Heat Pipe - a Super Conductor - Applications for Waste Heat Recovery and Heat Dissipation

[1]Syed Aslam, [2]Jakeer Husain, [3]Jai Sagar, [4]Moosa Shaik

[1,2,3,4]Mechanical Dept, Farah Institute of Technology, Chevella, Telengana, India

Abstract The energy consumption reduction has become a important requirement for all countries in the world. This fact is due to the constraints of Earth's natural resources, global warming and the increasingly high costs of energy consumption. With the modern era of miniaturization of equipments, heat pipes have attracted major attention in the field of heat transfer and also for waste heat recovery using heat pipe heat exchanger and utilization so as to economize the system.

Heat pipe based heat sinks are the best solution for most of the modern day equipments dissipating high heat flux. This paper presents a research on few applications of heat pipe heat exchangers for High Power Electronic, railway locomotives, LED lights cooling and HVAC Systems for efficient heat dissipation and waste heat recovery.

Keywords: Waste heat Recovery, Heat Pipe Heat Exchanger, Nano fluid, Thermosyphon

I. INTRODUCTION

Historical Development of heat pipes dates back to 1942 when the first Patent for a heat pipe employing a capillary wick for pumping liquid against gravity was applied by Gaugler (1942) In the words of Grover (1963,1964) who along his co-workers reinvented the "heat pipe" in 1963. A heat pipe is a "synergistic engineering structure which is equivalent to a material having thermal conductivity greatly exceeding that of any known metal". In other words , a heat pipe is a passive two –phase heat transfer device capable of transferring large quantities of heat with minimum temperature drop. In 1964, RCA was the first commercial organisation to perform heat pipe research.

Due to its commendable ability to transport heat energy, the use of heat pipe is becoming popular, starting from space shuttles, electronic industry, Energy conservation, renewable energy applications etc.

(Paper-**Heat Pipes for Steam Condensation)**

II. LITERATURE REVIEW

The special characteristics of heat pipes have made them attractive for use as heat pipe heat exchangers (HPHE).

Dunn and Reay (1) in his book reported various applications of heat pipes viz. Heat pipes in energy storage system , Heat pipes in chemical reactors, Heat pipes for space craft applications, Energy conservation and renewable energy applications. Heat pipes for food industry applications , Heat pipes in medical and surgical technologies, Cooling of gas turbines Amir Faghri (4) described in his book the application of heat pipes for heat exchanger applications. He described the Heat pipe heat exchanger (HPHE) is similar to a liquid-coupled indirect transfer type heat exchanger except that HPHE employs heat pipes or thermosyphons, which uses the evaporation and condensation of a working fluid within the heat pipe as the major heat transfer mechanism from the high temperature to the low temperature fluid, and do not require an external pump to circulate coupling fluid. He also stated that most of HPHE's use thermosyphons because they have higher maximum heat transport capacity and are easier to manufacture than wicked heat pipes. Faghri classified HPHE applications into three main categories

(i) Heat recovery in air Conditioning devices

(ii) Heat recovery from the process exhaust steam to preheat air for space heating

(iii) Heat recovery from the process exhaust steam for re-use in the process .

Various research workers reported the application of heat pipes for preheat combustion air in fossil –fired power plants and in process furnaces , the Heat exchanger using Heat pipes for heat exchange between metallic sodium and water, the Heat pipe type Heat Exchanger for use in combination with a fast breeder reactor , HPHE is the recovery of heat from exhaust gases in industrial plants, heat pipe coolers for electronic cabinets.

L.L Vasiliev in 2005 (25) reviewed usage of Heat pipes in modern heat exchangers. He reported that, heat pipes are very flexible systems with regard to effective thermal control. They can easily be implemented as heat exchangers inside sorption and vapour-compression heat pumps, refrigerators and other types of heat transfer devices. Their heat transfer coefficient in the evaporator and condenser zones is 10^3– 10^5 W/m^2 K, heat pipe thermal resistance is 0.01–0.03 K/W, therefore leading to smaller area and mass of heat exchangers. Miniature and micro heat pipes are welcomed for electronic components cooling and space two-phase thermal control systems.

