INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 4)
Available online at: www.ijariit.com

Fabrication and testing of thermal sheet to obtain performance characteristics for both heating and cooling operations

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ABSTRACT

The Thermal sheet is a sheet of thickness nearly equal to the real blanket. It has a tremendous advantage in the field of heating and refrigeration. It has the potential to replace the equipment's that are used in the heating refrigeration devices based on the conventional concept. Just like the conventional heating and refrigeration system where the different devices are used for the above mention process to carry out but with the help of thermal sheet is a single device can achieve. It can also be used with both high and low-temperature condition and its energy consumption as compared to conventional is highly efficient. This apparatuses that maintained a required thermal condition (T.C) of an object for the duration of time and the circulation of the fluid in the pipe are taking place. It can be configured so that it can be connected to different thermal energy reservoir boxes for producing desired heating and cooling effect. It is fully thermally insulated chamber. It has a pump which is used to transfer the fluid in the second pipe that locked in thermally insulated. Two reservoirs are used to maintain the heat. A cold substance (heat sink) it provides a cooling effect and a hot (heat source) storages box provided heating effect thus the thermal sheet are to maintained at the required temperature, so this process flowed and maintained at low and high temperature for deviation of a time period. In the heat flow from a cold body to a hot body from a hot body to cold body occurs through conduction, convection, radiation is required. Basically, its thermal sheet (T.S) is a structure that it can be used extensively for various purpose and in many application heating and cooling process through the sheet is done based on the heat transfer from into the sheet thus its necessary to make the one side sheet as perfectly conducting as possible. The above all are verified through the experiments cooling characteristics curves and heating characteristics curves of a thermal sheet.

Keywords: *Copper plate, Pipe, Working fluid, Pump, Foil paper, Insulating box, Heat source, Heat sink, Sheet thickens, Thermal condition thermal sheet, Thermal energy reservoir*

1. INTRODUCTION

The thermal sheet is a sheet-like device that can provide the desired thermal condition of cooling/heating with the use of the merely single device, no need of replacement of devices is required under changing thermal conditions.

In the process of reading the paper on 'thermal sheet', I learned many important basic points about this device. I came to know that it is a device that can be selectively heated or cooled for medical or therapeutically treatment of human body or maintaining another object at the desired temperature for fulfilling our other industrial purposes of keeping these objects protected from extremes of temperature. It comes with an important advantage that it can be used during both high and low-temperature conditions and most importantly it reduces our dependence on heaters or air conditioners. Other advantage includes its less energy consumption and highly efficient working. A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluid between two or more solid surface and a fluid or between solid particulates and a fluid at a different temperature and in thermal contact. The thermal sheet is a sheet-like a device which can be manufactured in various shapes and sizes, can have a thickness nearly same as a blanket. The purpose of using such structure for the sheet is to make it versatile in nature and to use it as a blanket to wrap it over the object to be cooled or being heated to produce the desired thermal effect.

It can be configured so that it can be connected to different thermal energy reservoir boxes for producing desired cooling or heating effect. It can be made of suitable material for fulfilling the needs of the application where it is to be used. Basically, its structure should be like a sheet so that it can be used extensively for various purposes and in many applications. Heating and cooling process through the sheet is done based on the heat transfer from and into the sheet. Thus, it's necessary to make the one side of the sheet as perfectly conducting as possible. For example, in our application of the thermal sheet that is in the making of laptop cooling pad using a thermal sheet, we have used the copper sheet on the conducting side of the sheet. And at the same time the other side of the thermal sheet that is in the contact of the environment, should be as insulating as possible in order to stop the losses due to leakage of heat to the environment.

2. BACKGROUND

The first cooling system for food preservation involves the use of ice. Artificial refrigeration begins in the mid-1750's and developed in the early 1800's. In 1834, the first working vapor compression refrigeration system was built. In 1902, first air conditioning device is developed by Willis Carrier. The refrigerator is a common household appliance that constitutes of a thermally insulated compartment and a heat pump (mechanical, electrical and chemical) that transfer heat from the inside of the fridge to its external environment so that the inside of the fridge is cod to a temperature below the ambient temperature of the room. We have seen that conventional devices of heating and cooling mostly came with a single property of either cooling only or heating only, and if some device based on conventional heating or cooling mechanism possess both properties then it becomes costly. Therefore, we must have a single device that can facilitate both heating and cooling and is also economical and easily maintainable**.**

It is as usual to use refrigerators and air conditioners for cooling purpose and heaters and other heating equipment for heating purposes. But these conventional devices of heating and cooling require a lot amount of energy and their maintenance cost is also very high. These heating and cooling devices also produce harmful gases that are injurious to the environment. Refrigerators produce gases that are responsible for the depletion of ozone layer. In our country, in many remote locations, the availability of power and resources is very low and thus it is much needed to seek for the alternative of these conventional devices. These conventional devices are not likely to be available outdoor or in a remote location.

