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Waste Heat Recovery of Boiler Plant Using Heat Pipe Heat Exchanger-Experimental Study

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Abstract

Hot air plays an import role in modem life. The consumption of hot air represents a significant part of the nation's energy consumption. One way of reducing the energy consumption involved, and hence the cost of that energy, is to reclaim heat from the waste warm air that is discharged to the sewer each day. The potential for economic waste air heat is recovery depends on both the quantity of heat available and whether the quality fits the requirement of the heating load. To recover heat from waste air in residential and commercial buildings is hard to achieve in quality because of its low temperature range.. The objective of this research was to develop a multiple Heat pipe heat exchanger for a waste air heat recovery system. The advantage of the system proposed in this work is that it provides useful energy transfer during simultaneous flow of cold supply and warm drain air. The design of the heat exchanger proposed for the present study is significantly different from those used previously. A component experiment is to be carried out to determine the performance characteristics of a wickless heat pipe heat exchanger with working fluid for heat pipe as nano fluid. By replacing the conventional fluid in heat pipe with nano fluid of the heat pipe heat exchanger enhancement in performance of heat pipe heat exchanger can be obtained. With the help of developed test rig energy saving potential for heat source at various temperature would be expected.

Keywords:*Heat pipe, Boiler, exhaust heat recovery, Heat pipe heat exchanger*

1. Introduction

Hot air plays an import role in modem life. The consumption of hot air represents a significant part of the nation's energy consumption. One way of reducing the energy consumption involved, and hence the cost of that energy, is to reclaim heat from the waste warm air that is discharged to the sewer each day . The potential for economic waste heat recovery depends on both the quantity available and also the quality fits the requirement of the heating load. To recover heat from waste air in residential and commercial buildings is hard to achieve in quality because of its low temperature range. Nevertheless, efforts to recycle this waste energy could result insignificant energy savings.[1]

The objective of this research was to develop heat pipe heat exchanger for a waste heat recovery in boiler plant .The advantage of the system proposed is this work is that it provides useful energy transfer during simultaneous flow of cold supply and warm air. While this concept is not new, the design of the heat exchanger proposed for the present study is significantly different from those used previously.[2]

Component experiments were carried out to determine the performance characteristics of a wickless heat pipe heat exchanger panel by using nanofluid. By replacing the conventional fluid in heat pipe with nano fluid of the heat pipe heat exchanger good performance can be obtained. A model of multiple type heat pipe heat exchanger panel will also develop to predict the energy saving that would be expected. [4]

The heat pipe heat exchanger is a self-contained, self-maintaining passive energy recovery device. It has a very high coefficient of thermal transfer utilizing vapor liquid flows. What is more amazing is that heat pipes have no moving parts, require no external energy (other than the heat they transfer), they are reversible in operation and are completely silent A heat pipe heat exchanger consists of three elements: a sealed container, a capillary wick structure and sufficient working fluid to saturate the wick structure. The container is vacuum sealed, the working fluid is in equilibrium with its own vapor. Heating any part of the external surface, causes instantaneous evaporation of the working fluid near that surface (the evaporator region) with the latent heat of vaporization absorbed by the vapor formed.

Heat is removed from the surface at the point of condensation by conduction, convection or radiation. A continuous process is established by the capillary pumping forces within the wick structure, thus returning the fluid to the evaporator section. In effect, we have a perpetual motion machine with no moving parts and requiring no energy of its own. Each heat pipe has a transfer efficiency of 99.3%.

2. Heat Pipe

The heat pipe is a vapor and liquid phase change device of very high thermal conductance that transfers heat from a heat source (hot reservoir) to a heat sink (cold reservoir) using capillary forces generated by wick material and the working fluid. It is similar to the thermo-siphon in few respects. It combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two interfaces. It is referred as superconductor of heat due to their fast heat transfer capability with low heat loss. Heat pipe consists of the evaporators section, adiabatic section, and condenser section. There are three regions separated as evaporator region, wick region and the condenser region. The working fluid is assumed to be liquid phase in the wick region and vapor phase in the evaporator region. Thermal input at the evaporator region vaporizes the working fluid and this vapor travels to the condenser section through the vapor region. At the condenser region, the vapor of the working fluid condenses by rejecting the latent heat. The condensate returns to the evaporator by means of capillary action in the wick. Originally, the heat pipe was first suggested by Gaugler in 1944. But the operational characteristics of heat pipe were not widely publicized until 1963 when Grover and his colleagues at Los Alamos Scientific Laboratory independently reinvented the concept. Since then many types of heat pipes have been developed and used by a wide variety of industries [5].

