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A STUDY ON HEAT PIPE, ITS TECHNOLOGY AND APPLICATIONS

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Abstract – *This paper presents a study of heat pipe which is one of the effective tool for transferring heat. The technology behind the heat pipe is to be discussed. The working fluid used in heat pipes are to be studied. The basic heat pipe structure and its working were to be studied. Heat pipe applications were to be detailed.*

Key Words*: *Heat pipe, thermosyphon, wick, VCHP, HPT

1.INTRODUCTION

Heat pipes are used for transferring heat from one space to another. It is one of effective method of transferring heat using working fluids which are used to suit various temperature ranges. In HVAC applications normally refrigerants are used as working fluid. The working fluid undergoes phase change from liquid to gas viceversa during which heat can be absorbed during evaporation and heat can be rejected during condensation.

2.HEAT PIPE STRUCTURE

Heat pipe is a simple device with no moving parts which transfer large amount of heat over large distances at constant temperature with no power requirement. It is a slender tube with a wick structure lined om the inner surface of the tube. A small amount of fluid at saturated state is filled inside the tube. The heat pipe consists of three sections

1. Evaporator section at one end
2. Condenser section at the other end
3. Adiabatic section in-between the two

Wicks are made of porous ceramic or woven stainless wire mesh. Heat pipes are generally cylindrical in shape. However, it can be manufactured in variety of shapes including 90^0 bend, spirals, flat layers with 0.3 cm thick. Cooling fins are attached to the condenser end to improve the effectiveness.

2.1 HEAT PIPE WORKING PRINCIPLE

The physical principle involved in heat pipe operation are as follows

1. At a specified pressure, a liquid vapourises or vapour condenses at a certain temperature called saturation temperature. (Fixing the pressure inside the heat pipe determines the temperature at which phase change occurs)

2. At a specified pressure or temperature, the amount of heat absorbed as a unit mass of liquid vapourises is equal to the amount of heat rejected as the vapour condenses.

3. The capillary pressure developed in a wick moves the liquid in the wick against the gravitational field as a result of capillary effect.

4. The flid flow in the direction of decreasing pressure.

2.2 WORKING OF HEAT PIPE

The heat pipe consists of three sections namely evaporator section, condenser section and adiabatic section. The evaporator section place in the hot region where the heat is to be absorbed. The fluid is heated by the hot region, the fluid evaporates and becomes vapour and moves up and reaches the condenser section through adiabatic section. In condenser section the vapour is condensed and the heat is rejected out and the condensate move down. In the adiabatic section the vapour and liquid phases of the fluid flow in opposite direction to the core and wick respectively with no heat transfer between the fluid and the surrounding medium

3.TYPES OF HEAT PIPE

Ther are several types of heat pipes listed below

1. Standard heat pipes and vapour chambers
2. Variable conductance heat pipes (VCHP)
3. Thermosyphon type
4. Loop heat pipes
5. Rotating heat pipes
6. Oscillating or pulsating heat pipe

Standard heat pipes and vapour chambers are used for cooling electronic devices where water is used as a working fluid.

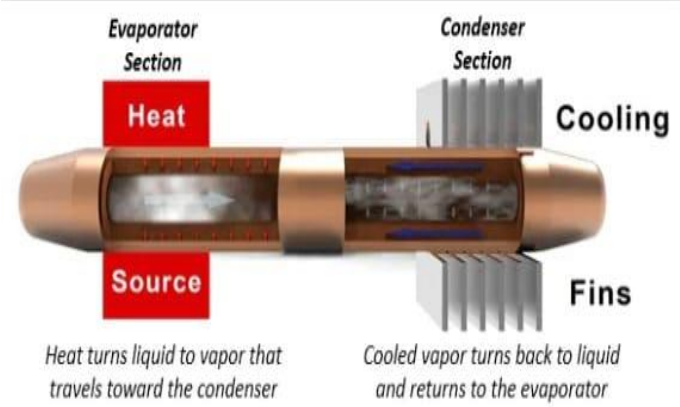

Fig.1 Standard heat pipes and vapour chambers

Variable conductance heat pipes minimizes temperature swings at the evaporator at the lower operating temperature range. Based on the changes in ambient temperature the device uses a varying degree of condenser fin area by limiting the vapour space inside the heat pipe. Adding a non-condensable gas such as nitrogen or argon to a standard heat pipe turns it into a variable conductance heat pipe (VCHP).