3. ADVANTAGES OF THERMAL SHEET

i. The apparatus can be used for both heating and cooling applications to reduce dependence on heaters and air conditioners.
ii. The apparatus can be used for both heating and cooling applications with minimum changes.
iii. This apparatus has the capacity to keep a surface/body at required thermal condition over a period of time.
iv. This apparatus is versatile in nature.

4. NEED OF THERMAL SHEET

It can be used in household, hotels, industries, offices, etc. The arrangement will be same but the materials and parts will be same as per the need. The thermal sheet can be manufactured in various shapes and sizes, can have a thickness nearly same as a blanket.

Thermal energy reservoir is the most important component of this device. It is configured with a thermally insulated chamber to hold a thermal reservoir substance. A hot reservoir substance (heat source) can provide heating effect and cold reservoir substance (heat sink) can likewise be used to provide a cooling effect. The chamber called as a thermal energy reservoir. The pump can be used to facilitate circulation of the fluid through the thermal energy reservoir and the thermal sheet. It is needed in order to transfer heat between the thermal sheet and hot/cold reservoir substance by circulating fluid in pipes placed in TER and thermal sheet using the pump.

Various type and size of pipe being used inside the assembly. Inside the thermal sheet, the pipes used can be a thin bore pipe with optimized dimensions for maximum heat exchange. The material of pipe has other desired properties such as thermal conductivity, high thermal strength, flexibility, high structural strength and resistance to corrosion. The heat transfer between the thermal sheet and hot/cold reservoir substance can take place through a fluid circulating in pipe/pipes placed in thermal energy reservoir and thermal sheet. The fluid flowing through the channel of these pipes should have desired properties such as low viscosity, high specific heat.

5. CONSTRUCTION OF DEVICE

5.1. Copper plate and pipes

The first and the most important thing we used is a sheet of copper, which has properties much similar to what it is needed to make the conducting side of the thermal sheet. Being economical it is best to fulfill our needs for the mentioned purpose. It is a soft, malleable and ductile metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a reddish-orange color. It is used as a conductor of heat and electricity, as a building material, and as a constituent of various metal alloys.

5.2. Insulating pipes

It is to be used only in those parts of the model where fluid has to flow through pipes and energy of working fluid is likely to dissipate into surrounding air. It can be made up of plastic, rubber or nylon or any other insulating but at the same time flexible material. It should be light but highly insulating. Its length will decide our freedom of possibility to move the sheet away from the thermal energy reservoir. It should be properly connected to pump and copper pipe so that there is no any leakage left.

5.3. Working fluid

Working fluid should be such that it has a low viscosity as well as highly conductive nature. It should be capable of transferring heat at higher rates. For cooling purposes, one of the cheapest and best examples is a solution of urea and water. Many other fluids can be used in various applications of the thermal sheet. One of the extreme fluid can be namely liquid nitrogen, but it is very costly thus is not practical.

5.4. Copper pipe coiling

The main component in the construction of thermal sheet device is making of the thermal sheet itself. We have designed a laptop cooling pad in which the thermal sheet is made up of copper pipe, copper sheet, glass wool, foian l paper and an insulating sheet. First and the foremost task was to design the arrangement of copper pipes beneath the copper sheet. The length and width of the

copper plate used in this device are 35cm and 40cm respectively. To obtain a uniform cooling or heating over the complete surface of the plate it is necessary that we make proper coiling of copper pipe over the maximum surface of the sheet. For this, we have used a spiral-shaped arrangement of copper pipe beneath the copper sheet. The copper pipe has been welded using a proper copper welding to connect the surface of the copper pipe with the lower surface of the copper sheet. The pipe has been beaten uniformly throughout its length to make it suitable for having a greater surface area of contact between sheet and pipes so that there can occur maximum possible heat exchange between the two. We have taken proper care to not allow any gap between sheet and pipes. The length of pipe used is about 5 meters. It's a 0.6 mm thick pipe which is capable of heat transfer and proper flexible to be used in any condition.

