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REVIEW ON CONVENTIONAL, MODERN HEAT PIPES AND ITS APPLICATIONS

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***Abstract** - The heat pipe is an innovative device capable of transferring large quantities of heat through relatively small cross-sectional areas, and with very small temperature differences. It is a highly effective passive device used to transmit heat. The first traditional heat pipe is a hollow cylinder filled with a vaporizable liquid known as thermosyphon. Now it is developed to cryogenic, Nano heat pipes. Heat pipes can be found in devices that we make use in our day to day life such as computer systems, solar panel and additional equipment that we utilize in our home, work and business that have a great deal of heat emissions thus, need cooling systems.*

Heat pipe technology is additionally utilized for waste heat recovery. Offices, factories, solar heaters and additional industrial structures benefit from this and save a great deal on energy costs. Even restaurants, stores and other more common structures can have a lot of energy savings by decreasing air conditioning loads and increasing thermostat settings through heat pipe technology. Heat pipes are even utilized to build structures on permafrost and stabilize the temperature to prevent the permafrost from thawing.

Key Words: Capillary action, Heat Pipes, Nano heat Pipes.

1. INTRODUCTION

A heat pipe heat exchanger is a simple device which is made use of to transfer heat from one location to another, using an evaporation-condensation cycle. The idea of the heat pipe was first suggested by Gaugler in 1942 .However, its independent invention by Grover in the early 1960s that the remarkable properties of the heat pipe became appreciated and serious development took place. The heat input region of the heat pipe is called evaporator, the cooling region is called condenser. In between the evaporator and condenser regions, there is another region known as adiabatic region. Components of Heat Pipe are Container, Working Fluid and Wick or Capillary Structure.In a solar collector, the condensation zone is arranged to be at a higher level than the evaporation zone so that the heat transport medium condensed in the condensation zone returns to the evaporation zone under the influence of the gravity. In that case there is no need for a capillary wick structure. In a solar collector, the condensation zone is arranged to be at a higher level than the evaporation zone so that the heat transport medium condensed in the condensation zone returns to the evaporation zone under the influence of the gravity. In that case there is no need for a capillary wick structure. Capillary action within the wick returns the condensate to the evaporator and completes the operating cycle. This system, proven in aerospace applications, transmits thermal energy at rates hundreds of times greater and with a far superior energy-to-weight ratio than can be gained from the most efficient solid conductor. Heat pipe technology is additionally utilized for waste heat recovery. Heat pipes are even utilized to build structures on permafrost and stabilize the temperature to prevent the permafrost from thawing. Heat pipes operate on a closed two-phase cycle and only pure liquid and vapour are present in the cycle.

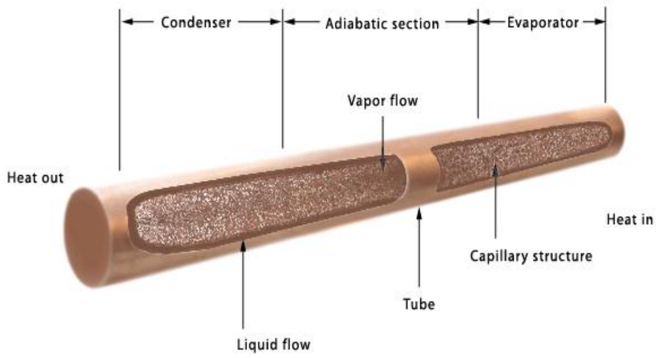

Fig 1. HEAT PIPE STRUCTURE

1.1 THERMODYANMICS CYCLE OF HEAT PIPES

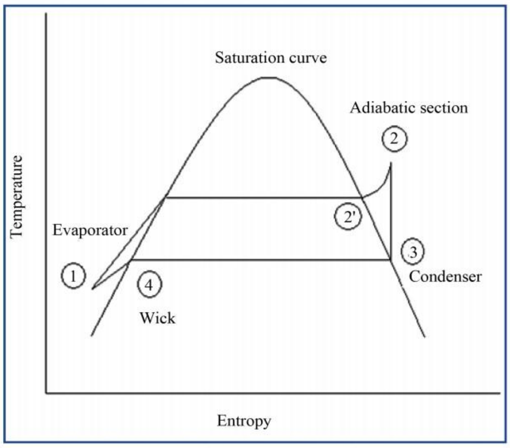

Fig 2. THERMODYANMICS CYCLE OF HEAT PIPES

This cycle is drawn between temperature and entropy. Otherwise known as T-S diagram. In this T-S diagram, We can know about Phase Changing process occurred in Evaporator and Condenser Section.