Thermal siphons ,Loop heat pipes, pulsating heat pipes and sorption heat pipes are the novelty for modern heat exchangers. Heat pipe air preheaters are used in thermal power plants to preheat the secondary–primary air required for combustion of fuel in the boiler using the energy available in exhaust gases. Heat pipe for solar collectors are promising for domestic use and also for energy recovery, from air to air, air to gas and liquid to liquid heat pipe heat exchangers

III. HEAT PIPE OPERATING PRINCIPLE

The Heat Pipe comprises of three elements – a sealed container, a capillary wick structure and a working fluid. The capillary wick structure is integrally fabricated into the interior surface of the container tube and sealed under vacuum. Thermal energy applied to the external surface of the heat pipe is in equilibrium with its own vapour as the container tube is sealed under vacuum.

Thermal energy applied to the external surface of the heat pipe causes the working fluid near the surface to evaporate instantaneously. Vapour thus formed absorbs the latent heat of vapourisation and this part of the heat pipe becomes an evaporator region. The vapour then travels to the other end the pipe where the thermal energy is removed causing the vapour to condense into liquid again, thereby giving up heat.

This phase change cycle continues as long as there is heat at the evaporator end of the heat pipe. This process occurs passively (no external electrical energy required)

A heat pipe can transfer up to 100 times more thermal energy than copper, the best known conductor. In other words, heat pipe is a thermal energy absorbing and transferring system and have no moving parts and hence require minimum maintenance

IV. PERFORMANCE OF HPHS

The heat pipe heat exchanger (HPHE) is a lightweight compact heat recovery system. It virtually does not need mechanical maintenance, as there are no moving parts to wear out. It does not need input power for its operation and is free from cooling water and lubrication systems. It also lowers the fan horsepower requirement and increases the overall thermal efficiency of the system. The heat pipe heat recovery systems are capable of operating at 315^{0}C. with 60% to 80% heat recovery capability.

Figures 1 & 2 show heat pipe operation and Comparison of temperature rise with time for conventional sinks with Heat pipe heat sinks (HPHS). Figures 3 & 4 show the typical graph for HPHS of heat dissipation vs Thermal resistance and shows various shapes and sizes of bare Heat pipes.

Heat pipes have become affordable for consideration as thermal management hardware in the past ten years, primarily as a result of widespread use in commercial electronics cooling. Figure 7 illustrates heat pipes used to transport heat from a source to an array of air-cooled fins, allowing the fins to be placed in a location easier to air-cool. Figure 6 show a 4kW Forced Cool HPHS for Railway locomotives (Capri Cables Pvt Ltd)

The high heat losses from press-pack or IGBT (insulated gate bipolar transistor) power devices can easily be conveyed outward via Heat pipes instantaneous cooling action. A unit consists of aluminum evaporator and condenser sections with copper heat pipes. Working fluids are chosen to suit the application (methanol, water). This heat sink offers high thermal performance, homogeneity of temperature under components, and easy maintenance.

