

A

Seminar report

On

Heat Pipes

Submitted in partial fulfillment of the requirement for the award of degree
Of Mechanical

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Preface

I have made this report file on the topic **Heat Pipes**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude towho assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

Acknowledgement

I would like to thank respected Mr..... and Mr.for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

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Introduction

A heat pipe is a device that efficiently transports thermal energy from its one point to the other. It utilizes the latent heat of the vaporized working fluid instead of the sensible heat.

As a result, the effective thermal conductivity may be several orders of magnitudes higher than that of the good solid conductors.

A heat pipe consists of a sealed container, a wick structure, a small amount of working fluid that is just sufficient to saturate the wick and it is in equilibrium with its own vapor. The operating pressure inside the heat pipe is the vapor pressure of its working fluid.

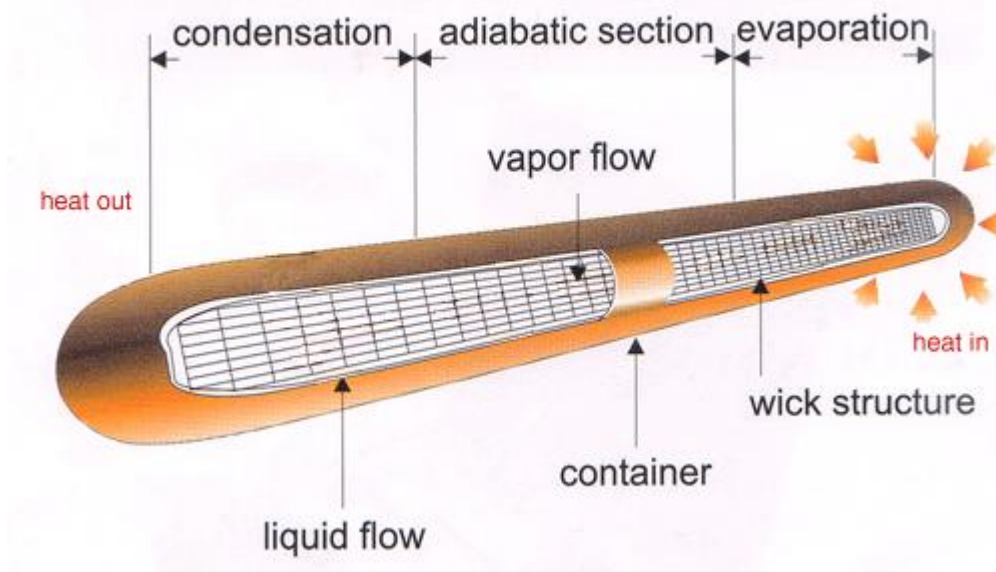
The length of the heat pipe can be divided into three parts viz. evaporator section, adiabatic section and condenser section.

In a standard heat pipe, the inside of the container is lined with a wicking material. Space for the vapor travel is provided inside the container.

How a Heat Pipe Works

A heat pipe is a closed evaporator-condenser system consisting of a sealed, hollow tube whose inside walls are lined with a capillary structure or wick. Thermodynamic working fluid, with substantial vapor pressure at the desired operating temperature, saturates the pores of the wick in a state of equilibrium between liquid and vapor. When heat is applied to the heat pipe, the liquid in the wick heats and evaporates. As the evaporating fluid fills the heat pipe hollow center, it diffuses throughout its length. Condensation of the vapor occurs wherever the temperature is even slightly below that of the evaporation area. As it condenses, the vapor gives up the heat it acquired during evaporation. This effective high thermal conductance helps maintain near constant temperatures along the entire length of the pipe.