The following process are discussed below processes,

Process (1-2) - Heat applied to evaporator (1) through external sources vaporizes working fluid to a saturated (2').

Process (2-3) - Vapor pressure drives vapor through adiabatic section (3) to Condenser.

Process (3-4) - Vapor condenses, releasing heat to a heat sink.

Process 4-1 Capillary pressure created by menisci in wick (4) pumps condensed fluid into evaporator section.

1.2 CONTAINER

The function of the container is to isolate the working fluid from the outside environment. The most common material available for the container copper, aluminium, and stainless steel. Copper is eminently satisfactory for heat pipes. The Container material mainly depends on compatibility, thermal conductivity and porosity. Aluminium and stainless steel which are readily available and can be obtained in a wide variety of diameters and wall thicknesses in tubular form. Pure copper tube is suitable, the oxygen-free high conductivity type is preferable.

1.3 WORKING FLUID

In a thermodynamics system, the working fluid is a liquid or gas that absorbs or transmits energy. Prime requirements of working fluids are good thermal stability, high latent heat, low liquid, vapor viscosities, high surface tension and acceptable freezing or pour point. Water is most commonly used working fluid for copper envelope which is mostly used for electronic cooling applications, since it is occurring in low to moderate temperatures, hence it will provide highest liquid transport factor. In aluminum envelope, ammonia is the most commonly used working fluid for spacecraft thermal control.

TABLE.1: WORKING FLUIDS OF HEAT PIPE

SL. NO	MEDIUM	MELTING POINT (◦C)	BOILING POINT (◦C)	USEFUL RANGE (◦C)
1	HELIUM	-271	-261	-271 to -261
2	NITROGEN	-210	-196	-203 to -160
3	AMMONIA	-78	-33	-60 to 100
4	ACETONE	-95	57	0 to 120
5	METHANOL	-98	64	10 to 130
6	WATER	0	100	30 to 200
7	MERCURY	-39	361	250 to 650
8	SILVER	960	2212	1800 to 2300

The operating temperature range of the working fluid increases, the heat transport capability increases

TABLE.2: HEAT PIPE CONTAINER MATERIAL AND ITS WORKING FLUID

S. NO	CONTAINER MATERIAL	WORKING FLUID	TEMP RANGE(◦C)
1	COPPER	WATER ACETONE	52 to 277 52 to 127
2	ALUMIMINUM	LIQUID NITROGEN FREON AMMONIA ACETONE	-213 to -173 -43 to 27 -73 to 27 52 to 127
3	STAINLESS STEEL	AMMONIA ACETONE	-73 to 27 52 to 127
4	NICKEL	AMMONIA	-73 to 27
5	GLASS	ACETONE	52 to 127
6	BRASS	ACETONE	52 to 127
7	TUNGSTEN	SODIUM SILVER LITHIUM	627 to 1227 1427 to 1927 1027 to 1627
8	CARBON STEEL	AMMONIA	-73 to 27
9	IRON	FREON	-43 to 27
10	NIOBIUM	SODIUM LITHIUM POTASSIUM	627 to 1227 1027 to 1627 527 to 927

1.4 EVAPORATOR SECTION

The heat passes from the external source is first enters this section. The heat pipe is a closed evaporator system consisting of a sealed, hollow tube whose inside walls are lined with a wick.

1.5 ADIABATIC SECTION

The vapor flow through between evaporation section to condensation section, no heat transfer [Q=0].