Advantages of heat pipe are as follows:

- They possess an extra-ordinary heat transfer capacity and heat transfer rate with almost no heat loss.

- Heat Pipe is a device that can transfer large quantities of heat without any power inputs

- There are no moving parts, there is no maintenance and nothing to break

- The life time of Heat Pipes is much more without any maintenance (generally 18 to 20 years)

- Very high thermal conductivity. (thermal conductivity up to 90 times greater than copper for the same size

While the evaporator experiences variable heat fluxes a constant condenser heat flux can be maintained. Efficient transport of concentrated heat Temperature Control. The evaporator and condenser temperature can remain nearly constant while heat flux into the evaporator may vary.The condenser and evaporator can have different areas to fit variable area spaces.

2.1 Principle of Operation

The main regions of the standard heat pipe are shown in Fig.1

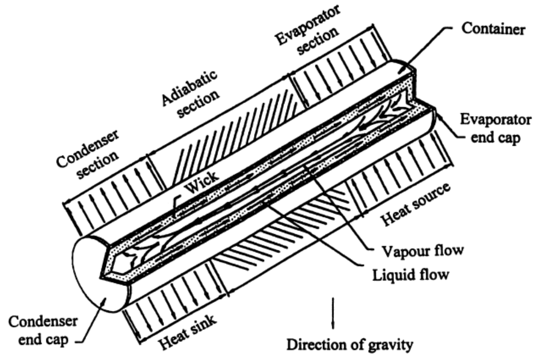

Fig. 1 heat pipe

Heat pipe consists of three components such as, the container, the working fluid .and the wick. Heat applied by a heat source at the evaporator section vaporizes working fluid in that section. This also creates a pressure difference that make the vapor flow from evaporator to condenser section where it condenses latent heat of vaporization. This liquid returns to the evaporator by means of a wick (via capillary forces) so that the heat pipe can continuously transport the heat of vaporization from evaporator to condenser. this process is capable to transport the heat from hot region to a cold region. Therefore, a heat pipe transport large amount of heat with a small temperature difference.

2.2 Heat Pipe Component and Materials

The three basic components of a heat pipe are as follows:

(i) The working fluid
(ii) The wick structure
(iii) The container.
In the selection of a suitable combination of the above, there is a number of factors may arise, and the principle bases for selection are discussed below

2.2.1 The Working Fluid

Purpose-

- To transfer the heat from source to sink.
- To generate vapor pressure.

The first consideration in the selection of the working fluid is the operating vapor temperature range. Within the approximate temperature range, there is a number of working fluids may exist and a variety of characteristics must be examined in order to determine the most acceptable fluids for the required application. In heat pipe design, a high value of surface tension is desirable in order to operate heat pipe against gravity and to generate a high capillary driving force. The vapor pressure must be sufficiently great over the operating temperature range to avoid high vapor velocities, which cause flow instabilities due to large temperature gradients setup.

The prime requirements are as Follows:

(i) Working fluid Compatibility with wick, wall material.
(ii) Thermal stability
(iii) Wet ability of wick and wall materials
(iv) High latent heat
(v) High thermal conductivity
(vi) Low liquid and vapor viscosities
(vii) High surface tension

3. Layout

Heat pipe heat exchangers are devices that made the exchange of energy (waste heat) from a waste heat source to a colder source. Figure shows the schematic diagram of the experimental apparatus. The system is composed of three major parts: boiler (for waste air preparation), heat pipe heat exchanger and devices for measurement and control of parameters. In the installation there are two circulating fluids: the hot agent (waste air) in the lower chamber of the heat exchanger and the cold agent (cold air) in the upper chamber of the heat exchanger. The heat pipe heat exchanger was equipped with 08 heat pipes arranged vertically at an angle of 90 ° (Figure 1). The working fluid used in heat pipe is nano fluid. The source temperature waste heat is regulated by boiler. Determination of efficiency of heat recovery will be achieved under the various temperature conditions.

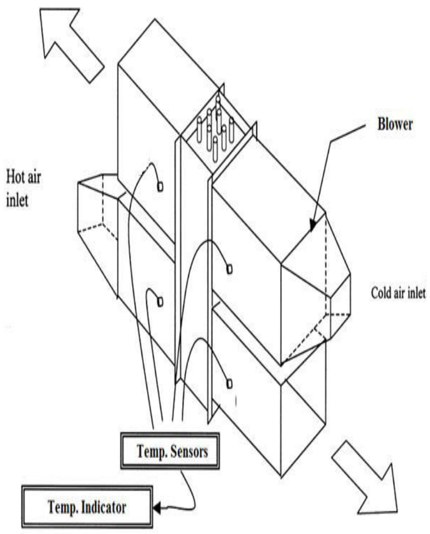

Fig.2: Schematic diagram of the experimental apparatus.