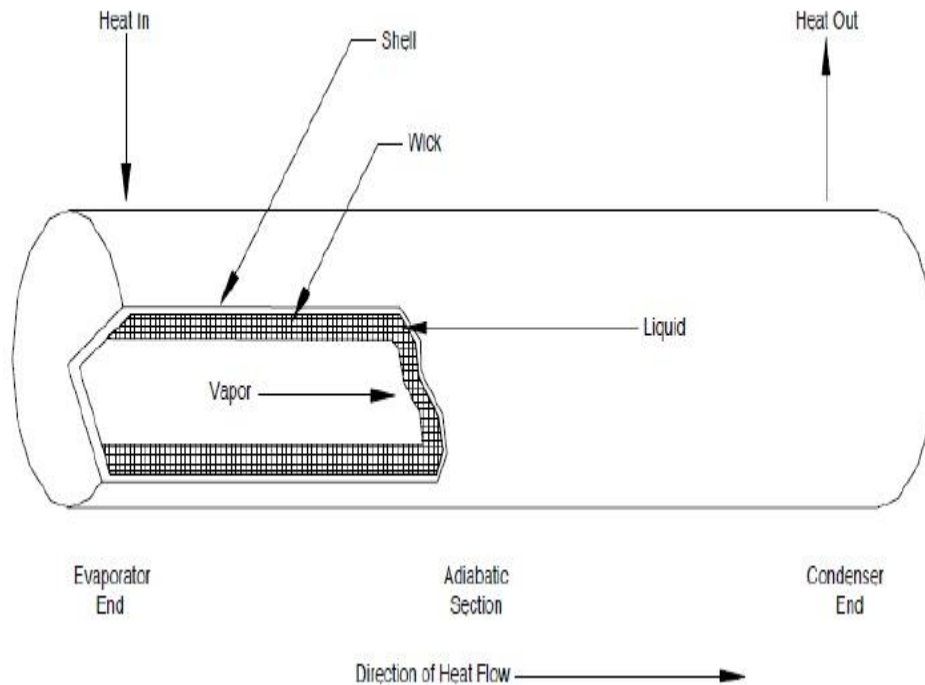
Attaching a heat sink to a portion of the heat pipe makes condensation take place at this point of heat transfer and establishes a vapor flow pattern. Capillary action within the wick returns the condensate to the evaporator (heat source) and completes the operating cycle. This system, proven in aerospace 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.

Basic components of a heat pipe

1. The container
2. The working fluid
3. The wick or capillary structure



Working fluid

The first consideration in the identification of the working fluid is the operating vapor temperature range. Within the approximate temperature band, several possible working fluids may exist and a variety of characteristics must be examined in order to determine the most acceptable of these fluids for the application considered.

The prime requirements are:

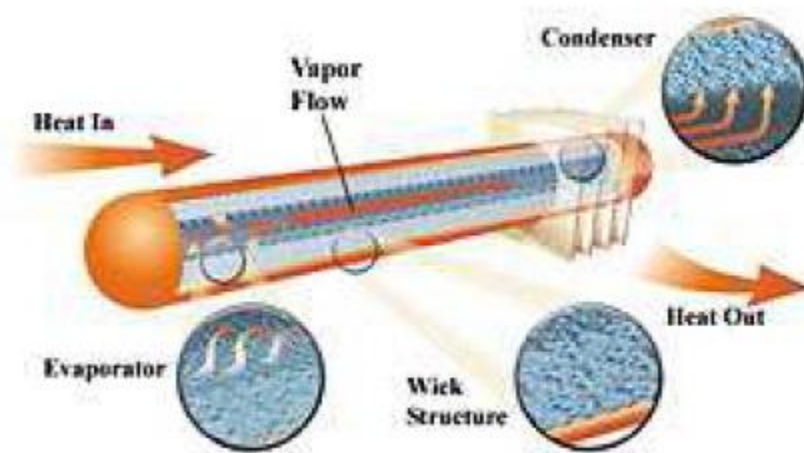
1. Compatibility with wick and wall materials
2. Good thermal stability
3. Wettability of wick and wall materials
4. High latent heat
5. High thermal conductivity
6. Low liquid and vapor viscosities
7. High surface tension

Wick

The wick structure in a heat pipe facilitates liquid return from the evaporator from the condenser. The main purposes of wick are to generate the capillary pressure, and to distribute the liquid around the evaporator section of heat pipe. The commonly used wick structure is a wrapped screen wick.