1.6 CONDENSER SECTION

The saturated liquid vaporizes and travels to the condenser, where it is cooled and turned back to a saturated liquid. In this section, it condenses a fluid from gaseous state to liquid.

1.7 WICK

The wick function is to generate capillary pressure to transport the working fluid from the condenser to the evaporator .The maximum capillary head generated by a wick increases with decrease in pore size. Therefore wick permeability is inversely proportional to pore size. The purpose of a wick in the heat pipe is to provide the necessary flow passages for the return of the condensed liquid and to maintain surface forces at the liquid-vapour interface for development of the required capillary pumping pressure. These are various structure of wick given in below figure.

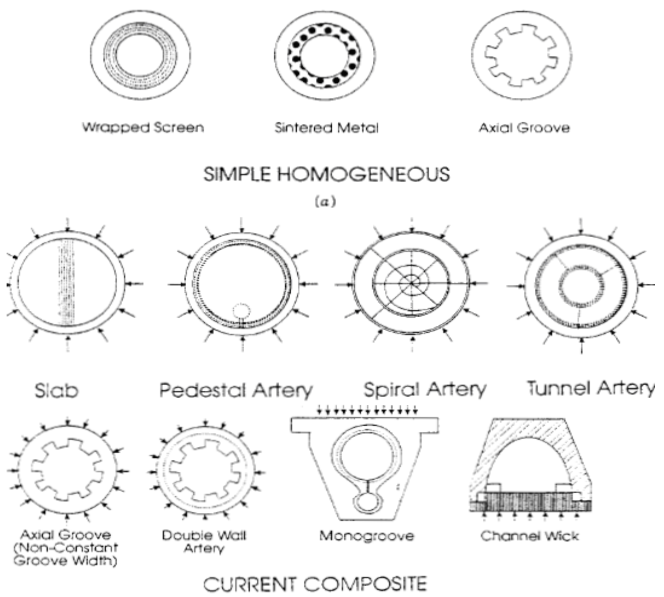

Fig 3.VARIOUS STRUCTURE OF WICK

2. LITERATURE REVIEW

Charles C et al [1] (1981) examined that the unique aspect of the heat pipe is the return of liquid condensate to the evaporator by capillary pressure differences. The capillary wick has resulted in several successful heat pipe designs for many applications. Since capillary pressure differences are typically small, heat pipe performance against gravitational forces has been limited.Seshan. S et al [2] (1985) voiced Heat pipe have great potential in the field of solar energy application apart from the many industrial application. It have capacity to transfer large quantities of heat through relatively small cross sectional area with very small temperature difference. A.K.Mozumder et al [3] (2010) conducted heat pipe with and without working fluid for different thermal loads to assess the performance of heat pipe.. Zhen –Hua liu et al [4] (2007) implemented to understand the nucleate boiling heat transfer of water–CuO nanoparticles suspension at different operating pressures and different nanoparticle mass concentrations Nanofluid as a new kind of functional fluid, has many unique characteristics. CuO nanoparticles suspension as a working fluid can significantly strengthen the heat transfer performance and the maximum power of the miniature flat heat pipe evaporator with micro-grooved surface under low pressure conditions. Leonard L. Vasiliev et al [5] (2005) conversed about very flexible systems with regard towards effective thermal control of heat pipe. This heat pipe is easily implemented as thermal links and heat exchangers in different systems to ensure the energy saving and environmental protection. Pawar.A.A et al [6] (2015) discovered working fluid of nanofluid using the thermal performance is higher followed by pure water as a for the wickless heat pipe. The heat transfer rate is found to increase by using solar tracking system for both cases, namely, pure water and TiO2/water Nano fluid. Zhao-Chun et al (2015) debates the heat transfer efficiency of the heat pipe and tube bundles heat exchanger is discussed in the two aspects of geometric features and thermal performance. Heat pipe exchanger has some special structural features and properties which were emphasized widely; it is not a high efficient heat exchanger when it is just used as a conventional heat exchanger in the industrial fields.

