

Let $T3$ = temperature of upper surface of pipe

The heat flow through pipe from upper to inner surface will be through conduction. If $T4$ is temperature of inner surface of pipe then it can be calculated by using Fourier's Heat conduction equation for a cylinder which is:

$$Q = \frac{2\pi.k.L.(T3 - T4)}{\ln\frac{r2}{r1}} \quad (2)$$

where Q is heat flow through cylinder in watts, k is thermal conductivity of metallic pipe in watts per meter per °C, $r1$ and $r2$ are inner and outer radius of pipe and L is length of pipe.

The temperature of inner surface of pipe plays an important role as this surface is in direct contact with water.

2.4 Between Pipe and Water

Since water is flowing inside the pipe so the heat flow from pipe to water is a mixed phenomenon of conduction as well as convection. So Nusselt's number is calculated to find convective heat transfer coefficient of water. This will include formation of boundary layer (both hydrodynamic and thermal) on inner surface of pipe.

Firstly, Reynolds number will be calculated which will help to determine type of flow of water. Then prandtl number is calculated at $T4$, temperature of inner surface of pipe.

Now it depends on flow that how Nusselt's number will be calculated and what kind of analysis will be performed. But convective heat transfer coefficient will be calculated from

$$Nu = \frac{h \times Lc}{k} \quad (3)$$

where Nu is Nusselt's number, h is convective heat transfer coefficient, k is thermal conductivity of water and Lc is characteristic length.

The final temperature of water is calculated by applying the theory of heat exchanger. If $T5$ is temperature of inlet of water and $T6$ is temperature of outlet of water then Fig 2 depicts the flow diagram of hot and cold fluid.

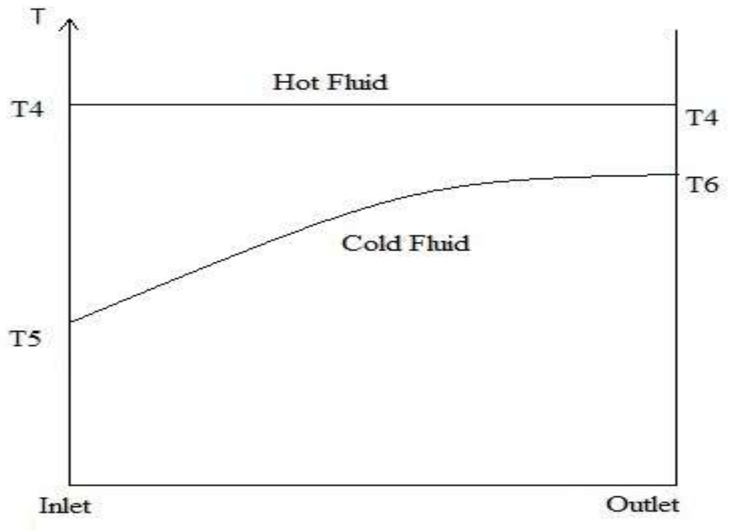

Fig 2. Flow Diagram of Hot and Cold fluid

Here we use LMTD (Logarithmic Mean Temperature Difference) method to calculate final temperature of water.

$Q = h \times A \times \theta m$ (4)

where $\theta m = \frac{\theta 1 - \theta 2}{\ln\frac{\theta 1}{\theta 2}}$ (5)

$\theta 1 = T4 - T5$ (6)

$\theta 2 = T4 - T6$ (7)

From these methods we will calculate $T6$ and finally calculate profit gained and try to maximize it by changes in system and methods to calculate this temperature.

III. DISCUSSION AND RESULTS

The above procedures are based on some assumptions. These assumptions helped to break the analysis into three simple heat transfer modes which were then sequentially analyzed. Without the assumptions the analysis would require numerical computation. In real we have to make a thermal model with these stages and solve them to produce results that can benefit the society from this system. If this system works then we can save most of money spent on non- renewable resources.

IV. ADVANTAGES AND DISADVANTAGES

All systems have some advantages and disadvantages. The advantages of this system are given below:

a) This system has a higher degree of reliability and durability.

b) Due to use of non- corrosive metallic pipes the chances of corrosion are reduced.

c) By using this system, convection of heat in the room just below the roof could be avoided and as a result the internal room temperature will drop.

The disadvantages of this system are:

a) This system is not very efficient in the days of winter or cloudy days.

b) The profit gained by installation of this system varies according to dimension of roof and quantity of water boiled by this system.

V. CONCLUSION

In the age of globalization, there is demand of inexpensive systems with better performance and the above given system meets this criteria. Further studies regarding flow of water inside pipe, concentration of heat can be done to produce a more efficient and optimized system. If analysis is performed regarding variation in material of pipe used, arrangement of pipe inside the roof, and dimensions of pipe, then better results could be produced which can be compared for efficiency and helps consumer to choose a system according to his/her choice. The main aim is to utilize as much solar energy as possible and save the environment from global warming. This system helps in reduction of global warming by absorbing heat on roofs in such a way that radiation of heat back in the atmosphere reduces.

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