Construction

A typical heat pipe consists of a sealed hollow tube, which is made from a thermoconductive metal such as copper or aluminium. The pipe contains a relatively small quantity of "working fluid" (such as water, ethanol or mercury) with the remainder of the pipe being filled with vapor phase of the working fluid. On the internal side of the tube's side-walls a wick structure exerts a capillary force on the liquid phase of the working fluid. This is typically a sintered metal powder (sintering is a method for making objects from powder, by heating the material until its particles adhere to each other) or a series of grooves etched in the tube's inner surface. The basic idea of the wick is to soak up the coolant.



Heat pipes contain no moving parts and require no maintenance and are completely noiseless. In theory, it is possible that gasses may diffuse through the pipe's walls over time, thus reducing this effectiveness. The vast majority of heat pipes uses either ammonia or water as working fluid. Extreme applications may call for different materials, such as liquid helium (for low temperature applications) or mercury (for extreme high temperature applications). The advantage of heat pipes is their great efficiency in transferring heat. They are actually a better heat conductor than an mass of solid copper.

As previously mentioned there is liquid vapor equilibrium inside the heat pipe. When thermal energy is supplied to the evaporator, this equilibrium breaks down as the working fluid evaporates. The generated vapor is at a higher pressure than the section through the vapor space provided. Vapor condenses giving away its latent heat of vaporization to the heat sink. The capillary pressure created in the menisci of the wick, pumps the condensed fluid back to the evaporator section. The cycle repeats and the thermal energy is continuously transported from

the evaporator to condenser in the form of latent heat of vaporization. When the thermal energy is applied to the evaporator, the liquid recedes into the pores of the wick and thus the menisci at the liquid-vapor interface are highly curved. This phenomenon is shown in figure. At the condenser end, the menisci at the liquid-vapor interface are nearly flat during the condensation due to the difference in the curvature of menisci driving force that circulates the fluid against the liquid and vapor pressure losses and body forces such as gravity.

Different Types of Heat Pipes

In addition to standard, Constant Conductance Heat Pipes (CCHPs), there are a number of other types of heat pipes. including:

- Vapor Chambers (flat heat pipes), which are used for heat flux transformation, and isothermalization of surfaces
- Variable Conductance Heat Pipes (VCHPs), which use a Non-Condensable Gas (NCG) to change the heat pipe effective thermal conductivity as power or the heat sink conditions change
- Pressure Controlled Heat Pipes (PCHPs), which are a VCHP where the volume of the reservoir, or the NCG mass can be changed, to give more precise temperature control
- Diode Heat Pipes, which have a high thermal conductivity in the forward direction, and a low thermal conductivity in the reverse direction
- Thermosyphons, which are heat pipes where the liquid is returned to the evaporator by gravitational/accelerational forces,
- Rotating heat pipes, where the liquid is returned to the evaporator by centrifugal forces

Vapor chamber or flat heat pipes

Thin planar heat pipes (heat spreaders) have the same primary components as tubular heat pipes: a hermetically sealed hollow vessel, a working fluid, and a closed-loop capillary recirculation system. In addition, a series of posts are generally used in a vapor chamber, to prevent collapse of the flat top and bottom when the pressure is lower than atmospheric, which is 100 °C for water vapor chambers.

There are two main applications for vapor chambers. First, they are used when high powers and heat fluxes are applied to a relatively small evaporator. Heat input to the evaporator vaporizes liquid, which flows in two dimensions to the condenser surfaces. After the vapor condenses on the condenser surfaces, capillary forces in the wick return the condensate to the evaporator. Note that most vapor chambers are insensitive to gravity, and will still operate when inverted, with the evaporator above the condenser. In this application, the vapor chamber acts as a heat flux transformer, cooling a high heat flux from an electronic chip or laser diode, and transforming it to a lower heat flux that can be removed by natural or forced convection. With special evaporator wicks, vapor chambers can remove 2000 W over 4 cm², or 700 W over 1 cm².

Second, compared to a one-dimensional tubular heat pipe, the width of a two-dimensional heat pipe allows an adequate cross section for heat flow even with a very thin device. These thin planar heat pipes are finding their way into “height sensitive” applications, such as notebook

computers and surface mount circuit board cores. These vapor chambers are typically fabricated from aluminum extrusions, and use acetone as the working fluid. It is possible to produce flat heat pipes as thin as 1.0 mm (slightly thicker than a 0.76 mm credit card).