M. Merriganm et al [8] observed that Heat pipes have been developed for operation in oxidizing atmospheres at temperatures above 1100 K. The heat pipes comprise a metallic liner and wick structure with a protective outer shell of an oxidation resistant material. Xianping Chen et al [9] (2016) specified Heat pipes are mainly used in electronic cooling system, which are removing increasing heat from an area of limited volume to the environment. Small HPs are widely used in electronics applications, which are normally limited by the compact structure and dimensions.Saffa Riffat et al [10] (2016) specified a three-part overview of progress of heat pipe technology and applications. Heat pipe technology has developed rapidly. Loop heat pipes and flat heat pipes with various structures have been fabricated. New mathematical models for optimum design and prediction of the performance of heat pipes have been developed. Stéphane Launay [11] (2012) conveyed about the design evaporator/compensation chamber of cylindrical design were initially preferred by the researchers and number of new chamber configurations have been proposed. The various geometries of evaporator/compensation chamber is a response to expanding applications of the loop heat pipe.Dilip Mishra et al [12] (2015) conduct experimental analysis of thermal performance of evacuated U-tube solar collector and states that effect of copper fin and U-tube in terms of its heat retaining capacity has observed that the thermal efficiency of evacuated u-tube collector has been improved by 10-15% then water-in-glass evacuated tube solar water heater.M.A.Sabiha et al [13] (2015) analysis the progress and latest developments of the evacuated tube solar collectors and states that evacuated tube solar collectors can temperatures easily and are able to preserve heat when the outside weather is cold and that efficiency can increase by using Nano fluid. M. Mahendran et al [14] (2012) presented that nano fluids has more thermal conductivity than the water therefore it can easily transfer heat. And the efficiency of the collector. It is mainly dependent on the geographic location, weather and climate because temperature will change in these above condition and finally said the efficiency can increase by Nano fluids.

If use of the Nano fluids, Efficiencies can be improved in the heat pipes.

3. COMPARISION CONVENTIONAL AND MODERN HEAT PIPES

3.1Variable Conductance Heat Pipe (VCHP)

If the pressure could be kept constant at a specified value, then a certain heat pipes operating temperature could be regulated. This can be achieved by expansion tank attached to the top of the heat pipes will enable this outcome. Thus, pressure would not build up during operation as it would in a standard heat pipes and the boiling would not be hampered by an excessive increase of pressure. Such a system is called a Variable Conductance Heat Pipe (VCHP).

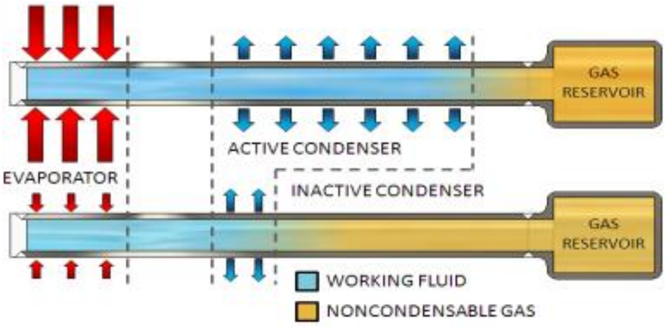

Fig.4. Variable Conductance Heat Pipes

3.2 Thermosyphons

Most heat pipes use a wick and capillary action to return the liquid from the condenser to the evaporator. The liquid is sucked up to the evaporator, similar to the way that a sponge sucks up water when an edge is placed in contact with a water pool. When the evaporator is located below the condenser, the liquid can drain back by gravity instead of requiring a wick. Such a gravity aided heat pipe is known as a thermosyphon.

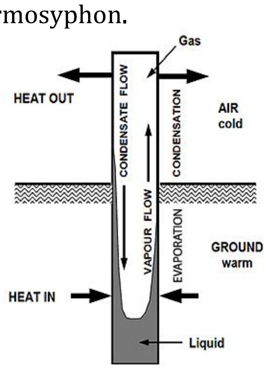

Fig.5. Thermosyphons

3.3 Loop Heat Pipes

Loop heat pipes (LHP), are an attractive alternative for heat regulation. In the loop heat pipes the capillary pumped evaporator is used instead of a boiler. Such an evaporator is more flexible from the point of view of its orientation space and is more compact. In the LHP there is a possibility to use an evaporator above the condenser.