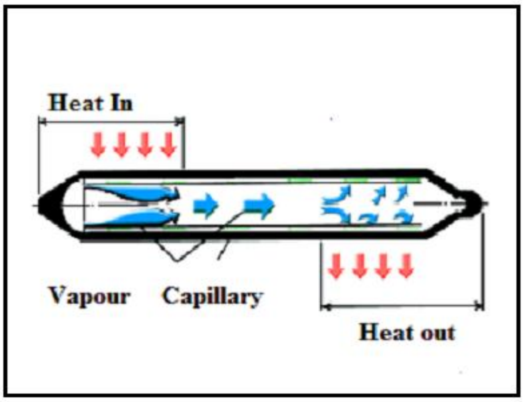

Fig.1 shows Heat pipe operation

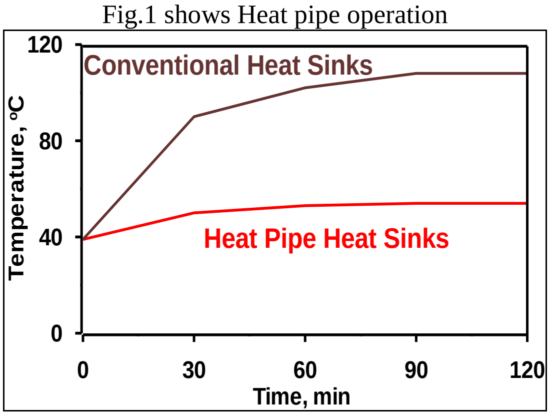

Fig.2 shows graph of T vs time for convention sinks and HPHS

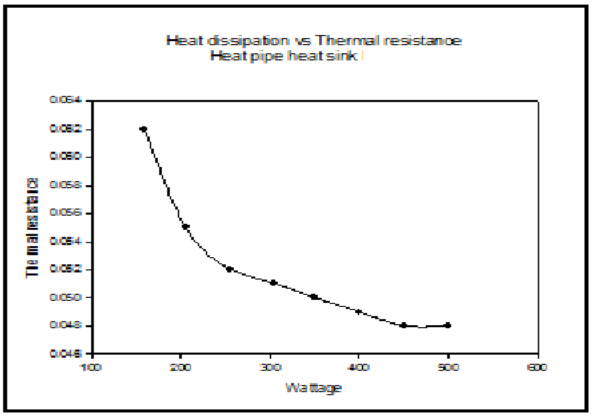

Fig.3 shows the typical graph for HPHS heat dissipation vs Thermal resistance

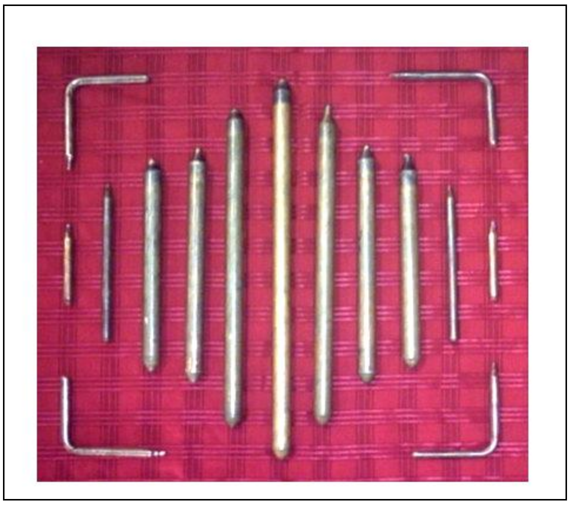

Fig. 4 shows various shapes and sizes of bare Heat pipes

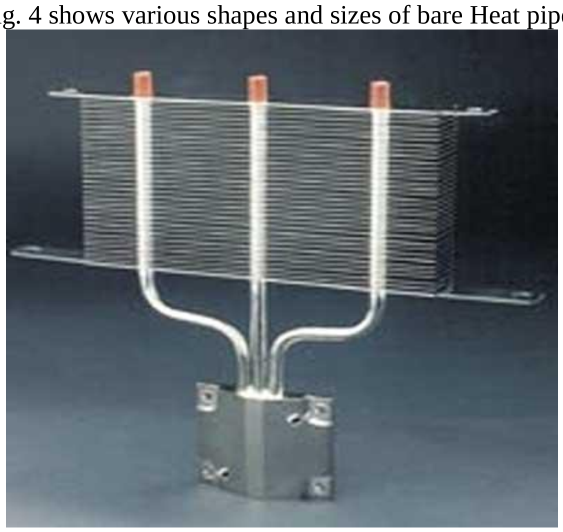

Fig. 5 illustrates heat pipes transporting heat from a source to an array of air-cooled fins