6. WORKING OF THE MODEL

The working principle of the model is very simple. The highly conducting fluid is on, one side in the contact of the thermal sheet and on the other hand it is in the contact with the temperature of the medium inside the thermal energy reservoir. Thus, it is capable of taking, heat from one part to another part if it can be circulated uniformly. The conducting fluid is flowing through the copper pipes and inside a closed loop of pipes, circulating with the help of centrifugal pump which is connected in series the pipes. Keeping in mind that no any working fluid is leaking out of the pipes, the working is now based on working of a centrifugal pump, which is responsible for the circulation of working fluid in the pipe. Now we know that we can perform both heating and cooling with the help of the same thermal sheet. The working procedure of thermal sheet under these two conditions can be explained in next topics.

6.1. Thermal sheet in cooling purposes

For using the sheet for cooling purposes, the thermal energy reservoir acts as a heat sink. In these situations, thermal energy reservoir is to be filled with an extremely cold substance which can withdraw heat from the working fluid flowing inside the copper pipe. Thus, the fluid in the copper pipe becomes cold and it is circulated with the help of centrifugal pump to the copper pipe situated in the thermal sheet through the insulated plastic pipes. This cold fluid enters the thermal sheet pipes. The fluid in the pipe can take heat from the body in contact with the sheet. Air trapped in the pores of the sheet can be maintained at low temperature by the circulation of cold fluid. This will provide constant cooling to the body in contact with the sheet. The fluid circulating in the pipe can take heat from the sheet. Thus, the temperature of the fluid rises inside the copper pipe in the thermal sheet. This fluid is under constant flow due to centrifugal pump pressure. Therefore, this fluid will again reach the thermal energy reservoir, flowing into the pipe. Thermal energy reservoir will again act as the heat sink and fluid inside the copper pipe gets cooled. Thus, heat is delivered to the heat sink which is none other than the thermal energy reservoir. This cycle is repeated again and again and thus the required thermal conditions of cooling can be obtained as per our needs. For cooling, we are using ice cold water in our application but many other options can be used for different applications of the thermal sheet. Liquid nitrogen, ammonia, and other coolants or compressed gases can be used for this purpose. Working fluid, we are using is water in our application but the urea-water solution can also be a good option for simple applications of the thermal sheet.

6.2. Thermal sheet in heating purposes

In the same way, high temperature can be made available at the thermal sheet surface by using heat source as a thermal energy reservoir (T.E.R) and fluid flowing in pipes can take heat from the thermal energy reservoir and thus supply this heat to the thermal sheet. For this purpose also heating is obtained using the same cycle of operations as in cooling. The centrifugal pump can be used to circulate the heated fluid in the pipe.

7. OBSERVATIONS

7.1. Observation table for cooling

Table 1: Observation table for cooling

Time	Ambient temperature	Sheet top Temperature	Sheet base Temperature	Temperature of water
t = 0	35	35	35.1	10.6
t = 1	35	31.5	31.8	10.6
t = 2	35	28.9	29	10.9
t = 3	35	28.3	28.9	10.9
t = 4	35	27.1	28.1	11.0
t = 5	35	26.5	27.8	11.1
t = 6	35	26.1	27.1	11.2
t = 7	35	25.7	26.8	11.3
t = 8	35	24.8	25.1	11.3
t = 9	35	23.3	24.8	11.4
t = 10	35	23.1	24.9	11.5
t = 11	35	22.8	23.8	11.5
t = 12	35	22.8	23.5	11.6
t = 13	35	22.8	23.5	11.7