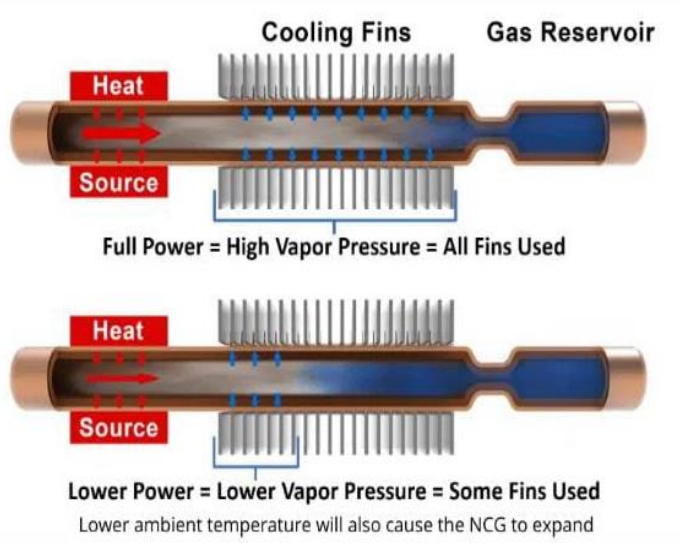

Fig.2 VCHP

Thermosyphon type is a wickless heat pipe sometimes have grooved wick to increase the surface area of the internal valve and permit liquid condensate to move easily to evaporator.

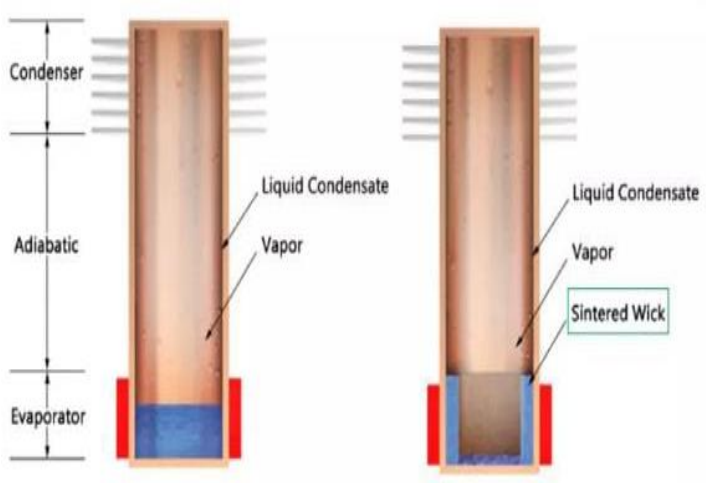

Fig.3 wickless and partial wick thermosyphons

Loop heat pipes is similar to loop thermosyphon type but can operate against gravity with the evaporator above the condenser. The operation depends on the high vapour pressure of the fluid to force the liquid condensate to the evaporator. Generally, ammonia is used as the working fluid having operating temperature range -40^{0}C and 70^{0}C

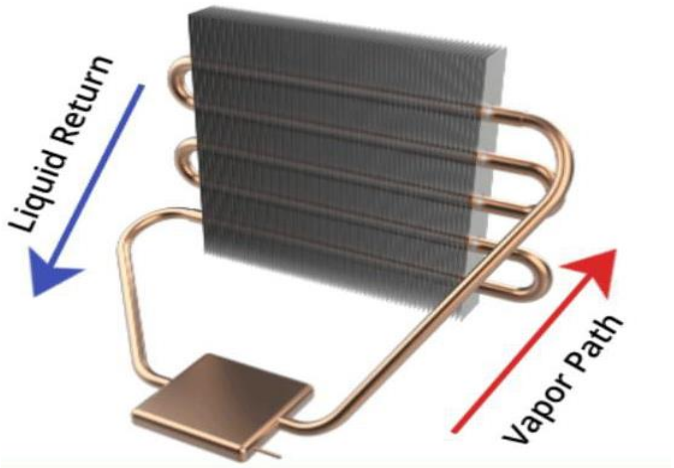

Fig.4 Loop thermosyphon

Rotating heat pipes depends on rotational force to move the liquid condensate back to the evaporator. When vapour turns into liquid condensate the centrifugal force generated by the rotating pipe moves the liquid back to the evaporator end. These type of heat pipes used to remove heat generated in motors and other rotating machineries such as RF rotary joints in tele communications.

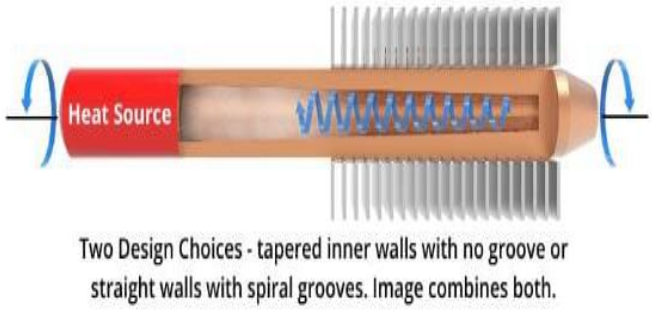

Fig.5 Rotating heat pipe

In oscillating or pulsating heat pipes a wickless closed loop tube consisting of series of U-shaped bends is in the evaporator based and in condenser fin. Main advantage is, it works over longer distances than standard heat pipe.