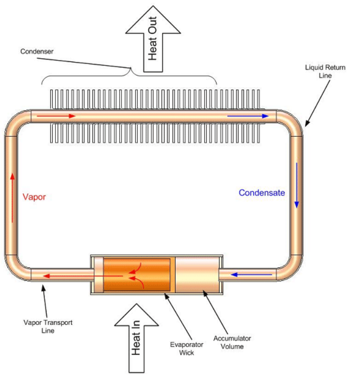

Fig .6. Loop heat pipes

3.4 Flat Plate Heat Pipes

Flat Plate is a traditional cylindrical heat pipes, but are rectangular in shape. Used to cool and flatten temperatures of semiconductor or transistor packages assembled in arrays on the top of the heat pipe.

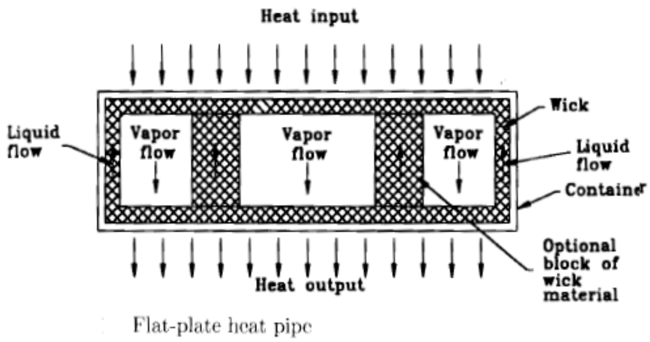

Fig.7. Flat Plate heat pipes

3.5 Micro Heat Pipes

Micro heat pipe is a small metal pipe with a capillary structure (wick) on the inner wall. The micro heat pipe is a vacuum inside with a small quantity of working fluid. When a section of the micro heat pipe is heated, the heat is quickly transferred to a lower temperature section of the micro heat pipe in the following way the working fluid evaporates at the heated section than vapor moves to the lower temperature section and thus vapor condenses in the lower temperature section.

3.6 NANO HEAT PIPE

Heat pipes with Nano fluid as working fluid can be referred as Nano heat pipe. The heat transfer capability of the all heat transfer devices including heat pipe is limited by the working fluid transport properties. To overcome these limitations, the thermo physical properties of the working fluid have to be improved. Using Copper Nano fluid with Aqueous Solution of n-Butanol is used in Nano heat pipes.

3.7 Spaghetti Heat Pipes

The small diameter 3 mm, bendable SS spaghetti heat pipes are similar to pulsating heat pipes, but have a compact condenser and large surface evaporator. It is filled with ammonia, shown in is disposed inside the refrigerator chamber in such a way that food can be kept within the refrigerating temperature range as uniformly as possible. Thus it is thermally linked with an evaporator of the sorption refrigerator and has a good thermal contact with this evaporator.

4. DISCUSSION

4.1 Applications of Heat Pipes

Heat pipe technology is additionally utilized for waste heat recovery. Offices, factories and additional industrial structures benefit from this and save a great deal on energy costs. Even restaurants, stores and other more common structures can have a lot of energy savings by decreasing air conditioning loads and increasing thermostat settings through heat pipe technology. Heat pipes ae even utilized to build structures on permafrost and stabilize the temperature to prevent the permafrost from thawing.

4.1.1 Electronics Cooling

Small high performance components cause high heat fluxes and high heat dissipation demands, cooling of electronics equipment's is necessary to prevent the further damage internal parts, heat pipes plays a major role in This cooling process. Common heat pipes used in electronics cooling Micro heat pipes, Capillary looped heat pipes, flat plate heat pipes and Variable conductance heat pipes. Since many semiconductors are small in size, micro heat pipes is used for cooling individual semiconductors or an array.