7.2. Characteristics graph for cooling of thermal sheet

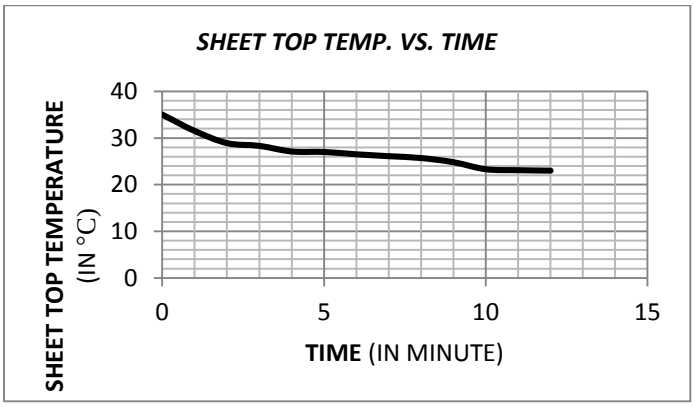

Fig. 1: Sheet top temperature vs. time graph

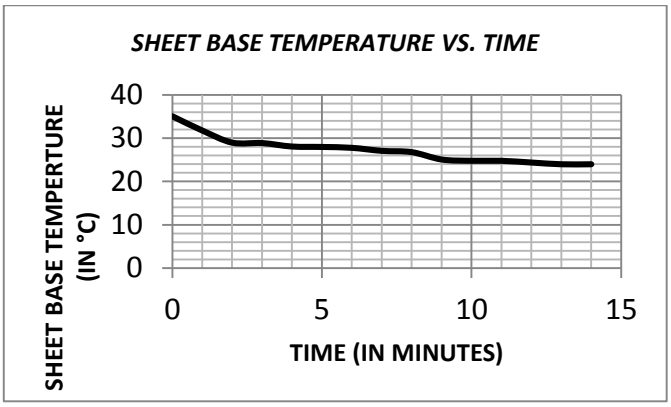

Fig. 2: Sheet base temperature vs. time graph

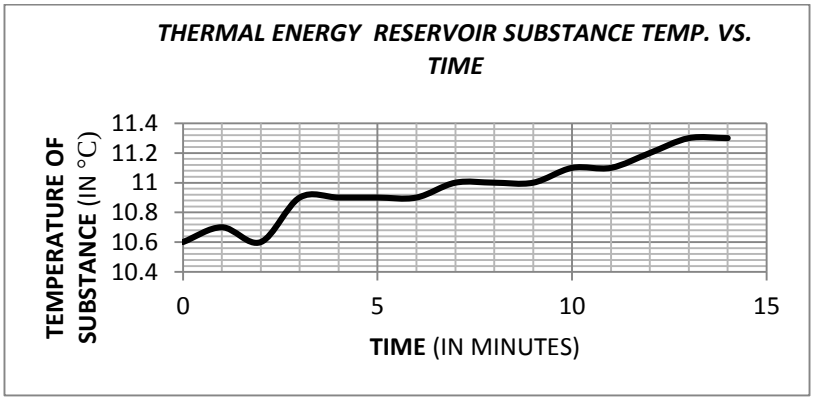

Fig. 3: Thermal energy reservoir substance temperature vs. time graph

7.3. Observation table for heating

Time	Ambient temperature	Sheet top Temperature	Sheet base Temperature	Temperature of water
t = 0	35	35.0	35.1	78.1
t = 1	35	64.7	65.0	70
t = 2	35	61.2	62.0	77.1
t = 3	35	59.3	60.3	77.5
t = 4	35	57.4	58.1	74.2
t = 5	35	55.2	56.1	73.5
t = 6	35	53.2	55.8	72.5
t = 7	35	52.0	53.1	72.3
t = 8	35	51.9	53.0	72.1
t = 9	35	51.7	52.9	70.0
t = 10	35	51.5	52.8	69.9
t = 11	35	51.4	52.5	69.8
t = 12	35	51.3	52.3	69.7
t = 13	35	51.3	52.3	69.7