Fig. 6 shows 4 KW HPHS for Railway locomotives

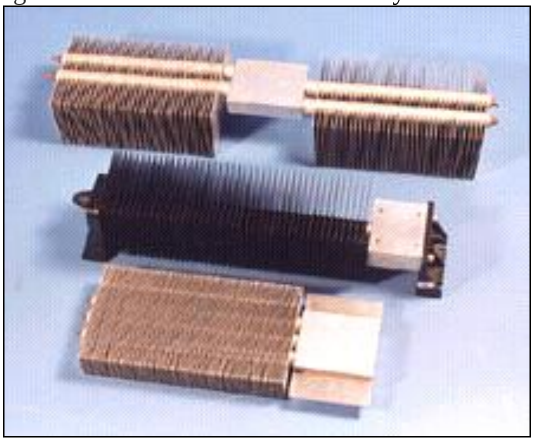

Fig. 7 shows HPHS Assemblies

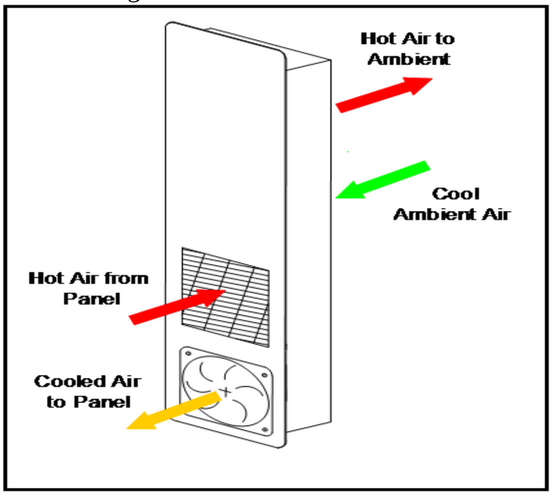

Fig. 8 shows Cooling an electrical enclosure & cabinet using HPHS

Figure 7 shows various HPHS Assemblies and Figure 8 shows HPHS for applications in Cabinet and electronic panel coolers.

Figure 9 shows Heat pipe application in HVAC System.

The Following are the advantages of Heat Pipe Heat Sinks when applied for heat dissipation and waste heat recovery

V. ADVANTAGES OF HPHS

A. In heat dissipation Applications

- Applying the principle of heat pipes to heat sinks, a far superior dissipation of heat can be achieved.
- CAPRI manufactures following Heat Pipe based heat sinks.
- Natural Convection – in range of 10W to 4.5kW and,
- Forced Convection – in range of 100W to 5kW.
- High thermal conductance - higher wattage removed.
- Capability to control thermal flux.
- 20 to 40% reduction in weight and volume.
- Very long life (>10-20 years).
- Cost comparable to conventional extruded heat sinks.
- No maintenance – No moving parts.
- No restriction on orientation of heat sink.

B. Heat Pipe in Heat Recovery Application(HVAC)

- Requires no energy to run
- No maintenance
- No cross contamination
- Can be sized to suit the ductwork or AHU
- Small footprint
- Easy condensation removal
- Significant Energy Savings

When using cooling coils to dehumidify, the air must be cooled until it can no longer hold its original quantity of water vapour. This usually requires that it is cooled down below what would be considered a comfortable supply temperature and it becomes necessary to reheat the air before supplying to the room.

Energy is therefore being used to cool the air and condense the water vapour and also to reheat the air after cooling. Figure 9 shows the application of HP in HVAC system.

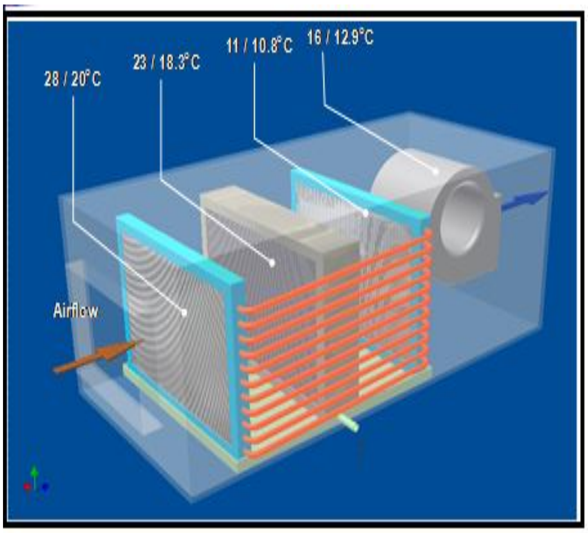

Fig. 9 shows Heat pipe application in HVAC System

C. Other typical heat pipes industrial Applications includes the following :

Process to Space Heating: The heat pipe heat exchanger transfers the thermal energy from process exhaust for building heating. The preheated air can be blended if required. The requirement of additional heating equipment to deliver heated make up air is drastically reduced or eliminated.