4. Experimentation Overview

Actual experimentation will be conducted to Performance investigation of heat recovery heat pipe heat exchanger by using nano fluid with variable mass flow rate. An arrangement will be made to measure and vary the heat input with the help of boiler. The hot and cold air temperatures will be measured with the help of RTD's mounted at different locations of ducts. Four RTD's are to be fixed inside of ducts at inlet and outlet of hot and cold air in order to measure temperature. Heat input will be varied from different mass flow rate of exhaust of boiler. By varying the mass flow rate of the hot air at high temperature will pass on heat pipe heat exchanger.

A) Heat pipe heat exchanger

Heat pipe heat exchanger consists of eight hard drawn copper seat pipes 16 mm diameter each. Evaporative section of heat exchanger will be in contact of flow of hot air and condenser section will be in contact with cold air (the air which is to be heated). Heat pipe are designed, manufactured and inserted in the existing evacuated tubes available in the collector .Figure 5.2 shows schematic of heat pipe heat exchanger .Parameters regarding the proposed eight heat pipes are finalized such as material of the heat pipe, heat pipe diameter, and length of heat pipe, length of evaporator, condenser section, and diameter of condenser, filling ratio and volume concentration of BN nanofluid.

Fig .3. Actual heat pipe

HPHE contains eight individual heat pipes Figure 2 under staggered arrangement shown in and specifications of unit are, three rows of heat pipe BN/H_20 nanofluid as working fluid (Volume concentration 2%)

6. RESULTS AND DISCUSSION

The experimental performance of heat pipe heat exchanger was experimentally evaluated. Experimentation was carried out to investigate the effect of heat input and mass flow rate of hot and cold air streams on the effectiveness of heat exchanger. On the basis of the observations recorded the effectiveness of heat exchanger for particular heat input and mass flow rate of hot and cold air streams were calculated. The variation of effectiveness of heat exchanger with heat input i.e. source temperature and mass flow rate of air streams are represented graphically. The effect of mass flow rate on evaporator side temperature drop and condenser side temperature rise.

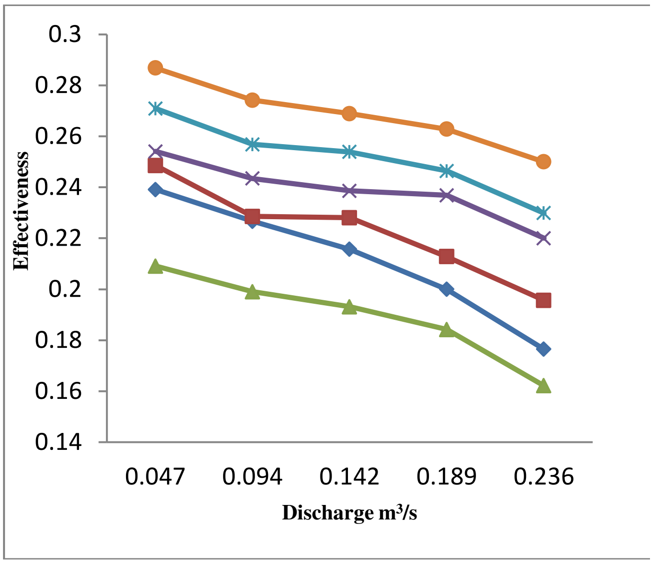

Fig .4 Variation in effectiveness of HX with stream flow rate

6.1 Effect of Air Stream Flow Rate on Effectiveness of TPCT Heat Exchanger

Figure 4 shows the variation in effectiveness with air stream flow rate under different heat input. It has been observed that effectiveness of heat exchanger decreases with increase in air stream flow rate of hot side and cold side and gives its numerical values.

6.2 Effect on Temperature Difference at Evaporator Section of TPCT Heat Exchanger

Variation in temperature difference observed at evaporator section because of heat absorption at evaporator section of the heat exchanger this occurs because of variation in air stream flow rate and heat input. The findings of variation in temperature difference depict that with increase in heat input temperature difference increases for given mass flow rate of air. For given heat input with increase in mass flow rate of air the temperature difference decreases. The numerical and graphical variation of the temperature difference is shown