7.4. Characteristics graph for heating of thermal sheet

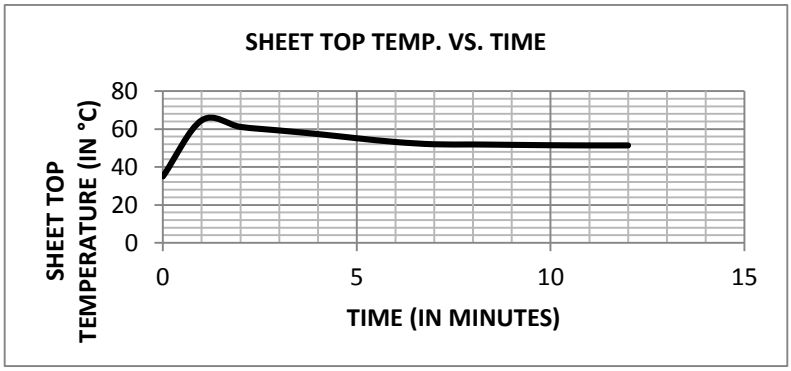

Fig. 4: Sheet top temperature vs. time graph

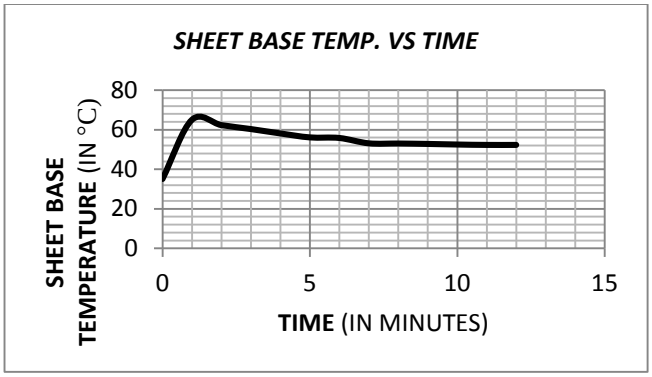

Fig. 5: Sheet base temperature vs. time graph

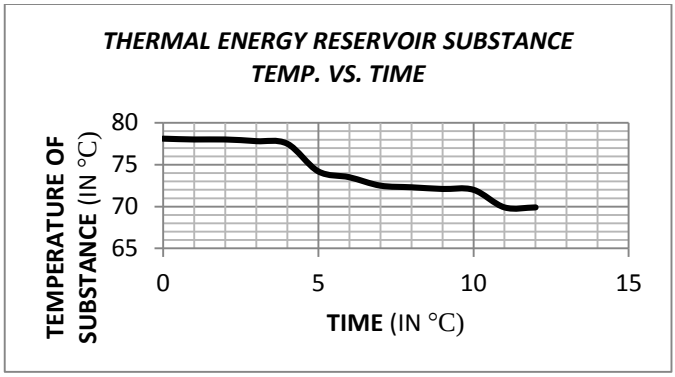

Fig. 6: Thermal energy reservoir substance temperature vs. time graph

8. DISCUSSION

The characteristic curves and the observation tables have shown that the temperature of the sheet has uniformly rising over the period of heating and cooling. The curve drawn for the case of cooling shows that when the temperature of the cold water was about 10 °C, the initial temperature of the sheet was about ambient temperature. Then the pump is started and the liquid inside the pipe start circulating. The temperature of the sheet decreases uniformly over the time and thus almost uniform curve for cooling is obtained. We can see that there are no abrupt changes in temperature and the device is giving result properly in the cooling situation. Likewise in heating case, the temperature of the sheet was initially ambient temperature and the temperature of hot water was about 78 °C. The pump is then started and thus there occurs a steep rise in the temperature of the sheet firstly. After that with the change in temperature of water in the thermal energy reservoir box the temperature of the sheet also decreases slowly and uniformly. Thus the observations in the case of heating show that the apparatus is extremely sensitive to the temperature of the medium in the thermal energy reservoir box and therefore the device is performing its functions properly. Also in the case of cooling the device is reacting properly to the changes in the temperature of the liquid in the reservoir. The temperature of water in the thermal energy reservoir is also shielded from the temperature outside the reservoir due to the proper insulating wall of the reservoir. But due to some heat losses, there is a gradual change in the temperature of the water inside the thermal energy reservoir and thus there are some fluctuations in the temperature of water over the time. But it is decreasing almost with a uniform rate.

So after observing all the aspects, we can reach to a final device which is able in transferring the heat from the thermal energy reservoir to the sheet and also from the thermal sheet to the thermal energy reservoir also. Using other effective materials, the efficiency can also be increased multiple times.

9. CONCLUSION

On considering the results obtained in the observation tables based on the working of this device, in both heating and cooling conditions, it can be inferred that the device is performing its function properly and efficiently and the operation of this device is very plain. Also, the curves show that the device is working almost uniformly over the period of time, in both heating and cooling operations and thus the working of the device is efficient and uniform. Finally, we have made a device that is cheap in operational cost and can provide the thermal conditions of both heating and cooling in an efficient manner, merely using this device. One of the most important aspects while making and operation of the device is its eco-friendly nature since no any component is used while making it that can affect our environment and neither its operation is harmful to our habitat.

So, summing up all the qualities of this device we have successfully made a device that can uniformly and efficiently provide the thermal conditions of heating and cool both, with the use of the only single device in an eco-friendly and cost-effective manner.

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