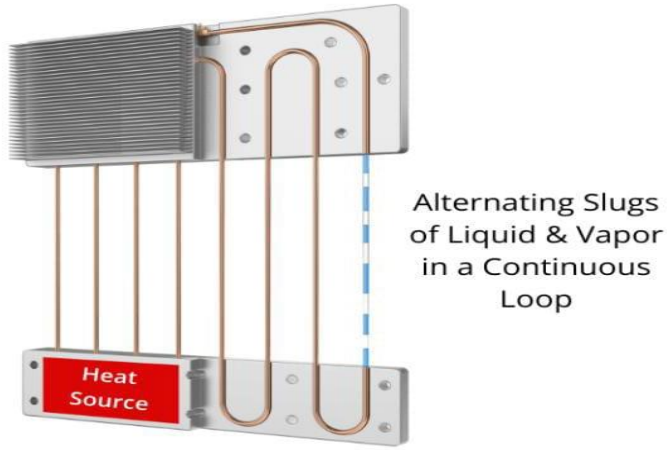

Fig.6 Oscillating heat pipe

4.HEAT PIPE WORKING FLUIDS

The desirable characteristics of the working fluid used in heat pipes are

1. Good thermophysical properties.
2. Large heat of vapourisation.
3. High surface tension to ensure better capillary effect.
4. Compatible with wick material.
5. Chemically stable.
6. Non-toxic.
7. Less expensive.

The heat pipe selection depends on the operating temperature range in-turn depends on the working fluid selection and its operating pressure. For water the triple point temperature and the critical point temperature are 0.01^0C and 374^0C respectively. Water undergoes phase change from liquid to vapour or vapour to liquid in this temperature range only. Therefore, water is not a suitable working fluid for applications involving temperature beyond this range. Fluids like helium with operating temperature ranges -271^0C to -268^0C used in cryogenic applications. Liquid metals like lithium can be used in the temperature range of 850^0C to 1600^0C. Refrigerants such as NH_3, Fe_{11}, Fe_{21}, Fe_{22}, are also used as working fluids in heat pipes depending on the applications and operating temperature range.

Working fluids such as He, Ar, O_2 and Kr are used in cryogenic heat pipe which operates in the cryogenic temperature range between 4K to 200K.

NH_3, acetone, freon compounds and water are used in low temperature heat pipes which operates in the low temperature range between 200K and 500K.

Working fluids such as Hg and S are used in the intermediate temperature heat pipe which operates between the temperature range of 450K to 750K.

Working fluids Na, Li, Cs and Ag are used in the high temperature heat pipe which operates between the temperature range above 750K. The various working fluids used in heat pipes and their operating temperature range is listed in table .1

Working Fluid	Temperature Range (^{0} C)
Helium	-271 to -268
Ammonia	-78 to -30
Water	5 to 230
Mercury	200 to 500
Cesium	400 to 1000
Sodium	500 to 1200

Table.1 Temperature ranges for certain fluids used in heat pipes

5.HEAT PIPE APPLICATIONS

Heat pipe have been used in many applications due to their high thermal conductivity and its ability to maintain constant temperature even heat flux fluctuates. Some applications are discussed briefly here

5.1 AEROSPACE APPLICATION

Heat pipe plays a vital role in air craft cooling and temperature stabilization in aerospace due to the distinct advantages of low weight, less maintenance, highly reliable over other heat transporting devices.

5.2 HEAT EXCHANGERS

Due to flexibility in design heat pipe can be easily used as heat exchanger in VCR system, air conditioning system etc.,

5.3 INDUSTRIAL APPLICATION

Industries such as metallurgy, power plants, oil refineries etc., use heat pipe for their major heat transportation solutions. For example, heat pipe can be used in thermal power plants to pre-heat the air used in the combustion of fuel in the boiler.

5.4 ELECTRONIC COMPONENT COOLING

One of the largest applications of HPT is the cooling of electronic components such as CPU, circuit boards, transistors etc., its application is desirable due to its compact form.

5.5 CHEMICAL INDUSTRIES

Most of the chemical industries use heat pipe for solving heat transportation problem. For example, in spray drying of powdered material require hot air at a temperature of 450^0C to 600^0C are even more, HPT can be applied in this area. High temperature heat pipes are used in hot air furnace.

5.6 SOLAR APPLICATION

For solar distillation, evacuated heat pipe collectors are used in the system for generating heat required for the distillation process.

For solar cookers heat pipes are utilized in transporting heat from the heat source to destination

5.7 MEDICAL APPLICATION

For treatment of an inflamed vagina, rectum or pelvis and some gynecological and rectal condition heat pipe is used as a cooler which cools the mucous membrane

3. CONCLUSIONS

This article is concluded with

- The heat pipe can transfer heat without any moving parts so that it is noiseless, maintance free and highly reliable equipment.
- Heat pipe solves many complicated heat transporting problems.
- Heat pipe can be effectively used where limitations in volume constrains.
- Due to its enormous application heat pipe can replace other existing heat transporting device in future.
- It is a compact heat transporting device effectively used for wide temperature range heat extraction and rejection

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BIOGRAPHIES

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