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HEAT PIPES, THEORY AND PRACTICE

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This lecture introduces operational and design principles for heat pipes. A heat pipe is essentially a passive device that can quickly transfer heat from one point to another. They are often referred to as the "superconductors" of heat as they possess an extra ordinary heat transfer capacity and rate with almost no heat loss. The heat transferred from the hot source evaporates the fluid in the wick, causing the vapor to expand into the center core of the heat pipe. The latent heat of vaporization is carried with the vapor to the cold end of the tube, where it is removed by transference to the heat sink as the vapor condenses. The condensate is then carried back in the wick to the hot end of the tube by capillary action and by gravity (if the tube is tilted from the horizontal), where it is recycled. This two-phase heat transfer mechanism results in heat transfer capabilities from one hundred to several thousand times that of an equivalent piece of copper.

The heat pipe is compact and efficient because i) the finned-tube bundle is inherently a good configuration for convective heat transfer in both ducts, and ii) the evaporative-condensing cycle within the heat pipes is a highly efficient method of transferring heat internally.

The effects of different factors on the performance of the heat pipe: compatibility of materials, operating temperature range, diameter, power limitations, thermal resistances, and operating orientation, will be considered in the lecture.

Heat pipes can be designed to operate over a very broad range of temperatures from cryogenic (less than 30 K) applications to high temperature systems (more than 2000 K). Until recently, the using of heat pipes has been mainly limited to space technology due to cost effectiveness and complex wick construction. There are several applications of heat pipes in this field, such as spacecraft temperature equalization component cooling, temperature control and radiator design in satellites. Currently heat pipe technology has been integrated into modern thermal engineering designs, such as terrestrial thermal control systems, solar energetics, etc. The increasing power and shrinking size of electronics components presents growing thermal management challenges. While solid metal conductors such as aluminum extrusions may provide acceptable cooling for individual components in certain situations, board level solutions with more advanced cooling technologies are needed in a growing number of applications. Heat pipes have emerged as an effective and established thermal solution, particularly in high heat flux applications and in situations where there is any combination of non-uniform heat loading, limited airflow over the heat generating components, and space or weight constraints. This lecture will briefly introduce heat pipe technology and then highlight its basic applications for passive thermal control.