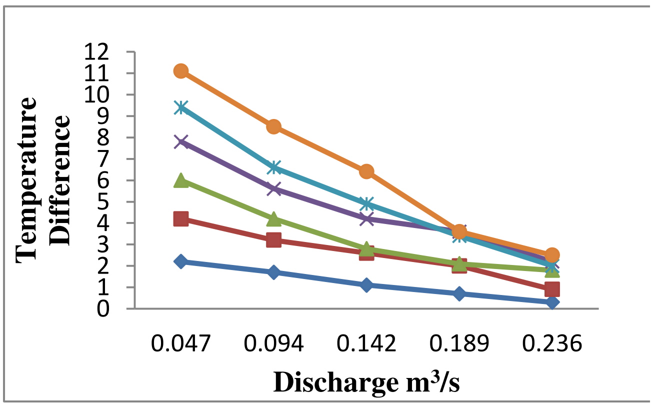

Figure 5 Variation in ΔT at evaporator section

6.3 Effect on Temperature Difference at Condenser Section of TPCT Heat Exchanger

The variation in the temperature difference at condenser section is due to the heat rejection by the heat pipe in heat exchanger to the cold air stream.

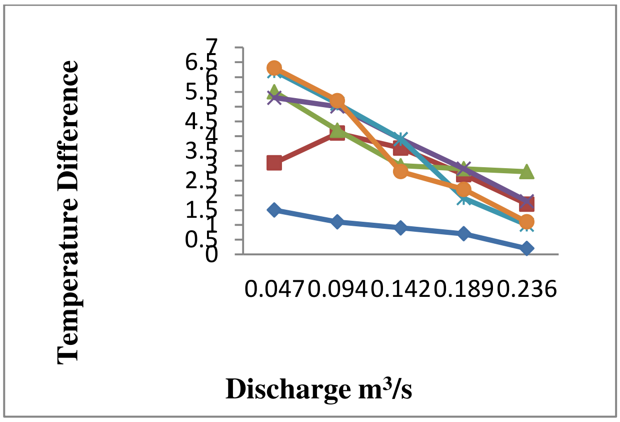

Figure 6 Variation in ΔT at condenser section (

CONCLUSIONS

1. The performance of heat pipe heat exchanger charged with BN/$H_2 0$ nanofluid increases with increase in source temperature.
2. Maximum effectiveness observed for proposed heat pipe heat exchanger is up to 0.28.
3. The results obtained for TPCT heat exchanger charged BN/$H_2 0$ nanofluid are superior with that of TPCT charged with conventional fluid
4. Enhancement in effectiveness of heat exchanger for current study is about 35% compared with the available literature.
5. Improvement in effectiveness of two phase closed thermosyphon heat exchanger charged with nanofluid is due to thermal conductivity enhancement of nanofluid.
6. TPCT heat recovery heat pipe heat exchanger can be suitably employed for heat recovery from low source temperature.

REFERENCES

Yodrak L., Sampan R., '*Waste Heat Recovery by Heat Pipe Air-Preheater to EnergyThrift from the Furnace in a Hot Forging Process*', American Journal of Applied Sciences2010. 7 (5),pp 675-681.

Noie-Baghban, Majideian G., '*Waste heat recovery using heat pipe heat exchanger(HPHE) for surgery rooms in hospitals*', Journal of Applied Thermal Engineering, 2000, pp 1271-1282,.

Wilkes G., Grant D., '*Angry Trout Cafe Kitchen Exhaust Heat RecoveryFinal Report for CARD Grant B42832*', Conservation Applied Research & Development (CARD) Program, 2012.

4. Niu J., Zhang L., ZuoH.,'*Energy savings potential of chilled ceiling combined with desiccant cooling in hot and*

humid climates', Energy and Buildings, 34(2002),pp 487-495.

5. Meyer A, Dobson R., '*A heat pipe heat recovery heat exchanger for a mini-drier*', Journal of Energy in Southern Africa ,February 2006, Vol. 17.
6. Mohammad A., '*Improving the Energy Performance of HVAC Systems in Operating Theatres by Using Heat Recovery Devices'*, International Journal of Renewable Energy Research, 2014 Vol.4.
7. Jadhav T., Lele M., '*A case study on energy savings in air conditioning system by recovery using heat pipe heat exchanger*', International Journal of Research in Engineering and Technology,Jan-2014 Volume: 03 Issue: 01.
8. Mostafa A., El-Baky, MousaM.,'*Heat pipe heat exchanger for heat recovery in air conditioning*' Milan, Italy, 14-17 May, 2006,Vol. 2, pp. 659-668.
9. Saman W. '*Performance of a thermosyphon heat exchanger in an evaporative air conditioning system*', Proc. 5th Australasian heat & Mass Transfer Conference, Brisbane, 1993.
10. Yau Y., Tucker A., '*The performance study of a wet six-row heat pipe heat exchanger operating in tropical buildings'*, International Journal of Energy Research 27, 2003, pp,187-202.