Process to Process: The heat pipe heat exchangers recover waste thermal energy from the process exhaust and transfer this energy to the incoming process air. The incoming air thus become warm and can be used for the same process/other processes and reduces process energy consumption.

The other applications in industries are:

- Preheating of boiler combustion air
- Recovery of Waste heat from furnaces
- Reheating of fresh air for hot air driers
- Recovery of waste heat from catalytic deodorizing equipment
- Reuse of Furnace waste heat as heat source for other oven
- Cooling of closed rooms with outside air
- Preheating of boiler feed water with waste heat recovery from flue gases in the heat pipe economizers.
- Drying, curing and baking ovens

- Waste steam reclamation
- Brick kilns (secondary recovery)
- Reverberatory furnaces (secondary recovery)

VI. CONCLUSION

This review on the application of heat pipe heat exchangers (HPHE) in HVAC system and other applications shows that HPHE are very efficient heat transfer devices, which can be easily implemented as thermal links and heat exchangers in systems to ensure the energy saving and environmental protection.

So by using HPHE, one can decrease the relative humidity in the conditioned space resulting in noticeably improved indoor air quality and reduce power demand.

HPHE also promise to improve greatly indoor air quality, and at the same time help conserve energy.

These heat recovery devices are still a new application before they can be used at commercial scales. This indicates that much more research is needed to understand the applications of these systems for energy saving.

REFERENCES:

[1] Firouzfar E., Attaran M., A review of heat pipe heat exchanger activity in Asia, Proceedings of world academy of science, engineering and technology. 2008; 30:1307-6884.

[2] Gaugler, R.S. US Patent 2350348. Appl. 21 Dec, 1942. Published 6 June 1944.

[3] Grover, G.M. US Patent 3229759. Filed 1963.

[4] Grover, G.M. Cotter, T.P. and Erickson, G.F. Structures of very high thermal conductance. J. App. Phys.1964;Vol. 35, P. 1990.

[5] Sauciue I., Akbarzade A., Johnson P., Chracteristics of two-phase closed thermosuphons for medium temperature heat recovery applications. heat Recovery Systems and CHP.1995; 15(7): P. 631-640.

[6] Tun-Ping Tenga, How-Gao Hsua, Huai-En Mob, Chien-Chih Chenc Thermal efficiency of heat pipe with alumina nanofluid. Journal of Alloys and Compounds. 2010 ; 504S: S380–S384.

[7] Jian Qu, Hui-ying Wu , Ping Cheng, Thermal performance of an oscillating heat pipe with Al2O3- water nanofluids. International Communications in Heat and Mass Transfer.2010; 37:111–115

[8] Yu-Hsing Lin , Shung-Wen Kang , Hui-Lun Chen, Effect of silver nano-fluid on pulsating heat pipe thermal performance. Applied Thermal Engineering.2008;28 :1312–1317.

[9] M. G. Mousa, Effect of Nanofluid Concentration on the Performance of Circular Heat Pipe. International Journal of Scientific & Engineering Research.2011; Volume 2, Issue 4.

[10] Dr. Hussain H.Ahmad Raqeeb H. Rajab, An Experimental Study of Parameters Affecting a Heat Pipe. Al-Rafidain Engineering.2010; Vol.18 No.3.

[11] Garner .S.D.,Heat Pipes for electronics cooling applications, Electronics cooling.1996; Vol 12,No.3.

[12] Abd El-Baky M, Mohamed MM (2007). Heat pipe heat exchanger for heat recovery in air conditioning. Appl. Therm. Eng., 27: 795-801