Variable Conductance Heat Pipes (VCHPs)

Standard heat pipes are constant conductance devices, where the heat pipe operating temperature is set by the source and sink temperatures, the thermal resistances from the source to the heat pipe, and the thermal resistances from the heat pipe to the sink. In these heat pipes, the temperature drops linearly as the power or condenser temperature is reduced. For some applications, such as satellite or research balloon thermal control, the electronics will be overcooled at low powers, or at the low sink temperatures. Variable Conductance Heat Pipes (VCHPs) are used to passively maintain the temperature of the electronics being cooled as power and sink conditions change.

VCHPs have two additions compared to a standard heat pipe: 1. A reservoir, and 2. A Non-Condensable Gas (NCG) added to the heat pipe, in addition to the working fluid; see the picture in the Spacecraft section below. This NCG is typically argon for standard VCHPs, and helium for thermosyphons. When the heat pipe is not operating, the NCG and working fluid vapor are mixed throughout the heat pipe vapor space. When the VCHP is operating, the NCG is swept toward the condenser end of the heat pipe by the flow of the working fluid vapor. Most of the NCG is located in the reservoir, while the remainder blocks a portion of the heat pipe condenser. The VCHP works by varying the active length of the condenser. When the power or heat sink temperature is increased, the heat pipe vapor temperature and pressure increase. The increased vapor pressure forces more of the NCG into the reservoir, increasing the active condenser length and the heat pipe conductance. Conversely, when the power or heat sink temperature is decreased, the heat pipe vapor temperature and pressure decrease, and the NCG expands, reducing the active condenser length and heat pipe conductance. The addition of a small heater on the reservoir, with the power controlled by the evaporator temperature, will allow thermal control of roughly $\pm 1-2^\circ\text{C}$. In one example, the evaporator temperature was maintained in a $\pm 1.65^\circ\text{C}$ control band, as power was varied from 72 to 150 W, and heat sink temperature varied from $+15^\circ\text{C}$ to -65°C .

Pressure Controlled Heat Pipes (PCHPs) can be used when tighter temperature control is required. In a PCHP, the evaporator temperature is used to either vary the reservoir volume, or the amount of NCG in the heat pipe. PCHPs have shown milli-Kelvin temperature control.^[15]

Diode Heat Pipes

Conventional heat pipes transfer heat in either direction, from the hotter to the colder end of the heat pipe. Several different heat pipes act as a thermal diode, transferring heat in one direction, while acting as an insulator in the other:

- Thermosyphons, which only transfer heat from the bottom to the top of the thermosyphon, where the condensate returns by gravity. When the thermosyphon is heated at the top, there is no liquid available to evaporate.

- Rotating Heat Pipes, where the heat pipe is shaped so that liquid can only travel by centrifugal forces from the nominal evaporator to the nominal condenser. Again, no liquid is available when the nominal condenser is heated.
- Vapor Trap Diode Heat Pipes
- Liquid Trap Diode Heat Pipes

A Vapor Trap Diode is fabricated in a similar fashion to a Variable Conductance Heat Pipe (VCHP), with a gas reservoir at the end of the condenser. During fabrication, the heat pipe is charged with the working fluid and a controlled amount of a Non-Condensable Gas (NCG). During normal operation, the flow of the working fluid vapor from the evaporator to the condenser sweeps the NCG into the reservoir, where it doesn't interfere with the normal heat pipe operation. When the nominal condenser is heated, the vapor flow is from the nominal condenser to the nominal evaporator. The NCG is dragged along with the flowing vapor, completely blocking the nominal evaporator, and greatly increasing the thermal resistivity of the heat pipe. In general, there is some heat transfer to the nominal adiabatic section. Heat is then conducted through the heat pipe walls to the evaporator. In one example, a vapor trap diode carried 95 W in the forward direction, and only 4.3 W in the reverse direction.