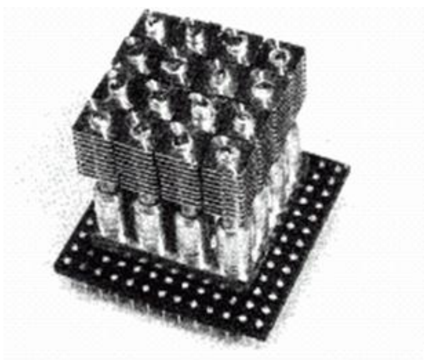

Fig.8. Micro heat pipe array

4.1.2 Aerospace

The spacecraft thermal control system has the function to keep all components on the spacecraft within their acceptable temperature range. Heat pipes also being used to dissipate heat generated by electronic components in satellites. An advanced capillary stricter which combined re- extract and a large number of micro grooves heat pipes evaporator was investigated in European space agency. A heat pies laser mirrors has been fabricated in order to test the feasibility of technology.

4.1.3 Heat pipes heat sinks (HPHS)

It one of heat pipes used for the electronic cooling applications. The most versatile feature of using heat pipes is the wide variety of geometries that can be constructed to take advantage of the available space around the electronics to be cooled.

Fig .9. Heat pipes heat sinks

4.1.4 Medicine and human body temp control

Another application of heat pipes is related to human physiology.

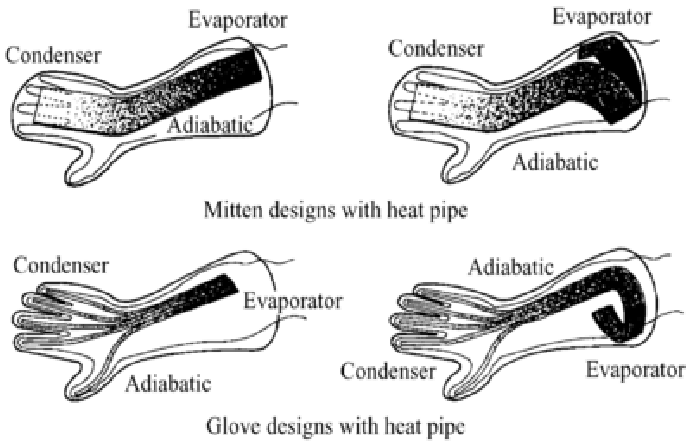

Fig.10. Heat pipes suit

A surgical probe including a cryogenic heat pipes is being used to destroy tumors in the human body the cryoprobe with reservoir of liquid nitrogen, which is maintained at approximately 77k.

A heat pipes suit with heat exchanger could allow the patients to be more exposed the overly warm or cold condition who are bedridden.

4.1.5 Flat Mini Heat Pipes (FMHP) and Heat Pipe Spreaders (HPS)

This technology allows direct attachment of heat dissipation fins and can be used in application for microprocessor etc.

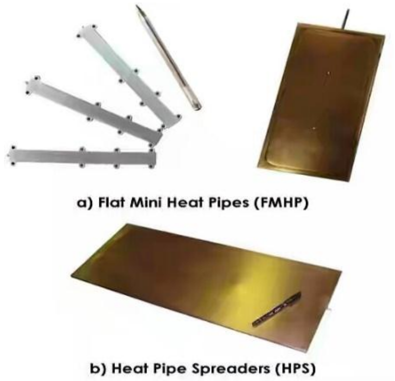

Fig.11. Flat mini heat pipes (FMHP) and Heat pipe spreaders (HPS)

5. CONCULSION

In this paper, we discussed briefly about the heat pipes construction, working and its application. Heat transfer characteristics of heat pipes seems to be growing continuously. It is also believed that many these new applications will be in the field of crystal growth. Heat pipes capable of operating in oxidizing atmospheres at temperatures in the range of 1100-1500 K. For Energy storage applications heat pipes where used transfer energy into underground storage are perhaps the most promising. Nano heat pipes are more advanced pipes used in aerospace. The several heat pipe concepts studied in this paper should provide seeds for thought on improving heat pipe performance capability.

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