A Liquid Trap Diode has a wicked reservoir at the evaporator end of the heat pipe, with a separate wick that is not in communication with the wick in the remainder of the heat pipe. During normal operation, the evaporator and reservoir are heated. The vapor flows to the condenser, and liquid returns to the evaporator by capillary forces in the wick. The reservoir eventually dries out, since there is no method for returning liquid. When the nominal condenser is heated, liquid condenses in the evaporator and the reservoir. While the liquid can return to the nominal condenser from the nominal evaporator, the liquid in the reservoir is trapped, since the reservoir wick is not connected. Eventually, all of the liquid is trapped in the reservoir, and the heat pipe ceases operation.

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. The wick allows the heat pipe to operate in any orientation, but the maximum adverse elevation (evaporator over condenser) is relatively small, on the order of 25 cm long for a typical water heat pipe.

Taller heat pipes must be gravity aided. 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. (See also: Perkins tube, after Jacob Perkins. Please note that a heat pipe thermosyphon is different than a thermosiphon, which transfers heat by single phase natural convection heat transfer in a loop.)

In a thermosyphon, liquid working fluid is vaporized by a heat supplied to the evaporator at the bottom of the heat pipe. The vapor travels to the condenser at the top of the heat pipe, where it condenses. The liquid then drains back to the bottom of the heat pipe by gravity, and the cycle repeats. Thermosyphons also act as diode heat pipes. When heat is applied to the condenser,

there is no condensate available, and hence no way to form vapor and transfer heat to the evaporator.

While a typical terrestrial water heat pipe is less than 30 cm long, thermosyphons are often several meters long. As discussed below, the thermosyphons used to cool the Alaska pipe line were roughly 11 to 12 m long. Even longer thermosyphons have been proposed for the extraction of geothermal energy. For example, Storch et al. fabricated a 53 mm I.D., 92 m long propane thermosyphon that carried roughly 6 kW of heat.

Loop heat pipe

A loop heat pipe (LHP) is a passive two-phase transfer device related to the heat pipe. It can carry higher power over longer distances by having co-current liquid and vapor flow, in contrast to the counter-current flow in a heat pipe. This allows the wick in a loop heat pipe to be required only in the evaporator and compensation chamber. Micro loop heat pipes have been developed and successfully employed in a wide sphere of applications both on the ground and in space.

Heat applications

Heat pipe heat exchanger enhancement can improve system latent capacity. For example, a 1°F dry bulb drop in air entering a cooling coil can increase the latent capacity by about 3%. Both cooling and reheating energy is saved by the heat pipe's transfer of heat directly from the entering air to the low-temperature air leaving the cooling coil. It can also be used to precool or preheat incoming outdoor air with exhaust air from the conditioned spaces.



Best application

- Where lower relative humidity is an advantage for comfort or process reasons, the use of a heat pipe can help. A heat pipe used between the warm air entering the cooling coil and the cool air leaving the coil transfers sensible heat to the cold exiting air, thereby reducing or even eliminating the reheat needs. Also the heat pipe precool the air before it reaches the cooling coil, increasing the latent capacity and possibly lowering the system cooling energy use.
- Projects that require a large percentage of outdoor air and have the exhaust air duct in close proximity to the intake can increase system efficiency by transferring heat in the exhaust to either precool or preheat the incoming air.

Applications to avoid

- Where the intake or exhaust air ducts must be rerouted extensively, the benefits are likely not to offset the higher fan energy and first cost.
- Use of heat pipe sprays without careful water treatment. Corrosion, scale and fouling of the heat pipe where a wetted condition can occur needs to be addressed carefully.

WWW.

Advantages

- Passive heat exchange with no moving parts,
- Relatively space efficient,
- The cooling or heating equipment size can be reduced in some cases,
- The moisture removal capacity of existing cooling equipment can be improved,
- No cross-contamination between air streams.

Disadvantages

- Adds to the first cost and to the fan power to overcome its resistance,
- Requires that the two air streams be adjacent to each other,
- Requires that the air streams must be relatively clean and may require filtration.

CONCLUSION

Heat pipe is a thermal super conductor under certain heat transfer condition they can transfer the heat energy 100 times more than available best conductive materials, because of negligible temp. Gradient exist in heat pipe.

The heat pipe has compactness, light weight, reversible in operation and high thermal flux handling capability makes heat pipe to use new modern era and in many wide variet application to overcome critical heat dissipation problem.

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